Paper—" Aspects of Dust Records, Dust Exposures and Silicosis "

At this stage of the proceedings, the President introduced Mr. R. S. J. du Toit, and said that before calling on Mr. du Toit to present his paper, he would ask Mr. Kitto to take the Chair, as he wished to make a technical contribution to the discussion. Mr. Kitto then took the Chair, and Mr. du Toit presented his paper. There were several contributions to the discussion.

Office-bearers and Members of Council for the Year 1959/1960

The President thanked the scrutineers for the work they had done, and announced the result of the ballot as follows:—

President: P. H. Kitto.

Vice-Presidents: J. H. Quilliam and D. F. H. Grave.

Members of Council: P. F. Cilliers, R. S. J. du Toit, J. A. Northcott, N. Paige-Pagani, J. P. Rees, L. A. J. Slabbert, F. C. Startup and P. J. Vermunt.

The retiring President congratulated Mr. Kitto, the newly elected President, and Mr. Quilliam and Mr. Grave, the two newly elected Vice-Presidents. He also congratulated the newly elected Council Members and formally handed over the affairs of the Society to the new President.

The President: Mr. Beadle, Ladies and Gentlemen, I would like to thank you very much for the honour you have bestowed upon me. I am fully aware of the many achievements of the past and the leaders who have been Presidents of this Society who have worked hard to accomplish this. I would like to pay tribute to our retiring President, Mr. Beadle. He has worked harder than any other member of the Society; not only has he worked willingly, but he does it because he enjoys it. If I did not have the support of the many other Council Members and the Vice-Presidents, I would not be able to carry on, and I am sure that Mr. Quilliam and Mr. Grave will help me and I am very pleased to see them in office. I am also very pleased that we have new blood on the Council, and I am quite sure that they will work hard to carry on the work of the Society.

Mr. Quilliam: On behalf of the newly elected Members and Mr. Grave, I would like to thank the members for conferring this honour upon us. I am sure that Mr. Grave and I will give our President our full support to maintain the achieved high standards of the Society.

The President said that before closing the meeting, he would like to invite those present to join him in a cup of coffee which would be served in the foyer. He asked the newly elected Council Members to remain with him in the hall for a brief discussion.

The meeting terminated at 11.40 a.m.

A CORRELATION BETWEEN SILICOSIS* AND THE DUST EXPOSURE OF SOUTH AFRICAN GOLD MINERS

By R. S. J. du Toit†

Mr. President, ladies and gentlemen,

It is indeed an honour to have been asked to read a paper to you today and I can assure you that it is a great pleasure to do so. The paper is based on a dissertation which I submitted to the University of the Witwatersrand.

Before commencing, I have a list of acknowledgements to make.

They are:

The Government Mining Engineer for permission to undertake the investigation and to publish this paper;

The Transvaal and Orange Free State

* I use the specific term silicosis rather than the general term pneumoconiosis because the dust dealt with is essentially silica dust.

† Technical Research Officer, Silicosis Research Section Unit of S.A. Mines Dept.

Chamber of Mines for permission to use certain information from records of service of employees;

The Pneumoconiosis Compensation Commissioner for permission to study the records of service of mine workers available at the Board;

The Director of the Pneumoconiosis Bureau for permission to select suitable cases and to use the medical findings of the Bureau in connection with the cases selected;

The Superintendent of the Routine Division of the South African Institute for Medical Research for permission to have access to the post-mortem reports on the lungs of mine workers by the Pathologists of the Pneumoconiosis Unit;

Dr. Ian Webster, Senior Pathologist of the Pneumoconiosis Unit, for extracts of post-mortem reports on the lungs of mine workers;

The Director of the Pneumoconiosis Research Unit of the Council for Scientific and Industrial Research for permission to have certain computations performed by a member of his staff.

I also wish to acknowledge advice received from:

Mr. J. P. Rees, formerly Director of the Dust and Ventilation Laboratories of the Transvaal and Orange Free State Chamber of Mines (now retired);

Mr. T. L. Gibbs, Deputy Government Mining Engineer;

Professor R. A. L. Black, Professor J. E. Kerrich, Mr. T. E. Edwards, Dr. H. S. Sichel, Mr. D. G. Beadle and Mr. J. de V. Lambrechts.

The author is also indebted to Mr. R. J. Pieterse for the diagrams.

SYNOPSIS

Calendar year trends in the dustiness per shift were prepared for about a dozen different classes of mine workers. The konimeter dust sampling records of the Government Department of Mines over the 24-year period 1931 to 1955, were used in the construction of these curves.

The work histories of 57 deceased European miners were analysed and by means of the above curves their total dust exposures were estimated.

Degree of silicosis was determined post-mortem, and statistical analyses show that although there is considerable scatter, there is nevertheless a significant correlation between degree of silicosis and total dust exposure.

CONTENTS

Part I: Dust Dosage

1.1 Introduction

First thoughts about the present investigation was had by about 1951, as a result of the views expressed by Beadle [1] and others concerning the performance and limitations of the konimeter. Then I studied the work by Patterson,[2] Lambrechts,[3 4 5] Rabson,[6] Davies, Aylward and Leacy,[7] Hasenclever,[8] and Roeber.[9] Further stimulus was had from the articles by Roach,[10 11] Wynn,[12 13] Wright [14] and Hatch.[15]

Finally, the following three factors really made me decide that it would be worth while to undertake the investigation: Firstly, there was uncertainty regarding the usefulness of konimeter results to indicate the silicosis hazard in mines; secondly, there were the konimeter results which were published since as long ago as 1931—something no other country in the world possessed; thirdly, there were the records of service kept of all European mine workers since as long ago as 1916, another item not to be had anywhere else in the world.

The Problem: The problem was to prove, if possible, whether konimeter counts were related to the silicosis hazard due to dust in mine air, and if so, whether the relation was sufficiently close to warrant the continued use of the konimeter as the dust sampling instrument on South African mines.

It was argued that the problem would be solved if the dust exposure of a mine worker was a measure of his degree of silicosis, where dust exposure is the product of time and dust concentration as measured by konimeter.

Unfortunately, the actual dust exposures of mine workers are not available. All we can do, therefore, is to make the best of a bad job and to estimate, as best we can, their dust exposures.

As a result of inaccuracies introduced by these estimates, also, as a result of the varying susceptibility of individuals to contract silicosis and furthermore, as a result of the fact that *only broad* classifications of the degree of silicosis in persons are possible, there will be a tendency to obscure any functional relationship between the two measures. Before dealing with the actual investigation I wish to say a few words about some of the general aspects of the dust problem.

1.2 Medical Aspects

Dust sampling is intimately associated with the medical aspects of the dust problem.

Of special interest is the anatomy of the respiratory system,[16] but space does not permit me to expand on this aspect.

The range of harmful particles: Of importance also is the range of harmful particles.

It is generally accepted that particles larger than about 5 micron do not represent a hazard because they would settle out before reaching the alveoli.

The relative importance of ultra microscopic particles, i.e., of less than about ¼ micron, is not such a simple matter and we have to admit that to date there is no evidence that such particles are harmless.

On the other hand there is the question of: **What is the best single descriptive parameter to measure ?**

One of the recommendations of the recent Pneumoconiosis Conference [17] covered this point and the recommendation reads: "that, in the light of the present available evidence, the best single descriptive parameter to measure, be considered the *surface area* of the respirable dust in the case of quartz dust."

