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Hon. Secretary — J. H. Quilliam, Esq., c/o Box 809, Johannesburg; Phone 31-1161.
Hon. Editor — D. G. Beadle, Esq., c/o Box 1169, Johannesburg; Phone 33-1034.
Hon. Advertising Manager — D. F. H. Grave, Esq., c/o Box 809, Johannesburg; Phone 33-2261.
Hon. Chief Abstractor — P. J. Vermunt, Esq., c/o Box 445, Springs; Phone 56-1161.

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RESEARCH ON DUST PROBLEMS BY THE PNEUMOCONIOSIS RESEARCH UNIT

(Summary of a talk given to the Annual General Meeting of the Mine Ventilation Society)

D. G. Beadle*

1. Introduction

The costs of compensation paid to miners in South Africa for pneumoconiosis and related diseases have been rising rapidly in recent years — Figure I shows the amount paid in compensation annually. In addition, the Government has recently had to provide, out of public funds, over £10,000,000 to meet liabilities in respect of mines which had closed down. These costs are very large and unless something is done to reduce the incidence of the disease, it is likely that they will continue to rise. Even now, the payments by mines for pneumoconiosis compensation form an appreciable part of their working costs — we all know the vital necessity of keeping down costs, particularly in the case of the so-called marginal mines. Ventilation and dust staff — the members of this Society — can and must play an important part in this task.

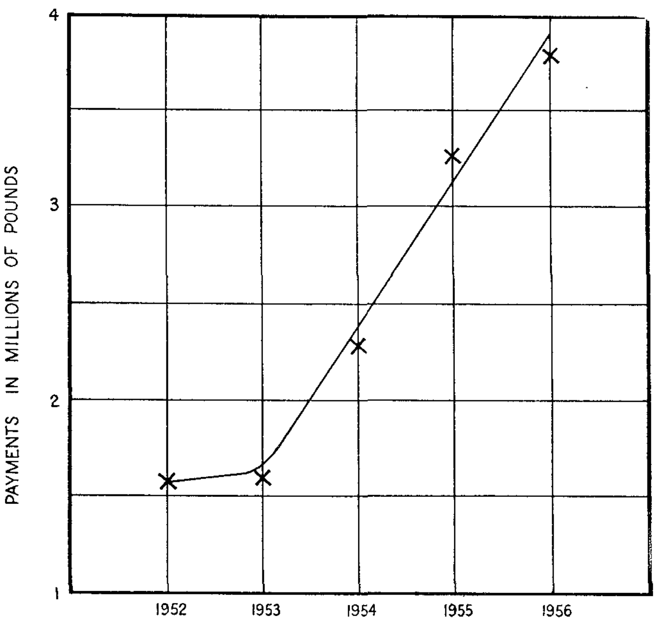

Figure I.

* Central Mining Finance Limited

It *is* possible to reduce the dust in the mines. By conscientiously applying known methods — better ventilation, adequate wetting down, good maintenance of machine drills, the use of clean water, installation of filters where necessary, proper maintenance of ventilation columns and doors, and seeing that men do not re-enter contaminated working places — much can be achieved. These are your responsibilities, through your managements.

In addition to this important day-by-day attack on the problem, there must be research into new methods of dust-sampling and dust suppression, and into the fundamental properties of dust, its effects, how it causes the disease, and so on. The research workers must discover and disseminate the information necessary for the practical men on the mines to apply to the problem.

For many years the gold mining industry and the Government Mines Department in South Africa have undertaken research on a considerable scale into the dust problem. Much has been achieved but much remains to be done. It must be clearly understood that such research can never achieve immediate spectacular results — even if some outstanding discovery led to the complete elimination of dust in our mines tomorrow, the disease would continue to appear in miners for many years to come due to their past exposure to dust. Once silica dust has been deposited in the lungs it continues to act, even if exposure to new dust ceases. It would need a new generation of miners to demonstrate in practice that the disease had finally been overcome. This fact should not, however, deter anyone from pressing on with research into dust and pneumoconiosis.

