The functional relationship between dust hazard and the rate of collecting funds to pay compensation for pneumoconiosis

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Discussion:

T. L. Gibbs,* (Honorary Vice-President and Fellow): In terms of the Pneumoconiosis Compensation Act of 1962, a Pneumoconiosis Risk Committee was established whose function it is to estimate (by whatever means the committee deems fit) in respect of every controlled mine the pneumoconiosis risk to which persons employed in a dusty atmosphere at that mine are exposed. In estimating such risk the committee may estimate different risks in respect of individual mines or parts of mines or classes or groups of mines or occupations or localities at mines. The pneumoconiosis risk may be reviewed and re-estimated at any time.

The Act provides further that the General Council for Pneumoconiosis Compensation shall apportion the levy imposed on owners of controlled mines on the basis of the pneumoconiosis risk determined by the risk committee and the numbers of persons employed in a dusty atmosphere.

The task of the risk committee is a most responsible one and also a very difficult and complex one in view of the many different types of mines, rock formations, dust conditions, etc. Quite obviously, comparisons between mines cannot be made on dust concentrations alone as different mineral dusts have different toxicity or pneumoconiosis response factors. However, with its present knowledge, the risk committee is satisfied that the risk at mines, other than coal mines, is related to the mean quartz-equivalent dust concentration to which persons are exposed and the estimation of risks is based on this relationship.

From the above, it will be clear that the work done by Dr du Toit on the problem of basing the current rate of levies to provide for pneumoconiosis compensation on the current dust hazard at mines has been of immense value to the risk committee.

Up to now the risk committee has not been able to obtain complete and accurate information on the dust exposure of persons at all mines — and, in fact, it is doubtful whether it will be economic or practicable to obtain this in the foreseeable future — but reasonable assessments have been possible from routine dust sampling in some cases and from periodic comprehensive dust surveys in others. As a temporary measure the risks of some mines were estimated initially on a group basis relating to average dust conditions and the type of rock and mineral mined, but as more information became available, differentiation between individual mines became possible. It is the aim of the risk committee to eventually apply such a differentiation in all cases and to ensure that within the bounds of practicability each mine pays for its risk and for its risk only. In this connection, the relationship between the levies and the amounts actually paid out in compensation are examined regularly.

In conclusion, I wish to add my congratulations to the author on his excellent paper. His findings will assist materially in the just administration of that very important piece of beneficial legislation, the Pneumoconiosis Compensation Act.

G. K. Sluis Cremer MD† (Visitor): Dr du Toit has made a valiant attempt to relate dust hazard and the rate of collecting funds for the purpose of paying compensation for Pneumoconiosis. In doing so he has had to make a number of assumptious, some of which touch on the medical aspects of pneumoconiosis. It is worth discussing whether these assumptions are justifiable.

Pneumoconiosis is defined in our Pneumoconiosis Act as permanent disease of the cardio-respiratory organs which is caused by the inhalation of mineral dust. To a non-medical person this definition has probably a clear cut meaning. The doctors however have to deal with such conditions as silicosis and asbestosis where there is a well defined dose response relationship to the inhalation of quartz and asbestos respectively and on the other hand chronic bronchitis where the relationship to dust inhalation is poorly defined and where certainly no clear dose response relationship has emerged after many investigations in this country and overseas. Nevertheless since 1953 about half of our certifications for Pneumoconiosis are on the grounds of chronic bronchitis i.e. the X-rays show no evidence of silicosis, asbestosis or other relevant disease. This fact must affect Dr du Toit's computations.

The next assumption we should examine is the manner in which toxicity factors have been allocated to the various mineral species. These allocations have in part been based on a restricted number of animal experiments carried out overseas but mostly in South Africa by Webster at the Pneumoconiosis Research Unit. To extrapolate the findings in a relatively small number of animal experiments to the expected reactious in man is a notoriously dangerous exercise.

Furthermore the bracketing together of all silicates (except asbestos) and the insoluble metal oxides is entirely unacceptable.

Talc (a hydrated silicate of magnesium) and muscovite mica (a silicate of aluminium and potassium) cause pneumoconiosis in their own right. On the other hand

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vermiculite (a hydrous silicate of aluminium, iron and magnesium), norite (a mixture of plagioclase and hypersthene — both complicated silicates), pyroxenite (silicate of iron, magnesium and calcium) are all examples of mineral dusts to which our miners may be exposed to in some of our mines but which on present evidence are not known to cause any reaction in the lungs in man or in experimental animals.

Sillimanite (aluminium silicate) and kimberlite (a mixture of silicate and non-silicate minerals) cause tissue reaction in the lungs of experimental animals but no human case of pneumoconiosis has yet been identified as resulting from the inhalation of these dusts.

It is difficult to understand why all acid soluble particles are allocated no risk at all.

Iron oxide both hematite (Fe_2O_3) and magnetite (Fe_3O_4) are acid soluble and yet cause pneumoconiosis. Sometimes this is benign but under some circumstances it is disabling and progressive and probably associated with a lung cancer risk as well.

As far as insoluble metal particles are concerned which are all allocated a toxicity factor of .2. Chromite ($Fe Cr_2O_4$) and cassiterite (SnO_2) cause pneumoconiosis which is definitely benigh, not disabling and not progressive.

Manganese oxide inhalation is sometimes associated with a high incidence and mortality from pneumonia but no pneumoconiosis is caused. Vanadium pentoxide is irritant to the upper respiratory tract but causes no pneumoconiotic changes in the lungs (i.e. no permanent disease).

Nothing is known about other metal oxides and this is also the case about the metal carbonates and sulphides.

As far as combustibles are concerned pure carbon can definitely cause pneumoconiosis and as far as Dr du Toit's suggestion that pneumoconiosis due to coal is not progressive the evidence is that in the more advanced grades it definitely is progressive even in the absence of further dust exposure.

Dr de V. Lambrechts* (Fellow): Dr du Toit must not take exception when I say that he has made the best of a bad job. It was necessary, I think, that somebody should tackle the almost impossible task of trying to quantify the relationship between dust and money collected and money paid out. I myself worked in this direction about 25 years ago and came to grief, in the face of so many imponderables. Dr du Toit, however, has in my opinion, achieved a large measure of success in spite of the fact that much of the evidence he was able to piece together unavoidably rested on frail foundations. This was not his fault and his thesis was as good as anybody could have made it under the circumstances; it was a case of "where needs must the devil drives."

Over the years, methods and standards of dust assessment changed several times; actual dust levels changed; medical diagnostic techniques improved; legal standards for certification changed several times; and there were other variables. Yet, out of all this confusion the author has managed to piece together what appears to be a workable formula deserving of practical implementation.

Towards the end of his paper the author very modestly refrains from suggesting that the authorities should implement his findings. I can see no reason, however, why serious thought should not be given to the framework which Dr du Toit has established, and actuaries might well take note.

This does not mean to say that further enquiry should not be made into the structure of the author's formulae, resulting possibly in some modification. I would like to comment on one such modification. This concerns mainly Table 5.1, Fig. 5.1 and Table 7.2 and specifically the relationship between dust index (d) and exposure time (t)

When one is faced with a mixture of "bad" and "good" estimates in any situation, it may be better to discard the bad ones and concentrate on the good ones, maybe only the single "best" estimate. This philosophy, I think, is applicable in the case of the author's Table 5.1 and Fig. 5.1. His straight-line curve in Fig. 5.1 (log scales) is highly dependent on what might well be the two most unreliable estimates, namely groups 4 and 5 (asbestos and coal dust respectively). Take away these two and the slope of a statistical "best fit" line could be almost anything.

On the other hand, Group 2, (Gold A, 1936-1963) probably provides by far the most reliable estimate of both exposure time and dust index. Here it is surprising that the author should have used a figure of 147 q.e.p.p.c.c. when he himself mentioned another figure of 182 q.e.p.p.c.c. on page 301 (Author's Reference 30 and 31). The latter was based on what must surely be the most reliable dust surveys yet made in the gold mining industry in this country namely the P.R.U. survey (1963), and confirmed by the Chamber of Mines Survey (1964/65). Why then not use an exposure time t of 25 years and a dust index d of 182 q.e.p.p.c.c. as the best estimates of these two parameters and pivot the straight line around this point so that $td = 25 \times 182 = 4\,550$? This is what I have done in the accompanying revised Fig. 5.1.