Although coming after I had completed the investigation it is of interest to consider how the konimeter count compares with the surface area of airborne dust. Lambrechts,[3] Rabson,[6] and Beadle [1] showed that the konimeter count was high for coarse dust and low for fine dust. Therefore, the konimeter tends to allow for the larger surface area of a coarse dust as compared with a fine dust for the same number of particles. It is of course doubtful whether the allowance is the correct amount. Be that as it may, the essence of the matter is whether the dust results can be correlated with medical evidence.

1.3 The dust results used

This brings me to the results I used.

There was the question of whether to use the results recorded by the Department of Mines, or whether to use those recorded by the Chamber of Mines, or whether to combine the two sets. I decided to use the results of the Department of Mines [18] only (as published in the Annual Reports of the Government Mining Engineer) in spite of the fact that the results of the Chamber are based on a much greater number of dust samples than those of the Department of Mines. The main reasons for this decision are as follows:

(1) all the mines did not always submit returns to the Chamber; e.g., in 1936, returns were submitted by only 24 out of the 35 working mines [19];
(2) the Chamber of Mines stopped publishing results of dust determinations by 1950;
(3) the different mines did not always use the same treatment technique [19];
(4) only by 1950 did the Chamber change over from immersion-ignition to ignition-immersion-ignition treatment whereas the Department of Mines changed to the latter method as early as 1942;
(5) the konimeter results published by

the Chamber were not cast in the same classifications as those published by the Department of Mines which would make a combination of the two sets of data very difficult;

(6) the classification made by the Chamber was not as suitable as the one made by the Department for the investigation undertaken;

(7) finally, it was doubtful whether any materially improved accuracy would result from a combination of the two sets of results.

Justification for using the dust counts recorded during routine inspections: A question that arose was whether the observations made by Inspectors of Mines could justifiably be used to represent conditions over the whole shift. The reason for such a question is the fact that the majority of dust samples taken by Inspectors of Mines are taken between about 9 a.m. and 12 noon, whereas the underground shift of most occupations extends for several hours on either side of this period and for some occupations over the full 24 hours of the day. The answer to the question lies in the fact that all the mines concerned employ Ventilation Officers [20] who keep an eye on the dust conditions in mine workings and in the fact that inspections by Government Inspectors of Mines may be made, and dust samples taken, whenever there is reason to believe that satisfactory standards are not maintained. (Complaints [21] to this effect may be made by any employee.)

Another point to consider was:—

The degree of bias of the recorded dust counts: The results as published by the Department of Mines are not completely free from bias [22] in the statistical sense.* The reason for the bias is that one of the main objects of taking dust samples is to " smell " out places with poor conditions, and having found them, to keep on taking samples there until conditions are satisfactory.

* This criticism, incidentally, applies also to the dust sampling results of most other concerns.

Hence, if there are two places to choose from, an Inspector, like any other person who has to see that dust production is kept down to the minimum, will be inclined to go to the place where poorer conditions are suspected or known to exist.

On the other hand, the Inspector of Mines has not always got such a choice, but mostly has to take dust samples in places where his routine inspections lead him to. On the whole, therefore, it was felt that the vast majority of dust spots could be considered as random samples so that the results recorded at different classes of underground places, over the same period, could be compared one with the other and similarly, the results recorded over different periods, at the same class of place, could be compared one with the other provided the dust assessment technique did not alter, or if altered, was allowed for. Hence, I was satisfied that there was justification for using the results recorded by Government Inspectors of Mines.

1.4 The dustiness of mine air at a number of strategic points

To simplify matters, it was decided to use the results recorded at only six of the underground points for which the Government Mining Engineer publish results.

The six strategic points chosen are:

(1) Air entering downcast shafts at surface.
(2) Air leaving downcast shafts before passing tipping stations.
(3) Air in main intake airways away from downcast shafts.
(4) Air in stopes.
(5) Air at development end faces.
(6) Air at the bottom of sinking shafts.

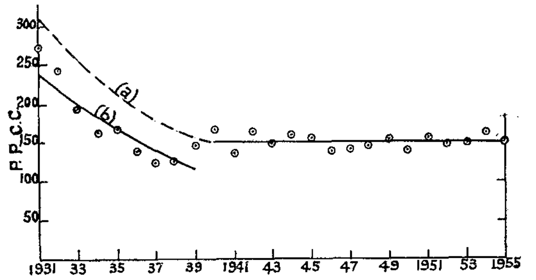
The variation in the dust count of mine air with calendar years: It was necessary to estimate the variation of the dust count with calendar years, and to do this the effects of the various techniques introduced over the years had to be allowed for. Estimates of the effects were obtained by comparing the results for successive periods during which the dust determination technique remained unaltered. A significant difference in the count between the end of one period and the beginning of another was assumed to have been brought about by the change in the technique.

The three periods of steady conditions: There are three periods during each of which the dust assessment technique remained practically unchanged. They are:

(1) 1931–1941.*
(2) 1942 [24] to 1948.
(3) 1949 [25] and onward.

* An altered classification was introduced in 1940 [23] which consisted of a distinction being made between dust samples taken in intake, working point, and return air, of stopes, development ends, and sinking shafts, and only two years later, viz., in 1942 was the ignition-immersion-ignition technique introduced, so that in the case of stopes, development ends, and sinking shafts, a difference between the first and the second period was due to the combined effect of these two changes.

An example of the method of dealing with one of the strategic points is depicted in Fig. 1, and a summary of the effects established of the various changes made in dust sampling technique, is given in Table I.



Calendar years.

FIG. 1. DUST COUNT IN STOPES.

(⊙) *Annual mean counts.*
(*a*) *Best estimate (present technique).*
(*b*) *Best fit to 1931-39 mean counts.*

The trends in dust concentration, from 1931 to 1955, for each of the six strategic points are depicted in Fig. 2.

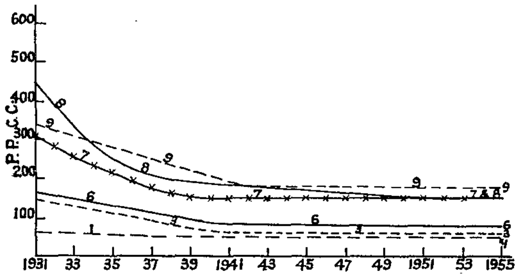


FIG. 2. SUMMARY OF DUST LEVEL VARIATIONS AT:

(1) Top of downcast shafts; (3) Bottom of downcast shafts; (6) Main intake airways; (7) Stope faces; (8) Development end faces; (9) Shaft bottoms.

1.5 The dustiness of an underground shift

Having got estimates for the dustiness of mine air at strategic points, the next problem was to arrive at estimates for the dustiness of the shift of underground workers.

The dustiness of an underground shift depends essentially on the position or positions in the mine where the shift is spent, and the shift dustiness of underground workers can be estimated from the proportions of the shift spent at or between these strategic dust levels. If the proportions of the shift were known, the mean dust level per shift could be computed. The actual proportions are, unfortunately, not known and estimates thereof have to be relied on.

Effect of errors in the proportions used: To estimate the mean dust level per shift of an occupation from the proportions of the shift spent at various dust levels, is the same as using loading factors to arrive at weighted mean values. In such cases, the accuracy of the factors are not of critical importance because relatively large errors in the loading factors affect the weighted mean value to a relatively small extent.

E.g., a 50 per cent. error in the loading factors of two quantities which differ as 2 is to 3, results in an error of only 10 per cent. in the weighted mean value.