Last year, as a result of the realization of the growing problem, the Government and the Mining Industry agreed to set up the Pneumoconiosis Research Unit (commonly abbreviated to P.R.U.) to undertake further research into the disease, and in particular to co-ordinate the existing efforts and to draw closer together the workers on the medical and physical, or engineering, aspects. This unit came into being on 1st April, 1956, as a C.S.I.R. Research Unit. Its funds are provided by the Mining Industry, the Government and the Mineworkers Union. The Director is Dr. A. J. Orenstein whose name is well-known and highly respected in this field.

The research work undertaken by the P.R.U. is divided into several fields — thus there is a pathological unit, a physiological unit, and a statistical unit, as well as the team undertaking research on dust problems. Some of the work on dust is undertaken by Central Mining Finance Limited under contract with C.S.I.R. and I propose in this paper to describe the two main projects on which we are working at present.

2. Drilling Dust

The Importance of Drilling Dust

It is a well-established fact that the European miners who work in the neighbourhood of machine drills tend to contract pneumoconiosis to a greater degree than those whose work underground is not carried out in such areas. Table I shows data extracted from reports issued by the Silicosis Bureau.

TABLE 1

Incidence of Silicosis
Production Rates Per 1,000 Men Examined

Year	No time on machine drills	Up to 50% on machine drills	Over 50% on machine drills
1944—1948 ..	1·9	5·0	12·2
1948—1951 ..	2·0	7·5	12·4

From this data the close relationship between the percentage of time spent in the neighbourhood of machine drills, and the incidence of disease is evident.

This does not necessarily prove that it is drilling dust which is the main factor in causing pneumoconiosis. Other theories have been suggested to account for the above relationship; for example, that men working at rock-breaking tend to be exposed more frequently (although only occasionally) to the very high concentrations of dust and toxic fumes caused by blasting, and that it is this occasional exposure which causes their greater incidence of lung dust disease. However some evidence on this point can be obtained from a study of the size distribution of the dust found in the lungs of miners who died of silicosis, and comparing this with the size distribution of the two different types of dust under consideration i.e. drilling dust and blasting dust. The comparison is more valid if the latter figures are corrected according to the lung retention of the different sizes of particle. The data are set out in Table II. It will be seen that the dust found in silicotic lungs resembles quite closely that produced by drilling. Presumably if blasting dust had been the main cause of silicosis in these men, the size distribution of the dust in their lungs would resemble the expected retention of blasting dust. The particles deposited in the lungs are, of course, subject to slow solution, to removal by phagocytes, possibly to some aggregation, and other effects which might influence their size distribution. Nevertheless it is difficult to postulate any reasonable theory to account for the dust residue in silicotic lungs being due more to the breathing of blasting dust than to the breathing of drilling dust. Again the indication of the available evidence is that drilling dust plays the main part in causing silicosis, but it is not conclusive.

For this reason we, at Central Mining Finance Limited, have been investigating in considerable detail the matter of reducing drilling dust. We feel that an appreciable reduction in drilling dust should result in a significant decrease in pneumoconiosis. Financial responsibility for this work was taken over by P.R.U. last year.

Description of Drilling Dust Test Chamber

We have established an underground drilling dust test chamber at Durban Roodepoort Deep Limited. Details are shown diagrammatically in Figure II, while Figures III and IV are photographs of parts of the test chamber.

The test chamber is located in an old 10 ft. × 10 ft. development end in country rock, of practically uniform composition throughout the length of the chamber. It is easily accessible from a nearby shaft.

Sixty feet back from the face an airtight timber barricade has been erected across

TABLE II

Particle diameter (microns)	% of this size retained in lung	DRILLING DUST		BLASTING DUST		% size distribution of dust from silicotic lungs
		Typical % size distribution	% size distribution of dust retained in lung	Typical % size distribution	% size distribution of dust retained in lung	
Under 0·2	±40	54	56	12	13	48
0·2	30	20	16	18	15	18
0·4	40	10	11	16	17	12
0·8	52	5	7	12	17	5
1·2	53	3	4	8	11	3
1·6	46	2	2	6	8	3
2·0	39	2	2	6	6	2
2·5	31	1·5	1	6	5	2
3·0	24	1	0·5	6	4	2
4·0	18	1	0·5	5	2	2
5·0	13	0·5	0	5	2	3