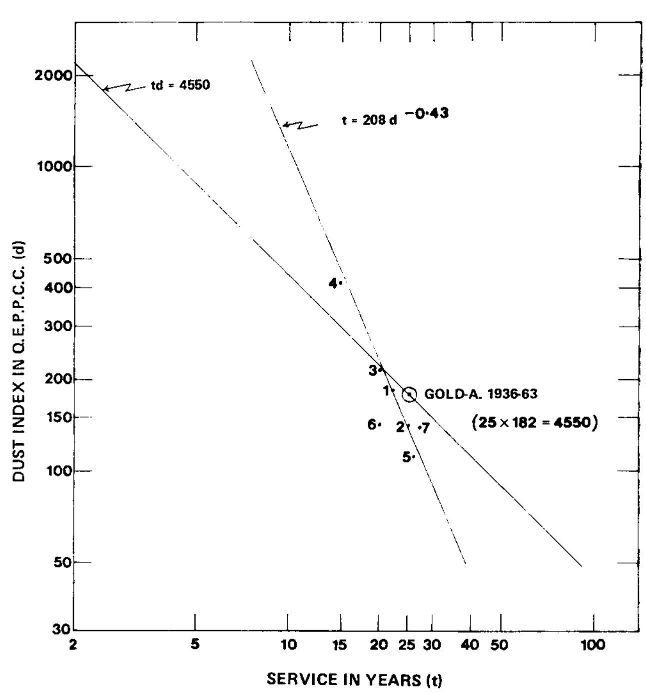

Fig. 5.1 (revised)

The reasons for regarding Group 2 as the most reliable are:

(i) A substantial number of Cases (527);

(ii) Smallest standard deviation in exposure time (6.1);

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(iii) Fairly steady dust level 1936-1963 (Fig. 4.1).

(iv) Most reliable dust surveys (P.R.U. and Chamber, 1963-65).

My proposed t/d curve in Fig. 5.1 (revised) of course implies that within limits, total dust dosage in particle years is the important parameter whereas Dr du Toit tries to make a rather dubious distinction between progressive and non-progressive pneumoconiosis. I prefer to make no distinction and to use the simpler concept. The other groups in the author's Table 5.1 can be made to fit the proposed new curve by relatively small adjustments to the relative toxicity scale on page 297 of the paper, whilst keeping quartz at unity.

Finally then, whilst supporting the author in his derivation of Equation 7.1, I would favour the idea of substituting exposure time (t) by 4 550/d and not differentiating between progressive and non-progressive types of pneumoconiosis.

J. E. Kerrich* (Visitor): I have watched the author work at his problem for many years and am deeply impressed by his dogged perseverence. It has been very uphill work. Look for instance at Fig. 2·2., giving proportion of new cases of pneumoconiosis per annum, and note that the legal definition of the disease has been changed five times in forty-five years. It is hard to construct a solid edifice on shifting sands. Nevertheless Dr Du Toit has collected an immense amount of numerical information, explained it, collated and criticised it and wherever possible analysed it in a way that has never been attempted before.

Much interesting information is given in Section 3.

For mines of Group A, for the period 1946/47 to 1950/51 we are given a picture of

(i) the distribution of white persons employed in dusty atmospheres by years of experience;

(ii) number of new cases of pneumoconiosis certified and years of exposure when certified.

The author stresses that t = mean length of exposure prior to being certified for the first time is the only pneumoconiosis index that is common to a number of other populations at risk and is perhaps the result of most practical value obtained in this section.

No mention is made of the age of the man when certified. Has this age been found not to affect the value of this index?

I note that the value of this index does depend on the presence of a few men with long exposure in the work force. Thus, in Table I only 2½% of those examined had over 25 years of exposure, but accounted for 31% of new cases. *If*, after 25 years of experience, these *few* men had decided to leave the mines, mean exposure prior to certification would drop from 21·8 years to 18·4 years, while conditions underground remained unaltered. This result lowers my confidence in the comparisons of mean exposures made in Table 3·6.

In section 4 measures of dust concentration are dealt with; estimates of the relative toxicity of various types of dust are introduced, together with the idea of quartz equivalent p.p.c.c. and we end up with Table 4·3 which gives dust indices in q.e.p.p.c.c. for the same types of mines as are shown in Table 3·6. I am not surprised to hear that some disagreement exists as to what numerical values should be allocated to relative toxicities.

In Section 5, an attempt is made to relate d = dust index in q.e.p.p.c.c. to t = mean exposure prior to certification using the data given in Table 5·1. It appears that a formula of the type $\log t = a + b \log d$ represents the data fairly well.

In principle I applaud this effort wholeheartedly. It is common cause that dustiness produces pneumoconiosis but this is the first formula I have seen that attempts to connect a measure of dustiness with a measure of the physical effects of dustiness.

As regards the trustworthiness of the data and the method of "fitting the formula":

For observations of t, information is given which enable us to estimate $s(t)$, the standard deviation of t, and hence obtain valuable information concerning the reliability of the given data. From standard formulae, estimates of $s(\log t)$ are obtainable.

For values of d no such information is given. Furthermore, these values depend on measures of the relative "toxicities" of various types of dust about which a considerable amount of disagreement exists. However, the best that can be done at present, when fitting a straight line to the data, is to *assume* that the values of d have much less uncertainty associated with them than have the values of t and then to fit the straight line by the method of *weighted* least squares assigning weights to the values of $\log t$ that are inversely proportioned to their standard deviations.

In his thesis, but *not* in his paper, the author states that this was the method that he employed.

I have checked his arithmetic and obtained essentially the same results as he did. So with $a = 2 \cdot 3181$ and $d = -0 \cdot 430$ we obtain the results given in the following table:

Class of mine	observed log(t)	estimated s.d. s(log t)	computed log(t)	obs.-computed
Gold A 27-49	1·3424	·0043	1·3411	+ ·0013
Gold A 36-63	1·3979	·0047	1·3927	+ ·0052
Gold B 33-53	1·3010	·0315	1·3110	— ·0100
Am.Asbestos	1·1761	·0236	1·1902	— ·0141
Coal	1·4150	·0123	1·4370	— ·0220
Copper	1·3010	·0512	1·3902	— ·0892
Diamond	1·4314	·0556	1·3950	+ ·0364

This shows more exactly (than in Fig. 5) that the point that lies closest to the line is the point that is most reliable. This answers a suggestion made by Professor Lamprecht in the discussion. It is also interesting to note that no observed value of $\log t$ is more than twice its corresponding value of $s(\log t)$ away from the line. This may be interpreted as showing that no sound statistical evidence exists for rejecting the line as a plausible form for the relationship between $\log t$ and $\log d$. Note, however, that one of the more reliable values of t, namely the one for Coal mines, is $1 \cdot 79\, s(\log t)$ away from the line. Is this a hint that the accepted value of toxicity for coal dust may need revision?

In Section 6, the author discussed the levying of funds for the payment of compensation. He begins by referring to the Act of 1962 and states that it embodies three principles:

(i) Money should be collected when the exposure to dust occurs.

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(ii) The money collected (and invested) should be just enough to provide the compensation required at the time when it fell due.

(iii) Each owner should pay for the damage caused on *his* mine.

These admirable principles envisage a type of sickness insurance scheme. Records for each miner, properly kept over a considerable period of time, will be required to run this scheme on a sound actuarial basis.

Fig. 6·1 gives official figures for annual sums levied and paid out in compensation for many years. Note the log scale employed. They are very intriguing. Why the wild fluctuations in levies between 1956 and 1969?

In Fig. 6·2 the author refers to Group B mines for Oct. '58 to March '62. He has sum L levied for *all races* and notes $L\%$ paid by each type of mine; e.g. $L\% = 12\cdot3\%$ for platinum mines and $39\cdot8\%$ for coal mines. He also has total sum C paid in *lump sum* compensation over the same period and notes $C\%$ paid by each type of mine; e.g. $C\% = 2\cdot5\%$ for platinum mines and $40\cdot1\%$ for coal mines, so that $L\%/C\% = 4\cdot92$ for platinum mines and $0\cdot99$ for coal mines. This shows, he claims, that platinum mines pay an unfair proportion of the total levy.