To simplify the computation, mine workers were classified into a few main groups for each of which the shift dustiness could be estimated for any particular calendar period.

1.6 The classification of mine workers into main groups

Officials and non-officials were considered separately. *The non-officials* were classified according to the position in the mine where the main portion of the shift is spent and on this basis, the following main classifications were made:

(1) Those employed essentially in and around shafts, referred to as SHAFT WORKERS;
(2) those employed essentially along travellingways, referred to as TRAVELLINGWAY WORKERS;
(3) those employed essentially along entrances to and exits from working

TABLE I

Summary of Allowances made for the Changes in Technique

Classification	Changes Made		
	Separation of intake, working point and return counts—(1940)	Acid Vapour to ig.–im.–ig. (1943)	1 % Vaseline in Xylol (1949)
Intake air at the top of downcast shafts (1) ..	Not applicable	Nil	* + 11 p.p.c.c.
Intake air at the bottom of downcast shafts (3)	Not applicable	+ 44%†	Nil
Air in main intake airways away from downcast shafts (6)	Not applicable	Nil	Nil
Stopes (7)	+ 27%†	Nil	Nil
Development ends (8)	+ 19%†	Nil	Nil
Shafts (9)‡	Nil	Nil	Nil

*The question of whether the effect of the change would be proportional to the count was considered but rejected in favour of a constant value on account of the fact that the altered technique resulted in an improved field which would be independent of the dust content of the air sampled.

†Effect of 1940 and 1942 changes combined.

‡The effects of the changes in technique could not be proved to have a significant effect on the annual means recorded, but allowance was made for an apparent disproportion in the number of spots taken during blowing over operations.

places where rock is excavated, referred to as MISCELLANEOUS MINERS;

(4) those employed largely along entrances to and exits from, but to a certain extent also in working places where rock is excavated, referred to as the " S.D.M." group, standing for stoping, development and miscellaneous mining;

(5) those employed essentially on the three main methods of rock excavation, viz., stoping, developing and shaft sinking.

1. The following occupations were included under SHAFT WORKERS:

Hoist Drivers, Onsetters, Shaft Timbermen, Underground Banksmen, Underground Storemen, Underground Pump Attendants, Underground Riggers, etc.

2. The following occupations resort under TRAVELLINGWAY WORKERS:

Loco Drivers, Haulage Timbermen, Underground Artisans (e.g., Fitters and Electricians), etc.

3. The following occupations were included under MISCELLANEOUS MINERS:

Drive Timbermen, Trammers, Pipe Fitters, Track Layers, Reclaimers, Sand Fillers, Waste Packers, Haulagemen, etc.

The following occupations were included in the " S.D.M." class:

Early Examiners, Learner Miners, G.M.T.S. — Apprentices, Assistant Miners, etc.

5. The fifth class constitute the virgin—rock breakers and this group was subdivided into:

Stopers, Developers and Shaft Sinkers.

Some occupations were regarded as combinations of the above such as development-cleaners, stoping-developers, stope-timbermen, etc.

The relative weightings of the strategic dust levels used for these groups of workers are given in Table II.

Mine Officials were treated differently. In their case it was argued that the dustiness of their underground shift would approximate the mean dustiness of the main groups of non-official workers whom they supervise.

TABLE II

Estimated Proportions of Shift at the Strategic Dust Levels

Type of Mine Worker	Dust Level Proportions						
	0·1	0·3	0·6 (See figure 2)	0·7	0·8	0·9	Total
Shaft Workers	0·50	0·50	—	—	—	—	1·0
Travellingway Workers	0·20	0·50	0·30	—	—	—	1·0
Miscellaneous Miners	0·10	0·25	0·50	0·10	0·05	—	1·0
Developers	0·05	0·10	0·50	—	0·35	—	1·0
Stopers	0·05	0·10	0·30	0·55	—	—	1·0
Shaft Sinkers	0·05	0·10	—	—	—	0·85	1·0

TABLE III

Method of Dealing with Officials

Type of Official	Combination
Underground Foremen and Engineers	Travellingway and Shaft Workers
Shift Bosses	Stopers, Developers, Miscellaneous Miners and Travellingway Workers
Mine Overseers, and Miscellaneous Officials	Those for Shift Bosses with shaft workers added thereto

The combinations made for this purpose are given in Table III.

* Samplers were given an extra 30 per cent. onto that of Miscellaneous Officials to allow for the extra dust to which they are considered to be subjected during the chiselling of samples.

The trends in shift dustiness thus obtained for the various main groups of workers are depicted in Fig. 3.

Skipmen presented a special problem because although their shift is essentially spent in the shaft area, the mean dust level to which they are subjected is above that for shafts because of the puffs of dust caused by the filling of skips, to portions of which skipmen are subjected. To allow for this, it was arbitrarily assumed that skipmen would on an average be subjected to a dust count 50 per cent. higher than that of " Shaft Workers."

Of interest in connection with shift dustiness are some *comparisons of " estimates " with " actual " observations*. Full shift dust studies were done in 1949 and 1950,[26] and also in 1926.[27] A comparison between estimates and actual observations for 1949-50 are given in Table IV.

To do a comparison for the 1926 results, it was necessary to extrapolate the dust curves from 1931 back to 1926 and, secondly, to allow for the changes in technique. Due to changes in technique, it was estimated that the 1926 results would have been about 30 per cent. higher had the present technique been followed. A comparison for the classes of workers on which actual observations were made in 1926 are given in Table V.

The agreement is good and shows that the method followed has some merit.

1.7 Dust exposures

The next step was to compute the dust exposures of underground workers from their records of service, but as the duration of the underground shift varies from one occupation to another, it was decided to allow for this. The following figures were considered reasonable estimates of the durations of underground shifts:

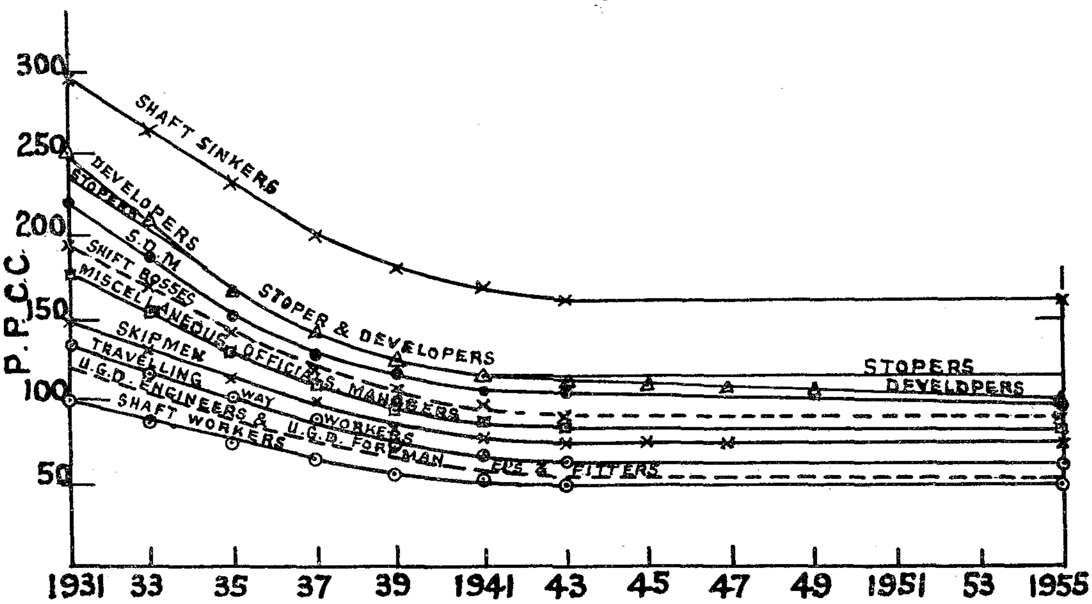


FIG. 3. SHIFT DUSTINESS.

