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SILICOSIS

**RECORDS OF THE INTERNATIONAL CONFERENCE
HELD AT JOHANNESBURG
13-27 AUGUST 1930**



GENEVA
1930

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INTRODUCTION

The International Labour Office has never under-estimated the importance of the silicosis problem, in which it has manifested a lively interest since its inception. It has in fact carefully followed scientific research effected, as well as the reports of practical men in the different countries, and it has made every effort to assemble and collect the extremely scattered scientific data relative to the subject.

Gradually, thanks to national and international meetings of doctors or experts in industrial pathology, and thanks especially to results obtained in those countries in which silicosis is legally compensated as an occupational disease, it has been rendered possible for the Office to tabulate completely the data obtained, and to draw up a programme of activity.

Simultaneously the workers' organisations affected have inscribed the silicosis problem on the agenda of their meetings. Notably is this true of the national stoneworkers' associations and in particular their International Federation which, since 1921, has at each of its meetings voted resolutions demanding that silicosis should be considered as an occupational disease and compensated as such. Other workers' organisations such as those of the miners, pottery workers, etc., have also adopted motions in support of this demand. In 1925 the international secretariat of the stoneworkers' organisation placed before the International Labour Office a request for inclusion of respiratory diseases amongst those entitling the worker to compensation.

On reception of this request the Hygiene Service of the Office in January 1926 addressed to a certain number of experts a questionnaire accompanied by a note explaining the object of the enquiry. The replies obtained were embodied in a report submitted to the Correspondence Committee on Industrial Hygiene during its meeting at Düsseldorf in 1928. The experts assembled by the Office engaged in a lengthy discussion on the problem of silicosis and adopted a resolution in which they requested the Office to delay inscription of silicosis in the list of diseases to be compensated

since, in their opinion, the problem in question was one which presented special complication and difficulty. Two points especially were said to call for further research, that is to say, precise diagnosis of the disease, and determination of the indispensable elements for establishing the degree of capacity of the worker to continue his work. The Committee asked the Office to continue the enquiry undertaken and to submit to it at a future session the data assembled.

Meanwhile Mr. Butler, Deputy-Director of the Office, during his journey in South Africa, discussed with those interested in the question the suggestion made by Dr. Orenstein, of calling an International Conference on Silicosis in Johannesburg.

Thanks to the generous aid of the Chamber of Mines it was possible to carry out this scheme, and the first proposal as to the holding of such a Conference was made to the Governing Body in June 1928. The Governing Body then agreed that a Conference of experts should be convened to study the medical aspects of silicosis and suggested that a Conference held at Johannesburg would afford an opportunity for experts from other countries to examine the remarkable work done by the Miners' Phthisis Bureau on the Rand. The Governing Body also expressed the hope that such a Conference might bring about closer international co-operation in the study of the disease and that it would endeavour to organise a programme of research on the subject.

In March 1929 the Governing Body approved a provisional agenda for the Conference as follows:

- (a) Medical aspects of silicosis (pathological and clinical);
- (b) Preventive measures;
- (c) Compensation.

Scientific investigations on the subject engaged in chiefly in German and in English speaking countries, the work effected by Committees appointed by the British Government in recent years, the results of the discussion of the report submitted to the International Congress of Occupational Diseases at Lyons, 1929—a discussion which dealt chiefly with the research effected by the Medical Research Bureau and the Miners' Phthisis Bureau in South Africa—as well as research engaged in in Germany, all these contributed naturally to paving the way for the calling of a Conference exclusively concerned with the problem of silicosis.

This Conference, in accordance with the decision of the Governing Body, met in Johannesburg from 13 to 27 August 1930.

In view of the length and cost of the journey to South Africa the funds available only allowed of the appointment of a limited number of experts. In the course of consultation with the Governments it, however, became apparent that certain Governments were willing to pay the expenses of delegates chosen by the Office in agreement with them, and it was therefore possible to issue an additional number of invitations and to increase both the size and the authority of the Conference. The Office is extremely grateful to the delegates who accepted its invitation, to the Governments which bore the expenses of certain delegates, and to the British Medical Research Council which undertook to defray the expenses of Professor Kettle.

The Office records with interest and appreciation that the United States, in accordance with its policy of participation in the activities of the International Labour Organisation, was represented by two delegates, the expenses of one of them being borne by the United States Government.

In order that the Conference might secure the fullest possible information on the work done in South Africa, there were also appointed a number of South African observers, who were able to be present at the meetings and to assist in the elucidation of questions in regard to which they were specially competent.

As soon as the delegates had been appointed, each was asked to write a paper either on the problem of silicosis or pneumoconiosis in his particular country or on that particular scientific aspect of the question with which he was specially competent to deal.

Certain firms at Johannesburg also kindly assisted the Office by the loan of microscopes, an epidiascope, and screens for the showing of radiographs, required for the exhibition of the slides and other specimens brought by the different experts to illustrate certain phases of their work.

The firm of Kodak, South Africa, presented the members of the Conference with an album containing photographs of anatomical-histological preparations and radiographs prepared by the services of the Miners' Phthisis Bureau and of the Medical Research Bureau. The delegates were also given opportunities of visiting these two institutions, as well as a gold mine and the sanatorium for fibrotic patients, and of studying the system of medical examination in force for native workers before they are passed for service in the mines.

Mr. Phelan, Chief of the Diplomatic Division, was appointed by the Office to be in general charge of the organisation of the Conference; *Dr. Carozzi*, Chief of the Industrial Hygiene Section, as technical expert of the Office; and *Messrs. Weaver and Little* and *Miss Macrae* to assist in the secretarial work. The material work of the secretariat was performed by members of the staff of the Chamber of Mines who were generously placed at the disposal of the Conference by the Chamber and who worked under the direction of the secretarial staff of the Office.

LIST OF MEMBERS

Australia

Dr. CHARLES BADHAM, Medical Officer of Industrial Hygiene, New South Wales Department of Public Health.

Dr. W. E. GEORGE ¹, Medical Officer-in-Charge, Bureau of Medical Inspection, Broken Hill.

Dr. KEITH R. MOORE ², Director of the Division of Industrial Hygiene, Commonwealth Department of Health, Member of the Committee on Industrial Hygiene of the International Labour Office.

Canada

Dr. GRANT CUNNINGHAM, Director of the Division of Industrial Hygiene, Department of Health, Ontario.

Germany

Professor Dr. BÖHME, Director, Augusta Hospital, Bochum.

Professor Dr. KOELSCH, State Industrial Medical Officer, Munich.

Great Britain

Dr. S. W. FISHER ³, Medical Inspector of Mines.

Professor ARTHUR J. HALL, Professor of Medicine at Sheffield University, Chairman of the Medical Research Council Committee to investigate pulmonary diseases from silica and other dusts.

Professor E. H. KETTLE, Professor of Pathology, St. Bartholomew's Hospital Medical School, University of London.

Dr. E. L. MIDDLETON ³, Medical Inspector of Factories.

Italy

Professor Dr. GIOVANNI LORIGA, Chief Medical Inspector of Factories, Member of the Committee on Industrial Hygiene of the International Labour Office.

Netherlands

Dr. W. R. H. KRANENBURG, Medical Adviser to the Labour Inspectorate, Member of the Committee on Industrial Hygiene of the International Labour Office.

¹ Representing New South Wales Government.

² Representing Federal Government.

³ Representing British Government.

Union of South Africa

- Mr. A. B. DU TOIT, Chairman, Miners' Phthisis Board.
 Dr. A. I. GIRDWOOD, Chief Medical Officer, Witwatersrand Native Labour Association, Ltd.
 Dr. L. G. IRVINE, Chairman, Miners' Phthisis Medical Bureau.
 Sir SPENCER LISTER, Director, South African Institute for Medical Research.
 Dr. A. MAVROGORDATO, Fellow in Industrial Hygiene, South African Institute for Medical Research.
 Dr. A. M. MOLL, Chairman of the Miners' Phthisis Medical Appeal Board.
 Dr. A. J. ORENSTEIN, Superintendent of Sanitation, Rand Mines, Ltd.
 Dr. Hans PIROW, Government Mining Engineer.
 Mr. F. G. A. ROBERTS, Technical Adviser, Transvaal Chamber of Mines.
 Dr. W. STEWART.

United States of America

- Dr. L. V. GARDNER, Trudeau Sanatorium.
 Dr. ALBERT E. RUSSELL¹, United States Public Health Service.

LIST OF OBSERVERS

- Dr. PETER ALLAN, Medical Superintendent, Nelspoort Sanatorium, Cape Province.
 Mr. G. E. BARRY, Legal Adviser, Transvaal Chamber of Mines.
 Mr. JAMES BOYD, Secretary, Anglo-American Corporation of South Africa.
 Mr. J. BUIST, Senior Dust Inspector, Transvaal Chamber of Mines.
 Dr. E. H. CLUVER, Department of Public Health, Pretoria.
 Mr. NORMAN P. DALE, Secretary, Miners' Phthisis Board.
 Mr. MALCOLM FERGUSON, Chief Inspector of Mines.
 Mr. D. SPENCE FRASER, Actuary to the Miners' Phthisis Board.
 Mr. W. GEMMILL, General Manager, Transvaal Chamber of Mines.
 Mr. G. R. HEYWOOD, Manager, Rose Deep, Ltd.
 Mr. H. R. HILL, Consulting Engineer, Union Corporation, Ltd.
 Mr. A. F. McEWEN, Chief Chemist, Transvaal Chamber of Mines.
 Dr. A. J. MILNE, Medical Officer of Health, Johannesburg.
 Dr. ALEXANDER MITCHELL, Secretary of Public Health, Department of Public Health, Pretoria.
 Mr. B. G. ORPEN, New Consolidated Gold Fields of South Africa, Ltd.

¹ Representing United States Government.

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- Dr. A. D. PRINGLE, Medical Superintendent, Transvaal Miners' Phthisis Sanatorium.
- Mr. C. S. RAATH, Member, Miners' Phthisis Board.
- Mr. J. P. REES, Dust and Ventilation Officer, Transvaal Chamber of Mines.
- Mr. F. G. A. ROBERTS, Technical Adviser, Transvaal Chamber of Mines.
- Mr. WALTER SCOTT, Assistant Consulting Engineer, Rand Mines, Ltd.
- Dr. F. W. SIMSON, Pathologist, South African Institute for Medical Research.
- Dr. J. M. SMITH, Miners' Phthisis Medical Appeal Board.
- Dr. A. SUTHERLAND STRACHAN, Pathologist, South African Institute for Medical Research.
- Dr. R. M. TRUTER, Miners' Phthisis Medical Appeal Board.
- Professor G. A. WATERMEYER, Professor of Mining, University of Witwatersrand.
- Dr. ANDREW H. WATT, Medical Officer, Rand Mutual Assurance Company, Ltd.
- Mr. C. J. WILLIAMS, Deputy Chairman, Miners' Phthisis Board.
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REPORT OF THE PROCEEDINGS

OPENING SITTING

Wednesday, 13 August 1930, 10 a.m.

Chairmen: Sir WILLIAM DALRYMPLE and Mr. E. J. PHELAN

The opening sitting of the International Silicosis Conference was held in the Selborne Hall, *Mr. E. J. Phelan*, Chief of the Diplomatic Division of the International Labour Office, was introduced by *Sir William Dalrymple*.

Mr. E. J. Phelan: My principal function this morning is to ask the Minister, Mr. Sampson, to open formally this Conference; but it might be interesting to you (and it would certainly be fair to him) if I first indicated briefly why the International Labour Office of the League of Nations in Geneva convened this Conference and what we expect it to do.

The International Labour Office is the executive secretariat of the International Labour Organisation. The International Labour Organisation is a society of fifty-five States. It is a purely official body which is the result of fifty-five States in the world having entered into a contract to collaborate for the improvement of conditions of labour. It began as you probably know at the same time as the League of Nations, and its Constitution is to be found in the Treaties of Peace. One of its original Members is South Africa. The Organisation has to have a secretariat—an executive to carry out its decisions; that executive is the International Labour Office, which I have the honour to represent here to-day.

Now, the International Labour Office is, as I have said, an executive body. It does not take decisions; decisions are taken by the International Labour Conference, which meets once a year and to which every member of the Organisation—that is to say, every one of the fifty-five Member States—sends a delegation composed of Government representatives, representatives of the workers and representatives of the employers. They compose the annual Conference in which is vested what I may call the sovereign power of the Organisation and they alone can formulate decisions, which later become international treaties. I want to make that clear, because the conference which Mr. Sampson is going to open in a few minutes is not that Conference; it is not the General Conference of the Organisation which can adopt Draft Conventions and Recommendations.

Before that General Conference actually meets to formulate decisions which Governments must take into consideration and which Governments, if they ratify, must observe, the function of the International Labour Office is to see that it shall have the fullest possible information at its disposal; therefore, long before the International Labour Conference

considers the taking of any decisions, the Office in Geneva is busy collecting, summarising and analysing information, translating laws and regulations, and attempting to make as complete a survey as possible of all the law and practice bearing on the question which, later, the International Labour Conference will discuss. This preparatory work of the Office covers the whole area of labour problems. The programme of the Organisation which is laid down in the Preamble to Part XIII of the Treaty of Peace is of the most comprehensive character.

I am not going to discuss that programme this morning; but it does contain, as you would naturally expect it to contain, a very specific reference to industrial disease; and therefore, among the studies which the Office is constantly carrying on with the ultimate object of some day or other going to the International Labour Conference for discussion and a decision, is the question of industrial disease. One section of the organisation of the Office is specially devoted to that work, and as its head we were fortunate enough to secure ten years ago a very distinguished European authority, Dr. Carozzi, who is with me here in Johannesburg to-day as the technical expert of the International Labour Office. The very important work which the Office has already done in the field of the study of industrial disease is due above all to Dr. Carozzi's vision, energy and intelligence. He has, in the course of ten years, built up a unique organisation; he has created a network of experts and technicians scattered all over the world, with whom he is in constant contact by correspondence; and, since science need not regard the political differences which sometimes separate political units, that network of medical correspondence covers, not only the members of the International Labour Organisation, but certain very important units which lie outside it, like the United States of America and Russia. Dr. Carozzi's work takes a material form in the publication every three or four months of a bibliography of everything he is able to discover which has been published on the subject of industrial hygiene. He is able to supply the Government services of the different countries and experts in industrial hygiene with some two or three thousand references a year, so that each of them, in dealing with his own work, can keep abreast of the work which is being done elsewhere. He has also been able to undertake the immense task of compiling an *Encyclopaedia of Occupation and Health*, the first volume of which will appear in a few months. To give you some idea of the field covered and the amount of work he has performed, it will be a volume of something like 2,200 pages.

You have now, I hope, some idea of the organisation which lies at the origin of this Conference—the International Labour Office, with its general responsibility for securing better conditions of labour, and the Industrial Hygiene Section with its particular interest in industrial disease.

But the Office does not by any means work only on paper. We have had the great advantage of having had at the head of the Office a great international figure, Mr. Albert Thomas, a man with outstanding qualities of leadership and a unique capacity for achievement. He realised from the beginning the danger of the Office becoming a mere Academy and the necessity that the officials of the Office, whenever the occasion might arise, should get away from purely paper work and gain as much direct experience of the problems with which we are dealing as possible. It was in pursuance of this policy that three years ago the Deputy-Director of the International Labour Office, Mr. Butler, undertook a visit to South Africa in order to become familiar with the labour problems

of South Africa, and with the object of intensifying relations between South Africa and the International Labour Organisation. During his visit here in Johannesburg, in conversation with Mr. Gemmill and other representatives of the Chamber of Mines, and Dr. Orenstein, his attention was drawn to the unique collection of material which had been made by the Chamber and by the officials of the Government in connection with silicosis. He saw at once the importance of making this knowledge internationally available and he accordingly discussed with Mr. Gemmill and Dr. Orenstein the possibility of discovering some method whereby the scientists and the officials of the other countries might be able to profit by the immense experience of that disease which is centred in this city. Out of those conversations grew the present Conference: out of those conversations grew the suggestion that it might be possible to convene an International Conference of experts to study the medical aspects of silicosis and the measures for its prevention.

The proposal was laid before our Governing Body, which is the executive council of the International Labour Office, and was approved by them; but South Africa being a very long way away from Geneva, and the International Labour Office being a far from rich body, it would have been difficult perhaps to have held this Conference if it had not been for the generosity of the Chamber of Mines; and I should like to-day, on behalf of the International Labour Office, formally to thank the Chamber of Mines for the generous assistance which has made the holding of this Conference possible. I should like also to ask Mr. Sampson to convey to the Government of the Union of South Africa the appreciation of the International Labour Office of the facilities which the South African Government has given to us, and of the generous way in which, as soon as it was consulted, it offered to give every assistance to the Conference and to lay before it all the material which it has in its possession.

But before I ask Mr. Sampson formally to open the Conference, the origin of which I have described, I would like to draw attention to an aspect of it which is not purely medical. This Conference, distinguished as it is by the scientists who have come from different countries in Europe, Africa, Canada, Australia and the United States of America, represents perhaps a more remarkable body of expert opinion than has ever come together to deal with the question of an industrial disease; but, important and remarkable as it may be in that respect, it is still more important and more remarkable in another respect. We in Geneva often feel that we are a long way from the distant countries, and I have no doubt that South Africans often feel they are a long way from Geneva and that Geneva is dealing with problems which are remote from South African preoccupations and that, to put it quite frankly, the League of Nations spends the greater part of its time discussing purely European problems. That is only a half truth. It is true that the League of Nations and the International Labour Organisation do spend a great deal of time discussing problems which are of major European interest; but it is not true that these problems, or the solution of them, has not a direct interest to the more distant countries. It is unfair to make these observations as a criticism of the League of Nations or of the International Labour Organisation. The League of Nations is not an international dictator; the League of Nations is not a super-State; the League of Nations is not some Martian body which meets in Geneva and decides what is good for France, or Italy, or South Africa or Australia. The League of Nations is exactly like the South African Parliament or the British Parliament or the German Parliament. It is in no wise different from the members which compose it; and when it meets in Geneva, its

activities are dictated by the influence of its most active members. The League of Nations does precisely what a Parliament would do when a majority in the Parliament decides on a certain course of action, and therefore it is not a just criticism of the League of Nations to say that its activities are too European. But it is perhaps a regrettable fact—a fact, however, for which the less active members of the League are themselves responsible and not some super-body.

Now, what is the corrective to that? What is the way in which the League of Nations can be led to pay more attention to non-European questions and to become really in its activities a more world-wide organisation? The only way in which that can be done is for the non-European States to bring their problems to Geneva and insist, as the European States do, that their problems shall be dealt with. South Africa has now taken the lead by furnishing an example of how this can be done.

The fact that this Conference is meeting in South Africa is therefore a historic occasion. It is the first Conference convened by the League of Nations which has met outside of Europe. It is true that the first International Labour Conference met in Washington, in the United States of America; but the first International Labour Conference was not convened by the International Labour Organisation nor by the League of Nations. It was settled in the Treaties of Peace, and it has not met in Washington since, for the simple reason that the United States did not join the League of Nations or the International Labour Organisation; and with the disappearance of the United States of America, the balance between the European and the non-European sides of the League was perhaps weighted in favour of Europe, so that European problems have played a predominant part in the discussions of Geneva.

To-day, for the first time, Mr. Sampson is going to open an International Conference officially convened by the International Labour Office of the League of Nations, meeting outside Europe and having as its object the study of a problem that is not by any means wholly European in its interest. For that reason, I think that I may say that this Conference marks a historic point in the development of the League's machinery. It shows, I think, too, that the South African Government has understood the real meaning of Membership of the League. The Covenant is not a final nor an absolute guarantee of the world's peace or of industrial progress or of anything else. The League is, and can be, nothing more than its Members make it. But the difference between the League world and the pre-League world is this: that in the pre-League world every State guided its policy in its own purely selfish interest. In the League world we hope that States will more and more consider, not what they can get out of the League, but what they can put into the League for the common good of the whole; and this Conference is a gesture of that kind. South Africa has asked these experts, through the intermediary of the International Labour Office, to come to Johannesburg in order to see what contribution South Africa can make towards the solution of a grave medical problem.

I cannot speak for the experts, but my impression is that South Africa has more to give than she can hope to receive. She has had a longer experience and she has accumulated a greater collection of material going back for a longer period than perhaps any other country. But the essence of South Africa's gesture is her desire to put at the disposal of humanity as a whole the peculiar knowledge which she has to offer for the solution of a very pressing problem in the industrial world. I can assure Mr. Sampson that that gesture is appreciated in Geneva to its

fullest; and though possibly South Africa may gain little direct benefit from this Conference, her reward is that she will have contributed to the good of humanity as a whole. I have now great pleasure in asking Mr. Sampson to open formally this International Silicosis Conference. (*Applause.*)

The Hon. H. W. Sampson, M.P. (Minister of Posts and Telegraphs): The problem of silicosis has been one of considerable gravity in South Africa, and the Government of the Union has therefore special reason to welcome the assembly in Johannesburg of this International Silicosis Conference.

Our Chairman, Mr. Phelan, has dealt very minutely with the particulars of the preliminaries that led up to this Conference, and has saved me the necessity of repeating those matters. I want to thank him very much for his exposition of the reasons for which the League of Nations exists. After all, as we get further and further from the war time of the past, commercialism will sometimes ask: what do we get out of the League of Nations? It is well we have one in our midst this morning who has explained to this assembly the spirit which led up to the formation of that body and the spirit in which this work is to be carried on in the future. I am quite sure that this audience is particularly interested in that matter, and I am sure they realise the necessity of getting the world closer together in dealing with world problems apart from the problems in regard to their own special countries. He has explained very fully how you, Gentlemen, come to be here this morning, and it is my duty to extend to you all a very cordial welcome in the name of the Government of the Union of South Africa. I welcome especially those who have come long distances to attend this Conference. Their presence here is a signal proof of the great international fellowship in scientific investigation and research which overrides all national boundaries, and affords so hopeful a manifestation of that growing international spirit which the International Labour Organisation embodies.

The presence of the representatives of so many countries and the high standing of the members of the Conference affords also an indication of the widespread distribution of the menace of silicosis and of the serious light in which it is regarded by the health authorities of many countries.

Silicosis is indeed, I suppose, individually perhaps the most important of all occupational diseases and one which, as we know, is a danger to health and life in many industries besides that of metal mining. The problem of "silica risk" and how it is to be countered forms to-day one of the most important preoccupations of industrial hygiene.

To the metal miner who works in certain kinds of hard siliceous rock the disease has everywhere been a special danger, and we in South Africa fully realise that our local problem is only part of a world-wide problem. We realise that the prominence which the disease has attained in this country has been due primarily to the great extent and unique geographical concentration of the great gold-bearing reef of the Witwatersrand, and to the extraordinarily rapid development of the mining industry which is based upon it, and the magnitude which that industry has attained.

The problem has thus been with us at once larger and more sharply concentrated and the deaths and suffering caused by that disease have been more clearly apparent than might have under other circumstances been the case.

It is impossible to state with any degree of definiteness what the entire ramification of the disease here has been. Statistics (and many of them

not comparative) are only available since 1911. But the enormous burden which the industry has to bear of nearly £1,000,000 per annum, totalling, I believe, some £15,000,000 for compensation claims since 1911 and arising chiefly from an average of 21,000 to 30,000 whites employed underground during that period, will convey to your minds the suffering to the victims and loss to the industry.

It took a good many years before the gravity of the situation in respect of silicosis was fully recognised in this country; but one may, I think, fairly state that from the time that it was fully realised neither the Government of the Union nor the mining industry have relaxed their efforts to control the situation.

The Union Government definitely recognised "miners' phthisis" as an occupational disease in 1911, and since that date no fewer than nine Acts of Parliament have been passed dealing with the matter of compensation to miners affected by silicosis, or to the dependants of deceased miners. From time to time also there have been incorporated in the Mining Regulations a large and increasing number of detailed provisions aiming at the prevention of the disease.

The mining industry has closely co-operated with the Department of Mines in the investigation and trial of preventive measures, and this fact has greatly facilitated the development of a systematic preventive policy.

For many years one seemed to see no very marked amelioration of the situation, although one realises that with such a disease as silicosis it takes a considerable time before changes in occupational conditions show their full effect.

I am glad now to learn from the Chairman of the Medical Bureau that the annual number of the cases of silicosis which are arising to-day in only about one-third of the number that were arising fourteen or sixteen years ago, and that a substantial improvement in the situation has occurred within the last three years. This is very welcome news, but we should wish for something even better, and if you, Gentlemen, can help us to do better we shall be very grateful.

It is perhaps too much to hope for that your deliberations will lead to any very great reduction in the incidence of silicosis; only a larger expenditure in preventive measures than many of our older mines are able to afford and continue to work can do that; but it will save many lives and much suffering, besides being of great financial assistance to the industry, if means can be found of arresting the disease or of preventing silicotic sufferers from infection with the tubercular germ. This we have hitherto tried to do by the arbitrary method of forcing a man to leave underground work; but the problem of finding him alternative employment is a difficult one, ranking, as he does, among the unfit, and leads to constant demands for more compensation.

I observe from the provisional programme of your discussions that every aspect of the silicosis problem will be dealt with. I am sure that this conjunction of the trained minds of many countries, each of you with a diverse and varied experience of the question, may be expected to have fruitful results. I have every confidence that this Conference will advance the knowledge of the causation and prevention of silicosis to a great degree. After all, it is prevention that counts most of all, and it is to the medical experts that we look for wise counsel in that direction. I wish you, Gentlemen, every success in your important task, the results of which, I am sure, will mark an important stage in the ultimate solution of this grave question. I have pleasure in declaring this Conference open. (*Applause.*)

The Conference was also addressed by *Dr. Keith Moore* (Australia), *Dr. Grant Cunningham* (Canada), *Professor Böhme* (Germany), *Dr. Middleton* (Great Britain), *Professor Loriga* (Italy), *Dr. Kranenburg* (Netherlands) and *Dr. Gardner* (U.S.A.) who expressed their thanks to the South African Government for the welcome which it had offered.

(The Conference adjourned at 12 noon.)

FIRST SITTING

Wednesday, 13 August 1930, 3.30 p.m.

Chairmen: MR. E. J. PHELAN and DR. L. G. IRVINE

Mr. E. J. Phelan: The first point is the election of the Chairman of the Conference.

ELECTION OF CHAIRMAN

Dr. Middleton proposed the election of *Dr. Irvine* as Chairman. *Dr. Gardner* seconded this proposal.

Dr. Irvine was unanimously elected Chairman.

The Chairman read the following telegram received from *Mr. Albert Thomas*, Director of the International Labour Office:

Please convey hearty greetings to Delegates and warmest wishes for a successful and fruitful conference. ALBERT THOMAS.

He also read the following letter received from *Mr. Thomas*:

LEAGUE OF NATIONS.

INTERNATIONAL LABOUR OFFICE,
GENEVA.

SIR,

On this, the first occasion upon which the International Labour Office has convened a Conference outside Europe, I venture to ask you to convey to its members my warmest wishes for its success, and to express to the Chamber of Mines my gratitude for the assistance which is making the holding of the Conference possible. I feel confident that the labours of experts drawn from four continents cannot but result in a substantial and valuable contribution towards the solution of the problem of industrial silicosis. The International Labour Office is happy to be associated with the Transvaal Chamber of Mines in this attempt to increase the protection of mine workers and workers in other silicotic industries against the dangers to which they are exposed from this disease.

I shall be grateful to you, Sir, if you will be good enough to convey my greetings and good wishes to the members of the Conference and to assure them that I shall watch the progress of their work with the deepest sympathy and interest.

I have the honour to be,

Sir,

Your obedient Servant,

(Sgd.) ALBERT THOMAS.

The President of the
International Silicosis Conference,
Johannesburg.

The Chairman proposed that this telegram and letter should be inserted in the Minutes of the Conference. *Dr. Orenstein* moved that receipt of this telegram and letter should be acknowledged and the thanks of the Conference expressed by cable.

The Conference unanimously adopted this proposal.

ELECTION OF VICE-CHAIRMEN

Dr. Loriga proposed the election of *Dr. Russell* as Vice-Chairman. *Dr. Pirow* seconded this proposal.

Dr. Russell proposed *Sir Spencer Lister* as second Vice-Chairman. *Professor Kettle* and *Dr. Loriga* seconded this proposal.

Dr. Russell and Sir Spencer Lister were unanimously elected Vice-Chairmen.

PUBLICITY OF PROCEEDINGS

Mr. Phelan: The Conference should decide at once whether its proceedings were to be public or private. He believed that the medical experts might prefer to conduct their discussions without the presence of laymen, but they might consider whether the closing session at which the suggestions and recommendations might be adopted should be public.

Dr. Middleton proposed that all proceedings should be private.

Dr. Loriga agreed.

The Chairman asked whether medical men not members of the Conference and representatives of the medical profession should be excluded.

Dr. Middleton: He was of the opinion that all sittings should be private unless the Conference otherwise resolved. It might at moments be useful to hold their discussions before a wider public, but an *ad hoc* procedure would allow this to be done.

Mr. Phelan asked whether *Dr. Middleton* had any objection to the issue of Press communiqués to keep the public informed of the progress of the Conference.

Dr. Middleton: Any communiqués should be approved by the Conference before they were issued.

Mr. Phelan: It would be difficult to consult the Conference daily for approval of communiqués, and he suggested that the staff might be allowed to issue communiqués to inform the Press of the progress made, but that where any references were made to differences of opinion, the Conference should first be consulted.

Dr. Mavrogordato suggested that a publicity committee be appointed.

Dr. Orenstein: The Resolutions Committee could fulfil this function.

Dr. Cluver: What would be the position of the medical Press? He was himself both an observer and the representative of the *British Medical Journal*, and the *Journal of Industrial Hygiene*.

Dr. Orenstein proposed that this question be referred to the Resolutions Committee.

The Chairman submitted the following text to the Conference:

1. The Conference as such should be regarded as private and the meetings confined to members and observers, and any publicity

given to its proceedings should be agreed to *ad hoc* by the Conference with the exception that a short resumé of the daily proceedings may be issued to the Press by the Secretariat.

2. Dr. Orenstein's proposal that Dr. Cluver's proposal, "a resumé of the proceedings might be drawn up on behalf of and for publication in the medical Press subject to the approval of the Resolutions Committee", be referred to the Resolutions Committee for a recommendation, is accepted.

The Conference unanimously adopted these proposals.

NOMINATION OF REPORTERS AND OF RESOLUTIONS COMMITTEE

Mr. Phelan: He proposed that the Resolutions Committee should consist of Dr. Irvine (Chairman), Dr. Russell and Sir Spencer Lister (Vice-Chairmen), Dr. Moore, Dr. Kranenburg, Dr. Böhme, and Dr. Orenstein.

He also proposed that reporters should be appointed for the three groups into which the subject was most easily divided as follows:

- (1) *Prognosis, After Care and Compensation:* Dr. Cunningham, Dr. Koelsch, Professor Hall.
- (2) *Preventive Measures:* Dr. Loriga, Dr. Badham, Mr. Roberts.
- (3) *Medical Aspects* (to cover Pathology and other subjects separately if necessary, but to submit a single report): Dr. Orenstein, Dr. Gardner, Dr. Middleton, Dr. Steuart.

The Chairman put to the vote the appointment of a Resolutions Committee constituted as proposed by Mr. Phelan.

The Conference unanimously appointed the Resolutions Committee as proposed.

Dr. Cunningham proposed that South Africa should be represented by a reporter upon "Prognosis, After-Care and Compensation".

Dr. Fisher seconded this proposal.

Dr. Orenstein: The South African point of view was that it would be better for the report to be drawn up uninfluenced by South African opinion.

Dr. Cunningham: It would be serious to omit all South African experience.

Mr. Phelan: The discussion would be open to all the members, and all that was proposed by the South African members was that it should be summarised impartially by overseas members.

Dr. Cunningham and *Dr. Fisher* withdrew their proposal.

The Conference unanimously appointed the reporters as proposed by Mr. Phelan.

Dr. Orenstein: Dr. Steuart, who had been appointed one of the reporters on "Medical Aspects", was an observer and not a member of the Conference.

Mr. Phelan: The International Labour Office was prepared to invite Dr. Steuart to be a member of the Conference.

Professor Kettle moved that Dr. Steuart should be invited to become a member.

The Conference unanimously adopted this proposal.

REPORTS OF THE PROCEEDINGS OF THE CONFERENCE

Mr. Phelan: A summary of the discussions of the Conference would be prepared by the Secretariat and roneoed, and members could hand in any corrections which they desired to make. The reports submitted to the Conference by the reporters for the three groups would eventually be published in a volume, which would include the various reports submitted to the Conference beforehand, and an account of the proceedings. This volume would also be published in French at a later date, and possibly in other languages. The non-technical discussions would be reported by the Secretariat. For technical discussions he suggested that speakers should prepare a summary of their own observations and hand it in to the Secretariat. In such cases delegates could hand in a summary in their own languages.

The Chairman asked whether the Secretariat would prepare a summary when the technical discussion was more in the nature of a debate than of a series of speeches.

Mr. Phelan: In such cases a stenographic note taker would be provided, and the Secretariat would also take notes. In this way a sufficiently accurate report would be obtained, which delegates would also have the opportunity of correcting.

Dr. Middleton asked whether the reporters would be required to take notes of the whole discussion.

Mr. Phelan: A distinction should be drawn between reports of the discussion and the reports eventually drafted to summarise the discussion. No disagreement was likely to arise over the summary of the discussion, but the reports themselves might be controversial. It was therefore desirable that the reporters should take some notes.

The Chairman suggested that speakers' summaries should be handed to the Secretariat within twenty-four hours.

PROGRAMME OF THE CONFERENCE

The Chairman: The programme proposed followed a logical sequence, viz. (1) Preventive Measures, (2) Medical Aspects, (3) Prognosis, After Care and Compensation. The South African reports were intended to serve as starting points for discussion, and the relevant parts of other reports would be taken at the same time. The subject matter rather than the papers themselves would be discussed. Papers 1 to 6 were more occupational in character than medical; anything bearing on the medical aspect could be discussed under the second heading, and anything bearing upon prognosis and compensation under the third.

THE CHAIRMAN'S SPEECH

The Chairman then addressed the Conference as follows:

Gentlemen, I have to thank you most deeply for the signal honour you have been good enough to confer upon me in nominating me as Chairman of this International Silicosis Conference. It is an honour which I am very proud to accept because I view it as a recognition of the place which the Miners' Phthisis Medical Bureau, whose work I have at the moment the privilege to direct, has gained for itself as a pioneer institution in

the field of industrial hygiene. I am only sorry that my predecessor Dr. Watkins Pitchford, who founded and organised the Bureau fourteen years ago during a time of stress and difficulty, and who directed its activities for a period of ten years thereafter, is not here to occupy in my place a position which he might so adequately have filled.

For myself I accept this honour with much diffidence. Although I have been in contact with the silicosis problem for eight and twenty years I am but a humble musket-bearer in the army of the Lord, and, when I face as I do now this friendly but critical gathering of the chosen experts in industrial medicine of many countries, I feel much like a company commander in a battalion of the line who is suddenly called upon to lead a composite force of all arms in a highly mechanised post-war army. Happily, little or no leading will be called for. But since you have been good enough to place me here I shall do my best to discharge the great privilege which you have conferred upon me, and which I esteem most highly.

My first duty is to welcome our visitors in the name of the mining and medical professions of South Africa as colleagues to meet whom is to us a very great pleasure and a unique opportunity. The other day when a solitary male hippopotamus which had wandered from Zululand along the coastal margin of Natal into the native territories beyond, a lonely tour of more than two hundred miles, reached a native kraal and rested with the cattle, the headman of the village gave orders that an ox should be slaughtered. This is the customary way in native circles to honour a distinguished visitor. Gentlemen, we hereby figuratively slaughter our ox in your honour. I hope that we shall establish at our meetings a close and friendly contact with each other which will make this Conference a landmark for each of us of good fellowship and good work done, and will make it also a notable landmark in the history of the silicosis problem.

That the International Labour Office has called this Conference to meet at Johannesburg is to us a great satisfaction. But it is a chastened satisfaction. For while we welcome the opportunity of having the benefit in the consideration of our local problems of the advice of so many trained minds, whose experience must in many respects have been different from our own, yet that satisfaction is tempered by the knowledge that probably the main reason why you have come to us is, that, owing to the magnitude and the unique concentration of the mining industry of the Witwatersrand, and to its rapid and intensive development within the space of a generation, the problem of silicosis has been with us at once of greater gravity, and has had results which have been more clearly apparent than might have been the case in other countries, in which the mining communities may be of older standing and individually perhaps relatively smaller and more scattered. Our satisfaction is tempered also by the fact that although after many years of intensive effort we can claim a very considerable measure of success, we have as yet reached no final practical solution of the difficult problem of the prevention of silicosis.

It is significant of the local attitude toward "miners' phthisis" that the initial suggestion to hold this Conference at Johannesburg should have come from Dr. Orenstein on behalf of the mining industry of the Witwatersrand, and that the Transvaal Chamber of Mines has actively co-operated with the International Labour Office and the Government of the Union of South Africa in making this meeting possible. Since the time that the gravity of the menace of silicosis was fully recognised there has been manifest a close co-operation between the Department of Mines

of the Union Government and the gold mining industry in the investigation and application of preventive measures. This wholesome spirit animated the work of the first Miners' Phthisis Prevention Committee, to which we in this country look back as having set on foot a really energetic and systematic policy of prevention. Our present meeting is the outcome of the same spirit, which alone can render possible a satisfactory solution of this grave question.

I do not wish to detain you overlong with preliminaries. You have come here to see things for yourselves and not to listen. But perhaps you will bear with me if I offer at the outset a few very general remarks upon the subject-matter of our programme, as viewed particularly in the light of our South African experience, inasmuch as this is the only aspect of the general problem of silicosis of which I have any direct knowledge. The papers which have already been contributed to the proceedings of the Conference are in your hands. Those prepared by local mining and medical men may appear to bulk largely in the programme, but they are designed to serve simply as an introduction to the general discussions on the several aspects of our subject. They will be taken as read, and will thus provide a short and happy method of disposing of the local contributors, and of opening the way to discussions, which, as is plain from the contributions from other countries which have already reached us, will be enriched by the results of wide and intensive studies of the general problem elsewhere.

The contributions already received from other countries, together with others which may be forthcoming, will fit naturally and most profitably into the course of the relevant discussions of the different aspects of our subject, and will be of especial value in widening their scope. In South Africa, so far, the silicosis problem has been practically a mining problem, and the local contributions are accordingly practically confined to the subject of the silicosis of the gold miner. The record of experience derived from other industries and other countries will serve to correct this apparent limitation. I trust, however, that you will forgive me if the few remarks I have personally to offer may also appear to have an unduly local colour.

§ 1. — The topics set down for our discussion follow a logical sequence. The first main subdivision of our programme deals with the causation and prevention of silicosis. The first six papers deal accordingly with the physical and chemical characters of the gold-bearing conglomerate and the contiguous country rock of the Witwatersrand reef, with the history of local occupational conditions, the nature of the preventive measures which have been adopted, and with the general history of silicosis on the Witwatersrand.

The problem of what constitutes "silica risk" and of how it is to be countered is obviously fundamental since if that can be solved the pathology of silicosis becomes of no more and no less special significance than that of any other disease, and the matter of compensation may be left to look after itself. The question of the aetiology and prevention of silicosis is plainly primarily a medical one, and I trust that this Conference will be able to contribute to the formulation of some definite lead in this respect, since without a well-informed and convincing lead from the medical side, the mining engineer or the industrialist must remain at a loss. As a world-famous engineer said at a recent Empire Mining Congress: "Let the physiologists tell us plainly what they want done, and we shall find ways of doing it for them." Hitherto the physiologists and other medical people have themselves been pursuing a painful process of self-education. Are we now in a position to do better?

We know that certain dusts which contain free silica are phthisis-producing dusts, and that other dusts which also contain free silica are not, and the accepted view at present is that the difference lies in the presence in the latter kinds of dust of other constituents, which nullify the harmful potentialities of silica. The facts are there, but their explanation is still somewhat obscure, although we can picture several possibilities. And can the facts be applied in a practical way to the prevention of silicosis, either in mining, or, if not in mining, in other industries in which "silica risk" exists, and in which dilution with other "antidote" dusts might be possible? The line hitherto taken in South Africa has led far away from any attempt in this direction, although Dr. J. S. Haldane has more than once called our attention to its possibilities.

The history of silicosis in South Africa, and indeed in all other countries, makes sad reading, and to those who have worked in close contact with the disease throughout, the personal experience has been more sad. To the actual sufferers it has meant cases of disablement or death which have run into thousands. I think that those of you who have read the several local contributions to the history of the subject, to which I have referred, must have been impressed by the manifest candour of the writers. Our ten years of ignorance, our further ten years of partial realisation, hesitation and tentative improvements, our eighteen years of increasingly energetic effort to deal with the problem have been set down without extenuation, and make up, I suppose, the common story of such things the world over, except that with us that story has been condensed into the period of one generation instead of being spread out over several or many.

The slow awakening to the gravity of the situation and to the fact that we have in silicosis a condition which is individually the most important of all occupational diseases, and one most difficult to deal with, particularly under mining conditions, is faithfully reflected in these papers. At the outset this circumstance was due in part to simple ignorance of the character and extent of the danger, in part to the dominance of the metal mining tradition of those days. The coal mining tradition stood then, as now, for ample ventilation to combat the danger of mine gases. The metal mining tradition, exempt as most metal mines are from any such obvious and immediate risks, was still content to rely upon natural ventilation. And there is an immense inertia in tradition the more so when it has become extensively embodied in actual material structure whether above or below ground.

The main lesson of the history of silicosis appears to be that in metal mines which create a phthisis-producing dust there are just as cogent reasons for ample ventilation as exist in coal mines, since in the last resort we are dealing, in an atmosphere laden with impalpable silica dust, with what is for practical purposes a dangerous gas, perhaps more extensively dangerous to life in its remote effects than are fire damp or black damp with their immediate and obvious risks. Had this been generally realised thirty or forty years ago we should have been spared at least a large part of our troubles. And although mine ventilation has for many years received great and increasing attention on these fields we are still to-day in this respect hampered and handicapped by the heritage of the old tradition, as embodied in the original layout and mode of working of the older mines.

It was not until the report of the Miners' Phthisis Medical Commission was published in 1912 that the widespread character of the menace of silicosis and the real gravity of the situation were recognised in this

country, and that year marks the beginning of the really energetic measures for the prevention of silicosis which have since been taken. Even so, medical men and engineers were still agreed that water was the main remedy.

Since that date preventive policy has been increasingly systematised in the measures summarised in several of the papers before you; measures which have incorporated and extended the many important preventive methods which had already been introduced.

They form to-day a large and complicated system. There are the "medical methods" of strict examination of recruits, and of the detection and removal of the subjects of active tuberculosis; and there are the "engineering methods", such as provision for adequate ventilation, and the regulation of shifts and blasting and also those methods which depend upon the use of water to prevent the escape of dust into mine air, or to lay it when actually in suspension. The success of this combination of measures has undoubtedly been great. One may claim, I think with truth, that the number of cases of silicosis which are arising annually to-day is only about one-third of the number which were arising fourteen or sixteen years ago. During the past three years there has been a continuous drop in the production rates of the disease. Nor do I think that the potentialities of our "present day" methods are by any means exhausted. Within the last ten years, to take one feature only, the whole practice of rockdrill work has been completely and favourably revolutionised, and such things take time to show their full effect. The improvement attained therefore has been substantial, and there is reasoned hope for further improvement in the future. But, although we are satisfied so far, we are also disappointed. We have scotched the snake, but we have not killed it. We realise in particular that although water will take one a large part of the way, it will not take one all the way, and that its use has certain positive disadvantages both hygienic and economic. Hence the minds of medical men and engineers are turning to-day to the question: have we not been overdoing water? Could we not do better with less water, and a greater extension of alternative methods? On this point the experience of other countries will be welcome.

§ 2. — The second main subdivision of our programme is concerned with the strictly medical aspect of silicosis.

In this section discussion will be opened by the papers on the "Aetiology of Silicosis" and on "Experimental Silicosis" by Dr. Mavrogordato. The pathology, radiology and symptomatology of silicosis as met with in South Africa are dealt with in three further papers. The first of these, contributed by Drs. Strachan and Simson, is written from the strictly pathological standpoint. The same writers have co-operated with members of the Medical Bureau in the preparation of the two succeeding papers on "The Clinical Pathology, Radiology and Symptomatology of Silicosis", in which that condition is considered particularly from the standpoint of its practical diagnosis as an occupational disease. These two papers present the conclusions drawn from a careful correlation of the results of pathological, radiographic and clinical examination in a consecutive series of 400 individual cases of silicosis occurring amongst European miners, in each of which a post mortem examination was performed, and in each of which a radiographic and clinical examination had been carried out within the six months preceding death. It is upon this triple correlation that the standards of diagnosis and classification adopted by the Medical Bureau are based. It forms at once the front line and the last ditch in our trench system of diagnosis.

It is common ground that it is the high potential predisposition to the

ultimate development of an active tuberculosis that is the chief factor in making silicosis the serious condition which it in most cases is. The relation between silicosis and tuberculosis has been repeatedly discussed, and will, one presumes, be once more thoroughly discussed at this Conference.

The view taken in these papers is that a non-tuberculous nodular fibrosis of the lung due to the arrest of silica dust within that organ is a definite and distinct pathological process, and is the predominant feature of the great majority of cases of what is clinically termed "simple silicosis" particularly in its earlier stages, and further that that process may advance *as such* up to a point, but to a very considerable degree without the intervention of tuberculous or other infection, even although the affected man is removed from underground work.

On the other hand, not only are a number of cases of silicosis obviously complicated from the outset by active tuberculous infection, but pathological observation leads one to the view that there exists in many and probably in most cases of clinically "simple" silicosis, from the time that it becomes definitely detectable, some latent circumscribed focus or foci of low-grade tuberculous infection in association with certain of the silicotic lesions.

Some such infective lesions may originate from persistent active foci dating back originally to a primary infection during early life: some may be due to a limited re-infection occurring during and associated with the early development of the silicotic process.

This feature forms one factor in the explanation of the tendency to the ultimate development of active tuberculosis which is manifest in so many cases of silicosis. The future history of the case will depend on whether such foci remain inactive, or become active and progressive or whether again a further infection occurs from a source outside the lungs. Other features in the situation however heighten that predisposition. The sites of the silicotic lesions offer possible points of arrest of bacteria in the lymphatic system of the lung. And probably the most important factor of all is the circumstance, as has been shown in particular by Gye and Kettle, that finely divided silica acts as a soluble cell poison and has in consequence a specific effect in determining the selection by a tuberculous infection of sites where silica is aggregated.

The local toxic action of silica may also go far to explain the characteristic modification of the silicotic process by chronic infections, and particularly by a chronic tuberculous infection, with the production of slowly progressive infective lesions of comparatively low virulence, accompanied by an excessive fibroid reaction, which form so striking a feature of many cases of the disease. To this characteristic modification of silicosis the general term "infective silicosis" or in the more restricted sense "tuberculo-silicosis" has been applied.

It would appear that the typical effect of silica dust when inhaled in excessive quantities over long periods is, generally speaking, first to cause a "dust bronchitis", then to produce the simple nodular "dust fibrosis" which is "silicosis", and finally to lead on to a condition of "infective silicosis" and a true "dust phthisis". But there are in individual cases many variations in the course of this development, determined mainly by the relative preponderance of the dust factor or of the infective factor, and by the earlier or later manifestation of the latter.

At this point I would call your attention to the photographic *Atlas of the Pathology and Radiography of Silicosis* which lies beside each of you. It contains a reproduction of the original illustrations to the three

papers I have just mentioned and has been prepared for and is presented to the medical members of this Conference through the courtesy and generosity of Kodak, South Africa. It will form, we hope, a useful addition to the literature of the Conference, and I am sure you will desire that the cordial thanks of the members of the Conference should be conveyed to the donors, Kodak, South Africa, for their handsome gift-book. To Dr. Steuart and myself it is especially pleasing, because the endeavour to secure satisfactory reproductions of radiographic negatives of chest conditions has hitherto been a standing heart-break; the reproductions achieved by the printer conveying for the most part nothing of any value, either to their authors or to other people. This is particularly unfortunate in the case of such a condition as silicosis, in the diagnosis of which radiography forms so essential an element. But the *Atlas* in your hands has, I think, made good this deficiency in a very satisfactory manner, so far at least as the material which it contains is concerned.

If I may be so bold as to offer the suggestion, I should wish to see this Conference consider particularly three points in connection with the pathology and diagnosis of silicosis.

First: Can we agree from the fundamental pathological standpoint upon a definition of what constitutes silicosis *regarded as a definite condition of disease*, the presence of which renders the affected man capable of being certified as suffering from a specific and identifiable occupational malady, which may constitute a valid basis for a possible claim for compensation in that respect?

Second: Can we agree upon a terminology which will render a description of the characteristic lesions and varieties and possibly the "stages" of silicosis mutually intelligible to observers in different countries?

Third: Can we agree upon a terminology descriptive of the various types of radiograph found in cases of silicosis, or other conditions of pulmonary fibrosis, which may similarly be mutually intelligible to different observers? The Medical Bureau has in this regard tentatively put forward its own private conventional terminology for the consideration of the Conference. Suggestions for improvement will be welcome.

I think it would be a matter of real value if some agreement could be reached on these three points which would facilitate mutual understanding in the future.

§ 3. — The third subdivision of our programme deals with the incidence and progression of silicosis, with the legal aspect of the disease, and with the question of compensation.

There are included here several papers, mainly from the administrative side, on the work of the Medical Bureau and the Medical Board of Appeal, on the sanatorium treatment of silicosis and on the examination of native mine labourers.

Finally the programme concludes with three papers which deal with the development of miners' phthisis legislation in South Africa, with the question of compensation and of other ameliorative measures undertaken by the Miners' Phthisis Board, and with the great monetary burden, past, present and prospective which the disease has placed upon the mining industry. Yet great as this burden has been it represents only a portion of the very serious economic loss which has been occasioned in South Africa by this "scourge of the metal miner"

Miners' phthisis, we are told in these papers, has been in this country the subject of five Government Commissions, the earliest having been appointed in 1902, of ten Parliamentary Select Committees, and of nine Acts of Parliament, the first of which was enacted in 1911 and the last, or what is for the present the last, in 1925. The subject has thus occupied a great deal of the attention and time of the legislature during the past nineteen years. In general each successive Act has been marked by an increase in the amount of the awards payable to fresh cases, and by additional provisions for surviving beneficiaries under previous Acts or for the dependants of deceased miners, and one cannot say whether finality in these respects has yet been reached. Legislation on the subject has in this way grown to be extremely complicated. I fear that those who approach the study of the present Act will find in it an extraordinary maze of "sage provisos, sub-intents, and saving clauses" which only those who know its history can hope to understand without a guide.

Such a legislative history in itself proclaims that the problem of compensation has proved to be a difficult one. And the standing difficulty as you will well understand is, that, viewing silicosis as an industrial "injury", the "injury" inflicted is in the majority of cases not a stationary one, but one which tends to get worse, yet which does so very erratically and in general over a period of a good many years. As I have said elsewhere the important point about an early case of silicosis is not what he is at the moment but what he may become. Mr. Spence Fraser has computed the average expectation of life of an early case of the disease when first notified, to be about fourteen years, with a wide variation above and below that average. In the earlier stages of silicosis in which disability may be absent and is at all events not serious, the real crux of the question is not so much medical as economic—it is almost wholly that of securing alternative employment by the men affected. In the later stage it is one of definite and permanent invalidity. The question of serious invalidity has been met since 1919 by the payment of a life pension to those who suffer grave incapacitation from the disease; the earlier stages are dealt with by single lump sum awards. The practical problem is complicated by the fact that in this country, in which most of the unskilled labour is done by the native, alternative avenues of employment especially for partially disabled men are probably less easy to find than in other more fully industrialised communities with a homogenous population. It may be suggested also that the term "miners' phthisis" itself has unfortunately acted as a deterrent in the obtaining of employment by beneficiaries and has also had, perhaps, in a good many instances, a subtle psychological effect in this and other directions upon the beneficiary himself. It seems unfortunate therefore that this term appears to have become entrenched in the titles of the local Acts although it is nowhere mentioned in their substance. This is not, one would suggest, an example to be followed.

One word in conclusion. The Medical Bureau by the sanction of the Minister of Mines has recently installed a new three-phase X-ray generator from which we hope for much and of which we invite your inspection.

May I also venture to call your attention to the plans of the proposed new Medical Bureau which adorn these walls. The Bureau has long outgrown the swaddling clothes generously presented at its birth by the South African Institute for Medical Research and has indeed long been hampered and even endangered by insufficient accommodation. These plans are a vision of a larger future. They are an earnest of how seriously the present Government of the Union regards the matter of silicosis in

South Africa and of the high standard of efficiency for which it is prepared to provide the means and of which it expects to obtain the realisation in the detection and investigation of the disease.

May I be permitted to offer a final suggestion, namely, that this Conference should not terminate without making arrangements for future international intercommunication upon this very important matter of silicosis and allied dust diseases by the establishment and maintenance for example of central libraries of the literature of the subject under the relevant Government department of each country, and possibly by formulating a provisional programme of future desirable lines of research, and by endeavouring to secure a greater international co-operation in carrying out such a programme than at present exists. The experience of different countries and different industries differs in important respects, and some systematic means of collating and comparing that experience might be found.

And now, Gentlemen, I have done. I must thank you for hearing me so patiently. I have attempted merely to offer you a very general perspective of the silicosis question in South Africa. I am well aware that this is but one of many aspects of the general problem which will occupy our discussions, and that it has many other aspects. But it is best to speak of what one knows.

VISITING MEMBERS' EXHIBITS

After some discussion it was agreed that the exhibits brought by visiting members should be shown at 8.15 p.m. on Friday, 15 August.

(The Conference adjourned at 5.55 p.m.)

SECOND SITTING

Friday, 15 August 1930, 2.30 p.m.

Chairman: DR. L. G. IRVINE

The Chairman proposed that the members of the Miners' Phthisis Medical Bureau and the medical staff of the South African Institute for Medical Research should be permitted to attend the sittings of the Conference.

The Conference unanimously adopted this proposal.

OCCUPATIONAL CONDITIONS AND METHODS OF DUST PREVENTION

Dr. Middleton: The scheme prepared by him and circulated to members of the Conference did not attempt to cover silicosis throughout the world, but only as it occurred in Great Britain. By "ætiology" in the title of his first heading he intended to cover all the factors in the causation of the disease silicosis.

The first factor was exposure to silica dust, by which he meant dioxide of silicon in a free state, and not chemically combined in the form of silicate. British legislation was based on the view that disease was

caused by silica dust, and a precise definition of what was silica dust was therefore necessary. During his own investigations into silica processes he had never been able to determine the standard of air dustiness which produced silicosis. He was aware that in South Africa and in Sydney, Australia, a figure was laid down in connection with preventive measures. It was however impossible to discuss a figure until all the facts were known. He suggested that the Conference might usefully lay down a basis for the comparison of results.

In England the apparent exposure to silica dust necessary to produce silicosis had been short; there was a case of fatal result from tuberculosis with evidence that it had been produced by silicosis after two and a half years' exposure.

A third factor which must be taken into account was the extent of exposure period plus latent period, and the relation of these to each other.

The influence of intermittency of exposure by alternation of occupations had preventive bearing. When dust was reduced by certain hygienic conditions silica was still present, but intermittent employment might save the worker from pulmonary disease or at least from disablement. This had already been attempted in some factories in Great Britain.

Another important aspect was the influence of the presence of other dusts on the occurrence and course of silicosis. Some dusts were referred to as restraining silicosis; this was said to be due to colloidal or to chemical action. Other dusts had a physical action in preventing inhalation by aggregation. Some rocks containing clay, for instance, produced large aggregations of particles too large to be carried to the alveoli.

As regards dusts other than silica which might produce evidence of lung change similar to silicosis, he pointed out that a worker might worsen his condition by passing from one industry to another. Asbestos damaged more rapidly than silica. Sandstone grinding was very largely replaced by the new forms of grinding, such as by emery; there was not yet sufficient evidence to indicate the effects on the health of the workers of these processes.

Different industries produced different types of pulmonary disease. Workers in the refractories industries and potters died alike of silicosis, but the type of silicosis was different. Living conditions might have some influence, but in highly skilled trades, such as that of stone masons, where the standard of living was good, the mortality was high.

Finally, as regards the occurrence of infective processes, he asked the Conference to express an opinion on the statement that silicosis was not developed in a healthy lung, but must be preceded by inflammation.

Dr. Russell: In the United States the proportion of silica dust in various industries varied from 1 up to 90 per cent. The medium between the two was probably the average type of dust. Granite dust in the United States contained less silica dust and a higher percentage of other chemicals, to which its inhibitory action had been attributed. The development of silicosis in the granite industry varied in direct proportion to the extent of exposure (30-35 per cent.).

Dr. Moore: The period of exposure necessary to contract silicosis depended primarily on the individual. In the Bendigo mines the silica content was over 90 per cent. On the West Coast of Tasmania it was about 60 per cent. and in Kalgoorlie a little more. The Bendigo statistics were not very trustworthy, since the miners were loth to be examined, but about ten years seemed to be the average period to produce silicosis.

In Kalgoorlie it was nearer sixteen years. Silicosis seemed to depend pretty accurately on the silica average in the country rock.

Dr. Böhme: German experience showed that sand blasters and grinders had well-developed silicosis sometimes after three years. Generally silicosis developed after nearly ten years. Comparable statistics were required in order to distinguish between various dusts. He did not believe that coal dust had any inhibitory effect. There were cases of workers employed on hard rock for three years and then working ten years as colliers who were still developing silicosis and were no more protected than those who had never worked as colliers.

Dr. Koelsch: In his short report just distributed, the question under discussion had been already emphasised, as well as the decisive influence of free silicic acid, and attenuation of the effect of silicic acid by combination with other substances, etc. As regarded the period of time required to develop the disease, he had seen two cases of severe silicosis after two-and-a-half years of employment on sand-blasting; the workers in question were aged twenty-five and thirty years respectively. Timely suspension of work might in the earlier states bring about retrogression of the silicotic changes. Yet in this instance, as likewise in the development of silicosis, the individual constitution and the resistance capacity of the tissues is of capital importance.

Dr. Fisher: Three factors were to be considered: (1) concentration of dust; (2) time; (3) percentage of free silica. It was desirable to use the same konimeter throughout, preferably that which gave the most delicate results. In Great Britain there was up to 60 per cent. free silica in mines. He would like to know whether this was a safe figure. He also asked the Conference to express an opinion as to the best konimeter. Two preventive measures were water and dust traps. He would like to see an efficient mask invented; a mask which did not obstruct respiration would keep back half the dust, and this might be sufficient if 300 particles per cubic centimetre was a safe count.

Dr. Badham: The air of parts of the Rand mines which he had seen did not contain 4 milligrams of dust per cubic metre since dust was not visible under that figure. At about 400 particles per cubic centimetre (using Owen's konimeter) dust particles below 10 microns with a size frequency ratio of 3 did not form a visible cloud.

The size frequency ratio of particles was important, for by its study it could be seen that in a dust such as that referred to, though the 1 micron particles were very numerous, the 2 micron particles contributed the greatest percentage of surface; for this reason he did not subscribe to the belief that ultra-microscopic particles were culpable in producing silicosis. He thought that further work should be done in dust counting to ascertain definitely the amount of silica which could produce silicosis. It appeared that the average exposure on the Rand was about 1 milligram per cubic metre, and if this was so then the prospects of their attack on the disease by reducing the amount of dust inhaled seemed rather hopeless.

He hoped that further attempts would be made in South Africa to correlate the konimeter counts with the sugar-tube results. He thought that Owen's konimeter was capable of doing all the work now being done on the Rand with another instrument and stated that it produced a record from which carbon particles and water-soluble salts could be eliminated by selective counting.

He thought that more attention should be given to the particulate

count and urged South Africans to try more recent methods of dust estimation.

Dr. Kranenburg: It was necessary to know how much silica was contained in different kinds of stone. In marble, for instance, silica was always present. Italian marble had 6.7 per cent. free silica and Belgian marble 1.2 per cent. The figures for samples of limestone were: Belgian, 1.1 per cent., 1.5 per cent., 0.1 per cent., 0.5 per cent.; French, 0.6 per cent., 0.4 per cent., 0.6 per cent.; German, 0.2 per cent.

Dr. Pirow (in reply to Dr. Fisher): The konimeter standard must depend on the percentage of free silica present. He had found with the Rand percentages that 300 particles per cubic centimetre could be taken as a standard, but he was not convinced that it was safe. Water and ventilation were the only preventives in South Africa. Dust traps had been tried, but the general opinion was that they were much too dependent on the personal element and could be applied only in isolated cases. Up to the present no fool-proof and practical masks had been produced. He did not agree with Dr. Badham on the relation between microns and the count of particles per cubic centimetre; 400 or 500 particles per cubic centimetre could be found; it depended on the fineness of the dust. Hand-drilling produced much coarser dust than machine drilling. It was usual to state the percentage of coarse particles (those above 5 and 10 microns). Owen's konimeter was used by the Mines Department as a check, but required too much care to be practical for routine work. He regarded the South African results as only comparative. Efforts to correlate konimeter and sugar-tube results had not been very successful. The concentration entirely depended on the percentage of free silica in the dust. The present concentration was known to be dangerous and attention was being given to the highest concentrations. Attempts were being made to standardise konimeter practice.

Dr. Cunningham: In Ontario gold mines the exposure necessary to produce ante-primary silicosis was nine to ten years. The percentage of free silica was about thirty to thirty-five. This period seemed short compared with South African experience. It was perhaps impossible to correlate the various dust-counting instruments used in different countries.

Sir Spencer Lister: There was some confusion in the term "silica content", which might refer to rock or to dust. Only the silica content and amount of the atmospheric dust mattered and the size of the particles. If very small particles were produced the weight standard was of small significance since the large particles were innocuous.

Dr. Macrogorato: He hoped the Conference would initiate an epidemiology of silicosis. They needed to know where it occurred, what was its comparative incidence, and what were the comparative conditions. Free silica in country rock was a very important factor, but they must know the percentage of free silica in the air, and also what other dusts were present. Of these dusts, which increased liability to silicosis? In Great Britain there were two kinds of firebrick with the same silica content, but the incidence of the disease was very different.

It was easy to remove all visible dust, leaving all the dangerous dust, so that size frequency was of great importance. A method which was effective for coarse particles might be useless for fine dust. Water would keep down dust, but how was dust to be removed when it was

once in the air? In rapid cases of the disease what part was played by the size of the particles?

Masks were most likely to be successful with a system of positive pressure, but he did not believe that other types of masks at present available could stop the dust without stopping the air when the wearer was at work.

South Africans used a dark ground konimeter count and believed that the results were as good as with oil immersion and a light ground. He agreed that 500 particles per cubic centimetre with a dark ground amounted to 1 milligram. When the count was down to 300 it meant a dark ground count in South Africa.

Dr. Kranenburg asked whether it was possible to free air of invisible dust by precipitation (flocculation).

Mr. Boyd: South African dust counts were regarded as empirical. The sugar-tube method had been retained for purposes of historical comparison. Finality had not been reached with the konimeter. It had needed much experiment to reach the present method of counting, which had now been in use for two years. A Committee was at present sitting to investigate methods and to devise a standard. Owen's konimeter was too delicate for routine work. In size classification the largest particles were found in the ore-bins, next in hand-drilling, and then in machine-drilling, which produced the finest dust except blasting.

Dr. Middleton: Working conditions in factories sometimes made the use of water or exhaust draught impossible and masks were therefore required. No standard mask existed, and those on the market were not of known value. The Home Office was investigating the possibility of a mask to protect against fine silica dust, while at the same time providing for an air pressure which would allow a man to wear it some time without fatigue.

He thought that the Conference should adopt a resolution of a progressive kind on the subject of correlating the results of dust counting. The percentage of free silica seemed to be in relation to the silicosis induced in the lungs, but this was an unproved assumption. He hoped that the Conference would draw up a scheme for the exchange of views and knowledge. The dust counts which he had reproduced in his paper led nowhere. He had always used Owen's konimeter and found it useful, but it was impossible to reach a standard for a safe dust figure. In South Africa conditions from mine to mine were fairly comparable, and it was therefore easier to arrive at a figure, though he was aware of the difficulties, partly due to the change in instruments and underground conditions. He did not personally favour dark ground illumination, because it did not eliminate carbon particles, which were very numerous in most dust samples in Great Britain. Silica dust tended to remain discrete, but it was impossible to say how far the same mixture of dust occurred in the atmosphere as in the smear. Where moisture was used to lay dust the number of particles below two microns in a droplet might be over 800. He urged that a uniform method should be adopted so as to render results comparable.

Professor Hall proposed that a sub-committee should be appointed to consider the possibility of standardising dust counts.

Mr. Roberts: A sub-committee would not have sufficient time to reach a satisfactory conclusion. A Joint Committee of the Mines Department and the Chamber of Mines had been working at the question for more than a year.

The sugar tube had given good results, but it showed weight and not numbers. An attempt was now being made to reduce numbers with the help of Owen's and other konimeters. Mining engineers would endeavour to carry out whatever the silicosis experts recommended. It was possible that ventilation ought to be increased and humidity decreased, even at the risk of more dust.

Dr. Loriga: He had nothing to add as cases of silicosis are rare in Italy, and such as have occurred have not been recorded in detail. He had therefore no communication to make in regard to the disease, but would like to ask the members of the Conference, in view of the fact that up till now exclusive mention has been made of silicosis: were there not other dusts which produced forms of pneumoconiosis other than silicosis?

Reference has been made to the outbreak of the disease after a lapse of ten, fifteen, and twenty years. How was it possible to measure such periods with any accuracy? Silicosis did not resemble an acute disease occurring at a given moment, but it was a disease with slow progressive evolution. What stage in the disease was considered to constitute its commencement? He believed it was when the lungs could no longer eliminate the dust so that the disease either increased, was arrested, or led on to death, but he would like to know what criterion was used in stating that a worker was now no longer healthy but must be regarded as silicotic.

Firstly, what dusts favoured or retarded the action of silica? And what dusts could reach the lungs and get fixed there? Neither the Sub-Committee nor the Conference could solve these problems. It would never be possible to say precisely what quantity of dust would provoke silicosis since it was not absolute quantity or quality that mattered but the relative quantity. One individual might resist a proportion of 100 particles per cubic centimetre, while another would react unfavourably to 50 particles per cubic centimetre; there was further the whole question of the rate of inhalation. A medical inspector who was inactive would inhale much less than a worker engaged in heavy physical labour. Accelerated respiration would in the latter case cause inhalation of particles which the former could not inhale. The special pathological aspect seemed, therefore, incapable of solution, but the general pathological side of the problem was already solved. In each case it was necessary to direct attention to the size of the particles, the rate of inhalation and possible penetration and fixation—that was in each given case, but a general estimation of these to meet all cases was impossible.

The Sub-Committee was therefore obliged to confine its attention to the hygienic and practical issue, that was: (1) to determine the standard amount of dust tolerable in the air of a mine for an individual of average health; (2) to determine means of assuring reduction of dust to this amount by analysing the air and to determine the best methods of estimating the dust present in the atmosphere.

In regard to (1) the standard would depend on such factors as quality and admixture with other dusts.

In dealing with the hygienic aspect secondary questions must be left out of account. The problem was that of reaching agreement as to a standard limit for all countries to be determined by future research.

Dr. Orenstein: Two different questions were answered by the dust count: (1) in a given industry it determined how conditions varied (where conditions, as on the Rand, were always comparable); and (2)

for critical scientific study an international standard could be laid down.

About 100,000 samples were taken annually on the Rand, so that a laborious procedure was impossible.

He added that "dark ground illumination" was not the true dark ground of the microscopist.

He suggested that the reporters might co-opt one or two experts to consider a recommendation for an international standard in dust counts for scientific research, and the Resolutions Committee should recommend the experts in question to the reporters.

The Conference unanimously adopted this proposal.

(The Conference adjourned at 5.10 p.m.)

THIRD SITTING

Saturday, 16 August 1930, 9.45 a.m.

Chairman: DR. L. G. IRVINE

PREVENTIVE MEASURES AND UNDERGROUND CONDITIONS

The Chairman suggested that the discussion should be broken into specific subjects.

I. *The Relative Value of the Use of Water and of Ventilation in the Prevention of Silicosis.*

Dr Mavrogordato: Water had three uses: (1) To keep dust out of the air at the site where the stone was broken; water was very efficient, but the finest dust would pass any form of water. (2) To give a "fly-paper" effect; this had been found less effective; tests made on the Rand in 1912 and 1913 proved that other preparations—e.g. Mr. Ussher's treacle—were no better than water; it was doubtful how much had been gained by keeping the place continually wet, since the air was thus very greatly humidified; when a development end had dried for two days it maintained 80 per cent. relative humidity, but when washed it went up to 100 per cent. almost immediately; it would therefore be desirable to revert to the "fly-paper" effect with some other preparation than water. (3) To remove dust from the air. Lord Lister had said at Berlin in the early eighties that he was ashamed of ever having suggested that spray could affect objects of the size of micro-organisms in the air. The Commission on the ventilation of the House of Commons came to the conclusion that fine particles could be blown through any water-screen. With a high temperature high relative humidity was a great inconvenience; organisms kept alive more easily in a wet atmosphere and this was very disadvantageous as regards infective silicosis. Even though the dust was not highly concentrated in the air, silicosis was still produced in a virulent form. The infective element, therefore, played a considerable part.

The effect of dust did not end with inhalation. He had produced a microscopic fibrosis in seven months with fine silica dust (flint). Progress continued over nine years, however, must be due to some element superimposed on the dust. The droplet of 800 particles to which Dr. Middleton had referred was bombarding the lung with shrapnel instead of rifle fire. It was difficult to infect an animal by blowing dry organisms, but 90 per cent. positive results were obtained from spraying. Water facilitated the entry into the lungs of particles in the air and it was therefore preferable to deal with dust by ventilation.

He doubted whether an effective ventilation system was possible. Silicosis was made in twelve years on the Rand, and in about ten years in Canada and Australia. But in English potteries and grinding a twenty-five year exposure was found. Dry methods of control therefore made silicosis much more slowly. In English collieries there were probably many abnormal lungs, but they had been at work twenty-five years or more. Wet surfaces should be kept down as much as possible and there should be all possible ventilation. Mines with a concentration of dust like the Rand would be much more healthy if this concentration were secured by dry methods. It was however impossible to avoid the use of water on the Rand and therefore the surface must be kept down by avoiding leaks in drills and diminishing all spraying; water would keep dust out of the air without great surface.

Dr. Middleton: In factories water and localised exhaust draught were the two main methods of dust prevention. Water should be used for the suppression of dust at its point of origin, and in some processes could be effectively used upon this principle. If sufficient water was used dust never arose, but ample water supply was essential. If no water could be used at the actual moment of fracture of rock steam had been found efficient, but it must be in a saturated condition. If steam was allowed to fall on a dust cloud at its point of formation, the dust would form aggregates and fall. Argillaceous matter in the dust facilitated the formation of aggregates.

The problem of high temperatures did not arise in factories, so that humidity and dissociation did not occur. Grinding with sandstone wheels of 2 to 7 feet diameter gave working faces of 2 or 3 to 18 inches. The idea at one time prevailed that dust was not produced at wet grinding but that if sparks escaped into the atmosphere dust would also. In Great Britain the revolving stone often dipped into a water trough, but Owen's konimeter had proved that the metal cut through the wet surface and gave rise to fine dust from the stone.

Dry grinding had once been the most dangerous industry; Calvert Holland, of Sheffield, had shown that no dry grinders in the middle of last century reached forty-five years of age. It was still carried on, but with an exhaust draught and the incidence of silicosis was now much less than among wet grinders. There was thus a strong argument for the use of exhaust draught.

British regulations required the suppression of dust as near as possible to its point of origin, either by water or by localised exhaust draught. The dust figure was sometimes very little reduced by exhaust draught—perhaps by 25 per cent. The failure of the localised exhaust draught was due to the idea that it had some selective effect. This was not the case. The system ought to be such as to remove a sufficient volume of air from the point of origin of the dust and to ensure a directional current. The addition of baffles at the sides of the workplace would enormously reduce the amount of air to be removed. It was a special

engineering problem to correlate the size and speed of the fan, the capacity of the duct, and the volume of air to be moved.

Processes were sometimes improperly carried on between the point of origin of the dust and the exhaust system. General ventilation should never be combined with a localised exhaust draught system unless the two could be correlated by some means. The pull of the fans caused directional currents towards them and the two systems together always produced eddies. Dust commonly escaped from the hood and passed directly upwards and was then diffused generally throughout the room, so that high concentrations could be counted.

It was hard to determine the relative value of water and exhaust draught; there was a place for each. Water was efficient where it could be easily and sufficiently used, generally outside the workroom; otherwise exhaust draught was necessary. It was impossible to lay down figures for efficient local exhaust draught; a linear velocity of 200 feet at the throat of the duct was usually enough to remove 80 per cent. of the dust. Where the source of dust was a rapidly revolving object, as in towing earthenware, there was much more difficulty in collecting all the dust. Water could not be used in the vast majority of factory processes.

He had been much impressed by the humidity in the Crown Mines. If even with the use of water minute particles of dust could still be determined in the atmosphere this was a definite argument against the use of water in confined spaces.

Dr. Badham: In textile mills one sees the use of various methods of securing humidity and among the methods used the value of conveying the air along wet tunnels has been recognised and applied, in fact he thought it is even more efficient than water atomizers. One can appreciate therefore the Rand humidity problem.

He agreed with Dr. Mavrogordato that water is of value at the sites of percussion or fracture—drilling, blasting, and breaking ore. He had no data bearing on the important question of whether the use of water increases infectious conditions.

He found some years ago that the use of the water blast did not reduce the number of particles of dust of micronic size in the air and Drinker of the U.S.A. has also shown this.

He was looking forward to getting useful data as to the parts played by infection and by dust in the production of silicosis. He had a group of sandstone masons who work in open air conditions, and are exposed to 4 milligrams per cubic metre or 400 particles per cubic centimetre of sandstone dust. From a recent investigation the incidence of silicosis among these stone masons did not differ much from that found in quarry men and sandstone miners. He was hopeful that future dissection of these figures may show how far the factor of infection comes into play underground in humid conditions. He came into daily touch with the problems described by Dr. Middleton and could appreciate his remarks. At the present time spray painting and the use of silica dust in paints used in spraying was providing them with a new industrial hazard.

Dr. Moore: The lead-smelting works at Port Pirrie received concentrates (slimes) from Broken Hill. They were shovelled from trucks into dumps in the open air. Hoses had been used to lay the dust, but the main result was to raise clouds of dust, and eventually the dumps were plastered with whitewash.

Dr. Böhme: The German Mines Safety Office has recently offered

a prize for protective measures against injury by stone dust, and many suggestions have been received and examined.

The formation of dry dust in drill holes can be diminished by the well-known methods of wet-drilling, but these methods cannot always be used.

Many methods of precipitating the dust which is diffused from the drill-holes in dry drilling have been proposed. Sprinkling with water has no effect in the case of the dangerous fine dust. On the other hand, previous trials have shown the value of a new method; dust from the drill-holes is caught at the mouth of the hole by newly formed soapsuds. Absorption of dust at the mouth of the drill-hole has also proved successful. In using this method it has been found valuable to draw off the particles of stone separately from the dust.

Amongst the masks which were sent in for examination, one model is especially worth mentioning. In this model the filtering surface is much enlarged by using the form of a sack, and at the same time the resistance to inhalation is greatly reduced.

Good ventilation at the place where drilling is going on is also of great importance.

The Mines Safety Office is continuing its investigations.

Dr. Cunningham: Granite cutters, moulders and grinders usually took twenty-five to thirty years to develop silicosis. These were dry operations, while under wet conditions miners develop the disease in between ten and twelve years. In some of these operations the dust exposure is roughly comparable.

Dr. Kranenburg: In 1912 Dutch stone masons wetted the working place where possible. He personally preferred exhaust draught.

The Chairman: No reference had yet been made to the very fine dust caused by blasting, for which water was ineffective, and ventilation was therefore the important alternative. The single shift system and the limitation of blasting to once in the twenty-four hours gave in conjunction with ventilation an important measure of protection against the risk of inhalation of dust from blasting.

The Miners' Phthisis Prevention Committee in 1916 had shown that 97 or 98 per cent. by weight of the dust could be removed after blasting or in drilling, by means of water, but their standard of dangerous dust was 12 microns, which was now known to be too large. A Joint Committee on Ventilation and Dust definitely reported in 1922 that the water blasts in use were ineffective in laying the fine dust produced by blasting. He did not believe, however, that the possibilities of present methods had been exhausted. The exclusive use of drills with axial water feed had not been made obligatory until 1926, but he agreed with Dr. Mavrogordato as regarded the disadvantages of water.

Mr. Roberts: While the water blast did not necessarily catch fine dust at the time of blasting, it did wet the ground while in process of being broken and thus tended to prevent the formation of dust when the broken ground was subsequently handled, e.g. shovelled into trucks; it also dissolved the noxious gases formed by the blast. Its present use was confined to development ends, and ventilation was arranged so as to replace after blasting all the air between the development face and the next through-ventilation connection.

Dr. Kælsch: He desired to draw attention to a question of fundamental importance. Research undertaken by Teleky (Düsseldorf) in Solingen—the German Sheffield—has revealed the fact that cases

of silicosis occur amongst wet grinders there with considerably greater incidence and of a more severe type than those affecting dry grinders. He thought he was in a position to confirm these observations from his own experience. The causes are to be sought, in fact, in the varying biological reaction of the system to wet dust imprisoned in the finest droplets of water, or to dry dust as the case may be; in the varying reaction, in other words, of the tissues in a damp or dry atmosphere.

Dr. Russell: There was a high incidence of silicosis and tuberculosis in grinding in Connecticut. The abandonment of wet grinding and substitution of dry grinding with an exhaust system had reduced the incidence materially, and much reduced the dust count.

Dr. Loriga: In regard to the use of water in mines he believed it was impossible to pronounce either a favourable or unfavourable verdict. It was essential to study carefully the conditions under which water is applied. In the various operations, which they saw yesterday and which were practically similar in all mines, the first in which the dust problem arises was that of drilling, when done by hand or by machinery utilising the dry method, in which case the amount of dust produced was great. With the use of waterfed drills the quantity of dust produced was reduced to a minimum. He believed there was no atomisation of water or projection of water droplets with dust in suspension, because the drill worked within a tube the wall of which prevented the atomisation of the water and the water left the tube in a liquid state; he considered the use of water not only necessary but indispensable.

The second phase of the work in which much dust was produced was blasting. Here the worker had to be protected not against dust alone, but especially against injurious gases. The workers were always removed to a distance, but the air currents from the blasting might arrive in other parts of the mine. What could be done to prevent this air laden with dust and injurious gases from reaching the parts of the mine in which workers are situated? Dry ventilation would not suffice. Ventilation alone was therefore inadequate except when the plan of the mine permitted of the air current being led off in another direction.

A water curtain at the end of the blasting area was useful to condense the gases and allay the dust, as Mr. Roberts had said, and would prevent poisoning as well as diffusion of dust.

The third very dusty operation was the handling and transport of rock debris and dusty material from the blasting, etc. It was necessary to discuss the utility of projecting water on to the material and walls of the mine and into the atmosphere. He was here in agreement with several of the previous speakers as to the danger of undue humidification of the air. It encountered various obstacles. It was likely to render the temperature conditions more harmful. Humid air, as was well known, was less tolerable than dry air at equal temperature, and humid heat was more likely to cause heat stroke than dry heat. Water spraying would prevent the dust from settling, it was true, but constant humidification of the ground favoured the evolution of certain disease germs, such as those of ankylostomiasis. While therefore it was advisable to use water for dust removal, recourse must also be had to ventilation and to those means of handling and transporting material least likely to raise dust.

In conclusion, it was impossible to express a decided opinion for or against the use of water. At certain moments it was extremely necessary—i.e. in drilling and in the elimination of noxious gases after blasting—but in addition it was essential to have air in large quantities

to provide at the same time for air renewal and removal of the dust and gas laden air.

The Chairman: The reporters might summarise the feeling of the Conference on this point and draw up suggestions for further research.

Dr. Orenstein: Data were of more value than opinions. What data were available on the reduction of small particles at the point of contact? Many localised exhaust draughts were applied in a very amateurish way. The speed of the rotating body and its situation in relation to the hood was important, because the rotating body acts in certain ways as a fan. The dust reduction was much smaller than it should be. He asked whether Dr. Russell could put on record the experience of his Department with two neighbouring sets of mines in Missouri. In one set of mines the lay-out made ventilation poor; in the other it was relatively good. Both worked quite dry, but in the better ventilated mines the incidence of silicosis was very low.

He was much impressed by the reduction of visible dust by water, but he doubted whether water did not do more harm than good.

It was noteworthy that silicosis had become much more virulent and that, except on the Rand, it was contracted only after many years. Was water or something else responsible for the situation on the Rand?

He was much interested by Professor Kettle's investigations into the solubility of silica. Only the nebula was dangerous and water could not wash those particles out of the air or make them settle on the walls. A film which had been made of drilling without water recorded an enormous amount of dust which was invisible to the naked eye.

Dr. Middleton: The Medical Research Council had set up a Committee to investigate pulmonary disease due to dust in industry. The speed of the sandstone wheel and the direction of the air current were very important factors. Wet grindstones in England turned in the direction opposite to their direction for dry grinding in Germany, while in Germany more stones were sometimes found in one room than in Great Britain. In dry grinding very rapid revolution of the grinding wheel needed much more closely localised exhaust draught.

Dr. Russell (in reply to Dr. Orenstein): The Missouri mines were worked out. Similar investigation, however, was proceeding in Oklahoma.

Dr. Kranenburg: There was a danger of heat stroke from radiant heat in tunnels in the Netherlands where there were temperatures of 90° and 124° F. If the men protected their heads there was no danger to health from dry heat.

II. *Possible Rôle in the Prevention of Silicosis of an Admixture of Adulterant Innocuous Dusts with Silica Dusts*

Dr. Mavrogordato: Adulterant dust might help the aggregation of fine particles in the air or might facilitate the exit of dust after inhalation. Phthisis dusts were those which overcame the lung's ability to get rid of them. Coal, limestone and other dusts retarded the accumulation of phthisis dust in the lungs, while other dusts, such as abrasive powders, encouraged silicosis. Metallic mineral dust would modify the behaviour of any free silica which was present in the air at the same time. It must therefore be decided whether artificial dust was to be used to cause aggregation or to assist expulsion from the lungs.

Dr. Kranenburg: A dust of voluminous particles, light in weight, should be introduced as high up as possible in the air, over some distance in the development end, subsequent to blasting. This dust must be such that it remains suspended in the atmosphere long enough to enable it to bring down any fine silica dust which may be in the air. What the nature of this dust should be was another question.

Dr. Böhme: Miners who have worked for several years as rock drillers and who later change over to hewing, contract silicosis in the same way as miners who continue to work as rock-drillers. It is not therefore possible to prove that the inhalation of coal dust has a favourable influence on the development of silicosis.

Dr. Mavrogordato: Any dust which assisted expulsion from the lung must be inhaled at the same time as the silica. In his experience the filling of the lungs with other dusts, whether before or after exposure to silica dust, did not favourably influence the accumulation of silica.

Professor Hall: This was a suitable subject for research. It seemed an extraordinary procedure deliberately to put a second foreign body in the lungs. He asked whether the effect of metallic mineral dust was favourable or not.

Dr. Middleton: Aggregation outside the body was very important and deserved investigation.

Dr. Gardner asked whether the accelerating effect of abrasive powders was chemical or not.

Dr. Fisher: Coal was dusted with shale which often contained 60 per cent. free silica. This was inhaled simultaneously with coal dust, but colliers nevertheless got solidified lungs. He always advised coal owners not to use dust containing free silica.

Dr. Badham: Autopsies and pathological study must clear up the causation of fibrosis.

Professor Kettle: It had been suggested that acute silicosis was due to alkali mixed with silica which aided the solubility of the silica. He did not understand how this could happen without acute damage to the lung tissue. The only case of acute silicosis alleged to be without tuberculosis which he had been able to examine proved to be definitely tuberculous. Judgment must be suspended upon the fixing action of alkali allied with silica dust.

Mr. Roberts: No precautions were taken against dust in the Mysore goldfields, but a man who had been employed there was found to be free from silicosis.

Dr. Orenstein: Professor Haldane's guarded proposal concerning the admixture of dust was intended not necessarily to prevent silicosis, but to prolong the period of useful work and render the disease less disabling. It was claimed that there was no disabling silicosis in Mysore or in Cripple Creek, U.S.A., although dust samples showed a considerable content of free silica in the vein and in the country rock. The U.S. Public Health Service reported, however, that there was considerable silicosis at Cripple Creek, and he was not convinced that the situation was not similar in Mysore.

Dr. Kelsch: Observations made in regard to workers on shell limestone, who had between times also worked on sandstone, revealed the fact that marked silicosis occurred, that is to say that the effect of the silica was predominant. It was not possible to establish a *clearly*

marked retarding effect due to the limestone dust. In any case the question of the prophylactic application of relatively harmless dust during work in an atmosphere laden with silica dust is one which must be approached with the utmost caution.

Dr. Gardner: Guinea-pigs dusted with marble dust showed no damage; quartz dust given later gave the same results as when no marble dust had been given,

Dr. Kranenburg: In the Netherlands the simultaneous inhalation of sand tone and limestone gave apparent protection.

Dr. Middleton: There was no evidence of silicosis from limestone alone.

Dr. George: At Broken Hill the ore is of extremely complex composition. It contains only 14 per cent. of free silica on an average, the other constituents being chiefly manganese silicate, lead sulphide and zinc sulphide. The country rock contains no free silica. In spite of this we find silicosis, and this, as you have seen, shows exactly the same radiographic picture as your silicosis on the Rand.

TABLE OF MINERALOGICAL COMPOSITION OF MINE ORES
(PERCENTAGES)

	North	Junct- ion North	Brit- ish	Block 14	B. H. P.	Block 10	Central	South	Zinc
Silica free	15.16	1.62	15.20	11.74	12.00	7.01	12.24	17.73	17.40
Silicates	39.57	66.41	48.77	47.43	46.28	57.25	37.81	24.37	33.28
Galena	17.69	14.34	13.69	16.88	14.64	12.76	16.87	18.38	18.21
Blende	22.03	14.05	19.64	21.48	23.74	20.07	29.20	26.95	19.92
Sulphides of copper	0.22	0.25	0.22	0.22	0.19	0.22	0.22	0.21	0.27
Sulphides of arsenic and anti- mony	0.09	0.07	0.10	—	0.07	0.09	—	{ 0.06 0.04	0.12
Calcium carbonate	5.24	3.02	1.70	2.57	2.73	2.60	3.79	11.15	10.80
Calcium fluoride	—	0.20	0.19	—	—	—	0.22	0.39	—
Pyrite or marcasite	—	0.04	0.21	—	0.15	—	0.30	0.32	—
Pyrrhotite	—	—	0.28	—	0.20	—	—	0.40	—
	100.00	100.00	100.00	100.32	100.00	100.00	100.65	100.00	100.00

An examination of the figures in the above table gives the following information. The figures in the table are arranged in the order of the mines from north to south.

The percentage of free silica in the average ore samples varies from 1.62 to 17.73. The ore is thus nowhere rich in silica, and in one mine the percentage is very low indeed.

The samples of country rock were obtained partly from the walls of stopes and partly from development drives. A number of samples were taken in each mine, the places sampled being chosen to give, in

the opinion of the mine managers, fair specimens of the general type of country rock encountered in the different mines.

Complete analyses were made of these samples. The results are given in the following table:

COMPOSITION OF COUNTRY ROCK FROM DEVELOPMENT DRIVES AND HANGING AND FOOT-WALL OF BROKEN HILL LODE

	Junct- tion North	British	Broken Hill Pty	Block 10	South	Zinc Corpor- ation
Silica, SiO ₃	63.90	64.34	59.64	59.10	64.66	60.26
Alumina, Al ₂ O ₃	15.22	15.58	16.82	18.20	14.88	17.97
Ferrous oxide, FeO	7.43	5.74	7.25	7.25	5.98	7.25
Ferric oxide, Fe ₂ O ₃	0.15	0.20	0.15	0.40	0.10	0.08
Titanium dioxide TiO ₂	2.34	0.98	1.96	2.50	2.46	2.10
Manganous oxide, MnO	2.33	2.46	3.25	2.40	2.56	1.74
Lime, CaO	1.30	2.60	0.85	0.66	1.32	1.01
Magnesia, MgO	1.09	0.76	0.73	1.25	0.84	1.44
Potash, K ₂ O	4.04	2.31	3.56	4.76	3.77	4.78
Soda, Na ₂ O	1.08	1.14	1.03	1.13	1.60	0.95
Sulphur, S	—	0.54	—	—	—	—
Water hygroscopic	0.20	—	0.35	0.15	0.06	0.20
Water combined	1.47	2.14	3.65	2.27	1.42	2.29
	100.55	99.66	99.24	100.07	100.00	100.07

These figures show a striking contrast to those obtained for the various ore samples. The composition of the ore samples from different parts of the lode showed very considerable variations. The composition of the country rock from different parts of the lode, on the other hand, shows a surprising uniformity. About 80 per cent. of this rock, in all the samples, is made up of aluminium and iron silicate. The bulk of the remainder is made up of silicates of potash and manganese. The only acid radical present in any quantity is silica.

Dr. Russell: Workers in the U.S.A. had lost cases in the Compensation Courts because the question of other dusts had been introduced. In U.S.A. silicosis seemed to develop in direct proportion to the silica content and the dust concentration. At Cripple Creek miners who developed silicosis left as soon as the altitude began to trouble them. Silicosis undoubtedly developed there.

Dr. Cunningham described two cases: the first a stone-cutter, who was employed for fifteen years on sandstone and then fifteen years on marble. The post-mortem showed the ash of the lung to contain 5 per cent. silica. The second, a miner who developed silicosis, left the industry and eight years later developed tuberculosis. The ash of the lung contained 45 per cent. silica.

While there is some evidence that with cessation of exposure to silica, in the absence of tuberculosis, much silica finally leaves the lung, marble dust may expedite this.

There have come to one's attention some cases in which silicosis developed in grinders who had worked for a short time on sandstone

and later for many years on artificial grindstone. Some miners with ten to twenty years' exposure to dust very low in free silica developed silicosis rapidly when they moved to an area with much higher silica exposure.

Some interest attaches to one case of pneumoconiosis in a worker with dust exposure limited to nine years' milling talc (magnesium silicate). The industry as a whole has not yet been investigated.

Dr. Russell: Italian workers who had been exposed to Carrara marble dust developed silicosis when working on granite in the U.S.A. as fast as the Scottish workers employed there.

Dr. Badham: Other dusts than silica could produce fibrosis. Cement workers in the United States had been known to suffer from diffused generalised fibrosis. Fibroses resulting from dusts containing little or no free silica should be put on record. Asbestos, talc, ashes, and certain silicates produced fibrosis.

Dr. Mavrogordato: Professor Haldane had added metallic dust to silica. Silica alone was not intense but acted by accumulation; metallic dusts gave inflammation; cobalt and manganese gave the more intense immediate reaction.

III. Dust Trapping and Dust Masks

Dr. Fisher: In dealing with this subject he would, of course, only speak of his own experience. The boring in and blasting of rock in a coal mine is an occasional and not a continuous process. The danger to the workers' health due to dust inhalation having been established, attention was focussed on ways and means of preventing this inhalation from taking place. His only remark about water was that a water-spray, as distinct from water passing down the drill is ineffective and it must be remembered that some dusts have a greater affinity for water than others. Water could not always be made use of, so dust traps were tried—there are several of them either in use or being tried out; two have definitely been approved of as efficient for their purpose.

They all work on the same principle, namely a jet of compressed air coming from the air supply to the drill draws off the dust and deposits it in a bag-container, made of a specially selected flannel, which allows the air to pass but retains the dust.

The weight of the trap shown is 26 lb. only, including the upright support which is telescopic, and which grips the roof and floor in virtue of a spring. It all fits into a long box; bags may be protected by being in some kind of cage.

Dust traps undergo a severe test—they are taken underground and to the actual face being worked. They are fixed up by an employee of the mine and numerous dust slides are taken while the drill is in operation, on many occasions Kotze or Zeiss and Owen's konimeters being used simultaneously.

The standard adopted was an indication of safety, being 300 particles per cubic centimetres with a Kotze konimeter, the slide being untreated in any way.

Whether ultra-microscopic particles pass through the back is of course a question he could not answer.

He would like to remind them that the Various Industries (Silicosis) Scheme, 1928—in force 1 February 1929—applies to coal mines and repeat what he mentioned yesterday, that the demand for these compact, and as far as he could test, effective dust traps exceeds the rate of supply.

He should think that with the serious problem of humidity and tuberculosis the use of dust traps could be reconsidered on the Rand.

As far as masks are concerned workmen have for many years tried to improvise a barrier of some kind that would prevent the dust from entering their lungs. These were practically useless—invariably the nose was exposed and most of the breathing done by the nose. He did not agree with the sweeping condemnation of all masks. There are processes in which the exposure risk is slight—men working on stone in the open, for instance—where a mask would so render the amount of dust breathed in negligible, and where it is not possible to draw off dust by exhaust. A mask made by Messrs. Siebe Gorman is being tried at a quarry where a man worked who died of silicosis. The mask is probably known to you all; it consists of a light rubber face piece, inhaled air has to pass through numerous wafer-like cotton filters, the expired air passing out by means of mica valves. He had worn one in an intense concentration of dust made by throwing it on his face and the back layers of the filters have, as far as ordinary observation goes—which he admitted is not far—been perfectly clean.

A mask which will mean the man being connected by a length of tubing to a main air supply will be limited in its application.

Dr. Cunningham described a mask of positive pressure type consisting of cloth covering the face, to which air is delivered, sufficient to keep the mask ballooned. The air escapes from the sides and front due to an air pressure inside, high enough to prevent ingress of air containing dust or fumes.

Dust counts in samples of air from inside were very low.

Granite cutters are wearing the mask without complaint except for the low temperature of air delivered during the first fifteen minutes of operation in winter time.

The mask is comfortable, inexpensive and effective, but limited in use to those who are relatively stationary at their work.

Dr. Böhme: Masks were objectionable because of the resistance to respiratory air. Masks were, therefore, being introduced presenting a large surface of small mesh which gave a higher resistance to dust and a smaller resistance to air.

IV. Adhesion of Dust by Hygroscopic Methods

The Chairman: These methods had shown no advantage over water, and since at that time the disadvantages of water had not been fully realised no further action was taken.

Dr. Orenstein suggested that Professor Hall might consider research into the question of masks on a labyrinth system without a filtering medium.

The Chairman read the following letter received from Mr. Ussher:

USSHER AND HALL INVENTIONS, PTY. LTD.

P.O. Box 3450, Johannesburg, 14 August 1930.

W. Gemmill, Esq.,
Chamber of Mines, Johannesburg.

DEAR MR. GEMMILL,

Re Silicosis.

As you may remember, I spent over a year underground in research *re* dust laying.

When a solution of crude treacle was used during blasting, no dust could be blown off the drive walls, etc., either a few minutes after blasting, or next morning.

When drives were sprayed twice within five or six weeks, the rock faces remained wet and sticky for over a year in places where water dried up in less than an hour.

Dust laid once by treacle was apparently laid for years—if not permanently. The cost of the process was only a fraction of the cost of dust-laying with water.

The then Government Mining Engineer reported to Parliament that “water would do all that treacle did, but that the effect of treacle was apparently permanent”.

In a second report he claimed, as a proof of the efficiency of water, that in a series of thirteen tests on the City Deep, the average dust content of the samples taken was only 1.6 milligrams, but this result was almost entirely due to treacle and not water.

I was informed that the Medical Officer on the City Deep reported that the death rate for the year had gone down from the highest on the Rand to the lowest, and that the number of cases of pneumonia among the natives had decreased by 50 per cent.

After considering all the reports of the experts and their tests, Sir Lionel Phillips decided to introduce my process in all mines controlled by the Central Mining and Rand Mines Corporations.

The Chamber of Mines opposed my patent, but Mr. Justice Wessels decided, after hearing the evidence, that I had proved the efficiency and novelty of my process, and ordered the patent to be issued.

The then Government Mining Engineer, having insisted that the Regulations as to the use of water must be carried out strictly, it was useless to proceed to lay dust with treacle, only to wash it all away next day.

Where treacle is used, no water-sprays are necessary, and no miner need get wet or work in over humid atmosphere from that cause. The relationship of the quantity of water used to eliminate the dust is roughly 500 gallons of water only, as against 1 gallon of treacle solution.

Even Mr. Stuart Martin, who was at first rather hostile to the process, afterwards said that in his opinion the use of my process would become more essential and inevitable as our mines increased in depth.

My patent has expired and I have no financial interest in the use of my process, but I would be glad of an opportunity of giving the results of my former labours to the Conference, and of answering any questions they care to ask me.

Yours faithfully

(Sgd.) *Lancelot Ussher.*

Dr. Orenstein: Treacle and other fluids had already been tried. The fall in the incidence of pneumonia was universal all over the reef, but it had not been sustained. A hygroscopic substance retained the large dust but minute dust did not settle on treacle, and even with the use of water treacle would be washed away.

The Chairman: The advantage of treacle was that it might reduce the use of water and thus reduce the humidity.

Mr. Roberts: The Mining Regulations required the use of water in quantity, and it was, therefore, impossible to experiment with hygroscopic substances.

Dr. Orenstein: The reporters should bear in mind the possibility of experimenting with hygroscopic and other sticky substances.

Mr. Phelan: The discussion had seemed to show that the dangerous dust might consist of particles so small that they were invisible. He had considerable diffidence in venturing anything in the nature of a suggestion to experts of such recognised competence as the members of the Conference, but the methods of counting dust particles to which reference had been made were apparently not applicable to the counting of particles of this minute size. He wondered, therefore, whether it would not be possible to adopt for the purposes of a dust count the experimental method used by J. J. Thomson for the counting of the number of ions in an ionised gas. The method followed was a simple one. A known volume of the gas was enclosed in a bell jar and ionised. The gas in question was given a degree of humidity and was ionised for example by exposure to X-rays. A sudden reduction of pressure caused the formation of a fog, the water condensing on the ionised particles. The fog was allowed to settle in the bell jar and the rate of fall of its upper surface was observed.

A formula discovered by Stokes established a relationship between the size of the drops and the rate of their settling and the diameter of the drops could, therefore, be calculated. If the total amount of condensation were measured, i.e. the volume of water condensed, the number of drops could then be calculated. It seemed to him that this method could be applied to air containing minute particles around which the water would condense instead of round the ions.

Dr. Orenstein: He believed that the British General Electric Company were experimenting with a method of this kind but he had been unable, as yet, to obtain their apparatus. Photographic and photo electric methods of dust determination were being tried.

(The Conference adjourned at 12.50 p.m.)

FOURTH SITTING

Monday, 18 August 1930, 9.30 a.m.

Chairman: DR. L. G. IRVINE

AETIOLOGY AND PATHOLOGY OF SILICOSIS

Dr. Mavrogordato: Some dusts acted favourably and others unfavourably on silica. Very little was known about their particular behaviour. Any inert, relatively insoluble dust which got into the lungs in sufficient quantity favoured fibrotic conditions; silica was only relatively insoluble.

A dusty lung was a wounded lung and its cleanliness or dirtiness, in the surgical sense, was of great importance. The terminal bronchioles and vestibules were the first places attacked and if they were damaged

the dust which had once passed the terminal bronchiole stayed where it was.

Observation had shown that the smaller incidence of silicosis among natives, as compared with Europeans was due to intermittent employment; natives who were employed continuously developed silicosis more rapidly than Europeans. The sputum of broncho-pneumonia cases indicated that a good deal of dust and pigment might be got rid of during broncho-pneumonia. The natives braved exposure to silica dust and subsequent rest enabled the bronchiole epithelium to recover and eliminate much of the dust by the same way in which it entered the lung.

As regarded the infective element, practically every fatal case in the Witwatersrand fields died with tuberculosis. But tuberculosis was not the only infective factor. Experimentally he had had no difficulty in producing chronic unresolving pneumonia by intra-tracheal injection of an animal that had previously been exposed to silica dust. There must be a definite infective element if simple silicosis progresses. One problem was to find out whether silica rock, like certain other inorganic material, set up an allergic state in the tissues and whether tissues which were allergic to silica were also allergic to tubercle. The relation between certain dusts and a subsequent tuberculosis might be explained if the dust which affected the same tissue as the tubercle toxin not only rendered it allergic to itself, but also allergic to tubercle without any secondary immunity to tubercle. He asked what intractable silicates would do in the absence of free silica and what certain other dusts would do which had been retained in the lungs of the silicotic, in the absence of silica?

Professor Kettle: Nowhere was there such an abundance of pathological material as in Johannesburg and he hoped to learn a great deal during the Conference. He was particularly anxious to hear more about the dry bronchiolitis which was apparently an early manifestation of silicosis. This condition might influence the deposit of silica in the lungs in several ways. Because of the destruction of the bronchial epithelium there might be a deficiency of mucus in the air passage, and dust might therefore pass more easily into the pulmonary tissue; or, because of the breaking down of a cell barrier dust-containing phagocytes might pass more easily into the peribronchial and pulmonary tissue; or the natural elimination of the dust from the lung might be interfered with. He would be glad to know in which direction this lesion was regarded as being particularly important.

He also hoped to have an opportunity of seeing more of the available material, and learning more about the histology of infective, especially, tuberculo-silicosis.

The suggestion had been made that silica might damage the tubercle bacillus as it did the tissues. This was to him a new conception because all his observations lead him to believe that silica aided the growth of the bacillus. This certainly appeared to be so *in vivo*, and he had a certain amount of evidence to show that silica added to culture media aided the growth of the organism *in vitro*.

How the silica acted in influencing the growth of the tubercle bacillus was still unknown, but it appeared likely that it was a metabolic phenomenon. He thought it was generally agreed that the action was a chemical one in that the silica undoubtedly was soluble in the tissues. This could be demonstrated by placing a suspension of silica in sealed collodion capsules embedded in the subcutaneous

tissues of rabbits. In two or three weeks the silica was dissolved and produced its effects on the neighbouring tissues.

He was also anxious to hear the opinion of the Conference on the animal of choice for experimental work on pneumoconiosis. From the anatomical peculiarity of its lungs, the guinea pig, which was so commonly used, appeared to him to be definitely unsuitable.

Dr. Gardner: Commenting on Dr. Mavrogordato's statement that ingested silica particles, in contradistinction to other types of ingested material, exert a preservative effect upon the phagocytes, he would like to call attention to the following observations.

Haythorn produced a limited degree of fibrous reaction in the ear of a rabbit by the injection of large amounts of coal dust. After the lapse of several months the injected particles are found in elongated compressed cells which resemble fibroblasts. If however an oedema is produced by constriction of the base of the ear or by immersion in very hot water the fibroblasts separate and the phagocytes again assume an ovoid or spherical form. This experiment demonstrates that the dust is still retained by monocytes and that it is not transferred to fibroblasts.

In the Saranac laboratory a variety of dusts, silica in various forms, granite, carborundum, aloxite, emery, etc., have been injected into the peritoneal cavity of guinea-pigs. At various intervals up to nine months thereafter samples of the peritoneal fluid when withdrawn still exhibit free phagocytes containing large quantities of ingested dust particles. If any of these cells are stained supravitaly, with neutral red, a delicate indicator of cell injury, there is no evidence that they have been damaged. Furthermore there is no evidence of disintegrated cellular debris in the *exudate*. However there is no way of marking the original host cells so that one cannot be sure that the dust particles may not have been taken up by a successive series of phagocytes. Nevertheless, as far as can be demonstrated, he has produced no evidence to show that ingested silica particles are more protective than any other type of dust. This line of investigation is still being pursued.

Professor Kettle had mentioned effects produced by silica dust upon the tubercle bacillus. He has been conducting a series of experiments to determine whether the development of a silicosis will alter the virulence of the bacilli of a superimposed tuberculous infection. For this purpose he has infected guinea-pigs by the inhalation of tubercle bacilli of an attenuated strain known in the laboratory as R. 1. In normal guinea-pigs such infection regularly produced isolated subpleural tubercles in the lung together with a massive involvement in the tracheobronchial lymph nodes. Macroscopic tubercle in the other viscera practically never occurs. Multiplication of the bacilli in the pulmonary tubercles brings about caseation after some four to six weeks. The bacilli then die off and healing of the focus by resolution within a period of eighteen months to two years is the result. The tubercle in the mediastinal lymph nodes likewise heals although there is often some residual fibrosis. Death from this infection almost never occurs.

If an animal, infected in this manner, be subjected to eight hours' daily inhalation of quartz dust over a period of two or more years it can be shown that after the elapse of three to five months the bacilli in the primary foci of infection do not die but apparently quite suddenly take on a new capacity for growth. The lesion spreads; at first locally and latterly by ulceration into the bronchi the organisms are distributed into all parts of the lung. The result is a generalised pulmonary tuberculosis, chronic in its course but usually fatal in outcome. The

pathological lesions are quite comparable to chronic tuberculosis in man, often with large trabeculated cavities. Macroscopic tuberculosis of the liver, spleen, and abdominal lymph nodes is the rule.

In order to determine if possible the cause of this renewed growth capacity of the attenuated tubercle bacilli in the silicotic lung, animals have been killed at intervals of one month after infection. Under proper aseptic precautions, portions of the lung, spleen and lymph nodes have been removed for culture and subinoculation into other animals. This experiment is not yet completed but in the majority of the sub-inoculated guinea-pigs the infection produced has been comparable to that produced by subcutaneous inoculation of cultures of the R. 1. strain, i.e. a non-progressive infection confined to the lymph nodes adjacent to the site of inoculation. In a certain number of sub-inoculated guinea-pigs the spleens have also been involved but such an effect can be produced by very large doses of this strain of tubercle bacilli. At the present time it would appear that the silicotic process in the lungs of the original series of animals has not increased the virulence of the bacilli used for infection but that a temporary alteration in environment has been produced which favours the continued multiplication of the organisms. Removed from this altered environment the bacilli again revert to their original state.

From the cultures obtained from the silicotic lung a study is in progress to learn whether bacterial dissociation is favoured by silicosis. No definite results are as yet forthcoming.

In vitro, bacteriological studies are in progress to discover whether the addition of silica in various forms to various culture media will favour the growth of the tubercle bacillus. Like Professor Kettle he had observed a definite reduction in the initial lag period after transplants have been made.

Professor Kettle had asked for an expression of opinion as to the most suitable animal for the experimental study of pneumoconiosis. At the Saranac Laboratory he had used guinea-pigs because of their cheapness and because large numbers may be kept in a relatively small space. As he would show in the lantern slides it is possible to produce quite typical silicotic lesions in this animal within a period of two years. However the rabbit has certain advantages. Its lung normally contains large amounts of tonsil-like lymphoid tissue located directly beneath the epithelium of the bronchi and bronchioles. If serial sections be cut through these areas it will be found that the general cuboidal or columnar epithelium lining the bronchi and bronchioles becomes attenuated and flattened over the centres of the lymphoid nodes. Such an arrangement permits a direct and rapid passage of dust-laden phagocytes from the air passage into the lymphoid tissue. As a consequence large quantities of dust soon collect in these regions which ultimately brings about the formation of silicotic nodules much more rapidly than in the guinea-pig.

He had unreported experiments on monkeys, two baboons and six rhesus monkeys exposed to the inhalation of granite dust. While far advanced fibrosis was produced after periods of one to two years, in every case accidental death from spontaneous tuberculous infection introduced a disturbing complication.

Before definitely deciding upon the most favourable animal for use in pneumoconiosis experiments he thought that other non-rodent mammals (cats, dogs, sheep and swine) less susceptible to spontaneous infection with the tubercle bacillus should be tried.

Dr. Strachan: As the result of observations made with Dr. Simson on the sputa of asbestos workers, they had come to the conclusion that the phagocytes had the power of elaborating a substance or substances, usually iron-containing, with which ingested particulate matter was isolated in the cell, and so the cell was protected against the action of this particulate matter.

In time the ingested particulate matter might be dissolved as could be demonstrated in the case of "asbestosis bodies".

Professor Loriga: In his opinion there was no material difference between the reaction of cells to various dusts; it belonged to the category of reaction by irritation. He did not believe in the chemical theory and considered that silicosis was not a different pathological entity to other pneumoconioses.

Sir Spencer Lister suggested the use of B.C.G. culture in experimental work on silicosis developing in dusted animals.

Dr. Gardner: Such experiments were being made in his laboratory.

Dr. Strachan (in introducing the discussion on the Pathology of Silicosis): In Dr. Simson's and Dr. Strachan's Report, they accepted as correct Miller's work on the lymphoid tissue of the lung, but subsequent investigations have led them to modify that acceptance.

They have examined a relatively large series of cases of status lymphaticus and have noted the distribution of the lymphoid tissue in the lung. There were no complicating lung lesions to obscure the picture. A series of photographs demonstrate that the lymphoid tissue in the lung is essentially and functionally related to the air-passages and to their terminations. The photographs show the absence of the tissue in the blood-vessel walls and also that where lymphoid aggregates occur in contact with pleura or trabecular the essential relationship is to the adjacent air-spaces. All the lymphoid tissue in the lung is functionally related to the air-passages and to their terminations. Any other apparent relationship is only accidental.

In cases other than those of status lymphaticus lymphoid tissue is present in the same situations though to a less degree. Any condition, such as silicosis, which may stimulate hyperplasia of lymphoid tissue will make it more manifest and they have frequently seen this in cases of silicosis.

The importance of the lymphoid tissue can be demonstrated from the atlas and from the series of large photographs elaborating the atlas. The dust cells accumulate in and around the sites where normally lymphoid tissue is present, but only round the smaller bronchi and the bronchioles and their terminations. They have never seen a true silicotic lesion in relation to the large cartilagenous bronchi.

There occurs a cellular fibroblastic reaction which terminates in a dense ball of hyaline fibrous tissue.

These lesions show first in the tracheo-bronchial glands, then in the pleural and finally in the lung substance.

There is a definite entity—simple silicosis—i.e., silicosis uncomplicated by infection, particularly tuberculous infection. This condition can progress to a considerable degree—even to massive fibrosis and in these cases biological tests for the presence of tubercle bacilli have proved negative.

In contra-distinction to simple silicosis there is a type in which infection plays a part and to which the term "infective silicosis" can

be applied. The chief type of infection is tuberculosis and then one may use the term tuberculo-silicosis.

The nodules are more exuberant in their fibrous tissue and more rapid in growth and central necrosis occurs early.

Degenerative changes of fatty nature sometimes followed by calcification are seen in simple silicosis but only very rarely is there necrosis. Necrosis may be taken as an indication of infection.

In the progress of the disease, in the simple type structures are displaced whereas in the infective type they are infiltrated and destroyed.

His experience during the last six years suggests that remote effects involving heart, liver and kidneys were not common in simple silicosis, and his impression is that such lesions are not any commoner in miners than in the general population; in infective silicosis where there is massive destruction and fibrosis associated with emphysema there may be however right-sided cardiac failure as a terminal phenomenon.

The picture of the "classical type" of miners' phthisis is in his opinion that of an infective silicosis.

Dr. Simson: Macroscopically, it is often difficult to distinguish between simple silicosis of massive type and tuberculo-silicosis.

Microscopically, some cases of tuberculo-silicosis show evidence of active tuberculosis in the lung tissue intercalated between the adjacent silicotic nodules. In other cases the usual signs of tuberculosis as evidenced by small round mononuclear cells, endotheloid cells, and giant cells are absent. Definite necrosis in the nodules, however, is present. In such cases, although tuberculosis might be suspected from the microscopical evidence, a biological test is the only reliable means of diagnosis.

He would add that in tuberculo-silicosis the tubercle bacillus is living on a medium mainly composed of fibrous tissue, and that this probably accounts for the slowly progressive nature of the lesion. In the lung tissue outside the limits of the silicotic nodules the disease advances much more rapidly as here the bacillus is living on a good medium which includes blood plasma.

The Chairman: It was a well-known fact that in tuberculo-silicosis infection was not readily communicable to members of the patient's family.

Dr. George asked the Chairman how he would decide whether death was due to or accelerated by silicosis and/or tuberculosis in the following cases:

- (1) When the cause of death is lobar pneumonia and simple silicosis is present.
- (2) When the cause of death is broncho-pneumonia and silicosis is present.
- (3) Death due to heart failure, with simple silicosis present.

The Chairman: He agreed with Dr. Strachan that the classical silicosis of former days had an infective element. Many of the miners then employed were Cornishmen who went home when their health began to fail and the majority of these were shown by post mortem to have died of tuberculosis. In miners who broke down suddenly and died, often within three months, there was rapid necrotic silicosis. But on the other hand many at that time died of heart failure with cyanosis and ascites and with no clinical signs of tuberculosis.

At the present day there was earlier manifestation of the tuberculous element, but there was enough normal lung left to place the patient in a better condition to control a tuberculous infection. The cases nowadays lived longer.

In reply to Dr. George he said that a certain rough justice had to be adopted. If a man had a well-marked silicosis and died of a primary cardiac lesion the Bureau would allow that silicosis had been contributory and the same applied to acute respiratory diseases.

Dr. Truter: At the time of the influenza epidemic of 1918 it had been impossible to differentiate between the case mortality of a man with a slight degree of silicosis and of a man with no silicosis at all.

Dr. Pringle: At Springkell Sanatorium and Wedge Farm Sanatorium it had been definitely concluded that fibrotic obstruction was an element in the cause of death; but these cases were not very numerous. The more impressive cases were those of simple silicosis suddenly breaking down. Post mortems had shown that the cause of the rapid breakdown was always the breaking down of a tuberculous infection.

Dr. Watt: In the influenza epidemic some men affected with a slight degree of fibrosis died, while others did better than the general population. He could not say whether the latter had acquired immunity in a previous epidemic.

Dr. Strachan: It might be worth while for the reporters to draw up a definition of silicosis and infective silicosis. A fresh report on the incidence of cancer of the lung should also be asked for.

Professor Kettle asked Dr. Simson for information on his experiments in inoculation, because it was well-known that tuberculosis in the guinea-pig was very variable in its manifestations.

Professor Böhme: There were a considerable number of cases of advanced silicosis in Germany which died of heart failure, with dilatation and failure of the right heart. These symptoms are due to fibrosis and emphysema of the lungs. The combination of silicosis and cancer was found only in the Schneeberger district, and was believed to be due to the inhalation of radioactive dusts.

Dr. Orenstein asked whether there was any experimental or pathological evidence to determine whether dilatation of the heart, and particularly liability to respiratory disease, was associated with pneumoconiosis.

Dr. Middleton referred Dr. Orenstein to the mortality data in the *Decennial Supplement* for 1921-1923 of the Registrar-General in Great Britain.

Dr. Kranenburg asked whether a person with a negative von Pirquet reaction was allowed to be employed in the mines. If so, was he treated with the Calmette vaccine?

The Chairman: It was impossible to make von Pirquet tests on the large number of men examined.

Sir Spencer Lister: Examinations carried out at the Institute for the past three years showed that 60 to 70 per cent. of the natives gave a positive von Pirquet reaction. The tests had been followed up in many cases and post mortems correlated with the results of the von Pirquet tests. It was found that a much larger percentage of deaths occurred amongst those natives who originally showed a positive von Pirquet reaction than amongst those whose reaction was originally negative. The Institute was at present experimenting with B.C.G. vaccine as a prophylactic in adults.

(The Conference adjourned at 12.50 p.m.)

FIFTH SITTING

Monday, 18 August 1930, 2.30 p.m.

Chairman: DR. L. G. IRVINE

Profesor E. H. Kettle showed microscopic preparations illustrating the modification of an artificial miliary tuberculosis by silica.

In the first series of experiments rabbits received four to eight intravenous doses of amorphous silica or of mine dust over a period of ten to fourteen days. They then received an intra-venous inoculation of living tubercle bacilli as did a control series of animals. In the animals prepared with silica, miliary tubercles were much more numerous than in the control animals, and bacilli were much more numerous in the lesions. The limitations of the experiment were discussed.

In the second series interstitial lesions were produced in mice by silica and other agents, particularly calcium. The mice then received tubercle bacilli intravenously. Tubercle bacilli are found in the silica lesions in much greater numbers than in the lesions produced by calcium.

A further series of sections illustrated preliminary experiments in the production of pulmonary lesions by the intra-tracheal injection of different forms of silica.

GENERAL TECHNIQUE OF DUST EXPOSURES

Dr. Gardner: Guinea pigs and rabbits are kept in cages along the walls of a room 6 by 8 feet in diameter and 8 feet high, provided with two windows 3 by 5 feet in diameter. A cloud of dust is maintained in the atmosphere of the room by apparatus located in an alcove, 6 feet from the nearest animal. This apparatus consists of a horizontal drum $2\frac{1}{2}$ feet long and $1\frac{1}{2}$ feet in diameter, placed 8 inches above the floor. Its top is open and in it rotates a metal paddle whose shaft projects from the end of the drum and then through the partition into an adjacent room in which is located an electric motor. By properly selected pulleys and counter shafting, the speed is so regulated that the desired dust concentration can be maintained. Ventilation is secured by opening one of the windows an inch or more from the top. The animals are kept, generally in pairs in 12 by 12 by 12-inch wire cages set on racks at the back and sides of the room. While it will be shown that the dust concentration progressively decreases from the floor to the ceiling, this factor is compensated by frequently changing the position of the cages on the racks.

As measured by the operation of the motor, the daily period of exposure is eight hours, but since the animals remain in this room during the night, the actual exposure is much longer, a considerable time being required for all the dust in the atmosphere to settle. In warm weather the period is somewhat shortened by opening the windows when the motor is stopped during the evening.

The dust concentrations employed for this work have approximated those of the worst industrial conditions. For asbestos dust we have maintained an average concentration of 46.5 million particles, 10 to 0.5 micra in diameter per cubic foot of air. Recently this concentration has been increased approximately ten times. In granite dust experimentation the concentration was much higher (288 million particles

per cubic foot). The figures for quartz and carborundum dust concentrations he neglected to bring with him but if his memory had not failed they are of the order of those mentioned for granite dust.

Marble Dust

The first experiments were made with marble dust from Proctor, Vermont. This substance contains less than 1 per cent. free silica. Exposure of normal guinea-pigs for periods as long as two years produced practically no changes other than a hyperplasia of the lymphoid tissues in the periphery of the lung, together with some dilatation of the deep lymphatic vessels.

Guinea pigs infected by inhalation of the low irritant strain of tubercle bacillus R. 1 did not develop a generalised pulmonary tuberculosis. But there was, however, a well-marked failure of the normal process of resolution in many of the tubercles associated with the development of calcification of their caseous centres. In the light of subsequent experiences with other dust this calcification is now ascribed to the fact that resolution was retarded and caseous matter was retained in the lung for a sufficient period for calcareous deposit to occur. A similar finding in carborundum dusted animals strongly suggests that the excess of calcium supplied by the inhaled marble was not the determining factor.

Granite Dust

The action of this dust upon the lung tissues is too slow to exert its maximum effects during the exposure periods possible in guinea-pigs. Inhaled particles are ingested by alveolar phagocytes which tend to accumulate in the air spaces along the terminal bronchioles and alveolar ducts. No evidence of fibrosis has been observed in the walls of such passages but only a slight chronic inflammatory infiltration. Considerable amounts of dust are carried by phagocytes into the lymphatic system. A certain number of dust cells can be found in hyperplastic nodules of lymphoid tissue in the periphery of the lung but no evidence of fibrosis is discoverable. Much more dust is accumulated in the tracheo-bronchial lymph nodes and here a true fibrosis of the silicotic type has been observed in animals exposed for two or more years. The lymph vessels in the lung are widely dilated from the hilum to the pleura but evidence of thrombi of dust cells is lacking. The cause of this dilatation was temporarily at least ascribed to the production of an obstructive fibrosis in the lymph nodes of the mediastinum.

Carborundum Dust

Inhalation produces in the normal guinea-pig a reaction similar to that of granite. Great masses of dust laden phagocytes are discovered in the terminal bronchioles and their alveoli. No nodular fibrosis has developed within a period of four years. In the tracheo-bronchial lymph nodes where much greater amounts of dust have collected there is true fibrosis which tends to be somewhat nodular in type. More marked than in any other dust studied are the changes in the connective tissues of the bronchi and large blood vessels. They are definitely thickened by the formation of extremely vascular granulation tissue which is infiltrated with numbers of lymphoid and phagocytic cells. Through this tissue course many greatly dilated lymph vessels.

Quartz Dust

The phagocytes which have ingested quartz particles exhibit a much greater degree of activity than those containing any other type of dust yet investigated. Instead of remaining for long periods in masses along the terminal bronchioles as in the case of granite and carborundum dust the quartz-filled cells which are present in great numbers actively migrate along the walls of the alveoli, atria, etc., until they reach the small terminal collections of lymphoid tissue. They surround these structures and rapidly invade them. The lymphoid elements at first undergo hyperplasia, but very shortly the newly formed lymphoid cells appear to decrease in number and are finally completely overshadowed by the mass of large clear-stained dust containing phagocytes. This collection of cells is then surrounded by a layer of cuboidal epithelium which sharply demarcates it from the surrounding tissues. Thus far no fibrosis is present but only a nodule perhaps similar to that which Dr. Mavrogordato has called a "pseudotubercle". In the centre of this area where innumerable particles of quartz have been concentrated fibroblasts begin to make their appearance. Their source has not been determined; they may have come from the original reticulum of the lymphoid nodule. A cellular fibrosis gradually replaces the entire nodule of phagocytes. Degenerative changes make their appearance at its centre and later the structure assumes the characteristic hyaline appearance of the fully formed silicotic nodule seen in the human being. Presumably the majority of the larger lesions form in the manner described about nodules of peripheral lymphoid nodules. Some may also develop within the alveolar septa or at least these become greatly thickened and often encroach upon and ultimately close the adjacent air spaces.

More rapidly than with other dusts, quartz particles are carried into the tracheo-bronchial lymph nodes and there provoke nodular fibrosis even earlier than occurs in the lungs.

The lung of the rabbit presents peculiar anatomical conditions which favour an early development of well-marked silicotic nodules. The lymphoid tissue being directly under the thinned-out bronchial epithelium can apparently "collect" phagocytes from fair-sized air passages with great rapidity. A case of extensive silicosis in the rabbit is illustrated in which dust exposure was continued for 6 months followed by a period of one year in a normal atmosphere. In rabbits killed at the end of the dust exposure there were great numbers of dust cells in the lymphoid tissues but fibrosis had barely begun to occur. After the elapse of the following year little or no elimination of the dust apparently occurred but on the contrary fibrosis had progressed at a rapid rate. The tracheo-bronchial lymph nodes, 18 months after beginning the exposure, are almost completely replaced by hyaline fibrous tissue.

Asbestos Dust Inhalation

The reaction to this dust has differed markedly from that of any of the above-described particulate dusts. Instead of coming to rest in the terminal alveoli as is the case with these types, asbestos particles and fibres are apparently largely caught in the irregular walls of the respiratory bronchioles. There, phagocytes engulf the dust particles but they do not, in the guinea-pig, migrate with them to the lymphoid tissues. Instead they remain *in situ* and as more particles are inhaled they tend to accumulate in the same location. Some of the material

is carried by the phagocytes directly into the walls of the near-by air passages. Solution of the dust takes place as indicated by the development of "asbestosis bodies". Possibly stimulated chemically by the dissolved silicate of magnesium, the fibroblasts in the walls of the respiratory bronchioles begin to proliferate and ultimately a tube-like formation of delicate fibrosis envelopes these structures. Contraction of this connective tissue constricts the air spaces so that their epithelial lining assumes the cuboidal forms of the atelectatic lung. This gives the involved area a gland-like appearance. The development of asbestosis bodies is thought to be a result of hydrolysis and solution of the magnesium silicate of the asbestos molecule. A theory of their formation is discussed. The reaction to inhaled asbestos dust within a period of two and a third years is strictly localised to the respiratory bronchioles. Intra-pulmonary and mediastinal lymphoid tissues play no obvious part in the defence against this dust.

The reaction of the rabbit's lung differs from that of the guinea-pig in that phagocytes do carry the inhaled asbestos into lymphoid tissues in this animal. Furthermore no typical asbestosis bodies have been discovered in this animal; evidence of fibrosis is likewise lacking. However the observations in the rabbit have only been carried over a period of 330 days.

Albino rats have also been employed and in them it has likewise proved impossible to discover an appreciable number of asbestosis bodies. The high frequency of pulmonary abscess in these animals may have been responsible for preventing the inhalation of an effective quantity of dust.

Radiograms of the silicotic and asbestosis guinea-pigs, taken both during the life of the animals and again after the lungs had been removed from the body have been shown. They demonstrate that much greater evidence of disease can be detected in the somewhat over-distended lung which has been removed from the thorax. The appearances are comparable to those encountered in human disease. In the discussion it would appear that the reaction to inhaled asbestos and to a lesser extent to granite and carborundum is analogous to the condition described as bronchiolitis by the South African observers.

From these studies of the effects of various types of inhaled dust it will be noted that connective tissues react to produce fibrosis in various portions of the lungs or their lymphoid tissues. With granite and carborundum fibrosis has been observed only in the tracheobronchial lymph nodes; with asbestos dust the reaction is confined to the walls of the respiratory bronchioles; with quartz dust reaction occurs both in intra- and extra-pulmonary lymphoid tissues as well as in the fine alveolar septa. It is believed that the difference in localisation of various dusts is a function of the action of these dusts upon the phagocytes which ingest them. Possibly this may be due to the degree to which the cells become filled with dust particles. Overloading would mechanically impede the migration of the phagocyte. In the case of asbestos dust the size of the ingested particles may also hinder transportation. As a working hypothesis it is proposed that any dust possessing the necessary chemical composition will provoke fibrosis when and where the phagocytes concentrate it in sufficient quantities in contact with pre-existing connective tissue cells.

Sir Spencer Lister: It was essential for the Conference to reach a conclusion on the question whether silicosis developed as a primary condition or was always dependent on a prior infective process, usually

tuberculous in nature. The animal experimentation seemed to point to the former conclusion.

Dr. Gardner: Care was taken to eliminate tuberculosis as a spontaneous infection.

Dr. Strachan: Dr. Gardner had shown how investigation into the effect of dust on the lungs should be carried on, and the difference between phthisis and non-phthisis dusts, viz. whether they were brought into contact with the connective tissues or not.

Dr. Moore: The necessity for dependence on radiographic findings in the diagnosis of silicosis and industrial pulmonary fibrosis in general has led to the use of diagnostic standards which must be regarded as very largely arbitrary in nature.

With this fact in view, a series of experiments has been undertaken at the Commonwealth Health Laboratory, Bendigo, with the object of correlating the radiographic with the histological findings in experimental animals subjected to conditions calculated to reproduce those experienced by miners working underground on a quartz reef.

The following report represents an interim statement of work accomplished to date, and the research is still proceeding.

Choice of animals. — The animals chosen for the experiment were Australian rabbits which were in the wild state at the commencement of the experiment. Many of them were not fully grown at the time of capture. Very little difficulty was experienced in keeping them in good condition during experimentation, and only three out of 120 died from illness or injury during the course of over six months. The normal life of these animals is three years.

Scheme of investigation. — In order to reproduce underground conditions of dusty atmosphere as closely as possible, boxes were constructed approximately 10 by 11 inches in area and 9 inches deep, provided with an inlet vent about three inches from the floor at one end, and an outlet vent near the lid at the opposite end. These vents were $\frac{1}{2}$ inch in diameter.

For the purpose of convenience in handling, these boxes were constructed in rows of ten and provided with a hinged lid over the whole length of the row, sawn at intervals to enable one box to be opened at a time. The interior of each box was fitted with a glass jar into which dipped a short length of curved piping connecting the interior of the jar to the inlet vent. In each jar was placed finely-powdered dust to a depth of 1 or 2 inches.

The animals were placed one in each compartment for one hour daily six days in each week, and, by means of a bellows, a dusty atmosphere was maintained in the box throughout that period. This atmosphere was sufficiently dust-laden to cause a readily visible haze in the box, and was maintained by blowing at five-minute intervals. During the rest of each day and at the week end, the animals were allowed to feed and rest in the pens.

The animals were weighed each week and weights recorded.

Variations in treatment. — The rabbits were divided into series for the purpose of representing the possible phases of simple silicosis and silicosis complicated by tuberculosis.

Series 1 comprised animals treated by quartz dust only.

In Series 2 the animals were treated throughout the experiment by quartz dust mixed with killed *B. tuberculosis*.

In Series 3 the animals were treated for three months with quartz dust only and after that with dust mixed with killed *B. tuberculosis*.

Series 4 is represented by animals subjected to the inhalation of killed *B. tuberculosis* for five minutes daily for seven days; then, after a fortnight's interval, subjected to daily dusting with unmixed quartz dust.

A fifth Series was treated by intra-pulmonary injection of 1 milligram of *bacillo-casein*¹, and then by daily dusting with unmixed dust.

These series were controlled as follows:

Series 1, 2, and 3 were controlled by rabbits to which no treatment was administered. Series 4 and 5 received treatment by killed bacilli and bacillo-casein respectively, but no further dusting.

The treatment of the series has been continued to date for a period of over six months in the case of Series 1.

Preparation of dust. — The dust used was obtained from mine dumps in Bendigo and was crushed to pass through a 200-mesh screen. The analysis of the dust is as follows:

	Per cent.
Silica SiO_2	92.46
Ferric oxide Fe_2O_3	6.27
Alumina Al_2O_3	0.53
Loss on ignition	0.36
Undetermined	0.38
	100.00

The dust concentration maintained in the boxes during the experiments has been estimated by the Owen's dust counter and has averaged 5,300 particles per cubic centimetre within half a minute of blowing, 2,200 within five to five and a half minutes of blowing and 2,000 within ten to ten and a half minutes. Thus a high dust concentration has been maintained in the boxes throughout the experiments.

Preparation of bacilli. — A human strain of *B. tuberculosis* obtained from the Commonwealth Serum Laboratories was cultured on glycerin bouillon medium for six weeks, then autoclaved at 120° C. for fifteen minutes. The culture was then filtered through paper, washed with saline, and the residue dried in a hot-air steriliser for three hours at 120° C. The dried killed bacilli were then ground in a mortar and bottled.

As required this bacilli dust was mixed with the quartz dust in a proportion estimated to subject each animal to a daily dose of 0.06 milligrams. The quartz dust was baked to destroy other infective agents prior to mixing.

The process described, according to Calmette², should not affect the toxicity of the bacillary endotoxins. Accordingly, this method was used to provoke a tissue response in the experimental animals with a view to providing a parallel to an exceedingly mild or unobservable tuberculous lesion in human beings.

For animals in Series 4 who were subjected to the inhalation of pure killed bacilli prior to dusting, a special box was made with glued and

¹ CALMETTE: *Tubercle Bacillus Infection in Man and Animals*, p. 53. 1923, English edition.

² *Op. cit.*, p. 70.

morticed joints. This box was divided into two compartments, a small one which contained the bacillary dust communicating with a larger one for the body. Two small observation windows were provided.

General procedure. — The rabbits were identified by numbered leg bands and were weighed weekly and the weights recorded. Those receiving infected treatment were segregated from the others, and boxes used for this treatment were not used for other animals.

From the commencement of dusting, animals from each series and control group were killed at stated intervals, a post mortem examination made with particular regard to the condition of the lungs, the lungs and heart weighed, the lungs radiographed by a special method and macroscopic preparations and microscopic sections prepared.

In Series 1 and 2 one rabbit from each was killed weekly for eight weeks, then one fortnightly for a further eight weeks; since then animals have been killed at four-weekly intervals. In Series 3, five rabbits were killed at intervals during sixty-seven days' dusting with infected dust, after two to two and a half months' dusting with simple quartz dust. In Series 4, the dusting period extended from seven to sixty-eight days in different rabbits, and in Series 5, from seven to thirty-nine days. Normal controls were killed at four-weekly intervals and controls to Series 4 and 5 at intervals of two or three weeks.

Method of killing animals. — At the commencement of the experiment, chloroform was used to kill the rabbits, but this was found to produce intense pulmonary congestion and was abandoned in favour of electrocution. It is not certain that this method is ideal, as in certain of the normal control animals a good deal of pulmonary congestion was observed. The first and second series of dusting were repeated on a fresh set of animals up to the eighth animal, using electrocution.

Examination. — At the post-mortem examination, after inspection of the lungs *in situ* the larynx was severed and the heart and lungs removed together. The heart was then removed and weighed, and the lungs were weighed also. One lung was then tied off at the bronchus for histological purposes and cut off.

Radiography. — The remaining lung with the larynx was then placed in a specially constructed vacuum box and inflated by negative pressure therein. Radiographs were then taken by a special technique for soft tissues.

Preparation of specimens. — The remaining lung was then dissected for the preparation of macroscopic colour specimens and for microscopic sections.

Results of examinations. — At this period, after six months' observation in the case of Series 1, and somewhat shorter periods in the other Series, the microscopic sections and radiographic films have been examined and the weights of the heart and lungs compared with the body weights.

Weights. — Comparison of the weights of the hearts freed from the vessels and the lungs and bronchi with uniform portions of the larynges with the body weights at death has failed to reveal any constant ratio. This is probably due to several factors amongst which varying stages of maturity of the subjects and the varying presence of acute infections and congestion are probably the most important. No constant growth curve has been obtained either, probably largely on account of the second factor mentioned above.

Microscopic sections. — The examination of these sections has hitherto

revealed few evidences of chronic change in the lung tissues although, in the later sections, an increase in the amount of fibrous tissues appears.

The characteristics observed relate to acute changes typified by peribronchial and sub-pleural vascular engorgement with patchy areas of pneumonia. Pleural thickening has been observed in some sections. These acute manifestations appear to come in waves, although there is a wide variation among individual animals in response to the treatment. Reaction appears to be more general in animals receiving tuberculous treatment.

Radiographs. — Certain films of the series show evidence of patchy pleural thickening, others show an increase in the strength of peribronchial markings, while others again show a general clouding of the tissues, in some cases approaching a mottled appearance. The typical picture of radiographic silicosis has not yet been obtained.

Correlation of radiographic with histological results. — Comparing notes from the microscopic sections, it becomes evident that the cloudy appearances on the films are due to acute pneumonic and congestive areas in the lungs. The chronic effects of dust inhalation are not so far evident radiologically.

Discussion. — At this stage in the experiments few conclusions can be drawn, but advantage has been taken of this unique occasion to present a progress report. Underground conditions have been fairly paralleled by the experimental conditions, and accordingly, it is hoped that the near future will show us the development of a chronic fibrotic pulmonary condition.

The observations completed so far, however, are not without interest in view of the greatly increased incidence of pneumonia among miners on new fields where a large proportion of the workers are young men, new to the occupation. This incidence and the mortality rate, are found to decrease as the years advance.

This feature has been discussed at length in the Report of the Royal Commission on Pulmonary Disease amongst Miners in Western Australia, 1911 (J. H. L. Cumpston), and the case is cited in this report of a young man, killed by an explosion while at work, whose lungs revealed at post-mortem examination, a pleuritic patch, and an apical area of pneumonia. This man had been employed underground for one year.

The incidence of pneumonia during the early days at Broken Hill (Australia) was pointed out by Armstrong and the South African experience in this direction is well known.

It is noteworthy that practically none of the animals killed showed emaciation or poor physical condition. The few exceptions were those suffering from hydatid infestation or from injuries inflicted by the other animals.

At the present time a few animals of Series 1 and 2 remain. Dusting has been suspended for the present and these animals will be killed and examined a later date.

(The Conference adjourned at 5 p.m.)

SIXTH SITTING

Tuesday, 19 August 1930, 9.30 a.m.

Chairman: DR. A. E. RUSSELL

A letter from Messrs. Kodak (South Africa), Ltd., was read, in reply to the Chairman's letter of thanks for the albums presented by Messrs. Kodak to the members of the Conference.

The Chairman requested Dr. Russell to take the Chair, as he was himself partly responsible for some of the papers now to be discussed. Dr. Russell took the Chair.

THE DIAGNOSIS OF SILICOSIS AS AN OCCUPATIONAL DISEASE

Dr. Irvine: The practical diagnosis of silicosis as an occupational disease was of great importance from the medico-legal point of view. It appeared to him also to be a subject upon which a considerable measure of agreement might be reached by the Conference. Although there were minor variations in the type of the disease met with in different countries the evidence adduced showed that it was everywhere substantially the same disease. Its general type for example was the same at Broken Hill in Australia as in South Africa despite the difference in the silica percentages in the respective rock dusts.

The standard of diagnosis which was needed was that of a condition of silicosis which either caused slight incapacity at the moment or which was of such a nature as to be a potential cause of incapacity in the future. It had to be a standard which was fair to both parties concerned, the workman and the employer.

It was claimed that such a standard could only be reached by a careful correlation of the results of pathological, radiological and clinical examination in a large series of individual cases. The Medical Bureau working together with the pathologists who carried out the routine pathological work on its behalf had been able to carry out such a correlation in a series of 400 cases.

The practical result was to show that *when interpreted in the light of such a correlation* a technically perfect radiograph taken instantaneously formed the most reliable single criterion in diagnosis. It was necessary, however, to supplement the radiological examination by a thorough clinical examination, including an investigation of the examinee's industrial and medical history before a final decision could be reached in any individual case.

The evidence obtained of the effect of the inhalation of silica dust in excessive quantities over prolonged periods was to show that it had in general the following phases:

1. A "*bronchial phase*" consisting mainly of the production of a dry bronchitis and bronchiolitis. This phase when fully developed appeared to give the radiographic picture of a generalised ramifying "fibrosis" or "commencing generalised fibrosis". There were already in this phase aggregations of pigment-bearing phagocytes.

But it appeared to him that the question of what was happening in the lung and respiratory passages during the long period of

exposure prior to the development of actual silicosis required further investigation, both experimental and by observation in the human subject.

2. A simple "nodular phase" based anatomically mainly upon the small aggregations of lymphoid tissue in the lung. This condition was actual "silicosis". It was a distinct and definite pathological entity characterised by a palpable miliary nodulation under the pleurae and in the lung substance, with fibrosis of the root glands. This condition dominated the picture of a clinically "simple" silicosis, and was progressive up to a point even in the absence of infection. But probably only in a minority of cases did it constitute the whole picture even in a clinically simple silicosis, since in a majority of cases of that condition some small latent focus or foci of tuberculous infection was commonly already present.

3. Ultimately in most cases of silicosis there arose an "infective phase" in which the silicotic process was modified by the presence of chronic infections and particularly by a chronic tuberculous infection with the production of areas of "massive fibrosis". Extensive massive fibrosis in a silicotic lung was usually of infective origin and the infection was most commonly tuberculous. Such lesions were apt to be slowly progressive, but might undergo prolonged arrest and might cause no constitutional symptoms. There was applied to them in a general sense the term "infective silicosis" or in a restricted sense the term "tuberculo-silicosis".

But one did not classify cases as "tuberculosis with silicosis" unless an active clinically detectable and deteriorating tuberculosis was present.

In individual cases of silicosis there were many variations in the course and type of the disease dependent mainly on the relative preponderance of the dust factor or of the infective factor, and on the earlier or later manifestation of the latter.

Tuberculous infection might affect a silicotic lung before silicosis developed, or secondly a limited reinfection of the lung might occur simultaneously with the development of the silicotic process, or thirdly, reinfection might occur after the silicotic process was established. The development of a limited area of tuberculo-silicosis at the site of an old persistent focus of primary infection was shown to the Conference.

There was accepted the importance of the view that silica was a soluble cell poison and that this circumstance is a factor in creating a predisposition to tuberculous infection, but this factor did not appear to enhance the virulence of the infection. One would emphasise the feature that a tuberculo-silicosis, as defined, was generally a process of low virulence, with frequently long periods of arrest, with a slow spread in the lung and to other organs, and with a low transmissibility of infection to other people.

As regards the practical definition of silicosis, a sparse palpable miliary nodulation of the lung was the South African definition of a slight degree of silicosis. In some cases of slight tuberculo-silicosis however there might be no disseminated miliary nodulation but merely a few limited areas of massive fibrosis in the apical or sub-apical regions with a scattering of infective nodules in their neighbourhood. Either condition would be shown in a good radiograph.

(A number of cases illustrating the correlation between the radiographic appearances and the actual pathological condition present in cases of silicosis were then demonstrated.)

In arriving at a standard of diagnosis for purposes of compensation it would be wise to rely as a general standard on the type of radiograph which showed indications of commencing nodulation, since this was definitely representative of a slight degree of silicosis. A certain amount of deviation from this standard might be allowed but only to expert examiners. The Bureau for example, as the result of its experience of the correlation described, recognised cases showing the radiographic appearances of a simple generalised arborisation, especially if accompanied by evidence of an infective element, as indicative of silicosis, provided these appearances had arisen in a miner under observation and were accompanied by definite evidence of respiratory disability.

He had no personal experience of any other type of silicosis than that produced on the Rand.

The South African Act recognised two conditions, "silicosis" and "tuberculosis with silicosis". "Silicosis" however might be predominantly "simple" in type without any indication of infection, or "partly infective" in type, in which group indications of latent infection were present. But one did not speak of "tuberculosis with silicosis" unless an active clinical deteriorating tuberculosis was present.

Some practical definition was needed from the pragmatic standpoint of what constituted silicosis, and he would also like to see the Conference come to some agreed classification of radiographic films.

Remarking on the tabulation in Paper 10 of the causes of death in cases of silicosis, he called attention to the preponderant role played by tuberculosis as the immediate cause of death and the relatively minor role played by acute respiratory diseases. In this connection however it was to be noted that in all cases in which active tuberculosis was demonstrably present that condition was returned as the cause of death although in some cases it was not the immediate cause.

He briefly called attention to the observation that the original physical type of the affected man has an important bearing on the type of the disease which is contracted and upon its clinical course.

Extensive investigations into physical tests had been carried out in the mining districts of Western Australia. A limited investigation of this nature had been made at the Bureau. These were the tests applied in the Air Force and similar organisations. In these institutions the man was bent on doing his best, as his job depended on his physical condition, but in the class of man whose financial outlook would be governed to a large extent by his doing his worst, he did not think that this means was helpful in estimating disability.

Disability was estimated from a clinical examination, the history of the man, and the general impression he made. In ordinary routine work the disability was estimated by common sense clinical methods. In the ante-primary stage the disability might be nil and did not exceed 25 per cent. In the primary stage disability due to the disease ranged from 25 per cent. to 50 or 55 per cent. More than 60 per cent. disability justified inclusion in the secondary stage.

Dr. C. Badham: He wished to draw attention to the fact that, although they found in certain industries, such as the Broken Hill silver mines, radiographic appearances which closely resembled those found in South Africa, nevertheless, remembering that they were dealing with a dust containing certainly not more than 15 per cent. of free silica, the rest of the dust being composed of intractable silicates, he was in no way convinced that the disease which they found in Broken Hill was the pure type of silicosis found in Johannesburg. The difficulty in their case was that they had in their State an Act which excluded from

compensation men who had been affected by silica dust. Many of these men had worked in dusts containing percentages of silica ranging up to 35 per cent., and from observations he was by no means convinced that the silica was the whole story of their disease. He found confirmation of that view in the fact that where they had, as in Broken Hill, 85 per cent. of silicates, most of them intractable, they found in the lung after death intractable and other silicates. It was therefore reasonable to assume that silicates had a considerable effect on the production of fibrous pneumoconiosis.

In regard to the inoculation of guinea-pigs with simple silicotic nodules, if the tubercle bacilli were of only low virulence, as those described by Dr. Gardner, he took it that such slight reaction would not be overlooked by the pathologists in the inoculation in Johannesburg of the simple silicotic nodules.

Dr. Gardner: The reaction was slight as far as generalised tuberculosis was concerned. This low virulent strain of bacilli injected into the guinea-pig often produced an enlarged, firm, palpable nodule, which could not be overlooked. He doubted very much whether the lesions produced by a human silicotic tubercle bacillus would be as slight.

Dr. Middleton: In Great Britain they had a series of conditions ranging from the inhalation of silica dust, containing about 98 per cent. free silica, down to dusts which contain a negligible quantity of free silica, or none at all. Medical examinations with radiological examinations had been made, and showed that the effect on the lung seemed to bear a relationship to a true silicosis in so far as the dust to which the sufferer was exposed contained free silica. By that was meant a type of silicosis produced by free silica dust similar to the dusts produced in South Africa. All the granites in Great Britain were not like the true granite of Vermont. They varied chemically, from about 33 per cent. of free silica to a low free silica percentage. In cotton and other textile workers there was a peri-bronchial type of fibrosis, which approximated to the fibrotic picture obtained in the low silica containing dusts. It was necessary to have names for other conditions which arose, because if compensation was made in respect of them, the awarding of such compensation would depend on the definitions and the indications given for making the diagnosis.

Dr. Russell: Vermont granite had a fairly consistent composition of silica. The average temperature half the year round was 36° F. The workmen worked in closed places, and they had very high percentages and a fairly consistent type of silicosis developing pneumonia. That was directly comparable to other parts of the States, where the men worked in the open, and did not require heating, and were also not in close proximity. In the South they had completed a study in the cotton industry, and found that the X-rays from these cotton workers were quite different.

Dr. Böhme: Edling in Sweden has described pneumoconiosis amongst miners in the Swedish coal mines. The coal worked in these mines is very soft and free from mineral impurities. The Röntgen picture resembles that of silicosis. Anatomical examination has, however, revealed that no fibrosis of the lung occurs, merely filling up of the alveoli and bronchioles with coal dust, together with atelectasis and congestion of the contiguous portions of the lung. Very varying anatomical processes may produce similar Röntgen pictures.

The forms of pneumoconiosis caused by silicates and coal require to be subjected to profound anatomical examination before the Röntgen picture can be accurately interpreted.

Professor Kettle: What was the exact anatomical lesion in the X-ray plates of ramifying fibrosis? In fig. 5 of the paper entitled "The Clinical Pathology, Radiology and Symptomatology of Silicosis", he could not see anything in the microscopic picture to correspond with the cases pictured there.

Dr. Fisher: He had been impressed by the small variety and amount of exposure to silica dust, and the gross changes found in the lungs after death. He had also been struck by the fact that although large cavities appeared in the lungs, the pathologist always insisted that there was absolutely no sign of tuberculosis. He thought that in future cases they should try to get biological tests carried out in some of these lungs.

Dr. Cunningham: The South African classification described by Dr. Irvine was in use in Canada. The cases among miners and granite cutters were divided into these stages for practical purposes. In addition however there was at least one other group of cases which had a mixed fibrosis, which the pathologist described as being due not to silica alone nor to tuberculosis alone, with little or no nodulation.

Professor Hall: Perhaps the most important point discussed was the attempt to come to some general agreement on the definition of silicosis, the definition of how it was to be recognised, and how some lead could be given to countries which had to consider the question of legal arrangements. There were one or two points on which he would like information. Was bronchiolitis one of the early conditions which arose in these miners? A great difficulty was to understand the position as regards tuberculo-silicosis. In considering the nomenclature, they had to consider the difficulty of the layman, who rather objected to the term "ante-primary". He would like to know if there was a simple silicosis of any importance apart from tuberculo-silicosis and silicosis with tuberculosis. Was it to be supposed that persons who became infected with tubercles and died of open tuberculosis later, had gone through a stage of tuberculo-silicosis which eventually had come into a stormy condition, or had they had a simple silicosis throughout until they got a late infection?

Dr. Irvine: To label a case "tuberculo-silicosis" and not a case of "tuberculosis with silicosis" was in a sense illogical, but there was a clinical and pathological distinction, and that was why the term "tuberculo-silicosis" was used. There were men who continued with their work, showing no constitutional disability who had a quite massive consolidation in their lungs. It would probably be wiser in the medico-legal aspect not to apply the term "tuberculo-silicosis" to such cases, but simply to say that they showed a silicosis or fibrosis of infective type.

Dr. Simson: During his stay in Sheffield he had quite an extensive experience with tuberculous guinea-pigs after inoculation, doing about forty or fifty a week. Tubercle bacilli of low virulence or in very minute doses might not give rise to any lesion. In such cases the body reactions were sufficient to destroy the bacilli.

In the experimental work carried out conjointly with Dr. Strachan the site of inoculation was carefully examined. Films were made

from any glands showing the slightest enlargement and examined in the usual way.

If there had been any doubt about enlarged glands they would have been reinoculated.

Dr. Strachan: There was no possibility of their having missed any lesions whatever. Negative results were obtained in every case, which showed that none were missed.

Dr. Gardner: In the older literature on silicosis a great point was made of lymphatic obstruction. It had always impressed him that probably this had played a very important part. In dusts such as carborundum they had been able to detect the presence of well-developed silicotic lesions in the bronchial lymph nodes, which were probably responsible for the development of a stasis in the affluent lymph vessels. What physiological activity or lack of activity might result in such a lymph stasis was something to be determined. With such a stasis the channel for the elimination of dust was obliterated. They had not found any dust containing phagocytes, except very rarely, in these dilated lymph vessels. This seemed to indicate that this process of lymphatic obstruction should be given a more prominent part.

There were apparently two types of disease in which silicosis and tuberculosis were co-existent. In one the tuberculous processes were atypical and did not conform to those encountered in uncomplicated cases. In another type lesions comparable to those found in simple tuberculosis could be identified.

The usual lesions of uncomplicated pulmonary tuberculosis are generally divided into three main groups:

- (a) Lesions of infection, the "primary complex";
- (b) Apical tuberculosis, a lesion of reinfection of endogenous or exogenous origin which tends to heal but may be re-activated and may spread at any time;
- (c) Acute and chronic involvement of the lower portions of the lung generally due to broncho-genic extensions from the apical focus.

Blood stream dissemination is more or less accidental in nature and plays little part in the evolution of chronic pulmonary tuberculosis.

In the radiographs exhibited to the members of the Conference there was one beautiful illustration of a "primary complex" in the process of activation by inhaled silica dust. Another series of films illustrated a definite picture of tuberculosis in the apex of a lung which under the influence of inhaled silica dust was actively spreading to involve the lower portions of the lung.

In his own experience the speaker had also seen several cases, chiefly in granite workers, in which an apical tuberculosis was spreading downward through the lung simultaneously involved with silicotic changes. In a series of six lungs from Barre, Vermont, two showed this type of change.

But in many of the radiographs exhibited to the Conference the specific evidence of typical tuberculous lesions were obscured by the silicotic changes.

The question arises whether the combination of tuberculosis with silicosis generally creates a new pathological condition in which the tuberculous elements are no longer typical in their appearance and mode of progression or whether these are only obscured by the concomitant reaction to the inhaled silica.

In attempting to answer this question it would be desirable to obtain exact information as to the incidence of detectable *apical* tuberculosis

both active and inactive in silicotic individuals and as to the frequency of spread of the infectious process into the lower portions of the lungs by aspiration from the bronchial tree.

The speaker also enquired whether it was possible to discover the source of infection in the atypical combinations of tuberculosis and silicosis. If such forms resulted from the combined action of the two irritants, the tubercle bacillus and the silica dust, were each necessarily present within a given tuberculo-silicotic nodule? If so by what pathway did the tubercle bacilli reach the site of reaction?

To mention an entirely new question—is the radiographer correct in ascribing all shadows seen in an X-ray film to the presence of fibrosis? A shadow is cast on the film by any substance which obstructs the passage of the ray through the normally air-containing lung. A pneumonic exudate or even congested and engorged blood vessel may exert such an effect. Why then in dealing with a chronic disease should any area of increased density in the radiogram be called fibrosis?

Dr. Strachan: There was a considerable body of opinion in South Africa agreed in involving lymphstasis as a factor in the development of silicosis. He was of opinion personally that lymphstasis, at least in the simple non-infective silicosis, played no part. Certain workers had shown by experiment that when the lymph glands were blocked with carbon there was no lymphstasis at all. There was, as Dr. Gardner had demonstrated, dilatation of the lymphatics, but there was no apparent interference with the flow of lymph in these dilated lymphatics. The dilatation of the lymphatics might be simply a part in the establishment of a collateral circulation, or opening up the circulation to permit of the further lymph glands being reached. That was their interpretation of the causes in the early simple silicosis. That would not account for the absence of dust cells in Dr. Gardner's cases, but their interpretation of their sections would indicate that there was no lymphstasis. Presumably there would be further findings of oedema, or something of that nature. The point of lymphstasis was important in relationship to the interpretation of the general ramifying fibrosis. It had been raised in that connection because in certain sections of lungs, particularly in the later stages, the lymphatics were filled with pigment and pigment-laden cells, but there were on the other hand cases which showed the typical general ramifying fibrosis in which there was no evidence of dilatation of lymphatics or of pigment-laden lymphatics. To reach a definite conclusion in regard to this condition, much more material would have to be examined.

As regarded statistics on the foci of the typical types of tuberculosis, he could state quite definitely that there were cases of these foci in South African silicotic cases.

Aspiration manifestation of silicosis in the silicotic cases occurred only in the infective cases, and in these only when the infection had gained the upper hand.

Infection elsewhere was a point which had not been emphasised sufficiently. Both in natives and Europeans there were certain cases in which the manifestations in the lung were minimum, if not absent, but in the lymph glands there was evidence of gross tuberculo-silicosis, and a not infrequent sequence of events in these cases was a dissemination of tubercle to other organs.

Dr. Gardner: He had found non-progressive tubercle in the abdominal viscera of about 25 per cent. of cases of simple chronic pulmonary tuberculosis. He did not feel however that the blood stream played

an important part in the dissemination of tubercle bacilli within the lung in the chronic stages of pulmonary tuberculosis. With regard to lymphstasis, a dilatation of the peripheral lymph vessels of the lungs appeared in the absence of an obstructive lesion in the tracheobronchial lymph nodes. In this case, the dilatation could only be related to intra-pulmonary irritation. He was anxious to discover whether this appearance was indicative of any change in the rate or direction of lymph flow.

Professor Kettle: He would still like an answer to his question about the bronchiolitis. He would like to know what was the significance of the pathological process. Was it because of atrophy of the epithelium and a defect of secretion, and therefore a matter of holding up of the dusts, or was it because of the lack of the mucous membrane that the dust got through so rapidly? Was there any evidence of an increased phagocytosis in these circumstances, or was it a question of an interference with the exit of the dust once it had been inhaled?

In experimental work he had been very much impressed by the determination of the dust in the phagocytes to the lymphatic vessels' system. It seemed that the lymphatic must enter into this process rather more than had come out in the various discussions.

Dr. Strachan: He did not deny that the lymphatic apparatus played a very important part in this condition, but it had an active and not a static part.

Professor Kettle: If the lymphatic glands were obstructed and filled with silica, there must surely be obstruction of the lymphatics.

Dr. Strachan: In the specimens at the Institute there was no difference from the normal lung. He thought the glands were enlarged and there was a certain amount of obstruction in the glands. If there had been stasis, and stasis of any degree, the pigment and the dust would remain in the lung.

Dr. Gardner: He considered that the abdominal lymph glands were involved. The individual abdominal viscera simply passed these dust cells through to the lymph nodes which drained them.

Dr. Strachan: If there was a blood stream infection one would naturally expect to find manifestations of the lesions in the spleen. These were extremely rare.

Bronchiolitis was put forward simply as an observed fact. As regarded the question of exit, it seemed that the bronchial epithelium was active in the process of carrying away material. What mattered was not so much the interference with the exit of the particles as the possibility of their increase. The bronchiolitis of asbestosis threw a considerable light on the subject in relation to the X-ray picture. The degree of bronchiolitis in silicosis was less than in the asbestosis. The reaction in asbestosis was much greater, and so great as to prevent the involvement directly of the terminal alveoli.

Dr. Mavrogordato: One of the difficulties the Conference would have to face would be the distinction between a silicosis and a pneumoconiosis. The problem was to get at silicosis as a specific occupational disease and define it. It was much more difficult to spread it to other types of pneumoconiosis. If a man was going to get a silicosis he would precede his silicosis with fibrous ramification. He had seen a number of workers getting on for sixty who would yet show lung fibrosis of that kind. They were apparently physically fit, as men in the neighbourhood of the sixties go.

Personally he did believe that lymph played a part. He looked at the spread from the lungs somewhat differently from Dr. Strachan. He thought that the fact that the pigment cells passed so rapidly up into the neck and down into the abdomen tended to support the supposition that the normal lymph flow was interfered with. An acute infection of the lung in a man who had not been exposed to dust for several months would show the alveoli filled up with pigment-laden cells. That suggested that the pigment-laden cells had been retained somewhere, not necessarily in the lymphatics. In his experience there was in these cases plenty of pigment-laden cells held up in the distended lymphatics. It seemed that at first there was an interference with the normal lymph flow, then a pretty ready passage in an abnormal direction, and then a holding up of the pigment-laden cells somewhere where they could get back into the lung.

Professor Hall: Whilst it was quite true that general fibrosis might go on to silicosis, yet quite a number of cases did not go on to simple silicosis.

Dr. Irvine: The radiographic picture of general ramifying fibrosis was a definite pre-silicotic phase. At post-mortem something like 50 per cent. of such cases showed slight silicosis in the sense defined. The practical working test was that if a man in that condition with a long service had developed the condition underground in the course of his service, and there was disability, generally with some emphysema, they were inclined to compensate at that stage, under these restrictions, but not in general. He would not for a moment say that any worker who showed that type of plate was entitled to compensation. A number of miners could go on for several years in that condition without progressing further, but if a man continued in his occupation, a definite silicosis usually followed in a year or two. A man might however develop that condition and remain in it practically indefinitely if he was removed from underground work. It was necessary to get at the facts of the "actual generalised ramifying fibrosis", which did not necessarily spell fibrosis.

Dr. George: A few figures with regard to Broken Hill miners may be interesting. In eight years, out of 160 mine workers withdrawn as suffering from simple silicosis 76, or 47.5 per cent. developed or died of pulmonary tuberculosis. A total of 66, or 41.2 per cent. died of all causes. The average age at death of those dying of pulmonary tuberculosis was forty-eight years; in those dying of other causes the average age at death was fifty-eight years. In eight years, of 101 men classified originally as suffering from silicosis plus tuberculosis there were living only 15—86 per cent. had died. In all but eight cases the cause of death was pulmonary tuberculosis. The average age at death of those dying of pulmonary tuberculosis was 49.7 years, and in those dying of other causes 51.6 years.

The chief causes of death in these two groups of men who did not die of pulmonary tuberculosis were: lobar or broncho-pneumonia 8, other respiratory disease 7, heart failure 8, chronic nephritis and/or cerebral hæmorrhage 11, malignant disease 4, surgical emergencies 2, suicide 2. With regard to the number of deaths from chronic nephritis and its complications, it must be remembered that many of these men had suffered from lead poisoning in addition.

Dr. Moore: In our experience at Kalgoorlie (Western Australia) and in Tasmania the performance of physical tests and the estimation of vital capacity was of very little aid in the diagnosis of silicosis.

Dr. Kranenburg: The X-ray of the sandstone workers showed, for 16 persons, mottling in 2 cases and snowstorm type in 5 cases. The X-rays of 74 Belgian limestone workers showed mottling in 5 cases.

Dr. Watt: The branching shadows in an X-ray film were caused by the blood vessels, by the lymph vessels, and by the supporting connective tissue. In heart disease, where there might be some increase in the vessels in the lungs, there were ramifying shadows, which might also be caused by the dilatation of the lymph vessels. The air-containing tubes threw a negative shadow. It was conceivable that the dilatation and blood vessels would give those shadows without necessarily a marked fibrosis.

(The Conference adjourned at 12.30 p.m.)

SEVENTH SITTING

Tuesday, 19 August 1930, 2.30 p.m.

Chairman: DR. A. E. RUSSELL

DIAGNOSIS (*continued*)

Dr. Böhme: He had heard that 70 per cent. or more of the natives had a positive von Pirquet reaction; he thought therefore that the conditions were not so very different from those in Europe. Most of the natives had a tuberculous infection in their youth; why were they so liable to contract tuberculosis when they came to the mines, or into contact with European people?

Dr. Mavrogordato: Very weak solutions had been used for testing purposes. Were they to use the same strength as in Europe, the positive reactions would probably be about 90 per cent. But whereas in Europe a positive reaction was regarded as related to a localised tubercle of a more or less chronic type, in South Africa the fact that a native had a positive tuberculin reaction did not make the least difference to his after-coming type of tubercle. It was at death generalised. In fact the natives who got the least tubercle were those who had a negative reaction. This was the exact reverse of the European experience.

Dr. Badham: It has been suggested by speakers that the appearances seen in the radiographs showing diffused generalised fibrosis are due to bronchiolitis or effusion.

He desired to point out that in certain of these cases there is no increase of sputum and the radiograph remains unchanged for three years after leaving dusty work.

The condition appeared to him to resemble closely the radiographic appearance of asbestos and he thought that he would find the pathology of these lungs to resemble that found in asbestosis.

He had not found this condition in individuals not exposed to dust.

Dr. Cunningham: It appeared that cases showing more general ramifying fibrosis did not get tuberculosis to anything like the extent that ante-primary cases did. Having in mind the fact that the amount

of simple tuberculosis was comparatively low, something must happen just short of ante-primary to make tuberculosis much more serious or much more frequent in these miners than earlier.

Dr. Irvine: Tuberculosis in a silicotic lung might arise from a persistence of a primary infection, or it might come along with the dust and develop practically simultaneously. He thought these latent foci either remained inactive, in which case the condition did not advance to an obvious condition, or, on the other hand, these foci became active, either rapidly or over a period of years. They became active and progressive either locally, or spread by inhalation, or through the blood stream and caused a definite tuberculous infection. There was the further possibility of reinfection from outside the lung after the silicotic process had become definitely established.

Professor Loriga: After the Lyons Congress, the Medical Labour Inspectorate in Italy had asked for collaboration from various experts in the study of the pathology of marble workers. Investigations were made by Dr. Turano at Carrara, and Dr. Bianchi at Massa, the chief centres of the marble industry. Further enquiries were carried out by Dr. Lovisetto, of Turin, and by Dr. Mussa. Their conclusions had already been submitted to the Conference. He exhibited various radiographs of the results obtained by these investigators.

Dr. Russell: Having regard to the apparently fairly long period of occupation in the marble industry, it appeared that in Italy it was the practice to teach school children a trade as part of the school curriculum. Children commenced learning in the marble industry from the age of ten years.

Dr. Gardner: He had had the good fortune of seeing a series of asbestosis films, which Dr. Lanza had in his possession. The majority of these cases were much like those Professor Loriga had shown, in that there was an accentuation of the linear markings in the chest film, with relatively little of the fine mottling. Dr. Irvine had shown a film that morning which showed more of the mottled appearance, which was perhaps a little more comparable with the picture obtained by the experimental disease in guinea-pigs.

Dr. Russell: Dr. Lanza was particularly interested in the incidence of tuberculosis in his people. He was of the opinion that they had more of a chronic bronchitis than a tuberculous complication.

Dr. Middleton: He had been recently associated with Dr. Merewether, of the Factory Department, in an enquiry on workers actually employed in asbestos factories at the time of the examination. The general result was to show that asbestos dust gave rise to pneumoconiosis of a fine type, distinct from the silicosis. A number of fatal cases had occurred in Great Britain, and he had been present at one or two of the post-mortem examinations. The findings were that the appearance of the lung corroborated the X-ray appearance, so far as the absence of the large nodules was concerned. There was a general fibrosis throughout the lung. Usually the end of the case was either tuberculosis or a broncho-pneumonia. The remarkable thing about asbestos disease was the apparent small involvement of the lungs when examination, either clinical or radiological, was carried out. The patient lost condition and went down hill fairly rapidly, when the clinical and radiological signs were scarcely to be made out. The incidence of tuberculosis in such cases was interesting.

Intensive study was being made with regard to prevention to ascertain

how far the dust could be eliminated from the industry and with regard to further legislation and compensation. A Bill had been before Parliament in the last few months to provide compensation for persons disabled by the pneumoconiosis due to asbestos dust.

Dr. Badham: No asbestosis disease had so far been found among Australian workers.

Dr. Orenstein: Asbestosis had been studied for some time by one of the medical men in South Africa in the mines of the Eastern Transvaal. Dr. Slade claimed to have found a number of cases of asbestosis with incapacity.

Dr. Irvine: Dr. Slade had sent up one man who had been in an asbestos mill for six and a half years, and showed quite a definite generalised arborisation in the radiogram, not quite of the silicotic type. It resembled it, but was a little more diffuse. Dr. Slade had been sending up to Drs. Simson and Strachan a large number of sputa from natives in which they had recovered asbestos bodies.

Dr. Simson: He had had the opportunity of examining material from six cases of pulmonary asbestosis from a mine in Southern Rhodesia. All showed definite fibrosis and two were complicated by active tuberculosis.

In a case with a history of exposure to dust for two months asbestosis bodies were found in the lung alveoli, but there was no evidence of fibrosis.

He was interested in the examination of sputa for asbestosis bodies with a view to determining whether their presence was an indication of pulmonary fibrosis. Dr. Strachan and he had examined sputa from fifty subjects who had worked in an asbestos mill. Asbestosis bodies were demonstrated in the sputa of forty-eight of these, and in most of them by the direct film method. The shortest exposure was five months. Another case had a history of four months' exposure to the dust of the mill and three months' exposure to underground conditions. Dr. Strachan and he were informed that underground conditions are not likely to cause fibrosis as there was no excess of injurious dust.

Professor Hall: One of the objects of the Conference was to arrive at some international standard which would be applicable to all countries for future investigations. He therefore moved the following resolution:

There is a pathological condition of the lungs due to the inhalation of free silica dust. It can be produced experimentally in animals. It can be detected by clinical, radiological and pathological means with sufficient accuracy to separate it from other pneumoconioses and to afford a fair basis for legislative measures.

Dr. Böhme seconded the resolution.

After some discussion, it was resolved unanimously, on the motion of Dr. Orenstein, that the resolution as amended by Professor Hall should be referred to the Reporters. The resolution as amended was as follows:

There is a pathological condition of the lungs due to the inhalation of free silica dust. It can be produced experimentally in animals. It can be detected by clinical and radiological means, which can be confirmed with the above pathological condition with sufficient accuracy to separate it from other pneumoconioses. It also affords a fair basis for legislative measures.

Professor Hall: The next step was to come to some general agreement, based upon the lines of the South African experience, on a definition of the three stages of silicosis. He moved the following resolution:

The *first stage* shall be defined as characterised by:

- (a) appearance of the earliest detectable physical signs of the disease;
- (b) radiographic appearance not less than the presence of nodular shadows together with an increase of hilum shadows, linear shadows and pulmonary reticulum, and
- (c) with or without impairment of capacity for work.

The *second stage* is characterised by:

- (a) the further development of the physical signs found in the first stage;
- (b) radiologically an increase in the area of the nodular shadows with a tendency to confluence of the individual nodules, and
- (c) the presence of symptoms with some degree of impairment.

The nomenclature classifying fibrosis in various degrees should be replaced by the terms "slight", "moderate" and "well-marked" linear radiation.

Dr. Orenstein seconded the resolution.

It was unanimously agreed to refer this resolution to the Reporters.

Professor Hall: He felt that the so-called infective silicosis, whether tubercular or not, would be much better left out altogether. There should be a separate heading "tuberculosis" with silicosis as a distinct condition.

Dr. Middleton: Tuberculosis should be recognised as an entity, and should be placed parallel with or alongside the three stages of silicosis.

Dr. Orenstein: In connection with silicosis it was necessary for the Conference to express an opinion as to whether tuberculosis was a disease which was accelerated by the presence of silicosis, or whether silicosis accelerated existing tuberculosis. He took it that the general opinion of the Conference was that the two were unconnected. If that was the case, he entirely agreed with Professor Hall's suggestion that tuberculosis should be dealt with as an auxiliary entity to silicosis, but before he would commit himself to that view he would like to know whether the delegates from other countries agreed.

Dr. Cunningham asked whether if silicosis and tuberculosis were defined as distinct conditions the "infective" type of case would be labelled "tuberculous".

Dr. Hall: No.

Dr. Irvine: The South African definition of tuberculosis was as follows:

That a man shall be considered to be suffering from tuberculosis if either he is expectorating the tubercle bacillus or is suffering from closed tuberculosis to such a degree as to seriously impair his working capacity.

They introduced the term "infective silicosis" because that was a pathological entity and because it was necessary to describe it in describing silicosis at all. They did not recognise tuberculo-silicosis as tuberculosis for the purposes of the Act until it was active and progressing and causing constitutional deterioration.

Dr. Orenstein: The Reporters could take it that the Conference agreed to the view that tuberculosis in relation to silicosis should be dealt with as a condition parallel to it and adding to the disability.

Dr. Moore: The question of radiographic technique had not yet been mentioned.

Dr. Russell agreed that it was essential to make some reference to radiography.

Dr. Orenstein asked if he was right in understanding that the Conference had accepted Professor Hall's proposal that in the present state of knowledge of the pathology of the disease the view was not considered justified that silicosis was essentially tuberculous, at least as seen in South Africa.

Dr. Russell replied in the affirmative.

(The Conference adjourned at 5 p.m.)

EIGHTH SITTING

Wednesday, 20 August 1930, 9.30 a.m.

Chairman: DR. L. G. IRVINE

DIAGNOSIS (*continued*)

Dr. Simson: In the lungs of subjects exposed to the influence of injurious dust there might be condensation of the tissues in and about the bronchioles, and these areas of condensed tissue might be responsible in part for the radiographic appearances known as linear radiations. Somewhere in the site of the condensed tissue, in silicosis the nodule of fibrosis developed.

In 1916 Drs. Watt, Irvine, Pratt, Johnson and Steuart demonstrated nodules appearing on the linear radiations, and defined this phenomenon as "segmentation of the linear shadows". Dr. Böhme likened it to beads on a string.

Dr. Gardner, when demonstrating cases of experimental asbestosis, showed radiographs of the chest of a living guinea-pig and of the lungs in a state of over-expansion from the same pig after death. In the living pig the radiograph showed radiating linear shadows, but in the over-distended lungs the radiating linear shadows had become segmented and appeared as a fluffy kind of mottling. This might account for the shadows seen in the peripheral part of the lung. Thickening of the bronchi, dilatation of bronchial lymphatic and blood vessels might account for the increase in the shadows near the root of the lung.

The Chairman: He agreed that in the bronchial phase "fibrosis" was a compromising term. Fibrosis or potential fibrosis did, however, occur in many cases which showed a radiograph of generalised arborisation, because this picture persisted afterwards, as if there were slight but definite fibrosis.

Dr. Gardner: Carborundum dust inhalation gave an example of increased vascularity. X-ray films of human cases exposed to carborundum dust showed a definite accentuation of the linear markings.

Dr. Watt: Stereoscopic films would show the nature of the shadow very much better.

PROGNOSIS AND AFTER-CARE

Professor Hall asked *Dr. Pringle* if he would elaborate the statements made in his paper (page 583) that "the amount of dust a patient may have and the degree of tubercular infection do influence prognosis, it is true; but I hold that the factor of individual resistance to tubercular disease is very great" and "the non-miner with pulmonary tuberculosis stands no better chance than a miner with silicosis complicated with tuberculosis". He would have thought tuberculosis complicated with silicosis had a very much diminished chance of recovery.

Dr. Pringle: The second statement quoted was qualified by the words "but in some of these cases the illness probably was contracted earlier in life". Non-miners seemed to die as early as miners. Where the patient was originally certified as in the ante-primary, primary or secondary stage of silicosis, silicosis did not seem to influence the period of life; it seemed to depend entirely on individual resistance to secondary (tubercular) infection. There were patients at the Springkell Sanatorium between sixty and seventy years old, which showed that individual resistance to tuberculosis was a considerable factor.

The Chairman: The figures of the Medical Bureau showed that silicosis with active tuberculosis at the outset led to earlier death than simple tuberculosis. The average silicotic had a much longer expectation of life. Infective silicosis meant not necessarily active tuberculosis but a chronic condition of tuberculous infection with silicosis, sometimes arrested, sometimes progressing. There were two legal groups: (1) silicosis which was predominantly simple or "partly infective" unaccompanied by obvious active tuberculosis, and (2) silicosis with obvious active tuberculosis. *Dr. Pringle's* remarks evidently referred to the second group.

Sir Spencer Lister: *Dr. Pringle* and the Medical Bureau's views seemed to be in conflict.

Dr. Orenstein: In his opinion the probability of survival of non-miners with tuberculosis was no better than for miners with silicosis and tuberculosis; the factor of age distribution entered largely into the picture; greater age meant greater survival, and miners were generally older than non-miners.

The Chairman: He agreed. Dust phthisis was a disease of later life than was tuberculosis, because of the fact that time was necessary for the predisposing condition of silicosis to develop.

Dr. Pringle: A large number of miners were certified as suffering from tuberculosis, but the tubercular element did not seem very active.

Dr. Badham: If silicosis and overt tuberculosis developed together the prognosis was very unfavourable. He asked whether *Dr. Pringle* referred to that type or to silicosis with a later development of tuberculosis. The expectation of life in these two groups was quite distinct.

Dr. Pringle: Cases were sent to Springkell by the Bureau as suffering from silicosis with tuberculosis, but the certificate did not distinguish

between chronic and active tuberculosis. The case in which the tuberculosis factor was not very active and the sputum negative tended to live a long time while the second type lived only a short time.

The Chairman: The Bureau's report showed that the maximum mortality for tuberculosis with silicosis fell between forty and fifty years of age. The numbers of deaths from tuberculosis in each year subsequent to the year of detection was fairly equally distributed.

Dr. Simson: In tuberculosis with silicosis the organism was living on a medium composed mainly of fibrous tissue which was not very nutritious as compared with the other type which was living outside the silicotic nodule.

Dr. Middleton: The age incidence of the disease was a very important factor. There were two crests in tuberculosis in the adult: (1) between twenty-five and thirty-five, and (2) between forty-five and fifty-five years of age. In the first group there was progressive tuberculosis with acute phenomena while the second group was remarkably free from these phenomena and the disease was much more chronic.

Active tuberculous foci outside the fibrous nodules tended to march alongside silicosis. Silicosis with tuberculosis improved with hospital treatment but there was a tendency to relapse later.

Dr. Böhme: Silicosis with overt tuberculosis in rock drillers generally went faster than tuberculosis alone. Most of the cases which he had seen were between 40 and 50 years of age.

The Chairman: The amount of fibrosis in the lung was a very important factor. Once a tuberculous infection had become manifest, the old type of silicosis progressed very rapidly, while the infective cases to-day ran a more chronic course.

Dr. Orenstein: The attempt to correlate the evidence statistically had shown the age distribution among miners to have shifted enormously during the last few years.

Dr. Russell: In the granite industry two types of tuberculosis occurred: (1) between the ages of twenty-four and thirty-eight which responded fairly well to sanatorium treatment, and (2) after twenty-five years' exposure to dust at an average age of forty-nine years; in this group the tuberculosis had a greater tendency to pulmonary hemorrhages and the course of the disease was unaffected by sanatorium treatment. The type of tuberculosis which did not respond to sanatorium treatment was also found among silicotic potters.

Dr. Gardner: He had carried out experiments on the same kind of animals of the same age and with the same doses. In the first experiment the infection was coincident with the exposure to dust. After three months the infection spread, ran a sub-acute course and ended in death from acute and chronic tuberculosis. In the second experiment the animal was exposed to quartz dust when tuberculosis had already been established. In this case there was a much greater tendency to fibrosis. In the third case silicosis preceded the tuberculosis infection. A very active tuberculosis was produced which in the majority of cases ended in death within 60 days.

Dr. Watt: The racial factor was also very important. The mining population had been drawn first from the densely populated areas of Great Britain and secondly from the country population of the Rand. The Bureau's examinations were so strict that the mining population

was now A 1. He had seen cases improve under sanatorium treatment, but ultimately the end came rapidly.

The Chairman: There was a slightly higher rate of progress among South African miners as compared with miners from overseas. Seventy per cent. of the silicosis cases were among the old Rand miners, and only 8 per cent. among the new Rand miners. The new Rand miners produced as little pure tuberculosis as the Royal Air Force. The present mining population was over 70 per cent. South African.

Dr. George: The Broken Hill statistics showed that in 1920: (1) 102 miners were withdrawn with silicosis with tuberculosis, and (2) 107 miners were withdrawn with uncomplicated tuberculosis. Of the first group only 15 were now alive, while 55 were alive in the second group. The average age of death from tuberculosis in the first group was 49.7 and in the second group 45.5. The average age of those still alive in the first group was 53.5 and 54.5 in the second group. He asked what percentage of Rand miners who obtained certificates actually got work.

The Chairman: All comers on the Rand were eligible for initial examination and some of these came up year after year. The actual number of examinees was at least 16,000. The new Rand miners who entered upon their fifth year of work did not amount to more than 50 per cent. of those of that group who had started work underground.

Dr. Cunningham: We would like to hear the opinion of the Conference on the subject of sending men compulsorily to sanatoria.

The Chairman: There was no compulsion in South Africa and there was no systematic feeding of the sanatorium. A tuberculosis dispensary had been established in Johannesburg, but it was closed down because so little use was made of it.

Mr. Spence Fraser: Dr. Pringle's statement was based on the fact that cases of silicosis with tuberculosis died at a later age than cases of uncomplicated tuberculosis. This, however, was to be expected, since they contracted the disease at a later age. In order to measure the rate of progression it was necessary to calculate the average time from the detection of the disease until death. Table IV in Dr. Pringle's paper appeared to show that the rates of mortality among non-miners were rather lower. He did not think that any case had been made out to show that non-miners had a shorter lifetime.

Dr. Orenstein: Statisticians and medical men were unable to draw any conclusion from vital statistics unless they could use them biometrically. Table IV had no particular meaning because it was not carried to finality. Owing to lack of data it was impossible to reach comparative figures of deaths from tuberculosis in the general population and the mining population. The economic factor had also to be considered, since the economic conditions in which the men found themselves before the disease might not be the same as when they had lost their employment owing to the disease. Statistics were available to show that the higher class of officials did not progress so rapidly as the ordinary worker. It was also necessary to measure the rôle played by physical and racial selection, which was becoming increasingly important; in that should also be included the rôle played by individual resistance to tuberculosis, which differed racially and individually. In 1918 to 1919, 9.6 per cent. of European underground workers had been employed ten years or more; in 1925 to 1926, 36 per cent. had been employed ten years or more. In 1918 to 1919, the silicosis peak occurred

at nine years, while in 1925 to 1926 it occurred at twelve years. It was of the utmost importance to have a biometric examination made of the material in order to discover whether miners' phthisis had been reduced or not.

Dr. Koelsch: The problem of the *connection between tuberculosis and silicosis* and of *prognosis* was very difficult and depended on numerous subsidiary factors—for instance that of early or late tubercular infection, of the spread of localised tuberculosis, of individual susceptibility, etc. By means of very extensive statistical investigation it was possible to gain some ideas on the subject. He had analysed the relative morbidity and mortality returns for well over 100,000 workers in dusty trades and compared them with similar figures for the local population. He was able to establish two critical periods:

The first at the age of about 20-25 years (= 5-10 yrs. of employment).

The second at the age of about 45-55 yrs. (= 30-40 yrs. of employment).

In the first group they had irritation due to dust and tuberculosis which causes death relatively rapidly. Amongst those of the second group conditions depend to a certain extent on the trend of dust—that is, on the silica content of the dust: amongst sandstone workers, for instance, there occurred severe tuberculosis with silicosis which relatively rapidly becomes fatal, while in the case of pottery workers for instance the disease followed a more protracted course.

In regard to sanatorium treatment he had not very much faith in it. As long as the workers remained in the sanatorium they were well, but as soon as they returned to work in a dusty atmosphere they went from bad to worse. The insurance society, therefore, undertakes, in the case of sandstone workers for instance, the application of sanatorium treatment only when the patient gives a written assurance that he will exchange his occupation for work in a dust-free industry.