References

Data obtained from the following sources:
Percentage retention in lungs — Brown et al (Reference 1).
Typical size distributions — Patterson (Reference 2).
Lung dust size distributions — Beadle (Reference 3).

the drive; a door in the barricade permits entrance to the test chamber. Fresh intake air is drawn from the main downcast air supply of the mine and forced through a 22½ in. diameter ventilation column by an electric fan; at the delivery of the column it is filtered through a flannel bag. The air is delivered 3 ft. from the face end of the test chamber and then sweeps through the chamber, leaving it through an opening of approximately 4 sq. ft. cut in the wooden barricade. The quantity of intake air ventilating the test chamber can be varied by a baffle plate on the intake end of the ventilation column. The air volume is measured by means of an orifice plate in the ventilation column, across which is connected an inclined paraffin gauge — this arrangement was carefully calibrated by means of four anemometers measuring the air flow. The actual total air flow through the chamber during a test is obtained by adding together the volume of intake air and the free volume of the compressed air used in working the drill.

The machine-drill under test is mounted on a bar-rig (see Figure III) and the thrust to it is supplied by a compressed air motor — preliminary investigations showed that the machine operator could not always provide a constant thrust during a days test, even if an airleg was used. This arrangement eliminates this human factor. The holes are drilled in the sidewalls of the test chamber.

The air and water supplies to the machine drill pass through adjustable pressure con-

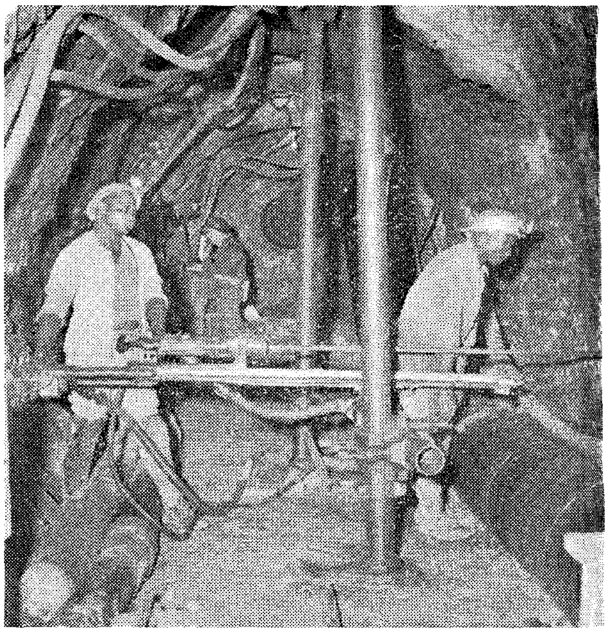

Figure III.

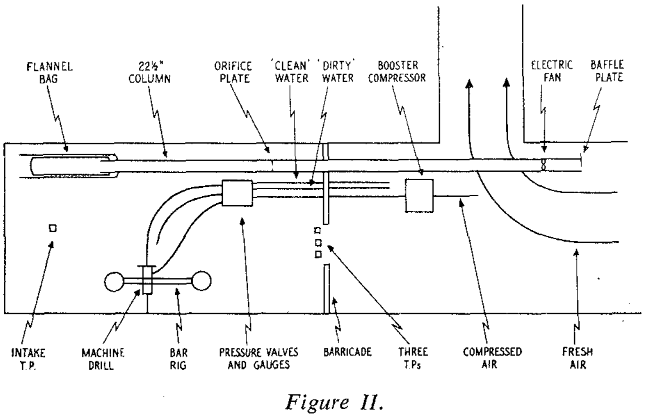

Figure II.