Non-Officials:
Artisans — 7 hours.
All others — 8 hours.
Officials:
A. Mining:
(i) Shift Bosses — 6 hours.
(ii) Mine Overseers — 3½ hours.
(iii) Managers — 3 hours (this occupation did not "come up").
B. Survey and similar officials:
(i) Juniors — 4 hours.
(ii) Seniors — 3½ hours. This occupation "came up" very seldom).
C. Engineering officials:
(i) Underground Foreman — 6 hours.
(ii) Underground Engineers — 3 hours. (This occupation "came up" very seldom.)

These figures were used to compute the dust exposures as the product of time

TABLE IV

" Actual " versus " Estimates " for 1949-1950

Class of Worker	Shift Dustiness: Estimates for 1950	Shift Dustiness: Actual Observations (1949-1950) during full-shift dust studies	Number Observed
1. Travellingway Workers	65 p.p.c.c.	66 p.p.c.c.	6
2. Skipmen	75 p.p.c.c.	78 p.p.c.c.	13
3. Miscellaneous Miners	83 p.p.c.c.	75 p.p.c.c.	16
4. Early Examiners	101 p.p.c.c.*	103 p.p.c.c.	27
5. Developers	103 p.p.c.c.	90 p.p.c.c.	43
6. Stopers	116 p.p.c.c.	120 p.p.c.c.	67
7. Shaft Sinkers	161 p.p.c.c.	180 p.p.c.c.	8

*As the mean of stopers, developers and miscellaneous miners.

TABLE V

" Actual " versus " Estimates " for 1926

Class of Worker	Mean Counts p.p.c.c.			" Actual " / " Estimated "
	Observed 1926	Obs. × 1·3 (" Actual ")	Extro-polated from 1931 (" Estimated ")	
Miscellaneous Miners	185	240	241	1·00
Early Examiners	206	300	268	1·13
Stopers	216	320	281	1·14
Developers	316	366	410	0·89
Shaft Sinkers	284	378	382	0·99
Samplers	240	325	313	1·04

(expressed in hours) and particles (as obtained from konimeter sampling).

From the records of service could be obtained the mine worker's occupations, the calendar period of each occupation and the number of shifts employed on each occupation. By means of the shift dustiness curves against calendar years (see figure 3), the mean *dustiness* per shift for each period of occupation could be computed. Hence, for each period of occupation, the dust exposure as the *product* of *time* and *dust concentration* could be estimated and hence the *total dust exposure* during a mine worker's whole underground career could be estimated. An example of such an estimation is given in table VI.

2. The Sample of Mine Workers

The next item I wish to deal with is the method of obtaining the sample of mine workers.

It was decided to base the investigation on *post-mortem,* rather than on X-ray findings because of the former being the more reliable finding. It means that *deceased* mine workers only qualified for selection. The cause of death, whether by accident, from sickness or from any other cause did not matter.

Only cases whose lungs were examined under the microscope were included.

Additional conditions laid down for the selection of cases were that they had to be European mine workers who:

(1) were found free from tuberculosis;
(2) commenced underground service after 1925;
(3) worked in controlled gold mines of the Witwatersrand and Extensions and the Orange Free State only;
(4) did not have breaks from underground service totalling more than five years;
(5) continued to work underground up to within five years of death;
(6) became deceased after 1955, and
(7) had more than 10 years' service.

During the period at my disposal, a total of 57 cases qualified for inclusion.

3. Medical Classification

From post-mortem examinations, the condition of the lungs with regard to silicosis, could be cast into the following broad classifications:

(0) No dust reticulinisation.
(1) Dust reticulinisation.
(2) Dust reticulinisation with collagenisation.
(3) Occasional islet.
(4) Few islets.
(5) Moderate number of islets.
(6) Large number of islets.
(7) Conglomeration. (None of the cases were in this state.)

The Composition of the Sample Selected: The composition of the sample selected with respect to class of mine worker is most probably not the same as that of the underground European labour force on account of the limitations that had to be laid down for cases to qualify for inclusion. However, a difference in composition does not matter because the investigation does not concern

TABLE VI

Computation of Dust Exposure in Particle-Hours

1	2	3	4	5	6
Oc.^{n} No.	Shifts	H* P S	H.p.† Oc.^{n} (2 × 3 ÷ 100)	P.P. C.C. (Mean Shift Dustiness)	P.H.p.‡ Oc.^{n} (4 × 5 ÷ 10,000)
1	526	8	42·6	231	98·4
2	169	8	13·5	234	31·6
3·1	201	8	16·1	159	25·6
3·2	29	8	2·3	211	4·9
3·3	331	8	26·5	147	39·0
4	268	8	21·4	133	28·5
5·1	114	8	9·1	125	11·4
5·2	94	8	7·5	121	9·1
5·3	95	8	7·6	118	9·0
5·4	13	8	1·0	159	1·6
6·1	330	8	26·4	131	34·6
6·2	294	8	23·4	100	23·4
6·3	49	8	3·9	126	4·9
6·4	24	8	1·9	95	1·8
6·5	69	8	5·5	94	5·2
7·1	178	8	14·2	111	15·8
7·2	134	8	10·7	119	12·7
8·1	833	8	66·6	87	57·9
8·2	30	8	2·4	116	2·8
9·1	282	8	22·5	84	18·9
9·2	23	8	1·8	64	1·2
9·3	29	6	1·7	91	1·5
9·4	1	8	0·1	116	0·1
10·1	271	8	21·7	83	18·0
10·2	6	6	0·4	90	0·4
11·1	9	8	0·7	83	0·6
11·2	46	8	3·7	83	3·1
12·1	131	8	10·5	83	8·7
12·2	109	8	8·7	83	7·2
12·3	46	8	3·7	83	3·1
12·4	282	8	22·6	83	18·8
12·5	1,963	8	157·0	50	78·5
				Total:	578·3

*Hours per shift.
†Hours per occupation.
‡Particle-hours per occupation.

the silicosis incidence of the present European labour force, but the relationship between the dust exposure of a person in general and his degree of silicosis. Nevertheless, the factors and the direction in which they could cause the composition to deviate from that of the existing European labour force are of interest, and they will be considered here.

(a) *Death* was the prime selector! The cause of death did not matter. It could be anything and *none* died from silicosis. A bias with respect to condition of the lung is, therefore, excluded, but the workers employed on the more dangerous occupations probably stood a better chance of being included than other underground workers.

(b) The second factor was the fact that the next-of-kin might receive increased (but not decreased) compensation as a result of post-mortem examinations where the deceased had in life not yet been certified to be in the second stage (and the consent of the next-of-kin was necessary for such examinations). Decreased compensation is not possible, because even if the deceased is at post-mortem found in a stage less advanced than he was in life certified to be, the compensation rate remains at that for the more advanced stage.

(c) The compensation factor also acted

in another way, viz., on account of the possibility of increased compensation to the next-of-kin, preference is given to post-mortem examinations on cases who were in life not in the second* stage of pneumoconiosis. This is done to cause the least possible delay in the payment of increased compensation where due.