Dr. George: In 1922 and 1923, thirty-four ex-Broken Hill miners suffering from uncomplicated silicosis were placed on irrigation blocks at Griffith, New South Wales. These blocks were situated on virgin country, they cleared the land, erected their dwelling houses with new timber and lived there with their wives and families. Compensation was paid throughout fortnightly, and advances of money and material were made by the Irrigation Commission. Grapes, apricots and citrus fruits were grown, the former two for sale after drying. The climate was cold, 2,000 feet high and in winter rather damp and the work necessitated fairly frequent work in wet conditions. The men were told that as they had no incapacity they would make a success of their new lives and were eager to take up the work. The men sent were selected after a special medical examination to ensure that they were suitable for the work. Almost from the commencement the scheme was a failure. The men could not stand up to the harder work—ploughing, hoeing, etc.—and soon several men abandoned their farms. Up to the present, of these 34 men 17 had developed or died of pulmonary tuberculosis, 1 had died of sudden cardiac failure and 1 of cerebral haemorrhage. There were about 9 of the men still on their farms, some of whom have definite tuberculosis. They owe sums varying from £2,000 to £3,000 on their farms. Repayments are due, but they are able only to keep going by using their fortnightly compensation payments to pay labourers to do the hard work. He had re-examined these men once yearly and was convinced that the symptoms of which they complain—dyspnœa on exertion, præcordial pain, palpitations, etc.—are genuine and that the miner with fully developed silicosis has a

definite disability for work of this nature. At the age of forty to forty-five a man who has been a miner all his life is unsuited to take up entirely different work which is entirely new to him. He is too old to educate different work muscles and in the attempt to do so develops fairly quickly symptoms and signs of cardiac strain. As the majority of these men have young families, from the point of view of their children no doubt this scheme justified itself to some extent.

Dr. Pringle: The experience at Springkell and Wedge Farm Sanatoria corroborated Dr. George's experience. Men certified as silicotics would not and could not do agricultural work. It was suggested that there was nothing to be gained by warning men to leave the mines because men who did so and received lump sum compensation, although excluded from the scheduled mines, could find employment in Rhodesia and in the asbestos mines in Barberton and elsewhere. He asked whether any special hospital provision was made for silicotics in other countries.

Dr. Middleton: No special provision was made for silicosis in Great Britain, but silicotics with tuberculosis were eligible for sanatorium treatment under the National Health Insurance Act.

Professor Hall: When considering the factor of economic conditions it might be taken into account that managers and other officials were perhaps less exposed to dust.

The Chairman: After a man had received a notification that he was silicotic he forfeited the right to any increase in compensation if he did not leave work within three months; but the number of silicotics who did not leave underground work was small. They progressed no worse than the men who did leave, but they were of a robust type and the majority were mine officials with better economic conditions and less exposed to dust. The Medical Bureau believed that men who continued underground work would be prejudicially affected, but only about 25 per cent.

Mr. Du Toit: The Miners' Phthisis Board had tried to make comparisons between silicotics established in the Cape Province as compared with silicotics at 6,000 feet altitude in the Transvaal. The Cape silicotics had not been able to remain long and had had to return to a higher altitude. The Transvaal silicotics, owing to the difficulties of the work and the extreme cold in winter, were not able to last long on a farm. These men nevertheless had originally come from rural districts. In both groups silicosis had progressed. About £3,000 per man had been expended unsuccessfully.

Dr. Russell: The experience with granite workers in the United States had been similar. The North Italians who had migrated to California to take up grape farming had failed and other granite workers had also failed at farming. They were unable to adjust themselves to new occupations.

Dr. Orenstein asked whether there was any other organisation elsewhere in the world established by private industry comparable to the South African institutions for the care of miners' phthisis cases.

Professor Böhme: Miners suffering from tuberculosis or tuberculosis and silicosis in Germany have for years back been treated in the phthisis hospitals of the Miners' Association (*Knappschaftsverein*). This Association is an insurance society against illness, invalidity and old age. The cost of insurance is borne partly by the employers and partly by the miners. Tuberculosis occurring in other occupations is treated at

the expense of the district insurance societies (*Landesversicherungsanstalten*). The expenses of this society are likewise borne partly by the employers and partly by the employees.

Professor Hall asked what was the effect of silicosis and tuberculosis on natives.

Dr. Orenstein: The incidence of silicosis, simple or not, on natives was relatively low, but it should be remembered that the mines population changed 100 per cent. per annum. The recorded mortality of 8 per cent. was much exaggerated and it could be assumed that intermittent employment gave considerable protection. Natives were more susceptible to tuberculosis, but racial immunity was being rapidly acquired.

The Chairman: Simple silicosis had been shown by radiographic examination to be much less frequent among natives, but the comparative incidence as between Europeans and natives was much the same, given similar conditions.

Dr. Watt: The natives did not breathe through their mouths and, therefore, were protected by a better filter than Europeans.

STATISTICS OF SILICOSIS

The Chairman: The figures showed that silicosis was definitely on the decline, especially among the new Rand miners.

Dr. Orenstein: Without casting any reflection upon the statistical work being done, it must be realised that it was very difficult to visualise all the factors without biological and engineering knowledge. The present statistics were perfectly reliable, but did not reflect the whole picture. It was impossible to say whether the real production of silicosis was more or less than that shown by the figures. Improved radiological technique was now more important than clinical diagnosis, and more diagnoses were now made.

He suggested that the money now set aside for compensating cases of the disease might be better spent upon rehabilitation methods. A pension for a disease which tended to progress might not be doing full justice to a man. South Africa spent about £800,000 a year on compensation and there were liabilities of £9,000,000. Under the present system in the ante-primary stage of silicosis a man was penalised if he did not leave the mine at once, and about £500 was given to a man thus thrown out of employment. He thought it might be better to wait until a marked degree of incapacity was reached and that search should be made for other avenues of employment. The farming experiments had not perhaps been efficiently conducted. There was room here for further investigation and research.

Professor Hall: The statistics of South Africa were so unique and of such importance to all countries which had to initiate legislation and compensation, that every step should be taken to make them as clear as possible. Biometrical statistics involved many other factors and it was desirable that all the material should be handled by the greatest biometrician obtainable.

Mr. Spence Fraser: A biometrician might obtain valuable results from the statistics, but it was very difficult to obtain an all-round man; a mixed Committee might perhaps be necessary. It was doubtful if the data existed to enable a biometrician to produce useful results.

If compensation for ante-primary silicosis had existed from the beginning the figures to-day would appear better to-day because more miners would have been excluded from employment in the earlier years. The duration of work was shown in the statistics as the main factor. The age figures published by the Bureau showed that the factor of age was of little importance; it did not, for example, affect mortality in the secondary stage. The ante-primary stage had not been constant owing to improved technique and other factors, and the production rate had consequently increased for some years, though that had been foreseen. The liability of the miner differed greatly according to the character of his occupation, but for purposes of compensation no distinction was made between the various occupations. The proportion of miners in the different occupations had not, however, changed to any marked extent. He thought that the statements in his and Dr. Irvine's paper of the decrease of production was a fair statement of the conditions.

Professor Kettle: The statistics were beyond criticism, but he hoped that a biometrician could carry out the widest possible survey.

Dr. Mavrogordato: Two factors were at work: (1) the change from a migratory to a fixed population, and (2) improvement in conditions, in which must be included the initial examination. He believed that as much ante-primary silicosis was made as ever, but it now took thirteen years instead of eight to nine years. This was probably due in part to selection of miners and the production rate would fall as the number of picked men increased. If the time taken to produce a clinical silicosis could be pushed up to twenty years silicosis could be considered as eliminated on the Rand from the social point of view.

The Chairman: From 1912 to 1916 compensation was awarded to men at quite as early a stage as at present. A large class of the miners now detected had begun work about 1912 and 1914. Diagnosis was based on the correlation of radiological and clinical evidence with the post mortem, and improved radiological technique alone could not, therefore, upset the balance. 256 cases were detected in 1930 as against 800 to 900 cases in 1912 to 1916. He did not believe as many ante-primary cases were now being made. The old Rand miners still accounted for 70 per cent. of the silicosis, but there was an improvement in the value of their production rates of 30 per cent. He did not agree that as much silicosis was made as ever but taking longer. Nor did he consider that the potentialities of their present methods had been exhausted.

Mr. Spence Fraser: The number of ante-primary cases last year was the same as the average for 1920 to 1923. The rates had decreased, which meant that the duration of working life was much greater, and that a larger number of miners got silicosis in later years. The mining population was much steadier and although there was the same number of cases the production of them was deferred. He thought that an improvement could be deduced from the figures given in his and Dr. Irvine's paper.

(The Conference adjourned at 1 p.m.)

NINTH SITTING

Wednesday, 20 August 1930, 2.30 p.m.

Chairman: DR. L. G. IRVINE

Dr. Mavrogordato showed lantern slides illustrating silicosis and tuberculosis in guinea-pigs and human beings.

STATISTICS OF SILICOSIS (*continued*)

Mr. Spence Fraser: The method of measuring silicosis production could be compared with the method of measuring mortality in a population. In the latter case the rate of mortality at any age was derived by comparing the deaths at that age with the population living at that age. In dealing with silicosis the number of miners working in each respective year of underground service was substituted for the population existing at each age, and certifications in the ante-primary stage were substituted for deaths. The methods were analogous. If the rates of mortality in a population were lower in any period than during a previous period, it was recognised that the mortality had fallen and that there had been an improvement in the position. In the same way, they found in South Africa that the rates of production of silicosis were lower to-day than at any previous period, and they had no hesitation in saying that the position had improved.

It was true that the annual number of new cases of silicosis to-day was about the same as in 1920-1923. A similar phenomenon was found in mortality statistics; the death rates could decrease, while the total number of deaths actually increased, because there was a different age-distribution of the population, many more being alive at old ages where the death rates were highest. The same thing had happened with regard to silicosis, since there had been a large increase in the number of miners working after long periods of underground service where the rates of production were highest. The true measure of the production of silicosis lay in the production rates showing the proportion of miners contracting silicosis in each year of underground service, and these rates showed a very substantial reduction in the incidence of silicosis.

Dr. Orenstein: The discussion had shown that the statistical methods of the Rand were not sufficient to give the facts which practical hygienists wished to know. Professor Hall's resolution aimed at closer and more detailed study in order to find out which factor contributed most to reduction. The present statistics did not give the fundamental data and he was not satisfied that they demonstrated a reduction in silicosis.

Dr. Cunningham requested information as to the number of cases of ante-primary silicosis among miners employed since the beginning of rigid initial examination, in whom tuberculosis had developed. If the numbers were large enough it might give some indication of the value of the initial physical examination.

The Chairman: Professor Hall's motion would be referred to the reporters.

LEGISLATION AND COMPENSATION

The Chairman: South African legislation had the peculiarity that : (1) the duration of time to render a miner eligible for a claim was very elastic; it was two years, with the reservation that the Board might allow a shorter period to count; (2) there was no restriction as to the date when the work had been carried out; (3) there was no restriction as to the amount of work done in other mines in South Africa or elsewhere before or after the work on the Reef.

Cases of ante-primary and primary silicosis received lump sum compensation, while grave incapacity or tuberculosis was pensionable. The ante-primary cases sometimes had disability up to 25 per cent. Primary cases could do moderate physical work and the secondary cases light work or none.

Dr. Middleton: While South African legislation made no provision for suspension in the early stage, under certain schemes in Great Britain any degree of silicosis was liable to immediate and total suspension, whether there was disablement or not. He asked, however, if this was justified or whether suspension would arrest the development of the disease. In some highly skilled industries, provision was made under special schemes to allow men with more than twenty years' work, or who were over forty years of age, to remain at work; this was done for economic reasons. The special schemes for silicosis were not all the same. Under the Refractories Industries and Sandstone Industry Scheme there were periodical examinations with compensation for partial or total disability or for death. Under the other schemes there was no periodical medical examination, but they followed the procedure under the Workmen's Compensation Act for occupational diseases, though they covered only total disablement or death, owing to the difficulty of recognising the disease in the earlier stages.

The Chairman: The ante-primary stage had been introduced in 1919 to secure the suspension of silicotic workers, at the earliest detectable stage of the disease in the hope that such cases would be non-progressive. That hope had not been realised. It was impossible to say that ante-primary cases would not progress; although they lived longer they reached the second stage faster than did the old primary cases.

Dr. Truter: Suspension from work lowered the worker's standard of living, and he therefore deteriorated more rapidly. A miner who continued to work lived as long or even longer.

Dr. Orenstein: Other employment could be found in an industrialised country but was impossible in South Africa. The ante-primary man had to choose between continuing at work with no increased compensation and receiving a lump sum (about £500) and finding other employment, which was difficult to discover at a wage equivalent to that gained by a miner. Their economic status was therefore lowered. He asked whether compensation really discharged the onus which lay upon society and whether the expenditure on compensation was applied to the best advantage.

Dr. Badham: He hoped the Reporters would frame resolutions to give guidance on the framing of compensation legislation.

Professor Hall: No single line of legislation or compensation could apply to all classes. In Great Britain, if there was no trade depression, a suspended man was able to find equivalent employment in some

other trade. Cases in the ante-primary stage which had been followed up had been able to carry on at work for five years. Skilled workers such as potters who had primary silicosis, with some degree of incapacity, were capable of doing their full work. Potters could not be treated in the same way because if they were suspended they could not find other work which was economically as good.

Mr. Du Toit: A number of South Africans had worked underground for two years or less in the scheduled mines and had subsequently been engaged in agricultural work. These men had never been out of South Africa and subsequent to their underground service in the gold mines had never done any other underground work, but nevertheless developed silicosis. For this reason the elastic period of two years' underground service, referred to by the Chairman, had been introduced in South African legislation. These men obviously had to be compensated. A number of men who had previously been miners in South Africa had during the past five years benefited under the South African Miners' Phthisis Act. These men had also done mining work elsewhere. It was an exceedingly difficult matter definitely to say where the disease had actually been developed. Then again, numbers of silicotic beneficiaries had left South Africa and had entered other mines and dusty occupations outside the Union of South Africa.

Silicosis had been found in men who worked in the Cornish tin mines, in the Welsh coal mines, the Cumberland iron ore mines, mines in Canada, in Australia and New Zealand. Miners and beneficiaries who had been employed there should have no claim on the funds of South Africa. Attempts were now being made to restrict South African ex-miners and beneficiaries under the Act who had subsequently engaged in mining work elsewhere from having any claim for compensation or further compensation, as the case might be, on South African Funds.

In regard to the question of rehabilitation, this was a most difficult matter because South Africa was a young country with few industries and it was not easy to find other employment for silicotic beneficiaries. South Africa was not essentially a great agricultural country in spite of what people might say. It was highly mineralised, and base metal mines absorbed a certain number of silicotics.

Then there was another important factor in South Africa with which other older countries had not to contend, namely, the enormous native and coloured population. This also made it very difficult to draft silicotics into other suitable occupations. It was impossible for silicotics to make good on the land as agriculturists since they could not stand exposure to all kinds of weather. He believed this had also been the experience in Australia, Canada, the United States and the United Kingdom. Road construction was also unsuitable. Asbestos mining was now known to be fatal and, in South Africa at all events there were very few other outside mines which could absorb all their silicotics. On the one hand, if silicotics were allowed to remain in their underground occupations without any restrictions, the position might be reached after a period of years when the gold mining industry would be entirely run by employees who were silicotics and this in the end was bound to affect efficiency. On the other hand, no State could be expected to legalise what amounted to slow suicide.

If continued employment underground was not dangerous to silicotics, then the South African legislation should be altered, but in the absence of reliable data there was no conclusive evidence either one way or the other.

A large number of South African silicotics had been placed in other suitable employment, but such employment was not always of a permanent nature. Then there were some beneficiaries who were unemployable. This class one naturally found in all sections of the community; it was a class which might be ruled out as not fit for employment. This class the South African Legislation never intended should be given employment unless of a very light nature and it consisted of men in the worst stage of silicosis or suffering from silicosis with tuberculosis. Beneficiaries belonging to this class were in receipt of monthly life pensions with inclusive allowances for their wives and children. After the death of a life pensioner no post-mortem or certificate as to the cause of death was required. The dependants were entitled to life pensions *ipso facto*.

Dr. Fisher: Alternative employment was impossible for coal miners. Colliers lived in small villages, and if they were unemployed their condition tended to become worse in a general way, as miners' nystagmus had shown, although of course neurasthenia was not part of silicosis as it was in miners' nystagmus. Light employment such as repairs on the main haulage roads at an agreed standard living wage was desirable.

Dr. George: At Broken Hill the medical authority was a Board which consisted of an independent chairman appointed by the Government, one doctor appointed by the employers, and one doctor by the workers. Medical benefits were given for pneumoconiosis and/or tuberculosis up to £125 per man. The Act was administered by a joint committee, two of whom were appointed by the workers and two by the employers, with an independent chairman, who was usually a stipendiary magistrate (a Government official). This committee had no power to interfere with the medical certificates. The condition of the miner had to be certified as reasonably attributable to employment in the Broken Hill mines. They were withdrawn in the ante-primary stage, but the Committee had to find work for them. Up to the present it had never yet been done, and silicotics therefore drew a full pension in many cases with no incapacity. At Broken Hill in case of death from any cause whatsoever the widow received a pension of £2 10s. a week, and children under the age of sixteen of 8s. 6d. per week.

At the start many men had not sustained injury from Broken Hill and the State therefore contributed half the amount, and the employers the other half. When injury was attributable to Broken Hill, the employer found the whole sum. Upon leaving the industry a man had to be examined by the Medical Bureau, and he could come up for examination at any time within the five years following.

Dr. Badham: In New South Wales there were three Acts, namely: (1) the *Broken Hill Act* which dealt with a special mining district; (2) the *Workmen's Compensation (Silicosis) Act*, which dealt with Sydney sandstone workers—a beneficiary might receive a maximum of £3 a week up to a total of £750, but there was no payment to dependants except in case of death; (3) the *Workmen's Compensation Act* (1926), which granted compensation for fibrous pneumoconiosis except at Broken Hill, with a maximum of £5 a week up to a total of £1,000. Diseases caused by silica dust were however excluded and despite the three Acts in New South Wales dealing with compensation for dust diseases of the lungs there was still a number of workers who were not protected.

Dr. Moore: In Queensland the Workmen's Compensation Act covered pneumoconiosis and silicosis. In Victoria and South Australia

silicosis was not included. In Tasmania, a few shillings a week were paid for silicosis. In Western Australia the Miners' Phthisis Act excluded tuberculosis or silicotic men from employment in the mines, but granted no compensation for silicosis. The Commonwealth Government paid a pension of £1 per week for total incapacity.

Dr. Cunningham: Disability and expense might be reduced if it were possible in industries in which silicosis develops rapidly, to remove men from exposure to silica without waiting for specific indications of silicosis and therefore without compensation, at some unknown point before the ante-primary stage is reached.

It would be worth a considerable expenditure to determine when tuberculosis becomes a more serious menace in a lung containing silica. A reduction of two or three years below the average exposure necessary for the development of silicosis would not materially increase labour turnover.

Mr. Barry: Silicosis in South Africa had given rise to nine Acts, four commissions, and many select committees. The average amount of compensation paid to a married man was £3,500. Up to October 1929, 7,633 beneficiary miners were alive; 2,271 of these were in the ante-primary stage, 2,306 in the primary stage, and 2,184 in the secondary stage. There were 2,014 widows and 3,538 children in receipt of pensions.

All this legislation was unfortunately retrospective, and it laid a heavy burden on employers, since many mines had shut down, and paid no retrospective compensation. The legislation contained anomalies such as the semi-compulsion upon a miner to give up underground work, but the lack of any regulation to prevent him taking up mine work elsewhere. Any miner who had been employed two years underground could work in another silicotic occupation and yet receive benefits. Two years' service at any date counted.

It was generally agreed that underground conditions had enormously improved in the last twenty years. The working life which had once been seven or eight years was now twenty years. The new Rand miner had a working life of about twenty-three years, notwithstanding which claims upon the Fund had increased. This was said to be due to the large number of old Rand miners, and to improved methods of diagnosis which kept the cases lower. It was also said, however, that the disease had become more progressive.

Under the Act of 1919 some mines closed down and were compelled to pay only a small portion of their liabilities. The Board collected about £1,000,000, all of which was given to old cases under the 1925 Act. The real cost of miners' phthisis was said to be £1,000,000 per year. The Government Actuary estimated the outstanding liability of the mines at £6,400,000.

When the 1925 Act was passed provision was made for each mine to set aside a sum annually to meet these liabilities. The cost to the mines of miners' phthisis was 7s. 6d. per underground European shift. The South African Act was the most liberal in the world, and the only Act that could be compared with it was in Ontario, where £100 was paid for ante-primary silicosis, £200 for primary silicosis and a pension of about £15 per month. It was impossible to alter the South African legislation without upheaval, because any new benefits granted produced thousands of retrospective claimants.

The Chairman: In South Africa there was no general national insurance Act for invalidity, and there was therefore a tendency to

treat the Miners' Phthisis Act as a kind of substitute for the Poor Laws. The question of compensation for simple tuberculosis might be referred to the Reporters. The cases which the Medical Bureau had certified as "simple tuberculosis" and which came to post-mortem were found in 50 per cent. of the cases to have a silicotic element. It was also desirable to remove simple tuberculosis cases from the mines, because of the risk of communication of infection to others.

Mr. Du Toit: The question whether compensation should be computed on a wage basis or on a flat rate should be referred to the Reporters.

Dr. Orenstein: Legislation had to differ according to the industrial conditions of various countries. The South African situation was quite peculiar, because the gold industry was not subject to the fluctuations of other industries, but was handicapped by the mental attitude of legislators to gold. The legislation on pneumoconiosis was extraordinarily illogical. The Reporters might consider whether any standard conditions could be applied to this disease throughout the world. Great weight was given in legislation to the necessity of fixing compensation for silicosis sufficiently high to stimulate prophylactic measures. The Reporters might consider whether silicosis could be called preventable. It was a misconception that removal from work in the earliest possible stage would prevent further development; if it was true that continued employment was really slow suicide, no man should be allowed to work in any dusty occupation at all. He proposed the following resolutions:

1. That endeavour should be made to deal with silicotics by rehabilitation, diverting for that purpose a portion of the funds made available under present conditions for compensation. Such rehabilitation schemes to be directed by specially constituted governing bodies.
2. That there appears to be reason to consider that there are no good grounds for compulsory removal of silicotics from their customary employment, unless such removal does not tend to lower markedly the economic level of livelihood of the silicotic or until his earning power has reached the level approximating that of the compensation.
3. That removal from employment of men in the fifth and sixth decades of life is generally inadvisable, until a high degree of incapacity is present.

(The Conference adjourned at 4.50 p.m.)

TENTH SITTING

Saturday, 23 August 1930, 9.30 a.m.

Chairman: DR. L. G. IRVINE

DRAFT REPORT ON PREVENTIVE MEASURES

The Conference considered the Draft Report on Preventive Measures and adopted it with the exception of Recommendation 4, after making various amendments.

(The Conference adjourned at 1.35 p.m.)

*ELEVENTH SITTING**Monday, 25 August 1930, 9.30 a.m.**Chairmen:* SIR SPENCER LISTER (Vice-Chairman) and DR. L. G. IRVINE

ARRANGEMENTS OF BUSINESS

Mr. Phelan proposed that the closing sitting of the Conference on Wednesday, 27 August, should be open to the Press after a certain hour, and that the recommendations adopted by the Conference should be communicated to the Press.

The Conference approved of this procedure.

THE MEDICAL ASPECTS OF SILICOSIS

The Conference proceeded to discuss the *Report upon the Medical Aspects of Silicosis, including Ætiology, Pathology and Diagnostics*, submitted by Drs. Gardner, Middleton and Orenstein. The Report was as follows:

The Reporters, Drs. L. U. Gardner, E. L. Middleton and A. J. Orenstein¹, beg to submit the following:

1. The Conference confined its discussion almost entirely to silicosis, as the other pneumoconioses are, with the possible exception of asbestosis, in the present state of available information, of less importance, and furthermore have not been subjected to sufficiently detailed study.
2. Silicosis is a pathological condition of the lungs due to inhalation of silicon dioxide. It can be produced experimentally in animals.
3. To produce the pathological condition, silica must reach the lungs:
 - (a) in a chemically uncombined condition, although the dust inhaled may be either a natural mixture of silicon dioxide with other dusts, such as occurs in granite, or an artificial mixture, such as scouring powder;
 - (b) in fine particles of the order of less than ten microns. There is no evidence as to the lowest limit of size in which the particles may be capable of producing the disease;
 - (c) in sufficient amount, and over a certain period of time; these two factors are reciprocal variants. The minimum of these two respective factors has not yet been determined.
4. Silica dust plays the dominant role in the production of silicosis, admixture of other dusts tending to modify the picture in the direction of that of other pneumoconioses, in some relation to the proportion of free silica inhaled.
5. There is experimental evidence that the solubility of silica in the tissues is an essential factor in the causation of silicosis.

¹ Dr. W. Steuart was unable to participate in the preparation of this report. He submitted a memorandum which is reproduced later as an Appendix.

6. Infection of the lung with *B. tuberculosis* or other pathogenic organisms, whether it occurs before, simultaneously with, or subsequent to the development of silicosis, alters the disease and influences it unfavourably, tuberculous infection being particularly unfavourable.

7. The establishment of a silicotic process in a lung renders the subsequent inhalation of other dusts, in themselves relatively innocuous, capable of producing serious pneumoconiosis.

8. It was suggested that intermittency of employment retards the onset of silicosis, but the evidence adduced in support of this, though suggestive is not conclusive, when the total period of exposure is not affected.

9. It was agreed that the microscopic pathological changes which may be produced by the prolonged inhalation of silica dust are:

(a) The development of a condition designated in South Africa as a dry bronchiolitis, characterised by an accumulation of dust filled phagocytes in or in relation to the terminal bronchioles, with possibly some desquamation of their epithelium.

(b) The accumulation of dust-containing phagocytes about and in the intra-pulmonary lymphoid tissue, and their transportation through the lymphatics into the tracheo-bronchial lymph nodes.

(The conditions described above under (a) and (b) do not constitute the disease silicosis.)

(c) The gradual development of fibrous tissue within such accumulations of phagocytes and the formation of characteristic nodules of hyaline fibrous tissue.

(d) Degenerative changes in these foci.

(e) The hyaline nodules increase in size by extension at their periphery.

Coalescence of adjacent nodules takes place and brings about involvement of further areas of the lung.

(The conditions described under (c), (d) and (e) constitute the disease silicosis.)

10. Macroscopically the changes observed in silicosis are:

(a) *In the early stage.* A variable number of palpable pearly-white nodules up to 2 or 3 mm. in diameter on the pleural surface of the lung. On section, the cut surface of the lung is studded with pigmented foci, widely scattered, a moderate proportion of which are only just palpable. The tracheo-bronchial lymph nodes are slightly enlarged and deeply pigmented, and may exhibit foci of fibrous induration.

(b) *Later stages.* The fibrotic nodules are increased in number, size and density, and coalescence of these may be found. The portion of the lung between the fibrotic nodules may be emphysematous. The tracheo-bronchial lymph nodes may be smaller in size than those seen in the early stage and are fibrosed.

11. The presence of tuberculous infection usually modifies the pathological appearance. Special attention was drawn to the three following types:

(a) In which the picture of silicosis above described may be little, if at all, modified, but in which only a biological test can demonstrate the presence of *B. tuberculosis*.

- (b) In which the coexistence of silicosis and typical tuberculosis lesions is easily recognisable.
- (c) In which the presence of tuberculosis is easily recognisable, but the existence of silicosis is more difficult to determine.

12. There is evidence that with *B. tuberculosis*, *in vitro* the period before growth becomes apparent is shortened in the presence of silica, and that *in vivo* an environment favourable to the continued growth of the bacillus is produced in the presence of silica, but the virulence apparently remains unaltered.

13. In *massive* silicosis cardiac hypertrophy and subsequent dilatation may occur. In silicosis with infective processes, cardiac changes may also occur.

14. No evidence was adduced in regard to involvement of kidney or liver.

15. For the diagnosis of silicosis as a disease it is necessary to take into consideration:

- (a) the employment history;
- (b) the symptoms and physical signs;
- (c) the radiological findings.

16. The disease can conveniently be divided into three stages, designated "first", "second", and "third" stages.

17. In the differential diagnosis of silicosis from other pneumoconioses a history must be established of exposure to inhalation of silica dust in a quantity reasonably commensurate with the clinical and radiological findings.

18. In the "first stage" symptoms referable to the respiratory system may be either slight or even absent. Capacity for work may be slightly impaired. There may be a departure from the normal in percussion and in auscultatory signs, and the radiograph must show an increased density of linear shadows, and the presence of discrete shadows, indicative of nodulation.

19. In the "second stage", there is an increase of the physical signs observable in the "first stage", and the radiograph shows an increase in the number and size of the discrete shadows indicative of nodulation with a tendency to their confluence. There must be some degree of definite impairment of working capacity.

20. In the "third stage" all the above conditions are grossly accentuated and indications of areas of massive fibrosis are usual. There is serious or total incapacitation.

21. Pulmonary tuberculosis may be present in any of the above described "stages" of silicosis, altering the symptoms, physical signs and radiographic appearances, and the degree of working capacity. Its presence must therefore influence the "stage" classification of the individual, which classification must in these circumstances be based more on the degree of loss of working capacity than on physical signs and radiographic appearances.

22. Radiographs may frequently be met with which show a slight, moderated, or well marked increase beyond the normal in radiating linear shadows. These may or may not be due to fibrosis.

23. The inhalation of asbestos dust produces a definite pneumoconiosis, which may occur also in association with tuberculosis, and deaths have been recorded.

This pneumoconiosis is associated with the presence in the lungs of "asbestosis bodies", but the mere presence of these bodies in the lungs or sputum does not constitute evidence of the disease.

For the diagnosis of this pneumoconiosis the same criteria as described for silicosis should be applied, *mutatis mutandis*.

There is not at present sufficient evidence to show definitely to what extent tuberculosis and this type of pneumoconiosis react upon one another.

24. There are other dusts, such as those from marble, coal, carborundum, etc., which may contain small quantities of silica and which produce demonstrable lung changes, radiographically resembling in some cases the appearances observed in early silicosis.

There is not a sufficient body of evidence available to enable a definite statement to be made of pathological changes in man. In animal experiments, the inhalation of carborundum dust over a period of four years has produced fibrosis only in the tracheo-bronchial lymph nodes; the lungs were entirely free of fibrotic changes. This, and collateral observations on inhaled granite and asbestos dusts suggest the hypothesis that to produce pulmonary fibrosis a sufficient concentration of a relatively insoluble dust must be brought by the activity of phagocytic cells into intimate contact with connective tissues. With the dusts last mentioned the migration of phagocytes, for at least a prolonged period, is ineffective in establishing such contact in the lung. Only in the tracheo-bronchial nodes are these conditions realised during a period of four years.

25. The Reporters beg to recommend that appropriate action be taken:

- (a) To establish an international classification of silicosis on the lines indicated in paragraphs 16 to 21 inclusive.
- (b) To enquire into the possibility of establishing an internationally comparable technique of radiography, and terminology of radiographic findings.
- (c) To institute further studies in the correlation of radiographic appearances, morbid anatomy and symptomatology of silicosis and silicosis with tuberculosis.
- (d) It is desirable that further scientific research into the ætiology, pathology and diagnosis of silicosis and other dust diseases should be undertaken on an international basis, at an early date.

APPENDIX

Memorandum on Radiography of Silicosis

By Dr. W. STEUART

With a view to obtaining uniformity in films of the thorax in cases of silicosis a description of the technique used at the Miners' Phthisis Bureau is given in detail.

The transformer receives three phase current and the secondary current is rectified by means of six valve tubes. Its output is much in excess of the capacity of present X-ray tubes.

The X-ray tube used is a metallic DN type. The distance from focus to film is 48 inches.

The length of exposure and penetration vary with the antero posterior thickness of the examinee according to the following table:

Depth of thorax in inches	Time in seconds	Kilovolts
7	0.1	61
7½	0.11	61
8	0.12	61
8½	0.15	62
9	0.175	62
9½	0.2	63
10	0.22	63
10½	0.23	64
11	0.24	64
11½	0.25	65
12	0.26	65
12½	0.26	66
Filament current 4.3 amperes	Current through tube 200 M.A.	

The man lies in the prone position on the cassette with the tube above him.

Kodak films and Agfa intensifying screens are employed. If other makes of screens and films are preferred allowance should be made in exposure and penetration as films and screens differ considerably as regards speed.

Cassettes are such that uniform contact between films and screens is secured.

The developing solution is made up according to Kodak's formula, but to every 5 gallons 4 lbs of sodium carbonate and 4 lbs of sodium sulphide are added.

The temperature of the developer is 65° F. and the time of development is five minutes.

Terms used in indicating the diagnosis on X-ray report form:

1. *Normal thorax.* — This is taken as that of a healthy youth of about eighteen.

The heart occupies a left medial position and is approximately triangular in shape, its shadow accounts for about one third of the area of the thoracic shadow. Its size and shape vary.

The right hilus is seen as a faint rather small shadow but the left is hidden by the heart.

The diaphragm is dome shaped on each side, the right being higher than the left. Its level is variable.

The pulmonary tissues throw no shadows so that between the ribs the skiagram should be uniformly clear.

Radiating from each hilus faint shadows can be made out due to the roots of the bronchial tree of bronchi vessels and supporting tissues.

The costal cartilages are transradiant.

2. *Rather more fibrosis than usual.* — This is really the normal thorax and is seen in healthy adults, but through the continuous inhalation of dust, smoke, etc., the hilus and bronchial tree shadows become accentuated, otherwise the picture is that of a normal thorax.

3. *More fibrosis than usual.* — This is an extension of the previous condition. The hilus shadows are denser and the bronchial tree shadows are more numerous and found throughout the thorax. It is seen in old people, in cases of chronic bronchitis, asthma, and in old healed infections. Though not an absolute bar to underground work it is a factor that goes far in deciding the rejection of an applicant for mining work.

Then come a series of classifications of conditions that arise from gold mining, viz.:

4. *Commencing generalised fibrosis.*

5. *Moderate generalised fibrosis.*

6. *Well marked fibrosis.*

7. *Very well marked fibrosis.*

8. *Gross fibrosis.* The commencing generalised fibrosis shows itself on the Witwatersrand after five or more years depending on the particular work done and the idiosyncrasy of the miner. It is a further accentuation of "more fibrosis" than usual and here and there small pin head shadows can be made out, the first indication of the typical "mottling" of silicosis.

Thereafter the mottling is common to all the others, the chief indication of the amount of fibrosis being the size of the nodules.

The nodule or unit of mottling varies from about one twentieth of an inch (1.25 mm.) in diameter in moderate generalised fibrosis to about a quarter of an inch (7 mm.) in gross fibrosis. These figures are of course merely approximate and not absolute.

9. *Fibrosis partly or mainly silicotic in type.* — This is deduced when the nodules are clearly cut in outline and uniform in distribution throughout the lung.

10. *Fibrosis partly or mainly infective in type.* — A slow infective process has the effect of increasing the size of the nodules in certain areas so that there is no uniform distribution as in pure silicosis. The outline of the nodules becomes fluffy instead of sharply defined. The usual infection is tuberculous, but syphilis and other chronic infective process may cause the same appearances.

11. *Appearances suggestive of tuberculous, $\frac{\text{right}}{\text{left}}$ lung.* — A sudden increase in the density of the hilus shadows, increased apical density or patchy shadows in other lung areas lead to the initialing of this item in the report.

12. *Apparently definite tuberculosis, $\frac{\text{right}}{\text{left}}$ lung.* — Tuberculosis is often so well established in periodical cases that there is practically no doubt as to the meaning of the shadows shown. The appearance can best be described by imagining some French chalk being thrown on the film and then rubbed round with the fingers. In the shadows produced dark areas of varying size may possibly be seen due to cavities.

The word "apparently" is retained because occasionally syphilis causes much the same kind of shadow.

13. *Peribronchial thickening; hilus thickening.* — From the experience obtained since the commencement of examining individuals

who wished to take up mining, it has been found that the accentuation of the shadows cast by the larger branches of the bronchial tree (called by the Bureau "Peribronchial thickening") and of the hilus shadows is a definite indication of tuberculous susceptibility and examinees are frequently rejected on this account.

14. *Pleural thickening* $\frac{\text{right}}{\text{left}}$ side.

15. *Pleural effusion* $\frac{\text{right}}{\text{left}}$ side.

Both of these conditions are readily noted by a radiographical examination and are considered important on account of their possible association with tuberculosis.

16. *Consolidation* $\frac{\text{right}}{\text{left}}$ side. — This diagnosis is given in the case of any dense shadow that does not alter its size and shape in different positions of the subject. The causes of consolidation are so numerous that unless there is some special indication in size, shape or position no diagnosis is attempted except possibly a query.

17. *Heart, asthenic or vertical in type.* — Although the heart shadows vary to a considerable extent within normal bounds, individuals having a tubular shaped heart or one casting a very small shadow, are regarded as "suspect" by the members of the Bureau for the same reasons noted in 13, 14, and 15.

18. *Heart enlarged.* — In most cases of cardiac disease and pericarditis the heart shadow usurps more than its normal share of the thoracic space, and attention is always drawn to this variation, as cardiac disability is often ascribed by outside medical practitioners as being due to silicosis.

19. *Aorta enlarged and aortic aneurysm.* — These items have frequently to be initialed and are often associated with patchy shadows suggestive of tuberculosis which however disappear after a course of appropriate treatment for specific disease.

20. Other changes, viz.:

(1) *Aerophagy.* — Occasionally at the left base it will be found that the phrenic shadow is pushed up into the thorax and that below it a negative shadow is shown. This is due to the subject swallowing air which distends the stomach and may cause discomfort.

(2) *Aneurysm of heart.* — The condition is very rare, only one case in 80,000 persons having been noted at the Bureau.

(3) *Atelectasis.* — Due to obstruction of a bronchus, gives a fan-shaped shadow radiating from direction of lung root which is as dense as a consolidation shadow.

(4) *Azygos lobe.* — In about one case in twenty thousand there is an abnormal azygos vein which leads to a shadow in the upper lobe of the right lung.

(5) *Bronchiectasis.* — This is indicated in skiagrams by No. 13, "peribronchial thickening". A definite diagnosis however can only be given after a lipiodol injection.

(6) *Bronchitis.* — Chronic bronchitis gives the picture described in No. 3, "more fibrosis than usual".

(7) *Calcification*. — Calcium is deposited in old inflammatory foci and in costal cartilage. It is often deposited in silicotic nodules and in lymphatic glands at the root of the lung. Its presence is indicated by an increased density of the shadow.

(8) *Carcinoma*. — Carcinoma may occur as a primary or secondary condition.

In the former case it leads to a consolidated area which increases in size. In the latter several shadows are seen which are circular and become larger and larger in diameter until the patient succumbs.

(9) *Emphysema*. — The lung tissue becomes more transradiant so that other shadows are accentuated owing to the increased contrast.

(10) *Empyema*. — The shadow is very dense and may occupy any part of the lung field.

(11) *Hodgkins disease*. — The thoracic involvement causes a dense mediastinal shadow.

(12) *Hydatid cyst*. — This is indicated by a dense oval shadow with a uniform contour.

(13) *Liver and subphrenic abscess* normally occur on the right side. The diaphragm is pushed up into the thorax.

(14) *Miliary tuberculosis*. — The appearance is practically the same as a moderate generalised fibrosis mainly silicotic in type.

(15) *Pneumonia*. — The shadow is dense and varies in size according to the severity of the disease.

(16) *Pneumothorax*. — The collapsed lung can be seen in the root area. It is surrounded by a uniform negative shadow stretching to the periphery.

The Conference adopted the Report.

The Conference decided that the Memorandum submitted by Dr. Stewart should be appended to the text of the Report.

Dr. Loriga dissented from the proposal which the Conference adopted to describe paragraph (a) and (b) of Clause 9 as conditions which did not constitute the disease silicosis, and paragraphs (c), (d) and (e) as constituting the disease silicosis, on the ground that these notes should properly be inserted in the Report on Compensation, since arbitrary legal limits might be laid down between the various pathological stages, while pathology must insist on the progressive nature of the evolution of the disease and could not properly indicate hard and fast divisions between its different stages.

The Chairman thanked the Reporters for the work which they had so ably performed.

(The Conference adjourned at 12.45 p.m.)

*TWELFTH SITTING**Tuesday, 26 August 1930, 9.30 a.m.**Chairman: DR. L. G. IRVINE*

PREVENTIVE MEASURES

The Conference considered the Revised Report of the Sub-Committee on Preventive Measures and adopted it. The Report is given below.

The Sub-Committee, consisting of Dr. Loriga, Dr. Badham and Mr. Roberts, appointed to deal with questions raised under this heading, begs to report as follows:

1. The Conference dealt with the matter of prevention at its sessions held on Friday afternoon and Saturday morning, 15 and 16 August 1930.

The first six papers and the papers presented by the visiting members, were taken as read, and discussed on broad lines, members having remarks to make calling freely upon their experience in regard to one or other of the various aspects of the question.

The feeling of the Conference was that the present opportunity should be used for an interchange of ideas with a view to mutual inspiration which would be of value in future research, rather than that it should be used for the purpose of arriving at conclusions and the making of recommendations.

2. It was generally agreed that so far as the present heading is concerned, the disease which it is sought to prevent is that which arises from the inhalation of free silica (SiO_2) as distinct from silica in chemical combination with other substances.

3. From the information supplied by various members, the disease becomes noticeable after widely differing periods of exposure to siliceous dust, depending apparently, upon:

- (a) The amount of dust inhaled;
- (b) the percentage of free silica contained therein;
- (c) the size-frequency (or fineness) of the particles inhaled;
- (d) the nature and sort of such other substances (including vapours and gases) as may be inhaled simultaneously, or otherwise;
- (e) the powers of resistance of the individual concerned;
- (f) the presence or absence of a complication by an infective process.

In regard to (a), it was agreed that by the use of water and other preventive measures the dust contents of air can fairly readily be reduced to ordinarily invisible amounts. In Australian experience this represents something in the neighbourhood of 4 or 5 milligrams per cubic metre, or say 400 or 500 particles per cubic centimetre when the particles are from 1 to 10 microns with a size-frequency ratio of 3. It was, however, evident from the discussion that it is impossible, under existing conditions, properly to correlate dust determinations made in different countries, in different industries and for different purposes, as well as for different immediate objects.

With regard to (b), it appeared from the information placed before the Conference that silicosis can be contracted through inhaling for

a sufficient period dust containing percentages of silica varying from say 95 per cent. down to from 30 to 35 per cent. and even lower.

In regard to (c), it was pointed out that with existing preventive measures carried out in certain mining areas there are now relatively few large particles in the air; and it appeared from the discussion that the greatest amount of harm is done by particles of less than say 3 microns in size. Some of the evidence seemed to suggest that particles of an ultra-microscopic size are factors in the causation of the disease, but evidence in this direction was not conclusive.

In regard to (d), the experience on the subject of certain members went to show that while exposure to various other dusts *simultaneously* with silica might affect the development of silicosis, the suggestion that other dusts might be used as an antidote against silica should be treated with great caution and reserve. Further research in this direction is urgently called for. It was pointed out that experimental evidence and practical experience under working conditions had shown that prior or subsequent inhalation of other dusts in no way delayed the development of silicosis.

In the course of the discussion under this heading some reference was made to the alleged immunity from silicosis in some districts where quartz in company with non-siliceous rock is mined, but it was pointed out that further investigation had shown in the one case that the allegation was unfounded in that the existence of silicosis had been obscured by the migratory nature of the working population; while in other cases it appeared that by reason, possibly, of the absence of laws relating to compensation, the medical evidence is not so complete as it might otherwise be, and there is sufficient room for doubt as to the exact position of the workers vis-a-vis silicosis. In all cases where there are laws relating to the compensation of silicotics it is but natural that the examination of the workers will be more thorough.

In regard to (e), it was generally agreed that this is an important feature, and there was a certain consensus of opinion that alternative employment and periods free from exposure to siliceous dust tended to increase the resistance and thereby delay the development of silicosis.

4. The discussion on methods for the prevention of dust and the inhalation thereof fell, on broad lines, under the following headings:

- (a) the use of water;
- (b) exhaust draught applied at or near the point of origin of the dust;
- (c) dust traps and masks;
- (d) ventilation;
- (e) other methods.

There was something said in favour of each of the methods referred to. It was agreed that no one method is applicable in all circumstances, but that in most cases, and especially in mining, there should be a combination of methods.

With regard to water, it was pointed out that as far as the Witwatersrand was concerned, it is used in three different ways, namely:

- (1) to prevent the formation of dust during the drilling of holes, in blasting, and the handling of broken rock;
- (2) for the wetting of all surfaces with a view to securing a "fly paper" effect in retaining dust which might settle on those surfaces;
- (3) for spraying into the air in order to allay dust which had been formed.

In regard to (1) it was generally agreed that the application of water at the site of percussion or fracture tends to minimise the formation of dust, but attention was drawn to the fact that in several operations, e.g. rock drilling, stone cutting, grinding, etc., sparks accompanied by dust escape even when the surfaces concerned are actually under a film of water.

In regard to (2), the view was expressed that since there is no particular reason why dust particles of the order of less than 3 microns should settle on the roof and sides of working places, and that they would settle on the floor only after many hours, the value of these wetted surfaces as dust catchers is probably small.

With regard to (3), it was pointed out that the dust particles with which the Conference was concerned are of the same order in size as micro-organisms, and that no one nowadays would expect to catch micro-organisms by means of a spray. In this connection it was mentioned as a matter of interest that Lord Lister, in his famous address delivered at Berlin, had stated that he felt ashamed of ever having suggested such a possibility in surgery.

The consensus of opinion was that as sprays are of little value for removing fine dust from the air and that since, further, a humid atmosphere and the presence of droplets had been shown experimentally to increase the risk of various infections their use should be restricted.

This view, however, does not necessarily apply to water blasts used on the Witwatersrand when firing in development ends, since while such blasts might not catch much of the finer dust (except by the subsequent condensation of water vaporised by the heat generated in blasting) they put into solution some of the noxious gases and wet the broken rock so as to prevent the escape of the dust when that rock comes to be handled.

In regard to (b), it was mentioned that exhaust draught was of great value in those processes of manufacture where there is an objection to the use of water. In some cases water cannot be used for fear of spoiling the material, and in other cases the workmen at times turn it off because it makes them wet. In all such cases, exhaust hoods should, if applicable, be used. It is necessary, however, that these hoods should be placed in close proximity to the work, and that regard should be had to the direction and speed of rotating objects. As an example of what could be done in manufacturing processes by the use of exhaust draught, cases were mentioned of a decrease in the incidence of silicosis which had followed the abandonment of wet grinding in favour of dry grinding with suitably applied exhaust draught. It was also pointed out that before exhaust draught was used for the dry grinding of metals this process was much more dangerous than wet grinding, but that since the introduction of efficient exhaust draught with dry grinding the position had been reversed.

(1) *Dust traps.* — As an example of the application of this method to the drilling of holes in mines, mention was made of an apparatus (such as is referred to below at the bottom of page 114) wherein the drill steel operates through an artificial collar held against the face of the rock; and through which ejector induced suction led the dust produced in drilling into a dust trap or filter. This apparatus was said to be very effective and popular in certain collieries to which laws relating to silicosis had recently been applied.

(2) *Masks.* — It appeared from the experience of members that workmen submit readily to their use only when discomfort from the inhalation of noxious dust could thereby be avoided.

In some circumstances loose fitting masks of the pressure type wherein

a constant supply of fresh air under positive pressure is led in through a flexible tube, have proved very efficacious. Such masks, however, are useful only when the wearers can perform their work without the necessity of moving from place to place. The same applies to tight-fitting masks supplied with air at normal pressure through a tube from a distant source.

Other masks wherein air was inspired through a filtering medium such as cotton wool, sponges, etc., and expired through a light non-return valve, were also described.

Reference was also made to masks in which the air to be inspired is made to pass through a tortuous path and impinge on damp surfaces which will retain the dust.

The feeling of the Conference was that while the masks at present available may be of some value in special circumstances, and particularly in those cases where the formation of dust (and the consequent necessity for precautions) is intermittent; they are so unwieldy or interfere so much with respiration that their constant use is impracticable during hard work and especially in a hot and humid atmosphere.

In regard to (d)—Ventilation—there was but little direct discussion, it being agreed that good fresh air ventilation was desirable, and indeed essential. It was emphasised, however, that to be effective the ventilation currents must be properly split and directed so as to sweep all dust-laden air out of the mine or works, as the case may be, in much the same way as dangerous gases are swept out of collieries.

With regard to (e)—Other Methods—mention was made of the fact that some years ago an endeavour had been made on the Witwatersrand to prevent the roof and sides of main intake airways from drying up (and, incidentally, to secure the "fly paper" effect referred to in 4 (2) and in the remarks thereon) by spraying those surfaces with solutions containing molasses, calcium chloride, and other hygroscopic substances, but it had been found that these preparations absorb moisture so readily that they soon trickle down into the gutters.

In discussion on this matter it was pointed out that if there really are any advantages to be derived from the "fly paper" effect, these solutions, and other sticky substances, could again be tried in the event of it being found possible at a later date materially to reduce the humidity of the ventilating currents. It was also suggested that these solutions might be used instead of plain water, for preventing the formation of dust in drilling, blasting, and the handling of rock.

In dealing with the dust formed by blasting, especially by blasting in development ends, a suggestion was put forward that it might be possible to project into the air at the time of blasting relatively large particles of some innocuous flocculent dust which in its settlement or progress through the mine would catch the harmful dust in much the same manner as micro-organisms are caught in water purification plants.

A further suggestion put forward was that saturated steam might be of some value, it having been found effective in industry in certain special circumstances.

A still further suggestion put forward was that the escape of dust from drill holes might be prevented by the use of a preparation producing a foam.

5. During the course of the discussion, reference was made to the difficulties experienced by investigators in the different countries in properly appreciating each others findings. Some of those difficulties arise from there being no accepted standards for comparisons in regard

to various conditions, dust counts, and so on; and others, through lack of a uniform terminology. The Conference, therefore, decided to put forward the following suggestions in the hope that those investigators who were in a position to do so, and particularly the Research Division of the International Labour Office, would take them up so as to pave the way for some decisions and recommendations at a future Conference.

(1) While the methods of conducting and other details relating to the routine sampling of air are best left to each local authority, it seems highly desirable that for certain special critical and scientific studies of dust particles in air and their effects, there should be established some standard method which for this special purpose would permit of inter-industrial and inter-national comparisons; in this connection it is suggested that the instruments at present approved by the various experts should be taken into consideration. The results of these investigations should be communicated to the Research Division of the International Labour Office for correlation.

(2) That as photographic and photo-electric cell methods of dust determination have been successfully applied in certain special circumstances, research should be undertaken with regard to such methods, with a view to ascertaining their adaptability in other circumstances.

(3) In view of the chemical theory of the causation of silicosis, the importance of estimating the size frequency of particles has increased owing to the fact that the surface exposure (which varies greatly with different sized particles) is the chief factor in the amount of silica which goes into solution. It is suggested, therefore, that investigators should include in their work determinations of the size frequency of particles.

(4) (a) The Conference urges that the investigations suggested in paragraph (1) should be undertaken with the least possible delay in all countries which are interested in the problem.

In view of the thoroughness and outstanding work of research already carried out on the Witwatersrand, and in view of the special facilities which exist in that area, the Conference attaches special importance to the investigations which may be undertaken on the Witwatersrand and ventures to express the hope that they will be initiated at the earliest possible moment.

(b) The Conference recommends that as soon as the standard method referred to in paragraph 1 has been perfected it should be applied for the purpose of making at least one complete survey of the dust concentration in dusty industries throughout the world. The results of this survey should be communicated to the International Labour Office.

(c) The Conference considers that the survey recommended in (b) should include an investigation into the relative size frequency of the dust particles.

Every effort should be made to emphasise the fact that the prevention of silicosis must be achieved by means of a whole series of provisions relating to hygiene in mines—viz. chiefly by reducing production and diffusion of dust, by maintaining the purity of the air, and by means of personal hygiene;

(5) That no opportunity should be lost of stressing the importance of general and localised ventilation as one of the best hygienic measures in dusty industries.

(6) That the personal protection of the workers should not be exclusively confined to such protective measures as, for instance, the wearing of masks, but should be supplemented by secondary measures such as the provision of suitable change houses and shelters, and by the regulation of working hours, etc.

(7) That many of the points raised in the prevention and control of dust call urgently for investigation by the physicists.

Note. — The present Report does not concern itself with medical methods of prevention of silicosis.

PROGNOSIS, AFTER-CARE AND COMPENSATION

The Conference considered the Report on Prognosis After-Care and Compensation and adopted it, after making various amendments. The Report is as follows:

Reporters: Dr. Cunningham, Professors Hall and Koelsch, together with Dr. Badham (co-opted).

In presenting our report it has seemed best to deal with each subject separately.

Prognosis

This subject may be considered under four headings:

Question 1: What is the prospect of a man exposed to free silica dust as regards acquiring silicosis?

This has been considered on various factors:

(a) The nature, silica-content, size of particles, and concentration of the particular dust to which he is exposed.

Concerning many of these points exact information is not forthcoming and it is desirable that further scientific investigations should be carried out and the results carefully compared with the incidence of silicosis amongst the workers.

(b) Period of exposure to dust.

(i) Length of service.

That this is a factor of importance is in accordance with the views expressed by members of the Conference from every country represented.

The length of service necessary to acquire silicosis may be considerably prolonged by improvement in other factors.

(ii) Intermittence of exposure.

On this point the evidence forthcoming was not conclusive.

(c) Age of worker.

There is no evidence that *per se* this plays any important part.

(d) Physique of worker.

This is a factor of primary importance. An initial medical examination to ensure a certain standard of physique should be generally adopted in those industries in which the risk of exposure to silica dust is great.

Periodic medical examination of such workers is also essential.

(e) Race.

There is no evidence that this is a factor of importance.

Question 2: What is the prognosis in a case of silicosis if the affected man leaves the industry at the first stage of the disease (ante-primary stage of South African legislation) ?

The evidence on this point as regards various industries and from different countries is somewhat conflicting.

In South Africa on the whole the evidence shows that the downward progress of the disease is in most cases not arrested on leaving the industry.

In this connection the questions of so-called infective cases, of reduced economic conditions of life, and of the associated mental worries probably play no inconsiderable part.

The view taken by the Medical Bureau in regard to the so-called "infective types" of silicosis is that they do not come under the classification of tuberculosis with silicosis unless the conditions in respect of tuberculosis as laid down in the Act are complied with. The prognosis in such cases of infective silicosis is much less serious than in cases of tuberculosis with silicosis as the term is used in the Act. Such cases may live for many years in comparative comfort unless active tuberculosis intervenes. The preceding evidence points to the urgent necessity of further experimental study of the exact conditions connected with silicosis of infective type.

Question 3: What is the prognosis in a case of simple silicosis if he remains in the industry after the first stage (ante-primary) declares itself ?

The evidence from South Africa suggests that in so far as mining is concerned the continuation in underground employment of sufferers from silicosis will aggravate the progress of the disease, except in certain selected mining occupations.

As, owing to economic factors connected with compensation, only a very small number of the silicotics in South Africa do remain at work underground after the disease has declared itself, the evidence on this point is somewhat indefinite. It is stated, however, that there are at present about 150 men in this position, and it is said that their progress is no worse than those who have left the mines. Among these 150 men, however, are included a considerable number of higher officials whose duties do not now expose them considerably to dust and whose economic position remains as good as before.

It is desirable to obtain exact information as to how far continuation at work in occupations involving exposure to silica dust will influence the progress of the disease.

Question 4: What is the prognosis in a case of silicosis with tuberculosis ?

(N.B. Before attempting to summarise the views of the Conference on this point it is desirable to make clear exactly what we mean. According to the terminology used in South African legislation "tuberculosis, means tuberculosis of the lungs or of the respiratory organs" and is deemed to be present "wherever it is found by the Bureau either (a) that such person is expectorating the tubercle bacillus, or (b) that such person has closed tuberculosis to such a degree as seriously to impair his working capacity and render prohibition of his working underground advisable in the interests of his health".)

This is always serious.

It is worse:

- (i) when the tubercular infection occurs at the outset of silicosis;
- (ii) in younger than in older subjects;
- (iii) than in cases of tuberculosis alone.

*Recommendations**Prognosis of Silicosis*

1. Exact information is not forthcoming concerning many of the points relating to the nature, silica-content, size of particles and concentration of dust to which a man may be exposed and it is desirable that further scientific investigations should be carried out and the results carefully compared with the incidence of silicosis amongst the workers.

2. The physique of the worker is a factor of primary importance. An initial medical examination to ensure a certain standard of physique should be generally adopted in those industries in which the risk of exposure to silica dust is great.

Periodic medical examination of such workers is also essential.

3. The evidence points to the urgent necessity of further experimental study of the exact conditions connected with silicosis of infective type.

4. It is desirable to obtain exact information as to how far continuation at work in occupations involving exposure to silica dust will influence the progress of the disease.

Compensation from the Medical Point of View

1. Silicosis complicated or not by tuberculosis constitutes an occupational disease which may involve reduction of working capacity.

2. It should be left to competent authorities to decide, in accordance with their particular conditions, whether other forms of pneumoconiosis should be regarded as occupational diseases.

3. In establishing the amount of disability, account should be taken of the clinical and functional condition as a whole.

4. The determination of disability should be entrusted to an independent medical expert, or body of experts, possessed of the requisite clinical and technical knowledge, and having at his or their disposal suitable apparatus for effecting the examination.

5. It is suggested that removal from all industrial occupations involving exposure to noxious dust should be enforced in all cases of open tuberculosis.

6. Where legislation provides for the compulsory removal from occupations involving exposure to silica dust of workers affected by silicosis, it is suggested that such compulsory removal should not necessarily be applied to workers who have been in the same industry for a period of not less than fifteen years and have reached the age of forty-five years.

After-Care

1. Sanatorium treatment should be provided for suitable cases.

2. Hitherto most of the rehabilitation schemes have been unsuccessful. Further investigation into this problem is urgently called for.

(The Conference adjourned at 12.45 p.m.)

*THIRTEENTH SITTING**Wednesday, 27 August 1930, 10 a.m.**Chairman: DR. L. G. IRVINE*

The Chairman: The minutes of the previous Sittings, with the corrections made by members, would be taken as adopted. Any further corrections which members had to make could be sent to the International Labour Office in Geneva.

Mr. Phelan: The Conference might hold an informal conversation on the next steps to be taken in the question of silicosis.

The Chairman: The Government Departments concerned should maintain libraries on the question of silicosis.

Dr. Badham: The text of Recommendation IV (6) was incomplete. It was decided that the corrected text should be distributed immediately.

Sir Spencer Lister: The Conference might make a recommendation regarding the safe storage of X-ray films.

After some discussion, it was decided that this suggestion should be mentioned in the Minutes.

(At this point the representatives of the Press were admitted.)

Mr. Phelan: On behalf of the International Labour Office, he thanked the delegates for the work which had been brought to a successful conclusion. He realised that they had sacrificed their time and convenience in coming to this Conference. The special thanks of the Office were due to Dr. Russell and Dr. Gardner, who had recorded yet another proof of the unstinted scientific collaboration of the United States of America. The thanks of the International Labour Office were also due to the Chamber of Mines, and in particular to Mr. Limebeer and the Staff, without whose help the small Geneva staff could not have coped with the work. The thanks of the Conference were due to Messrs. Owen Jones, Ltd., for the loan of epidiascopes and microscopes; to the South African General Electric Company for the loan of X-ray stands, and to Messrs. Kodak (South Africa) for the album which they had presented to members. This was the first Conference which the League of Nations had convened outside Europe, and a certain risk was involved, for Conferences had been known to fail in Geneva. This Conference, however, was an unqualified success, largely due to the hard work of the delegates, and in particular to the Chairman, who had conducted a highly technical discussion with charm and fairness.

He presented the Chairman with a photograph of the members of the Conference.

Professor Hall moved a vote of thanks to the Chairman, to whose great clinical experience and to whose advice and help it was entirely due that the Conference had performed its work punctually and unanimously.

Professor Böhme seconded the vote of thanks and said that all the members of the Conference had admired the Chairman's expert knowledge and tact.

The vote of thanks to the Chairman was unanimously adopted.

The Chairman: He thanked the Conference for the honour which they had done him. His original trepidation at taking the chair had been replaced by a feeling of increasing pleasure in his task because of the extraordinary spirit of goodwill and co-operation which the Conference had shown throughout. He was much encouraged by the spirit of good fellowship shown between scientific workers of many scattered nationalities.

South Africans did not always realise that the problem of silicosis was world-wide and ramified into many other industries. The Conference had largely recognised and accepted South African experience, but equally valuable contributions had come from other countries. A large measure of agreement had been reached on the causation and nature of silicosis, but they had also been led to realise how much material was not yet known. For these reasons, the Conference had laid down lines for future investigation and research. He hoped the International Labour Office would keep the spirit of international co-operation alive. On behalf of the Conference he expressed his thanks to Mr. Phelan and the Staff of the International Labour Office, to the Chamber of Mines, to Dr. Orenstein, and to the various reporters.

Dr. Middleton moved a vote of thanks to the Vice-Chairmen.

Professor Hall seconded this vote of thanks.

The vote of thanks to the Vice-Chairmen was unanimously adopted.

Sir Spencer Lister thanked the Conference. Their duties had been light because the Chairman had borne the greater burden.

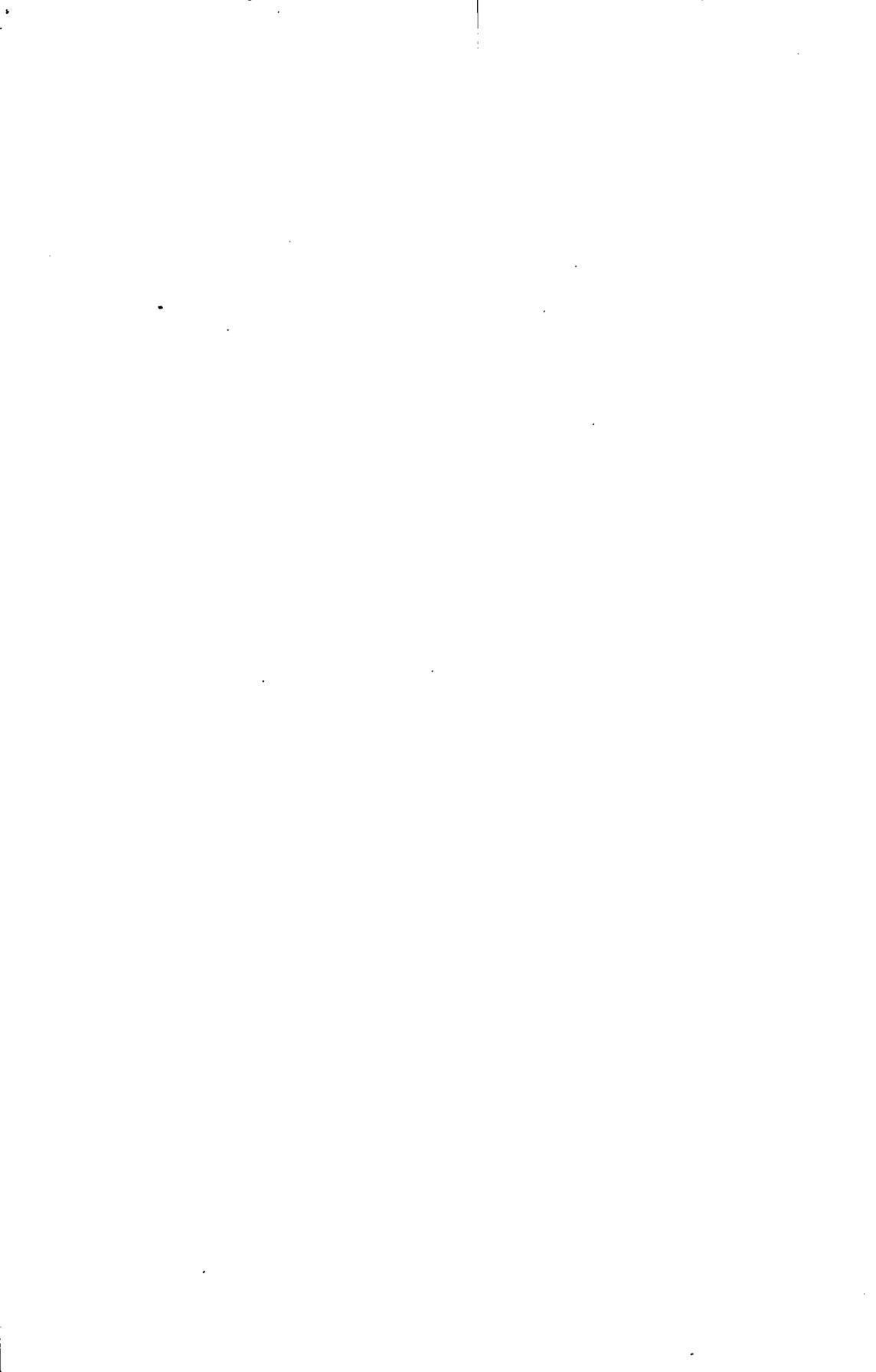
Dr. Russell also thanked the Conference and the International Labour Office for inviting him to be present. He was especially grateful to the Chairman and the South African members for their hospitality and friendship.

Professor Loriga: He had been more an observer than a collaborator. He had thought that some of the conclusions in the papers submitted to the Conference were exaggerated, but he was now convinced that South African scientists had a very profound and accurate knowledge of silicosis.

Dr. Kranenburg: The thanks of the Conference were due to Dr. Orenstein, to Dr. Carozzi, and to the members of the Staff of the International Labour Office.

The Chairman declared the Conference closed.

(The Conference adjourned sine die at 11.50 a.m.)



PAPERS
PRESENTED TO THE CONFERENCE

HISTORICAL REVIEW OF MINING CONDITIONS ON THE WITWATERSRAND AND THE CHANGES WHICH HAVE TAKEN PLACE SINCE THE EARLY DAYS OF THE FIELDS

BY A. E. PAYNE, A.R.S.M., M.INST.M.M., GENERAL MANAGER, VAN RYN DEEP, LTD.; HANS PIROW, D.SC., D.I.C. (LOND.), M.I.M.M., GOVERNMENT MINING ENGINEER; AND FRANK G. A. ROBERTS, M. AND P.P., S.A.J.E., TECHNICAL ADVISER, TRANSVAAL CHAMBER OF MINES

A review of mining conditions on the Witwatersrand from its inception to the present day is chiefly interesting on account of the rapid change which has taken place in these conditions and on account of the successive steps for the prevention of miners' phthisis which the change in conditions has necessitated.

At no time in the history of the Witwatersrand was the eventual development of the industry fully foreseen. As new problems arose, new methods were called for, and the dust prevention campaign led to sustained effort and continuous research.

In order, therefore, to present a complete picture of the changes which have taken place in mining conditions generally on the Witwatersrand, it is necessary to describe step by step the various phases through which the industry has passed.

Mining may be said to have started on the Witwatersrand in 1886, and the first stamp mill was started in the following year.

From this time up to the outbreak of the Anglo-Boer War in October 1899 it is estimated that an approximate total of 36 million tons was crushed, or a little more than is crushed per annum to-day.

The industry progressed slowly at first, and we find that the State Mining Engineer of the South African Republic in his report for the year 1898 records that there were employed only 9,854 whites and 73,354 natives in the mining industry; whilst the Government Mining Engineer of the Union of South Africa reported in 1928 that there were in the service of the mines of the Witwatersrand for that year 21,341 whites, 176 Asiatics and 194,362 natives

and other coloured persons. An analysis of the occupations of these employees would indicate that approximately 53 per cent. of the whites and 78 per cent. of the natives and other coloured persons were employed underground.

At first the workings were of course shallow, and in the oxidised or "free milling" zone, where the rock was relatively soft, friable and damp. The average depth to which this zone extended varied from place to place, but rarely exceeded 300 feet, and in some places was as little as 100 feet. From near the bottom of this zone the rock gradually became harder and more pyritic, until at vertical depths averaging in the neighbourhood of, say, 500 feet it had much the same characteristics as that which is being mined to-day.

By the year 1892 extensive deep-level companies had been formed, and drilling by machines had been introduced, principally at first for development work, and we find that the number of machine drills at work in 1896 was just over 1,000, increasing in 1899 to over 2,000 in number. These machines were of the rigged reciprocating type, and weighed up to 350 or even 400 lbs. each. They were operated mostly by miners from overseas with the assistance usually of two or three natives, but it was not until some years later that it became the practice for the natives themselves to operate the machines.

Though the "reef" had been intersected in deep boreholes, e.g. Rand Victoria Borehole in 1893, at a depth of 2,343 feet, and 1895 in the Bezuidenville Borehole at a depth of 3,127 feet, there had been very little thought for the ventilation of the mines as the depth and extent of workings increased, nor had the health of employees caused any anxiety in the minds of the managements or Government.

As long as the mines were working in the free milling zone very little dust was produced, and since the mines were shallow, and in consequence well ventilated, it is unlikely that the men came to any harm through dust.

We find that following the disturbances which gave rise to the Jameson Raid in 1895 the Government of the South African Republic appointed in April 1897 an Industrial Commission of Enquiry to look into the position of the mining industry. The records of that Enquiry can be searched in vain for any grievance as to conditions of health, or suggestion as to disability arising from the method of mining the banket.

It may be said that before the Boer War no one, or at least very few people, suspected that the mine dust was in any way injurious

to health. The few who did complain were mostly surveyors who had difficulty in taking some sights on account of the bad visibility caused by the dust, and they were laughed at and told that "everyone must eat a peck of dust before he died".

The conditions in those days, however, if compared with present standards, would appear to be very bad. Much of the drilling, especially in development ends, was done dry; blasting was permitted at any time during the shift provided it did not interfere too seriously with work, and cases of gassing were frequent. Broken rock was shovelled in a dry condition, and, generally speaking, the mines were so dusty that workmen at the end of their shift looked like millers. The shifts were materially longer than at present, the average being in the neighbourhood of ten hours. Night shift for ordinary work was common practice and the interval between shifts was very short; indeed, on development work there was no interval at all in some cases, the common practice being for the miner to drill over the round, turn on the compressed air and blast the cut, returning in about half an hour to blast the round, having in the meantime sent word to his mate on the surface that it was time for him to come down. These men thus worked no regular shift, but relieved each other whenever they happened to finish a round.

The conditions under which they lived would also be described as bad in comparison with those of the present day. There were but few change-houses, and where these were provided the tendency was for the men to refuse to use them. Most of the men lived in single quarters provided by the mining companies, two, and sometimes three, in a room which, while perhaps adequate in size, would be said to-day to be insufficiently ventilated. In the earlier days these rooms were made of wood and iron, and the variations in temperature were considerable. As time went on, however, it became customary to line such rooms, first with matchboarding and afterwards with sun-dried brick and plaster.

In regard to social amenities, places of amusement, recreation facilities, etc., it could be said that these were non-existent, meagre, or confined to the towns, with the result that many of the men, and especially the single ones, tended to congregate in bars and to indulge in month-end orgies.

On the medical side, the conditions on the Witwatersrand have never been very bad, except perhaps in the earlier days and during outbreaks of what was commonly called in those days "camp fever". Men were quick to realise the advantages of sick benefit

societies, and these were brought into being at a comparatively early date, and it can be said that, generally speaking, they were functioning with some success, especially on the larger mines, as far back as 1895-1896.

It is not until the Government Mining Engineer of the Transvaal Mines Department, in his report up to June 1902, introduces the subject of the health of workmen that any appreciation seems to have been given to the matter. In his report first mention is made of "miners' phthisis" as a disease "which seems to be peculiar to men employed in rock drill work". It must be understood that up to this time the breaking of ground in stopes was almost entirely done by hand labour, i.e. by native labourers drilling single handed. Machine drilling was confined to development work. Careful enquiry at this time elicited the fact that out of the 1,177 rock drill men employed on the Rand prior to the Anglo-Boer War, 225 or 16.75 per cent. were known to have died from miners' phthisis. The actual number may have been greater. It is certain, however, that if it had not been for the break in the working of the industry due to that war the mortality rate would not have been so fully realised. In considering this rate, however, it must be borne in mind that most, if not all, of the men concerned had worked previously in overseas mines in Cornwall, Australia, and elsewhere, and may have laid the foundation for their disease in these mines.

In 1902 the Governor of the Transvaal appointed a Commission to enquire into and report upon the prevalence and causes of the disease known as "miners' phthisis" and to make recommendations as to the preventive and curative measures which should be adopted. One outstanding result of their enquiry, which was made known in 1903, was that:

Although the incidence of the disease appears to be more marked in miners who have been working rock drills for some years, yet it is also found to prevail amongst miners who have never worked them;

and the Commission recommended, amongst other things, that:

- (1) The discharge of minute angular particles of dust in the mine air should be prevented;
- (2) The working places should be supplied with air in sufficient quantities to render harmless and sweep away all vitiated atmosphere.

The fact that other than rock drill miners were affected by this disease gave a spurt to improvements in the ventilation of workings

and in the use of respirators for those actively engaged in rock breaking.

Early development work was done by hand drilling, and headings were consequently on the small side. Practically all the early shafts were inclines with three relatively small compartments; and the drives were about 6 feet by 4 feet. When rock drills were introduced these dimensions were increased somewhat, but as a general rule the headings still remained small, namely, about 6 feet 3 inches by 5 feet 6 inches.

It can be said that most of the mines turned out to be poorer in depth than was expected, and this, together with heavy capital expenditure and other causes, necessitated increases in capacity materially beyond what the mines were originally laid out to produce, and brought about a congestion in the matter of handling rock, men and material.

In the year 1903 it was realised that, owing to the increasing average depth of the mine workings, it was no longer possible to allow the European miners to come up for their midday meal, and the fact that these men must in consequence remain in the mine for the whole duration of their shift was an additional urge towards the improvement in the distribution of the ventilating current, hitherto only due to the difference in pressure of the atmospheric conditions. Steps were taken to improve this pressure by various means, such for example as building up one or more of the compartments of the up-cast shaft; erecting drill sharpeners' furnaces at the bottom of the up-cast, and to a small extent in carrying light pipes from the face of drives to an up-cast shaft or raise.

Arising from the congestion referred to above, it was common practice for persons, and especially natives, to walk up long distances to get out of the mines. This position was gradually improved by the sinking of new shafts and the installation of larger and more powerful hoists, and in 1917 the Mining Regulations laid it down that the manager should provide arrangements for hoisting all persons when the height exceeds 500 feet measured vertically. (See Regulation 158 (25).)

In addition to the purity of the air, and freedom from gases due to the quantity of explosives used, attention was now first paid to the quality of the lubricating oils used in compressing air for the machines, through the exhaust from which it had been proved that in some cases dangerous gases had been disseminated into the mine atmosphere. At the same time attention was called to the use of damp and weak detonators, as well as to both the

overcharging and the undercharging of holes with nitro-glycerine explosives which result in the production of noxious fumes. In this same year (1903) the Chamber of Mines, a body formed in 1889 to represent the joint activities of the mining industry, offered prizes for the best method of allaying dust caused by machine drilling. The first prize was won for a water-spray or atomiser, and the second for a patented water-fed drill.

About this time improvements in machine drills designed to increase the speed of drilling began to make their appearance. The heavy old-fashioned type of reciprocating machines were gradually replaced by lighter and faster drilling ones, and a few machines of the Leyner hammer-drill type were introduced. These last-mentioned machines, however, employed hollow drill steel through which compressed air was blown in order to keep the drill bit free from chips, and they were thus, as dust producers, much worse than any of the machines which had hitherto been used. Indeed, they produced so much dust that it was usually impossible in development ends clearly to discern the operators. Dry air blowing machines of this type, however, did not remain in vogue for more than a few years.

It is at this stage that the industry was first confronted with the extreme conservatism of the operatives in the use of any dust-preventing devices. They objected to sprays designed to prevent the escape of dust formed in drilling and operated from the exhaust of the machine, on the ground that it made them too cold. They objected to sprays and the use of water generally, on the ground that it gave them rheumatism, and so on, and that they would just as soon die of miners' phthisis as of those other diseases which wet working places might cause; and they objected generally to any of the precautions which by occupying time tended to decrease their earnings. The Government, and indeed the industry itself, were forced therefore to recognise that outside the improvements in devices for dust allaying there would appear to be need for special legislation to enforce the use of any recognised means for the prevention of silicosis.

Act No. 54 of 1903, and the Mines and Works Regulations promulgated thereunder, is the first step of a long series of legislative measures to control the conduct of mines in the direction of the use of the best form of preventive measures, which continuous research in the cause and prevention of miners' phthisis showed to be desirable.

Starting with Chapter VI of the 1903 Regulations, containing

four regulations on ventilation, and one reference, Chapter IX, Regulation 97 (8), that the ganger shall be responsible that no person enters the working place "until the fumes caused by the explosives shall have been sufficiently dissipated", we have to-day Regulations in great number designed to control the ventilation; chemical analysis of air; limitation of blasting operations; exposure of persons to dust and fumes after blasting; the replacement of vitiated air by a certain volume of fresh air after blasting; the conditions for working in back stopes; the entry into working places; the use of water under adequate pressure in all working places; the use of water when tipping and handling broken ore; the use of water in drilling any hole; the clearing or blowing out of any hole after drilling; the use of tamping material in charging, and the quality of the lighting torch; the interval between blasting shift and return to work in the mine; the control of water blasts and auxiliary ventilation in development ends after blasting; etc. To ensure the proper observance of these precautions, responsibility is laid upon miners and officials of all grades from manager downwards. In a Code of Regulations, which twenty-five years ago could be comprised in a volume of 52 pages, we find now detailed Regulations for the health and safety of the mines comprising a volume of over 200 pages, of the same size, under Act No. 12 of 1911 and many subsequent revisions of the same under Government Notices.

It will be interesting to return to the history of the investigation into the disease of miners' phthisis, now bearing in mind that every relevant factor in prevention has in one way or another found its corollary in legislative injunction.

In 1907 the Government of the Transvaal appointed a Commission known as the "Mining Regulations Commission" to report on the working of the Mines, Works and Machinery Regulations, with special reference to (amongst other things) ventilation and the better protection of the health and safety of persons working in mines.

This Commission extended its enquiry over the years 1907-1910, and laid the foundation for the scientific investigation into the disease of miners' phthisis. We gathered that all true cases of miners' phthisis are primarily cases of silicosis, and that finally a tuberculous infection commorly becomes superimposed upon this condition and the symptoms and course of the disease alter accordingly. The suggestion arose also as to whether the exposure to noxious fumes might be a predisposing cause of miners' phthisis, and we were told that medical opinion was against exposure

to such fumes and that preventive measures should follow the lines of:

- (1) The prevention of dust inhalation;
- (2) The prevention or removal of noxious fumes resulting from explosives;
- (3) The prevention of silicosis.

By amendments to the 1903 Regulations the responsibility of the manager had already been extended to the compulsory use of water with machine drills, and to the prohibition of the removal of dry and dusty rock unless it had been wetted so as to prevent the escape of dust into the air. It was now for the first time recommended that responsibility should be placed on the manager for supplying the necessary water and on the miner for its use; and that inspectors of the Mines Department were to be instructed to pay special attention to its use (24 December 1908). On the adoption of these recommendations, the supply of water had to be made continuous, and all places where development work was carried out and every dry and dusty stope (when the natural strata are not wet) had to be kept damp. Blasting had to be so arranged that men working in other places were exposed as little as practicable to dust and smoke. The use of water by the miner was tightened up, and in drilling holes with any percussion machines he was enjoined to use a water jet or spray, and he was not allowed to enter a working place after blasting until the fumes had been sufficiently dissipated, unless he was wearing an effective respirator or other apparatus to prevent the inhaling of fumes or dust.

The next step was to enact that the miner should keep the floor and sides of his working place within a distance of 10 feet sufficiently damp to prevent dust being raised by the exhaust from his machine. Further, that rock to be shovelled should not only be superficially damp but should be kept damp in the process of shovelling. To ensure that these precautions were being carried out, and to combat the seeming indifference of rock drillers, it was laid down that a shift boss should report to the manager daily whether the requirements of these Regulations were being observed or not.

At about this same period (1908) attention was directed to contrivances for the catching of dust caused by the drilling of holes. Some of these had been used in Western Australia and in Cornwall, as substitutes for water jets and sprays which in the drilling of steeply inclined holes caused discomfort to the workmen, added humidity to the atmosphere, and were thought to tend

towards the production of ankylostomiasis and other diseases. These devices took the form of flexible collars fitting tightly against the rock, and through which the drill steel operated. In some cases the dust was caught in a bag, and in other cases it was sucked away by an air jet ejector and led into some form of dust trap. None of these devices, however, were successfully adopted.

In most mines in those days, and especially in those mines where the capacity of the reduction plant had been increased, there was an inadequate number of working places from which to obtain the necessary amount of ore. This shortage of working faces necessitated a heavy development programme, and a double shift method of working with blasting at least twice every twenty-four hours.

At about this same time and with a view to reducing the danger arising from the dust and fume caused by blasting, experiments were made with various methods of projecting into the air at the time of blasting in development ends a volume of finely divided water, and these experiments led ultimately to the general adoption of an apparatus known as a water-blast, which has now by regulation to be used at blasting time in all development ends and again before persons are permitted to re-enter.

When, as a result of the increased amount of development work, the number of working places became adequate, the custom of miners returning to their working places too soon after the blast was abandoned and single shift blasting introduced.

The consideration given to the incidence of tuberculosis by the Commission of 1907-1910 revealed the prevalence of this disease in particular amongst the native workers, and gave rise to the promulgation of preventive measures already known to be effective in combating this disease elsewhere than in mining. It initiated the examination of natives prior to engagement for mine work, and contemplated the possibility of having to take similar steps in the case of white workers. In both cases it was urged that infected workers should be excluded from the mines as soon as the disease had been diagnosed.

The sanitary arrangements underground were very bad in the early days. Indeed, it could be said that they were bad up to less than twenty years ago. At first no sanitary conveniences of any description were provided, and persons wishing to relieve themselves had no option but to walk out of the mine or to go into some disused workings. Afterwards it became customary for persons to use the rock boxes, so that the faeces would be hoisted with the ore. Later on, after the necessary provision of an adequate

number of latrines had been made, it was very difficult to break the natives of their bad habits and to educate them to use the latrines.

It was not until well after the Boer War that the mines began to provide drinking water underground. Prior to this the men made their own arrangements and either took water down with them or drank from one or other of the numerous water-bearing fissures.

Attention was now first drawn to the need for cleansing shaft stations and such waiting places as workmen were in the habit of using in the mines, whilst the housing conditions of both black and white were thoroughly reviewed. Change-houses for the white miners were made compulsory. Medical inspectors for the mines were recommended, and in the Johannesburg District this duty was taken over by the Medical Officer of Health of that town, and has been carried out very thoroughly ever since.

Another important consideration of the Commission was the duration of the working hours of mine employees. The chief ground for the reduction of working hours claimed by employees was that of health. The Commission found that there was no reason why work underground should be more unhealthy than work on the surface. In practice, however, this was found difficult to ensure. On the other hand, it was found that miners were not being employed more than eight hours a day at their work, the rest of the time being occupied in taking their meals, in getting to and from their working places, and in other ways. Recommendations were, however, drafted and later brought into force in Act No. 12 of 1911, limiting the hours of work to forty-eight hours per week, and the hours of certain employees to not more than ten per diem. The erection of underground drill sharpening shops was prohibited except under conditions controlled by the Mines Department.

This Commission, in investigating the quantity standard of air to be supplied in accordance with the 1903 Regulations, found that without detailed Regulations it was difficult to enforce. It turned its attention also to the quality of the air. It laid down a legal maximum for certain noxious gases, e.g. CO_2 , CO , and nitrous oxides. It pointed out that suitable mechanical appliances should be erected and operated to direct the ventilating currents when natural ventilation failed to operate; that old workings should be closed off, and plans should be kept to show the necessary stoppings and methods of control. In development work where machines were operated suitable arrangements were to be furnished for removing the dust, smoke and gases after a blast, and no man should return until the air was clear of such.

Undoubtedly a great deal of valuable ground was covered by this Commission, and the book of Regulations which, as above referred to, had been contained in 52 pages, was extended to 136 pages of the same size. The responsibility of the mine managers was extended to include the supply of clean water and suitable waiting places for native workmen and causing them to wait there, and powers were given them to take such disciplinary steps to enforce the requirements of the Regulations as the Inspector of Mines might direct or approve.

During the period covered by the 1907 Commission the mining industry had passed from the control of the responsible Government of the Transvaal to that of the Union Government of South Africa. A greater change was, however, taking place in the personnel of the operatives. In the early days of the industry the skilled white miner was almost entirely recruited from overseas, either from Europe, and principally from England, or from Australia. Owing to the incidence of the disease of miners' phthisis amongst these men, and to other causes, the mining field was ceasing to be attractive, and during the industrial trouble which arose in the industry in 1907 a large number of South African nationals were for the first time engaged by the mines and drafted into the occupation of mining, very largely as supervisors of the native gangs, and primarily, of course, in the less skilled operations of tramping, shovelling and other underground work. The South African national naturally lacked the mining knowledge of the overseas miner who had been brought up to mining since his childhood, and hence at first a great deal of care and training was necessary. In the course of time, however, the South African national began to get educated in this work, and at present over 60 per cent. of the employees of the mines are South African born, whilst a much larger percentage of those working underground are of that class.

The Union Government in February 1912 appointed a Miners' Phthisis Prevention Committee "to enquire into, by experimental and other investigation, and to report from time to time upon the improvement of, the methods for the prevention of miners' phthisis in the Witwatersrand gold mines, and to advise upon the introduction of a systematic and uniform policy and the amendments to the Mining Regulations which may be necessary for combating the disease". This Committee reported in March 1916 on its work up to the end of 1915, and finally in January 1919 on its conclusions. There were throughout this period preliminary

and special reports, as well as many memoranda submitted to the Government. Parallel with the growth of knowledge came legislative steps to enforce prevention, all the more necessary because of the change in the personnel of the miners and of the ignorance of the subject amongst them, now allied to the natural conservatism of the individual.

The material knowledge of the disease gained by this Committee was very great, but it may be said that in its conclusions it endorsed the already known fact that avoidance of the inhalation of air charged with injurious dust was the most important line of action towards the elimination of the disease amongst the operatives. With this fact in view, it was recommended that single shift blasting should be introduced; and the legal and moral responsibility of all mine employees was stressed as to the proper use of water for dust allaying purposes.

The Committee gained accurate knowledge of the incidence of the disease by medical examination of miners and a careful analysis of the silicotic condition of such men. Examination of the lungs of deceased miners gave rise to a knowledge of the size of the dangerous dust particles, and this led to the introduction of apparatus for the measurement of dust in the mine atmosphere.

At the same time it was first mooted that a careful selection of the recruits amongst the white miners would be an important preventive measure. It was also first suggested that main travelling shafts should be downcast and men should be kept out of upcast shafts after blasting "until the air is free from dust and fumes". The Regulations drafted to carry out the preliminary recommendations of this Committee were coded in an issue of the Mining Regulations of 1913. Briefly, the use of water for dust allaying purposes was extended and its use detailed. For example, the area round a working place to 25 feet instead of 10 feet had now to be kept wet. No one should enter, or permit anyone to enter, a close place after blasting within thirty minutes, and then only if the air was free from dust, smoke and fumes perceptible by sight, smell or other senses. The manager was called upon to arrange the time for blasting operations so that workmen should be exposed "as little as practicable" to the fumes and dust from blasting. The manager should supply a constant supply of "clean and odourless" water in pipes of not less than a certain size and not less than a certain pressure, such pipes to be carried to not less than a certain distance from the face. Water blasts were to be installed in every development end. No person should be allowed to remain in the

mine if the air contained dust, smoke or fumes perceptible by sight, smell or other senses. The cross ventilation of miners' back-to-back quarters was provided for. Miners must acquaint their native workmen of the requirements of the dust-preventing Regulations. The manager shall keep all main travelling ways wet as far as practicable; shall cut off from the ventilating currents old stopes; shall place ring sprays in downcast shafts not naturally wet. After 1 January 1915 no one shall be permitted to blast the cut and round separately in the same shift in the same development end. Finally, provision should be made for recording the measurement of dust in the mine air as periodically determined. The use of a water jet with a percussion machine should be coupled with "or the use of a drill with axial water feed". The collaring of holes with machines should have a special volume of water used in the process of collaring. The tube used for drilling holes should be inserted in the hole so that the water might be brought to the cutting edge of the drill. After a certain date only an axial water feed machine should be used for raising. The Inspector of Mines should fix an interval of time for each mine between the time of blasting and the next on-coming shift of workmen. An official should be appointed to each mine to report upon the water service, ventilation and prevention of dust.

It is useful to record the improvement over this long period of the conditions in the mines in the direction of dust prevention as reflected in the opinion of Mr. J. E. Vaughan, who had been away from the Rand as Inspector of Mines in Natal for some years and returned to note the marked improvement, and reported to the Government Mining Engineer under date May 1918 (*vide* Appendix No. 8, page 97, *Final Report of the Miners' Phthisis Prevention Committee*, Johannesburg, 10 January 1919). Improvement was noticeable in the attitude of the operatives to the many increased Regulations and the observance of them. There were improvements also in the water supply, dust sampling, and general cleanliness of the mines and working places. Water was everywhere being used; the air of the mines was free from visible dust; no dust was noticeable in the nostrils of the operatives. Improvements could still be made in the direction of the ventilating currents.

During this period there had been a further revision of the Mining Regulations. In 1913 the book was enlarged from 136 pages to 177, and in 1917 by a further addition up to 194 pages. There were of course additions for safety purposes other than those for the prevention of miners' phthisis.

The principal alteration in connection with Chapter VI on ventilation was that the amount of fresh air to be supplied for every person employed underground should be not less than 30 cubic feet of air per minute during the full period of twenty-four hours. The current should be suitably split and each ventilating district should receive its standard. Determinations of the quantity actually circulating should periodically be made. The replacement of air after blasting in dead ends was regulated and no working in back stopes was allowed without conditions imposed by the Mines Department. Provision was made for the duties of the ganger (Chapter IX) to wash over the face and immediate vicinity with water under adequate pressure before work was commenced. He was not allowed to use a percussion machine other than an axial water-fed machine without an additional water hose, nor a hand drill without a wet swab. Nor could he blow out a hole with compressed air unless he had first applied sufficient water to prevent the formation of dust. No person should allow water to run to waste. He shall report any cases of gassing, however slight.

It must not be supposed that all this time progress in the combating of the disease of miners' phthisis was confined only to such bodies of men as were working on the Government Miners' Phthisis Prevention Committee. The Chamber of Mines in 1914 appointed a Standing Committee on Dust Sampling. This Committee undertook the standardisation of methods for the determination of dust in the mines. It carried out periodic dust surveys of all the mines and created a laboratory for accurately determining the samples. At the same time it embarked upon a considerable field of research work, as well as being available for testing any dust preventive devices submitted to it or to the industry. Some of this work is carried on to-day by this Committee, and some has devolved upon the dust inspectors appointed on each mine according to the Mining Regulations. A ventilation expert attached to the Committee lectures to these mine dust inspectors, and the standard of knowledge is improving.

When water was first used for dust prevention and allaying, little or no effort was made to ensure its suitability for that purpose, and the nearest water available was used irrespective of whether it was clean or otherwise. As time went on it came to be recognised that dirty water when atomised might actually put dust into the mine air rather than allay it. The practice for some years past has been to use only clean water free as far as possible from fine silica particles, and approved by the Committee.

Through the chemical analysis of mine waters; of different kinds of mine rock; through the analysis of the dust produced by different kinds of machines; the analysis of air samples and the constant improvement of sampling methods, whether by sugar tube or konimetry, this Committee has a fine record of close and conscientious observance of the dust conditions of the mines. It is dealing to-day with dust particles both in quantity and magnitude of such small dimensions that the dust in the atmosphere of the mine can be compared to a possibly noxious gas which must be swept away and replaced by fresh air, rather than that any further means of allaying it could be attempted with success.

The Chamber of Mines also in December 1915 introduced on its own initiative a scheme for annual holiday leave, where under all mine employees, subject of course to certain conditions, receive an annual holiday on full pay (not exceeding 22s. per day). Under this scheme underground employees receive fourteen consecutive days' leave (of which the twelve weekdays are on pay) after one year of continuous employment; twenty-one days' leave after two years of such employment, and twenty-eight days' leave after three years, and there can be no doubt that this welcome break is of considerable value in preserving the health of mine employees.

The managers of the mines, several of whom had contracted the initial form of the disease of miners' phthisis, i.e. silicosis, were as a body very active in their insistence upon the best-known methods of dust prevention being strictly enforced. The method of single blasting has already been referred to, and was undoubtedly a most important factor introduced on the initiative of the managers themselves. Another important innovation was their recommendation in July 1915 (*vide Time and Labour Saving*, Association of Mine Managers, 1916) that a Central Bureau for the systematic examination of the physical fitness of men engaged in underground work should be established. This suggestion was adopted in 1916 by the Union Government, who in 1912 had framed legislation for the compensation of persons suffering from miners' phthisis. The trend of the Union Government's legislation in the matter of compensation for miners' phthisis does not come within the scope of this historical review of mining conditions on the Witwatersrand, and is therefore being dealt with under another heading. It must, however, be remarked that there is but little doubt that, following the increases in the amount of compensation awarded under the

Miners' Phthisis Acts, a number of persons, not realising the seriousness of silicosis and its tendency to progress into miners' phthisis, carelessly or deliberately and to the danger of others exposed themselves to dust and fume with a view to obtaining compensation. This particular phase lasted for some time, but it is not suggested that anything of the kind has been done in more recent years.

Following the efforts of the Miners' Phthisis Prevention Committee (1912-1918) previously referred to, the Mines Department instituted a systematic survey of the mines to ascertain in what way the provisions of the Regulations were being observed. This was found to be helpful to individual managers, and attention was particularly directed to ventilation, water blasts, night shift work, machine drills, shaft sinking and organisation, which still left room for improvement. In the matter of machine drills the Leyner type and axial water feed machines were rapidly replacing the reciprocating type of machine, and it was noticed that whilst the speed of drilling operations was increased by the application of water through the hollow-drill steel to the cutting edge, large quantities of dust were created by these machines through the passage of air down the hollow steel and the blowing up of small bubbles of air containing dust through the sludge discharged in drilling. These bubbles burst and, though containing exceedingly fine particles of dust, created a dangerous atmosphere for the operatives. It was found that, even in shaft sinking, where the shaft bottom was covered with water, the atmosphere at the shaft bottom contained dangerous quantities of dust when this type of machine was in use.

A long investigation commenced into the use of the Leyner type of machine and into the nature of the dust produced by it. It was found that by the use of a long piston the excess air could be prevented from passing down the drill to the cutting edge, and legislation was introduced to prohibit the use of any other than this type of machine, at first only in development work, and subsequently in all kinds of work, unless the machine was fitted with a front head release ring for the escape of air.

It followed from this investigation that the Government Mining Engineer should have power to prevent the introduction of any type of machine which might be dangerous to the operatives in its dust-creating properties, and also that for similar reasons he should have power to prohibit after due notice any type of machine already in use. Such powers were accordingly taken by the Government Mining Engineer under the Mining Regulations in 1922.

At this stage it will be of interest to point out that the heavy reciprocating drills of the early days drilled holes averaging from 6 to 7 feet in length with a diameter of about $2\frac{1}{2}$ inches at the collar and about $1\frac{3}{8}$ inches at the bottom. These machines in stoping rarely drilled more than four or five such holes during a shift.

The present-day hand-held jackhammers drill holes averaging from 3 to 4 feet in depth with a commencing diameter of about $1\frac{1}{4}$ inches and a bottom diameter of about 1 inch, and it is a common thing for these machines to drill as much as 120 feet in a shift; the average for the whole Rand being in the neighbourhood of 75 feet per machine shift.

Another point which may have some bearing on miners' phthisis is that prior to the outbreak of the Great War in 1914 the mines used blasting gelatine almost exclusively for development work, and 60 per cent. gelignite for stoping, the average strength of the explosives used being in the neighbourhood of the equivalent of 81 per cent. nitro-glycerine, whereas to-day the average strength used is in the neighbourhood of 55 per cent. nitro-glycerine. Another way of illustrating this change would be to say that prior to 1915, 0.83 lb. nitro-glycerine was used to break a ton, whereas the average consumed now is in the neighbourhood of 0.58 lb. nitro-glycerine per ton broken.

The so-called "contract" system has been a feature of mining on the Witwatersrand since the early days of the fields. It has been alleged that this system, which is in reality a method for paying European miners at piece-work rates, was to some extent responsible for the causation of miners' phthisis, in that men were induced under it to neglect precautions for the prevention of dust for the sake of additional gain. This matter of underground contracts was enquired into by a Government Departmental Committee in 1917, and this Committee found that the "contract system is not necessarily deleterious as regards the health or safety of those concerned, or morally unsound and against the public interest". (Conclusion No. 2.) (See paragraphs 32 and 33 of the report of the Committee.)

A further Miners' Phthisis Commission was appointed in 1920, primarily to deal with legislation for compensation. It went also fairly thoroughly into the preventive measures in use at the time. We find in this Commission's interim report the first reference to the suggestion that "the use of water for dust allaying is nearing the limit of its effectiveness and that therefore additional

methods, amongst which ventilation ranks foremost, will have to be relied upon for further progress in this direction". This knowledge was given to the Commission by the work of a Joint Committee of members of the Mines Department and the Chamber of Mines Dust Sampling Committee, who in particular investigated the efficiency of water blasts in development ends and the amount of air required after the blast to clear the end of dangerous dust particles (Reports 13/10/1922). This arrangement for attacking problems in ventilation was found to be useful, and was extended during the year 1923 to testing the best method of ventilating a close end when work was being carried on, especially drilling by machines. The quality of the intake air was thoroughly investigated and much knowledge obtained as to the direction in which improvements in the health conditions of the operatives could be made.

In improving the Leyner type of machine and reducing its dust-producing properties when air was allowed to pass down the hollow-drill steel, it was noted that the size of hole in the drill steel and the pressure of water were important factors in dust control. Whilst the long piston type was compulsory for use in close ends, the Government Mining Engineer intimated to the industry in April 1925 that he thought the time had arrived for prohibiting all machine drills passing air down the hollow jumper and that only machine drills approved by him should be permissible in all classes of work. He agreed to tests being made as to the relative importance of the many variables in the matter, but hinted that the adoption of a front head release to all machines immediately would appear to be justified, and arrangements to carry out this were made law as from 23 October 1926.

The tests conducted extended over a period of about two years, and were made in a test chamber at the Consolidated Main Reef mine, under the control of an Investigating Committee composed of members of the Central Mining and Investment Corporation's engineering staff and the Chamber of Mines Dust Sampling Committee. A report issued in July 1927 demonstrated that with release ports, maximum bore water tube and an extra hose for collaring, the dust produced by rock drills would be reduced to such a small amount as to render it a very minor factor in the production of silicosis.

This conclusion is of importance when it is considered that from 1923 onwards the number of jackhammer machines introduced into the mines increased, until to-day in many mines all ground is

broken by machine drills of this type. The care of the water tube is an important factor and has been very largely brought under control by the increase in length of the front head bushing and shank of the machine drill by which, primarily, better alignment of the drill steel is obtained.

Under the provisions of the Miners' Phthisis Acts Consolidation Act, No. 35 of 1925, a permanent Committee was appointed to watch the methods of preventing miners' phthisis already in force and to investigate any new ideas. Representation on the Committee is given to all bodies of workers, and it is hoped that the improvements in the future may come from such a body. For the present the Committee is chiefly concerned in the standardisation of methods of measurement of the dust contents of the air by the method of konimetry. It has also conducted certain investigation into the quantity of dust present in the intake air of the mines and the increase in dust contents of this air in its passage through the mine.

Difficulties in the maintenance of proper water tubes in machines have caused the Government Mining Engineer to give notice to the industry in June 1928 that the development of external water feed devices should be advanced as rapidly as possible and that the use of internal water tubes would be prohibited after some future and possibly early date.

The most recent difficulty is to combat the incidence of tuberculosis, and a Tuberculosis Research Committee is now sitting. It has promulgated the opinion that "the excessive use of water underground may do more harm than good in the efforts towards the prevention of this disease, and that it certainly is liable to produce deleterious effects on health in other directions, especially in the production of tuberculosis, a disease intimately associated with silicosis".

To sum up, it may be said that the steps taken to combat miners' phthisis on the Witwatersrand have been as follows:

1. The prohibition of promiscuous blasting during the shift.
2. The prohibition of blasting the cut and round separately on the same shift in the same development end.
3. The limitation of blasting (except in a few special circumstances) to one period only in each day, and the provision of a period of several hours (from three to seven depending on circumstances) after each blast during which persons are not allowed in working places, and the dust and fumes caused by blasting can be swept away.
4. The provision of waiting places which can be kept free from dust and fumes, so that at the end of the shift all workers can be hoisted without coming into contact with such dust and fumes.

5. The provision of improved water feed drills designed to prevent the formation of dust in drilling.
6. Improved ventilation and better distribution of the air available so as to first dilute and then remove the vitiated atmosphere.
7. The use of water in all cases for the prevention of the formation of dust, and for the allaying of such dust as may be formed in the various operations.

There is also another feature which must have had a most important effect on the mines of the Witwatersrand, namely, the establishment of the Miners' Phthisis Medical Bureau for the initial examination of all persons who wish to commence mining, and for the periodical examination of those who are engaged in that pursuit. This matter, however, falls under another heading and will not be dealt with in this historical review.

In regard to 7 above, namely, the use of water, it may be said that one of the outstanding features of the preventive measures which have been adopted on the Witwatersrand is the extent to which the use of water has been carried. Only a comparatively short time ago the mines were most prodigal in the use of water, which, without being exactly wasted, was "slopped about" everywhere, and no effort made to prevent the mine air becoming saturated, or nearly so, with water. Recently, however, and especially in the hotter and deeper mines, it has been borne in upon those responsible for their management that water in excess of that which served a useful purpose was being used, and that some of the ventilation and other problems connected with deep level mining were thereby being accentuated, and efforts were commenced to reduce excessive and unnecessary use of water. Great care will be necessary in introducing any changes; for having educated all operatives in the use of water; having provided the water at suitable pressure in every working place; and having encouraged its use by many contrivances, it will not be an easy problem to limit its use without endangering the effectiveness of the present organisation. The operatives do, however, require relief from the lack of cooling power in the ventilation currents of air in mines working at great depths. Any reduction in the saturation of the air will be beneficial in this direction. New legislation is being considered to impose a katathermometer standard on the management, and methods of mining are already being adopted which will facilitate the sweep of air up the working place, and if such a practice can be made general it is possible that the excessive use of water can be limited without re-creating the dust evil. A review of the history of the incidence of miners' phthisis

cannot close with a claim that it has been overcome. That the dangers are much lessened is readily acknowledged, but much yet remains to be added to the sum of human knowledge, and perhaps not least is the desire to find immunity from this disease for the operatives, white and black, of the Witwatersrand mines.

This historical review in the changes which have taken place in the mining conditions on the Witwatersrand would not be complete without some further reference to the changes which have taken place in the methods of working *vis-à-vis* their possible bearing on the matter of miners' phthisis. The more important of these changes may be summarised as follows:

1. The introduction of heavy rigged reciprocating machines operated by Europeans to replace native hand drillers in the wider and harder stopes.
2. The change-over to similar machines of a lighter type operated by natives under the close supervision of Europeans.
3. The change-over to machines of the hammer drill or Leyner type, including the change-over to air-fed hand-rotated hammer drills. Some of these machines used air only through the drill steel; others air and water, and some, especially the last mentioned, solid steel.
4. The elimination of machines which used air only through the drill steel and the substitution of machines using air and water or water only, with the simultaneous introduction of hand-held hammer drills.
5. The elimination of all forms of reciprocating drills and drills using solid steel, and the more general adoption of hand-held drills of the jackhammer type.
6. The introduction and general adoption of the cradle as well as hand-held machines designed to minimise the amount of air passing down the drill steel and to use as far as practicable water only.

Simultaneously with the changes enumerated above there has been a change over from hand drilling to machine drilling. This change is illustrated in the following tabulation:

Period: six months ending	Fathoms broken in straight stoping:	
	by hand	by machines
31 December 1914	52 per cent.	48 per cent.
31 December 1924	22 " "	78 " "
31 December 1926	12 " "	88 " "
31 December 1928	7 " "	93 " "

There have, of course, been a large number of other important changes of far-reaching effect, other than the ones referred to herein, but with the exception of the fact that the mines have become more extensive, deeper and consequently hotter, these other changes can have but little, if any, bearing on the miners' phthisis position.

CONCLUSION

The dust and ventilation problems on the Witwatersrand to-day can be said to be totally different from those prevailing at the beginning of this century. The systematic efforts which have been made since 1911 have resulted in the disappearance, for all practical purposes, of visible dust underground. Similarly, it can be claimed that, owing to improved organisation and mechanical ventilation, exposure to fumes or gases rarely occurs on these fields. Yet the main problem is far from being solved. The greatest obstacle to improvements at the present day lies in the fact that the workings are so far flung and so extensive as to make the cost of adequate ventilation for sweeping out the remaining invisible dust prohibitive on most mines.

The natural limitations consisting of the great depth of workings, narrow reef and large blocks of unpayable ground (particularly on the Far East Rand) in turn prevent any radical changes in mine layout.

It must, therefore, be realised that further improvements can only be gradually introduced. The definitive progress shown in the past, however, gives rise to the hope that such improvements will be effected and that thereby the incidence of miners' phthisis will be further reduced.

THE NATURE AND SOURCE OF DUST IN MINE AIR, TOGETHER WITH A BRIEF REFERENCE TO THOSE OPERATIONS WHICH PRODUCE DUST

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(SENIOR DUST INSPECTOR, TRANSVAAL CHAMBER OF MINES)

NATURE OF ROCK FROM WHICH DUST IS FORMED

The Witwatersrand System in which the gold mines are situated consists of a thick body of sediments which are said to have been derived from the waste of the Swaziland System.

The gold occurs in what are known locally as banket reefs. These reefs, of which the three principal ones are the Main Reef, Main Reef Leader, and South Reef, are conglomerate beds of closely packed vein quartz pebbles having a mean diameter of, say, from 2 to 3 centimetres, and bound together by a hard siliceous matrix.

These beds vary in thickness from a few inches to 6, 10 and even more, feet, and in the main they lie conformably with the adjoining strata, which may be described as a hard silicified quartzitic sandstone.

On the Central and West Rand the characteristics of the strata are much the same on both sides of the reefs. On the Far East Rand, however, the strata upon which the reef lies is of a finer grain and less siliceous than elsewhere, and is known locally as footwall shale.

The matrix of the banket contains a number of minerals, etc.¹, including osmiridium, and, as a curiosity, diamonds, but the most plentiful mineral is pyrites. The amount of pyrites contained in the reefs varies from place to place from about 1 per cent. to about 5 per cent., and averages in the neighbourhood of 3 per cent.

¹ Cf. R. B. YOUNG, Professor of Geology and Mineralogy at the University of the Witwatersrand: *The Banket of S.A. Gold Fields.*

The following are typical analyses of the reef and country rock at various places on the Rand:

FAR EAST RAND

	Hanging Wall (quartzite)	Reef (basket)	Footwall (shale)
	Per cent.	Per cent.	Per cent.
SiO ₂	94.62	88.54	62.13
Al ₂ O ₃	2.37	4.31	15.24
Fe ₂ O ₃	1.14	1.55	9.14
FeS ₂	—	1.31	—
CaO	0.56	0.57	0.45
MgO	0.15	0.61	7.85
Water	0.77	— (a)	4.27 (b)
	99.61 (c)	96.89 (c)	99.08 (c)

(a) Water not determined. (b) Loss on ignition. (c) Alkalis not determined.

CENTRAL RAND

	Country Rock (hanging and foot)	Reef (basket)
	Per cent.	Per cent.
SiO ₂	76.27	86.22
Al ₂ O ₃	14.09	5.85
Fe ₂ O ₃	4.71	1.97
FeS ₂	—	2.19
CaO	0.23	0.90
MgO	1.64	0.78
Water	2.25	— (a)
	99.19 (b)	97.91 (b)

(a) Water not determined. (b) Alkalis not determined.

WEST RAND

	Country Rock (hanging and foot)	Reef (basket)
	Per cent.	Per cent.
SiO ₂	86.18	88.86
Al ₂ O ₃	5.27	2.51
Fe ₂ O ₃	5.00	2.13
FeS ₂	—	1.53
CaO	trace	1.02
MgO	1.07	1.06
Water	1.54	1.53
	99.06 (a)	98.64 (a)

(a) Alkalis not determined.

NATURE OF DUST IN MINE AIR

The following is an analysis of the dust accumulated in the Transvaal Chamber of Mines laboratory from thousands of routine sugar tube samples of air taken in various parts of every mine on the Witwatersrand (after treatment with hydrochloric acid to dissolve out the filter paper ash):

	Per cent.
SiO ₂	80.69
Al ₂ O ₃	8.58
Fe ₂ O ₃	0.50
CaO	2.78
MgO	1.40
Loss on ignition	2.93 (a)
	96.88 (b)

(a) Includes organic matter, e.g. hairs from camel hair brush.
 (b) Alkalis not determined.

The above analysis does not reflect the presence of certain other constituents usually found in mine air, as revealed on konimeter slides under the microscope—for instance, water residue salts and carbon.

The water residue salts are derived from the atomisation of the mine water used underground, and the carbon particles from the candles and acetylene lamps.

In the case of a sugar tube or gravimetric sample the water residue salts are washed out, and the carbon particles are eliminated by the subsequent ignition, along with the organic matter of the filter paper used.

A konimeter spot, on the other hand, when viewed under the microscope shows up all the particles of whatsoever nature which were in the air sampled, and which were caught on the slide.

Until quite recent years, and before means had been devised for the elimination of such contaminating particles, the counts of konimeter spots were liable to serious error. Accurate counting of the *silica* particles was oftentimes impossible. This matter, however, will be referred to elsewhere.

SOURCES OF DUST

The principal operations which cause dust underground are:

1. Blasting.
2. The shovelling of broken rock.
3. The movement of rock in ore passes, ore bins, and the like.
4. Machine drilling.
5. Hand hammer drilling.

PHYSICAL NATURE OF DUST ARISING FROM THE ABOVE-MENTIONED
SOURCES

1. *Blasting*

Blasting produces large quantities of dust of all sizes. The larger particles soon settle and are caught by damp surfaces or by water blasts in development ends. Most of the other particles are swept away by the mine ventilating currents during the interval which elapses between blasting time and the time for resuming work, and it may be said the residual dust which may be left in the mine air currents is chiefly fine dust of the order of about one micron.

2. *Shovelling*

This work produces some coarse particles of dust, but the average size of the particles is from 2 to 3 microns and under.

3. *Ore Passes, etc.*

Dust from these sources is readily recognisable under the microscope, since it is usually made up of particles of from 3 to 5 microns and over, mixed with but little fine dust.

4. *Machine Drilling*

The dust from this source is usually fine, that is to say up to only 2 microns, with a few coarser particles.

5. *Hand Drilling*

The dust from this source is similar in appearance to that produced by machine drilling, but konimeter counts are usually lower.

AMOUNT OF DUST IN MINE AIR

The following tabulations (A, B and C) show the amount of dust in various places, and in different years, as determined in the manner stated:

TABULATION A. — SHOWING THE AMOUNT OF DUST IN MINE AIR, EXPRESSED IN MILLIGRAMS PER CUBIC METRE, AS DETERMINED FROM SAMPLES TAKEN THROUGH THE MEDIUM OF SUGAR TUBES BY THE DUST INSPECTORS OF THE TRANSVAAL CHAMBER OF MINES IN VARIOUS PLACES IN EVERY MINE

Place	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929 ¹
Main travelling ways	2.8	1.7	1.6	1.6	1.2	1.4	0.8	0.9	0.7	1.3	0.7	0.6	1.1	0.9	0.5
Development ends	6.9	5.8	5.4	4.4	3.5	2.9	2.3	2.4	1.9	1.2	1.0	1.1	1.2	0.8	0.8
Shafts	3.6	4.7	3.7	2.9	4.8	4.9	2.5	2.8	2.1	0.4	0.8	1.3	1.2	0.9	0.7
Stopes	3.4	2.7	2.9	2.2	1.9	1.7	1.3	1.2	0.9	0.7	0.7	1.0	0.9	0.6	0.7
Ore passes and bins	4.4	4.0	4.2	3.7	2.9	2.7	2.1	2.2	1.8	2.0	1.6	1.8	1.9	1.5	2.0
Sundry	3.7	5.0	4.0	3.0	2.5	2.0	1.4	1.3	1.2	1.4	0.8	1.0	1.0	0.6	0.6
General average	4.9	3.9	3.8	2.9	2.4	2.0	1.6	1.6	1.3	1.1	0.9	1.2	1.2	0.8	1.0
Upcast	2.6	1.4	1.9	1.4	1.2	1.2	0.7	0.7	0.6	0.8	0.5	0.8	0.8	0.4	0.5
Downcast	—	1.4	1.6	1.3	1.1	0.9	1.0	0.6	0.7	0.6	0.5	1.0	0.7	0.3	0.6
Total number of samples analysed	1,860	5,155	6,359	7,547	7,641	7,206	6,885	4,632	4,855	1,071	2,390	2,587	2,843	2,663	1,351

¹ Jan. to Aug. inclusive.

TABULATION B. — SHOWING THE AMOUNT OF DUST IN MINE AIR, EXPRESSED IN MILLIGRAMS PER CUBIC METRE, AS DETERMINED FROM SAMPLES TAKEN THROUGH THE MEDIUM OF SUGAR TUBES BY THE MINE DUST INSPECTORS ¹ IN VARIOUS PLACES IN EVERY MINE AND ANALYSED IN THE LABORATORY OF THE TRANSVAAL CHAMBER OF MINES

Place	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929 ²
Main travelling ways	—	2.3	2.0	1.5	1.2	0.8	0.5	0.6	0.8	0.7	0.8	0.7	0.6	0.7
Developments ends	6.0	4.4	3.6	2.5	1.9	2.1	1.7	1.5	1.1	1.1	1.1	0.9	0.8	0.7
Shafts	5.8	3.3	5.5	3.0	3.6	2.5	0.3	3.2	1.8	1.5	1.4	1.1	1.2	0.8
Stopes	4.8	2.9	2.2	1.6	1.2	1.3	1.0	0.9	0.8	0.9	1.0	0.8	0.7	0.7
Ore passes and bins	5.5	3.9	3.4	2.3	1.9	2.0	1.6	1.7	1.6	1.6	1.6	1.2	1.1	1.1
Sundry	4.7	2.6	2.5	2.0	1.5	1.6	0.9	0.9	0.8	1.0	1.0	0.8	0.7	0.7
General average	5.2	3.4	2.8	2.0	1.5	1.6	1.2	1.2	1.0	1.1	1.1	0.9	0.8	0.8
Upcast	3.4	2.1	1.6	1.2	0.7	0.8	1.1	0.5	0.6	0.7	0.7	0.7	0.6	0.6
Downcast	5.5	1.8	1.9	1.1	0.9	1.2	0.5	0.7	0.6	0.6	0.7	0.8	0.7	0.6
Total number of samples analysed	5,261	14,362	27,460	27,508	25,821	23,739	16,259	24,709	25,268	24,616	25,796	26,212	26,228	15,195

¹ Appointed under Mining Regulation No. 161/10.

² Jan. to June inclusive.

TABULATION C. — SHOWING THE AMOUNT OF DUST IN MINE AIR, EXPRESSED IN PARTICLES PER CUBIC CENTIMETRE, AS DETERMINED THROUGH THE MEDIUM OF KONIMETER SPOTS TAKEN BY THE DUST INSPECTORS OF THE TRANSVAAL CHAMBER OF MINES IN VARIOUS PARTS OF EVERY MINE

	1919	1920	1921	1922	1923	1923	1924	1925	1926	1927	1928	1929 ¹
Illumination	Light ground						Dark ground					
							Subdued reflector light					Full reflector light
	1.4 Condenser						1.2 Condenser					
Treatment	None						Acid immersion					
							Acid vapour					Ignition
Development ends	490	324	211	268	385	623	498	351	306	138	78	166
Shafts	468	303	303	167	261	361	420	242	378	120	78	109
Stopes	270	165	128	111	182	319	384	267	251	121	63	135
Ore passes and bins	240	129	155	154	185	289	356	240	246	146	105	247
General average	318	192	163	149	230	387	409	284	263	128	73	159
Intake air										106	47	89
Total number of spots	6,218	5,916	6,062	4,373	4,695	3,526	1,064	2,240	2,367	2,660	2,270	1,301

¹ Jan. to Aug. Inclusive.

TABULATION D. — GIVING A FEW TYPICAL ANALYSES OF MINE WATERS EXAMINED IN THE CHAMBER OF MINES LABORATORY

Locality	Far East Rand			Central Rand			West Rand		
Appearance	Cloudy	Muddy (rust)	Clear	Muddy	Turbid	Cloudy	Muddy	Cloudy	Clear
Reaction	Alkaline	Acid	Alkaline	Acid	Acid	Acid	Acid	Alkaline	Alkaline
Per cent. H_2SO_4	—	.003	—	.012	.026	.023	.042	—	—
Per cent. NaOH	.003	—	.002	—	—	—	—	.030	.004
Insoluble mineral residue: grammes per litre	.149	.054	.016	.298	.046	.026	.051	.050	.030
Particles under 12 microns: grammes per litre	.052	.018	.004	.070	.014	.009	.015	.028	.006
Percentage of particles under 12 microns	35	33	25	24	30	35	29	56	20
Remarks	Unsuit- able	Unsuit- able. Requires clarifi- cation	Very good	Unsuit- able	Passable	Very good	Unsuit- able. Requires clarifi- cation	Passable	Very good

WATER USED FOR DUST PREVENTION AND ALLAYING

The Mining Regulations lay it down that the manager shall, for dust prevention and allaying purposes “. . . . provide an adequate and constant supply of water which is clear and odourless”, and the Transvaal Chamber of Mines Standing Committee on Dust laid it down in 1916 that water containing more than 0.05 grammes of insoluble mineral residue per litre should not be used with water fed drills or atomisers, and when water was so used it should be periodically analysed in the Chamber's laboratory.

Tabulation D gives a few typical examples.

NATURE OF A DAY'S WORK UNDERGROUND

The work performed underground by a European will, of course, vary in accordance with the class of occupation in which he is employed. It may, however, be said that the European miners on these fields are occupied mainly in directing and supervising the work of natives, and it is proposed herein to follow the course of a day's work of a man engaged in ordinary mining, pointing out where the various operations produce dust, and making brief reference to the methods employed for its suppression.

When a miner enters his working place his first duty is to ascertain whether it is safe, and, if not, to cause it to be made safe. His next, and really simultaneous duty, is thoroughly to wet the roof and sides for a distance of 25 feet from where any work is to be performed. Both these operations at first, especially where water blasts are not used, raise a certain amount of dust, in the same way as water applied to a road from a watering cart tends to stir up dust.

In making safe some mines have used hollow punch bars attached to a water hose, so that water under pressure emerges from near the end of the bar. These bars, however, are not popular with the miners since they are not so readily handled, and since there is a tendency for the water to run back down the arm of the operator.

A place having been made safe in accordance with the various provisions of the Mining Regulations, the ordinary work of drilling, shovelling, and, if necessary, timbering, is commenced.

Most of the dust caused by drilling escapes during the small interval of time occupied in starting a hole, say during the drilling

of the first inch or two. This escape can be considerably reduced by playing from a hose a stream of water on to the rock being drilled, in addition to the ordinary supply which comes through the drill steel.

The following figures, which represent the average of a considerable number of special tests, reflect this reduction:

	Particles per cubic centimetre
Dust found in collaring when extra hose is not used . . .	75
Dust found in collaring when using extra hose . . .	49

After the miner has marked out the holes to be drilled and generally started his natives to work, he proceeds to perform sundry other duties, namely, the collection of his supply of explosives from the shaft station; the preparation of his charges; the marking of his native labourers' work tickets, and so on, exercising in the meantime a certain amount of supervision on the progress of the work generally.

The following time studies of certain classes of underground men were made during from May to August inclusive 1926 at the request of the Mines Department, and will serve to give an idea of how these classes of employees occupied an average shift:

	At stations and travelling to and from working place	Inspecting hanging and generally supervis- ing at the face	At miners' box	Charging and lighting up	Total
Percentage of total time					
Shaftsinkers	9.7	55.1	21.8	13.4	100
Developers	11.4	44.3	28.5	15.8	100
Machine stopers	12.2	58.6	17.4	11.8	100
Average	11.3	51.6	23.2	13.9	100

There has been no material alteration in methods of working since the dates upon which these studies were made, and they can be taken as representative of present day conditions.

After each hole has been drilled, and some time before the end of the shift, it is necessary that the holes shall be thoroughly cleaned out before the charge of explosives is put into them. Some miners cause each hole to be cleaned out immediately after it is drilled; others wait until just before charging time.

Until recently this cleaning out was done by compressed air applied through a pipe to the bottom of the hole for the purpose of blowing out all the mud and water in it. The more recently introduced method is first to wash out the holes with water under a considerable pressure through a pipe and then to dry the holes by causing the water to be sucked out by an ejector using a water jet as its source of power. By this method no compressed air is used, and less dust is projected into the mine air.

The following figures, which again represent the average of a number of tests, show the different amounts of dust produced by the two methods:

	Milligrams per cubic metre
Dust found in blowing out 5 holes with air blow pipe . .	45.9
Dust found when cleaning the same number of holes with water method	1.7

In considering these sources of dust, however, it must be remembered that either method occupies but a relatively short space of time, and that if, as is usually done, the sequence of blowing out the various holes is arranged in a direction against the ventilating current, the dust caused by the operation is quickly removed and does no harm to anyone.

While drilling is in progress the other operations of mining, such as shovelling the broken rock and loading it into trucks; timbering; track laying; pipe laying; track cleaning, and so on, are also performed. The Regulation already referred to, which requires everything within a distance of 25 feet from a point at which work is being done to be wetted and kept wet, has the effect in practice to cause in stoping the area between the whole length of the stope face and a distance therefrom of 50 or more feet to be wetted and kept wet, and in development work that practically the whole length of the heading shall be so treated. This being the case, the operations referred to, with the exception of the handling of the broken rock, cause little or no dust.

Various methods of handling the broken rock are in vogue to suit different conditions, the dip of reef, etc., but ultimately in all cases the ore is loaded into trucks and taken to ore passes and/or ore bins, whence it is loaded into the shaft conveyances and hoisted to the surface. Although the rock is kept wet during the process of handling and loading it can readily be understood that these processes cause a certain amount of abrasion of the rock and a consequent escape of dust. Particularly is this the case in ore

passes where the rock has to fall, roll or slide through considerable distances, and where the rock is being tipped from or loaded into trucks or other conveyances. In these cases a successful way of combating the dust is to provide sprays and to ensure as far as practicable that the ore passes, bins, etc., shall never be entirely empty, but shall always contain enough ore to prevent a free current of air which in passing through them might carry the dust into the main ventilating currents of the mine; also to provide a secondary ventilation system which by means of suitably sized pipes will draw off the dust and by-pass it into the return airways, or if this is not possible, into an air filter of some kind.

Various types of filters have been tried, and while some of them have proved moderately efficient as dust traps, the expenditure of power in relation to the quantity of air filtered is so great that they are only used in places where the dust-laden air can be treated in no other way. One such filter consists of several large sheets of moist flannelette through which the dust laden air is forced at low velocity by a fan. In some cases old workings are used as filters, with excellent results, but such use is not always practicable.

METHODS FOR DETERMINING THE DUST IN MINE AIR, AS PRACTISED ON THE WITWATERSRAND

BY JAMES BOYD, A.R.T.C. (GLAS.), F.I.C., F.C.S., A.M.S.A.I.E.

To the best of our knowledge the first determinations of dust in mine air on the Witwatersrand were carried out for the Miners' Phthisis Commission of 1902, with the following results:

Place	Dust in milligrams per cubic metre
Face of drive	424
do. do.	192
do. do. behind spray	42
100 ft. from face after blast	83
End of drive 5½ hours after blast	43
Stope	14
Stope	32
Raise	164

In 1910 the East Rand Proprietary Mines found as much as 1,500 milligrams in a drive.

In 1911 the systematic determination of dust was begun by the Consolidated Gold Fields Group. The method adopted was a gravimetric one, a known quantity of the mine air being drawn through a column of pure sugar, the sugar being then dissolved in distilled water, and the dust filtered off, ignited and weighed. The dust-laden air was aspirated through the sugar (which was contained in a tube) by various methods, the one generally adopted being to use a double-acting suction pump.

The capacity of the standard pump is about 3 litres per double stroke, the pump being calibrated against a standard wet meter. The tube used to contain the sugar is made of thick walled glass tubing, 5 inches in length by 1¼ inches in diameter, fitted at

the top with a solid rubber cork, and at the bottom with a one-holed rubber cork, through which passes a piece of glass tubing $\frac{1}{2}$ inch in diameter. At the bottom of the sugar tube is placed a small piece of cotton wool, this being used to prevent the sugar being drawn out in sampling. The sugar used is of such a size that it will pass a ten-mesh sieve and remain on a twenty-mesh sieve, and 40 grammes of the sugar is used per tube.

In taking a sample the tube is connected by a length (usually 6 feet) of pressure tubing to the inlet of the suction pump, and the required volume of air aspirated. This volume depends on the dustiness of the air, but is usually $\frac{1}{3}$ to $\frac{1}{2}$ cubic metre.

The tube is held at about the height of a man's mouth, and the sampling is done to windward of the pump, the tube being moved about so as to obtain a representative sample. After sampling, the tube is recorked, numbered, and a record made of the place sampled and the work in progress. The tube is then returned to the laboratory for analysis.

Up to 1913 all the dust found in a sample was regarded as dangerous, and was returned as total dust. The research of Dr. J. McCrae, however, proved that in the ash of a silicotic lung it was only the very fine dust that was found, the particles ranging in size from 12 microns downwards.

As the sugar tube determinations were of all the dust in the air, it became necessary, therefore, to devise some method of separating the coarse from the fine dust.

In 1915 Dr. J. Moir published details of a method for the separation of large and fine quartz particles. The method consisted of allowing dust in suspension to settle in water for a period of time, calculated from the size of the particles and from the rate of fall of quartz particles when suspended in water. The formula is as follows:

$$V = \frac{7D^2}{100000}$$

where V = velocity of fall in cm. per second.
D = diameter in microns.

In practice, the procedure to settle out particles above 12 microns in size was to allow the well-mixed suspension of dust to settle for four minutes for each centimetre of height of the liquid in a straight-sided beaker, siphon off the supernatant liquid (containing the fine dust in suspension), make up the residual liquid to the original bulk, allow to settle for two minutes for

each centimetre of height, siphon off, mix the two siphoned-off liquids, filter and weigh the dust.

In dealing with large numbers of samples, the time involved in this process was very great, and recourse was made to a mechanical method. It became possible to obtain very fine screening of some 350 mesh. A small truncated cone was made, the screening forming the base of the cone, and the sugar solution containing the dust was filtered through the cone on to a fine filter paper. The cone is then washed free of sugar solution, removed, and the filter paper containing the dust is then incinerated in a crucible, cooled, weighed, and the weight of dust determined.

As all sugar contains a certain amount of inorganic dust, it is necessary to make an allowance for this as well as for the weight of the filter ash. This is done by running a number of blank sugar tubes, which are treated in the same way as the tubes containing dust and the weight of dust found is taken as the weight of dust in the sugar plus the weight of the filter paper ash, the amount usually being about 0.7 milligrams per sample. The amount of dust found in mine air is returned as milligrams per cubic metre.

The method described above gives the weight of dust in a given quantity of air. It is, however, necessary to have a knowledge of the number of particles of dust in the air. This can be determined in a gravimetric sample by counting the dust in an aliquot part of the solution by means of a Haemocytometer or similar instrument; but this is a tedious method.

In 1916 Sir Robert Kotze, Chairman of the Miners' Phthisis Prevention Committee, devised an instrument to enable the particles of dust in mine air to be counted. This instrument, known as the *Konimeter*, consists of a valveless cylindrical suction pump of a cylinder capacity of 5 to 10 cubic centimetres. In this instrument a piston is depressed and held by a catch, and when it is released a volume of 5 cubic centimetres of air is sucked in through a nozzle, which is tapered and smoothly bored, with an orifice diameter of 0.6 millimetre. The air sucked in impinges on a glass slide which is placed 0.5 millimetre from the nozzle. The slide is made by cutting an ordinary microscope slide in half, and is held in position over the nozzle by means of a spring, the jet itself being surrounded by a rubber ring about 16 millimetres in diameter. This forms, with the slide in position, a small air-tight chamber. The slide may be moved over the chamber so

that samples of dust may be taken. The slide may be coated with a very thin coating of vaseline or glycerine jelly, or, if the sample is being taken in moist air, may be uncoated with any adhesive. The velocity of the air when it leaves the nozzle should be not less than 30 metres per second. To count the particles of dust in the spot, the slide is examined under a microscope, using a 16-millimetre objective, and an eye-piece of high power. An eye-piece micrometer ruled in sectors is used, the most usual sectors being either 9° or 18° . The spot is counted vertically and then the eye-piece is rotated through 90° and the spot counted again, the sum of the two counts giving the number of dust particles when 5 centimetres of air has been impinged.

A modified form of Konimeter is also used. In this instrument the glass plate on which the dust is caught is made circular and fitted into a toothed wheel which engages a pinion. By means of this device the plate is made to revolve under the jet and as many as sixty spots can be taken on the one slide. When the plate is removed from the Konimeter it is fitted into a special holder on the stage of the microscope, and by means of a toothed pinion is revolved under the objective so that each spot in turn comes into focus and can be counted.

When the Konimeter was invented, counting was done by means of ordinary reflected light, but it was soon found that, as the particles of dust are extraordinarily minute, they could not all be counted by this means. After much experimenting a method was evolved which is a modification of dark ground illumination. The method has for its object the securing of contrasts, and therefore a spot is used which allows the maximum illumination. In practice this is obtained by placing a dark ground spot of 10 millimetres diameter immediately below the condenser. This cuts out the central portion of the light pencil and allows the particles of dust to stand out clear, bright and easily countable. Illumination is obtained by using a 100 candle power $\frac{1}{2}$ -Watt ground glass bulb, which is placed about 9 inches from the mirror.

Just as the gravimetric sugar tube collects all the dust in the air, irrespective of size, so does the Konimeter collect the dust irrespective of kind, and irrespective of its nature.

It has been pointed out by Dr. Mavrogordato that all instruments delivering air at a high velocity through a narrow jet bring in the condensation principle, and that the resultant spots are not only precipitation spots but also condensation spots, so that if the moisture in the air contains salts in solution, these will materialise

as visible particles when the spot on the Konimeter is examined under the microscope. This does happen in the sampling of mine air by the Konimeter, and has been a source of error and of great trouble in Konimeter work on these fields.

Water used for dust allaying almost invariably contains soluble salts, and, as the air underground is more or less saturated with moisture, a Konimeter spot contains salts of sodium, calcium and iron. The Konimeter appears to exert a selective action in its collection of dust particles, and these are always of very small size. The soluble salts in the moisture in the air crystallise out in very minute crystals, and are nearly always indistinguishable from the quartz particles. Here then we have a source of very considerable error.

In addition, the illumination of the underground workings is by means of acetylene lamps and candles. Acetylene, as is well known, burns with a smoky flame, and large amounts of carbon in a very fine state of division are liberated, so much so that the gravimetric or sugar tube sample is often stained black by the carbon. The carbon particles by semi-dark ground illumination appear bright and shiny like the silica particles, and it is impossible to differentiate the one from the other. As far as our knowledge goes, carbon particles are not dangerous when breathed into the lung, and as in some places they are present in very large quantities in mine air, if counted in the Konimeter sample with the silica dust, an entirely wrong idea of the dangerousness of that particular sample of mine air would be obtained. Here there is another source of error in counting dust particles.

Experiments were conducted for some time in an endeavour to eliminate the soluble particles from the Konimeter samples, and a method devised by Mavrogordato, Moir and Ray proved satisfactory. These investigators found that most of the soluble particles could be removed by the action of hydrochloric acid vapour, which did not touch the silica.

The method adopted was to insert a watch glass over the spot, the watch glass having in its centre a small segment of filter paper saturated with a 15 per cent. solution of hydrochloric acid. In the case of spots on circular slides a rubber ring is placed round the periphery of the slide and a spare glass slide with the saturated filter paper in the centre placed on top of the ring, thus forming a small chamber with an atmosphere of hydrochloric acid gas. By this means most of the soluble salts were dissolved, but, unfortunately, not the carbon particles.

In 1927 McEwen and Thompson tried immersing the whole slide in a dilute solution of hydrochloric acid, washing in distilled water and drying. Instead of this somewhat drastic treatment removing the whole spot, they found that on examination under the microscope the particles on the spot shone up clear and bright with no trace of contamination by either carbon or soluble salts; the silica in fact looked clean and polished.

Many experiments were made to see if there were any loss of silica particles, but the results in many cases showed an increased count after treatment, as if some of the silica particles had been masked by carbon in the original count.

In 1925, on my suggestion, an attempt was made to eliminate carbon from the spots by ignition, using heat-resisting glass in the slide, but unfortunately it was not then possible to obtain a sufficiently transparent glass.

Recently it has been found possible to obtain a glass with heat-resisting properties which is also transparent under the microscope and free from flaws. McEwen and Thompson have made a large number of experiments with encouraging results. The slides are made of Chance's heat-resisting glass. On to the centre of the slide is poured a few cubic centimetres of the acid, and this is allowed to spread all over the slide covering the spots. The slide is then immersed in a basin containing distilled water, the washing being repeated twice, and finally the slide is immersed in hot distilled water and allowed to dry. The slide is then placed on a smooth fireclay tile in a cold gas muffle, and the gas lit. The muffle is kept at a dull red heat for thirty to twenty-five minutes, then the gas is turned off and the slide allowed to cool in the muffle. The silica particles when examined under the microscope after this treatment are clear and bright, and in many cases show a much larger count than before treatment.

This new method represents a very great advance, and enables more reliance to be placed on the accuracy of Konimeter samples.

SYSTEMATIC DUST SAMPLING ON THE WITWATERSRAND

Previous to 1913 no attempt had been made to determine systematically the amount of dust in the air of the mines of the Witwatersrand. In December of that year the Miners' Phthisis Prevention Committee, which had been appointed by the Government, caused the first dust survey of the mines to be carried out.

The samples were all taken by the gravimetric method, and gave the following results:

	Milligrams per cubic metre
General average	5.4
Drives	6.1
Raises	9.1
Winzes	5.0
Ore bins	5.5
Stopes	4.2

In May 1914 the Chamber of Mines established a department to investigate the dust conditions of the mines, and to suggest methods of preventing the formation of dust and its dissemination into the air of the mines. Visits were paid to each mine, and samples taken in as many of the working places as possible. Tests were made of various kinds of work likely to produce dust, and suggestions made for bettering conditions.

Since 1914, fifty-eight systematic dust surveys were made, showing the following results:

	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929
General average	4.9	3.9	3.8	2.9	2.4	2.6	1.6	1.6	1.3	1.1	0.9	1.2	1.2	0.8	1.0
Development	6.9	5.8	5.4	4.4	3.5	2.9	2.3	2.4	1.9	1.2	1.0	1.1	1.2	0.8	0.8
Stopes	3.4	2.8	2.9	2.1	1.9	1.6	1.2	1.2	0.9	0.7	0.7	1.0	0.9	0.6	0.7
Ore bins	4.4	4.0	4.2	3.7	2.9	2.7	2.1	2.2	1.8	2.0	1.6	1.8	1.9	1.3	2.0
Percentage over 5 mg.	27.0	23.0	20.0	13.0	10.0	8.0	4.0	4.0	3.4	2.5	1.7	1.1	1.2	1.2	1.9

It will be noticed from the above table that there is a steady diminution in the quantity of dust found in the various sections into which mine work is divided. Taking 5 milligrams per cubic metre as the danger mark, it will be noticed that whilst in 1915 27 per cent. of the samples were above that limit, it had fallen in 1928 to 1.2 per cent. and in 1929, owing to some high samples at ore bins, was 1.9 per cent.

In 1916 it was decided to appoint an official on each mine to investigate and report on the dust conditions, as it was recognised that the staff of inspectors appointed by the Chamber of Mines could not be expected to pay sufficient attention to all the working places on the mines. These inspectors were expected to pay surprise visits to see that things generally were in good condition.

The mine officials took samples in the same way as the Chamber's

officials, and all the samples were analysed in the Chamber's laboratory. The following table shows the more important of the results obtained:

	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929 (6 mths.)
General average	5.2	3.4	2.8	2.0	1.5	1.6	1.2	1.2	1.0	1.1	1.1	0.9	0.8	0.8
Development	6.0	4.4	3.6	2.5	1.9	2.1	1.6	1.5	1.1	1.2	1.1	0.9	0.8	0.8
Stopes	4.8	2.9	2.2	1.6	1.2	1.3	1.0	0.9	0.8	1.0	0.9	0.8	0.7	0.7
Ore bins	5.5	3.9	3.4	2.3	1.9	2.0	1.6	1.8	1.6	1.6	1.2	1.2	1.1	1.1

It will be noticed that the improvement in dust conditions indicated by the samples taken by the Chamber inspectors is corroborated by those taken by the mine inspectors.

KONIMETER SAMPLES

Since 1919 Konimeter samples have been taken as a matter of routine at the same time as the gravimetric samples.

Until June 1923, all the samples were counted by light ground illumination, with the following results:

	1919	1920	1921	1922	1923
Development	490	320	211	270	390
Stopes	270	165	130	110	180
Ore bins	240	160	150	150	190
General average	318	190	160	150	230

As before stated, dark ground illumination was introduced in July 1923, and the following results were obtained:

	1923	1924	1925	1926
Development	620	480	350	310
Stopes	360	390	260	250
Ore bins	280	350	250	250
General average	380	410	280	270

In 1927 the McEwen-Thompson method of treating the slides for the removal of soluble particles and particles of carbon was introduced, with the following results:

	1927	1928
Development	132	78
Stopes	119	62
Ore bins	142	105
General average	125	73

In 1929 the ignition method of treating the slide was introduced and in addition the spots were counted by using the full₂ reflectors of the microscope instead of subdued light.

Results	1929 Particles per c.c.
Development	165
Stopes	135
Ore bins	247
General average	159

CONCLUSIONS

The figures given show that there has been a vast improvement in the amount of dust present in mine air in 1929 as compared with 1914.

It may be asserted that neither of the two methods of sampling dust in mine air used on the Witwatersrand are methods which can claim any scientific accuracy. The errors which can be, and are, introduced through no fault of the operator are such as to render any claim to real accuracy untenable. The gravimetric method, sampling as it does all sizes of dust in the air, can easily be made to show very serious dust conditions by the presence of a few large (in the microscopic sense) particles of dust, whilst innumerable small dangerous particles of very light weight will not be reflected in the results obtained. The difficulty of separating the gravimetric sample into large (in the microscopic sense) and fine dust is so great that it is not practicable in ordinary routine work. On the other hand, as an indication of the dust conditions, the gravimetric method is useful and has done good work. The vast improvement in underground conditions on the mines of these fields can be traced to the results of gravimetric sampling as showing the condition prevailing.

Despite its faults and errors, the fact that, by the same method as was used in 1914, the average dust content of mine air has fallen from over 5 milligrams per cubic metre to round about 1 milligram, is an indication of the good work performed as the result of using the gravimetric method to call attention to bad conditions.

The Konimeter method has also its faults and errors, some of which have been already mentioned, such as its showing up all dust, whether dangerous or not, and its liability to contamination by carbon particles.

The result of long and painstaking research work indicates that it may be possible in the future to obtain a sample by the Konimeter method which will be a true indication of the amount of dangerous dust in the mine atmosphere.

In the meantime we can say that by using both methods we can obtain results which, if interpreted in a relative manner, give us a good indication of the dustiness, and consequently of the dangerousness from a phthisis-producing point of view, of the air of the mines. By using these methods and remembering that neither give accurate results, but rather results which are only an approximation to absolute accuracy, we can still hope for further improvement in the dustiness and ventilation of the mines.

MEASURES FOR PREVENTING THE FORMATION OF DUST, AND PRECAUTIONS DESIGNED TO PREVENT PERSONS INHALING SUCH DUST AS MAY BE FORMED, AND THE REGULATIONS RELATING THERETO¹

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MINERS' PHTHISIS COMMISSION'S FINDING

Little, if anything, had been done in the way of taking precautions to prevent persons from inhaling dust before the sitting of the Miners' Phthisis Commission in 1902-1903.

The finding of the Commission was that miners' phthisis was contracted as the result of miners inhaling dust-laden air, and the disease was to be found chiefly among rock-drillers in development ends, especially when employed on raising.

SOURCES OF DUST PRODUCTION

The chief sources of the dust inhaled by developers were as follows:

(a) *The drilling of dry holes* in raises and drive ends. In the former all the holes were drilled dry, in the latter the two top holes were drilled dry as well as the bottom cut holes. Holes inclined downwards had water poured into them by hand sufficient to prevent the drill from sticking. Samples of air taken close to the rock drill machine whilst boring a dry hole showed that there were 0.185 and 0.0839 grains per cubic foot of air respectively, and an

¹ The following notes will serve to give the reader a working knowledge of the steps which have been taken on the Witwatersrand on the subject matter of these notes. They will be found in some respects to overlap certain portions of the Historical Review of Mining Conditions on the Witwatersrand, p. 107, but this is clearly unavoidable.

analysis of air taken in a raise in similar circumstances gave as a result 0.072 grains per cubic foot.

(b) *The method of blasting* in development ends considered, at that time, to be necessary for obtaining good results.

It was the practice of the miner to charge up the cut holes completely, and the remaining holes partially, then to blast the cut and return to the end after a very short interval; he then completed charging up the remaining holes, i.e. put in the primer cartridges and tamped the charge, and blasted the round. Miners were even known to return after blasting the round to see how it had broken.

PRECAUTIONS

Among the first precautions taken to prevent the dust formed in drilling and blasting from being inhaled by the miner, was the use of inhalers and respirators.

Dr. Aymard's inhaler was a close-fitting mask placed over the nose and mouth of the rock-drill operator. This mask was connected to the air-cock operating the machine, whereby compressed air was supplied to the miner by means of a light flexible metallic tube about 6 inches long. It was not necessary for the mask to fit perfectly as the constant pressure of air prevented the ingress of dust. The objection raised to this form of inhaler was: first, the range of the wearer's movements was limited to the length of the flexible tubing; second, air from the compressors, at that time, occasionally contained dangerous quantities of CO and CO₂ due to having unsuitable lubricating oil in the compressors.

There were various makes of *respirators* used by the miners. The essential points which a respirator has to fulfil to be considered satisfactory were as follows:

- (a) It must fit closely to the face so that the whole of the inspired air would pass through the filtering material and not short-circuit between the face and the side of the mask.
- (b) The filtering material must be capable of arresting all the minute angular particles of dust in the air, but should not impede respiration.
- (c) The mask must be fitted with an outlet valve through which the expired air can escape freely.

From the original trials made with respirators, they were considered to have sufficient merit to permit the miner to return to the end of a drive shortly after blasting the cut to complete blasting the round, provided he wore a respirator. This was embodied in an addition to Regulation No. 146 of the Mines and Works Regulations gazetted on 29 December 1905, viz.:

- (6) After blasting in any end, raise or other place, no person shall return to that place until after the lapse of at least half-an-hour unless the air in such place has been cleared of the dust and smoke arising from such blasting, by efficient ventilation or other special means, or unless an efficient respirator or other apparatus is used to prevent the inhaling of such dust or smoke.

Also Government Notice No. 1278 of 1908, 146 (11), permitted a miner to enter a development end containing dust and fumes provided he wore a respirator. This practice was permissible until 30 October 1913.

The use of the respirator seemed a simple and effective solution of the whole matter, but it proved impracticable. The miners as a whole were averse to the use of respirators chiefly, perhaps, on account of the discomfort attending their use, e.g. extra effort required to inhale through the filtering material when working hard, and interference with speech and smoking. The valve was usually made of mica and got out of order very easily, so that the miner invariably replaced it by a piece of sponge. This was objectionable as it did not permit of the free escape of the CO₂ and moisture exhaled.

It was eventually ascertained that the filtering material did not arrest the very fine dust particles in size 10 microns and under, which were the most harmful, and the use of respirators was rapidly abandoned.

It is interesting to note here that in 1902 the Transvaal Chamber of Mines advertised a competition in papers in the United Kingdom, Europe, Australia, South Africa and America and offered prizes for the three best suggestions and devices for the prevention of miners' phthisis. There were 229 competitors' suggestions as under:

1. Respirators	41
2. Dust extractors and hoods	35
3. Water drills	9
4. Jets delivering water inside the hole	4
5. Jets delivering water at the mouth of the hole	60
6. Sprays	22
7. Atomisers	6
8. Medical	15
9. Miscellaneous	37

The judges condemned as quite impracticable and useless Classes 1, 2, 8 and 9, but the others are all in general use in some form or other.

FUMES AND DUST FROM BLASTING

From the evidence given before the Miners' Phthisis Commission in 1902-1903, it is evident that up to that time there had been few restrictions of blasting operations, and that persons working underground had been very frequently exposed to smoke and fumes; this latter state of affairs was particularly marked at the end of the one shift and the beginning of the other.

The Commission in its report did not lay stress on the necessity of avoiding exposure of men to blasting smoke in the mine, except in the case of miners returning to dead-ends immediately after blasting. The danger from dust produced by blasting was not then fully realised, and, although progress was made in allaying dust produced by machines, etc., by the use of water, it took some years before the effects of dust from blasting were finally controlled. The following extracts from reports of inspectors of

mines clearly show that even as late as 1911 the conditions on some of the mines were still very bad:

In 1908-1909 it was a common practice on a certain mine to send the night-shift down against the day-shift coming up—naturally the night-shift had to inhale smoke from blasting.

Occurrence in 1911 and the years immediately preceding it:

While taking dust samples in a stope about 6 p.m. in an atmosphere which was full of smoke, the night-shift arrived to begin work, and I understand that this was a daily occurrence.

No real advance was made until the Medical Commission issued its report in 1912, and definitely concluded that not only men working rock drills, but all men working underground were liable to contract miners' phthisis.

From this conclusion it was perfectly clear that the problem had resolved itself into not only allaying the dust produced by drilling machines and the removal of the broken rock, but reducing the dust content of the whole mine atmosphere, which was permeated with very fine dust particles, blasting operations being the most prolific source of dust and the most difficult to contend with. It was impossible to reduce the dust in the air created by blasting to a safe limit, and the only method to overcome its deadly effect was to remove the men before the smoke enveloped them and to keep them out of the mine until the fumes and dust were dissipated.

DOUBLE SHIFTS

One factor which had a very marked effect on the health of the miner was the double shift worked on all the mines of the Witwatersrand, i.e. a complete cycle of mining operations, cleaning, drilling and blasting, was performed on two shifts in the twenty-four hours. Owing to the duration of each shift being nine and a half to ten hours, there was insufficient time between the shifts to permit of the smoke and fumes from blasting operations to be cleared out of the mine before the arrival of the following shift, and almost invariably the on-coming shift was exposed to smoke and fumes. On Saturdays the position was even worse, as the afternoon shift was lowered immediately after the blasting of the morning shift; this had to be done in order to get a full shift in by midnight, as it was, and still is, illegal to work on Sundays.

When it became known that these conditions were exceedingly

injurious to health, the necessary change-over to single shift could not be effected at short notice, but had to be done gradually.

Generally all the stope faces in the mine were being worked, and to obtain the required tonnage for the mill these faces had to be drilled and blasted twice in twenty-four hours; to maintain the stope faces, development ends were being pushed ahead on double shift.

Summing up the position, the mines had to continue double shift until such time as sufficient faces were available to permit the breaking of the necessary tonnage to keep the mill supplied on the one shift only.

ALTERATIONS NECESSARY FOR SINGLE SHIFT WORKING

A further factor which delayed the change-over was that the mines were only equipped for double-shift working. Considerable alterations and additions had to be made in the plant and in the mine itself, e.g. compressors had to be duplicated to meet the greater demand for compressed air. Hoisting arrangements could not cope with the full complement of men on the single shift; the capacity of ore bins underground was too small; the number of rock drills had to be increased, etc. Apart from the time required to effect these alterations, a large amount of capital had to be found before they could be carried out.

PROGRESS OF THE SINGLE SHIFT

In 1907 some of the mines resorted to what was virtually a sixteen-hour shift, i.e. two eight-hour shifts, the one shift following directly after the other, blasting operations being carried out at the end of the second shift only. This was undoubtedly a step in the right direction, as it gave an interval of eight hours for the smoke and fumes to clear away before the following shift was sent down.

The year 1910 registered a further advance, in that some of the mines were on single shift, blasting at the end of the shift, i.e. the major portion of the work in the mine was done on the day shift, with a limited complement of boys and men on night shift to do the cleaning out.

By 1913 the majority of the mines on the Witwatersrand had changed over to single shift, the full night shift of practically equal strength to the day shift having become a rarity.

There is no doubt that the elimination of the double shift was one of the most important steps taken to produce healthy underground conditions, as well as doing away with an unduly expensive night shift expressed in the following terms by a witness before the Mining Regulations Commission, 1907:

Nearly all miners sleep underground on night shift, the average time slept being about four hours.

DURATION OF SHIFT

The duration of the shift also had a very important bearing on the health of the miner. It might almost be considered, other things being equal, as a measure of the amount of dust inhaled by the miner.

Prior to the Anglo-Boer War, miners were scarce, and the tendency was for contractors to take on as much work as was given to them; this entailed long hours underground, and it was not an uncommon practice for a contractor to have two gangs of natives working, one on day shift and the other on night shift. Although the latter practice eliminated itself as the mines became deeper and access became more difficult, nevertheless the tendency for contractors to work long hours underground persisted and became an established custom.

Up to 1909, the mines were still working shifts of ten hours' duration; the hours were, day shift 7 a.m. to 5 p.m., night shift 7 p.m. to 5 a.m. On the day shift the men were allowed one hour on the surface for lunch. In 1910 the hour for lunch was done away with, thus reducing the over-all period to nine hours. This was a very much better arrangement, as the men were hoisted an hour earlier; this gave them more daylight for outside recreation. It also increased the interval between shifts.

The nine-hour shift continued until Act 12 of 1911 was passed, limiting the hours of employment of persons underground.

Act 12, 1911

9. (1) No person employed to perform underground work in any mine shall work, and no person shall cause or permit any person so employed to work, underground for a longer period than eight hours during any consecutive period of twenty-four hours, or forty-eight hours during any consecutive seven days, exclusive of time occupied in going to or from the working place.

There is no doubt that the reduction of hours could only do good from the point of view of the miners' health, and, as far as reducing

the amount of work done was concerned, had little effect, as it was balanced by closer supervision and improved organisation generally.

Difficulties were met with at first in arranging shifts and hours, but were finally overcome. The eight hours was from face to face, and this led to difficulties in regard to time spent underground by the miners, the contractors being only too willing to remain at work in order to get the best results, the increased overtime being attributed to travelling delays, etc.

Regulations

In order effectively to control and give effect to the eight-hour shift, the following Regulations were promulgated:

158. In addition to his other duties and responsibilities under these regulations, the manager shall:

(24) Provide on mines other than coal and base metal mines under section 9 (2) (c) of the Act:

- (a) That a notice shall be kept posted up at each shaft head, showing the time within which shifts will be let down and hoisted up at the shaft head.
- (b) That the average time in getting miners, as defined in Act 19 of 1912, from the shaft head to their working place at the commencement of their shift, and back again at the conclusion of such shift, shall together not exceed thirty (30) minutes per miner for any one shift. In special cases, after application made through the Inspector of Mines, the Minister may grant such extension of the period of thirty minutes as he may consider to be necessary. Notice of such application shall be posted up at the mine for fourteen days before the application is sent to the Inspector of Mines.
- (c) That the mine overseer, shift boss or other official appointed by the manager for the purpose shall satisfy himself that no white person not exempt under section 9 (2) of the Act remains underground after the ordinary hoisting of persons employed on that shift is concluded, and shall record in a book to be provided by the manager, the name of any such white person so remaining underground, and the time when such white person reaches the surface.

The effect of these Regulations was to give the white man an average period of eight and a half hours underground, including travelling from the surface to his working place and back again.

Original Arrangement arrived at between the Transvaal Chamber of Mines and the South African Mine Workers' Union

That from 1 January 1918 the underground working week shall be forty-eight and a half hours bank to bank, the length of each shift to be counted from the first skip down to the first skip up, and the Saturday shift to be at least one hour less than the weekday shifts. (In practice the hours are eight and a quarter bank to bank on weekdays and seven and a quarter on Saturdays, with some minor exceptions, e.g. certain shaft sinkers and developers.)

These are the hours prevailing on all the Witwatersrand mines at the present time.

CONDITIONS PREVAILING IN THE MINES

Generally the adverse conditions which had to be overcome may be summed up as follows:

- (1) All men on the outgoing shift were not hoisted before blasting took place, and were in the mine for some time after blasting operations had taken place, and in many cases were exposed to smoke.
- (2) Some of the persons had to be hoisted in the upcast shafts, where the conditions were bad.
- (3) The persons actually blasting were often unable to avoid the smoke from blasting.
- (4) Promiscuous blasting was practised more or less throughout the shift.
- (5) The oncoming shift was lowered before the air was sufficiently clear.

To overcome Nos. (1) and (2) the mines had to resort to hoisting as many men as possible in the downcast shafts.

Special cages and conveyances were made to hoist the workmen as quickly as possible before the smoke overtook them in the upcast shaft. Doors and regulators were put in to keep back the smoke or to deflect it. Mechanical ventilators were temporarily stopped to delay the arrival of smoke at the shaft; suitable waiting places were provided for the up-going shift and kept supplied with fresh air from the compressors.

No. (3) was overcome to a great extent by arranging the blasting of individual places in a suitable sequence commencing from the upcast side and travelling against the air currents.

No. (4): blasting, except where absolutely unavoidable and in isolated instances only, was confined to the end of the shift.

No. (5): blasting at the end of the day shift, and increasing the interval between that shift and the following oncoming shift, was finally overcome by doing away with the double shift and blasting at the end of the shift only.

The concentrated attention given to the problem of successfully combating miners' phthisis led to the carrying out of necessary experiments by individual mines. As the problem became better understood, the tendency was for successful innovations to be automatically adopted into general practice.

The progress of these changes is reflected in the history of the changes periodically embodied in the Mining Regulations.

Regulations

On the recommendation of the Miners' Phthisis Prevention Committee, the following Regulations were eventually framed, and were embodied in the amendments published on 30 October 1913:

61. No person shall work, or remain, or be permitted or ordered to work, or remain in any place in a mine, if the air contains dust smoke or fumes perceptible by sight, smell, or other sense.

101. (33) A ganger or miner . . . shall only blast at the end of the shift, except where necessary, and then only with the permission of the mine overseer or the shift boss.

158. The manager shall:

- (4) Cause blasting operations and shifts to be so arranged that workmen shall be exposed as little as practicable to fumes and dust from blasting.

178.

- (2) All Regulations referring to the prevention of miners' phthisis shall, so far as they concern coloured workmen, be translated into the more important native languages and kept posted up in the compounds.

The First Miners' Phthisis Prevention Committee investigated the extent to which men were exposed to the dust and fumes from blasting at the end of the shift, and dust samples were taken on all the mines for the purpose of determining the amount of dust present in the air breathed by the oncoming shift. They found that the air after blasting contained extremely large quantities of dust, and that the presence of smoke is a sufficient indication of the existence in such air of an amount of dust which is very dangerous to health. Five minutes in such an atmosphere has probably a worse effect than a full shift spent in drilling holes in a drive with water well applied. This indicated that very stringent measures had to be taken to prevent persons from being exposed to fumes from blasting.

Largely on the recommendation of the Miners' Phthisis Prevention Committee, further amendments were added to the Regulations and promulgated in 1917; their object was to improve the conditions in mines in respect of dust and ventilation. The following are those applied to prevent persons being subjected to fumes and dust underground:

60. In any mine included in the list of mines framed under section 2 of Act 19 of 1912 (mines in which miners' phthisis may be contracted):

- (1) Blasting shall only take place once in every twenty-four hours, except as permitted under Regulation 106 (33), or for sinking vertical shafts, or after written permission has been obtained from the Inspector of Mines;
- (3) No person shall blast or be permitted or caused to blast the cut and round separately on the same shift in the same development end.

106. (34) Shall . . . only blast at the end of the shift except for removing obstructions in ore passes or box holes, or for the purpose of making the hanging safe, or for blasting misfired holes in development faces, and then only with the permission, in each case, of the manager, mine overseer or shift boss.

158. The manager shall:
- (4) Cause the times of the working shifts and of blasting operations in every section of the mine to be so arranged that workmen shall not be exposed to fumes and dust from blasting, unless this is unavoidable;
 - (5) Cause every person not engaged in blasting operations, or not required for the transport of the persons so engaged, to be hoisted to the surface or removed to the intake side of all places in which blasting is to be done, or to remain in a waiting place free from fumes and dust before blasting commences;
 - (6) Cause every person engaged in blasting operations or required for the transport of persons so engaged to travel to the surface in the downcast shaft, unless they can be removed from the mine before the fumes overtake them or can remain in a waiting place free from dust and fumes, until these have dissipated;
 - (7) Cause any person who is to work in the mine after blasting has taken place to enter the mine only after the places in which he has to travel or work are clear of fumes and dust, and after the expiry of an interval to be fixed for each mine by the Inspector of Mines;
 - (8) Supply to the persons who have to carry on blasting operations, lighting torches, which in burning evolve not more nitrous fumes, expressed in terms of NO_2 , than one-half of 1 per cent. of the weight of substance burned.
161. (9) A shift boss or other official of at least equal rank shall be present underground at each working shaft at blasting time and shall not travel to the surface before the persons engaged in blasting operations.
- (10) The manager shall, when the total number of persons employed underground, on any one shift, exceeds 1,000 persons, appoint one or more competent persons whose principal duty it shall be to examine and report to the manager on:
- (a) All matters relating to the mine's water supply, its quality, distribution and use,
 - (b) The condition of the necessary appliances for using water at each working place, etc.;
 - (c) The dust sampling of the mine;
 - (d) The condition of the mine relating to ventilation and health, etc.

The manager shall, by letter, notify the Inspector of Mines of the person or persons so appointed from time to time, and the reports made by them shall be open to the inspection of the Inspector.

143. (2) (c) Any person who has knowledge of dust or fumes in the workings during working hours, etc., shall record the matter without delay in the record book.
- (d) Verbal report of the above defective condition to be made to the shift boss or other official.

The following amendment was made as from 30 October 1913:

106. A ganger or miner who is the holder of a blasting certificate:

- (33) Shall not enter or allow any person to enter an end, raise, winze or other close place after blasting within thirty minutes after putting the water blast in action, and then only if the air is free from dust smoke, and fumes perceptible by sight, smell or other senses.

The practice of returning only when the drive, raise or winze was free of smoke, although an advance on the previous practice, was still unsatisfactory, as it frequently happened that the water blast was out of order when the miner blasted, or the water blast was put out of commission by the blast; the miners were very unwilling to lose the round, and there was nothing to prevent the men re-entering before thirty minutes had elapsed or before the smoke had been cleared out of the drive.

The practice of blasting the cut and round separately on the same shift was prohibited by Regulation 101 (3) from and after 1 January 1915, except with special permission from the Inspector of Mines.

By this time a considerable number of the mines had discontinued this practice and were blasting cut and round together, or had made provision for the cut being blasted on the one shift and the round on the following day by increasing the miners' working ends.

One or two mines continued to blast the cut and round separately on the same shift, availing themselves of the special permission granted under certain restrictions.

Finally the practice was totally prohibited in 1917.

With the improvements in drilling machines and methods applied at the present day, very little footage is lost by blasting cut and round together.

The 1925 Annual Report of the Transvaal Chamber of Mines Standing Committee on Dust Sampling records a steady and progressive decrease in the average amount of dust found in mine air since 1915.

Referring to Regulation 158 (8), the Miners' Phthisis Prevention Committee considered that exposure to nitrous fumes produced by blasting operations was a greater danger than that of possible chronic poisoning by carbon monoxide. The fumes of NO_2 are intensely irritating to the air passages and lungs, and the repeated inhalation of very small quantities would produce and maintain a chronic catarrhal condition, which would aggravate and accelerate the harmful effect of dust. As lighting torches were made up of blasting gelatine (a highly undesirable practice), it was advisable to limit the amount of NO_2 given off by torches.

The problem of extracting dust from mine air was also investigated by the Committee appointed to report on the ventilation of dead ends in 1924, but, although a certain amount of success was obtained, the experiments were not brought to a final conclusion.

This brings us up to date, and it seems as if only greater attention

to detail, and possibly various minor changes, can effect any appreciable improvement in conditions without radically altering our present system.

If preliminary investigations made along the lines recently suggested by Dr. Haldane with regard to dust dilution tend to support his hypothesis, it may be found possible to carry out practical tests on a working scale which if successful would lead to the complete elimination of miners' phthisis.

SUMMARY OF TESTS FOR DUST (BEFORE AND AFTER BLASTING)
PRESENT IN THE AIR OF WAITING PLACES OF THE SHAFTS OF
CERTAIN MINES OF THE WITWATERSRAND TAKEN 1914-1915
(MINERS' PHTHISIS PREVENTION COMMITTEE)

[Dust: mg. per c.m. = milligrams of dust (mineral) per cubic metre of air. Before blasting = Prior to shots being heard. After blasting = From time first shots heard up to the hoisting away of last cage load of employees.]

Mine	Average period occupied by sampling	Number of persons hoisted during sampling period				Dust samples (mg. per c.m.)			
		Upcast shaft		Downcast shaft		Upcast shafts		Downcast shafts	
		Whites	Natives	Whites	Natives	Before blasting	After blasting	Before blasting	After blasting
All	1 hr. 35 mins.	1,301	14,941	1,654	22,206	2.8	10.4	3.5	4.9

This table clearly shows the large number of persons who were hoisted in upcast shafts during blasting at this time, and the big increase in dust concentration to which they were exposed. In 1917 this was prohibited [see Regulation 158 (5)].

THE USE OF WATER FOR ALLAYING DUST

The use of water was recognised as the most efficacious method of allaying dust produced by the various mining operations. The best methods of applying it effectively were only arrived at after years of experience and innumerable experiments.

Among the devices first used for dust allaying were sprays and atomisers. In 1903 experiments with the various types were carried out to test their relative efficiencies as dust allayers, and

from the results of these tests Britten's atomiser was adjudged the best and awarded the Chamber of Mines first prize in the competition referred to previously.

At the outset water was not laid on to the working places; to operate the sprays and atomisers, drums were installed in the working place, and water carried in to them. These drums were connected to the compressed-air pipe, from which the necessary pressure was obtained to force the water out of the drum through a hose pipe to operate the atomiser or spray, which in turn was directed on to the collar of the hole being drilled whilst the drill was operating, thus damping the dust as it came out of the hole.

Sprays and atomisers were believed to be effective in allaying most of the dust produced during drilling and shovelling operations, and by 1906 many of the mines were equipped with them. Regulations were eventually promulgated to enforce their use. These devices were never popular with the miner; the atomiser charged the atmosphere with water, and everything within its range became saturated with water, including the miner's clothes; moreover in many cases the water was not clean, and the atomisers became choked and ceased to function. At their best, although allaying a considerable proportion of the dust formed, they did not prevent the very fine and most dangerous dust getting into the atmosphere. Gradually they were replaced by water jets, and ultimately (when water under pressure was available in abundance) by the hose pipe, sprays being retained only in such places as vertical shafts, and over ore boxes and ore passes.

ALLAYING DUST IN DEVELOPMENT ENDS

The first attempt to allay dust produced by blasting in the development ends was to place an atomiser about 70 feet from the face and put it into operation when the charge was lit up; the smoke and fumes from the blast passing through the atomised water were to a certain extent deprived of their dust content; this, however, had no effect on the broken rock and did not clear the end of the drive of smoke. To overcome this defect the water blast was devised and introduced on an experimental scale in 1907, and gradually became common practice throughout the Witwatersrand, its use being made compulsory by Regulation in 1911. The water blast is a simple device consisting of a single nozzle connected to both a water and compressed air supply by means of which a mixture of air and water is projected along

the drive to the face, wetting down the broken rock and displacing the gases produced by blasting operations.

INSTALLING PIPE LINES FOR WATER SUPPLY

By 1906 many of the mines were using dust-allaying appliances for certain classes of work, and, as previously explained, the water supply to operate the various appliances had to be carried by hand into the working place: a very unsatisfactory practice and not conducive to obtaining the best results, specially in places difficult of access such as raises. The mines realised the necessity of a better water supply and commenced to lay water pipes into the working places, obtaining water chiefly from underground sources, and by 1908 a large number of the mines were so equipped, and Regulations were promulgated for the enforcement of this practice. The Mining Regulations Commission's report was issued in 1910, and at that time efforts were directed principally to allaying the dust produced by drilling and shovelling operations, it being assumed that these were the two chief sources of phthisis-producing dust.

The Medical Commission report of 1912 dispelled this illusion, and from then the attack on dust became more general, i.e. water had to be used freely to water down each working place after blasting operations before work commenced. The water service had to be further improved to supply the greater demand, and in most cases clean water was taken down the shafts supplying underground reservoirs made for the purpose, and distributed at suitable pressure to the working places, travelling ways and all other places when its use was considered necessary.

The introduction of an adequate water supply was the key to the solution of dust elimination. By the abundant use of water the dust is not only allayed, but washed down into the drains and sumps, from where it is either bailed or pumped out of the mine.

WATER FEED ROCK DRILLS

The "Water Leyner" rock drill was first introduced into the mines as far back as 1902. The principle of this machine as a dust allayer was accepted as correct at the time and its maker was awarded the Chamber of Mines second prize. The conservativeness of the miner, the poor class of material of which hollow drill steel was then made, and the lack of a satisfactory water

supply delayed its successful introduction. In 1913 the "Water Leyner" drill and the Atlas drill, both passing water down the drill steel, were introduced on a number of the mines, and were very welcome from a health point of view. As time went on, reciprocating machines, both in stoping and development, were gradually eliminated by the water-fed machines, which apparently cut down dust production considerably.

At the end of 1916 a drilling machine known as the "dry" jackhammer was used; it worked with a hollow jumper, but exhaust air and not water passed down it. If a plentiful supply of water was turned into the hole by means of a jet, the dust results were at first considered satisfactory, but it was afterwards found that the air passing down the steel ejected considerable quantities of dust on escaping into the atmosphere. This led to experiments being carried out in 1919 with "wet" jackhammers, i.e. "axial water feed machines", and some of the mines changed over to these "wet jacks" in 1920, and gradually they replaced the "dry" type. The advent of the "Kotze" konimeter revealed the fact that internal water-feed machines produced extremely fine dust of the most injurious nature which had hitherto passed unnoticed. This defect was to a certain extent overcome in 1922 by re-designing the rock drill machines, fitting them with dustless pistons and later by the introduction of release ports into the front head of the machines. The former reduced the amount of air escaping from the cylinder to the chuck cavity, and the latter allowed most of the escaped air to pass out of the chuck cavity instead of passing through the axial hole in the drill steel. To reduce the amount of air passing down the steel, Regulations were promulgated prohibiting the use of short pistons in certain classes of work, enforcing the adoption of release ports, and requiring all machines to be tested by the Mines Department and approved before being passed for use underground. At present endeavours are being made to develop a satisfactory external water-feed machine, which will practically prevent any air passing through the steel, the sludging being done by water only.

OTHER SOURCES OF DUST

(a) *Dirty water supply.* — The machines atomise a certain amount of water, leaving the solid matter suspended in the air. The only check on this is to take samples of the water periodically and analyse them for solid matter (silica).

(b) *Blowing out drill holes.* — If this is done dry, it releases enormous quantities of dust, which should be washed out by water jets, avoiding the use of air if possible.

(c) *Blowing out sockets.* — Air should be avoided and water only used to wash them out.

REGULATIONS

Government Notice 1278 of 1908: Amendment to Regulation 146

Recommendations of the Mining Regulations Commission:

(5) Every place where development work is carried on, and where the natural strata are not wet, and every dry and dusty stope shall be adequately supplied at all times with suitable clean water. Such supply shall be continuous and shall be sufficient for effectively damping the broken ground and for allaying the dust caused by drilling operations.

146. (ii) The ganger or miner in charge of workmen shall be responsible that the following provisions be observed:

(1) No person shall in the drilling of holes use any percussion machine drill, unless a water jet or spray or other means equally efficient is provided and used so as to prevent the escape into the air of dust caused by the drilling.

(2) No person shall in any part of a mine remove any broken rock or ground, if such rock or ground is in a dusty condition, until it has been effectively damped so as to prevent the escape of dust into the air during removal.

Act 12 of 1911

60. In development faces and in winzes a water blast or similar apparatus for laying dust after blasting must be used.

101. (1) No person shall in the drilling of holes use or cause or permit to be used any percussion machine drill unless a water jet or spray or other means equally efficient is provided and used, so as to prevent the formation of dust by drilling, and unless the floor, roof and sides of the working place, to a distance of at least 25 feet from the face, be kept constantly wet.

When hand drills are used for drilling dry holes, a swab shall be provided and used around the drill at the collar of the hole.

(2) No person shall in any part of the mine move any broken rock or ground if such rock or ground is in a dusty condition, unless and until it and the floor, roof and sides of the working place, to a distance of at least 25 feet, have been effectively wetted and kept wet, so as to prevent the escape of dust into the air.

Amendment Published on 31 October 1913

106. A ganger or miner who is the holder of a blasting certificate:

(32) Shall, at any mine included in the list of mines framed under section 2 of Act 19 of 1912, not enter nor allow any person to enter any end, raise, winze or other close place after blasting

within less than thirty minutes after putting the water blast in action, and then only if the air is free from dust, smoke and fumes perceptible by sight, smell or other senses.

- (34) Shall in all development faces (except in the case of a winze being worked on single shift) immediately after lighting up, put into action the water blast, which he shall previously have tested. If as a result of such test, the water blast shall be found to be not in order, no blasting shall take place.

109. The following plans shall be kept in the office at every mine:

- (2) (b) A plan showing all the water pipes with their dimensions as well as all tanks, reservoirs, fixed and continuous sprays, and other devices for allaying the dust.

158. (6) (a) Provide or cause to be provided an adequate and constant supply of water which is clean and odourless at every working place which is not naturally wet. Such supply shall be sufficient for effectively wetting the broken ground and for preventing the formation of dust caused by drilling operations. Such water shall be supplied in metal pipes not less than one inch in diameter, at a pressure of not less than 30 lbs./sq.in. at each working place, when all sprays and jets supplied from the same pipe are working. Such pipes shall reach to within 50 feet from the face and from there a sufficient length of hose shall be provided and used to bring the water up to the face.

(b) Cause the surface in all working places, travelling ways and shafts, which are not naturally wet, to be kept wet as far as practicable.

(d) Provide in shafts, which are not wet, ring sprays at suitable points to prevent dust being carried with the air current.

(e) Provide a water blast as near as practicable to all development faces (except winzes worked on single shift).

161. (9) Each shift boss shall at the end of the shift pay special attention to the requirements of Regulation 106 (32).

Amendment Published on 30 May 1917

Regulation 60 to be amended to read:

- (2) Every drive, cross-cut, raise, incline shaft, and winze, and every working place in which there is no through ventilation current, shall be furnished, at a distance not exceeding 50 feet from the face, with a water blast, approved by the Inspector of Mines, which shall be continuously applied for at least thirty minutes after blasting, for the removal of dust and fumes, where the distance of such working place from the point at which there is connection with the general air current of the ventilating district exceeds 300 feet; an additional water blast shall be placed and used not more than 200 feet and not less than 100 feet from the water blast at the face.

Regulation 62:

- (3) No person shall stope or be caused or permitted to stope above any drive or level where there is no through connection from the stope to the drive or level above, except by permission of the Inspector of Mines, and then only on the condition that the ventilation of such stope is adequate, that the number of persons working therein is limited, and that when machine drills are used, such machine drills are provided with axial water feed.

Regulation 101: section (1) to be amended to read:

(a) No person shall in the drilling of holes use or cause or permit to be used any percussion machine drill other than an axial water feed drill, unless a separate water hose, furnished in the case of dry holes, with a narrow pipe at least 24 inches long, for inserting in the hole when drilling, is provided for each machine and used, so as to prevent the formation of dust.

(b) In collaring by means of a percussion machine drill, other than an axial water feed drill, the narrow pipe shall be removed from the hose, and the water from the hose shall be turned directly on to the collar.

(c) No person shall use or cause or permit to be used any hand drill unless water is applied or a wet swab is used around the drill at the collar of the hole, so as to allay the dust.

(d) No person shall use or cause or permit to be used, for the purpose of rising or of boxholing, any machine drill other than one with axial water feed.

(e) No person shall commence or continue to drill any hole, or cause or permit such commencement or continuation of drilling, unless the floor, roof, sides and broken rock of the working place to a distance of at least 25 feet from such hole have been thoroughly wetted and kept wet.

(f) No person shall blow out or be caused or permitted to blow out any hole with compressed air unless he has applied sufficient water in case there is not already a sufficiency to prevent the formation of dust during the process of blowing out.

Section (3): No person shall in any part of a mine perform or be caused or permitted to perform work of any kind liable to create dust, unless and until the floor, roof and sides of the working place to a distance of at least 25 feet have been effectively wetted and kept wet, unless such working place is naturally sufficiently wet to render the formation of dust impossible.

Regulation 106 (34) to be amended to read as follows:

(34) Shall at every mine included in the list of mines framed under section 2 of Act 19 of 1912 only blast at the end of the shift, except for removing obstructions in ore passes or box holes or for the purpose of making the hanging safe, or for blasting misfired holes in development faces, and then only with the permission in each case of the manager, mine overseer or shift boss. Before blasting such obstructions in ore passes or boxholes or for making the hanging safe, the ganger shall wet the ground thoroughly within at least 25 feet of the obstruction. When blasting misfires he shall observe the precautions prescribed in Regulation 106 (33).

Regulation 143:

(b) Any defect in the mine water service or dust-allaying devices, or in any appliances provided for the health or safety of persons working underground, shall be recorded in the record book by the employee having knowledge of such defect immediately on coming off shift.

Regulation 158:

- (6) (a) to be amended by the deletion of the words " which is not naturally wet " and the substitution therefore of the words, " which is not sufficiently wet to make the formation of dust impossible " ;
- (b) to be amended by the deletion of the words " as far as practicable " and the addition of the words " or regularly washed down " .

To be amended by the addition of the following new subsection :

- (f) Provide or cause to be provided at every ore bin, ore pass, or grizzly, unless exempted by the Inspector of Mines, a constant supply of clean water, which shall be applied during working hours at the openings of such ore bins, ore passes, and grizzlies, by means of efficient atomisers, which shall at all times be kept in good working order.

Regulation 158 to be amended by addition of the following section :

(23). Cause any surface dump as the Inspector of Mines may direct to be sprayed with a sludge of black soil, or otherwise dealt with in a manner satisfactory to the Inspector, so as to prevent the dissemination of dust or sand from it.

Regulation 161 to be amended by the insertion of the following section :

- (10) (a) All matters relating to the mines water supply, its quality, distribution and use.
- (b) The condition of the necessary appliances for using water at each working place and elsewhere.

Government Notice 1571 of 26 November 1918

Regulation 158: section (10) to be amended by the addition of the following subsection :

- (g) Provide and cause to be used in every crusher station and ore sampling room, appliances, such as suction fans, atomisers and sprays, which may be necessary for the effective prevention of dust arising from the operations conducted in such station or room.

Government Notice 1730 of 26 October 1921

Amendments to Mines and Works Regulations

101. (5) (a) No new type or make of machine drill may be used on the scheduled mines without the prior approval of the Government Mining Engineer, or may be continued in use unless that approval is ratified by him within one year, and after at least twenty (20) of the machine drills so previously approved have been in regular use on the scheduled mines to his knowledge for a period of six months.

(b) The Government Mining Engineer may prohibit the use of any type or make of machine drill in use on any scheduled mine. Such prohibition (etc.).

Government Notice 1863 of 16 November 1921

Regulation 102 is hereby amended as follows:

102. (3) At any mine the ganger or miner making the examination prescribed in sections (1) and (2) shall also *thoroughly wet* the roof, sides and floor, as well as the broken rock, before admitting to the working place the members of the gang, other than those required to assist him in making safe.

Government Notice 511 of 21 March 1923

Regulations 60 (2), 101 (1) (a), 101 (1) (b) and 161 (10) to be deleted and the following substituted therefor:

60. (2) Every tunnel and development end, such as a drive, cross-cut, raise, incline shaft or winze, shall be furnished *with a water blast* approved by the Inspector of Mines. Such water blast shall discharge within a distance of not more than 50 feet of the face being advanced, and shall be applied so as to effectively wet the face and broken rock for at least fifteen minutes immediately after blasting, and again for a further period of fifteen minutes *immediately prior to entry* by any person, provided that the Inspector of Mines may give written permission to the manager to vary these conditions on any mine or part therefor.

101. (1) (a) No person shall, in drilling a hole, use or cause or permit to be used any percussion machine drill using solid steel, *unless a water hose is provided for each machine*, and used so as to prevent the formation of dust. When drilling a dry hole the *water hose shall be furnished with a narrow pipe* at least 24 inches long, which shall be inserted in the hole. In collaring, except in the case of jackhammers in stopes, the full bore of the hose must be used for supplying water to collar.

101. (4) (b) No person shall, in drilling a hole, use or cause or permit to be used any axial water-feed drill, unless an adequate supply of water flows through the drill steel. In every tunnel and development end, such as a drive, crosscut, raise, incline shaft or winze, and in every stope included under Regulation 62 (3) no person shall, in drilling a hole, use or cause or permit to be used any axial water-feed drill, unless an additional water-hose is provided and the water from it turned directly on to the collar while collaring. No drill steel shall be used in any *axial water-feed drill, unless the diameter of the axial hole is at least one-quarter of an inch* throughout its whole length, when the diameter of the drill steel is one and one-eighth inch or over, and at least three-sixteenths of an inch, when the diameter is less than one and one-eighth inch.

161. (10) In any mine included in the list of mines framed under section 2 of Act 19 of 1912, the manager shall, when the total number of persons employed underground on any one shift exceeds one thousand persons, appoint one or more competent persons whose principal duty it shall be to examine and report to the manager on:

- (a) All matters relating to the mine's water supply, its quality, distribution and use.
- (b) The condition of the necessary appliances for using water at each working place and elsewhere.

On 4 July 1923 the following machines were prohibited:

(a) The short-piston Leyner drill, in all development work, except shafts and winzes, after 10 March 1924.

(b) The Model 21 Waugh Turbro drill (Standard) in all classes of work, after 10 January 1924.

Government Notice 2046 of 8 December 1923

Prohibiting the use of any machine drill used with either shell or cradle which passes or is designed to pass air through the drill steel with or without water in all development work except shafts and winzes, after 10 March 1924.