Is that necessarily correct? C is paid for *past* damage and L is collected to pay for *present* damage. If, during the period 1950-1960, (a) dust conditions had been fairly stable, but (b) the labour force in platinum mines had quadrupled, while remaining steady in coal mines, it seems to me that round about 1960, $L\%/C\% = 4$ or 5 for platinum mines might be quite fair. Others who have a knowledge of mining history that I lack will please comment on these ideas.

Continuing with section 6

Consider the j^{th} individual mine worker in a work force of W men. Suppose this individual will work for n_{ij} years is then certified and thereafter he (or his wife) is paid an annuity of C per annum for n_{2j} years. Every year until he is certified an amount L_j is to be levied and invested at $i\%$ per annum compound. The accumulated sum of these annual amounts L_j is, at the end of n_{1j} years to be just sufficient to provide the annuity C_j for the next n_{2j} years.

Formula 6·3 is the correct equation for obtaining L_j in terms of i, n_{1j}, n_{2j} and C_j for this jth individual.

For anyone who is given compensation in a single payment, $n_2 = 1$. If, after being certified, a man works on until debarred before he gets his annuity, the constants alter but the formula still holds.

At a particular moment of time a levy is to be made in connection with these W men. Of these an (unknown) number w will duly be compensated. Furthermore, a number W-w will leave the mines without any compensation. For them, no levy is required. Their C_j's are zero.

So for total work force W, total levy should be

$$L = \sum_{1}^{w} L_j = w\bar{L}$$

where $\bar{L}$ is the mean of the w individual levies.

Then, for this work force, mean levy per man

$$= \frac{w}{W}\bar{L} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

If I understand the author correctly, he claims that L/C or $\bar{L}/\bar{C}$ can be experessed by a *single* formula of the type given in 6·3 where C is the sum of the C_j (and $\bar{C}$ their mean) and the values of n_1 and n_2 used are some sort of average values of the n_{1j} and n_{2j}.

Mathematically this simplfication rests on an equation which can be satisfied by an infinity of pairs of values (n_1, n_2). Now, the author naturally wishes to choose a solution such that the values of n_1 and n_2 obtained can be meaningfully linked with the appropriate dust index via (5·1) and suggests taking n_1 as $\bar{n}_1$, the mean of the n_{1j} and n_2 as the mean of the n_{2j}.

Arithmetically, a rough check, using ten values of n_{1j} between 15 and 25, ten values of n_{2j} between 20 and 32, with C_j constant suggests that taking n_1 as $\bar{n}_1$ and n_2 as $\bar{n}_2$ produced an approximation to $\bar{L}$, that is about 10% too low.

A similar check, using values of n_1 between 10 and 15 and of n_2 between 15 and 25 gave a result that is about 25% too low.

Surely, (i) useful information concerning the distributions of n_{1j}, n_{2j} exists for various types of mines.

(ii) Guided by such information we should use a computer to simulate $\bar{L}$ for a wide variety of (hopefully) practical cases.

Furthermore, if these simulations are to be any guide as to the value of $\bar{L}$ in practical cases, we MUST take into account the facts that (a) Bantu mine workers are also compensated, (b) $n_2 = 1$ for a Bantu and (c) the Bantu have their own values of C_j. I stress this because the author's conclusions from formula 6·3 onwards appear to me to be based on white experience only. *Intrinsically*, these simulated values of $\bar{L}$ should be of interest. A *further* problem would then be to associate values of n_1 and n_2 with them that in turn can be meaningfully linked with appropriate dust indices.

We next require estimates of w/W. Such an estimate can be obtained as follows:

Suppose W_0 men enter the service together and could be observed until the last survivor leaves the service.

Their history could be tabulated as follows:

$x =$ years of service	number in service	number leaving service in a year	number certified for 1st time
0	W_0		
		$W_0 - W_1$	$f_0 = p_0 W_0$
1	W_1		
		$W_1 - W_2$	$f_1 = p_1 W_1$
2	W_2		
		$W_2 - W_3$	$f_2 = p_2 W_2$
3	W_3		
etc.		etc.	

Assume that

(i) A man leaves service when certified for the first time. (This is only one of many reasons for leaving the service.)

(ii) Conditions are "steady". That is, the same number W_0 enter service in each calendar year and $W_j - W_{j+1}$ is unaltered year by calendar year. Also, $p_j =$ probability that a man with j years of service is certified for the first time before completing $j + 1$ years of service remains unaltered.

Then, *at any moment of time* the work force W consists of W_0 recruits, plus W_1 survivors from W_0 who were recruits a year ago, plus W_2 survivors from W_0 who were recruits two years ago, etc.

So $W = \sum_{j=0}^{\infty} w_j$ and is constant.

Suppose a levy is made. At that moment of time provision has to be made *now* for all those who will be certified in the future.

Among the W_0 that number is expected to be $\sum_{j=0}^{\infty} p_j W_j$.

Among the W_1 that number is expected to be $\sum_{j=1}^{\infty} p_j W_j$.

Among the W_2 that number is expected to be $\sum_{j=2}^{\infty} p_j W_j$.

and so on.

So the total expected number to be provided for is

$$w = \sum_{0}^{\infty} (j+1)p_j W_j = \sum_{0}^{\infty} (j+1)f_j = n\bar{x} \qquad \ldots (2)$$

where $n = \sum_{0}^{\infty} n_j$ = total number certified for the first time in a year in the work force

and $\bar{x}$ = mean years of service, when certified for the first time.

Now consider Table 3·1. (Data for *white* miners of Group A only). Here, under the assumptions made, $n = 209$ and $\bar{x} = 21{\cdot}8$ years.

So $w = 4556$. Also $W = 25456$. Hence $\frac{w}{W} = {\cdot}179 \quad ..(3)$

Now consider the author's equation (6·8). Here as I understand him, he denotes $\frac{w}{W}$ by $S(1-p)^t$. I do not follow his arguments for arriving at this result. I gather however that $t = \bar{x}$ and note that he puts $S = 1$. I find that when $(1-p)^{21\cdot 8} = {\cdot}179$ then $p = {\cdot}076$.

However, on p. 305, "an analysis of the service distribution led the author to the impression that ·05 and ·03 were likely upper and lower limits for p for a population at risk such as White persons on mines of Group A."

Taking $p = {\cdot}05$, $(1-p)^{21\cdot 8} = {\cdot}318$. For $p = {\cdot}03$ it is ·512.

The remainder of the paper essentially follows on from eqns (6·3) and (6·8). I have criticised both these equations and note, regretfully, that if my criticisms are valid the value of the remainder of the paper is greatly vitiated.

I have also made suggestions concerning the estimation of $\bar{L}$ and $\frac{w}{W}$ which I hope will be of use to the author and to others interested in the problem of levying funds for compensation.

Finally, I urge most strongly that no practical use be made of the formulae in (6·3) onwards until the suggested computer simulations of $\bar{L}$ have been carried out and more light thrown on what average values of n_1 and n_2 should be used in these formulae under various circumstances, and how these can be associated with $\bar{n}_1$ and $\bar{n}_2$ and hence with the appropriate dust indices.

J. A. Carson (Visitor): Thank you, Mr Chairman, for the invitation I received to contribute to the discussion. I shall confine my remarks to the Pneumoconiosis Compensation Fund.

The aim is that the assets of the Fund should be sufficient to meet future liabilities which consist, firstly, of future payments to miners who have already been certified and to their dependants and, secondly, of future payments to miners not yet certified in respect of work already performed in dusty atmospheres and to their dependants. It is provided in the law that if the assets are more than sufficient to meet liabilities the difference is to be refunded to the mine owners; if the assets are not sufficient the difference is to be recovered from the mine owners.

It is, of course, desirable that variations in the rate of quarterly levy payable by each mine owner should be kept as small as possible and also that each mine owner should meet an equitable share of the total cost of compensation; these considerations are, however, secondary to the aim of maintaining the solvency of the Fund.

In practice there have at times been large variations in the number of new certifications. There have also been frequent amending statutes increasing the scale of compensation; since 1956 the increase in compensation for cases already certified has been met by the State but the increase in respect of cases certified after each change in the law has fallen on mine owners.