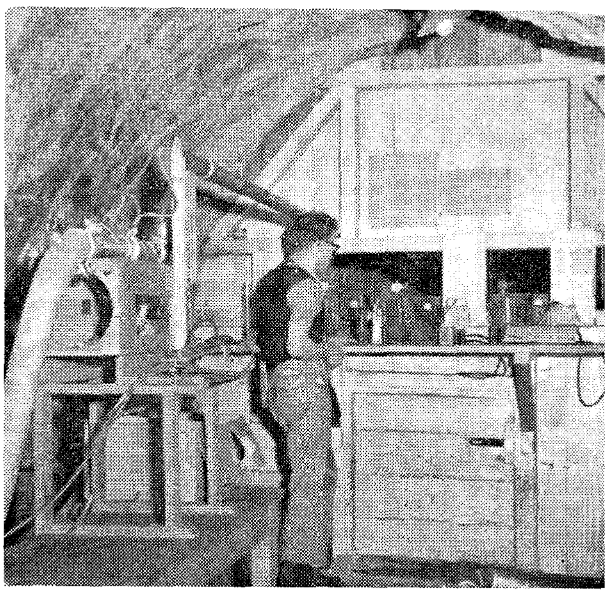

Figure IV.

trolling valves, which hold the pressure steady to the required values to better than 1 lb. per sq. in., and the actual pressures are read on gauges. The air flow to the drill is measured on a flow-meter. The compressed air supply line incorporates a booster compressor to enable high air pressures to be attained when required. The compressed air used for operating the drill is filtered before use. Tests showed that its dust content was negligible.

Two sources of water are available, and used as required — "clean water," namely Rand Water Board water passing through the mine's reticulation system and "dirty water," water which has been used in the mine and is being pumped back to the surface. The suspended solids and dissolved salt content of this water varies, and during each test a continuous sample of the water being used is taken by a drip-feed inserted into the supply line. The solids in suspension and solution in the water are measured in seven different ways, namely:

(i) The number concentration per c.c. of particles in suspension by the standard "deep-cell" method, after adding 5% cold HC1 (Ref. 4).

(ii) The same method, after boiling with 5% HC1 and allowing to cool.

(iii) By nephelometer (Ref. 5) (which gives a reading in arbitary units related approximately to the surface area of particles in suspension) — before adding any HC1 to the water sample.

(iv) Nephelometer — after adding 5% HC1 to the water sample, and waiting 30 minutes for solution to take place.

(v) Nephelometer, after boiling with 5% HC1 and allowing the water sample to cool.

(vi) The solids in suspension by weight concentration — determined by filtering and weighing the solids retained on the filter paper.

(vii) The solids in solution by weight — determined by evaporating the filtrate from (vi).

These various measurements are carried out because there is, as yet, no reliable published evidence on the best method of determining the dust content of water, or the effect of this dust on the dust added to the air when this water is "atomised" and then evaporates as occurs at the front head release ports of a machine drill. The information obtained by correlating the measurement of the dust content of the water (measured in these different ways) with the dust added to the air should produce useful information.

The amount of water atomised by each drill, during each test, is determined by measuring the absolute humidity of the air leaving the test chamber immediately before drilling starts, and again while drilling is in progress. The increase in humidity (grains per cubic foot of air) is converted to the actual water evaporating (in grains per minute) by multiplying by the air flow through the chamber.

A single thermal precipitator is used at the face end of the chamber to measure the dust concentration in the intake air — this is always small, of the order of 20 p.p.c.c. (particles per cubic centimetre).

Three thermal precipitators are mounted on a shelf at the opening in the barricade, and the air leaving the test chamber passes over them. There is usually good agreement between these three results and their mean is taken as the dust concentration of the return air. From this measurement (which is usually in the range 200 to 3,000 p.p.c.c. "before acid treatment") the intake air dust concentration is subtracted, and the result corrected to a standard air flow through the chamber of 1,000 c.f.m. The actual air flow found most suitable in practice is about 3,000 c.f.m. and special tests have shown that it is valid to correct the results to 1,000 c.f.m. by simple proportion.

Experimental Methods Used

The standard South African Government practice for testing the dust production of machine drills is to drill in an unventilated test chamber, relying on the exhaust air of the machine to carry the dust out to the sampling point. This method was tried at first but has the following disadvantages:

(i) The air in the test chamber rapidly becomes saturated after drilling starts. From this stage on, the water atomised at the front head release ports can no longer evaporate, and this source of dust (which may account for 80–90% of the total dust produced by a machine drill) may be seriously under-estimated.