THE GENERAL QUESTION OF MINE VENTILATION AND AIR RENEWAL, INCLUDING REFERENCES TO THE HEAT AND HUMIDITY PROBLEMS

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The ventilation of the mines of the Witwatersrand is now almost universally produced by means of fans. The fans may be placed at any suitable point either on the surface or underground. But, wherever placed, the purpose is to cause the air to enter the mine through a down-cast shaft or shafts, to pass through the working places, and to return to the surface through the returns and upcast shafts. The primary purpose is to ventilate the working places. These are naturally divided into two types, the development ends and the stopes. To facilitate the operations of mining, the reef containing the gold is cut up into blocks by driving tunnels, both on the level ("levels") and at the inclination of the reef ("winzes"). The operations involved in cutting out the blocks of reef (or "development work"), therefore, precedes the actual mining of the reef (or "stopping"). And as a general rule the fresh air is first directed to the development work and is afterward directed through the stopes.

The downcast shafts are generally used for lowering and raising men, material and rock, and for carrying compressed air and water pipes, as well as electrical cables. The timber framework of the shafts is kept wet by means of water sprays and in addition water often appears in the shafts from other sources. Hence the shafts are wet, and the air picks up a large amount of moisture during its passage into the mines and is kept correspondingly cool.

The air may pass in series through two or three shafts if the workings are at great depth, and then, towards the bottom of the mine, the air splits and travels out to the working places.

The velocity of the air in the splits is much less than in the shafts, and it is exposed to a much greater area of rock. Hence its temperature tends to rise rapidly towards the natural temperature of the rock. The rate of increase in temperature, however, is reduced to some extent by the evaporation of water and by the fact that the smaller the difference in temperature between the air and the rock, the slower is the rate of heat flow from the rock. Although most of the deep mines are very dry naturally, the floor of the levels leading to the stopes is wetted by water dripping out of the cars in which the broken reef is carried from the stopes to the shafts. The evaporation of this moisture tends to cool the air and so increase the heat flow from the surrounding rock. The result is that the wet bulb temperature rises as the air approaches the stopes.

In the development ends the workers are crowded together in a confined space (the "end"), whilst in the stopes they are more dispersed. Hence the need for large volumes of air is more vital in the development ends than in the stopes, and special attention is paid to the ventilation of the former. In 1923 a Committee was appointed jointly by the Government Mining Engineer and the Transvaal Chamber of Mines to consider methods of ventilating dead ends, particularly with the object of reducing the dust during drilling time to a minimum. This Committee recommended that development ends should be ventilated generally with at least 800 cubic feet of air per minute blown on to the working face by fans, or blowers delivering through large diameter pipes carried sufficiently near the face to produce a perceptible current of air there. As in some cases the mine air was not found to be sufficiently clean for this purpose, it was further recommended that in such cases a separate compressed-air jet delivering a minimum of 100 cubic feet of free air per minute be used. The air travels into the end through galvanised piping from 12 to 30 inches in diameter hung from the side of the drive; after ventilating the end the air travels out along the drive. In some cases, however, the air travels into the end along the drive and is sucked out through ventilation piping. But, by whichever system may be used, fresh air is supplied to the workers; the heat given off from the freshly exposed rock, from the workers and from their lamps is removed; and any dust that has escaped the water used to allay it is diluted and swept away. The length of tunnel that must be ventilated in this way is usually about 500 feet, and seven workers are engaged in the end with two machine drills.

The workers engaged in shovelling the broken rock and in other duties may raise the total number of persons in the level to about two dozen. In the larger tunnels the length may run into several thousands of feet and the number of persons in the drive be doubled. The quantity of air circulated varies according to the circumstances, from 800 cubic feet per minute to 4,000 or 5,000 cubic feet per minute.

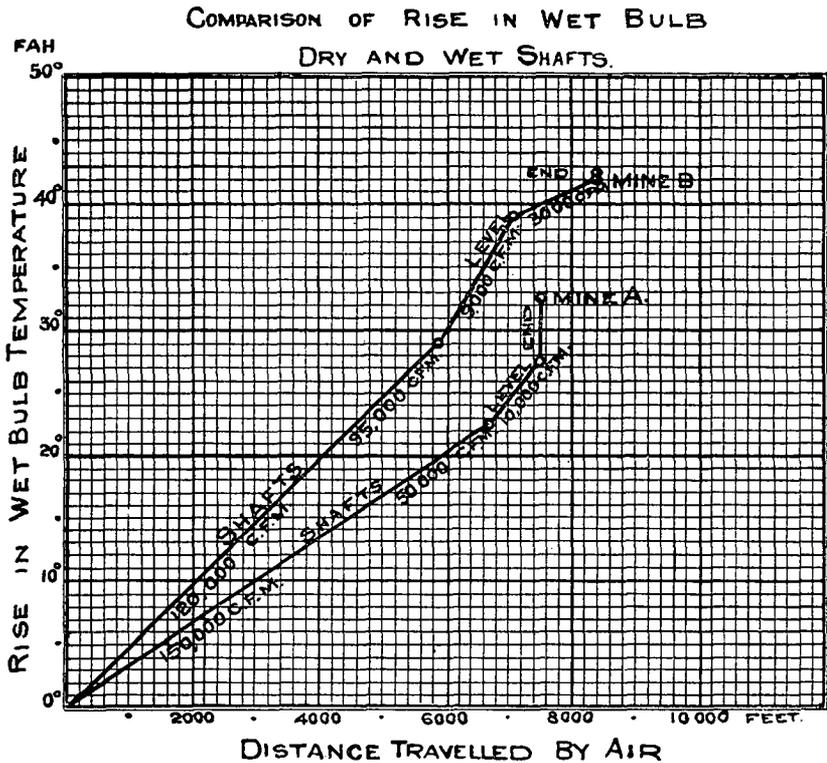
The development ends are generally situated in the lowest part of the mine and the stopes are then at a higher elevation. The ventilation is almost invariably arranged to pass up from the lower workings to those at a higher level, so as to take advantage of the natural tendency of heated air to rise from a lower level to a higher. The air, therefore, passes from the development ends to the stopes, though often the stopes are ventilated by air brought directly from the shafts. The air in its passage through the workings approaches saturation point. As it travels up the stopes, it continues for a time to be heated by contact with the warmer rock and to pick up more moisture from the artificially wetted surfaces. But, after a time, the air begins to cool by expansion and contact with cooler rock, so that in the higher stopes and in the return airways moisture begins to condense out. This is apt to produce a fog or mist. Mist may also be produced where warm air meets and mixes with cooler air, or in the neighbourhood of working compressed air machines. The air finally travels out through old workings and shafts to the surface. Where necessary, special ventilation shafts have been sunk at considerable cost to facilitate the return of the air to the surface.

In the stopes the air performs the same duties as in the development ends. Behind the working face in a stope there may, however, exist a very large open area, through which the air passes at a very low velocity. Small boosters of the Venturi type may then be employed to increase the rate of movement of the air along the face, or bratticing may be used to direct the air on to the workers.

The Village Deep mine has now reached a depth of 7,640 feet below surface, and is the deepest mine in the world. Some of the neighbouring mines are only a little less deep than this. At these great depths, the problem of supplying air sufficiently cool for work to be carried on efficiently has called for special attention. Air in passing down a shaft is compressed by the weight of the air above it. The work done produces heat which would under adiabatic conditions raise the temperature of the air $5\frac{1}{2}^{\circ}$ F. for

every 1,000 feet of depth. This heating effect is independent of the volume and cannot be reduced by the circulation of larger volumes of air. It so happens that on the Witwatersrand the rate at which the temperature of the rock rises from the surface downwards is almost the same, being about 5° F. per 1,000 feet in depth. This temperature gradient is extraordinarily slight and has been the decisive factor in permitting mining operations to be carried on to such great depths with copious use of water to allay the dust. For the evaporation of water reduces the temperature of the air far below that of the rock at the bottom of the intake shafts. This difference in temperature between the rock and the air sets up a flow of heat from the rock to the air which raises the temperature of the wet bulb to such a degree that it becomes difficult for the workers to get rid of their body heat produced during work. Although the evaporation of the water cools the air, the worker could not in any case receive any direct benefit, since the evaporation does not reduce the wet bulb temperature on which the ability of the body to get rid of its heat by sweating primarily depends. From the point of view of providing cool conditions, the use of water underground is therefore almost entirely objectionable. The flow of heat from the rock to the air can be stopped by the circulation of a sufficiently large volume of air which cools the rock for such a distance round the airway that the heat flow is negligible. For technical reasons it is difficult to produce a sufficient volume to effect this purpose even in shafts, and after the air has split it is quite impossible. Nevertheless experience has shown that by the circulation of large volumes of air the flow of heat from the rock can be diminished, and the conditions in the working places improved, not only because the wet bulb temperature is lower, but also because the cooling power of the air is increased by the increased rate of movement of the air.

Although normally the intake shafts of the Witwatersrand are wet, some of the shafts recently sunk are lined with concrete and cement, and equipped with steel and are in consequence comparatively dry. The graph on page 176 illustrates the wet bulb conditions in two development ends in different mines. In the case of Mine "A" the shafts through which the air passes are comparatively dry and in the case of Mine "B" are very wet. In both cases the shafts are vertical and the volumes passing are not widely different. The end at Mine "A" is 800 feet deeper than the end in Mine "B". In spite of this greater depth the wet bulb temperature in the Mine "A" end is much lower than that



in Mine " B ", mainly owing to the smaller rise of wet bulb temperature in the downcast shafts. A big rise in the wet bulb temperature takes place in the Mine " A " end owing to the water used there and the comparative dryness of the downcast air. This graph shows clearly the adverse effect of the evaporation of water underground on the wet bulb temperature. The actual wet bulb temperatures in the ends were:

Mine " A "	79° F.
Mine " B "	88° F.

The cooling power of the air as registered by the wet kathermometer was, with two Leyner type machine drills ¹ working:

	Millicalories per sq. cm. per second
Mine " A "	14
Mine " B "	7

¹ These machines each exhaust about 120 cubic feet of free air per minute.

In all the deep mines, in addition to providing as large a volume of air as is technically and economically possible to produce cool conditions, special attention is paid to the health of the workers, but this subject is dealt with elsewhere.

From this account it will be clear that the ventilation provides fresh air to the workers, ensures as far as possible cool working conditions, and with the help of water, keeps down the dust content of the air. After blasting (which only takes place once in the twenty-four hours) special conditions arise which are met by the prohibition of anyone entering the working places until sufficient time has elapsed for the smoke, fumes and dust to be swept away.

In order to ventilate the mines, very large fans have been installed. For instance, at the Government Gold Mining Areas the fan which ventilates the mine is capable of handling 900,000 cubic feet per minute at a water gauge of 7 inches. The fan is 30 feet in diameter and driven by a tandem compound engine developing 1,500 horse power. At the present time this is the largest mine fan in the world. On other mines are fans nearly as large. Mention might also be made of the propeller fan, which has proved particularly suitable for certain purposes. This is a recent innovation and is made up of one or more aeroplane propellers on a common shaft.

By means of these fans sufficient air is circulated to ensure that the quantity per person never falls below 30 cubic feet per minute. Indeed, although a very large personnel is employed underground, there is usually about 60 cubic feet per person per minute in circulation.

A REVIEW OF THE HISTORY OF SILICOSIS ON THE WITWATERSRAND GOLDFIELDS ¹

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THE GOLD-BEARING AREA OF THE WITWATERSRAND

Wherever mining operations are carried on on a large scale in silicious rock of "phthisis-producing" type, the menace of silicosis begins to appear so soon as the mining population has become a settled population, and especially is this the case where machine drills have been in extensive use.

That is the common experience, and that has been our experience in South Africa.

The prominence which the problem of miners' phthisis has assumed in this country has been due to the magnitude of the gold-mining industry, to the large number of miners whom it employs, and to its unique concentration upon a single large and continuous gold-bearing area. The problem has thus been at once larger and more sharply concentrated than in other countries, and the deaths and suffering caused by the disease have been more clearly apparent.

The gold-bearing area of the Witwatersrand extends for some thirty miles on either side of Johannesburg, the outcrop running roughly east and west, with the reef dipping to the south. The reef is a quartz conglomerate in a country rock of quartzite. Analyses published in 1916 in the *General Report* of the Miners' Phthisis Prevention Committee give the composition of the original ore, and of dust found in mine air. They show that the components of both are silica, silicates and pyrites. Dr. J. McCrae informs us that the probable order of the amount of free silica in the original ore is 75 to 80 per cent., but that in the dust, according to the published sample, it might be as low as 35 per cent. So far as the silicosis problem is concerned, it is only the very finest dust which counts, since only the minutest particles can be taken up by

¹ The writers are greatly indebted to Mr. F. G. A. Roberts, Technical Adviser to the Chamber of Mines, and to Mr. A. E. Payne, General Manager, Van Ryn Deep, Ltd., for valuable suggestions which have been incorporated in this paper.

"phagocytosis" into the lungs. Dr. McCrae, in his brief but classical paper on "The Ash of Silicotic Lungs" published some sixteen years ago, found that the mineral particles present in the lungs of miners who had died of silicosis were practically all under 5 microns, and 70 per cent. were under 1 micron in size.

SUBDIVISIONS OF THIS REVIEW

The history of silicosis on the Witwatersrand falls naturally into four periods:

- (1) *The initial period of gold mining on the Rand, from 1886 to 1899, that is, from the date of the first discovery of the reef until the outbreak of the South African War. One may fairly call this period, so far as local conditions are concerned, a period of ignorance of the dangers of silicosis.*
- (2) *The period of first realisation of the menace of silicosis and of tentative preventive measures, from 1901 to 1910.*
- (3) *The period of the introduction of a legal system of compensation for the disease, and of the trial of more systematic preventive measures, from 1911 to 1916.*
- (4) *And, finally, what one may call: The period of the "present-day" system of fully systematised measures of prevention, detection, and compensation, from 1916 to the present time.*

Our object in the following pages is to trace briefly the parallel and inter-related development of occupational conditions, of local knowledge of the disease, its types and its incidence, of the general legal attitude towards the problem, and of the general preventive measures which have been adopted.

I. — The Initial Period of Mining on the Rand from 1886 to 1889

This period was one of a large number of small "outcrop" mines.

When gold was first discovered on the Witwatersrand in 1886, the deposit was regarded as consisting of auriferous gravels which had become solidified in parts.

Even when it was found that the gold was contained in an inter-bedded conglomerate, most engineers were sceptical about the real value of the discovery, as past experience had shown that the mineral contents of such conglomerates were so erratic and patchy as to preclude large scale workings. The true significance of the discovery was only realised many years later.

The eventual growth of the industry was never foreseen, with the result that the original lay-out of the mines proved unsuitable for subsequent deep level working. Some ten years after the first discovery, deep boreholes intersected the reef at depths of 3,000 feet,

and led to the sinking of the first "deep level" shafts in 1898. During the first five years, mining on the Rand was largely confined to work in the oxidised zone which extended to a depth of from 60 to 300 feet. A considerable portion of the workings was open-cast, and, even when underground methods were resorted to, the ore was found to be comparatively soft and friable. It can, therefore, safely be said that the miners were exposed to little, if any, injurious dust during those days. Drilling was done by hand until about 1892, when large and heavy reciprocating machines, mounted on bars and driven by compressed air, were introduced in development ends.

From the beginning the mines have been worked by gangs of native labourers under the close personal direction of miners of European stock.

The European miners at that time were almost exclusively overseas men attracted to the Rand by high wages and bringing with them experience gained in other mining fields. To a large extent they came from Cornwall, where the population had been inured for centuries to mining conditions. The mining methods employed were crude, the development ends, which had been started by "hammer boys", were small and tortuous, following the reef exposure. No provision for mechanical ventilation was made, even when the workings reached depths of several hundred feet and when machine drills had been introduced in them.

When, however, the oxidised zone had been passed through, mining operations caused an excessive amount of highly silicious dust to be disseminated throughout the workings. In development ends, "cut" and "round" were blasted on the same shift, resulting in the miner with his assistants returning to the face through clouds of smoke and dust. Not realising the danger of exposure to this dust, neither the authorities nor the employees made any efforts to avoid exposure to it. Blasting took place at all hours, the miners, who were on contract and earned good wages, remaining underground until they had taken out their round or completed the blasting in their stopes. The sanitary conditions were equally unsatisfactory. No latrines were provided, and pollution of the working places was common practice. The living conditions on the surface were no better. Even when the tents and shacks, which served as shelter during the first few years, had been replaced by wood and iron and brick houses, living conditions were those of a typical mining camp. The water supply, which for many years was precarious, at times threatened

to fail altogether; fuel was expensive; and for a number of years ox-wagon transport had to be relied upon for bringing the bare necessities of life from Kimberley, over three hundred miles of bare veld. It is, therefore, not at all surprising that the foundations of the industry, laid under such trying conditions, should have been found unsuitable for the subsequent deep level exploitation.

One may fairly say that locally this period was one of practical ignorance of the menace of silicosis, although towards the end of the period, when some years had elapsed after the introduction of rockdrills, it became known that a proportion of the miners were becoming affected with disease of the lungs.

At the close of the period in 1899, there were 100 mines working, hoisting about 8 million tons per year. White employees numbered about 12,000, coloured employees nearly 100,000. The number of underground employees at this time is not recorded. About 2,000 rockdrills were in commission, all of the "dry" reciprocating type. The average stoping depth was about 800 feet. The maximum depth reached at this time was 3,400 feet.

II. — Period of First Realisation of the Menace of Silicosis and of Tentative Preventive Measures, 1901 to 1910

The awakening came when work was generally resumed on the Witwatersrand after the cessation of the South African War. It was then found that a large number of rockdrill miners who had previously been working on the Rand had died during the war period, or within a short time after resuming work in the mines.

In the *Report of the Government Mining Engineer (Transvaal) for the six months ending December 1901*, it was stated that of 1,377 machinemen employed before the war, 225 were known to have died between October 1899 and January 1902. These numbers would give an average annual death rate of 73 per 1,000. Facts such as these arrested the attention of the Government, the mining community and the general public, and in December 1902 the first (Transvaal) "Miners' Phthisis Commission" was appointed by Lord Milner "to enquire into and report on the disease commonly known as miners' phthisis". This body, usually referred to as the "Milner Commission", issued its Report in 1903.

THE MILNER COMMISSION, 1902-1903

This Report forms the first landmark in our local knowledge of the disease. An attempt was made by the Commissioners to procure a medical examination of all working miners, but the returns were incomplete, partly because many of the miners were reluctant to submit themselves to examination. However, 1,201 miners were examined; of these 15.4 per cent. were found to be affected by miners' phthisis and another 7.3 per cent. were suspected cases. Including the latter, the prevalence of the disease would thus appear to have been about 23 per cent., but this figure is probably too low. A very significant feature brought out in the Report is that, in spite of the number of newcomers required to replace the losses amongst rockdrill miners, the vast majority of the miners employed at this time still consisted of miners who had had their first and often a lengthy experience of mining overseas. Miners born overseas made up well over 90 per cent. of the total. The limited evidence adduced indicated that mining work in the Transvaal, especially rockdrill work, was more dangerous than similar work elsewhere, but the Commissioners were justified in the conclusion that previous mining work in other countries had contributed to some extent to the prevalence of the disease. In 1904 the *Report on the Health of Cornish Miners*, by Dr. J. S. Haldane and Messrs. Martin and Thomas, put the position from the Cornish standpoint. This Report contains the statement that the great increase which had occurred in recent years in the death rate amongst miners living in Cornwall had been due to the deaths of men who had worked rockdrills, and that "the great majority of these deaths are attributable to the effects of rockdrill work in the Transvaal or elsewhere abroad", although "a considerable number are attributable to work in Cornwall". One may believe that there was truth on both sides and the exceptional danger of rockdrill work in the Transvaal remained common ground.

The Transvaal Commission found that, although cases of miners' phthisis were chiefly noticeable amongst rockdrill miners, they were also found amongst miners who had never worked with rockdrills. The men affected were mostly younger men, their average age being thirty-five and a half years. The limited evidence available showed that the rockdrill miners affected by the disease, who had worked only in the Transvaal, had had an average underground service of under six years. The *Report on the Health of Cornish Miners* gives an average duration of service of 4.7 years for affected men who had worked only in the Transvaal.

The very dusty conditions then prevalent underground are shown by several gravimetric measurements published in the Commission's Report, which, although few in number, may be taken as fairly reflecting the position then existing. One may quote the following—the figures are milligrams per cubic metre of air: stopes, 14 and 32; raise, 164; face of drive, 192 and 424. The mines were very dusty, and they were also largely dry.

The sanitary conditions underground, especially in disused workings, were found to be frankly bad; no attempt at organised sanitation was made.

TYPE OF SILICOSIS PREVALENT AT THIS PERIOD

The type of silicosis produced by these conditions is described in a statement by the Transvaal Medical Society which the Commission published in full, and is illustrated also by the somewhat crude but nevertheless effective coloured plates attached to the Report. It was the "classical" type of silicosis, with heavy bulky lungs characterised by an excessive development of pathological fibrosis, which tended to obscure evidence of coincident infection, except as a rule in the terminal stage. Death occurred in either of two ways, by cardiac failure with dropsy and without emaciation or obvious signs of tuberculosis, or, on the other hand, by a rapid terminal tuberculosis. Local medical opinion at the time was that the majority of cases were "non-tubercular", although a "mixed fibroid and tubercular type" was recognised. Probably this conclusion was partly due to the migratory character of the early mining population; many of the deaths which occurred did so after the return of the men to their homes overseas. But Dr. J. S. Haldane and his colleagues, speaking from experience in Cornwall, were emphatic that, in the majority of cases, including returned Transvaal miners, death was due to tubercle. Obvious tuberculosis was however typically a late phenomenon. One should probably relate the "classical" type of silicosis seen in these years, in which the changes due to dust immensely predominated over obvious changes due to infection, mainly to the kind of occupational conditions existing, but to some extent also to the kind of miner who was exposed to these conditions. The miners of that time were drawn almost exclusively from older mining centres which had long been industrialised and they had presumably therefore a relatively high inherited or acquired immunity to tuberculosis. They were for the most part men of initially robust physique.

PREVENTIVE MEASURES ADOPTED

Certain general recommendations regarding dust prevention, particularly in development work, and regarding ventilation and underground sanitation, and the provision of "change houses" for miners, were made by the Commission. A phrase in the Report of the Transvaal Medical Society—"dry mining must as far as practicable become wet mining"—reflected contemporary opinion and indicated the main direction in which measures of dust prevention on the Rand have proceeded ever since.

As a result of the Commission's work certain Regulations were issued in 1904 and 1905, under Act No. 54 of 1903.

These Regulations required that sprays or jets were to be used with machine drills, that broken ground was to be damped in development places, and that blasting operations should be arranged so as to avoid exposure to dust, and they prohibited return to working places after blasting until the air was clear. Efficient ventilation was to be provided.

But, unfortunately, no effective means were prescribed to ensure that these measures should be actually carried out, and the inborn conservatism of the miners, who disliked innovations in traditional ways of working, did not help matters. A considerable improvement was unquestionably effected in the directions indicated, but it was not sufficiently thorough to produce very substantial results. The idea remained that the main cause of the trouble was rockdrilling and that rockdrill miners were almost the only sufferers. The very dangerous conditions produced by the widespread dissemination of blasting dust received quite inadequate attention.

OCCUPATIONAL CONDITIONS IN THIS PERIOD

The period 1901 to 1910 brought many "deep level" mines to the producing stage and the main changes in occupational conditions and mining methods during this period may be summarised as due to the greater depth and wider extension of the mine workings. The restricted area of many of the old "outcrop" mines combined with the fact that the dip of the reef was found to be considerably less in the deeper workings gave rise to a number of amalgamations of the smaller properties. Thus, whilst the tonnage hoisted and the gold produced rose steadily year by year, the actual number of mines on the Witwatersrand decreased. The average grade of the ore mined fell, and it became obvious that only those properties which could work on a large scale and

held a large area for exploitation could survive for any length of time. These amalgamations obviously had a marked effect on mining methods and also caused a great change in the mine ventilation. Boundaries between the small properties were stoped out, and even where this did not occur holings became increasingly frequent. As a result, the course of the natural ventilation currents underwent many changes. Although the result in individual cases was distinctly beneficial, yet the lasting effect of the many holings was definitely detrimental to a lay-out providing for efficient ventilation of all the working places. This heritage in the course of years became more serious, and at a later stage, when mechanical ventilation had to be resorted to, it was found that radical changes, though desirable, could not be effected except at a prohibitive cost.

The evidence of various dust samples taken during this period shows that dust conditions remained in general of much the same order as regards dangerous dust as they had been in 1903.

Much credit is due to the Chemical Metallurgical and Mining Society of South Africa for the active attention devoted by its members to the subject of miners' phthisis during these years, which served a very valuable educative purpose. The discussions which centred round papers contributed particularly by Drs. Macaulay and Irvine, Dr. James Moir and Mr. W. Cullen did much to extend the knowledge of the mining community regarding the nature and danger of miners' phthisis, to elucidate the nature of accidents from "gassing" underground, and to direct attention to the question of mine ventilation.

THE MINING REGULATIONS COMMISSION, 1907-1910

In 1907 a second Commission was appointed by the Government of the Transvaal—the "Mining Regulations Commission". Its primary reference was to revise and suggest amendments to the Mining Regulations; and in this connection its members devoted much attention to miners' phthisis, to the question of "gassing" accidents in the mines, and to mine ventilation and sanitation. Medical evidence was led by Drs. Macaulay and Irvine on the "Conditions affecting the Health of Underground Workers", and by Dr. G. A. Turner on the "Health of Mine Natives". From the evidence submitted by the former it was found that the local mortality from phthisis during the years 1905 to 1907 had been approximately six times higher amongst underground workers

than amongst other adult males on the Rand, but that the age period of maximum mortality fell somewhat later amongst the former, a feature which is recognised to be characteristic of "dust-phthisis".

The final Report of the Mining Regulations Commission was not issued until 1910. A revised code of Mining Regulations, based upon its recommendations was promulgated in 1911, and instituted many improvements, which began to take effect from the latter date and which represent the inauguration of the next period.

The chief of these improvements were the introduction of qualitative tests of ventilation, to supplement the quantitative requirements of older Regulations, and power was given to require the introduction of mechanical appliances where the natural ventilation current was insufficient. As before, the use of a water jet or spray was required in machine drilling; and the responsibility of the manager to maintain an adequate and constant supply of clean water for use for these appliances and for damping down working faces and broken rock in ends and stopes, was tightened up. An important innovation was the requirement that a "*water blast or other suitable appliance*" should be used in development ends to control dust from blasting, and further provision was made for the protection of all persons in the mine from fumes and dust, and for the prompt hauling of coloured labourers to the surface at the end of the shift. The ventilation of winzes was specially provided for. Responsibility was placed on the sectional officials to secure the proper observance of preventive regulations. Finally, back-to-back living rooms on the surface were prohibited, and underground sanitary organisation received detailed attention.

The result was that the use of water for dust-laying underground became from this time much more general. The following figures show very strikingly the effect of these measures, and the conditions existing at this time of transition.

DUST IN MILLIGRAMS PER CUBIC METRE

(Samples taken at the Bottom of an Upcast Shaft in a Deep-level Mine)

	Sept. 1911: No sprays	April 1912: Sprays	Sept. 1912: Sprays
9 to 10 a.m.	280	32	3.3
11.30 a.m. to 12.30 p.m.	130	21	0.2
2 to 3 p.m.	80	39	2.1
4.15 to 5.15 p.m.	100	14	17.1

An important event which is to be referred to this period was the opening in November 1911 of the Miners' Phthisis Sanatorium at Springkell, the capital expenditure being provided by the Transvaal Chamber of Mines. This institution has ever since filled a most valuable purpose in providing free special medical treatment of cases of miners' phthisis.

At the close of this period in 1910, the number of mines working was eighty-four. These mines were hoisting nearly 27,000,000 tons of rock per year. The white underground employees numbered over 10,000; coloured underground employees over 120,000. The average stoping depth was 1,100 feet; the maximum depth reached at this time was 4,500 feet. Some 5,500 rockdrills were in commission: all or nearly all were of the "dry" reciprocating type.

III. — Period of Introduction of a Legal System of Compensation for Silicosis and of Trial of More Systematic Preventive Measures, 1911 to 1916

The new Code of Mining Regulations published in 1911, which introduced this period, has already been noted. The important matter of hours of work underground was also dealt with at this time under Act No. 12 of 1911, which limited work at the face to eight hours per day and forty-eight hours per week. This had the effect in practice of an eight-and-a-half-hour day from bank to bank¹. The same year, 1911, witnessed also the first institution of a legal system of compensation for the disease. In the first session of the Union Parliament the Minister of Mines introduced a preliminary measure—the "Miners' Phthisis Allowances Act of 1911"—to provide temporary relief for men affected, pending more extensive legislation.

A "Miners' Phthisis Board" was appointed to administer the Act, and this body, with various subsequent changes in composition, still performs this very important office.

At the same time (June 1911) a further Miners' Phthisis Commission was appointed, composed entirely of medical men and hence known as the "Miners' Phthisis (Medical) Commission", "to enquire into the prevalence of miners' phthisis and tuberculosis on mines within the Union", and to advise from the medical point of view on provisions for legal measures for compensation.

¹ The practice since 1918 has been to work eight and a quarter hours bank to bank on weekdays and seven and a quarter hours on Saturdays.

THE MINERS' PHTHISIS (MEDICAL) COMMISSION, 1911-1912

The Report of the "Medical" Commission, issued in February 1912, forms the second landmark in the medical history of silicosis in South Africa.

The actual examinations made were more complete than in 1903, but they did not cover the whole of the underground employees. A general clinical examination was made of 3,136 working miners, supplemented by a special examination of 326 men, in which radiography was for the first time applied to the examination of cases on a fairly extensive scale by Dr. A. H. Watt, at the Simmer and Jack Hospital.

By these means the prevalence of definite cases of the disease amongst the working miners examined was found to be about 26 per cent., with an additional 5.5 per cent. of doubtful cases. This figure is somewhat higher than that found in 1903. It gives no reason, however, to conclude that the situation had retrogressed, since the earlier date; it probably merely reflects the result of a more extensive investigation.

Machine drillers were still the occupational group most affected, and the Commissioners concluded that, regarding this group, the statement made in the Report of the Transvaal Medical Society in 1903, that "the working efficiency of a rockdrill miner working under present conditions would be impaired or even exhausted after seven to nine years' work", still held good. Although other occupational groups showed much lower attack rates, no class of underground workers, including the supervisory staff, was free from serious risk of attack. The importance of the factor of tuberculosis in the course of the disease was fully recognised in the Report, in which it is stated that "in at least the great majority of cases tuberculous infection becomes towards the end superimposed upon the pre-existing silicosis". The Report adds that "there has been undoubtedly since 1902-1903 a distinctive alteration in the predominant clinical type of the disease".

The average duration of underground service in the whole class showing the first definite physical signs of the disease was 8.2 years, and the average age of those so affected 35.5 years: for machine-men, with South African experience only, the average duration of service was 6.1 years.

It was suggested that, for purposes of compensation, cases should be divided into three stages: early, intermediate and advanced, and that for the two latter a pension or annuity should be payable.

Pure tuberculosis was found to be comparatively rare amongst miners at work, and while the Commissioners were agreed that "miners' phthisis" was definitely an "occupational" or "industrial" disease, they were also agreed that pure tuberculosis could not be so regarded.

THE MINERS' PHTHISIS ACT OF 1912

The Report of the Medical Commission was the basis of the "Miners' Phthisis Act of 1912", which introduced for the first time a system of legalised compensation for the disease.

This Act has proved to be only the first of a long series of subsequent amending and consolidating measures, each of which has been marked in general by an increase in the amount of the awards payable to fresh cases, and by additional provision for surviving beneficiaries under former Acts, or for the dependants of deceased miners. It is unnecessary to trace the development of this complicated mass of legislation in detail, but some reference may be made to certain of its general aspects.

The system adopted in the Act of 1912 is of interest principally because it marked a definite policy, which has since been superseded.

Two "stages" of the disease were recognised—a "first" applying to "a miner who shows definite physical signs of miners' phthisis and whose capacity for underground work is thereby not seriously or permanently impaired", and a "second" applying to "a miner who has contracted silicosis in a marked degree and whose physical capacity for underground work is thereby seriously and permanently impaired".

Sums (whose total amount was limited) were paid for each stage in instalments. The miners contributed 2½ per cent. of their wages towards the liabilities for these payments in respect of new cases, and this system was continued until 1919. No award was payable to cases of pure tuberculosis.

A panel of medical examiners was appointed to carry out the medical examinations of European claimants and to certify as to their eligibility for an award. Natives suspected to be suffering from miners' phthisis were examined and certified by the Mines' Medical Inspector. The former system led to a considerable lack of uniformity in the standards of certification adopted. Increasing use was made by some examiners of radiography to supplement clinical examination, but this was far from general. Only those miners who made voluntary application for benefits were examined,

and no periodical examination of all working miners was provided for. Although a medical examination of new recruits was authorised, this also suffered from a very considerable lack of uniformity.

INCIDENCE OF SILICOSIS IN THIS PERIOD

The number of awards of benefit granted in these years to working and retired miners was very considerable and is shown in the accompanying table:

ORIGINAL AWARDS TO MINERS FOR SILICOSIS MADE BY THE MINERS' PHTHISIS BOARD FROM 1912 TO 1916

Year	First stage	Second stage	Total
1912-1913	698	1,632	2,330
1913-1914	1,087	993	2,080
1914-1915	912	367	1,279
1915-1916	540	243	783
1912-1916	3,237	3,235	6,472

At the outset of the period there existed a large number of "accumulated" cases amongst working and retired miners. If we make an allowance of 3,000 as the approximate number of these, the figures would suggest that some 800 to 900 new cases were arising in each year during this period. That this approximate estimate is probably fairly near the truth is further suggested by the fact that, after nearly 6,500 working or retired miners had thus been compensated during these four years and debarred from further underground work, the Bureau detected over 900 cases of "primary" and "secondary" stage silicosis amongst miners who were actually at work during 1916-1917. These facts indicate that the incidence of the disease at this period was decidedly worse than it has since become. It must be remembered that even the new cases arising during these years would on the average represent the cumulative effect of occupational conditions the beginning of which dated back to some eight or ten years previously.

The lack of uniformity in the medical standards of certification employed by different members of the "panel" of examiners, and of systematic means for the detection of fresh cases as they arose, resulted in a general feeling that the system adopted in 1912

was unsatisfactory. In 1916, accordingly, a Parliamentary Select Committee was appointed to reconsider the position. The Report of this body recommended the adoption of an altogether different policy.

One may note here that contributions to the local literature of the subject were made during this period by Dr. J. McGrae (1913), by Dr. W. Watkins Pitchford (1914 and 1915), and by Drs. Watt, Irvine, Pratt Johnson and Steuart (1916).

PROGRESS OF PREVENTIVE WORK FROM 1912 TO 1916

Following on the Report of the "Medical" Commission the Minister in February 1912 had appointed a "Miners' Phthisis Prevention Committee" under the chairmanship of Sir Robert Kotze. This body was an authoritative and representative one, composed of Government mine inspectors, mining engineers and mine managers representing the industry, working miners, medical men and other technical advisers. It was appointed "to enquire into and report upon methods for the prevention of miners' phthisis, and to advise on the introduction of a systematic and uniform policy". The composition of the Committee afforded an opportunity for continued close co-operation in preventive work between the Department of Mines and the industry. It may fairly be said that "the formation of this Committee marks the initiation of the first really energetic steps to stamp out the disease". Two interim Reports were issued by the Committee in 1912 and 1913, in which urgently needed steps were indicated. In 1913 a large number of Regulations were promulgated incorporating these recommendations. In addition to amplifying and more accurately defining existing Regulations, additional provisions were introduced. In 1913 it was required that *an adequate supply of water should be provided throughout each mine by means of a system of pipes*. This cardinal requirement led to much greater efficiency and uniformity in the provision of water for use with sprays and jets and water-blasts, and for wetting working-places and broken ground, and hence to a more extended and adequate application of these methods. In 1914 a further Regulation *prohibited the blasting of "cut" and "round" separately on one shift*, except by special permission of the Inspector of Mines. The practice so restricted had long been recognised as a peculiarly harmful and dangerous one.

Regular determinations of the dust in mine air had been begun by the Consolidated Goldfields Group in 1911. The first systematic

dust survey of *all* the mines was conducted by the Prevention Committee in 1913-1914. The general average result was 5.4 milligrams per cubic metre of air, the highest results being found in raises, drives and at orebins. These figures are much below the values of earlier observations, but still very considerably higher than recent results. In 1914 the Chamber of Mines established a special Dust Sampling Committee under the charge of Mr. James Boyd, and systematic surveys of workings in all mines have been carried out since that date by that Committee. In addition, since 1916 each mine has conducted its own dust surveys. The body of evidence so collected is now enormous, and provides useful guidance regarding dust conditions.

The method of dust sampling first employed was the gravimetric sugar-tube method, used with screening in order to exclude very large particles. In 1916 Sir Robert Kotze introduced a dust-sampling instrument which he named the "Konimeter". In that device a measured quantity of the air to be examined is made to impinge on an adhesive-coated microscopic slide, and the number of particles in the "spot" so produced is subsequently counted under the microscope.

For long there was controversy as to the relative merits of the sugar tube and the konimeter. It may be agreed that no one method of sampling the air for dust is satisfactory in all respects. The phthisis-producing properties of dust particles depend upon their size and upon their quality. Sugar tube or gravimetric methods do not discriminate size, and konimetric or optical methods do not discriminate quality.

The konimeter has two great advantages for routine work: a low konimeter count means safe conditions, while this does not necessarily apply to a low sugar-tube return. Further, the konimeter is handy, and can be used in observing rapidly changing dust conditions. The methods of konimeter work are at present being investigated with a view to standardisation by a Joint Committee of the Department of Mines and the Chamber of Mines. There can be no doubt of the value of this instrument, when properly used, for giving approximately accurate relative results which will serve as a sufficient guide for most practical purposes.

OCCUPATIONAL CONDITIONS DURING THIS PERIOD

During the years 1911 to 1916 mining methods on the Witwatersrand underwent a number of changes notably as regards

the lay-out of the mines, the ventilation systems and the type of machine-drill employed.

The greater depth to which the workings had penetrated, as well as the larger area over which they had extended necessitated larger shafts and development ends. It was also realised that in order to handle the increased tonnages and to improve ventilation, the drives and cross-cuts had to be laid out on as straight lines as possible, although the great bulk of the underground tramming was still being done by hand.

A more radical change took place in the ventilation systems of mines. In 1908-1909 the first large mechanical fans were installed on some mines and during the next decade all the deeper mines found it necessary to follow suit in order to clear the workings of fumes from blasting. The importance of ventilating currents in reducing the residual fine dust in the mine air had not yet been fully realised, when mechanical ventilation was installed.

An important change in the type of machine-drill came about when the reciprocating drill was superseded by the hammer type of drill. The latter was smaller and lighter, and thus more easily handled and its drilling speed was also considerably greater. The holes drilled by these machines were smaller in diameter but not only did the new machine drill more holes per shift than the old one, but in striking a larger number of blows per inch drilled, it also pounded the rock very much finer than did the reciprocating machine, and thus produced a greater proportion of fine dust. In addition, some types of hammer drill exhausted air only through the drill steel, with the result that excessive quantities of microscopic particles of dust were disseminated in the mine air, in spite of the fact that water was applied externally to remove the sludge from the drill hole. This new position had to be met by investigation into the use of air, or air and water, or water only with rock-drilling machines.

THE GENERAL POSITION IN 1916

One may note here an important development which had been going on during this period and the later years of the previous one. In 1903 over 90 per cent. of the miners employed on the Rand were men of overseas origin and the great majority of these had had previous mining experience elsewhere. But a steady increase had been proceeding since that time, particularly since 1907, in the number and proportion of miners of South African birth and training. It was noted by the Miners' Phthisis Medical Commission

in 1911 that in that year, 35 per cent. of the miners examined were South African born, and that, although 65 per cent. were of overseas birth, only 19 per cent. of the whole number examined had had previous mining service elsewhere. To-day 73 per cent. of the working miners are of South African birth, and 91 per cent. of the whole body have had their experience of mining solely in South Africa. The position has therefore been completely reversed since 1903. The industry has become throughout a genuinely South African industry. The recruits of South African birth have been drawn mainly from the rural community. It may be suggested that the presumably lower acquired immunity to tuberculosis in a population of this origin, may have contributed, along with the progressive reduction of dust in mine air, to the greater and earlier relative prominence of the element of tuberculous infection in our local cases, which had already begun to be noticeable before 1916.

The number of mining companies at work in 1916 was fifty-five. They employed underground over 11,000 Europeans and over 155,000 coloured employees. The rock hoisted per year was 32,000,000 tons. During the period the number of rock-drills in commission had increased from 5,500 in 1910 to 9,500 in 1916, and 40 per cent. of the rock mined was broken by rock-drills. The average stoping depth was 1,600 feet; the maximum depth reached was 5,250 feet.

IV. — Period of the "Present Day" System of Fully Systematised Detection and Prevention

The year 1916 was a cardinal year in the history of silicosis on the Rand. It was marked by two new departures—the institution of the Miners' Phthisis Medical Bureau, and the publication of the *General Report* of the Miners' Phthisis Prevention Committee. From 1916, therefore, we may suitably date the period of the "present day" system of detection and prevention of silicosis on the Rand.

THE MINERS' PHTHISIS ACT OF 1916 AND THE INSTITUTION OF THE MEDICAL BUREAU

The Miners' Phthisis Act of 1916 was the outcome of the Report of a Parliamentary Select Committee which sat in that year.

This Act continued the previously existing system of limited

awards for two "stages" of silicosis, but the amounts granted were increased in this year, and still further in the succeeding year. The two "stages" were now termed "primary" and "secondary". The interpretation given to the definition of the "primary" stage by the legal advisers of the Crown was that it should be held to include only such cases as showed some amount of disability; an interpretation in conformity with the general usage regarding cases of industrial "injury". The basis of compensation may have been temporarily somewhat affected by this decision.

A further step was taken by the inclusion under the Act of cases of pure tuberculosis when detected amongst miners actually at work. It was not conceded that pure tuberculosis is an occupational disease: the object was to remove from underground work cases of tuberculosis which were actual or potential sources of the communication of infection to others, and the award was granted to the affected miner simply in view of compulsory retirement from his occupation. The grant was originally made only to cases detected amongst miners at work during a period of one year from the date the system came into force. Later amending legislation, however, ultimately established the privilege of a miner to claim compensation for simple tuberculosis, provided that the condition is detected by the Bureau in a miner who is actually at work underground in a scheduled mine, or who has been so employed within not more than twelve months prior to the date on which the disease was detected.

Perhaps the most important innovation introduced by the Act of 1916 was the institution of the "Miners' Phthisis Medical Bureau"—as a central body of whole-time Government medical officials to conduct or control all medical examinations under the Act.

In the case of European miners the main functions of the Bureau have been:

- (1) To conduct an "initial examination" of all new recruits for the industry;
- (2) To conduct a "periodical examination" of each working European miner once every six months in order to secure the early detection of all cases of silicosis or tuberculosis which arise amongst the working miners;
- (3) To conduct a "benefits examination" of all miners or ex-miners who claim compensation in respect of the presence or suspected presence of silicosis or tuberculosis, and
- (4) To decide from the medical standpoint upon the claims of dependants of deceased beneficiaries.

In the case of native mine labourers, the "initial" and "periodical" examinations are conducted under Regulation by the mine medical officers acting as examiners under the Act. The Bureau, however, exercises general powers of supervision over these examinations and is directly responsible for the examination and final disposal of all natives suspected by the mine medical officers to be suffering from silicosis or tuberculosis.

The first Chairman of the Medical Bureau was Dr. W. Watkins Pitchford, on whom the heavy work of the initial organisation of that institution fell. Dr. Watkins Pitchford continued to direct the activities of the Bureau for a period of ten years up to September 1926, when he was succeeded by the present Chairman (Dr. L. G. Irvine).

SUBSEQUENT CHANGES IN THE PRINCIPLES OF LEGISLATION ON MINERS' PHTHISIS

Acts affecting minor changes in the system of compensation were passed in 1917 and 1918. Accumulating experience of the progressive character of most cases of silicosis gave support to the feeling that cases of silicosis should become eligible for compensation at the earliest detectable stage of that condition, irrespective of whether disability was present or not. It was hoped that, if this were done, the disease might be detected, and the men be given the opportunity of leaving underground work, while the condition was still non-progressive. This principle was therefore adopted in the Miners' Phthisis Act of 1919, which was the outcome of a further reconsideration of the problem by a third "Miners' Phthisis Commission" (1918) and by a Parliamentary Select Committee. Since the earliest stage of silicosis compensated under the previous Acts had been termed the "primary" stage, the somewhat anomalous expression "ante-primary" stage was introduced to designate the earlier condition which it was now intended to render compensatable. In this Act also simple tuberculosis was finally recognised, under the restrictions already mentioned, as a compensatable condition in miners. Judged from the preventive aspect, the wisdom of that decision is, we think, unquestionable. A further change of importance was the provision of a maintenance life pension for miners who had reached the "secondary" stage of grave incapacitation, with an allowance for their wives and children.

The "ante-primary" and "primary" stages were made compensatable by limited lump sum payments. Holders of a periodical certificate were entitled to remain eligible for a periodical examination provided that they presented themselves for examination at intervals not exceeding two years.

Minor amendments were effected in 1918 and 1924; a further Commission—the "De Villiers Commission"—re-examined the situation in 1921; and finally, in 1925, a new consolidating Act was passed—the "Miners' Phthisis Acts Consolidation Act of 1925". This measure aimed mainly at "levelling up" the awards granted to beneficiaries under the previous Acts to the scales of award instituted for new cases in 1919. The Act also required that medical officers appointed by mining companies to attend mine natives should be whole-time officers, power being reserved to the Minister to allow exemption in the case of small mines. This measure has tended to a more uniform and effective system of medical examination of natives for the purposes of the Act. Finally a "Medical Board of Appeal" was appointed with power to revise decisions of the Medical Bureau in respect of any examination at which the question of possible compensation was involved. This provision was made to meet the case of persons dissatisfied with the decisions of the Medical Bureau, and has added elasticity to the whole system. It cannot be said that complete satisfaction with the present system has been attained, and at present another Miners' Commission is once more reviewing the situation.

One may note here that further contributions to the literature of the subject have been made since 1916, particularly by Dr. A. Mavrogordato (1922 and 1926) and by Dr. W. Watkins Pitchford (1927).

THE "GENERAL" AND "FINAL" REPORTS OF THE MINERS' PHTHISIS PREVENTION COMMITTEE, 1916 TO 1919

The publication of the *General Report* of the Miners' Phthisis Prevention Committee in 1916 forms the second feature which makes that year a landmark in the local history of silicosis. This Report and the Committee's *Final Report* of 1919 contained a large number of further detailed recommendations aimed at the prevention of miners' phthisis. The work of that Committee was not, however, confined to the issue of general recommendations. Perhaps its most important work lay in the detailed survey of all

mining operations which it accomplished and the formulation of a detailed policy of dust control for each of these, the careful investigation of actual appliances suggested or in use for dust prevention which it carried out, and the illustrations published of those appliances which appeared best to meet their purpose. The Chairman of the Committee, Sir Robert Kotze, was, throughout the period of its sittings, in close touch in these respects with the officers of his department and with the technical advisers of the industry. An amended code of Mining Regulations, issued in 1917, embodied the cumulative result of the Committee's work.

Perhaps the most important additional measure introduced in 1917 was the provision that *blasting should take place only once in twenty-four hours, at the end of the day shift*. Blasting the "cut" and "round" separately on the same shift was now totally prohibited. Other related provisions were that work and shifts should be so arranged as to avoid exposing persons to fumes and dust from blasting, and that the night shift should only enter the mine after the lapse of an interval fixed by the Inspector of Mines. For control of the dust generated in blasting only an approved water blast was permitted.

The Regulations relating to ventilation were amplified. It was required that a prescribed minimum quantity of air must be provided for every person employed underground, and that the air must be suitably "split". Special requirements were made restricting back-stoping, and for the special ventilation of development ends. For machine drilling only a jet or a drill with axial water-feed was permitted.

Finally, it was provided that a special dust and ventilation officer should be appointed for each mine, and that regular dust determinations should be made.

In 1918 there followed Regulations enforcing dust prevention in crusher stations and assay rooms.

Subsequent to 1919 further investigations with effect in practice have been made by two Joint Committees appointed by the Department of Mines and the Chamber of Mines for special purposes—one on "Water Blasts and Ventilation" was appointed in 1921, and the second, on the "Ventilation of Development Ends" in 1923.

In 1921 a Regulation was promulgated giving the Government Mining Engineer control over the types and makes of machine drills which may be used on "phthisis" mines. Since then no new machine drill may be introduced without the prior approval of the

Government Mining Engineer, and a system of testing drills with regard to dust production has been established. The principal outcome of this provision has been that the *use of machine drills not provided with an axial water-feed has been prohibited since 1926.*

In 1916 the majority of rockdrills in commission were still of the "dry" reciprocating type. In 1918, 10,500 rockdrills were in use of which nearly half were of the hammer type, and 40 per cent. of these were "dry" drills. In 1928 the reciprocating type had practically disappeared, and 8,500 hammer drills, all of the "wet" type, were in commission.

To ensure observance of the Regulations inspections of the mines are being constantly made by the Government mining inspectors, who in many of their inspections aid their ordinary observation by taking dust samples with the konimeter. Control is also exercised by the industry itself through the Dust Sampling Committee of the Chamber of Mines, whose inspectors make routine sampling visits to the mines, as well as visits to obtain samples in connection with particular observations. The samples are taken either with the sugar tube or konimeter. They are examined at a laboratory maintained by the Chamber for that purpose, to which also the samples taken by the dust samplers on the individual mines are sent for examination and report.

Finally, the Minister in 1926 appointed a second Miners' Phthisis Prevention Committee, similar in constitution to the first, to carry on similar work.

OCCUPATIONAL CONDITIONS SINCE 1916 AND THE PRESENT POSITION

The development of that portion of the Witwatersrand goldfields situated between Benoni and the village of Nigel and popularly known as the "Far East Rand", did much to change the ventilation systems on the Witwatersrand. The areas of individual mines on this portion of the Rand are considerably larger than were those of the older mines. The reasons for this fact may be briefly indicated as follows:

These areas were known to contain extensive unpayable blocks of ground, the reef lay at depth without outcrops to the surface except in the extreme North West and South East, the dip of the reef was small, and a large amount of virgin ground was rendered available under the mining leases system.

As a result very little, if any, natural ventilation could be

hoped for, and the lay-out of the mines had therefore to be adapted to the requirements of mechanical ventilation. Again, efficient handling of the broken rock underground could only be obtained by means of mechanical haulages requiring large haulage-ways with the minimum of bends or constrictions, and thus also facilitating improved ventilation.

As a mining field the Witwatersrand to-day stands unequalled as regards the scale on which operations are carried on, the depth the workings have attained, the organisation involved, and the extent of the precautions taken to prevent miners' phthisis. Visible dust underground is as rare as it once was common, exposure to fumes from blasting if occurring at all is accidental, and sustained efforts are being made to provide improved ventilation.

The main difficulties encountered lie in the fact that the lay-out of many of the older mines is unsuitable and the necessary alterations could not be effected except at prohibitive cost. Although a great amount of attention is now paid to ventilation requirements in the original lay-out, the enormous expense of shaft sinking resulting from the great depth of the shafts and the hardness of the rock limit the area of the shafts very considerably. The danger of rock-bursts, the large unpayable areas which have to be driven through on certain mines, the close packing required for support, the narrow width at which stoping must be carried out in some mines in order to be payable, and the fact that the large ore reserves must be blocked out in advance are further factors which tend to limit the cross-sectional areas of these underground excavations, along which the main downcast current has to travel before reaching the actual working faces.

Again, these very working places are so scattered that extensive splitting of the air current is necessitated on most mines. A further complication arises from the fact that relatively few mines can be regarded as separate units as regards their ventilation systems. Holings into neighbouring mines are continually increasing, boundary pillars are being removed and the ventilation system of two or more mines must frequently be treated as one composite problem. On most mines the workings are interconnected to such an extent as to make the circulation of a main air current extremely difficult and costly. If the dust content of widely scattered stopes and development ends, in the latter of which most dust is created, is to be efficiently diluted, a good deal more ventilation will be required in such places, and on some mines the cost would be prohibitive.

At the present time the number of mines working on the Witwatersrand is forty-five but of these nine are small tribute companies working portions of mines which had previously been shut down.

The number of European miners employed is over 10,000 and of underground coloured employees over 147,000. The tonnage hoisted is over 36,000,000 tons per annum, practically all of which is broken by rock drills. The average stoping depth is 2,700 feet. The maximum depth attained is 7,638 feet (October 1929).

THE CHIEF FACTORS IN PREVENTIVE POLICY SINCE 1916 AND THEIR RESULTS

Following the summary review outlined in the last Report of the Medical Bureau one may say that since 1916 four kinds of preventive methods have combined to influence the situation.

Two of these make up what one may call the "engineering methods" aimed directly against the production or dissemination of dust in mine air. One may perhaps conveniently distinguish these as:

(1) "*Dry*" methods of prevention, by which one means measures which do not directly depend upon the use of water. These are the measures, already described, to secure an adequate standard of ventilation both general and local, to regulate the methods and times of blasting, to secure the arrangement of shifts and the times and manner of hoisting so that there should be no unnecessary exposure of any person to dust and fumes, and measures of a similar character. The general tendency to think of the use of water as the all-important measure in dust prevention has perhaps tended to an under-estimation of the cardinal importance of the provisions just mentioned.

(2) "*Wet*" methods of prevention, by which one means measures which depend directly on the use of water to allay dust at its source, or to remove it from the air when formed. Every mining operation is now covered by meticulous regulations having this object, of which we have already mentioned the chief. When in 1916 the Miners' Phthisis Prevention Committee found that the adequate use of water suitably applied would reduce the amount of dust generated in drilling and blasting by 97 or 98 per cent. by weight, it appeared that the problem had been solved. It had only been solved *so far*. The further statement made by the Committee that water would lay the dangerous dust in equal proportion to the coarser harmless dust has since required, and in our opinion still requires, re-investigation.

There is no doubt that the combined operation of these two groups of preventive measures has effected an immense reduction in the quantity by weight of dust in mine air. One may in illustra-

tion quote the following results of the gravimetric observations made by the Dust Sampling Committee of the Chamber of Mines:

Year	1915	1917	1919	1921	1923	1925	1927
General average	4.9	3.8	2.4	1.6	1.3	0.9	1.2
Development	6.9	5.4	3.5	2.3	1.9	1.0	1.2
Stopes	3.4	2.9	1.9	1.2	0.9	0.7	0.9
Orebins	4.4	4.2	2.9	2.1	1.8	1.6	1.9
Total samples	1758	6188	7491	6695	4872	2399	2869
Percentage of samples above 5 milligrams	27.0	20.0	10.0	4.0	3.4	1.7	1.4

Figures represent milligrams per cubic metre of air.

The other classes of preventive measures one may call the "medical measures".

Of these, two are of chief importance:

(3) The "initial examination" of recruits conducted or in respect of native labourers controlled by the Bureau. The object of this examination is to prevent the entry into the industry of persons suffering from respiratory diseases (including tuberculosis) or of persons who appear to be unduly liable to contract such diseases.

A very important result of the initial examination in the case of European miners has been the gradual introduction since 1916 into the general body of working miners of a group of men of specially selected physique, whom we call the "new Rand miners", and who now number over 8,300, or 54 per cent., of the whole body.

In the case of the mine natives there are three medical examinations of recruits, a preliminary sifting in the recruiting area, a principal examination at the Witwatersrand Native Labour Association's depot in Johannesburg, and a supplementary examination by the mine medical officers.

(4) The "periodical examination", similarly conducted or controlled by the Bureau, which aims at the detection of all cases of simple silicosis, tuberculosis with silicosis, or of simple tuberculosis, amongst the working miners and the mine natives. European miners actually in employment are examined by the Bureau every six months.

From the purely preventive aspect the most important consequence of the periodical examination is the permanent removal from underground work of persons found to be suffering from tuberculosis or tuberculosis with silicosis, who are thereby prevented from remaining as potential sources of dissemination of infection.

The number of cases of these conditions detected amongst European miners has fallen steadily during the past ten years and does not now constitute a serious menace.

The preventive aspect of the periodical examination is of more importance as it affects the native mine workers.

The periodical examination of native labourers is carried out, under the Act, by the mine medical officers, who are almost exclusively whole-time men and are an active, organised and progressive body. The system of examinations of natives on the mines is rather complicated.

Every native employee is weighed once in six weeks, and all who show more than a prescribed loss of weight are set aside for special medical examination; all natives with more than five years' service on any mine undergo a further special medical examination every three months, and all natives on leaving employment have to undergo a "final" medical examination. These are the prescribed examinations. In addition the medical officers examine the chests of all natives admitted to hospital for any cause. And finally the Chamber of Mines three years ago instituted an annual X-ray examination of long service natives. The whole system draws round the mine natives a serviceably close net of opportunities for detection of cases of silicosis and tuberculosis.

Suspected cases are sent to the Bureau for final examination and disposal.

The result of the examinations of mine natives discloses that simple tuberculosis and tuberculosis with silicosis taken together are decidedly more prevalent amongst them than amongst the European working miners. The reverse is true of simple silicosis.

Even so, when judged by European and American experience the attack rate for tuberculosis amongst mine natives is not alarming. But the actual number of cases detected annually is considerable, and, so far as underground conditions are concerned, it is from the mine native that the menace of tuberculous infection arises both in the production of cases of frank tuberculosis and in that of early infective silicosis amongst European and native employees alike. Hence the necessity of continuing the campaign to reduce all possible sources of tuberculous infection in the mining population to the fullest practicable extent.

One may add that three years ago a "Tuberculosis Research Committee", representative of the Government and of the Chamber of Mines, was appointed to make a fresh investigation of the tuberculosis problem.

THE INCIDENCE OF SILICOSIS SINCE 1916-1917

What now has been the practical result of all these intensive efforts ?

It is only during the past twelve years—from 1917-1918 onward—that we have been able to obtain from the published Reports of the Medical Bureau accurate figures regarding the new cases of silicosis which have actually arisen year by year.

During the whole of that period of twelve years there have been detected by the Bureau at the periodical examination of working miners 4,362 cases of simple silicosis, 382 cases of tuberculosis with silicosis, and 409 cases of pure tuberculosis.

Reduced to average figures these numbers represent, in the case of simple silicosis alone, *an average annual* production of 363 cases, amongst a population of 13,600 working miners, or 2.66 per cent.

The actual incidence has, however, varied considerably from year to year. Let us attempt to follow its general course, and for convenience let us divide the whole period into four shorter periods, each of three years' duration.

For the years 1917 to 1920 the incidence averaged 3.5 per cent., but the returns for these years were inflated by the inclusion of a considerable number of "accumulated" cases of early silicosis, which became compensatable as "ante-primary stage" cases in 1919-1920.

Partly owing simply to the removal of these accumulated cases, there followed in the years 1920 to 1923 a drop in production to an average of 1.9 per cent.

The next three years, 1923 to 1926, witnessed on the other hand a well-marked rise to an average figure of 3.3 per cent., culminating in a maximum peak of 3.8 per cent. (490 cases) in 1925-1926, a figure precisely double the average rate for 1920 to 1923.

This marked increase naturally attracted much attention and aroused misgiving.

But, as was first publicly pointed out by Dr. A. Mavrogordato, it had quite an innocent explanation. It was not attributable to a worsening of hygienic or occupational conditions underground.

The greater part of it was due to the simple fact that the mining population had become more settled and was growing older—older, that is, in length of underground service. During that period, accordingly, there had been a steady increase in the number of miners with long periods of service behind them and with a *correspondingly greater liability to contract silicosis*. Everyone

knows that, other things being equal, the longer a miner has worked underground the more liable he is to contract silicosis, and therefore the greater the number of miners with long service that are working the greater must be the number of cases of silicosis. That was one thing that was happening in these years. The remaining and lesser portion of the increase was attributable to a different cause. It was due to a temporary augmentation of the cases detected, occasioned by a further liberalisation in the standard of diagnosis of the earliest recognisable stage of silicosis, attained during these years by the Bureau, as the result mainly of improvements in X-ray technique, and of the consequent possibility of a more exact correlation between the radiographic, pathological and clinical signs presented in a large series of cases. A liberalisation of the standard of selection of this nature, however, only effects a material increase in the number of cases detected when it is being applied for the first time, and when, accordingly, two grades of the disease are being taken out at once. Once it has been applied all round to the whole body of working miners, the temporary increase disappears.

As the result of this investigation it was, therefore, possible to predict that this temporary increase, at least, would shortly disappear, and that the rise which it had occasioned would be succeeded by a fall. And the fall occurred in due course. In 1926-1927 the incidence of silicosis dropped back to 2.7 per cent.

But the further drop which has since occurred to a figure of 1.76 per cent. in 1928-1929 is even more satisfactory. It represents a genuine improvement *because it has been effected in the face of a continued increase in the number of older miners at work.*

When one makes allowance for the influence of that increase, one is able to state with entire confidence that the true production of silicosis, when measured (*as it can only be truly measured*) by the respective attack-rates for the disease amongst the miners at work in each corresponding respective year of underground service, shows a decided improvement upon the condition which obtained six years ago, before the intervening rise occurred.

The most striking evidence of improvement is seen in the returns for the specially selected body of men who have entered the industry since 1916, and whom we have termed the "new Rand miners". These men now number over 8,300 and are increasing year by year. Now whereas in the period from 1920 to 1923 the attack rate for silicosis amongst all miners who were working in their tenth year of service was 5 per cent., amongst the "new Rand miners"

working in their tenth year of service in 1928-1929 it was only 1.3 per cent. Part of this effect is certainly due to the better stamp of man of which the "new Rand miners" are composed. But if we allow an equal share to that factor this result is still remarkable. One cannot indeed anticipate that rates of this low order will continue when the "new Rand miners" enter the later periods of service, but there is no reason to suppose that they will even then reach the relatively high figures which the older miners have hitherto shown.

The duration of underground service amongst those miners who became silicotic during the past year was over twelve years. Of the 270 cases detected during that year, 90 per cent. had begun work prior to August 1916—prior, that is, to the beginning of the "present-day" period. One must remember, as we have said, that the cases of silicosis which arise in any one year are the cumulative result of the conditions obtaining during the previous ten or twelve years.

All of this is reassuring. But one must add a definite word of caution. Although we have turned a big corner in the matter of silicosis, one does not anticipate that the actual number of cases detected will show any significant further decrease in the immediate future. For, although the "new Rand miners" with their relatively lower attack rates are becoming more numerous and the older miners fewer, nevertheless, the older miners who remain, and there are still well over 5,000 of them, are every year getting still older in years of service, *and therefore more liable to contract silicosis*. The one factor will probably for some time balance the other, and, as a consequence one does not anticipate much, if any, actual decrease in the number of cases which will arise for a good many years to come.

SOME OUTSTANDING PROBLEMS

Reference may be made here to the recent strong move on the Witwatersrand towards reconsideration of the methods of combating miners' phthisis underground. The principal line which those concerned in that movement have taken has been to urge that "wet" methods of dust allaying should be replaced where possible by "dry" methods, and that, where "wet" methods are still found necessary, the amount of water used should be as small as possible. Two main factors have encouraged the movement. On

the one hand, there has been growing realisation of the discomfort, inefficiency, and even danger to life from heat stroke, arising from high temperatures combined with high humidities in deep and insufficiently ventilated mines. On the other, a strong medical opinion, in which the two medical joint authors of this paper share, has established itself to the effect that the rapidity with which many of our cases of "simple" silicosis pass to the "infective" type is in part connected with the increased facility of infection induced by the dampness and high humidity underground. There are, however, many problems to be solved before practical effect can be given to such a policy. While the comparative ineffectiveness of water in sprays or on wetted surfaces in removing from the air those very fine particles of dust, under 5 microns in diameter, with which we are concerned, is now well known, and was demonstrated in the case of the water blast, formerly looked upon as very effective, by the Witwatersrand Joint Committee on the Ventilation of Development Ends in 1923, it remains to be shown that ventilation can be increased or other means found to enable the sprays or wet surfaces to be wholly or partially given up without detriment. It has also to be shown that methods can be found which will in practice allow reduction in the very effective results of the use of water in checking the rise of fine dust from holes being drilled or from broken rock or ore being shovelled.

Another point which has to be considered is whether or not, when all that is possible has been done in cutting out the use of water for dust allaying, the amount of water naturally percolating into the mine shafts and working places or inevitably used for dust allaying will not still be sufficient to give high relative humidity in the mine air. It has to be remembered that less than 20 gallons of water will give a relative humidity of over 90 per cent. to 100,000 cubic feet of air at 87° Fahr.

Another type of preventive measure calls for consideration. It has been noticed for many years that in certain industries wherein silicosis production might be expected the disease has either been absent or of very low prevalence and has occurred very late in the working life of the employees. It has been suggested that this happy state of affairs may be related to the presence in the air, together with silica, of some particles that serve as an antidote. This hypothesis is particularly associated with the name of Dr. John Scott Haldane, and he called the attention of the Witwatersrand to its possibilities in 1918 and again in 1929. It is desirable to locate these industries and to secure data as to the actual amount of

dust of silica to which their employees are exposed and to confirm the reputed absence of silicosis by examinations of employees and some method of "follow-up" similar to that obtaining on these fields.

The whole matter is bristling with fascinating problems for both the scientific investigator and the practical engineer.

CONCLUSION

In conclusion a word may be said about the possibilities of future developments on these fields.

It would appear that although the life of a number of the existing mines is limited there are others whose production is likely to continue for twenty and more years, and in addition there are further areas of virgin ground which presumably will give rise to the opening up of new mines. It is, therefore, evident that the fight against miners' phthisis is likely to continue for many years to come unless a satisfactory solution to our present problems can be found. Judging by our experience of the past, it is practically certain that our mining methods will also undergo considerable changes in the future. The tendency exists throughout the Witwatersrand mines to adopt mechanical means for handling and transport of the broken rock and it is conceivable that this fact may have become an important factor in the prevention of miners' phthisis if, with the advance of engineering methods, a large proportion of the manual labour can be eliminated and thereby human exposure to phthisis-producing dust can be lessened.

AETIOLOGY OF SILICOSIS (DUST-PHTHISIS)

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While thanking the Conference for the honour done me, I remember that I am before an audience many of whom have travelled some six thousand miles to be present and are intimately acquainted with the subject. This is not the occasion to approach the matter in the spirit of a post-graduate lecturer.

The lungs are used to inhaling dust and used to getting rid of it, and one may perhaps recognise exposure to four main types of dust:

- (1) Dust that is harmless.
- (2) Dust that is usually harmless but may contribute to the mischief when inhaled in association with a harmful dust.
- (3) Dust that is usually harmless and may have actual prophylactic value when inhaled in association with a harmful dust.
- (4) Dust that is harmful.

When dealing with silicosis one is not concerned with dusts that are harmful by virtue of being irritant; such dusts make their mischief after a different fashion. Our concern is with what is now pretty generally known as "phthisis-producing dust". For a dust to be phthisis-producing it must possess certain qualities some of which may be enumerated as follows: it must be capable of overcoming the lung's physiological ability to rid itself of dust and of getting itself arrested, and of getting itself so arrested for a considerable time. As dust particles do not multiply of themselves, it must be relatively indestructible by tissues and tissue-juices.

Since the initial means of arrest is by phagocytosis, it must be of a size to lend itself to this process; that is to say, it must be about the size of the common pathogenic micro-organisms.

It must be too inert to bring about the ready destruction of the cells that take it up, and too inert to provoke a free production of the cells that take it up or to provoke the production of any considerable exudation. Dusts that when inhaled provoke a moist condition of the lungs associated with expectoration are not readily retained for long by normal lungs.

Dusts that lend themselves to arrest and the production of a dust-phthisis do not readily destroy the cells that take them up, and the laden cells tend to aggregate into what Koch called pseudo-tubercles. Here, then, is one means of arrest. A suspension of such dust injected intra-venously will be retained among other situations in the lungs, and will there set up a similar reaction to that which it sets up when inhaled. It is the exception for injected suspensions of particulate matter to behave in this fashion, and the procedure affords one means of testing the phthisis-producing qualities of a dust. Pseudo-tubercle production is another feature. For some years I have been interested in the fact that in tolerably pigmented lungs one may find areas clear to the naked eye, but surrounding an intensely black spot several millimetres across: much larger than the ordinary pseudo-tubercle. I have examined many of these spots in microscopic preparations, and usually they are aggregates of dust-laden cells surrounding a minute lymphoid nodule. I saw two such cases recently with Dr. Sutherland Strachan, and he tells me that he attaches considerable importance to the part played by such nodules in the arrest and distribution of dust. As to why these nodules should hold up some dusts rather than others is a further point. I am disposed to relate it to the prolonged preservation of the dust-laden cells, and attribute this preservation to the dust being slightly soluble. The pseudo-tubercle formation also suggests a chemical factor entailing a measure of solubility. There is a *vires acquirit eundo* quality about a dust-phthisis, and one suspects certain dusts of possessing the property of provoking an allergic response in the tissues which implies the need for their being to some degree soluble.

The dust that possesses these qualities and dominates the dust-phthisis of industry is dust of free silica, SiO_2 .

Clinical dust-phthisis is a protean disease and, as with other diseases, in considering its ætiology one must consider together the agent, the subject, and the conditions of exposure.

Let us start with the agent. You cannot have tuberculosis without the tubercle bacillus, and you cannot have a dust-phthisis without a phthisis-producing dust. So far so good; but the dust

or agent may be "pure" or "adulterated". In practice the agent is always more or less adulterated and, nowadays, the adulterant interests us perhaps more than the primary agent. The adulterant may be inanimate, that is to say other dust, or animate, that is to say micro-organisms. When I first came in real contact with the subject of dust-phthisis it was as assistant to Dr. J. S. Haldane, and I found my chief's attention particularly focussed on this question of the inanimate adulterant. This was getting on for twenty years ago, but in a fox-hunt Dr. Haldane would be found in front of the fox. The question was this: why, given the presence of a phthisis-producing dust, did those exposed seem on occasions to escape the disease, and why did the disease vary so widely both in incidence and severity? Obvious considerations such as intensity and duration of exposure did not cover all the facts. Colliers, for instance, might be exposed to phthisis-producing dust when drifting and shaft-sinking, yet they were held to be particularly fortunate in avoiding respiratory diseases in general and dust-phthisis in particular. In certain American mining districts the miners ought to have been suffering from the disease, but, as far as the evidence went, they were not doing so. It was possible that SiO_2 might vary in its nature or that certain other dusts when inhaled with SiO_2 might serve as an antidote. As Sir William Garforth used to say, where you find nettles there you find docks. It was on such an hypothesis that experiments were performed comparing the influence on animals of exposure to dust of free silica alone and to an equal dose of dust of free silica but with coal dust added¹. Different series of these experiments were performed over many years, some in Dr. Haldane's private laboratory at Oxford, some at St. Thomas's Hospital in London, and some at the South African Institute for Medical Research, Johannesburg. The results may be summarised by stating that coal inhaled simultaneously with silica did help silica out of the lung, but that previous invasion by coal did not appreciably hinder the settlement of silica, nor did a subsequent invasion of coal bring out settled silica. Coal dust is not the only dust that has this property; Professor E. L. Collis has pointed out that, in the manufacture of fire-bricks, the presence or absence of certain "clays" seems to decide the prevalence or absence of silicosis among the workers, although the exposure to silica dust is practically the same in amount and

¹ *Journal of Hygiene*, Vol. XVII, 1918, p. 439. *Publications of South African Institute for Medical Research*, No. XV, 1922, p. 15, and No. XIX, 1926, p. 19.

under similar conditions in each case. Of late years instances of this kind have accumulated; I shall confine myself to mentioning one of them.

By the courtesy of Dr. L. P. Stokes, in response to an enquiry, Dr. Orenstein was informed that on the Kolar Gold Field they had met with only one case of silicosis in a European who had not worked in a phthisis-producing industry elsewhere: this man had worked underground for thirty-eight years. Dr. Stokes adds: "We have not found primary fibrosis in any Indian cases." Pulmonary tuberculosis is increasing throughout India, and a latent tubercle infection is frequently made active by underground work.

Systematical medical examination of European employees, including an X-ray examination, is the rule on the Kolar Gold Field, so one may assume that silicosis is not arising. The mines are quartz mines, but until one knows the total silica and free silica in their rock one must beware of attaching too much importance to freedom from silicosis on this field.

Just as the presence of certain dusts seems to interfere with the ability of silica dust to settle in the lungs, so too the effective occupation of the lungs by silica dust seems to interfere with the ability of the lungs to rid themselves of dusts that do not settle in normal lungs. Does a phthisis-producing dust set up an allergic state? The analyses of the dust-content of the lungs of those who have died with a dust-phthisis always show the presence of dusts other than the incriminated dust, while in the case of our own sufferers the lungs are often as black as a collier's, even though the subject gave up mining years before his death. I have shown that, in our subjects, the "black" or pigment is mostly carbon from the soot provided by the acetylene lamps used underground¹. In experimental animals that have received heavy doses of silica dust by inhalation and then been left to live out their lives where they were exposed to smoke, then carbon is to be found in the silica-stricken areas of their lungs, though not elsewhere. I do not believe for a moment that this carbon did any harm, but I do suggest that, in the presence of a dust known to be phthisis-producing, all dust should be regarded as potentially harmful unless known to be helpful. In this context one may refer to the collections of coal dust to be found in the lungs of old colliers who have worked for many years at "hard-headings".

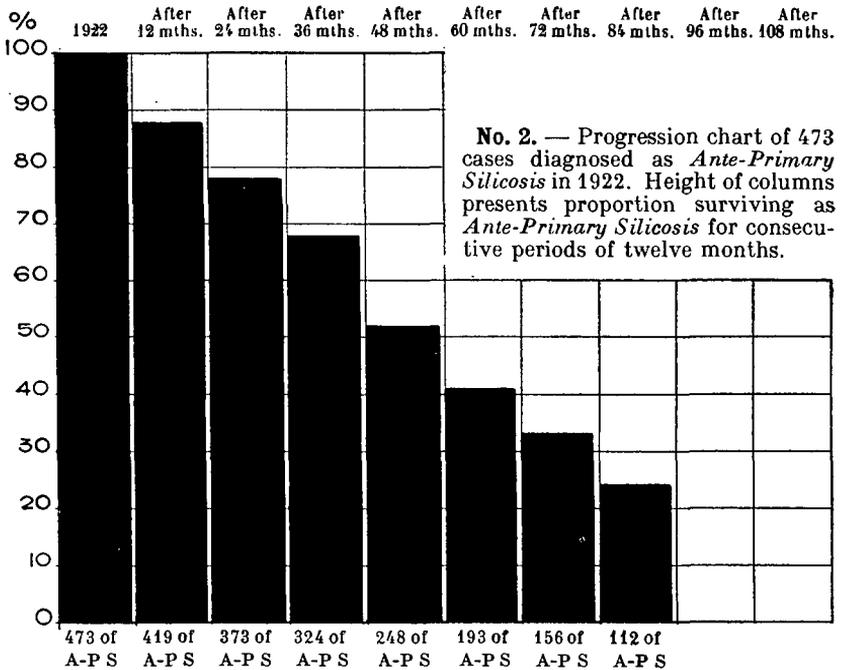
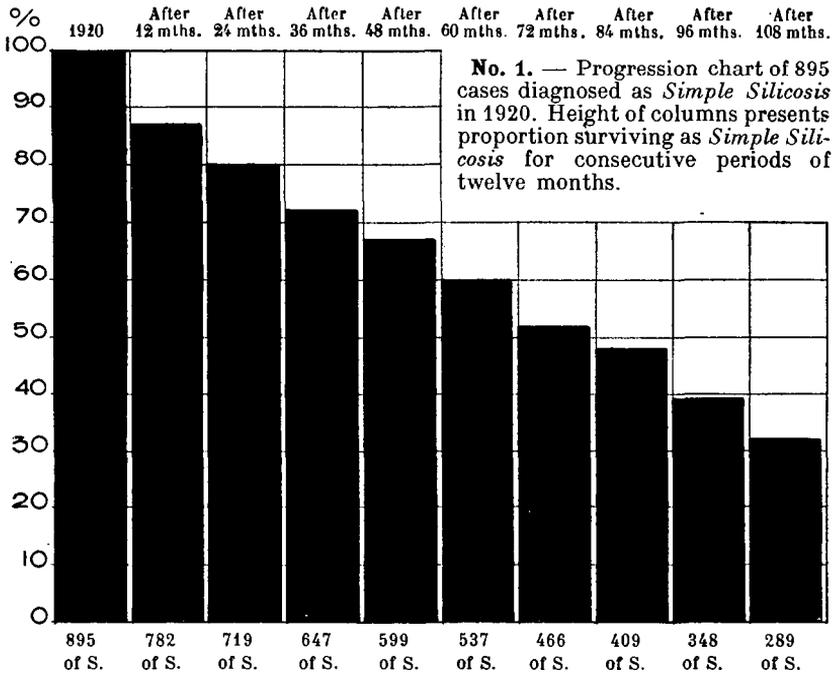
The question of the inanimate adulterant can be left here with

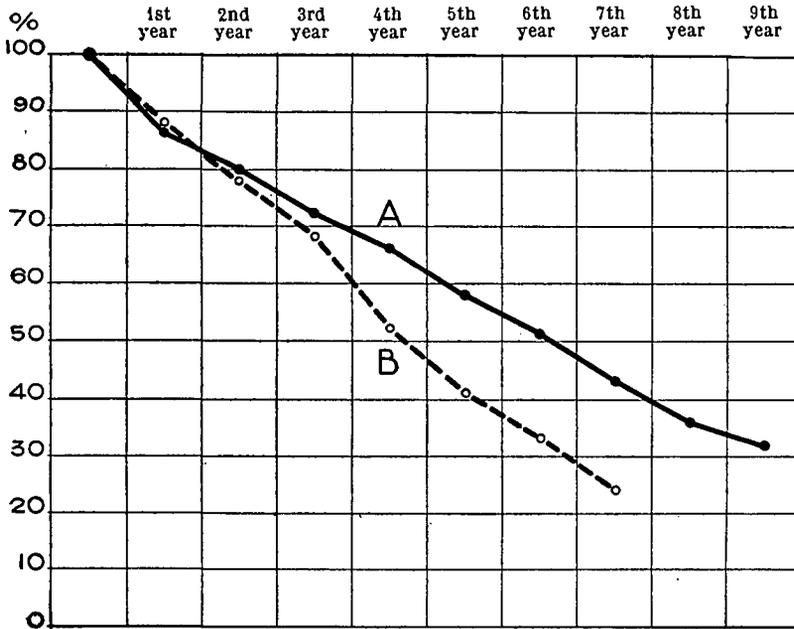
¹ *Publications of South African Institute for Medical Research*, No. XV, p. 54.

the comment that it suggests two lines of research; one of them very important. In the case of industries not associated with a serious incidence of dust-phthisis, although exposure to phthisis-producing dust appears adequate for its production, then the specific antidote must be sought in case it is present, perhaps in small quantities, as an inanimate adulterant. In the case of phthisis-producing industries associated with an incidence of simple dust-phthisis beyond that which experience would lead one to expect, one must beware an inanimate adulterant in addition to other possibilities.

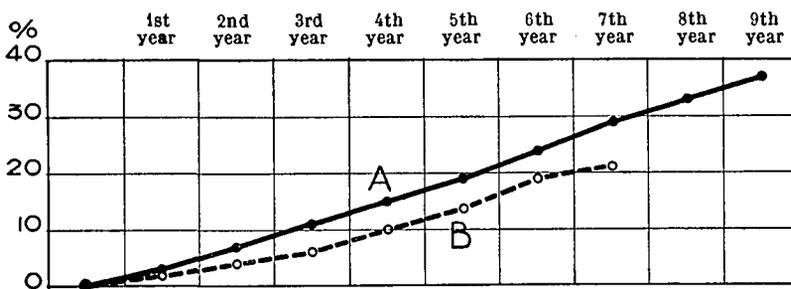
Let us turn to animate adulterants or micro-organisms. The distinction between "simple" and "infective" silicosis or dust-phthisis in a phthisis-producing industry is as important as the distinction "clean" and "dirty" cases in surgery. In this disease disability and death are always associated with a greater or lesser degree of the infective element, but in some industries and in districts with a high prevalence of dust-phthisis the disease persists for a long time in the clinically simple stage and progresses but slowly, while in other districts and industries the infective factor comes into evidence early, and often with the result that many cases show rapid progression even after the subject has given up a phthisis-producing occupation. Unfortunately, on the Witwatersrand we are confronted by the type of the disease in which the infective factor is of great importance. (See accompanying graphs by the Miners' Phthisis Medical Bureau, Johannesburg, 1920 and 1922, pages 214 and 215.)

Ante-primary silicosis is regarded by us as the earliest stage at which we can recognise a dust-phthisis as a specific clinical entity. Our miners' phthisis compensation is not based directly on the principles of accident compensation, consequently we do not require a subject to be disabled before being compensated. The data on which the graphs are based are taken from the Annual Reports of the Miners' Phthisis Medical Bureau. After six years only 156 survived as ante-primary silicosis, while 107 were dead—in the great majority of cases, of tuberculo-silicosis. The remaining survivors have progressed beyond the ante-primary stage, although nearly all of them gave up underground work on these mines when they were notified as suffering from the disease. With us, as elsewhere, the tubercle bacillus is the dominant infective factor in disability and death related to dust-phthisis. Dust-phthisis has always been with us on these fields, but a change in clinical type has been observed as the years go by.





No. 3. — Taken from Nos. 1 and 2. The progression curves of "Primary Silicosis (A) and "Ante-Primary Silicosis (B) compared. There is no gain in ability to arrest the disease.



No. 4. — Death curves of "Primary Silicosis" (A) compared with "Ante-Primary Silicosis" (B). There is a gain in expectation of life for ante-primary cases.

In the earlier days the dust was the dominant factor and the outstanding features were dyspnoea with cardiac-failure, dropsy, and oedema of gravity distribution. The disease, while much more prevalent, was running a different course. For many years past the disabled cases have been much more like an ordinary chronic tuberculosis, and the infective factor has been dominant. Some years ago the Medical Bureau introduced the term "silico-tuberculosis" to distinguish cases in which the infective factor was dominant from the cases of tuberculo-silicosis in which the dust factor was dominant. My colleagues, Drs. A. Sutherland Strachan and F. W. Simson, both of whom have had a wide post-mortem room experience of dust-phthisis, urge me to insist on the fact that the distinction between tuberculo-silicosis and silico-tuberculosis is clinical and not pathological. They point out that the lesion of tuberculo-silicosis is a specific pathological lesion and is neither the lesion of tuberculosis nor the lesion of silicosis. It is the same now as in hundred-year-old museum specimens. They add that there is no such thing as the specific lesion of silico-tuberculosis. With these contentions I of course agree; but one does not drop a term or classification that is useful clinically solely on the grounds that it does not fit in with pathological categories, nor have clinical terms always been introduced with an aftercoming pathologist in mind: one may perhaps add that a dust-phthisis does not start in the post-mortem room.

It might also be argued that what Dr. W. Watkins Pitchford has called the "gross characters of the silicotic lung" may differ in the two types of case. The "old" lungs were typically bulky; emphysema was present, but was far from being solely responsible for the bulk. The lungs, apart from the characteristic lesions of tuberculo-silicosis, rather suggested a pigmented fibroid phthisis, but they were twice the size they ought to be. The present lungs are not typically bulky, while emphysema plays a larger part in their bulk than it did in the old lungs, which did not collapse when removed from the body but stood up like plaster casts. I have discussed this question with Dr. Louis Irvine, the present Chairman of the Medical Bureau, and we both agree that, since the term "tuberculo-silicosis" fits both the clinical and pathological categories, it is misleading to bring into literature a term such as silico-tuberculosis that fits the clinical categories only. It is for this reason that Dr. Irvine himself has never liked this term.

The association between tuberculosis and dust-phthisis is proverbial, but the variation in the part played by tuberculosis is

almost equally proverbial. It is misleading to deduce the "silicosis rate" of an industry from its tuberculosis rate, even if one counts tuberculo-silicosis as tuberculosis. In many phthisis-producing industries tuberculosis does not become an important factor till well into the sixth decade of the worker's life and after getting on for thirty years of employment, yet a systematic examination of employees will disclose plenty of simple silicosis. An instance of such a state of affairs has been splendidly reported by Drs. E. R. Hayhurst, D. T. Kindel, B. E. Nyswander, and C. D. Barrett in the *Journal of Industrial Hygiene*, Vol. XI, 1929, p. 228. These observers point out that they were dealing with an open quarry, but, after all, silicosis was first systematically studied and its association with tuberculosis first satisfactorily defined in the case of workers in open quarries¹.

It is not difficult to recognise factors in a dust-phthisis which predispose to infection of lungs, but it is very difficult to see why identifiable factors should operate so differently.

I have been impressed by the following observations made chiefly on native miners. While dust of SiO_2 possesses the ability to settle permanently in the hostile territory of the lungs, this ability is only relative. In the case of a native who has worked many underground contracts on these fields and has died immediately on his return from his kraal, it is surprising how little pigment there *may* be in the lungs. If a native who has worked many underground contracts dies of pneumonia immediately on his return from his kraal the pulmonary alveoli will be found to be swarming with pigment-laden and silica-laden cells. These cells will have been loaded up months before and yet have remained sufficiently handy, sufficiently free and sufficiently well preserved to be poured into the alveoli. I incline to think that these cells have remained in the fluid but stagnant lymph of obstructed lymphatics, and that lymph persists for a long time fluid but stagnant in a distended obstructed lymphatic. The history is the same as that of a thrombosis: ultimately organisation occurs in each case. If invading pathogenic organisms be met by stale humoral and cellular elements, their survival would be facilitated. To borrow a term Professor Lyle Cummins has used in connection with tuberculosis, the effective occupation of an area of lung by a phthisis-producing dust sets up a "dead area" in the sense that this area is out of the free circulation.

¹ *Trans. Med. Chirurg. Soc. of Edinburgh*, Vol. I, 1824, p. 373.

One more feature may be adduced to illustrate the interference in normal lymph circulation that follows on effective occupation of the lungs by a phthisis-producing dust. Dr. Harvey Pirie and I have been much impressed by the promptness and ease with which inhaled dust gets past the lungs to be held up elsewhere. We have described what we call the silicotic or tuberculo-silicotic zone, and this zone includes glands in the portal fissure and glands round the stomach and pancreas as well as glands above the diaphragm other than the trachaeo-bronchial groups. The phenomena described—retention in the lung, mobility in the lung, and interference with the normal flow of lymph—are all such as should favour infection, but why do not they function more uniformly?

Before leaving the subject of phthisis-producing dust and its adulterants, I would emphasise my belief that intermittent employment is the most effective single measure against a phthisis-producing dust making a dust-phthisis. The simple silicosis rate is comparatively low in our native miners, most of whom are employed intermittently, and I relate this low rate to the fact that even a phthisis-producing dust before being finally fixed remains for some time under conditions that enable some of it to get out of the lung in favourable circumstances. Such favourable circumstances are intervals between periods of underground work of sufficient length to enable elimination to retard accumulation.

In this context the following feature may be recalled. Greenfield, later on Ziegler, and in recent times Collis and others, have called attention to the fact that although a dust-phthisis is a "dry" disease and a disease of the terminal portion of the bronchial tree, the small bronchioles are involved in the trouble and shed their epithelium. Intervals from exposure to a phthisis-producing dust affords this section of the lung's eliminating apparatus an opportunity for regaining lost efficiency.

To turn from the agent to the subject. To begin with, the initial examination of recruits to the mining industry that has been our practice since 1916 has amply justified the selection of men with good general physique and unimpaired respiratory apparatus. With exposure to a phthisis-producing dust, as in other circumstances, it is a case of one is taken and the other left. Workers differ greatly both in the ability to get rid of dust and in their ability to resist tuberculous and other super-imposed infections. While writing this paper I have seen the lungs of two miners,

one native and one European. Each had worked sixteen years underground and on machines; neither had a clinical silicosis. In both cases there was comparatively little pigmentation of lungs, and the native did not present the slightest suggestion of macroscopic silicotic lesions while in the European such macroscopic lesions as were recognisable were confined to the roots of the lungs.

The part played by the tuberculous factor varies from one phthisis-producing district to another. With us the tuberculous factor is perhaps the most serious aspect of the problem: so many of our men, although they give up mining, pass rather rapidly from silicosis without disability to silicosis with disability, and so on to tuberculo-silicosis. Some observers relate this phenomenon in part to difference in physical type and compare the short stocky Cornishman and his long-drawn-out simple silicosis with the tall lanky South African and his rapid development of the infective clinical type of the disease. I would also associate this difference in behaviour with the fact that the industrialisation of pastoral and agricultural districts is always associated with an initial rise in their tuberculosis rate. This initial rise is followed by a fall. The Western areas of the United States of America and Japan are modern instances. At present over 70 per cent. of our European underground complement are South African born, but this class only took up mining in considerable numbers since 1907. Before 1907 our European underground complement was drawn almost entirely from overseas. Other things being equal, the members of an underground complement with traditional spontaneous discipline will look after themselves better than those of a complement with no mining tradition.

The third factor for consideration in dealing with the causation and progression of silicosis or dust-phthisis is the conditions of work. The important part played by intensity and duration of exposure, and, in my opinion, by continuity of exposure, may be taken for granted. I am going to refer to conditions related to methods adopted for reducing intensity of exposure to dust and infection. At about the same time British and South African authorities were attempting to deal with risks due to dust underground. With the British it was coal dust and colliery explosions; with us it was silica dust and silicosis. Each party was confronted with the original choice between wet and dry methods. The British adopted dry methods and rendered coal dust non-explosive by mixing it with inert dust in preference to by wetting it. They were, of course, alive to the risk of introducing a phthisis-producing dust. Fifteen years'

experience has shown that the method adopted has put a stop to colliery explosions without raising the respiratory diseases rate of employees. It is quite possible that systematic examination of colliers will disclose silicosis or dust-phthisis without disability, but the method has justified itself.

South Africa chose wet methods. Circumstances alter cases and, on the Rand, we have neither colliery lay-out nor colliery ventilation as the given manœuvre ground. Up to a point the method adopted has been a success; the amount of air-borne dust has been greatly diminished and the incidence of silicosis has fallen. The reduction of dust by watering cannot, however, have all the credit for the fall in silicosis incidence; one must remember the important part played by improvement in ventilation and by selection of employees ("initial examination").

When one considers conditions of exposure as a factor in the causation of dust-phthisis, one remembers that this disease may arise in open quarries, workshops or mines. The peculiarity of conditions on the Witwatersrand lies in the following combination of factors:

Men are working at a high temperature with a high relative humidity.

Nearly all underground employees, both European and native, are drawn from a population occupied until recently with agricultural and pastoral pursuits.

The working population is, comparatively speaking, highly tuberculised. At any one time there will be rather over 9,000 Europeans and rather over 150,000 natives at work underground. The annual tuberculosis incidence on native miners is about 700 per 100,000 per annum. Opportunity for contact with tuberculosis is greater than usual.

Is this peculiarity in conditions associated with any peculiarity in the disease? One may say that the incidence rate of simple silicosis is not unduly high, but two points call for mention.

In the case of those affected, the mean duration of exposure before the disease is detected is about twelve years.

A large proportion of the cases pass on to the infective progressive type of the disease not long after the condition has been recognised in its simple form.

Granting that one takes on an occupation with an occupation hazard, there is a vast difference between risking disablement early in the fifth decade and risking disablement late in the sixth decade. When one remembers that but few South-African-born Europeans start underground work before they are twenty-five years of age, the fact that a serious proportion of those who contract silicosis are disabled in the first half of their fifth decade is the salient feature of silicosis on the Witwatersrand. The mean

duration of exposure before the disease is detected is on the short side, and the comparatively brief accumulation period cannot be accounted for by intensity of exposure. It must be born in mind that the majority of the cases that progress have given up underground work. One is driven to the conclusions that in considering conditions of exposure as a factor in the aetiology of silicosis one must consider them under two heads:

- (a) As a factor in simple silicosis.
- (b) As a factor in infective silicosis.

I will dismiss simple silicosis without further reference and turn to the infective type of the disease. Granted that tuberculosis is, and always has been, the dominant infective factor in silicosis or dust-phthisis, one must accept the fact that the underground workers on the Witwatersrand present a favourable soil for the implantation of this disease. I am not satisfied that this is the whole story. When workers are not exposed to high temperatures associated with a high relative humidity, the disease does not behave as it behaves on the Witwatersrand. Reference has been made to the Kolar Mine Field. There one has a population susceptible to tuberculosis working at a high temperature but at very low humidity: there is no evidence of a high silicosis rate, still less of a high infective silicosis rate. Certainly the fine ventilation of the Kolar mine must be considered in assaying their favourable position in respect to silicosis; but I cannot help thinking that the adoption of wet methods of dust control means the giving of too much consideration to simple silicosis and too little to the more formidable infective type of the disease.

In 1918, and again in 1929, Dr. J. S. Haldane called the attention of the Witwatersrand to the price that had to be paid for keeping down dust in a mine by water. As far as the recognised methods of estimation of dust can tell us, our workers are not exposed to higher concentrations than are workers elsewhere. Water has not failed in this respect. The fact remains that the disease with us is made rather more quickly and in a more vicious form than is the rule elsewhere. I cannot think that our experience on the Witwatersrand will encourage others to add a high relative humidity to other conditions of exposure to a phthisis-producing dust if they can possibly avoid doing so. As has been pointed out in another communication to this Conference¹, our selection of wet

¹ "Historical Review of Mining Conditions on the Witwatersrand", p. 107.

methods of dust control was largely dictated by our circumstances. Our *damnosa haereditas* did and does prevent us from realising colliery or Kolar ventilation conditions. What is left? Dr. Haldane urges us to seek the "inanimate antidote".

Remembering my audience, I have discussed the aetiology of silicosis or dust-phthisis in terms of mining in quartz; the condition of which I have first-hand experience. Members from overseas are far better qualified to discuss other aspects than I am myself. There is good reason to believe that colloidal silica is as dangerous as, if not more dangerous than, crystalline silica. Experience in the manufacture of certain abrasive powders suggests that certain colloids favour the production of silicosis when present in the air with SiO_2 . The investigators at the Amherst Quarries, Ohio, suggest that certain colloids hinder the production of silicosis and particularly of tuberculo-silicosis when present in the air with SiO_2 . Since the war, attention has been directed to asbestos as a cause of dust-phthisis. If South Africa is to become a centre of diamond cutting and polishing it may have another dust-malady in which to be concerned.

To summarise: when dealing with the aetiology of silicosis or dust-phthisis:

(A) One considers intensity, duration and continuity of exposure to phthisis-producing dust.

(B) One remembers that the association of adulterants animate and inanimate may influence both the production of the disease and its type.

(C) One fears that a high humidity favours infection by prolonging the life of pathologic organisms outside the body and facilitating their entrance into the body.

(D) One asserts that infection in a phthisis-producing industry should be thought of as it is thought of in a surgical ward or operating theatre.

(E) One feels that if a pastoral or industrial population is to turn to industry, they should think twice before turning to a phthisis-producing industry.

A PRELIMINARY STUDY OF THE PATHOLOGY OF SILICOSIS AS SEEN ON THE WITWATERSRAND

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In this study, an anatomical basis of silicosis is outlined.

The development of silicotic lesions, both uncomplicated and complicated by infection is described.

The macroscopic features are detailed and the complications indicated.

A small series of experiments on the relationship between tuberculous infection and silicosis is incorporated and a tentative conclusion arrived at.

ANATOMY

In the routine examination of a large series of lungs for silicosis and tuberculosis our attention was early drawn to the occurrence of pigmentation in the pleura, in the interstitial tissue and apparently in the lung parenchyma, and an explanation was sought for this phenomenon. The explanation was found to lie in the distribution of the lymphatics and of lymphoid tissue in the lung. For this reason it appears to us that a review of the anatomy of the lung with particular emphasis on the lymphatic apparatus is an essential preliminary to the study of the pathology of silicosis.

For our purpose it is sufficient if we consider the bronchi, lungs and pleurae.

The intra-pulmonary bronchi divide and subdivide throughout the lung and terminate in the lobular bronchioles. The bronchi and bronchioles are lined by ciliated epithelium. The bronchiole is succeeded by a slightly dilated portion known as the vestibule, in which the epithelium alters to a flattened type. The vestibule divides into several passages from three to six in number—the atria; these open out into two or more somewhat elongated passages—the infundibula, from which arise the alveoli or air-cells.

The lung parenchyma consists of lobules, which, though quite distinct from one another, are intimately bound together by connective tissue, the interlobular septa.

A terminal bronchiole with its subsequent divisions and air-cells and with the associated blood-vessels, lymphatics and nerves, forms the lobule.

Both lungs are covered by a thin transparent serous membrane which encloses the organ except at the root.

Beneath this membrane is a delicate connective tissue in which are to be found elastic fibres, blood-vessels, nerves and lymphatics; the subserous connective tissue is continuous with the trabeculae of the lung parenchyma.

In our experience early pigmentation occurs in certain definite sites in the lungs and pleurae; these sites are in the lymph-glands, in the sub-pleural tissue, in the interlobular septa and in the parenchyma in relationship to the terminal bronchioles, to the vestibules and to the atria.

The lymph-glands into which drain the lymphatics of the lung may be divided into four groups:

- (a) Broncho-pulmonary.
- (b) Superior tracheo-bronchial.
- (c) Inferior tracheo-bronchial.
- (d) Paratracheal.

The broncho-pulmonary glands lie in sites between a lobe of the lung and its bronchus.

The superior tracheo-bronchial group lies in the upper angle between the trachea and the main bronchus.

The inferior tracheo-bronchial group lies in the lower angle formed by the main bronchi at the bifurcation of the trachea.

The paratracheal group lies along the trachea in relation to the inferior laryngeal nerve.

The lymphatics of the lung are divided into two groups, superficial and deep.

The superficial forms a wide-meshed net-work in the subpleural connective tissue over the whole surface of the lung. From this net-work channels pass to the broncho-pulmonary glands at the root of the lung. Opperl¹ states that in addition to these channels, many small lymphatics pass from the superficial vessels by way of the interlobular septa to join the deep vessels arising around bronchi and blood vessels.

¹ OPPEL: *Lehrbuch der vergl. Mikr. Anat. der Wirbeltiere*, 1905, p. 746.

Scott and Beattie¹ remark that: "the superficial plexus is almost independent of the deep except at two points" but they do not mention where the points of communication are.

Miller² states:

In the human lung there are connective tissue septa much more largely developed than those about the primary lobules, which separate the secondary lobules from each other. In these septa blood and lymph vessels are associated with each other and *where they join the pleural vessels*³ there is always found a mass of lymphoid tissue.

Our observations have led us to the conclusion that communications between deep and superficial lymphatics must exist in order to account for the distribution of pigment in the interlobular septa and in the pleura. This distribution, in our opinion, is mainly in relationship to the perivenous lymphatics. The transport of pigment for any distance in the lung parenchyma is intra-cellular and by way of lymphatics and for this reason the early pigmentation of pleura implies communication between deep and superficial lymphatics.

The deep lymphatic vessels take origin in relationship to the branches of the bronchi and of the blood-vessels and terminate in the tracheo-bronchial glands.

According to W. S. Miller, lymphatics cannot be demonstrated in the branches of the bronchi beyond the terminal bronchiole except they be in relationship to the artery or vein.

In the larger bronchi the lymphatics form two plexuses—an inner sub-mucosal, and an outer peribronchial beyond the cartilages; as the branches of the bronchi become smaller the peribronchial plexus gradually disappears and only the sub-mucosal persists.

The pulmonary artery follows the bronchus in all of its subdivisions, dividing as it subdivides; each has its own system of lymph vessels and these are in communication at the places where the bronchus divides and at the distal end of the vestibule.

The pulmonary veins have also a system of lymph vessels which, like the arterial, are in communication with the bronchial system where the bronchus divides and also at the distal end of the vestibule where the bronchial system begins.

In the primary lobule of the lung, the bronchiole and the artery lie in the centre while the veins occur mainly in the periphery, only the venous radicles from the vestibule form veins within the lobule.

¹ SCOTT and BEATTIE: *Jour. Path. and Bac.*, Jan. 1928, Vol. XXXI, p. 54.

² MILLER: *Anat. Rec.*, 1911, Vol. V, p. 99.

³ The italics are ours.

As yet no lymphatics have been demonstrated in the walls of the alveoli. It is our opinion that lymphatics do not exist in this situation.

The examination of sections of carcinoma of the lung showing extensive lymphatic permeation revealed no involvement of the alveolar walls (*vide* fig. 1¹). Further, the absence of pigment in the alveolar walls in early cases of pigmentation without alveolar fibrosis is, in our opinion, in favour of the view that lymphatics do not exist in this situation.

In association with and intimately related to the lymphatics of the lung, there occur aggregations of lymphoid tissue, which may be in the form of simple aggregations, follicles or nodes.

This tissue is found in sites sub-pleural, peribronchial, periarterial and perivenous.

In the sub-pleural region the lymphoid tissue occurs as simple aggregations irregularly distributed, but showing very often at the points of junction of interlobular septa with sub-pleural connective tissue.

Lymph nodes and follicles are found on the larger bronchi where branching takes place; in the smaller bronchioles lymphoid aggregations, not follicles, are seen outside the muscular coat, lying between the bronchiole and the artery.

Lymphoid aggregations occur along the artery and then usually lie between the artery and the atria, not between the bronchus and the artery as in bronchial lymphoid tissue.

The perivenous lymphoid tissue is found commonly where a small vein joins one of the main trunks of the pulmonary vein; consequently these aggregations are frequently best seen in the interlobular connective tissue septa.

In this outline of lymphoid tissue of the lung we have followed W. S. Miller's ² description, which corresponds in the major details with the description given by Oppel ² and which is accepted and confirmed by Scott and Beattie ² in their recent work on tuberculosis in primates.

We are able also to confirm the observation made by Miller ² that in miliary tuberculosis the tubercles appear where he has described the normal occurrence of lymphoid aggregations.

Further, it is in these situations that the arrest of pigment takes place in the earliest stages of the development of silicosis.

¹ The illustrations (figs. 1-14) are given after p. 248.

² *Op. cit.*

As regards the epithelium lining the air vesicles the literature has been discussed in full by Cappell¹, and we agree that the lining consists mainly of nucleated squames and the lipoid-containing "septal cells".

Cappell² states that the alveolar phagocytes are derived from these two types of cell, and that some time after separation from the alveolar wall they become indistinguishable from one another.

A feature of importance in these cells is the presence of lipoid granules in the protoplasm.

THE DEVELOPMENT OF SIMPLE SILICOSIS

We have emphasised the importance of the lymphatic apparatus in the development of silicotic lesions, but before proceeding with the discussion of the development, it may be worth while recapitulating the main features of the defensive mechanism, which acts in the prevention and limitation of the invasion of the lung by dust.

In the nose and nasopharynx the anatomical structure provides a very efficient dust filter for the inspired air; the dust that escapes arrest may settle on the mucous membrane of the trachea and bronchi, whence by the action of the ciliated epithelium it is driven upwards and is removed in the sputum. Thus the air which reaches the alveoli, for all practical purposes, may be considered dust free.

Several factors may play a part in breaking down the defensive mechanism; of these, infection-producing disquamation of the epithelium of the upper air passages is an important one, while a great increase in the dust content of the inspired air may be another. In an atmosphere loaded with particulate matter, the filtering mechanism of the nose and nasopharynx is overcome, the lining epithelium of the upper air tubes becomes clogged and the air entering the alveoli contains relatively large amounts of dust. In our cases of silicosis both factors mentioned play a part, but the dominant one appears to be the great increase in the inspired air of respirable particulate matter. The greater part of the dust which finally reaches the alveoli, according to most authorities, is of a size comparable with that of pathogenic bacteria.

¹ CAPPELL: *Jour. Path. and Bac.*, July 1929, Vol. XXXII, p. 697.

² *Op. cit.*

In the reaction to the invasion of the alveoli by dust, phagocytosis is the essential feature and this is associated with proliferation of the lining epithelial cells, which become detached from the walls to form the alveolar phagocytes.

In the conditions under which miners work on the Rand, there is in the air, in addition to siliceous particles, a considerable quantity of finely particulate carbon; both are found associated in the development of silicotic lesions. The alveolar phagocytes or "dust cells" become pigmented by the carbon particles (pigmentation may occasionally be seen in cells still *in situ* on the alveolar walls) and the silicotic lesions also show a similar pigmentation. This pigmentation is of considerable help in tracing the development of the lesions as the siliceous particles are frequently so small that even investigation by polarised light is unsatisfactory.

At this stage it is worth while recalling the fact that not all dust which reaches the alveoli is retained within the lung parenchyma. Some of the cells which contain it reach the lumen of the bronchi and are removed in the sputum. The alveolar "dust cells" tend to accumulate in the small air passages—atria, vestibules and smaller bronchioles, and from there they pass into the tissues of the walls to the lymphatics. In our investigations we have not been able to demonstrate dust cells in the alveolar walls except in cases where there is a generalised fibrosis, probably of infective origin. We have, however, constantly noticed their accumulation in the small air passages, apparently just prior to their entrance into the lymphatic system. The first sign of the arrest of "dust cells" occurs at very definite sites in the lymphatic system—where lymphoid tissue has been described as occurring in the normal lung. In the earliest stage of the process the first places of arrest appear to be in lymphoid tissue about atria, vestibules and terminal bronchioles as the lumen of one or more of these structures can usually be seen in close relationship to the aggregations of "dust cells" (*vide* fig. 2). In our experience the true silicotic formation does not occur as a rule in relation to the larger bronchi. That the perivenous lymphatics are also involved in the process is obvious from the fact that the periphery of the lobule becomes delimited by deposits of pigmented cells and that interlobular septa and pleura also show the cell aggregates. With the exception of the subpleural connective tissue, however, true silicotic nodule formation is rarely seen in these situations.

An interesting and important feature noted in the bronchiole related to the pigmented cell aggregates in the peribronchia:

lymphatics, is the occurrence of desquamation of the ciliated epithelium (*vide* fig. 3). This "dry" bronchiolitis is a constant feature and may be an important determining factor in the lung invasion. It is also worthy of consideration from another point of view; the radiological examination of miners has revealed a condition which is, in the majority of cases, definitely presilicotic, and which is associated with a characteristic picture known as "fine ramifying fibrosis". This shows an appreciable increase in the extent of the shadows originating at the hilus of the lung and spreading fanwise into the lung substance. In the normal lung these shadows show the same distribution as the larger bronchi and possibly blood-vessels, but in radiographs showing increase the definition of the main trunks is better, and in addition shadows are seen extending almost to the periphery. The picture has previously been explained by postulating a diffuse fibrosis occurring in peribronchial and perivascular tissues associated with a mantling of bronchi and vessels with dust cells. In our experience the mantling of these structures with dust cells is not a constant feature even in moderately advanced cases of silicosis. It seems to us that some other explanation is required and for this reason the problem is being investigated. For the present, however, we would lay emphasis on the occurrence of the dry bronchiolitis which manifests itself before actual microscopic silicotic foci can be demonstrated.

The effect of arrest of the pigment-laden phagocytes has been described to be associated with a reaction which increases the lymphoid tissue. This increase has been noted by many observers, and by some, follicle formation with adenoid reticulum has been described. Lymphoid follicles in relationship to the smaller air passages were described as normal by Klein¹, though W. S. Miller² maintains that follicle formation in these sites does not occur apart from pathological changes. This increase may occur in the sites at which the pigmented cells of silicotic lesions are arrested. In the majority of cases we have not been able to demonstrate the increase in lymphoid tissue as it is almost certain to be obscured by the preponderance of pigmented cells. The further reactive phenomena seen in the early silicotic lesion becomes comparable with those which take place in a lymph gland, which is the seat of invasion by dust cells.

¹ KLEIN: Quoted by Miller: *Anat. Rec.*, 1911.

² *Op. cit.*

In the early pigmented mass, in suitable preparations, an occasional cell is seen to contain fatty material in addition to pigment. The fatty material may be an original element in the cell, as phagocytes derived from septal cells usually contain fatty material, or it may be a manifestation of degenerative changes taking place prior to disintegration of the cell. This appearance of fat in the earliest cell aggregations is, in our opinion, of considerable importance, for fat is present in all stages of the development of the true silicotic nodule. In the fully developed silicotic focus the fat is mainly extracellular, and this we take as presumptive evidence that the dust cells die and disintegrate. In addition to this, we have noted calcification of symmetrical character in some of these foci (*vide* fig. 4).

The silicotic nodule develops in the pigmented cell aggregate and appears as a small ball of well-formed fibrous tissue; only when this change takes place is the term silicotic nodule used.

On disintegration the phagocytes set free the irritant dust, which provides the stimulus for the reactive fibroblastic phenomena of silicosis. The cells taking part in the reaction are probably derived from the adventitial tissues of bronchiole and blood-vessel. If follicle formation occurs, as has been described, part of the fibroblastic reaction may be derived from the reticulum. Herring and MacNaughton¹ in their investigations of the lymphatic system in relation to the removal of particulate matter from the lymph stream summarise their conclusions as follows:

The phagocytic cells are arrested in the first lymph gland in the lymph stream. The cells carrying solid particles pass from the lymph sinuses of the gland into the lymphoid tissue of the cortex and medulla and eventually discharge their burden among the lymphocytes there.

The lymph gland is an extremely efficient filter and only allows solid particles to pass through it when these arrive in too great numbers at a time, or when the gland has become disorganised.

The lymphocytes of the lymphoid tissue act as a mechanical barrier against the particles and eventually the barrier is made more complete by the appearance in it of fibroblasts and the formation of fibrous tissue.

The foreign material is firmly enclosed, while the lymph sinuses are left open for the free passage of lymph.

The efficient filtering action of the lymph gland demonstrated by Herring and MacNaughton² probably also applies to the lymphoid tissue in the lung. The phagocytes are arrested and the pigment incarcerated while the lymph channels remain clear.

¹ HERRING and MACNAUGHTON: *The Lancet*, 3 June 1922, p. 1081.

² *Op. cit.*

As the first lymph gland in the stream is first involved and then the next in the series, so in the lymphoid tissue in the lung, viz. the aggregations in relation to atria, vestibules and bronchioles are first to show the reaction.

The lymphoid hyperplasia, which, as Herring and MacNaughton¹ conclude, acts as a mechanical barrier to the onward passage of the dust-laden phagocytes is followed by a fibroblastic reaction and a fibrosis.

The Development of the Silicotic Nodule in Lung Substance

In the aggregation of pigmented cells a small focus of fibroblasts appears (*vide* fig. 5). It may be oval or circular in shape and may occur in the centre of the aggregation or quite eccentrically; the site of its appearance is quite fortuitous but once initiated the succeeding changes proceed from this centre of origin (*vide* fig. 6). In some cases, the reaction appears almost of a granulation tissue type (*vide* fig. 7), but in the majority of cases there is little new formation of blood vessels. The earliest microscopic nodule is a very minute cellular fibroblastic accumulation of cells, arranged irregularly, some cells radially, some at the periphery arranged tangentially, and surrounded by pigmented dust cells and lymphocytes. The fibroblasts show little if any pigmentation. It would appear that the greater part of the carbon pigment is removed from the site in which the fibrosis is developing while siliceous particles are retained. This is a feature which can be demonstrated from the minute cellular focus to the well formed nodule.

The cellular character persists for a period during which the focus is enlarging, but soon collagen fibres are laid down and a ball of well formed fibrous tissue appears, which is surrounded by zones of fibroblasts, dust laden pigmented cells and lymphocytes. The fibrous tissue is arranged in a whorl-like manner in the central portion while at the periphery the appearance is that of concentric lamination. The increase in size of the nodule is always at the periphery by concentric lamination (*vide* fig. 8).

There are two striking features in the well-formed silicotic nodule—the absence, in the majority of cases, of appreciable quantities of carbon pigment and the presence of fat. With regard to the absence of pigment the nodule from the lungs of the Rand miner differs from specimens of British material which we have examined.

¹ *Op. cit.*

As to the fat, this makes itself manifest as soon as fibrosis takes place and increases in amount with the advance of the fibrosis. We have noticed that frozen sections show appearances suggestive of changes preliminary to calcification; the haematoxylin stain shows an alteration in the colour reaction of the material varying from the normal, through varying tints of violet right up to the intense bluish black of calcification. The tissue apparently contains a substance, which is readily soluble in the reagents used for the preparation of ordinary paraffin sections, for these show alterations of the staining reaction only when calcification is complete. Presumably some soap soluble in the reagents is a stage in the calcifying process, and this soap when brought into contact with the haematoxylin stain in frozen sections gives the modifications which we have noted.

Our opinion is, therefore, that in a considerable number of instances, changes just preliminary to calcification may be present in silicotic foci though not demonstrable by the ordinary paraffin section methods. In the advanced silicotic islet, calcification may occur and usually is in the centre and appears to be a condition quite apart from infection (*vide* fig. 4). A further noteworthy point in regard to the silicotic nodule is that, in some sections, the aggregation of dust cells appears to be surrounding pulmonary blood vessels and air tubes, and this suggests the possibility of subsequent fibrosis bringing about obliteration of the lumen. In our investigations the appearance of the fibrosis and its development do not suggest that obliteration occurs to any great extent in simple silicosis; the fully formed fibrous tissue islet appears to displace structures rather than to surround them.

The islets of fibrosis increase in size by a laminated type of growth at the periphery until ultimately they are readily detectable by the naked eye and are easily palpable. Though microscopically the fibrous tissue may show little or no pigmentation, the zone of arrested phagocytes at the periphery imparts a definite black colour to the naked eye appearance. The contrast between macroscopic and microscopic appearances is thus very striking.

As the condition of simple silicosis progresses, the nodules not only increase in size but also in number, so that there may be nodules in various stages of development in one lung, but they are all of the type described above.

We have mentioned that in the earliest stages the aggregates of dust cells occur in relationships to bronchioles, vestibules and atria. A silicotic focus may arise in one or more of these sites. If

they arise simultaneously, in their growth they may become contiguous and then confluent, producing a "composite nodule". This is seen macroscopically and palpated as a single nodule (*vide* fig. 9).

It has been stated that the nodular fibrosis produces an appearance which has been likened to a "string with beads on it". In our opinion the simile is not quite accurate. The arrangement is rather that of a staphyloid type; each element consisting of a silicotic nodule, single or composite, situated at the entrance to a lobule.

In some macroscopic specimens of simple silicosis there are seen massive areas of fibrosis, which superficially resemble similar areas to be described in infective silicosis. Close examination may reveal a nodular basis for the massive areas. Microscopic sections show numerous contiguous single and composite silicotic nodules between which there still survive some of the lung structures, e.g. bronchi, blood vessels and alveoli. In this type of lesion collapse of lung tissue occurs which may be the result of narrowing of the lumen of bronchus or bronchiole or more probably the result of displacement of tissue by the great number of nodules (*vide* fig. 10).

Changes in the Pleura

While the changes, which have been described, are taking place in the lung substance, similar changes occur in the subpleural tissue. These in the order in which they occur are — arrest of dust cells in aggregations, fibroblastic reaction and finally fibrosis with the formation of an islet surrounded by pigmented cells and lymphocytes. The process is modified, however, as soon as the islet reaches the surface. In the subpleural tissue it is entirely surrounded by pigmented cells, but when the fibrous tissue in its growth reaches the serous membrane, the pigmented cells become displaced, leaving that portion which projects on the surface free from these pigmented cells (*vide* fig. 11). In some of the older subpleural nodules the endothelial cells of the pleura have disappeared, and at that point the fibrosis is of a denser character and greater in amount. This suggests that the change is partly induced by friction of the opposing pleural surfaces. The macroscopic appearance of the silicotic islet from the pleural aspect is that of a small pearly white, slightly raised area and is then known as the "subpleural plaque". In the morbid anatomy of silicosis the subpleural plaque is a feature of some importance, and we emphasise here

that it is simply a nodule of silicotic fibrosis originating in sub-pleural tissue. It only involves the pleural membrane secondarily, in the course of its increase in size. Its site is probably determined, as in the lung, by the presence of lymphoid tissue; its development by the invasion of this tissue by dust cells.

Changes in Lymph Glands

Dust cells from lung and pleura are transported to the tracheo-bronchial and broncho-pulmonary glands respectively, and are arrested there. When the lung is invaded by dust, some of the phagocytes escape arrest in the lung foci and are carried by way of the lymphatics to the root of the lung. Probably only a few cells escape at a time from the region of each pigmented focus, but the sum of these cells from all foci is large. There is thus a relatively massive concentration of dust cells in the lymph glands. This concentration explains why gross pigmentation occurs in the root glands while lung and pleura still show relatively small amounts.

The pigmented cells pass from the afferent lymphatics into the sinuses and from there to the cords and nodes in the cortex and medulla of the gland. The dust cells die and disintegrate, set free the irritant particles which give rise, first, to lymphoid hyperplasia, then a fibroblastic reaction and finally a localised fibrosis. The nodule at this stage is similar in type to those seen in the lung or pleura. In some cases a dense hyaline change is seen presenting features which superficially resemble amyloid tissue, but sections of this material suitably stained give a negative result. The nodules occur in multiple sites in gland tissue, and there arise numbers of single islets which may coalesce to form composite islets, or in a further stage areas of massive fibrosis. This brings about destruction of the normal gland elements. Even when replaced by massive fibrosis, dilated lymph channels may be seen at the periphery.

In a proportion of cases calcification occurs without obvious signs of tuberculous infection. The changes we have observed in dust-occupied gland tissue are in agreement with the conclusions of Herring and MacNaughton¹ on the arrest of particulate matter in lymph glands.

The similarity between the changes seen in lymph glands to those which occur in lung substance and pleura is a further point in support of the view that the silicotic foci begin in lymphoid tissue in the lung substance.

¹ *Op. cit.*

Gye and Kettle¹ show that local inoculation of silica into subcutaneous tissues produces a definite and characteristic reaction, but this reaction differs from that seen in lymph glands and in the lung tissue.

We can find no evidence that silica produces the lesion of silicosis in tissues other than lung and lymph glands.

INFECTIVE SILICOSIS

The lesions we have just described are, in our opinion, due almost entirely to the effect of inhaled dust. We have now to consider what modifications arise when infection is associated with silicosis.

Some of these modifications present definite features to which the term "infective silicosis" has been applied. Amongst infections the one that really matters is tuberculosis, though we have to admit that others may play a part both in the spread of the fibrotic process and in modifying its characteristic features. To what extent infection, apart from tuberculosis, is responsible for the changes in infective silicosis has not yet been determined, but the question is being investigated.

There are two main aspects of the relationship between infection and dust. In the former dust modifies infective processes; in the latter superimposed infection modifies the reactive processes produced by the presence of irritant dust.

In the lungs of miners who have worked underground in a dusty atmosphere, silica particles may be present in considerable numbers without producing macroscopic or microscopic silicotic nodules. The local tissue resistance of such a lung is so lowered that relatively small doses of a pathogenic organism may produce infection. Further, Mavrogordato² has shown, in experimentally dusted animals, that an unresolved pneumonia occurs in a proportion of cases when the animals are subsequently exposed to infection by organisms other than the tubercle bacillus. This may explain the relatively frequent occurrence of unresolved pneumonia in native miners, whose lungs show little or no evidence of silicosis. These manifestations are not included in the group "infective silicosis", though they may be due to the modifications of the infective process by dust.

¹ GYE and KETTLE: *Brit. Jour. Exp. Path.*, 1922, Vol. III, p. 245.

² MAVROGORDATO: *Publications of the South African Institute for Medical Research*, 1926, Vol. III, No. 19, p. 32.

Superimposed infection modifying the reactive processes produced by irritant dust is best seen in tuberculo-silicosis. Other organisms may play an important part in these changes, but up to the present it has not been determined to what degree.

The term "infective silicosis" should be confined to conditions in which infection produces changes in the reactions to dust.

As the tubercle bacillus is by far the most important organism which modifies silicosis, we shall confine our discussion to its effects.

Tuberculosis is essentially a disease of the lymphatic system, and when tubercle bacilli settle in the lungs they do so in lymphatic tissue. Miliary tubercles we have noted in sites in which lymphoid tissue has been described as normal; the same sites in which aggregate the pigment laden phagocytes which initiate the changes of silicosis. It is possible then, that the two reactive processes may occur simultaneously in relationship to one site. In such circumstances an islet of fibrosis of some size is produced relatively rapidly, but the fibrosis differs somewhat from the ball of well-formed, dense fibrous tissue of "simple silicosis". In the centre of the islet the definition of the elements is lost, and appearances suggestive of central necrosis are seen, while at the periphery granulation tissue is more abundant. The typical tuberculous reaction, however, is absent. There is no follicle formation; no obvious aggregation of endotheloid cells and no giant cell formation (*vide* fig. 12). An islet may thus be the result of the combined process, and may be termed a tuberculo-silicotic islet; in this the tuberculous process is masked to a great extent.

In other cases the naked-eye appearances of an islet of similar size may suggest tuberculosis round the periphery, and this is confirmed microscopically. In this case infection had evidently occurred after the silicotic process had been well established.

It is difficult to estimate the relative incidence of the two types of tuberculo-silicosis.

The records of the Miners' Phthisis Medical Bureau show that a considerable proportion of miners, diagnosed as simple silicosis progress to the condition of tuberculo-silicosis. If they live long enough they die of tuberculosis, even if they have been removed from the working conditions in which the silicosis was set up. Of the cases diagnosed as simple silicosis on radiological and clinical grounds, some correspond with those, which are seen post-mortem to show the macroscopic features of simple silicosis and yet have the microscopic stigmata of tuberculosis with silicosis. These are cases of tuberculo-silicosis even though diagnosed in the first

instance as simple silicosis. The progress of the condition is slow, and although silicosis predisposes to tuberculous infection, it also has a limiting or inhibitory effect on the infection, as though the bacilli were incarcerated in the reactive fibrosis, or that the virulence of the organism was altered by the presence of silica. In other cases of simple silicosis, there is no tuberculous infection in the beginning, but this becomes superimposed later and tuberculo-silicosis is again produced. The terminal result is similar and it is this similarity which renders difficult the determination of the relative incidence of the two types.

The progress of the fibrosis in infective silicosis differs somewhat from that of simple silicosis. In simple silicosis we have shown that composite islets arise in relationship to the bronchioles, and that relatively large areas of fibrosis arise as a result of apparent confluence of contiguous islets in an area heavily affected by the silicotic process. What interstitial change does occur is almost certainly related to infection. A clean silicotic lung—admittedly a rarity—shows little change in the lung parenchyma beyond the silicotic foci and the changes in the air tubes.

In tuberculo-silicosis, however, we have a condition where increase of fibrosis occurs by direct extension. Lymphatics, interstitial tissue and alveoli may all be involved in this manner; although the lesion may be initiated as discrete islets, in time a diffuse fibrosis is set up. A considerable number of nodules may have been embedded in this tissue, but with the advent of necrosis and increasing generalised fibrosis their distinguishing characters are lost.

An area of diffuse fibrosis, generally designated "massive", shows considerable pigmentation with carbon, irregular foci of necrosis and frequently some caseation. Giant cell systems and tubercle follicles are exceedingly rare. In frozen sections, fat may be demonstrated in considerable quantity.

Massive areas of fibrosis apparently arise in several ways.

In simple silicosis where numerous single and composite islets become contiguous the appearance simulates massive fibrosis. Although called massive, close inspection shows that it is composed of definite islets of fibrosis still retaining their distinctive nodular character (*vide* fig. 10).

A second mode of development arises in infective silicosis. In this too a nodular character may still be seen as the distinctive feature of the massive area, but unlike the simple type there is evidence of coalescence and minute foci of caseation may occur (*vide* fig. 13).

These two types may resemble one another macroscopically, in that each presents a greyish black coloration and has a nodular character. The points whereby they may be distinguished are evidence of coalescence of the nodules, distinct foci of caseation, and the colour is more grey in the infective type.

A third type of massive fibrosis is seen in which there is no evidence of nodular character. In this there is an ill-defined, diffuse necrosis. The colour is again grey from the combination of pigment, fat and necrosis (*vide* fig. 14). There may also be present areas of unpigmented necrosis. This is a manifestation of infection probably always tuberculous in origin. It is produced by the coalescence of numerous tuberculo-silicotic foci with subsequent breaking down of the tissue to form one mass. Often at the margin of such an area it is possible to distinguish the outline of some nodular foci.

Though tuberculosis may produce the modification which is known as tuberculo-silicosis, some cases in which silicosis is present show obvious local tuberculous foci. Sometimes they are unmodified and sometimes associated with an area of pigmented fibrosis. The condition may remain localised or there may be an acute terminal spread; silicotic lesions and tuberculous lesions occurring without one modifying the other.

Endarteritis obliterans has been described by some authorities as an essential factor of silicosis, but we have been unable to convince ourselves that this is so. In tuberculo-silicosis vessels may be obliterated in the progressive, massive interstitial fibrosis.

MACROSCOPIC APPEARANCE OF THE SILICOTIC LUNG

When a miner dies and an autopsy is performed, the lungs are removed and sent to the Miners' Phthisis Medical Bureau for examination. This examination is essentially a macroscopic one; only in certain cases where confirmation is required is a microscopical investigation made. It is thus seen that from the practical administrative aspect, the macroscopic features of silicotic lesions are of considerable importance.

A minute silicotic focus in the lung in the earliest stages is not palpable, though the small pigmented islet may be visible; only on microscopic examination can fibrosis be detected. As the focus enlarges a stage is reached when it becomes palpable. On section of the lungs it projects slightly above the cut surface. The small palpable islet is the first macroscopic manifestation of silicosis in the lung substance.

It is obvious that, from the administrative point of view, the occurrence of an occasional small palpable islet cannot be held to constitute the disease silicosis. Certain degrees of the condition have therefore been determined which have been found to correspond with arbitrary stages in its progress, and with definite estimated degrees of disability. These degrees of silicosis are known under the terms, "slight", "moderated", "well-marked", and "very-well-marked". They indicate to the Bureau the relative number and size of the macroscopic lesions present in the lung substance. Thus in slight silicosis the lesions may be small and moderately numerous, or medium-sized to large and sparse; in the moderate degree the lesions may be numerous and small, or moderately numerous and large; in the well-marked degree, the lesions are numerous and large; while in the very well-marked degree they are very numerous and large.

In appreciating the degree present the whole lung substance has to be considered, for it is found that in a proportion of cases the lesions may be very limited in site, so that though they may be numerous and large where they occur, the greater part of the lung substance may be free from silicotic manifestations.

The terms small, medium-sized and large are used for islets of diameters up to 2 millimetres for the small, varying from 2 to 4 millimetres for the medium and from 5 millimetres to a centimetre for the large.

It is difficult to give a precise meaning to the words sparse, moderately numerous and numerous, as such a meaning could apply only in cases where the lesions were diffuse and more or less symmetrical throughout the whole lung substance. On the cut surface of the lungs in early cases of silicosis, the diffuse symmetrical distribution occurs in a minority of cases. More frequently the lesions are localised to restricted areas, where they may be moderately numerous or even numerous, but if the same number were spread over the whole lung symmetrically, they would be considered sparse. Less often a similar distribution may be met with in moderate and well-marked degrees.

Standards have been elaborated for the assessment of degrees of silicosis, where the islets are more or less symmetrical in distribution.

According to them, the word "sparse" is used when the distribution of the palpable islets on the cut surface of the lung is of the order of one silicotic islet in each square whose side is 5 centimetres in length; moderately numerous when the square has a side of 3 centimetres in length; numerous when the square has a side of

2 centimetres in length and very numerous when the square has a side of less than 2 centimetres in length.

From our definitions it is seen that the varying degrees of silicosis are not sharply defined, but merge gradually into one another.

Similar criteria are adopted for tuberculo-silicotic lesions.

Silicotic lesions, on the Rand, are pigmented and show up black, but not all pigmentation is silicotic. The presence of silicosis is determined not by pigmentation, but by the appreciation of a definite amount of palpable fibrosis in the lung substance.

In presilicotic conditions, there is accumulation and concentration of pigment in the root glands, but in them occur the first signs of fibrosis. At first the glands are slightly enlarged, slightly firm to the touch and pigmented by carbon. The pleura shows a definite increase in pigment, which tends to outline the periphery of the subjacent lobules, and the lung substance shows pigmentation in the form of discrete non-palpable islets.

As silicosis develops the glands are definitely enlarged, pigmented and firm to the touch. The subpleural pigmentation increases in amount and there is incipient plaque formation. The subpleural nodules have probably just reached the serous membrane and are seen as fine pin-point pearly white foci, surrounded by a ring of pigment. They are palpable but scarcely project above the surface. The serous membrane is still smooth and glistening. Sometimes there are patchy areas of pleural opacity, which are probably associated with infection. In the lung substance, sparse small islets of pigmentation become palpable. On section the lungs show moderately numerous discrete islets only a few of which are palpable. All islets are black in colour whether palpable or not.

With further advance of the disease, there is progressive fibrosis in the lymph glands, small subpleural plaques are formed, and the palpable islets in the lung parenchyma increase in size and in number so that a stage is reached when the lung section shows moderately numerous discrete islets of pigmentation, the majority of which are palpable and project above the cut surface of the lung. A slight amount of marginal emphysema may be noted and chronic bronchitis is present.

In the well-marked and very well-marked degrees of silicosis, the lungs may not be much increased in size, but show an increase in weight. Emphysema, particularly in the marginal regions and at the apex, is present as a more or less constant feature. There is also a chronic bronchitis with thickening of the walls of the larger bronchi. The root glands are enlarged, sometimes excessively so.

The pleura shows plaque formation to a marked degree, particularly at the apices and along the posterior borders of the lungs. The interlobar pleura is rarely affected. Opacities, patchy thickening and adhesions are usually present, though they are not purely silicotic in origin, but are the result of infection. The lungs on section show moderately numerous or numerous large palpable islets, black in colour but often with a greyish tinge in the centre. Massive areas of fibrosis may be present, in which, even on macroscopic examination, the individual islets may be recognised. The massive fibrosis is generally a little less dense in colour; the colour being rather a greyish black than pure black. In some cases, plaque formation has been noted on the diaphragmatic pleura, while in a relatively large number there is fibrosis of silicotic character in the gland groups in the posterior mediastinum, at the cardiac end of the stomach and in the upper part of the abdomen. In the case of the latter, they are found particularly around the pancreas and in the portal glands at the hilus of the liver. This extension is more commonly seen in tuberculo-silicosis, and we explain it as mainly retrograde spread along lymphatic channels, which communicate between the lung root glands, posterior mediastinal glands and the diaphragm; or more directly by way of the mediastinal pleura.

The macroscopic detection of tuberculo-silicosis in the early stages is attended with great difficulty. The islet is usually large, grey in colour and shows evidence of rapid growth or enlargement, though none of these factors is essentially characteristic of superimposed tuberculous infection. The large amount of fat contained in the islet is sufficient to explain the change in colour. The occurrence of numerous islets restricted to the sites of election for tuberculous infection may suggest that the lesions are tuberculo-silicotic. Probably such lesions are of infective type, but the paucity of suitable material for biological tests leaves the question still open.

In a well-marked case of tuberculo-silicosis, the root glands are grossly enlarged, of steel grey colour, sometimes with foci of caseation, sometimes of calcification. There are dense adhesions on the pleura with much scarring and patchy thickening associated with local emphysema. Plaque formation may be a prominent feature. Section of the lung shows numerous large grey islets, some with points of caseation. In localised parts numerous islets become confluent forming massive areas of fibrosis, a frequent site for which is just under the pleura, and towards the upper parts of the lobes of the lungs. These areas may show foci of caseation, evidence of

breaking down and even actual cavity formation. Chronic bronchitis with great thickening of the bronchi is present. In a number of these cases there is no evidence of overt tuberculosis, but a proportion do show active tuberculosis with cavity formation and broncho-pneumonia.

DISTRIBUTION OF LESIONS

The first lesion associated with silicosis appears in the root glands; next pleural involvement is seen, and cases may show plaque formation with enlarged glands with little evidence of the disease in the lung substance. In early cases the site of the lesions of the lung shows great variation. They may appear more or less symmetrically throughout both lungs or they may be more numerous towards the apices and in the posterior parts of the lungs. Occasionally they are localised in small areas; the localisation being most frequently seen at the apices.

In more advanced cases the nodules tend to be more symmetrically distributed. In some well-marked cases with numerous islets, the islets near the pleura are small, while those near the root are large and in the intermediate zone they are of medium size. This is not a constant feature, but is seen sufficiently frequently to be worthy of note.

COMPLICATIONS

The most important complication of silicosis is tuberculosis. If a silicotic patient does not die of some other disease or by accident, he will ultimately die of tuberculosis. Tuberculosis may appear early and give rise to tuberculo-silicosis, or may occur relatively late and produce obvious lesions of overt tuberculosis associated with excavation and tuberculous broncho-pneumonia. Sometimes the manifestation is a terminal miliary tuberculosis originating in a focus in some other organ. With tuberculosis there may be a chronic tuberculous pleurisy, showing a greatly thickened and adherent pleura. The lungs may be firmly anchored, particularly at the apices and this may play a part in the development of yet another complication—bronchiectasis.

There is bronchitis of a chronic type in all cases of well marked silicosis. The walls of the bronchi are much thickened and in some cases there is a diffuse dilatation giving rise to a fusiform type of

bronchiectasis; occasionally a saccular bronchiectasis is seen, usually associated with chronic pleurisy. The evidence of bronchiectasis is sufficient to be noteworthy, but it is much less than might be expected in view of the constant bronchitis and chronic pleurisy.

Associated with the chronic bronchitis in silicosis or tuberculo-silicosis, there is gross emphysema. Large bullae are frequently seen along the margins and in the apical regions. We have met with one case of pneumothorax, due to rupture of a large bulla in a tuberculo-silicotic lung.

In certain cases when pneumonia affects a silicotic lung there may be non-resolution and organisation. This is seen in both lobar and broncho-pneumonia. In other cases, particularly in natives, gangrene is not an uncommon event.

Oedema and congestion are frequently seen, but these are usually explained as terminal phenomena.

One other complication in the lung substance remains to be discussed — the incidence of primary carcinoma and its association with silicosis. We have met with seven cases of carcinoma in a series of European miners, all being carcinomata of bronchi. In a series of autopsies on Europeans carried out by us at the General Hospital, Johannesburg, only two cases of carcinoma of the lung have been observed. The number of cases is too small to permit of any accurate assessment of the place of silicosis as an etiological factor in carcinoma of the lung, but the possibility must be kept in view.

Changes associated with silicosis and tuberculo-silicosis may occur in organs apart from the lungs; particularly is this so with tuberculo-silicosis. In the glandular advance of tuberculo-silicosis we have seen the "caval" gland of the heart to be the seat of tuberculo-silicosis and the pericardium the seat of tuberculosis. As described by Shore¹, the caval gland is intrapericardial and drains into the lower tracheo-bronchial group. If the caval gland is involved in tuberculo-silicosis or tuberculosis it must be so by retrograde spread. The site of this gland and its relation to the tracheo-bronchial group may explain one mode of spread of tuberculosis from the lung to the pericardium.

As regards the heart itself, it is often stated that silicosis produces changes in the heart associated with hypertrophy. We have not been able to demonstrate this. Even in cases of gross fibrosis and emphysema, there has been little alteration in the weight of

¹ SHORE: *Jour. Anat.*, April 1929, No. 63, p. 291.

the heart and little evidence of hypertrophy. When the cause of death is cardiac failure, emphysema and interstitial fibrosis are sufficient, as a rule, to account for the cardiac disability. Disease of the coronary vessels may also aggravate the condition.

Disease of the blood vessels is common on the Rand. It usually takes the form of atheroma and is not infrequently associated with calcification. This change may appear early in life. We have noted atheroma with calcification in cases as young as twenty-one years, and in females as well as males. Vascular disease is common amongst miners on the Rand, but does not appear to be more so than in members of the general population.

We have noted chronic nephritis in a proportion of cases, but in how far this is caused by vascular disease or by the silicotic process it is difficult to determine. Our impression, which is yet to be confirmed, is that the incidence of chronic nephritis is no greater in miners than in members of the general population.

With regard to the liver, we have not noted any preponderance of cirrhotic changes in silicotics. A few have shown haemochromatosis, but haemochromatosis is relatively common in both Europeans and natives in Johannesburg.

Apart from complicating tuberculosis of the lungs and mediastinum tuberculosis may be seen in other parts of the body. Normally it would appear that silicosis tends to localise the tuberculosis, but we have seen numbers of cases, in which there is evidence of metastatic foci occurring in other organs. At autopsy, such a case may show grossly enlarged tuberculo-silicotic root glands, extensive genito-urinary tuberculosis and a terminal miliary tuberculosis. This type of case is more commonly seen in natives but it also occurs in a small proportion of white miners. Similarly in cases where there is no evidence of overt tuberculosis in the lungs or root glands there may be tuberculomata in the brain and tuberculous meningitis.

EXPERIMENTAL INVESTIGATION OF TUBERCULOUS INFECTION IN SILICOSIS WITHOUT OVERT TUBERCULOSIS

As some authorities have suggested and maintained that silicosis is infected by tuberculosis in its earliest stages, it seemed advisable that the problem should be investigated from this point of view.

Not every lung sent for examination is suitable for this type of investigation. The specimens are rendered useless as a result

of delay in transit and consequent putrefaction, or having been placed in fixative. Even in autopsies performed by ourselves many of the lungs showed post-mortem changes which rendered them useless for biological tests. Further, in a considerable number of cases the lungs were the seat of necrotic and caseous lesions, in which the tubercle bacillus was readily identified by ordinary bacteriological methods. These factors explain why so small a number of cases have been submitted to biological tests over a comparatively long period.

The material originally selected was from early cases of silicosis in which there was no suspicion of tuberculosis. The material for inoculation was selected from root glands, subpleural nodules and nodules from the substance of the lungs. Subsequently tissue was obtained from more advanced cases where tuberculo-silicosis was suspected. In one case only (J.R.B.) was there any sign of overt tuberculosis, but even in this case tissue was carefully selected from portions of the lung showing no active tuberculosis.

The silicotic lung, as is well known, is a "dirty" lung, but the tissues used for the tests were taken as aseptically as was possible in the circumstances. In the experiments the tissue was ground up both with and without the aid of sterile sand, in a minimal quantity of sterile saline. When thoroughly ground an emulsion was made in about 4 cc. of sterile saline and the whole inoculated into the left groin of a guinea-pig.

A few of the guinea-pigs died of septicaemia, but the majority lived sufficiently long for evidence of tuberculosis to develop.

An abstract made from the protocols of the various experiments is given in table I.

The experiments up to the present are few in number but are being continued when suitable material is made available.

From the few results recorded it is impossible to express any dogmatic opinion, but it is permissible to suggest certain conclusions.

The terms in the table, silicotic nodule, lung, small or large and black, indicate respectively: the material used, the site from which taken, size and colour and presumed absence of infection. The site also applies to root glands and tuberculo-silicotic area—and grey indicates presumed presence of infection but does not necessarily imply it.

With the black silicotic nodule, the results have been uniformly negative.

In the cases labelled tuberculo-silicotic as a result of naked-eye examination, a large percentage of positive results have been

TABLE I

Case	Degree of silicosis	Guinea-plg.	Date inoculated	Material inoculated	Date of death	Cause of death	Result
J.M.McD	Very occasional islet	1.A	20. 5.27	Silicotic nodules, lung. Small, black	30. 5.27	Enteritis Killed	Negative
		1.B	20. 5.27	Silicotic nodules, lung. Small, black	25.11.27		Negative
A.J.R.	Very occasional islet	3.a	15. 6.27	Silicotic nodules, lung. Small, black	11. 9.28	Killed Killed	Negative
		3.b	15. 6.27	Silicotic nodules, lung. Small, black	11. 9.28		Negative
H.P.B.	Very occasional islet	4.a	17. 6.27	Subpleural plaque large, grey	29. 7.27	Tuberculosis Killed	Positive
		4.b	17. 6.27	Silicotic nodules, lung. Small, black	11. 9.28		Negative
A.S.	Slight silicosis	2.a	27. 5.27	Subpleural irregular scars	25.11.27	Killed Killed	Negative
		2.b	27. 5.27	Silicotic nodules, lung. Small, black	25.11.27		Negative
S.F.D.	Slight silicosis	7.a	19. 9.27	Subpleural plaques grey	11. 9.28	Killed Septicaemia	Negative
		7.b	19. 9.27	Silicotic nodules, lung. Small, black	5.10.27		Negative
G.L.Q.	Slight silicosis	11.a	10. 9.28	Silicotic nodules, lung. Small, black	1. 2.29	Lobar pneumonia Splenic abscess	Negative
		11.b	10. 9.28	Silicotic nodules, lung. Small, black	9. 1.29		Negative
W.A.S.	Slight silicosis	12.a	15. 9.28	Subpleural and deep large irregular foci	2.10.28	Pyaemia Tuberculosis	Negative
		12.b	15. 9.28	Root glands tuberculo-silicotic	6. 3.29		Positive
W.W.	Moderate silicosis	6.a	8. 7.27	Silicotic nodules, lung. Small, black	11. 9.28	Killed Killed	Negative
		6.b	8. 7.27	Silicotic nodules, lung. Small, black	11. 9.28		Negative

M.R.C.	Moderate silicosis	8.a	27.10.27	Silicotic nodules, lung. Small, black	11. 9.28	Killed	Negative
		8.b	27.10.27	Root glands soft, black	31.10.27	Septicaemia	Negative
L.W.P.	Moderate silicosis	9.a	27. 1.28	Silicotic nodules, lung. Moderate size, black	30. 1.28	Septicaemia	Negative
		9.b	27. 1.28	Large silicotic nodules. Tuberculo-silicotic	30. 1.28	Septicaemia	Negative
T.de B.	Moderate silicosis	16.a	31.12.28	Large area tuberculo-silicosis	20.11.29	Killed	Negative
		16.b	31.12.28	Large area tuberculo-silicosis	20.11.29	Killed	Negative
T.C.C.	Moderate silicosis	17.a	4. 1.29	Root glands tuberculo-silicotic	9. 1.29	Killed	Negative
		17.b	4. 1.29	Root glands tuberculo-silicotic	9. 1.29	Septicaemia	Negative
J.R.	Moderate silicosis	10.a	12. 4.28	Silicotic nodules, lung. Large, black	12. 7.29	Killed	Negative
		10.b	12. 4.28	Silicotic nodules, lung. Large, black	12. 7.29	Killed	Negative
C.J.S.	Moderate to marked silicosis	13.a	17.10.28	Tuberculo-silicotic nodules, lung	12. 7.29	Tuberculosis	Positive
		13.b	17.10.28	Tuberculo-silicotic nodules, lung	15.12.28	Enteritis	Negative
P.J.A.	Moderate to marked silicosis	14.a	30.11.28	Root glands tuberculo-silicotic	5. 7.29	Tuberculosis	Positive
		14.b	30.11.28	Nodules from lung tuberculo-silicotic	14. 6.29	Tuberculosis	Positive
V.J.D.	Moderate to marked silicosis	19.a	23. 4.29	Small root glands tuberculo-silicotic	20.11.29	Killed	Negative
		19.b	23. 4.29	Small root glands tuberculo-silicotic	20.11.29	Killed	Negative
C.M.J.	Well-marked silicosis	5.a	17. 6.27	Subpleural plaques black	18. 6.27	Septicaemia	Negative
		5.b	17. 6.27	Nodules from lung tuberculo-silicotic	5. 8.27	Tuberculosis	Positive
J.R.B.	Very well-marked silicosis	18.a	9. 4.29	Massive area tuberculo-silicotic	12. 7.29	Killed	Positive
		18.b	9. 4.29	Root glands tuberculo-silicotic	12. 7.29	Killed	Positive

obtained. These cases were, with two exceptions, in a state of marked tuberculo-silicosis. In one exception (H.P.B.) the tissue was taken from the subpleural region but was grey in colour, in the other (W.A.S.), though showing no tuberculo-silicosis of the lung itself, was from a gross tuberculo-silicotic gland.

If any conclusion can be drawn from the results of these experiments it would seem that they indicate that silicosis does exist and progress as a separate entity apart from tuberculosis. Further, as a result of our examination of the weights, the progress of the animals and the type and number of the tuberculosis lesions found, it would appear that an attenuated type of organism is associated with tuberculo-silicotic lesions.

SUMMARY

The site of the silicotic lesions in the lungs appears to have an anatomical basis. This is related to the positions in which lymphoid tissue has been described.

The first evidence of change in the lung as a result of the inhalation of irritant dust is a "dry" bronchiolitis.

The manifestations of the silicotic process appear first in relationship to terminal bronchioles, vestibules and atria.

The silicotic process is a fibroblastic reaction followed by a dense fibrosis of nodular type, in which fat accumulation occurs in all stages and increases *pari passu* with the size of the nodule.

Massive fibrosis may result from the progress of uncomplicated fibrosis.

Infection modifies the silicotic process in the direction of excessive fibrosis.

The important infective factor is tuberculosis.

The macroscopic changes are usually seen, first in lymph glands then in pleura and lung substance.

The main complications are related to tuberculosis; others present are chronic bronchitis and emphysema.

Silicosis may exist and progress without superimposed tuberculous infection.

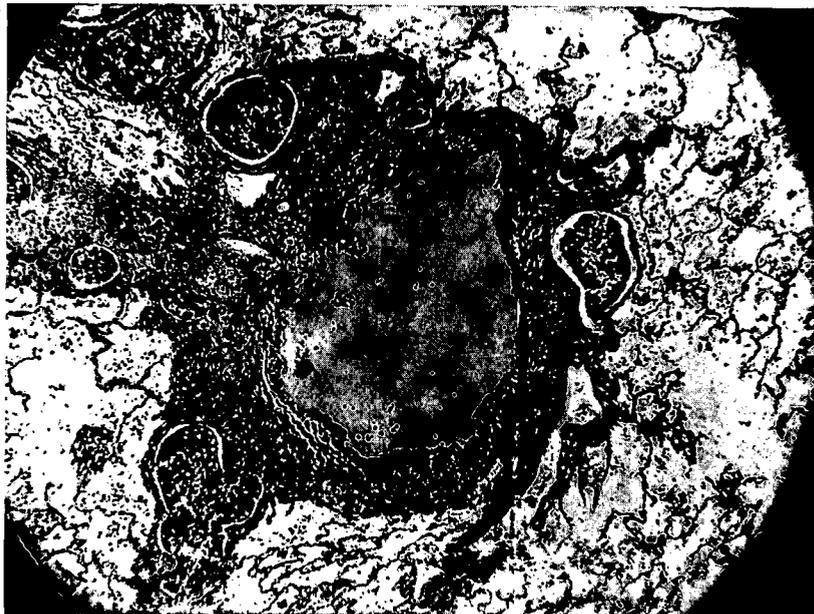


FIG. 1. — From a case of primary carcinoma of the lung with widespread lymphatic permeation. Section shows a bronchus in cross section, portions of septa, and surrounding air vesicles. The carcinoma-filled lymphatics are shown in the wall of the bronchus and in the septa, while the alveolar walls remain free from the growth.

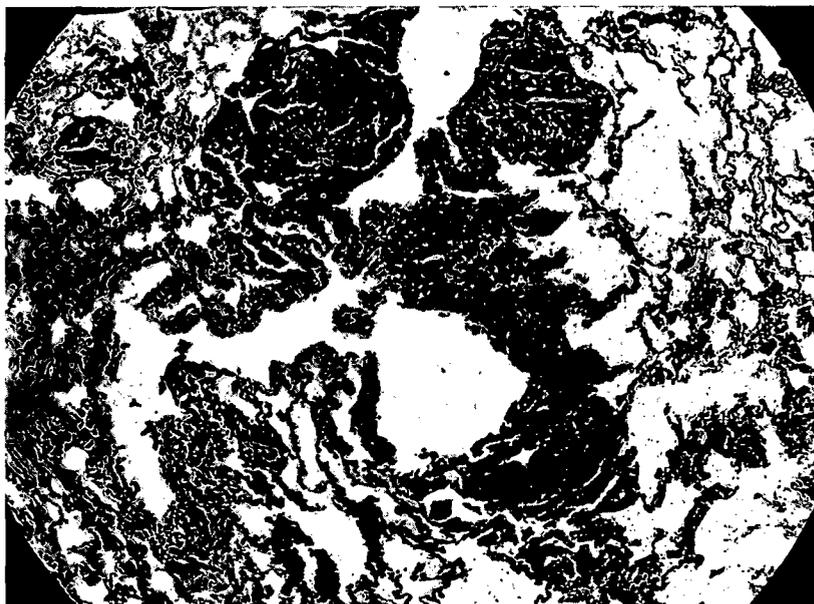


FIG. 2. — From a case of slight silicosis. This section shows the entrance to a lobule with several aggregations of pigmented cells. It is in these aggregations that the future silicotic nodule develops.

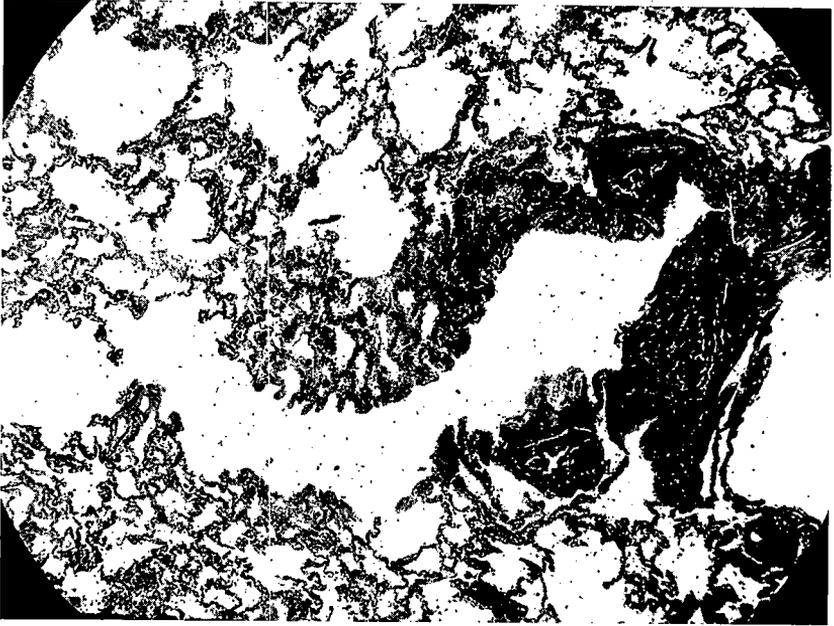


FIG. 3. — Dry bronchiolitis from a case of slight silicosis. Section of lung showing terminal bronchiole, vestibule, etc. Pigmented cells are present in the walls and almost complete denudation of the lining epithelium is shown. There is no evidence of exudate.

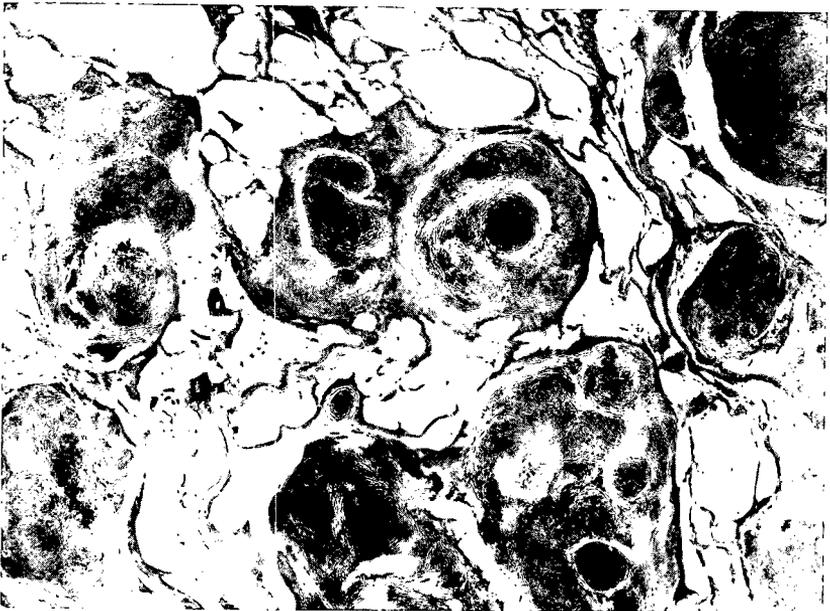


FIG. 4. — Very advanced silicosis. A small, well-defined, circular area of calcification is shown in the centre of one of the nodules. This type of change is also seen in nodules of less advanced cases.

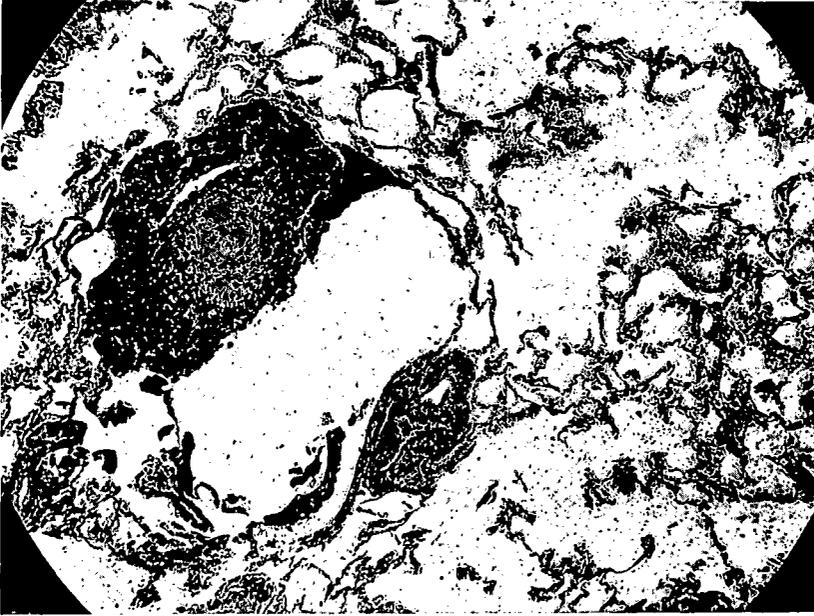


FIG. 5. — From a case of early silicosis. Section shows an aggregation of pigmented cells in the wall of a bronchiole. In the centre of the pigmented mass the early, cellular, fibroblastic reaction is seen.

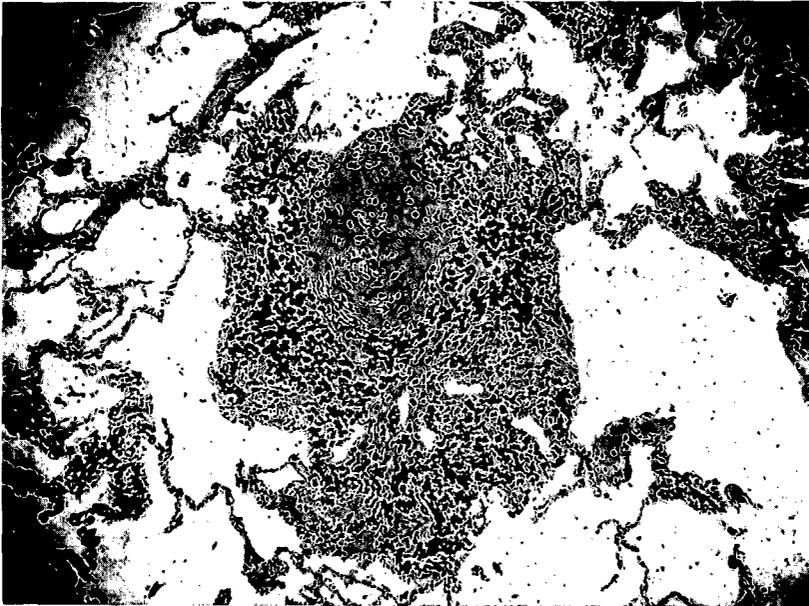


FIG. 6. — Early simple silicosis. Higher power section of pigment cell aggregation, with slightly more advanced central fibroblastic reaction.

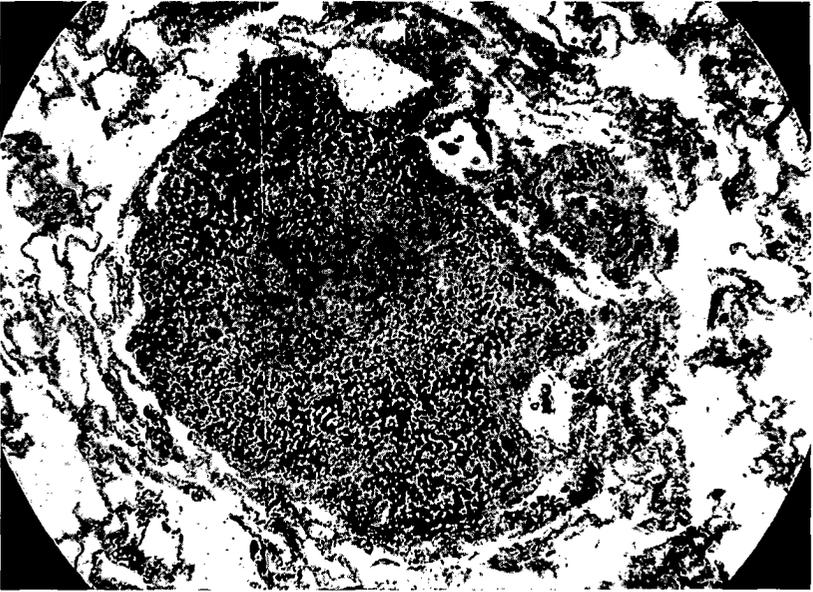


FIG. 7. — Slight silicosis. Infective type. A pigment cell aggregation is shown with central fibroblastic change. This is the cellular type resembling granulation tissue. Blood vessels are absent. In the later stages, when fibrosis has taken place, breaking down of the central mass occurs early.

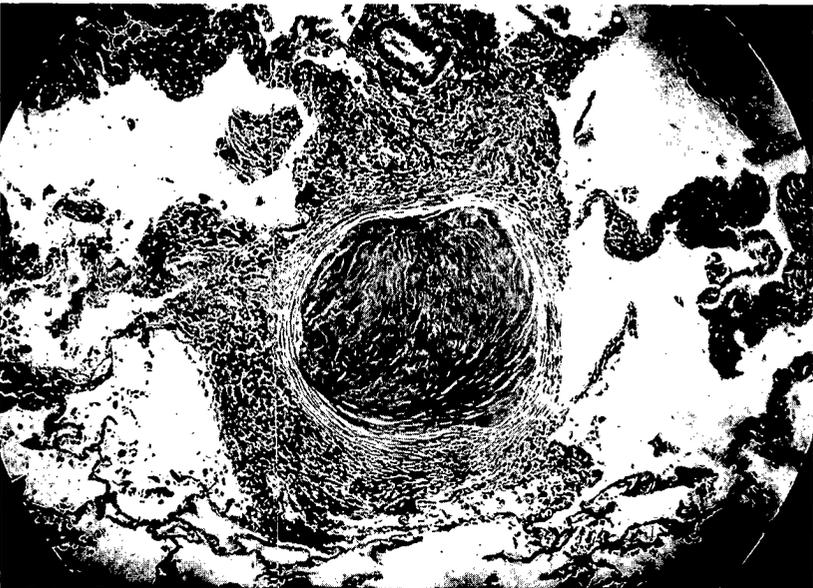


FIG. 8. — Early simple silicosis. Section shows a fibrotic nodule situated in the region of a terminal bronchiole. It consists of a mass of irregularly arranged, well formed fibrous tissue in the centre, surrounded in turn by concentric laminae of fibrous tissue, fibroblasts and pigmented cells. Dust cells and almost the whole of the carbon pigment have disappeared from the fibrous tissue zone. There is no evidence of breaking down.

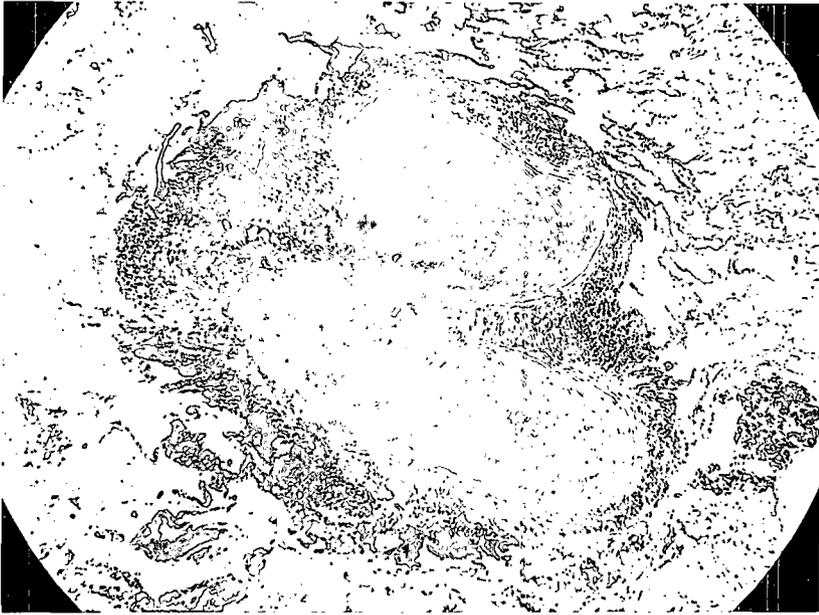


FIG. 9. — Early simple silicosis. A composite nodule is shown. It consists of at least three centres of origin. Each centre represents the original site of a mass of pigmented cells in relationship to a bronchiole, vestibule or atrium.

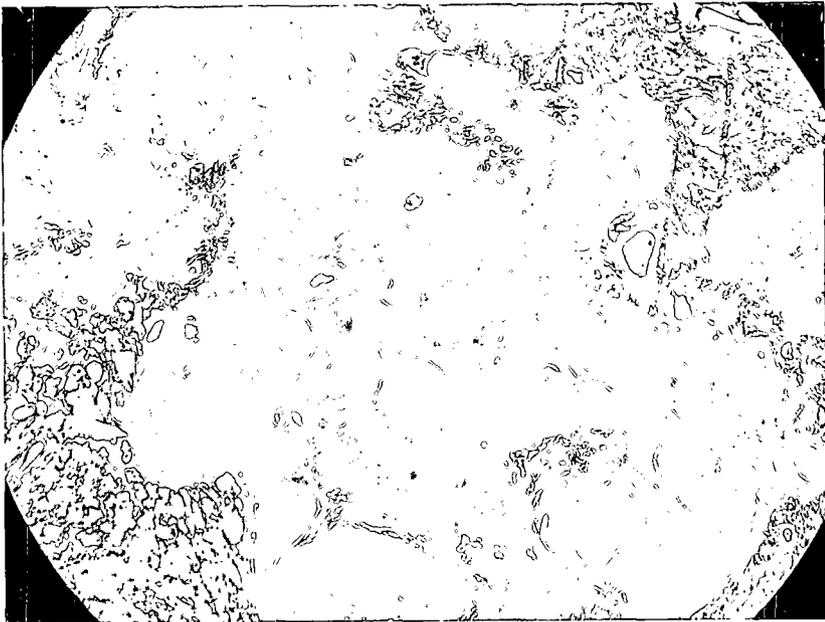


FIG. 10. — Well-marked silicosis. Massive area of single and large composite islets. The islets are contiguous, causing compression and collapse of the intervening lung tissue. The bronchioles are probably occluded in this type of change. The larger blood vessels appear to be unaffected. All these nodules are composed of dense fibrous tissue and show no breaking down or other sign of infection.



FIG. 11. — Well-marked silicosis. Two large, well-developed subpleural nodules are shown in this section. Where the nodules approach the surface no pigmented cells are seen. As a rule the subpleural islet is more flattened, it projects above the surface and a thicker layer of laminated fibrosis is seen just under the pleura.

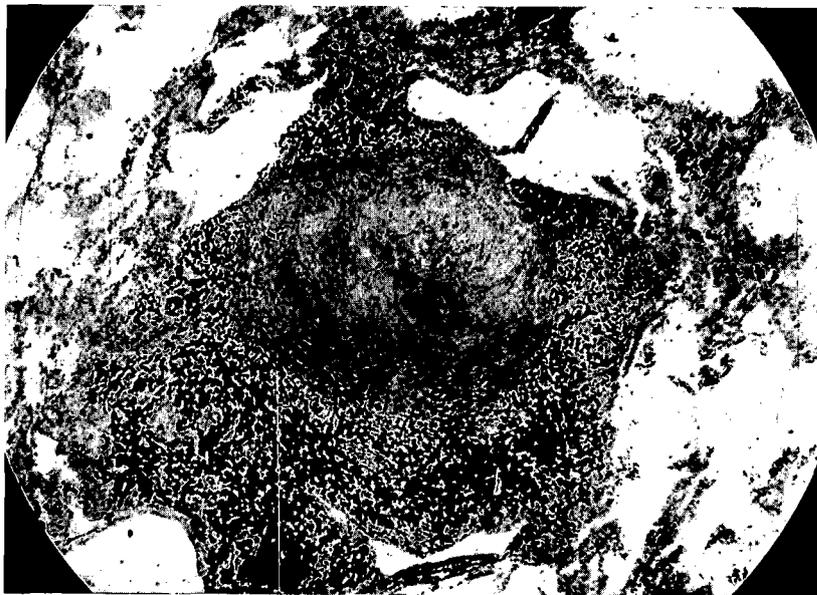


FIG. 12. — Early silicosis. Infective type. This nodule consists of a central mass of fibrous tissue, which shows a tendency to break down. This is surrounded by a very cellular fibroblastic layer and an outer pigment cell zone. In a later stage the central portion will become quite necrotic without any of the usual signs of tuberculosis.

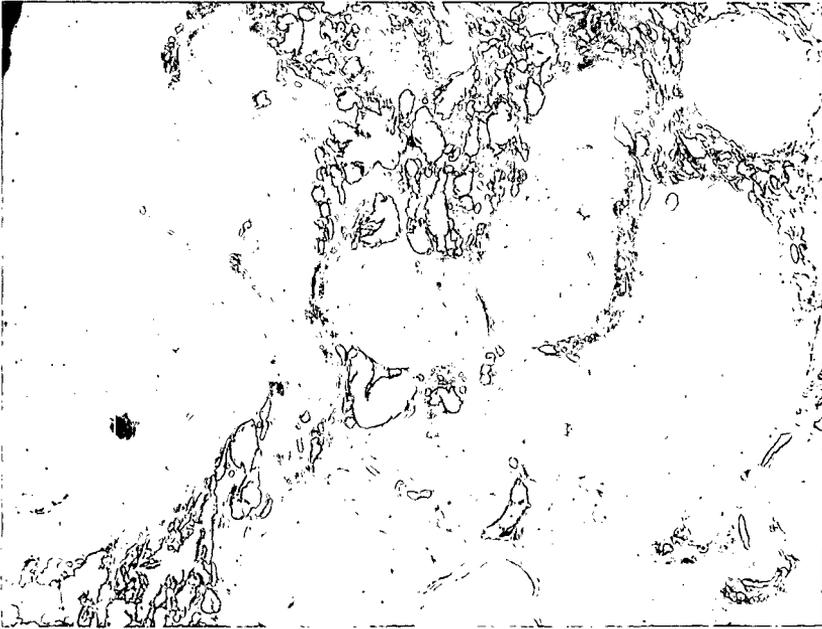


FIG. 13. — Advanced tuberculo-silicosis. This section shows a second type of massive fibrosis. It consists of numerous nodules, many of which have coalesced. In the larger masses there is evidence of central caseation. The usual signs of tuberculosis (follicle formation and giant cells) are absent. Material such as is shown here usually gives a positive biological test for tuberculosis.

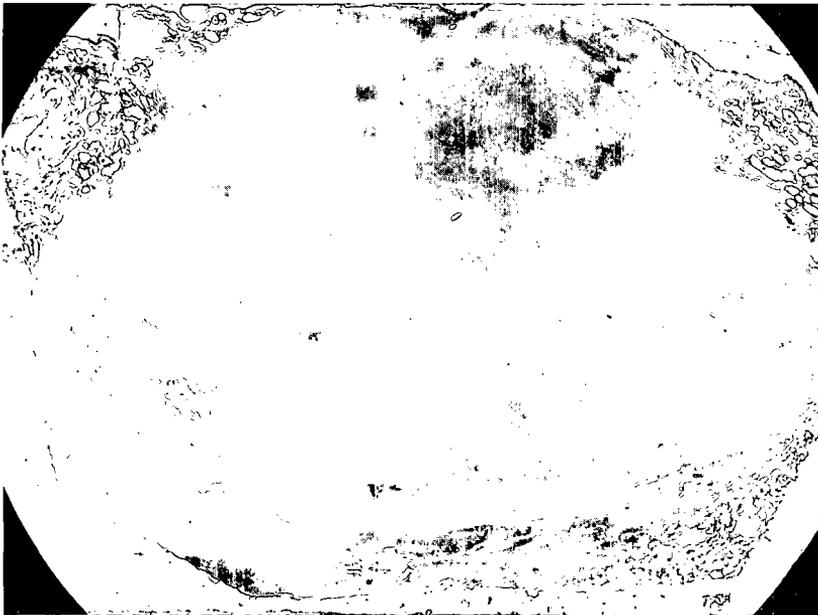


FIG. 14. — Advanced tuberculo-silicosis. This section shows a massive area of tuberculo-silicosis. The nodules have coalesced and the whole structure has become converted into a pigmented, necrotic mass. Tubercle follicles and giant cell formations are absent. This type of lesion also gives a positive biological test for tuberculosis.

THE CLINICAL PATHOLOGY, RADIOLOGY AND SYMPTOMATOLOGY OF SILICOSIS

TWO PAPERS

INTRODUCTORY

The object of these two papers is to present a concrete account of silicosis *as met with in South Africa*, from the several aspects of its clinical pathology, radiology and symptomatology, and particularly from the aspect of the correlation which has been found to exist between the results of these different methods of investigation of the disease, as an aid to formulation of precise criteria for its practical diagnosis.

Such precise criteria are of much practical importance, since silicosis has become in many countries the subject of a legal system of compensation as an "occupational disease", but their formulation is a matter of some difficulty, inasmuch as the silicotic process develops from minute beginnings extending over a considerable period of time, during which health and functional activity are in no way disturbed. It is therefore of practical importance to determine at what point that process produces results which can be regarded as a condition of definite "disease". The diagnosis in such circumstances must be "pragmatic" rather than simply academic.

It is impossible, in our experience, to deduce a practical standard of diagnosis from accounts of the disease furnished separately by the pathologist, the radiologist, and the clinician. Clinical examination is obviously an essential factor in the decision in any individual case, since it provides us with important information, which we cannot otherwise obtain, regarding the general and local condition of the patient, the degree of incapacitation, if any, which exists, and the presence or absence of complication by active infection, or by disease of other organs. But in the case of such a disease as silicosis, in which, in respect of the diagnosis of the earliest stages of the condition, clinical evidence is in many cases inconclusive and may be misleading, such evidence taken by itself is an insufficient guide. The standard of diagnosis which we seek, while in no way ignoring the clinical factor, should rest as far as possible upon an objectively demonstrable basis. Only so can we reach an approximately uniform standard and one which can be described in terms which are generally intelligible to other people.

Physical measurements of respiratory function, such as vital capacity, respiratory force, etc., give results which are objective so far as they go, but they show such considerable individual variations, and are so readily modifiable by subjective factors, including the psychological attitude towards the test of the person examined, that they do not in themselves supply a sufficiently precise guide.

There remain in the living subject radioscopy and radiography, and in the last resort the pathological condition found after death. Radiography, again, has its limitations, since on the one hand not all forms of pulmonary fibrosis which it reveals, even in miners, are of silicotic origin, and on the other hand certain types of radiograph which do not show unequivocally "specific" signs of silicosis, may yet in certain circumstances be legitimately regarded as affording evidence of the presence of a silicotic factor in the case. One can only obtain full value from the radiograph when one is able to interpret it in the light of experience derived from extensive pathological observation. Only when one has been able to *correlate* the results of pathological observation in a large number of cases with radiographs taken from the chests of the same individuals shortly before death, and with the results of clinical examination made during life, is one in a position to obtain the accurate knowledge which is required to formulate a reliable general standard of diagnosis. The very extensive material at the command of the Miners' Phthisis Medical Bureau in each of the three directions mentioned has enabled it to effect this triple correlation in a large series of cases. The systematic "periodical" examination of working miners which forms one of its main functions has provided it also with the opportunity of observing, in many hundreds of cases, the first appearance of the earliest clinical and radiographic signs of silicosis, and to follow their subsequent development.

An accurate standard of diagnosis in silicosis should rest on the triple correlation described. But, when this has been effected, it will be found that, when interpreted in the light of this correlation, *a radiograph which is of high technical quality, and which is taken instantaneously, forms the most reliable single diagnostic criterion which we possess.* It provides us with a general basis of diagnosis which is at once objective and trustworthy, in so far that it narrows down the issue by the exclusion of cases which do not show certain determined characteristics. But it is never the only factor in a decision. The final adjudication in any individual case must always incorporate the additional evidence supplied by expert clinical examination, which indeed is frequently the deciding factor, particularly in borderland cases. It is assumed also, as a matter of course, that the previous industrial and medical history of the individual has been thoroughly investigated. In the light of what has been said it will, we think, be found convenient to deal with the subject of our discussion under two main headings. It is proposed, therefore, first to discuss briefly some aspects of the clinical pathology of silicosis, considered particularly in relation to pathological diagnosis. This will provide us with a summary view of the general character and course of the disease. Thereafter the clinical and radiographic diagnosis of silicosis will be dealt with.

The two papers submitted are the result of team work. Drs. A. Sutherland Strachan and F. W. Simson, of the pathological staff of the South African Institute for Medical Research, who conduct the routine pathological work for the Bureau, have taken a large part in the preparation of the first paper, which embodies several important new observations made by them upon the pathology of the disease. Dr. Simson is also responsible for the illustrations representing the pathology of simple and infective silicosis (see figs. 1 to 10). Dr. W. Steuart, Radiologist to the Bureau, has collaborated in the preparation of the sections relating to radiography in the second paper. Members of the Bureau have also rendered valuable co-operation, particularly Drs. E. H. Phillips and S. W. Verster in recording and classifying the series of over 350 "correla-

tion" cases, Dr. D. A. Ogilvie in investigating the causes of death in cases of silicosis, and Dr. J. G. McMenamin in recording the distribution of the different varieties and degrees of fibrosis, as indicated by the radiograph, amongst initial examinees and working miners. Mr. J. H. Dowds, of the University of the Witwatersrand, conducted the series of physical tests on non-silicotic and silicotic miners, the general results of which appear in the second paper. The series of prints illustrating radiographic appearances in silicosis (films 1 to 22) have been reproduced by Kodak, Ltd., Johannesburg, from negatives taken at the Bureau. The Chairman of the Bureau (Dr. L. G. Irvine) is responsible for the actual form of both papers, which with several modifications follow closely and in parts verbally the lines of a communication on the subject contributed by him to the meeting of the Permanent International Committee for the Study of Occupational Diseases held at Lyons in 1929¹.

One may add that the conclusions set out are based almost wholly upon the practical experience gained by the writers from the material made available from the work of the Medical Bureau. They will be found, however, to be in substantial agreement with the presentation of the subject in the paper on "Silicosis on the Witwatersrand", by Watt, Irvine, Steuart and Pratt Johnson, published as an appendix to the General Report of the Miners' Prevention Committee in 1916².

Since in these papers we are dealing solely with South African silicosis, the references made to the work of other writers have been practically confined to the local literature of the subject.

The figures and films mentioned in the two papers are given after page 294.

I. — THE CLINICAL PATHOLOGY OF SILICOSIS

BY L. G. IRVINE, M.A., M.D., C.M., B.SC. (PUB. H.) (EDIN.), CHAIRMAN, MINERS' PHTHISIS MEDICAL BUREAU; F. W. SIMSON, M.B., CH.B. (EDIN.), PATHOLOGIST, SOUTH AFRICAN INSTITUTE FOR MEDICAL RESEARCH; AND A. SUTHERLAND STRACHAN, M.A., B.SC., M.D. (GLASGOW), PATHOLOGIST, SOUTH AFRICAN INSTITUTE FOR MEDICAL RESEARCH

There are two factors which are predominant in the course of cases of silicosis as we meet them in South Africa — silica dust and tuberculous infection. Other factors, such as intercurrent non-tuberculous infections, may modify the course of the disease, and may indeed not infrequently be the immediate cause of death

¹ L. G. IRVINE: "The Diagnosis of Silicosis as an Occupational Disease." *Rapports; Réunion de la Commission Internationale Permanente pour l'étude des Maladies professionnelles*, p. 43. Lyons, 1929.

² A. H. WATT, L. G. IRVINE, J. PRATT JOHNSON and W. STEUART: "Silicosis ('Miners' Phthisis') on the Witwatersrand." *General Report of the Miners' Phthisis Prevention Committee*, p. 81. Pretoria, 1916.

in silicotic miners as in other people. But apart from this circumstance, the predominant factors are those just named. The typical history of an average case is that it begins as a dust fibrosis and ends as a dust phthisis. Without dust there would obviously be no silicosis, but, without the predisposition to tuberculous infection which the presence of silica dust in the lung induces, silicosis would not be the gravely disabling and fatal disease which, in its later stages, it becomes.

One uses the term "simple silicosis" to describe a condition of fibrosis of the lungs which is produced by the long continued inhalation of siliceous dust, and its subsequent entry into and arrest within the lung, and which is unaccompanied by overt signs of active tuberculous infection. This is the condition of the immense majority of cases in the earliest detectable stage of the disease, at which it first becomes notifiable, and at which also by far the greater number of the men affected cease work underground.

The significance of such a case, however, is not what it is at the moment, but what it may become. At the moment the affected man is, generally speaking, quite in good health and has at the most only a comparatively slight impairment of working capacity. But in the majority of cases the disease tends sooner or later to advance. There are wide individual variations. Some may remain stationary practically indefinitely. Others may remain stationary for long periods, and may then begin to show signs of advance. In others again the progress of the disease is rapid from the first. But, although these individual variations occur, the general tendency to advance is on the whole fairly uniform. And, although an uncomplicated silicosis may, and does, in itself progress, and will do so up to a point even if the man affected ceases to work underground, the most important factor which accounts for the progressive tendency manifest in most cases of the disease is *infection*, and particularly tuberculous infection. The "simple silicosis" tends in most cases to become an "infective silicosis". The terminal stage of the disease, if it be reached, is one of obvious active tuberculosis in the silicotic lung. But not all cases reach that stage.

In the present paper an attempt is made to present a brief review of the respective roles played by the factor of dust and the factor of infection in the course of the disease, considered particularly in their bearing on the practical question of diagnosis, and of the differentiation of the several "stages" of the disease of which a system of legal compensation must take account.

THE DUST FACTOR IN SILICOSIS — THE ORIGIN OF THE SILICOSIS PROCESS

The genesis of the silicotic process has been repeatedly described¹, and, although variations may exist in the precise interpretation of the phenomena observed, there is substantial agreement as to the general facts. By "the silicotic process" one means the fibrotic changes produced in the lungs by the repeated inhalation over long periods of a "phthisis-producing" dust which contains free silica, in quantities greater than can be successfully dealt with by the physiological protective mechanisms of the respiratory organs.

Dr. J. McCrae² and later Drs. Watkins-Pitchford and J. Moir³ showed many years ago that it is only the minutest particles which gain entry into the lungs, and this observation is in conformity with the fact that their mode of entry is by phagocytosis.

Even if the expulsive functions of the epithelium and musculature of the air-passages remain intact, dust particles may reach the alveoli and some may be taken up into the lungs. The extent to which this will happen will depend upon the intensity of the exposure to dust and upon the physiological efficiency of the defensive structures and function of the respiratory passages and alveoli.