Factors (b) and (c) were probably responsible for the stage reached during the investigation that, when 51 cases qualified for inclusion, only two cases were beyond the second stage.

It was then decided to specially select from there onwards, only cases beyond this stage. Only six cases could be found within the time at my disposal.

4. The Results Obtained

The results obtained are given in Table VII and depicted in Fig. 4. As can be seen there is a very wide scatter and in order to test the association between silicosis and dust exposure, the results were analysed statistically.

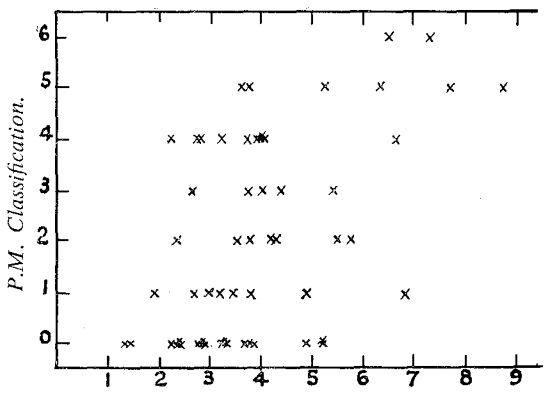


FIG. 4.

Silicosis vs. Konimeter particle hours.

5. Statistical Analysis

Random Theory: A question that arises in connection with the sample selected is whether random theory holds. To provide the answer to this question, the method of obtaining the sample will be restated briefly: I set up a " screen " for a certain period. *All* the cases which passed the screen were included. This gave cases No. 1 to 51. Only 2 out of these 51 cases were beyond classification " 4 " on the Pathologists' scale. The screen was then altered so as to include only cases beyond this stage from there onwards. These cases naturally had to satisfy all the other conditions previously laid down.

This produced the final six cases, viz., Nos. 52 to 57.

As explained before, the sample selected is most probably not representative of the composition of the underground European labour force, neither with respect to class of worker nor with respect to the prevalence of silicosis.

However, the sample may be subdivided into *classes* with respect to silicosis, and as far as I can judge, the dust exposures in each class is a random sample of the population of dust exposures of that class. Furthermore, the dust exposures appear to be normally distributed because the cumulative frequency distributions of the dust exposures plot on fairly straight lines on probability paper.

Random estimation theory was, therefore, assumed to hold and the association between silicosis and dust exposure, was assessed by using the variance ratio test [28] (on the advice of Prof. Kerrich). The calculations are given in Table VIII.

The variance ratio test compares the variance *between* classes with the variance *within* classes. As there are 57 observations that can be cast into 7 classes, there are 50 degrees of freedom *within* classes, and 6 degrees of freedom *between* classes.

The variance between classes comes to 9·32, and the variance within classes comes to 1·71. The variance ratio is, therefore, 5·45. For 6 and 50 degrees of freedom the variance ratio is 4·93 for the 99·95 per cent. level. The variance ratio, therefore, reaches beyond the 99·95 per cent. level which is very, very significant.

For purposes of comparison, the association between silicosis and years of service, between silicosis and underground shifts and between silicosis and the estimated underground hours, were also assessed in the same manner as described for particle-hours,

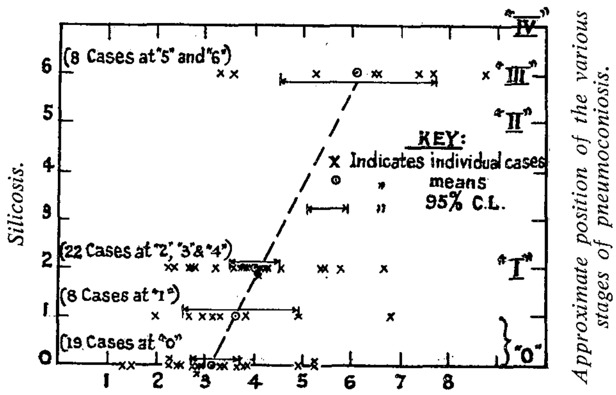
* Full compensation is paid to the next-of-kin from the second stage onwards.

TABLE VII

The Results Obtained

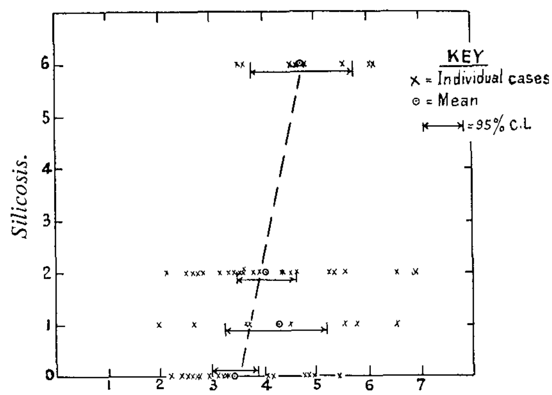
Observation No.	Years Service	UGD Shifts (1,000's)	UGD Hours (10,000's)	Particle Hours (Millions)	P.M. Finding	Bureau Certification
1	11·8	2·84	2·27	2·44	0	0
2	21·0	5·65	4·52	6·52	6	III
3	21·1	5·97	4·77	3·22	0	0
4	15·7	3·97	3·17	3·24	4	I
5	12·3	3·02	2·17	2·22	4	I
6	28·9	8·24	6·59	6·82	1	I
7	17·2	4·63	3·71	2·98	1	0
8	20·6	3·18	2·55	1·32	0	0
9	14·9	4·76	3·81	3·55	2	I
10	20·8	5·55	3·42	2·36	0	0
11	19·9	4·56	3·66	3·43	1	0
12	31·8	7·34	4·17	3·95	0	I
13	23·3	6·61	5·29	3·82	2	I
14	26·4	6·99	5·58	5·78	2	I
15	29·0	7·97	5·41	5·24	0	0
16	27·3	7·24	5·79	4·97	1	0
17	23·1	5·00	3·26	2·28	0	0
18	12·6	3·20	2·55	2·86	0	0
19	16·9	4·45	3·56	4·01	4	I
20	28·8	8·20	6·56	5·39	3	I
21	17·9	4·21	2·95	1·49	0	0
22	13·8	3·42	2·73	2·41	0	0
23	15·0	4·11	3·28	2·95	0	0
24	19·6	5·77	4·60	4·54	3	I
25	21·0	4·56	3·65	4·03	3	I
26	25·1	6·67	5·33	6·68	4	I
27	15·4	3·36	2·69	2·79	4	I
28	20·4	5·71	4·55	4·03	4	I
29	16·9	4·54	3·59	4·22	2	I
30	17·5	4·94	3·93	3·78	3	I
31	14·7	3·48	2·78	2·86	0	0
32	27·5	7·88	5·52	3·45	1	I
33	14·9	3·90	3·11	3·25	0	0
34	16·5	4·47	3·21	3·34	0	0
35	21·7	7·23	5·04	4·95	0	0
36	27·6	6·84	2·74	3·73	4	I
37	19·8	5·52	4·32	4·09	4	I
38	19·0	4·32	3·46	3·82	0	0
39	18·3	4·32	3·45	3·91	4	I
40	14·1	3·59	2·87	2·76	4	I
41	13·8	3·13	2·51	2·64	3	I
42	19·5	4·23	2·67	2·67	1	0
43	15·0	3·39	2·00	1·99	1	0
44	25·7	6·80	5·44	5·28	5	II
45	15·2	5·45	4·36	2·34	2	I
46	26·2	8·71	6·97	5·50	2	I
47	21·0	6·21	4·50	3·83	1	0
48	21·5	4·65	3·33	4·29	2	I
49	25·7	7·00	4·90	3·69	0	0
50	22·8	5·40	2·58	2·77	0	II
51	25·8	5·68	4·09	5·23	0	0
52	19·7	4·45	3·56	3·76	5	II
53	27·0	7·57	6·06	7·39	6	IV
54	27·2	6·97	5·58	7·76	5	II
55	30·3	7·83	6·15	8·76	5	II
56	20·3	5·43	3·60	3·60	5	II
57	23·1	6·04	4·85	6·38	5	III