In these circumstances the practice developed of basing the levy on the cost of new awards in the latest year under review, with certain adjustments, and I doubt if any other method will be satisfactory.

The question arises whether any of the formulae in Dr du Toit's paper, with or without modifications, are likely to be used in connection with the actuarial calculations for the Fund.

Dr du Toit's method of calculation, possibly with the intention of simplification, implies that certifications occur after an assumed average period; that levies are paid for a second assumed average period and that compensation is paid for a third assumed average period. Actuaries, on the other hand, have long been accustomed to use mortality and other tables in which events are distributed over the whole range of ages or years of service entering into the problem.

I shall now give some examples of the results produced by Formula 7.5 in relation to Gold mines of Group A, using the average values of the variables in Table 7.1.

Formula 7.5 assumes that in respect of every miner entering the gold mining industry levies will be paid for precisely 1.5 × 22, that is 33 years. There is no wastage factor similar to the $(l-p)^t$ factor in paragraph 6.2 for estimating miners contracting pneumoconiosis. Indeed, a wastage factor of this type should be attached to the levies paid in each year of service.

In Table 3.4 Dr du Toit suggests that, on certain assumptions, out of every 345 miners entering the industry, 23 will contract pneumoconiosis, that is, about 7%. In Formula 7.5 the percentage contracting pneumoconiosis is assumed to be $100\ (1—.04)^{22}$, that is, about 40%.

Finally, taking the average annual amount of compensation at R500 a year (see the example at the end of paragraph 7.2) and the period for which compensation is paid as 50 less 22, that is 28 years, Formula 7.5 assumes that the average cost of a new award at the date of certification will be 500 × 13.4, that is R6 700. There are so many factors entering into the cost of an award — ages, number of wives and children, the rates of reclassification and mortality at each age — that it could only be a coincidence if the cost of an award calculated by Dr du Toit's formula proved to be reasonably accurate.

I hope the meeting will not think my remarks are too critical; I speak as an actuary about the parts of the paper devoted to actuarial theory.

W. L. Le Roux (Visitor): This paper by Dr du Toit is very interesting from an academic point of view. It involves the use of statistical and economic analyses of physical sampling results for the purpose of reducing a health problem which has an effect on labour relations. I do not consider myself qualified to comment on the statistical or academic virtues of the paper, but the fact that the author was awarded a doctor's degree on the strength of the underlying thesis is the best testimonial that can be asked for. I therefore wish to congratulate Dr du Toit on his achievement. However, I would like to raise a few questions about the legal position which is at the base of the whole problem.

In his introduction the author states that "if compensation is related to pneumoconiosis and if pneumoconiosis is related to dust, it follows that compensation is related to dust". He also states the legal position, namely that "A fund has been established to which employers are obliged to contribute as and when persons are exposed to dust."

The first question which arises is whether the right party is being held responsible? It certainly is the employer's duty to make sufficient ventilating air available and supply water and the necessary labour, hoses, spray nozzles, filters and other appliances which are required for dust allaying in each working place in a mine. It is impossible to put a reliable figure to the cost of all these items, but it is definitely considerably in excess of the sum spent on compensation for pneumoconiosis. In the case of one these items it is possible to make a reasonable estimate. Last year 13 500 000 cfm was being filtered underground, mainly at tips. Just the electric power which is used to drive the filter fans costs more than R400 000 per annum. But is it not the employee's duty to make the best use of these expensive commodities?

This question reminds one of the story about Gamat whose beautiful and popular wife had a baby every year. When his family had grown so big that he could no longer afford to feed it, he decided that the only way to put a stop to the process was to commit suicide. He climbed a tree and tied a rope to a branch and he was putting the noose around his neck when he suddenly dropped the rope and asked himself: "Gamat, how can you be sure you are hanging the right man?"

The problem is complicated by the fact that the dust in each worker's ambient air is caused partly by himself and partly by other workers upstream of him. If each employee had been responsible for all the dust in his own ambient air, a suggestion which has been made in the past could have been very effective. I am referring to the idea of paying a large bonus to each man who has worked underground for a given number of years, say 25 or 30, without contracting silicosis. It may even be a good policy to pay this bonus in addition to the existing compensation which is paid to those who do contract silicosis.

Another weakness of existing legislation is that workers are compensated for having pneumoconiosis in a degree which has absolutely no ill effects. viz. 20 to 50 per cent impairment of cardio-respiratory functions. One cannot think of any good reason why compensation should be paid for less than 50 per cent impairment.

Finally there is the problem of finding an equitable way of determining the mean dust level of any particular mine. The Chamber of Mines Dust Sampling Unit carried out two statiscally based dust surveys of gold mines in recent years. In three mines which I know well and in which there have been no changes in management policy which could have affected dust levels, the first changed its position from 3rd best in the first survey to 41st best out of 44 mines in the second survey, the second from 9th to 37th and the third from 41st to 22nd. Thus the first two would have had to increase their contributions considerably after the second survey, while in the other case the contribution would have been considerably reduced if Dr du Toit's formula had been applied—and in neither of the three cases would management have been able to explain the reason for the change.

Thus, even if the employer is to be regarded as the guilty party, it would appear that a much more reliable sampling method is required before differential levies can be applied on a fair basis.

Dr. W. S. Rapson (Fellow): In the conclusion to his paper Dr. du Toit states that "except in the case of very dusty mines, a relatively small reduction in the dust index calls for a relatively large reduction in the levy index, and this provides powerful incentive towards improved dust conditions". It is a logical consequence of this, that the system which he has evolved will operate fairly only if, *inter alia*, it is possible to determine the dust index of an individual mine for each year with acceptable accuracy.

So far as the gold mines are concerned, the Chamber has over the past few years had experience of how very difficult it is to do this. A brief description of the problems which have been encountered is therefore relevant to his paper.

For the greater part these problems concern the strategy to be used in the taking of dust samples for determination of a dust index for a mine. A number of procedures have been used or have been suggested for obtaining an overall figure for a mine. The most significant of these are the following:-

(*a*) Methods based on the taking of a konimeter sample at a predetermined proportion of the sites at which personnel are met during the traversing by a sampler of the whole or a predetermined portion of a mine. In a survey reported by Lambrechts[1] in 1963, one konimeter sample was taken for every person encountered. In a later survey (1964/1965) by the Chamber of all its member gold mines, one konimeter sample was taken for every third person encountered, and in a still later survey (1968/1969) by the Chamber, one konimeter sample was taken for every third person encountered, but only one third of each mine was surveyed.

(*b*) A method based upon thermal precipitator sampling at strategic points throughout mines. This method was developed by the Corner House Laboratories and has been compared by the Chamber with procedure (*a*) by parallel observations by the two methods on three mines.

(*c*) Monitoring by continuous gravimetric sampling at strategic points throughout mines.

(*d*) Occupational sampling, based upon the taking of samples whilst following selected personnel throughout a number of shifts.

(*e*) Continuous sampling whilst moving through working areas. This could be either by personal gravimetric samplers, or by thermal precipitator.

The advantages and disadvanatages of these various procedures are still under consideration from various points of view such as their suitability for the purpose, the availability and reliability of equipment, the labour and logistics problems which they present, their relative costs, and the extent to which the conditions which are observed, in mines under survey, are representative of their normal conditions.

Major difficulties have arisen in respect of the procedures (a) and (*b*) since statistical analysis of the data from, for example, the 1964/1965 and 1968/1969 surveys by the Chamber, has shown that the confidence limits for the survey averages for individual mines when only the definable sources of variation are taken into account are very wide indeed, varying from $\pm$ 14% to $\pm$ 30% for different mines at the 95% level.

At this level of accuracy, which is unlikely to be exceeded by any method of which there is experience to date, the possibility for error in the calculations for individual mines of levy indexes based on such dust indexes would be very great indeed.

REFERENCE

1. South African Council for Scientific and Industrial Research, Pneumoconiosis Research Unit, Report No. 3/63.

M. J. Martinson* (Fellow): The paper introduced this afternoon represents a courageous attempt by Dr du Toit to establish a rational basis for the pneumoconiosis levy, and for this he deserves our unstinted admiration; if later the tenor of this contribution should seem critical it ought not to be construed as an attack on Dr du Toit or his paper, but rather as criticism of features of the complex set of circumstances which forms the subject-matter of the paper.