But one effect of the repeated inhalation of abnormal quantities of silica dust is to produce in time a dry bronchitis and bronchiolitis, with eventually a greater or less amount of denudation of the epithelium particularly of the bronchioles. This condition may be found in lungs which have undergone long-standing and repeated exposure to dust, even in cases which do not yet show definite signs of silicosis. It must eventually produce a situation which

¹ A. H. WATT, L. G. IRVINE, J. PRATT JOHNSON and W. STEUART, *op. cit.* W. WATKINS-PITCHFORD: "The Industrial Diseases of South Africa." *S. A. Medical Record*, 1914, Vol. XII, No. 3, p. 33.

— "The Gross Characters of the Silicotic Lung." *Med. Jour. of S. Africa*, 1915, Vol. X, No. 10, p. 167.

A. MAVROGORDATO: *Studies in Experimental Silicosis and other Pneu-moconioses*. S.A. Inst. Med. Res. Publ. XV. 1922.

— *Contributions to the Study of Miners' Phthisis*. S.A. Inst. Med. Res. Publ. XIX, 1926.

² J. MCCRAE: *The Ash of Silicotic Lungs*. S.A. Inst. Med. Res. Publ. III, 1913.

³ W. WATKINS-PITCHFORD and J. MOIR: *The Nature of the Doubly Refracting Particles seen in Microscopic Sections of Silicotic Lungs*. S.A. Inst. Med. Res. Publ. VIII, 1916.

directly and increasingly facilitates the entry of dust into the lungs. *It appears to be an important factor in the original development of definite silicotic changes in the lung substance, and to be an important factor also in the further development of the latter.*

When silica dust enters the alveoli it does so in company with fine pigmented carbonaceous particles, derived chiefly from the smoke of lamps and candles. The latter are taken up into the lungs by the same agency and follow the same distribution as the silica dust, and thus give to the lesions produced by the latter their characteristic pigmented appearance. *But mere excess of pigmentation in a lung does not necessarily spell silicosis, and, on the other hand, in mines in which there is little smoke there may be silicosis without any marked excess of pigmentation.* In the cases we see on the Witwatersrand the silicotic lesions are always pigmented. But the relation is accidental, not essential, and the amount of pigmentation which is present does not in itself afford a measure of the degree of silicosis which may exist.

In the alveoli the dust and pigment particles are taken up by the "alveolar phagocytes" or "dust cells". Some of these are expelled by way of the air passages and are expectorated; some, and in time many, enter the lymphatic channels of the lung. The "dust-cells" tend thereafter to follow the course of the lymph channels by way of the peribronchial, perivascular and septal lymphatics within the lung, and of the rich sub-pleural lymph plexus, to the lymph glands at the root of the organ. In all of these situations many "dust cells" with their loads of dust and pigment undergo arrest, and the most important seats of arrest are the sites in which small aggregations of lymphoid tissue have been shown to exist in the normal lung¹ in relation particularly to the peribronchiolar and perivascular lymphatics. The site of election for arrest in the lung substance appears to be at the entrance to the lobule; in the subpleural region it is at the points of junction of the lymph systems of the lungs and pleurae. At these sites the dust cells become aggregated in small discrete "clumps", and these points of clumping become the eventual seats of origin of the fibroid "nodules" which form so characteristic a feature of the developed disease. Given continued exposure to dust, the process is a cumulative process.

Observation of many lungs in the earliest stages of the silicotic

¹ Cf. especially W. S. MILLER: "Distribution of Lymphoid Tissue in the Lung." *Anatomical Record*, 1911, Vol. V.

process has shown that fibrosis with associated pigmentation begins first in the lymph glands at the root of the lung. There appears next, most commonly, some increase in pigmentation in the visceral pleurae, with, in parts, some irregular areas of slight opacity, or of more definite thickening, indicative of concurrent infection, past or present. The pigmentary changes in the pleurae are usually at this stage of the process definitely in advance of the similar changes which in turn become apparent in the lung substance.

The latter show on the cut surface of the organ as small discrete pigmented islands, *unassociated as yet with visible or palpable fibrosis*. Microscopic examination shows that the pigment is almost wholly aggregated in the sites of clumping already described as being associated with small aggregations of lymphoid tissue, and in some of these small rounded foci of fibro-blastic reaction may be observed. The alveoli are not affected; the septa show no appreciable thickening; the lungs retain their normal resilience on handling. But there is some amount of associated bronchiolitis and bronchitis. These changes precede the appearance of definite palpable "nodulation"; at the most a very occasional small palpable islet may be detected here and there, under the pleurae, or in the lung substance.

Although the pathological development in the silicotic process is continuous and cumulative from the earliest minute beginnings of fibrosis, the changes produced up to this point, when considered from the standpoint of their effect upon respiratory function, do not constitute a definite degree of "silicosis". They tend, however, to produce a characteristic modification of the radiographic appearances, described in the Bureau's terminology as a "commencing generalised fibrosis" (cf. film 6). It is suggested that this is in some and probably in large measure associated with the accompanying bronchitis and bronchiolitis, but it may be in part also due to a fine fibrosis originating around the peribronchial and perivascular lymphatics.

The microphotograph shown in fig. 5 illustrates the condition present.

THE DUST FACTOR IN SILICOSIS — "SIMPLE SILICOSIS"

If one employs the term "simple silicosis" to designate a condition of silicosis which is unaccompanied by a clinically detectable or "overt" tuberculosis, one may say that, viewed from the practical standpoint of effect upon respiratory function, *the develop-*

ment of an appreciable degree of "simple" silicosis coincides with the appearance of some amount of palpable miliary "nodulation" under the pleurae and in the lung substance. We shall expand this statement in a moment.

This condition of "nodulation" supplies a general and readily recognisable standard of diagnosis, and is the distinctive feature of the disease, particularly in its earlier stages. The individual silicotic "nodules" develop as a reactive fibrosis in the sites of the minute "clumps" of "dust cells", of which we have spoken (cf. fig. 6). They form irregular "beadings" along the course of lymphatic channels, particularly, as has been said, at the entry to the lobule, and in the subpleural area.

As the process of fibrosis increases, the individual nodules coincidentally increase in size and number, so that they eventually become distributed more or less widely throughout the lung substance, although they show a predilection first and throughout for its upper and posterior portions, and are always less obvious in the more freely movable lower and marginal regions of the lung. Under the pleural surface they have a similar general distribution. The subpleural nodule is typically a firm, somewhat flattened "plaque". In the lung substance the individual nodule shows as a dense, black, rounded structure, which projects slightly from the cut surface, and is definitely palpable as firmer than the surrounding lung tissue, from which it is sharply marked off. The microscopic structure of the developed nodule is characteristic. In the centre is a core of typically acellular fibrosis, in which the fibres are disposed irregularly, with dust and pigment particles, derived from disintegrated dust cells, lying apparently free between the meshes. Around the central area are concentric layers of fibres, in the outermost of which the cellular elements are for the most part apparent. The peripheral zone is still unorganised, and is crowded with "dust cells" laden with dust and pigment.

The growth of the nodule is snowball fashion, by concentric additions at the periphery. At first of "small" size (up to 2 mm. in diameter), the individual nodule may, as the disease advances, reach a size of 5 mm. or thereabouts; one would call the latter type of nodule "large".

The silicotic "nodule" forms so conspicuous a feature of silicosis that for the purpose of rapid diagnosis one may describe the stage or "degree" of an uncomplicated or "simple" silicosis in terms of the number, size and density of the nodular elements seen upon the cut surface of the lungs, when these organs are laid open by

the knife. The Medical Bureau, for the practical medico-legal purposes of its work, which demands the classification of the disease into definite "stages", is accustomed to distinguish four "degrees" of simple silicosis — "slight", "moderate", "well-marked" and "very well-marked". And, speaking in general terms, it may be said that, in the two former the nodules are "small" and respectively "sparse" or "moderately numerous"; and that in the two latter they are "medium" to "large" in size, and "numerous" or "very numerous".

The distinctive characteristic of the silicotic process is that it begins as a fibrosis which affects independently, simultaneously or in succession, many different points in the lungs, so that *the developed disease is typically a generalised disease*. And this character of generalised change is equally apparent in the radiograph and in the complex of physical signs and symptoms which distinguish the condition. There are exceptions, however, to this statement, to which we shall presently refer.

THE MACROSCOPIC APPEARANCES IN "SIMPLE SILICOSIS"

It will be sufficient, from the aspect of pathological diagnosis, to describe, in illustration of these general observations, the macroscopic appearances of a typical case of "simple" or uncomplicated silicosis of a "moderate" degree, it being understood that by "uncomplicated" one means a case of silicosis in which there are no obvious signs of active tuberculosis or other infection. In examining the lungs one should look for evidence of fibrosis in the three sites mentioned — in the root glands, in the pleurae, and in the lung substance.

In such a case the root glands will be found to be somewhat enlarged, deeply pigmented, and firmer to the touch than is normal. The surfaces of the visceral pleurae are for the most part smooth and glistening. They show, however, a moderate or even considerable excess of pigmentation, in part merely in the form of a marbled outlining of the underlying lobules of the lung, in part as a more diffuse pigmentation, with areas of slight thickening, affecting particularly the upper half of the organ. Where areas of well-defined thickening are present an infective origin of these may be assumed. The inner, interlobar and diaphragmatic surfaces are less affected. In association with these changes there will be found scattered over the areas which show more marked pigimentary change a moderate number of small, sub-pleural nodules

or "plaques", which give the appearance and "feel" of a fine mammillation.

The cut surfaces of the lung itself will also show excess of pigmentation in the form of moderately numerous "small", discrete pigmented islands, and a considerable proportion of these insular areas will be found to be the sites of well-defined, "small", firm, rounded and definitely palpable nodules of silicotic type. Except for this, the normal resilience of the lungs on handling is retained. The general appearance is thus one of a more or less generalised "small" miliary nodulation of moderate amount. The general character of the condition present is indicated in figs. 1 and 7. It is also very well brought out in the radiograph of such a case (cf. film 9). In the radiograph both lung fields will be seen to have, throughout, a characteristic "mottled" appearance, produced for the most part by the shadows thrown by individual "small" nodules. This characteristic discrete "mottling" is the one "specific" radiographic sign of silicosis. At this stage of silicosis, microscopic examination shows that, except perhaps in the immediate neighbourhood of the nodules, there is no evidence of alveolar fibrosis. Nor is there evidence of any definite thickening of the interlobular septa or the trabeculae of the lung. A slight degree of emphysema may be present. Apart from the effects of the coincident bronchitis and bronchiolitis, any interference with respiratory function which may exist would appear to be due to some slight limitation of the expansibility of the lungs; but, judged by measurements of vital capacity, this is not on the average at all marked.

This is the general picture. There is, however, a type of case in which the presence from the outset of an infective element in the process of silicotic fibrosis is strongly suggested.

It is not uncommon, for example, to find that in some cases the pigmented fibrotic lesions take the form of more massive and uniform, although still moderate, areas of fibrosis, or of a cluster of unusually large irregular nodules, confined or practically confined to the apical regions of the lungs, and associated with a well-marked thickening of the overlying pleura. The remaining portions of the lung show no obvious silicotic lesions.

Or again, we may find nodules of this larger atypical form, scattered or clustered here and there, in lungs whose general condition is that of the more uniformly distributed miliary nodulation of a typical silicosis.

These atypical nodules do not conform to the description

previously given. They are larger and more irregular in shape than the typical silicotic nodule, generally a greyish black in colour, and stippled perhaps with points of necrosis and sometimes of caseous or calcareous change. Their minute structure differs also from that of the typical silicotic nodule. Although portions of these larger nodular formations may show the typical concentric arrangement of fibres, in other portions the fibres may be found to be distributed in irregular zones enclosing focal areas of necrosis. One or two of the root glands corresponding to the areas in which these irregular nodules are present may be found to show a similar appearance.

One has for long held the view that in most cases lesions of this atypical character are indicative of past or present infection and that many at least are the product of a localised low-grade tuberculous infection, occurring during the development of the silicotic lesions, and this is the more probable inasmuch as dust and the tubercle bacillus are both phagocyted by the same type of cell. Where caseation or focal necrosis is present the association of an infective element is clear. Further, a series of animal inoculation experiments recently carried out by two of us (F. W. Simson and A. S. Strachan) with material derived from lesions of this type, which showed no obvious evidence of tuberculous infection, has demonstrated its presence in a considerable number of instances.

One concludes therefore that in many cases of clinically "simple silicosis", even at its earliest detectable stage, an element of low grade and latent tuberculous infection may already be present in association with certain of the "silicotic" lesions. And the circumstances suggest that in such cases the infection is at least frequently an infection by inhalation¹.

Just as one finds in a precedent or coincident bronchitis and bronchiolitis a determining factor in the original development of a definite condition of silicosis in the lung substance, so here one appears to find at least one determining factor in the advance from a clinically "simple" to a clinically "infective" silicosis, which characterises the further history of a majority of cases of the disease.

The same qualifications regarding the possible presence of limited foci of low-grade infection applies equally and usually in greater measure to the later stages of clinically "simple silicosis".

¹ A. MAVROGORDATO: "Contributions to the Study of Miners' Phthisis", *op. cit.*

The more marked degrees of "simple silicosis" show more marked changes of the same general type as those described above. The nodules in the lung substance are for the most part larger and usually more abundant, and microscopical examination shows that many are of composite structure, resulting from the fusion of several originally more or less distinct small nodular formations. The pleurae also show more marked nodulation and more definite thickening. In the more advanced stages bronchitis is well marked and the bronchi are obviously thickened. So, too, may be the septa and trabeculae, but this condition is never gross. Growth of the nodules, particularly where they are closely aggregated, produces some obliteration of alveoli, but apart from this, alveolar fibrosis is not an obvious feature except in areas where infection is present. There is always in the later stages some amount of emphysema. Figs. 2 and 8 show the condition in "well-marked", and "very well-marked" cases, and this is also well portrayed by the radiograph (films 11 and 13).

THE INFECTIVE FACTOR IN SILICOSIS — "INFECTIVE SILICOSIS"

Silicotic lungs, like other lungs, may become at any time the seat of a complicating infection. This is the more likely because, as Dr. Mavrogordato is fond of saying, "the silicotic lung is generally a dirty lung". The accompanying bronchitis in itself makes it so. Evidence of infection may be obvious — lobar pneumonia may be found, or influenzal pneumonia, or an acute caseating tuberculosis, or a terminal miliary tuberculosis, each presenting its usual distinctive pathological features.

More chronic or less massive acute infections tend, however, to produce somewhat atypical results in a silicotic lung; *they tend to stimulate the development of fibrosis in the area affected by them.* This is particularly the case with low-grade tuberculous infections, although the tendency is not confined to such infections alone.

It is common knowledge that a lung affected by silicosis is peculiarly prone to become infected with tuberculosis. Several circumstances may contribute to this predisposition. First, there is the point emphasised by Mavrogordato¹ that the humid, dust-laden atmosphere of a mine forms a vehicle which directly facilitates the entry of the tubercle bacillus into the lung. We have already stated that pathological observation has led one to the belief that,

¹ *Ibid.*

in many cases of clinically apparently uncomplicated silicosis there is evidence of an early association of an element of low-grade tuberculous infection with certain of the developing silicotic lesions, and the distribution of these "infective" lesions is frequently very suggestive of an inhalation infection. Active tuberculosis may develop later on from such original foci, or may be due to further infection from other sources within or outside the lung.

A second circumstance is that the sites of silicotic lesions provide possible points of arrest of bacteria in the lymphatic system of the lung.

And finally there is to be considered the view which has recently been advanced on experimental evidence by Gye and Kettle, namely, that finely divided silica acts as a soluble protoplasmic poison, particularly to endothelial cells, and has in consequence a specific effect in determining the selection by a tuberculous infection of sites where silica is aggregated¹. One may regard all of these factors as contributory to the predisposition in question.

As we have said, typical acute tuberculous lesions are frequently met with in silicotic lungs, practically unmodified. But it is very characteristic of silicosis that, when a chronic tuberculous infection affects a silicotic lung, it tends to pursue a modified and atypical course — it runs to excessive fibrosis. Small infections may go no further than to produce a scattering of large nodules of the "infective" type already described; or these may be clustered or become coalesced to form limited areas of consolidation. In more extensive infections the process takes the form of a more diffuse infective fibrosis, with the production of large masses of uniform consolidation, in which, however, the original "nodular" basis may still be discernible. In the earlier stages of their development both the isolated nodules and the larger masses are typically of a pale grey colour and of only moderately dense consistence, and indications of caseation may sometimes be apparent in them. In old-standing cases the colour is dark grey or black, and the consistence is often extremely dense, so that the larger areas may form, at this stage, more or less extensive and sometimes very extensive areas of a massive pigmented "fibroid consolidation", such as appears in no other disease (see figs. 3, 4, 9 and 10). In some cases these areas may show no macroscopic signs of tuberculosis; in others,

¹ W. E. GYE and E. H. KETTLE: "Silicosis and Miners' Phthisis", *Brit. Jour. Exper. Path.*, 1922, Vol. III, p. 241; and E. H. KETTLE: "Influence of Silica in determining B. Tuberculosis Infections", *Brit. Jour. Exper. Path.*, 1924, Vol. V, p. 158.

however, areas of caseation or of a terminal necrosis with softening or cavitation may be present, and tubercle bacilli may be recovered from the necrotic material. It is to this characteristic product of the *conjunction* of a tuberculous infection with silicosis that the term "tuberculo-silicosis" was originally applied¹. "*Tuberculo-silicosis*" is the modification produced in silicotic lesions by a chronic tuberculous infection. Similar changes are found in the corresponding root glands.

We have pointed out that the "infective" nodule is typically of larger size than the nodular formations of an uncomplicated silicosis, and one may say in general that in any case of silicosis an unduly large size or a marked irregularity in size in the islands of fibrosis, or a marked tendency to their coalescence is suggestive of the presence of an infective element. These variations are well brought out in the radiograph (compare, for example, films 11, 13 and 15 with films 12, 14 and 16). Indeed, in cases of advanced silicosis many of the nodules may be of the "infective" type, whether by activation of an original minute included focus of infection, or by further infection at the periphery of the nodule.

The account which has just been given of the manner in which the presence of a chronic tuberculous infection in a silicotic lung results in the production of infective lesions marked by an excessive fibrosis, suggests that other infections may in the same circumstances produce similar results. One may agree with Mavrogordato² and others³ that this may occur and that areas of massive fibrosis may in some instances be the end result of the organisation of local areas of unresolved "pneumonia" of non-tuberculous origin. Again, in a good many instances of "fibroid consolidation" the appearances, both macroscopic and microscopic, suggest a simple growth and close aggregation of originally discrete silicotic nodules, in which there are no indications of tuberculous or other infection. Such a condition might result from obliteration of individual lobules and local collapse. *With the exception of the type of lesion just described, massive fibroid consolidation in the silicotic lung spells infection, past or present; and in the majority of instances the infection is tuberculous, and the lesions are "tuberculo-silicotic".*

The gross infective lesions which we have described are not often

¹ L. G. IRVINE, *op. cit.*

² A. MAVROGORDATO: "Studies in Experimental Silicosis and other Pneumoconioses", *op. cit.*

³ W. WATKINS-PITCHFORD: "The Industrial Diseases of South Africa", *op. cit.*

seen in a lung which is otherwise in a stage of quite early silicosis; they are typically a late complication. Nevertheless, in some instances, as has already been noted especially in cases which are clinically of a "phthinoïd" type, well-marked circumscribed lesions of this character may be found from the first, particularly in the apical regions, although in the remainder of the lung little or no evidence of silicotic change may be present. In such cases the distribution of the lesions is that of a simple apical fibroid tuberculosis.

When a tuberculous infection develops acutely in a silicotic lung, the downward progress of the case is usually rapid. But the modification of a *chronic* infection by its conjunction with silicosis, which we have described, appears to tend to two results. The excessive fibrosis which is produced tends, on the whole, to retard the spread of the infective process to other portions of the lung and to other organs of the body, but at the same time renders it less susceptible of "cure". The retardation and limitation of the infection which may thus be occasioned is illustrated in the film which is shown as film 18 taken from a mine official who was awarded compensation some years ago as the subject of tuberculosis with silicosis, with evidence of sub-apical infection of both lungs. The condition of this man's lungs has remained practically unchanged for five years.

Another feature of interest is frequently seen in old-standing cases of silicosis, namely the presence of extensive calcareous deposits in the nodules, indicated by the particularly bright appearance in the negative of the shadows thrown by them. In some cases the great majority of the nodules may show calcareous change. Film 17 is a good example. That this is the condition which such radiographs represent has been proved post-mortem. In view of the fact that calcareous deposit may occur in any lesion associated with excessive fatty deposit, one is not justified in accepting the hypothesis that this condition is indicative of a previous widespread tuberculous infection of the silicotic lung. It is nevertheless a striking phenomenon.

One may add here a few further observations. As we have seen, some amount of bronchitis is a constant concomitant of silicosis. Emphysema, however, is not an important feature in the early stages, although it is commonly present and may be well marked in the more advanced conditions. Cardiac dilatation and hypertrophy is uncommon in the cases we meet with nowadays, and its amount when present appears to be dependent on the degree

of emphysema which exists. The presence even of extensive areas of fibroid consolidation does not in general appear to lead either to dilatation or hypertrophy of the heart. Bronchiectasis is definitely a rare complication. The results of the examination of a large series of urines in silicotic and non-silicotic miners¹ do not suggest that impairment of renal function is more common in the former than in the latter, and pathological observation supports this conclusion. Nor, so far as our local experience goes, does silicosis appear to predispose to hepatic cirrhosis.

TYPES AND GENERAL COURSE OF CASES OF SILICOSIS

From what has been said it will be apparent that the actual pathological condition found in individual cases of silicosis will present many variations. The accompanying illustrations (figs. 1 to 4) may serve to give some indication of the appearances which may be met with in different types of case in miners of European stock. Figs. 4 A and 4 B represent the more grossly infective type of tuberculo-silicosis which is more characteristically met with in certain cases of the disease in native mine labourers.

There is a very significant difference of type in cases of silicosis, according as the dust factor or the infective factor is predominant in its causation or in its development. The first condition, in which the dust factor predominates because exposure to dust is heavy, produces the type of case with which we were familiar in the first twelve or fourteen years which succeeded the turn of the century; the mines then were very dusty and they were dry. It was marked by the presence of extensive fibroid consolidation, with large, bulky, heavy lungs, in which the excessive development of fibrosis overwhelmed and frequently almost wholly obscured the evidence of coincident infection, except as a rule in the terminal stage. This is the "classical" type of silicosis. But those who are familiar with the history of silicosis on the Rand are aware that, during the past fourteen years or so, coincidentally with the improvement of dust conditions underground, there has occurred a progressive modification in the cases which have arisen, so that the prevalent type of infective silicosis with which we are familiar to-day is one in which the infective factor is predominant, or at least more evident, and the dust factor is relatively less prominent than formerly.

¹ *Report of Miners' Phthisis Medical Bureau for year ending 31 July 1928. Pretoria, 1929.*

Sufferers from silicosis of the "classical" type frequently retained a robust general appearance to within a few months of death. And although, of those who died from the disease, the majority died of a rapid terminal breakdown, with cavitation and emaciation, in many other cases death resulted definitely from heart failure, with cardiac dilatation, cyanosis, ascites and cedema of the lower limbs, without clinical evidence of active infection and without emaciation. One has not seen the latter mode of death for a good many years. Those who nowadays die directly from the disease do so with obvious signs of active tuberculosis, from progressive asthenia, or from hæmorrhage.

The cases which have originated within the past nine or ten years have exhibited up to a point a more progressive tendency. One reason for this may be that the diminution of dust in mine air has tended to a diminution of the limiting and retarding influence of excessive fibrosis upon the spread of infective lesions in and beyond the lung. On the other hand, in the later type of case the final stage of serious incapacitation appears to be more prolonged. The terminal break-down in the older "classical" type of case was apt to be much more rapid.

For although this change in the type of silicosis has been in part directly due to a change in occupational conditions, it has also been due in part to a change in the type of miner. The Witwatersrand miners in the early days, before and just after the South African War, were almost wholly men of overseas birth and training, derived from older long-settled and industrialised mining communities, men for the most part of originally robust physique, with a relatively high immunity to tuberculosis. But, especially in the last twenty-two years, there has been a steady increase in the number and proportion of miners of South African birth, drawn mainly from an agricultural instead of an industrialised community, and with, it may be presumed, a lower inherited or acquired immunity to tuberculosis. To-day miners of South African birth form over 70 per cent. of the "working miners", and during the past five years these men have contributed a majority of the new cases of silicosis which have arisen. One finds too to-day that men of the robust, broad-shouldered, deep-chested type (figs. 11 and 12) still run rather to the "classical" type of silicosis, and when they have acquired the disease they tolerate it much better. The originally "phthinoïd" type of man, on the other hand (figs. 13 and 14), runs rather to the infective type of the disease and, having less respiratory and constitutional reserve, does not stand it so well.

We have in these remarks laid so much stress upon the importance of the infective factor in silicosis, as it occurs on the Witwatersrand, that it is perhaps desirable once more to emphasise the fact that it is uncommon to find a condition of clinically obvious tuberculosis present at the stage at which a silicosis first becomes detectable. The very great majority of cases of silicosis found amongst working miners, when first detected, are *from the clinical standpoint* cases of uncomplicated or "simple" silicosis, without evidence of obvious or "overt" tuberculosis. Nevertheless, in our belief, it remains true to say that we should not think of "simple" silicosis merely as a dust fibrosis, but as being, at least in many cases, a dust fibrosis, which from its beginning as a clinically detectable condition, is linked up with an element of latent tuberculous infection. The after-history of these cases is in this respect significant. In the majority of instances, as we said at the outset, silicosis is a progressive disease. The outlook of the individual case is mainly dependent upon whether the infective element remains "bottled up" and inactive, or whether, on the other hand, it becomes active, or a further infection occurs from outside the lung. There are wide individual differences, dependent no doubt in part upon constitutional, nutritional and environmental factors, but the tendency of the majority of cases to advance is, on the average, singularly uniform.

It may be well, in order to give concreteness to this picture, to quote a few definite figures¹. During the three years 1920 to 1923, 728 cases of "simple silicosis", in what is legally termed the "ante-primary" stage of the disease, were detected amongst working miners. These were cases of a "slight" or of a "moderate" degree of silicosis. At the end of the sixth year subsequent to the year of their detection, 557 of these men, or 76.5 per cent., were alive. Only some 26 per cent., however, were approximately in their original condition; 27 per cent. were in the intermediate, and some 23 per cent. were in the advanced stage of the disease. Twenty-three and a half per cent. had died, and in 18 per cent. death had been due to silicosis or to a cause (such, for example, as an acute respiratory infection) to which silicosis was regarded as having been contributory. The remainder had died from causes unconnected with silicosis.

One may put these facts in another way. Mr. Spence Fraser, Actuarial Adviser to the Union Government, informs us that the

¹ *Report of Miners' Phthisis Medical Bureau for year ending 31 July 1929* (in press).

average expectation of life of a case of silicosis when first detected is 13.66 years. Some, of course, will die much sooner than that; others will live longer. But *on the average* an early or "ante-primary" case will advance to the intermediate or "primary" stage in about four and a half years, and the "primary" stage case will reach the "secondary" stage of grave incapacitation in about another four years. The average time that such a miner remains in the secondary stage until he dies is seven years.

These figures indicate very clearly *the inherently progressive tendency manifest in most cases of silicosis*. That tendency depends almost wholly upon the factor of infection, and for practical purposes, apart from acute intercurrent respiratory disease, the infection which matters in these cases is tuberculosis. It is possible that the infective factor plays a more prominent role in silicosis on the Witwatersrand than it does elsewhere, since, with us, the European miners, generally speaking, work as overseers practically side by side with a very large number of native mine labourers. The African native is more susceptible to tuberculosis than the European, and, although judged by the standard of European communities the incidence of tuberculosis amongst the mine natives is not excessive, it is, by reason of their number, sufficient to constitute a definite menace. We may add that amongst the mine natives the incidence of silicosis is relatively much smaller than amongst European miners, not because the former are less susceptible to the effects of dust when subjected to similar conditions¹ but because, in general, the natives work on comparatively short individual contracts, and their total service is, on the average, not only much shorter but also less continuous. The latter fact has a very important bearing upon the hygiene of silicosis. As Dr. Mavrogordato has said, "Intermittent as opposed to continuous employment is perhaps the most effective single measure against silicosis"². For these reasons, in contrast to the position amongst the European miners, the overwhelming majority of cases of compensatable disease which arise amongst mine natives are cases of active, uncomplicated tuberculosis, or, in those of longer service, of active tuberculosis preceded or accompanied by an element of silicosis³. It is from the side of the mine native, so far as

¹ W. WATKINS-PITCHFORD: *Report of Miners' Phthisis Medical Bureau for year ending 31 July 1924*, p. 33.

² A. MAVROGORDATO: "The Aetiology of Silicosis", *Rapports, Réunion. Commiss. Perman. pour l'étude des Malad. Profess.*, p. 15. Lyons, 1929.

³ *Report of Miners' Phthisis Medical Bureau for year ending 31 July 1928*. Pretoria, 1929.

underground conditions are concerned, that the danger of tuberculous infection arises, both in the production of cases of frank tuberculosis and of early infective silicosis amongst European and native employees alike.

THE IMMEDIATE CAUSES OF DEATH IN CASES OF SILICOSIS

We may suitably conclude this account of the clinical pathology of silicosis with the subjoined tabular statement of the actual causes of 543 deaths which have occurred amongst 1,623 cases

IMMEDIATE CAUSES OF 543 DEATHS OCCURRING IN 1,623 CASES ORIGINALLY CERTIFIED AS HAVING "SIMPLE SILICOSIS"

Immediate cause of death	Originally primary stage cases: 372 deaths	Originally ante-primary stage cases: 171 deaths
	(a)	(b)
Silicosis with tuberculosis	257 (69%) ¹	116 (68%) ¹
Silicosis in secondary stage without obvious tubercu- losis or other specified inter- current disease	28 (7.5%)	7 (4%)
Influenza	7	2
Bronchitis	3	—
Pneumonia	13 (3.5%)	8 (4.6%)
Other diseases of respiratory system	1	—
Malaria	3	1
Dysentery	2	—
Enteric fever	—	1
General paralysis of insane	2	—
Syphilis	—	1
Aneurysm, aortitis and angina	3	2
Valvular disease of heart	4	2
Other diseases of heart	3	1
Cancer of lungs (primary)	—	1
Cancer all other sites	7	6
Chronic rheumatism	1	—
Alcoholism	1	—
Cerebral haemorrhage, etc.	3	1
Other diseases of nervous system	—	1 (acute mania)
Nephritis	3	4
Other genito-urinary diseases	1	—
Diseases of prostate	—	2
Cirrhosis of liver and hepatitis	5	1
Appendicitis	—	1
Intestinal obstruction	1	—
Hernia	1	1
Other diseases of digestive system	2	1
Deaths by accident or injury	14 (3.7%)	10 (5.8%)
Other causes	2	1
Undetermined	5	—
Total	372	171

¹ The percentages shown are percentages of the total deaths.

originally certified when first detected as being the subjects of "simple silicosis". These cases fall into two groups:

1. The 895 cases of "simple silicosis" in the "primary" stage detected amongst working miners during the three years 1917 to 1920. Of these men, 372 had died up to 31 July 1929, and the immediate causes of death are tabulated in column (a).

2. The 728 cases of "simple silicosis" in the "ante-primary" stage detected amongst working miners during the three years 1920 to 1923. Of these men, 171 had died up to 31 July 1929, and the immediate causes of death are tabulated in column (b).

It will be seen that in both groups of these cases approximately three-quarters of the total deaths were caused directly by the disease, and that the evidence showed that recognised tuberculosis was present in 68 or 69 per cent. The close similarity in the proportion of deaths from tuberculosis with silicosis in the two groups is remarkable, since the cases in the latter group were detected when in a "slight" or "moderate" degree of silicosis only, whereas in the first group all were cases in which the disease had begun to produce some degree of disability. The inherent predisposition to tuberculosis in cases of silicosis is nevertheless seen to be practically the same in both groups, and the figures give an approximate measure of that predisposition. The only other feature of this return to which we may call attention is that acute respiratory infections, namely bronchitis and pneumonia, even when taken together with influenza, account for only some 6 per cent. of the total deaths in each group.

II. — THE RADIOLOGY AND SYMPTOMATOLOGY OF SILICOSIS

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GENERAL

The variations in the pathological and clinical types of the disease-complex we term silicosis, which depend partly upon the relative and actual prominence of the dust factor or of the infective factor in the cases concerned, and partly upon the type of man who is exposed to the influence of these factors, render a succinct account of the radiology and symptomatology of silicosis a matter of some difficulty.

From the medico-legal and clinical standpoint the Miners' Phthisis Medical Bureau divides the cases it deals with into the two classes of "simple silicosis" and "tuberculosis with silicosis", according as the silicotic condition present is unaccompanied or is accompanied by *obvious, active, or "overt" tuberculosis*.

"SIMPLE SILICOSIS"

All cases of silicosis which do not exhibit signs of active tuberculosis fall, therefore, under this classification, into the broad class of "simple silicosis".

Quite a number of cases which are so classified may nevertheless present radiographic or clinical indications of a past or present infective element, which is not definitely active. Hence the Bureau distinguishes in cases of "simple silicosis" between a "predominantly silicotic" type and a "partly or predominantly infective" type of case, the latter term being applied to cases presenting clinical or radiographic indications of an old or inactive infection. The pathologist would no doubt regard cases of the latter type as instances of "infective silicosis". But they are not cases of "tuberculosis with silicosis" in the medico-legal and clinical sense above defined.

Clinically one finds that the "robust" type of man runs, as has been seen, more to the purely silicotic or non-infective type, and evidence of infection is in such cases typically a late phenomenon. The "phthinoid" type of man, on the other hand, tends rather to the infective type from the outset. Between these extremes, however, there is a large number of intermediate cases which incline some to the one side, some to the other, in physical or in radiographic type.

If, however, one makes allowance for these variations in the disease, it is possible to divide the cases of "*simple silicosis*" which one meets with into three broad groups — the "slight" and "moderate" cases, the "well-marked" cases, and the "very well-marked" or "advanced" cases. As is to be expected in a disease which is in most instances progressive, these "stages" merge successively into one another. Nevertheless, the bulk of the cases in each group exhibit, on the average, a general correspondence in pathological condition and radiographic appearances and in the complex of signs and symptoms and degree of disability which they present.

We have seen in the preceding paper that, from the practical standpoint of effect upon respiratory function, the appearance of an appreciable or "slight" degree of silicosis may be taken to coincide in general with the development of some amount of *visible and palpable fibrosis* in the shape of a sparse "small" miliary nodulation under the pleurae and in the lung substance. This is the standard of pathological diagnosis which experience has led the Medical Bureau to adopt, and it is in this sense that the term "slight degree of silicosis" is used in the present paper.

We have seen also that, as a consequence of its mode of origin, a developed silicosis is typically a more or less "*generalised*" condition. This is an important diagnostic point, inasmuch as this feature of "generalisation" characterises alike the pathological changes, the radiographic appearances and the clinical signs of silicosis in each of its stages. Although there are exceptions in some cases of predominantly infective type, in which the lesions may be more localised and the physical signs may be correspondingly altered, the statement just made is generally applicable.

The recognition of a developed case of silicosis usually presents no difficulty. One has already called attention to the symmetrical "mottling" of the lung fields, with small and typically discrete shadows, which characterises the radiograph of an established case of what we may term a "moderate degree" of silicosis. One calls this appearance "specific", and this kind of "mottling", dependent upon the presence of miliary nodulation, is the *only* specific radiographic sign of silicosis.

In the film shown (film 9) this appearance is quite obvious, and it becomes more obvious still in later "stages" of the disease.

Difficulty in the matter of diagnosis can hardly arise in such established cases. The sole difficulty is naturally with cases which have not yet reached this stage of development. The question we have to answer is: "At what point can we say that the 'earliest detectable' clinical and radiographic signs of a 'slight' but appreciable degree of silicosis, in the sense above defined, are present?"

We have said that a radiograph of high technical quality, properly interpreted, provides the most reliable *single* diagnostic criterion of silicosis. It may be convenient, therefore, to begin this part of our discussion by describing the indications of the presence of pulmonary "fibrosis", as shown by the radiograph, up to the point at which these indications afford definite evidence of the existence of an appreciable degree of silicosis.

THE ROUTINE RADIOLOGICAL PRACTICE AT THE MEDICAL BUREAU

The number of persons who have to undergo radiological examination at the Medical Bureau during the forenoon of each day averages about 120. For this reason alone the examination made is practically entirely solely a radiographic one — radioscopy is not employed as a routine method, although one fully recognises its supplementary value in detailed individual examination.

The X-ray plant used is a "Polydor", with four-valve tube rectification of the high-tension current. Its capacity is from 35 K.V. effective to 115 K.V. effective; the output is 250 M.A.

The tubes used are line focus tubes, the "Philips' Metallix" fine focus, and the Siemens' "Phoenix Radion" medium focus, both with water-cooled anode.

The tube setting is 40 K.V. effective, with 3.8 A. heating current, giving an output of 50 M.A. Focal distance, 29 inches. Exposure, $\frac{1}{10}$ - $\frac{1}{5}$ second for patient with average depth of chest. Films "Kodak contrast". Intensifying screens are used at present on both sides of the film.

The Bureau's radiologist (Dr. W. Steuart) is at present investigating in Europe whether the installations using high capacity tubes, with long focal distance, recently introduced there, would prove suitable for the work of the Bureau.

TERMINOLOGY ADOPTED BY THE BUREAU TO DESCRIBE THE VARIOUS TYPES OF RADIOGRAPH

In order to secure consistency in the description of the large number of radiographs with which it has to deal daily, the Medical Bureau has found it necessary to create a private conventional terminology, descriptive of the various general grades of radiographic appearances indicative of pulmonary "fibrosis". The Bureau's radiologist, in reporting upon negatives, first classifies them into one of the following eight groups:

1. "Normal Thorax" (N.T.).
2. "Rather more Fibrosis than usual" (R.M.F.U.).
3. "More Fibrosis than usual" (M.F.U.).
4. "Commencing generalised Fibrosis" (C.G.F.).
5. "Moderate generalised Fibrosis" (M.G.F.).
6. "Well-marked Fibrosis" (W.M.F.).
7. "Very well-marked Fibrosis" (V.W.M.F.).
8. "Gross Fibrosis" (G.F.).

The term "fibrosis" is here used to indicate merely the amount of fibrous tissue in the lung, as indicated by the radiograph, whether that amount be within the normal limits, as in the first two or three classes, or be abnormal, as in the others. Each general group, except the first, contains two or more subdivisions; e.g. a "Well-marked Fibrosis" may be "mainly silicotic" or "partly (or mainly) infective in type", and the particular variety present is also specified in the radiologist's report. Further, each grade may be accompanied by appearances indicative of special conditions, such as "suggestive of tuberculosis", "apparently definite tuberculosis", "pleural effusion", "empyema", "pneumonia", "enlarged heart", "aortic aneurism", "pericarditis", etc. These also are noted, if present.

The report on any individual case is made very simple by the radiologist merely initialling the relevant description upon a stereotyped form. A specimen form is attached as Appendix "A"¹ and the radiographic appearances therein reported upon are seen to be a "moderate degree of fibrosis, silicotic in type, with apparently definite tuberculosis left lung". In this manner a hundred radiographs can easily be reported upon in much less than as many minutes.

The terms used to describe varieties of "fibrosis" are quite arbitrary and conventional, but an attempt has been made to relate them to the radiographic appearances actually shown, and to the pathological conditions indicated by these. The terminology is employed merely as a means of rapidly placing any particular negative in its appropriate approximate "bin". Presumably all radiologists use an analogous private code, and the Bureau does not claim any particular value for the terminology which it employs, other than that of the practical convenience of securing a working uniformity of description. The precise meaning of the terms used is explained below, but for convenience of reference we append here a schematic statement which may render their general significance and relations more apparent.

The above scheme shows in tabular form the general classification of radiographic appearances adopted by the Bureau. To any one of these may be added, if the relevant indications are present, such particular additions as:

- "Pleural thickening" or "pleural effusion".
- "Hilus thickening" or "peribronchial thickening".

¹ Page 294.

TABLE I. — NOMENCLATURE OF TYPES OF RADIOGRAPH EMPLOYED BY MINERS' PHTHISIS MEDICAL BUREAU

General group	Subdivisions			
	(a) Simple	(b) Partly or mainly Silicotic in type (p. or m. Sil.)	(c) Partly or mainly Infective in type (p. or m. Inf.)	
1. N.T. Normal Thorax	Normal shadows	—	—	<p>If the radiograph shows indications of active Tuberculous infection, substitute for Group 1, or add to any of the other groups, "Suggestive of Tuberculosis", or "Apparently definite Tuberculosis"</p>
2. R.M.F.U. Rather more Fibrosis than usual	<i>Simple</i> (slight increase of fibrosis in normal situations)	—	<i>p. or m. Inf.</i> (as in (a), with indications of old or inactive infec- tive element)	
3. M.F.U. More Fibrosis than usual	(Further increase of fibrosis in normal situa- tions; "large branch fibrosis")	—	"	
4. C.G.F. Commencing generalised Fibrosis	<i>Simple</i> (generalised fine arborisation throughout both lung fields; "small branch fibrosis"; "the leafless tree")	<i>partly Silicotic in type</i> (as in (a), with partial "small" specific mottling)	<i>p. or m. Inf.</i> (as in (a), with indications of in- fective element not definitely active)	
5. M.G.F. Moderate generalised Fibrosis	<i>Simple</i> (as above, but more marked)	<i>Silicotic in type</i> (symmetrical "small" mottling throughout both lung fields)	<i>p. Inf.</i> (as in (a) or (b), with indications of infective ele- ment not definitely active)	
6. W.M.F. Well-marked Fibrosis	—	(Symmetrical "medium" mottling)	(as in (b), with indications of in- fective element not definitely active)	
7. V.W.M.F. Very well-marked Fibrosis	—	(Symmetrical "large" mottling)	"	
8. G.F. Gross Fibrosis	—	(Gross mottling)	"	

- "Consolidation" not regarded as tuberculous, e.g. from pneumonia.
- "Heart enlarged" or "heart asthenic in type".
- "Aorta enlarged" or "aortic aneurysm".
- "Other changes, e.g. "? neoplasm", "? hydatid", etc.

The term "fibrosis" is here used merely to indicate the amount of fibrous tissue in the lungs, as shown by the radiograph. The increase in "fibrosis" indicated in Groups 2(a) and 3(a) is within limits which are not in general of pathological significance. The increase indicated in Group 4(a) is of pathological significance, but is not *necessarily* of silicotic origin; the same is true of Group 4(c). Group 4(b) is specifically indicative of a "slight" degree of clinically simple silicosis; Group 5(b) of a "moderate" degree. Groups 6(b), 7(b) and 8(b) indicate, respectively, a "well-marked" and finally a "gross" degree of clinically simple silicosis.

RADIOGRAPHIC APPEARANCES IN MINOR DEGREES OF "FIBROSIS"

This being premised, one may proceed to indicate the precise meaning of the terms used and their application to diagnosis. The type described as "Normal Thorax" (N.T., film 1) ought perhaps to be described as the "ideal" normal thorax. It is present in only a minority of adult males of working age.

The type described as "Rather More Fibrosis than Usual" (R.M.F.U., film 2) shows, as compared with the former type, a slight increase of fibrosis in normal situations. The difference is not in general of pathological significance; indeed this type of plate is probably the most common amongst healthy adult males of working age. It shows the heart shadow of the normal shape; the hilus shadows are of normal density and extent; and radiating from these are the branching shadows thrown by the larger bronchi and blood vessels, which extend some distance into the lung fields. *Between and beyond these shadows the lung fields are clear.* Even in "normal" radiographs taken from perfectly healthy persons there may be found a few sharply defined bright spots in the lung fields and a similar appearance in one or two of the root glands, indicative of an old healed "primary" tuberculous infection in early life, which has left no other trace.

The next type of film is that termed by the Bureau's radiologist "More Fibrosis than Usual" (M.F.U., film 4). It shows an advance on the previous type in the form of an increase in the number and extent of the branching shadows spreading from the hilar areas. These are now more numerous, and may generally

be traced almost to the periphery of the lung. They remain, however, dendritic or linear in form. The hilus shadows are rather more obvious; the heart shadow remains normal in shape. The condition represents a further increase in fibrous tissue in normal situations. It may be described as a "large branch fibrosis", the shadows shown in the lung fields being for the most part thrown by the larger branches of the bronchial or vascular trees. This type of film is not necessarily, or even as a rule, of pathological significance. It is seen in about 25 per cent. of all initial examinees, and in well over 50 per cent. of those of forty-five years or over, since there is, as life advances, a normal increase in the fibrous tissue of the lung framework. This type of radiograph is frequently seen in cases of chronic bronchitis and bronchial asthma and chronic valvular disease of the heart, and is common, together with other signs, in cases of "old healed tuberculosis". As is to be expected, it is more common in miners, age for age, than in those who have not been underground; but pathological evidence shows that it is not in itself indicative of silicosis.

MINOR DEGREES OF "FIBROSIS" OF INFECTIVE TYPE

Running parallel to the two simple types of radiograph just described, there are two other types (films 3 and 5) which, although similar in most respects, nevertheless show certain definite differences. They show respectively practically the same amount of fibrosis as in the "rather more fibrosis than usual", or "more fibrosis than usual" types which we have discussed. But in each case the evidence of fibrosis is now accompanied by features which distinguish these films rather sharply from the former ones, inasmuch as *in each the fibrosis is associated with signs indicative or suggestive of a limited amount of former tuberculous infection* of hilar or peribronchial type. It is associated with a change in the shape of the heart to the narrowed, elongated, "asthenic" or "vertical" form, and with a definite or marked increase in the hilus and bronchial shadows, indicative of glandular enlargement and peribronchial fibrosis of infective origin. Denser shadows cast by markedly fibrosed or calcareous lesions may be apparent at or near the hilus region, or here and there in the lung fields. Clinically, individuals who show this type of radiograph may be quite healthy and fit for ordinary work, but they are not in general of robust physique. They are almost always under weight, sometimes markedly so, with a flat or flattish chest, a defective posture,

sometimes with "winged" scapulae, and they usually are somewhat languid-eyed or "deep-eyed". They have, in short, as a rule the characteristic physical stigmata of the "phthinoïd" type of individual, associated with radiographic indications of an old "healed" pulmonary infection. The Medical Bureau therefore labels this type of radiograph "Rather More Fibrosis than Usual, partly Infective in type" (R.M.F.U. p. Inf., film 3), or "More Fibrosis than Usual, partly Infective in type" (M.F.U., p. Inf., film 4).

Those who are familiar with the radiographs shown by cases of simple tuberculosis will at once recognise these varieties.

It is remarkable how close the correlation between the radiograph and the clinical condition generally is in this group of cases. Cases of this class are never passed for underground work by the Bureau. But there is no difficulty in obtaining representative films of each of these varieties in persons who have never worked underground; indeed, some 4 per cent. of the average "healthy" males of working age, who present themselves as possible recruits for mining, have radiographs actually or approximately of one or other of the types shown in films 3 and 5. *Films of this character are not in general indicative of silicosis*; they are generally speaking indicative of an old tuberculous infection.

"COMMENCING GENERALISED FIBROSIS"

Silicosis, as we have said, is a *generalised* condition, and the earliest type of radiograph which gives indication of a commencing generalised increase of fibrous tissue in the lung is that indicated by the next group of films, which are termed "Commencing Generalised Fibrosis" (C.G.F., films 6, 7 and 8). In the Bureau's terminology there are three varieties of this group: 1. "Simple Commencing Generalised Fibrosis" (film 6); 2. "Commencing Generalised Fibrosis, partly Silicotic in type" (film 7); and 3. "Commencing Generalised Fibrosis, partly Infective in type" (film 8). The terms may seem cumbrous, but they represent definite distinctions.

The feature common to them all is the appearance of a well-marked generalised fine "arborisation" in the lung fields. The radiograph shows an advance on the previous type (M.F.U., film 4) in the appearance of additional finer dendritic or reticular shadows cast by the smaller air tubes or blood vessels and apparent more or less generally throughout the lung fields.

In the variety termed "Simple Commencing Generalised Fibrosis" (S.C.G.F., film 6) the description just given is all that is apparent. The heart shadow is normal; the hilar shadows are increased; the lung fields show the generalised arborisation which we have described. The appearances suggest the branching of a leafless tree *in which the smallest branches have now become apparent*. There is no evidence, however, of any definite amount of specific silicotic "mottling". The appearance described cannot be regarded as being unequivocally "specific" of silicosis. Similar indications may be given by other conditions, by peribronchial tuberculosis (to which we shall refer in a moment), by chronic bronchitis not associated with special exposure to dust, possibly by pulmonary syphilis, and may be found in some cases of chronic cardiac or cardio-vascular disease. It is sometimes seen in coal miners who arrive from overseas to apply for work in the gold mines, and does not appear in them to lead to anything more serious or to be accompanied by any incapacity. It begins to be evident in a small percentage of our miners who have worked about ten years or so underground, and is found in them to correspond in general to the condition of fine thickening of the branches of the bronchial and vascular trees, unassociated with palpable fibrosis, which was described in the previous paper, as preceding the development of a definite condition of silicosis. It was there suggested that this characteristic appearance was probably in large measure dependent upon changes in the bronchial tree induced by bronchitis and bronchiolitis. Pathological investigation shows that, in a majority of instances, the lungs of individuals who have shown this appearance in radiographs taken during life do now exhibit definite evidence of silicosis post-mortem. *This particular type of film therefore cannot be taken as affording a general standard diagnostic of the presence of silicosis.* On the other hand, in a *minority* of cases, a "slight" degree of silicosis has been found post-mortem in individuals whose chests during life had shown a simple fibrosis of this type.

THE EARLIEST "SPECIFIC" RADIOGRAPHIC INDICATIONS OF SILICOSIS

The second variety of the group of radiographs we are discussing is termed "Commencing Generalised Fibrosis, partly Silicotic in type" (C.G.F., p. Sil., film 7). The general background of "arborisation" is the same as in the radiograph last described.

But in some areas here and there, commonly first towards the upper poles of one or both lungs, *local evidence of specific "mottling" is beginning to appear*. The leafless tree is beginning to put on leaves. Pathological evidence shows that in practically all instances this appearance in the radiograph represents the sparse beginnings of palpable miliary nodulation, which marks the development of a "slight" degree of silicosis. The clinical signs will be found also to correspond, and the conjunction clinches the diagnosis.

In all cases in which the appearance described is found to develop in a miner, or is present in a claimant whose industrial history includes a period of several years' work underground, a diagnosis of silicosis may safely be made. *The Medical Bureau, accordingly, accepts a radiograph of this type as the general radiographic standard of diagnosis of the "earliest detectable" stage of simple silicosis. It is the earliest type of film which gives unequivocal specific evidence of the disease.*

In practice, however, the Bureau is accustomed to allow a certain degree of latitude in the application of this general standard, inasmuch as pathological evidence shows, as we have said, that a slight degree of silicosis may sometimes be found after death in individuals whose chests during life had shown the appearance merely of a simple "commencing generalised fibrosis". If these appearances develop under observation in a miner during the course of underground work and are accompanied by a coincident development of *definite* clinical evidence of pulmonary fibrosis, and of some respiratory disability not attributable to other causes, a diagnosis of a "slight" degree of silicosis may be made. The possible presence of bronchitis and bronchiolitis is of importance in this respect. But in such cases the confirmatory clinical evidence must be unmistakable, and the occupational history convincing.

The same qualification applies to the evidence afforded by the third type of film of this group, named "Commencing Generalised Fibrosis, partly Infective in type" (film 8, with which we may associate film 10). These films are similar in general character to those already referred to (films 3 and 5) as illustrating minor degrees of "fibrosis" of infective type, but they show a more extensive condition of "fibrosis". Like these they are indicative in general of an old tuberculous infection. They resemble the type of film shown in cases of a limited degree of simple apical fibroid tuberculosis. Indeed, beyond one or two enlarged and fibrosed root glands and a possible old pleural scar and a few cretaceous or fibroid nodules at the apices or elsewhere, there is

usually very little macroscopic change detectable post-mortem in lungs which have shown appearances of this sort during life. Radiographs of this type may be met with amongst individuals who have never been underground at all. But they are certainly commoner amongst miners who have spent a good many years underground than amongst non-miners. Such appearances may be accompanied by no deterioration of general health or respiratory function in the individuals concerned. Nevertheless, a certain proportion of cases of the type, represented by films 8 and 10, occurring in miners, have been found, post-mortem, to show evidence of a slight degree of slowly progressive tuberculo-silicosis. This takes the form usually of one or two circumscribed areas of tuberculo-silicotic consolidation at or towards one or both apices, with a scattering of smaller nodules in the neighbourhood, with thickening and perhaps adhesion of the overlying pleura, and with similar tuberculo-silicotic changes in the corresponding root glands. If these lesions are enough to "matter" they will, with practical certainty, be indicated in a good radiograph. But there is no generalised silicosis. One is here dealing with a *slight localised degree of tuberculo-silicosis*. Persons showing this condition are usually spare and not robust, and incline to the "phthinoid" type of chest.

It is accordingly the practice of the Medical Bureau that, when a radiograph of this infective type of "Commencing Generalised Fibrosis" (film No. 9), with indications of localised apical change, is found to have developed during the course of his employment in a miner who, although showing no signs of active infection, presents evidence of some progressive deterioration in general condition and respiratory function, together with physical signs of pulmonary fibrosis, to certify the presence of a *slight degree of tuberculo-silicosis*. Such a condition is the characteristic expression of a limited tuberculous infection in a person exposed to the inhalation of dust in moderate amounts.

One hopes that what has so far been said regarding the diagnosis of the "earliest detectable stages" of silicosis has not left a sense of indefiniteness. The position amounts to this. The *general* diagnostic standard is the film, which shows the first indications of specific "mottling" (film No. 7), and a considerable majority of the cases notified fall into this group. But pathological evidence indicates that we are justified in extending our basis of selection to include a certain number of cases whose radiographs are of the "simple" or "infective" varieties of "simple generalised fibrosis",

provided that we have ample support from the clinical side and from the industrial history in so doing. That is the position which corresponds to the facts of the case. But this situation suggests all the more the desirability of placing all decisions which may lead to awards under a system of compensation in the hands of a specially selected body of whole-time examiners, whose expert experience of all aspects of the question will enable them to give an impartial decision.

THE CLINICAL SIGNS IN A "SLIGHT" OR "MODERATE" DEGREE OF "SIMPLE SILICOSIS" ¹

One may now consider the nature of the clinical signs which are usually present at the "earliest detectable" stage of silicosis.

It will readily be understood that, in a condition whose pathological beginnings are fine and generalised, and whose development is extremely gradual, the symptoms will be correspondingly insidious in their onset and more elusive in character than is the case with most other lung diseases. This is certainly so, and constitutes the unquestionable and unavoidable difficulty in diagnosing the disease by ordinary clinical methods in its earliest stage.

The usual *symptoms* of silicosis in its "earliest detectable stage" are *slight shortness of breath on exertion*, with some amount of *irritative cough*, typically a dry cough with little or no expectoration, often worst in the morning and sometimes inducing vomiting. There may also be some complaint of occasional slight pains in the chest. Even these symptoms may be absent, and, in not a few cases, miners, when notified that they have contracted a "slight" degree of silicosis, may be unaware that there is anything the matter with them. Further, these symptoms in themselves are not peculiar to silicosis, and in no case is the Medical Bureau influenced in its decision *solely* by such subjective evidence. In general one may state that at this stage respiratory disability is, at the most, slight, and it may be altogether absent.

To come now to *physical signs*. In the earliest stage of a "simple silicosis" there is no departure from the normal standard of nutrition, except in individuals of an originally poor physique. Loss

¹ The succeeding portions of the present paper are based, with however a considerable amount of expansion and modification, upon an account of "The Diagnosis of Silicosis and Tuberculosis in the practice of the Medical Bureau", prepared by one of us (L. G. IRVINE) in conjunction with Dr. J. M. SMITH, and published in *The Proceedings of the Transvaal Mine Medical Officers' Association*, Vol. I, No. 6, Sept. 1921.

of weight, which occurs coincidentally with the development of signs of silicosis, and which cannot be attributed to other causes, definitely suggests an infective element in the case.

The conformation of the chest usually shows little or no alteration, although the upper chest may show some flattening. The percussion note is typically of *average* normal quality. The practically constant clinical signs are:

1. A certain lack of elasticity of the chest wall during the movements of respiration, together with
2. A somewhat reduced air entry, and
3. A characteristic alteration of the inspiratory murmur from the normal "vesicular" character to a higher-pitched or "harshened", "thinned" and commonly somewhat shortened type, the expiratory murmur, although somewhat prolonged, remaining fainter than the inspiratory.

This type of breath-sound is very characteristic, with some modifications, of silicosis in all its stages, and this clinical sign has also the significant character of more or less complete *generalisation*. It is first noticeable at the anterior, lateral and basal regions.

In a minority of cases, however, the breath-sounds may be simply diminished, but breath-sounds which are simply diminished or which, on the other hand, are merely somewhat louder or more "pronounced" than normal, are not specially characteristic of silicosis.

Usually there are no accompaniments, but a stray rhonchus may be heard here and there.

This complex of physical signs is almost constantly present in cases of a slight degree of "simple" silicosis. The cough may be put down to the coincident bronchitis and bronchiolitis, the recurrent pains to slight intercurrent local pleurisies.

The clinical condition is not much more marked in each of its components in cases of a "moderate" degree. The radiographic appearance of the latter condition is, however, now quite distinctive. It is that described by the Bureau as a "Moderate Generalised Fibrosis, Silicotic in type" (M.G.F. Sil., film No. 9), to which we have already referred. The partial indications of the specific "mottling" shown in film No. 7 are replaced by a symmetrical and practically uniform distribution of this appearance over the whole of both lung fields. The latter are seen to be occupied practically throughout by numerous small discrete shadows cast by individual nodules or (in part) by slightly thickened air tubes or blood vessels caught "end on". We are here obviously dealing

with an established condition of silicosis, and its radiographic appearance is now unmistakable. It is simulated by no other condition, except by some cases of acute miliary pulmonary tuberculosis. In the latter, however, although the distribution of the small discrete shadows is practically identical, the individual shadows are less well defined, and clinically the differential diagnosis should present no difficulty.

Individuals who show the "infective" type of "slight" or "moderate" silicosis are most often of "phthinoid" conformation and aspect, and, apart from these characters, the physical and radiographic signs may be more marked at the apical regions of the lungs.

CLINICAL AND RADIOGRAPHIC SIGNS IN A "WELL-MARKED" DEGREE OF "SIMPLE SILICOSIS"

The description of the later stages of silicosis need not occupy us long. In cases which have passed from the earlier stage of a "moderate" to that of a definitely established "well-marked" degree of simple silicosis the radiographic and clinical signs are very distinctive.

The *radiographic appearances* are those shown in the type of film termed "*Well-marked Fibrosis of Silicotic type*" (W.M.F. Sil., film No. 11). This exhibits the characteristic "mottling" in a more marked degree. The individual shadows are larger, although they may not be more numerous. They are of a fairly well defined, rounded or sometimes annular form, generally discrete, but sometimes, in places, merging somewhat into one another. The heart remains of good shape. This is the characteristic picture.

If, on the other hand, the "mottled" shadows are irregular in shape, size and distribution, and are accompanied by a change in the heart shadow towards the vertical type, the presence of an infective element, which is commonly tuberculous, may usually be assumed, although there may be no clinical indications of active pulmonary infection. Compare in this respect film 11 with film 12.

In a fair proportion of cases another and very striking change may be manifest, namely, that many or most of the individual shadows may be seen (in the negative) to be abnormally bright and sharp, owing to an increased density of the individual nodules (film 17). Pathological evidence has confirmed the view which had previously been taken by the Bureau that this remarkable

and suggestive feature is due to calcareous deposit occurring in the nodules, and this change may extend to the great majority. No microtome will touch them.

Finally, one may add that a coarsely "mottled" appearance may be seen also in some cases of simple broncho-pneumonic tuberculosis. But in these the appearance is rarely generalised throughout both lungs, the shadows of "mottling" are less sharply defined and may commonly be seen to merge into a more diffuse opacity at the apex or round the hilus.

The *clinical signs* in the intermediate or "well-marked" stage of simple silicosis show a corresponding advance upon those of the earlier stages. They now present a characteristic complex.

In a case of average or of robust type the man is usually quite well nourished, and indeed is not at all infrequently well above the normal weight. The upper chest is typically somewhat — but "smoothly" — flattened or "sloping" but is not markedly retracted, as in chronic tuberculosis (cf. fig. 12). The character of the chest movement is modified, as much, however, by an alteration in the *quality* of the movement, which is sluggish and lacking in elasticity, as by a mere reduction of the *range* of movement, although some amount of reduction is the rule.

The percussion note, without being definitely "dull", is usually somewhat flattened, particularly posteriorly.

The air entry is somewhat shortened and thinned. The breath sounds are also typically somewhat shortened and present almost constantly and more definitely the characteristic thinning and harshening of inspiration, together with a prolonged but fainter expiration, already described, although in a small minority of cases, at this stage also, the breath sounds are simply "diminished vesicular" in character.

The silicotic chest, in the absence of complication due to infection, is typically a "dry" chest, although sometimes fine crepitations, due to congestion, may be heard towards the lateral and basal margins, or a few rhonchi may be heard here and there. Cough too, if complained of, is usually "dry" and irritative, often of the morning "emetic" type.

In the cases which we see nowadays cardiac dilatation, except when dependent on intrinsic disease of the heart, is quite exceptional at this stage of silicosis.

Cases of silicosis in the intermediate stage are usually fit for "moderate" physical work; indeed, a number of cases who show the radiographic signs of a well-marked silicosis may lead a full,

active life, without obvious interference with respiratory function. But in an average case there is an amount of dyspnoea on exertion which definitely impairs the working capacity.

Simple silicosis of the "classical" type is not typically a wasting disease. As we have said, even in well-marked cases the general condition and appearance may be quite good, and there is actually in a number of cases a tendency to gain weight coincidentally with the onset of detectable evidence of the disease. In others, however, there is loss of weight, and this is more common in those whose radiographs are of the "infective" type which I have described, circumstances that suggest the presence in such cases of an element of latent infection.

THE ADVANCED STAGE OF "SIMPLE SILICOSIS"

Twenty years ago it was common enough to meet with advanced cases of "simple" silicosis which were not obviously of an infective type. To-day one meets with cases which can fairly be described as such, generally speaking only in men of originally robust physique. A characteristic example is shown in fig. 11, already referred to.

The *radiographic signs* in such cases are those of a medium or large, close mottling, and the shadows may be seen here and there to have coalesced, giving the appearance of limited areas of more diffuse opacity (films 13 and 15). If the shadows show much lack of definition and are unduly large or irregular in size, with a definite tendency to local coalescence, it is probable that an infective element is present in the case (films 14 and 16). Indeed, the first radiographic indication of the supervention of an active tuberculosis is frequently the occurrence of a blurring of the outline of the "mottled" shadows which, in previous radiographs taken in the same case, may have been well defined.

Few cases of advanced silicosis are without some infective element, although this may be latent and not apparent clinically.

In advanced cases of the "classical" type (films 13 and 15) the *clinical signs* are very pronounced. The general nutrition may be quite good; many cases indeed are somewhat obese. There are, with few exceptions, some cyanosis and some obvious dyspnoea; in some the expression may be rather "anxious". The chest is smoothly flattened, without however showing marked retraction. The intercostal and supraclavicular spaces may show no obvious hollowing. The configuration resembles that of a moderate emphysema, and a greater or less amount of emphysema is a

constant feature of the condition (cf. fig. 11). Expansion is decidedly impaired, both qualitatively and quantitatively, and the range of movement is decidedly limited. The percussion note is flat, without being absolutely dull, although there may be local areas of dullness due to thickened pleura. To the percussing finger the normal resilience of the chest wall is impaired. The vocal resonance may be generally increased, but frequently it lacks "ring", and so too may the voice. The air entry is decidedly reduced and short. The respiratory murmur is *short* and high-pitched, sometimes thin, sometimes rather blowing, although it may (but much less usually) be merely much reduced and faint. The condition of the pleuræ may to a large extent account for these differences. There may be signs of localised consolidation, but these, if extensive, point to an infective complication.

As we have said, it was formerly not uncommon for cases of advanced silicosis to die from a progressive heart failure, with cardiac dilatation, cyanosis and dropsy. But death by progressive heart failure occurs very rarely nowadays, since few cases now exhibit the excessive degree of fibrosis which determined that mode of death. A definite cardiac dilatation secondary to silicosis is relatively uncommon in the cases we meet with at present, although some amount of fine crepitation, due to congestion, is very frequently present towards the lateral and basal margins of the lungs. Nor is there any evidence in our cases of a higher proportion of instances of disordered renal function amongst silicotic than amongst non-silicotic miners.

To-day cases such as we have just described are uncommon. The greater number of advanced cases of "miners' phthisis" are nowadays cases of "tuberculosis with silicosis"; and the majority of the remainder, who have so far escaped an active breakdown, and for that reason are still classed as "simple silicosis", nevertheless show clinical and radiographic indications of the presence of a latent infective element. (Cf. films 14 and 16.)

Cases of advanced silicosis are in general fit for light work only, or for no physical work whatever, although even at this stage some may be able to lead a moderately active life.

FUNCTIONAL TESTS IN CASES OF "SIMPLE SILICOSIS"

A preliminary series of functional tests was carried out at the Bureau both upon miners and non-miners by Mr. J. H. Dowds, of the Witwatersrand University, in 1924; and a further and more

extended series of similar observations was conducted by him at the beginning of the present year, in order to obtain an approximate measure of several of the clinical features found in silicosis, and in order to determine the possible value of such tests in diagnosis.

Observations were made upon 500 cases, which were divided into five groups, each represented by 100 individuals. The groups chosen for observation were:

1. "First Periodicals" i.e. men who had been underground for not more than six months and all of whom had passed the "initial" examination of the Bureau as new recruits.

2. "Short-service Miners", i.e. men working in their fifth, sixth or seventh years of underground service; all of these men also had passed the initial examination of the Bureau.

These two groups are therefore comparable with each other, since all had undergone special selection in respect of their physique prior to entering on underground work. The observations made in these 200 cases may be of particular value in the future when the further history of these men is followed.

3. "Long-service Miners", i.e. men working in their eleventh, twelfth and thirteenth years of underground service. Very few of these men had passed the initial examination of the Bureau, and they were in general a group the members of which had not undergone any special selection. They are therefore not, as a class, comparable with the first two groups, but they are comparable with the two succeeding groups, which are also in general composed of men who had not passed the initial examination of the Bureau.

4. Cases of "Ante-primary" stage silicosis, examined either at the time of their certification or at their first re-examination thereafter.

5. Cases of "Primary" stage silicosis.

With only one or two exceptions, all of these men had worked underground solely on the Witwatersrand. Men under twenty or over fifty years of age were not examined, the latter precaution was taken in order to exclude persons suffering from simple senile changes. Very obese men were excluded, also cases of chronic heart disease, subjects of present or recent illness or recent operation, and persons suffering from hookworm infection, or those in whom there was evidence of tuberculosis, or men who obviously were not trying to execute any of the tests properly. With these exceptions, the men were taken as they came.

The sequence of the tests used was: resting respiratory rate, resting pulse rate, stool-stepping test, chest expansion, vital capacity, total lung ventilation per minute, blood pressure (silicotics only) and haemoglobin percentage.

TABLE II. — AVERAGE RESULTS OF PHYSICAL MEASUREMENTS
IN CERTAIN GROUPS OF NON-SILICOTIC AND SILICOTIC MINERS

	Group I: 100 first periodi- cals	Group II: 100 short- service miners	Group III: 100 long- service miners	Group IV: 100 ante- primary stage silicotics	Group V: 100 primary stage silicotics	Group VI: 10 secondary stage silicotics
Age (years)	25	34	38	40	42	44
Height (cm.)	170	170	169	171	169	170
Weight (kg.)	70	70.5	66.5	70	66.5	67
Mean standard weight (kg.)	66.5	68.0	68.5	71	69.5	70.5
Service underground (years)	0. 4m.	6. 7m.	12. 4m.	12	9. 11m.	10
Respiratory rate (per minute):						
At rest, standing	18	19	20	23	23	24
Increase immediately after exercise	3	4	5	6	7	7
Increase remaining after pulse return- ed to normal	1	2	5	5	5	4
Pulse rate (per minute):						
At rest, standing	77	77	81	87	86	86
Maximum increase after exercise	31	28	28	27	27	27
Time (seconds) for return to normal	34	42	45	53	53	67
Chest circumference at end of normal expi- ration:						
2 ins. above nipple (cm.)	92	92	91	93.5	90	91
2 ins. below nipple (cm.)	85	85	85	86.7	85	87
Average range of ex- pansion between full inspiration and full expiration (cm.)	9	8	7	6.5	5.5	4
Actual vital capacity (cc.)	4710	4440	4090	4020	3610	3190
Percentage deviation of vital capacity from calculated stan- dard value	+10.7	+4.4	-3.2	-6.3	-14.6	-24.9
Ventilation per minute (cc.)	10790	10680	11340	11440	11720	12690
Ditto, per kg. body weight	154	151	170	163	176	189
Alteration respiratory rate on breathing through spirometer	-0.5	-0.4	+0.7	-0.4	+1	+1.5
Tidal air (cc.)	663	603	589	583	539	506
<i>Ventilation per min.</i> ÷ Vital capacity	2.31	2.43	2.81	2.91	3.31	4.41
Resp. rate (spirometer) × Ventilation per minute ÷ Vital capacity	41.3	46.6	59.8	64.1	80.5	121.2
Percentage haemoglo- bin	89	89	89	89	89	89
Blood pressure:						
Systolic	—	—	—	131	130	131
Diastolic	—	—	—	93	91	91
Pulse pressure	—	—	—	38	39	40

Flack's test (respiratory force) was not employed, as its results in the preliminary series of observations were erratic. An effort-test of stool-stepping (10 times in 30 seconds; height of stool, 20 inches) was employed instead, and the alterations of pulse and respiration were observed.

The average results are shown in table II.

In the last vertical column a series of observations on ten secondary stage cases has been added; the number is small, but the results so far as they go are consistent.

These observations show a progressive diminution in chest expansion in silicotic cases. The vital capacity is also progressively reduced, but only slightly so in ante-primary stage cases; in primary stage cases the average reduction is of the order of 15 per cent.; the resting respiratory rate is increased and the breathing becomes proportionately shallower.

These results are of interest, but the great variations shown by individual cases in each group and the element of uncertainty which might readily be introduced by the subjective factor in such tests render them of little value in diagnosis. The observations on the average blood pressure in cases of silicosis are of interest from their negative result.

" TUBERCULOSIS WITH SILICOSIS "

By the term " Tuberculosis with Silicosis " one means silicosis complicated by clinically obvious, active or " overt " tuberculosis. Mere indications from the radiograph or from physical signs of limited areas of consolidation do not lead one to place a case in this class unless there are local or constitutional signs of *active* tuberculous infection. Active tuberculosis may be present from the first appearance of detectable signs of silicosis, but this is uncommon. It may supervene at any stage in the progress of what has previously been from the clinical standpoint a condition of simple silicosis. But it is most common as a terminal complication in well-marked or in advanced cases of the disease.

The diagnostic indications of silicosis complicated by tuberculosis are that the signs, particularly the radiographic signs, of *both* conditions are present.

In the radiograph, in addition to the generalised signs of silicosis in one or other of its stages, indications of more or less extensive " blurring " or of more marked local opacities indicative of areas

of definite consolidation appear (see films 19, 20, 21 and 22). The heart shadow also may show a change to the asthenic or "vertical" type.

The radiograph is particularly helpful in such mixed conditions, especially when these are seen for the first time, and it is usually decisive. It is a common and easy course, when a case of active tuberculosis is met with in a miner, to *assume* the presence of a silicotic element. But such a diagnosis, when made on clinical grounds alone, is in very many cases merely presumptive. The only objective *proof* of such a conjunction during life is the radiograph, which will almost invariably give precise and accurate indications of the actual condition present. In some instances, however, the appearances produced in the radiograph by an extensive bilateral tuberculosis may altogether obscure the distinctive indications of an underlying silicosis. In such cases one is compelled to fall back on the probabilities of the case, taking into consideration the previous condition of the individual and the duration and character of his underground service. The same observation applies to some old-standing cases of chronic "tuberculo-silicosis", in which the distribution of the lesions resembles that of a fibroid tuberculosis, and in which no indications of a generalised silicosis may be present.

On the *clinical* side the supervention of *active* tuberculosis is shown first usually by a definite and progressive loss of weight, by the appearance of evidence of localised areas of infection in the lungs or pleurae, with their characteristic physical signs, by increased cough and expectoration, sometimes with hæmoptysis, and commonly by a rapid break-down in the patient's condition. Examination of the sputum for the tubercle bacillus should, of course, always be made; its presence is a more ominous sign in tuberculosis complicated by silicosis than in cases of simple tuberculosis. It is a characteristic feature that, when an overt tuberculosis becomes manifest in a case of well-marked silicosis, the amount of dyspnoea appears to be quite out of proportion to the actual extent of the infection. This is one side of the picture. The other side is that, as we have already said, not a few cases of "tuberculo-silicosis", in which the infective element is less acute, may run a very chronic course, with a well-marked tendency to retardation and limitation of the infection (cf. film 18).

In conclusion, an interesting observation may be mentioned, namely that the onset of a tuberculous infection in a lung in which no radiographic or clinical signs of silicosis were previously detectable

may sometimes bring to light a condition of what Watkins-Pitchford has termed "latent silicosis" ¹. The infection appears to select the sites in the lung where minute aggregations of silica are already present, and thus to assume the characteristic "miliary" distribution of a silicosis. This feature, when it occurs, commonly does so within a comparatively short time of the appearance of evidence of infection.

LEGAL DEFINITIONS OF THE "STAGES" OF SILICOSIS

We should have liked to add a few remarks regarding the differential diagnosis of silicosis, but what has been said is possibly sufficient to indicate the general features which distinguish that disease from other pulmonary conditions, and one does not wish to extend this discussion unduly.

It may, however, be of interest from a practical point of view to quote in conclusion the definitions of the three legal "stages" into which, for purposes of compensation, cases of silicosis are classified under the Miners' Phthisis Act of 1925, of the Union of South Africa. This will enable one to form an idea as to how the varying types of case which we meet with may be fitted into a legal system of compensation.

The definitions of silicosis in the Act mentioned (section 76 (2)) are as follows:

2. For the purposes of this Act . . . the expression "silicosis" shall mean silicosis of the lungs. A person shall, for the purposes of this Act, be deemed to have or to have had silicosis

- (a) in the *ante-primary stage*, when it is found by the Bureau that the earliest detectable specific physical signs of silicosis are or have been present; whether or not capacity for work is or has been impaired by such silicosis;
- (b) in the *primary stage*, when it is found by the Bureau that definite and specific physical signs of silicosis are or have been present, and that capacity for work is or has been impaired by that disease, though not seriously and permanently;
- (c) in the *secondary stage*, when it is found by the Bureau that definite and specific physical signs of silicosis are or have been present, and that capacity for work is or has been seriously and permanently impaired by that disease, or when it is found by the Bureau that tuberculosis with silicosis is or has been present.

¹ W. WATKINS-PITCHFORD: "The Silicosis of the South African Gold Mines." *Journ. Indust. Hygiene*, Vol. IX, No. 4, p. 113.

The definition of tuberculosis (section 76 (3)) reads as follows:

3. For the purposes of this Act . . . "tuberculosis" shall mean tuberculosis of the lungs or of the respiratory organs. A person shall, for the purposes of this Act, be deemed to be suffering from tuberculosis whenever it is found by the Bureau either

- (a) that such person is expectorating the tubercle bacillus; or
- (b) that such person has closed tuberculosis to such a degree as seriously to impair his working capacity and render prohibition of his working underground advisable in the interests of his health.

It may be noted that the terms "is", "are", "has" or "have" in the above definitions apply to the cases of living miners; "has been"; "have been" or "have had" to those of deceased miners.

We may add one or two explanatory observations upon these definitions:

1. It will be noted that cases of *tuberculosis* do not come within the provisions of the Miners' Phthisis Act unless they are either "open" cases or cases which are productive of *serious* impairment of working capacity. Minor degrees of "old" healed tubercle or "latent" tubercle which do not cause serious incapacity are not cases of "tuberculosis" as defined.

It is recognised that it is very undesirable for any person who is the subject of active simple tuberculosis to continue to work underground, alike in his own interest and that of his fellow workmen. All working miners who are found to have simple tuberculosis are therefore debarred from further work and are given a "lump sum" award. But this award is regarded not as compensation for "injury" done, since simple tuberculosis is not an occupational disease, but as a payment for compulsory loss of employment. A miner can only obtain an award for simple tuberculosis if the condition is detected while he is at work or within a year after he has ceased underground work. No such limitation of time is applied to cases of silicosis or tuberculosis with silicosis.

2. In the system of awards of compensation in respect of *silicosis* the gradation in legal "stages" is applied solely to cases of "simple" silicosis, under which designation are included cases of the "tuberculo-silicotic" type which do not present evidence of active infection. The criteria adopted depend partly upon clinical considerations and partly upon the degree of incapacitation for work of the affected man. In the "ante-primary" stage there need be no incapacitation; the sole criterion here is the presence of the "earliest detectable specific physical signs of silicosis". In the two later stages the physical signs must be "definite", but the important consideration is the degree of incapacitation. This bears a general although not an exact relation to the degree of silicosis present.

In general it may be said that the "ante-primary" stage includes cases of a "slight" or of a "moderate" degree, as these terms are used in this paper; the "primary" stage includes "well-marked" cases fit

for moderate physical work; the "secondary" stage includes "advanced" cases fit for light or no work. The three legal stages thus correspond closely with the stages of "simple" silicosis as described in this paper.

3. Since the onset of active tuberculosis in a silicotic subject is generally in itself sufficient to produce a "serious and permanent" incapacitation, the law prescribes that all cases of *tuberculosis with silicosis* shall be classed as being in the "secondary" stage, no matter what the actual degree of silicosis may be.

APPENDIX "A"

MINERS' PHTHISIS MEDICAL BUREAU

INITIAL
SPECIAL
PERIODICAL
BENEFITS.

"X"-RAY REPORT

Bureau No.....

Board No.

Name.....

Date.....

Initials of Radiographer.	No.	The Skiagraph shows:—
	1	Normal Thorax.
	2	Rather more Fibrosis than usual.
	3	More Fibrosis than usual.
	4	Commencing generalised Fibrosis.
W. S.	5	Moderate generalised Fibrosis.
	6	Well-marked Fibrosis.
	7	Very well-marked Fibrosis.
	8	Gross Fibrosis.
W. S.	9	Fibrosis, partly /mainly SILICOTIC in type.*
	10	Fibrosis partly/mainly INFECTIVE in type.*
	11	Appearances suggestive of TUBERCULOSIS ^{RIGHT} / _{LEFT} lung.
W. S.	12	Apparently definite TUBERCULOSIS RIGHT / _{LEFT} lung.
	13	Peribronchial thickening.* Hilus thickening.*
	14	Pleural thickening ^{RIGHT} / _{LEFT} side.
	15	Pleural effusion ^{RIGHT} / _{LEFT} side.
	16	Consolidation ^{RIGHT} / _{LEFT} side.
	17	Heart asthenic,* vertical* in type.
	18	Heart enlarged.
	19	Aorta enlarged.* Aortic aneurysm.*
	20	Other changes, viz.

CHAIRMAN'S NOTES.

Total Underground Service { Claimed _____
Confirmed _____

Machine drills _____

Crushers, etc. _____

Mining elsewhere _____

Weight-index _____

Chest-movement _____

Pulse { Before exam. _____
After „ _____

Capacity for work _____

Remarks _____

* Delete terms not applicable.

Macroscopic Appearances in Silicosis

SIMPLE SILICOSIS¹

FIG. 1. — Moderate degree of simple silicosis. The lung shows considerable excess of pigmentation, with moderately numerous "small" to "medium" sized palpable silicotic nodules. (Cf. fig. 7 and film 9.)



FIG. 2. — Very well-marked degree of simple silicosis, with "large" miliary nodulation. (Cf. fig. 8 and film 13.)



¹ Figs. 1 to 4 are taken from the lungs of European miners.

INFECTIVE SILICOSIS



FIG. 3. — Very well-marked degree of silicosis, with many large irregular nodules and some areas of fibroid consolidation. No overt tuberculosis.



FIG. 4. — Very extensive tuberculo-silicotic consolidation, without overt tuberculosis. There is marked emphysema, and emphysematous bullae are visible at the marginal portions of the diaphragmatic surface of the lung.

TUBERCULO-SILICOSIS IN LUNGS OF NATIVE MINE LABOURERS

These photographs illustrate the more grossly infective type of tuberculo-silicosis which is more characteristically seen in certain cases of the disease occurring amongst native mine labourers.

FIG 4 A. — Very extensive tuberculo-silicosis in lower lobe, with active tuberculosis. Complete destruction of upper lobe. Lung of a native mine labourer.



FIG. 4 B. — Very extensive dense fibroid consolidation of tuberculo-silicotic character, with tuberculous cavitation in upper lobe. Lung of a native mine labourer.



Microphotographs on Uniform Scale (1 × 9)

(To illustrate the Scale of Lesions in Silicosis)

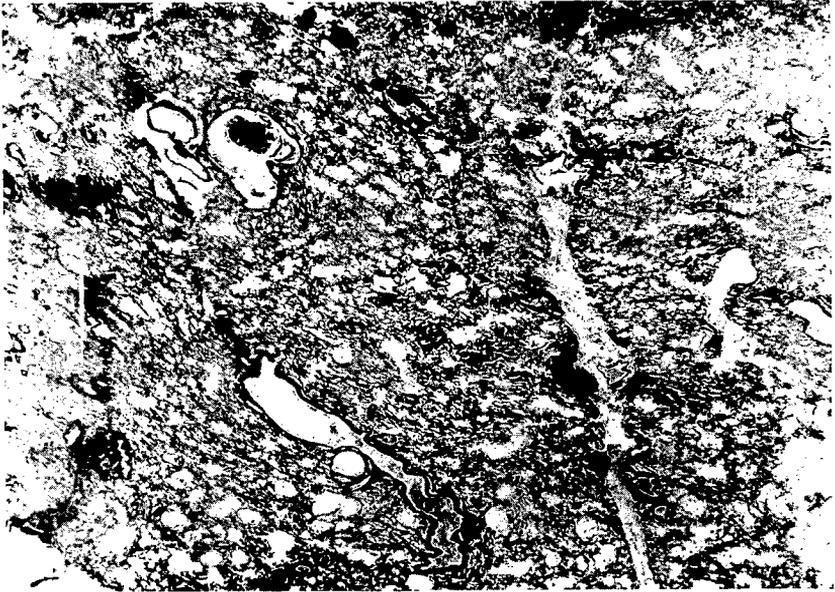


FIG. 5. — Condition corresponding to most radiographs of "Commencing Generalised Fibrosis". There is some excess of pigmentation, with one or two minute foci of fibro-blastic reaction. Bronchiolitis is present. The lung is congested.

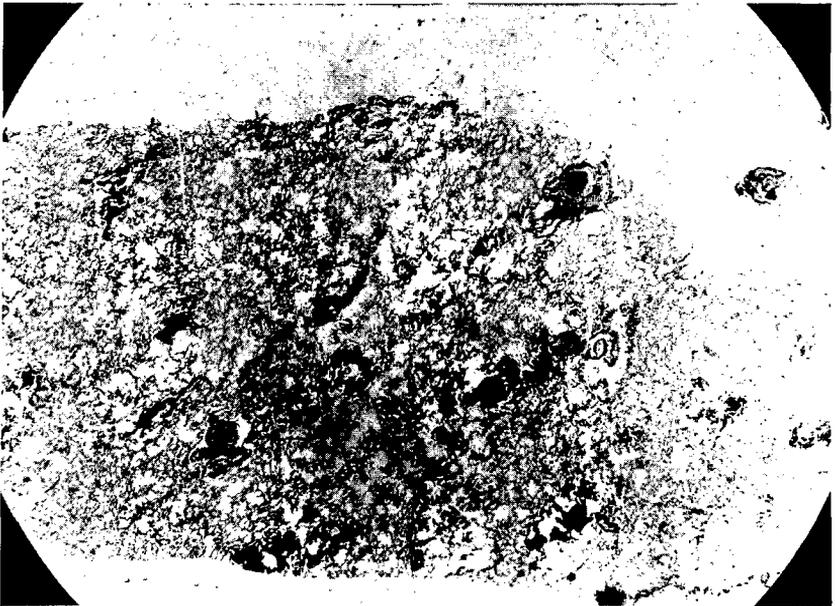


FIG. 6. — Slight degree of simple silicosis, with "small" miliary nodulation. The nodules shown are just palpable; there is no necrosis.

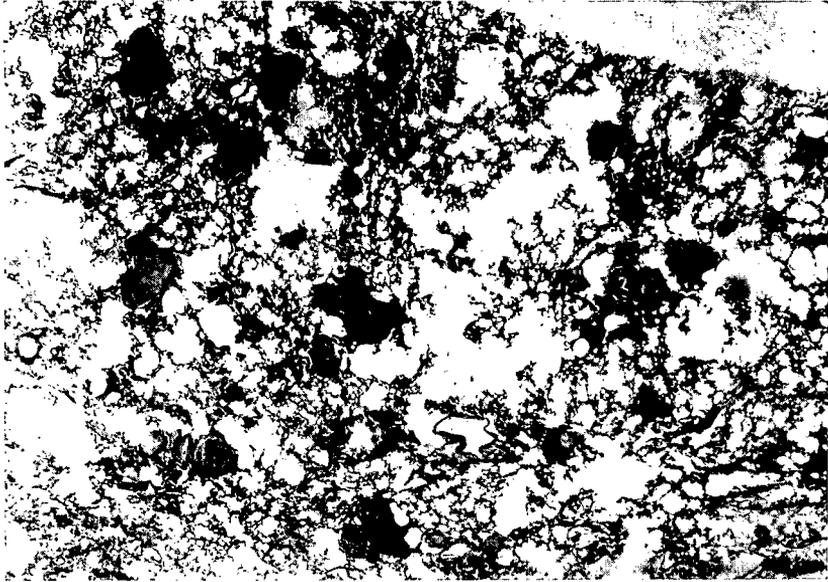


FIG. 7. — "Moderate" degree of simple silicosis. "Small" and "medium" sized nodules; the composite character of most of the latter is well seen; none show necrosis. There is some amount of emphysema, and the lung is congested. (Cf. fig. 1 and film 9.)

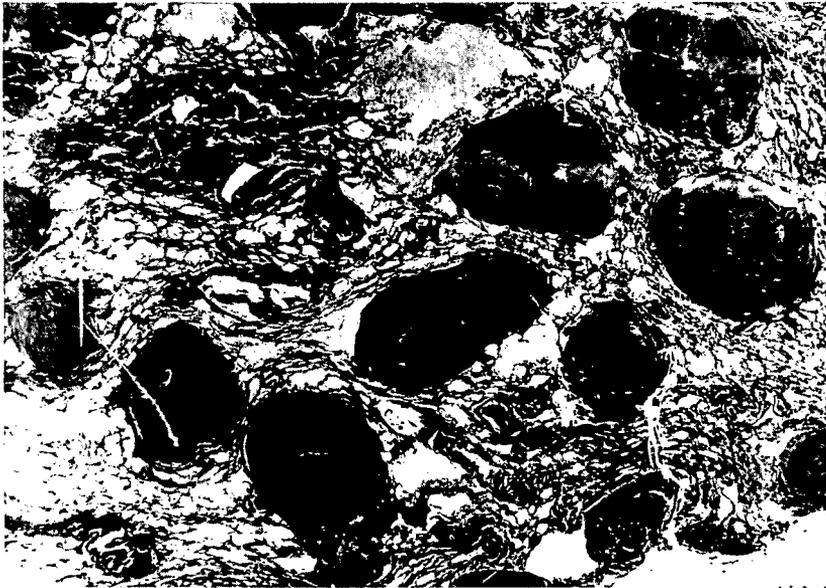


FIG. 8. — "Very well-marked" or "advanced," degree of simple silicosis. The section shows a cluster of "large" nodules of silicotic type. Most are of composite structure: none show necrosis. (Cf. fig. 2 and film 13.)

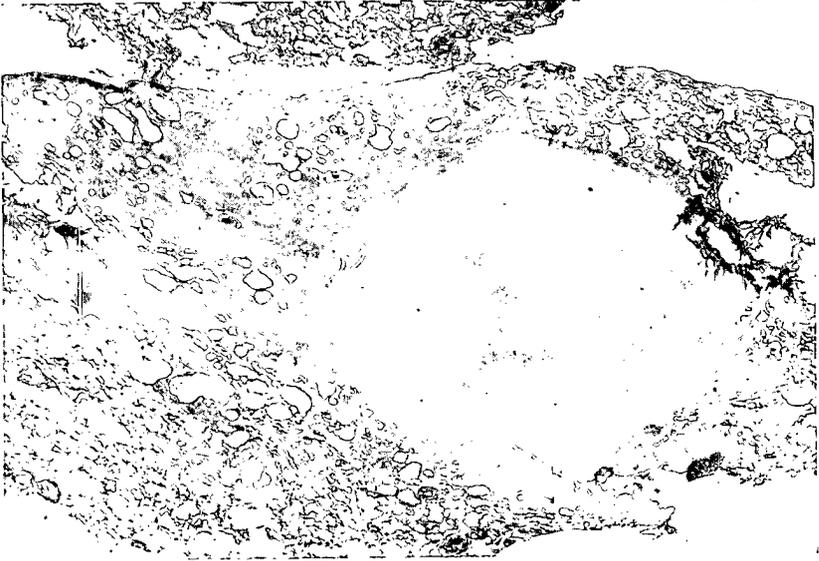


FIG. 9. — Tuberculo-silicosis. "Very large" isolated tuberculo-silicotic nodule, with massive necrosis.

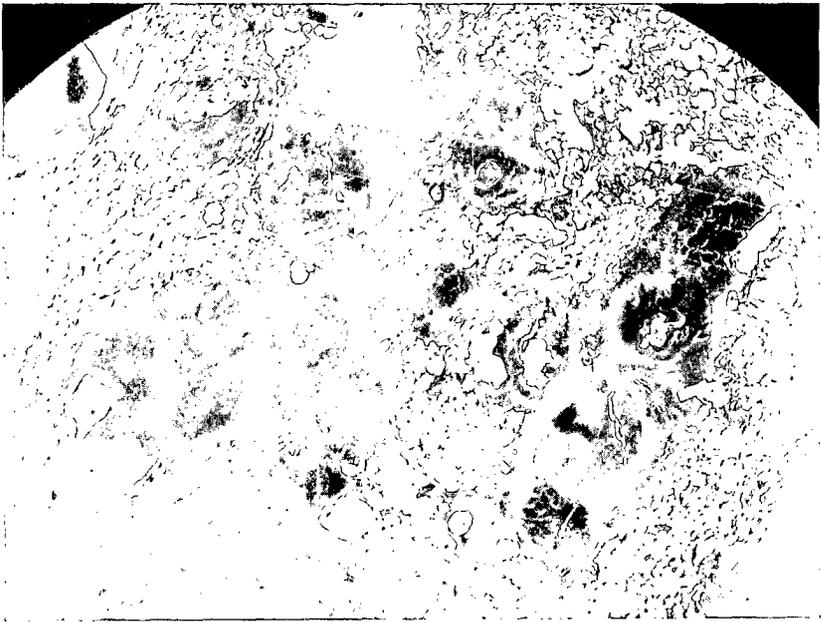


FIG. 9 A. — Infective nodules associated with slight degree of silicosis. The silicotic islets are small and are embedded in limited areas of tuberculous infection.



FIG. 40. — Tuberculo-silicosis. Section from an area of massive tuberculo-silicotic consolidation. Foci of active tuberculosis are present.

Physical Types in Silicosis

THE ROBUST TYPE

FIG. 11 B.

FIG. 11 A.

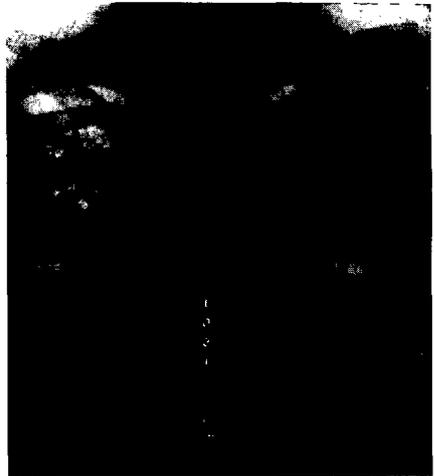


FIG. 11 A. — Photograph of case of advanced silicosis in elderly man of originally robust type. Note the characteristic "semi-emphysematous" conformation of the chest and the tendency to obesity which is common in this type of case.

FIG. 11 B. — From a radiograph of his chest. This man is still actively engaged as a surface mine official. He was first found to have silicosis over twelve years ago.

FIG. 12 B.

FIG. 12 A.

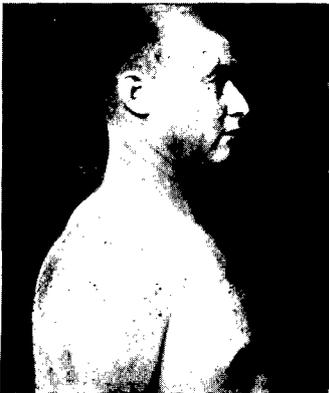


FIG. 12 A. — Photograph of well-marked case of simple silicosis in individual of originally robust type. His radiograph, FIG. 12 B, shows a well marked silicosis of the "classical" type. This man is still actively engaged as a senior underground official, and states that he is as well as ever; he plays golf and goes shooting when on holiday. He was first certified to have silicosis eight years ago.

THE PHTHINOID TYPE

FIG. 13 B.

FIG. 13 A.



FIG. 13 A. — Photograph of well-marked case of tuberculo-silicosis in originally phthinoid type of man.

FIG. 13 B. — A print of his radiograph. It shows bilateral sub-apical consolidation, the appearances being those of a fibroid phthisis. The lesions have remained stationary for at least five years. He is in fair but not good health, but is still engaged in fruit farming. He was first found to have silicosis eleven years ago; he was then a highly placed mine official. (Film 18 is also taken from this case.)

FIG. 14 B.

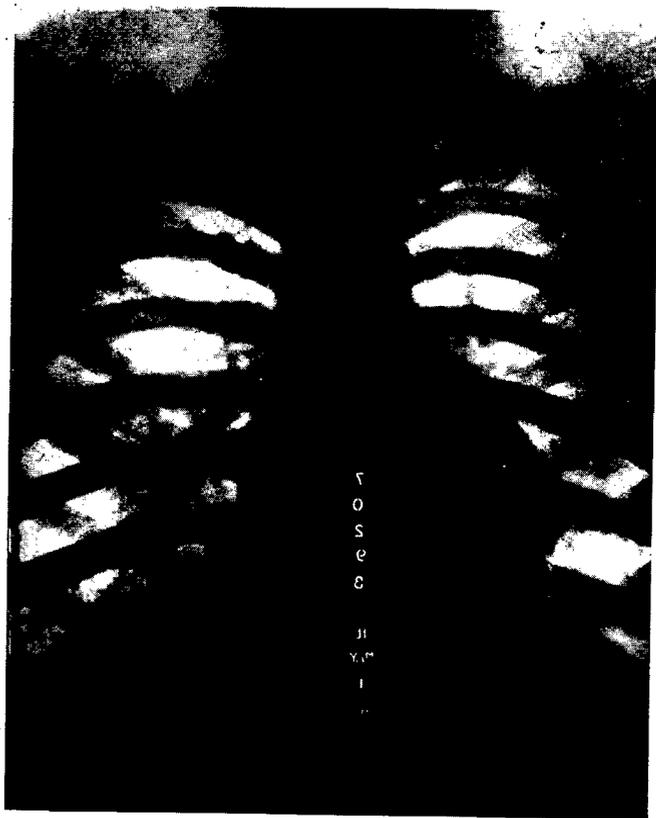
FIG. 14 A.



FIG. 14 A. — Photograph of case of moderate silicosis in an initially phthinoid type of man.

FIG. 14 B. — A print of his radiograph, which is of infective type. This man is quite healthy, but short of wind; he is employed as an assistant storekeeper. He left underground work twenty-one years ago.

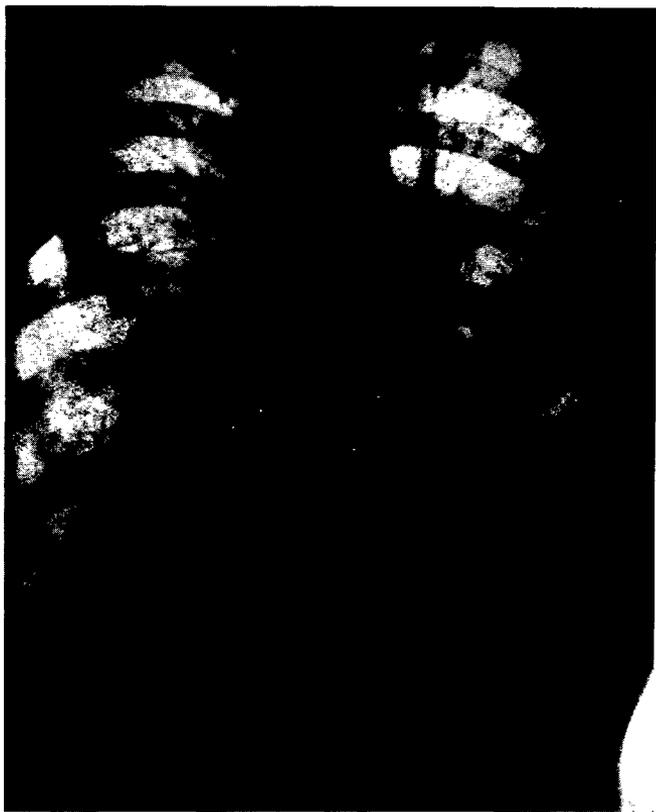
Series of Radiographs to Illustrate the Radiology of Silicosis



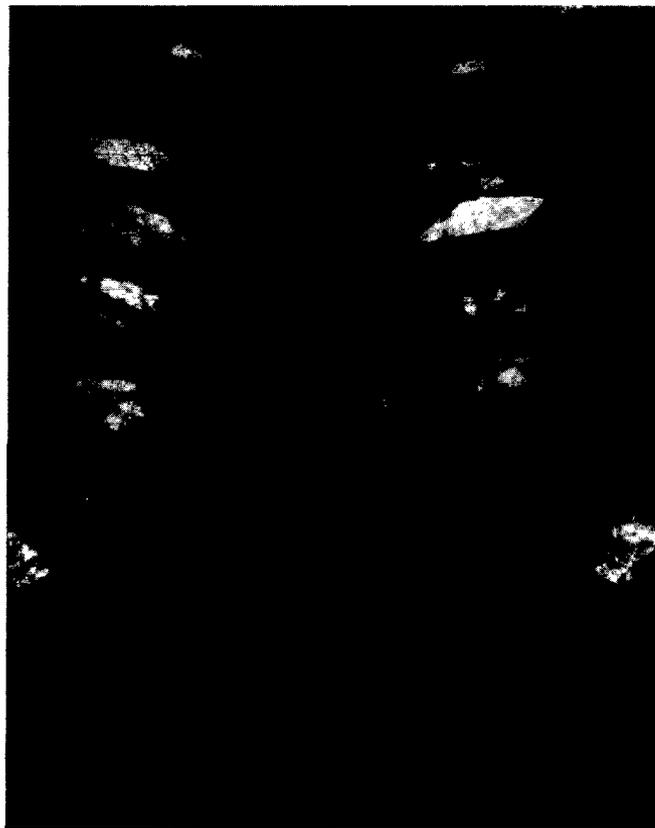
FILM No. 1. — Normal Thorax.



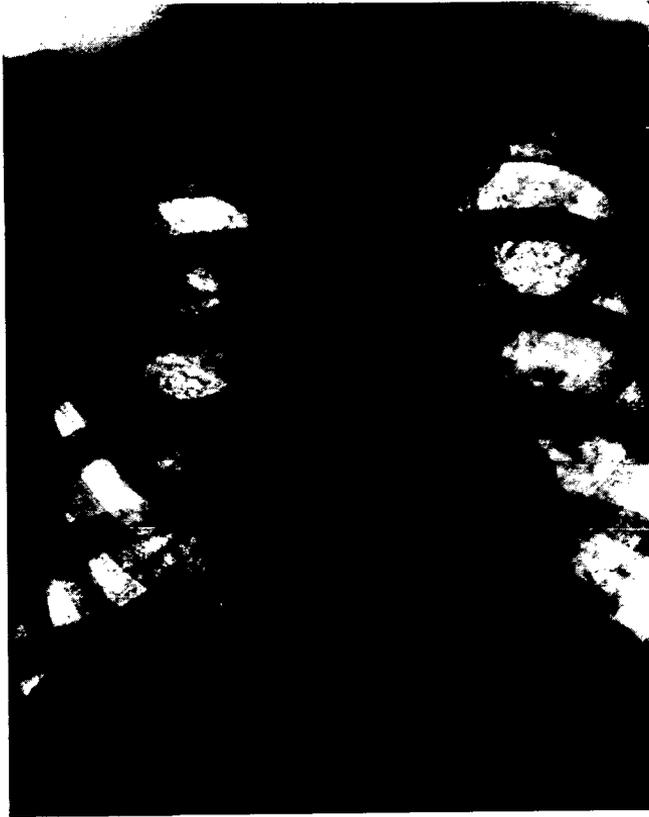
FILM No. 2. — Rather More Fibrosis than Usual.



FILM No. 5. — More Fibrosis than Usual,
partly Infective in type.



FILM No. 6. — Simple Commencing Generalised Fibrosis.



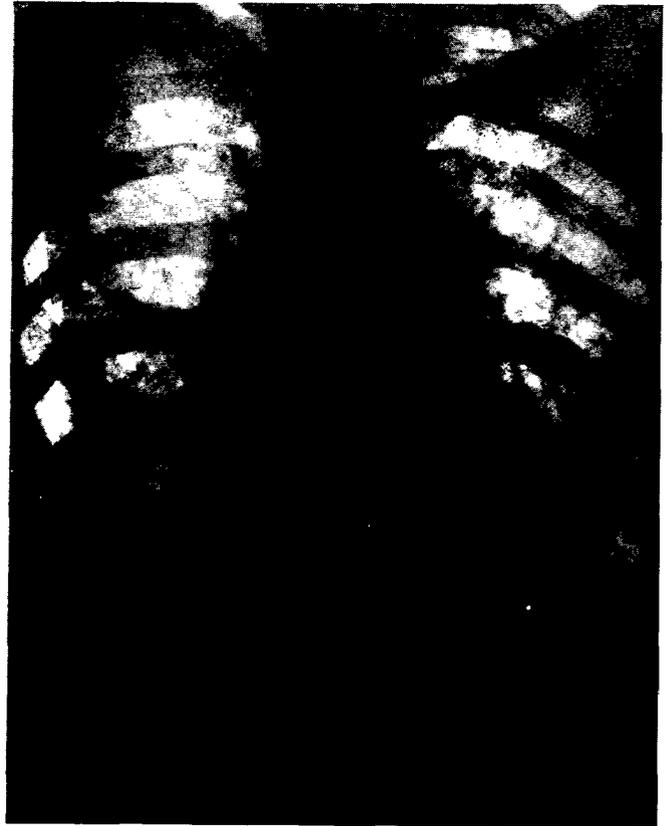
FILM No. 7. — Commencing Generalised Fibrosis,
partly Silicotic in type. Characteristic film of slight degree
of Silicosis.



FILM No. 8. — Commencing Generalised Fibrosis,
partly Infective in type.



FILM No. 9. — Moderate Generalised Fibrosis, Silicotic in type.
Moderate degree of Silicosis. (Cf. figs. 1 and 7.)



FILM No. 10. — Moderate Generalised Fibrosis,
partly Infective in type.



FILM No. 11. — Well-marked Fibrosis, Silicotic in type.
Well-marked degree of Silicosis



FILM No. 12. — Well-marked Fibrosis,
partly Infective in type.



FILM No. 13. — Very well-marked degree of Fibrosis, Silicotic in type. Very well-marked Silicosis. (Cf. figs. 2 and 8.)



FILM No. 14. — Very well-marked degree of Fibrosis, partly Infective in type.



FILM No. 15. — Gross Fibrosis, Silicotic in type.
Advanced Silicosis.



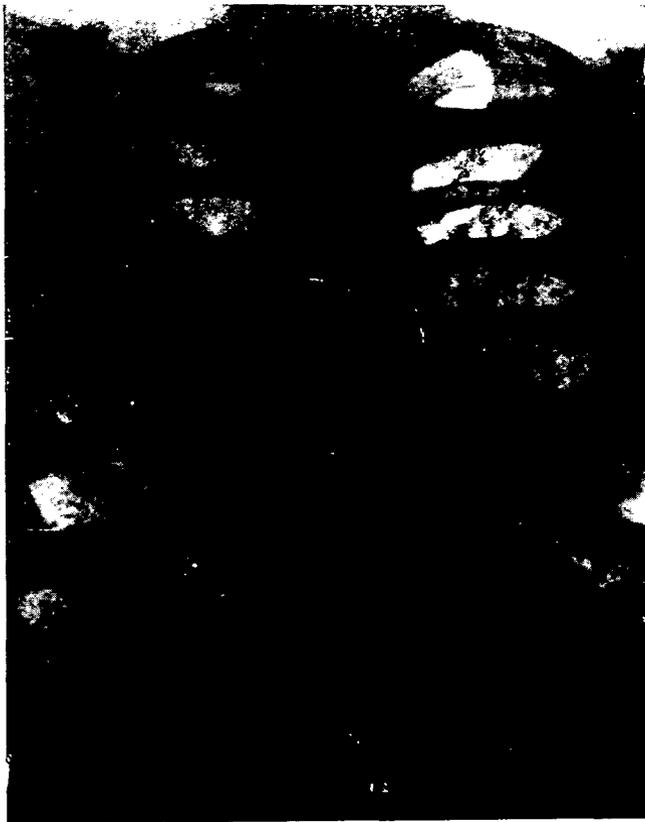
FILM No. 16. — Gross Fibrosis, partly Infective in type.



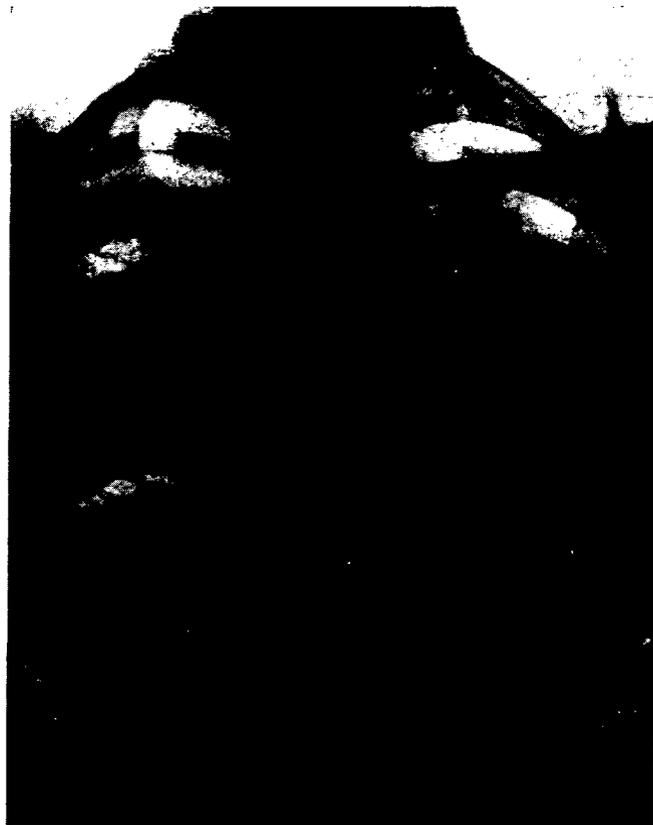
FILM No. 17. — Well-marked Silicosis,
with general Calcareous Deposit in nodules.



FILM No. 18. — Case of very chronic Tuberculo-silicosis.
The lesions shown have remained stationary for five years.



FILM. No. 19. — Moderate degree of Silicosis
with Tuberculosis.



FILM No. 20. — Well-marked degree of Silicosis
with Tuberculosis.



FILM No. 24. — Very well-marked degree of Silicosis with Tuberculosis or Tuberculo-silicosis. (Cf. fig. 3.)



FILM No. 22. — Advanced Silicosis with Tuberculosis, or Tuberculo-silicosis.

SILICOSIS IN AUSTRALIA

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HEALTH, AUSTRALIA

The rapid increase in the population of Australia which marked the latter half of last century was due in great part to the discovery in several parts of the Continent of rich alluvial gold fields. A large proportion of the migrants of this period came from mining districts in England and other countries.

The resultant stimulus to prospecting brought about the discovery of other metalliferous deposits, and to-day many of the Australian mining fields bear names such as Bendigo, Broken Hill, Kalgoorlie, which are almost household words.

The conditions under which deep mining was carried out in the earlier days exacted a heavy toll of lives from those who were connected with the industry. The advent of modern procedure involving the use of water in drilling and more meticulous attention to ventilation, dust prevention and the regulation of blasting has doubtless resulted in saving many lives. Silicosis has been demonstrated in many of the mining fields and a high death-rate from pulmonary diseases, including tuberculosis, has been evidenced in association with the industry. The following table shows the increase in mortality from phthisis during the development of the mining industry in the Bendigo district:

ANNUAL MORTALITY FROM PHTHISIS PER 10,000 OF POPULATION
AMONGST MALES AGED 21 AND UPWARDS

Period	Bendigo and district	Victoria
1870-1872	35.33	22.15
1880-1882	60.44	26.89
1890-1892	77.90	26.37
1900-1902	77.36	23.18
1903-1905	62.29	20.81

The following table shows the mortality in the occupational group, mining and quarrying, as compared with the average general mortality during the years 1908-1914. These figures are taken from a table published by the New South Wales Board of Trade in 1919:

State	Average number of mining employees	Average number of deaths per year	Death-rate per group	Annual death-rate per 1,000 population
New South Wales	37,715	593	15.7	13.9
Victoria	16,363	508	31.0	27.5
Queensland	13,586	282	20.7	18.5
South Australia	6,614	84	12.7	11.2
Northern Territory				
Western Australia	16,118	218	13.5	12.0
Tasmania	5,662	58	10.2	9.1
Commonwealth	96,058	1,743	18.2	16.1

New South Wales

INVESTIGATIONS AND ENQUIRIES

During the reticulation of Sydney with a system of sewers attention was focussed on the conditions under which the men were working, and a Sewer Works Ventilation Board was appointed in 1902 to enquire into the working conditions and to recommend, where possible, any means of improvement whereby the work might be rendered less hazardous.

The principal country rock on which Sydney stands is sandstone containing over 90 per cent. of silica.

The Board found that "for many years past miners employed on this class of work (tunnelling) suffered acutely from a disease which was for a long time known by the rather misleading term 'sewer disease', but as the complaint became more widely known it was strongly suspected that dust was the chief cause of the mischief".

The Board blamed the fumes of explosives and the expired air from the lungs of the miners in tunnels, imperfectly ventilated, as causes contributory to the high mortality, but stated that the dust from hammering, drilling and the use of the pickaxe was probably the sole cause of the disease once known as "sewer disease".

The first recommendation of the Board was the prevention of

dust. Next, efficient ventilation was recommended and suitable change-house accommodation. The work of a sewer miner in tunnelling sandstone was regarded by the Board as a dangerous occupation and a day of six hours was recommended for these men.

In 1907 another Committee was appointed in Sydney to enquire and report on methods of excavation in trenches and tunnels through sandstone where blasting operations are limited or not permissible, and as to whether the methods in use might be improved and made less dangerous to the workers by the use of rock-cutting or boring machinery. The terms of reference of this Committee also included an enquiry into rates of pay and hours of work.

The Committee reported that the best method of preventing diseases from dust would be the introduction of machinery. Six hours were recommended as a day's work, and it was also recommended that £500 should be made available for experiments with rock-cutting machinery. Exhaust ventilation was advised in place of forcing air to the working face.

In 1912 a reported epidemic of pneumonia at Broken Hill was investigated by Armstrong, who reported that the death-rate from pneumonia among underground miners in that locality during 1910-1912 was 6.5 per thousand or nearly four times as great as that for all males in New South Wales. The death rate from pneumonia for females in Broken Hill was only slightly higher than that for females in the rest of the State.

In 1914 a Royal Commission was appointed to enquire into the mining industry at Broken Hill. With regard to industrial diseases, this Commission stated that pneumoconiosis and plumbism were among the risks of a miner's calling, while other diseases—for example, pneumonia—were added risks of the calling, but not strictly industrial because they affected others than miners. From unanimous medical testimony the Commission concluded that pneumonia was more prevalent, severe and fatal, among miners in Broken Hill than in any other class in the State. While attributing sudden changes in temperature as the prime cause, the Commission advanced the opinion that dust inhalation in any form would predispose to the disease.

This Commission expressed the opinion that pneumoconiosis was practically unknown at Broken Hill and blamed mining in other States for such cases as had been noted. Tuberculosis was a disease to which the Broken Hill miners, as elsewhere, were peculiarly subject, and the presence of tuberculous patients in a mine was considered particularly dangerous.

This Commission recommended exclusion from mines of men suffering from tuberculosis or pneumoconiosis, medical examination prior to employment, compensation of sufferers from pneumoconiosis or tuberculosis, and that the dependants of the latter should be a charge on the State.

In 1916 a forty-four-hour week was granted by the Commonwealth Court of Conciliation and Arbitration for underground men at Broken Hill, largely on account of the association between working conditions and the incidence of pneumonia and tuberculosis.

In 1919 the New South Wales Board of Trade, in response to a request by the Government, after reviewing the available information concerning pneumoconiosis, concluded that, while there was an undue mortality from pulmonary disease in the case of stone masons and sandstone quarrymen working on stone containing free crystalline quartz, there was not sufficient evidence to form an opinion as to the prevalence of these diseases among miners, and recommended that a Technical Commission of Enquiry be constituted to ascertain the actual facts, "using clinical and radiological means". As a result of this recommendation, in December 1919 a Technical Commission was constituted to examine the miners at Broken Hill. This Commission, for the first time in Australia, used X-rays as a means of diagnosis of silicosis as an occupational disease.

In its preliminary report the Commission records the results of examination of 4,337 mine employees. In 370 of these, the examinations were incomplete. Of the total, 193 cases of pneumoconiosis were diagnosed, 90 in the first stage, 44 in the second and, in 59 cases, complicated with tuberculosis. In addition, 39 cases were definitely diagnosed as suffering from pulmonary tuberculosis only, and in a further 26 it was thought "highly probable that these persons were suffering from uncomplicated pulmonary tuberculosis".

The Commission defined the stages of pneumoconiosis on which the diagnoses were founded as follows:

A person in the first stage of the disease shows no impairment of his working capacity and of his general health. The photographs taken with the X-rays show the presence of an early fibrosis in the lungs.

A person in the second stage exhibits a more advanced fibrosis in the X-ray photographs and in some individuals clinical evidence of the presence of the disease.

In the third form, radiographic and clinical evidence of infection with tuberculosis is present.

Tubercular infection may supervene in either the first or second stage of pneumoconiosis.

The Commission found that pneumoconiosis arises in Broken Hill as a result of inhalation of dust among those persons who have been engaged in drilling and blasting underground and concluded that " pneumoconiosis arising as a result of work in Broken Hill only progresses so slowly that no impairment of working capacity occurs previous to infection with tuberculosis ".

The Commission recommended exclusion from the mines and compensation of all persons suffering from tuberculosis; also that no person suffering from pneumoconiosis should be allowed to continue working on the mines. The reasons given for the last-mentioned recommendation were: increased liability of such persons to tuberculosis and pneumonia, and other pulmonary diseases will be more severe and more fatal; such persons should follow an open-air occupation, agricultural or pastoral, and will thus be brought less frequently into contact with other persons and less often exposed to tuberculous infection; they should be kept under observation and a scheme for employment prepared.

In a further report in 1922 on 6,538 miners, the Commission stated that the form of pneumoconiosis found at Broken Hill is characterised by changes along the air passages and beneath the pleural covering of the lungs and by scanty affection of those parts directly concerned with respiratory exchanges. This form of pneumoconiosis was stated to differ from those found among miners at Bendigo, Cobar and Kalgoorlie, and among rock-choppers in the Sydney sandstone.

Of 2,618 underground men examined, 266 showed pneumoconiosis, 113 in the first stage, 51 in the second stage, and 102 complicated by tuberculosis; 107 additional men were diagnosed as suffering from tuberculosis only.

As a result, two Special Rules applying to the Broken Hill district were incorporated in the Mines Inspection Act of New South Wales regulating firing as far as possible to the end of shift, and requiring the moistening of ore being filled or moved in any working place, to prevent the escape of dust.

A Bureau of Medical Inspection was established to follow up the work of the Commission by examination of applicants for employment under the Workmen's Compensation (Broken Hill) Act, 1920.

Dr. S. A. Smith, of the Technical Commission, later analysed certain important features of the relationship between pneumoconiosis and tuberculosis.

He found that of 8,966 men examined, 322 showed changes due to dust; of these, 148 or 46 per cent. suffered from tuberculosis.

Of the remaining 8,644 who showed no changes due to dust, 161 or only 2 per cent. suffered from tuberculosis.

Of the 177 men showing simple fibrosis the subsequent history was followed for two and a half years and resulted as follows:

Place	Total number	Number who developed tuberculosis
Broken Hill	101	27
Adelaide	19	7
Melbourne	6	—
Sydney	2	—
Ballarat and Bendigo	3	1
Newcastle	1	1
Griffith	34	1
River and Country	11	—
Cities	132	36 (27 per cent.)
Country	45	1 (2 per cent.)

Dr. Smith concludes that "changes in the lungs due to inhalation of mine dust produce a definite susceptibility to the development of pulmonary tuberculosis; that the development is most frequently not an activation of an old lesion but a new infection, and that the frequency of infection is proportional to the number of persons with whom the affected worker is daily brought in contact".

As a matter of interest, it may be mentioned here that the Broken Hill silver-lead lode was discovered in 1883 and still represents the main source of Australia's lead production, supporting a town of 17,000 inhabitants as well as the township of Port Pirie comprising a further 13,000 inhabitants. At this port the Broken Hill ore is smelted and the pure lead and other metals obtained. Mining operations are at present carried out to a great extent in sulphide ore which is sparsely intermixed with a gangue of rhodonite, a manganese compound with a low free silica content. Analyses of the country rock at Broken Hill have shown the silica content, free and combined, to vary between 60 and 70 per cent., of which less than half is free silica.

Broken Hill now represents the only considerable metalliferous mining field in active working in New South Wales, although many miners are still employed in tunnelling and quarrying operations in Sydney, working in siliceous rocks, chiefly sandstone.

In 1922, the New South Wales Board of Trade, in conjunction with the Commonwealth Department of Health investigated

clinically and radiologically the prevalence of pulmonary diseases amongst workers in sandstone and other siliceous rocks in the metropolitan district of Sydney. Of 716 men examined, 123 were found to be suffering from silicosis. Using the standards set down by the Broken Hill Commission, 47 of these were diagnosed as being in the first stage, 38 in the second and 38 were stated to be suffering from pneumoconiosis complicated by tuberculosis. In 16 men, pulmonary tuberculosis only was diagnosed.

In 1927 Dr. Charles Badham drew attention to a series of cases in which the X-ray films showed a very fine type of fibrosis (*Report of Director-General of Health, New South Wales, 31 December 1927, p. 102*). These cases came from tunnels around Sydney where the country rock contains a high proportion of combined silica. Dr. Badham considers that the fibrosis probably differs from true silicosis and suggests the term "Silicatosis" for such cases.

STANDARDS OF MINE VENTILATION

The Broken Hill Technical Commission in its report of 1922 regarded ventilation as the most important factor in the removal of dust from the mines, and stated as its opinion that an air current exceeding 20 feet per minute was sufficient to keep the suspended dust below the quantum necessary to give rise to pneumoconiosis. While this amount of air movement was not obtainable in large stopes, it was recommended that the working of mines be laid out to ensure as far as possible an air velocity of 20 feet per minute. Dependent on the dilution of the concentration of dust by a large volume of air, the Commission found that the passage of 5,000 cubic feet a minute past any working place would be sufficient to prevent the accumulation of dust in the air during the conduct of mining operations, except in the immediate neighbourhood of drilling operations without adequate water supply or where heaps of dry ore were being shovelled. The Commission stated that water must be used to assist ventilation in keeping down dust in these operations.

In 1924, Dr. Badham considered that 60 linear feet of air-movement per minute were necessary to keep the dust content low. He prescribed a standard of 200 dust particles per cubic centimetre for sandstone tunnelling and said that this "could in all well-ventilated works be halved". Dr. Badham used the Owens' dust sampler in his work, checking his results by gravimetric methods.

LEGISLATION

In 1920 a Workmen's Compensation (Silicosis) Act, 1920 (No. 13 of 1920), was passed in New South Wales to amend the Workmen's Compensation Act of 1916. The purpose of this Act was to enable the provision of a scheme of compensation to be paid by the employers to workmen certified to have suffered death or total disablement from fibroid phthisis or silicosis of the lungs, or from that disease complicated by tuberculosis or from any other pulmonary disease caused by exposure to silica or other dust, also to those men who though not totally disabled are found on medical examination to be suffering from any of the above diseases to such an extent as to make it dangerous to continue work in the industry. This Act applied to any man engaged in work involving exposure to silica dust, who had been continuously resident in New South Wales during five years immediately preceding the date of death or incapacity and who had been employed as specified for not less than three hundred days during that period, or to men who had been resident for five years out of seven and had been employed for at least five hundred days in that period.

Under this Act was produced in 1927 the Workmen's Compensation (Silicosis) Scheme No. 1, applying to stonemasons, quarrymen, rock-choppers and sewer miners in the Sydney area who are eligible under the residential and employment qualifications mentioned above, and who have been certified in accordance with the conditions prescribed in the Act.

Under this scheme the question of the award, amount and apportionment of compensation rests with the judgment of a Joint Committee appointed by the Minister under the scheme. Provision is made for the immediate payment of compensation by the employer in accordance with the general rate for the State in the case of death or total disablement and, where men are suspended from work owing to silicosis, but not totally disabled, for the payment after two weeks of a sum which will supplement, if necessary, his earnings making them equal to his previous earnings. This sum is paid from a general fund maintained by subscriptions from the employees, and which may be subsidised from time to time by Parliamentary vote. The subscriptions are fixed and levied as necessary by the Minister and the fund is administered by the Joint Committee. Provision is made under this scheme for the payment of lump-sum compensation, and the appointment of medical authorities for periodical examination and certification. The

onus for arranging preliminary medical examination is thrown on the employer, and the workman is obliged to submit himself for periodic and other examinations, to give the necessary true information in respect of his employment and not to re-engage in any industry affected by the scheme after suspension.

Employees in the mining industry at Broken Hill come under a special Act known as the Workmen's Compensation (Broken Hill) Act, 1920 (No. 36 of 1920), which is also construed with the Workmen's Compensation Act, 1916. This Act includes a scheme known as the Broken Hill Mines (Pneumoconiosis-Tuberculosis) Compensation Scheme.

The present medical authority under this scheme is appointed in Broken Hill by the Minister and includes the medical officer in charge of the Bureau, which has been in operation since 1922. Prior to the introduction of the scheme which is similar in details of operation to the Silicosis Scheme No. 1 described above, the Technical Commission of Enquiry represented the authority.

Victoria

GENERAL

The history of metal mining in Victoria is concerned mainly with gold, which was discovered on four large alluvial fields between July and December 1851. Of these fields the only one in which there has been any activity of recent years is Bendigo. Deep mining was commenced in this place shortly after 1870. The country rock consists of quartz, slates and sandstones with a high silica content. The field at present is in a very low state, less than a hundred men working underground where formerly there were thousands. At one time there were fifty-three shafts in operation, over 2,000 feet deep and several over 4,000 feet, the deepest reaching 4,614 feet.

The Ballarat field in which lode mining was formerly practised, although at no great depth, has been closed down for many years.

INVESTIGATIONS AND ENQUIRIES

In 1907 Summons submitted a report on miners' phthisis to the Committee of the Bendigo Hospital, stating that there was undue mortality among Bendigo miners and that this was due

to respiratory diseases, notably tuberculosis. He classified the cases examined according to two clinical types:

1. A pure fibrosis of the lungs, non-tuberculous in origin, which is silicosis.
2. The mixed type with a tuberculous infection in a fibroid lung.

Of those affected with either type, 47 per cent. had specific bacilli in the sputum. Summons stated that "although only 47 per cent. of cases are infected, all miners dying of lung complaint die of tuberculosis".

No further work of this nature was undertaken in Victoria until 1920, when D. G. Robertson investigated clinically the conditions amongst miners in Bendigo. He found the incidence of tuberculosis higher in Bendigo than in the rest of the State, and attributed this to the presence of old miners affected with pulmonary disease. A compensation scheme was recommended.

In 1928 the Commonwealth Department of Health conducted an investigation into the health and working conditions of employees in the metal-mining industry in Victoria and Tasmania at the request of the Commonwealth Court of Conciliation and Arbitration. In Bendigo sixty-one men were examined radiologically and clinically, representing 37 per cent. of the total metalliferous mine employees in the district. Among underground workers 9.4 per cent. were diagnosed as suffering from silicosis uncomplicated and a further 7.5 per cent. from silicosis and tuberculosis. Of all workers, 3.3 per cent. were found to be suffering from tuberculosis only.

MINE VENTILATION

In 1906 Summons stated that it is "unnecessary to demand that a fixed volume of air be supplied to the working faces for the quantity is only a means to produce the quality and to maintain less than 0.15 per cent. of carbon dioxide in the air".

The investigation by the Commonwealth Department of Health in 1928, referred to above, included an examination of the working conditions. In respect of three mines visited at Bendigo it is noted that the temperatures ranged from 61° F. to 76° F. and the relative humidity averaged 88 per cent. The dry katathermometer cooling power averaged 4.9, a figure stressing the need for improvement in ventilation. The recommendations included in the report of the mining engineer who conducted these inspections stated that in all drives and cross-cuts over 100 feet, and rises and winzes over

30 feet in length or depth, artificial means of ventilation should be adopted unless bratticing is effectively carried out. Further recommendations include the supply of an extra hose for wetting heaps of broken ore when shovelling, special precautions for supplying water when "collaring" and against fogging from machines, and the restriction of firing to times at which the mine will be empty of workers.

LEGISLATION

Industrial pulmonary diseases including tuberculosis are not included in the schedule of diseases for which compensation is paid in Victoria and no other legislation exists dealing with this subject.

The Mines Act, 1914, of Victoria contains the following clause relating to drilling: "No hole shall be bored or drilled by machinery underground unless a jet or spray of water shall be directed into and around such a hole."

Queensland

GENERAL

Gold was first discovered in Queensland at Gympie in 1867. The country rock in this field consists largely of limestone, shales and slates. In 1872 the Charters Towers field was discovered, and in 1882 the Mount Morgan gold and copper deposit was found and has been worked practically up till the present day. The country rock at Mount Morgan consists of limestones, banded claystones and tuffs with quartz-porphry dykes and sills and contains a fairly low silica content. Copper has been discovered at Cloncurry and mixed metallic deposits at Herberton and Chillagoe. All these fields are at present inactive, and the most active field at this time in Queensland is the Mount Isa silver-lead lode situated west of Cloncurry, far inland. The work at present in this area is wholly developmental.

COMMISSIONS AND ENQUIRIES

In 1911 a Royal Commission was appointed in Queensland to enquire into the working conditions in Queensland mines in relation to the health of the miners.

This Commission concluded that pulmonary fibrosis was not as common in Queensland as in Victoria and Western Australia, but

that pulmonary tuberculosis appeared to be a relatively frequent cause of death among metalliferous miners in Queensland. Recommendations were made dealing with dust-prevention, ventilation and sanitation.

The Commission considered that miners suffering from pulmonary or laryngeal tuberculosis should be excluded from underground work, provided that means be taken to deal with the predisposing causes of infection among miners and among the general population, also providing that the difficulties in connection with the medical examination and the collection and distribution of funds be overcome in a reasonably economical manner.

LEGISLATION

In 1915 the Queensland Government granted to mine employees suffering from pulmonary diseases a weekly allowance.

The Workers' Compensation Act, 1916 to 1926, of Queensland awards compensation for death or incapacitation from earning full wages at the work at which he was employed, as a result of certain industrial diseases. The list includes "silicosis of the lungs, miners' phthisis, pneumoconiosis, pulmonary tuberculosis".

South Australia

Although in the past copper was mined extensively at Wallaroo and Moonta, the mining industry of this State is now very small and confined to a few scattered enterprises. No investigations or enquiries have been made dealing with the health of miners.

Industrial pulmonary diseases are not subject to compensation.

Tasmania

GENERAL

Although small in area this State is very rich in mineral resources. Gold has been mined in the Northern part of the island and tin-sluicing and mining is still carried on in the North-eastern part, but it is the West coast on which the larger mining operations are now practised. The two most important fields are at Mount Lyell and Rosebery. At the latter place an extensive zinc field is being

developed around the site of two older mines, but relatively few men are employed here at present. At Mount Lyell a rich deposit of copper ore was first discovered in 1897. About 500 men are still employed underground here. The country rock is partly a conglomerate with quartzite pebbles embedded in a cementing matrix, and partly a schist. The silica content of the schist averages 60 per cent. and that of the conglomerate about 90 per cent. The ore contains about 63 per cent. silica, probably 50 to 60 per cent. in the free state.

INVESTIGATION

The only investigation into the health and working conditions of metalliferous mine employees in Tasmania was made in 1928 by the Commonwealth Department of Health. Reference has already been made to the Victorian portion of this enquiry.

In Tasmania the various mining centres were visited in turn and men examined clinically and radiologically practically at the mine-head. For radiological purposes a portable plant was used and was installed in the mine offices or in some suitable place close to the mine. At several mines the management permitted the men to undergo examination while on duty, and these men were brought to the surface during the working shift, examined and then returned to work.

In all, 650 mine employees volunteered for examination, comprising 65 per cent. of those available.

Of 314 underground employees, 5.9 per cent. were shown to be suffering from uncomplicated silicosis and 2.1 per cent. from silicosis with tuberculosis. Of all workers examined, 1.1 per cent. were found to be suffering from tuberculosis only, 1.2 per cent. in underground and 1.0 per cent. in surface workers.

Inspection of the industrial histories of examinees showed that there was a definite incidence of silicosis among those who had worked underground in Tasmania only, and also in Mount Lyell only, although in neither case was the incidence as high as that observed in Victorian mine employees. The incidence of tuberculosis, either alone or complicating silicosis, was found to be much lower in Tasmanian miners than in those examined at Bendigo.

MINE VENTILATION

The working conditions in Tasmanian mines were inspected and form the subject of a portion of the report in the above investigation.

The temperatures recorded ranged from 47.5° F. to 69° F. and the average relative humidity was 92 per cent. The dry katathermometer cooling power averaged 7.1, indicating satisfactory ventilation. Dust counts made with the Owens' instrument and checked by a gravimetric method were on the average satisfactory, but unnecessarily high in some places.

The recommendations regarding mine hygiene quoted in the section dealing with Victoria apply also to Tasmanian mines.

LEGISLATION

No industrial diseases are subject to compensation under Tasmanian law, although an Act was passed during 1929¹ in an endeavour to provide miners disabled through industrial disease with a pension.

Western Australia

Gold was discovered at Northampton in Western Australia in 1842 and at Kimberley in 1882, but it was not till the discovery of the Coolgardie field in 1893 and the later discovery of the adjacent Kalgoorlie field that the mining industry of the State began to flourish. To-day many fields are in operation in various parts of this large State, employing over 4,000 men, about 3,000 of whom work in the famous "Golden Mile" between Kalgoorlie and Boulder City. The mines here are worked in some instances to a depth of over 3,000 feet in a country rock consisting of quartz diabases, calc-schists and acid amphibolites. An analysis of the dust collected in a dry-crushing mill and measuring less than 10 microns in diameter shows 43.58 per cent. silica. The approximate proportion of free quartz in this dust is 19 per cent.

INVESTIGATIONS AND ENQUIRIES

The Western Australian gold-mining industry has been the subject of more Royal Commissions than that of any other State.

The first of these was a Royal Commission appointed in 1905 to enquire into the ventilation and sanitation of the mines in Western Australia. This Commission expressed itself as unable to form an opinion as to the degree to which miners suffered from pulmonary disorders. Although only two cases of silicosis of local origin had been reported to the Commission, the local hospital returns showed that diseases of the respiratory system fell heavily upon miners.

¹ INTERNATIONAL LABOUR OFFICE: *Legislative Series*, 1929, Austr. 2.

Assuming that the necessity for proper ventilation and sanitation was proven the Commission concerned itself with prescribing standards and procedures designed to secure efficiency in these.

The exclusion of persons suffering from tuberculosis of the respiratory organs from underground working was recommended, but not adopted, by the Government at that time.

In 1910 a Royal Commission was appointed to report upon pulmonary diseases among miners. The report of this Commission concluded:

The miner is more liable to lung disease generally than the average male over fifteen years of age. The miner is less long-lived than the average male over fifteen, partly on account of greater liability to lung diseases.

Tuberculosis of the lungs is on the increase among miners and is twice as prevalent as among all males over fifteen.

Pneumonia among the acute, and bronchitis, asthma, emphysema and fibrosis of the lungs among the chronic, lung diseases are more prevalent among miners than among males over fifteen.

Mine employees were physically examined and the conclusion was drawn that fibrosis of the lungs could be detected amongst various groups of men in increasing percentages according to exposure to silica dust at work; also that exposure over comparatively long periods was necessary before the onset of recognisable symptoms. Machine mining and dry-treatment work were noted as prominent causes of fibrosis, especially machine work. Non-machine miners and truckers were found to be affected although to a less extent, and after much longer periods. Tuberculosis was not commonly found. The principle was laid down that "any man suffers from fibrosis to the extent to which he is exposed to the continued inhalation of mineral dust. If there be no dust, there will be no fibrosis, and conversely, the continued inhalation of dust certainly produces some fibrosis".

The findings of the Commission prompted the appointment of another Royal Commission in 1911. This Commission found that "pneumoconiosis without the super-imposition of other diseases of the respiratory organs had not yet attained very alarming proportions in Western Australia, and if the precautions suggested be carried out gold mining will become very little more injurious to health than other industries".

Standards of procedure in respect of ventilation and dust prevention were prescribed and, for the first time in Australia, the recommendation was made that men suffering from tuberculosis or pneumoconiosis be excluded from mine work, and in order to

secure that this be effectively done, that every man should be medically examined before employment and all miners be medically examined at intervals of six months. The tuberculous person and his dependants were recommended as charges of the State and the pneumoconiosis patients to be compensated under an insurance scheme.

In 1925 as a result of the recommendation of the above Commission, an arrangement was made by the Western Australian Government whereby the Commonwealth Department of Health made a complete physical and radiological examination of all metalliferous mine employees in Western Australia. This was carried out in Kalgoorlie at the Commonwealth Health Laboratory and in the surrounding country districts by a travelling unit equipped with a portable X-ray apparatus.

The following standards of diagnosis were adopted:

"Normal." — No evidence of pulmonary lesions due to dust, tubercle bacilli or any other cause.

"More fibrosis than normal." — Lung abnormality but not silicosis or tuberculosis.

Three types are recognised: (a) healed or inactive lesions not due to dust; (b) reticular markings accentuated as from arteriosclerosis, old age, auto-intoxication, high blood pressure or renal disease; (c) the same accentuated linear markings from dust. Dust other than siliceous may cause this but is not progressive. The appearance radiographically is of a fine network but without mottling. It should be noted, however, that where tuberculosis also is present these come under "silicosis plus tuberculosis".

Subjects in this class were not reported under the Miners' Phthisis Act because: (i) the X-ray technique could not then secure uniformly reliable pictures; (ii) the same appearance was obtained in certain non-silicotic subjects; (iii) absence of symptoms; (iv) a clear definition was necessary of the group of cases coming within the meaning of the Act.

"Silicosis, early." — Fine mottling throughout; often breathlessness, cough and sputum; no physical signs.

"Silicosis, advanced." — Coarse mottling of the small "snowstorm" variety; often symptoms; phagocytic cells in the sputum containing dust; chest movements restricted in all movements; absence on inspection of the inspiratory bulging movement of the upper anterior part of the chest in the triangular areas between the lines joining the acromioclavicular and sterno-clavicular joints and nipple on each side; dull to percussion; restricted air-entry and harsh broncho-vesicular murmur; rales often heard at bases.

"Silicosis plus tuberculosis" and "Tuberculosis only". — Diagnosed on established clinical standards.

During 1925 and 1926 a total of 4,067 miners were examined. The results of this examination may be tabulated as follows:

	Number with silicosis	Per cent. of total	Silicosis plus tuberculosis	Per cent. of total	Tuberculosis only	Per cent. of total	Number examined
Surface workers	117	6.6	27	1.5	6	0.3	1,759
Underground workers	538	23.3	116	5.0	6	0.3	2,308
Total	655	16.1	143	3.5	12	0.3	4,067

Silicosis was not found in any case under forty years of age or with less than five years' underground work.

Since 1926 examinations have been made of the mine employees in Western Australia annually by the Commonwealth Department of Health. Of 2,290 men previously classed as normal in 1927, 30 or 1.3 per cent. were found on re-examination to be suffering from silicosis uncomplicated, and 13 or 0.5 per cent. from silicosis with tuberculosis. A further 3 or 0.2 per cent. had tuberculosis only. Of 491 diagnosed as silicotics, 86 or 17.5 per cent. showed silicosis with tuberculosis. In 1928, of 2,822 men classed as normal in the previous year, 48 or 1.7 per cent. had progressed to silicosis only, 11 or 0.4 per cent. to silico-tuberculosis, and 3 or 0.1 per cent. were found to be suffering from simple pulmonary tuberculosis. Of 425 silicotics, 25 or 5.9 per cent. showed signs of tuberculous complication on re-examination. In 1929, of 2,293 normals re-examined, 100 were diagnosed as silicotics. A further inspection of these cases, however, made it evident that the majority of these diagnoses were due to the introduction of improved plant and radiographic technique. It was considered that in only 26 or 1.1 per cent. of cases a definite advance had occurred in the disease.

MINE VENTILATION

In 1905 the Royal Commission on the Ventilation and Sanitation of Mines laid down the first standards of air-composition for mines in Western Australia. This prescribed a maximum of 0.15 per cent. of carbon dioxide and a maximum temperature of 85° F. in any part of the mine.

When this subject was brought under consideration by the Royal Commission of 1911 no standards were recommended, the Commission considering that further enquiry on the subject was necessary.

LEGISLATION

The first practical results of the recommendations of the Royal Commission of 1911 was the Miners' Phthisis Act of 1922 which was passed with the object of removing persons suffering from pulmonary tuberculosis from the industry, and the payment of compensation until suitable employment could be found for them. This Act was proclaimed on 7 September 1925, and provided that:

- (a) Every person engaged in mining operations be required to submit himself when required to an appointed medical officer for examination;
- (b) If on examination he is found to be not suffering from tuberculosis, he shall receive a certificate to that effect;
- (c) If on examination he is found to be suffering from tuberculosis, the Minister may prohibit his employment in any mine;
- (d) If on examination he is found to have developed definite symptoms of miners' phthisis uncomplicated by tuberculosis as to indicate that further employment in, on or about a mine may be detrimental to his future health, the Minister shall notify him accordingly.

Compensation for tuberculosis amounts to the ruling rate of pay in the districts in which the sufferer was employed at the time of prohibition of employment, until other suitable employment is found and offered by the Mines Department.

Under the Miners' Phthisis Amendment Act of 1925, if any prohibited person is or has become unable to work at any suitable employment, compensation as above shall cease to be payable, but such person shall be entitled to receive compensation not less than as prescribed by the scale of relief in force at the commencement of this Act, under the rules of the Mine Workers' Relief Fund, and similar compensation is accorded the dependants on the death of any such person.

SILICOSIS IN BELGIUM

BY DR. D. GLIBERT, BRUSSELS

The study of silicosis may even at the present time be said to have made very little progress in Belgium. Only the stage of establishing contact with this important problem has been reached, and the efforts of a few experts are at present concentrated in first of all bringing to the notice of medical circles knowledge of the results obtained in countries where for years back the question has been thoroughly investigated. It may be asserted that the question of the diagnosis of silicosis has so far hardly received the attention of the great majority of medical practitioners in our country.

As regards public opinion, almost complete ignorance reigns in regard to this matter. The workers' organisations themselves, representing as they do the most interested parties, would appear to show little or no concern in regard to the problem. At most a few articles have appeared in the daily political press, but this isolated effort has met with no echo.

In official administrative spheres action has consisted in the appointment of a non-official committee, but up to the present no really practical measure has been taken to obtain a comprehensive view of the subject.

This delay would appear to be due to several causes, the principal of which are as follows:

The Government, and more particularly the medical factory inspectorate, has at its disposal neither radiographic installations nor the experienced staff required for this delicate research work.

The extremely restricted credits granted are besides earmarked for definite purposes which exclude the possibility of the use of funds for effecting costly studies of this kind. It would be necessary, in order to form a well-grounded opinion on the subject, to examine a great number of patients, to have at one's disposal numerous radiographs, and in consequence to

involve relatively high expense. Nevertheless, thanks to special subsidies voted with a view to Government participation in the Liège Exhibition, the medical factory inspectorate has been able to make a certain number of radiographs which will be submitted to public view on the stands of the group designated "Social Insurance and Social Welfare". This will ensure effective propaganda amongst those best adapted to profit by a knowledge of the question.

The obstacles referred to above, however, are far from being those most radically opposed to a practical and extensive study of silicosis in Belgium.

The economic state of the country together with its industrial requirements are at present such that the greatest care must be taken to prevent manual labour from quitting certain industries in which, up till quite recent times, labour has been rather scarce. In principle employers are in favour of research effected in relation to the health of their workers. Many of them even encourage such research, yet all of them are insistent on the necessity of progressing with discretion and preferably limiting action to profiting by circumstances when workers spontaneously present themselves for medical examination, complaining of symptoms connected with the respiratory system. It is evident that in such conditions there is a risk that lack of positive data in sufficient number may yet delay the solution of the problem in Belgium for a long time.

It is good to be able to add, with a view to qualifying the lack of encouragement in the preceding paragraphs, that a new fact has just occurred which is capable of modifying considerably the situation. The Government has just granted a considerable subsidy (100,000,000 francs) for the anti-tuberculosis campaign.

Silicosis being often complicated with this disease to such a point that the two are associated under the names silico-tuberculosis and tuberculo-silicosis, it will probably be possible to organise a fairly extensive enquiry relative to silicosis properly so called. So far unofficial contact has been established with the medical authorities on whom shall rest the responsibility of organising this great campaign, which is in course of preparation. The above facts, however, only constitute matter for hope. In the meantime, a few facts are given below which show that here and there isolated research workers are engaged in praiseworthy efforts with a view to contributing by their personal research to a solution of the problem.

Dr. Courtois, attached to the Marcinelle Sanatorium, an institu-

tion founded fairly recently, presented to the last sitting of the Society of Scientific Studies on Tuberculosis an excellent work on the relation between tuberculosis and anthracosis occurring amongst sanatorium patients drawn from the mining population. The discussion of the question thus instituted will eventually be carried further.

Dr. Denet-Kravitz, Director of the Medical Social Dispensary of the Henricot Factories at Court-St. Etienne (Metallurgy), has interested himself particularly in the question.

In a note which he has sent me he states:

The first victims of silicosis which I had a chance of observing before the war or immediately after the armistice were authentic tubercular subjects dying more of tuberculosis than of pneumoconiosis properly so called.

I have since then (in 1920) systematically examined all the workers who, amongst those submitted to me for examination, seemed to me likely to develop silicosis, the examinations in question being therefore preventive examinations of "non-sick workers".

My first observations, published in January 1924, in the *Belgian Tuberculosis Review*, led to the following conclusions:

- (1) Radiography is the only means of following the disease in its initial stages, clinical examination and radioscopy being insufficient.
- (2) At the outset of the disease there is seen to develop a bundle of shadows, the accentuation of normal vascular and bronchial shadows starting from the hilum and spreading fanwise, then subsequently, contemporaneously with the lengthening of these shadows, a reticulated area which becomes closer and closer.
- (3) Most frequently the apices are clear.
- (4) The affection is not necessarily bi-lateral.
- (5) Aggravation of the process is not in proportion to the length of exposure to the dust, the individual factor here playing a role of great importance (lymphatism).

I should like to draw attention to the fact that the results of my examinations are in accordance with the already old histological results obtained by Arnold, which showed the anatomopathological modification of the lymphatics.

In consequence of other observations published in the *Belgian Tuberculosis Review*, March-April-May 1926, I was led to conclude a scleroginuous fibrotying action of the silica.

In the March-April 1928 number of the same *Review*, I described a case of nodular pulmonary sclerosis, interesting by reason of the fact that I had had the man in question under observation since 1921, at which time he still presented a negative radiological image and that having radiographed him periodically I had seen develop little by little an image comparable, one might say, to that of the corymbiform granular form of pneumoconiosis starting from the hilar regions, and that though the patient had been for a long time withdrawn from the action of the vulnerating agent the process had continued (see Böhme). The B.C.G.

reaction (Calmette-Guerin test) had always been negative as well as the test for the bacillus in the sputum.

In No. 6, March 1928, of the *Review of Industrial Accidents*, I resumed my former observations, drawing a striking comparison between them and the works of Drs. Leon Bernard, Potter and Thomas on pulmonary sclerosis with arrested development, containing radiology identical with that which I had found for the sclerotic subjects at the outset—identical to such an extent that I was forced to ask myself if different causes might not be capable of setting up phenomena of the same character in specially predisposed subjects.

In the early cases which I have been able to observe there could have been no question of tuberculosis. In the pseudo-granular case (*le cas de pseudogranulie*) perhaps there is association, even though there ought to be taken into account the fact that this case has been developing for nine years back.

Finally, Dr. Stassen, Director of the Provincial Institution at Liège for the Study of Occupational Diseases, sends me the following communication:

Pneumoconioses other than pulmonary anthracosis have also been made the subject of certain researches in the Province of Liège. On the initiative of the Permanent Deputation an enquiry was made in 1924 in the district of the Ourthe and Amblève quarries with a view to discovering whether diseases of the respiratory passages were particularly frequent amongst the quarrymen.

All the quarrymen suffering from pulmonary affections who believed in any direct or slight connection between such affection and defective working conditions were invited by posters to present themselves at certain hours fixed in advance for examination by the medical investigators. The latter in the course of their visit at the same time established contact with the medical practitioners in the neighbourhood of the quarries.

The enquiry lasted for six weeks, one sitting being held each week: 20 workers suffering from affections of the respiratory passages offered themselves for examination; 5 cases were retained as possibly being due to silicosis.

Two cases were radiographed, but the radiographic plates as well as the radiosopic images did not permit in any case of the detection of the characteristic signs of silicosis. The plates assembled did not differ remarkably from the radiographic plates of lungs infected by tuberculosis.

Amongst the tunnellers and perforating-machine men employed in excavating roads through stone strata in the coal mines we have found about 10 cases which might be suspected of being silicosis. As in the case of the quarrymen, however, the radiographic plates were not characteristic and might be confused with plates of other affections having no relation to the working conditions of the men in question.

SILICOSIS IN CANADA

BY J. G. CUNNINGHAM, M.B., DIRECTOR, DIVISION OF
INDUSTRIAL HYGIENE, DEPARTMENT OF HEALTH, ONTARIO

From east to west in Canada, there is a widely diversified mineral production. Some of these operations are on a large scale. Gold is mined in nearly every Province. Nickel is limited to Ontario and asbestos to Quebec. Copper is important in British Columbia, Ontario and Quebec.

In manufactured products, Canada is second among the countries in the British Empire, and in terms of their gross value 80 per cent. of this industrial activity is centred in Ontario and Quebec. It is natural that industrial hygiene activities should have developed first in these two Provinces. Ontario established a Division of Industrial Hygiene in the Department of Health in 1920, and in Quebec such a Division was established in the Public Health Department of McGill University in 1928.

"Miners' phthisis" was included in the list of compensatable diseases enumerated in the Workmen's Compensation Act of Ontario in 1917. Its legal interpretation requires the presence of silicosis with active tuberculosis in a miner. The first case was compensated in 1924 on medical evidence submitted by Dr. C. D. Parfitt.

In the Alberta Workmen's Compensation Act, the disease in 1928 was designated: "Pneumoconiosis which shall be deemed silicosis, siderosis, lithosis in quarrying, cutting, crushing, grinding or polishing of stone, or grinding or polishing of metal. Mining." No cases have been compensated.

The Nova Scotia and British Columbia Workmen's Compensation Acts, while they do not specify silicosis as a compensatable disease, enable the workman to claim compensation for disease due to occupation as though it were a compensatable injury.

In Saskatchewan, the Workmen's Compensation Act, not yet in operation, provides for compensation of industrial workers suffering from silicosis, and for making regulations for the prevention of this and similar industrial diseases when necessary.

In Manitoba, in 1929, a Bill was introduced to the Legislature providing for the compensation and prevention of silicosis. This was set aside pending the recommendations of a General Committee now considering the existing Workmen's Compensation Act. In the meantime, the Mines Department has drafted rules, not yet in effect, intended to control the hazards from dust and tuberculosis in mines. Recently, the Provincial Department of Health has established a clinic for the examination of gold miners to determine whether silicosis is present.

In Ontario, silicosis has been the subject of clinical enquiry, particularly in the mining industry, in quarrying and among granite cutters. The pathology of the disease has been studied. The results follow.

Attention was first directed to the subject in 1924 in an article, "Silicosis in Ontario Gold Mines", by Dr. J. H. Elliott, who reported physical examination findings in eleven men who had been engaged in underground work in the Porcupine mines in Ontario for more than seven years with no other exposure to silica dust. Three of these men presented evidence of silicosis, indicating that the disease was being produced in this mining area. The recommendation was made and carried out that these men be placed at work on the surface away from exposure to dust. Up to the present time, two of them have progressed to the primary stage of silicosis and the other one has died with ante-primary silicosis complicated with tuberculosis.

SURVEY OF GROUPS OF MINERS

In 1925 and 1926, a further survey was made by the Industrial Hygiene Division of the Ontario Department of Health, covering the four principal mining areas, all situated in the Northern part of the Province, viz. Porcupine, Kirkland Lake, Cobalt and Sudbury.

Miners with more than five years' experience underground in the individual mining area and with no exposure to silica dust elsewhere were to present themselves for physical examination. Some were included who had worked underground elsewhere.

The examination findings based on consideration of both physical condition and X-ray manifestations are reported in terms of the

classification of stages of silicosis, developed by the South African Miners' Phthisis Medical Bureau. The interpretation of these standards was made possible through the guidance of Dr. J. M. Smith, of the South African Miners' Phthisis Medical Appeal Board, at the time of his visit to Ontario in 1927.

It is unnecessary to outline the details of the clinical classification or the pathological findings upon which it is based. These have been described in detail by W. Watkins-Pitchford in the *Journal of Industrial Hygiene* for April 1927, and by L. G. Irvine and A. Mavrogordato in the 1929 Report of the Convention of the International Commission for the Study of Occupational Diseases.

The years of exposure are based on statements made by the man at the time of examination. The occupational history was detailed from the time the man left school. Where, in view of age, it was apparent that this was incomplete, the history was carefully reviewed.

TABLE I. — SURVEY EXAMINATION FINDINGS, 1925 AND 1926

Mining area	Number of examinations	Stage of silicosis	Number of cases	Average years of exposure		
				Same area	Elsewhere in Ontario	Outside Ontario
Porcupine	236	Ante-primary	29	9	1	1
		Primary	9	9	0	0
		Secondary	8	10	3	4
Kirkland Lake	280	Ante-primary	11	3	5	5
		Primary	2	(Both outside Kirkland Lake)		
		Secondary	2	(Both outside Ontario)		
Cobalt	398	Ante-primary	6	11	2	6
		Secondary	1	12	0	0
Sudbury	306	Ante-primary	6	7	2	2

With one exception, the secondary cases were cases of silicosis with tuberculosis. This survey was the first chest examination conducted in these areas to include large numbers of miners. The findings, therefore, represent an accumulation of cases.

Extensive chemical and petrographical examination of mine rock samples to determine their free silica content, or dust counts to determine the number or proportion of silica particles under ten microns in mine air, have not been made.

The type of rock encountered varies considerably from area to area, from mine to mine in the same area and even from level to level in the same mine, so that the degree of exposure even for one occupation can be only approximate.

From the examination of such analyses as have been made, enquiry at the Ontario Department of Mines and the Dominion Geological Survey suggests that estimates may be made of the average free silica content likely to be encountered as appear in table II.

TABLE II. — CASES OF SILICOSIS WITH EXPOSURE IN ONE MINING AREA ONLY

Mining Area	Years of operation of area up to 1926	Probable percentage SiO_2	Number cases ante-primary	Average exposure in years	Number cases primary	Average exposure in years	Number cases secondary	Average exposure in years
Porcupine	14	25-35	17	9.5	9	9.5	3	10.6
Kirkland	8	25-35	0	—	0	—	1	5
Lake								(crushers)
Cobalt	22	5-10	1	9	0	—	1	12
Sudbury	31	5-10	1	8	0	—	0	—

A few dust counts recorded in the article referred to above, "Silicosis in Ontario Gold Mines", made with the Palmer Spray apparatus¹ and not distinguishing free silica from other dust present, showed the highest count under wet conditions as 17,400,000 particles under 12 microns in size per cubic foot of air. This cannot give more than a mere suggestion as to the exposure involved.

The average number of years of exposure of cases of silicosis among the men whose employment in mines was limited to the area in which they were examined during this survey follows.

Reference to tables I and II shows that, of the cases in the Porcupine area, over one-half had developed in that area. The average duration of exposure of these cases was low at 9.5 to 10.6 years.

¹ Comparative efficiencies of the Palmer Spray Machine, Sugar Tube and Greenburg and Smith Impinger are given as 1 to 2.1 to 5. (*Comparative Tests of Instruments for Determining Atmospheric Dusts*; Public Health Bulletin No. 144, United States Public Health Service.)

The rock conditions are such that exposure is high in free silica at times and very low at other times. Wet conditions have partly obtained since the early days of this mining area.

The Kirkland Lake area has not been in operation for a sufficient length of time to give any indication as to how much silicosis the area may produce.

It is interesting to note that in Sudbury and Cobalt, with a very low exposure to silica dust, among 300 and 400 men examined respectively, many of whom had worked underground in one or the other of these areas for twenty years and more, there appeared only three cases of silicosis advanced as far as the ante-primary stage. These men had worked underground for eight, nine and twelve years.

However, apparently in a few individuals even the low concentration of free silica encountered in this area can produce the disease.

A later case of secondary silicosis from the Cobalt area was a case of advanced silicosis with tuberculosis, with exposure in this area underground for twelve years and in the mill for five years. The lungs presented pigmented, visible, palpable nodules, widely distributed, a few of them, particularly under the pleura, at the right apex, large enough to conform to the outline of lobules. There was comparatively little pleural thickening, but extensive cavitation at the left apex and consolidation of the remainder of the left lung.

It should be recorded that in the Cobalt area, where the ore itself contains from 30 to 35 per cent. arsenic, in 398 examinations with stereoscopic X-rays of underground miners, most of them with over twenty years' exposure, there was no case of lung cancer.

In 1926, there was added to the list of compensatable diseases in the Workmen's Compensation Act, "Silicosis occurring in mines". Three stages of silicosis, ante-primary, primary and secondary are defined as in the South African Miners' Phthisis Act. To receive compensation for silicosis, the miner who has developed the disease must have been exposed to silica dust in his employment in Ontario for periods amounting in all to five years preceding disablement. The Act did not apply to those who had left their employment previous to April 1926, but these cases might be compensated as "miners' phthisis" cases if silicosis and tuberculosis with positive

sputum was present. In such cases, the requirement for exposure is shorter.

In April 1928, an amendment to the Mining Act provides for physical examination on employment and yearly thereafter of each workman employed underground in all mines except those exempt by the Chief Inspector of Mines. At the same time, a "Certificate of Freedom from Pulmonary Tuberculosis", in force for twelve months from the date of issue, is to be given to the workman, certifying that he is free from tuberculosis of the respiratory organs. This certificate is to be retained by the manager or superintendent at his request, during the period of employment, and returned to the workman on its termination or at the time of periodic examination. In the same year, an amendment to the Workmen's Compensation Act provided for the appointment of medical officers to carry out the physical examinations required under the Mining Act and defined tuberculosis of the respiratory organs as present, when on examination it is found that, (a) "such person expectorates the tubercle bacillus", or (b) "such person has closed tuberculosis to such a degree as to seriously impair his working capacity and to render prohibition of work underground advisable in the interests of his health".

By this time, the mine operators, of their own initiative, in the Porcupine and Sudbury areas, had already provided for physical examination with X-rays, of underground miners employed, and of applicants for employment. This procedure has been extended to all four mining areas. Examinations are conducted under the supervision of the Workmen's Compensation Board by physicians employed by it and paid out of assessments levied on mine operators for silicosis compensation purposes. Miners appear for examination in accordance with a pre-arranged schedule. Those meeting the requirements at initial or periodic physical examination are given a certificate in accordance with the Act. For identification, a photograph of the man with his X-ray number is taken at the same time and attached to the certificate. Cases of silicosis or silicosis with tuberculosis discovered in the course of these examinations are submitted by the examiners to the Workmen's Compensation Board. The claims include history of employment, medical history, record of physical examination findings with stereoscopic X-ray films of the chest.

When the history of exposure to silica dust in employment in Ontario mines for at least five years has been verified, the claims

are passed for review to a Silicosis Referee Board composed of three members of the Ontario Department of Health. As a rule, the claimant is given physical examination by any two members of the Referee Board, which makes periodic visits to the camps for this purpose. The cases are then considered by all three members and a unanimous decision regarding the diagnosis is transmitted to the Workmen's Compensation Board.

As in the case of claims for accidents and other occupational diseases under the Workmen's Compensation Act, there is no appeal from the decision of the Workmen's Compensation Board except through the Board itself. Any claim may be re-opened for the Board's further consideration by the workman or employer, at any time, if new evidence is available.

Miners with a compensatable stage of silicosis are notified by the Workmen's Compensation Board that their claims have been allowed. At the same time, they are informed that if they continue in work exposing them to silica dust, and should the disease progress, they will be entitled to no further benefits. Should the miner cease work in which he is exposed to silica dust, and should the disease progress, he is then entitled to further compensation depending on the stage to which he ultimately progresses. When tuberculosis is present, the miner does not receive a certificate and cannot be employed.

The Silicosis Referee Board indicates when, in its opinion, the compensated cases should be re-examined for any purpose.

FINDINGS IN FIRST EXAMINATIONS OF ALL EMPLOYED MINERS

Hague and McBain reported, in an article entitled, "Silicosis as an Industrial Hazard in Ontario Gold Mining", in approximately 3,000 examinations of miners employed underground in the Porcupine area, 39 ante-primary, 28 primary and 27 secondary cases of silicosis.

In Kirkland Lake in 1929, in 1,793 first examinations, there were 6 ante-primary, 6 primary and 4 secondary cases of silicosis. Their exposure averaged seven years in Ontario and four years elsewhere.

In Cobalt in 1929, in 662 first examinations, there were 7 ante-primary, 2 primary cases and one secondary case, with an exposure averaging thirteen years in Ontario and three years elsewhere.

In Sudbury in 1927 and 1928, among 1,434 first examinations, there were 6 ante-primary cases with an average exposure of twelve years in Ontario and none elsewhere.

COMPENSATED CASES OF SILICOSIS AMONG MINERS

Compensated cases are reported as from the mining area in which the claimant was last employed. Movement from one area to another is not infrequent. All cases in which the diagnosis has been established, have not necessarily been compensated, because of failure to satisfy other requirements of the Act. From April 1926 to 1 January 1930, there have been compensated 91 ante-primary, 58 primary and 33 secondary cases of silicosis. The proportion of secondary to total cases is high.

Up to 1 January 1930, of the compensated cases, one ante-primary case compensated in 1927 has progressed to primary and one ante-primary case compensated in 1928 has progressed to secondary. Three primary cases compensated in 1926, two primary cases compensated in 1927 and one primary case compensated in 1928 have progressed to secondary.

In the Porcupine area, of 27 secondary cases compensated to 1 January 1930, 15 have died. Of 17 secondary cases compensated in 1926, 9 died in 1926. Since then 10 more secondary cases have been compensated and 6 have died. In the 15 death cases, the period which elapsed between the time they were compensated, which in most cases was shortly after disability arose, and the date of death, averaged sixteen months. The compensated secondary cases still living at 1 January 1930 have averaged twenty-seven months since compensation was awarded.

Some interest attaches to the group of cases among the claims for compensation submitted from the Porcupine area, which have been examined by the Silicosis Referee Board.

TABLE III. — CASES FROM PORCUPINE AREA EXAMINED BY SILICOSIS REFEREE BOARD, 1927-1930

Distribution of all cases		Distribution of 35 secondary cases	
Stage of silicosis	Number of cases	Stage of silicosis	Number of cases
Ante-primary	20	Uncomplicated secondary	4
Primary	9	Ante-primary and tuberculosis	7
Secondary	35	Primary and tuberculosis	6
		Secondary and tuberculosis	9
		Silicosis and tuberculosis	9

In this group, just under one-half of the cases are complicated with tuberculosis. Nine cases reached the secondary stage before

the development of tuberculosis, but in most of them signs of active tuberculosis followed rapidly.

Among the secondary cases are two which developed tuberculosis some years after leaving the mines for work in the forest. One had worked underground in the Porcupine area for six years up to 1920 and one had worked in the Porcupine area for seven years up to 1919, that is, the development of tuberculosis was nine years and ten years after removal from exposure. These cases did not meet the requirements of the Act and were not compensated.

The "silicosis and tuberculosis" cases were mainly cases which came to attention early in the work when tuberculosis already masked the late evidences of advancing silicosis that may have been present. In a few cases, the silicosis was of the massive bilateral type with signs and symptoms indicative of superimposed tuberculous activity.

The tubercle bacillus has not been demonstrated in the sputum of silicotics with tuberculosis as early, or as readily as might be expected. This holds for both examination of smears, using concentration methods and also for animal inoculation. Animal inoculation has frequently produced a typical lesion, months before the detection of the organism by repeated examinations of smears. In seven secondary compensated cases positive sputum was detected on an average nine months before death.

It is impossible to indicate what yearly incidence of silicosis among miners in these areas may be expected. The arrangements for examinations have not been completed for a sufficient length of time to warrant conclusions.

APPLICANTS FOR EMPLOYMENT

The number of rejections on physical examination with X-rays, varies from area to area, from 5 to 10 per cent. of those sent from the mine employment office. This percentage is very low compared with South African experience, but may be influenced by the form of certificate, which certifies only "to freedom from tuberculosis" without reference to fitness for underground work, although in the examinations this may be taken into account.

In one area, where the numbers employed have largely increased recently, among 4,700 examinations of applicants in two and a half years, there were 22 cases of ante-primary silicosis and one case of secondary silicosis, all from outside Ontario. In this respect, examinations have acted as a protection against claims on mines operating in Ontario, for which they are not responsible.

SIMPLE TUBERCULOSIS

The Survey of 1925 and 1926 involved single physical examinations with stereoscopic X-ray films, so that there was no opportunity to determine definitely the presence of tuberculosis in suspected cases. Most of the men examined had been employed in mines in Ontario for over five years.

TABLE IV. — INCIDENCE OF "SIMPLE TUBERCULOSIS" ON SURVEY OF GROUPS OF MINERS IN 1925 AND 1926

Mining area	Number of examinations	Cases of tuberculosis
Porcupine	236	10
Kirkland Lake	280	8
Cobalt	398	10
Sudbury	306	5

Reference to the report by Hague and McBain on the findings in the first year's examinations at Porcupine shows under tuberculosis that the first two groups designated those "showing positive sputum" and those "showing a definite risk" taken together, and the last two groups, those "with slight risk" and those with "apparently non-significant peribronchial tuberculosis" taken together present a relative incidence among employees and among applicants expressed as 2:1. The group of employees "showing positive sputum" and "showing definite risk", were 2.6 per cent. of those already employed.

In this area, in 1929, after two periodic examinations among 2,330 employees, there were 6 cases of simple tuberculosis, similar to the yearly incidence among European miners in South African gold mines. Three of them were Finlanders.

In Kirkland Lake, in 1929, among 1,800 first examinations of employees, there were 12 cases of simple tuberculosis.

In Cobalt, in 1929, among 662 first examinations of employees, there were 5 cases of simple tuberculosis.

In Sudbury among 1,434 first examinations of employees in 1927 and 1928, there were 23 cases of simple tuberculosis. In 1929, among 1,958 examinations of employees there were 4 cases of tuberculosis. In this area among 4,700 applicants, there were 149 cases of tuberculosis, and suspected tuberculosis.

Tuberculosis is not compensatable. There can be little doubt that

as the importance of dust and tuberculosis in the mines has been more generally recognised, a number of men with tuberculosis or suspected tuberculosis have discontinued underground mining before the initial examinations were completed.

In an investigation by the Commonwealth Department of Health, among 4,067 gold miners in Western Australia (Kalgoorlie), there were 0.3 per cent. with simple tuberculosis.

The Report of the Technical Commission of Enquiry to investigate "the prevalence of miners' phthisis and pneumoconiosis in the metalliferous mines at Broken Hill" showed 1 per cent. of underground miners with simple tuberculosis.

In New South Wales, of 716 men examined, not all miners but with some exposure to silica dust, there were 16 cases of simple tuberculosis (2.2 per cent.).

In Bulletin No. 162, the United States Public Health Service reports the tuberculosis rate for all ages among 10,000 male industrial workers as 2.5 per cent. and among foundry workers as 1.9 per cent.

TABLE V. — COMPARISON OF MORTALITY STATISTICS OF "UNDERGROUND MINERS AND ALL MALES OVER 15 YEARS", 1925 TO 1929, BY AREA

Mining area	All males, deaths, pulmonary tuberculosis	Estimated proportion miners to adult male population	Miners' deaths, pulmonary tuberculosis	Miners' deaths, all causes	Miners' deaths, pneumonia	All males, deaths, pneumonia
Porcupine	22	Per cent. 60	13	94 + 33 ¹	24	54
Kirkland	6	45	5	33	2	3
Lake						
Cobalt	5	25	4	54	5	12
Sudbury	18	55	3	46	7	54

¹ One accident.

The figures are small. Sanatorium deaths from tuberculosis are allotted to the area from which admission to the Sanatorium was made. The proportion of the population in the lower age group is probably higher in these areas than in most communities. No important increased proportionate mortality is shown to exist for tuberculosis. It is high for pneumonia in Porcupine.

The available information suggests that there are no important

variations in the number of cases of simple tuberculosis from one area to another and that there is no marked increase in these miners over those employed in mines elsewhere or in other heavy trades.

TUBERCULOSIS IN CHILDREN OF MINERS

In the course of one of the clinics conducted by Dr. G. C. Brink, of the Tuberculosis Section of the Preventable Diseases Division of the Department of Health, there were examined 73 children in the centre of the Porcupine area. Forty-six of these were the children of miners. There was among them one child with positive tuberculosis and 19 showing a positive tuberculin reaction. These children were between the ages of one and fourteen. Among 27 children whose fathers were not miners, there were 8 showing a positive tuberculin reaction.

COST OF SILICOSIS IN MINERS

An ante-primary case is awarded \$500, a primary case \$1,000, and a secondary case, total disability. For total disability, the workman receives $66\frac{2}{3}$ per cent. of his previous wages, medical and hospital care. In the event of death, a pension is paid in accordance with the number of dependants.

Ninety-one ante-primary, 58 primary and 33 secondary cases of silicosis, of which 18 have died, have cost \$268,356. Of this amount \$111,496 was for the death claims. In addition, there has been set aside \$282,500 for continuing claims and \$69,000 for claims reported but not adjusted.

CONTROL OF DUST

The Mining Act of the Province of Ontario requires the control of dust underground.

Every dusty place where work is carried on in a mine must be adequately supplied with clean water under pressure. In a few mines, wet conditions prevail naturally, but in all mines, stopes, raises and drifts are kept wet. The use of wet drills since 1924 has been compulsory and water is used in collaring holes.

Attempts are made to limit dust generated in handling ore by the suitable location and design of ore passes. On account of climatic conditions, hoisting shafts are necessarily upcast shafts, thus the dust created at ore passes is carried up and out of the mine,

instead of being distributed through it. Canvas screens continuously supplied with water have been used in front of ore pass openings.

The Mining Act provides that the times for blasting shall be so fixed that the workman shall be exposed as little as possible to dust and fumes. As a rule, blasting is done at the end of the second shift so that the mine is idle until the first shift of the next day comes on duty. After blasting, a small amount of water is turned into the air lines which are operated to blow out the fumes, thus a mist is created which assists in carrying down dust. This is looked upon as one of the most important measures that have been adopted from the standpoint of both fumes and dust.

In some cases, blasters are using masks of the filter type. Dust counts made of samples of air from within these masks have shown an important reduction in the count.

The rock temperature with the depth reached has not risen above 67° F., so that heat is not a problem in these mines. Relative humidity is about 95 per cent. In winter, the difference in temperature at the surface and underground favours natural ventilation. In some of the mines, huge fans have been installed in shafts, delivering from 150,000 to 250,000 cubic feet of air per minute giving a linear velocity up to 8 miles an hour in drifts. These fans, on account of climatic conditions cannot be operated during the winter except where the air is led into the mine through old workings not in use. Auxiliary fans delivering fresh air through canvas or metal tubing to development faces are widely used. In one instance, a special shaft has been built for forced ventilation and in another, a special compartment in a shaft has been set aside to assist natural ventilation in the removal of fumes and dust.

GRANITE CUTTERS

In Ontario in 1924, there were examined 110 men quarrying and crushing rock for use in the manufacture of ferro-silicon. The free silica content is high. The exposure in most cases was limited to a few years for the summer months only.

There were 5 ante-primary and 3 secondary cases of silicosis, all but one having had exposure elsewhere. The single case referred to had exposure at the crusher for four years of six months each, and none elsewhere. At the time of examination, three months before his death, there was dyspnoea, marked on exertion, poor expansion with indrawing of the intercostal spaces and evidence

of consolidation in the upper portion of both lungs. The X-ray presented massive consolidation to the fourth rib anteriorly on each side with less dense shadows and mottling in the fourth and fifth interspaces. Pathological examination revealed a massive fibrosis of silicotic type in the upper two-thirds of both lungs. The case has been fully reported by Dr. A. R. Riddell in an article entitled "A Case of Silicosis with Autopsy". Further examination of this case, showed the presence of small tubercles in the spleen, and the cell reaction suggests that the lung was involved.

At this time, 1924, silicosis was compensatable only as "miners' phthisis in mines". Locally, such a situation left operating companies open to civil suit for silicosis contracted in other industries.

In 1925, in Ontario, provision was made for the compensation of cases of stone workers' or grinders' phthisis in quarrying, cutting, crushing, grinding and polishing of stone or grinding or polishing of metal. In 1926, pneumoconiosis was added to the list of compensatable diseases to apply to the same industries as stone workers' or grinders' phthisis. The difference lies in interpretation of the Act. The presence of silicosis with active tuberculosis and positive sputum is required under grinders' phthisis.

Exposure of granite cutters in this Province is mainly from the dust from Barre light granite, Quebec Stanstead granite, Georgia granite and Balmoral red granite. The first three contain about 35 per cent. free silica. Many of these granite cutters have cut sandstone or been exposed to dust from the sandblast.

A few dust counts, made with the Palmer Spray apparatus, have shown big variations at the breathing level of workers using different kinds of tools. With the use of the heavy picker for surfacing, counts ran from 106,000,000 to 220,000,000 particles of dust (not SiO_2 alone) under 10 microns in size, per cubic foot of air. The shop air away from these tools was usually under 5,000,000 particles per cubic foot. No detailed study of dust content of air was made.

In 1928 and 1929, the Industrial Hygiene Division conducted examinations of 133 granite cutters with over fifteen years' experience in the trade, with the results shown in table VI.

There are roughly 500 granite cutters in the trade in the Province, so that the accumulation of cases is not high. Attention is rather arrested by the number of granite cutters who have worked twenty years or more at the trade without presenting more than an increase in fibrosis of the lungs, producing no symptoms. The

proportion of complicated cases to total cases is high compared with that found in the survey of miners.

TABLE VI

Stage of silicosis	Number of cases	Average years of exposure	
		In Ontario	Elsewhere
Ante-primary	19	20.6	11.1
Primary	5	27.6	4.5
Secondary	10	19.3	13.1

It is interesting to note that these cases present findings on physical examination with X-rays, which make it possible to divide them in accordance with the classification of ante-primary, primary and secondary. The secondary cases reported, with one exception, were cases of silicosis and tuberculosis. Only a few of them presented massive consolidation similar to that described as occurring among Barre, Vermont, granite cutters. While some of the secondary cases have died, none have come to autopsy.

The shops are, as a rule, small, frequently with only one or two cutters, so that most of them do all types of work. Many of these shops have indifferent exhaust equipment for the removal of dust, especially from surfacing machines. The work is done under dry conditions and the floors are covered with rock dust.

In March 1929, the Silicosis Act for the "better prevention of silicosis among stone workers" was passed in Ontario. This Act requires examination on employment and periodic examination of granite cutters. The details for these examinations have not yet been arranged. The Factory Inspection Branch of the Department of Labour will supervise appliances used for the control of dust when this Act comes into force.

A positive pressure mask, devised by Dr. F. M. R. Bulmer, of the Division of Industrial Hygiene, is in fairly widespread use among granite cutters. It is easily adjusted, comfortable and inexpensive. Suitable cloth is held over the face by rubber bands which tie behind the head. It is ballooned with filtered air, from a compressor, which escapes from the sides and front of the mask to keep it cool and to prevent inspiration of dust or fumes. It is not intended as a substitute for the mechanical control of dust.

TABLE VII. — A FEW ADDITIONAL CASES REFERRED TO THE DIVISION FOR EXAMINATION

Occupation	Stage of silicosis	Number of cases	Average years' exposure
Sandblaster	Secondary	1	15
	Primary	1	40
Moulders	Primary	1	23
	Secondary	1	12
Grinders	Ante-primary	1	{ 2½ (sandstone) 8½ (artificial)
	Primary	1	{ 8 (sandstone) 5 (artificial grindstone)
	Primary	1	40 (sandstone)
	Secondary	1	12 (sandstone)

These were all cases with nodular fibrosis, and considered with other cases reported, having various types of exposure to silica, suggest that the inhalation of dust, for a period, containing free silica alone, may determine the widespread distribution of fibrosis.

In the course of investigation of hazards to health in other industries, the following physical examinations with X-rays, of interest in reference to silicosis, have been conducted.

TABLE VIII. — EXAMINATION OF WORKMEN EXPOSED TO DUSTS OTHER THAN SILICA

Industry	Number of men examined	Average years' exposed	Approximate SiO ₂	Physical findings
Cement workers	26	19	Per cent. 1	No silicosis
Brick and tile workers	34	19.3	1-10	No silicosis
Grain elevator workers	68	16.7	3	No silicosis
Artificial abrasive, manufacture and use (silicon carbide and aluminium oxide)	68	7.9 ¹	0.3	No silicosis

¹ Twenty-seven of these 68 men had an average exposure of thirteen years.

PHYSICAL EXAMINATION FINDINGS

In Ontario miners the symptoms present in the ante-primary stage of silicosis have been an irritating cough, frequently in the morning, with shortness of breath on moderate exertion, rather more than is expected. On examination there have been no

characteristic signs. Frequently, there is diminished expansion, sometimes very marked, with slightly diminished resonance in the upper two-thirds of the chest and breath sounds diminished and sometimes slightly higher-pitched, no appreciable change in voice transmission. As the condition progresses, these symptoms and signs are emphasised, that is, diminished resonance, high-pitched breath sounds with apparent shortening of the inspiratory phase compared with expiration. Rales are seldom heard unless tuberculosis complicates the condition. The X-ray presents increased hili shadows and linear markings with diffuse mottling, frequently more marked in the inner and middle zones on the right side.

The advent of tuberculosis has manifested itself by an aggravation of existing symptoms and others common to tuberculosis, and in the X-ray by a less discrete outline to the nodular shadows with local conglomeration, usually in the upper third of one or both lungs.

Among the granite cutters, after a much longer exposure to dust containing free silica, the manifestations of the disease were much the same as in miners, contrary to the experience of Jarvis¹ and later, Russell² with Barre, Vermont, granite cutters. Rather than a massive local fibrosis suggesting itself by the physical signs, decreased expansion, diminished resonance, high-pitched breath sounds and diminished voice transmission limited to one area bilaterally, with corresponding conglomerate shadows in the X-ray and the remainder of the lung fields fairly clear, the distribution of fibrosis in the Ontario cases, as a rule, has been the same as that presented by the miners, although the linear markings often cast deeper shadows and discrete nodules are more common in the hili shadows, probably associated with longer continued exposure to dust. However, in a few cases, more frequently in granite cutters than in miners, localised conglomerate shadows extending from the hilum outward and upward appeared as the important X-ray manifestations of the disease. The other physical findings in such cases were localised.

When tuberculosis supervened even in these cases, it was usually apical and not basal, as in the Barre, Vermont, granite cutters.

¹ D. C. JARVIS: "A Conception of the Chest Röntgen-Ray Densities Based on a Study of Granite Dust Inhalation." *American Journal of Roentgenology*, April 1922, Vol. IX, No. 4, p. 266.

² A. E. RUSSELL: *The Health of Workers in Dusty Trades*. [2. Exposure to Siliceous Dust (Granite Industry).] United States Public Health Bulletin No. 187.

PATHOLOGY

The pathological findings in some of these cases have been discussed by Riddell and Rothwell in "Some Clinical and Pathologic Observations on Silicosis in Ontario".

Here observations were made corresponding to those described by South African workers as the basis for their classification of cases. Attention is drawn to atypical cases in which there was widespread invasion of lung tissue by fibrous tissue without palpable nodules but with "fibrous whorls" in microscopic section.

In these cases, there was moderate exposure to free silica and the ash of the lungs showed a comparatively high silica content.

The marked difference between the silica content of the ash of lungs in adults not especially exposed to silica dust and that among miners is indicated, with a description of the gravimetric method used for the chemical determinations. Since that time, E. J. King, reporting difficulty with the use of Isaacs' method for the estimation of silica in tissue, described a micro method for this purpose which depends on the production of yellow silicomolybdic acid, which gave accurate results.

Studying these with other lung specimens, T. H. Belt, at work in the Pathological Department of the University of Toronto, reported in "Silicosis, Its Pathology and Relation to Tuberculosis" the result of a comparison between the silica content of the ash of the lungs of silicotics and the number of particles of silica to be seen in adjoining portions of the same lung with the polarising microscope.

The invisible portion designated "occult silica" was greatest where fibrosis was most extensive, i.e. few particles to be seen, a high silica content on chemical examination, and extensive fibrosis, are related. This appears to support the theory of Gye and Kettle that crystalline silica produces its ill-effects on account of a slow chemical change, probably to colloidal form.