(ii) In tests in our test-chamber it was found that under unventilated conditions, the dust measurement at the outlet of the chamber was a function of the distance of the drill from the outlet. Since in the course of a long series of experiments it is obviously necessary to drill at different distances from the outlet, this will introduce an undesirable variable.

(iii) Other tests showed that in a large test-chamber, such as ours, the time taken for the dust to build up to a steady equilibrium at the sampling point, with unventilated conditions, is very long and the concentration may in fact not have reached a steady level when sampling starts. This will require a large increase in the number of holes drilled and the time for each test.

For these reasons, it has been preferred to make the tests with a ventilated chamber. The machine usually operates $\pm$ 30 ft. from the sampling point, and with 3,000 c.f.m. flowing through a 10 ft. $\times$ 10 ft. chamber, it is obvious that the time taken for the dust from the machine to reach the sampling position is of the order of one minute. Coagulation or settlement of fine dust in this time is likely to be negligible. Tests showed that under the ventilated conditions the measured concentration was independent of the distance of the machine from the sampling position, within the range of distances used in the tests. Tests were made of the rate at which the dust concentration built up at the sampling position, and it was found that equilibrium was reached within about one minute, with an air flow of approximately 3,000 c.f.m.

It is known that collaring the hole produces more dust than actual drilling, but since collaring only lasts for a small fraction of the total time spent on drilling a normal hole, this source of dust measured on a dose basis (i.e. concentration $\times$ time) been shown to be less important than actual drilling dust. However to eliminate its effect all holes are collared on a day prior to an actual test.

There are two main sources of dust in drilling — (i) the dust produced by the disintegration of the rock being bored — both by the action of the bit at the bottom of the hole, and by the rubbing of the drilling steel (jumper) against the sides of the hole and (ii) the dust produced by atomization and evaporation of the water used when some of it is sprayed out at high velocity through the front head release ports of the machine. These fine droplets of water evaporate rapidly (if the air is not saturated) and any dust contained in the water is then released into the air. If the water also contains any salts in solution (which is normally the case), these salts will also be left behind in the air when the water evaporates, and will either be found as a skin around a dust particle or as a pure particle of salt. If sufficient dust particles are present in the water it is believed that the salts will crystalize more readily around a convenient nucleus such as is provided by the solid particles in suspension. Thus the typical particles produced by atomization of water containing both suspended and dissolved matter probably have a nucleus of a solid particle (often silica) surrounded by a skin of salt.

These two sources of dust will be referred to for convenience as (i) "jumper dust" (ii) "machine dust." When both are measured together, the results will be referred to as the "total dust" produced by a machine drill.

Considerable time was spent attempting to evolve accurate methods of measuring separately the "jumper dust" and the "machine dust." At first it was thought that the "jumper dust" could be measured by placing a suction hood over the hole, with a hole in the hood through which the jumper passes, and sucking away the dust through a flexible duct to a sampling box containing three thermal precipitators, and that the "machine dust" could be measured by enclosing the whole of the machine in an airtight casing through which the jumper passes and leading away the dust produced by the machine to another sampling box with three other thermal precipitators. Numerous tests were made but it was found that the results obtained were completely unreliable, inconsistent and inaccurate. The counts were usually lower than the true dust from the particular source. Any method based on this system may lead to serious errors of measurement.

A second method tested was to erect an air-tight wooden brattice extending from floor to roof and parallel to the sidewall in which the holes are drilled and to have the machine on one side of the brattice, with the jumper passing through a hole in the brattice and then entering the rock. Although this arrangement appeared to be satisfactory from the dust sampling point of view, there were practical objections from the point of view of drilling a large number of holes in this way and the method was abandoned.

The method finally adopted of segregating the two sources of dust is to use a suction hood around the jumper and over the hole and, using an ejector, to exhaust this dust outside the chamber without attempting to measure its concentration. Dust measurements are then made at the normal position at the barricade and show the "machine dust" production.