but the levels of significance reached, were much lower than that for particle-hours. For silicosis versus underground hours, the 96 per cent. level was reached which is, therefore, just significant; for silicosis versus underground shifts, only the 80 per cent. level was reached, whilst for silicosis versus underground years, only the 60 per cent. level was reached. (Compare Figs. 5, 6, 7 and 8.)



Particle-hours in millions.

Fig. 5. Particle Hours.



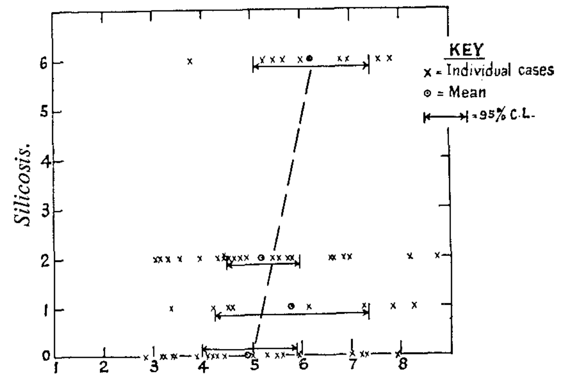
Number of hours underground in ten-thousands.

Fig. 6. Hours.

Part VI: Concluding Remarks

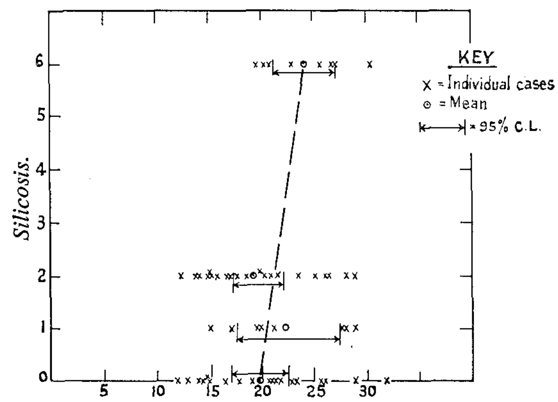
1. (a) *The instrument*

In view of the strong association between degree of silicosis and particle-hours, there is no need to replace the konimeter with another instrument before a significantly closer association can be established between degree of silicosis and dust exposure, as based on the results actually recorded or else very likely to be recorded during *routine* rust sampling with the other instru-



Number of shifts in thousands.

Fig. 7. Shifts.



Years of service.

Fig. 8. Years.

ment. I wish to make it clear, however, that I do not mean to say that there is no need for experimentation to try and find a better instrument.

(b) *The method of treatment*

What applies to the instrument also applies to the method of treatment of slides.

2. *Application*

What is really needed is the association between given dust exposure and degree of silicosis, but this is not readily obtainable in practice. However, as a given degree of silicosis has been found to be strongly asso-

TABLE VIII

Variance Ratio Test for Particle-Hours

P.M. Classification	Particle hours in millions	n	Σx	$\bar{x}$	Σx^2	$n\bar{x}^2$	$\Sigma(x-\bar{x})^2$	s^2
0	2·44 5·24 2·95 3·82 3·22 2·28 2·86 3·69 1·32 2·86 3·25 2·77 2·36 1·49 3·34 5·23 3·95 2·41 4·95	19	60·43	3·181	214·4373	192·4186	22·0187	1·223
1	6·82 2·67 2·98 1·99 3·43 3·83 4·97 3·45	8	30·10	3·790	129·5190	114·0790	15·4400	2·2057
2	3·55 5·50 3·82 4·29 5·78 4·22 2·34	7	29·50	4·204	132·5414	124·3214	8·2200	1·370
3	5·39 2·64 4·54 4·03 3·78	5	20·38	4·076	87·1626	83·0689	4·0937	1·0234
4	3·24 4·03 2·22 3·73 4·01 4·09 6·68 3·91 2·79 2·76	10	37·46	3·746	153·7002	140·3252	13·3751	1·496
5	5·28 3·60 3·76 6·38 7·76 8·76	6	35·54	5·923	232·6356	210·5034	22·1322	4·426
6	7·39 6·52	2	13·91	6·955	97·1225	96·7441	0·3794	0·379
		57	227·38	3·989	1,048·6052	907·0188	85·6591 141·5864	(S.S.D. within) (S.S.D. between)

df	*S.S.D.*		s^2
6	Between classes	55·9273	9·321
50	Within classes	85·6591	1·713 = 1·333²
56	Total	141·5864	

$v^2 = 5{\cdot}445$ (6,50 d.f.)

(compare with 4·93 at 99·95% level) [29]

ciated with the particle-hours, the opposite must follow, viz., that a given number of particle-hours must be strongly associated with the degree of silicosis.

In view of the *wide* scatter of particle-hours for a *given* degree of silicosis, it will not be of much practical value to attempt the prediction of the degree of silicosis in *a person* from his particle-hour exposure as estimated in this investigation. Nevertheless, the *mean* particle-hours obtained for a given degree of silicosis may serve as a useful guide to aim at in order to keep the *mean* degree of silicosis in a *population* of workers below a certain level.

The mean relationship obtained (see figure 5) reveals that if it is requred to prevent the *mean* degree of silicosis in a *body of men* from getting beyond that at which the *mean* certification is likely to be for pneumoconiosis in the first stage, the *mean* dust exposure should not get beyond about 4 million particle-hours.

Example:

An example calculated from the figure of 4 million particle-hours to contract pneumoconiosis in the first stage is of interest.

Take developers. The estimated mean dustiness per shift of a developer (by 1955) is about 100 p.p.c.c.

At 8 hours per day and at 290 shifts per year, it will, therefore, take a developer under present-day conditions about 17 years to accumulate 4 million particle-hours (if he always remains on development).

A person cannot start as a developer right from the first shift, because experience in the " miscellaneous " class of work is essential, where the dust exposure is less than that as a developer. This will lengthen the period to accumulate 4 million particle-hours of dust exposure towards, say, 20 and more years, which figure compares favourably with that found in practice.

3. *Records of Service*

In view of the significant association obtained between degree of silicosis and underground hours, it is recommended that the underground hours per shift be added to records of service in future and, furthermore, that the feasibility of arriving at the mean dustiness per shift via routine dust sampling by mine ventilation officers and of also recording this figure on the records of service be investigated. (This, I believe, is done for coal miners in West Germany.)

With such a procedure, it would be possible to detect persons who accumulate dust exposures undesirably rapidly. Steps could then be taken to retard their dust exposure accumulation rate. This could be achieved in a variety of ways such as: reducing the dust levels of their working places, moving them to working places with lower dust levels, getting them to use dust protective equipment, shortening their underground shift, reducing the number of their underground shifts per week and so on.