No silica particles were noted in the fibrotic nodules, but they appeared in the zones surrounding these nodules, which were occupied by young fibroblast and endothelial cells. With few or no silica fragments, the presence of a healed lesion suggested the absence of any irritant and the assumption that the silica by this time has changed to silica gel. With this conception of the sequence of events, fibrosis will continue for some time after exposure has ceased, until the silica already in the lung has been

rendered innocuous. This is noted in explanation of the clinical progress which takes place in uncomplicated silicotic cases after removal from exposure to silica.

In the cases with tuberculosis, the fibrous nodules largely escaped caseous necrosis, but the zone surrounding them in which the silica particles lie was necrotic and without any evidence of cell reaction except at its edge. Extensive cell reaction occurred in the normal lung and away from the fibrotic areas. So that it is inferred that tuberculosis gains a foothold in the areas surrounding the fibrous nodules called "silica nests", and that so long as these areas have not become fibrosed the increased liability to the spread of tuberculosis infection exists.

G. C. Cameron, associated with the Banting and Best Chair of Medical Research, has been good enough to abstract for this summary an unpublished paper describing "An Experimental Study of Elimination of Silica from the Lung", 1 January 1930:

The work was based upon the observation personally conveyed by Professor Oskar Klotz that the lung alveoli of anthracotic subjects dead of pneumonia often contained many phagocytes which were heavily laden with carbon. We sought therefore an agent which upon introduction to the air spaces of the lungs would promote emigration of phagocytes and at the same time be innocuous to the subject. It was presumed that the emigrating phagocytes would carry with them their previously ingested content of silica.

It was found that rabbits might be enclosed in a chamber the atmosphere of which was heavily charged with paraffin oil in droplet form, as discharged from an atomiser. Prolonged exposure of several hours daily did not seemingly impair the health of the animals.

Histologic study of the lungs of such animals showed that exposure for an hour sufficed to disperse oil widely throughout the lungs, and that oil could be demonstrated in the lungs as long as fifteen weeks after the cessation of exposure. The oil promoted very active emigration of phagocytes to the alveoli, from where it was presumed they were expectorated with a full capacity of oil. Oil was observed in the parenchyma of the lungs in only one of the twenty-seven rabbits exposed. In this instance, the oil was evidently being conveyed along the lymph channels and was demonstrable in small amounts in lymph nodes. In none of the animals did the oil occasion fibrosis that might occlude air spaces.

Rabbits exposed to an atmosphere highly charged with finely particulate quartz dust both before and during the exposure to oil spray were killed, and the lungs examined histologically and chemically. The production of histologically demonstrable silicosis was not achieved during the period of observation and chemical estimation of silica in the lung by the colorimetric method of King¹ did not indicate that elimination of silica from the lung, in the sense of complete expectoration,

¹ E. J. KING: "Estimation of Silica in Tissues." *Journal of Biological Chemistry*, 1928, Nov. 1928, p. 25.

was accomplished. As the chemical procedure would not differentiate between silica in the tissue and silica in the air spaces, however, it was felt that this result did not indicate complete failure of the method.

The *process* of elimination of particulate foreign matter from lung parenchyma by administration of oil spray was demonstrated by experimentation with carbon. Rabbits were made anthracotic by intravenous administration of India ink and then subjected to oil spray. The air spaces of the lungs of these animals contained many cells which had ingested both carbon and oil, apparently to the limit of their capacity. Lungs of control animals untreated by oil showed absence of phagocytes in the air spaces but very many cells heavily laden with carbon in the parenchyma. The lungs of animals intensively treated with oil showed microscopically some months after cessation of treatment approximately as much carbon as the untreated controls, so that the practicability of oil spray as a therapeutic measure was not proven. Experiments are proceeding.

SUMMARY

(1) The cases reported indicate that silicosis, as defined by the standards of the Miners' Phthisis Medical Bureau of South Africa, is contracted in gold mining in Ontario. The number of cases in proportion to the number employed underground is not high, but the time required for the development of these cases is relatively short. The proportion of silicosis cases complicated with tuberculosis is high.

(2) The number of cases and deaths from simple tuberculosis is little, if any, higher than that found in mines elsewhere.

(3) Granite cutters in Ontario develop silicosis with manifestations similar to those presented by Ontario miners. The proportion of cases found during the survey of those employed at the trade for more than fifteen years, is low, having in mind the skilled nature of the employment and the consequent high percentage with long service. The period of exposure to silica dust in all cases is long. The proportion of silicosis cases complicated with tuberculosis is high.

* * *

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¹ This Bibliography is limited to Canadian references.

APPENDIX

THE MINING ACT

CERTIFICATE OF
FREEDOM FROM PULMONARY
TUBERCULOSIS

Serial Number Date

Name

Address

Nationality.....

Married Single Age.....

Signature of Workman.....

Personal Photograph
Full Face View

Photograph to be also signed

The Workmen's Compensation Board
ONTARIO

This certifies that I have examined

.....
 whose photograph is attached hereto
 and have found him free from tuber-
 culosis of the respiratory organs.

If required by the Manager or
 Superintendent, this certificate shall
 be delivered to him, and shall remain
 in his custody until the holder is
 discharged.

DATE OF INITIAL EXAMINATION

.....
 1. Date due for re-examination

.....
 Examined— Doctor's Signature

.....
 2. Date due for re-examination

.....
 Examined— Doctor's Signature

.....
 3. Date due for re-examination

.....
 Examined— Doctor's Signature

*N. B. — The holder of this certificate must be re-examined not later than twelve months from
 date of initial examination, and annually thereafter.*

SILICOSIS IN GERMANY

I. — PRESENT STATE OF THE SILICOSIS PROBLEM IN GERMANY

BY PROFESSOR A. BÖHME, BOCHUM

INTRODUCTION

The exposition of the present state of knowledge relative to the silicosis problem in Germany should be preceded by a short discussion of the principal features of its development in our country. Only a few names need be mentioned. The first German author to deal with injury to the lungs of miners caused by inhalation of dust, and to designate such injury as an occupational disease, was Paracelsus, who, about 1534, published his work entitled *Miners' Phthisis and Other Miners' Diseases*. In the second half of the nineteenth century, German pathologists and clinicians made considerable progress in regard to research connected with diseases caused by dust.

Zenker ¹ provided the anatomical, and Kussmaul ² the chemical, proof of the deposit of inhaled dust, especially silicic dust in the lungs. The name pneumoconiosis was invented by Zenker, who described in detail the anatomical picture of the dusty lung. Merkel ³ studied the tubercular changes in siderotic lungs. The fundamental experimental and anatomical research engaged in by Arnold ⁴ constituted considerable progress. He succeeded in producing experimental dust fibrosis of the lung, and in distri-

¹ ZENKER, in *Deutsches Archiv für klin. Med.*, 1866, Vol. II.

² KUSSMAUL, *ibid.*, Vol. II.

³ MERKEL, *ibid.*, 1887, Vol. XLII.

⁴ ARNOLD: *Untersuchungen über Staubinhalation und Staubmetastase*. Leipzig, F. C. W. Vogel, 1885.

guishing clearly between that and tuberculosis. Eulenberg¹ definitely affirmed that silicic acid causes serious fibrotic disease of the lungs.

A close connection between the inhalation of dust with a quartz content and tuberculosis has been revealed repeatedly by statistical data: Oldendorff², Sommerfeld³, Moritz and Röpke⁴ and others draw attention to the high mortality rate from tuberculosis amongst metal grinders; Lewin (1863), Hirt⁵, Wilbrandt⁶, Eulenberg, Sommerfeld⁷ and others to similar conditions amongst pottery workers.

For extensive hygienic research relative to the dust content of the atmosphere, to the deposit of dust, to the self-protecting mechanism of the system against injury due to the dust, we are indebted to Lehmann and his collaborators⁸.

CLINICAL PICTURE OF SILICOSIS

The clinical picture of the silicotic lung could only be studied in the case of very advanced disease forms prior to the introduction of Röntgen ray examination. Bäumlér⁹ describes the symptoms, and lays stress on the cirrhotic character of the accompanying tuberculosis.

The accurate diagnosis of silicosis during life, as well as in its early stages, and investigations relative to its incidence in the several occupations involving exposure to this risk, as well as a study of its development, were only rendered possible by the introduction of the Röntgen diagnosis. On the basis of earlier discoveries, Staub-Ötiker¹⁰, the next writer to describe in detail the radiographic picture of the silicotic lung as found in metal-grinders, also distinguished the various stages of the disease. Numerous further radiographic and clinical studies have since been effected. Comprehensive expositions of the subject are provided

¹ EULENBERG: *Handb. d. Gewerbehyg.* Berlin, 1876.

² OLDENDORFF, in *Zentralbl. f. allgem. Gesundheitspfl.*, 1882.

³ SOMMERFELD, in *Beil. z. Hyg. Rundschau*, VII. Jahrg., No. 1, 1897.

⁴ MORITZ and RÖPKE, in *Zeitschr. f. Hyg. u. Infektionskrankh.*, Vol. XXXI.

⁵ HIRT, in *Krankheiten der Arbeiter*, Vol. I. Breslau, 1871.

⁶ WILBRANDT, in *Vierteljahrsschr. f. gerichtliche Mediz.*, Vol. XXIV.

⁷ SOMMERFELD, in *Deutsche Vierteljahrsschr. f. öffentliche Gesundheit*, 1893, Vol. XXV, No. 2; *Handb. d. Gewerbekrankheiten*, Berlin, 1898.

⁸ LEHMANN, in *Archiv f. Hygiene*, Vol. LXXV; also in *Arbeits- u. Gewerbehygiene*, Leipzig, 1919; LEHMANN, SAITO and GEFRÖRER, in *Archiv f. Hyg.*, Vol. LXXV.

⁹ BÄUMLER, in *Münch. med. Wochenschr.*, 1909, No. 10.

¹⁰ STAUB-ÖTIKER, in *Deutsches Archiv f. klin. Med.*, 1916, Vol. CXIX.

by Stähelin¹, Ickert², Jötten and Arnoldi³, Lehmann-Engel-Wenzel⁴. The lines followed by the above researches are somewhat as follows:

In very many dusty trades, as, for instance, among bakers and millers, who suffer from bronchitis, often amongst coal miners (hewers), and likewise in the initial stages of silicosis, there is found an enlargement and mottling of the hilar shadow, thickening of the trunk shadows proceeding from the hilus, intensifying of the outline of the lungs which reaches to the border of the chest and shows arborification, giving a picture resembling a network, with prominence of the bronchial tubes in the form of longish cavities with a double-edged border. From the anatomical point of view such a picture corresponds to a type of bronchitis—a filling-up of the peribronchial and perivascular lymph cavities with coal dust, without fibrosis; also eventually to an initial dust fibrosis of the lung.

Such a picture is found, for instance, frequently amongst rockdrillers in coal mines, where, associated with initial fibrosis, there is found considerable deposit of coal dust in the lung.

Among cement workers, polishers in the knife-grinding industry, and coal miners (hewers), this picture is very frequent. Symptoms are not as a rule associated with these slight modifications unless there is bronchitis. The pictures above described do not indicate silicosis.

Where definite fibrosis develops, the knots of the reticulated area are seen to thicken, the single outline of the lung resolves itself into small round spots which are partly ranged one behind another like beads in a necklace, or there may be seen, quite apart from the outline of the lung, various small spots within the lungs, at first more especially in the centre, but which gradually invade and cover the outline of the lung. This picture is characteristic of dust fibrosis, as met with more especially after inhalation of quartzitic dust, but possibly also after deposit of coal dust or graphite.

With the development of the disease, the fine mottling spreads over the lungs in an almost symmetrical manner, though the right side is somewhat earlier and more intensely involved than the left.

¹ STÄHELIN, in *Handb. d. norm. u. pathol. Physiologie*, Vol. II, p. 515. Berlin, 1925.

² ICKERT: *Staublunge u. Staublungentuberkulose*. Berlin, 1928.

³ JÖTTEN and ARNOLDI: *Gewerbestaub- u. Lungentuberkulose*. Berlin, 1927.

⁴ LEHMANN-ENGEL-WENZEL: "Der Staub in der Industrie", Beiheft z. *Zentralblatt f. Gewerbehyg. u. Unfallversicherung*, Vol. IX.

The apical zones are usually less affected than the other parts of the lung, but in the end they also generally become involved. According to the nature of the dust, the Röntgen slides reveal at this stage certain differences. According to Kaestle, the mottling shows deeper shadows and sharper edges the higher the quartz content of the dust. He has thus observed a specially intensive mottling in workers engaged in sandstone quarries; such pictures are also met with in the case of steel-grinders, who work with wet sandstone. The mottling becomes gradually more intensive and larger, but the spots seldom exceed a few millimetres in diameter. They may in places be so thick as to appear to overlap.

Regarded from the anatomical point of view, the small spots cluster round fibrotic foci, with a rich dust content which in their central zone are mostly transformed into hyaline. Signs of infection, especially of a tubercular nature, are not in general to be found in these small nodules. With the developing thickness of the fine mottling, the elasticity and vital capacity of the lung becomes reduced, and there arises a certain amount of dyspnoea on effort (*Arbeitsdyspnoe*). A dry cough is often met with; sounding reveals, however, bronchitic respiration only in a fraction of the cases—at least where stonecutters are concerned. The percussion note (*Klopfschall*) is as a rule hardly worth considering. Where the radiographic picture reveals special thickening of the fine nodules, the sound may in this region be somewhat shortened, as for instance, where the side, in the axillary region or the interscapular region is heavily involved. In some forms of silicosis bronchitis appears to play a rather important part.

In the further development of the disease, there are recognised on the Röntgen plate, large, dense, circumscribed masses of shadow, often enclosed by sharp edges, which frequently develop symmetrically, but also at times asymmetrically. Favoured situations for these massed shadows are the sides of the infraclavicular regions on each side, and also those parts which project in a lateral direction from the hilus. These masses of shadows with large mottling may become greatly extended in the course of a few years and finally cover the greater part of the lung.

It is especially the middle and upper parts of the lung which generally become filled with these masses of hard cicatricial tissue showing a strong tendency to shrinkage, whilst in the lower parts of the lung there develops a marked secondary emphysema to which the indurated changes formerly present there gradually give place. Descending trunk shadows reaching from the large shadow

masses down to the diaphragm, and intense displacement of the diaphragm complete the picture. Ultimately it not infrequently happens that an enlargement of the heart is established radiographically. With the increase in indurated phenomena there sets in also marked diminution in the percussion note (*Klopfschall*), modifications of the respiratory murmur, which may at times be softer and at times harsher. Rales are then usually rare. The capacity for chest expansion and for displacement of the border of the lungs, as well as the vital capacity, become gradually reduced until finally dyspnoea occurs on the slightest movement or even while the patient is at rest. Expectoration is often entirely absent even in these serious stages of the disease. The temperature is normal. Finally, there may occur marked symptoms of cardiac insufficiency with stasis of the pulmonary and general circulation. This state is responsible for the death of the patients. Clinically the picture presented up till the end in such cases is that of the purely silicotic lung.

Anatomically there may be found a fibrotic, in part hyaline, tissue which reveals no signs of tuberculosis infection, and likewise in animal experiments shows no connection with tuberculosis. In yet other cases, even when during life no symptoms of tuberculosis, were present, post-mortem examination reveals at the same time histological tubercular changes, and it may ultimately occur that the histological examination reveals no tuberculosis, whilst animal experiment and cultures show positive results. The possibility must therefore be admitted that, at least in some of the fibrotic cases showing large nodules but developing clinically, without symptoms of tuberculosis, latent tuberculosis infection nevertheless plays a part.

Very frequently there occur grave cases of silicosis in which, after long observation, definite tuberculosis is seen during life to be associated with silicosis.

There are often seen on the Röntgen plate, showing finely mottled silicosis, on one side in the upper part large spots with a tendency to spreading and cavitation. Such areas almost always develop later into overt tuberculosis. In the case of forms of silicosis with large mottling it is often very difficult to tell from the Röntgen picture whether overt tuberculosis is in course of development. A preference for the apical zones, asymmetry of the thickening processes, cavernous destruction and a small and vertical form

of the heart, are indications of this state, but fairly often the Röntgen picture provides no differential criteria.

Clinically, loss of weight, night sweats, reduced strength, fever, occurrence of increased dullness, bronchial murmur, resonant rales in the apical zones, acceleration in the sedimentation test, are signs of active tuberculosis. Proof of the presence of the tubercular bacillus is often provided by animal experiment earlier than microscopically. A positive local and general reaction to tuberculin may on occasion be of value for the diagnosis of an active form of tuberculosis, but in general the tuberculin reaction and likewise the complement fixation test is of no great diagnostic significance in regard to the foregoing questions.

Koelsch¹ and Kaestle² designate the stage of fine mottling as the first stage of silicosis, associated with slight dyspnoea after effort.

The second stage is connected with the formation of larger and thicker foci and is characterised by increasing breathlessness, pressure and stitch in the chest, dry morning cough and a tendency to obstinate catarrh arising from cold.

To the third stage there belong forms with extensive and massive shadows, clinically marked dyspnoea, strong intense fits of coughing frequently accompanied by expectoration which is often slight, pains in the chest and disturbance of the circulation. The above distinctions have also been accepted by other research workers (Von Döhren³, Reichmann⁴ and Schürmann⁵). Still further investigators have likewise distinguished three stages, which do not, however, correspond to the above.

Thus where an exchange of views is desirable it is advisable—at least so long as no uniform designation has been established—to avoid the classification into first, second and third stages, and preferable to designate the dominant characteristics of each stage.

COURSE OF THE DISEASE

Extensive observations in the various dusty trades are still lacking in this connection. Böhme reports on the course of the disease during a certain number of years (two to eight) as affecting

¹ KOELSCH: "Schwere Staublungenerkrankungen", in *Arbeit und Gesundheit*, No. 12, Ausdehnung der Unfallversicherung auf Berufskrankheiten, Berlin, 1929.

² KAESTLE, in *Fortschr. auf dem Gebiete der Röntgenstr.*, 1928, Vol. XXXVII.

³ VON DÖHREN: "Zur Klinik der Staublung" in *Die gewerbl. Staublungen-erkrankung*, Berlin, 1929.

⁴ REICHMANN: "Ueber die Begutachtung der Gesteinstauberkkrankung", *ibid.*

⁵ SCHÜRMAN: "Gewerbestaub, seine Bekämpfung, usw.", *ibid.*

150 stonecutters in the Ruhr coalfields. He confirms the gradually deteriorating condition of many silicosis cases after quitting work in dusty trades, observed by the South African investigators and the frequent development of these into serious forms of open tuberculosis. Of those showing incipient induration after two and a half years, about 26 per cent. had grown worse, and in a third of these active tuberculosis was confirmed. In cases of the typical fine mottled stage of the disease, after about two and a half years there was observed in 40 per cent. of the cases an increase in induration, and about a third of these showed active tuberculosis. Amongst those cases showing large hard masses of cicatricial tissue there was altogether an increase of induration amounting to 72 per cent., whilst overt tuberculosis was confirmed in half of these cases. The presence of tuberculosis was often established by means of experiments on guinea-pigs earlier than microscopically. Where, in the case of serious modifications due to dust, overt tuberculosis supervened, death usually occurred within a few years. Also in the case of slight changes due to dust, overt tuberculosis mostly followed a progressive course, though extensive improvements were also encountered. As a result of observation continued for several years, it was not infrequently remarked how, together with a state of general well-being, indurated centres gradually suffered extension and suddenly revealed cavernous formation with expectoration of the tubercular bacillus. Such observations point to the fact that already at an early stage the tubercular infection is latent in these indurated foci. Dust tuberculosis would appear to develop often for a period of years in the form of slow progressive indurated latent tuberculosis. The state of the patients is characterised by general well-being and freedom from toxic symptoms. Probably the blocking of the lymphatic channels prevents rapid dissemination of the infection and resorption of toxic substances. There finally occurs, nevertheless, in these advanced cases, collapse of the tissue and overt tuberculosis. Only in the minority of the cases does the process come to a complete standstill. Also in the finely mottled forms of silicosis lengthy observation often results in establishing definitely associated tubercular infection. Radiographically, such cases are characterised by forms showing larger apical or sub-apical foci, which mostly reveal a decided tendency to progress.

Our continued clinical observations have resulted in confirmation of the South African views as to the great significance of tuberculosis in regard to the production and progress of serious forms of silicosis.

On the other hand, clinical and anatomical investigations (see below) lead to the view that even serious and extended processes of induration *may* occur subsequent to the inhalation of quartz dust alone, and that such processes may, even after the patient has quitted the dusty trade in question, show continuous development up to a point at which, as a result of increasing pulmonary fibrosis, cardiac insufficiency of the right heart occurs, which leads to death by symptoms of stasis.

The association of silicosis and tuberculosis would often appear to follow a more favourable development than in the case of the stonecutters whom we had under observation. Kreuser reports on pottery workers who for decades showed overt tuberculosis. Holtzmann and Harms¹ and Roessle² speak of the benign nodular development of dust tuberculosis amongst pottery workers. Ickert³ makes similar observations in regard to miners in the Mansfeld ore district.

ANATOMICAL RESEARCH

Since the research engaged in by Arnold, fibrosis due to dust has in general been recognised as a disease *sui generis* and distinguished from tuberculosis. It has, however, been admitted on all sides that very often tuberculosis is associated with dust fibrosis. Nevertheless, the majority of Germans are of opinion that in this case these two processes are to be sharply distinguished one from another, and that dust inhalation, as such, may lead to extensive pulmonary fibrosis without associated tubercular infection.

Schmorl⁴, Staub-Ötiker⁵, Arai⁶, Koopmann⁷, Böhme and Schridde describe such cases of pure silicosis of serious development in which careful macroscopic and microscopic examination yielded no signs of tuberculosis.

Schridde⁸ emphasises the histological similarity which exists between dust fibrosis (stone) with cicatricial keloid, and modifications of the *ulcus callosum ventriculi*, and assembles these processes

¹ HOLTZMANN and HARMS: *Zur Frage der Staubeinwirkung auf die Lungen der Porzellanarbeiter*. Tuberkulose-Bibliothek, 1923, No. 10.

² ROESSLE, in *Beitr. z. Klinik d. Tuberkulose*, Vol. XLVII, No. 2.

³ ICKERT: *Staublunge und Tuberkulose bei den Bergleuten des Mansfelder Kupferschieferbergbaues*. Tuberkulose-Bibliothek, 1924, No. 15.

⁴ ROSTOSKI, SAUPE, SCHMORL: *Zeitschr. f. Krebsforschung*, 1926, Vol. XXIII.

⁵ STAUB-ÖTIKER, in *Archiv f. klin. Med.*, 1916, Vol. CXIX.

⁶ ARAI, in *Virchows Archiv*, 1920, Vol. CCXXVIII.

⁷ KOOPMANN, in *Virchows Archiv*, 1924, Vol. CCLIII, p. 423.

⁸ SCHRIDDE, in *Klin. Wochenschr.*, 1928, p. 582.

under the name of "keloidosis". He sees in keloidosis a particular reaction of the connective tissue to simultaneous physical and mechanical irritation in subjects with a special inborn susceptibility. Böhme finds in about two-thirds of the sections of lungs affected by dust an accompanying active tuberculosis, and in about one-third pure modifications due to dust without tuberculosis. In several cases, designated anatomically as pure dust fibrosis of serious development, the guinea-pig experiment gave negative results. In one or two cases in which clinically and anatomically no signs of tuberculosis were discerned, animal experiments and culture of tuberculosis bacillus gave opposite results.

In opposition to these views, Ribbert¹ had at an earlier date advanced an opinion that all indurated anthracotic nodules of the lungs in the hilar lymph glands owed their production, not to dust alone, but to simultaneous chronic infection, chiefly with tubercular bacillus. Merkel² also has concluded from his anatomical findings that simultaneous inhalation of dust and tubercular bacillus occurs and that these exert a double action in the production of the majority of dust fibrosis.

Hübschmann³, similarly on the basis of histological research, holds the opinion that at least all extensive processes of hard cicatricial tissue in dust fibrosis are due, not to dust alone, but to the simultaneous influence of the tubercular bacillus, and even in cases in which small nodules are present, he found many to be of a typically tubercular character, and alongside this, transition to pure hyaline nodules, so that he also assumes tubercular ætiology for small nodular forms of the disease.

Ickert⁴, like Mavrogordato, distinguishes two varieties of small nodules: the majority are small fibrotic nodules, in the midst of which a blood-vessel is situated. These he calls block nodules, and attributes them to the influence of dust. Besides these nodules, there are found nodules similar in formation to the so-called "Puhl focii", in connection with the production of which an infectious agent plays its part. Thus, though opinions differ in relation to the significance of tuberculosis in regard to the development of serious forms of dust fibrosis, it is nevertheless generally recognised that fine nodular modifications may arise purely from

¹ RIBBERT, in *Deutsche med. Wochenschr.*, 1906, p. 1615.

² MERKEL, in *Deutsches Archiv f. klin. Med.*, 1888, Vol. XLII.

³ HÜBSCHMANN, in ICKERT: *Staublung und Tuberkulose bei den Bergleuten des Mansfelder Kupferschieferbergbaues*. Leipzig, 1924.

⁴ ICKERT: *Staublung und Staublungentuberkulose*. Berlin, 1928.

the effect of dust. It is likewise admitted that also in many cases of serious silicosis, success has not attended any method of establishing proof as to the presence of tubercular infection, including also animal experiment.

As a consequence of serious pulmonary fibrosis, there is often met with in pure cases of lungs affected by dust a considerable dilatation and hypertrophy of the right ventricle, and also symptoms of stasis in the general and pulmonary circulation. The nutritional condition and the strength of the patient in such cases often remains very good up till death.

Our workers in dusty trades are exposed to very considerable injuries from dust, and there is therefore frequently found on dissection forms such as were frequently met with formerly in South Africa, though at the present time as a consequence of the successful campaign against dust, such forms have become much rarer in the above-mentioned country.

It has always struck the workers in dust fibrosis research that in cases of dust fibrosis complicated with tuberculosis very slight specific tubercular changes are to be found in the areas containing hard cicatricial tissue, and that the extensive fresh tubercular foci are met with rather in those parts of the lung which are free from fibrosis. Likewise in the bronchial glands there are often no large tubercular modifications to be found. Fränkel¹ has already regarded as the cause of this phenomenon the block of the lymph passages by dust induration, which prevents transport of the tubercular bacillus and causes the tubercular process to be limited for a long time to one spot, and to develop chronic induration. Jötten and Arnoldi have confirmed by their animal experiments this blockade of the tubercle bacillus. Roessle² attributes only slight importance to the lymph block. He is rather inclined to the view that a specific influence on the connective tissue peculiar to silicic acid, is the cause of the fibrotic character of dust tubercles, and is even in favour of the therapeutic application of silicic acid as a remedy against pulmonary tuberculosis.

While the block of the lymph vessels on the one hand obstructs the spread of the tubercular processes, on the other it hinders the cleansing mechanism of the lung from acting in rejecting tubercle

¹ FRÄNKEL: *Spezielle Pathol. u. Therapie der Lungenkrankheiten*. Berlin, 1904.

² ROESSLE, in BRAUER: *Beitr. z. Klin. d. Tuberk.*, Vol. XLVII, 1921.

bacilli and other infectious agents which have penetrated it, and so provides, perhaps, the explanation of the increased tendency of cases of dust fibrosis to develop tubercular infection (Fränkel).

SCHNEEBERG LUNG DISEASE

A disease of special character, connected with the inhalation of stone dust, is the Schneeberg lung disease, a combination of dust fibrosis and cancer of the lungs which has been frequently observed amongst the miners in the Schneeberg Mines on the borders of Saxony and Bohemia. As the researches of Rostoski¹, Saupe and Schmorl in confirmation of former observations prove, about one-half of the older miners die of this disease. The condition in question is pulmonary carcinoma, of slow and partly horny growth inside the pneumoconiotic lung with metastases in the hilar gland and partly also in other organs. Amongst the population of the district not occupied in the mines, such frequency of pulmonary carcinoma is not met with, and it must therefore be induced by the occupation in question. One condition necessary to its production is dust induration, but this is not the only condition. Frequency of pulmonary carcinoma has, indeed, in the last decades, been by many authorities (Von Hampeln, Schmorl²) stated to be related to increase of dust due to industrialisation and traffic. It should, however, be noted that in other industrial regions, as, for example in the Ruhr district, in spite of the frequency of diseases due to dust, complication with pulmonary carcinoma has hardly been noticed. As a further condition for the production of pulmonary carcinoma in the case of Schneeberg disease, there have therefore to be taken into account certain properties of the ore extracted there. The ore in question is chiefly cobalt and bismuth, with an arsenic and radium content. It is just this mixture of arsenic and radium which is perhaps of significance. It is recommended in every case where ore with a radium content is extracted, that attention should be paid to the possible presence of pulmonary carcinoma. The practical importance of the Schneeberg lung disease is at present not great, as the number of workers engaged in the local mines is diminishing considerably, and hardly exceeds fifty. Its theoretical interest, however, is all the more important.

¹ ROSTOSKI, SAUPE and SCHMORL, in *Zeitschr. f. Krebsforschung*, 1926, Vol. XXIII.

² VON HAMPELN, in *Grenzgeb. d. Med. u. Chir.*, 1922, Vol. XXXVI.

EXPERIMENTAL SILICOSIS

Lehmann¹ and his pupils Saito, Gfrörer, and Katayama² proved by animal experiment that about 50 per cent. of inhaled dust is retained by the nasal mucous membrane. A further amount is retained by the walls of the bronchial tubes, and withdrawn thence by the action of the ciliated epithelium into the pharynx, whence it passes into the digestive canal. Only 4 to 24 per cent. of inhaled dust arrives in the lungs.

The older investigations in regard to experimental production of pneumoconiosis, including those of Arnold, were mostly undertaken with very considerable quantities of dust, which greatly exceeded those which have to be taken into consideration in connection with human pathology. Acute injuries resulting from dust were caused by these large amounts of dust, especially bronchopneumonia, which, at first of a secondary order, ultimately led to fibrosis, which cannot be directly compared with human fibrosis without further investigation. Pure inhalation experiments with small measured quantities of dust gave—in the absence of infections—hardly any, or very slight, reactive fibrotic processes.

Gross³, using a mixture of soot and quartz dust for inhalation in the case of rabbits, failed entirely to produce fibrosis. Lehmann made cats and guinea-pigs inhale for a considerable time porcelain dust in concentration similar to that inhaled in the porcelain industry. In this case likewise no fibrotic changes took place.

Cesa-Bianchi⁴ instituted experiments in regard to the signification of simultaneous tubercular infection. The dust concentrations used by him, though very considerable, were not, in themselves, sufficient to produce notable histological modifications, apart from a few cases of pneumonia. The animals previously subjected to dust were thereafter infected with small amounts of weakened cultures of the tubercular bacillus. These animals almost all died of tuberculosis of the lungs of a grave form, whilst the infected control animals which had not been previously subjected to dust, showed no tubercular modifications, or very slight tubercular affections. In these cases, tuberculosis was therefore obviously favoured by dust inhalations. Chalk and gypsum dust had less effect than grindstone dust and anthracite dust.

¹ LEHMANN, SAITO and GFRÖRER, in *Archiv f. Hyg.*, Vol. LXXV.

² KATAYAMA, in *ibid.*, 1916, Vol. LXXXV.

³ GROSS, in *Beitr. z. Pathol. Anat. u. z. allgem. Pathol.*, 1927, Vol. LXXVI.

⁴ CESA-BIANCHI, in *Zeitschr. f. Hyg. u. Infektionskrankh.*, 1913, Vol. LXXIII.

Henius and Richert¹ did not succeed in proving the influence of the inhalation of coal dust on rabbits infected with tuberculosis.

Wedekind² has, on the other hand, observed arrest of tuberculosis of the lungs in the case of rabbits infected intravenously, through previous or subsequent intravenous injection, of the suspension of coal dust.

Remarkable progress was effected by the large-scale experiments of Jötten³ and his collaborators, whose methods are distinguished from those of earlier research workers especially by exact dosage of the dust used, and by the method of infecting with tubercular bacillus. After intensive dusting during two to five months with fired vitrified porcelain dust, the laboratory animals showed a highly developed proliferating reaction of the endothelium of the capillaries of the lungs, which induced serious disease and eventually death. The dust was found on the mucous membrane of the respiratory passages, in the alveoli, in part filling these out completely, in the inter-alveolar and inter-lobular tissues, in the peribronchial, perivascular and sub-pleural tissues, and in the tracheo-bronchial lymph nodules. The greater part of the dust formed an inter-cellular deposit. Fine unfired porcelain dust of almost similar SiO₂ content, but richer in kaolin and coal dust, caused qualitatively similar, but much slighter modifications. Two months after the inhalation had stopped, the coal dust had for the most part disappeared from the lungs, whilst the porcelain dust was firmly fixed therein.

With a lesser concentration there appeared, even after use of fired porcelain dust, no particular symptoms of disease. The septa were somewhat thickened in parts through cell proliferation, and there was also a slight fibrosis of the septa. The dust deposit was similar to that in the previous case, but smaller.

After inhalation of lime dust, lime particles were found in the lungs only in very sparse amount. Lime was immediately and completely dissolved.

By application of massive concentration of dust, the changes in the lungs brought about by dust alone were therefore very slight. In order to study the effect of dust inhalation on simultaneous tubercular infection, the rabbits were subjected to an intertracheal infection with droplets by means of spraying with a tuberculous bacillus emulsion. In one part of the experiment, a striking similarity

¹ HENIUS and RICHERT, in *Zeitschr. f. Tuberk.*, 1926, Vol. XLVI, No. 2.

² WEDEKIND, in *Klin. Wochenschr.*, 1928, No. 19.

³ JÖTTEN and ARNOLDI: *Gewerbestaub u. Lungentuberkulose*. Berlin, 1927.

to the conditions in the case of human beings was encountered in the following manner: the animals were first subjected to a weakened infection by the use of drops, and later, after or during prolonged dust inhalation, were reinfected with a stronger intravenous dose of tuberculous bacillus. It was found that with the exception of lime dust, all the kinds of dust applied favoured the settling and dissemination of the tuberculosis infection. The danger of various kinds of dust is given in descending order in the following series: steel grinding dust, coarse pottery dust, fine pottery dust, coal dust and soot. The last two were indeed probably less harmful than grindstone and pottery dust, but showed, however, in contrast to the controls, an undoubted favouring of tuberculosis, an observation which is of importance in the face of many statements to the contrary, which are mostly based on insufficient material. The most dangerous kinds of dust are those rich in quartz. They are distinguished by the fact that they are retained in a considerably firmer manner by the lung tissues than coal and soot. Lime (CaO_2H_2) inhalation does not favour tuberculosis infection—it may even perhaps be said to give rise to a certain arrest of the process. In the case of animals reinfected with porcelain dust, there occurs a marked tendency to the development of connective tissue round the tubercular foci, as is characteristic in the case of human beings where there is a combination of injury due to dust and tuberculosis.

Jötten and Arnoldi consider, as also did Fränkel at an earlier date, the obstruction of the lymph channels by dust as of importance in the causation of the unfavourable effect of dust on the progress of tubercular infection. The lymphatic system in the presence of dust-fibrosis is consequently no longer in a position like the dust-free lung—to effect its task, namely, to reject disease stimulants which have penetrated into it.

The results of research are in accord on many points with those established by Mavrogordato, but indicate further an effect, though a slight one, of coal dust and soot in favouring tuberculosis.

Later, similarly conducted experiments by Jötten and Kortmann¹ have shown that stone dust, with a 57 per cent. silicic content (SiO_2) applied to prevent coal dust explosions in mines, produces a similar effect to the fired porcelain dust, whilst cement dust (20 per cent. SiO_2) and limestone dust only slightly favoured tubercular infection, and basic slag dust not at all.

¹ JÖTTEN and KORTMANN: *Gewerbestaub und Lungentuberkulose*. II. Teil. Berlin; Springer, 1929.

CHEMICAL EXPERIMENTS

Chemical experiments show that where pneumoconiosis is present to a considerable extent, silica has been deposited in large quantities in the lungs. Böhme, in examining rockdrillers' lungs, has found a close relation to exist between the amount of deposited silicic acid and the gravity of the fibrosis. Where the quartz content (and silicates) of the fresh lung substance amounted to over 0.7 per cent. (reckoned as dry substance over 3 per cent.), there was found an extended cicatricial fibrosis, with quantities ranging between 0.3 and 0.6 per cent. a moderate or average extent of fibrosis, and with smaller quantities of quartz very little or no fibrosis. Even in the same lung, the more seriously indurated centres proved to be richer in quartz than the less indurated parts. The highest quartz content found in a rockdriller's lung was 2.25 (calculated as fresh substance) or 8.77 per cent. (calculated as dry substance). The value is almost as high as that formerly found by Langguth in the case of a haematite cutter, namely, 11.9 per cent. (calculated as dry substance), the highest amount known to me in medical literature. The silicon is contained in the acid insoluble fraction of the silicotic lungs not only in the form of SiO_2 , but in smaller portions also as aluminium or alkali silicate. We find in the hydrochloric acid insoluble fraction, 74 to 83 per cent. SiO_2 , 13 to 22 per cent. Al_2O_3 , 3.7 per cent. alkali oxide together with small amounts of MgO or Fe_2O_3 . The coal content of the silicotic miner's lung may be extraordinarily high, up to 5.44 per cent. of coal reckoned as damp substance (21 per cent. as dry substance). In the case of serious pneumoconiosis affecting graphite millers, Koopmann¹ found 12.93 per cent. of graphite (reckoned as dry substance). On the other hand, amounts of 1.4 per cent. of coal (reckoned as wet substance) were supported without reaction by the lung tissues.

INFECTIOUSNESS OF DUST TUBERCULOSIS

All doctors in districts where dangerous dusty trades have been carried on have for centuries back (Agricola) noticed that a high mortality rate from lung diseases amongst the men was accompanied by a considerably lower mortality rate for the women and children. It has been concluded therefrom that dust-tuberculosis is but slightly infectious. This fact is indeed explained by the widely

¹ KOOPMANN, in *Virchows Archiv*, 1924, Vol. CCLIII, p. 423.

recognised poverty in bacilli of the sputum, yet recent accurate observations have nevertheless shown that the frequency of tuberculosis amongst women and children in the families of workers in dusty trades is higher than the average; Ickert¹ and Redeker² have found by radiological examination of the children of Mansfeld miners a frequency of cases of calcified tubercular foci in the lung amounting to twice that for children in the other industrial areas, and further, that active tubercular forms occurred five times as frequently amongst the schoolchildren in the Mansfeld mine districts as in the surrounding country districts. According to Kreuser³, the tuberculosis mortality amongst members of the families of pottery workers is distinctly higher than that for women and children belonging to the families of other workers in the same area (3.1 as opposed to 1.7).

INCIDENCE OF SILICOSIS

There are not so far available research results which embrace the total number of workers engaged in any given industry, yet an extensive series of observations has already been furnished in regard to many industries.

Rockdrillers in Mines

Silicosis is met with more rarely amongst the coal miners in the Ruhr coal district, but on the other hand, more frequently amongst the rockdrillers engaged in drilling the layers of stone situated between the beds of coal, blasting the stone, and removing the debris. Amongst these rockdrillers silicosis has considerably increased subsequently to the introduction of mechanical drills, as a consequence of the larger amount of dust produced. At the instigation of the Ruhr Miners' Society (Ruhr Knappschaft), there was undertaken in the winter of 1928-1929 clinical and radiological (plate of the lungs) examination of 3,318 rockdrillers working in the mines, in order to determine the presence of alterations due to dust. According to Schürmann⁴, of the above workers:

1,261	had worked as rockdrillers for	5 years
1,095	" " " "	10 "
441	" " " "	15 "
305	" " " "	20 "
246	" " " "	25 "

¹ ICKERT: *Staublung und Staublungentuberkulose*. Berlin, 1928.

² REDEKER, quoted by ICKERT.

³ KREUSER, in *Beitr. z. Klinik der Tuberkulose*, 1926, Vol. LXIII.

⁴ SCHÜRMAN: "Gewerbstaub", in *Die gewerbliche Staublungenerkrankung*. Berlin, Springer, 1929.

Of these 3,318 individuals, 80.56 per cent. showed no modifications due to dust, 19.44 per cent. showed modifications due to dust distributed as follows:

	Per cent.
Slight alterations	14.74
Alterations of slight to average severity	2.26
Alterations of average severity	1.84
Alterations of average severity to grave alterations	0.42
Grave alterations	0.18

Examinations made by Böhme amongst working rockdrillers provided similar figures. Greater accumulation of indurated symptoms due to dust is found only after about ten years' occupational experience, but even after five years and, exceptionally, after two years changes of average severity are to be met with. Investigations amongst working rockdrillers do not comprise all severe disease forms, since the victims of these have mostly been already obliged to give up work. Such cases are much more frequently encountered in the course of investigations covering miners suffering from diseases of any kind in hospitals. Likewise the frequency of pneumoconiosis is naturally considerably greater amongst these, since workers with pronounced dust diseases are to be found assembled in the hospitals, and whilst, as a result of the high average age of hospital patients, many workers formerly suffering from latent silicotic disease have at those ages passed into the stage of overt silicosis. Böhme found, during an examination of 301 rockdrillers in a hospital in the last three years, the following figures:

TABLE I

Length of employment on rockdrilling	Number of workers examined	Incipient to slight silicosis	Silicosis of average severity	Severe silicosis	Total
Years					
10	124	41	10	5	56
10-20	133	54	15	7	76
20-30	34	11	7	4	22
Over 30	10	1	2	3	6
	301	107	34	19	160

From this survey there is easily recognised the increase in more serious forms accompanying duration of employment at rockdrilling.

The occurrence of dust fibrosis at all stages amongst rockdrillers is also reported from other German coal districts (Upper Silesia and the Saar district), though statistical data in regard thereto are not so far available; likewise, the presence of silicosis is known amongst ore miners in the Saar and in the Mansfeld mines.

Ickert¹ observed exceptionally, even after two to five years, typical changes; but extensive fibrotic forms only after at least ten years.

In the Mansfeld copper district the mortality rate from tuberculosis is, according to Redeker (quoted by Ickert) three times as high for the men as for the women. The tuberculosis mortality rate reckoned over 10,000 living units, amounts in the local mining communities to 36.5 as opposed to 10.7 in the other Prussian country districts. The peak of the mortality rate for the local miners, and indeed for general affections as well as for tuberculosis, lies between fifty and sixty years of age, that is to say, as high as that for all dangerous dusty trades.

Böhme met with an overt form of tuberculosis amongst rockdrillers having completed over ten years of employment, at the rate of 3.5 times as frequent as that for coal miners with a similar period of employment.

Quarry Workers

According to Domann² there were in 1907 70,000 workers engaged in stone quarries and in establishments for the manipulation of stone.

Thiele and Saupe³ have found amongst quarry workers in the Elbe sandstone district changes due to dust amounting to a very high percentage. This depends on the one hand on the very high quartz content of the stone, and on the other on the fact that victims of dust still continue to work in the dusty trades, whilst in the coal districts they are removed from work on rockdrilling as soon as possible after they are found to be suffering from the disease in question. Tuberculosis is often found in combination with dust fibrosis amongst the sandstone workers in Saxony. Table II again provides statistical data.

¹ ICKERT: *Staublung und Staublungentuberkulose*. Berlin, 1928.

² DOMANN: *Die Steinhauerlung*. Veröffentl. aus dem Gebiete der Medizinalverwaltung. Berlin, 1925.

³ THIELE and SAUPE: *Die Staublungenerkrankung der Sandsteinarbeiter*. Berlin, 1927.

TABLE II

Length of employment Years	Number of workers examined	Injuries due to dust		
		Slight	Average	Severe
Up to 5	9	1	—	—
” ” 10	9	1	2	—
” ” 15	8	6	1	—
” ” 20	19	13	4	—
” ” 25	19	10	6	1
” ” 30	24	9	11	4
” ” 35	10	4	4	2
” ” 40	11	1	10	—
” ” 45	2	—	—	2
” ” 50	1	—	1	—
	112	45	39	9

Kaestle¹ found, among 40 variegated sandstone workers, 25 suffering from silicosis, and amongst 133 white sandstone workers 38 suffering from silicosis. Amongst the variegated sandstone workers silicosis was not only more frequent but occurred oftener in the severer forms, whilst amongst the white sandstone workers the slight forms predominated. The sandstone worked contained about 80 per cent. of crystallised SiO_2 . Kaestle draws attention to the fact that the isolated foci induced by this particularly quartzitic dust were distinguished radiographically by the depths of the shadows and the sharpness of the border lines. Nürburg siliceous chalk contains 89 to 97 per cent. of quartz, mostly in an amorphous form. Among 39 workers, who, moreover, had been employed at the most for fifteen years, 8 were found to be suffering from dust fibrosis².

Amongst 93 granite workers (30 per cent. SiO_2) only 7 suffered from coniosis. Tuberculosis was suspected only in 2 cases.

Kaestle found, among other symptoms, amongst shell limestone workers (SiO_2 practically nil) inflamed hilar glands and sparse pulmonary foci with small mottling, but none of the changes corresponding to true silicosis and no tubercular lesions.

Cement Workers

The cement industry in Germany gives employment to 25,000 workers (Beintker)³.

¹ KAESTLE, in *Fortschr. d. Roentgenstrahlen*, 1928, Vol. XXXVIII, No. 6.

² KAESTLE, *loc. cit.*

³ BEINTKER: "Zementfabriken und Kalkbrennereien", in *Handbuch der sozialen Hygiene*, 1926, Vol. II. Berlin.

Cement contains about 19-22 per cent. SiO_2 , 62-65 per cent. CaO , 7-9 per cent Al_2O_3 . The silicic acid is for the most part contained in a fixed form, only 3 per cent. being free SiO_2 (Jötten)¹. According to Schott², cement workers seldom develop indurated dust focii of the lungs, and then only after ten years' employment. Out of 100 cases, mostly older workers, he found changes due to dust in 21 cases, which for the most part were of a slight variety. Kaestle, on examination of 93 cement workers, found only one typical case of pulmonary silicosis; in five further cases there were slight changes of the hilus and surrounding areas, which he likewise attributed to the effect of dust. The tendency to tubercular changes could not be proved. The tuberculosis mortality rate amounted in 1908 to 10.6 per 10,000, and was therefore very small. Perhaps the lime content of the cement exercises a favourable influence as regards tuberculosis. Sleswijk³ emphasises the fact that in the Dutch sandstone works the risk to the workers diminishes, the greater the lime content of the stone. The low tuberculosis mortality rate of marble-workers, plaster-burners and other workers handling materials with a lime content is known (Jötten and Arnoldi). The quantity of dust in the cement industry is in parts considerable, despite many measures of protection. Jötten found in the packing-room 20 mg. of dust per cubic metre, near the cement mills 160 mg., and near the ball mills 300 mg.

Quartz Millers

Injury due to dust is set up to a considerable extent in the case of quartz millers⁴.

*Pottery and Stoneware Industries*⁵

According to Koelsch (1914), there were 67,295 workers and employees engaged in the German china industry. Only about half of these were employed in connection with the production of china and exposed to china dust in large quantities. The other half consisted of decorators and helpers (painters, packers, machine workers, etc.); 25 to 40 per cent. of the employees were women.

¹ JÖTTEN: "Staublung und Staublungentuberkulose", in *Die gewerbliche Staublungenerkrankung*. Berlin, 1929.

² SCHOTT, in *Beitr. z. Klinik der Tuberkulose*, Vol. LXIX, No. 1.

³ SLEESWIJK, in *IV. Internat. Kongress für Unfallheilkunde und Berufskrankheiten*, Amsterdam, 1925.

⁴ DOMANN, *loc. cit.*

⁵ LEHMANN: *Ueber die Gesundheitsverhältnisse der Arbeiter in der deutschen keramischen, insbesond. der Porzellanindustrie usw.* Berlin, 1929.

The clay used contained about 25 per cent. quartz, 25 per cent. feldspar, and 50 per cent. kaolin (aluminium silicate). Froboese¹ found quantities of dust amounting to 3.5-161 mg. per cubic metre. The higher quantities were almost always found in the grinding rooms; in the other departments the quantities of dust for the most part only amounted to 5-20 mg., or on an average to 12.3 mg. Koelsch had at an earlier date found greater quantities. The installation of the factories was in general designated as hygienic. At points where there was more abundant dust production many kinds of exhaust apparatus had been successfully applied, as in the cases of polishing half-dry china objects, cleaning subsequent to first firing, kiln drawing, glazing, etc.

Holtzmann and Harms² found on radiological examination of 41, chiefly older, pottery workers, 19 cases of coniosis of average to severe type, and in three cases the symptoms of pronounced pneumoconiosis.

Examination of 85 workers belonging to china factories in Berlin revealed about 30 per cent. of the workers as suffering from changes due to dust. May and Petri³ examined radiologically 50 elderly pottery workers particularly exposed to the inhalation of dust, and suspected of clinical symptoms, and found slight thickening in the hilar area in 30 per cent., with incipient mottling in 26 per cent. and distinct mottling in 12 per cent. According to the extensive and protracted researches undertaken by Koelsch and Kaestle⁴ at Selb, the chief centre of the Bavarian pottery industry, 145 out of 455 porcelain workers, or about one-third, revealed radiologically symptoms of dust fibrosis, mostly of a slight degree, and a smaller number in the second and third degree. The male workers suffered more frequently (38 per cent.) from changes due to dust than the women (25 per cent.). The reason for this difference is chiefly to be found in the shorter length of employment in the case of women.

In 1.5 per cent. of the total number cirrhotic tuberculosis was confirmed, and the possibility of a combination of dust fibrosis and tuberculosis was admitted in a further 3.7 per cent. A frequent tuberculosis rate could therefore not be proved.

¹ FROBOESE, in *Archiv f. Hygiene*, 1925, Vol. XCV, p. 175.

² HOLTZMANN and HARMS: *Zur Frage der Staubeinwirkung auf die Lunge der Porzellanarbeiter*. Tuberkulose-Bibliothek, No. 10. Berlin, 1923.

³ MAY and PETRI: *Beitr. z. Klinik d. Tuberkulose*, 1924, Vol. LVIII, No. 2.

⁴ KOELSCH and KAESTLE: *Klinische und röntgenologische Untersuchungen über den Lungenbefund bei 500 Porzellanarbeitern*. (Not yet published, quoted by LEHMANN.)

Amongst the helpers in the pottery industry no forms of indurated tissue due to dust were met with.

Earlier statistical returns prepared by Sommerfeld ¹, Holitscher², Bogner ³, Leymann ⁴, Koelsch ⁵, all concurred in showing a high tuberculosis mortality amongst porcelain workers. At least, any variations were slight. On the basis of clinical researches Koelsch had earlier, in 1908-1912, found a higher morbidity rate for tuberculosis, and likewise Thiele ⁶ in 1920 in regard to the Saxon porcelain workers. Kreuser ⁷ also, in his capacity of insurance medical officer for the district of Merzig finds frequent causes of death from overt tuberculosis amongst pottery workers. The annual tuberculosis mortality rate per thousand amounted amongst the pottery workers to 4.4 per cent., and amongst other workers to 1.77 per cent.

The peak of the tuberculosis mortality rate among porcelain workers was reached, according to Kreuser, between the ages of fifty-one and sixty, whilst for the remainder of the local population the peak rate occurred between twenty-one and thirty. Thiele, Koelsch, Holtzmann and Harms find a similar age for the peak rate.

That the occupational risk is not the only decisive factor in regard to the tuberculosis mortality rate among porcelain workers has been shown by Vollrath ⁸ in a statistical work. In the various porcelain districts of Thuringia the tuberculosis mortality rate amongst these workers is lowest where the economic and hygienic conditions are most favourable, and vice versa. Koelsch ⁹ also proved, in regard to the Bavarian industry, that tuberculosis is of most frequent incidence in those districts where the pottery industry has been longest established, the calling descending from father to son, and where conditions approach those of town industries, whilst in other regions, where the industry was of later establishment, the plant more modern, and the workers living in country surroundings, the tuberculosis was less disseminated. Pathological and anatomical researches have been engaged in by

¹ SOMMERFELD, in *Deutsche Vierteljahrschr. für öffentliche Gesundheitspflege*, 1893, Vol. XXV.

² HOLITSCHER: "Krankheiten der Porzellanarbeiter", in *Weyls Handb. d. Arbeiterkrankheiten*, 1908.

³ BOGNER, in *Deutsche Vierteljahrschr. f. öffentliche Gesundheitspflege*, 1909, Vol. XLI.

⁴ LEYMAN, in *Zentralblatt f. Gewerbehygiene*, 1913 and 1915.

⁵ KOELSCH: "Staub und Beruf", in GROTJAHN and KAUF, *Handbuch der sozialen Hygiene*, 1912.

⁶ THIELE, in *Zeitschr. f. Tuberkulose*, 1921, Vol. XXXIV.

⁷ KREUSER, in *Beitr. z. Klinik d. Tuberkulose*, 1926, Vol. LXIII.

⁸ VOLLRATH, in *Beiträge zur Klinik der Tuberkulose*, 1921, Vol. XLVII.

⁹ KOELSCH: "Keramische Industrie", in *Handbuch der sozialen Hygiene*, Vol. II. Berlin, 1926.

Roessle of Jena. Out of 45 pottery workers, 20 (44 per cent.) were seen on post-mortem examination to have suffered from dust fibrosis, and 25 (50-55 per cent.) from tuberculosis.

From the fibrotic character of the tuberculosis of the lungs and the lack of caseous forms of pneumonia, Roessle¹ concludes that a favourable effect is exercised by porcelain dust.

The results of more recent researches undertaken amongst workers in the German pottery industries, are in agreement in proving that pneumoconiosis of the lungs occurs in a considerable number of cases. Controversy exists in regard to the question of whether tuberculosis is also frequent amongst these workers. Under favourable hygienic conditions, up to the present, incidence of overt tuberculosis has hardly been found to be above the average amongst workers engaged in the china factories. Kreuser's figures relative to the frequency of deaths from tuberculosis and those of Roessle relative to the incidence of tuberculosis as a factor in mortality amongst porcelain workers, point, on the other hand, to the fact that towards the end of life, tuberculosis occurred frequently amongst these workers. The contradiction between these points of view is only apparent. Probably many cases of fibrotic tuberculosis, which only became open late in life, have been disguised as dust fibrosis.

Metal-Grinders

The frequency of lung diseases amongst grinders has been recognised for a long time. Protracted hygienic, clinical and radiological researches have been recently instituted by Teleky, Lochtkemper, Rosenthal-Deussen and Derdack² in the highlands (Solingen-Remscheid district). Recognition of the connection between dust inhalation and lung disease had given rise to the introduction of regulations as to means of protection as early as 1875. Under the influence of these, and in connection with the general fall in the tuberculosis mortality rate, the health conditions amongst grinders has very considerably improved in Solingen, though less so in other places in the district.

In so far as the death registers permit of judgment of the circumstances, it was found that tuberculosis still occurred very frequently amongst grinders and that the rate was extremely heavy in certain

¹ ROESSLE, in *Beiträge z. Klinik d. Tuberkulose*, 1921, Vol. XLVII, No. 2.

² TELEKY, LOCHTKEMPER, ROSENTHAL-DEUSSEN and DERDACK: *Staubgefährdung und Staubschädigungen der Metallschleifer*. Berlin, 1928.

places. The tuberculosis mortality (inclusive of dust fibrosis) relative to 10,000 living, amounted in Solingen to 14.7 for the total male population, and 29.9 for the grinders. In Remscheid the differences were much greater. The tuberculosis mortality return for the male population amounted to 17.0, whilst on the other hand the corresponding rate for grinders reached 97.6. In Solingen as well as in Remscheid, a very remarkably high peak for tuberculosis mortality was revealed for workers of 50 years of age, as Collis and Teleky have frequently shown to be the case in regard to occupational tuberculosis. Very remarkable is the difference between the tuberculosis mortality for grinders in the two adjacent towns of Solingen and Remscheid. Teleky ascribes this to the difference between the hygienic conditions of the industry in the two places.

With the help of Owen's apparatus Rosenthal-Deussen and Teleky estimated the amounts of dust in various workplaces; they then established the fact that in winter the amount of dust was about three times as great as in summer, in consequence of the lack of ventilation and the production of soot from the heating apparatus. The result of comparative analysis at working posts can be seen from table III:

TABLE III. — ESTIMATIONS OF DUST IN GRINDING ROOMS ¹

Occupation	Dust figures at the working-post	
	Summer	Winter
Wet sandstone	1,047	2,546
Dry sandstone, with dust removal	785	
Artificial grindstone, dry, without dust removal	647	
" " " with dust removal	246	
" " " with mechanical removal	428	
" " wet, automatic	203	
" " " hand work	295	
" " with oiling	605	
Dry emery polishing, without dust removal	419	1,424
" " " with dust removal	244	
Fine emery polishing, without dust removal	358	
" " " with dust removal	238	
Dry buffing, without dust removal	526	
" " without dust removal, with oiling	674	
" " with dust removal, with oiling	263	

¹ Rosenthal-Deussen and Teleky.

It follows from this that by far the greatest amounts of dust are developed during the wet grinding of sandstone—an established fact which is in accord with the findings of the English and American research workers. The dust figure is lower in the case of grindstones provided with ventilation apparatus, and likewise in the case of artificial grindstones and emery polishing.

The artificial grindstone consists of artificial corundum (Al_2O_3) or silicon carbide (SiC). Also emery (30-40 per cent. corundum, a little Fe_2O_3 , 2-8½ per cent. SiO_2) is used. Emery polishing is effected by leather bands coated with emery (or colcothar, chalk, diatomaceous earths). The dust figure becomes considerably diminished by the application of exhaust devices during the use of artificial grindstones, and likewise during emery polishing. Oiling does not reduce the dust figure. During wet grinding on sandstone the dust produced is especially rich in quartz particles. Large amounts of dust arise during rounding and splitting of sandstone.

Lochtkemper examined clinically and radiologically 100 grinders, with a view to determining the presence of injuries due to dust. The results of this examination are given in table IV.

TABLE IV

	Number examined	Free form dust fibrosis	Suffering from dust fibrosis		
			I	II	III
Polishers	11	4	7	—	—
Fine emery polishers (plierster)	9	—	9	—	—
Dry emery polishers (plierster)	15	4	8	2	1 ¹
Artificial grindstone	14	2	10	2	—
Dry sandstone	15	4	1	8	2
Wet sandstone	36	—	19	6	11
	100	14	54	18	14

¹ Had worked for twenty-three years in the same room on wet grinding.

The classification of the three stages of the disease differs from the usual practice, in so far as that all cases evolving with thick, fine mottling are included in Group III; these have been recorded by other research workers as changes of slight—or, as the case may be, average severity.

The cases in the first group only show very slight changes. It is true that changes due to dust are found amongst all the groups of workers, but the very severe changes are found almost exclusively

in the case of sandstone grinders, and here again, these predominate in the case of wet grinding.

Polishers, emery polishers, and artificial grinders show only increase of the linear marking of the lung with single mottling, and increased trunk shadows at the basis of the lung. When at all exposed to the influence of quartz dust, these groups of workers only come in contact with very small quantities.

Lochtkemper and Teleky recommend, amongst others, the following hygienic measures of improvement: substitution of artificial grindstones for sandstone as far as possible; separation of emery polishing rooms from the ordinary grinding rooms, and effective dust exhaust devices.

Various Occupations

The occurrence of a typical form of silicosis is known in Germany amongst workers producing and handling fireproof (with a quartz content) stone-ware (schamotte-silica-stone), amongst moulders in iron foundries who make the moulds for castings, amongst workers engaged in sand-blasting; and amongst glass-grinders. Statistical returns as to the frequency of silicosis amongst these workers are, however, still lacking.

Coal Miners (Hewers)

Among hewers in coal mines, also, radiological examination reveals, amongst other symptoms, slight indurated areas due to dust. The frequency of this affection may be seen from the following table, prepared by Böhme:

Length of employment Years	Number examined	Initial changes	Fine mottling	Appearance of the formation of hard cicatricial tissue	Severe thickening	Number of cases of indurated forms
0-10	24	0	1	0	0	1
10-20	94	16	9	0	0	25
20-30	74	17	9	0	0	27
30-40	31	12	9	1	0	22
	223	45	28	1	0	75

The frequency and intensity of the changes thus increases, as in other dusty trades, with the length of employment, but the disease hardly ever proceeds beyond the stage of fine mottling. Anatomical examinations have established that the condition in

question consists of a true small nodular dust fibrosis. Often the cause may be sought in a mixture of quartz with the dust. The coal hewer may also, on occasions, inhale quartz dust which is produced in his neighbourhood, or which he himself raises in removing stones in his proximity. Large quantities of coal dust can, however, in themselves produce a certain form of fibrosis. The quartz content chemically proved to be present in such lungs with coal dust nodules is, however, extraordinarily low. Collis also has observed pneumoconiosis amongst coal miners, especially coal trimmers. In the least severe cases the Röntgen ray revealed changes consisting only in an increase in the linear marking of the lungs. Anatomically this stage often corresponds merely to the filling-up of the perivascular and peribronchial lymph areas with coal dust, without fibrosis worthy of mention.

Severe dust changes are at times observed amongst graphite workers. Quite pure and soft Swedish coal may indeed become deposited in considerable amount in the lungs, and give rise to a mottled X-ray picture, but according to Edling¹ it is not productive of fibrosis. Hollmann² found, amongst 33 workers in a carbon pencil factory exposed to pure coal and graphite dust without admixture of stone, three certain cases of dust fibrosis, and besides these, sixteen cases in a pre-fibrotic condition.

The mortality from tuberculosis among the miners in the Ruhr district was before the war, at the figure 71 per 10,000, less than that for most other occupations. During the War and after the War it rose considerably, and then gradually fell. It would be considerably less were not stonecutters, with their high tuberculosis mortality, included in the returns.

LEGISLATIVE PROVISIONS IN REGARD TO COMPENSATION³

By an Order of the Ministry of Labour, dated 12 May 1925, a number of occupational diseases have been assimilated to occupational accidents for the purpose of compulsory compensation.

Silicosis was not at that time included under those occupational diseases subject to compulsory compensation, though the Schneeberg lung disease, that peculiar disease occurring amongst the miners of the Schneeberg ore district, which evolves with the formation of carcinoma in a silicotic lung was included.

¹ EDLING, in *Acta radiologica*, Vol. VI.

² HOLLMANN, in *Zeitschr. f. Tuberkulose*, 1928, Vol. LII, p. 394.

³ Cf. BAUER, ENGEL, KOELSCH, KROHN: "Die Ausdehnung der Unfallversicherung auf Berufskrankheiten", in *Arbeit und Gesundheit*, 1929, No. 12.

In accordance with the Order of 11 February 1929, by which the list of occupational diseases subject to compulsory compensation was considerably extended, "severe pneumoconiosis" (silicosis) was also included, in so far as it occurred as the result of occupational activity in the following industries:

- (a) Establishments engaged in sandstone extraction, manipulation and manufacture.
- (b) Metal grinding establishments.
- (c) Pottery factories.
- (d) Mining undertakings.

In the case of severe dust fibrosis combined with tuberculosis of the lungs, tuberculosis is regarded as pneumoconiosis (silicosis) for the purposes of compensation.

Right to compensation is therefore confined to *severe* pneumoconiosis. As "severe" are considered, according to the German legal interpretation, in general injuries and diseases which involve a reduction of the earning capacity of the patient by at least 50 per cent. The right to compensation has a fairly extensive retrospective effect. Injuries are taken into consideration when the disease has obviously been caused as the result of occupational activity subsequent to the date 31 December 1919 in one of the industries mentioned.

The insurance is effected as in the case of the German accident insurance, through employers' co-operative societies (*Berufsgenossenschaften*), that is, special bodies founded with a view to execution of the provisions in regard to accident insurance, and protection against accident, which collect the funds necessary for their purpose from the employers in the branch of industry concerned. These societies grant, in accordance with the legal prescriptions, on the occurrence of "severe pneumoconiosis", benefit, the amount of which is dependent upon the degree of earning capacity; they further accord benefit to the next of kin when the occupational disease has been the real cause of death.

The societies are further in a position to grant "transitional allowances" independent of the extent of the occupational loss of earning capacity when continuation of the former occupational activity is to be feared as an agent in aggravating the disease. This "transitional allowance" is intended to enable the patient to enter another occupation which does not expose him to risk.

Tuberculosis of the lungs combined with severe pneumoconiosis is regarded from the point of view of compensation as pneumoconiosis itself.

The occupational disease is subject to compulsory compensation, and also subject to compulsory notification. Notification is obligatory for the employer as well as for the doctor in charge of the case. Notification has to be made at the *insurance office*, which proceeds to thorough examination by a doctor appointed for the purpose—"geeigneter Arzt". The society decides as to the proposed payment of benefit. Appeal to the Reich Insurance Office against their decision is possible.

In future, the institution of protective measures against silicosis in the industries affected will also come within the competence of the societies.

PROPHYLAXIS IN REGARD TO DISEASES FROM DUST

According to Thiele and Saupe, in the Elbe sandstone district it is the practice to wet the stone frequently, in order to reduce the amount of dust produced. Many attempts have been unsuccessfully made in regard to the wearing of respiratory masks. The workers always felt themselves unduly hindered in their work by these.

In the grinding industries, the use of ventilators in the workrooms, and of dust exhaust apparatus at the working posts has been compulsory for several decades. Processes which cause considerable dust production, such as the splitting of grindstones, have to be deferred to the close of the working shift. Teleky demands, further, that as far as possible sandstone should be replaced by artificial grindstone, and that effective dust exhaust devices should be installed, together with the separation of polishing and grinding operations.

In the china industry, also, the provision of exhaust dust apparatus, and means of maintaining the workrooms in a state of cleanliness are required. The hygienic conditions have been greatly improved during the last decades, and further improvement may be expected by the erection of partition walls to shut off very dusty processes from other departments, and by the covering-in of edge mills and similar devices in dust-tight compartments. Koelsch, further, demands thick, smooth flooring, cleaned daily by wet process, daily cleaning of the working post and tools, special working clothes, and adequate washing facilities.

In mining, many efforts have been made to prevent the production of dust and to further its removal. Many rockdrillers tie wet sponges in front of their noses, others wear respiratory masks of

various patterns; most workers, however, are opposed to such measures, since they are apt to hinder work. The "duster" who sprinkles stone dusts as a protective measure against coal dust explosions, regularly wears a protective mask. Continuous sprinkling with water of drill holes is very much practised, but the contact with material which becomes wet during this process, as well as wetting of the workers' clothes, has been found extremely trying. Dry exhaust removal of dust from drill holes, on the principle of the vacuum cleaner, has likewise been applied in many places.

A prize essay recently issued on the subject of measures of protection against dust contains many new proposals, the efficacy of which time alone can prove.

In many dusty trades, the wearing of helmets with a provision of fresh air has become an established custom, as, for instance, in sand-blasting.

Where convenient, as, for instance, in the case of ball grinders, an effective protection from dust is provided by enclosing the apparatus in a dust-tight cover.

There must be emphatically demanded thorough medical examination before entry into the occupation of rockdrilling, combined with the rejection of unfit applicants, and likewise periodical radiological examination.

Of great importance for the protection against many severe forms of pneumoconiosis, is the campaign waged against tuberculosis. All individuals manifestly tubercular must be kept away from work in trades involving exposure to quartz dust. The well-organised campaign against tuberculosis engaged in for several decades past, has succeeded in bringing about a reduction in the tuberculosis mortality and morbidity rates, but during the war and post-war periods these figures again increased very considerably. In recent years there has occurred a fresh reduction as compared with the pre-war figures, and it is hoped that a further fall in the tuberculosis rate may exert a favourable influence on the campaign against the severer forms of pneumoconiosis.

The brilliant success encountered in connection with the application of well-organised measures for dust reduction in South Africa leads to the hope that in Germany also the campaign against pneumoconiosis will be crowned with success.

II. — TYPES OF DUST AND SILICOTIC LUNGS:
COMPARATIVE STATISTICAL AND
CLINICAL-RÖNTGENOLOGICAL RESEARCHES IN BAVARIA

BY PROFESSOR KOELSCH, MUNICH, IN COLLABORATION WITH
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According to the theory of pneumoconiosis founded by Zenker, Professor of Pathology in the Bavarian University of Erlangen, in the year 1865, all changes of the pulmonary tissue caused by different kinds of dust were up to the beginning of the present century considered as fairly similar, though chalicosis (lung changes due to stone dust) took a specially predominant place in regard to its pathological and clinical effects.

The notions of the action of the various types of dust were at that time standardised in an essentially morphological manner, it being assumed that it was particularly the pointed and sharp-edged dust particles which caused mechanical wounds of the pulmonary tissue and thereby in combination with dust deposits set up injuries. Only with the observations of the last decades, and in particular the thorough investigations effected in the last fifteen years have the former theories been fundamentally altered. To-day it is recognised that the varied types of dust must be judged in a fundamentally different manner, that in this connection the decisive factor in regard to effect is not so much the morphological-physical activity of the various types of dust, but rather the content of free crystallised silicic acid (quartz). Where it is a question of mineral dust, where dust with a mineral, metallic, vegetable or similar content is raised, the deciding factor in settling the question from the point of view of industrial medicine is the relative presence of free silicic acid; it need hardly be added that the amount of dust, the duration of exposure to it and other external factors also play their part.

Wherein does the specific effect of silicic acid consist? In addition to morphological properties such as hardness, sharp glass-like fracture, there come also into consideration certain chemical-necrotic fibro-plastic effects, interference with the cleans-

ing mechanism of the lung in regard to dust removal, disturbance of the bactericidal power of the blood and other factors; these problems still await solution at the present time.

It is, besides, now known that the various forms of pneumoconiosis manifest fundamental differences from the pathological-anatomical and clinical points of view—that in reality it is only injuries caused by dust with a silicic acid content, the so-called “silicosis”, which are of practical importance. Finally, it is necessary to distinguish between “dusty lungs” and pneumoconiosis, for not every “dusty lung” as regards silicosis implies disease in the clinical sense, involving a right to compensation; only in the case of average and severe forms is it possible to speak of pneumoconiosis. The same is true of uncomplicated silicosis; yet in the latter case certain complications may be brought about especially through accompanying tuberculosis (silico-tuberculosis, tuberculo-silicosis) or through secondary disturbances of the circulation; such complications may under certain circumstances, even in cases where röntgenological examination reveals but slight symptoms, lead to the belief that severe illness is in question. The present-day view in regard to the problem is somewhat as described above.

The author had already commenced some years ago to prove these views statistically and clinically by large-scale investigations. In the last few years over *1,200 workers in various branches of industry involving exposure to mineral dust* were clinically and röntgenologically examined with the collaboration of the röntgenologist Dr. Kaestle: for the majority of this group of workers available history in regard to morbidity and mortality from diseases of the respiratory passages was also taken into statistical consideration. The data provided by these investigations, will be given in a comprehensive manner in the following part of this Paper, and dealt with, with the exception of granite, in order of the specific danger attaching to the dust as regards pneumoconiosis, beginning with the occupations known to be the most dangerous.

(1) The foremost place is occupied by *sandstone workers*.

Our investigations covered workers from the variegated sandstone district on the lower Main (Miltenberg, Marktheidenfeld) and from the white sandstone district on the middle Main (Eltmann, Zeil). The material worked consisted of quartz granules of varying size baked into a conglomerate with argillaceous cement. The total silica content amounts to 80-85 per cent.; it consists almost

entirely (90-100 per cent.) of free silicic acid. The microscopic picture of the *fine dust* reveals considerable quantities of quartz crystals. Statistical analysis of the data furnished by the General Local Sickness Fund at Marktheidenfeld revealed the fact that sandstone workers there (calculated on the full working complement) showed on a four-year average, in respect of pulmonary tuberculosis, a morbidity rate about five times that for the remaining insured male population of the same age. The rate for other diseases of the respiratory system was likewise higher (10.50 as against 7.71), while the rates for all other disease forms including accidents occurring amongst sandstone workers were lower (the total being 59.18 as against 61.88). In the case of the General Local Sickness Fund of Miltenberg, the three-yearly average showed a considerable excess for sandstone workers for all forms of disease of the respiratory system including tuberculosis (15.8 as against 5.2). In the case of the Trade Sickness Fund of the firm Ph. Holzmann, the rate for diseases of the respiratory tract, including tuberculosis, amounted for the three-yearly average affecting sandstone workers, to 1.25 per cent., while for the remainder of the insured workers it was 0.90 per cent.

The *death register* showed the following results (three-yearly average):

District	General mortality		Tuberculosis, lung diseases	
	Stone-workers	Other males	Stone-workers	Other males
	Per cent.	Per cent.	Per cent.	Per cent.
Marktheidenfeld	5.60	1.64	5.32	0.2
Miltenberg	3.83	1.64	3.11	0.2

About 173 workers in all were covered by the *clinical röntgenological examination*. Whilst deposits of stone dust were only found to a small extent, 1 per cent. in the case of workers with a five years' record of work, the amounts found in the case of workers old in the trade grows to such an extent that workers with a twenty to forty years' record showed up to 76 per cent. affected by severe injuries due to dust. Taken all in all there was found in the case of 36 per cent. of the workers indisputably positive lung changes as indicating silicosis, of which five were probably combined with tuberculosis.

The Röntgen ray picture showed here quite typical changes; in pronounced cases both lungs were found to be fairly evenly infiltrated with numerous isolated foci, characterised by strikingly profound shadows and sharp borders of the isolated foci; the foci with fine mottling gave the appearance of small shot (bird shot). The site favoured was the middle and lower region of the lungs. There were also found pictures showing broadened flakelike foci distributed fairly symmetrically over both lungs; these massive broadened foci were likewise characterised by the depth of their shadows. To these were added massive hilus nodules with sharply outlined arborification, and further, not uncommonly pleuritic changes, adhesions, etc. The general impression is one of a severe mass of dust infiltration of the pulmonary tissues.

(2) In the neighbourhood of Neuburg on the Danube, the so-called *siliceous chalk* is extracted, which contains about 86-97 per cent. of silicic acid mostly in a free state. Thirty-nine of the workers engaged there were examined clinically and radiologically; the majority had, it is true, been working in the trade for under ten years (frequent change of occupation!). Most of these were found to be relatively healthy; on the other hand, eight showed clear signs of silicosis, mostly in the form of mixed large nodular and fine mottled foci; the shadows were somewhat less profound; between numerous soft shadow areas with relatively sharp outlines lay solitary thick foci with profound shadows resembling those typical of pure sandstone pneumoconiosis.

(3) Less on account of its place in the order of danger, but rather on account of the type of Röntgen picture connected with it, an account of the *granite stone industry* may be added here. Granite dust contains between 61 and 82 per cent. of silicates; the content in free crystalline silicic acid is said to amount to about 25-30 per cent. The physical combination of the quartz crystals is probably a very firm one in this case. Statistical analysis of the data of the General Local Sickness Fund for the Passau district, counting upwards of 1,600 granite workers (full working complement) amongst its members, showed more favourable figures relative to respiratory diseases including tuberculosis of the lungs in comparison with similar age-groups amongst the remaining male members insured. Likewise the mortality rate for granite workers as against that for the general male population in the same district was in nowise excessive. It was even, on the other hand, more favourable: mortality rate from all diseases (three-yearly

average) 0.56: 2.11. The mortality rate for tuberculosis was 0.14: 0.16 per cent. The anamnestic and clinical investigation next covered 200 granite workers of the lower Bavarian forest. It revealed in general more favourable conditions than had been expected. A thorough clinical and röntgenological examination of a further 93 granite workers from the Fichtelgebirge was effected later, almost 82 per cent. of the workers in question having been engaged in the occupation for upwards of ten years (up to fifty years); 64 of these showed no symptoms of any kind. Clinical findings in respect of subjective complaints were present in the case of 20 workers, yet the röntgenological examination showed in all these cases fairly normal conditions.

Clear pneumoconiotic changes were only established in the case of 5 workers in all (out of 93)—that is, hardly 5 per cent. of the workers in question having a record of work as granite cutters of between twenty-five and thirty years. The pneumoconiosis of the granite workers examined by us is characterised by more or less numerous, fairly thick, small foci of the size of those produced by sandstone pneumoconiosis, by arborification starting from more or less distinct enlarged and thickened hilar markings, especially in the right towards the basal and also the other regions of the lung. The speckled shadows are localised as in other types of silicosis, that is to say in the middle and infraclavicular lateral regions of the lungs. In the cases examined by us the small foci did not in general attain the thickness of the finely mottled forms found amongst victims of sandstone pneumoconiosis; solitary nodules approached this thickness. The smaller content of crystalline silicic acid in firm combination with other harmless accompanying minerals may indeed be considered to be the chief reason for the diminished biological effect of this mineral dust in general on the lungs.

(4) Special interest has been taken in *porcelain workers*, the dust risk to which they are exposed having for long been disputed. The possibility of contamination of the atmosphere by dust in the porcelain industry is freely admitted. I have determined the presence at various working posts of concentrations of between 22 and 205 and over milligrams of dust per cubic metre of air. The porcelain contains 42-66 per cent. of clay (aluminium silicate), 17-37 per cent. feldspar (potassium aluminium silicate), 12-30 per cent. quartz (free silicic acid). In the glaze there is about 30 per cent. of quartz, 30 per cent. feldspar, 26 per cent. calcspar,

10 per cent. porcelain fragments and smaller quantities of other mineral by-products. The dust is very fine and very volatile, though it is necessary also to take into consideration the fact that owing to the hardening process (vitrifying) a part of the free silicic acid in the quartz enters into combination with the potassium and aluminium.

I had long ago undertaken comprehensive statistical research in regard to the liability of porcelain workers to diseases of the respiratory passages or tuberculosis, the results of which, similar to those achieved by earlier authors, confirmed the high morbidity and mortality rates of these workers from diseases of the respiratory passages, including tuberculosis. As an example I established the fact that in certain typical porcelain districts of Bavaria perceptibly higher mortality rates occurred amongst porcelain workers for tuberculosis and other chronic lung diseases in comparison with members of the general population belonging to similar age-groups—in Selb and Rehau a fourfold, in Tirschenreuth, Kronach, Teuschnitz a two or two-and-a-half times increased mortality rate. Similarly the actual porcelain makers showed an increased morbidity rate for respiratory diseases—for instance, in Selb 11.22 per cent. as against 8.44 per cent. for the other workers in the same factories. Clinical examination (without röntgenological plates) revealed, in the case of about one-half of the 1,000 porcelain workers examined, changes in the lungs which must be ascribed to injury due to dust. It was possible to prove correspondence between duration of employment and changes in the lungs.

There was effected a further clinical and röntgenological examination of 500 workers. In this case it was found that about 55 per cent. of the male workers and 35 per cent. of the women workers, giving an average of about 45 per cent., showed changes of the lungs of varying degree due to dust.

Critical consideration of the data provided by these examinations lead to the following conclusions.

In the case of workers who had been engaged in the porcelain factory for a few years there was entirely lacking specific dust changes of the lower respiratory passages or where present at all these showed but slight development. In the case of *older workers* with a relatively short duration of work the changes were more plainly seen and more obstinate than in the case of *younger workers* with the same duration of employment. Here an important part is played by the vitality of the entire constitution and of the respiratory system as a defence against injury, and in regard to the

self-cleansing mechanism for removal of the dust which has penetrated into the respiratory passages. With advancing working experience the symptoms of dust infiltration of the respiratory organs increase from the subjective, clinical and röntgenological point of view.

The first signs of dust in the lungs of porcelain workers are revealed röntgenologically by numerous shadow patches of almost similar size distributed over the two central parts of the lung being about a pin's head in size or a little over. The shadow patches are relatively soft and the borders are of average sharpness. In places there is to be seen in addition signs of chronic bronchitis and peribronchitis, especially in the infraclavicular and lower, but also in the upper and lateral parts of the lungs in the form of bands with a double contour and showing nodular swellings in their course.

Besides these changes there occur, especially after long occupational activity and with advancing age more or less widespread, broad, thickened areas in the lungs, mostly in the middle regions, reaching from about the clavicle to the upper end of the lowest third of the lung.

Dry pleuritic changes (hairlike lines in the lungs, displacement of the diaphragm, thickened reticulated areas) are often met with even in the case of incipient forms of porcelain workers' pneumoconiosis; on the other hand, exuding pleurisies are seldom met with in cases of pure pneumoconiosis. Secondary changes of the heart (dilatation, hypertrophy) are by no means rare in such cases of severe pneumoconiosis affecting porcelain workers. Obstructed blood vessels and obstruction in the parenchyma and interstitial spaces complicate the Röntgen picture turning it in its entirety or in part into an inextricable chaos.

Inflammation of the lungs, bacterial infection especially accompanied by tuberculosis to which porcelain workers are beyond doubt more liable as compared with the general population, may at any time lead to premature death in the case of these porcelain workers, whose lungs and circulatory organs are already impaired. In some cases, tuberculosis was found, also cavernous phthisis of tubercular origin affecting porcelain workers who had been employed up to a late age; in such cases it is indeed possible to speak of the retarded effect of indurated lung changes. No accurate knowledge is available to enable us to ascertain how many porcelain workers—men and women even in their *early* years in the incipient stages of porcelain pneumoconiosis, that is at the

irritation stage, are eliminated on account of pulmonary tuberculosis infection and take up other employment or meet with premature death.

(5) *Chamotte industry.* — By “chamotte” is meant fired clay with a high melting point which is ground down, mixed with ordinary clay and fired to make bricks. This mass contains about 70-75 per cent. of aluminium, about 2.5-3 per cent. of spar, about 20-26 per cent. of quartz, and the total silica content amounts to 25-30 per cent.; the free silicic acid becomes combined with the potassium and aluminium to a considerable extent in the firing process (vitrifying), so that in this way the free silica content is eventually considerably reduced: “probably free silica is hardly present any longer in the finished article”. The dust is relatively large grained, heavy and less volatile.

Examination was made of 234 chamotte workers. The data provided by the investigation was so arranged that two groups were formed according to the röntgen findings: group I with negative or harmless röntgenological results, and group II with positive results. Group I comprised 184 individuals (78.63 per cent. of all examined), of whom nearly 65 per cent. had been in the industry upwards of ten years.

Group II comprised 50 people (= 21.37 per cent.), most of whom were of advanced age; 92 per cent. had been in employment for upwards of ten years. Subjective complaints predominated in regard to this group though 20 workers made no complaints. Clinical examination of the respiratory organs revealed for half this group changes from the normal condition; 15 men belonging to the group, however, showed no clinical symptoms. Röntgenologically, there was established fairly plain results of dust in the lungs, which may be summarised thus in passing. Once again there was revealed lack of correspondence between complaints, and clinical and röntgenological findings to such an extent that workers with fairly severe objective symptoms were free from complaints, or again that workers with subjective complaints showed relatively slight objective signs, and so on. *The Röntgen picture* showed chiefly, sparse, multiple, fine mottled isolated foci, distributed in various ways over the lungs with masses of thickened reticulated areas and hilum markings; the shadows were soft and in this respect occupied a place somewhat between those of porcelain and cement coniosis; they were relatively small with sharp outlines. The lungs often showed a particularly wavy

appearance as if sown with small grains of grit. The broad shadow patches were distributed either uniformly over the whole lung, the basic parts being slightly less involved, or (more rarely) over the lateral parts of the lungs.

In general, it was possible in this case also to establish the fact that those with a long duration of employment showed greater injury from dust than those with a shorter record of work, that however in spite of this fact, even in the case of a record of ten to twenty years' work, the changes due to the presence of dust in the lungs only attained a moderate degree. It was not possible to observe here cases of the three stages of the disease. Almost three-quarters of the total number of workers examined having upwards of ten years of employment in the chamotte industry showed *no or only very harmless* pulmonary symptoms on röntgenological examination. In any case the results of our investigations here were by no means without value in regard to the distribution of injuries of the respiratory passages due to dust, since they served to indicate that the dust raised in the manufacture of chamotte contains little free silicic acid, but on the other hand has a rich clay content.

(6) *Shell limestone.* — Shell limestone consists for the most part as its name implies of mussel shells which are bedded in clay, also principally of carbonate of lime and clay with, as the case may be, an admixture of iron. Free silicic acid is not present, or at least only in traces.

Statistical analysis of the data provided by the General Local Sickness Fund for the Würzburg district, to which all of the more important establishments of the Bavarian shell limestone industry belong, showed, in the three-yearly average, that the shell limestone workers as opposed to the remaining male members insured, were more favourably placed both as regards general morbidity rates and morbidity rates for respiratory diseases, including pulmonary tuberculosis.

Likewise the mortality rates would appear to be by no means less favourable than those for the general male population. The first (merely anamnestic-clinical) examination covered 200 workers, of which 72 per cent. had been upwards of ten years in employment. Two-thirds of them were designated as quite healthy; in the case of one-third only slight symptoms of the respiratory passages were confirmed. Better results were afforded by the later clinical röntgenological examination of a further 124 workers most of

whom had been more than ten years in employment; of these 81 had previously worked exclusively in the shell limestone industry (Group I); 14 of these showed dust deposits in the pulmonary tissue with no complaints or very slight complaints. Röntgenologically there was found in 8 of those examined large hilum glands, at times with a brighter nucleus and a thicker capsule. Four examinations revealed sparse fine mottled foci distributed over the lungs irregularly, and atypical as regards site; in 2 cases there were fine mottled foci with nodes in the hilum. The fine mottled foci were soft in shadows, not very thick and at the same time fairly plainly outlined in contrast to their surroundings.

That fine mottled foci are seldom found in the lungs of limestone workers, in spite of the dust evolved during the work, is partly explained by a certain solubility of lime dust in the respiratory passages, by its rapid elimination, and partly by the tendency of lime particles to coalesce and so to become too big to penetrate into the deeper respiratory passages. They irritate the mucous of the larger bronchial tubes and are in part reabsorbed and in part eliminated. It is seen from these investigations, that also limestone under certain circumstances may cause alteration of the lungs as indicating pneumoconiosis if only it is allowed to exercise its effect for a sufficiently long time. Still these pictures are clearly distinguished from Röntgen pictures for instance of sandstone or porcelain workers. Group II (43 workers) had also manipulated sandstone for some time as well as shell limestone, 29 of them having handled more shell limestone and less sandstone (M workers)—14 the opposite (S workers). In the case of the M workers, 13 showed a normal condition of the lungs, 6 border symptoms and only 10 (34 per cent.) lungs with a dust deposit. Of the S workers, on the other hand, 10 (71 per cent.) showed clear changes in the lungs due to dust.

If Groups I and II be compared it is found that in manipulating pure shell limestone (Group I) the percentage figure for negative pulmonary cases is by far the predominant one and the figure for clear cases of pneumoconiosis is considerably less, whilst under the influence of sandstone dust (Group II) these relations are reversed. It may be deduced therefrom that work amongst sandstone even when—and this is almost constantly the case amongst our people—work has only been carried on for a few years (mostly three to five or to eight) and when years and decades have already elapsed since the employment in question, always leaves traces in the pulmonary tissues, which it is true very often

remain latent from a subjective or clinical point of view, but can nevertheless be "brought to light" by the Röntgen rays. Whether and to what extent the later work among shell limestone may have influenced favourably the residual effects of work among sandstone we do not dare to decide with certainty.

As far as the Röntgen picture in particular for Group II (combination of earlier work among sandstone with later employment in an atmosphere of shell limestone dust) is concerned, the following comprehensive account may be given: in this group there are found clear pictures of sandstone coniosis resembling those above described; there may be recognised in this case in the typical pictures of lungs resembling grains of small shot the one-time influence of a mineral dust with a high quartz content on the lung. There are found in part also on lung pictures with typical sandstone-coniosis foci resembling those found in shell limestone-coniosis: less profound shadows than in the case of the fine shot shadows, with fairly sharper outlines; also enlargement of the hilum glands and thickened areas are found. It is true that under the influence of subsequent work in an atmosphere of shell limestone the traces and effects of earlier work on sandstone had not been—or at least had not been constantly—eliminated but have rather persisted.

(7) *Cement.* — In cement dust (lime-aluminium-silicate) there is found 19-26 per cent. of silicic acid, though in general combined with calcium oxide and alumina in a non-soluble form.

If the following morbidity rates are made to refer to 100 workers per annum they provide percentages as follows: diseases of the upper respiratory passages, 6.6; diseases of the lungs (inflammation, tuberculosis, pleurisy), 4.2; 2.4 per cent. were treated annually for pulmonary tuberculosis (2.6 per cent. of the cases of sickness); in none of the cases referred to was an abnormal duration of illness established; most of the cases of sickness recovered after from three to four weeks. Of the cases of bronchial catarrh none lasted longer than thirty days; cases of inflammation of the lungs with a duration of from three to six weeks correspond to the clinical type; cases of delayed resolution (over fifty days) were not observed to any extent. The mortality rate for cement factory workers showed no difference from that for the local population at the same ages, but rather remained considerably under the average for the district; the tuberculosis mortality rate in particular was within ten years under the average for the whole Bavarian population.

The anamnestic-clinical examination of 600 cement factory workers showed no unfavourable results; in about 10 per cent. bronchitis, etc., was present; in about 15 per cent. of the cases changes in the respiratory murmur as indicating a dust deposit were observed.

Recently a further 93 workers were thoroughly examined clinically and röntgenologically, 85 per cent. of whom had been in employment for upwards of ten years; 79 of these showed negative röntgenological results, though a few suffered from slight complaints; 4 further cases showed relatively benign tubercular processes without a considerable rôle being played by the presence of dust; 4 further cases showed border signs, 6 clear signs of pneumoconiosis (5 of these with over ten years of occupational activity). There was only *one* picture of the pulmonary form of pneumoconiosis. The 5 remaining cases belonged to the hilar form, that is to say, there was found enlarged and thickened hilum markings—mostly with small thickened deposits—and thickened arborification of the hilum in parts of the lungs only, or all over. Only 2 of the cases observed by us showed these phenomena in a pronounced form, the remainder in a slight form. Pure cementoconiosis as revealed by our investigations was slight in extent and benign; it was clearly distinguished from sandstone workers' silicosis; the foci shadows were softer, less profound, the characteristics of the "fine shot lung" are lacking in cement workers' coniosis. Thickened foci are also found here in isolated areas.

Now how is this relatively favourable effect of cement dust to be explained? The high limestone content has been alleged to be 66-67 per cent., of which the favourable influence on tubercular processes is well known. Likewise the solubility of the cement in water containing carbonic acid is of importance as regards the self-cleansing mechanism of the body. Perhaps its capacity for swelling also plays a part, and thereby facilitates the resorptive influence of the carbonic acid (Schott and others). Most important of all however would appear to be the fact that cement dust—in contrast to dust with a high percentage of pure silicic acid—does not remain free in the tissues but is greedily absorbed by the dust cells and removed. There is lacking here—just as in the case of lime and gypsum dust—the capacity for forming typical fibroses.

(8) Finally mention should also be made of workers engaged in handling basalt and melaphyr chiefly in *macadam* factories. The total silicic acid content is here said to amount to about 50

per cent.; free (crystalline) silicic acid is however not present. The statistical clinical examination covered 200 workers, 70 per cent. of whom had a ten years' record of occupational activity. Since the anamnesis as well as the clinical examination provided no striking results, and further the analysis of the sickness returns revealed no increased disease liability for this category of workers as compared with similar groups in the same district, röntgenological examination was dispensed with.

The outcome of the examination of groups of workers exposed to mineral dust of varying composition may be summarised as follows:

The *statistical* morbidity and mortality returns, as well as in particular the clinical-röntgenological examinations, show clearly that the fundamental principle is as follows: the greater the quantity of free silicic acid in the dust the more dangerous it is for the lungs—thus it is also found in reality that in the case of occupational groups brought into contact with substances rich in free silicic acid (sandstone, so-called siliceous chalk, to some extent also porcelain) there exist increased morbidity and mortality rates from chronic lung diseases (silicosis, silico-tuberculosis); on the other hand statistical returns are the more reassuring the less free silicic acid is present in the dust in question (workers handling cement, clay, chalk, etc.). Similar results and, in truth, still more sharply emphasised, are provided by the Röntgen picture. Here we find in accordance with the composition fairly characteristic pictures relative to the dissemination, form, thickness, outline of the shadow foci: on the one hand with the presence in abundance of free silicic acid either massed broad foci with profound shadows or more frequently, multiple, fine mottled or nodular foci with sharp outlines and striking depth of shadow of the isolated foci (lungs resembling fine shot). On the other hand the lower the percentage of free silicic acid in the dust the more the argillaceous and calcareous elements predominate the softer, the less sharp edged will be the outlines and the less profound the shadows—whether it is a question of isolated foci or conglomerated shadows. A trained research worker will in this way be able to deduct from a good Röntgen plate the relative content of the dust in question in free silicic acid, or the amount of clay or lime elements present, with a fair degree of certainty.

It is not going too far to say that the *röntgenologically demonstrable property of the biological reaction of the respiratory organs towards inhaled dust* is a good test of the content of the dust in free

silicic acid. Where doubt exists as to the content of inhaled dust in free silicic acid on the basis of analyses, the Röntgen picture can furnish in *typical cases* an important indication as to the chemical activity of the type of dust in question, and its content in fine SiO_2 , whether the latter has been contained from the outset in the dusty product manipulated, or has been liberated during the mechanical processes of manufacture.

We are of course quite aware that in addition to the silicate content many other factors must be taken into consideration in regard to the development and type of symptoms of the pneumoconiosis: for instance, duration of work, working posture, and especially the constitutional factor, on which later depend to a high degree the rapidity of development of the silicosis, the self-cleansing mechanism of the lungs, the distribution of the dust deposit and of fibrosis in the pulmonary tissue and so on. Nevertheless we desire to insist with all possible emphasis on the decisive part played by free silica in the development of silicosis. This knowledge appears to us to be of special import, particularly in regard to measures of prophylaxis to be adopted by the practising factory surgeon in isolated establishments, and also for procedure in regard to the handling of the pneumoconiosis problem from the legal aspect in regard to compensation.

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SILICOSIS IN GREAT BRITAIN

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INTRODUCTION

The aim of this paper is to bring within review the industries and processes in which the workers are exposed to the inhalation of silica dust. Throughout, the use of the word "silica" has been confined to the dioxide of silicon, SiO_2 , as it occurs free in nature in the form of quartz, flint, chert, etc. Although materials are dealt with which contain free silica mixed with other substances either naturally, as in granite, or artificially, as in earthenware, no substance is regarded as coming within the scope of this paper in which the silica is wholly united with other elements in chemical combination. It is necessary to make this limited application of the word "silica" quite clearly understood, because the compounds known as silicates will, sooner or later, have to be studied systematically as the causes of pulmonary disease in industry. There is abundant evidence already that the silicates cannot be regarded as a single group showing a uniform effect on the pulmonary tissues and producing the same results of disablement and death of those affected. There is also sufficient evidence to show that the action of the silicates is different from that recognised as typical of the action of free silica.

One of the problems raised by bringing together facts such as are grouped in this paper is that relating to the action on the lungs of mixed dusts. While it appears to be true that free silica tends to produce its characteristic effects whether inhaled alone or in admixture with other dusts, it seems equally true that its action is influenced to a greater or less extent by such dusts. When the accompanying dusts happen to be silicates which are capable themselves of producing effects, the resulting changes in the lung tissues, the influence on function and the reaction to infections become extremely complicated.

The need for close investigation of all the possible circumstances in which these dusts produce destruction of function is emphasised by observation of the cases of disablement and death which are brought to light at the present time, more or less by hazard.

The principal facts regarding the action of silica are generally accepted, but we are still far from being able to explain the apparently

unequal results of exposure to the inhalation of even unmixed silica dust. To gain a better understanding of this problem it is necessary to place side by side as much of the evidence as can be brought together, from all sources where the problem exists.

The scope of this paper is confined almost entirely to matters which have come to the notice of the writer as Medical Inspector of Factories in the Factory Department of the Home Office. In the sections on mining, material has been supplied and guidance given by Dr. S. W. Fisher, H.M. Medical Inspector of Mines, whose help is gratefully acknowledged.

A number of dust-counts have been included in this paper. These have been made during various investigations within the last eight years. The instrument used for collecting the samples was Owens' jet dust-counter, and for counting, a microscope giving a magnification of from 900 to 1,000 diameters was used. In all cases, unless otherwise stated, all particles over about half a micron in size are included in the total count. In most cases an estimate is given of the proportion of the total number of the particles which appeared to consist of the dust under investigation, as distinguished from soot particles which constitute the greatest difficulty in accurate counting in most of these cases. The technique employed is similar to that described in the *Annual Report of the Chief Inspector of Factories, 1922*¹.

Each industry or process has been dealt with as far as possible under the following heads: definition; distribution geographically; employed persons; operations and processes at which silica dust is liable to be inhaled; special character of the silica dust and reference to other dusts and other modifying conditions as to the form and concentration of dust in the atmosphere; evidence of silicosis being produced; methods of prevention and special legislation; compensation.

The industries and processes include (1) refractory materials; (2) grinding of metals; (3) sandstone; (4) granite; (5) slate; (6) coal mining; (7) tin mining; (8) pottery; (9) sand blasting; (10) silica milling; (11) scouring powders; (12) flint crushing; (13) flint knapping; (14) millstone dressing.

References to the literature and official papers are given at the end of each section.

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REFRACTORIES INDUSTRY

For the purposes of legislation it has been necessary to define this industry, so far as the use of silica is concerned, in its limited sense. For this purpose the term " refractory materials " refers to materials used in the construction of furnaces, flues, crucibles, etc., on account of their resistance to heat, when they are subjected to the cutting action of flue gases, the influence of slags, and of sudden changes in temperature¹; and in the making of moulds in which metals are cast. They contain over 80 per cent. of silica.

The refractory materials in the raw state consist of silica rock of high silica content, usually from 92 to 98 per cent. They include ganister, quartzite, siliceous sandstone, quartz-schist or conglomeratic quartzite². Natural sand, flint and chert also may be used.

Distribution

These materials are widely distributed throughout this country. The chief sources of supply are Yorkshire, Derbyshire, Cheshire, North and South Wales, Durham and the south of Scotland, that is to say, in the coal measure districts. In the majority of cases the materials are manufactured near the spot where they occur in the quarries and mines.

Employed Persons

About 3,000 persons are employed at present in the industry, of which about 5 per cent. are women.

Processes

Various processes, from the quarrying or mining of the raw material to the handling of the finished product, may give rise to dust.

The raw material may be in the form of natural sand, as from the pocket clays of Derbyshire and deposits in the south of England. In getting out this material from the quarries or sandpits, the exposure to silica dust, though by no means absent, is relatively slight, for two reasons: (a) the grains of sand are of too large a size

¹ Cf. Bibliography, No. (1).

² Cf. Bibliography, No. (2).

to be inhaled; (b) there is always moisture present, from about 5 to 15 per cent., which fixes the finest particles. In addition to the action of the moisture, aggregation is assisted by the presence of a pellicle of kaolinitic material—of considerable importance from the health point of view since even when the material has been dried, crushed and made up into bricks, there remains a tendency for the minute particles to adhere so as to form aggregates too large to be inhaled. This protection, however, is only partial, and counts of atmospheric dust taken with Owens' dust-counter, for example, at making silica bricks and setting bricks in the kiln, show 1,000 to 3,000 particles per c.c. of air.

Quarrying and mining of solid rock involves definite exposure to silica dust, even when the surface of the rock is wet. Drilling, blasting and breaking with hammers, are always attended by the liberation of much fine dust. In these processes the action of the wind in removing the dust from the breathing point of the worker is one of the most important safeguards. The processes of crushing, grinding and sieving, which are usually carried on in more or less open sheds; mixing the materials into a plastic form for the manufacture of bricks and the subsequent manipulation by hand in moving the bricks to and from the drying floors, are attended by evolution of dust. Setting the dried bricks in the kilns is one of the most dangerous processes in the industry, and it is extremely difficult to solve the problem of dust suppression, since the use of moisture or exhaust draught is practically impossible. The use of a respirator for this process, if a suitable one could be devised, standardised to protect even to 50 per cent. efficiency, would be a useful measure, possibly with alternation of occupation, though this is a specially skilled job with ordinary kilns. The solution of the problem probably lies in the use of kilns which do not have to be entered and in which no skill is required.

Evidence of Silicosis being Produced

From 26 February 1911 to 18 December 1916, 36 deaths of ganister workers in the Stocksbridge district of Yorkshire showed 24 deaths due to phthisis and "ganister" disease; other respiratory diseases accounted for 5 deaths.

The Reports of the Medical Board of the Refractories Industries (Silicosis) Scheme show cases of silicosis or silicosis with tuberculosis certified from the time of appointment of the Medical Board in May 1925 to the end of 1928, as follows:

TABLE I

Period	Without impairment of capacity	With impairment	Total disablement	Death	Suspended for tuberculosis only
1 May 1925 to 31 December 1926	6	55	10	15	2
1 January 1927 to 31 December 1927	4	27	6	20	4
1 January 1928 to 31 December 1928	4	25	6	18	2

Records of 18 post-mortem examinations of the fatal cases in 1928 show that 9 were certified due to silicosis and 9 to silicosis with tuberculosis.

Of the former group the average age was 59 years and the average period of employment in the refractories industries was 22.6 years. In the latter group the average age was 49½ years and the average period of employment 17.6 years.

A complete description of the pathology of a ganister miner's lung, affected by silicosis with tuberculosis, is given in the *Annual Report of the Chief Inspector of Factories, 1900*, pages 487 to 494, with illustrations and chemical analysis of the ash. The amount of inorganic ash found in two samples formed 3.20 and 3.01 per cent. of the weight of dried lung. Silica, present as SiO₂, was 24 and 36 per cent. respectively of the inorganic ash, the remainder being chiefly iron, aluminium and calcium.

Prevention

Reference has already been made to the subject of prevention in this industry. For mining and quarrying with pneumatic drills, water supplied through the hollow drilled steel is a partial remedy. Suction with collection in a specially constructed bag filter is applicable. At crushing, grinding and other processes with the use of machinery, efficient exhaust draught combined with the use of water or steam spray, is nearly always possible. Moving materials on drying floors and to and from kilns is very difficult to control and calls for constant vigilance and cleanliness.

Refractory Materials Regulations have been in force since April 1919. They provide for suppression of dust on the lines indicated.

Compensation

The first scheme of compensation for silicosis was made for the refractory industry in 1919, under the Workmen's Compensation (Silicosis) Act, 1918, and came into operation on 1 February 1919. From that date until the end of 1928 awards of compensation have been made in 423 cases, including 121 cases of death. The present scheme, made under the Workmen's Compensation (Silicosis) Acts, 1918 and 1924, came into force on 1 May 1925. It provides for a Medical Board for the purposes of certification and periodic medical examinations.

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GRINDING OF METALS

In relation to silicosis the processes concerned in the grinding of metals are confined to those in which grindstones composed of natural or artificial sandstone are used.

The grinding of metals may properly be said to include, in addition to the actual grinding, those processes incidental to it

which are carried on at the factory where the grinding takes place; these are: (1) racing, (2) hacking, and (3) rodding or scaring of the grindstones.

Distribution

The principal divisions of the industry and the chief centres at which they are carried on are as follows: (a) steel knives and forks, scissors, razors, surgical instruments—Sheffield; (b) saws, knives for plantation work, metal cutting and woodworking, reaper sections, chisels, augers, screwdrivers and similar tools—Sheffield, Birmingham and Glasgow; (c) scythes, sickles and shears—Sheffield and Worcestershire; (d) edge tools—Birmingham district and Sheffield; (e) files—principally Sheffield, also other engineering centres; (f) textile machinery and components—throughout Lancashire and Yorkshire, also in Cheshire, Scotland and Belfast; (g) stoves, grates, ranges—principally Falkirk, also various other districts; (h) locomotive parts—principal railway centres.

Grindstones are obtained chiefly from the millstone grit sandstones from Derbyshire and the Sheffield and Newcastle districts.

Employed Persons

Reports compiled for January 1926 showed the persons employed on grindstones to be 3,710. In addition, some 3,600 persons were employed in other processes within a radius of 20 feet from the grindstones.

The figures for the different trades are as follows:

TABLE II

Trade	Number of stones	Numbers employed	
		Grinders	Others in proximity
Cutlery: Sheffield	880	882	510
Other districts	107	93	100
Edge tools: Sheffield	623	660	400
Midlands	303	282	131
Other districts	166	145	200
File grinding: Sheffield			
hand	200	120	—
machine	130	110	—
Textile machinery	550	471	583
Locomotive and general engineering	378	369	824
Stoves, grates, etc.	163	148	162
Foundries	147	153	286
Miscellaneous	292	277	389
	3,939	3,710	3,585

Since the time these figures were prepared, there has been a considerable increase in the number of manufactured abrasive wheels brought into use to replace sandstone wheels. This of course has the effect of removing the workers on these grindstones from processes under review and therefore from the risk of silicosis, properly so called, although the latent liability to the disease from exposure in the period of employment remains.

The Inspector of Factories in Sheffield reports that a rough census of the number of grindstones in use in Sheffield in 1926 and in 1929 records a notable change towards the artificial wheels during the three years. The numbers are:

	1926	1929
Cutlery and edge tool trades	1,540	654
Miscellaneous grinding (by hand) . .	70	8

An estimate of the number of grindstones and artificial abrasive wheels in use at the end of 1929 is as follows:

	Grindstones	Artificial wheels
Hand grinding cutlery and edge tools	468	966
Machine grinding circular saws . . .	31	13
Machine grinding files	104	5
Machine grinding long saws	51	8
	654	992

Operations and Processes

Males only are employed on grinding on sandstone. In the Sheffield trades the hand-grinders serve a term of apprenticeship commencing just after school age. Machine-grinding is done by men who have worked for a time at hand-grinding or some other trade. Occasionally racing of grindstones is done by labourers, but usually it is done by the grinders themselves.

For the purpose of this paper reference is made only to grinding when mechanical power is used in moving the grindstone. In a few factories, in the Sheffield district especially, water power is used; in the great majority of cases steam or internal combustion engines are used.

Grinding may be done wet or dry, and the metal being ground may be moved by hand or by mechanical power on a machine. In wet grinding, the grindstone is mounted on a horizontal shaft, and water is laid on from a tap or spray above the stone, or the lower part of the stone dips to a small extent into a trough beneath

it containing water. It is sometimes contended by grinders that the grit which collects in the water of the trough from attrition of the stone is necessary for the process, but in some cases the trough is drained, the water being laid on at the top of the stone. The wet grit mixed with particles of metal produced in grinding is known as "swarf".

In wet hand-grinding the grinder sits on a heavy saddle-shaped stool called the "horsing", or straddles on a suspended board. He exerts considerable pressure on the metal which he holds in his hands, or when a suspended board is used a metal piece on the front of this is used to increase the pressure. Except in a few special kinds of grinding, the grindstone revolves in a direction away from the grinder. In wet hand-grinding localised exhaust draught is only rarely provided.

In dry hand-grinding the metal parts being ground are usually of small size, and localised draught is always provided. The grindstones revolve either towards or away from the grinder, depending on the class of work.

Wet grinding is also done by machines, especially in the manufacture of files, saws, large machine-knives and reaper-knives. In this form of grinding the metal being ground is fixed in a part of the machine which moves under or across the revolving grindstone.

The processes of dressing the grindstones are very important from the health point of view, on account of the amount of dust produced. They are "racing", that is, trueing the surfaces of the grindstone before it is brought into use for the first time; and "hacking" and "rodding" or "scaring", which are processes of dressing the grinding face of the stone and are carried out frequently in the course of a day's work.

Characters of the Silica Dust

Attrition of the grindstone occurs in all processes in the grinding of metal, and varies in amount with the consistence of the stone, the hardness of the metal, the shape of the article being ground, and the amount of force exerted, and thus depending on the extent to which the stone is cut in the process. Dust is produced as a result of this attrition; its composition corresponds with that of the grindstone, with some added particles from the metal articles being ground. It is doubtful if the metal particles are inhaled in any substantial amount, as they are present only to a very small extent in atmospheric samples of dust.

The amount of dust produced varies within very wide limits in different classes of grinding, and under varying conditions. Gravimetric estimations show that in steel table-blades wet hand-grinding, for example, from 88 to 220 milligrams of dust per 10 cubic metres of air were present in the atmosphere at breathing level. Numerical estimation with Owens' dust-counter shows as an example of a high count at hand-grinding of scythes, 3,205 particles in 1 c.c. of air (in a district where other dusts were at a minimum). Even higher counts are obtained at the processes of racing and "scaring". These counts include dust which occurs as free particles in the atmosphere. In addition, dust contained in droplets of moisture, that is, "swarf", are also potential sources of danger when they become dry. An example of the amount of dust contained in a droplet was obtained by counting the particles deposited on a microscope cover-slip in wet hand-grinding table-knives. The dry deposit from the droplet measured 2 millimetres in diameter and the particles composing it numbered, by counting and calculation, 4,383. They appeared to consist entirely of particles from the grindstone and measured from 24μ down to the limit of visibility under a magnification of 900 diameters.

The size of the particles produced in the grinding of metals on sandstone wheels and found in the atmosphere at the breathing level of the worker, is found by the microscopic examination of samples taken with Owens' dust-counter. As a rule the samples show that from 90 to 97 per cent. of the sandstone particles are under 2μ in greatest diameter, i.e. are capable of being inhaled into the alveoli of the lungs.

The grinding of metals on sandstone wheels has been recognised for generations as a cause of silicosis and increased mortality from tuberculosis. Especially in Sheffield "grinders' rot" has been notorious and past records of that city show the effects of this on the mortality rates¹.

Statistics are not available for silicosis as a separate disease, but reference is continually made to high mortality rates from tuberculosis. In the city of Sheffield such statistics are kept very carefully with reference to the occupation, so that figures from that city may be quoted.

For the five years 1923 to 1927, the numbers of deaths of grinders from pulmonary tuberculosis were 34, 35, 31, 28 and 38. On the basis of the Census of 1921 this gives mortality rates per 1,000 grin-

¹ Cf. Bibliography, No. (1).

ders living of 6.9, 7.2, 6.3, 5.7 and 7.8, contrasted with rates amongst all persons over fifteen years of age of 1.2, 1.1, 1.1, 1.0 and 1.0 respectively.

These figures agree closely with those of an investigation carried out at the Sheffield Municipal Tuberculosis Dispensary into the particulars relating to all persons over the age of fifteen who died during 1919 and 1920 of pulmonary tuberculosis and who had been examined by the tuberculosis staff and the diagnosis confirmed by them. The mortality rate for grinders in this series was 7.02 per 1,000 living while the rate in the general population of Sheffield was approximately 1.0 per 1,000 living.

Dr. Rennie, Chief Tuberculosis Officer for the city of Sheffield, has provided data which show that in 1928, 25 grinders died of silicosis with or without tuberculosis, and in 1929 (1 January to 22 November) 29 died from these causes. The average age in 1928 was 49.4 years and in 1929, 54.8 years.

The following table includes particulars of 11 fatal cases, which have come to the notice of the Factory Department and in which the diagnosis has been verified by post-mortem examination:

TABLE III

No.	Age	Industry	Occupation	Period of employment	Duration of symptoms	Period of disablement	Cause of death	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1.	45	Textile machinery	Grindstone dresser	Years 10	20 months	8 months	Silicosis and tuberculosis	Left lung weighed 36 ozs. Right lung weighed 28 ozs.
2.	54	Edge tools	Grinder	32	20 years	3 weeks	Silicosis and tuberculosis	Died of hæmoptysis
3.	44	Files	Hand-grinder	30	1 year	6 months	Silicosis and tuberculosis	
4.	38	Files	Hand-grinder	24	6 years	8 months	Silicosis and tuberculosis	Died of hæmoptysis
5.	51	Iron foundry	Grinder of castings	29	2 years	16 months	Silicosis and tuberculosis	
6.	59	Cutlery	Table-blade grinder	46	5 months	1 month	Silicosis and tuberculosis	Tuberculosis of knee at time of death
7.	38	Edge tools	Grinder	18	11 months	4 days	Acute pneumonia and silicosis	X-ray showed silicosis 13 months before death
8.	60	Files	Hand-grinder	35	2 years	6 months	Silicosis and tuberculosis	
9.	52	Files	Hand-grinder	30	—	13 months	Silicosis and tuberculosis	Tuberculous meningitis at time of death
10.	64	Edge tools	Grinder	35	2 years	2 months	Silicosis and tuberculosis	
11.	53	Textile machinery	Grinder	—	4 years	11 weeks	Silicosis and bronchitis	Did much "racing" of grindstones

Characters of the Disease

“ Grinders’ rot ”, the name formerly given to the silicosis occurring in metal grinders on sandstone, is a type frequently associated with tuberculosis. The period of exposure required appears to vary much with the concentration of the dust in the atmosphere.

A grindstone dresser who was employed in a large textile machinery factory, dressing about seventy stones a week, died of silicosis with tuberculosis after six years of the work, that is, over a period of ten years, four of which were spent in the army.

In the case of grinders, who do their own racing and dressing of the stone, the duration is usually from twenty to forty years, commonly about thirty-five years.

There appear to be two types of the disease: one in which tuberculosis supervenes, the commoner form, and a non-tuberculous type in which pneumonia, oedema of the lungs and heart failure occur. The first form usually shows only a short period of symptoms before the onset of tuberculosis, which usually runs a rapid course, and is frequently marked by severe haemoptysis. In the second form, symptoms appear later in life with increasing dyspnoea, while the clinical examination discloses greatly diminished air entry in the lungs, especially the bases.

The morbid anatomy of the two types is rather distinctive. In the common tuberculous form, there are large irregular areas of consolidation showing more or less caseation and breaking down. Usually there remains some lung tissue relatively free from tubercle and in this the nodules of fibrous tissue can be made out. The pleuræ are densely and extensively adherent. In the non-tuberculous form the lungs are usually bulky, studded throughout with fibrous nodules, often discrete and with the intervening tissue showing emphysema and pneumonic change. The pleural surfaces are covered with discrete whitish nodules.

Methods of Prevention

There are two codes of Regulations made under section 79 of the Factory and Workshop Act, 1901. One of these codes, the Grinding of Metals (Miscellaneous Industries) Regulations, 1925, came into force on 1 November 1926, except that in certain of these Regulations involving structural alterations application was deferred for a period of two years. The other code, the Grinding

of Cutlery and Edge Tools Regulations, 1925, came into force on 1 January, 1926, except that the application of Regulations requiring certain structural alterations was deferred until three years later. So far as they are concerned with suppression of dust in the grinding of metals and dressing of grindstones, the provisions of the two codes are similar, that for the cutlery and edge tools being generally somewhat more stringent. These two codes replace a single code of Regulations which came into force on 1 December 1909. The requirements of the Regulations are as follows:

- (1) A hood and duct with localised exhaust draught must be provided for all racing, dry grinding or glazing.
- (2) Racing must be done in a separate room in cutlery and edge tools shops, excepting shops in use before January 1926. In these shops it is allowed to be done when no other work is going on in the shop, provided the shop is cleaned before work is resumed.
- (3) General exhaust and inlet ventilation must be provided, adequate to secure a continuous movement of air from the grinder and to renew the air of the room, twelve—in the case of cutlery and edge tool shops, fifteen—times per hour.
- (4) Wet grinding must be carried on in a separate room from glazing or other processes.
- (5) An adequate supply of water is required for “hacking” and “rodding”, or alternatively adequate provision for intercepting the dust.
- (6) The rooms must be of a certain minimum height, windows must be adequate, properly glazed and kept clean.
- (7) Floors and walls must be so constructed as to be capable of being cleaned, and all belts, shafts, etc., efficiently covered.
- (8) There must be adequate drainage for water.
- (9) All floors, walls, ceilings and fixtures must be cleaned periodically.
- (10) Spitting is prohibited.
- (11) Cloakroom accommodation must be provided.
- (12) Grindstones must not be less than the prescribed distance apart.

Since these Regulations came into force considerable success has followed efforts to attain improvement in the methods of dust suppression in both the racing of grindstones and in grinding of metals. Two inventions have been introduced for removing dust at racing of grindstones, which provide powerful suction downwards through the trough over which the grindstone is hung. In one case the process is done dry and the dust is removed by a short wide duct to a portable bag filter. The efficiency of the localised exhaust apparatus appeared to be of a high order when tested by atmospheric air samples, as it effected a reduction in the number of stone particles from about 5,000 to 800 in a cubic centimetre. The other arrangement consists of a copious supply of water laid

on at the point of contact of the racing tool and the provision of an exhaust duct connected up with a main exhaust trunk. The application of the exhaust downwards in both cases leaves the view of the operator and his access to the grindstone unrestricted. An apparatus has been brought into use recently for providing exhaust draught in wet hand-grinding on grindstones. Tests of atmospheric dust showed a considerable reduction in the number of particles. The increasing use of machine-grinding and extensive replacement of grindstones by artificial abrasive wheels, which are more readily adaptable to methods of dust suppression, may be regarded as important factors for the future reduction of cases of silicosis in the grinding of metals.

Compensation

A scheme of compensation was made for metal grinders under section 47 of the Workmen's Compensation Act, 1925. This scheme is on different lines from those for the refractories and sandstone industries in that it applies substantially the procedure under the Workmen's Compensation Act in regard to scheduled diseases. It provides for payment of benefits only in cases of total disablement and death.

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SANDSTONE INDUSTRY

The sandstone quarrying and dressing industry represents perhaps the most widespread of all silicosis-producing industries. The sandstones include the sedimentary silica rocks and the industry covers all processes in getting the material from the quarry or mine and the manipulation of the material with a view to manufacture, sale, or use.

Distribution

To a great extent processes in cutting, shaping, dressing, and crushing of the stone are carried out near the places where it is got from the quarry or mine. Thus, the industry finds its most important centres in the sandstone producing districts, the northern, central and south-western countries of England, and the south and east of Scotland.

Employed Persons

About 12,000 men are at present employed in the industry in getting the stone and in processes carried on in the same premises or in the same ownership as the quarries or mines. In addition to this there are masons and others employed in masons' and builders' yards throughout the country.

Operations and Processes

The workers include rock-getters, who work at the stone face in quarry or mine; quarrymen or stonecutters who rough hew the blocks; masons who shape and carve the stone to dimensions or patterns; planers, sawyers and turners who operate stone-cutting machines; drillers with hand (pneumatic) or steam-drills; crusher-men; labourers and cranemen; and builders, "fixers" or "wallers" who frequently do some dressing of the stone.

Characters of the Dust

The proportion of silica in sandstones varies from over 99 per cent. in certain quartzites. In many sandstones used for building and the manufacture of grindstones and pulpstones the silica forms from 75 to 95 per cent. of the rock. The rock consists more or less of

quartz grains, mixed with a variety of other minerals and held together by a cement of varying composition and proportion. The composition, amount and hardness of the cement are important factors in determining the dangerous character of the dust produced.

In a series of 140 atmospheric dust determinations taken with Owens' dust-counter in the various processes in quarrying and dressing sandstone and granite, certain general conclusions were reached regarding the production of dust liable to be inhaled by the workers. The action of wind has the most important beneficial influence for workers employed in the open. Unfortunately the worker is not always able to stand to windward of the point of origin of the dust produced by neighbouring workers. For example, a sample taken at breathing level of a man dry drilling a quarried block of Derbyshire sandstone with an Ingersoll jack-hammer, $1\frac{5}{8}$ -inch drill, gave 469 particles in 1 c.c., while another sample taken 8 yards to leeward gave 1,867 particles in 1 c.c. The stone-mason working in closed or partly closed sheds is liable to be exposed to dust produced by his neighbours as well as on his own work. Danger is increased by the practice of brushing the dry dust and debris from the surface of the stone and by blowing with the mouth while carving.

Wetting the surface of the stone by rain has some influence in diminishing dust, more especially in "getting" the stone from the quarry, but it has little effect in reducing the fine dust given off by the action of a cutting tool.

Stone-crushing plants are frequently found in quarry sites for using up rubble for making road material. At the crushers, elevators and screens, dense clouds of dust are frequently given off and travel for considerable distances, so that though few workers may be employed on the crusher-house plant, many may be subjected to the dust produced by it.

Particulars of atmospheric dust samples, taken with Owens' jet dust-counter, are given in table IV.

Evidence of Silicosis being Produced

An investigation into the occurrence of silicosis among sandstone workers was made for the Home Office by Drs. Sutherland and Bryson and a report of the investigation was published in 1929. During this enquiry 454 workers were examined clinically, and of these 266 were selected for radiological examination. The results of the examinations are collected in table V.

TABLE IV

Origin of sandstone	Process	Position	Weather	Number of particles in 1 c.c.	Percentage over 2 μ	Remarks
Newton, Elgin	Cutting wedge holes	—	Fine	216	2	Mineral particles often very fine. About 20% soot particles.
do.	Dry drilling vertical blow-hole	—	do.	457	6	Many fine particles. Soot negligible.
do.	do.	—	do.			Very sparse record — not counted.
do.	Operating planing machine	In shed	do.	198	4	At least 50% soot.
do.	Dressing sandstone with punch	Open air	do.	271	1.6	Many mineral particles very fine. About 50% soot.
Craigleith, Edinburgh	Picking wedge holes	do.	Wind, damp	1,530	1	Majority of particles are refractive. Some soot from crane engine.
do.	do.	do.	do.	1,470	1	do. do.
do.	Shovelling wet stone into cracker jaws	Open shed	—	1,217	1.3	Considerable amount of soot.
do.	Wheeling away barrow from stone breakers	Open air	Wet	1,759	0.5	Much soot, clumped at parts.
Ravelstone, Edinburgh	Picking wedge holes	Sheltered from wind	—	6,687	3.5	Practically all particles stone. Obvious dust.
Corncockle, Lockerbie, Dumfries	At "roughing" machine	In planing shed	—	173	5	Soot negligible. Some splashes.
do.	Using finishing tool	10-ft. to leeward of planing machine	—	96	2.5	Soot negligible.
Locharbriggs, Dumfries	Blowing hole clear	—	—	723	8	Some aggregates. Large number of very fine particles. No soot.
Corsehill, Annan, Dumfries	Bedding a stone with chisel	Open shed	Windy, wet	698	8	Many fine particles under 1 μ . No soot.
do.	Roughing stone in planing machine	Just outside shed	do.	64	4	A very sparse record.
Brunton, Gosforth, Northumberland	Turning up very dry grindstone	Closed shed	—	1,711	8	Some aggregates. Very little soot.
do.	Turning up grindstone (wet)	—	—	1,470	7	About 10% soot.
do.	Feeding grit to saw (wet)	Saw shop	—	—	—	Soot particles with few scattered mineral particles. Sample not counted
Henwick, Alnwick, Northumberland	Wedge holing in dry stone	—	Raining	686	4	About 50% soot. Some aggregates.
do.	Scappling stone block	—	do.	—	—	Obscured by much soot. Mineral particles scanty. Sample not counted.
do.	Feeding wet sand to saw	Saw shed	—	—	—	Soot from crane engine. Numerous soot particles. Sample not counted.
do.	Dressing walling block with scutching hammer	—	—	72	19	Mineral particles scanty.

TABLE IV (continued)

Origin of sandstone	Process	Position	Weather	Number of particles in 1 c.c.	Percentage over 2μ	Remarks
Elsdon, Northumberland	Scappling large block	Open air	Dry	614	7	Soot negligible. Very few clumps.
do.	do.	do.	do.	3,096	7	Soot not included. Nearly all particles discrete. Practically no soot.
do.	Cutting wedge holes	do.	do.	3,120	9	
do.	Drilling on rock face	Sheltered position	do.	84	13	No cloud of dust.
do.	Operating stone planing machine	—	—	33	10	Mineral particles scanty. Considerable amount of soot.
Darney, West Woodburn, Northumberland	Wet drilling sandstone	—	Dry	265	1.3	Negligible mineral particles. About 90% soot.
do.	Making wedge holes	—	do.	1,952	0.4	About 80% soot. Other particles mineral.
Redgate, Wolsingham, Durham	Putting moulding on dry stone with chisel	—	—	518	6	Small amount of soot.
do.	Operating planing machine	—	Dry	650	9	Very little soot. Other particles mineral.
Bankend, St. Bees, Cumberland	Dressing with 4 inch chisel	Open shed	—	—	—	Refractive particles not numerous. Sample not counted.
do.	Cutting wedge holes	Open air	—	994	4	Practically all particles are refractive. Very few soot particles.
Lazonby, Carlisle, Cumberland	Dressing a flag	do.	Wet	325	8	
Remington, Penrith, Cumberland	Bottoming race on post	Open air	Wind, raining	132	4	About 20% soot.
Bowscar, Penrith, Cumberland	Holing in quarry bottom	do.	Some wind, raining	319	5	Large number of very fine particles. Soot negligible.
Highfield, Penrith, Cumberland	Dressing dimension block with scutching hammer	do.	Windy raining	33	3	Very sparse record.
Ousel Nest, Bolton, Lancashire	Dressing stone with punch	do.	Windy	156	7	Smaller particles down to very fine dimensions and sometimes occur in splashes.
do.	Dry drilling rock on post	do.	do.	433	5	Many particles very fine. No soot.
do.	Holing block on post	do.	do.	66	7	Some particles in clumps. No soot.
do.	Feeding crusher	do.	do.	1,132	5	No soot.
Cox Green, Bolton, Lancashire	Dry drilling	do.	Windy, dry	2,844	10	No soot.
do.	Feeding crusher	do.	do. do.	277	4	Many fine particles, some in splashes. Very little soot.
do.	Dressing stone with chisel	do.	Dry, windy	144	5	No soot.
Hall Cown, Bacup, Lancashire	Sawing	Saw machine shed	Raining	343	0.7	Not more than 10% of count mineral. Great majority of particles soot, mostly discrete.
do.	Making kerb with chisel	Masons' shed	Raining hard	1,060	6	No soot.
Britannia, Bacup, Lancashire	Dressing kerb with chisel	Open shed	do.	951	11.0	High number of large particles. Soot negligible.

TABLE IV (continued)

Origin of sandstone	Process	Position	Weather	Number of particles in 1 c.c.	Percentage over 2 μ	Remarks
Endon, Kerridge, Cheshire	Cutting wedge holes	Open air	Windy	524	3	About 40 % soot.
do.	Dressing dry stone with chisel	2-men shed	—	566	8	About 5 % soot.
do.	Cutting wedge holes	Open air	Windy	222	2	Over 50 % soot.
do.	Making setts	1-man shed	—	—	—	Very sparse record and a large number of particles are soot. Not counted.
Arnagill, Masham, Yorkshire	Cutting wedge holes	Open air	Slight wind, damp	578	1.5	About 50 % soot.
do.	Cutting race on post	Sheltered position	Not raining	5,181	10	Many very fine particles and some overlapping.
Stancliffe, Darley Dale, Derbyshire	Dry drilling	—	Raining	469	2.2	Probably all the particles are derived from the stone. Very little soot (from cranes).
do.	do.	—	do.	1,867	3.6	All particles are stone. Very few aggregates.
do.	Feeding cracker	Crusher house	do.	482	2.5	50 % soot particles.
Birchover, Matlock, Derbyshire	Controlling machine for dressing grindstones (water applied)	—	—	1,144	4.3	All particles are stone.
Kalmesgate, Edinburgh	Putting head on soft free-stone with toothed chisel	Open shed	Windy, wet	1,879	0.6	Very large amount of soot.
Northumberland and Durham	Putting head on sandstone with hammer and pointed chisel	do.	do. do.	2,442	3.7	About 60 % mineral, rest soot. Many refractive particles.
do.	Putting a head on hard grey sandstone with hammer and square chisel	do.	Windy	1,626	0.7	Considerable amount of soot.
do.	Putting a head on a close-grained stone with hammer and square chisel	do.	do.	1,132	7.0	Much of stone dust in aggregates.
Woodhouse, Northumberland	Planing	do.	do.	916	1.8	Stone particles less than 50 %; few aggregates.
Shawk white, Cumberland	Dressing with chisel	do.	Damp	197	11.0	All particles refractive
Shawk red, Cumberland	do.	do.	Dry	687	14.0	No soot. Many aggregates.
Remington, Penrith, Cumberland	Facing red sandstone with chisel	do.	Raining	542	4	No soot. Large proportion fine discrete particles. Soot negligible.
do.	Punching stone with hammer punch-tool	do.	Light wind Raining	91	4	Some aggregates. Soot negligible.
Endon, Kerridge, Cheshire	At planing machine	—	—	421	3	Over 50 % soot.
do.	Putting head on stone	In shed	—	927	8	Soot negligible.

TABLE V. — SUMMARY, SHOWING THE NUMBER OF WORKERS EXAMINED IN THE VARIOUS OCCUPATIONS, AND THE NUMBER OF CASES OF FIBROSIS AND OF SILICOSIS

Occupation	Clinical examinations		Radiological examinations	
	Total	Cases of fibrosis	Total	Cases of silicosis
Masons	171	122	116	57
Rock getters	65	32	33	13
Quarrymen	115	72	67	33
Planers	39	21	23	5
Sawyers	14	1	3	—
Turners	4	—	2	—
Quarry labourers	15	2	4	—
Wallstone dressers	8	8	7	4
Drillers	5	2	3	—
Crushermen	5	2	3	—
Builders	4	2	1	—
Carvers	2	2	—	—
Labourers to masons	2	1	1	—
Cranemen	5	1	3	—
Total	454	268	266	112

These figures do not represent the proportion of affected workers in the industry, because, for the purposes of the enquiry a large proportion of workers were selected with longer periods of employment, and of those selected for radiological examination a fairly high proportion showed clinical evidence of some degree of fibrosis.

Silicosis was found to arise in the occupations of mason, rock-getter, quarryman, planer and wallstone dresser. The presence of the disease was verified by radiological examination in these occupations. From the clinical evidence and from the similarity of occupation to one or other of the above, it was concluded that the carver, turner and driller are exposed to a risk of silicosis. In the case of the remaining occupations no definite evidence was obtained from radiological examination, but this does not imply that they are all free from the risk. In the occupations where silicosis was demonstrated by radiographic examination the disease appeared to become more common after forty years of age and after twenty years in the stone industry.

With regard to the varieties of stone met with during the investigation, cases of silicosis had undoubtedly been caused in some instances by one particular stone. In Derbyshire, stones of Darley

Dale, Birchover, Whatstandwell and Tansley; in Northumberland and Durham, Blaxter, Darney and Heworth; in Lancashire, Woolton, and Lancaster, and Halifax local stones; in the west of England, Bristol and Forest of Dean stones. On the other hand, no evidence could be gathered to show that there was any sandstone that could be said to be innocuous to the workman.

Although silicosis is not a reportable disease under the Factory and Workshop Acts, the Factory Department has received from time to time reports of fatal cases occurring in various industries, and especially has this been the case during 1929 owing to the action of His Majesty's Coroners in holding inquests and notifying inspectors of factories in regard to such cases. The coming into force in the beginning of that year of schemes of compensation for silicosis in certain industries has probably been another reason for bringing the matter to the notice of the Department.

Between March 1929 and January 1930, seventeen fatal cases of silicosis have occurred in which the diagnosis has been established by post-mortem examination, and particulars of which have been brought to the notice of the Factory Department (cf. table VI).

Methods of Prevention

These depend on the application of: (1) copious supplies of water or (2) exhaust draught, at the point of origin of the dust, that is, the point of contact of the cutting tool with the sandstone. An example of each of these methods is given.

(1) In dressing grindstones at a quarry in Derbyshire, a machine is used on which the grindstone is laid on a table which revolves slowly on a vertical axis. The tool is made to traverse slowly over each of the surfaces of the grindstone, and, at the point of contact a water pipe supplies water at a pressure produced by compressed air in the water tank at 70 lbs. pressure per square inch. It is not necessary for the attendant to be closely over the tool during the process. This arrangement has all the appearance of efficiently suppressing dust at the point of origin, and it is disquieting to find that an atmospheric dust sample taken at breathing level of the man operating the machine gave 1,144 particles in 1 c.c., all of which were stone particles and many of very fine dimensions, with only 4.3 per cent. over 2μ . It appears that the dust, produced in a deep cut with great pressure as in this machine, on a hard quartzite rock, cannot be completely arrested by water alone, especially the fine particles. It is probable that exhaust draught will be necessary in addition to the water.

Another example comparing wet and dry turning of grindstones is given in table IV (Brunton, Gosforth).

At another quarry at which grindstones are made, an exhaust

TABLE VI

Occupation	District and stone	Age	Period of employment	Period of symptoms	Period of incapacity	Cause of death	Remarks
Mason	South Wales (Forest of Dean and Bath stone)	41	—	Some years	8 months	Tuberculosis with silicosis	
Mason	Leeds (Yorks)	65	50	6 years	6 "	Silicosis plus tuberculosis	Worked in open sheds.
Mason	Stoke-on-Trent	48	32	2 "	8 "	Silicosis plus tuberculosis	
Mason	Huddersfield (Yorks)	49	33	2 "	18 "	Silicosis plus tuberculosis	Open shed or open air.
Mason (On planing machine)	Huddersfield (Yorks)	54	28	13 "	5 years	Silicosis	Left industry 10 years before death owing to signs of mason's disease. No evidence of tuberculosis post-mortem.
Stone planer (Quarry)	Huddersfield (Yorks)	56	40	—	None	Silicosis plus tuberculosis (hæmoptysis)	Work in machine sheds.
Mason	Chester, Cefn, Darley Dale, Brunskill, (Yorkshire)	41	23	5 years	1 month	Silicosis plus tuberculosis (broncho-pneumonia)	Work in open. 50% of stone sandstone; 50% Portland stone.
Mason (pavior, railway)	Stratford (Flagstones and patent Victoria stone for station platforms)	50	21	Some years	10 months	Silicosis (broncho-pneumonia)	Work mostly in the open.
Mason	Bristol	60	36	7 years	2 years	Silicosis with tuberculosis	
Mason	Lancaster (Lancaster and Darley Dale stones)	44	15 (from age 14 to 21 and 36 to 44)	10 months	10 months	Silicosis plus tuberculosis (hæmoptysis)	Silica formed 14% of total mineral matter and iron oxide 9% in the lung. (D. S. Ashcroft, M.B.)
Mason	Darwen (Lancashire)	59	44	A few years	3 "	Heart failure due to silicosis	
Quarryman stone dresser	Huddersfield (Yorks)	57	40	A few weeks	1 week	Silicosis (broncho-pneumonia)	In open air and in open sheds.
Mason	Birmingham Hollington stone (Staffordshire)	52	32	12 months	8 months	Silicosis plus tuberculosis	
Mason's labourer	London (? stone)	58	? 10 (before 1906; afterwards on limestone)	10 years before death	2 years	Fibrosis of lungs. Silicosis (non-tuberculous)	Silicosis diagnosed by X-ray in 1906. Probable exposure to silica dust before then. History not obtainable.
Mason	Leeds (Yorkshire)	51	35	10 years	1 year	Silicosis plus tuberculosis	
Mason	Harrogate (Yorkshire)	47	20	6 months	6 months	Silicosis	
Stone crusher-man	Leeds (Yorkshire)	49	17	—	9 "	Silicosis plus tuberculosis	

apparatus is used in which the dressing tool is carried by the pivoted duct which is connected with a settling box by a flexible extension.

(2) The application of exhaust is illustrated by the apparatus designed by Captain Hay, of the Safety in Mines Research Board, for use with rock drills in mines, and adapted by him, in conjunction with His Majesty's Office of Works, to hand pneumatic tools for dressing stone¹. The appliance for use in mines is already on the market. That for stone-dressing is demonstrated by a special exhibit at the Home Office Industrial Museum, London.

The method adopted to trap the dust is to fit, as near as possible to the cutting point of the tool, a hood through which exhaust draught is provided by an ejector provided with a jet, designed to operate off the compressed air supply. The air containing the dust from the working point is carried to a special filter bag, which, in the case of mines is suspended in the working, but in stone-dressing would be installed outside the workplace in an enclosed ventilated cabinet.

Experiments have been carried out with the dust trapping apparatus in use and the results controlled by samples taken with Owens' dust-counter. The results show that the device provides a high degree of protection. Samples taken with the device in operation gave counts up to 150 particles in 1 c.c. of air, while samples taken with the exhaust cut off gave counts of over 2,000 particles in 1 c.c. of air. A sample taken at the ventilation opening of the collecting bag cabinet indicated that only a small proportion of the finest particles of stone dust passed through the filter bag and escaped to the outside air.

These two examples do not cover all the processes in quarrying and dressing of sandstone, but they might form a basis for methods of dust suppression from which modifications for the other processes can be adapted.

Legislation in Force for Prevention

In processes in quarries where the stone contains not less than 80 per cent. of silica, a code of Special Rules made under the Quarries Act, 1894, is applied by the Mines Department². This code corresponds with the Regulations for Refractory Materials under the Factory and Workshop Act, but in the case of quarries the Special Rules are applied whether the material is to be used as refractory material or not.

The chief provisions of the Special Rules are as follows:

1. Rock drilling by mechanical power to be provided by efficient water jet or other efficient means to prevent escape of dust.
2. Stone to be broken by manual labour in the open air only, and a wet canvas cloth to be used to prevent escape of dust, or suitable respirators to be provided and renewed unless the work is carried on so as not to expose the workers to the inhalation of dust.

¹ Cf. Bibliography, No. (7).

² Cf. Bibliography, No. (1).

3. Machines for crushing and grinding of stone (*a*) to be provided with exhaust draught and dust collecting appliances, or with efficient water or steam spray or other arrangement to prevent escape of dust; or (*b*) to be entirely enclosed.

4. In sawing, planing and turning the stone to be kept wet.

5. Workmen dressing stone not to work nearer than 6 feet from each other.

6. The dressing of stone not to be carried on in any closed shed unless exemption is granted on the ground of exhaust ventilation being provided.

Compensation

A scheme of compensation known as the Sandstone Industry (Silicosis) Scheme, 1929, came into force on 1 April 1929 and applies to all workmen employed in the sandstone industry, as defined in the scheme. For the purposes of the scheme the industry means all processes in or incidental to the getting or manipulation of sandstone with a view to manufacture, sale, or use, which are carried on at or within the close or curtilage of any mine or quarry or at any premises worked in conjunction with a mine or quarry, wherever situate.

For the purposes of the scheme, "sandstone" includes ganister, gritstone and quartzite rocks, but does not include rotten stone or natural sand.

The scheme does not apply to: (*a*) premises to which the Refractories Industries (Silicosis) Scheme, 1925, applies; (*b*) any premises not being part of a mine or quarry, for the manufacture of silica flour; (*c*) where sandstone is only occasionally worked and without explosives or mechanical power; (*d*) certain employments carried on apart from the processes; (*e*) certain processes in the manufacture of artificial stone; (*f*) any mine or quarry in which the stone worked is proved, by chemical analysis, to contain not more than 50 per cent. silica (free and combined).

This scheme is on the lines of the Refractories Industries (Silicosis) Scheme, and by it special medical provisions have been made whereby a specialist medical board carries out periodic medical examinations and examinations for certificates of compensation of all the persons to whom the scheme applies. The medical board consists of whole-time medical men with their administrative centre in Sheffield, which is a convenient centre for this and the refractories industries, which shares with this scheme the services of the same Medical Board. Subsidiary centres of the Board are established at Bristol and Newcastle-on-Tyne.

The scheme provides for compensation in cases of partial and

total disablement or death due to silicosis and silicosis with tuberculosis.

Those workmen in the sandstone industry who are not employed in or in connection with a mine or quarry are not included under the Sandstone Industry (Silicosis) Scheme. For these workmen provision is made under the Various Industries (Silicosis) Scheme, 1928, which is on the lines of the Metal Grinding Industries (Silicosis) Scheme, 1927, which provides for compensation in cases only of total disablement or death.

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GRANITE INDUSTRY

The granite quarrying and dressing industry may be regarded as including all processes in getting the material from the quarry and manipulation of the material with a view to manufacture, sale, or use.

Granites and allied rocks of igneous origin are characterised by a crystalline structure, more or less apparent, and a certain hardness or toughness which demands special methods for quarrying them and adapting them for use. From the point of view of the production of silicosis it is important to distinguish the true granites, or acid igneous rocks, from the intermediate and basic igneous rocks, having regard to the proportion of free quartz in their composition.

Distribution

True granites are found in Cornwall and Devon, the Lake district of England, and in several districts in the west and north of Scotland. Other igneous rocks, resembling granite, are distributed

in many parts of England, Wales, and Scotland. The processes are carried on for the most part at or near the district in which the rocks are quarried.

Operations and Processes

The occupations in the granite industry may be classified, for the present purpose, as follows: labourers, getters, drillers, sett-makers, kerb-dressers, crushermen, building masons, monumental operatives, polishers.

(1) *Labourers* are unskilled workers employed in removing overburden, loading and filling granite, and they may assist in blocking, or getting, or drilling.

(2) "*Getters*" are skilled quarrymen who get the granite from the quarry face, roughly square it into blocks of suitable size. The group includes blockers and rockmen.

(3) *Drillers* include workmen employed in all forms of drills—hand drills, steam drills, wet and dry air drills.

(4) *Settmakers* shape the setts or stone blocks for road material by means of hand hammers. They work in a shelter or open shed.

(5) *Kerb-dressers*, sometimes referred to as masons, particularly in Leicestershire.

(6) *Crushermen* include all workmen employed in crushing mills and in concrete works. The group includes breakermen, screenmen, oilers, labourers about the mill, and loaders.

(7) *Building masons* are skilled workmen engaged in cutting and dressing granite in builders' yards. Some of these work only with hand tools and others use pneumatic tools. The use of the pneumatic tool varies considerably in different districts. In Cornwall it is used to a comparatively slight extent. In Aberdeen the pneumatic tool was found to be more in evidence among building masons. These pneumatic tools may be for cutting or surfacing. Building masons work in open sheds.

(8) *Monumental operatives* or monumental masons. This group includes squarers, duntermen, finishers, and turners working in monumental yards. The squarer uses a hand chisel and a pneumatic cutter. The dunterman is employed in operating the pneumatic dunter or surfacing machine. The finishers use the pneumatic tool almost exclusively for their work. Turners work with a power driven lathe. The squarers can work in a shed by themselves or in the same shed as finishers. The duntermen work in widely open sheds in the yard. Turners are, as a rule, in the same shed as the polishers.

(9) *Polishers* are employed in monumental yards. Polishing is a wet process; it may be done by hand, but, as a rule, machinery is used.

Characters of the Dust

The composition of the dust given off in the processes depends on the character of the stone being worked. In the so-called true granites there is a varying proportion of free silica in the form

of quartz. In the other igneous rocks the proportion of quartz varies to a considerable extent, and in some of the igneous rocks, including some foreign stones, free quartz may be absent.

True granite consists of orthoclase felspar, quartz, and mica. The chemical composition is distinctly acid, there being from 65 to 75 per cent. of silica. In intermediate rocks, for example the syenites and diorites, the silica percentage varies from 60 to 55; while in the basic rocks—dolorite and gabbro—the silica content is from 45 to 55 per cent. The proportion of free silica as quartz varies considerably in different specimens; for example, in some of the Aberdeenshire granites: Rubislaw, 23 to 29 per cent., Sclattie, 27 per cent.; Kemnay, 20 per cent.; Peterhead 10 per cent.

In the city of Aberdeen, the centre of the monumental granite trade, a large proportion of foreign stones are worked, amounting to over 80 per cent. of the output. Many of these foreign stones are not true granites and have a low quartz content. For example, Emerald Pearl (Norway), 13 per cent.; Bonaccord Black and Green (Sweden), no free quartz; Balmoral Red (Sweden) 11 per cent. In others the quartz content is high; for example, "Glencoe", from Finland, contains 35 per cent. quartz.

With regard to the conditions of work, there is a definite opinion amongst men who have worked in America that the risk there is greatly increased with the use of closed sheds, rendered necessary by severe cold weather. Work is not done in this country under quite the same conditions; this is especially true of work done near quarries, whilst in Aberdeen, though sheds are covered in, free ventilation is maintained.

The atmospheric dust produced at most of the processes in granite quarrying and dressing was sampled with Owens' jet dust-counter, at the place of work. Table VII gives particulars of the results of the examination of these samples. The conditions which favour the production of dust or its suppression are similar to those which affect similar processes in the sandstone industry. Speaking generally, however, there appears to be less tendency for the dust from granite to rise to the breathing level of the worker.

Evidence of Silicosis being Produced

A Medical Enquiry was made for the Home Office, in conjunction with the Mines Department, in 1929 by Drs. C. L. Sutherland, S. Bryson, and N. Keating, members of the Medical Board under the Refractories Industries and Sandstone Industry (Silicosis) Schemes,

TABLE VII

Origin of granite	Process	Position	Weather	Number of particles in 1 c.c.	Percentage over 2 μ	Remarks
Rubislaw, Aberdeen	Making "crossing setts"	Open shed	Fine, wind	566	13	Practically all particles are mineral.
do.	Making setts	In shelter	do. do.	469	23	Larger number of large particles.
do.	Drilling side hole in block	Open air	do. do.	4,796	7	Practically all particles are mineral.
do.	Drilling vertical hole	do.	do. do.	434	7	Practically all particles are mineral.
Scatlle, Bucksburn, Aberdeen	Alr-drilling	Quarry bottom	Dry	3,337	3.6	Practically all particles mineral. Soot negligible.
do.	Hand-drilling	—	do.	—	—	Scattered particles of mineral only seen. Scanty record. Not counted.
Persley, Bucksburn, Aberdeen	do.	To leeward	Strong wind	87	1.7	Mineral particles nearly all fine, chiefly in diffuse splashes. No soot.
do.	Punching sett	Shelter of shed	Windy	138	10	Very little soot.
Kemnay, Aberdeen	Attending crusher and screens	Open air	do.	951	11	Particles almost colourless. Soot negligible.
do.	do.	do.	do.	1,313	7	Similar to above; but more fine particles.
do.	Clearing crusher jaws	On platform	do.	2,422	13	Many discrete fine particles. Soot negligible.
do.	Screening dust from crusher	—	do.	2,783	7.5	Similar to above, but more fine particles.
do.	Making crossing setts	Open shed	do.	204	12	Particles sometimes occur in loose splashes.
Kemnay, Aberdeen	Making steps	Open shed	Windy	3,145	8	Discrete particles. Many angular fragments. Soot negligible.
Balmeddle, Aberdeen	Feeding crusher jaws	—	do.	253	12	Some aggregates. No soot.
do.	Attending below elevators	—	do.	2,325	13	Some aggregates around larger particles. Some soot, nearly all in clumps.
do.	Wet drilling at face	—	do.	343	1.5	Soot from crane engine. About 70% soot; rest mineral, all fine.
Blackhill, Longhaven, Aberdeen	Between 2 men drilling granite	Top of quarry	Some wind, dry	84	3	Soot negligible.
Guite, Longhaven, Aberdeen	Between 2 men hand drilling granite	—	do.	96	3	Similar to above.
Bonawe, Taynullt, Argyll	Dry drilling	—	Slight wind, sunny	180	6	Soot negligible.
do.	Axing a nridged sett	—	do.	674	8	Soot negligible.
do.	Dry drilling for pop holes	—	do.	2,434	8	No soot.
do.	Wet drilling same hole	—	do.	259	5	Considerably larger number coloured particles than above and fewer larger particles. No evidence of clumping.
do.	Using sett hammer	—	do.	56	9	Some splashes. Soot not included.
do.	Feeding crusher jaws	Crusher-house	Slight wind, bright	951	11	Some aggregates. Many particles from 5 μ to 8 μ . Soot not included.

TABLE VII (continued)

Origin of granite	Process	Position	Weather	Number of particles in 1 c.c.	Percentage over 2 μ	Remarks
Bonawe, Taynuilt, Argyll	Working below screens	Crusher-house	Slight wind, dry	2,325	16	Many particles over 5 μ up to 15 μ . No soot.
Craignair, Dalbeattie, Kirkeudbright	By the screens	Small crusher-house	—	614	14	
do.	Feeding gyratory crusher	Shed open one side	Windy	2,325	13	Many large aggregates. Soot negligible.
do.	Filling 3/8th inch crushed granite from shoots	Large crusher-house	Damp, windy	—	—	Record sparse and ill-defined. Not counted.
Cove Bay, Kincardine	Dry drilling vertical hole	—	—	1,506	4	Very few aggregates. Soot negligible.
do.	Dry drilling breast hole	—	—	1,144	5	Similar to above.
do.	On platform looking over plant	Crusher-house	—	915	17	Large number of particles, many rounded.
Eskdale, Cumberland	Hand drilling for pop hole	—	Dry	602	4	A few aggregates. No soot.
Waberthwaite, Cumberland	Rock drilling with wet tripod air drill	—	—	265	10	Mineral particles nearly all in small aggregates, studded over with soot particles. Nearly all discrete particles are soot, clumped in parts.
do.	Dressing sett	Open shed	—	205	6	Some small aggregates. Very little soot.
Embleton, Cumberland	Shovelling crushed stone into elevator	Crusher-house	Dry	2,265	15	Some close aggregates. No soot.
do.	Settmaking	1-man shed open one side	do.	675	9	No soot.
do.	Dry drilling	—	do.	1,349	3.5	Majority of particles very fine. Very little aggregation. Soot practically negligible.
Threlkeld, Cumberland	Filling tubs from hoppers at granulator and screens.	—	do.	2,024	13	Many large close clumps and masses. Soot almost absent.
do.	Feeding stone crusher	—	do.	976	25	Considerable number of clumps.
Shap Fell, Westmorland	Making setts	Open shed	do.	626	8	Many fine particles adherent to larger particles; others in splashes. Soot negligible.
do.	Dry drilling	Mouth of open shed	do.	7,447	6.8	Many fine discrete particles and a few clumps. Soot negligible.
do.	do.	Quarry face	do.	6,675	6.0	Resembled above in general characters.
do.	Crushing	Crusher feed	do.	3,157	10	Some clumps of mineral particles and some splashes. Soot clumped.
Mount Sorrel, Leicester	Air drilling on block	Open air	Windy	482	5	Particles mostly discrete. No soot.
do.	Screening while machine starting to run	In screening house, provided with exhaust draught	—	168	9	Larger mineral particles in clumps. Some soot.
do.	Stone passing in screens	do.	—	229	8	Considerable amount of soot.

TABLE VII (continued)

Origin of granite	Process	Position	Weather	Number of particles in 1 c.c.	Percentage over 2 μ	Remarks
Mount Sorrel, Leicester	Screening	Under hatch cover in housing while stone was passing	—	—	—	Record too dense to count. Particles overlapping.
do.	Crushing	Crusher-house	—	2,362	13	A considerable number of very fine particles.
do.	Settmaking	In shed	Windy	409	5	Some very fine particles in groups. Soot negligible.
Groby, Leicester	At tarring plant	Rail track in the open	do.	3,120	25	Many large masses and aggregates
do.	Operating shoot hopper	Tar mixing plant	do.	4,555	23	Many large masses and aggregates of stone particles. Some soot in fine particles.
do.	At mixing cylinder	—	—	2,699	21	Much dust in masses.
do.	Feeding cracker jaws	In covered shed	—	933	10	Particles nearly all discrete.
Dalbeattie, Kirkcudbright	Feeding gyratory crusher	Open shed	Windy	747	11	Many very fine particles. Some aggregates. No soot.
Eskdale, Cumberland	Feeding cracker jaw	do.	do.	5,157	11	10% of particles soot; others mineral.
Waberthwaite, Cumberland	Crushing plant	On staging where aerial ropeway delivers buckets	do.	2,524	10	Many very fine particles, some in splashes. No soot.
do.	No work being done	Artificial flag shed	do.	96	8	Control for above sample. No soot.
Craignair, Dalbeattie, Kirkcudbright	At little dunter	Open air except for head cover	Windy	120	12	
do.	Turning a pillar on machine	Turning shed, door open	do.	36	6	A few aggregates of fine particles. Some soot clumped — not counted.
Craignair, Dalbeattie, Kirkcudbright	Rough dressing granite stone with punch	Open shed	Windy	855	9	Soot absent.
Creetown, Kirkcudbright	Putting bed on stone with chisel	—	do.	1,337	6.3	About 50% of particles stone dust. Some aggregates.
do.	Putting bottom bed on headstone with pneumatic chisel	—	do.	130	12	Soot negligible.
do.	Using pneumatic surfacing ool	Closed shed	—	2,470	12	Soot negligible
do.	Dressing top head of stone with punch	do.	—	397	15	Soot negligible.
do.	Lettering headstone with chisel	Carving shop	—	265	13	Soot negligible.

the report of which is in course of preparation. The investigation was carried out on the lines of that for the sandstone industry and included the clinical examination of 494 workers, of whom 211 were examined radiologically. The results of the radiological examinations are given in the following table:

TABLE VIII

Occupation	Number examined	Number X-rayed	Silicosis found on X-ray
Labourers	7	2	—
Getters	52	17	1
Drillers	66	25	1
Settmakers	88	41	1
Kerb-dressers	30	13	—
Crushermen	105	36	8
Building masons	85	45	16
Monumental masons	54	29	9
Polishers	7	3	—
Totals	494	211	36

In the cases of silicosis, the stage reached, as shown by X-ray examination, together with the district in which the workers were examined, are shown in table IX.

TABLE IX

Occupation	Area	Number positive	Stage of silicosis
Getter or blocker	Leicestershire	1	Ib.
Settmaker	Cumberland	1	Ia.
Crushermen	Cumberland	2	Ia, Ib.
	Leicestershire	3	Ia, Ia, IIc.
	North Wales	3	Ia, Ia, IIb.
Masons	Cornwall	8	Ia, Ia, Ia, Ia, Ia, Ia, Ia, Ib.
Building masons	Aberdeen	8	Ia, Ia, Ia, Ia, Ia, Ia, IIa, IIa.
Monumental masons	Aberdeen	9	Ia, Ia, Ia, Ia, Ia, Ib, Ic, IIa, IIc.
Driller	Cornwall	1	IIb.

Note. — The getter or blocker had worked most of his time as a settmaker. The driller had worked much longer in tin mines than in granite. Therefore no cases among blockers and drillers really.

TABLE X. — PARTICULARS OF CASES OF GRANITE WORKERS, DIAGNOSED AS SHOWING SIGNS OF SILICOSIS BY RADIOLOGICAL EXAMINATION, WITH A NOTE ON THE CHARACTERS OF THE SHADOWS

District and stone	Age	Occupation	Period of employment	Symptoms	Stage of silicosis	Remarks
1. Leicestershire (Syenite. Total silica = 66.48 %)	50	Crusher	27	Slight cough and sputum	Ia.	Finely granular disseminated fibrosis.
2. do.	51	Crusher	30	—	Ic.	Very finely granular disseminated fibrosis. Nodules present.
3. Leicestershire (Total silica = 67.16 %)	59	Crusher (Foreman for 24 years)	35	Dyspnoea	Iic.	Nodules present.
4. do.	44	Settmaker and Blocker	22 } 10 }	—	Ia.	Very slight nodulation in the upper and middle zones. At bases only fine striation.
5. North Wales (Total silica = 58.06 %)	53	Crusher Coal mine 5 years, of which 2 were on cutting hard ground	26 } 5 }	Slight cough and sputum	Iib.	Rather dense fine shadows middle zones. Apices rather clear.
6. do.	73	Crusher Screens	47	Dyspnoea, cough and sputum	Ia.	Fine diffuse shadows, except left middle zone, which is clear.
7. do.	53	Crusher	25	Slight dyspnoea cough and sputum	Ia.	No definite localising signs.
8. Cumberland (Total silica = 67.18 %)	52	Crusher	28	—	Ia.	Increased mottling with very slight, rather fine nodulation.
9. do.	52	Crusher Quarryman	20 } 19 }	—	Ib.	Middle zone on the right, slight faint mottling. Less on the left.
10. Cumberland (Diorite, total silica = 75.22 %)	75	Settmaker Blocking	41 } 20 }	Very slight cough	Ia.	Slight increased mottling, very slight nodulation.
11. Aberdeen (local, home and foreign granites)	48	Monumental operative Dunterman squaring and finishing	19 } 9 }	Pain in the chest and dyspnoea	Iic.	Marked deep irregular shadows in all areas, with clear spaces between.
12. do.	52	Monumental operative (4 years on Blue Pennant, South Wales; 3 months on Derbyshire grit)	32	—	Ia.	Marbling and mottling. Not very definite nodules.
13. do.	56	Monumental operative (6 years in United States)	42	Some dyspnoea	Iia.	Increased root shadows. Slight fine mottling and nodulation left middle zone.
14. do.	55	Granite mason (Home granites) (2 years in United States)	38	Slight dyspnoea and sputum	Ia.	Diffuse fine nodulation and much fine mottling.
15. do.	57	Monumental Building (2 years in United States) (Mostly home granites)	5 } 34 }	Dyspnoea on exertion	Ia.	Rather dense thickening. Slight nodulation.

TABLE X (continued)

District and stone	Age	Occupation	Period of employment	Symptoms	Stage of silicosis	Remarks
16. Arberdeen (local, home and foreign granites)	53	Stone cutter Fixer (including pneumatic tool; 20 years in closed sheds). 20 years on home granite	Years 24 } 6 }	—	IIa.	Definite nodulation over both lungs.
17. do.	51	Monumental operative	35	—	Ia.	Increase fine striation and reticulation. No definite nodules.
18. do.	52	Monumental operative (24 years on pneumatic tools, 10 years in United States)	34	Some dyspnoea	Ic.	Considerable amount of fine nodulation in middle zone and right base especially.
19. Aberdeen (Local, home and foreign granites)	50	Monumental operative (Pneumatic tool 2 days a week last 15 years. One year in United States)	32	Some dyspnoea 4 years	Ia.	Fine mottling and increased shadows.
20. do.	61	Monumental operative Building 5 years	45	Slight cough occasionally	Ib.	Mottling with fine nodules.
21. do.	58	Monumental operative Squarer Finishing	35 } 6 }	Tightness of chest 2 to 3 years. Slight cough	Ia.	Fine mottling and nodules, right upper. Much increase of striation.
22. do.	60	Stone dresser, (7 years in South Africa on granite)	38	Dyspnoea on exertion. Slight cough	Ia.	Much fine mottling with fine nodules, diffuse over both lungs.
23. do.	58	Building mason	41	—	Ia.	Much fine mottling and nodules over outer zones.
24. do.	63	Building mason	41	Dyspnoea, increased over the last 10 years	Ia.	Much mottling and diffuse fine nodules, especially in the outer zones.
25. do.	62	Building mason (South Africa 6 years, United States 1 year)	44	Dyspnoea 1 year. Sputum in the morning	IIa.	Definite nodulation in both lungs.
26. do.	67	Building mason (United States 2 years, South Africa 12 years, of which 5 on sandstone)	52	Dyspnoea on exertion 2 years	Ia.	Very little nodulation. Increased striation.
27. do.	64	Pneumatic dunter Stone cutter	30 } 18 }	Dyspnoea 3 years	Ic.	Much fibrosis with fine nodules.
28. Cornwall (Total silica = 72.05 %)	50	Granite mason	30	Slight dyspnoea	Ib.	Rather dense woolly shadows. Nodulation at parts.
29. do.	52	Granite mason (United States 2 years)	27	Dyspnoea 6 years	Ia.	Increased fine striation and slight fine nodulation.
32. do.	48	Mason (2 years on Blue Pennant sandstone)	32	—	Ia.	Increased fine striae. No definite nodules.
31. do.	65	Granite mason (Last 25 years on dunter. United States 22 years on dunter)	49	—	Ia.	Rather dense diffuse fine nodular shadows, all areas.

TABLE X (continued)

District and stone	Age	Occupation	Period of employment	Symptoms	Stage of silicosis	Remarks
30. Cornwall (Total silica = 72.05 %)	44	Air driller 5 years. Worked in granite Tin miner on top Tin miner underground (including 5 years with jack hammer)	Years	Dyspnoea 8 years	Ia.	Nodulation on finely woolly base in upper zones only.
			9			
			3 ½ } 18 }			
33. do.	58	Mason (3 years in United States, 8 years on Blue Pennant sandstone)	42	—	Ia.	Increased striation with fine mottling and very fine nodules
34. do.	58	Mason (5 years in South Africa, all on granite)	39	Dyspnoea on exertion	Ia.	Increased striation with fine nodules.
35. do.	68	Mason	54	Tightness of the chest on exertion	Ia.	Increased striation, very fine nodules, especially the middle zone.
36. do.	58	Granite mason	35	Dyspnoea on exertion for 6 months. Slight cough	Ia.	Increased hilus shad- ows, mottling and fine nodules on the outer middle zone and right base.

Examination of the radiograms in the positive cases classed as silicosis shows that the prevalent type of the shadows indicating fibrotic changes is somewhat different from that found in workers exposed to silica dust in other industries. In the radiograms of granite workers there are usually the increased hilus, linear and reticular shadows, but instead of the discrete, dense nodules found to a greater or less extent over the whole of both lungs, there is a diffuse, cloudy or woolly effect with more or less definite fine or very fine nodules occurring in areas irregularly placed over the lungs. In the whole series the radiogram showing the most discrete nodules of the silicotic type is in the case of a man who worked for nine years as a driller on granite, but had been employed for eighteen years as a tin miner underground. Amongst the other cases, who had been almost exclusively employed on granite, there appears to be some relationship between the composition of the rock and the character of the fibrosis, as shown on the radiogram. The difficulty of obtaining accurate histories of workers employed exclusively on any particular rock in this country makes it impossible to draw substantial inferences on this point, but it might be kept in mind for future investigation into the effects of dusts such as silicates.

Table X gives some particulars of employment of the workers in granite, diagnosed as cases of silicosis by the writers of the Medical Report referred to, and notes by the present writer on the radiograms examined independently.

Clinical evidence of fibrosis, as distinguished from radiological evidence of silicosis, was found in 260 cases, or 52.6 per cent. of the 494 workmen examined.

The distribution in districts and occupations is shown in table XI.

Comparing the results of the medical examinations in the sandstone industry and the granite industry, the proportion of cases of fibrosis amongst sandstone workers was 59 per cent. of those examined, compared with 52.6 per cent. in the case of granite workers. The cases of silicosis in sandstone workers was 42 per cent. of those radiologically examined, and 17 per cent. in the case of the granite workers.

If fibrosis of the lungs, diagnosed by clinical examination, be regarded as representing a slighter or earlier involvement of the same character as silicosis, then it would seem that granites and the igneous rocks of granite type produce less injury to the lungs than do the sandstone. Having regard to the appearances of the radiograms in the two series of workers, there is a probability of a difference in character of the types of fibrosis produced by the two kinds of dust, and this probability is increased by the proportion of cases of fibrosis in the granite series showing an approximation to that found in the sandstone series, while the proportion of silicosis cases remains far behind.

Methods of Prevention

The processes in the granite industry are similar to those in the sandstone industry, and the principles of dust suppression in the one case can usually be applied in the other. In the granites and allied rocks generally, the rock is harder or tougher than in the sandstones, and in the processes of quarrying, more drilling has to be done. In cutting and surfacing pneumatic tools are more often used on granites. The dunter or surfacing machine gives rise to much dust and it is difficult to apply exhaust draught owing to the wide movements of the tool and the vibration produced. Drilling could be dealt with by the application of water spray or hollow drill feed, or by the Hay type of exhaust apparatus. Cutting and turning will require specially adapted exhaust which could be provided on the lines suggested under Sandstone.

There are no special regulations in force in factories or workshops in connection with granite working, but the general provisions of the Factory and Workshop Act, 1901, apply.

TABLE XI. — CASES DIAGNOSED CLINICALLY AS FIBROSIS OF THE LUNGS, AND RADIOLOGICALLY AS SILICOSIS, WITH THE DISTRICTS AND OCCUPATIONS

(The proportion of cases of fibrosis are stated as a percentage of the workers examined. The proportion of cases of silicosis are stated as a percentage of the workers radiographed.)

District	Occupation	Number examined	Fibrosis	Number radiographed	Silicosis
Leicester-shire	Labourers	2	—	—	—
	Getters	22	10	9	1
	Drillers	14	3	7	—
	Settmakers	26	15	9	—
	Kerbdressers	30	13	13	—
	Crushermen	67	22	12	3
		161	63 (39.1%)	50	4 (8%)
Cumberland	Labourers	4	—	1	—
	Getters	11	4	4	—
	Drillers	9	4	5	—
	Settmakers	13	8	10	1
	Crushermen	14	8	6	2
		51	24 (47%)	26	3 (11.5%)
Cornwall	Labourers	1	—	1	—
	Getters	8	3	2	—
	Drillers	9	3	4	1
	Masons	34	22	23	8
		52	28 (53.8%)	30	9 (30%)
North Wales	Getters	11	5	2	—
	Drillers	10	9	3	—
	Settmakers	18	12	6	—
	Crushermen	11	10	9	3
		50	36 (72%)	20	3 (15%)
Aberdeen-shire	Drillers	24	9	6	—
	Settmakers	31	21	16	—
	Crushermen	13	6	9	—
	Building masons	51	28	22	8
	Monumental masons	54	41	29	9
	Polishers	7	4	3	—
			180	109 (60.5%)	85
	Totals	494	260 (52.6%)	211	36 (17%)

Compensation

The granite industries are not at present included in any scheme of compensation for silicosis.

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SLATE QUARRYING AND DRESSING INDUSTRY

The industry is concerned with the quarrying of the rock and making into slates for roofing, structural, blackboard, sanitary and electrical uses.

Distribution geographically and the numbers of persons employed are given in the following table of wage earners employed in slate mines and quarries in 1928:

TABLE XII

Division	County	Number employed	
1.	Aberdeen	10	} 361
	Argyll	300	
	Banff	9	
	Caithness	2	
	Dumbarton	9	
	Perth	31	
2.	Cumberland	92	} 184
	Westmorland	92	
5.	Lancashire	332	} 9,751
	Isle of Man	24	
	Carnarvon	6,161	
	Denbigh	223	
	Merioneth	2,972	
	Montgomery	39	
6.	Cardigan	7	7
7.	Carmarthen	46	} 74
	Pembroke	28	
8.	Cornwall	473	} 530
	Devon	5	
	Somerset	52	
		10,907	

Operations and Processes

In the open quarries of North Wales the slate is got by means of blasting and wedging. Suitable sizes of slate so obtained are conveyed to the mills. Overburden consisting of inferior slate, igneous rock and soil has to be removed as the quarry extends.

In the mills the large blocks are sawn to required sizes, by power-driven circular saws cutting across the grain. The smaller blocks are then split by means of a broad flexible chisel and a mallet, and cut to rectangular form either by hand or by the revolving blades of a machine.

In some small quarries there are no mills and the splitting is carried out in the open. The occupations may be divided into (a) rockmen who work at the mine or quarry; (b) labourers who assist rockmen in the quarry and remove overburden; (c) drillers who use pneumatic drills; (d) millmen who are employed in sawing, splitting and dressing; (e) saw sharpeners, mechanics, etc.

The distribution of persons in the different occupations can be seen from the following figures taken from two large slate quarries in North Wales:

TABLE XIII

	Quarry A	Quarry B
Rockmen, that is, getters, all of whom can do drilling	91	64
Quarrymen, that is, slate makers, including sawers, splitters and dressers	234	271
Labourers, including trammers, rubbishmen, etc.	96	129
Day men, including slate loaders, tradesmen and ropeway men	89	97
	510	561

Special Characters of the Dust

Slate is the typical cleaved rock. The most important constituents quantitatively are silica, free as quartz and combined as silicates, alumina, iron, alkalis and other bases. Silica as quartz exists in Penrhyn (Welsh) slates to the extent of from 34.66 per cent.

to 43.26 per cent., while total silica (free and combined) is from 57.75 per cent. to 63.01 per cent.¹

A series of dust counts taken with Owens' jet dust-counter at slate quarries in North Wales in 1926, gave the following results:

At the Quarry:

- (1) At breathing level of a driller dry drilling with pneumatic drill, 674 particles in 1 c.c., 8 % over 2 μ .
Many very fine particles in the sample.
- (2) At breathing level of a driller on quarry-top dry drilling a vertical hole in slate with Ingersoll pneumatic drill, $\frac{3}{4}$ ". Wind blowing the dust away. Slight rain.
566 particles in 1 c.c., 10 % over 2 μ .
- (3) Dry drilling as in (2). Sample taken 3 yards to leeward of the drill hole, 361 particles in 1 c.c., 7 % over 2 μ .
- (4) Dry drilling at breathing level of a breast (horizontal) hole, about 18" above ground, in slate quarry-top, 650 particles in 1 c.c., 25 % over 2 μ .
Many large aggregates account for the high proportion of larger particles.

In the Mills:

Quarry A.

- (1) At breathing level of a man at the saw table in slate dressing shed, 1,036 particles in 1 c.c., 17 % over 2 μ .
There are many aggregates, varying in size from 2 μ to 10 μ , and consisting of a very few to several score of particles, most of which are between 1 μ and 2 μ in size. The great majority of the particles are irregularly rounded. Some are plaque-like, and a very few are angular. Most are almost colourless and there is a fairly regular sprinkling of deep red or black or dark green particles; the coloured particles being nearly always in aggregates. An aggregate is counted as one particle, so that the presence of these reduces the count.
- (2) Near the middle of the same shed, 2,361 particles in 1 c.c., 11 % over 2 μ .
The general characters of the particles are like those of No. 1, but there are larger aggregates and a higher proportion of fine particles.
- (3) In a slate dressing cubicle off the large shed. At breathing level between two men, one splitting and one dressing with a hand knife, 855 particles in 1 c.c., 15 % over 2 μ .
The general characters are similar to those of (1) and (2).
- (4) In another cubicle off the same shed, four men working, two splitting and two dressing with hand knives, 241 particles in 1 c.c., 23 % over 2 μ .
A higher proportion of large particles and aggregates than in (3).

Quarry B.

- (1) Near the centre of the dressing shed (in this shed splitters and dressers work in a large room and not in cubicles as at Quarry A), 1,494 particles in 1 c.c., 8 % over 2 μ .
- (2) Near the same point as (1), at breathing level of splitter, 3,325 particles in 1 c.c., 6 % over 2 μ .
There is a very large proportion of extremely fine particles and aggregates of large numbers of these fine particles.
- (3) In the same dressing shed, at breathing level of a dresser working at a revolving slate dressing machine, 927 particles in 1 c.c., 9 % over 2 μ .
Fairly large aggregates of many fine particles, reducing the count.

¹ Cf. Bibliography, No. (1).

The general appearance of the microscope samples obtained at these processes conveys the impression that slate dust tends to form aggregates readily.

Evidence of Silicosis being Produced

In 1926 Dr. T. W. Wade, of the Welsh Board of Health, made an investigation into an alleged high mortality rate from tuberculosis amongst slate workers in a district of North Wales. Dr. Wade's observations and conclusions are contained in pages 28 and 29 of his Report¹. He says:

The mortality tables of the Gwyrfaï Rural District exhibit over a long series of years a very high death-rate from tuberculosis of the respiratory system, which is considerably higher for males than for females. The mortality figures from this disease, both for males and females, show high death-rates during the young adult periods of life. The maximum mortality rate for males is, however, reached during the old-age period of life, and this high mortality at the later age chiefly determines the difference between the male and female death-rates from tuberculosis. It is probably true that the high death-rates from tuberculosis of the respiratory system among young adults of both sexes are produced by the same influences. The great majority of the women are engaged in domestic duties in their homes, wherein the men spend a part of their daily life. It is reasonable to assume that the differences between the male and female mortality rates at the later stages of life are in large measure the result of influences outside the home. . . .

The mortality tables in the Report show that in the earlier periods of working life "other males" are less favourably placed than "workers in the slate industry", but that from thirty-five years of age onwards, and particularly in the later ages of life those engaged in the slate industry are very unfavourably placed.

The standardised mortality of males aged sixty to sixty-five, in certain occupations, given by the Registrar-General in the Decennial Supplement for 1921² shows that the comparative mortality figures for slate miners and quarriers compared with 1,000 for all occupied and retired civilian males, were, for respiratory tuberculosis 1,594; diseases of the respiratory system 703; bronchitis 520; pneumonia 451; the comparative mortality figure for all causes being 944, as compared with 1,000 for all occupied and

¹ Cf. Bibliography, No. (2).

² Cf. Bibliography, No. (3).

retired civilian males. Contrasted with these low figures for respiratory disease other than tuberculosis is the high rate for valvular disease of the heart, which is 1,647 amongst slate miners and quarriers, compared with 1,000 for all occupied and retired males.

While the local mortality rates and the occupational mortality rates point to a high mortality rate from pulmonary tuberculosis, there is little evidence that respiratory disease independent of tuberculosis is excessive.

On the evidence I think there is little doubt that the workers in slate sheds are subjected to an injurious dust . . . The late age at which the mortality curve for tuberculosis of the respiratory system reaches its maximum may be due to the fact that the amount of dust in slate sheds is not very great and also that slate dust when moistened makes up into a clayey material which makes expulsion from the respiratory passages more assured than otherwise.

A Medical Enquiry was undertaken by the Mines Department in 1928. It was carried out by Drs. Sutherland and Bryson, who issued a Report in the form of a *Memorandum to the Health Advisory Committee of the Mines Department*. The investigation was made in North Wales in the district which was the subject of Dr. Wade's enquiry. Clinical examinations were made of 120 workers and from amongst these 61 were selected for radiological examination.

The results of examination in the various occupational groups were as follows:

Rockmen. — Fifteen rockmen were examined clinically and 6 radiologically. No case of silicosis was found. The average age of the group was 52.5. The average number of years spent as rockmen was 18.6, but the average time spent in the industry of this group was 30.8 years.

Drillers. — Six drillers were examined clinically and 3 were X-rayed. An average of only 3 years had been spent in drilling. No silicosis was revealed.

Millmen form the largest occupational group. The total number examined clinically was 96 and radiologically 52. Of those X-rayed 14 were found to be suffering from silicosis. The average age for this group was 46.37 years, and the ages ranged from 19 to 71 years. The average period in the occupation as millmen corresponds very closely to the average time spent in the industry. A number of the millmen had worked in coal mines for a few years and of these 7 had been employed in hard heading work. None of these was included among those X-rayed.

Clinical examinations show that severe fibrosis exists amongst the older millmen. Fibrosis is also present in the older rockmen, but to a less extent. In the drillers there is evidence of fibrosis of a slight degree, but in the remaining two occupations no evidence was found.

The 14 cases of silicosis found among the millmen could be placed as follows: 12 in the first stage, one in the second, and one in the third. The earliest age at which silicosis was found was 40 years. Most of the cases, however, occurred in the 50-59 years age-group. The earliest period of occupation group to show fibrosis was 20-29 years, but the majority of cases occurred in the 40-49 years group.

Tuberculosis, apart from silicosis, was diagnosed in three instances—one rockman and two millmen. The radiograph in these cases showed no definite indication that silicosis was present. The case of silicosis in stage 3 was also probably accompanied by tuberculosis.

Three of these cases were in the age-group 60-69 and one in the 40-49 years group. The number of years employed in the slate industry in the 4 cases was 26, 42, 47 and 53 years respectively.

In four of the cases no symptoms were complained of. In 6 cases the sole complaint was shortness of breath; a further 2 had cough and dyspnoea and the remaining 2 complained of cough, spit and dyspnoea. Dyspnoea was therefore the most common symptom. Pain was not complained of in any of the cases.

In view of the ages reached by many of the workmen while still remaining fit for work, it may be assumed that there is no general disability occurring amongst these workmen from exposure to dust in their occupations. The rockmen show lower age periods, but their work is rendered arduous by reason not only of the heavy character of the work itself, but also by the climbing from the deep quarries which their work involves. This would not be possible with a severe degree of respiratory disease. It is possible that a considerable degree of vocational selection is present and this is borne out by the standard of physique, which the Report shows to be much higher in rockmen than in millmen. Amongst rockmen no men were examined over 30-39 years' employment, but it is in this period that most of the cases of silicosis are found amongst millmen, namely, 9 cases out of 14; so that, although there appears to be less exposure to dust in the work of rockmen than in that of millmen, there is not sufficient evidence to make it possible to say that cases of silicosis would not occur amongst rockmen if later employment periods were reached.

The presence of tuberculosis, fibrosis, and silicosis has been established. Is it possible to establish also a relationship between them? The Report shows that fibrosis and silicosis occur in this industry and since extraneous sources of dust have been, to a great extent, excluded by the selection of cases for examination, it may be assumed that this change in the lungs is due to the inhalation of slate dust. The view is generally accepted that fibrotic changes due to the inhalation of silica dust react unfavourably towards tuberculosis, and the same may be true of slate dust which contains free as well as combined silica.

It seems extremely probable that the cases of pulmonary tuberculosis occurring for the most part at advanced ages, in subjects who have been exposed to the inhalation of dust and developed fibrosis, are of a very chronic character. The period of infectivity extends over many years and since the presence of the disease is not suspected, precautions against the spread of infection are not taken. The opportunities for the spreading of the disease are considerable in the case of millmen in slate factories, and the control of the excessive incidence of tuberculosis amongst these workers appears to depend upon the removal of sources of infection.

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- (3) *Registrar-General's Decennial Supplement*, 1921. Part II: "Occupational Mortality". His Majesty's Stationery Office, 1927. Price 7s. 6d.

COAL MINING

The distribution of the coal-mining industry in Great Britain is indicated in the following table of employed persons.

TABLE XIV. — NUMBER OF WAGE EARNERS ON COLLIERY BOOKS IN EACH OF THE MINING INDUSTRY ACT DISTRICTS OF GREAT BRITAIN ON 8 FEBRUARY 1930

Division	County	Numbers employed
1.	Fife and Clackmannan	23,847
	The Lothians	13,824
	Lanarkshire	51,332
	Ayrshire	12,815
		101,818
2.	Durham	142,108
	Northumberland	49,333
	Cumberland	10,090
	Westmorland	
		201,531
3.	Yorkshire, South	118,082
	West	53,279
		171,361
4.	North Derby	52,239
	Nottingham	51,277
	Leicester	11,072
	South Derby	3,792
		118,380
5.	Lancashire and Cheshire	76,334
	North Staffordshire	28,800
	North Wales	14,967
		120,101
6.	South Wales and Monmouth	180,856
	Part above and Forest of	
7.	Dean	5,506
		186,362
8.	Cannock Chase	23,342
	Warwick	17,061
	South Staffordshire and Worcester	4,932
	Kent	4,694
	Somerset	3,895
	Shropshire	2,786
	Bristol	1,011
		57,721
Total in Great Britain		957,274

The processes underground in a coal mine, which may involve exposure to silica dust are:

- (1) **Ripping:** taking down the roof or top of roadway, to make height;
- (2) **Brushing:** ripping or blasting of the roof and the using of debris for building stone packs;
- (3) **Driving a hard-heading:** a drift, tunnel or roadway driven in rock or through hard measures;
- (4) **Driving a cross measure drift:** driving a roadway in such a direction as is necessary to form a travelling road from stratum to stratum.

The drills used are mostly of the percussive type, operated by compressed air. Table XV indicates the number and distribution of coal mines in which drills are used, and special measures adopted for dealing with the dust. The table includes mines in which measures are required to be taken under section 78 of the Coal Mines Act, 1911, for the use of water sprays or jets or other efficient means when drilling in ganister, hard sandstone or highly siliceous rock "the dust from which is liable to give rise to fibroid phthisis".

In the "Midland and Southern" Division where such dust is not liable to be produced, there is one colliery where dust traps are used because the men prefer to do all drilling in this way, even although there is a low percentage of silica in the rock.

Special Characters of the Silica Dust

The dusts met with in these processes are mainly those evolved from (1) clift, bind or shale, which may contain as much as 40 per cent. to 60 per cent. free silica; (2) rock, bastard rock or sandstone, in which the free silica may range from 60 per cent. to 85 per cent.

The following particulars are from three mines where highly siliceous rock is worked.

	Mine A	Mine B	Mine C
Free silica in the rock.	57.0 %	73.3 %	73.2 %
Combined silica	6.5 %	9.9 %	4.3 %
Dust counts during boring (Owens' jet dust-counter, particles in 1 c.c.)	2,290	2,180	2,220

Excluding the large particles and masses, the average size of the particles was 1.5 μ and they were generally angular and of crystalline structure with here and there opaque mineral matter resembling coal.