The suction hood is then removed from the hole, the machine is encased in an air-tight cover, and the dust from the machine is passed outside the chamber. The dust measurement at the barricade now shows "jumper dust" production. In both cases of course the intake air dust concentration is subtracted from the measurements. These two hoods are both shown in Figure V, although of course only one at a time is actually used.

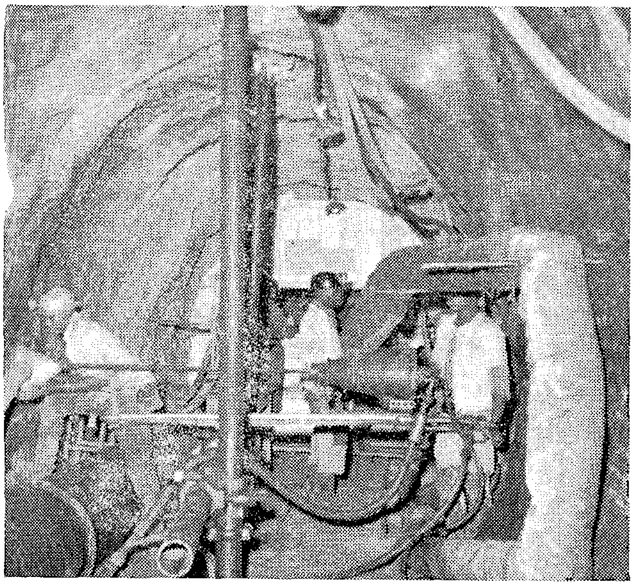

Figure V.

In an actual test two European observers (ventilation and study department) take part, with four or five Native assistants. Special tests showed that the movements of these personnel during their duties caused a negligible amount of dust, usually less than 30 p.p.c.c. When all is ready, the machine is started drilling in the collared hole, and the thermal precipitator measuring the intake air is started. Two minutes later the thermal precipitators at the outlet sampling position are started.

The study observer supervises the drilling, controls and records the air and water pressures, and measures the time taken for the machine to penetrate a further 48 in. into the rock — this is usually of the order of 5 to 15 minutes. The drilling steel is marked before the tests with two paint marks 48 in. apart to simplify this measurement. To overcome the possible effect on dust production of wear of the bit, a new tungsten carbide borer is used for each hole.

The ventilation observer undertakes the dust sampling, takes temperature readings (from which the absolute humidity is determined from tables), supervises the collection of the water samples, measures the air flow through the chamber, and records all relevant data.

Each test is made with the machine drilling a single hole. Dust sampling stops when the hole is completed.

After each hole is drilled fresh air is allowed to sweep through the chamber for at least 10 minutes, a time which both calculations and actual test have shown to be adequate to remove all dust from the previous test.

If any serious fault occurs during an experiment, e.g. the machine fails to operate normally, that test is ignored, and is repeated. In a normal days work about 12 tests can usually be made, although up to 18 tests have been completed in a hard days work.

The slides containing the dust samples are brought to surface and are treated and counted in our dust research laboratory at Head Office. The microscope counts of the slides are made in two ways — firstly, after ignition at approximately 550° C., which removes carbon and oil particles, and organic matter, all of which, if present in the air, will be deposited with the dust, and secondly, after the above ignition followed by treatment in hot 50% HCl to remove soluble inorganic salts produced by evaporation of the water, and further ignition. It is known however that this so-called "acid-treatment" of the slides tends to remove a variable percentage of the silica particles in the dust samples. An improved method of removing the salts from the slides without disturbing the silica particles, is urgently required.

These two methods of counting thermal precipitator samples are however standard procedure on the Witwatersrand and are commonly known as, respectively, "before acid" and "after acid" counts. For details of the procedure see "Quality of Mine Air" (Ref. 6). In the present state of knowledge, it is probably advisable to pay attention to both counts in determining the dust production of a machine drill.

The optical microscope used for counting the slides has a magnification of x1500 and reveals particles down to approximately 0·13 microns diameter (Ref. 7). All particles seen under the microscope are included in the count. The average size distribution of the particles in our tests is shown in Table III.

The water samples taken during a test are also brought to surface and analysed in the various ways listed above.

All the data collected is recorded on special report sheets, and all calculations, etc., are checked by an independent computor. The data is then referred to the statisticians for analysis.