In this contribution I propose to start by commenting on a number of specific issues arising directly out of the paper, and thereafter to discuss a few more general matters raised by the paper as a whole.

1.1 *The statement of the problem*

The premises that financial liability for pneumoconiosis compensation should be directly related to occupational dust exposure seems so patently obvious on equitable grounds alone that one wonders what other rational bases might be used for allocating liability. Despite its comparitively long history and its importance to mine owners and mineworkers alike, little is known about this aspect of the administration of the Pneumoconiosis Act, and it would have been interesting had the author seen fit to outline the past and present policy of the Risk Committee as regards allocation of the levy.

Apart from principles of equity, it seems to me that there is little prospect of improving dust conditions underground until the liability of each mine is assessed individually on the basis of environmental conditions. For most mines the financial threat would be of little consequence because the cost of the levy per unit of production would remain marginal compared to other working costs,† but on the other hand the pressures generated by adverse assessments would undoubtedly act as far a greater stimulus for improving conditions than the propaganda campaigns currently favoured by the industry.

1.3 *The certification of persons with pneumoconiosis*

Having recognised a causal connection between dust exposure and disease the author then proceeds to measure disease in terms of statutory certifications, presumably because these were the only published data available to him.

This raises three points. Firstly, it is abundantly clear from Figure 2.1 that statutory amendments to the 1962 Act and its predecessors have given rise to a series of arbitrary changes in the certification rate of White and Coloured mineworkers, and no doubt further changes will be introduced in time to come. Secondly, although the Miners' Certification Committee may make every effort to operate within the terms of the statutory definition and the five 'standards' laid down by the Minister, certification necessarily involves a considerable degree of subjective appraisal and in the ultimate analysis the rate of certification is inevitably affected by the Committee's composition and other extrinsic factors. Thirdly, it has been said on good authority that certification is today sometimes based on chronic bronchitis alone; we also know that metal miners are heavy smokers and that there is a causal relationship between smoking and chronic bronchitis. How can the Certification Committee distinguish between chronic bronchitis caused by the inhalation of mineral dust, and chronic bronchitis caused by the inhalation of cigarette smoke?

It seems to me that if one wants to establish a meaningful relationship between dust exposure and disease — and such a relationship is absolutely fundamental to rational discussion on any aspect of the pneumoconiosis problem — one must define human response in less arbitrary terms than the bare certification rate. The medical histories of South African mineworkers are surely unsurpassed anywhere in the world both as regards quality and quantity, and ought surely to contain quantitative data on the clinical, radiological, physiological, pathological and (even) psychological responses needed in a study of this sort. Whatever the author's reasons may have been for not using medical data, it would seem that in general far too little use is made of this storehouse of information.

1.5 *The population at risk*

South African mining engineers no doubt appreciate why the author confines his study to White and Coloured mineworkers — thus excluding any reference to Asiatic and Bantu mineworkers — but for the benefit of other readers the author might perhaps have elaborated on the point. Elsewhere he quotes the Minister of Mines as stating in 1962 that the mining industry lost about 30 000 White and about 300 000 Bantu workers 'as a result of pneumoconiosis' between 1912 and 1962; for Whites (plus Coloureds) the corresponding population at risk is given in Figure 1.1, but since no figures are given on the numbers of Asiatics and Bantu at risk it may be worth quoting the following data on the average number of persons at work underground in 1968 taken from the Government Mining Engineer's Annual Report for the year in question:

**Senior Lecturer, Department of Mining Engineering University of the Witwatersrand.*

†In 1968 the forty-seven principal gold mines milled 76.68 million tons at a total working cost of R482.4 million (i.e. R6.29 per ton milled) for a working revenue of R771.9 million. For the year ended 30 September 1968 the annual levy in respect of Class A mines was R1.6 million, representing a cost of about 2 cents per ton milled.

	White	Coloured	Asiatic	Bantu
Large gold mines	20 165	60	—	286 571
All other mines	5 396	227	53	93 980
Total South Africa	25 561	287	53	380 551

These figures do not include a relatively small number of persons employed on surface in statutory 'dusty occupations' (and also eligible for certification), but the numbers are adequate for placing the problem in its correct perspective. It is perhaps worth noting that the ratio of White to Non-White miners working underground in large gold mines has declined over the years from about 1:10 in 1953 to nearly 1:15 today.

Since this appears to be a continuing trend, and since Non-Whites because of the nature of their jobs are likely to be exposed to higher dust concentration than Whites, a similar analysis in respect of Non-Whites may be desirable.

The figures incidentally serve to emphasize the dominant role which the gold mining industry continues to occupy as regards the total population at risk.

4.0 *The assessment of the hazardous dust concentrations in mine atmospheres*

Under *Composition* the author lists the 'relative toxicities' of various minerals, and very properly expresses his misgivings about the absolute values of the factors used. Surely, however, the 'relative toxicities' of the commoner minerals can be established by systematic epidemiological studies? I imagine that the data needed for such an exercise must already be on record in the files of the several agencies involved in the problem.

Quite apart from the pathogenic properties of the individual minerals, we do not know nearly enough about the possible synergistic action of other contaminants in mine air — such as radon and radon daughters, the oxides of nitrogen, and some of the aromatic hydrocarbons — in the aetiology of pneumoconiosis.

4.1 *Dust measurement*

The continued use of the konimeter as the principal dust sampling instrument in South African mines has been criticised on so many occasions that I do not propose to re-open the topic here. We also know that the handling of the instrument is suspect, and the combined effect of these two factors is to leave a large question mark in this contributor's mind against the validity of the dust indices calculated by the author. The author has obviously tried to make the best possible use of the data available to him, but in the ultimate analysis one simply cannot make a silk purse out of a sow's ear.

At the same time I am firmly convinced that, given the will, it is technically and economically feasible to assess rigorously the cumulative total dust exposure experienced by mineworkers in individual mines. This is not the occasion for going into ways and means of tackling this problem, but it may be remarked that Beadle[1] has already convincingly demonstrated a possible approach in gold mines in this country; regardless of any other considerations, however, it would seem imperative that the task of designing and implementing the necessary sampling programme be given to an independent agency reporting direct to the Minister on a par with the annual reports of the Director of the Miners' Medical Bureau and the Pneumoconiosis Compensation Commission.

Now for a few more general remarks on the paper.

Firstly, it is a little surprising that Dr du Toit makes no attempt to correlate his findings (and in particular his exposure — response relationship) with similar studies in South Africa, Germany and Britain. Confining attention to more recent South African studies, Wiid[2] presented a preliminary report to the 1959 Johannesburg Pneumoconiosis Conference on a study which seems to have covered some of the ground considered in the present paper; in 1965 Beadle[1] delivered a paper on 'An epidemiological study of the relationship between the amount of dust breathed and the incidence of silicosis in South African gold mines' at an international symposium in Britain; and at the 1969 Johannesburg Pneumoconiosis Conference Beadle *et al*[3] brought the 1965 study up to date. Beadle's work in this field is outstanding by any criterion, and the author's failure to refer to it is puzzling.

Secondly, I find it depressing that the author nowhere permits himself to express even the most guarded optimism about future trends in the incidence of pneumoconiosis in South Africa. Nor, probably, is there much room for optimism when such data as are available indicate that dust conditions in the large gold mines, for example, have deteriorated marginally over the past twenty years. On the face of it South Africa seems to have tacitly accepted the present incidence of pneumoconiosis as part of the price that must be paid for a prosperous minerals industry. This may be a perfectly legitimate attitude based on grounds of public policy, but it does present a striking contrast to the view prevailing in some of the larger mining fields overseas, where complete elimination of pneumoconiosis is the declared objective and there is tangible evidence that this objective is treated seriously and sincerely. In this connection one may perhaps quote section 2 of the U.S. Federal Coal Mine Health and Safety Act of 1969 (Public Law 91-173), which reads as follows:

2. Congress declares that —

(*a*) The first priority and concern of all in the coal mining industry must be the health and safety of its most precious resource — the miner;

(*b*) deaths and serious injuries from unsafe and unhealthful conditions and practices in the coal mines cause grief and suffering to the miners and to their families;

(*c*) there is an urgent need to provide more effective means and measures for improving the working conditions and practices in the Nation's coal mines in order to prevent death and serious physical harm, and in order to prevent occupational diseases originating in such mines;

(*d*) the existence of unsafe and unhealthful conditions and practices in the Nation's coal mines is a serious impediment to the future growth of the coal mining industry and cannot be tolerated;

(*e*) the operators of such mines with the assistance of the miners have the primary responsibility to prevent the existence of such conditions and practices in such mines;

(*f*) the disruption of production and the loss of income to operators and miners as a result of coal mine accidents or occupationally caused diseases unduly impedes and burdens commerce; and

(g) it is the purpose of this Act (1) to establish interim mandatory health and safety standards and to direct the Secretary of Health, Education, and Welfare and the Secretary of the Interior to develop and promulgate improved mandatory health or safety standards to protect the health and safety of the Nation's coal miners; (2) to require that each operator of a coal mine and every miner in such mine comply with such standards; (3) to cooperate with, and provide assistance to, the States in the development and enforcement of effective State coal mine health and safety programs; and (4) to improve and expand, in cooperation with the States and the coal mining industry, research and development and training programs aimed at preventing coal mine accidents and occupationally caused diseases in the industry.