TABLE XV. — DRILLING IN ROCK LIKELY TO BE DANGEROUS FROM THE POINT OF VIEW OF SILICOSIS AND MEASURES TAKEN TO DEAL WITH DUST

Division	Number of mines	Total number of drills in use	Measures taken to deal with dust	Number of drills used when no measures taken to deal with dust	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
Scotland	20	57	With 4 drills respirators are used. With 10 drills water put into boreholes.	43	
Northern	20	208	With 74 drills water sprays used.	134	50 drills are in use at one mine where no precautions are taken but Inspector states conditions are naturally damp.
Yorkshire	23	192	With 16 drills, respirators used. With 45, water or wet brattice applied. With 3 water put into boreholes. With 2 water flows through hollow drills	126	One mine where respirators are used a Hay Dust trap is to be ordered.
North Midland	3	23	With 2 drills, water jets in use. With 21, respirators in use	Nil	Of the total number of drills not all are in use regularly. At one colliery (20 drills) trials are being made of dust traps.
North Western	4	Not given	At one mine respirators used. At one mine dust trap used. At one mine dust collectors being installed	1 (mine)	
Cardiff and Forest of Dean	18	Not given	At 3 mines dust traps used. At 9 mines water spray used. At 2 mines respirators used	4 (mines)	At 4 mines where water sprays or respirators used, dust traps are on order.
Swansea	29	54	With 8 drills dust traps used. With 15 drills water sprays used. With 2 drills respirators used	29	One mine where water sprays in use, a dust trap is on order.
Midland and Southern	Nil	Nil	Nil	Nil	At one colliery dust trap used with hammer drills in every type of rock.
Totals	117	534 (where given)	219	337	

Evidence of Silicosis being Produced

During recent years evidence has been accumulating which shows that certain workers employed below ground in coal mines contract a disabling and even fatal fibrosis of the lungs. Some particulars are given in the table below of fatal cases where the diagnosis has been verified by post-mortem examination, and which have come to the knowledge of the Mines Department.

These cases, although at first sight they seem so varied, when reduced to main factors show that all the men worked for a certain time in rock. Many of the men who drive cross measure drifts do no other form of underground work, but there is also a large number of workers who work on the coal face or as repairers during most of their time and only do brushing or ripping from time to time.

Where the post-mortem findings indicated silicosis there has always been a definite history of stone drilling, though the period of such employment may have been short or even very short.

TABLE XVI

No.	Age	Occupation	Period of employment	Duration of symptoms	Period of disablement	Cause of death	Remarks
1.	46	Coal miner	Years 15	Months 18	Months 7	Silicosis and tuberculosis	Worked in hard ground nearly all of 15 years (South Wales).
2.	—	Labourer and coal miner's assistant	6 (on hard ground)	—	—	Silicosis and tuberculosis	Hard ground = 56.1% total silica. Clift with occasional beds of sandstone (South Wales).
3.	38	Hard heading hammer drill	9	9	6	Silicosis and tuberculosis, pleurisy and nephritis	8.631 grammes of dried lung yielded 0.31 grammes silica (South Wales).
4.	47	Hard ground borer coal miner	3 17	—	5	Silicosis, anthracosis and acute bronchitis	Pennant rock; respirators worn during last 5-6 years. No water used with the drills (South Wales).
5.	54	Hard ground 1914-1921	7	Years 2	3	Silicosis and tuberculosis	Hard ground, mostly clift (South Wales).
6.	54	Coal miner	25	4	3 yrs.	Silicosis	18 years ago worked on hard ground, rock contained 37.8% free silica (Somerset).
7.	36	Coal miner	22	5	—	Silicosis and tuberculosis	Ash of lung contained 18.4% of silica. 20 years ago used hand drills (South Wales).
8.	59	Coal mine "repairer"	—	4	6 mths.	Silicosis	Always worked in hard headings, shale and Pennant rock.
9.	49	Mine sinker and making overcasts	14	—	—	Massive silicosis cerebral hæmorrhage, vascular degeneration	Stone = 51.3% free silica.

It is impossible as yet to arrive at the true incidence of silicosis in the coalfields, but now that the condition has been brought within the application of the Various Industries (Silicosis) Scheme a more uniform standard of diagnosis may be expected and systematic records are more likely to become available.

Preventive Measures

These either take the form of the application of water as a spray or through a hollow drill, or the extraction of dust by means of an exhaust dust trap. Those mostly in use are: (i) the Hay original model, (ii) the Hay modified model, of which there are 90 in use (February 1930) (the whole of the equipment weighs only 27 lb.), and (iii) the Sgonina.

Legislation

The Coal Mines Act, 1911, section 78, enforces the use of water sprays or jets or other efficient means when drilling in ganister, hard sandstone or highly siliceous rock "the dust from which is liable to give rise to fibroid phthisis".

General Regulations (Statutory Rules and Orders, 1920, No. 873) dated 3 June 1920, apply to all mines under the Coal Mines Act, 1911, in which ganister or other stone containing not less than 80 per cent. of silica (SiO_2) is worked with a view to sale or manufacture.

Compensation

The Various Industries (Silicosis) Scheme, 1928, which came into force on 1 February 1929, includes provisions for the payment of compensation in cases of total disablement or death due to silicosis or silicosis accompanied by tuberculosis in workmen employed in "drilling and blasting in silica rock, in or incidental to the mining or quarrying of other minerals".

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TIN MINING

Distribution

The mining and quarrying of tin ore in this country is almost entirely confined to Cornwall.

Employed Persons

In 1901, 3,678 men were employed underground, and 2,690 males and 357 females above ground. The Census for 1921 gives 2,098 workers below ground and 1,004 males and 37 females above ground and in open workings.

In 1928 the number of wage earners was 2,800. There are employed on rock drills some 700 men, and 240 rock drills are in use. Of these, 220 are provided with water jets or sprays and 20 are without.

Characters of the Dust

Dust arising from drilling, blasting and handling the material is derived from the hard stone (containing 1 to 4 per cent. of binocide of tin) of which the lodes consist, and from the containing rock, consisting of granite and "killas".

Evidence of Silicosis

In the *Registrar-General's Decennial Supplement for 1921*, it is stated that the mortality of tin and copper miners in Cornwall is excessive; the comparative mortality figure from all causes is $3\frac{1}{4}$, and for underground workers $4\frac{1}{3}$ times the average. It is pointed out that at this time the industry was depressed and probably most of the able-bodied men had secured mining work elsewhere. Almost all causes contribute to this excess mortality, but chiefly tuberculosis and respiratory diseases. The phthisis death rate is $12\frac{1}{2}$ times the normal and that for respiratory diseases 6.3 times. "No other occupation in this country suffers to anything like the same extent from silicosis, or illustrates like these men the liability of this condition to lead to tuberculosis." Deaths from chronic interstitial pneumonia numbered 27 out of the 2,110 underground tin miners; compared with 60 deaths from this cause amongst 912,126 coal miners.

Besides the dust in tin mining itself, a factor in producing the high incidence of silicosis and tuberculosis in the past was the practice among tin miners of working for a time in the gold mines of South Africa, where in former times the amount of silica dust in the atmosphere was very great and the incidence of silicosis was correspondingly high. There is no doubt, however, that tin mining in Cornwall has produced silicosis in persons who have not worked outside of this country. The following case illustrates this.

A tin miner who died in November 1928 had worked underground in two tin mines in Cornwall for at least seventeen years, and had never been in South Africa.

Post-mortem examination of the lungs was made and the following condition was found. The surface of the right lung was rough and the basal lobe was disintegrated owing to dense adhesions of the pleura, which was torn. The inter-lobar fissures were obliterated by adhesions. The left lung appeared to be voluminous and dark grey in colour. The pleural surface was free from adhesions, except between the lobes, and showed sub-pleural nodules, about 2 mm. in diameter, with white centre. The right lung, on section, was of a dark grey colour, thickly studded with nodules averaging 2 mm. to 3 mm. in diameter. The nodules were hard to the touch and could be easily removed from the adjacent tissue. At the right apex there was a dense mass of fibrous tissue, about the size of a walnut, with whitish bands. The lower lobe showed a red congestion with sanæous exudation. The left lung on section was seen to be studded throughout its whole extent with nodules similar to those found in the right lung. There was, however, more inter-nodular tissue and much of this was emphysematous, especially on the anterior aspect. There was no evidence of tuberculous change at any part of the lung on macroscopic examination. The glands about the bifurcation of the bronchi were enlarged, matted together, and almost black in colour. In consistence they were as hard as cartilage. On section, they showed almost black surface with white fibrous striæ and fine mottling as of nodules.

Microscopic examination of the lungs shows the nodules to be composed of a centre of structureless substance, with few distinguishable cellular elements and with groups of dust particles, numerous at parts. This area is surrounded by bands of fibrous tissue, the elongated nuclei lying at right angles to the radius of the nodule. Outside of this is an area of less densely formed fibres, with a considerable cellular infiltration and many blood vessels. In this zone cells are seen with well-stained nuclei containing dust particles

in the protoplasm. Giant cells are seen in the inner zone of fibrous tissue. In the alveoli and in the interalveolar septa, numerous cells are seen loaded with dust particles; many cells containing particles are seen around the larger blood vessels: in these the majority of the particles are under 1μ and many appear to be carbonaceous. Larger particles with a crystalline appearance are to be found in the interalveolar tissue.

Section of a bronchial gland shows great increase in fibrous tissue arranged in nodules, and with thick deposits of dust in the tissue between the nodules.

Methods of Prevention

A Report on the health of Cornish miners¹ states that "the dust produced by rock drills can easily be prevented by a very small water jet. The dust from blasting in close ends can be laid by a powerful jet of water and air; and can in any case be avoided by the man".

Metalliferous mines are worked under Special Rules under the Metalliferous Mines Acts.

Compensation

The Various Industries (Silicosis) Scheme, 1928, applies to all workmen employed on or after 1 January 1929 in certain processes. Amongst these is included, "drilling and blasting in silica rock, in or incidental to the mining or quarrying of other minerals". The Scheme provides for the payment of compensation in cases of total disablement and death.

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POTTERY INDUSTRY

This industry includes several distinct branches, the subdivision being determined by the nature of the article manufactured and the materials entering into the composition of the ware. The principal

¹ Cf. Bibliography, No (1).

divisions are: (1) general earthenware; (2) china; (3) tiles; (4) sanitary earthenware; (5) electrical fittings; (6) jet and Rockingham; (7) sanitary fireclay; (8) stone ware; (9) coarse ware.

The subject of silicosis is especially bound up with the first five of these subdivisions, though the others have also some interest. For the purposes of this paper the term "pottery industry" will be restricted to subdivisions 1 to 5, and the others will be referred to by name where necessary.

Distribution Geographically

A large portion of the pottery industry is concentrated in the North Staffordshire Potteries, the city of Stoke-on-Trent. Other groups of potteries are found in Derbyshire, Scotland, Dorsetshire, Devonshire, Yorkshire, Shropshire, Worcester, Newcastle-on-Tyne, Bristol and other places.

Employed Persons

In a Census of Employees of the British Pottery Manufacturers' Federation, for 14 January 1926, the numbers employed in the five subdivisions of the industry referred to above were: males 18,424 and females 23,402. In the several subdivisions the numbers were:

	Males	Females
General earthenware	8,892	13,783
China (combined with earthenware).	2,041	2,810
China	1,835	2,806
Tiles	2,370	1,729
Sanitary earthenware	2,081	285
Electrical fittings	1,205	1,989
Totals	18,424	23,402

Operations and Processes

From the point of view of the production of silicosis the industry is divisible into two main parts: (1) earthenware, including general earthenware; sanitary earthenware, earthenware tiles and earthenware electrical fittings, and (2) china.

In the manufacture of earthenware the ingredients—ball clay, china clay, china stone, felspar, and flint, in a ground state—are mixed together in the form of liquid slip, from which the excess water is removed by pressing; the resulting composite body is made into the consistence convenient for the manufacture of the various articles. In the plastic state it is used by throwers, pressers, jiggerers

and jolliers, handlers, modellers, etc., in the potters' shops. So long as it remains moist it is harmless, but in the process of manufacture fragments fall on benches and floors, or adhere to the clothing of the workers, become dry and give rise to dust. After the article has been made in the plastic form, partly dried, it is frequently subjected to the process of towing, that is, application of tow or other similar substance to the surface of the article while it revolves on a mechanically driven disc, thus giving rise to large quantities of dust for which localised exhaust is required to be provided. In other cases the formed article in the "green" state is fettled, that is, irregularities of surface and edges are removed by hand by rubbing or scraping. This gives rise to dust as in the case of "towing", and with large articles such as sanitary ware the application of localised exhaust is difficult.

In the potters' shops, the body or slip may be used by the potter, "caster", in the liquid state instead of in the plastic state. When this is done it is poured into moulds of plaster of Paris and allowed to set. Afterwards the parts of the moulds are removed and the article in a semi-dry state is subjected to the process of fettling and finishing, as in the case of "thrown" or pressed articles.

When the articles shaped by the potter into their final form have been dried in a drying chamber to a condition known as "white hard", they are placed in "saggers"—large flat-bottomed basins made of fireclay—for firing in the oven. In the case of earthenware the material is "placed" in the saggers by "placers", the articles being prevented from touching the sagger or each other by interposing some siliceous sand or coarsely ground silica rock. In the case of china, however, the articles require much more support in the process of firing than do earthenware articles, and to provide this, finely ground flint is used. Flat ware is embedded in flint to a greater or less extent, by the processes of "placing", called "flinting", where enough flint is used to separate the flat ware when arranged in a pile in the sagger; "bedding" when the whole sagger full of ware is filled up with ground flint, and "setting", when a separate mould covered with flint is used for each piece of ware. Hollow-ware is treated on similar lines so far as its form will allow, cups and similar articles being placed with the rims, to which an adhesive is applied, in apposition. The process is known as "boxing" of cups.

In the processes of "placing" earthenware and china in saggers, the placers are exposed to dust produced in the manipulation of the placing material, a relatively coarse sand in earthenware, a finely

ground flint in the case of china. The processes in china placing are therefore relatively much more dangerous, involving handling of the more finely ground and more highly siliceous flint. The china "placers" rank amongst the most severely affected workers who contract silicosis in the pottery industry.

After the firing in the ovens, the saggars are removed by "biscuit" oddmen, who remove the ware now known as "biscuit" from the saggars, empty out the placing sand or flint and sift it for future use when mixed with a proportion of fresh or "green" placing sand or flint. After removal from the saggars the ware is placed in baskets and conveyed to the biscuit warehouse where it is subjected to a variety of processes to remove the adherent placing sand or flint, in preparation for glazing or underglaze decoration. The biscuit warehouse processes include hand brushing, placing in and removal from scouring machines, in the form of rumblers, "flat knocking", "batting" and fine brushing. All these processes in the biscuit warehouse give rise to dust from the adherent placing sand or flint. They are carried on almost entirely by women.

When the biscuit ware has been cleaned, no substantial risk of silicosis arises in the subsequent processes of manufacture until glazing and decoration has been completed. Then polishing and grinding are employed to remove blemishes, etc. This is done by means of a revolving wheel which may be composed of cork or stone, to which ground flint is applied mixed with water, or an abrasive wheel of carborundum or similar material may be used. Where flint is used, it gives rise to dust and is liable to produce silicosis.

Glazes contain some free silica, but the evidence that disabling silicosis is produced from this source is not conclusive.

The industry can be divided into some sixty occupations. Half of these are occupations in which the worker is exposed to the inhalation of silica dust to a greater or less extent. The following is a list of these occupations, with the approximate number of persons employed:

	Males	Females
1. Millmen	208	—
2. Slipmakers and dust house attendants	811	13
3. Modellers	64	1
4. Mould makers (dust of plaster of Paris)	555	6
5. Throwers and lookers-to ware	202	147
6. Turners and lathe treaders	471	295
7. Handlers	258	720
8. Plate makers and towers	583	788
9. Dish makers	138	132
10. Hand basin makers	92	132
11. Saucer makers	186	497

	Males	Females
12. Cup and bowl makers	75	702
13. Jiggerers and jolliers	307	535
14. China flat jiggerers and jolliers	74	16
15. Casters, earthenware and china	307	914
16. Sanitary casters	729	13
17. Hollow-ware pressers, earthenware and china	229	5
18. Sanitary pressers	132	1
19. Tile pressers	306	712
20. Electrical dust pressers	25	520
21. Fettleers (electrical fittings)	16	479
22. Sagger and marl grinders	760	—
23. Biscuit placers	1,158	23
24. Biscuit oddmen	272	16
25. Biscuit firemen	219	1
26. Biscuit warehouse	180	1,710
27. Glost placers and oddmen	1,723	162
28. Polishers and grinders	419	37
29. Tile slabbers	124	5
30. Labourers	526	3

The exposure to risk of dust inhalation in these occupations may be stated briefly as follows:

1. *Millers and mill labourers.* — Only men are employed. They carry out the preparation of flint—calcining, breaking, crushing and milling, and the exposure is to flint dust. They are also employed in grinding broken biscuit ware (pitcher) in the preparation of glaze; manipulation and milling china clay, ball clay, china stone, felspar; calcining and grinding of bone; grinding of marl and fireclay.

2. *Slipmakers* include slipmakers' assistants, slip pressers and press emptiers. It includes those employed in mixing and manipulation of the mixed materials for the body of earthenware, sanitary earthenware, china, fireclay, mixed fireclay and earthenware and marl. It also includes those engaged in the preparation of a material known as "dust" for the body of tiles and electrical ware. Further processes in the preparation of this dust consist in the drying and pulverising, remoistening and sifting, before the tiles or electrical fittings are pressed into their final shape.

3. *The potters' shop.* — In the potters' shop are those employed in the manufacture of the ware before it is fired. The group includes those engaged in the following occupations: throwers, turners and lathe treaders, hollow-ware and sanitary pressers, ornaments and figure makers, casters and spongers and fettleers for casters, handlers and handle makers, electrical and tile dust pressers and fettleers, machine workers (jiggerers and jolliers), plate makers, saucer makers, flat pressers, hand basin makers, dish makers, general jiggerers and jolliers, cup and bowl makers; also those workers attached to machine workers, towers, spongers, fettleers, scallopers, etc. In the potters' shop the workers are exposed to dust from the mixed body of the ware, the character of the dust varying according to the composition of this body.

4. *Mould makers* are employed in making moulds from plaster of Paris, to which dust they are alone exposed unless by proximity they are also exposed to dust from potters' shops.

5. *Modellers* are occasionally employed as mould makers as well as modellers of the ware.

6. *Sagger makers* are engaged in grinding marl, broken saggars, etc., and the sifting of such material in the manufacture of saggars by hand and by machine. The exposure is to dust of marl and a varying quantity of flint or ware body from old saggars, etc.

7. *Biscuit placers* and *biscuit oddmen* include those engaged in the handling and sifting of flint or sand in preparation for its uses in placing; in the placing or bedding of biscuit ware in the sagger house; in the preparation of the ovens, and in emptying the ovens and the removal of ware, sand and flint from saggars. In the manufacture of china, the bedding material is flint, and the workers in these occupations are exposed to dust of flint. In earthenware, sanitary, and other types of ware, the placing material is sand, and it is to the dust of this sand that workers are exposed.

8. *Biscuit firemen* include those employed in firing biscuit ovens, but not in connection with the bedding of biscuit ware.

9. *The biscuit warehouse* includes those engaged in handling the ware after its removal from the biscuit sagger house; in charging and emptying rumpers and other mechanical apparatus for cleaning the ware; in brushing, stopping, stamping, selecting and looking over the ware. The dust to which these workers are exposed is, in the case of china, flint; in the case of earthenware, the placing sand.

10. *Glost placers and glost oddmen* include those employed in the preparation of new saggars, by flinting and glazing the exterior and flinting the interior of the saggars; in the placing of glost materials, the filling and emptying of glost ovens, the emptying of glost saggars, and in brushing saggars. There is a slight degree of exposure to flint dust.

11. *Polishers and grinders* include those employed in the polishing and grinding of ware by the use of mechanically driven wheels, on some of which ground flint is placed, or by the use of a sandblast. Exposure is to finely divided flint dust.

12. *Tile slabbers* are employed cutting and grinding tiles for fitting. The dust is that of the fired tile body.

13. *Labourers* include all those engaged in sweeping the shops and yards and in cleaning localised exhaust plants, rumpers, sandblast, etc.

14. *Slip carriers and mould runners*. — The exposure to dust varies greatly according to the particular duties and the type of ware produced.

Special Characters of the Silica Dust and Reference to the Presence of Other Dusts

The composition and character of the dust to which workers in the pottery industry are exposed, vary according to the occupations and the branch of the industry in which the worker is engaged.

In the manufacture of earthenware, at which the slip or body is liable to become dry, i.e. at all parts of the process before the

first firing, the dust produced consists of the body, that is, a mixture of clays, china stone, felspar and flint in a fine state of division. China stone contains about 73 per cent. total silica, part of which is free as quartz. Flint is almost pure silica, containing 98 per cent. SiO_2 , in an extremely fine crystalline (crypto-crystalline) condition, set in colloidal silica which makes up 1.5 per cent. to 2 per cent. of the rock. Felspar contains about 64 per cent. of silica combined as silicates.

In the manufacture of china no flint is added to the body of the ware, which consists of calcined bone, china clay and china stone. A small amount of free silica as quartz is derived from the china stone.

The chemical composition of atmospheric dust in certain pottery processes has been determined by H. Oliver, B.Sc., in a Report on an investigation of atmospheric dust in pottery workshops¹ (the Report was for private circulation).

TABLE XVII. — TABLE OF COMPLETE ANALYSES OF DUSTS COLLECTED

No.	Process	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Loss on ignition	P_2O_5	Total	Remarks
2.	Towing Earthenware	53.80	Less than 0.01	16.80	0.90	2.80	0.90	2.60	2.50	20.00	—	100.30	
3.	Brushing Earthenware	62.08	0.48	16.36	0.80	2.44	0.12	1.10	3.00	14.08	—	100.46	Sand very dry. Centre of room.
4.	Dry Fettling China	36.34	0.00	26.54	0.48	16.64	0.02	1.92	1.84	8.18	8.26	100.22	
5.	Placing, etc. China Biscuit	96.20	0.00	1.74	0.12	0.68	0.00	0.08	0.64	1.04	Trace	100.50	Alumina and Phosphate indicate dust from green ware.
9.	China Biscuit Brushing	82.88	0.00	1.82	0.54	2.52	0.00	1.52	1.56	8.68	Trace	99.52	Alumina and Phosphate indicate abrasion of ware.
10.	Placing China Biscuit	74.80	0.00	3.16	0.64	2.84	0.04	3.70	1.50	13.12	Trace	99.80	
12.	Flint Sieving	84.80	0.00	1.20	0.48	3.48	0.16	2.80	0.90	6.08	—	99.90	

The relatively high alkalis and lime in every case indicate that these are general constituents of atmospheric dust, although a portion of the lime may be from the moulds and bats.

¹ Cf. Bibliography, No. (1).

An investigation into the dust content of the atmosphere of workplaces in the pottery industry was undertaken to provide a connecting link between the state of health found by examination of the workers and the hygienic conditions under which their work is carried on, with a view to the elucidation of the physical aspect of the causation of disease and to assist in the problems of the improvement of those conditions. The notes on the incidence of respiratory disease which follow the dust determinations in the occupational groups of this section have been taken from the Report of a Medical Enquiry carried out by Drs. Sutherland and Bryson in 1925¹, under the direction of the Home Office.

This section covers most of the occupations in which there is exposure to silica dust in the manufacture of earthenware and china, and in addition, some investigation into the stoneware branch of the industry. From the hygienic point of view the stoneware industry is probably similar to the jet and Rockingham branch of the industries, in which there is at present no conclusive evidence of incapacitating silicosis.

Flint Milling

While the preparation of powdered flint is essential for the manufacture of all classes of pottery except coarse ware, stoneware and fireclay, although in these it may be used for the glazes or surface body, it might be considered as separate from the processes of pottery manufacture. Although some potteries have their own flint-milling department either within the precincts of the pottery or in a separate factory, the industry of flint milling is commonly carried on by separate firms who may supply the flint for purposes other than pottery manufacture, and they may combine the milling of other materials with that of flint. Further, the workers in this industry do not belong to the Societies of Pottery Workers.

The methods in general use are as follows. Home or foreign flints are placed in a large kiln with fine coal and fired, continuously. As required, the calcined flints are removed, together with the ashes of the fuel, from a small orifice at the bottom of the kiln, and are washed by spraying with water from a hose or are shovelled dry into barrows and wheeled to the mill room or to a stone crushing machine. The flints may be broken by hand hammer, the remainder of the grinding being done wet in buhrstone mills, or a preliminary crushing may be done before the material is placed in the mills.

¹ Cf. Bibliography, No. (2).

The grinding is done with sufficient water to keep the mass fluid: from the mills it is passed to sedimenting tanks where the water is separated and the flint is dried by heat until it contains only from 5 to 10 per cent. of its weight of water. The mass is broken up and removed by shovelling as required. Dust is produced in removing the calcined flints from the kiln, though most of this dust is ash: any process of manipulating the flints in this condition

TABLE XVIII

Process	Number of particles in 1 c.c.	Percentage over 2μ	Remarks
(1) Raking calcined flints from the kiln	2,687	2.6	Most of the particles are mineral.
(2) Sieving flint chips from the kiln	2,289	2.8	The sample closely resembles (1).
(3) Sieving calcined flints with an enclosed mechanical shaker	1,793	0.7	Not more than 10% of the particles are mineral; others are soot.
(4) Shovelling crushed calcined flints into crusher: to windward	2,132	1.7	About 15% of the particles are mineral; others are soot.
(5) Charging the flint crusher; sample taken to leeward of machine	4,314	9.1	A dense sample; the amount of soot is negligible.
Compare (5) with the following sample taken at a pottery in Glasgow, at the crusher, under cover, where the material was kept wet with water from a hose.			
(6) Shovelling calcined flints, wet, into the crusher	458	6.8	A sparse record; particles evidently flint, varying in size from 1μ to 6μ .
Sample taken at a flint-milling factory in Glasgow, in a neighbourhood free from excessive dust and smoke, and in damp weather.			
(7) Control taken in yard, to windward of process	1,156	0.3	Most of the particles are soot.
(8) Shovelling calcined flints and ashes from the kiln: to windward	1,807	2.2	Particles apparently include flint, ash, and coal.
(9) Sieving ashes, containing flint chips, from the kiln: open air	1,325	0.6	About half of the particles are refractive, and probably some of this is flint.
(10) Shovelling calcined flints in the open: to windward	1,120	1.0	Fine ashes and some refractive material, probably flint.
(11) Breaking calcined flints with a hand hammer	1,446	0.6	Flint forms about 50% of the total.
(12) In the drying room, turning over masses of ground flint	1,530	0.8	Occasional large particles, apparently flint.

is liable to produce dust, shovelling, knapping by hand hammer, sieving and, especially, grinding in a stone-crushing machine. A small amount of dust arises in shovelling the dried flint into carts or bags, and where bags are used much dust may be produced in handling them.

Two series of dust samples were taken with Owens' jet dust-counter, one in Stoke and the other in Glasgow, and since the general atmospheric conditions are not comparable, the series are stated separately.

Samples taken at a flint-milling department in a pottery in Stoke-on-Trent are given in table XVIII.

The most dangerous process in the milling of flints for use in pottery manufacture is that of crushing the calcined flints in a machine crusher. Sometimes this is replaced by breaking with a hand hammer, with much less risk, especially if the flints are freely wetted during the process. A liberal use of water immediately after drawing the flints from the kiln and at the crushing process would minimise or remove the danger: while sieving could be done by covered machines or could be modified by a process of washing.

Silicosis was diagnosed by radiological examination in 3 flint-millers out of 7 examined; the earliest definite evidence occurred after employment for from ten to fifteen years. Fibrosis of the lungs was diagnosed by medical examination in 8 out of 13 flint millers examined, the earliest manifestation being after ten to fifteen years' employment.

Note. — Some of these classed as flint millers had been employed for various periods at other occupations in potteries or otherwise.

China

The following series of dust determinations represent processes which fall into three groups: (1) processes before biscuit placing, in which the dust is derived from the unfired body; (2) processes in biscuit placing, and (3) processes after the firing of the biscuit ware, in which the dust is derived from the flint, adhering to the articles as a result of the process of placing them in the saggars for firing.

In column (5) an estimate is given of the proportion of the count which consists of particles, apparently composed of flint. To arrive at the actual pollution of the atmosphere by flint it is necessary to estimate the number of particles of flint per cubic centimetre of air by taking the percentage given in column (5) out of the number in column (3).

(1) *Processes before Biscuit Placing (in the Potters' Shops)*

TABLE XIX

Process (1)	Position (2)	Number of particles in 1 c.c. (3)	Percentage over 2μ (4)	Remarks (5)
(1) Jollying hollow-ware	Jolly shop	5,350	1.1	About 20% of the particles are refractive; clumps and splashes.
(2) Dry fettling	Hollow-ware casting shop	6,916	2.5	At least 50% of particles are refractive; splashes, aggregates and clumps.
(3) Dry fettling	China casting shop	5,567	2.1	About 20% of the particles are refractive; splashes and loose aggregates. Numerous smoke particles, discrete and clumped.
(4) Fettling china hollow-ware	China potters' shop	4,470	0.9	Much soot. About 10% of the particles are refractive.
(5) Dry fettling on whirler	Jolly shop	6,169	2.3	About 30% of the particles are refractive; splashes and clumps. Considerable amount of soot.
(6) Dry fettling on whirler	Jolly shop	7,157	2.2	Over 80% of the particles are refractive; numerous splashes and closely aggregated masses.
(7) Dry fettling on whirler	Jolly shop	4,555	1.8	About 30% of the particles are refractive; others soot.
(8) Looking over and dusting	Greenhouse	3,615	2.0	About 40% of the particles are refractive; others soot.

This series of dust counts is sufficient to indicate that a source of danger exists in workrooms in which the china body is in the damp or even wet state. The dust is certainly derived from particles of dry material floating in the air of the rooms. In the wet processes the dust is produced from fragments falling on the benches, floors and clothing of the workers, where it dries readily in the high temperatures prevailing and is set free as adventitious dust. In the fettling processes, the ware is sometimes sufficiently dry to cause dust directly from the action of the fettling tool.

Silicosis was diagnosed by radiological examination in china saucer-makers employed 15-20 years, in flat jiggerers and jolliers employed 20-25 years, and in a sliphouse worker employed over 40 years. Fibrosis of the lungs was diagnosed, by medical examination of china workers, in sliphouse workers and in handlers, employed 10-15 years; in saucer-makers and flat fettlers, employed 15-20 years; in lookers-to-ware and flat jiggerers and jolliers, 20-25 years; in throwers, employed 25-30 years; in lathe-treaders, employed 30-35 years; and in turners and hollow-ware pressers, employed over 40 years.

(2) *Processes in Biscuit Placing*

In the manufacture of chinaware, the principal dust hazard is due to the use of flint as the placing material in which the green ware is fired.

The process, as denoted in column (3), relates to the variety of placing adopted with different forms and classes of ware. Control samples were taken, three in the yards of the potteries and one inside a placing room, in which no work had been done that day, for the purpose of comparison.

Looking at the data provided by the tests the actual number of particles of flint, that is, the percentage in column (5) of the number in column (3), the following facts appear. The lowest counts are controls; number (18) taken in Hanley with the wind blowing over Hanley Park, which gave 65 particles of mineral; and number (19) at Fenton, which gave 151 particles. The lowest placing sample is number (15) with 338 particles—flinting with a current velocity of 800 feet at an exhaust opening 24 by 2 inches. Four placing samples are recorded below 500 particles in a cubic centimetre, out of 29 samples taken at all the varieties of placing china biscuit ware. Eleven are over 500 and below 1,000 particles in a cubic centimetre. Eight are over 1,000 and below 2,000 particles and six are over 2,000 particles in a cubic centimetre.

Silicosis was diagnosed by radiological examination in 16 china-biscuit placers out of 22 examined: the earliest definite evidence was found after 10-15 years' employment. Fibrosis of the lungs was diagnosed by medical examination in 19 china-biscuit placers out of 25 examined, the earliest case occurring after 5-10 years' employment.

TABLE XX

No.	Process	Number of particles in 1 c.c.	Percentage over 2μ	Remarks
(1)	(2)	(3)	(4)	(5)
1.	Control: centre of yard	4,554	0.1	Over 90% of the particles are soot.
2.	Bedding saucers	6,175	0.5	30-40% of the particles are flint.
3.	Boxing cups	5,699	2.6	60% of the particles are flint.
4.	Control: centre of yard	2,602	0.3	Over 90% of the particles soot.
5.	Bedding	647	4.6	About 80% of the particles flint: some aggregates.
6.	Flinting	825	3.6	General characters similar to (5).
7.	Boxing cups	6,832	0.8	About 20% of the particles flint.
8.	Bedding	5,940	0.3	About 40% of the particles flint.
9.	Flinting	5,916	0.27	Characters similar to (8).
10.	Bedding	4,482	0.7	30% of the particles are flint.
11.	Flinting	5,615	0.5	30% of the particles flint: similar to (10).
12.	Bedding	3,807	0.3	10-20% of the particles flint.
13.	Boxing cups	5,097	1.1	40% of the particles are flint.
14.	Bedding	1,434	2.5	About 50% of the particles flint.
15.	Flinting	3,384	0.1	About 10% of the particles are flint: difference between 14 and 15 due to the effect of exhaust draught.
16.	Setting	2,554	0.6	20-30% of the particles flint.
17.	Bedding	2,530	1.3	About 30% of the particles flint.
18.	Control: outside	1,373	0.3	A few isolated mineral particles; others soot.
19.	Control: placing room	1,518	0.2	Off work all day: 10% of particles are mineral.
20.	Boxing cups	2,506	1.2	40-50% are flint particles: some aggregates.

TABLE XX (continued)

No.	Process	Number of particles in 1 c.c.	Percentage over 2μ	Remarks
(1)	(2)	(3)	(4)	(5)
21.	Bedding	3,338	0.1	40-50% are flint particles some fine clumping.
22.	Flinting	1,759	0.8	20% flint particles: clumping of soot.
23.	Bedding and flinting	4,808	0.5	40% flint particles: some clumps.
24.	Boxing cups	5,266	0.7	Similar to (23), but less clumping.
25.	Bedding	4,241	0.2	A large proportion of fine particles of flint.
26.	Boxing cups	8,989	0.4	About 15-20% are flint parts: fine clumping.
27.	Settinging	2,807	0.4	20-30% are flint particles.
28.	Boxing cups	3,060	0.3	About 20% of the particles are flint.
29.	Settinging	4,109	0.2	About 20% of the particles are flint.
30.	Settinging	2,723	0.9	About 30% are flint particles.
31.	Bedding	3,747	0.1	Only about 10% are flint particles.
32.	Flinting	4,964	0.2	About 10% are flint particles.
33.	Settinging	5,603	0.1	About 10% are flint particles.

(3) Processes after Firing of the Biscuit Ware

The series of dust counts given in table XXI, representing processes undertaken for the removal of adherent flint from fired china-biscuit ware, serves to show that a high degree of danger exists to the workers in these processes. An inspection of this work demonstrates the necessity for concentrating attention on the removal of as much of the flint as possible in the earlier processes after the ware is taken from the saggars. It is just in these early processes that the methods are inclined to be haphazard and the labour less skilled, with the result that the workers in subsequent processes are exposed to a high degree of risk.

Silicosis was diagnosed by radiological examination in biscuit-oddmen, employed 5-10 years, and in biscuit warehouse-women employed 15-20 years. Fibrosis of the lungs was diagnosed by medical examination in biscuit-oddmen employed less than 5 years, and in biscuit warehouse-women employed from 5-10 years.

TABLE XXI

Process (1)	Position (2)	Number of particles in 1 c.c. (3)	Percent- age over 2 μ (4)	Remarks (5)
1. Emptying sagers	Mouth of china biscuit oven	11,724	0.5	About 50% refractive particles; others soot.
2. Sifting flint	Hovel of No. 1 biscuit oven.	3,916	5.3	About 60% of the particles are refractive. Aggregates and masses.
3. Filling and drawing	Mouth of mechanical flat knocking machine.	11,544	0.6	Quite 50% of particles are refractive; others soot.
4. Emptying hollow-ware	Scouring shop	10,411	0.8	Over 50% of particles are refractive; others soot. Very few clumps.
5. Filling racks for drums	Scouring shop	9,194	0.6	At least 80% of the particles are refractive.
6. Filling racks of hollow-ware	Scouring shop	5,121	1.0	About 40% of the particles are refractive; others soot. Groups and masses.
7. Placing cups in racks	China biscuit scouring shop	7,423	1.3	About 30% of the particles are refractive, probably flint; others soot.
8. Removing cradles of ware	China biscuit scouring shop	5,964	0.2	Only about 10% of the particles definitely refractive.
9. Emptying scouring drum	Scouring shop	9,616	0.6	A large proportion, over 80%, of particles are refractive.
10. Emptying racks of hollow-ware	Scouring shop	5,157	0.9	About 40% of particles are refractive; others are soot.
11. Batting before printing	Scouring shop	10,399	0.3	Over 50% of particles are refractive. Dense sample.
12. Batting with jet of compressed air	Scouring shop	8,242	0.3	About 70% of the particles are refractive; others are soot.
13. Fine-brushing saucers with revolving brush	Scouring shop	7,073	0.5	Majority of particles are soot; not more than 20% are refractive. Soot thickly clumped at parts.

Earthenware

In the manufacture of earthenware there are many processes which give rise to dust: these may be divided into four groups; (1) the handling of the raw materials up to the completion of the "body"; (2) the fashioning and drying of articles of pottery; (3) the placing of biscuit ware, emptying saggars, and preparation for glazing; (4) the making and applying of glaze, glost placing and polishing. Other incidental occupations are mould and sagger making.

When the slip or body has been made, and passed to the potter to be fashioned into an article of pottery, portions of the body become detached and, falling on the benches or floor, become dry and are crushed and give rise to dust. This dust exists in the atmosphere of the workplace as free particles of the constituent ingredients of the body, and also as minute masses of all the ingredients together. Collected with the Owens' dust-counter and examined under the microscope, the particles are seen to consist of masses firmly bound together, aggregates of loosely attached particles, and splashes of particles which appear to have been held together until the mass struck the surface of the recording slide. Under these conditions the clay particles appear with a faintly differentiated outline, as contrasted with the angular or finely faceted and highly refractive flint or quartz particle. Discrete particles are also seen scattered throughout the field, both of the clay and the crystalline character.

The following samples were taken in the processes of manipulating the plastic "body":

TABLE XXII

Position (1)	Number of particles in 1 c.c. (2)	Percent- age over 2 μ (3)	Remarks (4)
1. Potters' throwers shop. Same factory as (2) and (3)	1,398	20	Many discrete refractive particles.
2. Turners' shop — a large room in which throwers also were at work	783	4.6	About 50% of particles are refractive.
3. Hollow-ware pressers' shop	1,265	2.2	Much of the sample is soot; there are discrete refractive particles.

TABLE XXII (continued)

Position (1)	Number of particles in 1 c.c. (2)	Percentage over 2 μ (3)	Remarks (4)
4. Hollow-ware pressers' shop—a very large room (same factory as (5))	1,458	3.6	50%-70% of particles are mineral.
5. Hollow-ware casters' shop—a large room	1,506	0.5	The splashes contain refractive particles.
6. Small jolly shop. General air of room at breathing level	916	5.6	Many close splashes. Impossible to count refractive particles in splashes.

In the above six samples the notable feature is the presence of splashes which account for most of the mineral content of the atmosphere, while free particles are comparatively scanty.

The following samples were taken at processes in manipulating the dried body, i.e. unfired or green ware:

TABLE XXIII

Position (1)	Number of particles in 1 c.c. (2)	Percentage over 2 μ (3)	Remarks (4)
7. In drying stove: a boy moving to and fro with ware and moulds	1,000	6.3	Much of the mineral matter is in clumps and splashes.
8. Jolly shop. Dry fettling edges of earthenware saucers	2,036	2.7	About 50% of particles are mineral, some discrete and some in splashes.
9. Flat pressing shop. Fettling plates in the green state	337	4.2	A very sparse sample.
10. Towing flat ware at a temporary bench, without exhaust: room warm	964	17.2	Most of the mineral material is in clumps and splashes. In this sample clumps are counted as single particles over 2 μ .
11. Towing. Same as (10) but with the instrument warmed to temperature of room or slightly above it, to test variation in formation of aggregates	1,048	8.9	Similar to (10) but shows slightly less clumping and is more uniform.

TABLE XXIII (continued)

Position (1)	Number of particles in 1 c.c. (2)	Percentage over 2μ (3)	Remarks (4)
12. Towing. Same factory as (10) and (11). Provided with localised exhaust	1,036	8.9	Character of sample resembles (10) and (11), and counts are remarkably similar. The effect of localised exhaust draught in this case is probably nil, or is counterbalanced by a current of dusty air drawn past the worker from the same or adjoining rooms.
13. Towing. Under hoods, with exhaust	1,747	3.0	Many splashes of mineral matter, also many free particles.
14. Towing. With localised exhaust and with a hood not in position	747	2.1	About 50% of particles are mineral, chiefly in splashes.
15. Towing. Same as (14) but with hood in position	807	1.4	Similar to (14) but soot particles are more frequently single, increasing the count.
16. Towing house in another factory. Under localised exhaust	3,012	1.0	Many of the particles are soot; less than 20% mineral.
17. Towing plates. Towing shop. With exhaust	1,590	1.1	Much soot. About 15% to 20% mineral.

Samples in which the dust is from the placing sand:

TABLE XXIV

Position (1)	Number of particles in 1 c.c. (2)	Percentage over 2μ (3)	Remarks (4)
18. Placing biscuit ware in saggars.	1,723	7.4	About 70% of particles are mineral, much in splashes.
19. In the kiln; one man inside, 4 men outside and one just outside, emptying saggars. Placing sand is a pounded sand	2,879	0.6	Great majority of particles are soot (80%); some of the mineral in splashes and clumps. Large sand particles scanty.
20. Biscuit warehouse. Brushing biscuit earthenware, 3 girls helping	2,108	0.6	About 90% soot. Mineral for the most part discrete.
21. Ornamenting shop. Ornamenting dinner-ware. Large room with windows open	1,108	0.7	Particles are chiefly soot, with a few scattered discrete and clumped refractive particles.

Of workers employed in the manufacture of earthenware in occupations in which the unfired composite body is handled, that is, from the sliphouse to towers and lookers-to-ware, 46 males and 15 females were examined radiologically. Silicosis was diagnosed in 26 males and 3 females. The male cases of silicosis were distributed amongst platemakers, handlers, dishmakers, throwers, jiggerers and jolliers, hollow-ware pressers and casters (some of whom had been employed previously as hollow-ware pressers). The female cases of silicosis were found amongst towers, fettlers-for-casters and cupmakers.

Fibrosis of the lungs was diagnosed by medical examination in 49 males out of 88 examined and in 12 females out of 89 examined. Bronchitis was found in 13 and some evidence of tuberculosis in 3 male workers.

Radiological examinations were made of 7 earthenware-biscuit placers and 1 case of silicosis was diagnosed. Two earthenware biscuit warehouse-women were examined radiologically and 10 medically, with negative results. Fibrosis of the lungs was diagnosed in 10 out of 18 male earthenware biscuit placers. The dust hazard to which these workers are exposed is that from the placing sand.

Tiles

Ornamental and plain tiles are made from a body resembling that of earthenware; in the case of white body there is up to about 40 per cent. of flint. In preparing the body for the press, the slip is freed from excess moisture by pressure, dried and ground. The dust given off into the atmosphere in the process of grinding the dried mass consists of the total constituents of the body, and as regards the tendency to aggregate formation and the physical separation of the particles, the conditions are similar to those obtaining in the manufacture of earthenware, in which the body becomes disintegrated about the benches, floors, stoves, etc., in potters' shops.

In one tile-making factory, 5 samples were taken at some of the dusty processes (cf. table XXV).

Another kind of dust is met with in tile manufacture—the

TABLE XXV

Process (1)	Position (2)	Number of particles in 1 c.c. (3)	Percentage over 2 μ (4)	Remarks (5)
1. Control	Grinding room. Taken at 2 p.m. work having been suspended for an hour	1,277	1.5	About 10%-15% of the particles are mineral some in aggregates.
2. Feeding hopper of grinding machine	Same grinding room at 2.35 p.m., work having been resumed at 2.15	3,868	12	Very dense sample with many aggregates. The whole count represents mineral.
3. Shovelling material into hopper. Most parts of grinding machine are enclosed, but a slight leakage with visible dust escaping	Grinding room of another factory	1,458	19.0	Most of material is in the form of clumps and splashes. Very little soot.
4. Control	Tile pressing room, taken at 1.55 p.m., work suspended since 1 o'clock	4,060	1.0	Great majority of the particles are soot; other particles apparently mineral, up to 4 μ
5. Tile pressing	Same room; sample taken $\frac{1}{2}$ -hour after work was resumed after dinner interval	3,530	1.8	Very much less soot than in (3), and great increase in mineral particles.

TABLE XXVI

Process (1)	Position (2)	Number of particles in 1 c.c. (3)	Percentage over 2 μ (4)	Remarks (5)
6. Brushing biscuit tiles	Biscuit warehouse	2,265	1.9	About 20 % of the particles are mineral; there are few aggregates.
7. Emptying sappers and looking over biscuit tiles	Biscuit warehouse	2,181	0.9	About 20 % of the particles are mineral. General characters similar to (6).

placing sand giving rise to dust in the biscuit warehouse when the tiles are removed from the saggars and looked over and brushed. This work is done by women and girls. Two samples were taken in the biscuit warehouse (cf. table XXVI).

Two tile-sliphouse men were examined medically and radiologically; one of these showed evidence of silicosis after being employed 25-30 years: in both workers a diagnosis of fibrosis of the lungs was made. Three male tile-pressers were examined radiologically and all of these showed evidence of silicosis, the earliest signs appearing after employment for 10-15 years. Six were examined medically, and of these 3 showed evidence of bronchitis and 2 of fibrosis of the lungs.

Nineteen female tile-pressers were examined medically and 5 also radiologically. In one case, employed 25-30 years, silicosis was diagnosed. Fibrosis of the lungs was found in 2 cases and bronchitis in 1 case.

Of workers exposed to dust from the placing sand, 3 placers were examined medically and radiologically. One man employed 35-40 years showed evidence of fibrosis of the lungs, but there was no evidence of silicosis in the group. One warehouse-woman was examined medically, with negative result.

Of tile slabbers, who are exposed intermittently to the dust of the finished tile, 3 were examined medically and radiologically; all showed evidence of fibrosis of the lungs, but none of silicosis. None of the men had been employed for more than 20 years.

Electrical Fittings

These articles may be made from a body consisting simply of ball clay, such as is used for stoneware articles, or from a composite body which resembles that of earthenware but contains usually only about 10 per cent. of flint. When the composite body is used the articles are formed by pressure from the so-called dust which contains about 15 per cent. of moisture (cf. table XXVII).

Composite Body

TABLE XXVII

Process (1)	Position (2)	Number of particles in 1 c.c. (3)	Percentage over 2μ (4)	Remarks (5)
1. Sieving damp dust	—	2,422	4.8	About 50% of the particles are mineral, most of them in splashes, refractive particles mixed with clay.
2. Pressing	Die-pressing shop	1,976	3.2	Some aggregates and splashes, accounting for most of mineral particles: about 40% mineral.
3. Between 2 dry fettlers	Fettling shop	1,855	1.7	Most of the particles are in splashes. About 40% mineral.
4. Precision grinding electrical fittings, unglazed or biscuit ware. Without exhaust	Fettling shop	2,096	4.7	About 40% mineral; most as discrete particles.

Stoneware Body

The articles are formed from plastic clay by pressure in moulds which are previously dusted with fine flint in a cloth bag; no obvious dust is produced in dusting the moulds (cf. table XXVIII).

TABLE XXVIII

Process (1)	Position (2)	Number of particles in 1 c.c. (3)	Percentage over 2μ (4)	Remarks (5)
5. Pressing small articles in moulds dusted with flint	Pressing shop	2,036	1.3	About 20% refractive particles; much of mineral in splashes.
6. Wiping dry dipped article to remove marks	Dipping house	2,097	4.2	About 50% of the particles refractive.

Fifty-one workers exposed to dust of the composite body of electrical fittings were examined medically and 21 radiologically. One man employed as a turner for 35-40 years, and two women employed as pressers for 20-25 years and 25-30 years respectively, were found to show signs of silicosis.

Fibrosis of the lungs was diagnosed in 1 jiggerer, 2 turners, 3 sliphouse men and 4 female pressers. Two of these pressers and 1 sliphouse man showed evidence of bronchitis.

Of those exposed to the dust of placing sand, one placer was examined and showed evidence of fibrosis of the lungs after employment for 25-30 years.

Sanitary Ware

The body may be fireclay or a white body similar in composition to that used for earthenware. The preliminary manipulation of the ingredients for the white body involve exposure to the dust of clay, Cornish stone and flint; while the processes of casting and fettling involve exposure to dust of the mixed body, as in the case of earthenware (cf. table XXIX).

It would not be possible to make a differential count of the highly refractive and other particles with polarised light, because of the illumination of the clay particles. This is one example, like that found in the manufacture of firebricks, of the effect of clays in fixing free silica particles in the atmosphere, and not within the lungs, and probably explains the diminished power of free silica to produce silicosis in the presence of clays, though the dust may be capable of producing other forms of respiratory disease and even fibrosis of the lungs ¹ (cf. table XXX).

TABLE XXIX

Process (1)	Position (2)	Number of particles in 1 c.c. (3)	Percentage over 2 μ (4)	Remarks (5)
1. Shovelling	Cornish stone drying beds	662	7.1	Splashes and some large refractive particles up to 16 μ .
2. Wheeling flint on to weigh machine	Slip making and weighing house	976	3.7	About 50% refractive material.

¹ Cf. Bibliography, No. (10).

TABLE XXIX (continued)

Process (1)	Position (2)	Number of particles in 1 c.c. (3)	Percentage over 2μ (4)	Remarks (5)
3. Loading charges of ground flint. Shovelling damp flint		1,180	0.7	About 80% of particles are clear (flint).
4. Sandpapering and brushing sanitary fitting.	Sanitary ware casting shop	1,771	8.8	A dense sample owing to large number of splashes.
5. Dry fettling	do.	1,000	3.2	Most of mineral matter in splashes. Discrete mineral particles form under 50% of other free particles.
6. Do.	do.	964	2.5	About 30% of particles refractive; others soot. A few splashes.
7. Sweeping floor	do.	1,674	11.7	Most of mineral matter in form of splashes. Highly refractive particles standing out from surrounding debris; these are probably flint.

TABLE XXX

Process (1)	Position (2)	Number of particles in 1 c.c. (3)	Percentage over 2μ (4)	Remarks (5)
8. Sandpapering and brushing biscuit sanitary ware	Stopping warehouse	554	14	About 80% of particles are discrete and rather coarse. Particles generally highly refractive.
9. Enamelling fireclay	Enamelled fireclay brushing department. Workers stopped for dinner 5 minutes before sample was taken	1,036	4.2	The larger particles and most of small ones are clear and refractive.

Thirteen sanitary casters were examined medically and 10 of these also radiologically. All of these had been employed previously as sanitary pressers and some also as earthenware hollow-ware pressers. Silicosis was diagnosed in 4 cases; fibrosis of the lungs in 7, and bronchitis in 3. Of sanitary pressers 7 were examined medically and 5 also radiologically. Silicosis was diagnosed in 2 cases after employment in this occupation for 25-30 years and previous employment as earthenware hollow-ware pressers. Five were found to show evidence of fibrosis of the lungs and 2 of bronchitis.

Of workers in sanitary ware exposed to dust from placing sand, 1 placer employed 25-30 years, was examined medically and radiologically, and fibrosis of the lungs was diagnosed. Two biscuit warehouse-women were examined medically, one of them also radiologically, with negative results: they had been employed for 18 and 20 years respectively.

Stoneware

The manufacture of stoneware is not regarded as part of the pottery industry in the ordinary sense. The trade is not carried on in North Staffordshire but is scattered throughout the country, especially in Scotland, and the workers are not members of the Pottery Workers' Trade Unions. The articles made include jam jars, stone bottles, teapots, spirit and chemical jars, electrical fittings, etc. The body consists entirely of ball clay made plastic by milling with water. Flint is present in the glaze and in the sagger wash (cf. table XXXI).

Polishing

The processes of polishing are carried out for the purpose of removing blemishes and thimble marks from the glazed ware. In general, the processes consist of abrasion by a rapidly revolving wheel or brush to which is applied finely powdered flint mixed with water; or the wheel itself is constructed of an artificial abrasive and flint is not used. The wheel or brush rotates in a direction downwards towards the operator. Close application of the worker is necessary. In some polishing shops localised exhaust draught is

TABLE XXXI

Process (1)	Position (2)	Number of particles in 1 c.c. (3)	Percentage over 2μ (4)	Remarks (5)
1. Drying stoves with revolving carriers	Jolly shop	723	10.0	About 50% of particles are mineral; others soot.
2. Working at lathes; ware carriers passing to and from room	Turning shop	735	15	Character of sample similar to (1) but larger masses present, up to 16μ , and a higher proportion.
3. Jollying	Jolly shop	1,385	2.9	Few discrete mineral particles; most of mineral matter occurs in splashes. Soot also present.
4. Jollying jam jars	Jolly shop — another factory	1,964	1.0	Mineral matter in splashes with refractive particles embedded, and as discrete particles which form about 10% of count.
5. Turning jam jars	Turning shop	1,844	2.8	Splashes which include refractive particles. Discrete refractive particles form about 10%.
6. Dipping articles for glazing	Dipping house			Sample taken showed no evidence of danger from liberation of flint particles from glaze into atmosphere.

Note. — Stoneware was not included in the branches of the industries in which medical and radiological examinations were made.

provided for each polishing lathe; in others no localised exhaust draught is provided. The dust from polishing consists of the abrasive thrown off by the wheel or brush; this is either flint or the material of which the abrasive wheel is composed. Dust from the ware will consist of fired glaze and is probably not important.

Four samples were taken in a large polishing shop in which 15 lathes were working. In this shop there is a system of localised exhaust ventilation by which a current velocity, averaging 1,500 linear feet per minute at the openings of the ducts, is obtained, and a total ventilation of 10 changes per hour of the air in the room. The shop measures $70 \times 37 \times 11\frac{1}{2}$ feet with a cubic content of approximately 30,000 cubic feet (cf. table XXXII).

TABLE XXXII

Process (1)	Position (2)	Number of particles in 1 c.c. (3)	Percentage over 2μ (4)	Remarks (5)
1. Polishing with flint on a revolving brush	Polishing shop	2,446	10.0	Refractive particles vary in size from 6μ down to under 1μ , and form about 50% of count.
2. Polishing on an alundum wheel, without flint	Polishing shop	1,337	3.3	Refractive particles form about 20%; others soot.
3. Polishing on a mica wheel, with flint	Polishing shop	1,687	2.6	Refractive particles not numerous, about 10%
4. Polishing on a cork wheel, with flint	Polishing shop	1,952	1.0	Refractive particles form about 10%.

At a china polishing shop in another factory 4 samples were taken; in this polishing shop there is no localised exhaust ventilation; the room is much smaller than in the above-mentioned polishing shop, and only 4 lathes were in use (cf. table XXXIII).

TABLE XXXIII

Process (1)	Position (2)	Number of particles in 1 c.c. (3)	Percentage over 2μ (4)	Remarks (5)
5. Polishing dish on cork wheel with flint	Polishing shop	2,265	8.8	A large proportion of particles are refractive.
6. Buffing dinner plate with brush, flint being applied	Polishing shop	1,988	13.3	Characters similar to (5), but large proportion of clumps.
7. 'Scaring' an alundum wheel	Polishing shop	4,145	10.3	Great majority of particles refractive.
8. Control; general air of polishing shop	3 yards from nearest working lathe	2,205	3.3	About half of particles refractive; others soot

Two samples were taken in an earthenware polishing shop in which there is no localised exhaust draught (cf. table XXXIV).

TABLE XXXIV

Process (1)	Position (2)	Number of particles in 1 c.c. (3)	Percentage over 2μ (4)	Remarks (5)
9. Polishing on cork wheel, with flint	Polishing shop	1,639	1.4	Between 30% and 50% of particles are refractive, apparently flint, discrete, with few aggregates
10. Polishing a large surface with flint on cork wheel	Polishing shop	2,157	3.3	Similar to (9) but slightly more dense.

Fourteen polishers were examined medically and eight of these also radiologically. Silicosis was diagnosed in a polisher of earthenware who had been employed for thirty-six years. Ten cases were diagnosed of fibrosis of the lungs, and in one case there was some evidence of tuberculosis.

Mould Making

A sample was taken at the breathing level of a mould maker in a stoneware pottery, while mixing plaster of Paris with water; this process occupies about three minutes at intervals of fifteen minutes throughout the working day. A flatware presser at work in the same room.

The sample is very dense and cannot be counted owing to crowding and overlapping of particles, and the presence of numerous aggregates. The individual particles are of various shapes, but the majority are of an elongated form with straight edges and right angles: they vary in size from 14 μ down to the limit of visibility. With polarised light the particles are diffusely luminous with here and there a brilliant point.

A mould maker in Hanley, aged sixty-five, who had been employed on plaster of Paris for fifty years, had no chest trouble and did not know of any mould makers who had suffered from "potters' asthma"; he was subject to frequent colds from the open doors and windows: he had had pneumonia three years ago and was laid up for two months. There was no evidence of irritation of the upper respiratory tract in the early period of employment or on resuming after a holiday.

Thirteen mould makers were examined medically and three of these also radiologically. Two cases of fibrosis of the lungs and one of bronchitis were diagnosed, but silicosis was not found.

Evidence of Silicosis being Produced

In the Report by Drs. Sutherland and Bryson, already referred to, the number of cases diagnosed as silicosis amongst the workers in the pottery industry examined during the medical enquiry, was given as 87 out of 250 examined radiologically.

The distribution in occupations is given in the following table:

TABLE XXXV

Occupation	Males			Females		
	Number examined	Number X-rayed	Silicosis found	Number examined	Number X-rayed	Silicosis found
Millers	13	8	3	—	—	—
Slipmakers and dusthouse attendants	24	13	3	2	—	—
Modellers	4	2	—	—	—	—
Mould makers	13	3	—	—	—	—
Throwers and lookers-to-ware	14	5	1	6	—	—
Turners and lathe treaders	16	3	1	8	3	—
Handlers	7	5	3	25	5	—
Plate makers and towers	20	11	7	20	4	1
Dish makers	6	2	1	1	1	—
Handbasin and chamber makers	6	1	—	4	1	—
Saucer makers	7	6	5	9	—	—
Cup and bowl makers	1	—	—	19	2	1
Jiggerers and jolliers	12	6	4	4	1	—
Flat jiggerers and jolliers (china)	7	5	3	2	2	—
Casters (earthenware and china)	13	6	4	22	6	1
Sanitary casters	13	9	4	—	—	—
Hollow-ware pressers	17	11	6	1	—	—
Sanitary pressers	7	5	2	—	—	—
Tile pressers	6	3	3	19	8	1
Dust pressers (electrical)	2	2	—	17	7	2
Fettlers	2	1	—	11	3	—
Sagger makers and marl grinders	22	9	3	—	—	—
Biscuit placers	48	33	17	—	—	—
Biscuit oddmen	12	7	2	—	—	—
Biscuit firemen	5	1	1	—	—	—
Biscuit warehouse	4	2	—	53	25	5
Glost placers and oddmen	9	3	1	—	—	—
Polishers and grinders	14	9	1	—	—	—
Tile slabbers	3	3	—	—	—	—
Labourers	9	4	1	1	—	—
Red marl workers	8	4	—	—	—	—
Totals	344	182	76	224	68	11

Since the coming into force of the Various Industries (Silicosis) Scheme, 1928, on 1 February 1929, fatal cases of silicosis, or at least the majority of cases, occurring in the Potteries district of Stoke-on-Trent, have been the subject of enquiry by His Majesty's Coroner. The results of these enquiries, together with the results of the post-mortem examinations, have come to the notice of the Factory Department, and some particulars of these cases are given in the following table.

TABLE XXXVI. — FATAL CASES OF SILICOSIS WHICH HAVE OCCURRED SINCE FEBRUARY 1929, AND WHICH HAVE COME TO THE NOTICE OF THE FACTORY DEPARTMENT

(The diagnosis has been verified by post-mortem examination)

Branch of industry	Process	Age	Period of employment	Period of symptoms	Period of incapacity	Cause of death	Remarks
1. General earthenware	Flint miller	48	Years 21	2 years	9 months	Silicosis and Tuberculosis	Exhaust applied during 21 years of employment. Dust sample showed 2,277 particles in 1 c.c., 10% over 2 μ .
2. do.	Miller's engineman 13 years Miller 25 years	51	38	1 ½ "	6 "	Broncho-pneumonia and silicosis	Silicosis diagnosed when an X-ray was taken for a broken collar bone. Silicosis in second stage.
3. do.	Miller	65	20	A number of years	2 weeks	Broncho-pneumonia and silicosis	
4. do.	Sliphouse labourer 33 years	54	42	7 months	4 months	Silicosis and tuberculosis	Mill dusty and exhaust was not applied till a year ago.
5. do.	Mill labourer 9 years						
6. do.	Boiler fireman and potter's oddman 29 years Mill labourer 14 years	55	43	3 years	5 "	Silicosis	
6. do.	Dish maker	48	34	Few years	10 days	Lobar pneumonia accelerated by silicosis	
7. do.	Saucer maker	50	33	8-9 "	5 "	Broncho-pneumonia silicosis and chronic bronchitis	
8. do.	Plate maker	61	51	Several years	1 ¼ years	Silicosis and tuberculosis	
9. do.	Jiggerer	39	22	7 "	2 weeks	Broncho-pneumonia and silicosis	
10. do.	Jiggerer	63	53	3 "	2 months	Silicosis	
11. General Earthenware	Presser and caster	58	48	4 "	2 "	Silicosis	
12. do.	Potters' shop 30 years Presser 10 years	58	40	6 "	6 years	Silicosis and tuberculosis	

TABLE XXXVI (continued)

Branch of industry	Process	Age	Period of employment	Period of symptoms	Period of incapacity	Cause of death	Remarks
13. do.	Presser and caster	47	Years 33	7 years	11 days	Silicosis	
14. do.	Flat presser and bowl jollier	58	48	1 "	1 year	Silicosis and tuberculosis	
15. do.	Hollow-ware presser	56	43	A number of years	6 months	Silicosis	
16. do.	do.	51	41	1 year	2 week	Silicosis	
17. do.	Hollow-ware jollier	53	40	2-3 years	3 days	Broncho-pneumonia and silicosis	Had not slept in bed for 5 months owing to dyspnoea.
18. do.	Sweeper of floors in potters' shops	63	50	?	5 months	Silicosis and tuberculosis	
19. do.	Biscuit placer or in Potters' shop	56	47	11 months	4 "	Silicosis and tuberculosis (hæmoptysis)	Was employed as a sanitary earthenware placer previously.
20. do.	Glost placer	59	49	?	1½ years	Silicosis and tuberculosis	No signs of lead poisoning.
21. do.	Glost placer	52	40	8 months	7 months	Silicosis and tuberculosis (hæmoptysis)	No signs of lead poisoning.
22. do.	Polisher	56	46	6 years	3 weeks	Silicosis	
23. do.	Polisher	44	27	2 "	1 week	Silicosis	
24. do.	Polisher	57	40	5 "	1½ years	Silicosis	
25. Sanitary earthenware	Presser and caster	53	38	9 months	9 months	Silicosis and tuberculosis	
26. do.	Presser and caster	65	57	Some years	1 year	Silicosis and tuberculosis	
27. do.	Presser and caster	64	50	Several years	6 months	Silicosis and tuberculosis	
28. China	Turner	53	41	3 months	3 "	Silicosis and tuberculosis	Work confined to china body.
29. do.	Plate maker	56	46	4 years	4 "	Broncho-pneumonia and silicosis	
30. do.	Saucer maker	56	40	2 "	1 year	Silicosis and tuberculosis	
31. do.	Sauce maker	62	52	"	5 months	Silicosis and tuberculosis	
	39 years Coal miner						
	5 years Slag crusher						
	Sagger crusher						
	3 years						
32. do.	Flat presser	62	54	2 years	2 "	Silicosis and tuberculosis	
33. do.	Biscuit odd-man (flint siever)	59	47	5 "	11 "	Broncho-pneumonia and silicosis	
34. Tiles	Earthenware plate maker	52	34	2 "	9 "	Silicosis and tuberculosis	Employed in coal mine 1 year.
	5 years Earthenware biscuit placer						
	4 years Tile glost warehouse						
	10 years Dust tile maker						
	15 years						
34. do.	Dust grinder	51	31	Some years	9 days	Silicosis and bronchitis	A coal miner in South Wales up to 20 years of age
	7 years Tile maker						
	24 years						
35. Electrical fittings	Dust grinder	56	44	" "	2½ years	Silicosis	

Methods of Prevention

The present Code of Regulations for the Manufacture of Pottery¹ was made in January 1913, and applies to all factories and workshops in which the manufacture or decoration of pottery or any process incidental thereto is carried on. For the purposes of the Regulations certain processes and technical terms are defined and a Schedule is appended, divided into two parts, Part I including lead processes and Part II other processes. Evidence was taken as to the working of the present Regulations by the Departmental Committee on Compensation for Silicosis dealing with the Pottery Industry².

In making certain recommendations the Committee believed that, except as regards the processes of fettling and china biscuit emptying, their proposals did not go beyond what is already the practice in some factories. So far as the Regulations are concerned the processes dealt with may be grouped under three headings: (1) those involving the use of powdered flint in the making of china ware; (2) certain processes carried on in potters' shops, and (3) other processes such as flint milling, polishing, sorting, and grinding.

(1) *Processes involving the use of powdered flint.* — In these processes the workers run the greatest danger of direct exposure to silica dust. They include: the placing of china ware in saggars; drawing of china biscuit oven and emptying of saggars; the process of flat knocking and flint sifting; emptying the ware from baskets and other receptacles, and scouring. The present Regulations require the provision of exhaust draught for (2) the processes of bedding and sifting (Regulation 7 (a) (vii)); (a) the removal of bedded ware from the saggars after firing (Regulation 7 (f)); (c) flat knocking and fired flint sifting (Regulation 7 (g)), and (d) scouring of biscuit ware which had been fired in powdered flint (Regulation 7 (a) (ix)).

The Committee's recommendations were:

(a) *China biscuit placing.* — The requirement of exhaust draught should be extended to include the "placing" of hollow-ware.

(b) *Drawing of china biscuit ovens.* — The requirement of exhaust draught should be extended to the emptying of all saggars if powdered flint has been used and not only to bedded flat ware.

(d) *China scouring shops.* — That exhaust draught should be required for (i) emptying of biscuit ware which has been fired in

¹ Cf. Bibliography, No. (3).

² Cf. Bibliography, No. (4).

powdered flint from baskets or other receptacles, except where special general ventilation is provided; (ii) filling and emptying of cradles or other receptacles when ware has been fired in powdered flint.

Cleaning of floors in china biscuit placing and scouring shops. — Regulation 12 (c) requires that the floors shall be impervious and thoroughly sprinkled and swept at least once a day. The Committee regarded the cleaning by vacuum as the most satisfactory method and should be encouraged. Failing that, an efficient moist method such as the use of damped sawdust.

(2) *Certain processes carried out in potters' shops.* — The evidence is that the dust in potters' shops arises mainly from two sources, (a) dirty floors and benches, and (b) the process of fettling.

(a) *Cleaning of floors and benches.* — The Committee recommend that an efficient moist method should be required as now recommended for china biscuit "placing" and scouring shops, and that every encouragement be given to firms to provide impervious floors on the lines suggested by the Research Committee of the National Council for the Pottery Industry. They also recommend that provision of sufficient accommodation be made for moulds and that arrangements should be made that the moulds be returned to the store and not left lying about the shop so as to impede the cleaning.

(b) *Process of fettling.* — Exhaust is at present required by Regulations for (1) fettling of flat ware by towing or sandpapering, with certain exceptions; (2) any other process of fettling on a wheel driven by mechanical power, except where (a) the fettler is fettling as an occasional operation, (b) fettling is done wholly with a wet sponge, or (c) fettling is done by the worker who has made the articles while the latter are still in a moist state. The Committee recommended that as the fettling of "white hard" ware is a very dusty process, if done on any wheel, whether driven by mechanical power or not, exhaust draught should be required for (i) all fettling of flat ware by towing or sandpapering; (ii) any other process of fettling flat ware except where (a) fettling is done with a wet sponge; (b) fettling is done while the articles are still damp. They further recommended that efficient exhaust draught should be required for all fettling of hollow-ware and other ware not dealt with above, unless the articles are so moist that no dust is given off.

Brushing of earthenware biscuit ware. — Efficient exhaust draught is required for this process under Regulation 7 (a) (viii) unless it is carried on in a room which has been certified by the Inspector of Factories to be adequately provided with general mechanical or other ventilation.

(3) *Polishing, sorting, and grinding processes.* — Exhaust draught can be required for these processes under Regulation 7 (m), but the Committee recommend that a definite requirement for exhaust draught be included in the Regulations.

The Committee recommended that in addition to those processes in which protective clothing was already required under Regulation 4, overalls and head coverings be required and worn by all workers

exposed to pure flint dust, and by young persons who carry scraps from potters' shops, and that accommodation for depositing clothing put off during working hours be required for all workers who are required to wear overalls.

Recommendation was also made that Regulation 6 (a), which prohibits workers from taking meals or remaining during meal times in certain rooms, should be extended to processes involving exposure to flint dust, and that messroom accommodation be correspondingly extended. Similarly, that Regulation 11, requiring washing accommodation, should be extended to include all persons whose occupations exposed them to powdered flint.

Self Inspection

The Home Office Committee of 1908¹ pointed out that to ensure satisfactory compliance with the Regulations, it is essential that every department of every factory should be under constant and regular supervision, which should be organised from within the factory. In accordance with their recommendations, Regulation 27 of the present Code requires the occupier of every factory to appoint a person or persons whose duty it is to carry out systematic inspections of the working of the Regulations in the factory and generally to enforce the observance of them. The evidence received by the Committee showed that in some of the larger works the system has resulted in considerable improvement. In the smaller works, however, equally satisfactory results do not appear to have been achieved. It appeared that this was partly due to the appointment of unsuitable persons and failure to allow sufficient time and facilities for carrying out the work. The Committee considered that the Regulations should be retained and should be more rigorously enforced, and expressed the view that conditions in potteries cannot be adequately controlled without daily inspection, and provided really suitable persons are appointed and given the whole-hearted support of the employers and workers alike, the Regulations should be invaluable.

Placing of China without Flint

The attention of the Committee was drawn to one or two practical experiments carried out by firms with a view to the abolition of the use of flint for china biscuit placing. In one case the setters for setting china flat ware are coated with a patent wash. Another firm have experimented satisfactorily with materials to take the place of flint for all placing of china biscuit ware. It seemed that it

¹ Cf. Bibliography, No. (5).

is within the range of possibility that at no distant date it may be practicable to supersede the present method of firing china ware in flint.

Compensation

Reference has already been made to the Report of the Departmental Committee on Compensation for Silicosis, dealing with the Pottery Industry. The Committee felt that a scheme on the lines of the Refractories Industries Scheme would have great advantages in that the interests of the employers and the workers could be adequately safeguarded and that in the long run it would prove more economical to the industry as a whole. A scheme of compensation was suggested on the lines of the Refractories Industries Compensation Scheme, but this was not given effect to. At present compensation is provided for under the Various Industries (Silicosis) Scheme, 1928¹, which came into force on 1 February 1929, and applies to all workmen employed on or after 1 January 1929 in the following processes in potteries:

(a) The milling of flint or crushing or grinding of silica rock or dried quartzose sand.

(b) Any process in or incidental to the manufacture of china or earthenware, including sanitary earthenware, electrical earthenware and earthenware tiles, up to and including the preparation for glazing, but excluding underglaze decorating, and modelling and mould making, where these processes are carried on in separate rooms.

(c) The polishing, sorting or grinding on a power driven wheel in connection with the grinding of glost ware, and tile slabbing.

The Scheme provides for compensation in cases of total disablement and death only.

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(2) *Report on the Incidence of Silicosis in the Pottery Industry.* By Drs. C. L. SUTHERLAND and S. BRYSON. His Majesty's Stationery Office, 1926. Price 1s. 6d.

(3) *Regulations for the Manufacture and Decoration of Pottery.* Statutory Rules and Orders, 1913, No. 2. His Majesty's Stationery Office. Price 2d.

(4) *Report of the Departmental Committee on Compensation for Silicosis dealing with the Pottery Industry.* His Majesty's Stationery Office, 1928. Price 1s. 3d.

(5) *Report of the Departmental Committee on the Dangers attendant on the Use of Lead and the danger of injury to health arising from Dust and other*

¹ Cf. Bibliography, No. (6).

Causes in the Manufacture of Earthenware and China. His Majesty's Stationery Office, 1910. Price 1s. 5d.

(6) *The Various Industries (Silicosis) Scheme, 1928.* Statutory Rules and Orders, 1928, No. 975. His Majesty's Stationery Office.

(7) *Mineral (Non-Metallic) Dusts, the Manufacture of Pottery, etc.* By Dr. J. T. ARLIDGE. London, Royal Sanitary Institute, 1893.

(8) "Phthisis in the Potteries." By Drs. J. MAGILL and J. B. McDougall. *Public Health*, Aug. 1916.

(9) "Dust Counting in the Pottery Industry, with Special Reference to Health Considerations." By Dr. E. L. MIDDLETON. *Transactions of the Ceramic Society*, Vol. XXIV, 1924-1925.

(10) "The Pulmonary Lesions produced by the Inhalation of Dust in Guinea Pigs." By H. M. CARLETON. *Journal of Hygiene*, Vol. XXII, No. 4, p. 438. July 1924.

SANDBLASTING

Sandblasting is the process of projecting sand or other grit by means of compressed air or steam against a surface. It is used: (1) in metal works to remove adherent sand and irregularities from castings and to produce a surface of desired quality; (2) for etching on glass.

The process is employed in many industrial centres throughout the country.

Both sexes are employed on sandblasting small articles, but men only on the heavier metal work. It is not possible to state the numbers employed in the process, which is a small subsidiary of the industries, but experience indicates that the process is receiving increasingly wide application.

In metal working sandblasting is employed for cleaning castings of all kinds and for producing a surface on the metal suitable for subsequent treatment. In metal work instead of sand, chilled iron shot, ground granite or flint may be used.

The article of metal may be placed in the open air and sprayed with the abrasive from a nozzle. Usually with large articles the work is done in an enclosed chamber, the worker being covered with protective clothing and provided with a helmet with an independent air supply. Small articles are done by adapting the process within a smaller closed cabinet before which the worker stands, passing his hands through guarded holes to direct the abrasive from the nozzle, while watching the process through a glass panel in the front of the cabinet.

In the etching of glass, the article is held against a stencil plate, the abrasive reaching it through the stencil and being retained in the machine by a suitable collar of rubber or other material. A

cabinet such as that used for treatment of metal articles may be used for glass.

The dust hazard in the cleaning of castings is from the moulding sand and from the abrasive, where this is sand or siliceous grit such as flint or granite. Where clean castings or other metal articles are treated the danger is from the siliceous abrasive alone. The sand, granite or flint, by repeated use in the machine, becomes finely comminuted and fine dust escapes in spite of the precautions required to be taken. Unwarrantable risks are incurred by workers in faulty methods, such as opening the door of the hand cabinet to look at or move the work, while the air within the cabinet is full of fine dust, instead of allowing the exhaust draught time to act before opening the door. In the large chambers the workers are sometimes found to leave the door partly open, thus interfering with the exhaust; or they may remove the helmet while still working in the dust laden air of the chamber.

Defects in the apparatus are bound to occur from time to time, and the closest attention is necessary to detect and remedy leaks. Even with the closest attention the process of sandblasting appears to carry a serious danger of producing silicosis where siliceous abrasive is used.

Five cases of silicosis, two of them fatal, have been brought to the notice of the Factory Department since August 1928, and as silicosis is not statutorily notifiable it may be presumed that other cases may have occurred.

Particulars of the five cases are given below:

TABLE XXXVII

Industry	Sex	Age	Period of employment in sand-blasting	Process	Diagnosis	Remarks
Cycle accessories	Male	Years 40	20 years	Cabinet type	Silicosis	Fatal. Radiogram shows numerous dark nodules over whole of both lungs; no tuberculosis. Diagnosis confirmed by radiograph. No tuberculosis.
Steel works	do.	—	12 "	? Chamber	do.	Occasional hæmoptysis; no other sign of tuberculosis.
Motor accessories	Female	—	—	Cabinet	do.	
do.	Male	21	12 months	do.	Silicosis and tuberculosis	
Carburetters	do.	54	7 ½ years	do.	do.	Fatal; diagnosis confirmed by post-mortem.

Regulations for the Grinding of Metals (Miscellaneous Industries)¹ came into force on 1 November 1925, and they include Regulations for sandblasting in the cleaning or smoothing of castings by a jet of sand, metal shot or grit or other abrasive, propelled by a blast of compressed air or steam.

The Regulations provide that: (1) sandblasting shall not be done in any room except in an enclosed chamber or cabinet in which no other work is ordinarily performed and at which efficient means are provided to prevent escape of dust to the outside of the chamber or cabinet. (2) No person may perform sandblasting in the open air or work within 30 feet of such unless he is wearing a suitable protective helmet and gauntlets; during sandblasting in a chamber overalls are also required. (3) The protective helmet must be provided with a supply of pure air, means of escape for exhaust air, and it must bear the mark of the person using it. (4) Before being used by another person the helmet must be thoroughly disinfected.

The prevention of silicosis would best be attained by the use of a non-siliceous abrasive such as metal grit, where possible. Some manufacturers have adopted this line primarily with the health of the worker in view.

Compensation

The Various Industries (Silicosis) Scheme, 1928, provides for compensation in cases of total disablement and death of workmen employed in foundries and metal works on " Sandblasting of metal or articles of metal by means of compressed air and with the use of quartzose sand or crushed silica rock or flint ".

Bibliography

(1) *Regulations for the Grinding or Glazing of Metals, or processes incidental to the Grinding of Metals or the Cleaning of Castings.* Statutory Rules and Orders, 1925, No. 904. His Majesty's Stationery Office. Price 2d.

(2) *The Various Industries (Silicosis) Scheme, 1928.* Statutory Rules and Orders, 1928, No. 975. His Majesty's Stationery Office. Price 3d.

SILICA MILLING

This industry is concerned with the grinding of silica rock, crystal quartz or silica sand, all containing a very high proportion, usually about 98 per cent., of free silica. The silica-flour so produced is used for many purposes, as the manufacture of scouring powders, paint fillers, wood fillers, silica glass, and for foundry use.

¹ Cf. Bibliography, No. (1).

The rock, quartz or sand is quarried and dried (the rock is sometimes calcined) and crushed and ground by machinery to a fine powder. In some works a system of exhaust draught is provided over the crushing, grinding, sieving and conveying machinery and the exhausted air is collected in filter bags, the finest powder being collected in this way.

The industry is not extensive; it is distributed near the source of the raw material, most being in the north-west of England. A considerable amount of ground silica is imported from the Continent and from America.

The amount of dust liberated in the processes is frequently very great. At a silica grinding factory where the machinery was enclosed and localised exhaust draught was provided, the following atmospheric dust samples were taken with Owens' dust-counter:

- (1) Outside. Filling a truck with silica rock from a rail dump,
229 particles in 1 c.c., 2% over 2 μ .
The wind disperses much of the dust here.
- (2) Feeding the crusher with silica rock,
1,169 particles in 1 c.c., 11% over 2 μ .
- (3) Same as (2).
1,385 particles in 1 c.c., 14% over 2 μ .
- (4) At a bagging shoot,
1,205 particles 1 c.c., 14% over 2 μ .
- (5) Same as (4).
1,096 particles in 1 c.c., 14% over 2 μ .

At this factory, dust escaped from a number of slight defects in the housings enclosing the machinery, as inevitably happens as a result of vibration, and the escaping dust was seen to rise upward. A dust sample taken on the staging above the tube mills, about 16 feet from the floor, gave:

4,061 particles in 1 c.c., 12% over 2 μ ,

indicating a high concentration of dust.

At a working where vein quartz was obtained and crushed to sizes from $\frac{1}{8}$ to 1 inch, the following counts were made from atmospheric dust samples taken at breathing level in some of the processes.

- (1) Hand drilling in the open; running water in the working,
15 particles in 1 c.c., 4% over 2 μ .
- (2) Feeding the crusher, wet,
168 particles in 1 c.c., 3% over 2 μ .
- (3) Weighing "fines" ($\frac{1}{8}$ inch) in the open,
385 particles in 1 c.c., 10% over 2 μ .
- (4) Bagging "fines", in shelter of a shed,
2,301 particles in 1 c.c., 10% over 2 μ .

From the low counts, which include many fine particles, it appears that work done in the open, on wet material, carries a low or negligible risk. The weighing and bagging processes here did not involve continuous exposure. As the working was at a remote spot in the hills, the counts may be regarded as free from extraneous dusts.

At a factory where pure quartz crystal is used, an atmospheric dust sample at breathing level of a girl sieving quartz under exhaust gave a count of

5,977 particles in 1 c.c., 10% over 2 μ .

By rearranging the work this process was entirely enclosed and the exposure of the worker to dust was obviated.

Evidence of Silicosis

One fatal case of silicosis with tuberculosis, the diagnosis confirmed by post-mortem examination, occurred in a silica milling factory. The man, aged fifty, had been employed for 3½ years up to a period four months before his death.

Methods of prevention include the use of water where possible and localised exhaust draught, especially when combined with enclosure of the machinery.

Compensation

The Various Industries (Silicosis) Scheme, 1928, includes "breaking, crushing, grinding, sieving, mixing or packing of silica rock, or of dried quartzose sand or any dry deposit or dry residue of silica or any admixture containing such materials; or any process incidental thereto"; and "handling or moving of silica rock, or of dried quartzose sand or any dry deposit or dry residue of silica, in or incidental to the processes mentioned in the foregoing paragraphs".

Bibliography

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PROCESSES IN WHICH GROUND SILICA IS USED

Silica enters into the composition of many industrial materials in virtue of one or other of its properties, as abrasive, inert filler, refractory material, insulator, or acid in vitreous bodies. In all the processes where the silica, dry, and in a fine state of division, is

liable to give off dust, the risk to health from its inhalation must be assumed, since the conditions are comparable with those known to produce silicosis in industries where its presence is found.

SCOURING POWDERS

Scouring powders are chiefly used as domestic abrasive cleansers. The manufacture consists in mixing the abrasive, which may be finely ground silica rock, or ground pumice, with other ingredients, soda ash, powdered soap, etc., and filling the mixture into cartons, packets or bags. Sometimes the ground abrasive is packed without admixture with any other substance.

Distribution

A considerable number of small undertakings were started, frequently as a subsidiary branch of another business, in widely scattered places over the country, in which the proprietors and workers had little or no knowledge of the risk to health or the means necessary for avoiding it.

Employed Persons

The number of employed persons fluctuates, but there are probably less than 500 employed. Men are usually employed on mixing machines, women and girls on packing.

The Processes

Except in a few of the largest works, the silica rock is obtained already finely ground. It is usually a highly siliceous quartzite rock, containing 96 to 98 per cent. free silica, and it may be calcined before being ground. The silica flour, as it is called, is mixed with powdered soda ash, soap, and sometimes other substances, either by hand with a shovel, or in a mixing machine. Filling of the cartons may also be done by hand, or the mixed powders may be conveyed automatically to mechanical fillers; the lids are then placed and fixed by a machine.

Characters of the Dust

The dust to which the workers are exposed is silica, before the process of mixing and in packing where no other ingredient is added. Frequently the silica is mixed with powdered soap, and with

carbonate of soda, and sometimes with gypsum, pumice, or other substance. The mixed powders, necessarily kept dry, are liable to give off dust in the mixing, conveying and filling machines. The presence of free alkali with the silica dust may have an important influence in producing injury to the lungs.

At one factory, that at which the fatal cases described later were employed, atmospheric dust samples were taken at breathing level of the workers, with Owens' dust-counter, with the following results. The particles were nearly all colourless, of irregular shape, and appeared to be derived from the process. No soot particles are included in the counts.

TABLE XXXVIII

No.	Process	Number of particles in 1 c.c.	Particles over 2 μ
1.	Emptying ground silica into the mixing machine	1,048	11
2.	Carton filling machine	1,193	20
3.	Putting lids on cartons	891	16
4.	Fixing lids by machine	735	6.5
5.	Filling cartons by hand	590	18

Localised exhaust draught was provided at all the processes.

Evidence of Silicosis

In one factory in which about 22 persons were employed in the manufacture of scouring powder, 4 deaths occurred within a remarkably short space of time. There was some evidence that 4 other workers at the same factory who were said to have died of pulmonary tuberculosis may have died from silicosis. These workers were employed in the factory before localised exhaust draught had been provided, when the employers were unaware of the danger to which the workers were exposed.

Brief notes on the 4 cases on which post-mortem examinations were made, are as follows:

Case I. — Died 16 June 1928, aged 19, female. Employed as a carton filler from March 1924 until May 1928—4²/₁₂ years. History of pleurisy: December 1927, cough and pains in the chest, temperature 99.6° F. No tubercle bacilli in the sputum. X-ray examination—appearance of miliary tuberculosis. Admitted to hospital 1 June and died 16 June 1928.

Post-mortem, showed poor general development, heart muscle soft and flabby; air passages congested and contained muco-pus; adhesions over the right pleura and fluid in the pleural cavity. The lungs were of firm consistence and were covered with grey nodules which showed a tendency to coalescence in the right lung. There were no cavities and no necrotic areas as in pulmonary tuberculosis. The bronchial and tracheal glands were enlarged, firm, grey, and not caseated.

Microscopic examination of the lungs showed dense nodules of fibrous tissue, with areas of necrosis and chronic catarrhal inflammation, and a terminal inflammation at parts due to pneumococcus. No tubercle bacilli were found in the lung, although prolonged search was made. The glands were necrosed and what appeared to be a few tubercle bacilli were found in them. Polarised light showed granules in large numbers in the lung and chest glands.

Case II. — Died 4 June, 1928, aged 17½, female. Employed as a carton filler from 9 October 1925 to 17 March 1928—21½ years. Since December 1927, she had complained of headache, nose bleeding and vomiting in the morning. She was treated for bronchial catarrh. She went into hospital on 30 April 1928 with a diagnosis of pulmonary tuberculosis. She suffered from dyspnoea. There was irregular pyrexia. The sputum was repeatedly negative on examination for tubercle bacilli.

Post-mortem examination: the findings closely resembled those described in Case I. Microscopic examination of the lungs showed numerous large fibrotic patches surrounded by a small cell infiltration, and in the interstices were finely granular pigmented or black deposits. The alveolar tissue was much reduced; the walls were thickened with fibrous tissue and the alveoli were filled with albuminous exudate. The general picture was that of chronic inflammation with fibrosis. The glands appeared to be almost completely fibrosed. There was no evidence of tuberculosis and tubercle bacilli were not seen.

Case III. — Female, aged 23. Employed from July 1919 to November 1928. She was usually employed on wax polishes and occasionally worked overtime in the scouring powder department. She would not work more than 6 hours in any week and for a few weeks only in any year. This employment on scouring powder began about 1921. She was ill about six weeks with cough, loss of weight and loss of appetite. Removed to hospital on 6 December and died on 3 January. While in hospital the chief symptoms were cough and dyspnoea. The sputum was scanty and was negative for tubercle bacilli at first, but later was positive. This patient was X-rayed in June 1928, and the film showed slight general diffuse fibrosis.

Post-mortem, the lungs showed the presence of silicosis and tuberculosis. In this case the silicosis was less advanced than in Case I. Microscopic examination of the lungs and glands showed deposits of silica revealed by polarised light.

Exposure to the dust of scouring powder over a period of 7 years and was intermittent. This difference in the history of exposure from Cases I and II appears to be of special interest in view of the differences in the nature of the silicotic lesions in the lungs and also of the presence of tuberculosis.

Case IV. — Male, aged 19, employed from February 1926 to April 1928. He was employed in the mixing room and on packing, about equally. He first complained of cough in August 1927. Off work five weeks. He was ill again in April 1928, and was treated in a

sanatorium. He went back to work for 9 weeks, but not on scouring powder, the manufacture of which had been given up. He was admitted to hospital on 28 January 1929 with open pulmonary tuberculosis, pyrexia, and emaciation. He died on 27 December 1929.

Post-mortem examination: lungs showed tuberculous cavities in all lobes. The remaining parts of the lungs were hard and contained a large number of hard nodules the size of a pea. Glands at the roots of the lungs were enlarged and very hard.

Microscopic examination of the lung showed chronic tuberculosis. The gland showed much fibrosis with patchy distribution of yellowish brown granular material, suggesting silicosis. In this case the silicotic process appeared to be present in the lungs in an early stage.

Prevention

Suppression of dust in the processes of mixing and filling are by no means easy. Even with exhaust draught, the powders, owing to dryness and fineness, are liable to liberate dust. Success appears to be best attained by making use of mechanical methods to the utmost extent, enclosing the machinery and applying exhaust draught to the housings so as to maintain an inward directional air current, and to all points where feeding or discharging takes place and dust is liable to be liberated.

Compensation

The Various Industries (Silicosis) Scheme, 1928, applies to workmen employed in certain specified processes which include sieving, mixing or packing of silica rock, or of dried quartzose sand or any dry deposit or dry residue of silica or any admixture containing such materials; or any process ancillary thereto; and to the handling or moving of these materials in or incidental to the processes mentioned.

The Scheme provides for payment of compensation in cases of total disablement or death from silicosis or silicosis accompanied by tuberculosis.

Bibliography

The Various Industries (Silicosis) Scheme, 1928. Statutory Rules and Orders, 1928, No. 975. His Majesty's Stationery Office.

FLINT CRUSHING

Apart from the milling of flint for use in pottery manufacture, flints are crushed for poultry grit and for grit for sandblasting, and sandpapers. The industry is a small one, employing few persons, and is carried on chiefly in the south of England.

The flints are broken in a stone crusher, passed through rotary sieves and sorted into required sizes. The processes are usually carried on in open sheds and localised exhaust draught is provided at the points where dust is produced.

The dust is of raw (uncalcined) flint and the amount produced would undoubtedly involve risk of silicosis, but in most of the processes there is no constant exposure or close application of the workers, and the open character of most of the works buildings allows of the free action of wind.

In this, as in all the silica industries, the actual danger cannot be assessed, as silicosis is not a reportable disease under the Factory and Workshop Acts. As many of the processes belong to ill-defined industries, the labour turnover is considerable and the nature of a man's employment may be lost sight of should he develop symptoms and signs of silicosis some years after he has left it.

FLINT KNAPPING

The making of flints for flint-lock guns or pistols. This ancient industry is confined to the village of Brandon in Suffolk. It was investigated by Dr. E. L. Collis in 1911.

The numbers employed have steadily diminished in the last fifty years. In 1911 about 12 men, and in 1929, 5 men only were employed, and these not constantly owing to fluctuations in the demand.

The interest of this industry lies in its antiquity and the fact that it is a pointer to, if not a measure of, the danger of inhalation of flint dust—almost pure silica—carried on in small workshops in rural surroundings and therefore unaccompanied by the other industrial hazards so frequently met with in silicosis producing occupations.

The process consists of splitting flints with a hand hammer into pieces about 1 by $\frac{3}{4}$ inch in size, flat on one side and with bevelled edges on the other side, the faces showing the typical conchoidal fracture of flint. The flints are packed in small sacks of 200 and are exported for bartering with natives of Africa. The hammer blows fall on the flint with remarkable rapidity and with each blow a small, scarcely perceptible, cloud of fine dust is liberated.

Two samples of atmospheric dust were taken at breathing level of two men knapping flints. The counts gave 1,313 and 1,192 particles in 1 c.c., with 1.4 and 2 per cent. particles over 2μ respectively. Most of the particles were under 1μ in size. Some

dust is liberated when the work benches are cleared of debris, but mixed with this dust is chalk from the outside of the flints.

The evidence of silicosis being produced is, at present, entirely statistical. From data provided by the Registrar-General's Department, Collis reported 27 deaths during the twenty-five years 1886-1910. Of these, 21 were from phthisis, 2 from other respiratory disease, and 4 from other causes. The average age at death of the 21 who died from phthisis was 42.3 years. The death rate was 41.0 per 1,000 living compared with 0.8 for the Brandon Rural district and 1.58 for all males, England and Wales, for the same period.

Methods of Prevention

As the workers maintain that the flint must be dry for proper working, water cannot be employed. Localised exhaust draught would be too costly for this decadent and precarious industry in which no mechanical power is used. Respirators, standardised to protect against this very fine dust, would be difficult to attain, but at least partial protection might be afforded in this way, and, together with the intermittency of the work and the possibility of working in the open air, as is done in summer, sufficient relief from exposure might be attained to carry the worker through his life without a disabling degree of silicosis.

Compensation

The Various Industries (Silicosis) Scheme, 1928, covers the breaking of flint. Probably there is no one employed in this industry at present who comes within the definition of "workman" in the Workmen's Compensation Act, 1925.

Bibliography

The Various Industries (Silicosis) Scheme, 1928. Statutory Rules and Orders, 1928. No. 975. His Majesty's Stationery Office.

MILLSTONE DRESSING

This is an occupation in which a comparatively small number of persons are employed. It consists in dressing the millstones for the grinding of corn in distilleries, corn and fodder mills, and for grinding chocolate in chocolate factories.

The process is carried on in many districts throughout the country, where the mills exist.

The persons employed may be specially skilled men who have learned the trade and are solely employed on the process, or the work may be done as a part-time occupation.

The corn mills consist of two circular stones placed horizontally. They may be composed of any hard stone but are usually a hard quartzite grit, chert or buhrstone—a chalcedonic form of silica—or artificial stones. Dressing of the stones is done with an adze-shaped steel tool, by chipping along the ridges which run radially from the centre. During chipping a slight cloud of fine dust rises.

Two cases of death from silicosis and tuberculosis in millstone dressers have come to the knowledge of the Factory Department recently. The first case was of a man, aged fifty-four, employed as a cornmillers' stone-dresser since boyhood, with the exception of a few years in the Army in early manhood. Eight months before his death he gave up work on account of dyspnoea and loss of weight. X-ray examination showed silicosis and tuberculosis.

Post-mortem examination confirmed the diagnosis. There were besides the tuberculous lesions, innumerable nodules of silicotic fibrosis confirmed by microscopic examination.

The stones dressed by this man were 90 per cent. Derbyshire silica rock, the remainder French buhrstone.

The second case was a man who died, aged thirty, from silicosis and tuberculosis, but no post-mortem examination was made. He was constantly employed from boyhood on dressing Derbyshire millstones in a corn mill. He became totally disabled by the disease, six months before his death.

Prevention of inhalation of dust in the process could be achieved by the provision of localised exhaust draught, but this would have to be by a flexible duct so that the hood could be moved during the process of chipping the stone which remains in situ.

Compensation

The Various Industries (Silicosis) Scheme, 1928, applies to workmen employed in "sawing, planing, dressing, shaping, cutting, or carving of silica rock". For the purposes of the Scheme silica rock includes quartz, quartzite, ganister, sandstone, gritstone and chert.

Bibliography

The Various Industries (Silicosis) Scheme, 1928. Statutory Rules and Orders, 1928, No. 975. H. M. Stationery Office.

PNEUMOCONIOSIS IN ITALY

BY PROFESSOR GIOVANNI LORIGA,

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Italian research workers have furnished several interesting contributions to the knowledge of respiratory diseases due to the inhalation of dust. This is proved by the bibliography on the subject, which during the last twenty-five years has enriched knowledge of this question and which comprises numerous studies and results of experimental research on the pathological action of dusts, numerous clinical observations on diseases of the respiratory system met with in workers engaged in dusty operations of various kinds, as well as accurate investigations into the health conditions of special groups of workers exposed to forms of pneumoconiosis. In addition, however, other references to pulmonary diseases of these workers are frequently to be found in other books and monographs.

Nevertheless, it must be recognised that the study of these disease forms has not been so extended or profound in Italy as in certain other countries, especially the Anglo-Saxon countries and Germany. The scarcity of contributions by Italian scientists is evident, in particular, in regard to that form of pneumoconiosis which accompanies mining or operations connected with stone or clay, and which has been fully studied in other countries under the designation of "miners' phthisis".

In seeking the cause of this phenomenon, it is not, in our opinion, possible to plead either the limited number of workers engaged in dusty operations in our mines, quarries or other places in which stone or clay is manipulated, or the temporary character of most work of this kind (such as, for instance, in the case of workers

engaged in the excavation of railway tunnels or in the paving of streets), or hygienic conditions superior to those in other regions, or again the instability of most of the workers in question who, as is well known, quit work very readily in the dusty trades and immediately find other occupations. Further, in Italy, analogous conditions and inconveniences are found in similar occupations, hardly differing at all from those attaching to the corresponding work in other countries.

It is almost certain, on the other hand, that the reason why Italian medical bibliography on the subject is not so rich as that of the other countries above referred to should be sought in the small number of workers affected by miner's phthisis who come under medical observation, and especially in the fact that it is a question of isolated cases, or rather that pneumoconiosis does not assume the character of a mass infection or a focal disease, and that therefore it is not strictly related to a given locality or to a certain quality of material, as would appear to be the case in other countries.

It is, however, very probable that the limited extension and the less serious nature of the cases depend on the fact that in our country the composition of the minerals extracted or worked presents a relative poverty of siliceous material.

It is well known, in fact, amongst medical men that the most dangerous mineral dusts are those of a siliceous nature, since the presence of silicic acid gives to the dust particles greater hardness and a remarkable irregularity of form by means of which their surface becomes very rough, sharp and cutting and they are therefore rendered capable, not only of considerable injury to the tissues, but also of remaining insoluble amongst these. Recent studies, the conclusions of which have been confirmed by the Papers presented by Mavrogordato and Irvine to the fourth meeting of the Permanent International Committee for the Study of Occupational Diseases (Lyons, April 1929), and have given support to the older statements of Weigmann and of Lubenau, lead to the belief that the most harmful dusts are those containing siliceous oxides (SiO_2 = silicic anhydride or bioxide of silicon). To this category belong quartz dusts and those of its various forms (rock crystal, agate, amethyst, chalcedony, jasper, onyx, opal) as well as siliceous sand, fossil dust, granite and sandstone.

There would, on the other hand, be considered in the second place, that is, as of average harmfulness, the *silicates*, those of the heavy metals: for instance, silicates of copper (malachite and azurite)

and of zinc (calamine) or others variously mixed with other clays (asbestos, mica, slate, kaolin, cement).

Besides the poverty in silica of the mineral deposits, there must, however, be kept in mind, in our opinion, other factors concurring to augment or diminish the pathogenic capacity of all the dusts, especially when the disease attacks large groups of workers, and when the conditions in question vary greatly in different localities.

Such conditions are in the first instance those relative to the hygienic conditions obtaining in the workers' homes and in the workplaces, and secondly, *the duration of exposure* of the worker to the action of the dust.

Nevertheless, it is not difficult to recognise that many of those who insist on a special and extraordinary gravity of silicosis have overlooked almost entirely this influence, whilst they have attributed great importance to the physical properties of the dusts inhaled, when engaged in research for the causes thereof or in research relative to the pathogenic interpretation of the pneumoconiosis described by them. We suspect, on the other hand, that such information may play a role which will become preponderant when the study of the disease has been completed by enquiry into the physical and social environmental conditions.

We do not desire thereby to deny that more serious pulmonary diseases and also perhaps more rapidly developing forms are caused by siliceous dust, but we only wish to insist on the fact that in the first instance we cannot recognise any specific character in their pathogenic action, such as certain authors desire to do, some of whom have almost made of silicosis a separate disease to be distinguished from the general pathological picture of pneumoconiosis, presupposing even a hypothetical chemical or chemotactic influence exercised by the above-mentioned dusts on the lymphatics and other cellular elements.

It seems to us that this aspect of the problem may be highly interesting, but requires to be still further investigated and cleared up by means of accurate experimental research, since the statement has so far not been supported by sufficiently convincing proof.

Secondly, we must make certain reservations in regard to the specific nature of the supposed cause which imparts to silicosis the particular character of a focal disease or a mass disease, such as it has assumed in some countries, and therefore also in regard to the applicability of preventive and social measures edicted by the legislation in Anglo-Saxon countries and in Germany, to

other countries in which the disease above referred to does not present the same characteristics relative to its incidence and clinical gravity.

Obviously, in order to form a rational criterion in regard to this special aspect of the question, it would be advisable to take into consideration the other causative elements, mention of which has been made, and which seem to us of primary pathogenic importance, especially the following:

- (a) The social and hygienic conditions under which the work is carried out, whether relative to the working conditions and to the means of prevention and protection against dust inhalation or to the welfare conditions of the workers, which are of such great importance in determining their physical resistance to disease in general and to pulmonary affections in particular.
- (b) The intervention of the infectious tubercular factor. This factor constitutes in fact such a frequent complication as to leave the doctor almost constantly in doubt in regard to the gravity of the pneumoconiosis considered as a separate disease, since we do not yet possess sufficient criteria to enable us to effect a differential clinical diagnosis between *dust phthisis* and *tubercular phthisis* during the life of the patient, when the presence of the Koch bacillus in the sputum is lacking.

Another cause of doubt has recently been removed by the anatomo-pathological observations made by Mavrogordato, from which it would result that the large mononuclear endothelial cells, after phagocytizing the grain of silica, are not destroyed, but thus conserve their vitality and acquire besides the capacity of assembling and forming pseudo-tubercles.

This observation evidently creates another remarkable difficulty in regard to the differential diagnosis between the two diseases, also on the *anatomo-pathological* side, so much the more so as the same author recognises that *all the fatal cases* of miners' phthisis at present encountered in the Witwatersrand are manifestly cases of tuberculosis. How is it possible to determine, we ask, the moment at which the siliceous granulation stops and the tubercular process commences, and how is it possible to distinguish the one from the other by clinical and radiological examination and perhaps also by *anatomo-pathological* examination ?

No one can but see how far these two facts—that is to say, the formation of granules due to silica, and, on the other hand, the total mortality due to tuberculosis—diminish the great importance attributed by some research students to miners' phthisis as a special clinical disease, considered capable not only of causing death to certain workers but of creating a very serious *mass pathology*.

In the Latin countries, as mentioned by the eminent research workers, Professor Martin, of Lyons, and Dr. Glibert, of Brussels, the various and complex symptomatology attributed to miners' phthisis in Anglo-Saxon countries and in Germany is practically unknown, and it would therefore be advisable to engage in a detailed study of silicosis and the other forms of pneumoconiosis in our countries also.

With the precise intention of collaborating as far as possible in developing the knowledge of this most important problem of occupational pathology, which affects the great mass of workers, there have been undertaken in Italy, since the Lyons Congress, certain researches into the pathology of workers in the slate, asbestos and marble industries, the results of which will be communicated to the Johannesburg Conference.

In this preliminary paper, it is intended merely to set forth the present-day state of the pneumoconiosis problem in general in our country as derived from laboratory experiments, clinical, anatomical and statistical data assembled from various research workers who have dealt with the question, or from special investigations covering certain working establishments.

Without going back to the clinical and anatomical observations made by Ramazzini, Morgagni and other authors in past centuries, it is easy to affirm that the study of disease due to dust affecting the respiratory organs has not been neglected in the revival of interest in the subject of occupational disease to which our research workers have testified about the year 1900. Many publications have been devoted to the study of general questions relative to pneumoconiosis. Others deal in particular with the pathogenic action of certain qualities of dust.

In the experimental field there should be recalled in the first instance the researches of Biondi (1906), who, by making animals inhale *metallic* dusts collected in the workings of the Sardinian mines, succeeded in producing in them more or less diffused bronchitis and small foci of bronchial pneumonia.

He carried out, moreover, experiments by means of the ingestion

of inert dusts (non-metallic) and noted that these also produced a form of pneumoconiosis, but that grains of dust were not found, as in the case of pneumoconiosis, from inhalation in the bronchial tube and in the alveolar cavities, but only in the inter-lobular and inter-alveolar tissues and in the tissues between the inter-alveolar groups. Soon thereafter in order of time (1907) there appeared the study by Tommasi-Crudeli, chiefly anatomo-pathological in character, entitled "Destiny of the Dust Introduced into the Lung". Feliziani (1906) and Romby (1908) directed their experimental researches to the study of the intestinal origin of pulmonary anthracosis, the first denying, and the second affirming the possibility, in confirmation of the observations made by Biondi.

The question of pneumoconiosis was moreover discussed by Ruata in 1908.

Guerra-Coppioli, in 1911, resumed the question of the intestinal origin of anthracosis, arriving at a negative conclusion and asserting, on the other hand, that the lymphatic ganglia of the mesentery constitute an almost insurmountable obstacle to the small corpuscles coming from the intestine with the lymphatic current.

The report of Devoto and Cesa-Bianchi to the third National Congress for Occupational Diseases (Turin, 1911) must be considered as a complete survey of the whole question relative to the pulmonary pathology of dust inhalation. These authors have emphasised the difficulty of provoking pathological phenomena in the respiratory apparatus in the case of guinea-pigs kept for eight to ten weeks and four to six hours per day in a very dusty atmosphere, and the facility, on the other hand, with which these arise as soon as the guinea-pigs are forced to exercise mouth breathing by closing the two nostrils or even one nostril. They have besides found alveolar lesions on microscopic examination of guinea-pigs which had inhaled cement. They have moreover studied the relation between pneumoconiosis and tuberculosis, asserting that the animals subjected to the inhalation of very fine limestone dust are less susceptible to tuberculosis than those which have inhaled silica dust.

In the same year, Moscati had stated at the Congress of Physiology that the prolonged experimental inhalation of starch dust was capable of producing evident connective peri-bronchial and sub-pleural sclerosis, though of a mild form. He saw, however, that the grains of flour undergo in the lung notable modifications which may presumably be interpreted as phenomena of hydrolysis or ptyalin digestion and finally become absorbed.

Tedeschi and Abbo have produced experimentally serious phlogistic processes of the respiratory organs of guinea-pigs by making them inhale for some time dust collected in grain silos (1914).

Recently Aiello has demonstrated that phrenicotomy favours the production of pneumoconiosis in animals subjected to dust inhalation (1929). Recently again Mazzitelli (1929) has felt justified in stating on the basis of some of his experiments that inhaled marble dust is subject, though only in part, to evident processes of transformation, absorption and elimination, whilst Bianchi has affirmed that it causes evident processes of reaction and inflammation in the lung.

As an offset to this important series of research contributions, numerous other studies of a clinical and anatomo-pathological character exist which have furnished important information on the ætiology and pathogenesis of the pulmonary diseases derived from dust.

There should be recalled in this connection the interesting studies of Devoto on the relations between pneumoconiosis and catarrh of the pulmonary apical zones (1913), on the non-tubercular lesions of the pulmonary apex (1914), on the relations between pulmonary affections due to dust and tuberculosis of the lung (1925) and on pneumoconiosis in its initial stages (1925).

Tedeschi also has described special non-tubercular lesions of the pulmonary apex (1914).

Highly interesting are, moreover, the histological and chemical researches of Boattini and Lo Faso on the essence of pulmonary anthracosis (1928), from which the said authors have drawn the conclusion that the particular colouring of the anthracotic lung is certainly due in part to the presence of iron, but that this fact does not afford justification for substituting siderosis for the conception of anthracosis, and that the anatomical and pathogenic conception of pulmonary anthracosis should not be in any way modified.

Ferrannini has measured the respiratory capacity of individuals engaged for many years in bagging flour, and who were decidedly free from tuberculosis (1911). In about half of these he found the pulmonary capacity to be more or less markedly reduced, that is to say, an indication of diminution of the respiratory surface due to encumbrance of the pulmonary alveoli. He was able, moreover, to demonstrate the presence of starch in the sputum of a few individuals, not microscopically but chemically, and also

found there albumen, which he supposes to be derived from the gluten in the flour.

Another work of great importance has been completed by Bonanno (1928), who has studied from the clinical and radiological aspect eighteen cases of pulmonary silicosis in miners from the South African gold mines.

Meda also has completed some observations on the radiological picture of pneumoconiosis (1927). A few isolated cases of pneumoconiosis produced by different dusts are worthy of special attention.

Devoto and Cesa-Bianchi have reported the case of a glove maker, who during life had suffered from chronic bronchial catarrh and who, having died as a result of inter-current nephritis, showed during the pathological macro- and microscopical examination pneumoconiosis due to talc powder.

Ferrannini has studied a case of pneumoconiosis from cement, characterised by asthma and pulmonary emphysema in an individual whose occupation was handling cement (1928). His pupil, Sorrentini, had described a case of pneumoconiosis from flour (1923).

Fiori has moreover published particulars of a rare case of pneumoconiosis due to barium (1926).

Quite as numerous, and perhaps more interesting from the point of view of the discussions likely to take place in the international field in regard to dust pathology, are studies effected relative to the health conditions of groups of workers engaged in various dusty trades.

It would seem advisable to summarise rather fully the results of these investigations, since in them, rather than in clinical or anatomical findings pertaining to single individuals and laboratory experiments, we are likely to find elements useful in resolving the problems connected with the study of silicosis.

In a great many publications of various natures, clear indications are given not only of the incidence of the disease in question, but also of the high mortality rate from pulmonary diseases amongst workers engaged in the dusty trades of mining, quarrying or stonework. Mention shall, however, be confined here to recording a few of the more characteristic results taken from enquiries made on the spot.

Biondi (1906) had observed that amongst the miners in the mines of Sardinia the greatest damage due to the mechanical action of dusts occurs when the gangue of the mineral extracted contains silicates. He had moreover noticed that coal miners

were almost all addicted to coughing and continued to expectorate an entirely black sputum even some time after they had quitted their occupation. In the workings of the mines of Bergamo, on the other hand (1907), he found minor injuries due to dusts, perhaps because the workers in these mines worked intermittently, the work in the mines alternating with agricultural pursuits. In a few miners, however, especially in the older men, Biondi met with cases of pharyngitis and bronchial catarrh with dark sputum due in great part to the black smoke of the candles used, and he observed that acute affections of the respiratory apparatus affected these workers more seriously and were of a more obstinate nature.

Frongia (1908), in twenty-six post-mortem examinations of miners from the Sardinia mines, effected with a view to studying pneumoconiosis, noted that the cause of death was in most cases an acute infection (pneumonia), but he found, nevertheless, very frequently amongst these workers serious and diffused arteriosclerosis, emphysema and anthracotic foci, with more or less diffused softening of the tissues and presence of gangrenous foci containing a black broth-like matter, that is to say, the characteristic finding of black phthisis. On the other hand, foci of bronchoectasia due to tubercular infection were only met with by him in five cases. Eighty per cent. of the fatal cases amongst the miners were not therefore cases of tuberculosis infection. Nevertheless, Frongia asserts that black phthisis would not represent the essential cause of death of the worker in any of the cases.

Pieraccini (1926) has noted amongst stonebreakers of fifty to sixty years of age (working on the roads), remarkable emphysematous conditions and ordinary forms of catarrh. Amongst the road-menders, however, he found many who showed a pronounced tolerance in the matter of resisting irritations due to dust.

Also in the sputa of these workers little addicted to coughing and who only suffered from time to time from catarrhal secretions from the nose and mouth, there was found dust in such quantity that it sufficed to take the secretion between the fingers in order to feel the presence of sand.

Pieraccini recalls that the working atmosphere in road-mending is one of the most dusty which exist (at least for many months of the year) and that the road dust which he examined was highly dangerous, since it contained amorphous silica to the extent of 22.47, with a content of aluminium and oxide of iron amounting to 4.45.

Evidently, however, the slight frequency of pulmonary affections among road-menders is due to the fact that they inhale the dust intermittently, and that for this reason it does not succeed in injuring the bronchial mucous membrane.

Vernarecci has studied mortality from respiratory diseases among *workers in some dusty trades* in Rome during the biennial period 1921-1922, and has established the following figures:

(a) Macaroni makers and millers	{	tuberculosis = 16.66 per cent. of all deaths
	{	other pulmonary diseases = 33 per cent.
(b) Stone masons and marble workers	{	tuberculosis = 14.80 per cent. of all deaths
	{	other pulmonary diseases = 14.15 per cent.
(c) Carpenters and cabinet makers	{	tuberculosis = 18.6 per cent. of all deaths
	{	other pulmonary diseases = 16 per cent.
(d) Masons	{	tuberculosis = 15.56 per cent. of all deaths
	{	other pulmonary diseases = 21.11 per cent.

The total mortality for all pulmonary diseases is therefore not excessive, since it averages about 30-36 per cent. of all deaths.

In a contribution relating to the injuries to health suffered by workers engaged in making vases (earthenware vases) in Sardinia, Marcello (1908) refers to the frequency of affections of the respiratory organs amongst workers engaged in turning.

Contradictory data exist relative to the incidence of pulmonary diseases amongst workers engaged in the cotton industry. Whilst Tassinari (1892) found amongst 100 weavers in the hospitals of Pisa in the years 1885-1890 a death rate of 2.07 from tuberculosis and amongst the other women in the hospital only 1.57, Pierotti during medical examinations effected in a cotton factory at Pontedera found:

- (1) That amongst the male workers (comprising mechanics, firemen, cotton printers and finishers) there were found to be suffering from chest affections during the medical examination 15.5 per cent., or 10 per cent. affected with chronic febrile catarrh and 5.5 per cent. with tuberculosis (2.2 per cent. of which showed certain tuberculosis and 3.3 per cent. of which were doubtful).
- (2) That amongst the women, on the other hand (all engaged in spinning, weaving and teasing), only 7.9 per cent. suffered from chest affections, more precisely 4.3 per cent. from chronic catarrh without fever, and 3.6 per cent. from tuberculosis (of which 1.61 per cent. revealed a positive diagnosis and 1.45 per cent. were doubtful).

Amongst workers in the alabaster industry, where for the most part work is carried out in narrow, badly ventilated workrooms unprovided with exhaust ventilation, and requires faulty posture on the part of the workman, who is obliged to inhale large quantities of dust (sulphate of lime), Pieraccini has found a certain incidence of catarrhal affections of the respiratory passages, but he has not given the proportion which these constitute of the deaths in the general population. De Hieronjmis and later De Guasta have found amongst these workers a high percentage of tuberculosis.

Besides these generic observations on the pulmonary pathology in a few dusty trades, we possess certain more extensive and important studies relative to certain special materials from mines and quarries generally regarded as involving greater risk for the health of the workers engaged in their extraction and subsequent manipulation.

Such materials are lime, cement and plaster, asbestos, slate, sulphur, marble and silica. On account of their interest and of the more accurate knowledge which we possess concerning them, it would seem advisable to give here a more detailed account of these.

CEMENT, LIME, AND PLASTER

Pesenti, at Alzano Maggiore, and Rota and Finzi, in Casale Monferreto and neighbouring districts, have contemporaneously (1906) dealt with the health conditions of workers manipulating lime, cement and plaster. Pesenti clearly affirms the high incidence of pneumoconiosis amongst workers in cement and plaster, but omits to provide proportional statistics. The conclusions which he draws from post-mortem examinations effected by him are, on the other hand, more explicit.

In one case he found that the process of pulmonary sclerosis had penetrated into the pleura, which was remarkably thickened and had lost all elasticity. In the lungs, disseminated amongst the sparse centres of normal parenchyma, were to be seen real connective islands thickened and hard, in the centre of which were found a nucleus of cement which grated under the knife. These were true pneumoliths. Similar alterations of connective neo-formations affected the lymphatic channels and the peribronchial tubes. A middle bronchial tube contained a broth-like mixture of cement; the mucous membrane of it was encrusted with pulverulent deposits; here and there were to be seen bronchial ectasia of varying dimensions.

The parenchyma free from incrustation showed the characteristic signs of vicarious emphysema.

In six other autopsies of workers in the cement industry, the author found sclerosis localised at a few points of the lung, circumscribed and nodular.

These forms of nodular, partial, broncho-pulmonary sclerosis follow, the author affirms, a slow evolution, and provide few subjective symptoms. He noted dyspnoea, loss of weight, night sweats, pleximetric and stethoscopic phenomena, and sputa similar to those of tuberculosis in the case of an individual in whom tuberculosis was not discovered, neither macro- nor microscopically, at the autopsy.

The case in question was only one of multiple nodular sclerosis of the lungs.

The author believes that the cement dust inhaled neither produces tuberculosis nor favours the evolution thereof, but he merely formulates this opinion as a hypothesis. These observations made by Pesenti are highly interesting, for they present very clearly the picture of the various forms of pneumoconiosis without tuberculosis, and also provide an idea of the varying nature of the clinical picture according to the gravity of the disease.

The study made by Rota and Finzi amongst workers in the cement and lime industry is predominantly clinical and statistical in character. They found that the morbidity and mortality rates for these workers (excavators, kiln workers, transport workers, crushing machine operators and baggers) are not higher than those of other workers. The diseases to which they are subject most frequently, however, are diseases of the respiratory apparatus, and besides, they often die at an early age. In fact, out of 63 deaths amongst the *permanent* workers engaged entirely in lime and cement work, 28 died before the age of forty and 11 under fifty. The cause of death was in 20 out of 63 cases due to pulmonary diseases, or, more precisely, in 9 cases to acute pneumonia, in 2 cases to pleuro-mediastinitis and in the other 9 cases to tuberculosis. The authors remark that there is no truth in the statement that lime-kiln workers enjoy a certain immunity from tuberculosis as averred by Halter. On the contrary, they found that the greatest toll to this disease was paid by the kiln workers. For instance, in the commune of Casale, 9 deaths of kiln workers out of 35 were due to tuberculosis.

During physical examination of 248 factory workers, Rota and Finzi found in 122 cases harsh respiration in the upper respiratory

passages, due certainly, they assert, to an incipient pneumoniocosis or infiltration of dust in the peribronchial lymphatic channels. Harsh respiration was found more frequently in workers employed for a long time, and especially in those who had already worked for ten to twelve years. The proportions in which it was present were the following: 52 out of 128 workers engaged at the kilns, 18 out of 26 workers engaged in transporting stone, 43 out of 50 crushing machine operators, baggers and porters of sacks.

Many workers were also found to be emphysematous.

ASBESTOS

From an interesting statistical study made by Scarpa, it would appear that out of 30 workers (9 male workers and 21 women who had been engaged in manipulating asbestos in the mines or factory laboratories for weaving this mineral, and who were being treated in the department of the Turin Polyclinic under the direction of the author from 1894 to 1906), only one showed simple catarrhal lesions of the respiratory apparatus. The other 29 suffered from tuberculosis. All died in less than a year after the first medical examination, since the disease in a short time brought about destructive and ulcerative lesions of the lung. The author claims therefore that the asbestos industry is one of the most dangerous of those industries involving predisposition to pulmonary tuberculosis.

SLATE

Already, in a communication dealing with the enquiry into conditions of factory workers completed in 1877 by the Ministry of Agriculture, Industry and Commerce, the sulphur mines of Sicily and the slate quarries of Liguria were designated as dangerous and liable to provoke special forms of ill-health in consequence of the nature of the work engaged in by the workers, as well as on account of the extremely heavy and trying work involved.

In a communication presented to the third National Congress for Occupational Diseases (Turin, 1911), Devoto and Cesa-Bianchi have stated that "in the district of Chiavari there has been observed a progressive loss of weight leading to premature death of workers (in the slate industry) without there being encountered, so it is affirmed, the tuberculosis bacillus".

In *La Medicina del Lavoro*, 1929, No. 7, Devoto relates having found in the library of the Economic Society of Chiavari two monographs by Professor G. A. Mongiardini, of the University of Genoa

(1809 and 1812), and an Honours Thesis by Dr. G. B. Ravenna (1812), which illustrate the life of workers engaged in slate extraction in the quarries of Lavagna, and which contain many observations in regard to the diseases of the respiratory apparatus in question as well as many post-mortem findings. Also, a monograph by Dr. N. Della Torre, published in 1840 and entitled "Guide to the Quarries of Lavagna", contains many clinical and sociological data relative to these workers.

Devoto himself records, moreover, that during the Congress of Italian Scientists, held in Genoa in 1846, there was discussed the pathology and hygiene of work in the slate quarries and that a priest, Giuseppe Ravenna, summarised all the medical and sociological studies on the subject in a publication dated 1879 and entitled "Memoirs of Lavagna". All the elements furnished by this publication were co-ordinated in 1929 by Dr. Carlo Picchio, a pupil of Devoto, who made it the subject of his Honours Thesis.

The following are the principal data which have been extracted therefrom. Slate contains 25 per cent. of silica, 10 of aluminium, 35 of calcium and 30 of various other materials. About 1834 there existed in Monte-s.-Giacomo (Cogorno) seventy slate quarries, now abandoned, and the whole population of the region (about 4,000 persons) was engaged in working the slate, the men as excavators and cutters and the women as transport workers.

It would appear that the mortality was not high for that period, since Della Torre relates that from 1828-1837 there occurred in Cogorno only 422 deaths out of a population of 1,800 inhabitants (23.44 per cent.). It would seem, however, that males died prematurely, since from 1800 to 1816 more than half of them died before reaching fifty-five years of age, and in the period from 1780-1830 Della Torre found that only one man for each 10 women reached the age of seventy. Dr. Picchio, in scrutinising the death register from 1800 to 1816, noted that tuberculosis constituted a very frequent cause of death. Mongiardini also had drawn attention to the fact of the frequent incidence of pulmonary tuberculosis, and Ravenna had, moreover, written that the dust, being composed of "small particles, without doubt rough, hard, sharp, and having prominent points, calculated to wound and cut" when inhaled for a long time, could produce in the lungs changes sufficient to favour the outbreak of tuberculosis, which disease was commonest amongst the workers in question. Ravenna himself carried out a post-mortem examination of a quarryman and a stonecutter, and found only evidence of pulmonary tuberculosis without dust deposit.

The existence of true pneumoconiosis is demonstrated by the findings of an autopsy effected by Mongiardini on the corpse of a certain worker G. B. Binasco, aged fifty, an excavator at Cogorno. He found "the lungs fully more voluminous than the normal, of a dark red colour and variegated with blackish lines in the interior, similar to the colour of slate. There were multiple adhesions, especially of the left lung, which showed tophaceous concretions, and amongst these, a cyst as large as an egg, filled with ash-coloured pus. The back part was far more than half scirrhus, and almost stony and most difficult to cut into with a knife. The pleura and the right lung were sewn with tubercles, many of which were as big as a large hazel nut (*noce avellana*) and contained a blackish humour, others a very fine black powder which blackened the fingers and resembled wet and pulverised slate. The lung showed great hardness under the scalpel, which in cutting became toothed like a saw. Vesicles were found full of an earthy powder; many had coalesced, filled with the said powder, and seemed to form cysts."

The symptomatology presented by all the sick workers is described by Mongiardini, as well as Ravenna, in an almost identical manner—the state of denutrition more or less advanced to the point of approaching cachexia, dyspnoea, emphysema, chronic bronchitis. There is, however, some divergence between the views of the two authors as to the interpretation of the origin of the disease, since Mongiardini had at first denied and then (after the autopsy on Binasco) admitted the existence of dust in the atmosphere of the quarries, and Dr. G. B. Ravenna, on the other hand, admits that one of the principal causes of the diseases of quarrymen is the inhalation of slate dust, whilst he did not admit the existence of special diseases amongst the workers manipulating slate in the open, especially when protected against inhalation of the dusts.

Sulphur

In 1892, Dr. Giordano, of Lercara, described under the name of *theapneumoconiosis* a process of chronic broncho-pneumonia accompanied by abundant deposits of sulphur in the pulmonary tissue and in the peribronchial glands of sulphur miners. Giordano had had the opportunity of effecting a single autopsy on a miner, aged fifty-one, who had worked in the mines from the age of six and had died as a result of chronic broncho-pneumonia. In the lungs and in the bronchial glands there was found a great quantity of sulphur dust, but Giordano had also treated many miners suffering

from chronic bronchial catarrh with rales, dyspnoea, cyanosis and emphysema, in the bluish-grey sputa of whom there was found a more or less extensive amount of sulphur dust accompanied or not by pus corpuscles, elastic fibres and bacillus of Koch, according as to whether tubercular infection had followed the pneumoconiosis or whether it was merely a question of pneumoconiosis in a pure form. He affirms, besides, having seen miners who had quitted their occupation still expectorating, not intermittently but constantly, pale bluish-grey matter two, seven and even twelve years later.

The observations of Giordano were confirmed by Lattuca at Casteltermini and by Ricevuti at Caltanissetta, all of whom, as a result of numerous autopsies on miners who had died by accident or had been killed, found in the lungs an emphysematous state, bronchial catarrh, greyish pigmentation, and besides, small nodules very compact and resistant, disseminated in the tissues, which grated under the knife and which varied in volume from the size of a grain of millet to a pea or larger, and which presented on section a surface of a blackish-grey colour.

Carapelle and Gabrielli, though not denying the existence of the pneumoconiosis, have expressed doubt as to its frequency; the first on a basis of theoretical considerations founded on the small quantity of fine dust daily inhaled by the miners, and the second, because, having had the opportunity of taking part in a number of autopsies on miners and having read the accounts of a number of other necroscopic examinations (in all eight cases), he felt unable to confirm the presence of infiltration of the lung by sulphur dust, whilst he found in all the cases a considerable extent of anthracosis. Giardina, however, has confirmed having observed in a sulphur worker who died of ankylostomiasis the complete findings accompanying *Zenker's pneumoconiosis*, and he provides the following picture of the anatomical finding in the case of sulphur workers:

The pulmonary tissue is rugged to the touch and grates under the knife; on the surface revealed in section there are bluish-grey stains and greyish nodules which extend to the size of a pea and are at times isolated or at other times grouped together round a caseified centre, or again surrounded by a more or less manifestly inflamed area. In the most serious cases, moreover, there are observed cavities in consequence of gangrene occasioned by compression exercised on the capillaries by the interstitial sclerosis. The bronchial tubes, here and there ectatic, are filled with muco-pus, and charged with a pigment recalling the fine dust of the mines. The alveoli have thickened walls and are moreover charged with purulent matter. The marginal areas of the lungs are emphysematous and the bronchial ganglia swollen and greyish in colour.

Numerous statistical data have moreover confirmed the frequent incidence of pulmonary diseases amongst sulphur workers.

Di Giovanni reported to the Congress for Occupational Diseases at Palermo (1907) that 47.4 per cent. of the sulphur workers examined presented chronic affections of the respiratory passages which ranged from chronic catarrh with emphysema to pneumoconiosis.

The Health Officer of Caltanissetta has reported in the years 1896 and 1897 the deaths of 250 sulphur workers, of which 199 (79.20 per cent.) were due to bronchial and pulmonary diseases. The Health Officer of Serradifalco has attributed to diseases of the respiratory passages 8 out of 19 deaths (42.10 per cent.) which occurred in 1898 amongst the sulphur workers of the commune. Dr. Ricevuti has, moreover, reported that of 739 deaths which occurred amongst the population of Caltanissetta as a result of pulmonary diseases in the triennial period 1896-1898, 308 (41.67 per cent.) were sulphur workers.

It is not, on the contrary, known precisely to what extent tuberculosis exists amongst this category of workers. Zampa has asserted that it is very rare amongst the sulphur workers of Romagna. Giordano, Burruano and others have said the same of the Sicilian sulphur workers.

Yet, as Giardina has justly observed, it is difficult to admit that sulphur dust is the almost exclusive cause of the extraordinary frequency of diseases of the respiratory apparatus occurring amongst sulphur workers, and that perhaps but little tuberculosis is diagnosed on account of the fact that the bacteriological proof is often neglected.

MARBLE

The pathology of marble workers is at present the subject of an interesting controversy. Frascchetti, subsequent to an enquiry on marble workers in Rome, had drawn attention to the fact that work of this nature predisposes the workers to contract pulmonary diseases, and Calderai had previously noted the very frequent incidence of these disease forms in the workers of Serravezza. During the years 1928 and 1929 there were published two works of greater importance which arrived at opposite conclusions from one another.

Dr. G. Bianchi, of Massa, as a result of clinical, radiological, anatomical, and statistical observations and animal experiments, has concluded that:

- (1) The inhalations of fine marble dust cause alteration of the upper respiratory passages and disease symptoms (rhinitis, pharyngitis, bronchitis) such as to render null the protective function of these passages, which are no longer able to offer resistance to the penetration of the fine dust itself into the pulmonary alveoli.
- (2) The fine dust, having arrived in the alveoli, gives rise to pathological processes such that the various defensive means possessed by the alveoli are weakened, if not abolished.
- (3) The bacillus of Koch finds in the pulmonary tissue a ground favourable to its development and its pathogenic action.

The facts on which Dr. Bianchi bases his conclusions are as follows:

A group of rabbits kept for ten months in the marble laboratories presented bronchial and broncho-pulmonary symptoms, consisting in œdema, hyperemia, tumefaction, desquamation of the bronchial mucous membrane, casts composed of peelings of the epithelium and catarrhal secretions of the smaller bronchial tubes and the alveoli, intense vascularisation and production of new connective tissue in the interstitial tissues, obstruction of the ganglia of the hilum. Some of these rabbits, inoculated with the bacillus of Koch in various ways, developed tuberculosis of a much more serious and rapid evolution than others, which had not previously been subjected to dust inhalation.

Many workers showed the entire symptomology of forms of chronic bronchial catarrh and pulmonary sclerosis, and died of an insufficiency of the right ventricle or of acute complications which supervened, amongst the most frequent of which were tubercular infection.

Radiography of the respiratory apparatus has shown in the most simple forms of "marbloconiosis", disseminated shadows, more dense towards the hilum, with an area varying from the size of a grain of rice to a small nut, and with peribronchial striae. In the cases complicated with tuberculosis, the specific tubercular foci develop preferably where the more intense shadows of pneumoconiosis are situated and evolve during a long time on the traces of already existent peribronchitis.

Further the cavitory lesions from the bacillus of Koch in pneumoconiotic subjects never assumed a considerable extension and rarely gave rise to large cavities. An anatomical, and pathological examination has revealed emphysema, sclerosis of the pulmonary tissue, the presence of hard nodules (pneumoliths) and other features of less importance.

Finally, statistical returns have demonstrated that the percentage of deaths from tuberculosis amongst marble workers is very high.

Dr. M. Mazzitelli, of Carrara, on the other hand, in studying the statistics of the causes of death of the population of Carrara, has observed that the tuberculosis mortality figures are very low amongst the marble workers since "out of 13,000 workers in

two years there occurred 38 deaths, that is to say, 26 amongst workers in the open, in an atmosphere slightly or not at all dusty, and 12 amongst those daily subjected to dusty work in the laboratories". He therefore concludes that marble dust is not an element which can cause tuberculosis, not to speak of causing predisposition to it. Besides he injected five times in succession, at periods separated by one month's time, 2 grammes of white marble dust (almost pure carbonate of lime) directly into the lower lobe of the right lung of a guinea-pig, and this animal not only remained free from any troubles but continued to gain weight and to multiply. Twenty-four hours after the fifth injection the lung of the guinea-pig subjected to radioscopic examination showed no opacity at the point of injection and the autopsy showed that the lungs were normal in form, volume and colour, and that their surface was smooth and glossy. The peribronchial glands were, however, well developed and firm. Microscopic examination revealed absolute absence of marble crystals, slight signs of an inflammatory process, with small infarcts, desquamation of the alveolar epithelium and infiltration of the septa. The other guinea-pigs inoculated, on the other hand, with dust from coloured marble, from granite, or dusts of mixed marble and granite, presented on post-mortem examination various lesions, such as adhesive pleurisy, degenerative processes, necrosis, etc.

A chemical analysis having been made of the lime in the lungs of the animals inoculated the smallest calcium content was found in the case of the guinea-pig injected with white marble dust and the largest in the case of that injected with dust from a mixture of coloured marbles.

From the results of this and other enquiries of less importance the author arrives at the following conclusions:

- (1) Dust of Carrara marble is subject in the animal system to processes of absorption and elimination.
- (2) A true dust pneumoconiosis from marble does not occur, at least as a usual phenomenon in consequence of work.
- (3) Dust from Carrara marble cannot therefore be considered as phthisogenic.

It is difficult to pass judgment on these conclusions, which are in open contrast to those formed by Bianchi.

SILICA

In regard to the importance of silica dusts as the cause of pneumoconiosis, we possess a single clinical study by Giglioli, carried out by a good method and, therefore, of much weight. Amongst the mercury mines of Monte Amiata there are some which have an argillaceous and damp gangue and one which has a siliceous gangue. Pieraccini had already remarked that amongst the workers who were engaged in the latter mine (Cornacchino) there occurred a high incidence of broncho-pulmonary affections and pulmonary tuberculosis, and an enquiry effected later by Drs. Puccinelli and Ginanneschi has confirmed the existence of this fact.

Giglioli found that in many of the miners at Cornacchino and in almost all those who worked at the top of the road, where the air is richer in silica dust, there occurred after two to three years of work broncho-pulmonary affections with coughing, breathlessness, emphysema, dusty but not hæmorrhagic expectorations, almost always without fever and without marked decline. In general, however, after a more or less lengthy period which may last even five years fever sets in, the expectoration becomes hæmorrhagic, there occurs at times hæmoptysis and organic decline becomes evident. There appear, in short, all the signs of pulmonary tuberculosis. There is, consequently, almost always a well-marked pre-tubercular period, which may evolve slowly without tubercular complications and which corresponds to the so-called miners' phthisis as it has been precisely described in the Transvaal Rand Mines by the English Royal Commission of 1906.

More recently than Giglioli, Mazzi (1913), on the basis of animal experiments and clinical observations, has come to the conclusion that silicon (in the special form of silicates) causes chronic intoxication of the system and acts especially on the blood in exercising a general anæmia-producing action.

* * *

From this summary account of the studies effected in Italy in the last twenty-five years on the problem of pneumoconiosis confirmation is afforded of the fact that this question is well known amongst our research workers, who have examined it from the

experimental point of view as well as the clinical and anatomic-pathological point of view and have availed themselves on various occasions of the means of proof furnished by semiology, radiology, histology and histo-chemistry in order to diagnose the disease or recognise its pathogenesis, in the same way as they have had recourse to statistics and to a study of the objective conditions in order to arrive at an idea of its social importance.

It is not our intention here to provide a reasoned and critical survey of the results at which they have arrived or of the conclusions which they have drawn, and still less to discuss the methods of enquiry which have been adopted in certain investigations.

We only wish to draw attention to a few points which seem to us to be the most interesting for those desiring to study pneumoconiosis and bring into relationship its pathogenesis in the individual with the social risk which it represents for certain categories of workers.

It seems evident, in our opinion, from the studies quoted that there exists the possibility of the manifestation of chronic bronchopulmonary affections, more or less serious in character, amongst all the workers engaged in dusty industries, manifestations possessing clinical and anatomic-pathological characteristics analogous to the disease described by Zenker under the designation of "pneumoconiosis". Almost all the research workers are in agreement in recognising that there exists a varying degree of harm in the various dusts which can be determined in accordance with their physical characteristics (hardness, insolubility, sharpness of the surface of the particles). Silica dust has always been recognised as the most harmful, but less hard and more easily absorbed dusts, such as, for example, flour dust, are also capable when inhaled for a long period in large quantity of overcoming the means of defence of the system and producing irritative phenomena or inflammatory symptoms, of penetrating into the structure of the tissues and there producing considerable lesions. But whether on the basis of studies completed in Italy or of those carried out in other countries referred to at the beginning of this paper, it seems to us that there still await solution certain problems of pathology which are amongst the most interesting from the point of view of hygiene. These points are: (a) the possibility of pneumoconiosis assuming the character of a disease with progressive evolution, that is to say, whether its evolution continues even after removal of the patient from the dusty atmosphere, and (b) the possibility of its assuming a severity sufficient to endanger life of itself,

without infective complications and especially apart from tuberculosis.

Only after having thoroughly verified our data in regard to these fundamental questions shall we be able eventually to engage in a study of the reasons explaining why in a particular locality the *individual disease* assumes the character of a *mass infection* and becomes a menace to the whole community.

The key to the solution of these questions resides, in our opinion, in the capacity to diagnose pneumoconiosis during life and in being able to discriminate between it and other pulmonary diseases, especially between it and tuberculosis.

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APPENDIX

Professor Loriga, when showing his collection of radiographs, distributed to the Members of the Committee the following four short summaries describing the research engaged in by his collaborators. He distributed also a volume containing the original reports, presented by the Italian Ministry of Corporations.

PNEUMOCONIOSIS IN MARBLE WORKS

BY DR. GIACOMO BIANCHI,

DIRECTOR OF THE ANTITUBERCULOSIS DISPENSARY AT MASSA

In my capacity of Director of the Antituberculosis Dispensary of Massa for some years past I have devoted attention to the possible presence amongst the marble workers of a pneumoconiosis lesion. I have subjected to careful clinical and radiological examination a group of about 250 workers engaged in work in more or less closed workrooms, such as sculptors, rough hewers, modellers and workers in the grinding rooms.

There were excluded all cases of suspected syphilis and other chronic lesions, with the result that the study covered seventy-three workers engaged in marble, having no inherited disease or previous disease history and free from definite or suspected symptoms of affections of the respiratory passages which might come under the category of common infections.

Thus, as can be seen on the radiograms shown, radiography has revealed diffuse nodes of thickened tissue, spread over almost the whole respiratory surface. In these cases there can only be determined a slight percentage (20 per cent.) of functional alterations with symptoms of chronic bronchitis and equally of pulmonary emphysema.

I then engaged in experimental research by exposing several series of rabbits to marble dust inhalation in the workrooms and killing them after a long period; one series of animals was killed after exposure lasting over two years.

It was recognised that all the animals suffered from the broncho-pulmonary lesions described in the text, clearly revealed by the accompanying microphotographs of histological preparations which show in an evident manner the presence of marble crystals, in particular in the sub-pleural network, in the peribronchial connective tissue and in the lymphatic ganglions.

On the basis of these clinico-radiological examinations and experimental researches I have arrived at the following conclusions:

1. The marble dust inhaled during work by the men in marble workshops causes anatomo-pathological lesions characterised by diffuse foci of peribronchitis and interstitial pneumonia.

2. The above-mentioned lesions can be observed radiologically amongst workers exposed for several years to the dust and they are accentuated in proportion to the time spent in the workshops.
3. The anatomico-pathological lesions do not cause functional disturbances except in the case of a small proportion of the workers and it is not possible to deny that inherent constitutional factors are connected with the appearance of these functional disturbances.

PULMONARY ASBESTOSIS

BY DR. DOMENICO LOVISETTO

My investigations have dealt with workers handling pure asbestos, and asbestos mixed in very small quantities with cotton or other vegetable fibres. They relate to two distinct periods: the first extending from 1902-1912 and the second from 1912 to the present time. I have considered it advisable to keep the data relative to these two periods separate since the first relates to workers employed on the manufacture of asbestos under very unfavourable and unhealthy conditions as regards the industrial organisation, as well as the type of worker employed.

Very frequently workers suffer from forms of rheumatism, of bronchial pneumonia and some of them from tubercular affections. Patients suffering from chronic broncho-pulmonary forms of disease of a non-tubercular character were in general men and women who had worked for several years in the said establishment; the morbid process with slow but progressive evolution was characterised by absence of fever and spitting of blood. The initial symptoms affected the upper respiratory passages, with persistent cough particularly trying during the winter season with little or no expectoration.

In the most severe cases (workers engaged in the industry for many years in the most dusty workrooms) besides the above-mentioned symptoms there was noted diffuse broncho-pulmonary pneumonia especially at the basis of the thorax with symptoms of pulmonary sclerosis.

I have never known patients to die of these disease forms.

I also visited each year workers presenting manifest signs of tubercular lesions. A careful examination of these cases and a conscientious study of their case history led me to the conclusion that these tuberculous complications, almost always affecting young workers, only occurred in the case of workers with hereditary predisposition or who had suffered from lesions rendering them susceptible to tuberculosis prior to commencing work in the asbestos industry or again to those who had lived with tuberculosis patients.

At the end of this period my personal experiments led me to conclude that asbestos dust is dangerous on account of the irritation which it causes in the respiratory tract and that in proportion to the amounts of dust inhaled and the years spent under the conditions described, it may cause a clinical picture similar to that designated in English "pulmonary asbestosis"; on the other hand it cannot set up tuberculosis. Where this disease occurs it must be considered as stimulation of earlier latent tubercular foci or it is a question of causes other than inhalation of asbestos dust.

In the second period extending from 1912 to the present time and following on the erection of a factory construction complying with the

most hygienic modern precepts, conditions amongst the workers have greatly improved and further the workers were only engaged after selection by thorough medical examination. It must also be remembered that the periodical medical examination reveals at the outset the presence of morbid symptoms even when these are still very slight.

A conscientious examination of all workers in the factory has led to the following conclusions.

Workers who have only worked with asbestos for two or three years generally suffer from redness of the throat and from frequent and violent coughing not, however, accompanied by expectoration; they show no other subjective symptoms.

On the other hand amongst workers who have been working upwards of five years in the factory and who by reason of the process on which they are engaged are exposed to the inhalation of dust in greater quantities, I have been able to note slight signs of pulmonary changes. During examination of the thorax I have often observed a slight limitation of inspiratory movement and on percussion more or less obvious dullness at the bases, more frequently to the right than left side with diminution of the respiratory murmur.

Amongst those with over ten years' exposure to the inhalation of asbestos dust I have noted in addition to the above-mentioned symptomatology, some generalised pleuritic rubs with very harsh vesicular rales. Amongst these workers the size of the heart especially the right side seems almost always considerably enlarged and the second pulmonary sound accentuated. There is neither fever nor night sweats. At times the patients suffer from gastric troubles though only to a slight extent. In more serious cases a certain degree of anorexia is noted which usually makes its appearance after the twentieth year of employment. An examination of the sputum of those patients suffering from expectoration disclosed almost always the presence of particles of asbestos.

Whilst radiographic examination of workers engaged for a few years only, and of those but little exposed to the inhalation of the dust is almost always negative, amongst the others on the contrary I found very frequently the presence of more or less intense and diffuse shadows particularly corresponding to the base with hilar markings and diminished chest expansion. A short rest is quite sufficient for rendering these patients once more fit for work.

During the five years three deaths occurred amongst workers in the factory and they were due: the first to arteriosclerosis, the second to broncho-pneumonia in the form of influenza and the third to tuberculosis, probably due to family infection.

Amongst all the patients examined during these last months, three only showed symptoms sufficient to warrant suspension of work.

It transpired from the history of these three patients that two of them (the first and the third cases) had worked on asbestos for about ten years, whilst the second had only followed the occupation for three years, and that though showing symptoms characteristic of those who inhale asbestos dust over a long period, they showed morbid phenomena of varying types modifying the characteristic asbestosis lesion.

In the first case there was anorexia, dyspnoea, intermittent fever, marked loss of weight, on examination of the patient: generalised pleuritic friction, diminution of the respiratory movement, more marked on the right side, dullness at both bases, with attenuated vesicular murmur and very harsh respiration at the bases. On radiographic

examination there was noted considerable reduction of the transparency of the two lungs, especially of the lower lobes and at the bases, increase of radiographic density in the hilar regions with intensely opaque striation, which became thickened and irradiated in the pulmonary parenchyma. Dyspnoea and anorexia are the symptoms currently noted amongst those workers who have for long years inhaled asbestos dust, but the fever has a different aetiology.

In fact the first patient at the age of twenty had suffered from sero-fibrous pleurisy, and a considerable decrease in weight (10 kg.) which occurred quite recently, fever, generalised friction of the pleura, diminution of the transparency of the right lung, point to the presence of a lesion, probably tuberculous, of the pleura and the right apical region.

In this case I think that a lesion, probably tuberculous with slow evolution, became superimposed on a fairly marked pneumoconiosis.

The same may be said of the second patient. In fact the case in question was one of an emaciated individual who at nineteen years of age had suffered from dry pleurisy and who last year had been spitting blood; morbid processes of the pleura are present and are still active. It should be noted that the aetiological factor "asbestos" assumes a lesser importance since the patient had been employed in the factory for nine years only and had been engaged on an operation which was almost free from dust production.

In the third case the patient in question was a woman who had lived for years with a tubercular husband and who had been working for ten years in a very dusty atmosphere manipulating blue asbestos, which, as is well known, contains the kind of dust which exerts the strongest effect. She showed besides a very advanced degree of pneumoconiosis and in addition pleurisy as demonstrated with proof by the radiographic examination which revealed in a clear manner the presence of pleurodiaphragmatic adhesions. The presence of blood-stained sputum likewise points to a pulmonary affection of another type.

Examination of the sputum has shown in the three cases the presence of asbestos fibres. The Koch bacillus test for tuberculosis was negative.

In conclusion, inhalation of asbestos dust in the long run causes pneumoconiosis; the period required for the manifestation of this pathological state is at least five years. There is a direct ratio between the quantity of dust inhaled and the pneumoconiosis; the higher is the dust concentration the less time is necessary for the manifestation of fibrosis. It can reach complete development after a period of seven to nine years and it can cause death after thirteen years on condition that the individual is continuously exposed to the risk in a very dusty atmosphere.

When the cause of the inhalation of the asbestos dust is withdrawn the pneumoconiosis process is generally arrested.

The functional injuries caused by the inhalation of asbestos dust occur very slowly and are characterised by dyspnoea on effort, and by a slight insufficiency of the right heart, the patient after being attacked may work for a long time with brief spells of rest.

It is very doubtful whether pulmonary asbestosis favours the occurrence of acute pulmonary affections though the anatomical conditions of the sclero-fibrous lung which cause a slowing down of the blood circulation in the lung (pulmonary stasis) may justify the supposition of a more ready development of the pathogenic germs in the respiratory passages.

Pulmonary asbestosis is a disease in itself which must not be confused with other diseases of the lungs; it is an occupational disease non-infectious and non-contagious. It is of slow progressive evolution but

when the irritant action of the asbestos dust inhaled has ceased the fibrous process is generally arrested.

Cases with a fatal issue are rare and at the present time, with modern means of protection, with highly perfected exhaust and ventilation apparatus they should no longer occur.

Pulmonary tuberculosis is on the other hand an infectious disease of slow progressive and quite characteristic evolution; and the anatomopathological data and pathogenesis are likewise typical.

It may be conceded that the inhalation of particles of asbestos, by causing chronic irritation of the respiratory passages of the lung, may favour in a limited number of cases, installation of the Koch bacillus.

CLINICAL AND RADIOLOGICAL NOTES ON PNEUMOCONIOSIS DUE TO ASBESTOS

BY DR. GIOVANNI MUSSA

Dr. Mussa reports the result of examinations of workers employed in the Nola Canavese factory for the treatment of asbestos and india rubber.

All the workers who have worked for some time in the establishment show lesions of pneumoconiosis which can be recognised clinically and radiologically.

Very often previous case history provides no positive data and individuals showing lesions in a fairly advanced state do not feel any particular discomfort.

The first signs experienced subjectively are: breathlessness on slight fatigue, dry cough and later expectoration of small quantities of mucous.

Clinical examination reveals in many of the cases more or less accentuated dullness in the right infrascapular fossa of the scapula—region in which the vesicular rales are harsher and the vocal and tactile tremor more accentuated.

There is sometimes cardiac transversal dilatation; the apex beat is displaced a little beyond the nipple line; the second sound more accentuated at the base, sometimes with duplication of the aortic second sound.

The radioscopic examination reveals: marborisation distributed bilaterally in the hilar and perihilar zones which in the most advanced cases considerably reduces transparency. Sometimes there is infiltration of the bases. The apices are almost always free and motile. Examination of the sputum has not revealed the presence of asbestos crystals.

No case of association of pneumoconiosis with tubercular lesions was met with.

RADIOLOGICAL AND CLINICAL STUDIES EFFECTED AMONGST THE CARRARA MARBLE WORKERS

BY DR. LUIGI TURANO

DIRECTOR, INSTITUTE OF RADIOLOGY, CIVIL HOSPITAL, CARRARA

I have examined 105 workers in regard to each of whom, subsequent to clinical examination, and wherever possible, examination of the sputum, radioscopic and radiological examinations were made. I have examined workers employed in marble grinding and in other workshops

where there was intense grinding, taking care to examine workers of all ages, with all grades of working experience (in point of time—maximum fifty years) and from all kinds of work: sculptors, rough hewers, sawyers, polishers.

I have met with pleuritic lesions (remains of basal pleurisy, interlobular hyperplasia, etc.) in a proportion of about 10 per cent. and these in view of their extent I am tempted to connect with the effect of dust inhalation, for though the dust does not become accumulated on account of its facility for becoming dissolved in the respiratory parenchyma it nevertheless produces very probably pleuritic reactions by reason of the continuous irritation which it sets up.

I must state that in all those cases in which I found alterations of the pleura there were no tubercular antecedents (with the exception of two cases), but on the other hand as will be seen later there were clearly noted changes in the radiograph of the lungs.

I only found 4 per cent. of cases of calcification, a percentage which it will be agreed is too low and which rules out of account the possibility of carbonate of lime—inhaled, even in a continuous and intense degree as is the case for workers in the marble industry — becoming localised and accumulating in the pulmonary tissues.

The fact which struck me next was, however, that of having found in 28 per cent. real changes in the radiograph of the lung, consisting in a very marked reinforcement of the latter, in an arborescent aspect and a thickening of the vessels themselves.

Now if all the radiographs shown be examined this strongly reticulated aspect of the vascular network, the alterations in which may be due to the following causes, will be clearly seen:

- (1) either the vessels are affected by the thickening process (very probably phenomena of endoperiarteritis) as found in the case of workers subjected to dust inhalation, as has been clearly demonstrated by pathological anatomy;
- (2) or there are phenomena of actual lymphangitis, as shown by certain radiographs;
- (3) or the vascular network which in many cases stands out against the great transparency of the pulmonary field may be interpreted as a change of slight extent due to emphysema which reaches a high incidence rate among the workers.

However that may be, the facts which I have just mentioned provide such ample evidence, that it is unnecessary to insist further on the fact; on the other hand I can merely advance hypotheses relative to the interpretation of the symptoms, since it is evident that only verification by post-mortem examination can reveal the truth.

The above-mentioned alterations correspond to what I had noted with regard to the initial stage of pneumoconiosis, for they are lesions of slight importance. In no case did I find distinctly diffuse nodular pictures as are usually met with in pneumoconioses and especially in those produced by silica and by iron.

On the other hand, the observations which I have made in regard to radiographs of tubercular marble workers established bacteriologically are interesting.

In the case of five workers who showed the Koch bacillus in the sputum and who had a previous tubercular history the radiological examination provided strange pictures as will be seen on the relative plates. In one of them is seen opacity of the medial region of the left lung with dissemination of small shadows certain of which show blurred

outlines, others clear outlines, whilst the apical and subapical regions are perfectly free.

In another case on the other hand there is seen (fig. 4)¹ in correspondence with the lower region of the right lung an opaque patch as large as a tangerine with blurred outlines, whilst the remaining parts of the lung and in consequence the apices and the subclavicular regions are perfectly free.

It is unnecessary for me to stop to demonstrate the fact that such radiological pictures are very rare, I might even say atypical in proportion to the ordinary aspects of pulmonary tuberculosis, which we have the opportunity of observing. Yet this atypical character, these strange forms of tuberculosis which occurred in the case of two workers—sculptors who had been working one for 27 years and the other for 5 years on white and coloured marbles—are due according to available evidence to associated tuberculosis and pneumoconiosis; that is to say, that the silica dust contained even in very slight quantity in the marbles, in particular in the coloured marbles, had in my view, on account of conditions which we are unable to detect, encountered special predisposition suitable to its fixation and association with tuberculosis, thus rendering possible pulmonary tuberculosis in sites which are atypical for this disease.

I must in closing recall that studies particularly of a statistical nature conducted by the Director of the Health Bureau of Carrara, Dr. Mazzitelli, have clearly revealed the fact that tuberculosis at Carrara does not show special gravity as revealed by the mortality rate for workers. Yet this infection does not however on the other hand, as erroneously believed by some, follow a particularly benign course, first because the marble dust becomes dissolved in the pulmonary tissues and consequently the tubercular lesions are not influenced by inhalation of marble dust.

In conclusion the changes met with amongst Carrara marble workers may be classed in the initial stage of pneumoconiosis, that is to say comprising the least serious forms of the disease, such as the very marked reinforcement of the pulmonary outline, due as demonstrated by the personal observations just quoted, to the processes of arteritis and lymphangitis, and in certain cases equally to conditions of emphysema usually present amongst those workers.

I have also found frequent pleuritic changes which can be related to inhalation of marble dust, but never however lesions of the pulmonary parenchyma.

The radiological aspect of pulmonary tuberculosis amongst the workers examined is on the other hand highly important, since it shows an atypical picture on which are noted lesions with unusual sites and apical and subclavicular regions unaffected. It is this fact which has led me to admit the probability of a combination of pneumoconiosis and tuberculosis.

Finally statistical as well as radiological data justify absolute exclusion of the theory of a particular benign or malignant course of tuberculosis amongst marble workers, as likewise of any kind of predisposition to the said specific disease.

¹ This refers to the radiographs exhibited by Dr. Loriga, which are not reproduced here.

SILICOSIS IN THE NETHERLANDS

BY DR. W. R. H. KRANENBURG,

MEDICAL ADVISER TO THE FACTORY INSPECTORATE AT THE HAGUE

INTRODUCTION

Our knowledge of silicosis is based chiefly on information obtained through the introduction of the Stonemasons Act and the medical examinations of adult workers in the stonemasons' industry established in pursuance of that Act.

PREVIOUS HISTORY

"Stonemasons' disease" was for many years classified with tuberculosis, where at the present time it would in many cases be more accurately diagnosed as pseudo-tuberculosis. This is not a matter for surprise when it is considered that, in the light of our present knowledge, the symptoms of this disease may take a form similar to those of lung tuberculosis, and when the statistics of that time are studied.

According to Sommerfeld¹, on a medical examination of 2,013 stonemasons in 1899, 169 were tuberculous, while 10.8 per cent. were noted as strongly suspected of tuberculosis.

The higher death-rate than in less unhealthy occupations, which was to be expected from the bad health conditions among stonemasons, appears from two Dutch statistical returns relating to death-rate according to occupation calculated for various age-groups for ninety-six occupations and combinations of occupations.

During the years 1891-1896 the death-rate among stonemasons

¹ *Verhandlungen der Deutschen Gesellschaft für öff. Gesundheitspflege zu Berlin, Sitzung vom 26. März 1900.*

calculated for all men between eighteen and fifty years of age was greater than in any other occupation and the same was the case in the period 1896-1900. Even such injurious occupations as compositor, cigar maker and diamond cutter show a considerably lower death-rate.

It is noteworthy that in the age-group 18-24 years the death-rate differs little from the average for all occupations, while the highest death-rate is to be noted in the age-group 36-50 years. The difference in the mortality figures increases with the length of employment in the occupation. In the statistics covering the same period of five years relating to causes of death according to occupation and age, the mortality from diseases of the respiratory organs in the age-group 18-50 years is seen to be considerably higher among stonemasons than the average for all occupations.

In the period 1886-1898 Sommerfeld mentions that out of 952 stonemasons ¹ dying in those years, 87 per cent. died of diseases of the respiratory organs, in connection with which it should be remembered that in Germany a great deal of sandstone is worked, as was formerly the case in the Netherlands, while in Belgium a large quantity of limestone from the local quarries is worked.

ENQUIRIES PRECEDING THE INTRODUCTION OF THE STONEMASONS ACT, 1911

Various important enquiries into the life and health of stonemasons in the Netherlands were carried out which, as a result of the indisputable evidence of the unfavourable health conditions, led to the introduction of this Act.

In the annual reports of the Factory Inspectorate for 1903 and 1904, a detailed and carefully prepared report was published by the then assistant factory inspector, C. J. P. Zaalberg, relating to conditions and evils in the stonemasons' industry.

In 1906 177 stonemasons were examined by Dr. Elias ² in Rotterdam, but without an X-ray examination. As a result of symptoms agreeing with those in tuberculosis, 22 stonemasons were considered as suffering from tuberculosis and a number of others as more or less suspect.

¹ Workers in stone, not quarry workers.

² S. ELIAS: *Iets over steenhouders en hun oek*. Rotterdam, Immig & Zn., 1909.

In the same year a Commission¹ was appointed, on the proposal of the Directorate of the Social-Technical Association of Democratic Engineers and Architects, to carry out a more thorough enquiry into the injurious effects of stonemasons' work and the necessary measures for remedying the evils. With the co-operation of various doctors 356 stonemasons were medically examined, with the result that 52 were found to be obviously suffering from lung tuberculosis and 62 suspected of this disease. No sufficient grounds were found for the high death-rate from tuberculosis in the use and abuse of alcohol, fatiguing labour, or the vibration of the chest from the stroke of the hammer.

The microscopic structure of various kinds of stone dust examined confirmed the impression that granite and sandstone constituted a danger owing to the fine texture of the dust and the small cohesion of the dust particles. Even then the question was discussed whether the inhaling of particular kinds of dust prepares the ground for the tubercle bacillus.

Various data given below are taken from the report of this Commission.

Kinds of Stone

Natural stone is worked in the Netherlands for various purposes in a great variety of kinds and is for the most part imported from abroad.

Natural stone is only found in the Netherlands itself in certain places in the south of the country; limestone in the Pieters Mountain near Maastricht in South Limburg; sandstone and limestone near Kunrade. A kind of freestone is used on a large scale in the Netherlands for engineering works and in domestic building, which is generally known to stonemasons as "blue stone" and which is a natural limestone obtained from a number of Belgian quarries. In addition to this limestone other kinds of limestone are employed, such as Morley, Roche d'Euville and Savonnière, from the quarries in the north and north-east of France, and marble from Italy, Belgium and Greece. Granite is imported from Sweden, Norway, Germany and Scotland. The dust both from the Belgian limestone and the French limestone is regarded by stonemasons as less troublesome than sandstone dust. The use of sandstone is chiefly confined to monumental buildings and to decoration, while

¹ STEENHOEWERSARBEID EN STEENHOEWERSZIEKTE: *Rapport*. Rotterdam, 1910.

building proper is carried out with brick. In addition to the above-mentioned sandstone quarried in the country, sandstone from Teutoburg, Oberkirchen, Bentheim, Gildehausen, Bremer and now also Nivelstein sandstone, imported from Germany, and Bollendorf, Pilsen, La Rochette, Udelfangen and Borne sandstone from Luxemburg are worked.

As the result of many years' experience the Dutch stonemasons regard the Teutoburg as the most injurious to health of all kinds of sandstone, the Oberkirchen, Bentheim and Gildehausen, among others, as somewhat less injurious, while the Bremer sandstone is also considered as among the dangerous kinds. The Udelfangen and Borne sandstones are less feared and are assimilated to such limestones as d'Euville, Morley, etc.

It has been shown in a remarkable way by a chemical analysis for determining the lime content of various kinds of stone, carried out by the chemical engineer De Voogt in his laboratory, on the proposal of Sleswijk¹, of Delft, that a parallel exists between the estimate of the dangerousness of particular kinds of stone from sandstone to limestone and the presence or absence in greater or less degree of lime.

The following table gives a summary of these results:

Sandstone free from lime	Limestone, Belgian limestone, and lime sandstone containing lime
Oberkirchen Bentheim Gildehausen Red Bremer	Udelfangen sandstone contains 13 per cent. lime. Roche d'Euville limestone 16.7 per cent. Hard Morley limestone 17.9 per cent. Soft Morley limestone 27.2 per cent. Belgian limestone 20.4-21.4 per cent. Shell limestone 25.7 per cent.

The mixture of lime seems to exercise a favourable influence on the dangerousness of sandstone. The same appears to apply to clay and coal dust².

Collis and Gilchrist³ however observed in coal-heavers after several years' work " signs similar to those widely regarded as characteristic of silicotic fibrosis ".

¹ *Bedrijfshygiënische vraagstukken Tijdschr. v. Soc. Hyg.*, 19th Year, 1917, No. 4.

² HEFFERMANN and GREEN: *Journal of Industrial Hygiene*, Vol. X, 1928, No. 10, p. 272.

³ *Journal of Industrial Hygiene*, Vol. X, 1928, No. 4, p. 109.

Stonemasons' Tools

The tools most in use in stone working are illustrated in figs. 1, and 2. Nos. 1-7 (fig. 1¹) are chisels of various kinds and weights which are manipulated by means of a wooden hammer varying in form and weight; the pointed chisel (3 and 4) is used for cutting away larger protrusions on the stone; the Bouchard chisel (7) is used for obtaining an equally rough pointed surface. All these tools, in the working of stone, give rise to dust. The fact of the toothed chisel (6) becoming blunt and consequently unuseable has led to the invention of a handle provided with a slot in which an inset piece with teeth of various kinds is inserted (6a), which has proved economically more advantageous.

In addition to the chisels, the tools shown in fig. 2, Nos. 10, 11, 12, 13 and 14, are in use.

The Bouchard hammers (10 and 11), heavy iron hammers with wooden handles, are chiefly used in the working of Belgian limestone. On sandstone the point of the hammer soon becomes blunt, which is uneconomical. The stonemason's beam (13 and 14) is used for the same purpose as the Bouchard hammer and consists of from ten to seventeen pointed chisels placed side by side and fixed by a wedge in an iron frame with an iron handle. These tools are much heavier and consequently much more fatiguing to work than ordinary chisels, while the creation and dispersion of dust is considerably greater.

Working Position

It is obvious that the chance of inhaling dust is influenced by the position of the stonemason while cutting. The cutting of the stone is the dangerous work which is generally carried out in a sitting position, in connection with which a crouched position is to be condemned. (See fig. 3.)

Age of Commencing Work

In the enquiry by the Commission into the age at which stonemasons commence work, it was found that formerly even children of ten, eleven and twelve years of age in not inconsiderable numbers (106 out of 356 stonemasons examined) chose this dangerous occupation as their calling.

¹ The illustrations (figs 1-4) are given after p. 534.

Hours of Work

The hours of work varied from 10 to 13 per day. Piecework led to great over-exertion owing to the desire to earn a great deal in a short time.

Housing Conditions and Workplaces

The housing conditions were not worse than with other classes of workers. Workplaces were generally in a miserable condition, lacking sufficient ventilation, too low and too small. The lack of open spaces and open sheds for outdoor work in fine weather were among the defects noted.

Abuse of Alcohol

Irregular living and abuse of drink are commonly regarded as causes of the outbreak of "stonemasons' disease". As regards the abuse of drink, this was certainly considerable, especially among pieceworkers, although it is well known that a noticeable diminution is observable in this respect.

Conclusions

The conclusions of this important report are, briefly stated, the following: tuberculosis among stonemasons should be regarded as an occupational disease. The health conditions of stonemasons in the Netherlands are very unsatisfactory, the death-rate from lung tuberculosis and diseases of the respiratory organs abnormally high. Stone dust, and particularly the dust arising in the working of many kinds of sandstone, must be regarded as the primary cause of the abnormal sickness and mortality figures. The working of Belgian limestone and other kinds of limestone is less prejudicial to health. The introduction of a law for the combating and prevention of "stonemasons' disease" is considered as urgent.

Measures for Protection

The following are considered as measures for the protection of health: preliminary medical examination of young workers before entering the occupation, not earlier than sixteen years of age, followed by periodical re-examination; removal from the occupation of cases of incipient tuberculosis, and at the same time the assimilation of this occupational disease to an industrial accident; limitation of hours of work to eight hours a day, with regulation

of rest periods; strict regulations relating to the arrangement and use of workplaces; the requirement that certain kinds of stone should be worked in a moist condition; prohibition of the working of certain kinds of sandstone, together with prohibition of their importation, and prohibition of the use of the stonemason's beam.

The wishes expressed on the basis of this report, and the minimum demands made for measures for the protection of stonemasons, led in a short time to the introduction of the desired legislation.

THE STONEMASONS ACT, 1911-1921 ¹

This Act, containing regulations relating to the special risks to safety and health connected with the work of stonemasons, came into force in 1913 ² and was amended in 1921 ³.

Its principal provisions are summarised below.

The employer must see that the workplaces and their accessories and the methods of work comply with certain regulations ⁴. The distance between the chisels used by persons doing stonemason's work on different pieces of work must be at least 70 centimetres, when working sandstone on one and the same block 1½ metres, in the case of stone other than sandstone at least 1 metre except in the case of fine work. Stones worked, being sandstones or other stones, which absorb water without involving any serious difficulty in working, must be kept moist. The use of the stonemason's beam in such work is prohibited and also the use of the Bouchard hammer, where the same weighs more than 3¼ kilograms, except in working granite. An open space for working in the open air must be available in the workplace. The hours of work per day, which were originally limited to nine for workers over seventeen years of age and seven and a half for young workers under seventeen years of age, have since the amendment of the Act in 1921 been fixed at eight hours a day and forty-five hours a week for workers over eighteen years of age and seven and a half hours a day and forty-two hours a week for workers under that age. The rest period after three and a half hours of work must be at least half an hour. Piecework is prohibited for young persons under eighteen years of age. Employment in stonemason's work is prohibited for young persons under fourteen years of age.

¹ *Staatsblad* 315, Act of 7 October 1911.

² 1 March (sections 2 and 4 on 1 May).

³ 11 Nov. 1921, *Staatsblad* 1167.

⁴ *Steenhouwersbesluit* 1913, *Staatsblad* No. 38, amended 1923, *Staatsblad* No. 297.

COMPULSORY MEDICAL EXAMINATION

Every stonemason under twenty-one years of age must be in possession of a stonemason's card, which is issued to him after medical examination carried out free of charge, if it does not appear that the performance of stonemason's work will give rise to any special danger to his health. If the examination took place before eighteen years of age, the stonemason's card ceases to be valid after one year and a fresh examination must take place. A person to whom a card is refused may, within fourteen days of the date borne by the notification of such refusal, apply to the Minister of Labour, Commerce and Industry for a re-examination, for which one or more medical practitioners are designated.

The compulsory examination of adult stonemasons, that is to say, at twenty-one years of age and over, was introduced for the first time after the amendment of the Act in 1921. A stonemason's card is issued irrespective of the result of the examination. If at the date of the examination the stonemason is eighteen years of age or older, the card ceases to be valid after the expiry of three years from that date. Before 1921 an adult stonemason could be medically examined free of charge voluntarily with a view to ascertaining whether the performance of stonemason's work would involve special danger to his health.

*Compulsory Examination of Stonemasons
under Twenty-One Years of Age*¹

Medical examinations before and after entering the occupation are at present carried out by five medical practitioners in permanent service belonging to the Central Service of the Factory Inspectorate and by private medical practitioners appointed in accordance with a specified scheme. Examination has in certain respects a preventive effect, in so far as it dissuades persons of weak constitution from choosing the stonemason's trade, in the anticipation that they will be rejected. Examination has resulted in the weeding out of young persons with defective lungs. During the first years after the Act came into force not a few young persons were rejected. Thus in 1913, out of 266 examined, 29 were rejected; in 1914, out of 254 examined, 23 were rejected; while in 1924 and 1925 only one person was rejected out of 120 and 146 respectively examined.

¹ DEPARTMENTAL COMMITTEE FOR THE DIAGNOSIS OF SILICOSIS: Home Office, London, 1929. (Cf. "The Value of Initial and Periodic Examination.")

The grounds for rejection are various: mostly lung defects, also general debility, kidney diseases, curvature of the spine, chronic otitis media, insufficient nasal respiration, etc. It has not been possible up to now to take X-ray photographs of the lungs of young persons between fourteen and eighteen years of age.

Compulsory Examination of Adult Stonemasons

The compulsory medical examination of adult stonemasons, that is to say, at twenty-one years and over, is based on section 3, subsections (1) and (8) of the Stonemasons Act, 1921. The periodical examination takes place at the expiration of three years from the time when a stonemason's card was issued irrespective of the result of the examination. There is no question therefore of rejection, as in the case of stonemasons under twenty-one years of age. If the result of the examination so requires, the examining medical practitioner gives the stonemason instructions as to the precautions to be adopted in connection with his work and the manner in which he should live in order to avoid injury to his health, so far as possible.

Co-operation of the Factory Inspectorate with the Public Health Inspectorate and the Consultation Offices for Tuberculosis

This co-operation has made it possible to obtain a considerable number of X-ray photographs of stonemasons examined in the Consultation Offices for tuberculosis in various localities in the Netherlands. The supplementing of clinico-physical examination by an X-ray photograph has proved of great importance for forming an opinion of lung affections due to the inhaling of stone dust.

Medical Examination of Stonemasons

As a general rule every stonemason is examined, in accordance with a uniform scheme for the whole country, by two medical practitioners, one a medical officer in the Factory Inspectorate and one an examining medical practitioner of the Consultation Office for Tuberculosis. Where this is not possible, the examination is carried out by two medical officers of the Factory Inspectorate. The stonemason is summoned to attend for examination at a specified centre by the district chief of the Factory Inspectorate.

The first general examination of adult stonemasons took place in 1923, the second in 1926 and the third in 1929, so that it has been possible, although not in a large number of cases, to compare with

each other the clinico-physical condition of the lungs of the same person at the three dates and three X-ray photographs.

The subjoined table gives a survey of the total number examined and the X-ray photographs taken in the above-mentioned years.

Year	Number examined	X-ray photographs ¹	
		Total taken	With positive results
1923	963	274	232
1926	889	111	97
1929	799	69	57

¹ In addition a number of X-ray examinations were made without photographs being taken.

How indispensable X-ray examination is as a supplement to clinico-physical examination for the purpose of judging the state of health may be seen from the subjoined table taken from the first general examination of 1923.

CLINICAL AND X-RAY EXAMINATION OF 274 CASES, CLASSIFIED
ACCORDING TO THE NUMBER OF YEARS OF EMPLOYMENT
IN THE OCCUPATION

Lung Affections noted in 1923

	Years of employment							Total examined
	0-5	5-10	10-20	20-30	30-40	40-50	50-60	
Clinical, affection; X-ray examination, no affection	—	1	1	4	2	1	—	9
Clinical, no affection; X-ray, affection	—	8	41	50	24	11	1	135
Clinical, affection; X-ray, affection	—	4	17	34	30	8	4	97
Clinical, no affection; X-ray, no affection	—	1	12	17	3	—	—	33
	—	14	71	105	59	20	5	274

From the above figures it will be seen that in nearly half the number of cases the X-ray examination gave more information than the physical examination. In a corresponding statement on 69 cases from the general examination in 1929, lung affections

are not shown clinically in 19 cases, but are shown in the X-ray examination, and in 38 cases both clinically and by X-rays.

Subjective Complaints and Objective Phenomena

It is noticeable that in the general examination of stonemasons in 1923, 1926 and 1929, few complaints were received as to the state of health of the patients; most of them felt quite well, though a certain number complained of shortness of breath when moving. Here and there men complained of coughs with little or no sputum, which explains why altogether an examination of the sputum was made in only 48 cases, with positive results as to the presence of tubercle bacilli in 11 cases. After inhaling stone dust for many years, complaint was made of irritation in the throat and a stifling feeling in the breast, with relative shortness of breath, an inclination to cough and expectoration, especially on rising in the morning. Generally speaking, percussive irregularities are few and auscultatory phenomena more striking: rough, heightened or weakened respiratory rustling, lengthened or jerky breathing in one or both apices or other places, also cracking and dry snoring noises, varying in strength and area, seldom damp or crackling. Coughing and sputum which is not characteristic often only occur when bronchitis appears as a complication.

The X-ray picture ¹ of pneumoconiosis, due to the dust of various kinds of stone, does not differ in its various degrees from those given for silicosis by various investigators ²: (1) enlarged hilus-shadow, increased appearance of the retiform tissue and linear shadows; (2) increased appearance as in (1), and the appearance over a wide area of stippled shadows (mottling), and (3) appearance as in (2) and nodular shadows, large close mottling.

The question of the mutual relations between pneumoconiosis and tuberculosis, whether the tuberculosis only appears in later years as an infection on a foundation of silicosis—tuberculo-silicosis—or the silicosis is secondary to tuberculosis latent in youth and manifesting itself later—silico-tuberculosis—appears to be more

¹ Out of 274 cases radiologically examined, 42 showed no affection. For information as to the special cases (139) of silicosis, reference should be made to the reports on this head concerning stonemasons employed for many years in the occupation in the medical examinations of the Factory Inspectorate in 1923. Not all cases are summarised, where there are similar cases with insignificant differences. (*Centraal Verslag der Arbeidsinspectie over 1923. Algemeene Landsdrukkerij, 1924.*)

² Jarvis, Sutherland and Bryson. Irvine includes incipient mottling in the first stage.

and more answered in this sense¹, that each of the two processes favours the development of the other, and that the tubercle bacillus, appearing as a secondary factor, often seriously threatens health and life. In this connection the case is noteworthy of a stonemason forty-seven years old who, on a clinical and X-ray examination, showed an affection of the apex of the right lung without exhibiting radiologically any degree of silicosis after thirty-four years' work on sandstone.

A concise critical survey of the position of the question of silicosis and tuberculosis appeared in connection with the proceedings of the Fourth Meeting of the Permanent International Committee for the Study of Occupational Diseases at Lyons in 1929 under the signature of Böhme in *Klinik und Silicosis II*, which also contained a study by Mavrogordato on the ætiology of silicosis.

The clinical distinction between tuberculo-silicosis and silico-tuberculosis², as Watkins-Pitchford justly remarks, makes no essential difference to the fundamental pathological processes.

Since 1923, 16 stonemasons have died, of whom 9 died from pulmonary tuberculosis; only in 2 cases was it possible to confirm the clinico-radiological examination by a post-mortem examination. Dutch stonemasons generally die at home and not in a hospital, so that a post-mortem examination rarely takes place. That in a number of cases the triad—clinico-physical examination, X-ray examination, and post-mortem examination—is necessary for the definitive judgment of the process is obvious. On a post-mortem examination of a stonemason sixty-six years old, numerous permanent foci were found in both lungs, and here and there caverns with secondary tuberculosis of the wall, although the X-ray photograph had not sufficiently demonstrated this. The man died of hæmorrhage from a cavern as large as a fist.

Dust Content of the Air in Working Various Kinds of Stone

A certain number of analyses of air for determining the dust content were made by the factory inspector, Scholte, close to the mouth of a stonemason. When working moist Oberkirchen sandstone the results were 45.8, 99 and 109 mg. per cubic metre of air;

[Text continued on page 526.]

¹ BÖHME and LUCANUS: *Deutsche Medizinische Wochenschrift*, 53rd Year, No. 38, p. 1604.

² WATKINS-PITCHFORD: *Journal of Industrial Hygiene*, Vol. IX, No. 4, April 1927.

	In 1923		Kinds of stone worked in order of working from youth onward before 1923	Clinico-physical results		
	Age	Years in occupation		1923	1926	1929
1	38	26	Belgian limestone, sandstone, ¹ marble	—	—	Snoring sounds 2 apices
2	37	25	Belgian limestone, sandstone (not much)	Percussion dull left upper	—	—
3	44	32	Belgian limestone	—	—	—
4	34	21	Belgian limestone	—	—	—
5	35	23	Belgian limestone, sandstone (not much)	—	—	—
6	62	50	Belgian limestone, marble (not much)	—	Snoring sounds	—
7	53	40	Sandstone, Belgian limestone, granite	—	—	Bronchial breathing right
8	45	33	Sandstone, Belgian limestone, granite	Snoring sounds	Snoring sounds	—
9	52	32	Belgian limestone	—	Snoring sounds	—
10	34	20	Belgian limestone	—	Snoring sounds	Weak breathing right
11	27	14	Belgian limestone, granite, sandstone	Percussion dull left upper	—	As in 1923
12	38	26	Sandstone, Belgian limestone	Snoring sounds	—	—
13	46	33	Belgian limestone, marble (very rarely)	—	Percussion dull left	Heightened breathing
14	39	27	Belgian limestone, sandstone	—	—	—
15	57	43	All kinds of stone	—	Snoring sounds	Snoring sounds right.
16	36	23	Belgian limestone, marble, sandstone	Snoring sounds, weak breathing	—	Weak breathing
17	34	21	All kinds of stone	Snoring sounds	—	Percussion dull, right upper
18	31	19	Belgian limestone, sandstone	Snoring sounds	—	—
19	30	15	Belgian limestone, sandstone (rarely)	—	—	—
20	33	21	Belgian limestone, sandstone (rarely)	—	—	—
21	31	18	Sandstone, Belgian limestone	—	—	—
22	35	21	Belgian limestone, sandstone	—	—	—
23	40	26	Sandstone, Belgian limestone	—	—	—
24	38	20	Marble, Belgian limestone, sandstone (seldom)	Snoring sounds	Snoring sounds	Heightened breathing left upper
25	53	41	Marble, Belgian limestone, sandstone (seldom)	—	—	—

¹ First stage: hilum shadows and linear shadows (and reticular).

² Second stage: mottling.

X-ray results			Various observations
1923	1926	1929	
—	Stippled lung ²	Snowstorm lung ³	1926-29, marble worked
—	—	1st stage (incipient)	1923-29, Belgian limestone worked.
—	1st stage (incipient) ¹	Stippled lung	Same kinds of stone as before 1923
—	—	Stippled lung	Same kinds of stone as before 1923
—	—	Stippled lung	Same kinds of stone as before 1923
—	1st stage (incipient)	Same	Same kinds of stone as before 1923
1st stage (incipient)	Same	Same	1923-29, Belgian limestone; cough
1st stage (incipient)	Same	Same	1923-29, Belgian limestone, marble worked
1st stage (incipient)	—	—	1923-29, Belgian limestone
1st stage (incipient)	Same	More linear shadows	1923-29, Belgian limestone, sandstone
1st stage (incipient)	Same	Same	1926-29, Belgian limestone, not much sandstone
1st stage (incipient)	Same	More linear shadows	1923-29, no stone cut
1st stage (incipient)	Stippled lung	Same	For 2½ years short breathing, same kinds of stone
—	—	1st stage	1923-29, same kinds of stone
Stippled lung	Same	Same	1923-29, Belgian limestone, sandstone
Stippled lung	Same	Same	{ 1923-26, Belgian limestone and marble 1926-29, sandstone
Stippled lung	Increase	Same	
Stippled lung	Same	Same	Same kinds of stone as before 1923
Stippled lung	Same	Same	In 1926 left more linear shadows, same kinds of stone
Stippled lung	Same	Same	Same kinds of stone as before 1923
Stippled lung	Same	Same	1926-29, all kinds worked
Stippled lung	Same	Increase	1926-29, sandstone worked
Stippled lung	Same	stippled lung	1923-29, sandstone, Belgian limestone
Stippled lung	Same	Same	Same kinds of stone as before 1923
Stippled lung	Same	Same	1926-29, Belgian limestone, marbled worked

³ Third stage: shadows as first and second stage and nodular shadows, large close mottling.

	In 1923		Kinds of stone worked in order of working from youth onward before 1923	Clinico-physical results		
	Age	Years in occupation		1923	1926	1929
26	42	29	Belgian limestone, much sandstone	Weakened breathing apices	Same	Same
27	36	21	Sandstone (much)	—	—	Percussion dull right upper
28	61	49	Marble	Snoring sounds	Percussion dull both apices	Snoring sounds
29	43	27	All kinds of stone	—	Snoring sounds	Snoring sounds left lower back and weakened breathing
30	47	33	Belgian limestone, not much sandstone	Snoring sounds	—	—
31	44	32	Belgian limestone, sandstone	Snoring sounds	More snoring sounds	Snoring sounds and percussion dull
32	61	48	Belgian limestone, sandstone	Snoring sounds	Same	Percussion dull upper
33	56	42	Sandstone, Belgian limestone, marble	Weakened breathing	Same	Same
34	40	26	Much sandstone	—	—	—

with dry stone 58.7 and 87.3 mg.; in working dry Belgian limestone, 58.5 and 159.4 mg. per cubic metre of air.