4. *Recorded annual means*

The value of the mean dust counts recorded in the Government Mining Engineer's Annual Reports would be greatly enhanced if the observations taken where conditions were suspected or known to be bad, and those taken where conditions were suspected or known to be good, such as those taken to check that improvements called for had been effected, were kept seperate from those taken at random.

The value of the records would be further enhanced if the confidence limits to the means could be given.

In conclusion, Mr. President, I wish to express the hope that this investigation will help to reduce the number of persons contracting silicosis in years to come.

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Contribution to Mr. du Toit's Paper by D. G. Beadle

For many years I have been convinced that one of the major problems to be solved in connection with silicosis is to establish the relationship between the amount of dust breathed and the effect of this dust on the human lung. This was a view widely held at the recent Pneumoconiosis Conference in Johannesburg, which recommended further work on the subject. It forms the basis of the elaborate Pneumoconiosis Field Research in Great Britain and the "Occupational Dust Sampling" project in which I am assisting the South African Pneumoconiosis Research Unit.

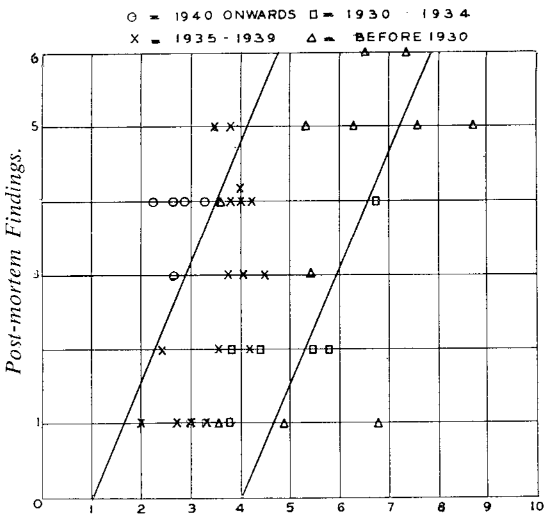
Only when we have this information established on a scientific basis will we be able to set scientific standards of dust levels to be aimed at as, at present we do not know, even if we do achieve the arbitrarily set standards to which we try to work, whether pneumoconiosis will be prevented.

In selecting a subject for his thesis—on the attainment of which I want now to formally congratulate him—Mr. du Toit very courageously selected this field. I say courageously because it is a very complicated field, full of frustrating pitfalls and often complete blanks in our knowledge; it also requires a tremendous amount of work to handle the data one accumulates. I imagine Mr. du Toit must have spent many hundreds of hours of his spare time making the numerous calculations involved in obtaining the results which he had, of necessity, had to quote so briefly today.

Mr. du Toit has obviously had to face up to many difficult decisions while carrying out this work. For example, who would care to have to predict what the dust concentrations were in development ends in say 1928, as they would have been if measured by present-day konimeters and present-day techniques? I have made a detailed study of Mr. du Toit's full thesis, and I would like to place on record that, in matters such as these, Mr. du Toit has made decisions which cannot be seriously challenged. He may not have always obtained the correct figures, but I do not think anyone could have made better estimates.

He has described the methods he used, and I have no constructive comments to offer on them. I must confess, however, that I remain extremely sceptical of his ultimate claim that his work shows " there is a strong association between degree of silicosis and konimeter particle-hours." I do not think this claim is warranted by the graph he has displayed. I do agree that when he plots " particle-hour " against post-mortem findings he obtains a *better* correlation than when he plots shifts or hours, but I know that several of our local statisticians do not agree it is a *strong* correlation. His data undoubtedly shows that putting in the konimeter count does improve the relationship but nevertheless there is such a tremendously wide scatter in the data that one must reserve judgement on the actual value of the correlation.

For example, 5 million particle hours can lead to anything from no silicosis to stage 5.



Particle-hours in millions.

Mr. du Toit has been kind enough to let me have access to his detailed calculations and to copies of some of the basic data. I have examined this in some detail, and can take the results a little further. In this figure I have replotted his data in a slightly different form, the important change being that the years in which the men started their mining careers are identified. One sees at a glance that this is one factor which has a tremendous influence on the data. All those men who contracted silicosis with very short dust exposures are those who joined the industry very recently; those who tolerated a much greater dust dose before developing a given stage of the disease are the " old-timers " who started before 1930. This shows that konimeter particle-hours is *not* by any means the only factor involved.

There can be various explanations for this effect. To suggest a few only—

(i) Men entering the industry in the period 1940 onwards were far more susceptible to the disease—did the demands of wartime lead to a relaxation of the standards set by the Bureau for new admissions to the industry ?

(ii) Mr. du Toit's dust data for the various years might be wrong. Perhaps there has been much more dust since 1940 than he allowed for, and perhaps there was less in the pre-1930 days than the figures he used. Adjustments in this direction would improve the " fit " of his points very greatly.

(iii) The konimeter may not be measuring the dust correctly. Mr. du Toit's time graphs show that the konimeter dust counts decreased significantly with time, but the fit of this data shows it does not fully account for the variations in disease. The konimeter is very sensitive to coarse dust, and possibly this is the only type of dust which has been reduced over this period; possibly the amount of fine dust—which is more dangerous—has not been decreased; it may even have increased. One can easily explain by this hypothesis this " date-of entry " effect I have demonstrated.

(v) Possibly men vary greatly in their susceptibility to equal dust dosage. Perhaps the post-1940 entrants in Mr. du Toit's data represent highly susceptible men and he has been left with only the most resistant men of the pre-1930 entrants.

I do not know if one of these, or some other explanation, is the true reason for the effect I have demonstrated. All I can say at this stage is that factors other than konimeter count must have a big influence to account for the scatter in the data.

Mr. du Toit quite rightly says that any decision to replace the konimeter should depend on whether improved apparatus will show a significantly better relationship. I have applied the data we have obtained to date in our occupational dust sampling project to Mr. du Toit's data, and we can claim that the fit of our thermal precipitator data is better than the fit of our konimeter figures, but we have insufficient data to warrant any decision being made at this stage. Whichever parameter we use to plot against the post-mortem finding we still get a very large scatter in the points.

I might add that our konimeter values obtained by actual measurement of the average daily dust exposures of different occupational groups do not agree very well with some of Mr. du Toit's assumed figures for the present day. For example, he assumes that underground foremen artisans have a present-day average dust exposure of 60 p.p.c.c. I agree that this class of men normally works in or near intake air just beyond shaft bottom, but Mr. du Toit's figure assumes that they do not create much dust themselves. In practice these men, particularly fitters, create quite a lot of coarse dust, released from the material they work on, and the konimeter gives high readings when sampling such dust. Our actual observed figure for this class of men is that their average daily dust exposure, by konimeter count, is over 200 p.p.c.c. Mr. du Toit has said that men should not be exposed to more than approximately 4 million particle hours to have a reasonable chance of awaiting pneumoconiosis. On this basis most artisans should contract a similarly advanced stage of pneumoconiosis after about 12 years—I think this is far from the truth !

Incidentally, I strongly support his suggestion that individual dust exposure records should be kept for all underground personnel.

I think that before we can draw any valid conclusions from the data presented, or the data I myself have obtained to date, we must go very much more deeply into the whole problem. There are many uncertainties about the present figures—

(i) Are Mr. du Toit's 57 cases representative of the whole mining population ?