The 1969 Act was enacted after a searching Congressional Hearing had heard evidence on all aspects of occupational health and safety in U.S., British and German coal mines, and if one were looking for a ready made mineworkers' charter the U.S. Act would provide an admirable framework for it.

Finally, if we accept that public policy in South Africa demands a reduction in the incidence of pneumoconiosis, I suggest that this will only be effected by a complete reappraisal of the entire problem, starting possibly in the field of environmental engineering. Even more important, perhaps, the attack in all fields of the problem must be imbued with far greater urgency than has been displayed in this country over the past fifty years or so. Here I am reminded of what Mr Henry Doyle of the U.S. Bureau of Mines is recorded as having said[4] when adjourning the recent (November 1969) symposium on respirable coal mine dust held in Washington D.C. After announcing that the symposium proceedings would hopefully be published within the commendably short time of six weeks. Mr Doyle expressed the hope that the proceedings would be so out of date in two years time that another symposium would be necessary. This observation connotes a rate of progress completely unrealistic by our standards, but one which we must emulate if we have any serious intention of changing the situation.

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3. Beadle, D. G., Sluis-Cremer, G. K. and Harris, E., 'The relationship between the amount of dust breathed and the incidence of silicosis—an epidemiological study of South African European gold miners'; Proceedings of the International Pneumoconiosis Conference, Johannesburg, 1969. (To be published.)
4. Proceedings of the Symposium on Respirable Coal Mine Dust, Washington D.C., November 3-4, 1969; Bureau of Mines Information Circular IC 8458, United States Department of the Interior, Washington D.C., 1970.

G. J. van Jaarsveld* (Fellow): As a colleague of Dr du Toit I want to congratulate him on this contribution to the solution of one of the very real problems in this complicated mechanism of compensation for industrial disease. The fundamental reasoning is sound and conforms to basic scientific principles, and when we arrive at the formual,

$$t = 208d^{-0.43},$$

we have the feeling that two elusive quantities have at long last been joined in a usable relationship.

However, the discerning scientist, the penetrating mathematician, will want to know how true this equation is. Have we used sufficient dust samples, have we studied sufficient miners especially in the case of the Group B mines? I am not going to try and answer these questions. There were no doubt many problems attached to the various ramifications of a study of this nature and perhaps the criticism I would like to offer is that I feel that the dust samples taken by the Chamber of Mines over the years should somehow have been incorporated in this equation.

Nevertheless, I am sure we all agree that this investigation was a very necessary one and has enriched our knowledge in this particular sphere, which in the final analysis is also the responsibility of the mining engineer, and not solely that of the actuary.

R. J. Page-Shipp (Visitor) and **Mrs E. Harris** (Visitor): This contribution is based on the reported work of the late Mr Derrick Beadle and most of the views expressed were originated by him in discussion of Dr du Toit's work with his staff and other interested parties.

While we sympathize (as do previous contributors) with the difficulties which faced Dr du Toit, we feel that the approach, to a similar problem, adopted by Mr Beadle yielded more reliable conclusions. We are thus (unlike previous contributors) able to offer criticism based on a parallel investigation.

Dr du Toit in the introduction to his paper states that his work is based on the following premise: "If compensation is related to pneumoconiosis and if pneumoconiosis is related to dust, it follows that compensation is related to dust." However, it has been shown by Beadle that "some factor other than dust exposure must play a predominant role in determining certification[1]". Time and again evidence has been found that, as long as certification includes cases of chronic bronchitis with no radiological evidence of silicosis, any attempts to relate dust exposure to certification will meet with little success.

If then, it could be shown that pneumoconiosis as presently certifiable, is related to variables other than dust, e.g. smoking habits, then logically these factors must be taken into account when determining compensation levies. A far better solution would be to determine the silicosis risk in terms of radiological evidence of the disease based on dust exposure and then to relate this parameter to the certification levy.

Beadle has, in fact, demonstrated the relationship between silicosis and dust exposure in mines of the Gold A group[2], and all further criticism of du Toit's work is on the basis of these findings.

du Toit states that the chance of developing pneumoconiosis is related to the (*i*) toxicity of the dust, (*ii*) the concentration of the dust, (*iii*) the length of dust exposure, and (*iv*) the physical condition of the persons at risk. The methods of taking into account the first three are open to criticism. (The fourth is not taken into account at all).

**Dept. of Mines.*

(*i*) Toxicity of the dust: No details are given as to how the relative toxicities were determined from the post mortem results. The relative toxicity of silicate particles is higher than that proposed by the ACGIH[3] (viz. 0.125); and furthermore the percentage quartz assumed (from analysis of rock samples) viz. 70 per cent, was considerably higher than the mean values for airborne dust found by other organisations (50 per cent).

(*ii*) Concentration of the dust: du Toit says that these relative toxicity factors are to be used to compute dust indices from number concentration. He also uses konimeter samples to determine the dust concentrations. This is not the place to stir up this controversy, but Webster himself has shown that the chance of developing pneumoconiosis is more likely to be related to respirable surface area than number concentration.

(*iii*) Length of dust exposure: Beadle in his study of a cohort of 1200 men who started work between 1934 and 1938, has shown that the working patterns of underground workers are exremely complex. Not only does the length of time underground vary, but the men change mines and occupations numerous times. Many spend months working outside the mining industry before coming back to mining. How then could years of service be a measure of dust exposure?

(*iv*) As for the physical condition of the person at risk, both the Miners' Medical Bureau and the Corner House Laboratories are working on the problem of individual susceptibility which has proved to be one of the most important variables in this study.

The conclusion drawn by du Toit from his Fig. 5.1 is that, since the relationship between the variables is not $td = k$, pneumoconiosis is progressive. In the cohort study we have found no indications at all that pneumoconiosis (in Gold A mines) is progressive.

The above points are criticisms of aspects of du Toit's method. However his whole approach is open to criticism. Data from Beadle's cohort study shows that there is no relationship between years of service to certification and the dust level in q.e.p.p.c.c. This data is based on hundreds of full-shift samples, taken and assessed under strictly controlled conditions. The cohort sample has been randomly chosen from the 1934-38 entrants and has been carefully followed through to the present day. The graph of this data is shown in Fig. 1, with du Toit's derived curve superimposed.

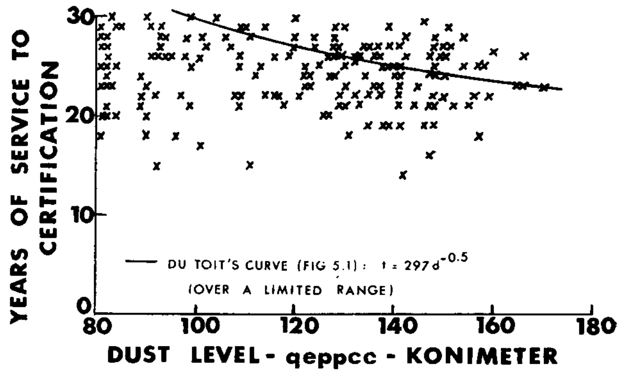

Fig. 1

In his conclusion du Toit states, "In principle, it is also clear that not only classes of mines, but individual mines could be more equitably assessed on this basis". Although the method proposed may possibly be useful for assessing the relative risks of the broad classes of mines as shown in his Fig. 5.1, it is most unrealistic to propose assessment of individual mines in this way. The data presented above shows that the relationship does not hold for the Gold A group mines; du Toit has advanced no argument to prove that it holds within any of the other classes either.