Teleky ¹ reports a typical case of silicosis ("snowstorm lung"), notwithstanding that the stone was worked in a moist condition, affecting a stonemason, who had worked on moist sandstone for fourteen and a half years.

Kinds of Stone Worked according to Quartz Content

It has already been mentioned that the stones worked by stonemasons in the Netherlands are sandstones free from lime, sandstones containing lime and limestones with varying lime content, including Belgian limestone and marble, and also granite.

On the first general examination of stonemasons in 1923 it was found that the working of sandstone had gradually diminished, on the two later periodical examinations that Belgian limestone was chiefly worked, and also marble and granite, and to a lesser extent,

¹ TELEKY: *Reichsarbeitsblatt*, 1929, No. 26, III, p. 229.

X-ray results			Various observations
1923	1926	1929	
Snowstorm lung (incipient)	Same	Increase	1923-26, sandstone, half year, 1926-29, Belgian limestone 1923-29, no stone worked
Snowstorm lung	Increase since 1923	Increase	
Snowstorm lung	Increase	Same as in 1926	Short breath, habitual cough, no sputum, only marble 1923-26, much sandstone; 1926-29, all kinds, short breathing, cough
Snowstorm lung	Increase	Increase	
Snowstorm lung (incipient)	Same	Same	1923-29, Belgian limestone and granite
Snowstorm lung	Same	Increase	1923-26, sandstone 1 year; 1926-29, all kinds of stone; before 10 years sandstone
Snowstorm lung (incipient)	Same	Same	1923-26, sandstone
Snowstorm lung	Increase	Increase	1923-26, Belgian limestone and marble; 1926-29, Belgian limestone and sandstone; cough, short breath
Snowstorm lung	Same	Same	Percussion over both lungs slightly dull; 1923-29, sandstone

sandstone. A new kind of sandstone worked in recent years is the Nivelstein¹ sandstone already mentioned, in which the quartz grains are held together by a quartz-like cement and not by lime, clay, iron oxide, glauconite, or other cements². The Netherlands sandstone from Kunrade is very rich in quartz. An analysis showed sand and insoluble silicates 54.17 per cent., calcium carbonate 39.6 per cent., clay and iron oxide 4.8 per cent., and traces of magnesium carbonate. No special experience as to the danger of the working of this kind of stone exists as yet. The hardness of sandstone is determined by the size of the granules and the nature of the cement. If the injurious agent in the various morbid changes in lung tissue presenting the clinico-radiological character of silicosis is held to be quartz, SiO₂, it is important to know the quartz content of the kinds of stone in use in order to form an

¹ Onderzoek Technische Hoogeschool, Delft.

² THIELE and SAUPE: "Die Staublungenerkrankungen der Sandsteinarbeiter". *Schriften aus dem Gesamtgebiet der Gewerbehygiene*, Neue Folge, 1927, No. 17.

opinion as to the danger to health in working these various kinds of stone. This applies to the various kinds of Belgian limestone, other limestones, and also to marble and various kinds of granite.

The following analysis is given of limestone of Belgian origin: CaCO_3 95.67 per cent., SiO_2 2.56 per cent., and small quantities MgCO_3 and Fe_2O_3 .

The Maastricht limestone (Netherlands) already mentioned contains, according to a three-fold analysis, chiefly calcium carbonate and also SiO_2 in quantities from 0.38 to 2.25 per cent. The Kunrade limestone also contains only small quantities. Shell limestone, a limestone with pipe clay as cement, is practically speaking free from quartz according to German analyses ¹.

Marble ² may contain quartz, according to an analytical examination by Riddell and Rothwell of the dried lungs of a marble worker; the ash contained on analysis 2.34 per cent. quartz, while that of the lungs of town dwellers contained 0.60, 1.28 and 2.67 per cent.

Granite ³ from the Fichtelgebirge (Germany) contains 30 per cent. quartz without cement, the quartz being found between the other constituents.

Comparison of the X-ray Photographs in a Number of Cases of the Same Stonemason Examined in 1923, 1926 and 1929

For the purposes of this comparison thirty-four cases have been selected which present a compendious picture. The X-ray photographs were taken in the same consulting offices for tuberculosis in Amsterdam, The Hague and Utrecht. The medical examinations were conducted by the same doctors.

The number of years in the occupation varies, as shown by the subjoined table, from fifteen to fifty years. From the above-mentioned report of 274 X-ray photographs taken in 1923, it appears that affections of the lungs demonstrable by X-ray examination only appear after five years' stonemason's work, and between the fifth and tenth years, and in increasing degree up to thirty to forty years' work in the occupation.

In the column indicating the kinds of stone worked these are mentioned in the order in which they were worked from youth onward.

¹ *Ibid.*

² *Journal of Industrial Hygiene*, May 1928, p. 147.

³ KOELSCH and KAESTLE: *Die gewerbliche Staublungenerkrankung 1929*. Supplement No. 15 to *Zentralblatt für Gewerbehygiene*, p. 72.

The particulars of the clinico-physical results give a compendious statement of the relatively few phenomena in general.

From this table it will be seen that before 1923 2 out of the 34 stonemasons had worked sandstone alone all their lives, 4 had worked successively sandstone and Belgian limestone, 16 Belgian limestone and sandstone, 4 Belgian limestone only, one Belgian limestone and marble, 1 marble only, and 6 sandstone, Belgian limestone and granite.

In the period 1923 to 1929, the number of sandstone workers increased to 4, the number of Belgian limestone, limestone and marble workers together from 6 to 11. The increase of silicosis from 1923 to 1929 appears from the following:

Year	No affection	Stage I	Stage II	Stage III
1923	6	8	11	9
1929	—	9	15	10

Out of 6 stonemasons (Nos. 1 to 6) with no signs of affection in 1923, No. 1 worked from 1926 to 1929 on marble alone, before that chiefly on Belgian limestone, and to a small extent on sandstone, and in 1929 was shown to have a snowstorm lung. Stonemasons Nos. 3 and 4 worked before and after 1923 on Belgian limestone only, and in 1929 each had a stippled lung, while stonemason No. 5 showed practically the same symptoms after a large amount of work on Belgian limestone and a small amount on sandstone both before and after 1923. Out of the above 34 cases, not one appears to have improved, even where, as in cases 12 and 27, no stonemason's work was carried out for as long as six years. On the contrary, a change for the worse is observable in case No. 27, who had previously worked considerably on sandstone, notwithstanding that he worked no stone at all from 1923 to 1929, while in case No. 28, who had worked all his life exclusively on marble, and in 1923 already showed signs of a snowstorm lung, an aggravation was observable in 1926. Altogether, 18 out of the 34 cases are shown to have become worse either in 1926 or in 1929.

Stonemason No. 22 shows in 1929 an aggravation of his stippled lung after working on sandstone from 1926 to 1929 and previously on sandstone and Belgian limestone, while No. 32 shows similar phenomena, at least to the eye, and the same is the case with No. 34, who had worked largely on sandstone all his life. It is

worthy of remark that out of the 9 stonemasons presenting the typical phenomenon of snowstorm lung, 1 had never worked on sandstone, 2 only on sandstone, and the other 6 sometimes Belgian limestone and sometimes sandstone, and, to a small extent, granite.

Influence of Various Kinds of Stone

From the X-ray photographs taken in connection with the general examination of stonemasons in 1923, a number have been selected relating to stonemasons who in the course of their lives had worked on certain kinds of stone and others who had worked on more than one kind of stone, for comparison of the condition of the lungs in connection with the number of years' employment in the occupation ¹.

KINDS OF STONE WORKED AND NUMBER OF YEARS' EMPLOYMENT IN OCCUPATION

Condition of the Lungs as shown by X-Ray Examination

Years in occupation	Sandstone			Belgian limestone			Marble			Sandstone, Belgian limestone, granite						
	No affection	Stages			No affection	Stages			No affection	Stages			No affection	Stages		
		I	II	III		I	II	III		I	II	III		I	II	III
10-20	-	-	1	-	9	7	1	-	2	-	-	-	1	12	3	-
20-30	-	-	2	5	9	14	5	-	1	1	-	-	3	15	20	5
30-40	1	1	1	1	4	9	3	-	1	-	-	-	1	8	6	4
40-50	-	1	2	-	1	5	2	1	-	-	-	1	-	3	3	6
50-60	-	-	-	1	1	2	-	1	-	-	-	-	-	-	-	-
	1	2	6	7	24	37	11	2	4	1	-	1	5	38	32	15
	16				74				6			90 ¹				

¹ Among these 90, there are 3 cases of silicosis + tuberculosis (sputum positive).

From the above table it appears that out of 16 sandstone workers, 2 were already in the second stage and 5 in the third stage of silicosis after twenty to thirty years' employment in the occupation, as compared with the Belgian limestone workers, among whom, out of a total of 74 stonemasons, after the same number of years' employment in the occupation, only 5 were in the second stage and none in the third stage. Among the 90 stonemasons who worked various kinds of stone, thus including sandstone, the pro-

¹ These photographs are reproduced after p. 534.

portion is more unfavourable than in the case of the Belgian limestone workers, taking the third stage as the test, although relatively favourable in comparison with the sandstone workers.

A striking fact is the large number of Belgian limestone workers (18) showing no affection after ten to thirty years' employment in the occupation, as against only 4 stonemasons working on all kinds of stone.

The third stage of silicosis is found among Belgian limestone workers in smaller numbers (2) after forty to sixty years' employment, and therefore after a greater number of years' employment than in the case of sandstone workers (7).

One question that arises is: why, in a particular case, the working on sandstone only produces no silicosis, and the working on Belgian limestone, with a low quartz content and much lime, does produce it ?

Workplace and Manner of Living

The condition of workplaces, although improved in many cases, still leaves much to be desired.

The stonemason's manner of living, compared with an earlier period, twenty to thirty years ago, has changed for the better, especially as regards abuse of alcohol. The irregular life of a stonemason working at piecework in company with others of youthful years, away from their homes, with insufficient rest at night, and abuse of alcohol, has injured the health of many for the rest of their lives. At the first general examination in 1923, 194 of the 963 stonemasons examined stated that they had drunk a great deal of alcohol in their youth.

A number of stonemasons have died during or shortly after work in the restoration of churches and other monumental buildings in which large quantities of sandstone are worked.

Dust Goggles and Respirators

Dust goggles or respirators are seldom used and certainly not regularly.

The wearing of a respirator while engaged in strenuous work becomes burdensome in the long run. By way of experiment a stonemason wore a respirator every day for a month during his work. After a certain time, the pores were stopped up with stone dust clogged together with the moisture from breathing.

INSTRUCTION OF STONEMASONS

Under section 9 of the Stonemasons Act, 1921, provision is made for instructions respecting the nature of the dangers to which stonemasons are exposed, and in regard to which precautions are to be taken; the printed instructions must be affixed in the workplace and a copy on a smaller scale delivered to the stonemason personally. In addition to this, since 1923, in most of the large towns lectures have been delivered and discussions held by the medical adviser and the medical practitioners attached to the factory inspectorate.

The use of sandstone alone as little as possible remains of great importance.

ASSIMILATION TO ACCIDENTS FOR THE PURPOSES OF COMPENSATION

Preparations are being made for the assimilation of this occupational disease to an accident in pursuance of section 87 (a) of the Accident Act, 1921, as amended in 1928¹.

CONCLUSIONS

The introduction and application of the Stonemasons Act has led to a clearer insight into the character of the "stonemasons' disease" and a more intelligent procedure in combating it by the improvement of the working conditions and personal hygiene of stonemasons.

The preliminary medical examination and annual re-examination of young stonemasons to a considerable extent prevents persons suffering from lung tuberculosis entering upon and continuing in stonemasons' work.

The periodical (three yearly) medical examination of adult stonemasons has shown the indispensability of X-ray examination for forming an opinion of lung affections.

The working of sandstone alone must be regarded as more injurious to the lungs than the working of limestone alone. The working of sandstone alone does not always lead to symptoms of silicosis and, on the other hand, the working of limestone alone (Belgian limestone, marble) does not prevent silicosis in a serious

¹ *Staatsblad* No. 223, 1928.

form. The working of sandstone and limestone alternately appears to produce less serious results in the same period than the working of sandstone alone.

Compulsory medical examination both in the form of preliminary examination and periodical re-examination should be introduced for sand-blowers as well as for stonemasons.

Silicosis as an occupational disease of stonemasons should be assimilated to an accident for the purposes of the application of the Accident Act.

APPENDIX

Silicosis and Sand-Blowing

Considerable use is now made in industry of the sprinkling of quartz sand (river sand) on metal objects for the purpose of cleaning and in the etching of glass. Sand-blowing is carried out by blowing fine dry sand¹ from a pipe under air pressure, the pipe being directed by hand on to the piece of work and the worker standing in a closed room with his eyes and face protected by a dust helmet into which fresh air is introduced from without by a tube at the back. In cleaning smaller objects the latter are carried in a closed box with a glass front along the stationary blow pipe, while the worker outside the box directs the pipe on to the object to be cleaned, his hands and arms being placed in leather or rubber gloves with armpieces attached to openings in the front of the said box.

The dust helmet is burdensome when working for a long time continuously at blowing and is therefore frequently taken off, when the continued scattering of dust by other workers in the same room leads to unavoidable inhalation. The wearing of a suitable respirator for a short time might be used as a remedy for this. A forty-four-year-old sand-blower in an engineering works died after three years' employment on such work. On the post-mortem examination silicosis was found to be present in an advanced stage, but there were no signs of tuberculosis. The man had frequently worked without a helmet. In the blowing of sand on metal objects it is beaten to a fine powder and the raising and dispersion of dust is enormous. It is well known that serious lung affections² in the form of silicosis in its various stages arise also among this class of workers. In a cycle factory in the Netherlands an X-ray photograph was taken of a worker who complained of shortness of breath and the result showed the characteristics of snowstorm lung, although the man had inhaled no dust during the last few years but had previously done so in considerable quantities.

¹ Steel granules are not used (*Centraal Verlag der Arbeidsinspectie Nederland*, 1925).

² *Zentralbl. für Gewerbehygiene*, May 1928, p. 149.

The quantities of SiO_2 that a lung can contain appear from an analysis of the dried lungs of a sandblower by Riddell and Rothwell¹, in which 16.83 per cent. SiO_2 was found.

There has been no regular medical examination of sandblowers in the Netherlands, nor yet in Germany².

In the work already referred to, *Das Sandstrahlgebläse*, the measures for preventing the injurious effects arising from the use of sandblowing apparatus are particularly described.

On a lesser scale than in industry sandblowing is used in the cleaning of the fronts of buildings. By this process brick, sandstone and limestone are restored to their natural colour. To prevent the dispersal in the surrounding space of the dust from the powdered sand, a large awning is suspended from 1 to 2 metres from the front, so that the worker who remains for a long time in a thick cloud of dust is insufficiently protected by his mask. In this case also signs of pneumoconiosis in a serious form are found.

¹ *Loc. cit.*

² *Das Sandstrahlgebläse: Schriften aus dem Gesamtgebiet der Gewerbehygiene*, 1928, Neue Folge, No. 21, p. 45.

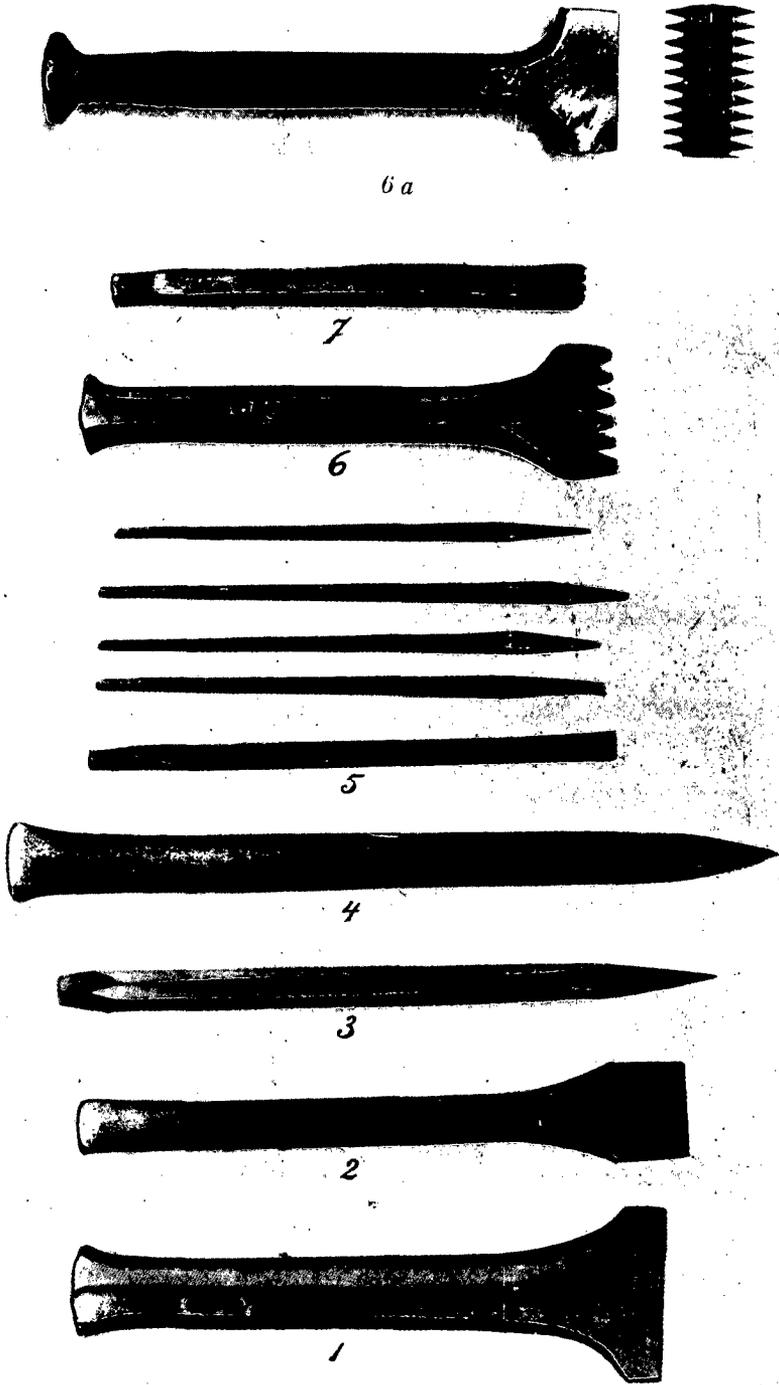


FIG. 1.

Silicosis in the Netherlands.
[To face p. 534.]

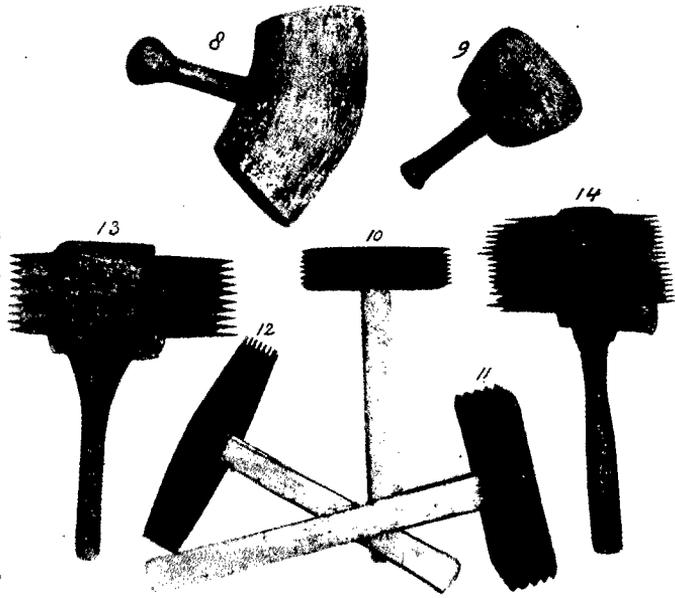
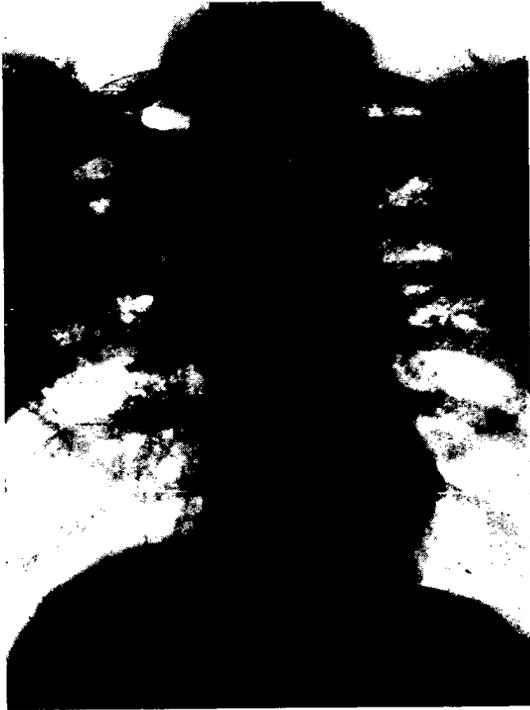


FIG. 2.



FIG. 3. — Stonemason at work (in good sitting position).

X-Ray Photographs of Various Cases



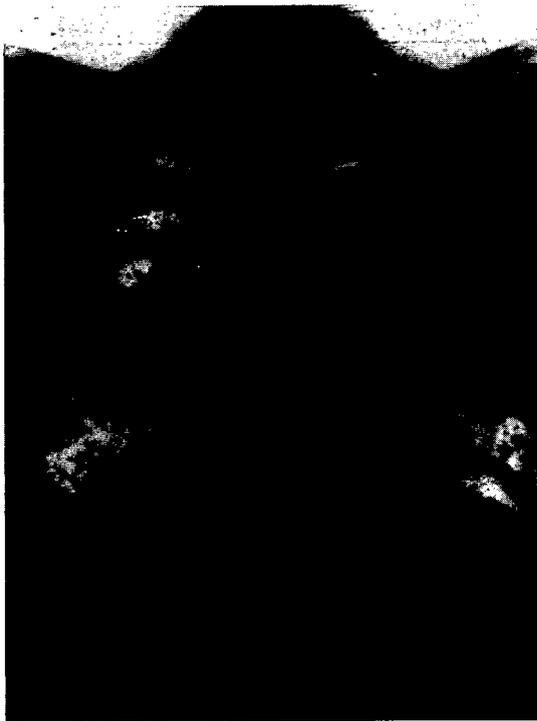
I



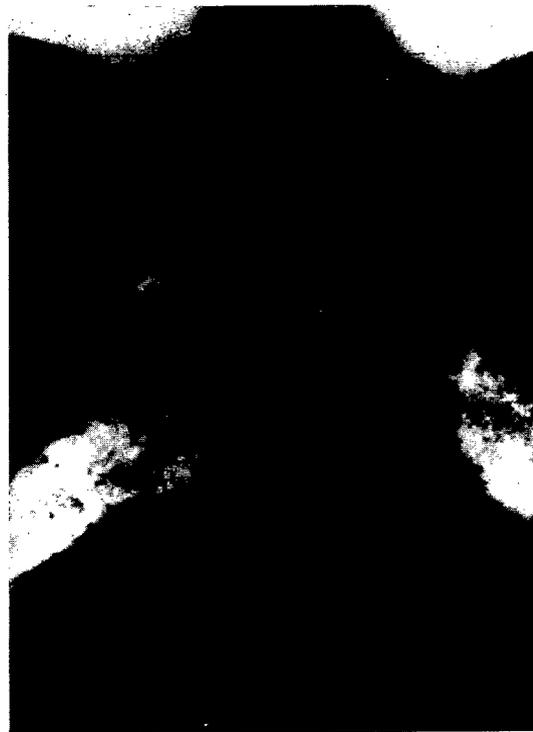
III

D. J., No. 29: 43 years of age; 27 years stonemason in 1923, before and after that date worked all kinds of stone.

X-ray photo. I: snowstorm lung, 1923. III: snowstorm lung, 1929, increased.

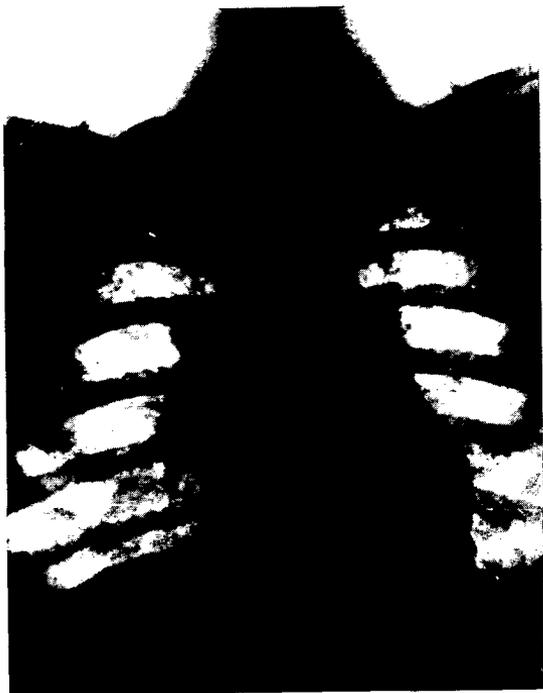


II

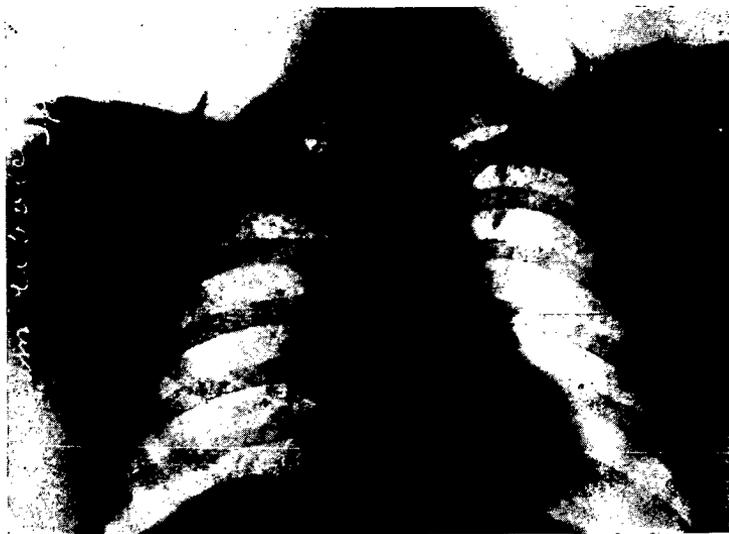


III

Ph. G. M., No. 27: 36 years of age; 21 years stonemason in 1923; before that date much sandstone;
from 1923 to 1929 did not work in stone, nevertheless increased.
X-ray photo. II: snowstorm lung, 1926, increased. III: snowstorm lung, 1929, increased.



I



III

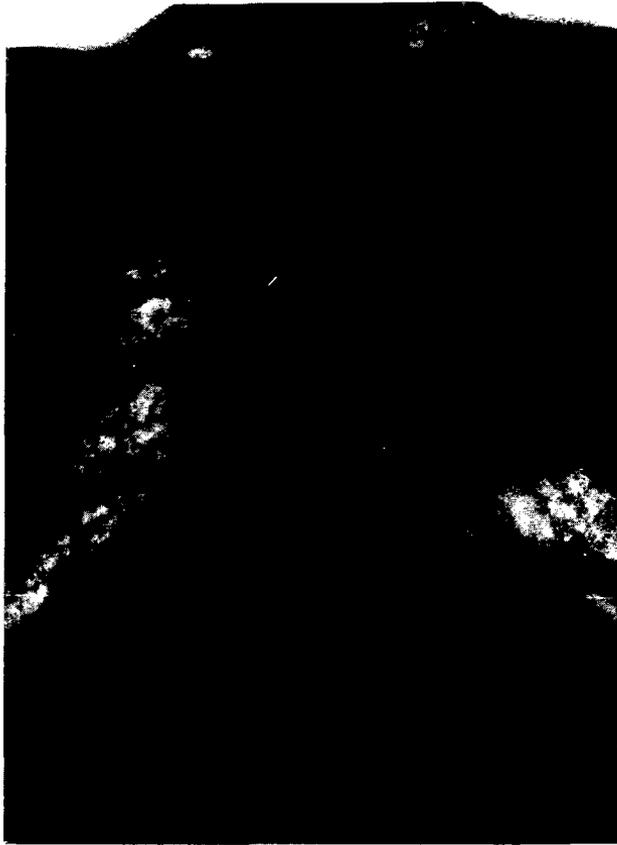
A M., No. 23: 44 years of age; 30 years stonemason in 1923. Before and after, sandstone and Belgian limestone.
X-ray photo. I: stippled lung 1923 (2nd stage). III: stippled lung 1929, remained the same since 1923.



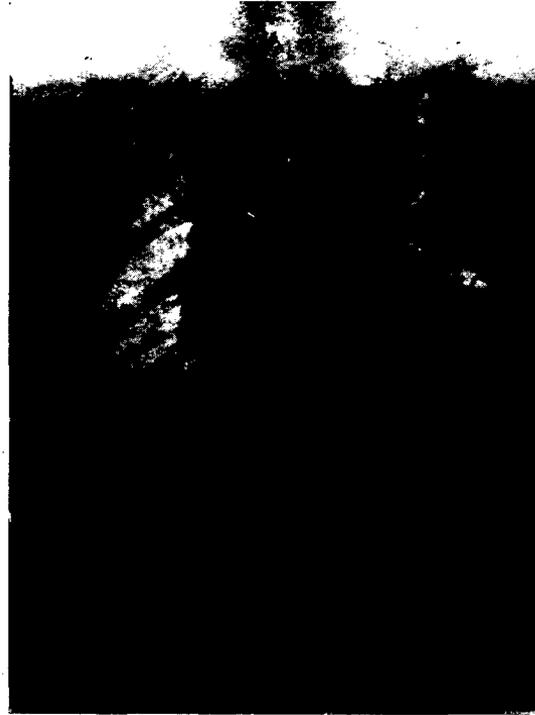
A. V., No. 11: 27 years of age; 14 years stonemason in 1923; before then all kinds of stone; after then not much sandstone.
X-ray photo: incipient fibrous lung (1st stage) 1926, the same as in 1923 and 1929.



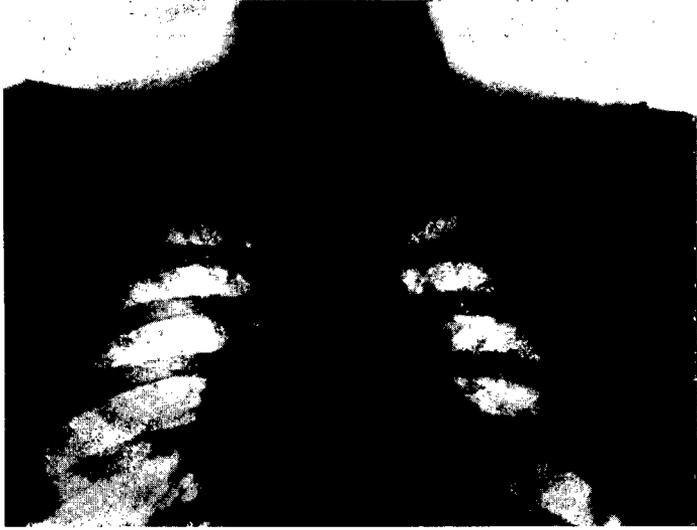
J. F. S.: 44 years of age; 32 years stonemason in 1923, before then all kinds of stone; died 1925. On post-mortem = silicosis + tuberculosis.
X-ray photog.: silicosis (3rd stage), right more than left.



J. J. W.: 64 years of age; 52 years stonemason in
1923; before and after, Belgian limestone only.
X-ray photo: snowstorm lung.



P. V.: 61 years of age; 49 years stonemason in
1923, before and after, marble only.
X-ray photo: snowstorm lung 1926, increased
after 1923, and remained the same in 1929.



F. v. B.: 44 years of age; 30 years stonemason in 1926,
before and after, only sandstone.
X-ray photo: no affection.

SILICOSIS IN THE UNITED STATES

BY DR. ALBERT E. RUSSELL,

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INTRODUCTION

Silicosis is rather widespread in the United States: it has been found to exist with a rather high incidence in a number of industries. There are other industries in which only a few workers are occasionally exposed to siliceous dust, but in which the effect of the exposure in these few dusty occupations is great enough to produce silicosis in a moderately advanced condition in a short time.

The principal industries in which silicosis occurs in its greatest incidence are enumerated below. It is not implied that all the workers in these industries are exposed to excessive amounts of dust.

Mining:

Anthracite coal
Bituminous coal
Gold
Silver
Zinc
Lead
Copper

Quarrying:

Granite
Sandstone
Limestone
Slate
Flint
Rock crystal (quartz)

Stone (finishing):

Granite
Sandstone
Building stone (various grades)

Pottery:

Emery wheels
Carborundum

Abrasive:

Sand
Sandpaper
Grinding

Glass

Mineral earth:

Silica flour
Sand

Spray coating:

Plumbing materials

Refractories:

Silica bricks

Construction:

Railways
Highways
Tunnels
Rock drillers in general

A number of occupations in industries are productive of dust, while the general nature of the industry in which it is carried on might not indicate that any dust hazard was prevalent. These are enumerated here:

Sand-blasting
Moulding (ores)
Grinding

Buffing
Cleaning
Polishing

There are numbers of dusty industries and occupations in the United States which do not necessarily present silica hazards, but they have an excess of dust, and in most of them silica is found in a small percentage, and no doubt plays its role in causing an excessive morbidity from respiratory diseases. Some of these are enumerated here:

Cement
Marble finishing

Graphite
Coal cleaning

Smelting:

Steel
Copper
Lead
Zinc

Textiles:

Cotton
Woollen

Grain elevators:

Wheat
Oats and other grain

Construction:

Building
House wrecking

Studies on the problems of dust removal are being made in laboratories at Harvard, Yale, and other universities. Much valuable work in this direction has been done by the U.S. Bureau of Mines at laboratories in Pittsburgh and in mines. The manufacturers of exhaust and ventilating equipment have also contributed greatly by study and experimentation to the improvement of dusty conditions in industry.

A very valuable experiment is being carried on in mines in Oklahoma. The Bureau of Mines, the Metropolitan Life Insurance Company, and the State of Oklahoma have combined to study the effects and remedies of the dust hazards encountered in mining.

The United States Public Health Service has made studies of certain industries to cover the various types of dust:

1. The cement industry, representing calcium dust.
2. Silver polishing, representing metal dust.
3. The granite industry, representing silica dust.
4. The coal industry, representing carbon dust.
5. The cotton industry, representing vegetable dust.
6. Street sweeping, representing municipal dust.

These studies have been completed and two have been published; others are in process of preparation.

Some of the industries where silicosis has been found in excess are briefly reviewed here.

MINING

Mining is one of the largest industries in the United States. It is widespread, being carried on in some measure in practically every State. Silicosis is a hazard which seems to be common to most mining operations. Its incidence and severity vary according to the variety of dust encountered and its concentration.

The efficiency of exhaust systems throughout the different mines varies greatly. Many companies are keenly interested in providing exhaust systems, and others give more attention to other problems.

The principal groups of mines in the United States are those producing the following ores:

Coal	Iron
Copper	Aluminium
Lead	Gold
Zinc	Silver, etc.

During recent years there has been much more machinery employed in mining than formerly, most of which is impelled by compressed air or electricity. These newer methods have increased the dust hazards to an appreciable degree. The coal miners, for instance, are reputed to have more pneumoconiosis in recent years than in the days when mining was accomplished by older methods.

The United States Bureau of Mines has been a very valuable agency in assisting in the alleviation of dust and other hazards in mines. The Bureau maintains a very excellent laboratory at Pittsburgh and at experimental mines near by. The Bureau workers have co-operated with mine operators and other agencies and are rendering a service which would otherwise be unobtainable. The chief surgeon and other medical personnel of the Bureau of Mines are supplied by the United States Public Health Service.

Coal Mining

Coal is produced in thirty of the forty-eight States and in Alaska. Six of these States produce less than 100,000 tons annually.

There are two varieties of coal produced in the United States, viz. anthracite and bituminous.

Anthracite Coal

Anthracite coal is produced in Pennsylvania. There are other deposits of anthracite (or near-anthracite), but these are not great

enough to produce in paying quantities. There were 157,743 wage earners in the anthracite coal industry in 1923 (U.S. Census). These were located in three counties in Pennsylvania.

Anthracite coal occurs in Pennsylvania in large veins and at varying depths. In earlier days there were out-croppings, which were mined with steam shovels in pit mines, but at present the mines are all underground. The mine shafts and tunnels are large and afford good opportunity for general ventilation. Anthracite coal has been produced on a large scale longer than bituminous coal.

The rock which is associated with anthracite coal contains 31 per cent. of free silica, and the possibilities of the occurrence of silicosis are obvious. The following table gives the percentage of silica in several industrial dusts which we have studied.

TABLE I. — CHEMICAL AND PETROGRAPHIC ANALYSIS OF THE DUST IN EACH STUDY

	Total silica (Percentage)	Quartz (free silica) (Percentage)
Silver polishing:		
Hollow-handle making room	22.2	1.7
Wet pumice (two samples averaged)	70.5	Less than 0.5
Brass foundry	73.3	19.0
Cement:		
Pack house	21.2	Less than 1.0
Crusher house, raw mill, stone house	16.8	6.5
Soft coal (bituminous):		
Coal dust	?	1.2
Rock dust	High	54.0
Hard coal (anthracite):		
Coal dust	?	1.5
Rock dust	High	31.0
Granite:		
Average	70.0	35.2

The anthracite miners develop acute bronchitis and, later, emphysema and miner's asthma. These chronic conditions, together with the effect of some rock dust, make it very difficult, even for those who are specialised in tuberculosis, to diagnose pulmonary tuberculosis. Obviously, tuberculosis is easily overlooked among coal miners. Routine sputum analysis will often give information as to whether or not a tuberculous infection is present.

The dust counts made in the anthracite mines studied by the

Public Health Service showed that the dustiness encountered by workers in the various occupations averaged as follows:

	Million particles per cu. ft.
Miners and mine labourers	124.2
Rock workers	81.9
Drivers and runners	36.5
Others	2.3

It was shown by petrographic analysis that a sample of coal dust from the anthracite mines contained 1.5 per cent. of crystalline silica as quartz.

The incidence of tuberculosis among coal miners has been a much debated subject; we found among those included in our study that tuberculosis did occur. In considering the causes of deaths from 1906 to 1926 in Wilkes-Barre, Pa., located in the heart of the anthracite region (deaths from all external causes were excluded, also data of the epidemic years), it was found that the cause of 11.4 per cent. of the deaths of coal miners was given as tuberculosis, while 6.5 per cent. of the deaths of other adult males in the same area was stated to be due to this disease (see figs. 1 and 2).

The earlier workers in anthracite coal mines in Pennsylvania were principally from Wales and Cornwall, England. At present, however, these people are in the minority, and Slavs and Southern Italians compose the greater numbers. The morbidity records which we have for a group of these miners show that alcoholism was a frequent cause of absence from work.

Bituminous Coal

Bituminous or soft coal is found in larger quantities in the United States than anthracite and is distributed over a much greater area. The deposits are usually in "drifts", for which reason the plan of the mines is different from those of anthracite coal. Most of the bituminous mines are entered horizontally, usually from a mountain side. The overlying stratum is of sandstone in some of the larger areas, schists and other varieties of stone in others. The drifts are low in many places, and necessarily the chambers and tunnels are small. This fact augments the dust hazards of bituminous mining. There were 545,798 wage earners in bituminous coal mines in 1919 (U.S. Census). Much of the coal is cut with machines and then loaded with shovels. Coal-loading machines are being introduced—their use lessens the amount of dust. Rock drilling is supposed to be done when the other operations are not in progress. (From a previous table it may be seen that analysis

shows that some of this rock (sandstone) contains 54 per cent. of quartz.)

The following figures show the extent of dustiness to which each one of these workers is exposed.

	Million particles per cu. ft.
Coal cutter (machine operators) . .	112.3
Coal loader	112.3
Rock driller	78.1

The pneumoconiosis of the bituminous coal miners is quite different from that of the anthracite miners, whose X-rays have been shown herein. The bituminous miners have not had asthma in the same incidence as the anthracite miners. In fact, miners' asthma among bituminous miners is considered to be rare.

The incidence of tuberculosis, likewise, has not been shown to be as great among bituminous miners as among anthracite miners.

It will be seen from the accompanying prints¹ that the pneumoconiosis of these workers is apparently not so severe as that of anthracite miners (film 3).

The coal is carried out of the mines usually by a small electric train. The silica hazard in these mines is augmented by the use of sand on the tracks of the coal trains; the sand becomes pulverised and the motion of the trains fans it into the air. In many of these mines (especially the smaller ones) ventilation is accomplished through the same tunnel, increasing the silica hazard by the diffusion of this dust. Conditions could be alleviated by the use of a material other than sand to increase the friction of the car wheels on the track.

From the accompanying print it may be seen that the motormen on these coal trains developed silicosis. No doubt the pneumoconiosis of the other mine workers is influenced by this sand dust (film 4).

Gold Mining

Gold is mined in California, Colorado, Nevada, South Dakota, and Utah. It occurs in other States, also, but is not mined extensively in those States. The mining is accomplished in California partly by hydraulic methods which eliminate the silica hazard; but as a rule there is a silica hazard in all the gold mines in the United States.

Gold is invariably found deposited in quartzite rock, the percentage of quartz, however, varying in different localities. Silicosis is known to occur in excess at most of the mines.

¹ These prints are given after p. 562.

It is said to occur with less frequency in the Colorado mines, which are moist, and naturally less dust is created in the mining process. The ore is found combined with volcanic rock which contains more than 20 per cent. of quartz. The altitude of these mines is above 10,000 feet, and belief is held by some that the cases of silicosis eliminate themselves because of dyspnoea, the affected workers seeking lower countries before diagnosis is made.

In Utah the mines are hot, and cooling air must be supplied for the comfort of the workers. The heat dries the mines, thus augmenting the dust hazards. The workers in these mines are reputed to have a high incidence of silicosis.

One of the oldest and largest gold mines in the United States is located in the Black Hills of South Dakota. The sick-benefit association of this mining company has reported the illness (eight days or longer) of its members to the Public Health Service over a period of five years. When the rates of illness among these gold miners are compared with those of other sick-benefit associations, it is found that the miners have 2.5 times as many respiratory attacks as the other groups. When the comparison is made in regard to each condition, it is found that influenza and grippe are 3.7 times as great among the miners. The outstanding condition, however, is pulmonary tuberculosis, which has an incidence 8.7 times as great as that of the other groups. This finding was to be expected, since we know that the workers are exposed to excessive amounts of a highly siliceous dust. No doubt these cases of tuberculosis are complications of silicosis, although we have no examinations of X-ray prints to furnish proof of this opinion.

Granite Manufacturing

The granite industry is one of the largest in the United States in the production of stone. It is excelled only by the marble, limestone and sandstone industries as to amount produced. Granite is used in monumental work principally, while marble, sandstone, and limestone are used more extensively as building materials.

The manufacturing of granite into monuments requires more manual labour than that of other stone, because of the extreme hardness of granite. The softer stones (marble, sandstone, and limestone) are easily manufactured with machinery, and much of the dust hazard is thereby eliminated.

The large granite centres in the United States are located in

Vermont, New Hampshire, Maine, Massachusetts, Connecticut, Rhode Island, New York, Minnesota, Wisconsin, and Georgia. There are numerous other localities where granite is found, but production is not carried on extensively in these places.

The hazard from granite is based upon its free silica (quartz) content, which ranges from 25 to 35 per cent.

A report of a study made by the United States Public Health Service of the dust hazard in this industry has recently been published—Public Health Bulletin No. 187. In this study it was shown that the workers engaged in finishing granite were exposed to dust in the concentration of 40 to 65 million particles per cubic foot (i.e. particles less than 10 microns in diameter). The general plant atmosphere averaged 20 million particles per cubic foot.

TABLE II. — CLASSIFICATION OF OCCUPATIONS INTO DUST COUNT GROUPS

Group	Occupation	Number of men	Average dust count. (Million particles per cubic foot)	
A	Hand pneumatic tool operators	565	59.8	} More than average plant dustiness
	Carvers; letterers	24	37.0	
	Others	25		
B	Surface machine operators	68	44.0	
	Tool grinders	20	27.1	
	Others	16		
C	Lumpers	} 146	} 20.2	} Average plant dustiness
	Boxers			
	Polishers ²			
	Cranemen			
	Bedsetters			
	Tool carriers			
	Mechanics			
Labourers				
D	Polishers ²	17	9.0	} Less than average plant dustiness
	Sand blast operators	4	6.2	
	Sawyers	10	4.6	
	Blacksmiths	10	2.5	
	Others ³ (no specific dust count, but low)	66		

¹ Hand pneumatic tool cutters during most of their time in granite, but before or later were in other occupations.

² All in Group C, except in one plant (where they had a separate shed).

³ Occupations were: derrickmen (22), engineers (10), machinists (9), foremen, manufacturers (9), etc.

The workers were grouped according to the intensity of exposure and are considered throughout the morbidity and mortality study

in these groups. Groups A and B were exposed to averages of about 27 million particles per cubic foot, and the average for some in this group reached 60 million; Group C averaged about 20 million particles; Group D averaged 10 million or less. Table II explains this classification.

Each part of the study (X-ray, physical examination, sickness records, and mortality) showed a direct relation to the extent of dust exposure and damage to the lungs and the extreme likelihood of final superimposition of a fatal tuberculosis.

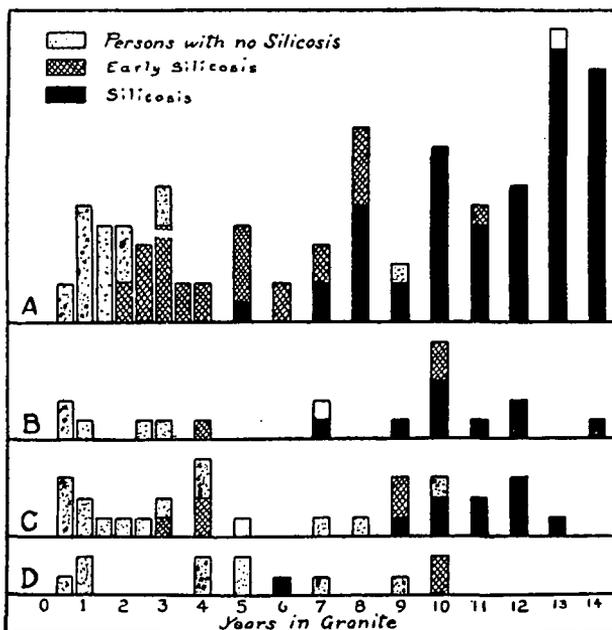


FIG. 1. — Persons with and without silicosis in the four dust count groups, by length of service.

The physique of the granite cutters was every good, and they usually remained in the industry after apprenticeship. Their wages were good (\$8-\$20 per day), and they worked forty hours a week for one half of the year and forty-four hours a week for the other half. The living conditions were usually very good.

Pleurisy (dry) was a common finding among the granite workers. The pulmonary disability (silicosis and tuberculosis) varied directly with the length of exposure. There was a tendency for patients about to break down with tuberculosis to have more respiratory diseases than they had had before this period. Silicosis was found

among many of the workers, in groups A and B after two years' service; after longer exposure silicosis occurred among them almost universally. Fig. 1 explains the incidence of silicosis among the various groups by length of service.

The amount of sickness from all causes showed a direct relation to intensity of exposure to dust. The following graph shows that length of service and intensity of exposure caused an increase in the incidence of sickness in Groups A and B (fig. 2).

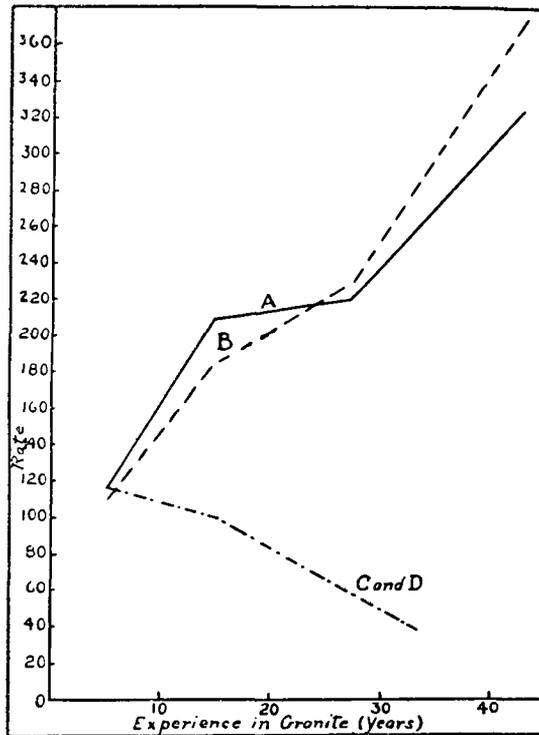


FIG. 2. — Incidence of sickness from all causes in the four dust count groups by length of service. Eight days and more (rate per 1,000).

The following graph compares the frequency of sickness of granite workers with that of certain other industrial groups. The group "General Sick Benefit" is given to represent more or less average industrial workers. From this graph it will be seen that the workers in dusty trades have a much greater incidence of all respiratory conditions (fig. 3).

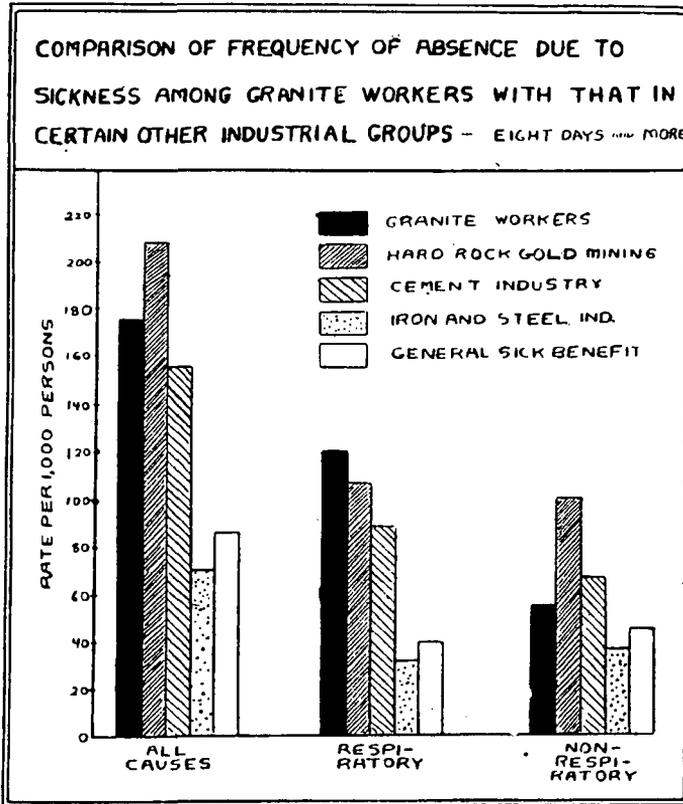
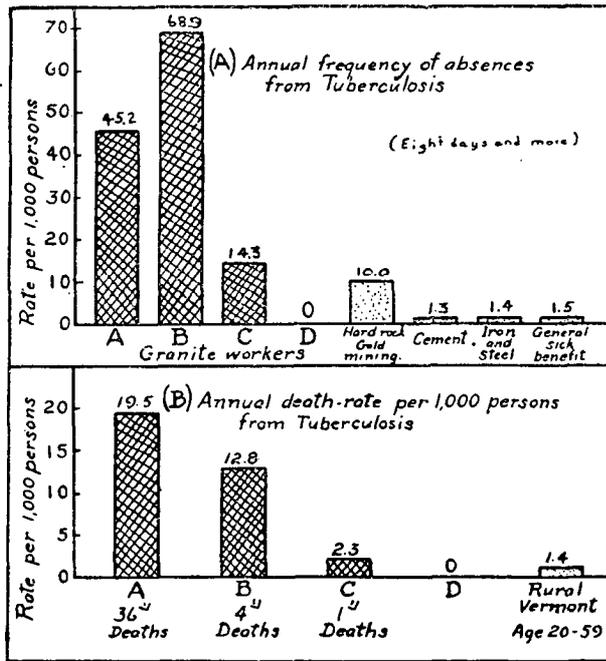


FIG. 3.

The sickness rates from tuberculosis (superimposed on silicosis) is next compared with those of other industries. Here we see the great preponderance of the incidence of tuberculosis. In the same graph the death rates of the various groups are compared with those of adult males in rural Vermont. It should be noted that the hard-rock gold miners used herein had not been in the industry as long as the granite workers (figs. 4 and 5).

When tuberculosis became a complication of silicosis, it usually made a rather sudden onset and pursued an unremitting course to a fatal ending. None of the cases became arrested. The age at death of these workers averaged 49 years, which included a few who undoubtedly had a latent tuberculosis on entering the trade, in which instance the disease resembled tuberculosis not complicated by silicosis; these latter cases, however, were few. It was difficult



1 From beginning of study to working up of report—about three years—among 972 workers: A, 614; B, 104; C, 146; D, 108.

FIG. 4. — (A) Annual frequency of absences from tuberculosis (eight days and more); (B) Annual death rate per 1,000 persons from tuberculosis.

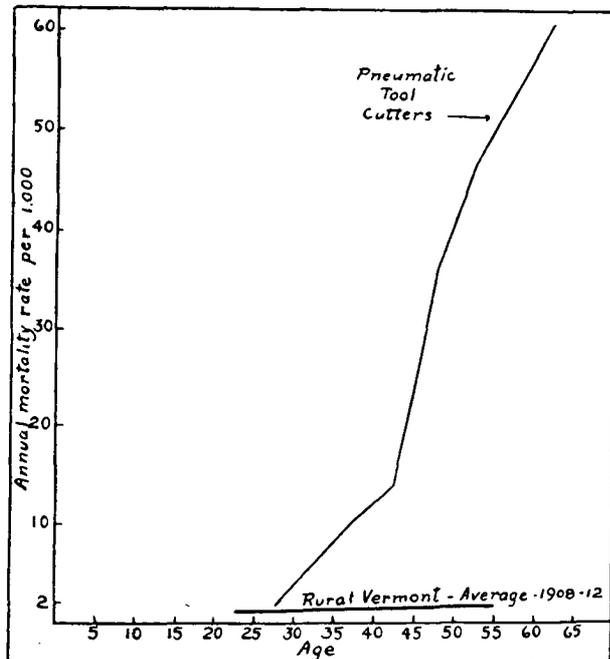


FIG. 5. — Age curve of mortality from tuberculosis among hand-pneumatic tool cutters and in rural Vermont (males).

to obtain specimens of sputum for analysis, but when the sputum was examined, it was usually found that the first specimen contained tubercle bacilli in great numbers. The length of a case of tuberculosis among these workers was usually about fifteen months, and termination was always death.

Tuberculosis occurred in the families of granite workers, but perhaps less frequently than in general practice, because of the excellent hygienic conditions of their homes; and also, the disease came on at an age (about fifty) when the children were no longer little, many of them being either grown up and at work or away at school.

Pneumatic tools were first employed in the granite industry about the beginning of the present century, and the tuberculosis rate has increased rapidly with their use. It is doubted if the maximum rate of tuberculosis has been reached. Since the introduction of the pneumatic method the rate has risen in proportion to the length of time for which they have been used, as follows:

1.5 per 1,000 . . .	1890-1894
10.8 " " . . .	1910-1914
19.5 " " . . .	1924-1926 (period of study)

Studies were made of many of the exhaust and ventilating systems in use in the local plants, and in no instance were they found to be adequate. A plant in another city was found to have an excellent system, by which, if it were properly maintained and operated, a safe atmospheric condition could be obtained. A paper on "The Efficiency of Dust-Removal Systems used in Granite Cutting" was presented in Public Health Reports, 18 October 1929. This paper gave specifications for exhaust and ventilating systems, together with dust counts found under varying conditions.

The accompanying X-ray pictures show silicosis and tuberculosis complicating it in granite workers. Tuberculous lesions in the base of the lung (usually right) were found as a rule among these cases. (See bulletin.) (Films 5 and 6.)

Granite Quarrying

Much of the quarrying of granite is accomplished by a wet process, and very little dust is generated. The worker is able, too,

to stand away from the pneumatic drill, which is attached to a stand. After being removed, the stones must be split into smaller sizes, and some dust is encountered here, but perhaps not in quantities sufficient to produce marked silicosis, and quarry workers in granite are certainly not reputed to have a high incidence of tuberculosis.

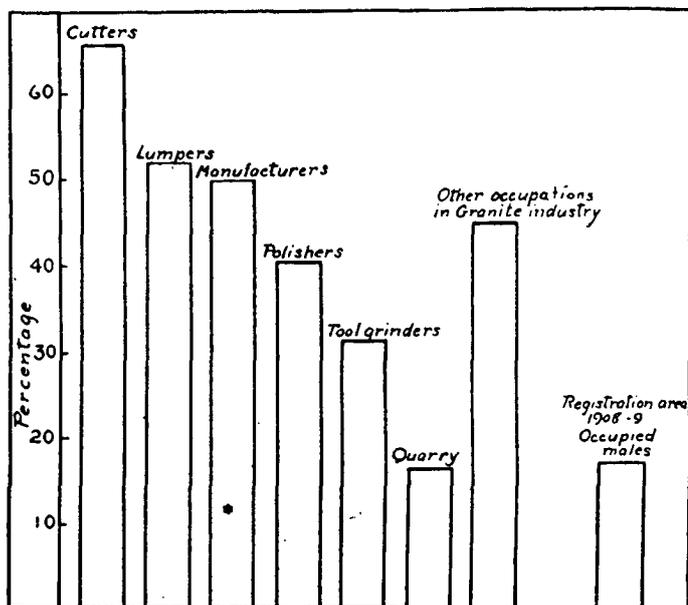


FIG. 6. — Proportionate mortality from tuberculosis¹ in specific occupations of granite industry compared with data for occupied males. Registration Area, 1908-9.

¹ Many were previously granite cutters.

The precaution taken to keep down dust in granite quarries is the provision of hose and water to keep the drill moist during the cutting operations. The splitting of the blocks is accomplished out in the open and usually after the stone has been removed from the quarry pit.

Sometimes a stone finisher will change his occupation to quarrying, and should he develop silicosis, its background might be his former occupation. A careful occupational history is necessary before silicosis can definitely be accredited to the occupation which

the worker followed immediately before his illness. Although the quarry worker in granite handles siliceous materials, it is thought that the hazard from dust is small.

It may be seen from the graph on page 548 (fig. 6) that the deaths of quarrymen from tuberculosis were less than those of occupied males in the registration area in 1908-1909.

MARBLE

Vermont, Georgia, and Tennessee are the principal marble producing States. Vermont was the pioneer in production of large amounts. Marble dust contains about 1 per cent. crystalline silica, with about 98 per cent. calcium. No silicosis has been shown among these workers. The Vermont State Sanitarium for Tuberculosis is only a few miles from one of the largest marble works, and according to its records, marble workers (unless they have previously worked in granite) are seldom admitted to the institution for treatment. Dr. E. J. Rogers, physician in charge of institutions and clinics for tuberculosis in Vermont, states that these workers rarely have tuberculosis. The calcium present in marble dust may be a factor in causing such a low incidence of tuberculosis among this group of workers. Tuberculosis has likewise not been reported to be in excess at other (newer) marble centres.

(Vermont marble must not be confused with Vermont granite.)

SANDSTONE

The sandstone industry in the United States centres in and around the States of Ohio and Indiana. The contact of the worker with the stone in quarrying and finishing is not so close as in the case of granite. Sandstone is less resistant and can be made into finished products by machinery much more easily than granite. Therefore it would not be supposed that workers in sandstone would be exposed to as much dust as granite workers. Certainly they are exposed to much less dust than miners, since much of their work is accomplished above ground and in the open.

A study which was made in one of these quarry sections was reported in the *Journal of Industrial Hygiene* in September 1929 (Vol. II, No. 7). Of 919 workers, 409 were found to be negative

for silicosis. The median age, however, of this negative group was twenty-seven years, and the average time of exposure to dust was less than four years. It was shown that by the time the workers were thirty-six years old and had had an exposure to dust of 7.41 years that 238 had "increased fibrosis". The incidence of silicosis increased with age and length of exposure, and the number of cases of tuberculosis also increased likewise. If these findings exemplify the silicosis hazard in the sandstone industry, we see that this hazard constitutes quite a health problem. The incidence of tuberculosis as a complication of silicosis in sandstone workers is much less than in the granite stone industry, being obviously a matter of intensity of exposure. There were no dust counts made in this study of sandstone, but from the nature of the occupations in this industry it is certain that the granite workers are exposed to much greater quantities of dust than this group of workers.

SPRAY COATING

The number of workers in this occupation has greatly increased in the United States in the past few years. There has been greater demand for plumbing materials, incident to the construction and modernising of homes, and the spraying of paints has in many instances replaced the older methods of brushing. The tremendous growth of the automobile industry has necessitated rapid methods of painting.

A committee on spray-coating selected by the National Safety Council recently studied the situation. Evidently lead is the main hazardous material encountered in the spraying of paints, but siliceous materials are occasionally employed. In the manufacturing of plumbing materials (bath-tubs, wash-basins, etc.), silica is frequently encountered. Erroneous ideas have prevailed as to the safety of "wet dust", but such dust has been shown to be capable of producing extensive silicosis. Vitreous enamel is stated to contain 43 to 47 per cent. of silica (much of which is evidently in the form of silicates). The committee recommends the use of a bisilicate of lead, which would lessen the hazard from both silica and lead. The committee also urged adequate exhaust systems for the spray booths and showed that with a poor ventilating system the air contained 445 million particles per cubic foot and that with exhausts of a better variety the counts showed only from 5 to 24 million particles per cubic foot.

SAND BLASTING

The use of sand blasting in the industries has become very widespread in the United States within a very short time. Many large manufacturers find use for sand blasting in some of their processes, whereas they have no other dusty trades.

From my own observations, I am convinced that sand blasting, unless done under proper conditions, is capable of producing silicosis more quickly than almost any other trade carried on in the United States. The sand-blasting machinery producers have taken cognisance of the great hazards of the trade and have instigated research towards instituting methods of control. Equipment for dust alleviation is available, but its efficiency depends upon its design, its proper installation, and its maintenance. Recently, blasting with steel grit has been tried, and obviously much less dust is produced with this medium, but the result is not the same as when sand is used; instead of a cut surface, more of a hammered effect is obtained. More recently carborundum has been used and with success. I believe that in time carborundum or other silicon carbide products will replace the use of sand or fine pebbles.

There are more than 10,000 workers in the United States employed in sand blasting, and as the labour turnover in this trade is great, many more people are exposed. Because of the delayed effect of silica dust in the lungs, it would be impossible to estimate the role which sand blasting plays in mortality from tuberculosis and other respiratory diseases.

Sand blasters nearly always use masks or helmets to protect them from dust. In some cases the operator does not wear a mask, but stands outside the cabinet and looks through a window and operates the hose through an aperture covered with burlap. The inadequacy of such equipment is great and cannot be too strongly condemned.

The Public Health Service and the National Safety Council have undertaken co-operative studies of sand blasting in the United States. The complete report of this work will be published jointly and will be available for distribution next year. The findings, although not yet complete, show that the dust concentration in two of the rooms in which counts were made reached 1,706.6 and 1,171.2 million particles per cubic foot. Helmets with positive air pressure were worn by operators, and samples of air taken from under the helmets contained 17.3 and 13.3 million particles per cubic foot, respectively. This is above the standard set for granite,

which is 10 million particles; also, sand contains a higher percentage of silica than granite. That these are dangerous amounts is quite evident, and forced ventilation of the sand-blast rooms is obviously very necessary. The accompanying X-ray print and history are from a patient who wore a helmet while at work (film 7).

The influence of positive pressure may be seen from the following statements. The air of one of the sand-blast rooms contained 894.7 million particles and the air from under the helmet with positive air pressure contained 8.4 million particles per cubic foot. A test was made in which the helmet was used without air supply. The room dustiness in this instance was 1,568.0 million particles, and the air under the helmet contained 437.7 million particles per cubic foot.

Case of silicosis in a sand-blast. Patient wore a mask.

W.M.: aged 46 years; Mulatto.

Sandblaster 7 years.

History of past health showed no diseases of any importance. No history of tuberculosis in family. Five years after this X-ray was made, patient died of tuberculosis (tubercle bacilli in sputum). (Film 7.)

ROCK DRILLING

Rock drillers are exposed to rock dust, which dust is produced in great quantities, by the pneumatic drills with which their work is accomplished. Moreover, the workers are usually labouring in "rooms", tunnels, or pits where natural ventilation is of little assistance.

Rock drilling is done extensively in the construction of highways, railways, tunnels, and excavation for buildings. An engineer engaged in inspection of construction work stated recently that on the island of Manhattan (New York City) alone there were 20,000 rock drillers. The rock in which these 20,000 drillers are working contains over 50 per cent. of quartz. This means that, when the labour turnover is considered, over 20,000 persons a year are exposed to dangerous amounts of silica. A study was made of rock drillers engaged in subway construction on Manhattan island and was reported in the *Journal of Industrial Hygiene*, February 1929. Fifty-seven per cent. of the workers examined were found to have silicosis, and tuberculosis was found (by X-ray) to be present in 9 per cent. of the cases examined.

Because of the insidious nature of silicosis the incidence of both silicosis and tuberculosis will no doubt greatly increase among these workers, inasmuch as they have undergone intensive exposure to rock dust in recent years.

Attention is being given to methods of dust prevention, but

the nature of the work and its frequent use in isolated situations, as in foundation work, construction of highways (rural), etc., make the problem of the prevention of dust more than difficult.

THE ABRASIVE INDUSTRY

In the abrasive industry, which manufactures a number of products, sand is invariably used. In some instances natural sand constitutes a large part of the abrasive material.

E. R. Hayhurst and other writers state that "during the last fifteen years of observations in the State of Ohio, there have appeared few reports of silicosis and these usually from the abrasive industries" (*Journal of Industrial Hygiene*, Sept. 1929, Vol. XI, No. 7).

I saw a worker suffering from moderately advanced silicosis who described his exposure to silica dust as occurring when he dumped sand on hot electric elements to be burned with other substances to produce abrasive material. He stated that great clouds of dust arose from the hot furnace and remained in the air for several hours. X-rays of a number of workers in this industry show that there was definite silicosis present, although in the early stages. These workers change their occupations frequently and do not have as many years of exposure as workers in a more skilled trade.

In a number of abrasive industries a silica hazard exists without, perhaps, attaining a degree sufficient to produce the great excess of tuberculosis that is found in other dusty trades.

Grinding is an occupation in the abrasive industry in which silicosis is known to occur in excess and with such severity that tuberculosis is a frequent complication. From the following table it will be seen that the workers in this occupation have an excessive death rate from tuberculosis.

TABLE III. — MORTALITY FROM TUBERCULOSIS OF THE LUNGS IN A CONNECTICUT AXE FACTORY, 1900-1919

	Death rate per 100,000
State of Connecticut	150
State of Connecticut (male population)	170
Axe factory district (3 towns, entire population)	200
Employees of axe factory (all)	650
Employees of axe factory, polishers and grinders	1,900
Employees of axe factory, others	160

This table was prepared by Professor C. E. A. Winslow, of Yale University, and Sanitary Engineer Leonard Greenburg, U.S. Public Health Service.

COPPER MINING AND SMELTING

The mining and refining of copper in the United States requires the services of over 60,000 persons. The largest copper mines are located in Arizona, Utah, Montana, and Michigan, the producing being indicated by the order given. Copper miners are reputed to have a high incidence of tuberculosis, and it is known that silicosis is quite prevalent among them. The incidence and severity of the condition depends on the variety of rock dust encountered and its concentration. The latter is better controlled in some localities than in others. Some of the big copper producers have installed elaborate ventilating systems and have incidentally been able to salvage enough ore to pay for the cost of operation of the exhaust system.

The smelting of copper also involves silica hazards; and inasmuch as arsenic is frequently found in connection with copper, a hazard from arsenic is also frequently encountered.

SAND

The use of sand seems to increase in America with each year. In 1921 845,008 tons of sand were produced in the United States, and greater quantities are used at present. The following industries use it in their processes of manufacturing:

Glass	Refractories
Foundries	Abrasives
Paving	(1) Grinding
Filter	(2) Polishing
Ballast	(3) Cleaning
Sandblast	

Sand varies in its content of free silica, but the amount present in it is always so great that the variations do not make much difference. As a causative agent of silicosis, sand rates very high.

The harmful effects of sand are well illustrated in the following quotation from a personal letter to me from one of the most eminent X-ray men in the United States:

We have just completed the examination of a few interesting cases. These men have been engaged as labourers in a plant where sand is pulverised to be used in the manufacture of sand soaps and other articles where pulverised sand is the essential part of the goods produced. It has been noted that a mottling, such as we have designated as the second stage of silicosis, is present in some of the men as early as

three months after starting the occupations. Massive consolidations were present within a year, and equal to those seen in hard rock miners of several years. In other cases, there was the conglomerate mottling indicative of the third stage, occurring in less than a year.

The men stated that the sand, before pulverisation, was heated to a high temperature, and when it escaped upon their skins, it would burn them, and it would take at least two weeks before their skins became sufficiently tough to handle the sand. We were wondering whether this hot sand, when in the finely divided state, was at a sufficiently high temperature to destroy the cilia in the lower air passages, because of the very quick presence of fibrosis.

We thought this group of individuals might be of interest to you to present at South Africa.

POTTERY INDUSTRY

Ohio leads in the United States in the number of pottery workers, employing almost 14,000 wage earners in this industry. New Jersey is second, with over 6,000 wage earners, and New York has about 3,000.

Silicosis has been known to occur among potters for a number of years, the silica dust being encountered in the glazing of pottery with silica flour. There are a few other occupations in which dust is generated, but these are of minor importance.

The silicosis of potters is of such severity that tuberculosis is a frequent complication; the tuberculosis does not usually occur, however, until about middle age or later. Newer methods are being employed in this industry and will no doubt lessen the amount of dust and consequently the incidence and severity of silicosis and tuberculosis among potters. One of the leading pottery companies in the United States has recently completed a very modern plant, during the planning and construction of which attention was given to the elimination of dust hazards.

Lead poisoning is also a hazard in this industry.

The print shows early silicosis in a potter (see film 8).

COMPENSATION FOR SILICOSIS IN THE UNITED STATES OF AMERICA

There are two groups of compensation laws in the United States of America—federal laws and State laws.

The Government of the United States pays compensation for silicosis under the Act which refers to civil employees of the United States and to persons whose employment entails movement from one State to another, as in the case of transport workers. An instance here is the Longshoremen's Act.

Silicosis is not directly named in a law allowing compensation

in the United States, but the language of the laws is sufficiently broad to cover occupational diseases in general, and silicosis is clearly included.

When a civil employee of the United States develops silicosis, he must file a claim; and quite unlike many of the States, the Federal Government sends a physician to examine the patient, and consider the case, which is then presented to the Employees' Compensation Commission where the award is made. Everything is accomplished without expense to the patient. He need not employ lawyers to present his case for him.

The case is considered as an injury produced by the inhalation of harmful dusts. The interpretation of the word "injury" includes not only accidental injuries, but also "such occupational disease or infection as arises naturally out of such employment" (section 40, Longshoremen's and Harbour Worker's Act, 1927). Specific occupational diseases such as silicosis are not defined, but the interpretation given above has been used to include silicosis, and compensation is paid the worker or his relatives.

The following States have legislation, as outlined below, which permits compensation within the confines of their own boundaries:

California	New Hampshire
Connecticut	New Jersey
Maine	Ohio
Maryland	Rhode Island
Minnesota	Wisconsin

The other States have no definite laws whereby the worker may obtain compensation. Some manufacturers in these other States feel morally obligated for silicosis and there have been instances in which a voluntary compensation has been paid. The amount paid varies, of course, according to circumstances, such as length of service, financial condition of the plant, etc. A number of plants in these States carry insurance on the workers which covers occupational diseases.

California

Article 20 of the State's Constitution has permitted statutes to be made covering workmen's compensation and insurance. Under a certain section the term "injury" is defined as follows: "The term 'injury' as used in this Act, shall include any injury or disease arising out of employment . . ."

Under the Statutes of California an industrial accident commission, which is composed of three members, has been constituted, and has complete jurisdiction over injuries covered by this Article, in regard to treatment, compensation, etc.

Connecticut

The physicians in Connecticut are required by law to report occupational diseases in the same way in which contagious diseases are reported. Section 2146 of the General Statutes of 1918 reads as follows:

Every physician having knowledge of any person whom he believes to be suffering from poisoning of lead, phosphorus, arsenic, brass, wood-alcohol, mercury or their compounds, or from anthrax, or from compressed-air sickness, or any other disease, contracted as a result of the nature of the employment of such persons, shall, within forty-eight hours, mail to the Commissioner of Labour and Factory Inspection a report stating the name, address and business of his employer, the nature of the disease, and such other information as may reasonably be required by said Commissioner ¹.

Section 5388, dealing with compensation of workmen for injuries, states that the word "injury" shall be construed to include any disease which is due to causes peculiar to the occupation and which is not of a contagious, communicable, or mental nature. It is evident that silicosis is covered. The Act states further: "If an injury arises out of and in the course of employment, it shall be no bar to a claim for compensation that it cannot be traced to a definite occurrence which can be located in point of time and place."

Under authority of this Act, five commissioners are appointed in Connecticut to hear such cases and are given power to make decisions granting compensation and to do other things necessary in the administration of the Act.

Maine

In the State of Maine, silicosis is not compensable. The State requires its physicians to report cases to the State Board of Health. No doubt the collection of data on occupational diseases will be very important in obtaining a law for compensation of disabled workers.

¹ Obviously silicosis would be included in reportable occupational diseases under the heading of "any other disease, contracted as a result of the nature of employment by such person".

Maryland

The same statements apply to Maryland as to Maine.

Minnesota

The physicians of Minnesota are not required to report silicosis. The workmen's compensation law does not include silicosis in its schedule, but according to section 67 (10) of the Statutes, claims for the compensation of silicosis may be made.

Nothing in this Act shall affect the rights of an employee to recover compensation in respect to a disease to which this section does not apply, if the disease is an accidental personal injury within the meaning of other provisions of this Act.

New Hampshire

The physicians of New Hampshire are required to report certain occupational diseases which are listed for them, and also "any other ailment or disease contracted as result of the nature of the patient's employment".

New Jersey

Silicosis is not compensable in New Jersey. The Compensation Act schedules a number of occupational diseases, but leaves out silicosis and adds: "Compensable occupational diseases shall not include any others than those scheduled."

New York

In the State of New York, again, we find the words "injury" and "personal injury" coming to the aid of silicotic patients. The law in this State does not specify that silicosis is a compensable disease, yet compensation is allowed because of the injury silica dust has done to the lungs.

Section 2, paragraph 7, of the Statute reads: "'Injury' and 'personal injury' mean only accidental injuries arising out of and in the course of employment, and such diseases or infection as may naturally and unavoidably result therefrom".

While silicosis is not mentioned, it is certain that it comes under the heading of an "injury", and still more emphatically so when it is complicated by tuberculosis. The phrase "diseases or infection as may naturally and unavoidably result therefrom" would make silicosis compensable. Further, section 48 of the Act makes the matter a bit clearer: "Nothing in this section shall affect the right

of an employee to recover compensation in respect to a disease to which this section does not apply, if the disease is an accidental personal injury within the meaning of sub-division 7 of section 2".

Five industrial commissioners are appointed by the Governor and are charged with the administration of the provisions of the Act and with the care of the State insurance fund, which is a State fund created for the purpose of insuring its employees against liability and of assuring the persons entitled to compensation. The fund consists of premiums, and employers and employments are prorated in collecting these premiums, in accordance with the difference in the extent of industrial hazards in their establishments.

The physicians in New York State are required to report industrial poisonings according to a list; silicosis does not, however, appear on the list.

Ohio

Ohio, like many other industrial States, requires the reporting of occupational diseases, but omits silicosis from the list of such diseases. The Compensation Act does not specially mention silicosis, but the term "occupational disease" automatically includes it in the list of compensable conditions.

Section 35 of the Act reads as follows:

For the purpose of providing compensation to workmen and their dependants, for death, injuries or occupational disease occasioned in the course of such workmen's employment, laws may be passed establishing a State fund to be created by compulsory contribution thereto by employers, and administered by the State, determining the terms and conditions upon which payment shall be made therefrom. . . . Such compensation shall be in lieu of all other rights to compensation, or damages, for such death, injuries, or occupational disease, and any employer who pays the premium or compensation provided by law, passed in accordance herewith, shall not be liable to respond in damages at Common Law or by statute for such death, injuries, or occupational disease.

Rhode Island

In Rhode Island the physicians are required by law to report occupational diseases according to a list which is provided them, and silicosis is not included. The list carries this phrase, which obviously includes silicosis: "Any other ailment or disease as a result of the nature of the patient's employment."

Wisconsin

The physicians of this State are likewise required to report occupational diseases from a list which omits silicosis.

The Act (Compensation of Workmen), under section 102, paragraph 34, states that the provisions include in addition to occupational injuries, all other injuries, together with occupational diseases growing out of and incidental to employment. Thus silicosis is included as a compensable disease.

An industrial commission, as in many other States, administers the intentions of this Act. Appeals are also heard by this commission, and if further recourse is necessary, may be taken to the Supreme Court.

Other States have legislation pending and several have attempted to pass a Silicosis Act which would specifically make silicosis compensable.

The great difficulty in obtaining compensation for silicosis is due to the fact that the disease is so insidious in its development that the patient may have changed from a dusty occupation before his illness becomes manifest. In such instances it is not a simple matter to tie up the disease definitely with the former occupation. Labour turnover is greatest in dusty occupations and in other hazardous trades. The great incidence of tuberculosis as a complication and usually as the immediate cause of disability, together with the inability of the medical profession, as a rule, to differentiate between silicosis and tuberculosis or to recognise their co-existence, makes the workers' chances fewer for obtaining compensation, even when the law allows compensation for silicosis.

Statistical studies of silicosis in the United States have been made by Frederick L. Hoffman, L.L.D., of the Prudential Life Insurance Company, and were published by the Bureau of Labour Statistics, Department of Labour, Bulletin No. 231, *Mortality from Respiratory Diseases in Dusty Trades (Inorganic Dusts)*, and Bulletin No. 293, *The Problem of Dust Phthisis in the Granite Stone Industry*.

Among the earlier studies that included the clinical consideration of silicosis was that made by Dr. A. J. Lanza, then of the United States Public Health Service, on the occurrence of silicosis among workers in zinc mines in Missouri. His work was published as U.S. Public Health Service Bulletin No. 85, and U.S. Bureau of Mines Bulletin No. 132.

Dr. L. U. Gardner has contributed materially to the knowledge of the pathology of silicosis by his animal experimentation, using different kinds of dusts. His studies were published in the *American Review of Tuberculosis*.

Other studies of lesser magnitude have been made and have been published in current journals.

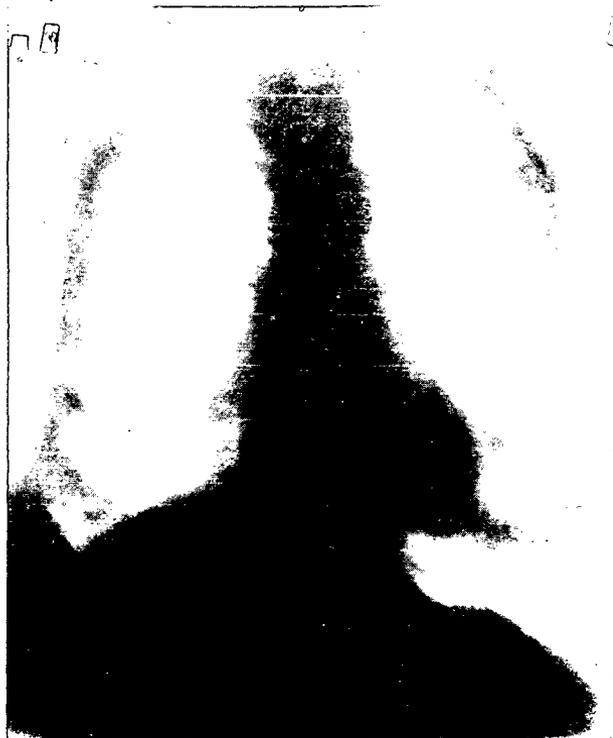
The report here presented is by no means inclusive as regards the incidence of silicosis in the United States, but rather covers briefly the industries in which this disease is most common. Silicosis, being so very insidious in its onset, unless the exposure is overwhelming, goes unrecognised in many instances for this reason. Other reasons for the non-recognition of silicosis are the fact that disability *per se* comes late in the disease, and the fact that when tuberculosis complicates it, the superimposed disease overshadows the silicosis. With the increase of study of industrial diseases we may hope that silicosis will be more easily recognised and that more definite data will be available concerning its occurrence.

OCCUPATIONAL ENVIRONMENT

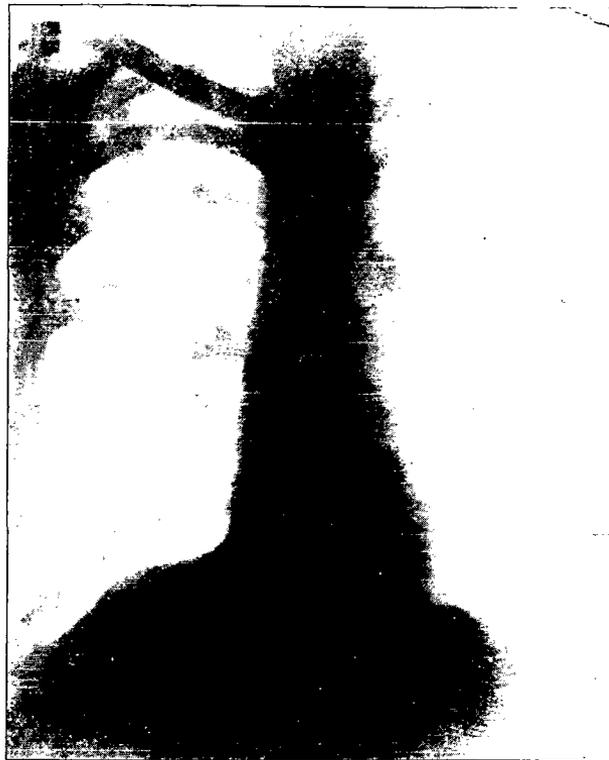
Uses of silica	Types of silica used
<p>Abrasive uses: In scouring and polishing soaps and powders. In sandpaper In sand-blast work Metal buffing, burnishing and polishing . For sawing and polishing marble, granite, etc. As whetstones, grindstones, buhrstones, pulpstones, oilstones, etc. Tube-mill lining Lithographers' graining sand Tube-mill grinding pebbles In tooth powders and pastes Wood polishing and finishing Refractory uses: In making silica fire brick and other refractories. Metallurgical uses: In making silicon, ferrosilicon, and silicon alloys of other metals, such as copper. As a flux in smelting basic ores Foundry-mold wash Foundry parting sand Chemical industries: As a lining for acid towers As a filtering medium In the manufacture of sodium silicate In the manufacture of carborundum Paint: As an inert extender Mineral fillers: As a wood filler In fertilisers In insecticides As a filler in rubber, hard rubber pressed and molded goods, phonograph records, etc. In road asphalt surfacing mixtures Ceramic uses: In the pottery industry as an ingredient of bodies and glazes. In the manufacture of ordinary glass In the manufacture of fused-quartz chemical apparatus, such as tubes, crucibles, and dishes. Decorative materials: In the manufacture of gems, crystal balls, table tops, vases, statues, etc. Insulation: Heat insulation for pipes, boilers, furnaces, kilns, etc. Sound insulation in walls, between floors, etc. Structural materials: Sand-line brick Optical quartz: For the manufacture of lenses and accessories for optical apparatus.</p>	<p>Quartz, quartzite, flint, chert, sandstone, sand, tripoli, and diatomaceous earth; all in finely ground state. Quartz, quartzite, flint, sandstone, and sand; coarsely ground and closely sized. Quartz, quartzite, sandstone, and sand, crushed into sharp angular grains uniform in size. Ground tripoli and other forms of ground silica. Sharp, clean sand graded into various sizes. Massive sandstone from very fine to moderately coarse grained. Chert, flint, and quartzite in dense, solid blocks. Medium to fine sand or rather coarsely ground silica and tripoli. Rounded flint pebbles. Various forms of pure silica finely ground. All forms of silica ground to medium fineness. Fairly pure quartzite known as gannister; not less than 97 per cent. SiO₂, nor more than 0.40 per cent. alkalis, tightly interlocking grains desired. Moderately pure sand, massive crystalline quartz, sandstone, quartzite, or chert. Massive quartz and quartzite. Ground sandstone, quartz, and tripoli. Fine sand and ground tripoli. Massive quartz or quartzite. Massive diatomaceous earth and tripoli, sand, finely granular quartz or quartzite, finely ground tripoli, diatomaceous earth, and other forms of silica. Pure pulverised quartz sand, pure tripoli, and diatomaceous earth. Pure quartz sand. Finely ground crystalline quartz, quartzite, and flint; also finely ground sandstone, sand, and tripoli. Finely ground crystalline quartz, quartzite, flint, tripoli, and other types of ground silica. Finely ground silica of all types. Flint, tripoli, and chert, and other amorphous silica preferred; also all other forms of very pure silica, all finely ground. Pure quartz sand. Very pure massive quartz preferred. Rock crystal, amethyst, rose quartz, citrine quartz, smoky quartz, chrysoprase, agate, chalcedony, opal, onyx, sardonyx, jasper, etc. Massive and ground diatomaceous earth. Do. Moderately pure, sharp, angular sand, preferably finer than 20-mesh, together with a small percentage of finely pulverised silica. Clear, colourless, flawless rock crystal or massive crystallised quartz.</p>

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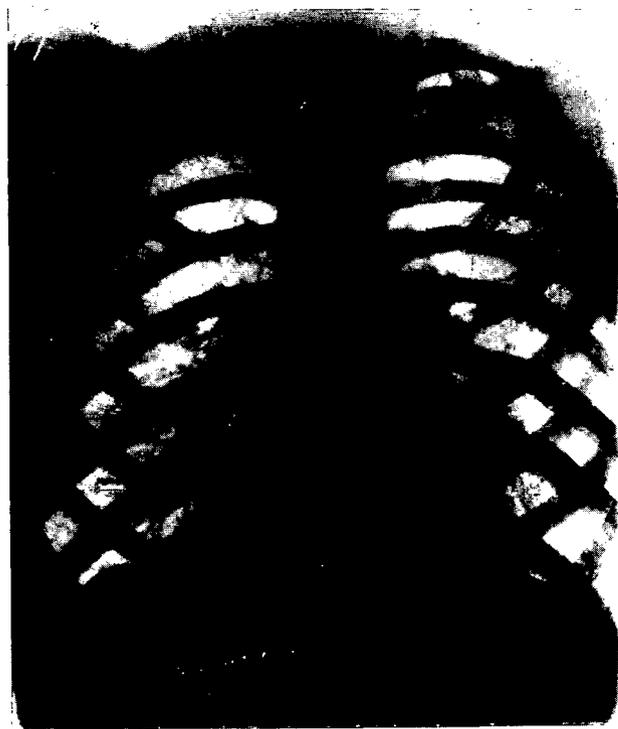
FILM 1.— Anthracite coal miner for thirty-five years.



FILM 2.— Anthracite coal miner for twenty-eight years.
Tuberculosis and anthracosis. Sputum contained
tubercle bacilli.



FILM 3. — Coal (bituminous) miner for eighteen years.



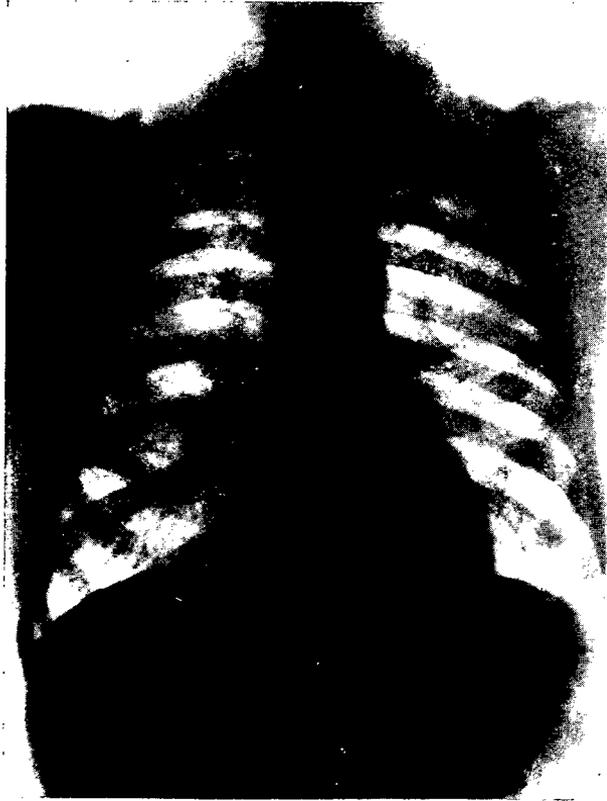
FILM 4. — Motorman (coal train) for seven years. Exposed to dust from sanding the tracks.



FILM 5. — Silicosis in a granite worker. An early tuberculosis is in evidence in the base of the right lung.



FILM 6. — Silicosis and tuberculosis in a granite worker. Tuberculosis lesion in base of right lung. Cavitation present. Tubercle bacilli were found in sputum. Basal tuberculosis was common among these workers.



FILM 7. — Sand blaster. Silicosis (tuberculosis two years later).



FILM 8. — Silicosis in a pottery worker.

APPENDIX

**INHALATION OF ASBESTOS DUST: ITS EFFECT UPON
PRIMARY TUBERCULOUS INFECTION**

BY LEROY U. GARDNER AND DONALD E. CUMMINGS

The following is a summary of a preliminary report on the experimental investigation of inhaled asbestos dust, dealing with the reaction in normal and tuberculous animals. The complete report will be submitted for publication in the Journal of Industrial Hygiene.

Guinea-pigs have been exposed for eight hours daily for periods as long as two and a third years to an atmosphere containing approximately 35 million particles of asbestos dust (Canadian chrysotile) 1.5μ and less in diameter. Rabbits and albino rats have been likewise exposed for shorter periods (330 days).

The experiments demonstrate that fibrous structures at least as long as 200μ can pass the protective mechanism of the upper respiratory tract and enter the lung. Anatomic evidence of injury to this mechanism is wanting.

Inhaled asbestos dust does not penetrate to the terminal alveoli of the lung as is the case with a particulate substance like quartz. The major portion is held up in the respiratory bronchioles. There phagocytosis takes place, and there the material remains localised, at least for a period of two and a third years. Phagocytes containing asbestos particles migrate into the lateral alveoli given off from the walls of the bronchioles, and considerable numbers ultimately penetrate into the adjacent connective tissues. In the guinea-pig, transportation of dust particles to intrapulmonary and mediastinal lymphoid tissues is so slow that changes in these structures play little part in the early development of asbestosis. In the rabbit, dust cells begin to appear in the lymphoid tissues of the lung within sixty days after starting the inhalation; thereafter, they are found in increasing numbers.

In the guinea-pig, fibrosis in the walls of the respiratory bronchioles and their lateral alveoli is first manifested after 500 days' exposure. Thereafter this type of reaction progressively increases in intensity and extent. The resulting atelectasis is responsible for a gland-like appearance, which is due to the contraction of the included alveoli and a consequent compression of the epithelial lining cells. In the rabbit sufficient time has not yet elapsed for fibrosis to be expected.

In the lungs of guinea-pigs, asbestosis bodies, apparently identical with those described in the human being, have developed after an exposure of approximately seventy days. In the rabbit these structures have not been discovered after exposures as long as 330 days. In the albino rat they are very rare. Only two small typical forms have been discovered in one animal exposed for seventy days. The prevalence of chronic infections of the lung in all members of this series is possibly responsible.

Asbestosis bodies apparently fail to form in the tracheobronchial lymph nodes. They may be transported in small numbers to these tissues and to areas of chronic pleurisy. They have not been discovered in the peritoneal cavity 100 days after injection of dust. In the subcutaneous tissue of the groin, typical forms were found 102 days after the injection of 3 milligrams of dust.

Asbestosis bodies are not present in asbestos dust previous to contact with animal tissues. They are produced by oxidation and hydrolysis of the chrysotile molecule. The formation of these structures is the first direct evidence that the body is capable of effecting chemical changes in inhaled silicate particles. The chemical processes involved have been discussed *in extenso*. Attempts at artificial production of asbestosis bodies *in vitro* have been partially successful; solutions of ferric chloride and sodium silicate have been made to combine in the presence of a fibre to produce more or less typical forms. The asbestosis body is therefore analogous to the well known "silica garden". Attempts to produce asbestosis bodies *in vivo* by the injection of dusts containing iron salts and silicates have thus far failed. The failure to produce them in tissues other than the lung and subcutaneous of guinea-pigs and man has not been explained.

Comparison between the localisation and the reaction to asbestos and other types of inhaled dusts has been shown. The points at which inhaled dust is localised in the lung or lymph nodes vary with the type. Granite remains within the pulmonary air spaces and produces no local reaction of fibroblasts for several years. In the tracheo bronchial lymph nodes characteristic silicotic nodules develop within two years. Carborundum likewise has failed to affect the stroma of the lung even in four years, but fibrosis in the lymph nodes has been observed. Quartz is rapidly concentrated by migrating phagocytes in the pulmonary and mediastinal lymphoid tissues. In these places it provokes an early and rapid multiplication of fibroblasts. Asbestos, as it is inhaled, is concentrated in respiratory bronchioles and their lateral alveoli. Phagocytes carry it into the walls, where fibroblasts are stimulated.

Lymph stasis plays little part in early asbestosis; the structure of this dust tends to localise it within the lung from the start. Lymph vessels are dilated in the absence of detectable obstruction. The dilatation may be a direct result of pulmonary irritation.

Primary tuberculous infection is influenced only to a limited degree by inhaled asbestos. This effect has been tested by inhalation infection of attenuated tubercle bacilli (strain R₁). One group of guinea-pigs was infected at the outset of dust inhalation; a second group, two years after beginning dust exposure. In normal guinea-pigs such infection produces tubercles in the lung and tracheobronchial lymph nodes comparable to the primary complex in man. The lesions caseate and the pulmonary foci heal by resolution. Spread of the infection with macroscopic disease in other viscera is very rare. In the first asbestos group infected, 32.2 per cent. of the animals showed some

evidence of spreading tuberculosis. New disease was sharply localised to areas where dust reaction had occurred. Rarely small cavities developed in such secondary foci. The tendency to healing by fibrosis was marked; at autopsy 40 per cent. of the cases showed healed fibrosis tuberculosis; macroscopic disease in the spleen and sometimes the liver was common. Dissemination appeared to begin in primary tubercles contiguous to foci of dust reaction. The contrast with animals similarly infected but exposed to quartz dust is marked. In them every exposure longer than five months resulted in generalised chronic tuberculosis of the lungs and other viscera.

For the second asbestosis group infected, the record is not yet complete. In them the localisation of the infection was atypical. Many bacilli were trapped in foci of dust reaction. Some produced local tubercles; others immediately entered the dilated lymph vessels and were transported to the tracheobronchial lymph nodes. Tuberculosis in these nodes sometimes occurred without involvement of the lung. Early diseases in the spleen and hepatic lymph nodes was the rule. The ultimate outcome of infection in this group has not yet been observed.

The combined action of asbestos dust and tubercle bacilli in the lung produced more fibrosis than did either agent acting independently.

THE MEDICAL EXAMINATION OF NATIVE LABOURERS ON ENGAGEMENT AT THE GOLD MINES OF THE WITWATERSRAND

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There are approximately 200,000 natives working on the gold mines of the Witwatersrand. A little more than half this number is drawn from areas within the Union of South Africa, of which the largest portion consists of the Xosa, Fingo and Pondo tribes of the Transkei (Cape Province), and the smallest portion comprises tribes drawn from Zululand and the Northern Transvaal. Basutos, Bechuanas and Swazis come from the three British Protectorates, and constitute the second largest portion.

All these natives are known as British South African natives.

The balance of the natives is obtained from Portuguese East Africa south of Latitude 22° South, and are known as East Coast natives.

METHODS OF RECRUITMENT AND TERMS OF SERVICE

British South African Natives

Almost one-half of these natives are not "recruited", but voluntarily come to the Witwatersrand and seek employment on the mines. The remaining natives engage through the representatives of the Native Recruiting Corporation stationed in the native territories, who advance the natives money to provide for the needs of their families and for the train fare and food to Johannesburg.

The non-recruited native on his arrival on the Witwatersrand selects a mine and engages himself for a period of service mutually agreed with the mine authorities, sometimes on a monthly basis.

The recruited native nominates a mine on attestation, and in the majority of cases is required to contract for a period of nine months.

In both cases the agreement of service is ratified by the issue to the native and the employer of a service contract prescribed by the Government.

Service beyond the registered period is terminable by the giving of seven days' notice on either side.

East Coast Natives

All these natives are dealt with by the Witwatersrand Native Labour Association.

Those seeking mine employment voluntarily make their way to one of the many camps maintained by the Association in Portuguese East Africa. From these camps the natives are drafted, either by steamer, railway or motor transport, to the Association's centralising depot at Ressano-Garcia, within five miles of the eastern border of the Union. The natives are forwarded twice weekly by rail from Ressano-Garcia to the Association's main distributing depot at Johannesburg.

East Coast natives are initially contracted for 313 shifts worked, but, in terms of the Convention recently concluded between the Portuguese and Union Governments, may re-engage for a further period or periods not exceeding 156 shifts worked, upon the completion of which the native may be called upon by the Portuguese authorities to return to Portuguese territory.

MEDICAL EXAMINATION IN THE NATIVE TERRITORIES

The British South African non-recruited native naturally has no medical examination prior to reaching the Witwatersrand; but all British South African recruited natives, with the exception of a few from areas where medical officers are not available, are examined by the local medical officers—usually Government district surgeons.

For the guidance of these medical officers a schedule has been drawn up by the Transvaal Mine Medical Officers' Association, and in it special attention is directed to diseases of the lungs.

The East Coast native has no searching medical examination until his arrival at the Association's depot at Ressano-Garcia, and only natives who are obviously ill or diseased are eliminated at the various camps.

At Ressano-Garcia, where the Association has a large depot and hospital, the Association's medical officers (one whole-time and one part-time) examine and (where necessary) re-vaccinate the natives, comprising gangs of 300-400 twice weekly, and those deemed fit for mine work are forwarded to Johannesburg.

At the request of the Tuberculosis Research Committee these natives have, during the last eighteen months, been given an intradermal tuberculin injection immediately prior to their departure for Johannesburg, and the reaction is recorded on their

passports twenty-four to forty-eight hours later, on their arrival in Johannesburg, and the medical histories followed up during the period of the natives' stay on the mines.

MEDICAL EXAMINATION ON THE WITWATERSRAND

All natives for employment on gold mines, non-recruited as well as recruited, and from whatever areas, are given a strict medical examination at the Witwatersrand Native Labour Association's central depot at Johannesburg, before being registered to the various mines.

After registration the natives are again subjected to a further medical examination by the mine medical officer on their arrival at each mine, and any who are considered to be unfit to commence work are returned to the W.N.L.A. depot for re-examination—clinical and radiographic—and possibly for detention in the depot hospital.

The only difference in the methods followed for the examination of the non-recruited and the recruited natives is that, in the case of the former, the mine examination takes place first, upon the native applying for employment.

DETAILS OF MEDICAL EXAMINATION AT THE CENTRAL DEPOT

There are usually about 170,000-180,000 recruits examined annually at the W.N.L.A. central depot, and the numbers presented for examination daily vary from 300 to 1,200.

A staff of six whole-time medical officers perform these examinations.

On arrival at the depot, every native takes a bath and is given soft paraffin soap with which to cleanse himself. His clothes are degerminised in a steam disinfectant. These precautions are necessary owing to the prevalence of typhus fever in the native territories.

After the clothes have been dealt with the natives are drafted in batches to the examination rooms, where they are first taught to breathe properly by trained native orderlies, i.e. in a manner suitable for auscultation. This may appear unnecessary, but in practice it is found to be essential and saves a great deal of time, for some of the natives are very nervous and apprehensive.

The boys are then lined up naked, in rows of about twenty-five,

before each medical officer, who carefully auscultates the chest, front and back, and a mark is made on the boy's chest on the detection of any abnormality, however slight. He is thereupon removed to a special examining room for re-examination by one of the medical officers, whose whole time is thus occupied. If considered necessary, the native is detained in hospital and X-rayed; his medical and labour history are enquired into, and a bacteriological examination is made of his sputum.

On the completion of auscultation of each row, an inspection is made of the limbs, eyes, glands and for the presence of any venereal disease, and those passed fit are sent to the depot Pass Office for registration.

A medical officer, when he has become accustomed to doing this work and has developed the power of concentration, is able to examine about sixty natives per hour, but requires a break of about half an hour after two hours' work. To many it may appear impossible to examine such a number with any degree of accuracy, but it must be realised that all that is demanded of the medical officer is the detection of an abnormality and not a diagnosis of the condition. After doing this work for several years the W.N.L.A. medical officers have naturally become proficient in the use of the stethoscope.

Occasionally defects are missed at this examination, but this is more likely to occur at the close of a heavy day.

It is on account of this possibility that a second examination is carried out by each mine medical officer, where the natives arrive on the mines in smaller numbers.

Every day, in spite of the schooling, there is always a number of natives who will not, or cannot, breathe suitably. It has been found necessary to X-ray the chests of such natives, for experience has proved a large proportion to have tuberculosis or silicosis. In many cases the poor breathing is done wilfully, the native hoping to escape detection by so doing.

DISPOSAL OF UNFIT NATIVES

Natives found unfit at the central depot, including those returned after the examination by medical officers on the mines, are dealt with as follows:

1. Natives who are ill are put in hospital and treated, and if the disease has been of a serious character are repatriated on convalescence.

2. Natives who are out of condition or merely "train-weary" are weighed and detained, under medical supervision, in the depot for a fortnight or longer. During this time the natives are periodically examined and only passed out when sufficiently improved for underground mine work. Those natives who do not improve to any extent are usually put on light surface mine work and not allowed to work underground until passed as fit therefor.

3. Natives with chest abnormalities are detained in hospital for investigation and treatment. Natives found to be non-tuberculous are discharged from hospital and afforded mine surface work.

All tuberculous cases, incipient or otherwise, are repatriated to their homes and warned not to return for mining employment.

Silicotic or tuberculo-silicotic cases are transferred to the miners' phthisis wards for examination by the Miners' Phthisis Medical Bureau, a body of medical men appointed by the Government to examine mine natives with pulmonary tuberculosis or silicosis with a view to determining the degree for compensation in terms of the Miners' Phthisis Act. Such natives are repatriated when fit to travel to their homes.

GENERAL REMARKS

An attempt has been made to give a brief résumé of the medical examination, as conducted on the Witwatersrand, of natives engaged for employment on the gold mines.

It is realised that this examination, thorough as the time-limit permits, is by no means definitely conclusive, but the whole problem is an extremely important and difficult one. It is felt that, whatever other method the circumstances may allow, it would still lend itself to criticism.

From the foregoing it will be realised that one of the chief difficulties is the large number of natives who have to be dealt with daily, and their examination completed, as far as possible, on the same day.

A stethoscopic examination alone (which is all that time permits) has its limitations. Early silicotic and early hilus tuberculous cases are missed, and obviously it is impossible to subject every native to a radiographic examination.

A radioscopic examination was undertaken, and over 2,000 natives were screened, but without the success hoped for. Obvious tuberculous or tuberculo-silicotic cases were detected, but all early conditions were not made apparent.

Another great difficulty is that a population which is extremely susceptible to tuberculosis has to be examined; many have the disease in a latent, undetectable form which, under their pastoral home conditions, would remain quiescent, but which, after the increased stress and strain of a few months' mining work, develops into an acute tuberculosis.

STATISTICAL TABLE

The subjoined table gives the numbers dealt with and the causes and percentages of rejections at the W.N.L.A. central depot from January to December 1928:

Class	Total examined	Total rejected	Causes of rejection			Percentage of rejection
			Tuberculosis	Defective lungs	Other causes	
East Coast recruits	44,668	3,782	272	960	2,550	Per cent.
East Coast re-engagements	14,642	217	39	112	66	8.69
British South African recruits	50,921	2,429	118	836	1,475	1.48
British South African non-recruited	40,525	1,011	34	368	609	4.66
British South African re-engagements	14,348	225	14	116	95	2.49
Contractors' natives	2,946	5	4	1	0	1.56
Total	168,050	7,669	481	2,393	4,795	4.56

SANATORIUM TREATMENT OF MINERS' PHTHISIS PATIENTS

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PROVISION FOR HOSPITAL CARE AND TREATMENT

The number of cases of miners' phthisis occurring in the early days of mining on the Rand with a considerable number of deaths drew the attention of the industry to the necessity of making some hospital provision for the treatment and care of such persons.

In 1908 negotiations took place with the Government, and in 1910—the Government contributing a site of 20 acres with a small building thereon—the Chamber of Mines erected and equipped the Springkell Sanatorium at a cost of some £50,000. To this Sanatorium were admitted all cases, whether of silicosis only or of silicosis complicated with tuberculosis.

In 1916 it was suggested that the purely silicotic cases should be housed in an institution quite separate from that in which there were cases of pulmonary tuberculosis, and with this end in view, in 1917, the Estate of the Wedge Farm was purchased by the Chamber of Mines, where a large and commodious country house was converted and adapted for use as a recuperative hospital much on the same lines as some of the earlier sanatoria in Scotland. Of course additions were necessary but in the end suitable provision was made for fifty beds. The entire cost of building and equipment in this instance was borne by the industry. Both these sanatoria are situated within a few miles of Johannesburg and are easy of access. Considerable provision is made for the free transport of patients and also for their relations and friends who wish to visit them.

In so far as Springkell is concerned, the annual cost of upkeep is in the neighbourhood of £20,000; with the exception of a £5,000 grant from the Government, this is borne by the Chamber of Mines. Since 1920, a limited number of paying cases have been admitted from the Military Pensions Department and from the Municipalities.

In respect of Wedge Farm the annual cost of upkeep is in the neighbourhood of £7,000 per annum—all provided by the industry.

When first opened, Springkell had accommodation for seventy-two patients; this has since been increased to a hundred.

The maximum accommodation at Wedge Farm is for fifty patients.

Climatically, the situation of both these institutions is ideal from a sanatorium point of view. Springkell has a northern aspect, situated in well-wooded country, with a hill on the south side protecting it from the occasional cold winds of the winter months. The Wedge Farm Sanatorium is situated on an estate well sheltered with trees. On the High Veld generally, and particularly within a few miles of the northern side of Johannesburg, the climate is ideal; with an altitude of just under 6,000 feet it is never very hot in summer, and only occasionally is it uncomfortably cold in winter. The protective quality of the Witwatersrand ridge can be felt immediately a short journey is made to the south. In winter it is very much colder in Johannesburg, and the winds are more persistent and constant. Sunlight we have practically every day of the year. I do not suppose that we have more than three days out of the 365 when the sun does not shine for the greater part of the day. Our rainfall averages about 20 inches per annum and is precipitated within the limited period of the summer months, and then almost invariably at night—occasionally in the late afternoon.

The grounds of both institutions are suitably laid out, and with the surrounding open country provide plenty of scope for exercise. There is a remarkable absence of dust.

The administration of both institutions is in the hands of what is known as the "Miners' Phthisis *Sanatorium* Board"; its functions are purely of a hospital nature. (This Board must not be confused with the Miners' Phthisis Board, which deals with financial matters, principally in respect of the compensation of silicotic and tubercular ex-miners.) The Sanatorium Board consists of representatives of the gold mining industry and of the Government, one of the latter's representatives being selected with particular reference to looking after the interests of the miners.

The cases admitted to either institution come from the body of men who have left the mines.

TYPE OF DISEASE

Those conversant with the literature of silicosis are well aware of the changes that have taken place in the type of the disease, as advance has been made year after year in controlling the dust underground. Only the earlier practitioners on the Rand could correctly describe both the clinical and pathological conditions that obtained in the early days. The names of Dr. Louis Irvine, the late Dr. Macaulay, Dr. Loeser and Dr. Andrew Watt are well known in this respect. Dr. Andrew Watt was in an unusually strong position, in that he made himself an expert radiographer to assist him in diagnosing the large number of cases that came to him. All experienced physicians on the Reef agree that the former cases of massive fibrosis caused by dust are no longer seen—nowadays, the silicosis is much more patchy in its distribution and the tuberculosis element predominates. Among post-mortems that I have done at Springkell, this change in the type of disease is confirmed, and among outstanding features one would mention the very patchy distribution of dust, the tendency for deposit at the posterior margins of the lungs, and particularly in some cases tough, hard fibrosis round the roots of the lung. The last mentioned has an important clinical significance in that where this condition arises early in the mining career of the individual, incapacitation soon results, an incapacitation out of all proportion to the amount of dust in the general structure of the lung. Clinically, these cases early exhibit marked short-windedness, and an attack of bronchitis in these cases quickly develops further into emphysema, and, before long, involvement of the heart.

TREATMENT

With the tendency in latter years for the tuberculosis element to be more pronounced, it cannot be expected that the treatment of cases of tuberculosis complicated with silicosis is much different from the main principles of routine treatment adopted in hospitals and sanatoria for pure pulmonary tuberculosis in other countries. In so far as cases of pure silicosis are concerned, a great deal depends on the amount of dust a patient may have in his lungs and whether he is free or not from secondary infections of the pneumococcal and streptococcal varieties.

We may take it, then, that in so far as the ante-primary or primary stage silicotic individual is concerned, institutional treatment is required solely as a recuperative measure in general, and in particular for any accidental affection he may have, such as bronchitis, asthma, and troubles of this type.

But with respect to the cases of miners suffering from pure tuberculosis or silicosis complicated with tuberculosis, the routine

treatment that is adopted for pulmonary tuberculosis in every hospital and sanatorium obtains, with the reservation that in some respects particular attention is given to some outstanding symptomatic and objective conditions.

Cough

With this symptom the great majority of cases do not differ from the purely tubercular, but in a few the cough is of a markedly paroxysmal nature, so severe as to cause vomiting, loss of wind and collapse. The usual well-known sedative cough mixtures are exhibited, and in a limited number the simple remedy of black currant infusion; a glass of hot milk will alleviate a cough that keeps the patient awake.

Dyspnoea

The pure tuberculosis patient has this complaint, but the miner with a lot of dust has it aggravated. The attacks come with lightning suddenness and cause the patient great alarm and distress. When it threatens to be dangerous, and particularly when it is so bad as to render the patient almost helpless, the quickest and most satisfactory treatment is a hypodermic injection of $\frac{1}{6}$ grm. of morphia. Probably, before one reaches this line of treatment, turpentine stupes, cough mixtures and stimulants are tried. They help a little, but the good effect does not last.

Apart from the two above-mentioned troublesome conditions, treatment resolves into general hospital care and discipline, and the exhibition of such special forms of medication as are advocated from time to time.

General

All patients sleep on open verandahs, balconies, shelters, or open-air wards. The principles of constant rest in bed for some cases and graduated exercise for others are observed. Meals are taken at regular hours, with rest before and after. Special attention is directed to try and meet the vagaries of a patient's appetite. I mention this, because at Springkell this feature stands out. It requires at times a lot of personal attention to detail, and certainly makes ward work heavier.

The preparations of malt and cod liver oil, pure cod liver oil, and emulsions cannot be freely given in a locality where the atmospheric temperature is uniformly mild and warm. As a matter of fact, my experience among tubercular patients is that where the appetite is good and the ordinary meals satisfactorily taken, these "extras" are of little avail. There is a limited number of individuals who do benefit by these preparations, but the general routine use of cod liver oil is contra-indicated here, as in such a number of cases patients appear to contract dyspepsia and become "liverish" (patients' word).

Of the more direct methods of attack on the disease, we have tried here during recent years, amongst others, Bruschettini's Vaccine, Sodium Morrhuate, Dreyer's Diaplyte Vaccine, and Sanocrysin. These have been extensively tried in Europe, and there is no need to discuss them fully. Sodium Morrhuate gave good results in a few cases—we cannot say more; Sanocrysin was given in a series of thirty-three cases. Of these, sixteen went to work or were well enough to work, six improved considerably in general health, in seven treatment had to be stopped, and four died. Early and advanced cases were treated, gradual dosage used, doses varied from 0.15 to 1 grm., and the reactions were of the same type met with wherever Sanocrysin has been used. The digestive and gastric upset was, however, predominant, and in one case a very severe skin reaction (with constitutional symptoms) occurred even although only a stage of small dosage had been reached. Early and advanced cases were treated, both among miners and non-miners.

Collosol Antimony (1 c.c. twice a week) is being tried and appears to benefit some cases; I have not had long enough experience of it to speak more definitely.

Solarium Treatment.

This has never been the success in South Africa that it has been in European countries and the reasons are obvious: in the summer months direct exposure to the sun, except under most careful conditions, is too risky—the sun is too hot. This form of treatment is not the success in pulmonary cases as it is with bone and joint disease. In South Africa there is only very little trouble of the last-mentioned description among children. Occasionally one does come across a pulmonary tuberculosis patient who co-operates heartily and intelligently with the physician and in some of these cases good results are obtained. Note we are at 26° S. latitude on the Rand—at Cape Town the conditions may be more favourable for this form of treatment.

Collapse Therapy

Artificial pneumo-thorax is used, but I think the percentage of cases that are amenable to this particular therapy is of the same small percentage as obtains in other countries. With a tendency now for there to be more of the tubercular factor in the pulmonary troubles of underground workers, the field for the use of artificial pneumo-thorax will extend from year to year, and I know of one physician who uses this form of treatment in cases of pulmonary tuberculosis among ex-miners.

Effect of Locality and Altitude

At the Sanatorium, our altitude is 5,600 feet, latitude 26° South (Cape Town is at sea level, latitude 34° South).

In sanatoria, the time inevitably comes when some patients ask for a "change", either to another institution or discharge to go to a different locality. In the majority of cases with silicosis and pulmonary tuberculosis, the coast towns are not favourable. Cape Town in the winter months has a cold, wet and rainy season, somewhat resembling parts of Great Britain—it is in great contrast to the sharp bracing winter of the Transvaal uplands. Durban, also a coastal town, is very hot and humid in summer—the stimulating effect on body metabolism of our perfect Transvaal climate during most of the year must resemble the same conditions as obtain in the situations of the Swiss Sanatoria.

Apart from climatic change, it is a good thing to give periodical leave of absence to patients who show a tendency to become "stale". They return with improved appetites and settle down more contentedly for further treatment.

Quack Remedies and Patent Medicines

We have had our full share of these; their names are legion; and the faith of human patients in the alluring label remains unshaken until too late. The most recent was a "remedy" widely advertised along the Reef; and our opposition and condemnation of it threatened a libel action; but we stood our ground and the case fizzled out. The "remedy" claimed to cause the lungs to excrete or throw off the particles of silica! A second patent remedy was an electrical contraption of wires and wood for enveloping the chest. A third consisted of an oil saturated with fine coal dust; this was taken "*per os*", the coal intended to cause excretion of silica; the inventor apparently knew nothing of Haldane's and Mavrogordato's work. But the promising cures not materialising, combined with the unpleasant taste of the oil, soon finished off this remedy.

SYMPTOMS

I will now deal briefly with our local experience with some of the symptoms commonly met with in cases of pulmonary tuberculosis.

Haemorrhage

It does not appear that among miners with tuberculosis infection there is any greater percentage of haemoptysis cases than there is among the non-mining tubercular community, and the characteristic features of haemoptysis are the same. It is confirmed that only a very small number of cases of pulmonary haemorrhage are immediately fatal. These are of the sudden overwhelming type when death occurs within a few seconds. The great majority of cases of haemorrhage apart from the above, vary in quantity from mere "colour" up to a pint or two pints of blood. Most of these cases recover from the haemorrhage. To control this haemorrhage, the injection of morphia hypodermically is the only satisfactory, and certainly the quickest method of arrest. Hypodermic injection

of haemoplastic serum and colossal calcium do help, but they are not the bedrock of treatment which enables the physician to leave the patient with an easy mind. In respect of the two latter methods of treatment mentioned, in my experience it is wrong, and may be dangerous, to exhibit them too early. The theoretical basis of the arrest of pulmonary haemorrhage is to cause the quick clotting of the blood to close up the source of the bleeding. But there are some cases apparently in which haemoplastic and calcium may induce such clotting that the patient is embarrassed by the collection of blood clots in the bronchi, and his suffocation may be caused by his inability to get rid of such clots quickly. I would cite one case of a heavily built man who was having a moderately severe haemorrhage only, but whom I found quite unconscious and cyanosed. The heroic method I adopted was on these lines. I argued that if left as he was he must surely die—it was imperative to get some air into the lungs; and I therefore hoisted up his legs and stood him on his head. Immediately large clots of blood were ejected from the bronchi; and within a few minutes the patient restored to the prone position was resting comfortably in his bed.

Sweating

Night sweats do not appear to be so frequent among miners affected with tuberculosis as with non-miners. I have not had any success with pharmacopoeial remedies well known to all. I believe rather that as good results as any will be obtained by using the sleeping mat as advocated by Marcus Patterson, and also in some cases by the use of autogenous vaccines.

Loss of Appetite and Loss of Weight

Among miners, this complaint appears to have the same features as among non-miners. As a general rule, where the appetite remains good, not only will the weight take care of itself, but this type of patient always stands a better chance of eventual recovery.

Gastritis and Intestinal Upset

These are commonly met with in all cases of pulmonary tuberculosis.

Tubercular Laryngitis

Over a period exceeding twelve years I have not yet found a case among miners. It may be mere coincidence: if it is not, it is a

remarkable feature. In the more advanced cases nearing the fatal termination of their disease, one gets tubercular ulcers in the pharynx, and I have no doubt that in a percentage of these cases some infiltration of the larynx would be found at post-mortem examinations.

Tubercular Testis and Fistula in Ano

Both these combinations appear to occur less among miners than in non-miners.

Alcoholism

This bugbear of all hospitals and institutions that house patients over an extended period is also among our administrative problems. Speaking of alcoholism *per se* with respect to its relation to prognosis in cases of pulmonary tuberculosis, I must say that excessive imbibing of alcohol periodically by a certain type of patient does not appear to have any devastating effect in respect of accelerating the progress of the disease. The prognosis is worse only when alcoholism is associated with unusually bad living conditions with concomitant bad feeding, poverty, and undue exposure to inclement weather conditions.

Infectious Element of the Disease

At the Springkell Sanatorium we have an annual admission rate of more than 100 tuberculosis-infected ex-miners, and this institution has been open for the admission of patients for some eighteen years. I do not know of an instance of any member of the family of a tubercular miner having contracted the disease from living in the same house with such tubercular individual. It is just possible that the standard of living among miners in the Transvaal is higher than it is among the poorer tubercular, badly-housed families in Europe; this observation applying to food, clothing and accommodation; the equable climate and strong sunlight-attack on the bacilli may be the real controlling factors.

INSTITUTIONAL MONOTONY

We do our best to try and relieve this by granting patients perhaps a little more freedom and leave than has hitherto been considered necessary. In addition, there is a reading room, billiard room, a very good library, and the daily newspapers with the European magazines are easily available. There is a bowling

green, and a particularly fine "open air" concert pavilion where entertainments are frequently given. A large wireless installation has been established which receives from the Johannesburg Broadcasting Station; and several patients have their own individual receivers.

OCCUPATIONS

Whenever and wherever possible, if the patient is fit, he is given occupation if he wants it; and we have had, and have, patients doing the following work: Office clerks, telephone operators (these must be negative tuberculosis sputum cases), motor-drivers, painters, carpenters, bricklayers, gardeners, and handymen. Patients are also employed in poultry keeping, the Sanatorium providing buildings, runs, and fowls; the patient does the work and buys the food—we purchase the eggs. We have tried giving patients outside work to do of the farm-labouring description; but it has consistently failed.

THE FACTOR OF DISABILITY

Among miners and ex-miners, there is great variation in respect of disability among individuals classified in the same group, whether that group be Pure Tuberculosis only, Primary Silicosis, Silicosis in the Secondary Stage, or Silicosis complicated with Pulmonary Tuberculosis. With any tubercular factor in lung disease, the activity or dormant condition of the infection generally determines the degree of disability. There is marked difference in the disabling factor of silicosis when this is still in the primary stage. Possibly, however, the most important consideration must be the presence or absence of secondary infections—bronchitis the most common. Lastly, the general health of the individual complicates the situation. "Phthisis" is so much talked about that the individual fails to realise that the cause of his disability may be disease or disorder in some organ of the body other than the lungs.

This variation in disability is commented on here owing to its influence in advising patients with respect to occupations. The types of patients we admit to this institution will never establish a colony like that at Papworth—the local conditions are so entirely different. Those with a knowledge of the efforts made by the Miners' Phthisis Board to establish ex-miners on land settlements will all agree that these ventures have been disappointing. I must here take the opportunity of making some observations with

respect to the disposal of the ex-miner patient after he leaves the institution. Finding suitable employment for these patients is with us just as acute now as was the same problem for the partially incapacitated ex-soldier immediately after the Great War. Only the very smallest percentage will ever make even a bare living on the land, and even these must have very little physical incapacitation and some capital. A few million pounds of good money have been lost in this country by unfortunates who had dreams of combining an "open-air" life with occupations such as farming, poultry-keeping, and vegetable gardening. The average tubercular patient is entirely unfitted for this kind of work. I now advise all discharged patients to try and get back to the job for which they were trained and to which they are used, and not to be obsessed unduly with the "open-air" factor. This advice can be taken by non-miners if they so choose, with reservations for such as school teachers (sputum positive tuberculosis) who come in contact with young children. Those who handle foodstuffs (grocers, butchers, bakers, dairymen, and the like) are definitely debarred from returning to their previous occupation. But the ex-miner obviously cannot return to underground work, and only a small number have been trained in some other occupation before they took up mining. A few ex-underground workers, such as timbermen, builders, and mechanics, can get work of this nature on the surface; but for the rest the problem is very difficult. Certain it is that they are better off to continue as employees even at small pay rather than sink such money as they may have in agricultural and farming adventures.

STAFFING

In respect of the Sanatorium at Springkell, the nursing staff required does not differ essentially from staffing in similar institutions in other parts of the world.

At the Wedge Farm, however, where patients of the recuperative convalescent type are admitted, the staffing is very small, consisting of a matron and two nurses for an average of roughly forty patients. It is seldom that nursing is required for very bad bed cases. For the benefit of those accustomed to the staffing of hospitals in Europe it might be mentioned that a great deal of the ward work, such as scrubbing floors and sweeping, is done by native boys. The employment of native boys for this work at the two sanatoria under consideration is made easier by the fact that only males are admitted.

TRANSFERS

Wedge Farm Sanatorium is reserved for silicotic cases, and Springkell for tubercular patients. It is unknown for a silicotic patient to develop tuberculosis while resident at Wedge; but patients still classified as

being "without tuberculosis" are sometimes admitted to Wedge and on examination by the Medical Officer are found to be suffering from active pulmonary tuberculosis or give a positive tuberculosis sputum; they are, naturally, immediately sent to the proper institution.

The most common aetiological factor in the superimposition of pulmonary tuberculosis are attacks of "bad cold", influenza, and pneumonia.

ADMISSIONS, SPRINGKELL

Since this Sanatorium was opened in 1911, 2,482 miners and non-miners have been admitted. Up to 31 March 1929, roughly one-third have died, 1,530 have been discharged, and at that date there were still remaining in the Sanatorium eighty-four patients.

DISCHARGES

These numbered 1,530. The average length of residence of a patient at Springkell is about four months. Were it not for certain economic conditions, and the fact that miners reside here as free patients, I have no doubt that the number of discharges would be higher and the term of residence of shorter duration.

DEATHS

Deaths at Springkell average roughly one-third of the admissions. The death rate is an appalling one to quote, but as a criticism of curative treatment it is useless and misleading.

Springkell having been originally built by an industrial body, the factor of being able to select one's cases does not exist. We admit cases in all stages of the disease; and in the very early years, owing to certain local conditions, apparently the great majority of cases admitted were very advanced and in some instances moribund. Within the last ten years I doubt whether there has been a genuine case of death ascribable solely to a heavy deposit of dust in the lungs. In practically all the silicotic cases that remain free from the tubercular complication and that now have a fatal termination, the cause of death is something other than lung trouble. In my experience at the Wedge Farm the great majority are due to cardiac and renal trouble, and these cardiac and renal conditions do not appear to differ in any way from those obtaining among the civilian population who have not worked underground. A certain number of deaths, in so far as the lungs are concerned, are precipitated by influenza, acute bronchitis and pneumonia. Apart from pulmonary tuberculosis (or its complications) as the cause of death, in a certain percentage of cases the cause of death is from some malady not connected with silicosis or pulmonary tuberculosis. On the average at Springkell this figure amounts to

10 per cent. of the total deaths; and at the Miners' Phthisis Board for the years 1922-1927 the number of deaths stated as being "due to causes other than miners' phthisis" among the beneficiaries under the Act was as high as 22 per cent. The age at death remained at an average of forty-five years, but recently is higher. The amount of dust a patient may have and the degree of tubercular infection do influence prognosis, it is true; but I hold that the factor of individual resistance to tubercular disease is very great. Patients have been admitted with definite pulmonary tuberculosis and have survived for thirteen years; others admitted with apparently the same degree of infection do not live thirteen months.

It has previously been mentioned that within the last nine years we have admitted at Springkell non-miners as well as miners; and this enables me to say that the non-miner with pulmonary tuberculosis stands no better chance than the miner with silicosis complicated with tuberculosis; at any rate, in the average age at death of the two classes the non-miner dies at an earlier age, but in some of these cases the illness probably was contracted earlier in life.

RESISTANCE TO DISEASE

Early practitioners on the Reef will recollect the very great number of years that some individuals continued their underground work with apparent immunity from pulmonary tuberculosis, in spite of the fact that they had in their lungs heavy deposits of dust. In recent years there is no question of doubt, but that the silicotic element has been greatly diminished; and yet a large number of miners become fatally ill with pulmonary tuberculosis. Whether in the old days the rapid formation of lung fibrosis did in some way protect the individual from secondary infections it is hard to say; the fact does remain, however, among cases of pulmonary tuberculosis sent to the Sanatorium, that the presence of some silicosis in the lung does not make the vast difference in prognosis that one might expect.

Nationality may be one of the factors. In the very early days the British miners predominated; latterly the South African born miners predominate. In particular, the number of Cornish and North Country miners has diminished to a most remarkable extent.

After some years spent among these pure tuberculosis, and silicosis plus tuberculosis patients, one gets the impression that there are certain individuals who follow definite types in the manifestation of the disease itself. One finds burly heavily built men where the

tendency is not for pulmonary tuberculosis to dominate the clinical course, but rather a development of such conditions as bronchitis and asthma; in these cases there is only negligible loss of flesh, and in the end trouble is nearly always cardiac. On the other hand one admits tall, gaunt, lightly built miners where the tubercular disease follows definitely the destructive course that obtains among members of the non-mining community.

TABLE I. — ADMISSIONS AT SPRINGKELL AND WEDGE FARM SANATORIA, FROM 1 JANUARY 1912 TO 31 MARCH 1929

Year ended	Springkell		Wedge Farm: Miners only
	Miners	Non-Miners	
31 December 1912	131	—	—
1913	157	—	—
1914	143	—	—
1915	108	—	—
1916	108	—	—
31 March 1918 (15 months)	141	—	—
1919	142	—	65
1920	99	17	79
1921	150	13	93
1922	148	17	86
1923	145	14	67
1924	136	21	84
1925	135	25	87
1926	108	25	74
1927	112	36	100
1928	118	30	102
1929	124	45	85

(a) During the year 1917, it was decided to have the future financial and statistical years not as for a calendar year, but for a period of twelve months beginning on 1 April one year and ending on 31 March of the year following. Financial and statistical figures had, however, already been included for the year 1916 as ending on 31 December. Under the new conditions inaugurated in 1917, the statistical figures therefore were made up for a period of fifteen months from 1 January 1917 to 31 March 1918. From 1 April 1918, all annual figures are calculated for the period 1 April to 31 March accordingly.

(b) The Wedge Farm Sanatorium was opened only in June 1918. The number of admissions (65) was therefore for a period of nine months only—June 1918 to 31 March 1919.

(c) In so far as the admissions to Springkell are concerned, it will be noted that in the figures as from 1919 onwards there are three columns; 1 and 2 showing admissions of miners and non-miners to Springkell, and column 3 showing the number of admissions to Wedge Farm.

(d) At the Wedge Farm it is not always sickness that determines a patient's admission. The economic factor at times bulks very largely. The ex-miner who has left his work in the ante-primary and primary stages of silicosis does not receive an annual pension, but is granted a lump sum. In a great many cases this lump sum soon disappears either through indiscretion or through unwise adventures into investments or occupations where the capital has been lost. These unfortunates often find it difficult to get employment, and just as often are admitted to Wedge Farm to give them an opportunity to rest up for a while until they can get a job.

TABLE II. — ANNUAL ADMISSIONS AT SPRINGKELL

Year	Total	Miners		Non-miners: Tuberculosis
		Silicosis and tuberculosis	Pure tuberculosis	
1920	116	84	15	17
1921	163	123	27	13
1922	165	128	20	17
1923	159	127	18	14
1924	157	107	29	21
1925	160	119	16	25
1926	133	97	11	25
1927	148	100	12	36
1928	148	102	16	30
1929	169	112	10	47

The Medical Bureau was established in 1917. It was only a natural sequence that among a group of specialists who concentrated on the examination of lungs, clinically and radiographically, as the years progressed their estimation of the degrees of silicosis should be modified. Any such modification would naturally mean that once the new standard was accepted a number of miners would become classified as having silicosis where previously a negative result would be given. This may account partly for the variations in the table above. With respect to miners classified as suffering from pulmonary tuberculosis only, there is no indication, so far as the classification is concerned, whether such pulmonary tuberculosis is purely fibrotic and inactive (old tuberculosis fibrosis) or whether the disease is in an active condition.

It will be noticed that the percentage of discharges on annual admissions shows small variation, remaining within recent years more or less constant between 60 and 70 per cent.—this is, respecting the miners admitted.

TABLE III. — DISCHARGES

Year ended	Miners						Non-miners		
	Springkell			Wedge			Admis- sions	Dis- charges	Per- centage of admis- sions
	Admis- sions	Dis- charges	Per- centage of admis- sions	Admis- sions	Dis- charges	Per- centage of admis- sions			
31 December 1911	34	5	14.7	—	—	—	—	—	—
1912	134	67	51.1	—	—	—	—	—	—
1913	157	103	65.6	—	—	—	—	—	—
1914	143	102	71.3	—	—	—	—	—	—
1915	108	83	76.9	—	—	—	—	—	—
1916	108	58	53.7	—	—	—	—	—	—
31 March 1918 (15 months)	141	67	47.5	—	—	—	—	—	—
1919	142	91	64.1	65	45	69.2	—	—	—
1920	99	65	65.6	79	64	81.0	17	3	17.7
1921	150	76	50.7	93	88	94.6	13	3	23.1
1922	148	74	50.0	86	77	89.5	17	10	58.8
1923	145	90	62.1	67	66	98.5	14	8	57.1
1924	136	96	70.6	84	85	101.2	21	14	66.7
1925	135	89	65.8	87	90	103.4	25	14	56.0
1926	108	74	68.5	74	76	102.7	25	14	56.0
1927	112	71	63.4	100	92	92.0	36	27	75.0
1928	118	79	67.0	102	95	93.1	30	36	120.0
1929	122	79	64.7	85	93	109.4	47	32	68.0

For the miners admitted at Wedge Farm, the percentage rate of discharges on admissions is very high, emphasising:

(a) The economical factor already mentioned in the notes on the Wedge Farm admissions.

(b) The factor of disability. To have such a high percentage rate, it must follow that the general health of the Wedge Farm admissions is good.

Non-miners. — Except for the extraordinary figure for 1918, the discharge percentage rate remains fairly constant from about 60 to 70 per cent.

In the table given above, there has been a tendency since 1916 for the percentage death rate on admissions to become less each year at Springkell. Within recent years it has remained fairly stable at 30 per cent. or a little over. This rate is in sharp contrast with the very low rate for the purely silicotic cases at Wedge Farm.

Among non-miners there appears to be more variation—the figures ranging from 14 to 46 per cent.

TABLE IV. — DEATHS

Year ended	Miners						Non-miners		
	Springkell			Wedge			Admis- sions	Deaths	Per- centage of admis- sions
	Admis- sions	Deaths	Per- centage of admis- sions	Admis- sions	Deaths	Per- centage of admis- sions			
31 December 1911	34	1	2.9	—	—	—	—	—	—
1912	131	46	35.1	—	—	—	—	—	—
1913	157	48	30.6	—	—	—	—	—	—
1914	143	36	25.2	—	—	—	—	—	—
1915	108	41	37.9	—	—	—	—	—	—
1916	108	53	49.1	—	—	—	—	—	—
31 March 1918 (15 months)	141	59	41.9	—	—	—	—	—	—
1919	142	50	35.2	65	2	3.1	—	—	—
1920	99	48	48.5	79	3	3.8	17	5	29.4
1921	150	63	42.0	93	2	2.2	13	6	46.2
1922	148	52	35.2	86	2	2.3	17	5	29.4
1923	145	56	38.7	67	1	1.5	14	2	14.3
1924	136	42	30.9	84	2	2.4	21	7	33.3
1925	135	50	37.0	87	2	2.3	25	7	28.0
1926	108	33	30.6	74	2	2.7	25	11	44.0
1927	112	58	51.8	100	1	1.0	36	4	11.1
1928	118	36	30.5	102	2	1.9	30	5	16.6
1929	124	37	29.8	85	4	4.7	45	7	15.5

TABLE V. — TOTAL DEATHS AND AVERAGE AGE AT DEATH IN
SPRINGKELL SANATORIUM

Year ended	Miners and non- miners		Miners		Non-miners	
	Total deaths	Average age at death	Total deaths	Average age at death	Total deaths	Average age at death
31 December 1911	1	—	1	—	—	—
1912	46	41.0	46	41.0	—	—
1913	48	41.3	48	41.3	—	—
1914	36	43.4	36	43.4	—	—
1915	41	42.6	41	42.6	—	—
1916	53	42.4	53	42.4	—	—
31 March 1918 (15 months)	59	43.8	59	43.8	—	—
1919	50	45.7	50	45.7	—	—
1920	53	42.90	48	43.4	5	38.2
1921	69	45.4	63	45.28	6	43.16
1922	57	44.23	52	44.79	5	38.4
1923	58	48.46	56	48.79	2	39.5
1924	49	46.30	42	46.50	7	42.28
1925	57	47.10	50	47.06	7	47.42
1926	44	45.34	33	46.24	11	42.63
1927	62	47.68	58	48.34	4	35.50
1928	41	51.8	36	52.0	5	51.8
1929	44	56.2	37	57.7	7	48.1

In table V, the figures apparently point that among miners the tendency is for the age at death to advance. Among non-miners, the average age at death is lower for every year since these two classes of cases have been admitted. The lowest average age at death is thirty-five for non-miners; and for a period covering the same number of years, forty-four for miners.

PERSONAL EXPERIENCES OF MINERS' PHTHISIS ON THE RAND, FROM 1903 TO 1916

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In this paper I shall only attempt to give my personal experiences of mining conditions and of the incidence and nature of miners' phthisis between the years 1903 until the formation of the Miners' Phthisis Medical Bureau in 1916.

If I should appear to use the first personal pronoun too frequently I hope I shall be pardoned.

At the latter end of 1902 I was appointed Medical Officer to one of the large mining groups on the Witwatersrand, and I had the advantage of having charge of what, in those days, was a well-equipped small hospital for European employees. In close proximity, there was a Chemical and Metallurgical Laboratory, the staff of which was keen and alive to the importance of the problem of trying to combat the disease by preventive methods in allaying dust and providing pure air underground. The industry owes much to the vision and initiative of the Consolidated Gold Fields of South Africa in providing means to carry out experiments and investigations into underground conditions affecting the health of their employees, and in starting reforms, before any legislation made these compulsory.

After the occupation of Johannesburg, during the Anglo-Boer War, the mines gradually started work. They had been lying idle for over two years, and the miners had either been on service or had been at the Coast or in England.

The mining population in those days was a very different one from what it became later. The managers and officials were mostly of American nationality and a very large proportion of the miners

were Cornish or North Countrymen. They practically had all come from overseas and there were very few South African born miners or officials. The miners were skilled men and had spent their lives from boyhood in the practice of their trade. They had lived under conditions where they had been exposed to the infection of tuberculosis from infancy, and were born of parents who had likewise been exposed. Consequently, they had an immunity to tuberculous infection, and the type of miners' phthisis they developed was more of what we classified as pure silicosis, or tuberculo-silicosis, in contrast to the commoner type which developed later—silico-tuberculosis. After the Anglo-Boer War the Deep Level Mines began to be developed. In some, at this time, the shafts had struck the Reef at great depth, and some had not got down to it. Ventilation was bad; the formation of dust was practically unhindered. The practice of blasting the "cut" and the "round" in the same shift was universal. Work was paid for by results, and the earnings of men were large. The attitude was "Let us eat, drink and be merry, for to-morrow we die".

Very soon the price had to be paid. Many men died or became unable to carry on any work on account of increasing dyspnoea. Cough was not a predominant symptom except in the early morning, on rising. These patients coughed until vomiting was induced without bringing up much expectoration. Ultimately, in very many cases, cardiac failure either sudden and acute, or chronic, supervened, and death resulted without obvious signs of tuberculous infection. Pneumonia, in those days, was a very fatal disease. Sanitation above and below ground was primitive, and there was no water-borne system of sewerage in existence. The water supply was bad, and careful people boiled all the water and milk they consumed. Enteric fever was prevalent.

A Commission was appointed by Lord Milner, in 1903, to enquire into the prevalence of silicosis, and although the medical examinations were not conducted by specialists and X-ray examination was not then employed, about 20 per cent of the miners examined showed signs and symptoms of pulmonary disease.

The late Dr. Donald Macaulay and Dr. L. G. Irvine, the present Chairman of the Miners' Phthisis Medical Bureau, were working at the silicosis problem, and read papers on the subject to the Chemical and Metallurgical Society.

In 1911 another Commission was appointed to report upon the incidence of Miners' Phthisis. This Commission reported, as the result of the examination of 3,136 miners at work, that 32 per cent.

were classed as having miners' phthisis in one or other of its stages. The means of arriving at an accurate diagnosis were not so refined as they are now, and the men were only examined once.

Owing to the generosity of the Board of the Simmer and Jack Hospital, I had been permitted to purchase three X-ray machines, discarding the first ones purchased as improved machines were produced. A standard of X-ray diagnosis had thus been arrived at, but it was not possible to get good plates with the short exposures that obtained then. Films with double screening had not been introduced, and gas tubes were in use.

An attempt was made to correlate the X-ray appearances of films, taken during life and after death, with the signs, symptoms and post-mortem appearances—macroscopic and microscopic. Chemical estimations were also made by the late Dr. Jas. Moir as to the character and amount of inorganic material in the lungs. The men were examined by a number of different medical men, and their standard of normality naturally varied. The majority of the members of the Commission were engaged in practice, and the work had to be carried out in time taken from their practices.

The Commission classified cases of miners' phthisis into four stages:

- | | | |
|-------------------|-----------------------------------|-----------------|
| <i>Class I.</i> | Borderland cases, 5.5 per cent. | |
| <i>Class II.</i> | Early cases, 21 per cent. | |
| <i>Class III.</i> | Intermediate or advanced fibrosis | } 4.5 per cent. |
| <i>Class IV.</i> | Advanced cases incapable of work | |

These figures do not include any miners living on the Rand who had already relinquished work.

The opinion was formed that a miner *might* develop miners' phthisis after two years' work underground, but not sooner.

In 1912, Dr. L. G. Irvine and the author read a paper before the Transvaal Medical Society on miners' phthisis, the causation, signs and symptoms, stages, pathology, diagnosis and treatment of the disease; in which X-ray prints of silicosis were shown.

As a result of the report of the Commission, the first Miners' Phthisis Act was passed and came into operation on 1 August 1912.

Under the Act, miners' phthisis was defined as silicosis of the lungs and silicosis had to be found to be present by definite physical signs before any case could be described as miners' phthisis.

Pure tuberculosis was not miners' phthisis and was not compensatable. In a later Act pure tuberculosis was made a compensatable condition when it occurred in miners. Any under-

ground worker found to be suffering from open tuberculosis was removed by law from underground work, as he was considered a source of infection to his fellow-workers.

An advisory Medical Committee was appointed to examine applicants for benefits under the Act. This Board consisted of three practitioners, each, for the East and West Rand and six practitioners for the Central Area. X-ray examination was recognised as an aid to diagnosis, but was not universally employed. The examiners were not whole-time men. Each applicant had to be examined independently by two members, and on their report his case was dealt with by the Miners' Phthisis Board and compensation paid or not.

I think all will agree that the work of this first Advisory Committee was not entirely satisfactory. The members were engaged in general practice and their standards were unequal.

Previous to starting work underground every miner had to be medically examined. This examination was carried out by the mine doctor. Here again, the personal element entered and standards varied. For example, a man might be rejected by one doctor and go to another on a different mine and be passed, and, once being in possession of a certificate of fitness, would be permitted to work on any mine on the Reef.

The Commission had scheduled the Mines of the Transvaal as either phthisis-producing or non-phthisis mines. All the gold mines of the Witwatersrand were in the former category.

Another result of the Commission's Report was the formation of the Miners' Phthisis Prevention Committee. This Committee (consisting of Government officials, mining officials and workmen, chemists, consulting engineers and medical men) co-ordinated all the work which had been and was being done for the prevention of the disease, and they issued a report in 1916, as the result of which the present Miners' Phthisis Medical Bureau came into being. The work and functions of the Medical Bureau is dealt with by the Chairman of the Bureau.

Such is a short sketch of the history of miners' phthisis before the formation of the Bureau. My personal experience and that of my colleagues are contained in the paper "Silicosis on the Witwatersrand", published as an appendix to the report of the Miners' Phthisis Prevention Committee in 1916.

But much work and research had been done in the meantime.

I can only speak of work done in the Deep Level Mines of the Consolidated Gold Fields Group.

It was recognised from post-mortem examinations that the dust factor was the first problem to be tackled. I well remember going underground in 1903 to watch the effect of dust-laying appliances in drilling with machine drills. When the drill was working, it was impossible to see the face a few feet away, and we all came to the surface covered with white dust. This was the usual experience, not only with machine drillers, but the "hammer boys", especially those drilling upper holes, came to the surface with their faces and upper parts of the body white with dust.

Mr. McArthur Johnston, soon after, started sampling the air by the sugar tube method. This was a fairly accurate method of estimating the quantity of dust but not the size of the particles. It was, however, an index of the efficiency of the dust-allaying methods with which we were experimenting.

It was recognised from the investigation of the various Commissions that the rock drill miner, especially the machine developer, acquired the disease sooner than the miner who did not work with machines. This was probably due to the inhalation of fine dust produced in drilling. But there were other factors. The blasting of "cut and round" in the same shift, for example. The miner first blasted the cut and then returned to the face, as soon as possible, to charge and blast the round. In doing so, he not only inhaled dust produced by blasting but also the fumes of the explosives used. In the early days, cases of gassing were frequent, but the miner appeared to acquire a degree of immunity to the effects of "gas" provided that the detonation of the explosive was complete; unfortunately, this was not always the case.

Blasting accidents where the miner and his "boys" sustained terrible injuries, often entailing the loss of sight, were common.

Methods used to prevent the formation of dust were experimented upon and developed, and they all entailed the use of water. Whether this is the ideal method of dealing with the problem is now in doubt.

The manager of the Simmer Deep Mine had had much experience in coal mining in Scotland, where much attention had to be paid to ventilation. The Simmer Deep about 1911-1912 was the deepest mine on the Rand. The temperatures were high (average wet bulb, 80° F.).

In July a ventilation exhaust fan had been installed at the Rudd Shaft of the Simmer Deep. The adjacent shafts on either side were thus downcast shafts. The Rudd Shaft was used entirely for ventilation. Before the installation of the fan the amount of air coming out of the shaft was 105,703 cubic feet per minute. Shortly

after, 200,000 cubic feet were passed. The purity of the air was tested by its CO₂ content. There was a great improvement as the result of more efficient ventilation.

In 1907, in sampling one of the main air ways of the Jupiter, the adjoining mine to the Simmer Deep, and connected with it, 0.57 per cent. CO₂ was contained in the air, whereas in sampling a "dead end" in the Simmer Deep in 1912, 0.15 per cent. was found and in the upcast air in the shaft it was 0.17 per cent.

In every operation of mining, dust was raised, so that the disease was not confined to the driller, but the lasher and trammer and every man working underground, including shift bosses, samplers and mine captains, were liable to contract miners' phthisis.

Attempts were made to reduce the dust by wetting the downcast shafts, by making the air from the workings pass through screens of vapour formed by ordinary gas burners through which clean water was forced by gravitation, by watering the rock which was being shovelled or moved, by watering down the working places after blasting, and by using jets of water into the holes when drilling and by use of the water blast after blasting. Rock drills with hollow drills to convey water during drilling were introduced later.

What perhaps did more good than any of these was the introduction of blasting in one shift, only, in the twenty-four hours and the prohibition of blasting "cut and round" in the same shift.

Single shift blasting was first introduced on the Simmer and Jack Mine, and considerably later became universal.

About this time, as the result of examinations by the medical examiners, the opinion was formed that a miner could possibly develop silicosis two years after he started underground work in these mines.

In 1907 a strike occurred, and, as a result, many overseas-born miners left the country for good. This was due partly to economic conditions and partly to the high morbidity amongst underground men.

Home-born miners, now, do not come in large numbers to the Witwatersrand, on account of the strictness of the initial examination by the Miners' Phthisis Medical Bureau. A very high standard of general health is required, and if there is any evidence of pulmonary abnormality they are rejected and stranded in this country.

A new type of miner was introduced from the South African veld and farms. He came of a race quite well developed and set up physically but with little acquired immunity to tuberculosis, and

the type of the disease, miners' phthisis, began to change and become more of an infective type.

Accurate figures are not available, as the present Miners' Phthisis Medical Bureau had not been started.

On the Simmer and Jack an investigation was made as to the amount of infection which existed underground and on the surface. Visible samples of sputum in the ladderways and workings were collected and examined. Samples were also taken on the surface and from the compound rooms. More samples were found to be tuberculous underground than on the surface, but this might be due to the effect of dryness and sunlight on the surface. The results only proved that there was a good deal of open tuberculosis on the mines.

At the end of 1913 a number of white rats were placed underground at the top of a stope where air containing fumes and dust after blasting passed. These rats were killed after varying times spent underground, and excellent specimens of silicotic lungs were obtained. These specimens formed the basis of a report by Dr. Pratt-Johnson, which is contained in the paper presented to the Miners' Phthisis Prevention Committee in 1916 by the writer and colleagues.

It had been asserted that animals did not develop silicosis underground, but wild rats had only been examined—and they probably had not lived long underground—and some ponies on the Crown Mines.

Perhaps a similar experiment, under working conditions, would help to test Dr. Haldane's thesis that dusting with coal dust would be as efficient as water in preventing silicosis.

The Witwatersrand Mines still produce silicosis, but it takes very much longer to develop.

The type of the disease has changed, and tuberculosis predominates—pure tuberculosis is now compensatable.

Miners' phthisis is a compensatable disease, and finality has not apparently been reached as to how much compensation a sufferer is to receive.

The payment of compensation is a very great burden on the industry and may make the difference as to whether a low-grade mine may run at a profit or not. Therefore, apart from the humanitarian aspect, the prevention of miners' phthisis is a problem of great economic importance.

The man starting underground work to-day is in the A1 Class owing to selection at the initial examination of the Miners' Phthisis

Medical Bureau, and it should be our endeavour to keep him so by improving underground conditions, by providing healthy living conditions on the surface, and by obtaining his co-operation in preventing the disease.

The amount of dust in the underground workings has been very much reduced, but in the deep level mines this reduction has been obtained by saturating the mine air with moisture. Cases of heat stroke are becoming not uncommon, especially amongst natives who have not become accustomed to working in places with a high wet bulb temperature, although attempts to get them "into training" before putting them to work in hot places are invariably made.

I have not discussed the question of miners' phthisis in natives, as it is many years since I have had practical experience in dealing with this part of the problem. The native is more prone to pure tuberculosis and acute diseases of the lung than the European, but does not develop silicosis so rapidly, probably because he has frequent long spells when he goes back to his kraal to live the life of a gentleman attended by as many wives as he can afford, and, lastly, by the anatomical arrangements of his air passages. The South African native is not a mouth-breather.

I have not attempted to give any statistics or figures. These will be available in other papers. The Witwatersrand has led the way in the study of this very ancient disease, because, unfortunately the disease has been more prevalent here than in any part of the world, and the opportunity for research and study has been made possible by the generosity and business acumen of the leaders of the industry.

THE FUNCTIONS OF THE MINERS' PHTHISIS MEDICAL BUREAU AND THE GENERAL SYSTEM OF MEDICAL EXAMINATIONS CONDUCTED UNDER THE MINERS' PHTHISIS ACT

BY L. G. IRVINE, M.A., M.D., C.M., B.SC. (PUB.H.) (EDIN.),
CHAIRMAN, MINERS' PHTHISIS MEDICAL BUREAU

The Miners' Phthisis Medical Bureau was instituted under the Miners' Phthisis Act of 1916, and commenced its work on 1 August of that year. It is a body of whole-time Government medical officials and has been since the above date responsible for conducting or directing all medical examinations under the Miners' Phthisis Acts.

Its first Chairman was Dr. W. Watkins-Pitchford, who already held and continued to hold the post of Director of the South African Institute for Medical Research. Partly owing to this conjunction of offices on the part of the first Chairman, the Bureau has, since its inception, occupied premises in the Institute block of buildings. The arrangement has proved useful in many ways, especially owing to the proximity which it affords the Bureau to well-equipped laboratories. Administratively, however, the Bureau is a totally distinct organisation. It is strictly and solely a Government institution in the Department of Mines. All appointments to it are made by the Minister of Mines and Industries. On Dr. Watkins-Pitchford fell the heavy task of organising the new institution, and he continued to direct its activities for a period of ten years. In September 1926, he was succeeded as Chairman by the present writer, when the personal connection with the Institute terminated.

The examining medical officers composing the Bureau at first numbered six; later, as the amount of work increased, the number rose to ten, and for the past few years it has been eight. The senior examiner, Dr. C. C. Murray, is also Vice-Chairman.

Dr. W. Steuart has since the inception of the Bureau occupied the part-time post of radiologist. The official pathologist (Dr. A. Sutherland Strachan) is Lecturer on Pathology at the University of the Witwatersrand and a member of the pathological staff of the South Africa Institute for Medical Research. The Bureau has thus the advantage of obtaining an independent pathological opinion in arriving at decisions in cases which involve pathological investigation. A secretary and a technical and clerical staff of nineteen complete the establishment.

In respect of all miners of European extraction, termed officially "European miners", the chief duties of the Bureau are as follows:

1. To conduct an "initial examination" of all persons who desire to enter for the first time upon work underground in any of the gold mines of the Witwatersrand area—called "the scheduled mines".
2. To conduct a "periodical examination" of all working miners, with the object of detecting cases of silicosis, tuberculosis with silicosis, or simple tuberculosis which may arise amongst them.
3. To conduct a "benefits examination" of all claimants for awards under the Act as possible subjects of one or other of these diseases.
4. To investigate and decide all claims preferred by the dependants of deceased miners, on the ground that such miners had been the subjects of silicosis or tuberculosis.

The precise scope of these examinations will be explained more fully later on.

The similar examinations of Eurafrikan and Asiatic miners, termed "Non-European miners", are also carried out directly by the Bureau.

In respect of the very large number of "native labourers" employed in the industry, the official initial examination is carried out at the central depot of the Witwatersrand Native Labour Association by the medical staff of that organisation. The periodical examinations are conducted on the mines by the mine medical officers. All of these officials act as medical examiners under the Miners' Phthisis Act. The Bureau exercises a general supervision over all of these examinations by means of periodical visits of inspection to the mines. All native labourers suspected by the mine medical officers of being the subjects of tuberculosis or silicosis are, however, sent forward to the Bureau for final examination and disposal by it. This is the general system.

The Bureau is also charged with the compilation of a statistical account of the incidence of silicosis and tuberculosis as shown by the results of the examinations made during each year. This

statement is published in the annual Report of the Chairman of the Bureau.

A general idea of the amount of work performed by the Bureau in each year may be gained from the following table.

TABLE I. — SUMMARY OF THE WORK OF THE BUREAU FOR THE YEAR ENDING 31 JULY 1928

Nature of examination or investigation	Number of examinations	Number of individuals dealt with
Examinations for "initial" certificate (Europeans)	9,251	8,122
Examinations for "periodical" certificate (Europeans)	26,394	14,726
Examinations for "special" certificate (Europeans)	2,507	1,523
"Benefits examinations" (Europeans)	3,900	3,463
Claims in respect of deceased European miners	449	428
Claims for allowances to children of beneficiaries	87	85
Examinations of non-European miners during life	108	104
Examinations in respect of deceased non-European miners	9	9
Examinations of native labourers during life	1,795	1,795
Examinations in respect of deceased native labourers	429	429
Total routine examinations	45,077	30,684
<i>Supplementary Investigations</i>		
Post-mortem examinations:		
Europeans	227	—
Others	438	—
Admissions to Bureau Ward for special observation	558	—
Special visits to sick miners at their homes	39	—
Visits of inspection to scheduled mines	149	—
Total	46,488	—
Daily average	153	—

The Bureau possessed on 31 July 1928 medical and radiographic records of 71,288 European miners, and 21,736 non-European miners and native labourers. During the year a total of 42,524 portrait negatives of European miners were made, for purposes of identification. Natives are identified by fingerprints. The number of radiographs produced during the year was 36,660.

All pathological investigations made on behalf of the Bureau are carried out at the South African Institute for Medical Research. The amount of this work, as shown by the number of specimens examined and reported upon during the year was as follows: lungs (pairs), 665; specimens of urine, 657; specimens of sputum, 23,426; specimens of blood, 962 (Wassermann test, 733; General, 229); specimens of faeces, 87; miscellaneous, 3.

The wealth of pathological material made available through the work of the Bureau is thus apparent. This circumstance has enabled the Bureau to carefully correlate the results of pathological, radiological and clinical examination in a large series of cases, and it is upon the results of such a correlation that its standards of diagnosis are based.

The routine of examination to which each person is subjected *at each examination in any of the four classes mentioned* is as follows: (1) his photograph is taken for purposes of identification, and his signature is also photographed on the same negative; (2) a radiograph of his chest is taken; (3) his weight and height are measured, in trousers and socks, without boots; (4) he is subjected to a clinical examination by a member or members of the Bureau. All persons who are considered by the examining medical officer to be probable or are actual subjects of silicosis or tuberculosis are examined by at least two members of the Bureau.

The examinations are completed each day before 2.30 p.m., when the Bureau meets as a whole to decide upon all cases examined during the day. The examiner or examiners in each case report to the Bureau the result of their examination, the radiograph of the examinee is inspected, and if the case is in any way doubtful it is then discussed by the Bureau. *The final decision is in all cases taken by the Bureau as a whole.* Any possible personal idiosyncrasy on the part of individual examiners is thus eliminated and a uniformity of standards as far as possible secured. But the Bureau maintains a continuous investigation of its material and methods, in order, if possible, to improve the latter and to secure the greatest efficiency possible.

In addition to this routine procedure, free use is made by the Bureau of the Observation Ward in the building occupied by it. Any man in respect of whom special observation is required is admitted to the Observation Ward for a period of three days. His temperature is recorded, the sputa of three consecutive days and the urine examined, a Wassermann test is made, and any other laboratory investigations which may be required are carried out.

During the year, 543 European miners were in this way admitted to the Observation Ward or, in a few cases, to the General Hospital, Johannesburg, for special observation.

Miners of whom examination for the purposes of the Act is required, and who are too ill to be brought to the Bureau, are examined at their homes by a member of that body; thirty-nine such visits were paid during the year.

Further, a "review" examination is readily granted by the Bureau in the interval between the statutory examinations, in the case of miners in respect of whom the Bureau is informed that the health of the individual has deteriorated since the last examination, or in the case of applicants for the initial certificate whose health appears to have improved; 923 such examinations were made during the year.

The system of examinations would thus appear to be as thorough and elastic as is possible in the circumstances *which necessitate dealing with over 30,000 individuals annually.*

Some comments on each class of examination may perhaps be of interest, and it may be well to deal first with the examination of European miners and later with that of non-European miners and native labourers.

EXAMINATIONS OF EUROPEAN MINERS

Examination for the Initial Certificate

The "initial certificate" is a certificate of fitness for underground work granted by the Bureau after examination, and the Act requires that any person who desires to enter for the first time upon employment as a "full-time" miner in a scheduled mine must possess such a certificate. The initial certificate certifies that the holder "is free from any disease of the lungs and respiratory organs, and is in other respects physically fit for underground work". All certificates issued by the Bureau are in card form, bearing on the back a photograph of the holder and of his signature, and specifying the date on which the certificate ceases to be valid. The initial certificate is valid for six months. At the end of that period the holder, provided that he has in the interval been employed as a "full-time" miner, becomes entitled to appear at a "periodical examination" as a "working miner".

The object of the initial examination is to debar all persons who have or appear to have more than an average liability to contract silicosis or tuberculosis from entering upon underground

work in scheduled mines. The standard of selection adopted must accordingly be a reasonably strict one. The following were the general results during the year 1927-1928:

TABLE II. — RESULTS OF INITIAL EXAMINATIONS
(EUROPEANS), 1927-1928

	Total	Born in South Africa	Born overseas
Number of candidates examined	8,122	6,696	1,426
Percentage rejected:			
Temporarily	43.34	—	—
Permanently	18.62	—	—
Number of examinees passed	3,090	2,435	655
Percentage of examinees passed in each class	38.04	36.37	45.93

The high preponderance of South African born candidates is a prominent feature. It will be noted that only 18.6 of the total examinees were permanently rejected, while the "temporary" rejections amounted to over 43 per cent. The latter class comprises those in whom the Bureau finds defects in health or physique which may be remediable. These persons are eligible for re-examination after the lapse of such a period as may, in the opinion of the Bureau, suffice for the removal of these defects, and experience has led that body to give a rather wide latitude in this direction, especially to young and immature would-be recruits. A considerable proportion of such candidates eventually succeed in obtaining an initial certificate.

One very important result of the initial examination has been to introduce into the general body of working miners a gradually increasing number of men of specially selected physique. Those of this selected class who had not worked underground on the Rand prior to 1 August 1916, and who have not had previous service in other mines elsewhere, are termed the "new Rand miners". These men now number over 8,300 and constitute over 54 per cent. of the total body of working miners. The fact that these men have up to the present shown surprisingly low attack-rates for silicosis appears to indicate that the system of selection provided by the initial examination of the Bureau has filled an important preventive function.

The Periodical Examination

By the "periodical examination" is meant the statutory examination of all "working miners" with the object of detecting the presence or absence of compensatable disease amongst them.

The term "working miner" includes, along with all "full-time" miners working beneath the surface, all persons working on or about crusher-stations, or in a sample crushing room or assay office, or in a change-house or on any tailings dump. All of these classes of employee are included under the Act as "working miners" and are subjected to the "periodical examination". The "full-time" miners working underground form the vast majority. The four other classes are included — change-house attendants in order to exclude tuberculous subjects from that employment, the others because their occupation is considered to expose them to some risk of contracting silicosis.

"Working miners" who are in employment must present themselves for examination at intervals of not more than six months. Those who are not employed remain eligible for the periodical examination for an indefinite period, *provided* that they present themselves for examination at intervals of not more than two years from the date of expiry of the last periodical certificate issued to them. If they fail to do so, they are subjected again to an "initial" examination. As a result of this provision the number of working miners examined in each year by the Bureau usually exceeds the *average* number of miners in actual employment underground by about 40 per cent. The provision permits the miner to leave the mines for considerable periods without forfeiting his eligibility to return to underground employment later on.

The "periodical certificate", which is issued by the Bureau after examination to the "working miners", certifies simply that the holder "is not suffering from tuberculosis", and entitles him to continue in or offer himself for employment in any of the occupations specified above. Once it has been granted, the certificate is periodically renewed in the case of all miners who remain eligible and submit themselves for examination, *unless* the holder is found upon examination to be suffering from tuberculosis or tuberculosis with silicosis. In the latter event the miner is debarred from all further underground work in the scheduled mines. Any miner who has accepted an award as the subject of silicosis is likewise debarred from further underground work in these mines and ceases therefore to be eligible for a periodical certificate.

The purpose of the periodical examination is, as has been stated, the detection and notification of all cases of the three "compensatable diseases" — "simple silicosis", "tuberculosis with silicosis" and "simple tuberculosis"—which exist amongst the "working miners".

By "*simple silicosis*" is meant silicosis *without* a definitely recognisable or "overt" tuberculosis; by "*tuberculosis with silicosis*" is meant silicosis *with* overt tuberculosis; and by "*simple tuberculosis*" is meant tuberculosis of the respiratory organs, without detectable silicosis.

Any "working miner" who is found to be suffering from one or other of these conditions is notified to that effect. If his condition is one of tuberculosis with silicosis or simple tuberculosis, he is obliged to relinquish underground work immediately. If he is found to have simple silicosis, it is optional for him to apply to the Board for an award of compensation and to leave underground work, or to remain at work and postpone taking an award. Should the miner, however, remain at work for a period of longer than three months after receipt of a notification that he has silicosis, he forfeits during his lifetime all right to an award, other than that to which he would have been entitled at the date of his first notification. Few miners, however, continue to work underground after they have been notified as being silicotic. In 1927-1928 there were at work only 144 unretired silicotic miners, a very considerable majority of whom were mine officials.

The subjoined table illustrates the scope and general results of the periodical examinations conducted during the past three years:

TABLE III. — RESULTS OF PERIODICAL EXAMINATIONS FOR THE THREE YEARS 1926-1927 TO 1928-1929 (EUROPEANS)

	1926-1927	1927-1928	1928-1929
Number of examinations made	24,815	26,542	27,073
Number of individual miners examined	13,654	14,726	15,492
Cases detected:			
Unretired "old" cases of silicosis	127	144	154
"New" Cases:			
Simple Silicosis	364	283	270
Tuberculosis with Silicosis	2 ¹	0	5 ¹
Simple Tuberculosis	42	32	44

¹ These cases occurred in unretired silicotic miners.

It may be added that, during 1927-1928, no fewer than 318 additional examinations were made for special reasons in the interval between the statutory examinations, and that, of the "working miners" examined, 203 were admitted to the Observation Ward for more detailed examination.

Examinations for the "Special" Certificate

The "special" certificate is granted by the Bureau, after examination, to a number of persons whose work takes them underground from time to time, but who are not "full-time" miners. Surface artisans going underground now and then for repair work or for similar occasional duties, mine inspectors, some mine managers and others who do not spend their full time underground fall into this class. These persons also are examined by the Bureau once in six months, particularly since most of them have been at one time full-time miners and had then been exposed to the ordinary risk of contracting silicosis. Such special examinations number about 2,500 per year in respect of some 4,500 persons so employed. A very few cases of silicosis or tuberculosis are detected from time to time amongst these men, and those who are so detected are compensatable under the provisions of the Act.

"Benefits Examinations"

"Benefits examinations" are carried out in claims for awards made by or in respect of living miners. It is to be noted that, in the case of claims for awards made by miners who have been found to have silicosis or tuberculosis or both conditions at a periodical examination, no further examination is required precedent to the first grant of benefits. When, however, such miners make application for *further* awards, they become subject to the "benefits examination" of the Bureau. A small number of retired miners, who have not previously been found at a periodical examination to have silicosis or tuberculosis, and who apply for awards, are also included in the "benefits" return.

The main object of the "benefits examination" is thus the *re-examination* of existing beneficiaries, in order to ascertain whether they have progressed to a further stage of the disease and have therefore become entitled to further awards.

The number of benefits examinations conducted in 1927-1928 was 3,900 in respect of 3,463 persons. The extent to which

re-classification takes place is indicated by the fact that, in this one year, out of 2,709 silicotic beneficiaries examined, 502 were certified to have become entitled to further awards, and 291 of these to have become entitled to receive life-pensions.

Claims made in respect of Deceased Miners

During the year the number of claims made by dependants of deceased miners numbered 428. A large number of these claims were made in respect of miners who had died overseas regarding whom the Bureau had had no previous information or opportunity of securing that an adequate examination was made during life, and in such cases particularly a large amount of enquiry and expenditure of time was frequently necessary to enable the Bureau to obtain sufficiently reliable information to enable it to come to a just decision on the presumptive evidence available. The great importance *in the interests of the dependants* of such a simple procedure as a sputum examination in cases of suspected tuberculosis is very frequently entirely overlooked by the medical men who attend such cases during life, and the extremely valuable evidence afforded by a radiograph in cases where the presence of silicosis has not previously been demonstrated, but is merely presumed, is very far from being adequately realised, even in centres where a radiographic examination is readily procurable. The Bureau deals with such cases on their merits, but is sometimes placed in much difficulty owing to the paucity of reliable evidence of the actual condition present at death.

Appeal Examinations

The Miners' Phthisis Act of 1925 established a Medical Board of Appeal with power to revise decisions of the Bureau in respect of examinations involving a possible grant of an award. Two of its three members had previously acted for many years as members of the Bureau. In 1927-1928 the Board of Appeal, according to the returns notified by it to the Bureau, considered 722 cases referred to it, and the Bureau's decision was altered in respect of 44 of these.

EXAMINATIONS OF NON-EUROPEAN MINERS

The number of non-European miners employed underground amounted in 1927-1928 to 426 persons; 104 claims were made by

non-European miners or ex-miners, 42 of whom were found to have silicosis, 8 to have tuberculosis with silicosis, and 8 to have simple tuberculosis. By the courtesy of the Witwatersrand Native Labour Association, these examinations and the initial and periodical examinations of non-Europeans are carried out by members of the Bureau at the central depot of the Association.

EXAMINATIONS OF NATIVE MINE LABOURERS

The native labourers undergo, as in the case of European miners, an "initial" and "periodical" examination, and also an additional examination, termed a "final" examination, on the termination of their underground employment. The magnitude of this task becomes apparent from the fact that some 194,000 natives were employed upon the mines during 1927-1928, and that the total complement is replaced to the extent of approximately 90 per cent. during each year. These examinations are not carried out directly by the Bureau, but by the mine medical officers acting as examiners under the Act. The Bureau, however, exercises a general supervision and control over this work, mainly by means of periodical visits of inspection by delegated members of that body to the different mines. Drs. C. C. Murray and G. H. Knapp have carried out this important function for many years. Each mine is visited several times in each year.

The Act prescribes that all medical officers in medical charge of natives on the mines should hold whole-time appointments, except in the case of a few small mines, to which the Minister is empowered to grant exemption from this provision. The mine medical service on 31 July 1928 comprised thirty-six whole-time and four part-time appointments, including in these the medical staff of the Witwatersrand Native Labour Association Central Depot, at which the "initial" examination of all native recruits is conducted.

The general system of procedure in regard to native labourers may be briefly summarised:

1. The *initial examination* is in practice a threefold process. There is a preliminary medical examination in the recruiting areas, a principal and official medical examination at the Native Labour Association's Depot, and a supplementary examination by the mine medical officer.

2. The *periodical examination* under the Regulations of the Act of 1925 consists of two parts:

- (i) *Each native employee, whether working on surface or underground, is weighed, obligatorily every three months, actually according to the general practice once in six weeks. Any native who has lost 5 lbs. in weight*

between two successive examinations, or 6 lbs. between three successive examinations, is set apart for stethoscopic examination by the mine medical officer. It has been found that approximately 66 per cent. of bacteriologically verified cases of simple tuberculosis amongst mine natives have previously shown a loss of weight of this amount at their periodical examinations. This appears to be the limit of the efficiency of this method of mass examination, which has been adopted in view of the large number of natives concerned and the necessity of not interfering unduly with their daily routine of work and meals.

(ii) *An additional separate stethoscopic examination is made of all natives who have worked upon any one mine for a period of five years or more.* The object of this examination is particularly the detection of possible cases of silicosis or tuberculosis with silicosis in those natives who have worked underground for long periods.

3. *The final examination.* Every native employed underground undergoes, on leaving underground employment, a "final" stethoscopic examination, and can only be discharged if he is found by the medical officer to be free from silicosis and tuberculosis.

These are the examinations prescribed under the Act. In addition, the mine medical officers, on their own initiative, have adopted the system of making a stethoscopic examination of all natives who are admitted to the mine hospital for any cause.

Finally, during the past three years the Chamber of Mines has instituted an annual radiographic examination of all natives who have worked on any one mine for five years or more, the results of which have had the great practical value of demonstrating that no large number of undetected cases of silicosis had existed on the mines.

The system as a whole draws round the mine native labourers a serviceably close net of opportunities for the detection of silicosis and tuberculosis.

The Act prescribes that all native labourers in whom a medical "examiner" finds signs of tuberculosis or silicosis should be sent forward for examination and final disposal by the Bureau. In practice all such cases are transferred to the Central Hospital of the Witwatersrand Native Labour Association. Here a radiograph is taken of their chests, their sputum and urine are examined, and the weight and temperature recorded. They are then clinically examined by a member of the Bureau and the final decision is taken by that body on the evidence.

The following are the results of the examination of such cases by the Bureau during 1927-1928.

Average number of natives employed	193,076
Average number employed underground	147,375
Suspected cases sent forward for examination by the Bureau	1,795

Number of cases of compensatable disease detected amongst	
these	1,352
viz. simple silicosis	209
tuberculosis with silicosis	409
simple tuberculosis	746

The total number of cases of active tuberculosis detected was 1,155, or 5.89 per 1,000 of the total complement.

The periodical examination of the mine natives thus serves an important preventive function by eliminating from the underground complement cases, which, if they remained, would be potential sources of dissemination of tuberculous infection.



THE FUNCTIONS AND EXPERIENCE OF THE MEDICAL BOARD OF APPEAL APPOINTED UNDER THE MINERS' PHTHISIS ACT

BY MEMBERS OF THE APPEAL BOARD

The Medical Board of Appeal was established under the Miners' Phthisis Consolidating Act of 1925. The Board consists of three members and a Secretary appointed by the Minister of Mines and Industries. The functions of the Medical Board of Appeal are:

(1) The examination of any "miner" who is dissatisfied, on medical grounds, with the certificate of the Medical Bureau on any periodical examination, or on any examination for benefits, provided that he has not accepted any benefits under such an award made as a result of such certificate and provided further that he gives notice of appeal within three months after the receipt by him of the Medical Bureau's certificate of such examination. (The periodical examination is a compulsory six-monthly examination by the Medical Bureau of all working miners; if silicosis or tuberculosis is detected, a certificate by the Bureau must be issued accordingly.)

(2) The reviewing of the case of any deceased "miner" whose dependant is dissatisfied with the Medical Bureau's decision as to the cause of such miner's death.

The word "miner" is defined in the Act as "any person (other than a native labourer) who is or has been employed underground at a scheduled mine in any of the occupations specified in the Act". It is obvious from the above that the native underground worker has no right of appeal.

Every appellant is X-rayed and independently examined, clinically, by all three members of the Medical Board of Appeal. In the case of post-mortem claims all the pertinent records are considered, and, when available, the lungs are inspected. The lungs of deceased miners, on whom autopsies are performed, are preserved for six months.

A provision of the Act requires the Medical Bureau and the Miners' Phthisis Board to produce, if requested, to the Medical Board of Appeal all records in their possession in respect of any appellant.

The Medical Board of Appeal was established as a result of an insistent demand by miners and beneficiaries who, rightly or wrongly, felt that they were not getting what they considered a "square deal" from the Medical Bureau.

Before the establishment of the Medical Bureau in August 1916, large numbers of miners were compensated in either the primary or secondary stage of silicosis on certificates issued by two or three doctors from a panel appointed by the Government; when these cases came to be reviewed by the Medical Bureau it was found that a large percentage of them were not the subject of silicosis at all and were certified by the Bureau accordingly. This was undoubtedly one of the main factors that led to distrust of and dissatisfaction with the Medical Bureau. Another important factor in this respect is the irresponsible manner in which some medical practitioners will certify, without a thorough scientific investigation, that a particular miner is suffering from silicosis or tuberculosis or both when, in fact, he is free from disease of the lungs and may be suffering from a totally different complaint; a climax is reached when an inexperienced doctor, after post-mortem examination, certifies the presence of silicosis in lungs which show at most a slight excess of pigment. It is to be regretted that, in these cases of difference of opinion between private medical practitioners and the Medical Bureau, the latter should be suspected of incompetence or wilful injustice to the miner.

The constitution of the Medical Board of Appeal was a matter of some difficulty for the Minister of Mines, who had to make the appointments. The Act requires that the Appeal Board shall consist of three medical practitioners with special knowledge of diseases of the lungs and respiratory organs. The Minister realised that the appointment to the Medical Board of Appeal of medical men who were not at least as experienced as members of the Medical Bureau, would be ridiculous and might easily wreck the working of the Act; he therefore decided to divorce two of the senior members from the Bureau for appointment to the Board of Appeal.

This step has caused considerable dissatisfaction among miners, the contention being that these two members would be loth to upset the decisions of a body (the Medical Bureau) to which they formerly belonged. Why this suspicion should arise in the case of

medical men promoted to a higher body, and not in the case of the legal profession, is quite incomprehensible.

When it is considered that the Medical Board of Appeal has to review the decisions of an expert and highly organised and competent body such as the Medical Bureau, it is not to be expected that a large percentage of the decisions by that body will be altered on appeal. The members of the Medical Bureau work at high pressure, year in and year out, handling on an average nearly 150 cases per day; it is therefore impossible for them to devote to each individual case the time which the Medical Board of Appeal are able to do; as a direct result of this the Medical Board of Appeal is able, occasionally, to detect signs of very early silicosis or of tuberculosis which may have escaped notice previously; but these cases are really extraordinarily few in number.

It must be remembered that the law allows a period of three months from the date of the Bureau's last certificate within which a miner may give notice of appeal; it therefore often happens that the appellant does not appear before the Medical Board of Appeal until three or four months after his examination by the Bureau; during this time it is quite possible that silicosis or tuberculosis, undetected or perhaps only slightly suspected at the previous examination, may become manifest; this does, in fact, happen in a not inconsiderable number of cases.

In some cases the certificate of the Medical Bureau is altered by the Appeal Board, not because any new facts have been elicited, but because, in considering all the evidence which was previously available to the Bureau, the Medical Board of Appeal comes to a different conclusion. Since, according to the Act, the decision of the Medical Board of Appeal is final, it behoves this body, as it always earnestly endeavours, to neglect no line of investigation that may elucidate doubtful points in any particular case; in cases of genuine doubt, the benefit thereof is given to the appellant, especially in post-mortem claims.

Copies of the certificate of the Medical Board of Appeal are issued to the Miners' Phthisis Board and the Medical Bureau in every case; where the certificate of the Medical Bureau is altered, the reasons for such alteration are notified to that body.

The appellants who appear before the Appeal Board may be divided into two classes:

- (1) Miners who are certified by the Bureau to be free from silicosis and tuberculosis.

(2) Miners who have been certified by the Bureau to be in the ante-primary or primary stage of silicosis and those who have been certified to have tuberculosis without silicosis.

Class 1 consists mainly of working miners, but there are included in this class also miners who have ceased work on scheduled mines anything up to twenty or more years ago, and beneficiaries who were compensated by the old administration before August 1916, when the Medical Bureau was established, and who were subsequently certified by the Bureau to be not suffering from silicosis or tuberculosis. In this class, then, the Medical Board of Appeal must decide whether the appellant has silicosis or tuberculosis or both, or whether he is free from these diseases. It may be necessary, here, to draw attention to the fact that the term "miners' phthisis" does not appear in any of the provisions of the Miners' Phthisis Act; silicosis and pulmonary tuberculosis are the only two terms employed to denote disease which is compensatable under the Act.

The question now arises: What is silicosis? The Act does not define the term "silicosis", but it is now generally accepted in South Africa that silicosis is a generalised nodular fibrosis of the lungs caused by the inhalation, over a long period, of minute particles of siliceous dust. We have no intention of entering upon a description of the several stages of silicosis either from the pathological or clinical point of view; nor shall we refer to the changes resultant upon infection by the tubercle bacillus. The remarks which follow apply to "simple silicosis", i.e. silicosis without any clinically obvious tuberculous infection. Before dealing with the clinical diagnosis of a slight degree of simple silicosis, it is necessary to refer very briefly to the naked-eye appearances of a silicotic lung. For the purpose of administering the Act it is the considered opinion of the Medical Board of Appeal and of the Medical Bureau that it is not practicable to recognise any but macroscopic signs in the post-mortem diagnosis of silicosis. The earliest silicotic changes detectable by the naked eye are:

1. Enlarged, pigmented and fibrosed root-glands.
2. Sub-pleural plaque formation.
3. The presence, throughout the lung tissue, of more or less evenly distributed, discrete, small-sized, pigmented fibrotic nodules which project from the cut surface and are palpable.

These changes occur in the order given above; the root glands may be affected, as described, without any involvement of the lung

substance. A few scattered sub-pleural plaques may be palpable without any nodules being present in the lung, but we have never seen silicosis of the lung without palpable sub-pleural plaques. It may be asserted, therefore, that, if the pleura presents a normal appearance, section of the lung will not reveal any silicosis.

These small fibrotic nodules are represented in the X-ray picture by small round shadows which are more or less well defined and give the skiagram a typical "mottled" appearance.

According to the Act a person shall be deemed to have silicosis in the ante-primary (first) stage when it is found that the earliest detectable specific physical signs of silicosis are present. It is possible, in the majority of cases, for the expert ear to diagnose stethoscopically the presence of ante-primary stage silicosis; this diagnosis is based on a peculiar harshening and thinning of the breath-sounds with a slightly reduced air entry; this change in the character of the breath-sounds is, however, so subtle in early silicosis and is so often produced by other conditions that it cannot be said to be specific of silicosis.

In the ante-primary stage of silicosis there is no appreciable diminution of the range of chest expansion and there are no constitutional disturbances. It may be stated dogmatically, therefore, that the earliest detectable physical sign which can be said to be definitely specific of silicosis is the fine uniform mottling of the radiograph produced by the resistance of silicotic nodules to the passage of the Röntgen rays; in our experience there is no other condition that can produce this X-ray picture in an apparently healthy subject.

A mere increase or accentuation of linear or branching shadows in the radiograph caused by peribronchial and perivascular fibrosis due to other conditions, e.g. chronic bronchitis, tuberculosis, chronic cardiac disease, etc., must not be confused with the typical radiographic appearances due to silicosis. It is hardly necessary to mention that, for the purpose of the radiographic diagnosis of early silicosis, the X-ray film must be technically perfect.

As regards the inspection of X-ray films, we know of no artificial illumination which can compare with sunlight reflected from a white surface.

With reference to pulmonary tuberculosis, a provision of the Miners' Phthisis Act reads as follows:

A person shall for the purposes of this Act be deemed to be suffering from tuberculosis whenever it is found either:

- (a) that such person is expectorating the tubercle bacillus, or

- (b) that such person has closed tuberculosis to such a degree as seriously to impair his working capacity, and render prohibition of his working underground advisable in the interests of his health.

We do not intend discussing the diagnosis of early pulmonary tuberculosis; the extreme difficulty of arriving at a definite diagnosis in early sputum free cases is known well enough to all experienced workers in this sphere.