(ii) Is it correct to plot the six stages of pneumoconiosis on a linear scale, i.e., is the step from stage 1 to stage 2 equal to the step from say stage 5 to stage 6 ?

(iii) Can we draw reliable information from the cases who contracted pneumoconiosis within a very narrow time period ?

(iv) What about the many men who have already had long periods in dusty but have not yet contracted pneumoconiosis—will they not alter the whole picture when they become cases for study ?

(v) Has the best statistical technique been used to analyse this very complicated problem ?

We have a very wide field still open ahead of us in tackling the problem and much more work is needed before we can draw any valid conclusions. Although I am frankly doubtful whether Mr. du Toit's main conclusion can be substantiated at this stage I do sincerely congratulate him on his efforts. With the time and resources available to him he has done a magnificent job, but I hope he will agree that his effort is only a first " bite " at a very big apple. Mr. du Toit and I are working on parallel lines on this problem, but, unlike parallel lines, we do meet sometimes. We have had many stimulating discussions in the past, and I hope we shall continue to have them in the future. Mr. du Toit, I congratulate you on a paper and a thesis, which I have thoroughly enjoyed studying and which I consider a most useful contribution in a very important field.

Professor J. E. Kerrich

Mr. Chairman and Gentlemen, I should like to make the following comments on Mr. du Toit's paper.

Everybody knows that the dust in our gold mines causes silicosis among the miners. Yet no one really knows how much exposure to how much dust produces a given severity of the disease. Mr. du Toit set himself the task of trying to bridge this gap to some extent.

From the mining point of view he had

the individual miner's record of where he had worked and for how long and what type of work he had done. In addition he had government reports extending over many years on average dustiness at certain selected points in the mines, such as at the top of downcast shafts, at the bottom of downcast shafts, at stope faces, and so on, where dustiness was assessed by particle counts with a konimeter.

From the medical point of view Mr. du Toit had the actual state of the lungs for 57 deceased miners as assessed by post-mortem findings. Informed opinion made him doubt the value of the X-ray assessments of the state of the lungs. He preferred to wait until he had data on actual post-mortem findings and it took him three years to obtain as many observations as he did. A distressingly small sample? Admittedly, but nothing can be done about it, for a long time to come.

From the post-mortem findings each man was classified as belonging to one of seven arbitrary but carefully defined groups, representing medical opinion as to the progressive severity of the disease.

From the miner's record it was a comparatively simple matter to obtain (a) years of service underground, (b) thousands of shifts worked and even (c) ten thousands of hours underground. From the individual miner's record, plus government reports on average dustiness it was possible to estimate (d) his total exposure to dust in millions of particle-hours. A laborious business in each case.

Next the post mortem rating was plotted against (a), (b), (c) and (d) in turn. *In the sample* there is practically no association between rating and years of service, or between rating and shifts worked; there is slight association between rating and hours underground, and well marked association between rating and particle-hours.

What generalisations can be made from these results. What population does this sample come from and what does the sample tell us about the population from which it is drawn?

Mr. du Toit has laid down a method of obtaining observations from a population. In principle, he can obtain more and more of these observations. They come from a somewhat macabre " population " of dead miners whose dependants hope to obtain additional compensation as a result of the post-mortem findings. I shall term it the post-mortem population.

Two fundamental questions which must be sharply distinguished are:

(A) Is this sample a random sample from the post-mortem population?

(B) How closely does the post-mortem population resemble of the mining population as a whole?

Under A: In the sample Mr. du Toit could, and to some extent did preassign the post-mortem ratings. He could and did ask the doctors to pick out and examine lungs which were obviously badly affected. The result is that in the sample, the observed percentages of miners with ratings 0, 1, 2, etc., are *not* unbiased estimates of the corresponding percentages in the post-mortem population.

The results of this fact can be very important. Take an imaginary example, crude and over-emphasised to drive my point home:—

For miners with number of particle-hours lying between, say, 3 or 4 millions, the situation *might* be as shown at the top of the next page. Thus in the sample the average rating for those with the given number of particle hours would be 4·15; in the population it would only be 1·85.

Now, the basic question we want answered is, when we know from his record a miner's particle hours, what is the state of his lungs? And the estimate obtained from Mr. du Toit's sample is biased, to an unknown amount. I do not believe that this bias is anywhere near as startling as in the distorted example I have given, but the blunt fact is that it is there and it is unknown.

On the other hand, in the sub-group from the sample consisting of those who have a particular post-mortem rating, say, 2, Mr. du Toit had no control over each individual's measures (a), (b), (c) and (d). Within each sub-group I can see no reason to doubt that such measures are distributed at random and accept his estimates of the average value of, say (d) within each sub-group of his post-mortem population. If his confidence intervals for these results are wide it is because his sample was unavoidably small: but he has enough information to show that

	Anemometer Rods								
Rating	0	1	2	3	4	5	6		
Per cent. in sample	5	5	10	10	20	20	30	:	Total 100 per cent.
Per cent. in population ..	30	20	20	10	10	5	5	:	Total 100 per cent.

that his measure of particle-hours for the individual is associated with lung condition. I for one doubted originally if this could be done, and congratulate him heartily on his result.

Under B: Here I speak as a layman, but I think we are agreed that the post-mortem population is not quite representative of the mining population as a whole and do not know quite how this should affect our judgements.

In conclusion, in spite of minor criticisms, I think this is a valuable paper. I suggest that the next step should be to compare particle hours with a random sample of radiological estimates of lung condition, and would be interested to hear other people's opinions on this suggestion.

ANEMOMETER RODS

By B. J. R. Botha* and P. J. Finn*

Introduction

It is an accepted fact that comparatively large errors can be caused in some cases by holding an anemometer by hand (without a rod) in an airstream.

These errors arise from the following causes:—

1. Interference to the air flow through the anemometer caused by the observer's hand an arm. It should be remembered that when anemometer calibrations are carried out the anemometer is held in position by means of suspension wires and not held by hand.
2. Interference to the general pattern of air flow at the measuring station in small airways due to the presence of the observer's body.
3. Difficulty of achieving the principle of traversing equal areas in equal times. This difficulty is at its greatest in large airways and in awkwardly shaped airways.
4. Difficulty of maintaining the anemometer at right angles to the direction of the airstream (angle of yaw).

There are few cases where the provision of a well designed anemometer rod attachment will not enable the observer to do the job more easily, accurately and safely.

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Anemometer Rod for General Mine Ventilation Work

A rod for normal mine work should be light, portable and reasonably robust. It should provide variable rod extension lengths and be provided with a " swivel head " in order to enable the anemometer to be set at an angle to the rod. It should also be so designed that the rod attachment point to the anemometer casing is at the same position as the anemometer control lever.

Figure 1 illustrates such a rod. " A " shows the component parts of the rod. At the top left hand side can be seen the " stick end plug." This piece is 4 in long.

Then follows a 3 ft rod (or rods) manufactured from $\frac{3}{4}$ in diam. aluminium tubing with brass fittings at each end for screwing rods together.

Lastly, the " swivel head " fitting is seen. Note that this fitting has been designed so that the threaded spigot end (for attachment to anemometer) can be tucked away safely inside the " swivel head " body for protection when in transit underground.

When the three pieces as shown at " A " are screwed together the rod is ready for transport and has no screw threads exposed to possible damage.

On arrival at site the spigot end of the " swivel head " is swung out (see " A ") and the rod is then ready for attachment to the anemometer. This is achieved by screwing