REFERENCES

1. Beadle, D. G., Sluis-Cremer, G. K. and Harris, E. International Pneumoconiosis Conference Proceedings, Johannesburg 1969, p. 252.
2. Ibid. p. 253.
3. Threshold Limit Values for 1968. Adopted at the 30th Annual Meeting of the ACGIH. St. Louis, Missouri. May 13, 1968.

Author's Reply:

I thank every contributor. Each contribution assists the readers to see the subjects of dust, pneumoconiosis and compensation in a better perspective.

In the first place I am flattered by the compliments received. In the second place there is the constructive criticism. Herein lies the real value of a contribution. In the third place there is the destructive criticism. This gives me the opportunity to defend the approach in my paper.

I cannot possibly reply to all the points raised by every contributor. So, as in the case of my paper, to curb printing costs, I shall confine myself to some of the points raised.

Where I differ from any contributor, this should please not be taken as a personal attack.

My paper undoubtedly stands as a controversial one. I myself made a point of stressing the many uncertainties involved and of pointing out (see the last paragraph of Section 4.2. of my paper) that, being a study in retrospect, I was obliged to utilize, as best I could, available information and that this would limit the reliability of the indices arrived at.

On Dr Sluis-Cremer's point of chronic bronchitis, I find myself saying: How is it possible that a person can get certified to have pneumoconiosis (which is defined as "permanent disease of the cardio respiratory-organs which has been caused by the inhalation of mineral dust) when that person has chronic bronchitis if chronic bronchitis is, in the minds of those responsible for the certification, not considered to be related (or at least likely to be related) to dust?

If chronic bronchitis is indeed not related to dust, and if chronic bronchitis cases were eliminated from the cases I used, then the scatter of exposure time, t, versus dust index, d, would have been much smaller than that of the scatter diagram obtained. One may argue that the observed relationship emerged IN SPITE OF the bedevilling agent chronic bronchitis. That chronic bronchitis cases did affect the values arrived at for constants a and b in the formula $t = a.d^b$ is admitted, but the actual values of a and b are not as important as the fact that t is functionally related to d.

Chronic bronchitis does, however seem to pose the question of what importance to attach to combustible and acid soluble respirable particles in mine atmospheres in the future. For mines other than coal mines, such particles are normally done away with by heating and acid treatment before counting the respirable rock particles.

I do not agree with Dr Sluis-Cremer's argument that the assumed relative toxicities of the various minerals are unacceptable. If one objects to the relative toxicity values as estimated from animal experiments even in the absence of any better estimate, two questions arise:

(*a*) How then are relative toxicities to be determined within a limited period?

(*b*) Why conduct animal experiments at all?

Dr. Sluis-Cremer's point that haematite dust causes siderosis and that Fe_2O_3 particles which are soluble in acid should not be ignored, has in fact been taken care of in that the dust samples taken on metalliferous mines were heated (to about 550°C) before being acid-treated. During such heat-treatment Fe_2O_3-particles are oxidised to insoluble Fe_3O_4-particles which are not removed by acid-treatment and then get counted.

Dr Sluis-Cremer seems to have missed the qualifications in Section 4.0 of my paper that "theoretically, every size and type of particle included (in dust measurements) should be weighted according to the damage it can do to the human lung, but that, in actual practice, measurements are limited to the type of particle which is believed to cause most of the damage." He also seems not to have appreciated the point about the limitations of the dust indices referred to in Section 4.2 which flowed from the fact that the paper was a study in retrospect.

I agree with Mr Carson that the number of certifications per unit period is the best and absolute check of the levy-rate. This check, however, concerns the mean conditions during the past 20 to 30 years and cannot indicate what the correct current levy rates should be.

To get some idea of the violent effect which a small change in the standard of certification has, refer to Figure 3.1. With the aid of Figure 3.1 it can be shown that a small increase in the standard of certification at any point in time results in a large increase in the number of certifications during the year which follows the application of the more severe standard. The reason for this relatively large increase during the *first* year after the change is that the accumulated cases of previous years are *all* certified during the first year following the change.

I do not think that we have seen the end of changes in the standard of certification and, therefore of violent fluctuations in the annual certification rate. Hence, if current levy rates are based only on current certification rates we will continue to have violent fluctuations in current levy rates.

A lesson does, however, seem to have been learnt. This impression is gathered from a statement by the Pneumoconiosis Compensation Commissioner* on the levies imposed subsequent to the coming into force of the 1962 Act. The statement referred to reads as follows: "where it was customary to associate the rate of levy with initial certifications, the (Pneumoconiosis Compensation) council temporised by imposing a token levy only in respect of the first six months of operation of the 1962 Act until such time as a definite pattern in the rate of certifications emerged".

It is a pity Mr Carson does not suggest what sum per (White) case he, as actuary, would consider reasonable for the average person being certified after a period of, say, 22 years of service. At 500 cases per annum and at R7 000 per case the annual levy for White persons amounts to R3.5 million. Bantu persons used to receive a one sum benefit of about R500. At 4 000 Bantu cases per annum this amounts to R2 million. A total levy therefore of about R5.5 million per annum. Allowing R2 million p.a. for interest on the sum collected in respect of the damage already done, this gives a total annual sum of R7.5 million. From this calculation, the sum of R7 000 per case at 22 years of service seems a reasonable estimate.

The author appreciates Prof Lambrecht's positive approach in suggesting alternative values for constants a and b in the formula $t = ad^b$. If one assumes $d = 182$ for $t = 25$ it is automatically assumed that the mean dust index during the preceeding 25 years of exposure was 182 q.e.p.p.c.c. As this dust index was recorded for about 1965 and as the 25 years of exposure occurred during the period 1936 to 1963, it is then assumed that the mean dust index during that period was 182 q.e.p.p.c.c. (At 70% quartz, the mean actual concentration is assumed to have been 240 p.p.c.c.) This seems a reasonable assumption as far as the dust concentration is concerned. We now come to Professor Lambrecht's suggestion that certification occurs at *constant* dust dosage, txd. This entails that the type of pneumoconiosis dealt with is assumed to be non-progressive. For the Witwatersrand type of dust I would rather see a formula which caters for some degree of progressiveness, in other words, that constant b is put at less than unity. A value of $-\frac{1}{2}$ seems to be a reasonable first approximation. At this value, the value of constant a for pivoting the straight line on log-log paper about the point $t = 25$ for $d = 182$ becomes:

$$25 \times 182^{\frac{1}{2}} = 25 \times 13.5 = 338.$$

This gives $t = 338\ d^{-\frac{1}{2}}$ as against $t = 300\,d^{-\frac{1}{2}}$ as suggested in my paper. A difference, therefore, in the estimated years of exposure prior to certification of only about 13%. This seems a small difference for figures relating to the dust and pneumoconiosis problem.

Mr van Jaarsveld enquired why the Chamber of Mines results were not used to compute dust indices for mines of Group A. The main reasons for not making use of these results are:

(*a*) The Chamber discontinued publishing the results recorded by Mine Ventilation Officers many years ago.

*Report of the Pneumoconiosis Compensation Commissioner for the year ending 31st March, 1964, p. 8, *The Government Printer*, Pretoria.

(*b*) The published Chamber records do not go as far back as the records of the Department of Mines.

(*c*) In the early years there was a difference between the two organisations in the method of treating dust samples before they were counted — the Department heating slides before acid-treatment whereas the Chamber did not follow this procedure.

(*d*) There was serious doubt in the author's mind whether the effort expended in processing the Chamber results would lead to a material increase in the accuracy of dust indices that would emerge.