In order to make a diagnosis of closed tuberculosis in any particular case, we consider it essential that there should be present a combination of signs from the following three groups:

1. Constitutional signs and symptoms, e.g. anorexia, loss of weight, fever, lassitude, languid and hollow- or deep-eyed appearance, night sweats, etc.
2. Physical signs in chest, e.g. localised flattening of chest wall, restricted movement, impaired note on percussion, signs of consolidation, crepitations, etc.
3. Radiographic evidence, i.e. the presence of abnormal shadows of varying degree in the lung field.

In Group 1 nearly all the signs are the result of toxæmia which may be caused by conditions other than tuberculosis.

In Group 2 the signs may be produced by many conditions, e.g. catarrhal infections, unresolved pneumonias, bronchiectasis, pleural effusions, empyema, new-growth, gumma, etc.

In Group 3 shadows may be caused by thickened pleura, unresolved pneumonia, empyema, pleural effusion, new-growth, gumma, etc.

It is obvious, therefore, that a diagnosis of closed tuberculosis ought to be made only after a very careful and painstaking consideration of the whole symptom-complex, and after exclusion, by appropriate investigation, of the many conditions which so frequently produce signs and symptoms simulating those of pulmonary tuberculosis. Haemoptysis, for example, is sometimes a very early and important sign of pulmonary tubercle, but no clinician of experience would dream of making a diagnosis of pulmonary tuberculosis on this sign alone.

It is true that with long experience one is able, or one thinks one is able, to differentiate between the X-ray appearances caused by various lung conditions, but it is also true that with longer experience one becomes convinced, especially if one is also a clinician, that it is foolish to make a diagnosis of a lung condition from radiographic signs only.

We have seen radiographic shadows similar to those produced by tuberculous consolidation disappear like magic after anti-syphilitic treatment in Wassermann ++ cases, and after no treatment at all in cases of unresolved and clinically unsuspected localised pneumonias; we have seen a bilateral primary alveolar carcinoma with abscess formation give X-ray appearances identical with those of silicosis with tuberculous consolidation; a myxosarcoma simulating hydatid cyst and cases of generalised nodular tuberculosis with radiographic features almost indistinguishable from those of silicosis. Whereas in the diagnosis of early silicosis the radiographic is the most, if not the only, reliable sign, in the diagnosis of early pulmonary tuberculosis it must in the majority of cases take the place of corroborative evidence only; in fact, in quite a number of positive sputum cases there are no radiographic abnormalities at all.

A certificate by the Medical Board of Appeal to the effect that a miner is suffering from pulmonary tuberculosis becomes a legal document; on the one hand it means the disbursement of a large sum of money; on the other, if the person so certified is a working miner, he is legally debarred from work in a scheduled mine and will have great difficulty in obtaining employment elsewhere.

The matter is therefore a serious one, and a diagnosis of pulmonary tuberculosis should be made only when definite evidence of the disease is present; a diagnosis of so serious a disease ought never to be made in a haphazard manner, as is unfortunately only too often done, and the diagnosis should never be based on suspicion only. There is a vast difference between suspecting the presence of the disease and making a definite diagnosis; it is this difference which accounts for the large number of miners who are certified by irresponsible medical practitioners to have pulmonary tuberculosis and who are found by the Medical Board of Appeal or the Medical Bureau not to have the disease.

In the second class of appellants it is a question for the Appeal Board to decide whether the stage in which the appellant has been classified by the Medical Bureau is the correct one or not.

In a few cases the Bureau's certificate of ante-primary stage may be altered to primary stage, but the majority of alterations in this class are due to the decision of the Medical Board of Appeal that the silicosis in either the ante-primary or the primary stage already certified by the Bureau is complicated by the presence of pulmonary tuberculosis either open or closed.

For the purposes of the Act a person is deemed to have silicosis

in the secondary (pensionable) stage when it is found that he has definite and specific physical signs of silicosis, and that capacity for work is thereby seriously and permanently impaired, or when it is found that he has tuberculosis with silicosis; in the latter case the degree of silicosis is not qualified.

It is a peculiar, yet well-known, fact that if a miner on the Rand suffers from any chronic disease causing loss of weight, lassitude, cough, shortness of breath, etc., he becomes obsessed with the idea that "miners' phthisis" is at the bottom of his trouble. It is quite impossible to convince a miner suffering from serious cardiac disease that his cough and dyspnoea are due to his heart condition, or, in other cases, that his symptoms of ill-health are due to chronic bronchitis, chronic malaria, pyorrhoea, or anaemia, etc. Similarly, it is difficult for dependants of deceased miners who may have had a slight silicosis to realise that there are many causes of death to which silicosis does not predispose or contribute.

**STATISTICAL ACCOUNT
OF THE INCIDENCE AND PROGRESSION
OF SILICOSIS AMONGST THE GOLD MINERS
OF THE WITWATERSRAND**

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Definitions

In this discussion we shall employ the term "simple silicosis" to connote a condition of silicosis without obvious or overt tuberculosis, the term "tuberculosis with silicosis" to connote a condition of silicosis accompanied by obvious or overt tuberculosis, and the term "simple tuberculosis" to designate a condition of tuberculosis unaccompanied by detectable silicosis.

By the "prevalence" of any one of these conditions for any year is meant the total number of cases of that condition detected in that year amongst the "working miners" examined, and by the "prevalence rate" the ratio per cent. of the number of such cases to the total number of working miners. "Prevalence" thus includes the "new" cases which arise in the year specified *plus* the "old" cases of miners who have contracted the disease in previous years, but who have not retired from work underground.

By the "production" of any one of these conditions one means the number of "new" cases of that condition which are detected in any one year amongst miners who have been previously examined and found to be free from that condition. By the "production rate" is meant the ratio per cent. of the number of new cases of the particular condition specified to the number of such working miners examined.

The terms "ante-primary", "primary", and "secondary" stages of silicosis have the meanings set out in the Act of 1925.

The term "working miner" designates any European eligible for the "periodical" examination of the Bureau and includes, in addition to miners working below ground, a comparatively small additional number of persons working in assay offices, on or about crusher stations, in change houses and on tailings dumps.

The term "scheduled mines" designates the mines of the Witwatersrand area which are scheduled as "phthisis-producing" under the Miners' Phthisis Act.

The first and major portion of this paper deals with the statistics of silicosis amongst European miners, but reference is made in the concluding section to the incidence of silicosis and tuberculosis amongst native mine labourers employed on the scheduled mines.

I. — Evidence regarding the Prevalence of Silicosis during the Period prior to 1 August 1917

Accurate data regarding the production of silicosis were not available prior to the year 1917-1918, i.e. the year following the institution of the Medical Bureau. In 1916-1917 the Bureau carried out a complete examination of all working miners, but the cases detected during that year represent "prevalence", not "production". Unfortunately, therefore, no accurate information exists regarding the production of the disease at the time when conditions were at their worst.

There exist, however, certain data regarding the earlier periods from which some idea of the *prevalence* of silicosis during these years may be gained.

The two important landmarks in our local knowledge of the disease, during that time, are the Report of the first "Miners' Phthisis Commission" issued in 1903 and the Report of the "Miners' Phthisis (Medical) Commission" issued in 1912. Some additional but less comprehensive information is also obtainable from the Report of the "Mining Regulations Commission" issued in 1910.

These items of evidence have already been referred to in the "Review of the History of Silicosis on the Witwatersrand", which forms one of this series of contributions, and it is unnecessary therefore to discuss them in detail. For the sake of completeness, however, a brief reference to this evidence may be made here.

(1) The first official mention of "miners' phthisis" occurs in the *Report of the Government Mining Engineer (Transvaal) for the Six Months ending 31 December 1901*, in which it is stated that of 1,377 rockdrill miners, known to have been employed on the Rand prior to the outbreak of the South African War, 225 had died during the war period or up to the beginning of 1902. This represents an average annual mortality of some 73 per 1,000, but it must be recollected that it refers to a single occupational group and not to the whole body of working miners.

(2) The Report of the Miners' Phthisis Commission of 1902-1903 contains more extensive, but (for reasons for which the Commissioners were not responsible) far from complete information regarding the position at that time. Out of 4,403 miners officially stated to have been working underground in the gold mines of the Witwatersrand 1,210 were examined on behalf of the Commission: it is definitely stated that even on the mines on which this examination was carried out there were a good many abstentions. Of those examined 187, or 15.4 per cent., were certified to be affected by "miners' phthisis" and 88, or a further 7.3 per cent., were suspected cases. The prevalence rate was thus found

to be about 23 per cent., but this figure for the reasons given is probably an understatement. Over 90 per cent. of this first generation of Rand miners were of overseas origin, coming mostly from England, and over 80 per cent. had had previous mining experience elsewhere. The average duration of service amongst the small number of purely Transvaal miners affected was seven years, and in those of this group who had worked only on machine drills it was 5.75 years.

(3) The "Mining Regulations Commission" which reported in 1910 devoted much attention to the question of miners' phthisis.

From evidence submitted in a statement by Drs. Macaulay and Irvine on the "Conditions affecting the Health of Underground Workers on the Mines of the Witwatersrand", the Commission reached certain conclusions regarding the comparative mortality from the causes specified below of underground workers and of adult non-mining males. Taking the mortality from each of the causes specified amongst all non-mining adult males on the Witwatersrand during the period 1905 to 1907 as unity, the comparative mortality amongst underground employees for the same years is given as:

Phthisis, 6.3,
Other respiratory diseases, 1.7
All other diseases, 0.84.

The comparison is only an approximation, since the size of the two populations compared was only approximately known, no determination of the age distribution of the two populations compared was possible, and deaths from phthisis amongst retired miners occurring outside the Witwatersrand area were not included. The authors of the statement referred to also showed that the age period of highest mortality from phthisis amongst miners (thirty-six to forty years) fell somewhat later than that amongst the general adult male population: this is now recognised as a characteristic feature of "dust phthisis". They also showed by reference to data presented in a *Report on Miners' Phthisis at Bendigo* by Dr. W. Summons that, although the deaths from phthisis apparently affected a smaller proportional section of mine employees on the Rand, the development of the disease appeared with us to be more rapid. Over 80 per cent. of the phthisis deaths on the Rand lay between the ages of thirty and forty-five, attaining a maximum between thirty-five and forty. At Bendigo the main distribution lay more evenly between forty and sixty-five, reaching a maximum between fifty and fifty-five years.

(4) The next important item of evidence is furnished by the Report of the "Miners' Phthisis (Medical) Commission" which was issued in 1912. There were examined by this Commission 3,146 miners or about 27 per cent. of all the miners employed. The Commission divided cases of the disease into four stages. In the first of these, however, there were no definite physical signs of its presence, and the tentative diagnosis rested on symptoms and history alone. Excluding these doubtful cases, which amounted to 5.5 per cent. of the total number of men examined, the number of those showing definite physical signs of the disease amounted to 26.1 per cent. of the total. The majority of these cases, however, showed no impairment of working capacity. One cannot conclude from these figures that the true prevalence of miners' phthisis was greater than it had been in 1903, neither on the other hand can one find that any marked change had taken place since the former date.

Machine men were, as expected, found to be the heaviest sufferers, but no occupational group, including the supervisory staff was free from risk of attack.

Of those whose mining experience had been gained solely in South Africa, the average age of those slightly but definitely affected was 35 years, with an average underground service of 7.2 years. For those employed only in South Africa, and only on rockdrills, the corresponding figures were 33.6 and 6.5 years. A prevalence rate of 26 per cent. amongst the miners then employed would represent a total number of existing cases of nearly 3,000.

(5) The Miners' Phthisis Act of 1912 introduced a system of compensation for those affected by the disease. From this date, therefore, we have the additional information provided by the number of original awards granted annually by the Miners' Phthisis Board to living miners. These were as follows:

TABLE I. — ORIGINAL AWARDS FOR SILICOSIS OR TUBERCULOSIS WITH SILICOSIS GRANTED BY THE MINERS' PHTHISIS BOARD, 1912-1916

Year	First stage silicosis	Second stage silicosis, including tuberculosis with silicosis	Total
1912-1913	698	1,632	2,330
1913-1914	1,087	993	2,080
1914-1915	912	367	1,279
1915-1916	540	243	783
Total, 1912-1916	3,237	3,235	6,472

Unfortunately only approximate conclusions can be drawn from these figures regarding the probable production of "new" cases of silicosis during these four years.

There certainly existed at the outset of the period a large number of "accumulated" cases, which had first arisen in previous years. The figures also do not represent the outcome of a systematic examination of all working miners, but are awards granted to those who made voluntary application. Finally, owing to the system of medical examination then employed, the medical standard of selection for awards was far from being uniform.

But if we assume, as appears reasonable, that the number of "accumulated" cases amongst working and retired miners was about 3,000, the figures suggest that some 800 to 900 "new" cases were arising yearly. Support is given to this deduction from the fact that after some 6,500 cases had thus during these four years been awarded compensation and debarred from continuing their employment underground, the Medical Bureau in 1916-1917 detected at "periodical" and "benefits" examinations 907 cases of primary and secondary silicosis amongst the miners *who were actually at work during that year*. This deduction is merely an approximation. It suggests, however, that the

number of cases of silicosis produced during each of these years was about three times as great as that arising annually during the two years 1927 to 1929.

II. — The Production of Simple Silicosis from 1917 to 1929

We possess in the annual Reports of the Miners' Phthisis Medical Bureau accurate statistics of the production of silicosis since 1917-1918, based on the number of cases detected at the "periodical" examinations of the working miners. The cases shown in these returns do not quite represent all the "new" cases which have arisen amongst the miners who have been at work since August 1917, since a certain number of miners, particularly in the first two years of the period were first detected not at a "periodical" but at a "benefits" examination. Since, however, these did not amount over the whole period to as much as an additional 7 per cent. the data obtained from the periodical examinations give a substantially accurate representation of the position.

Table II, reproduced from the Report of the Medical Bureau for the year ending 31 July 1929, provides the general data for the subsequent discussion. The salient features of this table are shown also in block diagram in fig. 1 (p. 628), which has been prepared by the kindness of Mr. H. Goodwin from the similar diagram published in recent Bureau Reports.

It has been found convenient for the purposes of this discussion to divide the returns into four triennial periods, each of which is found to have certain characteristic statistical features. It will be observed that the number of cases of tuberculosis with silicosis, although very important during the first period, has since then undergone a steady although not altogether uniform decline, and during the fourth triennial period has become insignificant. Having mentioned this fact, we propose to deal in this discussion solely with the production of cases of "simple silicosis".

This has shown, as will be seen from table II, col. 2, rather remarkable variations from year to year, which require explanation. It may be well therefore to have clearly in mind the factors which may influence the figures of production in a population such as we are dealing with.

Factors which Influence the Production of Silicosis

Four such factors exist, the effect of each of which is independent of that of the others.

TABLE II. — NEW CASES OF SILICOSIS, TUBERCULOSIS WITH SILICOSIS, AND SIMPLE TUBERCULOSIS DETECTED AT PERIODICAL EXAMINATIONS, 1917-1918 TO 1928-1929

Year (1 August to 31 July)	Miners examin- ed (1)	Simple silicosis			Tuberculosis with silicosis		Simple tuberculosis	
		Number of cases		Pro- duction rate per cent. (3)	Num- ber of cases (4)	Pro- duction rate per cent. (5)	Number of cases (6)	Pro- duction rate per cent. (7)
		Prim- ary and se- cond- ary (2 a) ¹	Ante- prim- ary (2 b)					
1917-1918	13,474	153	—	1.179	116	0.861	35	0.259
1918-1919	14,071	349	—	2.539	120	0.852	36	0.256
1919-1920	14,664	398	(556)	2.787	24	0.163	39	0.266
Total 1917-1918 to 1919-1920	42,209	900		2.195	260	0.616	110	0.260
Annual average	14,070	(1,456) 300 (485)		3.551	87		37	
1920-1921	13,641	17	219	1.757	17	0.125	44 (Open 25) (Closed 19)	0.322
1921-1922	13,450	5	254	1.951	24	0.178	22 (Open 14) (Closed 8)	0.164
1922-1923	12,689	2	255	2.049	19	0.150	25 (Open 17) (Closed 8)	0.197
Total 1920-1921 to 1922-1923	39,780	752		1.916	60	0.151	91	0.228
Annual average	13,260	251			20		30	
1923-1924	12,159	1	318	2.652	20	0.165	11 (Open 10) (Closed 1)	0.090
1924-1925	12,587	1	427	3.438	28	0.222	18 (Open 10) (Closed 8)	0.143
1925-1926	12,823	0	490	3.859	7	0.055	61 (Open 30) (Closed 31)	0.476
Total 1923-1924 to 1925-1926	37,569	1,237		3.328	55	0.146	90	0.239
Annual average	12,523	412			18		30	
1926-1927	13,654	0	364	2.691	2	0.015	42 (Open 22) (Closed 20)	0.308
1927-1928	14,726	0	283	1.941	0	0.000	32 (Open 23) (Closed 9)	0.217
1928-1929	15,492	0	270	1.761	5	0.032	44 (Open 36) (Closed 8)	0.284
Total 1926-1927 to 1928-1929	43,872	917		2.111	7	0.016	118	0.269
Annual average	14,624	306			2		39	

¹ Three cases of secondary stage silicosis were detected in 1917-1918, and 2 in 1918-1919. With these exceptions the cases in col. (2 a) are primary stage cases only.

Note — The figures in brackets in col. (2) and (3) represent the numbers and rates of production which would result from allotting the 556 "new" cases of ante-primary silicosis detected in 1919-1920 to the three years 1917-1918, 1918-1919, and 1919-1920.

(1) *The occupational and hygienic factors which produce the disease.* — It is obvious that the worse the underground conditions the greater the number of cases of silicosis which will be produced, and the better the conditions become the fewer the cases which will arise. But changes in occupational conditions take time to produce their effects. The cases of silicosis which actually arise in any year represent on the average the cumulative effect of the occupational conditions obtaining during the previous ten years or so. The average duration of underground service in scheduled mines, worked by those miners who have actually in any year become silicotic, has amounted during the years under discussion to from nine years and five months at the beginning to twelve years and eight months at the end of the period.

One cannot therefore account for the striking variations which are shown in the production of simple silicosis during these twelve years by corresponding sudden changes in the occupational factor. The effect of the latter can only be approximately measured when the influence of other disturbing factors has been excluded.

(2) Obviously also the number of cases produced will depend on the number of working miners examined—these numbers are shown in col. 1 of table II. But what is of more importance from our point of view is the *number of miners working at each year of underground service.*

TABLE III. — INCIDENCE RATES PER CENT. FOR SIMPLE SILICOSIS AMONGST ALL MINERS WORKING IN EACH YEAR OF UNDERGROUND SERVICE IN THE PERIODS SPECIFIED

Years of underground service	Incidence rates for primary silicosis, 1918 to 1920 ¹	Incidence rates for ante-primary silicosis, 1920 to 1923 ²	Incidence rates for ante-primary silicosis, 1928-1929
	(A)	(B)	(C)
		The 'Standard' rates	
— 1	0.00	0.00	0.00
— 2	0.03	0.03	0.00
— 3	0.08	0.05	0.00
— 4	0.21	0.14	0.06
— 5	0.74	0.34	0.22
— 6	1.78	0.85	0.46
— 7	2.97	1.55	0.77
— 8	4.21	2.70	1.22
— 9	6.00	4.12	1.81
— 10	8.94	5.00	2.55
— 11	13.00	5.60	3.24
— 12	13.91	6.10	3.70
— 13	14.28	6.50	4.09
— 14	14.46	6.79	4.51
— 15	14.56	6.98	5.31
— 16	14.60	7.06	6.22
— 17	14.58	7.10	6.52
— 18	14.48	7.11	6.70
— 19	14.33	7.09	6.75
— 20	14.13	7.04	6.68

¹ Including 5 cases of secondary silicosis detected in this period.

² Including 24 cases of primary silicosis detected in this period.

Note. — The rates shown are "graduated" rates prepared from the observed data, for the periods specified, published in the annual Reports of the Medical Bureau.

Other things being equal, the incidence of silicosis is a function of duration of service, the liability to attack increasing with increase in the number of years worked.

This feature is very clearly apparent in the data shown in table III. If we select the results shown in col. *B* as a standard, chosen because during these years the production of silicosis was fairly uniform, one finds that at the fifth year of service the incidence was 0.34 per cent., at the tenth year 5 per cent. and at the fifteenth year 6.98 per cent. It will be seen that up to the sixth year the incidence is very slight; these "short service" miners, as Dr. Mavrogordato pointed out some years ago, produce very little silicosis. But amongst the "long service" miners with over six years' service, the incidence rises sharply thereafter to the levels shown. It follows, therefore, that provided the incidence rates remain constant over a series of years, the number of cases of silicosis which are produced will directly depend almost wholly upon the number of miners who are working in the later years of service. This is an important consideration, inasmuch as since 1917-1918 the mining population on the Witwatersrand has steadily become a more settled population, and there has been in consequence a progressive increase in the number of miners working in the later years of service.

This feature is clearly shown in table IV.

TABLE IV. — DISTRIBUTION OF WORKING MINERS IN THE UNDER-MENTIONED YEARS IN TERMS OF YEARS OF SERVICE WORKED

Year	Total working miners examined	Total in 1st to 6th years of work ('short service' miners)	Total with over six years of work ('long service' miners)	Number working in 7th to 12th years	Number working in 13th year or over
	(A)	(B)	(C)	(D)	(E)
1917-1918	14,519	10,719	3,802	—	—
1918-1919	14,719	10,345	4,374	3,929	445
1919-1920	15,056	9,868	5,188	4,668	520
1920-1921	13,470	8,146	5,324	4,881	443
1921-1922	13,282	7,146	6,136	5,551	585
1922-1923	12,542	5,914	6,628	5,890	738
1923-1924	12,026	4,469	7,157	6,127	1,030
1924-1925	12,449	4,772	7,677	6,395	1,282
1925-1926	12,698	4,792	7,906	6,321	1,585
1926-1927	13,525	5,667	7,858	5,919	1,939
1927-1928	14,582	6,683	7,899	5,502	2,397
1928-1929	15,333	7,470	7,863	4,943	2,920

It will be seen from these data (col. *C*) that whereas in 1917-1918 the miners with over six years' service numbered only 3,672 or 26 per cent.

of the whole, their number thereafter steadily increased to 7,906 in 1925-1926, since which date it has remained approximately constant. But, even so, this "older" group of miners has itself been steadily becoming "older" in general composition. In the first triennial period the miners with over twelve years' service, who have the highest attack rates, made up (col. *E*) only about one-tenth of the "long service" group. In 1923-1924 they had risen to about one-seventh and in 1928-1929 to well over one-third of all miners having more than six years' service. *Other things being equal*, the effect of this remarkable change must have been to cause a continuous increase in the number of cases of silicosis arising from year to year. It has had such a result, but, owing to the fact that other factors have influenced the position, it has not had the full effect which it otherwise would have had. One such factor has been a steady but not altogether uniform decline in the incidence rates at each year of service, which is well shown in table III.

(3) The third factor which may influence the number of cases of silicosis is a *modification of the standard of selection of diagnosis of cases*, on the part of the medical examiners, i.e. in the present case on the part of the Medical Bureau. If the Bureau improves its technical standard of diagnosis, so that it is enabled to detect silicosis at an earlier stage than formerly, there will naturally be for the time an increase in the number of cases detected. But that increase, so far as it is material, will be temporary only. A liberalisation in the standard of selection of this nature only effects a material increase in the number of cases detected when it is being applied *for the first time*, and when accordingly two grades of the disease are being taken out at once. Once it has been applied to the whole body of working miners, the temporary increase practically disappears. A striking example of the effect of this factor is shown in table II under the year 1919-1920, when the ante-primary stage of the disease was first made compensatable. In that year there were detected under the old standard (the primary stage) 398 cases (col. 2 *a*), and under the new standard (the ante-primary stage) 556 cases (col. 2 *b*) producing the high peak of 954 cases in all for this one year alone (cf. fig. 1).

(4) A fourth factor which may influence the production of silicosis is a possible *alteration in the general physique of the working miners*. This factor has also been operative during the years under review, since the effect of the initial examination of the Bureau has been to introduce into the general body of working miners a specially selected body of men, whom we call the "new Rand miners", and who in 1928-1929 numbered over 8,300 or 54.5 per cent. of the whole body. But the effect of this intrusion did not make itself felt to any noticeable extent until well after the period 1920 to 1923. Even in 1924-1925 only 716 of these men had passed the six years' line and only an insignificant number had then reached their ninth year of work.

These considerations make it plain that in discussing the actual production of silicosis during these twelve years one has to bear in mind that there have been *four independently variable factors* influencing the position, an alteration *in any one of which* will affect the number of cases of silicosis which are detected from year to year.

*Discussion of the Course of Production of Silicosis
from 1917-1918 to 1928-1929*

Bearing these considerations in mind we may now consider in detail the returns presented in table II and fig. 1.

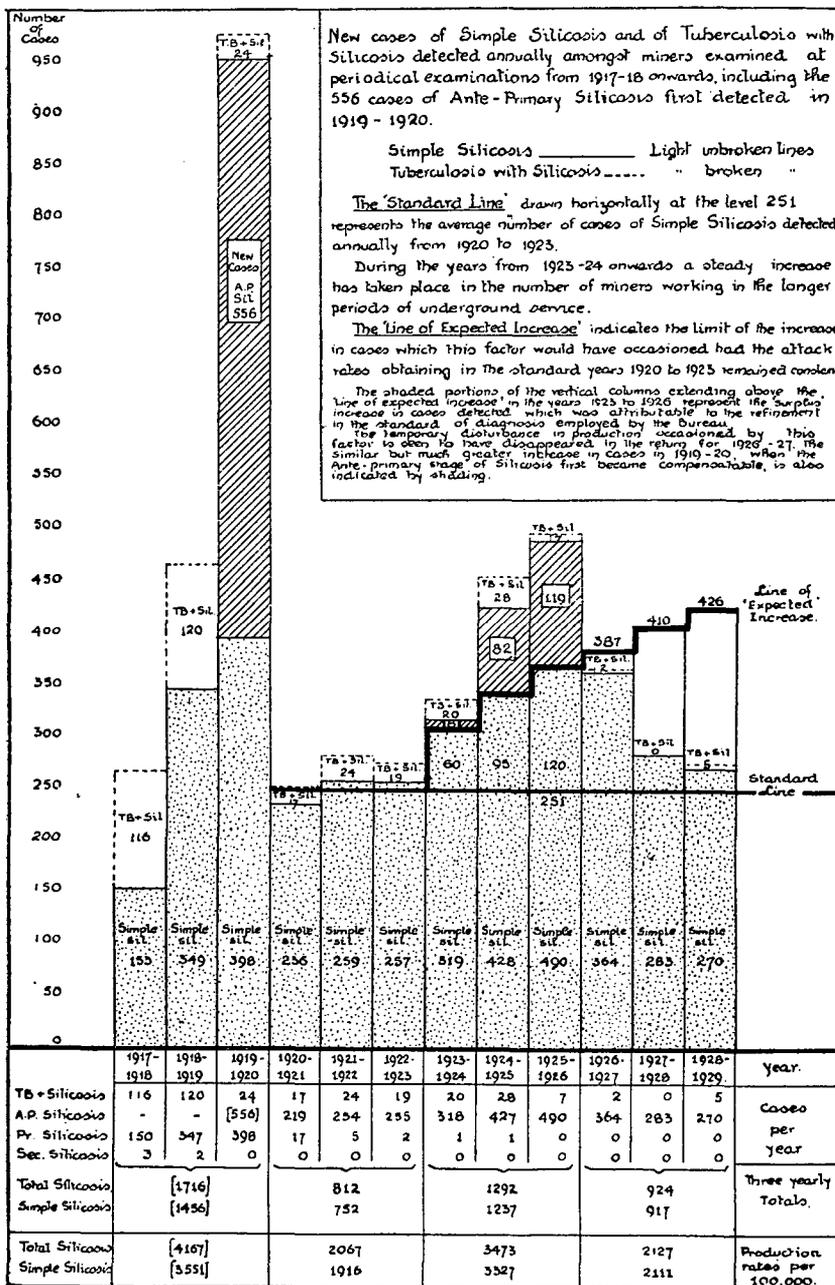
Period 1917 to 1920. — It will be seen that during the first three years there was a staircase rise from 153 cases of primary silicosis (with a very few secondary stage cases) in 1917-1918 to 398 cases in 1919-1920, capped by a peak of 556 cases of "ante-primary" silicosis in the latter year.

(1) The rise in the production of primary silicosis is not difficult to explain. These were war years during which a large number of the "long service" miners were absent on active service and their places were filled by new recruits. With the termination of the war and the return to work of many former miners the number of "long service" miners (table IV, col. C) rose from about 3,800 in 1917-1918 to about 5,200 in 1919-1920. This fact explains a large part of the increase although not all of it.

It was also found, however, that the attack-rate for silicosis amongst the "long service" miners was in the two later years practically double (6.79 and 6.84 per cent.) what it had appeared to be in 1917-1918 (3.42 per cent.). The difference is probably to be accounted for by the fact that under the Act of 1916 it was not compulsory for the Bureau when it found a miner to have silicosis to notify him to that effect. As a consequence, many miners who were at work in 1917-1918, instead of appearing at a periodical examination, applied for a benefits examination, and those who were found at such an examination to be silicotic did not figure as they otherwise would have done in the "periodical" returns. The return of cases of silicosis detected at periodical examinations in 1917-1918 was thus artificially lowered. The Act of 1917 by making it compulsory for the Bureau to notify all individuals who were found at a periodical examination to have silicosis removed this source of confusion in later years.

(2) The second feature of these three years is the very large total return of cases of silicosis for 1919-1920. These figures, as we have said, are the result of a change in the standard of diagnosis on the part of the Medical Bureau. Up to 1919-1920 the standard of diagnosis had been what was termed the "primary" stage of silicosis. It was based on the implication of the Act of 1916 that some amount of disability should be present before a case of silicosis was to be regarded as compensatable. This attitude rested on the analogy of compensation for physical "injury". It was however soon felt that since silicosis is in the majority of cases a progressive disease, the miners affected by it should become compensatable at its "earliest detectable" stage, whether disability was present or not. This change was introduced by the Act of 1919 and the "earliest detectable" stage was labelled the "ante-primary" stage. In 1919-1920 accordingly 556 cases of ante-primary stage silicosis were detected, the majority being accumulated cases, although all may reasonably be presumed to have arisen during the period 1917 to 1920. The returns for 1919-1920 illustrate on a large scale the effect of a change in the Medical Bureau's standard of diagnosis. The 556 cases of "ante-primary" stage silicosis *plus* the 398 cases of primary stage silicosis detected, made a total for the year of 954 cases.

FIG. 1. — PRODUCTION OF SILICOSIS IN ALL FORMS FROM 1917-1918 TO 1928-1929



Period 1920 to 1923. — The next three years witnessed a remarkable change. The obvious temporary “skimming” effect of the introduction of a more liberal standard of diagnosis has disappeared and the production falls in a very striking way. Further, although the number of “long service” miners continued to increase from about 5,200 in 1919-1920 to some 6,600 in 1922-1923 (table IV, col. C), and one would therefore have expected that the number of cases of silicosis would also have increased, this did not happen *because simultaneously the attack rate for silicosis amongst the “long service” miners fell.* Their attack rate had averaged, in the first three years, 5.8 per cent. — it fell to an average of 3.8 per cent. in 1920 to 1923. It dropped quite suddenly from 6.8 per cent. in 1919-1920 to 3.9 per cent. in 1920-1921. One may regard the first three years as having been the last in which the production substantially reflected the cumulative effect of the conditions which had obtained in the period from 1906 or 1907 onwards to the date of the detection of these cases. The second three years represent the culmination of the first decade of the better conditions, which began about 1911 and 1912. A comparison of the rates of incidence per year of underground service shown for the cases detected in these two respective periods in table III, cols. A and B, confirms the view that we are here dealing with two different types of case, two different “generations” of miners. It must be remembered in this connection that in few cases, particularly in these earlier years, was a miner’s service unbroken.

At all events the one tendency—a fall of 35 per cent. in the average attack rate of the “long service” miners—cancelled the effects of the other, namely, a 35 per cent. increase in their average number, and the production of silicosis remained practically stationary. The standard of diagnosis of the Medical Bureau also remained practically the same for these three years so that no disturbing influence arose from this factor. The production of silicosis during this period was thus moderate and fairly uniform. We have therefore selected these years (1920 to 1923) as “standard years” by reference to which the production of silicosis in the succeeding years could be measured, and with this object we have taken the rates of incidence at each year of service worked which obtained during this period, and which are shown in table III, col. B, as “standard rates” of incidence.

Period 1923 to 1926. — The next three years show a different state of affairs. There is again a staircase rise in the production of silicosis to a second peak of 490 cases in 1925-1926 comparable on a smaller scale to the peak of 1919-1920, and due in part to a similar cause. The total increase in these three years over the annual average of 251 cases for the “standard” years 1920 to 1923 was 485 cases in all (table II, col. 2). This increase aroused some alarm and created some misgiving as to the efficacy of the preventive measures employed. But, as Dr. Mavrogordato was the first publicly to point out, it had quite an innocent explanation. The position has been fully analysed in the recent Reports of the Medical Bureau. The falling attack rates (3.9, 3.8 and 3.7 per cent.) of the “long service” miners during this period did not at all suggest that occupational conditions had in recent years altered for the worse.

The explanation of the increase lay in quite another direction. Reference to table IV will show that there had been going on during these years a steady increase in the number of miners at work in the later periods of underground service in which the liability to silicosis is highest. Making the assumption that the attack rates at each year of underground service which had obtained in the period 1920 to 1923 had remained

constant, one applied these rates to the *number* of miners working at each corresponding respective year of underground service during each of the three official years 1923 to 1926. The result was to show an "expected" increase during these respective years of 60, 95 and 120 cases or 275 cases in all, constituting 57 per cent. of the total increase of 485 cases. (Cf. table V.)

TABLE V. — COMPARISON OF ACTUAL AND "EXPECTED" INCREASE IN CASES OF SIMPLE SILICOSIS, 1923 TO 1929

Year	Actual	Expected	Actual less expected	
			Plus	Minus
Annual average, 1920-1923 (standard)	251	251	—	—
1923-1924	319	311	8	—
1924-1925	428	346	82	—
1925-1926	490	371	119	—
1926-1927	364	387	—	23
1927-1928	283	410	—	127
1928-1929	270	426	—	156

There still remained, however, a considerable surplus increase of 209 cases, 8, 82 and 119 in the respective years, which could not be explained in this way. The residual increase was attributable to a second factor which became operative during these years, namely, to a further liberalisation in the standard of diagnosis of the "earliest detectable" stage of silicosis, which was attained during this period by the Medical Bureau owing mainly to improvements in radiographic technique, and to the consequent possibility of a more exact correlation of the results of clinical, radiographic and pathological investigation in a large series of individual cases. The operation of this process, which was substantially completed in 1925-1926, was to repeat, although on a smaller scale, the peak of 1919-1920. Since December 1925, the effects of the process described have been accentuated to some extent by the additional cases resulting from the decisions of the Medical Board of Appeal, which commenced its work at that date. These are included in and go to augment the returns shown in table II.

From the result of this investigation it was possible to predict that the temporary increase due to the operation of this process of deeper selection of cases would shortly disappear. This prediction was realised. In 1926-1927 the number of cases of simple silicosis detected dropped from the 490 cases of the previous year to 364.

Period 1926 to 1929. — The next three years show a decided falling tendency in the production of silicosis (table II, col. 2).

The sudden drop of 126 cases in the production for the year 1926-1927 was attributable mainly to the substantial completion of the process of deeper selection of cases by the Medical Bureau, which had been proceeding during the previous years. Some such fall had been predicted. But

reference to table V shows that not only had the obvious surplus increase due to this factor totally disappeared, but that the actual number of cases had dropped below the "expected" number by 23. The further fall to 283 cases in 1927-1928 and to 270 cases in 1928-1929, is even more satisfactory because it has been effected in face of a further increase in the number of miners working in the later years of service (table IV). In 1925-1926 there were at work 1,585 miners with over twelve years' service—in 1928-1929 their number had risen to 2,920.

If one makes allowance for the influence of this latter factor one may state, with entire confidence, that the true production of silicosis when measured, as it can only accurately be measured, by the respective incidence rates of the disease amongst miners at work in the corresponding respective years of underground service, has undergone a decided improvement since the period 1920 to 1923. Reference to table V or fig. 1 will show that had the rates of the "standard" period remained constant, the number of cases of silicosis to be "expected" in 1928-1929 would have been 426 — they were actually instead 270, a decline below the "expected" number of over 36 per cent. The comparative rates of incidence are given for 1928-1929 and 1920 to 1923 in table III. When, further, one compares the former with the rates obtaining for the primary stage of the disease in 1918 to 1920 the improvement is even more decided. In this respect it is well to note that 90 per cent. of the 270 cases of silicosis detected in 1928-1929 had commenced work on the Rand prior to August 1916, prior, that is, to the commencement of the "present-day" period of preventive policy. The figures appear to indicate that there has been, during the past three years, a decided fall in the true incidence rates of the disease similar to that which occurred after 1919-1920. It is mainly in these later years that one would expect the results of the improved preventive policy introduced in 1916-1917 to effect a substantial modification of the production of the disease.

The Present Position and the Future Outlook Regarding the Production of Simple Silicosis

It is important from the point of view of the outlook regarding the probable course of production of silicosis in the near future to analyse a little more fully the reasons for the decline below the "expected" standard during the past three years. The actual amount is indicated in the last vertical column of table V, and in fig. 1.

For this purpose it is desirable to follow the recent practice of the Medical Bureau, and divide the body of working miners into three classes for separate consideration. These classes are:

Class A — "*new Rand miners*", i.e. miners who have worked only in the mines of the Witwatersrand, and only since 1 August 1916.

Class B — "*old Rand miners*", i.e. miners who have worked only in the mines of the Witwatersrand, but who commenced work before 1 August 1916.

Class C — "*miners, Rand and elsewhere*", i.e. miners who have worked on the mines of the Witwatersrand and also in mines elsewhere.

The particular importance of Class A lies in two facts: (1) that all of these miners have passed the "initial examination" of the Medical Bureau, and (2) that they have been exposed solely to the improved occupational conditions existing since 1916, and have not been affected in any way by mining work elsewhere. This class is naturally a growing one and numbered, in 1928-1929, 8,360 out of the total of 15,333 working miners at that date, or 54.5 per cent. Nevertheless, no miner of Class A had at that date worked for more than thirteen years, and only an insignificant number had reached their thirteenth year of service. In time, but not for a very considerable time, the production of simple silicosis for all miners will depend mainly on the production in this class.

Class B has formed in the past the most numerous group, but it is naturally a decreasing class, and in 1928-1929 it included only 5,672 persons, or 37 per cent. of the total body of working miners. It is still, however, the most important group for the production of silicosis, contributing 197 of the 270 cases of simple silicosis which arose during that year.

Class C is likely always to be a small class, the number of miners included in it in 1928-1929 being 1,301, or 8.5 per cent. of all the working miners. But it contributed during the year more than its proportionate quota of cases.

TABLE VI. — COMPARISON OF ACTUAL AND "EXPECTED" CASES IN THE THREE CLASSES OF WORKING MINERS, DURING THE YEARS 1926 TO 1929

Year	Cases of simple silicosis					
	Class A		Class B		Class C	
	Actual	Expected	Actual	Expected	Actual	Expected
1926-1927	9	48	301	293	54	46
1927-1928	11	67	215	297	57	46
1928-1929	22	84	197	295	51	47
Totals	42	199	713	885	162	139
Actual less expected	—157		—172		+ 23	
Ratio of actual to expected	21 %		81 %		117 %	

A comparison of the "expected" cases, according to the production rates for the standard years 1920 to 1923 (table III, col. *B*) with the actual cases of simple silicosis arising in each of these three classes during the past three years leads to the following interesting results.

It is only necessary to emphasise here the very low production in Class A. This production, however, is as yet dependent upon the rates for the first thirteen years of service only. For that period the incidence rates for each year are for this class very much below the rates for the other two classes, and the curve of incidence does not as yet show any tendency to swing upwards to meet the curves of the other classes in later years. But it is impossible to be too definite with regard to the future. One cannot, of course, anticipate that production rates of the same low order will continue when the "new Rand miners" advance into the later years of underground service. But there is no reason to suppose that even then their incidence rates will reach the relatively higher rates hitherto shown by the two other classes, since the causes producing such low production in the past should have a similar effect at later years of service.

The difference in production rates between the "new" and the "old Rand miners" is due to the facts that the former are specially selected men, and that they have throughout their total period of service been subjected to improved occupational conditions. There are no data which enable one to state how much of the difference can be ascribed to each of these causes. One may reasonably ascribe the decline below the "expected" production which has likewise become evident during the past two years amongst the "old Rand miners" (table VI) to the fact that with each succeeding year a larger proportion of the service of the members of this group also has been passed under improved occupational conditions. The higher production of the "miners, Rand and elsewhere" may reasonably be ascribed to the effect of previous mining work elsewhere.

All of this is re-assuring; nevertheless we must add a word of caution. Although one is justified in concluding that the Rand has turned a big corner in the matter of silicosis, one does not anticipate that the actual number of cases detected will show any significant further decrease in the immediate future. For although the "new Rand miners" with their relatively lower attack-rates are becoming more numerous, nevertheless the older miners who remain — and there are still over 5,000 of them — are every year

growing older in years of service, and therefore more liable to contract silicosis. The one factor will probably for some time balance the other, and one does not therefore anticipate much, if any, actual decrease in the number of "new" cases of simple silicosis which will arise for some years to come. That is the position to-day.

One may in conclusion discuss briefly certain other minor factors that may or may not influence production.

The age of the miner would not appear to exert much influence upon production, the data being inconclusive.

It is similarly not possible to say whether miners born in South Africa are subject to higher or lower production rates than those born overseas. The evidence indicates that there is no significant difference.

The particular class of underground occupation engaged in is certainly an important factor in production. No satisfactory statistics have however been accumulated on this subject, partly because such information has not been required for any particular

TABLE VII. — NEW CASES OF SIMPLE SILICOSIS DETECTED AMONGST MINERS WHO HAVE WORKED UNDERGROUND ONLY IN SCHEDULED MINES, DISTINGUISHING BETWEEN MACHINE-DRILLERS AND OTHERS WITH PRODUCTION-RATES PER CENT. — 1 AUGUST 1927 TO 31 JULY 1928

Period Worked	Total miners examined (1)	Machines only		Machines and other work				No machines		Cases of silicosis and production-rate per cent. (9)
		Number examined and percentage of total (2)	Cases of silicosis and production-rate per cent. (3)	Over 50 % machines		Up to 50 % machines		Number examined and percentage of total (8)		
				Number examined and percentage of total (4)	Cases of silicosis and production-rate per cent. (5)	Number examined and percentage of total (6)	Cases of silicosis and production-rate per cent. (7)			
Up to 6th year	6,255	55 (0.88)	0 (0.000)	465 (7.43)	1 (0.215)	1,085 (17.35)	0 (0.000)	4,650 (74.34)	2 (0.043)	
7th to 12th year	5,023	47 (0.93)	6 (12.766)	736 (14.65)	37 (5.027)	2,466 (48.70)	57 (2.330)	1,794 (35.72)	13 (0.725)	
13th to 18th year	1,876	19 (1.01)	2 (10.526)	245 (13.06)	27 (11.020)	913 (48.67)	47 (5.148)	699 (37.26)	26 (3.720)	

purpose, and partly because miners frequently change from one class of occupation to another. The respective proportions of miners engaged in occupations that are more or less hazardous probably do not differ appreciably from year to year, although in each year they may be made up of different individuals, and the factor of occupation has therefore not influenced statistics dealing with the miners as a whole. There can be no doubt, however, that production is higher among machine-drillers, and amongst those handling broken rock, than amongst those in other occupations, and the factor of occupation would need to be taken into account should the financial system be revised to include differential payment according to occupation. Table VII, showing the production of silicosis for the year 1927-1928 for machine-drillers and others, is of interest (it is taken from the Bureau Report for the year ended 31 July 1928, page 25).

III. — The After-History of Cases of Silicosis and the Progression of the Disease

It has been shown that there has been a considerable decline in the production of silicosis, but unfortunately this has not been accompanied by a corresponding fall in the progression of silicosis, and instead the disease has become of a more infective, and therefore of a more progressive, type. This phenomenon has been discussed in other papers of this series. It may indeed be stated that the importance of the production of a new case of silicosis in the ante-primary stage lies, not in the fact that the miner has silicosis in that stage, but in the likelihood that the disease will progress, first to the primary stage and then to the secondary stage, within a relatively short period.

It thus becomes of importance to measure the rate of progression of the disease. The progression is measured by the "stages" of the disease, and for this purpose the "secondary" stage is treated as including cases of silicosis plus tuberculosis.

Comparison of Progression in Cases originally Certified Respectively as Primary and as Ante-Primary Silicosis

The following table traces the subsequent history (so far as it is known) of 895 cases originally certified as being in the primary

stage of silicosis during the three years from 1 August 1917 to 31 July 1920:

TABLE VIII. — SUBSEQUENT HISTORY OF ORIGINAL PRIMARY STAGE CASES CERTIFIED DURING THE THREE YEARS 1917-1920

	Surviving as		Total surviving	Transfers to secondary stage during year	Died during year while	
	primary stage	secondary stage			in primary stage	in secondary stage
New cases	895	—	895	84	30	11
End First year	781	73	854	48	15	23
„ Second year	718	98	816	60	13	26
„ Third year	645	132	777	41	9	38
„ Fourth year	595	135	730	53	10	24
„ Fifth year	532	164	696	62	14	34
„ Sixth year	456	192	648	51	15	31
„ Seventh year	390	212	602	52	14	31
„ Eighth year	324	233	557	24	11	23
„ Ninth year	289	234	523	—	—	—

Note. — The first year represents a period of between one year and two years and averages about eighteen months.

The percentage of these original primary cases surviving in the primary and secondary stages, and the percentage who have died from the outset, at the end of the third, sixth and ninth years respectively are as follows:

Percentage	End of third year	End of sixth year	End of ninth year
Surviving as primary	72.1	51.0	32.3
„ „ secondary	14.7	21.4	26.2
Died while primary	6.5	10.2	14.6
„ „ secondary	6.7	17.4	26.9

The following table traces the subsequent history (so far as it is known) of another group of cases, namely, the 728 cases originally certified as being in the ante-primary stage of silicosis during the three years 1920-1923, and the 1,235 cases similarly certified in the ante-primary stage during the three years 1923-1926:

TABLE IX. — SUBSEQUENT HISTORY OF ORIGINAL ANTE-PRIMARY CASES CERTIFIED RESPECTIVELY DURING THE PERIODS 1920-1923 AND 1923-1926

	Surviving as			Total surviving	Transfers during year to		Died during year while		
	ante-prim-ary stage	prim-ary stage	second-ary stage		prim-ary stage	second-ary stage	in ante-prim-ary stage	in prim-ary stage	in second-ary stage
Certified during the period 1920-1923									
New cases	728	—	—	728	46	28	18	—	6
End First year	636	46	22	704	63	30	7	3	15
„ Second year	542	100	37	679	86	45	5	2	12
„ Third year	429	161	70	660	81	59	8	6	24
„ Fourth year	320	197	105	622	59	62	5	1	27
„ Fifth year	241	208	140	589	32	47	9	3	20
„ Sixth year	192	198	167	557	—	—	—	—	—
Certified during the period 1923-1926									
New cases	1,235	—	—	1,235	117	56	46	1	7
End First year	1,016	116	49	1,181	195	56	16	3	24
„ Second year	774	283	81	1,138	159	71	11	6	23
„ Third year	593	376	129	1,098	—	—	—	—	—

Note. — The first year represents a period of between one and two years and averages about eighteen months.

The percentages of these original ante-primary cases surviving in the various stages, and the percentages of those who have died from the outset, at the end of the third and sixth years, are as follow:

Percentage	1920-1923 cases		1923-1926 cases: End of third year
	End of third year	End of sixth year	
Surviving as ante-primary	59.0	26.4	48.0
„ „ primary	22.1	27.2	30.5
„ „ secondary	9.6	22.9	10.4
Died while ante-primary	4.1	7.1	5.9
„ „ primary	.7	2.1	.8
„ „ secondary	4.5	14.3	4.4

These figures lead to certain interesting comparisons. At the end of the sixth year, out of the 895 original primary cases certified during the three years 1917-1920, 27.6 per cent. had died and 21.4 per cent. survived in the secondary stage, while out of the 728 original ante-primary cases certified during the

three years 1920-1923, 23.5 per cent. had died and 22.9 per cent. survived in the secondary stage. Bearing in mind that the ante-primary stage is an earlier stage of the disease than the primary stage, the comparison shows that there has been a higher rate of progression among original ante-primary cases, and it exemplifies the change in the form of the disease to a more infective type. A comparison of the percentages "surviving" and "died" at the end of the third year for original, ante-primary cases certified respectively during the three years 1920-1923 and during the three years 1923-1926 shows that the change to a more infective type of disease has continued within recent years.

These conclusions might have been reached by other methods. If the original ante-primary cases be traced until they die in the ante-primary stage or until they progress to a further stage, the average annual rate of progression among those surviving in the ante-primary stage at the beginning of each year is, to the primary stage 17.2 per cent., to the secondary stage 3.0 per cent., total 20.2 per cent. The first year (averaging eighteen months) following the date of certification has been omitted, since for this period there is a halt in the progression of the disease, the total annual rate of progression being only 8.2 per cent. If the primary cases who have been transferred from the ante-primary stage be similarly followed until they die in the primary stage or until they reach the secondary stage, the average annual rate of progression to the secondary stage among those surviving in the primary stage at the beginning of each year is found to be 20.2 per cent. This rate of 20.2 per cent., applicable to the progression to the secondary stage of primary stage cases who have been transferred from the ante-primary stage, may be contrasted with the annual rate of progression to the secondary stage applicable to original primary cases certified during the three years 1917-1920, which was found to be 8.3 per cent.

The reasons for these results have already been discussed. The original ante-primary cases, and particularly those certified in more recent years, are representative of a different body of miners from those originally certified in the primary stage during the three years 1917-1920, they have worked under different conditions during the greater part of their underground employment, and they are subject to a more infective type of silicosis.

It is desirable to emphasise an important change that has taken place in the general body of miners. In the early days

the immense majority of the miners were men of overseas birth who had been drawn from older mining communities which had long been industrialised, but in later years, and especially since 1907, there has been a steady increase in the number of South African-born miners, who are drawn mainly from the rural districts, and who now constitute over 70 per cent. of the working miners. When a pastoral or agricultural population turns to industry, a rise in the tuberculosis rate of that population is to be expected, and this rise will be accentuated if the industry selected should be a phthisis-producing industry. This, as Drs. Mavrogordato and Irvine have recently put it, is largely the position in South Africa to-day. Although the increasing proportion of South African-born miners has apparently not led to an increase in the production of new cases of silicosis, there can be little doubt that it has been an important influence in the change in the nature of the disease to a more infective and progressive type.

The annual rate of mortality amongst ante-primary cases while they remained in the ante-primary stage, but excluding the first year, averaged 1.7 per cent. During the first year, when the rate of progression was low, the annual rate of mortality was 2.3 per cent. *The annual rate of mortality among primary cases transferred from the ante-primary stage*, while they remained in the primary stage, was 1.9 per cent. The corresponding *annual rate of mortality among the cases originally certified primary* during the period 1917-1920, while they remained in the primary stage, was 2.3 per cent. These figures do not call for any remark except that a low rate of progression would appear to be accompanied by a rather higher rate of mortality.

Mortality of Miners in the Secondary Stage of Silicosis

It is more important to consider *the mortality of miners in the secondary stage*, where the "secondary" stage has again been taken to include cases of silicosis plus tuberculosis. Miners in the secondary stage have since 1 August 1919 received monthly allowances, and a mortality experience was taken out in respect of all such miners, whenever certified, who were in receipt of allowances during the nine years from 1 August 1919 to 31 July 1928; the experience covered 3,438 cases.

This investigation showed the following features:

(a) The most important factor influencing mortality was the period that had elapsed since miners were certified in the secondary stage.

(b) The ages of the miners were not a material factor, except at very old ages, but the number of such miners was too small to influence the general results.

(c) The mortality among miners with silicosis plus tuberculosis was much heavier than among miners with silicosis in the secondary stage without tuberculosis.

(d) The mortality among miners certified in the later years under review was lower, after taking into account the period elapsed since certification, than among miners certified in the earlier years.

These features, with the exception of that mentioned under (b), have now to be considered.

(a) *The rates of mortality according to the period elapsed since certification, calculated in respect of cases certified after 31 July 1919, were as follow:*

Year after certification	Annual rate of mortality per cent
1st	18.7
2nd	21.3
3rd	19.1
4th	20.1
5th	18.2
6th	14.5
7th	16.2
8th	5.5
9th	14.7
	} 9.0

(b) It will be observed that the mortality is very heavy for some years following certification, but the survivors after a number of years are subject to lower rates. This feature of the lower mortality among the relatively few survivors after some years is seen more clearly by considering the cases who were in the secondary stage prior to 1 August 1919, and who are dealt with in (c) below.

(c) The mortality was calculated separately for cases of silicosis plus tuberculosis, and for cases of silicosis in the secondary stage without tuberculosis, in respect of miners who were granted

allowances as from 1 August 1919 and who were in the secondary stage prior to that date; the results are as follow:

Year from 1 August 1919	Annual rate of mortality per cent.	
	Silicosis plus tuberculosis	Silicosis in secondary stage without tuberculosis
1st	21.9	9.8
2nd	20.3	10.6
3rd	15.3	9.0
4th	12.1	9.8
5th	14.8	7.9
6th	12.7	9.2
7th	13.1	7.8
8th	10.1	9.3
9th	7.9	6.5

This table gives results which were to be expected, but the table is also of interest in showing the lower rates of mortality among survivors who had been in the secondary stage for some years.

(d) The feature of decreasing mortality according to the year of certification is shown in the following table, which gives, in respect of cases certified in the secondary stage after 31 July 1919, the percentage of the actual deaths that occurred to the deaths that would have been "expected" on the basis of the mortality for all years combined.

Year certified secondary	Percentage of actual to expected deaths
1919-1920	110
1920-1921	137
1921-1922	99
1922-1923	95
1923-1924	119
1924-1925	89
1925-1926	88
1926-1927	75
1927-1928	88
All years	100

This feature of decreasing mortality is thought to be temporary. It will be observed that the mortality of the last four years has remained fairly constant, and having regard to the more progressive type of disease shown in recent years, it would appear that the mortality of future secondary cases should tend to be higher.

*Average Expectation of Progression in Cases Originally
Certified as Ante-Primary Stage Silicosis*

A general summary of the results relating to the progression and mortality of ante-primary cases certified from 1920-1921 onwards may be given in an interesting way. The average period spent by a miner in the ante-primary stage, from the date of certification until he dies in that stage or until he progresses to a further stage, is 4.59 years. For a miner transferred to the primary stage from the ante-primary stage, the average period spent in the primary stage, from the time he is certified primary until he dies in that stage or until he progresses to the secondary stage, is 3.85 years. The average period spent by such a miner in the secondary stage, from the time he is certified secondary until he dies, is 7.26 years.

The average future lifetime of a miner certified in the ante-primary stage cannot, of course, be obtained by adding together these three separate periods of years, because to do so would leave out of account the fact that those dying while in the ante-primary or primary stage could have no lifetime in a further stage or stages, and also the further fact that those progressing direct from the ante-primary stage to the secondary stage could have no lifetime in the primary stage. The figure has been correctly calculated, and the average future lifetime, or expectation of life, of a miner certified to be in the ante-primary stage is 13.66 years.

*Mean Duration of Underground Work and Average Working
Lifetime of a Miner*

The *mean duration of underground service* in all the new cases of silicosis which have arisen amongst those miners who have worked only in scheduled mines is shown below for each year since 1918-1919 (the data are extracted from the Reports of the Medical Bureau):

Year certified	Mean duration of underground service	
1918-1919	9	2
1919-1920	9	6
1920-1921	9	1
1921-1922	9	7
1922-1923	9	5
1923-1924	10	3
1924-1925	10	3
1925-1926	10	10
1926-1927	11	9
1927-1928	12	1
1928-1929	12	8

The increase in the mean duration of underground service is due not only to an improvement in underground conditions, but to two other factors. The first of these factors is the progressive intrusion into the body of working miners of a specially selected group with relatively low attack-rates for the disease, namely, the "new Rand miners". The second influence is to be found in the fact that the mining community has become more and more a settled community with a continually increasing proportion of miners with relatively long periods of underground service. Even allowing for these two factors, however, the increase in the mean duration of underground service is undoubtedly a satisfactory feature.

Although the mean duration of underground service among miners contracting silicosis is of interest and has to be recorded, it has to be pointed out that this mean duration does not represent the average working lifetime of a miner, since it leaves out of account the fact that many miners still working with relatively long periods of underground service have not yet contracted silicosis, and also the further fact that a number of miners have left underground employment without contracting silicosis. It is necessary, therefore, in considering the true average working lifetime of a miner, to take these further factors into account.

The question of *the average working lifetime* is a difficult one to answer. In the first place, the rate of production of silicosis has been changing, and it is necessary to adopt a reasonable basis for production; it was assumed that the rates of production of simple silicosis during the year 1928-1929 would apply throughout

the miner's working lifetime. Secondly, a miner may give up underground employment owing to the contraction of simple tuberculosis or of silicosis plus tuberculosis, the average rates found to be applicable within the last few years were here adopted. Thirdly, underground employment may be terminated owing to death, which might occur through a mine accident or for some other reason, or employment may be terminated through a breakdown in health owing to a mine accident or otherwise. Fourthly, it was presumed that miners would not voluntarily give up underground work. On this basis (and the assumptions appear to be reasonable) a miner might expect to have a working lifetime of nearly eighteen years. We are of the opinion that this average working lifetime of nearly eighteen years represents fairly the average conditions existing at the present time.

It should be added that a miner commencing work now could anticipate an average working lifetime considerably exceeding eighteen years. It is impossible to state with any degree of definiteness what his future working lifetime is likely to be, since the rates of production of "new Rand miners" are available for only the first thirteen years of their underground service, and it is impossible to say what the rates will be in later years, but there can be no doubt that it will be considerably in excess of eighteen years.

IV. — The Prevalence of Silicosis and Tuberculosis amongst Native Labourers on the Gold Mines of the Witwatersrand

A brief reference may be made in conclusion to the general statistics which are available regarding the prevalence of silicosis and tuberculosis amongst native mine labourers.

Table X shows the general data regarding the prevalence of simple silicosis, tuberculosis with silicosis, and simple tuberculosis amongst native mine labourers employed on the mines of the Witwatersrand since 1916-1917. The general system of detection of these conditions amongst mine natives has been described in other papers in this series.

A comparison of the returns here presented with those for European miners in table II shows several very striking differences.

Although in the first two years 1917-1918 and 1918-1919 a very considerable number of cases of silicosis complicated with active tuberculosis was detected amongst the European working

TABLE X. — PREVALENCE OF SIMPLE SILICOSIS, TUBERCULOSIS WITH SILICOSIS, AND SIMPLE TUBERCULOSIS AMONGST NATIVE LABOURERS IN THE GOLD MINES OF THE WITWATERSRAND, 1916-1917 TO 1927-1928

	1916-1917	1917-1918	1918-1919	1919-1920	1920-1921	1921-1922	1922-1923	1923-1924	1924-1925	1925-1926	1926-1927	1927-1928
Average number all mine natives	191,202	180,415	171,959	178,571	168,547	160,600	179,182	178,006	179,881	177,368	184,937	193,976
A. — Cases simple silico- sis detected Prevalence rate per cent.	91 0.047	31 0.017	47 0.027	126 0.070	134 0.079	45 0.027	75 0.041	119 0.066	85 0.047	201 0.113	238 0.129	209 0.108
B. — Cases tuberculosis with silicosis detected Prevalence rate per cent.	252 0.131	232 0.128	378 0.219	394 0.220	276 0.163	203 0.126	327 0.182	312 0.175	359 0.200	434 0.245	409 0.221	397 0.204
C. — Cases simple tuber- culosis detected Prevalence rate per cent.	1,103 0.576	946 0.524	789 0.458	794 0.444	810 0.480	580 0.361	663 0.370	585 0.328	456 0.253	561 0.316	787 0.425	746 0.385
Combined prevalence rates per cent. : Silicosis in all forms (A + B)	0.178	0.145	0.246	0.290	0.242	0.153	0.223	0.241	0.247	0.358	0.350	0.312
Tuberculosis in all forms (B + C)	0.707	0.652	0.677	0.664	0.643	0.487	0.552	0.503	0.453	0.561	0.646	0.589
All compensatable dis- eases (A + B + C)	0.754	0.669	0.704	0.734	0.722	0.514	0.593	0.569	0.500	0.674	0.775	0.697

Note. — The returns for 1924-1925 onwards do not as in previous years include cases detected amongst the small number of Eurafriean miners.

miners, the number of cases of that condition has markedly declined since that date, and during the past three years has practically reached vanishing point. The number of cases of "open" or active simple tuberculosis arising amongst European miners has never for the last three triennial periods averaged more than 0.18 per cent. The overwhelming majority of cases of compensatable disease amongst European miners since 1919-1920, have been when first detected cases of simple or uncomplicated silicosis.

The reverse is true of the native mine labourers, amongst whom the great majority of cases of compensatable disease are cases of active simple tuberculosis, or, in those with longer service, of active tuberculosis preceded or accompanied by an element of silicosis.

The incidence of simple silicosis amongst the mine natives is relatively small. The low figures for the prevalence of this condition recorded for the first nine years may present an underestimate of the true position, since at that time no systematic investigation of the prevalence of silicosis amongst mine natives was made. But in 1926 a systematic annual radiographic examination of all natives with more than five years' service on any one mine was instituted by the Chamber of Mines. The result, as the figures from 1925-1926 onwards indicate, has been to secure the detection of a considerably larger number of cases of simple silicosis, but the prevalence rate for this condition still remains low as compared with that amongst European miners. It is not that the native labourer is less susceptible to silicosis than the European miner, given an equal intensity and an equal duration of exposure to dust. This was shown by Dr. Watkins-Pitchford in the Bureau Report for 1923-1924. The difference is to be explained by the fact that the service of the mine native is in general much shorter and less continuous than that of the European miner.

On the other hand, the higher susceptibility of the African native to tuberculosis is a matter of common knowledge, and that disease frequently assumes in the native the acute "infantile" type, particularly amongst new or recent recruits. Even so, when judged by European or American standards, the incidence of tuberculosis amongst mine natives, even when taken to include cases of active tuberculosis with silicosis, is not alarming. But the actual number of cases is considerable. It amounted in 1927-1928 to over 1,100 cases, each a potential source of dissemination of infection.

It will be noted in the returns presented in table X that the

prevalence of simple tuberculosis fell steadily from 0.58 per cent. in 1916-1917 to 0.25 per cent. in 1924-1925. During that period, the general working conditions on the mines and the medical system of detection of cases remained substantially unaltered.

The Miners' Phthisis Act of 1925, however, provided that the medical service for mine natives should thereafter be a whole-time service, and introduced further provisions to improve the methods of detection employed. It will be noted that the number of cases of all three of the conditions specified in the table underwent thereafter a simultaneous increase. It is reasonable to assume that much of this increase has been due to the improved system of detection employed from 1924-1925 onwards. Sufficient time has not however elapsed to determine whether the increase which has been observed since that date will prove to be temporary only, or will be found to be permanent.

REVIEW OF THE DEVELOPMENT OF SILICOSIS LEGISLATION IN SOUTH AFRICA, WITH PARTICULAR REFERENCE TO COMPENSATION

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It had long been known that miners engaged in metalliferous mining in hard rock were prone to suffer, to a greater extent than did the general population, from chronic disease of the lungs or respiratory organs. This excessive incidence of lung disease is not a feature peculiar to the mines in the Transvaal and has been the subject of serious attention and of official investigation in almost every important mining area, especially since the introduction, many years ago, of rockdrills into mining practice.

In the Transvaal the excessively high mortality from miners' phthisis which had occurred, especially amongst rockdrill miners, during and just after the Anglo-Boer War arrested the attention of the Government and the mining community; and in 1902 a Commission was appointed to enquire into the extent to which the disease prevailed, to ascertain its causes and to recommend preventive and curative measures. Since then the subject of miners' phthisis has continuously occupied serious attention; the nature, prevalence, causation and prevention of the disease; the benefits to be granted to persons suffering from the disease and their dependants, and other matters incidental thereto, have been investigated and reported upon by numerous Parliamentary Select Committees and Commissions (judicial, medical and otherwise) and many important papers bearing upon the disease have been contributed to scientific societies, all of which have done much to elucidate the many problems connected with the subject.

The earlier investigations and enquiries showed that preventive measures had become an urgent necessity, and since then steps have been taken, from time to time, by the Government in South Africa and the mining industry to secure the better regulation of mining work, to introduce methods to prevent the generation and dissemination of dust in the mines, to improve the ventilation of the mines and to protect the health and safety of persons working in the mines; and an enormous advance has been made in this connection.

Four Commissions, in addition to the Commission of 1902 mentioned above, have been appointed to investigate the subject of Miners' Phthisis and other matters incidental thereto, namely:

- (i) The Miners' Phthisis Medical Commission appointed under the Miners' Phthisis Allowances Act, No. 34 of 1911, to enquire into the prevalence of miners' phthisis and pulmonary tuberculosis on mines within the Union of South Africa. This Commission, which consisted of seven medical practitioners, reported on 2 February 1912.
- (ii) Commission to enquire into the working of the Miners' Phthisis Acts. This Commission reported on 7 December 1918.
- (iii) Commission, with a Judge as Chairman, to enquire into the working of the Miners' Phthisis Act, No. 40 of 1919. This Commission reported on 16 April 1921.
- (iv) Commission to enquire into the working and administration of the Miners' Phthisis Acts, Consolidation Act, No. 35 of 1925, which is at present in force. This Commission is at present carrying out its investigations.

Ten Select Committees on Miners' Phthisis have been appointed by Parliament and these Committees reported on 23 May 1912; June 1914; 20 April 1916; 12 June 1917; 22 April 1918; 30 May 1919; 20 July 1920; 9 April 1924; 14 July 1925, and 25 March 1929.

Nine Acts, dealing with *Compensation for persons found to be suffering from miners' phthisis (silicosis) and their dependants and other matters incidental thereto*, have been passed by the Parliament of the Union of South Africa; namely:

- | | |
|--|-----------------------------|
| (a) Miners' Phthisis Allowances Act, No. 34 of 1911. | } Called the
"prior Law" |
| (b) Miners' Phthisis Act, No. 19 of 1912. | |
| (c) Miners' Phthisis Act, Amendment Act, No. 29 of 1914. | |
| (d) Miners' Phthisis Act, No. 44 of 1916. | |
| (e) Miners' Phthisis Act, Amendment Act, No. 44 of 1917. | |
| (f) Miners' Phthisis Acts, Further Amendment Act, No. 24 of 1918. | |
| (g) Miners' Phthisis Act, No. 40 of 1919 (called the "principal Act"). | |
| (h) Miners' Phthisis Act, Amendment Act, No. 35 of 1924 (called the "previous Act"). | |
| (j) Miners' Phthisis Acts, Consolidation Act, No. 35 of 1925 (the "present Act"). | |

(Note. — Only the Acts of 1912, 1914, 1916, 1917 and 1918 are included in the term "prior Law".)

The Miners' Phthisis Allowances Act, No. 34 of 1911 (which is not included in the prior Law), came into force on 12 May 1911, and was superseded by the Miners' Phthisis Act, No. 19 of 1912, which came into force on 1 August 1912, and was amended by the Miners' Phthisis Act, Amendment Act, No. 29 of 1914, which came into force on 1 August 1914. The Miners' Phthisis Act, No. 44 of 1916, came into force on 1 August 1916, repeals the Miners' Phthisis Acts of 1912 and 1914 (with the exception of certain sections thereof), was amended by the Miners' Phthisis Act, Amendment Act, No. 44 of 1917, which came into force on 1 August 1917, and was further amended by the Miners' Phthisis Acts, Further Amendment Act, No. 24 of 1918, which came into force on 22 May 1918. The Miners' Phthisis Act, No. 40 of 1919 (the principal Act), came into force on 1 August 1919, repeals the Miners' Phthisis Act

of 1911, the unrepealed sections of the Miners' Phthisis Acts of 1912 and 1914 and the Miners' Phthisis Acts of 1916, 1917, and 1918 and was amended by the Miners' Phthisis Act, Amendment Act, No. 35 of 1924 (the previous Act), which came into force on 1 August 1925. The Miners' Phthisis Acts, Consolidation Act, No. 35 of 1925, the present Act, came into operation on 1 August 1925, and repeals the Miners' Phthisis Act, No. 40 of 1919 (the principal Act), and the Miners' Phthisis Act, Amendment Act, No. 35 of 1924 (the previous Act). It consolidates and amends the laws relating to miners' phthisis and is at present in force.

The making of awards and payments of compensation to miners' phthisis sufferers and their dependants is placed under a Board styled the "Miners' Phthisis Board", consisting of a Chairman and not less than three or six other members who are appointed by the Government. This Board has power to collect, by means of levies on the mines enumerated in the scheduled list published under the Miners' Phthisis Act, the necessary funds for the payment of compensation and for carrying out the other functions of the Board.

Since 1 August 1916 all medical matters and the certification of claims for compensation were placed under a body of medical practitioners styled the "Miners' Phthisis Medical Bureau", consisting of a Chairman and a number of medical practitioners appointed by the Government.

On 1 August 1925 a special Medical Appeal Board, consisting of a Chairman and two medical practitioners having special knowledge of diseases of the lungs and respiratory organs, was appointed by the Government. The function of the Appeal Board is to deal with appeals by persons who are dissatisfied with the decisions of the Medical Bureau.

SUMMARY OF COMPENSATION PROVIDED UNDER THE MINERS' PHTHISIS ACTS

The following is a summary of the main provisions under which benefits were granted in terms of the above-mentioned Miners' Phthisis Acts and the various regulations published under those enactments. Unless an express statement to the contrary is made, the Board was not precluded from granting benefits to miners and dependants who were not resident in the Union of South Africa.

Miners' Phthisis Allowances Act, No. 34 of 1911

Allowances under this Act could be granted, in the absolute discretion of the Board, to persons (and their dependants) who were or had been employed in the scheduled mines (certain gold mines in the Transvaal) and were wholly or partially incapacitated by miners' phthisis (silicosis) from pursuing their avocations or were suspended on account of such disease by any rule or regulation in that connection.

To all intents and purposes, the benefits under the Act were *ex-gratia* grants pending the introduction of miners' phthisis

legislation of a more comprehensive nature and any payments made thereunder were to be deducted from the benefit to be granted under any subsequent Miners' Phthisis Act. In cases where further benefits were so granted, the awards have been treated as original awards under such subsequent Act, the beneficiary being deemed to be a non-beneficiary for the purposes of granting further benefits thereunder.

The funds under the control of that Board were limited and in a number of cases benefits were refused, the applicant being advised to re-apply at a later date. No benefits were provided for the dependants of a deceased miner unless the miner had been granted benefits under the Act. The provisions of the Act and the Regulations thereunder precluded the Board from granting benefits to miners not resident in the Union of South Africa.

Applicant miners were medically examined by the Miners' Phthisis Medical Commission established under the Act to investigate and report upon the extent to which miners' phthisis was prevalent amongst persons employed upon the scheduled mines and awards were made on the certificates of that body.

The amount of the benefit in each case was limited to £250, but, except in a few cases in which single sums of £100 to £250 were granted or in which the applicant and his wife and children were repatriated and granted small monthly payments for a few months, the award made was usually £15 to £20 payable immediately, to enable the applicant to discharge his debts, and £8 15s. per mensem for a few months; in many cases the monthly payments were prolonged until the next Miners' Phthisis Act (No. 19 of 1912) came into operation on 1 August 1912.

Miners' Phthisis Act, No. 19 of 1912

Under this Act a miner in the earlier (primary) stage of miners' phthisis (silicosis) became entitled to £8 per mensem for a period *not exceeding twelve months* and in the later (secondary) stage *not exceeding* £400 (lump sums being in each case payable at the discretion of the Board for debts, repatriation, farming, business, etc.). A miner granted £96 and thereafter found to be in the later stage, became entitled to an amount not exceeding £304 (£400 less £96).

The miner had, however, first to satisfy the Board that he had been employed underground on the scheduled mines during the four years immediately preceding the date of this claim, and if

he had been so employed for a period or periods amounting to less than two years during such four years he had also to satisfy the Board that he had contracted miners' phthisis on the scheduled mines.

Applicant miners were medically examined by two (or in special cases three) medical advisers to the Board, the Mines Medical Inspector and a number of medical practitioners being appointed by regulation as medical advisers. Applicant miners resident outside the Union of South Africa were examined and reported upon by medical practitioners registered as such in the country where the applicant resided, and the medical advisers granted certificates after considering such reports. Awards were made in accordance with the decisions of the medical advisers.

Dependants (wholly or partially dependent) of a deceased beneficiary miner became entitled to an amount of £400 (less the amount paid to the miner), payable in instalments, provided the Board was satisfied that the miner died of miners' phthisis, and dependants of a deceased non-beneficiary miner became entitled to £400 (payable in instalments) provided the Board was satisfied that the miner had died of miners' phthisis and was qualified to receive an award under the Act, viz. if the miner had died prior to the commencement of the Act (1 August 1912), the period of *four* years mentioned above, during which the Board had to be satisfied that the deceased had been a miner on scheduled mines, was the four years immediately preceding the commencement of the Act (1 August 1912), but if he died after the commencement of the Act the said period was the four years immediately preceding the date of the application by the dependants.

The Board could, in its discretion, contribute (in addition to any benefits which could be granted to dependants) an amount not exceeding £20 towards the reasonable expenses of medical attendance and burial of a miner who died from miners' phthisis, while a beneficiary under the Act or while his claim to any benefit thereunder was being investigated.

A miner was defined by the Act as a person of European descent who, before or after the commencement of the Act, performed or had performed as his regular occupation any class of work underground (i.e. below the surface) on a scheduled mine (excluding managers and managing directors).

A native (i.e. any member of the aboriginal races or tribes of Africa) who had been employed underground as a native labourer on the scheduled mines became entitled to an amount *not exceeding*

£20 (to be assessed by the Director of Native Labour) if found by the medical advisers to have had miners' phthisis in the earlier (primary stage), and to an amount not exceeding £50 (to be assessed as aforesaid) in the later (secondary) stage. In the event of the death of such a native who had not been granted benefits, his dependants became entitled to an amount of £10 if the Director was satisfied that he had died from miners' phthisis and had a wife, child, parent or other person dependent upon him.

Deductions amounting to 2½ per cent. could be made by the companies (which owned or worked the scheduled mines) from the earnings of the miners employed by them, and the companies were required to contribute to the funds of the Board 5 per cent. of such earnings during the two years ended 31 July 1914, and thereafter 7½ per cent. Persons who were employed underground on the scheduled mines and who were neither Europeans nor natives (i.e. coloured persons, Indians, Asiatics, etc.) could elect that, for so long as they were so employed, the aforesaid deductions should be made from their earnings by the mining companies. Such a person, so electing, became entitled during the two years ended 31 July 1914 to benefits, within the discretion of the Board, not exceeding half those which could be granted to a miner, and after 31 July 1914, to the benefits which could be granted to the miner, according to the circumstances applicable to each case. Failing such election, such a person became entitled to the benefits prescribed by the Act for a native.

The Act of 1912 was amended by the next Miners' Phthisis Act (No. 29 of 1914), which came into force on 1 August 1914.

Miners' Phthisis Act, Amendment Act, No. 29 of 1914

Under this Act the term "underground work" was extended to include work "on or about the rock crushers in a crusher station" and provision was made for a final decision by the Government Mining Engineer as to whether any person was a "miner". The said official gave a general ruling that any person who spends, in any month, more than half his working time underground or on or about the rock crushers in a crusher station was to be deemed to be a miner under the Act during that month.

The benefit to be granted to miners in the earlier stage of miners' phthisis was increased by the Act to an amount not exceeding £200. A miner who had been granted benefits (£96) under the 1912 Act, or his dependants, could be granted, at the discretion of the Board,

an amount not exceeding £100, provided the claimant was permanently resident in the Union of South Africa, was in need of assistance and made application before 1 August 1915.

Dependants of a deceased miner who had died from any cause became entitled to the balance of the award granted to the miner before or after the commencement of the Act, provided the dependants applied within nine months from the date of his death. Dependants of a beneficiary miner also became entitled to benefits as provided by the 1912 Act for such cases, if pre-existent miners' phthisis was the chief contributing factor in the causation of his death, but, save as regards the dependants mentioned above, the dependants of a deceased beneficiary or non-beneficiary miner were required to make application within two years of the date of death of the miner, failing which the benefit could not be granted.

Special provision was made for *ex-gratia* grants (not exceeding £10,000 in all) to dependants of deceased non-beneficiary miners who died of miners' phthisis prior to the commencement of the 1911 Act (12 May 1911), provided the dependants were permanently resident in the Union of South Africa, were in need of assistance and made application before 1 August 1915.

The Acts of 1912 and 1914 were repealed by the next Miners' Phthisis Act (No. 44 of 1916), which came into force on 1 August 1916.

Miners' Phthisis Act, No. 44 of 1916

Under this Act, the benefits provided were:

An amount not exceeding £300 (in instalments) to a non-beneficiary miner found, between 1 August 1916 and 1 August 1918, to have primary silicosis; the unpaid balance to be granted in instalments to his dependants, wholly or partially dependent, in the event of his death. An amount of £400 (payable £10 per month if married and £8 per month if unmarried) to a non-beneficiary miner found, between 1 August 1916 and 1 August 1918, to have secondary silicosis (the unpaid balance of £400 to be granted in instalments to his dependants, in the event of his death), but if the £400 had been paid *to the miner*, payments *to him* could be continued until £750 had been paid, provided he was a permanent resident in the Union of South Africa on and after 1 August 1916, and was in need of financial assistance. An amount not exceeding £375 (in instalments) to a miner found, after 1 August 1918 to have silicosis (in either the primary or secondary stage); the unpaid balance to be granted, in instalments, to his dependants, in the

event of his death. An amount of £300 (in instalments) to a miner found to have tuberculosis without silicosis, provided he was thereby prevented, prior to 1 August 1917, from working underground on scheduled mines and had been so employed after 1 May 1916; the unpaid balance to be granted in instalments to his dependants, in the event of his death. An amount not exceeding £750 (payable £12 per month if married and £10 per month if unmarried) to a miner found to have tuberculosis with silicosis provided he was thereby prevented, prior to 1 August 1917, from working underground on scheduled mines and had been so employed after 1 May 1916; the unpaid balance to be granted in instalments to his dependants, in the event of his death, if they were permanent residents in the Union of South Africa on and after 1 August 1916.

The silicotic miner had, however, first to satisfy the Board that he had been employed as a miner on scheduled mines after 1 August 1908, and, if he had been so employed for a period or periods amounting to less than two years since that date, that he had contracted silicosis on scheduled mines.

Dependants of a deceased miner whose claim was under investigation when he died became entitled to the benefit (in instalments) which he was then entitled to. Dependants of a non-beneficiary miner (who had not lodged a claim with the Board, who had been proved by post-mortem examination to have died from silicosis or any other cause if silicosis was present as a contributing or predisposing factor and who had qualified to receive a benefit under the Act) became entitled to £300 (in instalments) if the miner died between 1 August 1916 and 1 August 1918, and £375 (in instalments) if the miner died after 1 August 1918.

A miner who had been granted benefits under the earlier Acts for primary silicosis (£96, £196 or £200) became entitled, at the discretion of the Board, to a further amount not exceeding £100, provided he was a permanent resident in the Union of South Africa on and after 1 August 1916, was in need of financial assistance owing to his suffering from silicosis and made application prior to 1 August 1917 (if such a miner was found to have secondary silicosis he became entitled to the benefit—not exceeding £400—provided for such cases under the earlier Acts less the amount paid to him for primary silicosis); in the event of his death the balance to be granted, in instalments, to his dependants. A miner who had been paid the full amount of £400 under the earlier Acts for secondary silicosis became entitled to a further £350 (payable £10 per month if married and £8 if unmarried), provided he was a permanent resident in the

Union of South Africa on and after 1 August 1916, and was in need of financial assistance; in the event of his death the balance to be granted in instalments to his dependants.

A miner who had been granted benefits for the primary stage and thereafter was found to be in the secondary stage became entitled to the secondary stage benefits, less the amount previously granted.

A miner who had silicosis but was not eligible for and had not received a benefit under this or the earlier Acts could be awarded an *ex-gratia* grant, and dependants of such a miner who had died from silicosis or from a disease of which silicosis was a contributing or predisposing factor could also be awarded an *ex-gratia* grant, provided that, in both cases, the claimant was in need of financial assistance, was a permanent resident in the Union of South Africa on and after 1 August 1916 and applied before 1 August 1917; the amount available for these grants being £20,000.

Applicant miners and native labourers were medically examined by the Miners' Phthisis Medical Bureau which had been established under the Act for this purpose, and benefits could only be granted, under this Act, in accordance with the certificates of that body.

The definitions of "miner" and of "underground work" in this Act were the same as the definitions under the Act of 1912 as amended by the Act of 1914.

Provisions were made in this Act empowering the Board:

- (i) to acquire land to be devoted to small agricultural holdings and to establish on such holdings beneficiary miners and other suitable persons,
- (ii) to assist financially, by means of loans or otherwise, in establishing or carrying on industrial undertakings which undertook to employ or were employing, at the Board's request, beneficiaries or dependants of beneficiaries,
- (iii) to open and conduct a bureau, or co-operate with other labour bureaux and other institutions, for obtaining employment for beneficiaries or dependants of beneficiaries, and
- (iv) to assist financially in defraying the expenses of transport of beneficiaries to places where employment for them had been obtained.

The provisions of Act No. 19 of 1912 regarding the following were re-enacted:

- (i) contributions by the Board towards the funeral and medical expenses of deceased miners,
- (ii) benefits for miners' phthisis (silicosis) to natives and their dependants, and
- (iii) election by persons, other than miners or natives, to have deductions made by the mining companies from their earnings and the benefits to be granted to such persons.

A native labourer who had been employed underground on the scheduled mines and who was discharged from such employment after 1 August 1916 and prior to 1 August 1917, on the ground that he had tuberculosis, became entitled to the benefits provided in the Act for a native labourer for primary silicosis, if the tuberculosis was not complicated by silicosis, or to the benefits provided for secondary silicosis, if the tuberculosis was complicated by silicosis.

The Act of 1916 was amended by the next Miners' Phthisis Act (No. 44 of 1917), which came into force on 1 August 1917.

Miners' Phthisis Act, Amendment Act, No. 44 of 1917

Under this Act the amounts to be granted to miners and dependants were fixed at £300, £375, or £750 (as the case may be) instead of "an amount *not exceeding* such sum"; the amount for secondary silicosis was increased from £400 to £750 (i.e. miner—non-beneficiary under the Miners' Phthisis Acts of 1912 and 1914—need not necessarily be "resident" to qualify for the additional £350, and the unpaid balance of the £750 could be granted to his dependants, in the event of his death). The date "1 August 1917" in the Act of 1916 was extended to "1 August 1918". Dependants of a deceased miner who had been granted £750 for tuberculosis with silicosis need not necessarily be "resident" to qualify for the unpaid balance of the amount awarded to the miner. Benefits for tuberculosis with or without silicosis to be granted only if such tuberculosis was found at the *periodical* examination of a miner (compulsory medical examinations, by the Miners' Phthisis Medical Bureau, of working miners, at intervals of six months). Further benefits (subject to "residence" and otherwise, as in the Act of 1916) to a miner who had been granted an award under the Acts of 1912-1914 for primary silicosis, namely, £300 (less previous benefits of £96, £196, £200 or £296, as the case may be) if found to have primary silicosis, tuberculosis without silicosis or to be unfit for underground work by reason of silicosis though not primary or secondary, and £750 (less previous benefits), if found to have secondary silicosis. Further benefits (subject to "residence" and otherwise, as in the Act of 1916), to a miner who had been granted an award under the Acts of 1912-1914 for secondary silicosis (not necessarily the full amount of £400), namely, £500 (less the previous benefit) if found to have primary silicosis or to be unfit

for underground work by silicosis, though not in either the primary or secondary stage, and £750 (less the previous benefit), if found to have secondary silicosis or tuberculosis with or without silicosis. *Ex-gratia* grants, provided for miners and dependants by the Act of 1916, could also be awarded (on the same terms and conditions as to "residence" and otherwise, as in the Act of 1916) to dependants of beneficiaries who died prior to 1 August 1916.

Provisions were made in this Act empowering the Board:

- (i) to assist, by means of loans, beneficiaries who are already established in business or in farming operations, and
- (ii) to contribute amounts not exceeding half the cost of establishing and maintaining a sanatorium for purely silicotic patients.

The Acts of 1916-1917 were amended by the next Miners' Phthisis Act (No. 24 of 1918), which came into force on 22 May 1918.

Miners' Phthisis Acts, Further Amendment Act, No. 24 of 1918

Under this Act the date "1 August 1918" in the Act of 1916 (before and after amendment by the Act of 1917) was extended to "1 August 1919". The *ex-gratia* grants, previously mentioned, could also be awarded (on the same terms and conditions as before); to *dependants of deceased beneficiaries who had not received further awards under the Acts of 1916 or 1917* (instead of *dependants of beneficiaries who had died before 1 August 1916*) and a further amount of £40,000 was available for the *ex-gratia* grants provided by the Acts of 1916 and 1917 and this Act.

The Acts of 1916, 1917 and 1918 were repealed by the next Miners' Phthisis Act (No. 40 of 1919) which came into force on 1 August 1919.

Miners' Phthisis Act, No. 40 of 1919 (the Principal Act)

Under this Act a miner (non-beneficiary under the prior Law) became entitled to a one-sum benefit, for the ante-primary or primary stage of silicosis or tuberculosis without silicosis (calculated on his *month's earnings*) as is provided in the present Act (No. 35 of 1925) (*vide* paragraph (j) hereof) and such a miner became entitled to an award of a monthly allowance (pension) for secondary silicosis or tuberculosis with silicosis (calculated on his *month's earnings*) as is provided in the present Act (No. 35 of 1925) (*vide* paragraph (j) hereof) *except* that the tuberculosis whether with or

without silicosis was to be found at a *periodical examination* (compulsory medical examinations, by the Miners' Phthisis Medical Bureau, of working miners), that the silicotic miner had first to satisfy the Board that he had been employed underground on scheduled mines for at least two years since 1 August 1908, or that he had contracted silicosis on such a mine and that additional allowances could not be granted to a miner for more than three of his children, for his invalid children who were over sixteen years of age when the miner became entitled to the allowance or for his stepchildren (unless they had been "adopted" before the grant of any benefit to him).

The conditions, attached to awards of monthly allowances (pensions) to miners and dependants under the Act of 1919, were similar to the conditions attached to such awards under the present Act (*vide* paragraph (j) hereof).

A miner who had been granted a one-sum benefit for ante-primary silicosis could become entitled to a further one-sum benefit for primary silicosis or tuberculosis without silicosis and a miner who had been granted a one-sum benefit could become entitled to a further award of a monthly allowance for secondary silicosis, but in both cases only if he had applied for benefits within the prescribed period of three months from the date on which he had been first notified after 1 August 1919, that he had silicosis (in unsuccessful appeals the period was one month from the date he was notified of the result of the appeal).

Dependants of a deceased beneficiary miner (non-beneficiary under the prior Law) became entitled to the balance of the award made to the miner, but if the miner was in receipt of a monthly allowance or had died from secondary silicosis or any other cause if secondary silicosis was present as a contributing or predisposing factor, the dependants became entitled to an award of a monthly allowance. Dependants of a deceased non-beneficiary miner became entitled to such benefit (for ante-primary or primary silicosis) as the miner would have been entitled to, had he not died, but, if secondary silicosis was the cause of his death or was present as a contributing or predisposing factor in the causation of his death, the dependants became entitled to an award of a monthly allowance. Dependants of a deceased beneficiary miner to or in respect to whom benefits had been granted under the prior Law became entitled to awards of monthly allowances, if the miner died prior to 1 August 1919, but, if the miner died after that date, only if silicosis was present as a contributing or predisposing factor

in the causation of his death; these dependants had to apply before 1 August 1920, and had to be resident in Africa (south of the Equator) on and after 31 July 1916, or the date of the miner's death (whichever was the *later*). Dependants of a non-beneficiary miner who had died between 31 July 1916 and 1 August 1919, and had qualified to receive benefits under the prior Law, became entitled to an award of a monthly allowance on the terms and conditions precedent to the grant of such an award to the dependants of a prior Law beneficiary miner who had died after 1 August 1919.

Dependants (other than the widow and a child under sixteen) could not be granted an award of a monthly allowance *unless* they were *wholly* dependent upon the deceased miner; the widow of a miner could not be granted an award of a monthly allowance if she had re-married; and an allowance could not be granted for more than three children of a deceased miner.

A miner who had been granted benefits under the prior Law on the grounds of silicosis and had secondary silicosis or tuberculosis with silicosis became entitled to an award of a monthly allowance, provided he was resident in the Union of South Africa on and after 31 July 1916. A miner who had been refused the additional award under the Acts of 1916, 1917 and 1918, owing to his not having been resident in the Union of South Africa, as required by that enactment, became entitled to that additional award if he returned to South Africa before 1 June 1919 and was in necessitous circumstances.

Awards to miners, native labourers and dependants could only be granted on certificates of the Miners' Phthisis Medical Bureau which had been established under the Act of 1916.

The Board could, in its discretion, contribute in addition to any benefit which could be granted to dependants an amount not exceeding £25 towards the reasonable expenses of burial and of medical attendance during the last illness of a deceased miner who had been a beneficiary under this Act or the prior Law or who, in the opinion of the Bureau, died from silicosis or from any other cause if silicosis was present as a contributing or predisposing factor.

A miner was defined as any person (other than a native labourer and therefore included a non-European, such as a coloured person, Indian, Asiatic, etc.) who was employed underground on the scheduled mines in any of the forty-five occupations specified in the Act, or any other occupation which necessitated the incumbent spending 100 or more working hours per month underground.

"Underground work" comprised work beneath the surface of a

mine, upon or about rock crushers in a crusher station and in a sample crushing room or assay office. Underground work on a gazetted mine was deemed, for the purposes of granting benefits, to be underground work on a scheduled mine.

The provisions of Act No. 44 of 1916 and Act No. 44 of 1917 regarding the following were re-enacted:

- (i) land settlement,
- (ii) loans to industrial undertakings,
- (iii) employment bureaux,
- (iv) transport expenses of beneficiaries,
- (v) loans to beneficiaries, and
- (vi) contributions for silicotic sanatorium.

Provisions were made in this Act empowering the Board,

- (i) to provide for the training in trades and industries of beneficiaries, and
- (ii) to establish co-operative workshops for beneficiaries.

The provisions of the Act of 1912 regarding deductions from the earnings of miners for the purposes of the Board's funds, which provisions had remained in force under the Acts of 1916, 1917 and 1918 were *not* re-enacted in this Act of 1919 (or any subsequent Act).

An inspector of mines (employed underground in connection with the scheduled mines) who retired from the public service before attaining the age of retirement prescribed under the pension statute applicable to him, and whose retirement was due to the fact that he had contracted silicosis, became entitled either:

- (i) to one year's salary which he had been in receipt of at the date of his retirement, in addition to the pension payable to him under such pension statute, or
- (ii) to have five years added to his period of pensionable employment for the purpose of calculating his pension on such retirement.

In the event of such an inspector having died, from silicosis or from any other cause if silicosis was present as a contributing or predisposing factor, before attaining the age of retirement, as mentioned above, or within five years after retirement in the afore-said circumstances, his dependants became entitled to an amount representing one year's salary which he was in receipt of at the date of his death, in addition to any other benefits allowed to them by the pension statute in the event of his death while in the public service.

A native labourer who had been employed underground on scheduled mines after 31 July 1912, and who had not been granted benefits under this Act or the prior Law became entitled to benefits—

- (i) for silicosis in the ante-primary stage: twelve times his *month's earnings* (as defined in the present Act (vide paragraph (j) hereof),
- (ii) for silicosis in the primary stage or tuberculosis without silicosis: eighteen times his *month's earnings*, and
- (iii) for secondary silicosis or tuberculosis with silicosis: twenty-four times his *month's earnings*.

In cases of tuberculosis with or without silicosis, he must however have been so found at a "final" examination (compulsory medical examination, by the Miners' Phthisis Medical Bureau, of a native labourer when leaving his employment permanently or otherwise, after having been employed underground on a scheduled mine for a period exceeding one month).

In the event of the death of a native labourer who had not been granted benefits under this Act or the prior Law and who had died from silicosis or from any other cause if silicosis was present as a contributory or predisposing factor, his dependants became entitled to such benefits as the native labourer would have been entitled to had he not died.

The Act of 1919 was amended by the next Miners' Phthisis Act (No. 35 of 1924) which came into force on 1 August 1924.

Miners' Phthisis Act, Amendment Act, No. 35 of 1924
(the Previous Act)

Under this Act the miner or his dependants became entitled to the additional benefits as if the miner had applied within the prescribed period, provided he had ceased underground work on scheduled mines within three months after the first notification that he had silicosis.

A prior Law beneficiary miner or his dependants became entitled to benefits, as if such prior Law benefit had not been made, provided the miner had *lawfully* worked underground on scheduled mines after the grant of such prior Law benefits.

Awards made from the Consolidated Revenue Fund (*Special Grants*) to dependants of a prior Law beneficiary miner who had died too late to enable them to apply before 1 August 1920 were deemed to be awards lawfully made under the Act.

The date before which the dependants of a prior Law beneficiary

miner (who died after 1 August 1919) had to apply for an award of a monthly allowance was extended to twelve months from the date of the miner's death, and, if the miner was in receipt of or entitled to an award of a monthly allowance, silicosis need not, necessarily, have been a contributing or predisposing factor in the causation of his death.

Widows in receipt of monthly allowances became entitled to a one-sum payment (twenty-four times such allowance) on remarriage.

A South African widow who had left South Africa with her husband (a prior Law beneficiary miner), and was therefore not entitled to an award of a monthly allowance, became entitled to such an award, as if she had been resident in South Africa at the date of his death, provided she had returned to South Africa within two years of the said date.

Additional allowances could be granted to and in respect to children (under sixteen years of age) in excess of three in number.

The Acts of 1919 and 1924 were repealed by the present Act (No. 35 of 1925) which came into force on 1 August 1925.

Miners' Phthisis Acts, Consolidation Act, No. 35 of 1925
(the Present Act)

Under this Act benefits are granted by the Board to miners and dependants of deceased miners: (1) who had contracted silicosis during or in consequence of underground employment on scheduled mines or a mine at any time on the list of scheduled mines or on gazetted mines, or (2) who were found to have tuberculosis without silicosis within twelve months of their having ceased such underground work and had been employed on such underground work for a period or periods amounting to at least two years.

Dependants are such members of a deceased person's family as were dependent upon him for maintenance and had not contracted a marriage since the date of his death, namely, his widow and children under sixteen years of age (including illegitimate children born before the date of the Bureau's certificate that he had secondary silicosis or tuberculosis with silicosis), failing whom, his other relatives by consanguinity or affinity in a certain order of preference.

Awards to miners, native labourers and dependants can be granted only on certificates from the Miners' Phthisis Medical

Bureau (established under the Act for medical purposes) that such miners or native labourers have silicosis or tuberculosis or both those diseases and awards to dependants of a deceased miner or native labourer can be granted only on certificates from the said Bureau either that the deceased had silicosis or tuberculosis or both or that he had died from silicosis or from any other cause with which silicosis was present as a contributing or predisposing factor.

A miner or the dependants (of a deceased miner), dissatisfied with the decision of the said Bureau, may appeal in the prescribed manner from that decision to the Medical Board of Appeal, and certain special cases of miners who went on active service and who had been refused benefits under the Miners' Phthisis Acts and also under the War Special Pensions Act, No. 42 of 1919, can be dealt with by the Joint Medical Board. Under such circumstances the certificate of the Medical Board of Appeal or the Joint Medical Board (as the case may be) is deemed to be the certificate of the Bureau for the purposes of the Act.

Awards are calculated on the *month's earnings* of the miner or native labourer being one-sixth part of the amount earned by him for the 156 days he worked, as such, last prior to the date he was first certified by the said Bureau to have developed silicosis or tuberculosis to a degree entitling him to benefits under the Act. A return of earnings for the number of days mentioned is usually obtained from the mining company or companies concerned but, if the amount of the earnings cannot be so ascertained, the *month's earnings* of the miner or native labourer is to be determined by the Board or the Director of Native Labour (as the case may be). The *month's earnings* of a miner to or in respect to whom benefits have been granted under the prior Law is deemed to be £30. In cases where original awards are made after 1 August 1925, fractions of £1 in the month's earnings of a miner are reckoned as £1 if the fraction is 10s. or more and are disregarded if less than 10s.

A miner who has been granted benefits under the prior Law and who has *lawfully* worked underground on scheduled mines after the grant of such benefits is deemed to be a miner who has *not* been granted benefits under the prior Law.

ONE-SUM AWARDS

A non-beneficiary miner who has silicosis in the ante-primary or primary stage or tuberculosis without silicosis is entitled to an award

payable in one sum. The award to a miner who has silicosis in the ante-primary stage is calculated as follows:

Twelve times that part of his month's earnings which does not exceed £29 3s. 4d.

Six times that part which exceeds £29 3s. 4d., but does not exceed £37 10s.

Three times that part which exceeds £37 10s.

The amount of the award for silicosis in the primary stage is that payable for the ante-primary stage with an addition of 50 per cent. and the amount of the award for tuberculosis without silicosis is the same as that for the primary stage of silicosis. A miner who has been granted a one-sum award for ante-primary silicosis becomes entitled to a further one-sum award, 50 per cent. of such previous award, for primary silicosis or tuberculosis without silicosis, provided he had applied for benefits or ceased underground work on scheduled mines within three months of the date he was first notified after 1 August 1919 that he had silicosis.

One-sum awards could not be granted under the Acts in force prior to the commencement of the principal Act (1 August 1919), and the averages of the one-sum awards made, since that date, are:

£401 for ante-primary silicosis, without tuberculosis,
£581 for primary silicosis without tuberculosis, and
£534 for tuberculosis without silicosis; the maxima being £803, £1,216 and £805 respectively.

AWARDS PAYABLE IN MONTHLY INSTALMENTS

A miner who had been refused the additional benefits under the Acts of 1916, 1917 and 1918, owing to his not having been resident in South Africa as required by that enactment, becomes entitled to that additional award if he returned to South Africa before 1 July 1924.

A miner who has been granted benefits under the prior Law and who has silicosis in the ante-primary or primary stage or tuberculosis without silicosis is entitled to an award, *in such instalments as the Board may decide*, calculated, as mentioned above, on *his month's earnings* (viz. £30), but the amount of the prior Law benefit must be deducted from the amount so arrived at. (An amount of £355 represents the award, for ante-primary silicosis, calculated on *month's earnings* of £30, and an amount of £532 10s. represents such an award for primary silicosis or tuberculosis without silicosis.) A miner who has been granted benefits under the prior Law and who

has silicosis in the secondary stage or tuberculosis with silicosis is entitled to an award, *in such instalments as the Board may decide*, of £750 less the amount of such prior Law benefits, unless such miner is entitled to an award of a monthly allowance, as mentioned below.

The dependants of a deceased miner are entitled to the award, *in such instalments as the Board may decide* for the ante-primary, primary or secondary stage of silicosis, or tuberculosis with or without silicosis if the miner was, at the time of his death, entitled to such an award, unless the dependants are entitled to an award of a monthly allowance, as mentioned below.

AWARDS OF MONTHLY ALLOWANCES (PENSIONS)

A non-beneficiary miner who has silicosis in the secondary stage or tuberculosis with silicosis is entitled to an award of a monthly allowance.

A miner who has been granted a one-sum award becomes entitled to a further award of a monthly allowance for secondary silicosis or tuberculosis with silicosis, provided he had applied for benefits or ceased underground work on scheduled mines within three months of the date he was first notified after 1 August 1929 that he had silicosis.

A miner who has been granted benefits under the prior Law and who has silicosis in the secondary stage or tuberculosis with silicosis is entitled to an award of a monthly allowance, provided he was resident in South Africa on and after 31 July 1916 or the date on which he was first granted any benefits (whichever is the *later*).

The dependants of a miner who died after 1 August 1919, and to or in respect to whom benefits had not been granted under the prior Law, are entitled to an award of a monthly allowance: (1) if the deceased miner was in receipt of or entitled to such an award, or (2) if the Bureau certifies before or after his death that he had silicosis in the secondary stage or tuberculosis with silicosis or certifies that he died from silicosis or from any other cause with which silicosis was present as a contributing or predisposing factor.

Under the principal Act, an award of a monthly allowance could not be granted to the dependants of a deceased non-beneficiary miner who had died from silicosis or from a cause with which silicosis was present as a contributing or predisposing factor *unless* the deceased miner had silicosis in the secondary stage at the time of his death. In the other cases in which silicosis (though not

in the secondary stage) was a factor in causation of death of the miner, the dependants became entitled to the award, payable *in such instalments as the Board may decide*, which the miner, had he not died, would have been entitled to for silicosis in the ante-primary or primary stage (as the case may be). The present Act provides that in such a case the award, if granted to the widow and children (under sixteen years of age) of a deceased miner, can be converted into an award of a monthly allowance on certain conditions.

The dependants of a deceased miner to or in respect to whom benefits had been granted under the prior Law are entitled to an award of a monthly allowance: (1) if the deceased miner was in receipt of or entitled to such an award, or (2) if the dependants were resident in South Africa on and after 1 July 1916 or the date of the miner's death (whichever is the *later*), and the Bureau certifies that the miner died from silicosis or from any other cause with which silicosis was present as a contributing or predisposing factor.

The dependants of certain deceased non-beneficiary miners were refused *ex-gratia* grants under section 11 (b) of the Miners' Phthisis Act, No. 44 of 1916, on the grounds that they were not in necessitous circumstances, as required by that section. Provision is made in the present Act for awards of monthly allowances to be granted to the dependants in such cases, as if such prior Law awards had been made.

A South African widow and the children (under sixteen years of age) of a deceased miner who had left the Union of South Africa with the miner and are, on that account, not entitled to an award of a monthly allowance become entitled to such an award, as if they were resident in the Union of South Africa at the time of his death provided they have returned to the Union of South Africa within two years of such date and have not since the date of such return left the Union of South Africa for any purpose whatever.

CALCULATION OF MONTHLY ALLOWANCES

A monthly allowance granted to a miner is calculated as follows:

For the miner. — One-half of that part of his month's earnings which does not exceed £20; one-quarter of that part which exceeds £20, but does not exceed £28 6s. 8d., and *one-twentieth* of that part which exceeds £28 6s. 8d.

For his wife. — If dependent upon him and if he was married to her before 1 August 1919 or the date of the Bureau's certificate entitling him

to an award of a monthly allowance (whichever date is the *later*): *one-fifth* of the total amount payable for the miner.

For each of his dependent children (legitimate and certain adopted and stepchildren) not exceeding three in number, until such child attains the age of sixteen years: *one-tenth* of the total amount payable for the miner.

For each such child in excess of three. — *One-twentieth* of such amount.

(i) The amount payable for a wife or child ceases upon the death of such wife or child or on the marriage of such child.

(ii) An allowance is not payable to a miner for a wife or child of a marriage contracted by the miner after 1 August 1919 or the date of the Bureau's certificate entitling him to an award of a monthly allowance (whichever date is the *later*).

(iii) An allowance is not payable to a miner for more than three children for any period prior to 1 August 1924.

(iv) An allowance is not payable to a miner for his illegitimate children.

(v) Subject to paragraph (ii) above, an allowance is payable to a miner for a child born after the date of the Bureau's certificate entitling him to an award of a monthly allowance.

(vi) An allowance is payable to a miner for an adopted child if adopted before the date of the *first* certificate of the Bureau entitling him to an award under the Act and if the child has been solely or mainly dependent upon him since the date of adoption.

(vii) An allowance is payable to a miner for his dependent stepchildren if they are the legitimate children of his wife to whom he was married before 1 August 1919, or the date of the Bureau's certificate entitling him to an award of a monthly allowance (whichever date is the *later*).

(viii) An allowance is payable to a miner for his child over the age of sixteen years, if such child is, in the opinion of the Bureau, unable to earn a living by reason of ill health or physical or mental incapacity, and such an allowance can be continued for so long as, in the opinion of the Board, it might reasonably have been expected that the miner would have continued to contribute to the support of the child. (Such a child is deemed, for the purposes of the Act, to be a child under sixteen years of age.)

(ix) An allowance granted to a miner is payable from 1 August 1919 or from the date of the Bureau's certificate entitling him to such an award or from the date the miner finally ceased underground work on scheduled mines (whichever date is the *latest*), but if the miner was, for any reason, not entitled to such an award under the principal Act or the previous Act the allowance is not payable from a date prior to 1 August 1925.

A monthly allowance granted to the dependants of a deceased miner is calculated as above, except that:

(1) *Widows and children (under sixteen years of age)* are entitled to double the allowance prescribed for the miner for his wife and children (under sixteen years of age).

(2) *Dependants wholly dependent*, if the miner left no widow or child under sixteen years of age, are entitled to the allowance which would have been payable to the widow.

(3) *Dependants partly dependent* if the miner left no dependants as mentioned in (1) and (2) above, are entitled to an allowance equal to the average monthly support accorded by the miner but not exceeding the allowance which would have been payable to the widow.

(4) Children of a deceased miner include also:

(a) His unmarried illegitimate children if born before 1 August 1919, or the date of the Bureau's certificate that he had silicosis in the secondary stage or tuberculosis with silicosis (whichever date is the *later*).

(b) His unmarried legitimate children of a marriage contracted after the date of the Bureau's certificate entitling him to an award of a monthly allowance.

(5) The allowance prescribed for the children mentioned in (4) above (or any other dependant under sixteen years of age) is the same as that prescribed for the legitimate children of the deceased miner.

(6) An allowance granted to the dependants of a deceased miner is payable from the date of death of the miner, but if the miner died before 1 August 1925, and the dependants were not entitled, for any reason, to such an award under the principal Act or the previous Act, the allowance is payable from 1 August 1925.

A monthly allowance granted to a miner or dependant ceases in the event of the death of such miner or dependant and the allowance is reduced, accordingly, in the event of the death of any of the dependants included in the award. An allowance granted to a widow or dependant (other than a child under sixteen years of age) ceases in the event of marriage, subject to the payment of twenty-four times the allowance payable for one month. An allowance granted to a dependant (other than a widow or child under sixteen years of age) is to be continued for so long as, in the opinion of the Board, the deceased miner could reasonably have been expected to continue to contribute to the support of the dependant.

The allowance granted to a beneficiary will cease and determine when an amount of £750 has been paid, should the beneficiary have been resident outside the Union of South Africa when the award was made or should the beneficiary leave the Union of South Africa permanently or without the written permission of the Board granted for temporary purposes. In the case of a miner the amount of £750 is calculated from the date of the award of a monthly allowance; in the case of a dependant from the date of the award to the dependant, if the dependant was resident in the Union of South Africa at the date of the miner's death but, if the dependant was not so resident, from the date of the award of a monthly allowance to the miner or the dependant (whichever is the *earlier*).

A beneficiary, in receipt of a monthly allowance, who desires to leave South Africa for *other than* temporary purposes (i.e. per-

manently) can be granted a passage by the Board to his or her destination together with an amount for incidental expenses on the journey.

Awards of monthly allowances could not be made under the Acts in force prior to the commencement of the principal Act (1 August 1919) and the average amounts of the monthly allowance awards made since that date are:

Miner: £17 19s. 7d. per mensem (for himself, his wife and two or three children).

Widow of deceased miner: £4 18s. 4d. per mensem.

Children (not exceeding three and under sixteen years of age) of a deceased miner: £2 9s. 3d. per mensem each.

Children (in excess of three and under sixteen years of age): £1 4s. 10d. per mensem each.

Other dependants: £4 1s. 10d. per mensem.

The amount of the *maximum* monthly allowance granted to a miner (for *himself*) is £19 7s. 8d.; the miner, being single, could not be granted additional allowances for dependants; the award was calculated on his *month's earnings* of £74 and he had previously been granted a one-sum award of £1,216 for primary silicosis, being the amount of the maximum one-sum award under the Act. The amount of the *maximum* monthly allowances granted to a miner (for himself and his dependants) is £28 1s. 3d., the miner having been granted a monthly allowance for himself, his wife and eight children. The amount of the *maximum* monthly allowance granted to a widow (for herself) is £7 14s. 2d. and in the same case a monthly allowance of £3 17s. 1d. was granted to a child, the widow receiving £11 11s. 3d. per mensem for herself and the child. The amount of the *maximum* monthly allowance granted to the dependants of a deceased miner is £20 17s. 2d., allowances having been granted to the widow and nine children. The largest number of children in respect to whom additional allowances were granted to a miner is eleven, the miner having been granted a monthly allowance of £23 11s. 6d. for himself, his wife and those eleven children. The largest number of children of a deceased miner to whom a monthly allowance was granted is nine (three cases), in one case the widow and those nine children were granted a monthly allowance of £20 17s. 2d., as mentioned above, and in the other two cases £20 13s. 6d. and £19 17s. 2d.

Payments to the miners will, in many cases, continue for several years and, on their demise, awards of monthly allowances will be made to their dependants (mainly widows and children). Payments in respect to children will, in almost all cases, continue until each

child attains the age of sixteen years and it can be reasonably anticipated that payments to the widows will continue, *on an average*, for about twenty years and to the other dependants for about ten years.

In numerous cases the beneficiaries (miners and dependants of deceased miners) have been in receipt of monthly allowances since the commencement of the principal Act (1 August 1919).

The Board may contribute (in addition to any benefit which can be granted to dependants) an amount not exceeding £25 towards the reasonable expenses of the burial of and medical attendance during and incidental to the last illness of a deceased miner who was a beneficiary under this Act, the previous Act, the principal Act or the prior Law or who, in the opinion of the Miners' Phthisis Medical Bureau, died from silicosis or any other cause if silicosis was present as a contributing or predisposing factor.

A miner is defined as in the principal Act, and six occupations are added to the forty-five occupations specified in that Act. These fifty-one occupations and any other occupation necessitating the incumbent spending 100 or more hours per month underground renders him a "miner" during the month in which he is so employed and provision is made that eleven occupations on the *surface* of a mine (to which other such occupations can be added by Government Notice) renders the incumbent a "miner" during each day he is employed *underground* (if less than 100 hours per month). Two such occupations have been added to the list by Government Notice.

"Underground work", as defined in the principal Act, is extended to include also work in a change-house or on any tailings dump.

Provisions are made empowering the Board:

- (i) to provide for the training in trades and industries of beneficiary miners, their wives and children and beneficiary widows and children,
- (ii) to conduct a bureau or to co-operate with other bureaux for the purposes of obtaining employment for such persons as are mentioned in (i) above,
- (iii) to assist financially, by means of loans or otherwise, in establishing or carrying on any undertaking in which beneficiary dependants or dependants of beneficiary miners are employed or will, at the Board's request, be employed,
- (iv) to assist financially in defraying the reasonable expenses incidental to the transport of beneficiary miners, their wives and children (under sixteen years of age) to places within the Union of South Africa where employment for such miners has been obtained,
- (v) to contribute an amount not exceeding half the cost of establishing and maintaining one or more sanatoria for purely silicotic patients,

(vi) to establish or assist in establishing co-operative workshops for such persons as are mentioned in (i) above, and

(vii) to condone the delay (due to certain circumstances arising out of the 1914-1918 war) in cases where the making of an application or the return to South Africa within a prescribed period is a condition precedent to the grant of benefits under the Miners' Phthisis Acts.

The provisions of the principal Act and the prior Law regarding land settlement and loans to beneficiaries established in business or farming operations are *not* re-enacted in the present Act.

If an inspector (including an assistant inspector, deputy inspector, or sub-inspector) of mines or an inspector of mining leases employed in connection with the scheduled or gazetted mines contracts silicosis or tuberculosis or both, he and his dependants are entitled to benefits under the Act, as if he were a miner, in addition to the pension or other benefit payable under any pensions statute applicable to him.

The provisions of the principal Act regarding benefits, for silicosis of tuberculosis or both, to native labourers and their dependants are re-enacted in the present Act.

SUMMARY OF PROVISIONS TO MEET CLAIMS FOR COMPENSATION

The provision of compensation for claims by sufferers and their dependants, and the expenses of carrying out the various functions of the Board, are provided out of a fund termed the Miners' Phthisis Compensation Fund, which is under the control of the Board.

For the purposes of this fund the Board has power to make quarterly levies upon employers who own or work the scheduled mines (i.e. those mines wherein the mineral dust is, in the opinion of the Minister of Mines, of such a nature as to cause silicosis) to provide the amount which the Board considers necessary for the purposes of the Compensation Fund for the quarter.

(1) Under the prior Law:

Compensation Fund. — Quarterly levies by Board of amount actually required for payment of benefits. The amount levied to be assessed in proportion to the average number of miners employed per month by each employer during the period of three years immediately preceding the quarterly levy. The Government Mining Engineer to furnish the statement of average number of miners.

Insurance Fund. — Every employer to make a contribution on or before the tenth day of each month in respect of every person employed underground as a miner, or on or about rock crushers in a crusher station of a mine during the previous month. Such contribution, from 1 August 1912 to 31 July 1914, to be 5 per cent. of the earnings of each person so employed, the employer being empowered during this period, to recover from such employees one-

half (50 per cent.) of the amount contributed to the Fund. From 1 August 1914 to 31 July 1919, the contribution by employers was $7\frac{1}{2}$ per cent. of such earnings, and in turn they were entitled to recover one-third ($33\frac{1}{3}$ per cent.) of the contributions to the Fund, from the earnings of the particular employees.

(2) Under the Principal Act of 1919 the quarterly levy on each employer was assessed as follows:

- (a) 45 per cent. on the earnings of underground miners.
- (b) 35 per cent. based on the silicosis rate of the mine.
- (c) 20 per cent. based on the amount which the employer is assessed for normal income tax during the last accounting period under the Income Tax Act.

(3) Under the present Act of 1925 the amount levied quarterly from each employer is assessed as follows:

- (a) 30 per cent. based on the earnings of underground miners.
- (b) 50 per cent. based on the silicosis rate of the mine.
- (c) 20 per cent. based on the amount which the employer is assessed for normal income tax during the penultimate accounting period under the Income Tax Act.

From the commencement of the principal Act (i.e. 1 August 1919) to 31 July 1925, an amount of £200,000 per quarter was levied by the Board from the scheduled mines, except during the nine months ended 30 April 1922 when £150,000 was levied per quarter.

Under the present Act the levies have been maintained at £200,000 per quarter, except during the first two months after the Act came into force, when the sum of £200,000 was levied for these two months.

Under the Act of 1924 a special fund termed the "Outstanding Liabilities Fund" was incorporated under the Compensation Fund, and in terms of that Act the Government Actuary was required to determine annually the total outstanding liabilities of the Compensation Fund and to apportion such liabilities between the various employers. The outstanding liability of each employer to the Compensation Fund becomes immediately payable to the Board when the mine of the employer is closed down or ceases operations. This provision was also incorporated in the present Act, and by arrangements between the Board and the various employers steps have been taken by the latter, where they are in a financial position to do so, to set aside amounts annually against their outstanding liabilities, based on the probable life of each mine. The annual determination of the outstanding liabilities of the Compensation Fund, as determined by the Government Actuary at 31 July 1929, amounted to a present value of £8,296,365, against which the amount standing to the credit of the Compensation Fund and the Outstanding Liabilities Fund at that date amounted to £1,896,365, leaving a net outstanding liability of £6,400,000.

STATISTICS

The following are brief particulars of the expenditure and awards under the Miners' Phthisis Acts:

(1) Miners' phthisis compensation: annual expenditure in connection with miners (excluding natives) and dependants:

From	1.5.1911 to 31.7.1912	£50,601
„	1.8.1912 to 31.7.1913	£355,644
„	1.8.1913 to 31.7.1914	£487,677
„	1.8.1914 to 31.7.1915	£545,178
„	1.8.1915 to 31.7.1916	£391,860
„	1.8.1916 to 31.7.1917	£378,389
„	1.8.1917 to 31.7.1918	£603,292
„	1.8.1918 to 31.7.1919	£411,427
„	1.8.1919 to 31.3.1920	£885,901
„	1.4.1920 to 31.3.1921	£798,040
„	1.4.1921 to 31.3.1922	£544,584
„	1.4.1922 to 31.3.1923	£535,186
„	1.4.1923 to 31.3.1924	£498,494
„	1.4.1924 to 31.3.1925	£711,437
„	1.4.1925 to 31.3.1926	£951,152
„	1.4.1926 to 31.3.1927	£965,864
„	1.4.1927 to 31.3.1928	£852,503
„	1.4.1928 to 31.3.1929	£829,500
	Total to 31.3.1929 is	£10,796,729
	Total to 30.9.1929 is	£11,208,015

(2) The nine Acts can be divided into four groups because the basis of compensation and benefits under each group differ, and therefore the Acts under each group should be read together.

AVERAGE ANNUAL EXPENDITURE UNDER THE FOUR GROUPS

<i>Group (A)</i>	1.5.1911	
Acts of 1911,	to	£372,354
1912 and 1914.	31.7.1916	per annum.
<i>Group (B)</i>	1.8.1916	
Acts of 1916,	to	£469,811
1917 and 1918	31.7.1919	per annum.
<i>Group (C)</i>	1.8.1919	
Acts of 1919	to	£693,526
and 1924.	31.7.1925	per annum.
<i>Group (D)</i>	1.8.1925	
The Consolidation	to	£911,747
Act of 1925.	31.7.1929	per annum.

(3) Miners' phthisis compensation expenditure in connection with native labourers and their dependants. — The total amount paid under the various Acts up to 31 July 1929 is £702,036.

Monthly expenditure. — The average monthly expenditure on compensation in respect of miners' phthisis sufferers (excluding natives) and their dependants during the last five years amounted to approximately £72,000.

The cost of administration in connection with the Miners' Phthisis Board, the Miners' Phthisis Medical Bureau and the Miners' Phthisis Medical Board of Appeal, which is borne by the Government, during the past year amounted to approximately £53,000.

The number of miners (excluding natives) and the number of widows of miners who have been awarded compensation under the various Miners' Phthisis Acts up to 31 October 1929, amount to:

(a) Miners	13,866
(b) Widows	5,093

THE ACTUARIAL VALUATION OF THE OUTSTANDING LIABILITIES UNDER THE SOUTH AFRICAN MINERS' PHTHISIS ACT

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The outstanding liabilities, and their gradual redemption by the mines, form an important part of the general system that has been adopted in the Union for financing the benefits granted in respect of miners' phtthisis. This financial system is not necessarily the most suitable for adoption in other countries, and it is well to preface this paper with a brief review of the financial systems that may be adopted.

The *assessment method* will first be described. Each year's income would be just sufficient to meet the payments falling due during the year and no fund would be accumulated. This is the method adopted, for example, by the Dominions for financing old-age pensions to the general population, each year's payments being met by the Government out of its revenue for the year, and no moneys being kept in hand in respect of future payments under existing pensions or of the accruing liability in respect of those approaching the age when pensions become payable. While it is possible to defend the method in the case of a Government dealing with the general population, the method is not a sound one for financing miners' phtthisis benefits.

Payments of benefits are likely to be lower in the early years and to increase later. This would certainly be so if, as is likely, the benefits take the form of pensions or payments by instalments, and the difficulty would be accentuated if there should be more than one stage of the disease so that the miner might progress from the first stage to the second stage (and possibly to a third stage) and receive further benefits. Under a sound financial method the payments should, as far as possible, be equalised from year to year.

If the time should arrive when the mining or other industry would cease to exist, there would be a large outstanding liability, no fund would be available to meet it, and future payments of benefits would have to be made by the Government out of its own revenue. These payments might be a heavy burden on the country, especially as the Government would also lose the taxation it would doubtless have imposed on the industry. This difficulty would arise before the industry had actually ceased to exist, because for some years previously the miners' phtthisis benefits would probably form too heavy a burden for the declining industry and the Government would be compelled to come to its assistance.

The *insurance method* will now be considered. Under the contracts issued by a life assurance company, premiums are paid in advance and the company accumulates a fund which, together with future premiums, is sufficient to meet its liability for all future claims. On a claim arising, the money is available to meet it; if the claim should take the form of a pension, the capitalised value of the pension would be available.

The insurance method is undoubtedly the best that can be used for financing miners' phthisis benefits provided circumstances permit of its adoption. Contributions would be paid in advance during the working lifetime of the miners, and when miners are certified to have miners' phthisis, the money would be available to pay immediate benefits and also to meet future benefits payable to the miners on reaching a further stage or stages of the disease, and to their dependants on their death.

It may not be out of place to issue a warning to those contemplating an insurance scheme. It is impossible to estimate accurately in advance the various contingencies that it is necessary to take into account in the calculation of the contributions and in the periodical valuations, and it is therefore essential that there should be a quick and easy means of adjusting the contributions according to the actual experience. It will be necessary to amend the basis of calculations frequently, and any consequent change required in the contributions should receive immediate effect.

A disadvantage of the insurance method is that it necessitates the accumulation of a large fund. This fund would be in the nature of a trust fund, since it would all be required, together with future contributions, to meet future payments of benefits. Unfortunately, legislators do not always appreciate the object of such a fund, and they might be tempted to use the fund as an easy means of increasing the benefits without any further apparent cost to the country. It is therefore desirable that the insurance fund should be called by such a name, and protected by such legislative provisions, that it cannot be used for any other purpose than that for which it has been accumulated.

The insurance method cannot always be adopted, since usually benefits would be granted only after the mining or other industry had been in existence for some years, by which time a substantial liability would have accumulated.

Modified assessment and insurance methods. — Various modifications of the assessment and insurance methods might be adopted. The assessment method may be modified by making each year's income exceed each year's payments, so that a fund, whether adequate or not, would be accumulated against future liabilities.

The insurance method could be modified in many ways, and usually the modification would depend upon the circumstances of the particular industry and country. The natural modification would be to provide that benefits for miners' phthisis to be created in the future would be met by insurance contributions and by an accumulated insurance fund, while benefits for miners' phthisis created in the past would be met by assessment contributions. The contributions for past phthisis might be made rather larger than assessment contributions in order gradually to overtake the existing liability and ultimately to attain a pure insurance method.

METHODS ADOPTED IN THE UNION

The financial method which has been adopted in the Union during the last few years is of such a special nature that in order to understand why it was adopted it is desirable to review the methods previously employed.

The first Compensation Act was passed in 1911, and was only intended to deal with the position temporarily while a comprehensive measure was being discussed.

In 1912 an Act was passed which laid down a financial basis on a modified insurance method. The benefits were financed by means of two funds, the Miners' Phthisis Compensation Fund and the Miners' Phthisis Insurance Fund. The Compensation Fund was responsible for the payment of benefits "to persons entitled thereto who make application for such payment within the period of two years immediately succeeding the commencement of this Act" or to whom allowances were granted under the 1911 Act. The Fund consisted of: (a) quarterly levies on the mines, (b) interest on any investments, (c) a contribution of £100,000 from the Government for the purpose of assisting the poorer mines and (d) the balance of the fund under the 1911 Act. The Insurance Fund was responsible for the payment of other benefits, that is, in respect of persons entitled thereto making application after the expiration of two years from the commencement of the Act. The Fund was financed by contributions from the mines and from miners, which were at the rate of 5 per cent. of wages (2½ per cent. from mines and 2½ per cent. from miners) during the first two years of the Act and at the rate of 7½ per cent. of wages (5 per cent. from mines and 2½ per cent. from miners) thereafter. The Fund also received the interest earned on its investments, together with any fines imposed for the contravention of Mining Regulations dealing with the prevention of miners' phthisis.

Amending Acts were passed in 1914, 1916, 1917 and 1918, which all gave additional benefits, but while the Government contributed in part to some of these additional benefits, the general financial system was not affected. The benefits payable under these Acts were in the form of lump sums payable by monthly instalments.

In 1919 a further Act was passed which provided for amounts payable in one sum for the first two stages of the disease, and for monthly allowances or pensions payable to miners in the third stage or to the dependants of such miners. At the same time a new financial system was introduced.

The amount of the Insurance Fund, about £675,000, was transferred to the Compensation Fund, which Fund alone is responsible for the payment of benefits. Quarterly levies are imposed on the mines for "such an amount as may in the opinion of the Board be required during that period of three months for the purposes of the Compensation Fund". This quarterly levy has been at the rate of £200,000 (except for three quarters when it was £150,000), since the commencement of the Act. The Act also required mines to pay certain amounts on closing down, but these amounts were found to be less than the proper share of the outstanding liability that should be paid by such mines and this provision was amended in 1924. In 1924, and again in 1925, further Acts were passed granting further benefits and modifying the payments by mines upon closing down.

When a mine closes down, it is required to pay its correct proportion of outstanding liability. The first calculation of outstanding liability as defined by the 1924 and 1925 Acts was made as at 31 July 1922, and after taking into account the amount of the Compensation Fund, it amounted to £4,650,000. The 1924 and 1925 Acts added greatly to the outstanding liability, which by 31 July 1929 had increased to £6,400,000. The proportion of the outstanding liability due from a mine upon closing down is paid into a separate Outstanding Liabilities Fund, but from this Fund a certain amount is transferred each year to the Compensation Fund for current purposes.

OUTSTANDING LIABILITY

The explanation of the calculation of the outstanding liability will be facilitated by taking, as an example, the typical case of a miner whose monthly earnings were £35 3s. 4d. and who has a wife and one child under age sixteen. On being certified in the ante-primary stage of silicosis (which is the first stage of the disease) and leaving underground employment, he would receive £386. Should he progress to the primary stage, he would receive a further £193. If he had been first certified in the primary stage the award would have been £579. Should he further progress to the secondary stage of silicosis, he would receive a monthly allowance or pension; the annual amount would be £149 2s. in respect of himself, £29 16s. 5d. in respect of his wife, and £14 18s. 2d. in respect of his child, giving a total of £193 16s. 7d. A miner suffering from

tuberculosis is regarded for the purpose of benefits as if he were in the primary stage of silicosis, and one suffering from silicosis plus tuberculosis as if he were in the secondary stage of silicosis, and the primary and secondary stages will be taken to include such cases. If a miner in the secondary stage should die, his dependants would receive a pension which in our typical case would be £89 9s. 2d. If a miner in the ante-primary stage or primary stage should die, and if the Medical Bureau should certify that he died from silicosis or from any other cause with which silicosis was present as a contributing or predisposing factor, his dependants would receive the same pension as if the miner had been in the secondary stage, that is, in our typical case, £89 9s. 2d. The miners are practically all Europeans, but include a few coloured persons.

Natives are also entitled to certain benefits which are paid direct by the mines to the Director of Native Labour on the natives' behalf, except that if a native should have worked on a mine that has closed down and he should afterwards be entitled to benefit, the amount would be paid from the Compensation Fund. There are other miscellaneous benefits such as the payment of funeral expenses.

The Compensation Fund is also responsible for payments to the Board's Trades and Industries Fund, contributions to the Sanatorium and the like, as well as gratuities to retiring officers of the Board or to the dependants of deceased officers; but under the law such payments are not taken into account in calculating the outstanding liability.

A description of the items taken into account in ascertaining the outstanding liability each year is contained in the following ten paragraphs, and it should be explained that no statistics are given since they are dealt with in a separate paper reviewing the statistics of miners' phthisis. The rate of interest used in discounting estimated future payments is taken throughout at $4\frac{1}{2}$ per cent. per annum.

(1) *Existing monthly allowances or pensions to dependants.* — The pensions to widows and children of deceased miners are easily valued, the widows' pensions ceasing on death or remarriage (though on remarriage she receives two years' pension) and the children's pensions ceasing on death or attainment of age sixteen. Other dependants may be included where the miners left no widows. The mortality of widows is taken according to a standard table, and their rates of remarriage are based upon their own experience.

(2) *Existing pensions to miners.* — In valuing the pensions to miners, it is necessary to take into account the chance of their wives dying during their lifetime, of children dying or attaining age sixteen, and of further children being born, since these contingencies would affect the amount payable. The mortality of miners is taken according to a special mortality table, based upon the experience of miners in the secondary stage; in this experience the age is neglected and the mortality depends upon the time elapsed since miners were certified.

Under this head there is also included the value of reversionary pensions to dependants on the future death of miners at present in receipt of pensions. The contingencies stated above and in item (1) have to be taken into account, including, it will be observed, the chance of a present wife remarrying after the miner's death.

(3) *Future awards to miners in the primary stage and to their dependants.* — Miners in the primary stage must either: (a) die while still in the primary stage, or (b) progress to the secondary stage, and the rates of mortality and of progression have been calculated from the accumulated past experience.

If the miner dies while in the primary stage, there has to be taken into account the chance of silicosis being a contributing or predisposing factor, together with the value of the pension that would then be payable to his dependants.

In the case of miners progressing to the secondary stage, the value of the benefit at the time of being certified in the secondary stage can be calculated on the lines laid down in item (2), and would include the value of the reversionary pension to dependants on the subsequent death of the miner.

(4) *Future awards to miners in the ante-primary stage and to their dependants.* — In the case of miners at present in the ante-primary stage the calculations are rather more complicated, because the miner may: (a) die while still in the ante-primary stage, (b) progress to the primary stage, (c) progress to the primary and secondary stages during the same year, or (d) progress direct to the secondary stage. The rates for these contingencies have been calculated from the accumulated data.

For miners dying in the ante-primary stage the present value of the pensions to dependants (provided silicosis was a contributing or predisposing factor in death) is calculated on the same lines as the similar liability in the previous item.

Miners progressing to the primary stage will receive a lump sum, and in addition there has to be included the liability for death while in the primary stage or progression to the secondary stage as in the previous item.

For miners progressing to the primary and secondary stage in the same year, the liability at the time of progression is represented by the lump sum on becoming primary and by the pension to the miner on becoming secondary and to his dependants on his subsequent death as in item (2).

For miners progressing direct to the secondary stage, no lump sum is payable, and the liability at the time of progression is calculated as in item (2).

(5) *Future awards to prior Law miners and to their dependants.* — Prior Law miners are those miners who received benefits under the Acts (excluding the 1911 Act) prior to the 1919 Act.

Where prior Law miners are at present in receipt of monthly allowances, the value of the reversionary pensions to their dependants are already included under item (2).

Certain benefits may still be payable to prior Law miners, and if they receive pensions their dependants will also receive reversionary pensions. Certain dependants of prior Law miners (who are not entitled themselves to further benefits) are also entitled to pensions on the death of the miners if silicosis was a contributing or predisposing factor towards death.

It is difficult to obtain an accurate estimate under this item. The number of prior Law miners can be estimated and a further estimate made of the number of miners or their dependants likely to benefit in the future, from which the liability can be calculated. Alternative calculations are made by a process of extrapolation from the awards granted in recent years. The method of calculation is not satisfactory, but fortunately the class is a decreasing one.

(6) *Future awards to miners certified by the Bureau who have not yet received awards and to their dependants.* — Certain miners who have been certified by the Bureau as having silicosis or tuberculosis are still working at the date of valuation. Those with tuberculosis must give up underground work, and those with silicosis must give up work within three months or else forfeit certain benefits. Excluding miners with silicosis who have not given up underground work within three months, the liability for those in the ante-primary stage is the lump-sum award plus

an amount calculated as in item (4); for those in the primary stage the lump-sum award plus an amount calculated as in item (3); and for those in the secondary stage an amount calculated as in item (2). For those who did not give up work within three months, only the reduced benefits would be taken into account.

(7) *Balances of lump-sum awards and similar items.* — Certain benefits are payable by instalments to prior Law miners, and some balances are still outstanding. Benefits under the later law may, in certain circumstances, be payable by instalments at the discretion of the Board. In certain cases where miners have gone overseas the total amount payable is limited to £750. In all these cases the liability is taken as the balance still outstanding.

(8) *Future awards to working miners not yet certified.* — The rate of production of silicosis or tuberculosis increases with the period the miners have worked underground, and the outstanding liability at any time must be debited, in respect of the past service of working miners, with a portion of the cost of future awards to miners who are still working and who are free from silicosis or tuberculosis. It is to be noted that in a pure insurance scheme a considerable liability would be included under this head.

An alternative way of regarding this item would be to assume that all the mines closed down at the date of valuation, in which case there can be no doubt that many of the miners working at the date of valuation would be found subsequently to be suffering from silicosis.

It is difficult to obtain an accurate estimate. There are two methods of approach indicated above, that is: (a) to estimate the present value of future awards to the present working miners, and to debit part of that present value to the service of such miners prior to the date of valuation, and (b) to assume all the mines closed down, and to estimate the present value of future awards to such miners on the basis of specially reduced rates of production. Neither of these methods is satisfactory, but between the two it is possible to decide upon an amount.

(9) *Miscellaneous items.* — Under this item are included a few miscellaneous items such as funeral expenses and the liability for the benefits to native labourers after a mine has closed down.

(10) *The amount of the Compensation and Outstanding Liabilities Funds.* — The amounts of the liability under the first nine items are added together, and the amount of the Compensation and Outstanding Liabilities Funds is deducted therefrom, the balance forming the outstanding liability at the date of valuation.

The outstanding liability represents the amount that it is estimated would be required, in addition to the amount standing at the credit of the Compensation and Outstanding Liabilities Funds, if all the Mines closed down as at the date of valuation.

The outstanding liability is apportioned among the mines concerned, and on any such mine closing down during the year following the date of valuation, it is required to pay its portion of the outstanding liability. The amount is paid into the Outstanding Liabilities Fund, from which every year there is transferred to the Compensation Fund for current purposes the total interest earned on the Fund together with 5 per cent. of the amount of the mean Fund, this annual transfer being intended to give, in a rough and ready way, the amount required each year to finance the awards in respect of phtthisis created by the mines that have closed down and have paid their portions of outstanding liability. It should be added that from a purely financial point of view there is no object in having two separate Funds, but from a wider practical point of view it is desirable that there should be a separate Outstanding Liabilities Fund, in order to emphasise that the moneys are trust moneys paid into the Fund for the special purpose of financing the awards for which the portions of outstanding liability have been paid.

There is another matter of interest in connection with the outstanding liability. The amounts to be paid by mines closing down in the future are high, and it is desirable that the Board should have security for their due payment. It has been arranged that the mines (with the exception of a few poor mines) will set aside sums annually which, accumulated with interest over their probable future lifetime, should amount to the estimated amounts payable when they close down. The question of the formation of a Trust Fund to deal with the accumulation of these annual sums is at present under consideration. It should be noted that if a mine should close down and be unable to meet the whole of its outstanding liability, the shortage would, at the next valuation and apportionment, be automatically allocated as an addition to the outstanding liabilities of the remaining mines.

QUARTERLY LEVIES

In order to have a proper appreciation of the nature of the outstanding liability, it is desirable to explain the relation between the quarterly levies and the outstanding liability.

It is first necessary to state the annual charges that must be met from the levies or other sources if the outstanding liability, after taking closed mines into account, is to remain constant from year to year. These annual charges are as follow:

(a) The outstanding liability calculated at any 31 July will, if correctly estimated, provide for all payments of benefit in respect of phthisis created up to that date, and the current levies must therefore pay for the cost of any present and future awards in respect of phthisis created during the ensuing year. Though not strictly accurate, this amount may be taken as the cost of the awards to miners under new cases of phthisis certified during the year, and of future awards to such miners and their dependants.

(b) The next charge consists of the annual interest on the outstanding liability, this interest being calculated at the valuation rate of $4\frac{1}{2}$ per cent. If all the mines actually closed down at the date of valuation, the total outstanding liability would be received in cash or securities, and interest would be earned thereon. With the possible exception of the portion of the outstanding liability paid in respect of any mines closing down during the year, no interest is earned on the outstanding liability, and this interest has consequently to be met out of current levies.

(c) The last charge consists of a number of miscellaneous items which are not taken into account in calculating the outstanding liability. Such items comprise the appropriation to the Trades and Industries Fund, gratuities to officers, and other items of a similar nature.

Let the position be considered in 1925 when the 1925 Act granting further benefits had become law, and when the outstanding liability had become part of the financial system. The levies were to be for such amounts as would be required for the purposes of the Compensation Fund; these purposes were naturally interpreted to mean the current payments, but instead it should be taken as the annual charges, which are at present, and have been for some time, in excess of current payments. It was also the intention of the financial system that the "annual transfer" from the Outstanding Liabilities Fund to the Compensation Fund should likewise be used for these purposes. The quarterly levies should therefore be for such amounts that the annual amount payable in levies, together with the "annual transfer", should be sufficient to meet

the annual charges. Let it be considered how this system would work in different circumstances.

If the mines remained at the same working capacity from year to year, and no new mines were opened, then as the mines closed down the levies and the outstanding liability would both be affected. The "annual transfer" would increase, while the number of new cases of silicosis, with fewer miners, would gradually decrease, and the result would be that the total levies would decrease to such an extent that the levies on each remaining mine should remain approximately constant; if the rate of production should decrease, the levies on each mine should similarly decrease. The outstanding liability would be gradually reduced because of the payments by mines closing down (after allowing for the "annual transfers") and the reduction would approximately be of such an extent that the portion of outstanding liability applicable to each remaining mine should remain constant. When the last mine closed down, the total amount standing to the credit of the Outstanding Liabilities Fund and of the Compensation Fund should be sufficient to meet all future liabilities.

If the mines should expand and new mines should open, the position would be more favourable, because the outstanding liability, representing the accumulated liability of past years, would be spread over more mines and over larger mines, and it would become a smaller burden relative to the increased operations of the mines. The outstanding liability would, in theory, remain for a longer time than if no new mines were opened or if other mines had not expanded, because it would be payable in part by mines with longer lifetimes, but in practice the outstanding liability would finally become unimportant and could be met by a margin in levies.

The actual position has been unfavourable in one aspect, and favourable in another. The levies plus "annual transfers" have not been sufficient to meet the annual charges, and although a number of mines have closed down and paid substantial sums for outstanding liability, the total outstanding liability has increased instead of decreased. The favourable feature has been that the remaining mines have expanded to a sufficient extent to maintain the output of gold, so that the mines have, as a whole, further resources to meet the increased burden. Special circumstances existed to increase the annual charges within recent years, and it is hoped that, with the reduction in new cases of silicosis, the position will soon be reached when without any increase in levies the annual charges will be met by "annual transfers" and by

levies. It should also not be overlooked that substantial sums have already been set aside on trust by the mines towards meeting their outstanding liabilities.

The financial system thus adopted in the Union, while dictated by the fact that a very heavy liability was thrown on the industry by means of the 1919 and later Acts without adequate funds to meet it, may be regarded as working satisfactorily. As stated earlier, however, it is not necessarily the system that should be adopted in other countries.

THE WORK OF THE MINERS' PHTHISIS BOARD AND OF THE MINING INDUSTRY IN PROVIDING EMPLOYMENT FOR SILICOSIS SUFFERERS AND THEIR DEPENDANTS

BY C. J. WILLIAMS, DEPUTY CHAIRMAN, MINERS' PHTHISIS
BOARD; C. S. RAATH, MEMBER, MINERS' PHTHISIS BOARD;
AND B. G. O. ORPEN, PRESIDENT, ASSOCIATION OF MINE
MANAGERS

The following notes are in respect of European miners and their dependants.

EMPLOYMENT OF SILICOSIS SUFFERERS

The employment of silicotics has engaged the attention of the mining industry since the passing of the first Miners' Phthisis Act of 1911 and its subsequent Amendments of 1912, 1914, 1916, 1917, 1918, 1919, 1924 and 1925.

In October 1916 a Silicotic Employment Office was opened under the ægis of the Association of Mine Managers in order to assist phthisis beneficiaries to find employment. The running expenses of this office were provided by the Transvaal Chamber of Mines.

The following classes of work were reserved for silicotics, as far as possible, on the mines; they were also reserved for employees who had been permanently injured by accident:

- Banksmen.
- Motor attendants.
- Motor trolley drivers.
- Meter house attendants.
- General surface work (unskilled).
- Preparation and cartage of mining timber.
- Caretakers, single quarters.
- Recreation hall and swimming bath attendants.
- On sorting stations when separated from crushers.
- Ore loading and transport work.
- Jumpermen or drill sorters on surface.
- Surface sandfilling.
- Reduction works assistants (unskilled).

Secretarial, time office, etc.
 Firemen.
 Stationary engine-drivers.
 Surface pump stations.
 Compound guards and watchmen.

As a result of enquiries which have from time to time been made, the maximum number of jobs on the mines which might be filled by silicotics provided that suitable men were available and the jobs became vacant, is estimated to be in the neighbourhood of 1,000.

The work of the Silicotic Employment Office was carried on until the passing of the 1925 Act. It was thereafter agreed by all parties concerned that the matter of finding employment for beneficiary silicotic miners should be taken over by the Miners' Phthisis Board.

In June 1926 the appointment of an official under the control of that Board took place.

This official was designated the Employment Officer and the position, since its inception, has been filled very ably by Mr. W. J. Carbis, himself a silicotic, who has now taken over all the work originally carried out by the Silicotic Employment Office.

The Secretarial Department of the Association of Mine Managers, however, still keeps in touch with the matter and continues to compile statistics in connection therewith.

Records to date show that:

The total number of applications registered from October 1916 to 31 August 1929 was	5,223
The total number of individuals for whom employment has been found during this period was	3,875
The total number of jobs found for these men during this period has been	6,119
There are still on the books	344

Employment was found for these men on gold, platinum, coal, base metal and asbestos mines, on railways, farm settlements, and various industrial undertakings in the Union of South Africa.

The miners who first became beneficiaries under the original Act were principally, what is termed in this country, "oversea men", drawn from the mining districts of Great Britain, chiefly from the counties of Cornwall, Cumberland, Northumberland and Durham. A large percentage of these men returned to their native homes on becoming silicotic. In fact, it has been authoritatively stated that, up to date, 75 per cent. of the miners who have contracted miners' phthisis are overseas men.

Then followed the 1914 Act, passed shortly before the outbreak of the Great War. It is remarkable that a large number of men who had been certified to be in the early stages of silicosis, joined various field units in which they served. Many of these men served to the conclusion of hostilities. A number of silicotics, who remained on the Witwatersrand, were able to obtain employment rendered vacant by the more fit men who had joined the Army.

During an official business visit to Great Britain in 1926, Mr. C. J. Williams observed that many men, who were in the first stages of silicosis, and who had returned to England, were engaged in various occupations there, principally mining, and appeared to be as competent to do the work as those men who had not been declared silicotic.

In this connection, it might be of interest to quote from a Memorandum prepared by the Chairman of the Miners' Phthisis Medical Bureau (Dr. Watkins-Pitchford) in 1919, in response to certain enquiries made by the Silicotic Employment Office:

The ante-primary stage of silicosis is not associated with any apparent impairment of capacity for work. Workers who are certified to be in this stage are usually men in good health and able to perform a full day's work. A complete abandoning of hard-rock mining and the following of some wholesome occupation should secure that the prospect of life and health of such men is little if at all depreciated.

The primary stage of silicosis is associated with some impairment of the capacity for work although the impairment is not of a serious and permanent nature. In the great majority of instances the reduced capacity for work is not admitted by the man himself; he is, usually, to all appearances, in vigorous health.

Silicosis is not a communicable disease: it can be contracted only by the long-continued inhaling of dust containing minute particles of free silica. The association of silicotic with non-silicotic workers is entirely free from risk to the latter.

A more recent statement made by the present Chairman of the Medical Bureau, Dr. L. G. Irvine, in an address delivered to the Association of Mine Managers on 20 July 1928 is also of interest:

Dust *per se*, of course, can and does produce a fibrosis of the lungs which affects particularly their expansibility. But an uncomplicated dust fibrosis, at all events as dust conditions are to-day, will not very seriously incapacitate a man, nor will it directly kill him.

The following information regarding the incidence of miners' phthisis is derived from the returns of the Miners' Phthisis Medical Bureau:

EUROPEAN MINERS: NEW CASES OF SIMPLE SILICOSIS, TUBERCULOSIS WITH SILICOSIS, AND SIMPLE TUBERCULOSIS, DETECTED AT PERIODICAL EXAMINATIONS, 1917-1918 TO 1927-1928

Year	Simple silicosis		Tuber- culosis with silicosis	Total silicosis	Simple tuber- culosis	
	Primary and se- condary	Ante-primary				
1917-18	153	} 1,456	116	269	} 35	
1918-19	349		120	469		} 1,716
1919-20	398 + (556)		24	422 + (556)		
1920-21	17	219	17	253	44	
1921-22	5	254	24	283	22	
1922-23	2	255	19	276	25	
1923-24	1	318	20	339	11	
1924-25	1	427	28	456	18	
1925-26	—	490	7	497	61	
1926-27	—	364	2	366	42	
1927-28	—	283	0	283	32	
Total				4,469	365	

There are at present living in South Africa, south of the Equator, approximately:

	Men
Suffering from silicosis in ante-primary stage	2,500
In the primary stage	2,350
In the secondary stage (tuberculosis plus silicosis)	2,200
Simple tuberculosis	360
Total	7,410

With regard to the number of silicotics employed in various parts of the Union of South Africa, Mr. Williams has made the following estimate:

On surface work, scheduled mines	800
On mines other than scheduled	450
By municipalities on the Witwatersrand	250
By private industries and persons	350
By railways and public works	200
On relief works	250
On alluvial diggings	350
Engaged in farming operations	350
Established in business	100
Total	3,100

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SILICOSIS

(SUPPLEMENT)

Resolutions adopted by the
International Conference held at Johannesburg
13-27 August 1930

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RESOLUTIONS ADOPTED BY THE SILICOSIS CONFERENCE

I. Report upon the Medical Aspects of Silicosis, including *Ætiology*, Pathology and Diagnostics

Reporters: Drs. L. U. GARDNER, E. L. MIDDLETON
and A. J. ORENSTEIN ¹

1. The Conference confined its discussion almost entirely to silicosis, as the other pneumoconioses are, with the possible exception of asbestosis, in the present state of available information, of less importance, and furthermore have not been subjected to sufficiently detailed study.

2. Silicosis is a pathological condition of the lungs due to inhalation of silicon dioxide. It can be produced experimentally in animals.

3. To produce the pathological condition, silica must reach the lungs:

- (a) in a chemically uncombined condition, although the dust inhaled may be either a natural mixture of silicon dioxide with other dusts, such as occurs in granite, or an artificial mixture, such as scouring powder;
- (b) in fine particles of the order of less than ten microns. There is no evidence as to the lowest limit of size in which the particles may be capable of producing the disease;
- (c) in sufficient amount, and over a certain period of time; these two factors are reciprocal variants. The minimum of these two respective factors has not yet been determined.

¹ Dr. W. STEUART was unable to participate in the preparation of this report. He submitted a memorandum which is reproduced later as an Appendix. The report, including the memorandum, was adopted by the Conference at its Eleventh Sitting, 25 August 1930.

4. Silica dust plays the dominant role in the production of silicosis, admixture of other dusts tending to modify the picture in the direction of that of other pneumoconioses, in some relation to the proportion of free silica inhaled.

5. There is experimental evidence that the solubility of silica in the tissues is an essential factor in the causation of silicosis.

6. Infection of the lung with *B. tuberculosis* or other pathogenic organisms, whether it occurs before, simultaneously with, or subsequent to the development of silicosis, alters the disease and influences it unfavourably, tuberculous infection being particularly unfavourable.

7. The establishment of a silicotic process in a lung renders the subsequent inhalation of other dusts, in themselves relatively innocuous, capable of producing serious pneumoconiosis.

8. It was suggested that intermittency of employment retards the onset of silicosis, but the evidence adduced in support of this, though suggestive, is not conclusive, when the total period of exposure is not affected.

9. It was agreed that the microscopic pathological changes which may be produced by the prolonged inhalation of silica dust are:

(a) The development of a condition designated in South Africa as a dry bronchiolitis, characterised by an accumulation of dust-filled phagocytes in or in relation to the terminal bronchioles, with possibly some desquamation of their epithelium.

(b) The accumulation of dust-containing phagocytes about and in the intra-pulmonary lymphoid tissue, and their transportation through the lymphatics into the tracheo-bronchial lymph nodes.

(The conditions described above under (a) and (b) do not constitute the disease silicosis.)

(c) The gradual development of fibrous tissue within such accumulations of phagocytes and the formation of characteristic nodules of hyaline fibrous tissue.

(d) Degenerative changes in these foci.

(e) The hyaline nodules increase in size by extension at their periphery.

Coalescence of adjacent nodules takes place and brings about involvement of further areas of the lung.

(The conditions described under (c), (d) and (e) constitute the disease silicosis.)

10. Macroscopically the changes observed in silicosis are:

- (a) *In the early stage.* A variable number of palpable pearly-white nodules up to 2 or 3 mm. in diameter on the pleural surface of the lung. On section, the cut surface of the lung is studded with pigmented foci, widely scattered, a moderate proportion of which are only just palpable. The tracheo-bronchial lymph nodes are slightly enlarged and deeply pigmented, and may exhibit foci of fibrous induration.
- (b) *Later stages.* The fibrotic nodules are increased in number, size and density, and coalescence of these may be found. The portion of the lung between the fibrotic nodules may be emphysematous. The tracheo-bronchial lymph nodes may be smaller in size than those seen in the early stage and are fibrosed.

11. The presence of tuberculous infection usually modifies the pathological appearance. Special attention was drawn to the three following types:

- (a) In which the picture of silicosis above described may be little, if at all, modified, but in which only a biological test can demonstrate the presence of *B. tuberculosis*.
- (b) In which the coexistence of silicosis and typical tuberculosis lesions is easily recognisable.
- (c) In which the presence of tuberculosis is easily recognisable, but the existence of silicosis is more difficult to determine.

12. There is evidence that with *B. tuberculosis*, *in vitro* the period before growth becomes apparent is shortened in the presence of silica, and that *in vivo* an environment favourable to the continued growth of the bacillus is produced in the presence of silica, but the virulence apparently remains unaltered.

13. In *massive* silicosis cardiac hypertrophy and subsequent dilatation may occur. In silicosis with infective processes, cardiac changes may also occur.

14. No evidence was adduced in regard to involvement of kidney or liver.

15. For the diagnosis of silicosis as a disease it is necessary to take into consideration :

- (a) the employment history;
- (b) the symptoms and physical signs;
- (c) the radiological findings.

16. The disease can conveniently be divided into three stages, designated " first ", " second ", and " third " stages.

17. In the differential diagnosis of silicosis from other pneumoconioses a history must be established of exposure to inhalation of silica dust in a quantity reasonably commensurate with the clinical and radiological findings.

18. In the " first stage " symptoms referable to the respiratory system may be either slight or even absent. Capacity for work may be slightly impaired. There may be a departure from the normal in percussion and in auscultatory signs, and the radiograph must show an increased density of linear shadows, and the presence of discrete shadows, indicative of nodulation.

19. In the " second stage ", there is an increase of the physical signs observable in the " first stage ", and the radiograph shows an increase in the number and size of the discrete shadows indicative of nodulation with a tendency to their confluence. There must be some degree of definite impairment of working capacity.

Third 20. In the "~~first~~ stage " all the above conditions are grossly accentuated and indications of areas of massive fibrosis are usual. There is serious or total incapacitation.

21. Pulmonary tuberculosis may be present in any of the above described " stages " of silicosis, altering the symptoms, physical signs and radiographic appearances, and the degree of working capacity. Its presence must therefore influence the " stage " classification of the individual, which classification must in these circumstances be based more on the degree of loss of working capacity than on physical signs and radiographic appearances.

22. Radiographs may frequently be met with which show a slight, moderated, or well marked increase beyond the normal in radiating linear shadows. These may or may not be due to fibrosis.

23. The inhalation of asbestos dust produces a definite pneumoconiosis, which may occur also in association with tuberculosis, and deaths have been recorded.

This pneumoconiosis is associated with the presence in the lungs of "asbestosis bodies", but the mere presence of these bodies in the lungs or sputum does not constitute evidence of the disease.

For the diagnosis of this pneumoconiosis the same criteria as described for silicosis should be applied, *mutatis mutandis*.

There is not at present sufficient evidence to show definitely to what extent tuberculosis and this type of pneumoconiosis react upon one another.

26. There are other dusts, such as those from marble, coal, carborundum, etc., which may contain small quantities of silica and which produce demonstrable lung changes, radiographically resembling in some cases the appearances observed in early silicosis.

There is not a sufficient body of evidence available to enable a definite statement to be made of pathological changes in man. In animal experiments, the inhalation of carborundum dust over a period of four years has produced fibrosis only in the tracheo-bronchial lymph nodes; the lungs were entirely free of fibrotic changes. This, and collateral observations on inhaled granite and asbestos dusts suggest the hypothesis that to produce pulmonary fibrosis a sufficient concentration of a relatively insoluble dust must be brought by the activity of phagocytic cells into intimate contact with connective tissues. With the dusts last mentioned the migration of phagocytes, for at least a prolonged period, is ineffective in establishing such contact in the lung. Only in the tracheo-bronchial nodes are these conditions realised during a period of four years.

25. The Reporters beg to recommend that appropriate action be taken:

- (a) To establish an international classification of silicosis on the lines indicated in paragraphs 16 to 21 inclusive.
- (b) To enquire into the possibility of establishing an internationally comparable technique of radiography, and terminology of radiographic findings.
- (c) To institute further studies in the correlation of radiographic appearances, morbid anatomy and symptomatology of silicosis and silicosis with tuberculosis.

- (d) It is desirable that further scientific research into the ætiology, pathology and diagnosis of silicosis and other dust diseases should be undertaken on an international basis, at an early date.

APPENDIX

Memorandum on Radiography of Silicosis

By Dr. W. STEUART

With a view to obtaining uniformity in films of the thorax in cases of silicosis a description of the technique used at the Miners' Phthisis Bureau is given in detail.

The transformer receives three phase current and the secondary current is rectified by means of six valve tubes. Its output is much in excess of the capacity of present X-ray tubes.

The X-ray tube used is a metallic DN type. The distance from focus to film is 48 inches.

The length of exposure and penetration vary with the antero posterior thickness of the examinee according to the following table:

Depth of thorax in inches	Time in seconds	Kilovolts
7	0.1	61
7 ½	0.11	61
8	0.12	61
8 ½	0.15	62
9	0.175	62
9 ½	0.2	63
10	0.22	63
10 ½	0.23	64
11	0.24	64
11 ½	0.25	65
12	0.26	65
12 ½	0.26	66
Filament current 4.3 amperes	Current through tube 200 M.A.	

The man lies in the prone position on the cassette with the tube above him.

Kodak films and Agfa intensifying screens are employed. If other makes of screens and films are preferred allowance should

be made in exposure and penetration as films and screens differ considerably as regards speed.

Cassettes are such that uniform contact between films and screens is secured.

The developing solution is made up according to Kodak's formula, but to every 5 gallons 4 lb. of sodium carbonate and 4 lb. of sodium sulphide are added.

The temperature of the developer is 65° F. and the time of development is five minutes.

Terms used in indicating the diagnosis on X-ray report form:

1. *Normal thorax.* — This is taken as that of a healthy youth of about eighteen.

The heart occupies a left medial position and is approximately triangular in shape, its shadow accounts for about one third of the area of the thoracic shadow. Its size and shape vary.

The right hilus is seen as a faint rather small shadow but the left is hidden by the heart.

The diaphragm is dome shaped on each side, the right being higher than the left. Its level is variable.

The pulmonary tissues throw no shadows so that between the ribs the skiagram should be uniformly clear.

Radiating from each hilus faint shadows can be made out due to the roots of the bronchial tree of bronchi vessels and supporting tissues.

The costal cartilages are transradiant.

2. *Rather more fibrosis than usual.* — This is really the normal thorax and is seen in healthy adults, but through the continuous inhalation of dust, smoke, etc., the hilus and bronchial tree shadows become accentuated, otherwise the picture is that of a normal thorax.

3. *More fibrosis than usual.* — This is an extension of the previous condition. The hilus shadows are denser and the bronchial tree shadows are more numerous and found throughout the thorax. It is seen in old people, in cases of chronic bronchitis, asthma, and in old healed infections. Though not an absolute bar to underground work it is a factor that goes far in deciding the rejection of an applicant for mining work.

Then come a series of classifications of conditions that arise from gold mining, viz.:

4. *Commencing generalised fibrosis.*

5. *Moderate generalised fibrosis.*

6. *Well marked fibrosis.*

7. *Very well marked fibrosis.*

8. *Gross fibrosis.* The commencing generalised fibrosis shows itself on the Witwatersrand after five or more years depending on the particular work done and the idiosyncrasy of the miner. It is a further accentuation of "more fibrosis than usual" and here and there small pin head shadows can be made out, the first indication of the typical "mottling" of silicosis.

Thereafter the mottling is common to all the others, the chief indication of the amount of fibrosis being the size of the nodules.

The nodule or unit of mottling varies from about one twentieth of an inch (1.25 mm.) in diameter in moderate generalised fibrosis to about a quarter of an inch (7 mm.) in gross fibrosis. These figures are of course merely approximate and not absolute.

9. *Fibrosis partly or mainly silicotic in type.* — This is deduced when the nodules are clearly cut in outline and uniform in distribution throughout the lung.

10. *Fibrosis partly or mainly infective in type.* — A slow infective process has the effect of increasing the size of the nodules in certain areas so that there is no uniform distribution as in pure silicosis. The outline of the nodules becomes fluffy instead of sharply defined. The usual infection is tuberculous, but syphilis and other chronic infective process may cause the same appearances.

11. *Appearances suggestive of tuberculosis, $\frac{\text{right}}{\text{left}}$ lung.* — A sudden increase in the density of the hilus shadows, increased apical density or patchy shadows in other lung areas lead to the initialing of this item in the report.

12. *Apparently definite tuberculosis, $\frac{\text{right}}{\text{left}}$ lung.* — Tuberculosis is often so well established in periodical cases that there is practically no doubt as to the meaning of the shadows shown. The appearance can best be described by imagining some French chalk being thrown on the film and then rubbed round with the fingers. In the shadows produced dark areas of varying size may possibly be seen due to cavities.

The word “ apparently ” is retained because occasionally syphilis causes much the same kind of shadow.

13. *Peribronchial thickening; hilus thickening.* — From the experience obtained since the commencement of examining individuals who wished to take up mining, it has been found that the accentuation of the shadows cast by the larger branches of the bronchial tree (called by the Bureau “ Peribronchial thickening ”) and of the hilus shadows is a definite indication of tuberculous susceptibility and examinees are frequently rejected on this account.

14. *Pleural thickening* $\frac{\text{right}}{\text{left}}$ *side.*

15. *Pleural effusion* $\frac{\text{right}}{\text{left}}$ *side.*

Both of these conditions are readily noted by a radiographical examination and are considered important on account of their possible association with tuberculosis.

16. *Consolidation* $\frac{\text{right}}{\text{left}}$ *side.* — This diagnosis is given in the case of any dense shadow that does not alter its size and shape in different positions of the subject. The causes of consolidation are so numerous that unless there is some special indication in size, shape or position no diagnosis is attempted except possibly a query.

17. *Heart, asthenic or vertical in type.* — Although the heart shadows vary to a considerable extent within normal bounds, individuals having a tubular shaped heart or one casting a very small shadow, are regarded as “ suspect ” by the members of the Bureau for the same reasons noted in 13, 14 and 15.

18. *Heart enlarged.* — In most cases of cardiac disease and pericarditis the heart shadow usurps more than its normal share of the thoracic space, and attention is always drawn to this variation, as cardiac disability is often ascribed by outside medical practitioners as being due to silicosis.

19. *Aorta enlarged and aortic aneurysm.* — These items have frequently to be initialed and are often associated with patchy shadows suggestive of tuberculosis which however disappear after a course of appropriate treatment for specific disease.

20. Other changes, viz.:

(1) *Aerophagy.* — Occasionally at the left base it will be found that the phrenic shadow is pushed up into the thorax and that below it a negative shadow is shown. This is due to the subject

swallowing air which distends the stomach and may cause discomfort.

(2) *Aneurysm of heart.* — The condition is very rare, only one case in 80,000 persons having been noted at the Bureau.

(3) *Atelectasis.* — Due to obstruction of a bronchus, gives a fan-shaped shadow radiating from direction of lung root which is as dense as a consolidation shadow.

(4) *Azygos lobe.* — In about one case in twenty thousand there is an abnormal azygos vein which leads to a shadow in the upper lobe of the right lung.

(5) *Bronchiectasis.* — This is indicated in skiagrams by No. 13, "peribronchial thickening". A definite diagnosis however can only be given after a lipiodol injection.

(6) *Bronchitis.* — Chronic bronchitis gives the picture described in No. 3, "more fibrosis than usual".

(7) *Calcification.* — Calcium is deposited in old inflammatory foci and in costal cartilage. It is often deposited in silicotic nodules and in lymphatic glands at the root of the lung. Its presence is indicated by an increased density of the shadow.

(8) *Carcinoma.* — Carcinoma may occur as a primary or secondary condition.

In the former case it leads to a consolidated area which increases in size. In the latter several shadows are seen which are circular and become larger and larger in diameter until the patient succumbs.

(9) *Emphysema.* — The lung tissue becomes more transradiant so that other shadows are accentuated owing to the increased contrast.

(10) *Empyema.* — The shadow is very dense and may occupy any part of the lung field.

(11) *Hodgkins disease.* — The thoracic involvement causes a dense mediastinal shadow.

(12) *Hydatid cyst.* — This is indicated by a dense oval shadow with a uniform contour.

(13) *Liver and subphrenic abscess* normally occur on the right side. The diaphragm is pushed up into the thorax.

(14) *Miliary tuberculosis.* — The appearance is practically the same as a *moderate generalised fibrosis mainly silicotic in type.*

(15) *Pneumonia*. — The shadow is dense and varies in size according to the severity of the disease.

(16) *Pneumothorax*. — The collapsed lung can be seen in the root area. It is surrounded by a uniform negative shadow stretching to the periphery.

II. Report of the Sub-Committee on Preventive Measures ¹

Reporters: Dr. LORIGA, Dr. BADHAM and Mr. ROBERTS

1. The Conference dealt with the matter of prevention at its sessions held on Friday afternoon and Saturday morning, 15 and 16 August 1930.

The first six papers and the papers presented by the visiting members, were taken as read, and discussed on broad lines, members having remarks to make calling freely upon their experience in regard to one or other of the various aspects of the question.

The feeling of the Conference was that the present opportunity should be used for an interchange of ideas with a view to mutual inspiration which would be of value in future research, rather than that it should be used for the purpose of arriving at conclusions and the making of recommendations.

2. It was generally agreed that so far as the present heading is concerned, the disease which it is sought to prevent is that which arises from the inhalation of free silica (SiO_2) as distinct from silica in chemical combination with other substances.

3. From the information supplied by various members, the disease becomes noticeable after differing periods of exposure to siliceous dust, depending, apparently, upon:

- (a) The amount of dust inhaled;
- (b) the percentage of free silica contained therein;
- (c) the size-frequency (or fineness) of the particles inhaled;
- (d) the nature and sort of such other substances (including vapours and gases) as may be inhaled simultaneously, or otherwise;

¹ Adopted by the Conference at its Twelfth Sitting, 26 August 1930.

- (e) the powers of resistance of the individual concerned;
- (f) the presence or absence of a complication by an infective process.

In regard to (a), it was agreed that by the use of water and other preventive measures the dust contents of air can fairly readily be reduced to ordinarily invisible amounts. In Australian experience this represents something in the neighbourhood of 4 or 5 milligrams per cubic metre, or say 400 or 500 particles per cubic centimetre when the particles are from 1 to 10 microns with a size-frequency ratio of 3. It was, however, evident from the discussion that it is impossible, under existing conditions, properly to correlate dust determinations made in different countries, in different industries and for different purposes, as well as for different immediate objects.

With regard to (b), it appeared from the information placed before the Conference that silicosis can be contracted through inhaling for a sufficient period dust containing percentages of silica varying from say 95 per cent. down to from 30 to 35 per cent. and even lower.

In regard to (c), it was pointed out that with existing preventive measures carried out in certain mining areas there are now relatively few large particles in the air; and it appeared from the discussion that the greatest amount of harm is done by particles of less than say 3 microns in size. Some of the evidence seemed to suggest that particles of an ultra-microscopic size are factors in the causation of the disease, but evidence in this direction was not conclusive.

In regard to (d), the experience on the subject of certain members went to show that while exposure to various other dusts *simultaneously* with silica might affect the development of silicosis, the suggestion that other dusts might be used as an antidote against silica should be treated with great caution and reserve. Further research in this direction is urgently called for. It was pointed out that experimental evidence and practical experience under working conditions had shown that prior or subsequent inhalation of other dusts in no way delayed the development of silicosis.

In the course of the discussion under this heading some reference was made to the alleged immunity from silicosis in some districts where quartz in company with non-siliceous rock is mined, but it was pointed out that further investigation had shown in the one case that the allegation was unfounded in that the existence of silicosis

had been obscured by the migratory nature of the working population; while in other cases it appeared that by reason, possibly, of the absence of laws relating to compensation, the medical evidence is not so complete as it might otherwise be, and there is sufficient room for doubt as to the exact position of the workers vis-à-vis silicosis. In all cases where there are laws relating to the compensation of silicotics it is but natural that the examination of the workers will be more thorough.

In regard to (e), it was generally agreed that this is an important feature, and there was a certain consensus of opinion that alternative employment and periods free from exposure to siliceous dust tended to increase the resistance and thereby delay the development of silicosis.

4. The discussion on methods for the prevention of dust and the inhalation thereof fell, on broad lines, under the following headings:

- (a) the use of water;
- (b) exhaust draught applied at or near the point of origin of the dust;
- (c) dust traps and masks;
- (d) ventilation;
- (e) other methods.

There was something said in favour of each of the methods referred to. It was agreed that no one method is applicable in all circumstances, but that in most cases, and especially in mining, there should be a combination of methods.

With regard to water, it was pointed out that, as far as the Witwatersrand was concerned, it is used in three different ways, namely:

- (1) to prevent the formation of dust during the drilling of holes, in blasting, and the handling of broken rock;
- (2) for the wetting of all surfaces with a view to securing a "fly paper" effect in retaining dust which might settle on those surfaces;
- (3) for spraying into the air in order to allay dust which had been formed.

In regard to (1) it was generally agreed that the application of water at the site of percussion or fracture tends to minimise the formation of dust, but attention was drawn to the fact that in several

operations, e.g. rock drilling, stone cutting, grinding, etc., sparks accompanied by dust escape even when the surfaces concerned are actually under a film of water.

In regard to (2), the view was expressed that since there is no particular reason why dust particles of the order of less than 3 microns should settle on the roof and sides of working places, and that they would settle on the floor only after many hours, the value of these wetted surfaces as dust catchers is probably small.

With regard to (3), it was pointed out that the dust particles with which the Conference was concerned are of the same order in size as micro-organisms, and that no one nowadays would expect to catch micro-organisms by means of a spray. In this connection it was mentioned as a matter of interest that Lord Lister, in his famous address delivered at Berlin, had stated that he felt ashamed of ever having suggested such a possibility in surgery.

The consensus of opinion was that as sprays are of little value for removing fine dust from the air and that since, further, a humid atmosphere and the presence of droplets had been shown experimentally to increase the risk of various infections their use should be restricted.

This view, however, does not necessarily apply to water blasts used on the Witwatersrand when firing in development ends, since while such blasts might not catch much of the finer dust (except by the subsequent condensation of water vaporised by the heat generated in blasting) they put into solution some of the noxious gases and wet the broken rock so as to prevent the escape of the dust when that rock comes to be handled.

In regard to (b), it was mentioned that exhaust draught was of great value in those processes of manufacture where there is an objection to the use of water. In some cases water cannot be used for fear of spoiling the material, and in other cases the workmen at times turn it off because it makes them wet. In all such cases, exhaust hoods should, if applicable, be used. It is necessary, however, that these hoods should be placed in close proximity to the work, and that regard should be had to the direction and speed of rotating objects. As an example of what could be done in manufacturing processes by the use of exhaust draught, cases were mentioned of a decrease in the incidence of silicosis which had followed the abandonment of wet grinding in favour of dry grinding with suitably applied exhaust draught. It was also pointed out that before exhaust draught was used for the

dry grinding of metals this process was much more dangerous than wet grinding, but that since the introduction of efficient exhaust draught with dry grinding the position had been reversed.

(1) *Dust traps.* — As an example of the application of this method to the drilling of holes in mines, mention was made of an apparatus (such as is referred to on page 114 of the main volume) wherein the drill steel operates through an artificial collar held against the face of the rock; and through which ejector induced suction led the dust produced in drilling into a dust trap or filter. This apparatus was said to be very effective and popular in certain collieries to which laws relating to silicosis had recently been applied.

(2) *Masks.* — It appeared from the experience of members that workmen submit readily to their use only when discomfort from the inhalation of noxious dust could thereby be avoided.

In some circumstances loose fitting masks of the pressure type wherein a constant supply of fresh air under positive pressure is led in through a flexible tube, have proved very efficacious. Such masks, however, are useful only when the wearers can perform their work without the necessity of moving from place to place. The same applies to tight-fitting masks supplied with air at normal pressure through a tube from a distant source.

Other masks wherein air was inspired through a filtering medium such as cotton wool, sponges, etc., and expired through a light non-return valve, were also described.

Reference was also made to masks in which the air to be inspired is made to pass through a tortuous path and impinge on damp surfaces which will retain the dust.

The feeling of the Conference was that while the masks at present available may be of some value in special circumstances, and particularly in those cases where the formation of dust (and the consequent necessity for precautions) is intermittent; they are so unwieldy or interfere so much with respiration that their constant use is impracticable during hard work and especially in a hot and humid atmosphere.

In regard to (*d*)—Ventilation—there was but little direct discussion, it being agreed that good fresh air ventilation was desirable, and indeed essential. It was emphasised, however, that to be effective the ventilation currents must be properly split and directed so as to sweep all dust-laden air out of the mine or works, as the

case may be, in much the same way as dangerous gases are swept out of collieries.

With regard to (e)—Other Methods—mention was made of the fact that some years ago an endeavour had been made on the Witwatersrand to prevent the roof and sides of main intake airways from drying up (and, incidentally, to secure the “fly paper” effect referred to in 4 (2) and in the remarks thereon) by spraying those surfaces with solutions containing molasses, calcium chloride, and other hygroscopic substances, but it had been found that these preparations absorb moisture so readily that they soon trickle down into the gutters.

In discussion on this matter it was pointed out that if there really are any advantages to be derived from the “fly paper” effect, these solutions, and other sticky substances, could again be tried in the event of it being found possible at a later date materially to reduce the humidity of the ventilating currents. It was also suggested that these solutions might be used instead of plain water, for preventing the formation of dust in drilling, blasting, and the handling of rock.

In dealing with the dust formed by blasting, especially by blasting in development ends, a suggestion was put forward that it might be possible to project into the air at the time of blasting relatively large particles of some innocuous flocculent dust which in its settlement or progress through the mine would catch the harmful dust in much the same manner as micro-organisms are caught in water purification plants.

A further suggestion put forward was that saturated steam might be of some value, it having been found effective in industry in certain special circumstances.

A still further suggestion put forward was that the escape of dust from drill holes might be prevented by the use of a preparation producing a foam.

5. During the course of the discussion, reference was made to the difficulties experienced by investigators in the different countries in properly appreciating each others findings. Some of those difficulties arise from there being no accepted standards for comparisons in regard to various conditions, dust counts, and so on; and others, through lack of a uniform terminology. The Conference, therefore, decided to put forward the following suggestions in the hope that those investigators who were in a position to do so, and particularly the Research Division of the International Labour

Office, would take them up so as to pave the way for some decisions and recommendations at a future Conference.

(1) While the methods of conducting and other details relating to the routine sampling of air are best left to each local authority, it seems highly desirable that for certain special critical and scientific studies of dust particles in air and their effects, there should be established some standard method which for this special purpose would permit of inter-industrial and inter-national comparisons; in this connection it is suggested that the instruments at present approved by the various experts should be taken into consideration. The results of these investigations should be communicated to the Research Division of the International Labour Office for correlation.

(2) That as photographic and photo-electric cell methods of dust determination have been successfully applied in certain special circumstances, research should be undertaken with regard to such methods, with a view to ascertaining their adaptability in other circumstances.

(3) In view of the chemical theory of the causation of silicosis, the importance of estimating the size frequency of particles has increased owing to the fact that the surface exposure (which varies greatly with different sized particles) is the chief factor in the amount of silica which goes into solution. It is suggested, therefore, that investigators should include in their work determinations of the size frequency of particles.

(4) (a) The Conference urges that the investigations suggested in paragraph (1) should be undertaken with the least possible delay in all countries which are interested in the problem.

In view of the thoroughness and outstanding work of research already carried out on the Witwatersrand, and in view of the special facilities which exist in that area, the Conference attaches special importance to the investigations which may be undertaken on the Witwatersrand and ventures to express the hope that they will be initiated at the earliest possible moment.

(b) The Conference recommends that as soon as the standard method referred to in paragraph 1 has been perfected it should be applied for the purpose of making at least one complete survey of the dust concentration in dusty industries

throughout the world. The results of this survey should be communicated to the International Labour Office.

(c) The Conference considers that the survey recommended in (b) should include an investigation into the relative size frequency of the dust particles.

Every effort should be made to emphasise the fact that the prevention of silicosis must be achieved by means of a whole series of provisions relating to hygiene in mines—viz. chiefly by reducing production and diffusion of dust, by maintaining the purity of the air, and by means of personal hygiene.

(5) That no opportunity should be lost of stressing the importance of general and localised ventilation as one of the best hygienic measures in dusty industries.

(6) That the personal protection of the workers should not be exclusively confined to such protective measures as, for instance, the wearing of masks, but should be supplemented by secondary measures such as the provision of suitable change houses and shelters, and by the regulation of working hours, etc.

(7) That many of the points raised in the prevention and control of dust call urgently for investigation by the physicists.

Note. — The present report does not concern itself with medical methods of prevention of silicosis.

III. Report on Prognosis, After-Care and Compensation ¹

Reporters: Dr. CUNNINGHAM, Professors HALL and KOELSCH, together with Dr. BADHAM (co-opted)

In presenting our report it has seemed best to deal with each subject separately.

Prognosis

This subject may be considered under four headings:

Question 1: What is the prospect of a man exposed to free silica dust as regards acquiring silicosis?

This has been considered to depend on various factors:

(a) The nature, silica-content, size of particles, and concentration of the particular dust to which he is exposed.

¹ Adopted by the Conference at its Twelfth Sitting, 26 August 1930.

Concerning many of these points exact information is not forthcoming and it is desirable that further scientific investigations should be carried out and the results carefully compared with the incidence of silicosis amongst the workers.

(b) Period of exposure to dust.

(i) Length of service.

That this is a factor of importance is in accordance with the views expressed by members of the Conference from every country represented.

The length of service necessary to acquire silicosis may be considerably prolonged by improvement in other factors.

(ii) Intermittence of exposure.

On this point the evidence forthcoming was not conclusive.

(c) Age of worker.

There is no evidence that *per se* this plays any important part.

(d) Physique of worker.

This is a factor of primary importance. An initial medical examination to ensure a certain standard of physique should be generally adopted in those industries in which the risk of exposure to silica dust is great.

Periodic medical examination of such workers is also essential.

(e) Race.

There is no evidence that this is a factor of importance.

Question 2: What is the prognosis in a case of silicosis if the affected man leaves the industry at the first stage of the disease (ante-primary stage of South African legislation) ?

The evidence on this point as regards various industries and from different countries is somewhat conflicting.

In South Africa on the whole the evidence shows that the downward progress of the disease is in most cases not arrested on leaving the industry.

In this connection the questions of so-called infective cases, of reduced economic conditions of life, and of the associated mental worries probably play no inconsiderable part.

The view taken by the Medical Bureau in regard to the so-called "infective types" of silicosis is that they do not come under the classification of tuberculosis with silicosis unless the conditions in respect of tuberculosis as laid down in the Act are complied with.

The prognosis in such cases of infective silicosis is much less serious than in cases of tuberculosis with silicosis as the term is used in the Act. Such cases may live for many years in comparative comfort unless active tuberculosis intervenes. The preceding evidence points to the urgent necessity of further experimental study of the exact conditions connected with silicosis of infective type.

Question 3: What is the prognosis in a case of simple silicosis if he remains in the industry after the first stage (ante-primary) declares itself ?

The evidence from South Africa suggests that in so far as mining is concerned the continuation in underground employment of sufferers from silicosis will aggravate the progress of the disease, except in certain selected mining occupations.

As, owing to economic factors connected with compensation, only a very small number of the silicotics in South Africa do remain at work underground after the disease has declared itself, the evidence on this point is somewhat indefinite. It is stated, however, that there are at present about 150 men in this position, and it is said that their progress is no worse than those who have left the mines. Among these 150 men, however, are included a considerable number of higher officials whose duties do not now expose them considerably to dust and whose economic position remains as good as before.

It is desirable to obtain exact information as to how far continuation at work in occupations involving exposure to silica dust will influence the progress of the disease.

Question 4: What is the prognosis in a case of silicosis with tuberculosis ?

(N.B. Before attempting to summarise the views of the Conference on this point it is desirable to make clear exactly what we mean. According to the terminology used in South African legislation "tuberculosis means tuberculosis of the lungs or of the respiratory organs" and is deemed to be present "wherever it is found by the Bureau either (a) that such person is expectorating the tubercle bacillus, or (b) that such person has closed tuberculosis to such a degree as seriously to impair his working capacity and render prohibition of his working underground advisable in the interests of his health".)

This is always serious.

It is worse:

- (i) when the tubercular infection occurs at the outset of silicosis;
- (ii) in younger than in older subjects;
- (iii) than in cases of tuberculosis alone.

Recommendations

Prognosis of Silicosis

1. Exact information is not forthcoming concerning many of the points relating to the nature, silica-content, size of particles and concentration of dust to which a man may be exposed and it is desirable that further scientific investigations should be carried out and the results carefully compared with the incidence of silicosis amongst the workers.

2. The physique of the worker is a factor of primary importance. An initial medical examination to ensure a certain standard of physique should be generally adopted in those industries in which the risk of exposure to silica dust is great.

Periodic medical examination of such workers is also essential.

3. The evidence points to the urgent necessity of further experimental study of the exact conditions connected with silicosis of infective type.

4. It is desirable to obtain exact information as to how far continuation at work in occupations involving exposure to silica dust will influence the progress of the disease.

Compensation from the Medical Point of View

1. Silicosis complicated or not by tuberculosis constitutes an occupational disease which may involve reduction of working capacity.

2. It should be left to competent authorities to decide, in accordance with their particular conditions, whether other forms of pneumoconiosis should be regarded as occupational diseases.

3. In establishing the amount of disability, account should be taken of the clinical and functional condition as a whole.

4. The determination of disability should be entrusted to an independent medical expert, or body of experts, possessed of the

requisite clinical and technical knowledge, and having at his or their disposal suitable apparatus for effecting the examination.

5. It is suggested that removal from all industrial occupations involving exposure to noxious dust should be enforced in all cases of open tuberculosis.

6. Where legislation provides for the compulsory removal from occupations involving exposure to silica dust of workers affected by silicosis, it is suggested that such compulsory removal should not necessarily be applied to workers who have been in the same industry for a period of not less than fifteen years and have reached the age of forty-five years.

After-Care

1. Sanatorium treatment should be provided for suitable cases.
 2. Hitherto most of the rehabilitation schemes have been unsuccessful. Further investigation into this problem is urgently called for.
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