According to Dr Rapson the accuracy of the mean dust level of an individual mine as determined from the dust surveys done by the team of the Chamber of Mines amounted to a standard error of from 14 to 29%. This accuracy should be viewed in the light of the range of individual mine mean dust levels. It is a pity Dr Rapson does not disclose the range of individual mine mean dust levels. I should say there is a factor of at least 2 between the lowest and the highest mine mean. Furthermore, the individual mine mean indices could, for practical purposes, be computed for calendar periods of five years during which period five dust surveys can be conducted. Assuming a mine mean standard error of say, 22% per survey, the mine mean standard error for 4 surveys would come down to 22 ÷ $5\frac{1}{2}$% i.e. to say 10%. This is quite satisfactory for the purpose of differentiating between individual mines. Levy indices could then be determined annually as based on moving five year mean dust indices.

The mines could be classified into a limited number (say ten) of broad levy index categories.

It is doubtful whether absolute accuracy will ever be attained. In this connection I recall a remark by Dr A. J. Orenstein years ago: "If you want to wait for perfection before doing something, you will wait for eternity!"

Mr le Roux would like to see "a much more reliable sampling method before differential levies can be applied on a fair basis". My approach was motivated by a desire "to be fair".

Admittedly, some mines would, at times, not be treated as fairly as others, but a system of differential levy indices would be much better than the current situation where, in my opinion, practically half the mines are treated unfairly as compared with the rest of the oines.

The *main* question is whether or not a system of differential levies based on dust will result in generally improved dust conditions with a resultant decrease in the pneumoconiosis incidence.

Mr Martinson finds the omission to refer to the late Mr Beadle's work puzzling. I recall that the major part of the work for my thesis was completed (1964), before Mr Beadle's work was reported on (1965).

Another reason is that Mr Beadle's work, as well as the work in England and Germany concern persons in the same class of mine viz. coal mines in England and Germany and gold mines in Wiid's and Beadle's cases.

Mr Page-Shipp and Mrs Harris compare my approach with that of Beadle.

It is not claimed that number concentration was a better dust hazard index than respirable surface area — I was obliged to use a dust index *common* to the broad classes of mines and one which was used as long ago as 1930. Neither is it claimed that years of service was the best index of dust exposure. Its limitations are pointed out in Section 3.1.

The fact that two crude indices could be related suggests that each index must have some merit.

It is not advocated that the indices used by me should continue to be used when better indices become available. Similarly, if the quartz contents of the *airborne* dust of all the broad classes of mines were known, these values would have been utilised rather than the quartz contents estimated from rock samples.

For silicates in general, a relative toxicity of $\frac{1}{4}$ is utilised whereas the ACGIH advocate $\frac{1}{8}$; the two factors are of the same order when viewed in the light of the accuracies dealt with in pneumoconiosis problems.

I do not advocate my approach in the place of Beadle's but in the absence of the information necessary for Beadle's approach I would recommend mine rather than doing nothing.

Professor Kerrich points out that current levy L varies as the current number of persons employed. That is so, but although L signifies the money collected to pay for *present* damage, $L\%$ in the levy check factor, $L\%/C\%$, signifies the percentage of the money collected in the *past* in respect of the damage then done to pay compensation at *present*. Hence, variable $L\%$ does not fluctuate as the *current* number of persons exposed, but as the number exposed during a certain (long) period in the past. In fact, $L\%$ applies to the *same* period in the past to which total compensation sum C applies.

Professor Kerrich has difficulty with the proportion of persons $(1 - p)^x$ expected with pneumoconiosis. My approach envisages a number of persons, exposed to a dust concentration which could cause pneumoconiosis in every person exposed for not less than t years. Let the labour complement of the mine, or group of mines, be N. Consider the N persons who start their exposure at time zero.

My approach envisages that the total number of persons exposed to dust *and from whom money is collected*, will remain *constant* at N as time proceeds, but that amongst this number, those with exposure X years after time zero will be given by $N(1 - p)$ where p is the annual proportion of persons dropping out from the number who started at time zero.

In practice, those who drop out are replaced by others, but these persons have at time t after time zero all been exposed for *less* than time t and are, in view of the assumption, not expected to have pneumoconiosis.

Hence, the approach envisages money to have been collected from N persons for t years and that this money will be available for compensation to $N.S.\ (1 - p)^t$ persons.

In the example utilised by Professor Kerrich, proportion p dropping out was determined at 0.076 as against a likely maximum of 0.05 estimated by me. This estimate caters for depleting agents such as death and change of occupation. Proportion p can of course assume *any* value from zero up to 1. One factor which is likely to increase p seriously is the scare of contracting pneumoconiosis. When a person has been exposed for the period at which his comrades develop pneumoconiosis he says: "I am getting out before I also get pneumoconiosis!". It is suspected that this agent was responsible for the value of 0.076 calculated by Professor Kerrich from the data in Table 3.1.

Is the assumed toxicity for coal dust perhaps too low?

The difference between the observed and the expected mean service period (i.e. we expect a longer mean service period than observed) can be due to any of the following:

(*a*) Under-estimate of the quartz content.

(*b*) Under-estimate of the relative toxity of coal dust.

(*c*) Under-estimate of the dustiness.

(*d*) Under-estimate of the true average service period.

The suggestion of a computer programme:

The author is pleased that Professor Kerrich has mentioned this because there is a wealth of information in the Department of Mines which is not yet utilised due to the absence of a ready method to recover the information from where it is kept and due to the complicated calculations involved.

Notices

THE THIRD INTERNATIONAL GEOCHEMICAL EXPLORATION SYMPOSIUM

(Summary Account)

This Symposium, co-sponsored by the Canadian Institute of Mining and Metallurgy and the Society of Economic Geologists, was held in Toronto, Canada in April, 1970. Over 700 delegates attended from 26 countries.

Ninety papers were presented at the symposium and another 18 papers were read by title. The programme included:

An Opening Session, Five General Sessions, a session on Remote Sensing Methods, a session on Geochemical Prospecting for Petroleum and Natural Gas, a session on Primary Halos and Lithogeochemical Methods, and a session on Statistics and Evaluation of Geochemical Data.

The delegates were welcomed by Dr J. M. Harrison, President of the Canadian Institute of Mining and Metallurgy and Dr C. H. Smith, Regional Vice-President, North America of the Society of Economic Geologists.

Dr D. R. Derry of Toronto delivered the opening address to the Symposium entitled 'Geochemistry—the link between ore genesis and exploration'. Dr Derry considered the various hypotheses on the origin of economic mineral deposits and expressed his belief that the next ten years will show evidence of an increased proportion of ore bodies that owe their origin, at some stage in time, to supergene agencies. He stressed that 'there are no sharp divisions between processes that form and destroy ore bodies at or near surface and those that form or destroy them at a depth of 20 kilometres in the earth's crust. The more we understand about the migration and concentration of metals the more accurately we can apply this knowledge to searching for unknown concentrations, whether at rock surface or at depth. To learn more about these processes of ore genesis we must rely on geochemical studies co-ordinated with field observations'.

The five general sessions included accounts of progress in geochemical prospecting in different countries of the world, case histories describing the application of soil, stream sediment, geobotanical and biogeochemical techniques, papers on the behaviour of different elements under varied environmental conditions, discussions on analytical methods and the use of stable isotopes in mineral exploration.

It is anticipated that the proceedings of the Symposium will be published late in 1970 or early in 1971 as a Special Volume of The Canadian Institute of Mining and Metallurgy. All registrants at the Symposium will receive a copy of this publication and copies will be available for purchase.

At a special meeting called during the Symposium, charter members of the Association of Exploration Geochemists approved a constitution and elected an interim Council which will organize procedure and formulate policy during the coming year. The interim president of the Association is J. Alan Coope, Newmont Mining Corporation of Canada Limited, Toronto, Canada.

More information on the constitution and membership in the Association will be distributed to learned societies and technical magazines in the near future. Membership will be open to exploration geochemists in all countries of the world.

SOUTH AFRICAN COUNCIL FOR PROFESSIONAL ENGINEERS

Report on Registration

The Professional Engineers Act (Act 81 of 1968) came into force on the 14th February, 1969. At the time it was recognised that the success of the Act would depend in large measure on the extent to which engineers in South Africa would become registered professional engineers in terms of the provisions of the Act. The promulgation of the Act and its provisions relevant to registration were the subject of considerable publicity during 1969.

This has resulted in a rate of application for registration far beyond the capacity of the very active committees set up for this purpose by the South African Council for Professional Engineers (SACPE).

To give some idea of the task before these committees and before SACPE itself, which must ratify each case,