TABLE III

Diameter of particles (microns)	Percentage number
Less than 0·5	65
0·5—2·0	31
2·0—5·0	4
Over 5·0	<0·1

3. Results Obtained

We have made a very large number of tests, approximately 1,000, in this test chamber. This has involved taking and counting about 4,000 thermal precipitator samples.

Our first object was to determine if different makes or types of machine drill produced roughly the same amount of dust, or whether their dust production varied significantly. We have tested 9 common makes of machine drill, which between them account for about 90% of all rock drills in use on the Witwatersrand. Six to eight machines of each type were drawn randomly from current use in the mines. These machines were used to drill under carefully controlled conditions as regards air and water pressure, and the type of water used. All results are corrected to an air volume diluting the dust of 1,000 c.f.m.

The results of these tests are still being analysed statistically but it is quite obvious from the raw data that there is a highly significant difference between the average dust production of drills of different types. Thus the average dust production of the "best" drill (from the dust production aspect) is of the order of 200 p.p.c.c. ("before acid treatment") and 20 p.p.c.c. ("after acid treatment") while the "worst" drill produced an average of nearly 5,000 p.p.c.c. and 60 p.p.c.c. respectively.

The reason for these considerable differences has been investigated. One factor that makes a considerable difference is the length of the spline of the piston which is exposed in the cylinder, at the moment the exhaust port opens.

This effect is shown in the simplified diagram in Fig. VI, showing an "open spline" or "short piston" machine. The splines of the piston are exposed while the exhaust port is still closed, i.e. while there is still air at high pressure in the cylinder. Some of this air then escapes through the splines and enters the front head of the machine, which also contains some of the water being fed from the water tube to the axial hole in the jumper. The air has two ways of escaping from this front head — much of it escapes through the front-head release ports but takes with it some of the water. Due to the high velocity at which it passes through the release ports it "atomises" the water, i.e. reduces the water to very fine droplets, causing the well-known fog at the release ports. Due to their small size these particles evaporate very rapidly, and if the water has contained any dust in

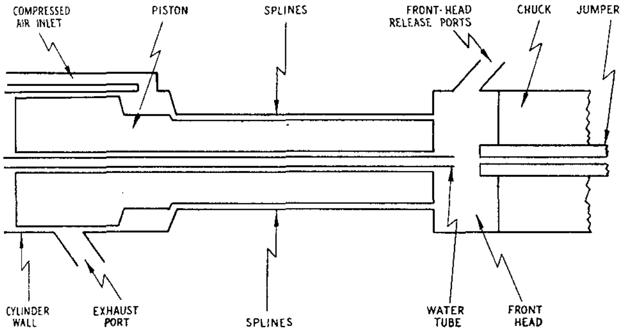

Figure VI.—STANDARD MACHINE. Splines open before exhaust port opens.

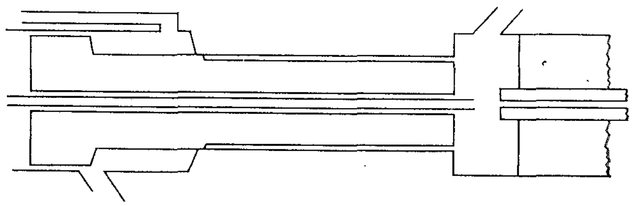

Figure VII.—SEALED-SPLINE MACHINE. Splines still sealed after exhaust port opens.

suspension this dust will be released into the atmosphere.

The balance of the air escapes down the axial hole in the jumper with the water and these bubbles of air in the water may carry dust produced at the bottom of the hole out into the atmosphere where it is liberated when the bubble of air "bursts."

In the so-called "sealed-spline" or "medium-piston" machine (Fig. VII) the splines of the piston only expose in the cylinder after the exhaust port has opened, i.e. when the pressure in the cylinder is greatly reduced. The flow of air into the front head is thus greatly reduced. In the so-called "long-piston" machine (Ref. 8), the splines never expose, and this leakage of air is further reduced.

Our tests have shown that the longer the length of spline exposed in the cylinder before the exhaust port opens, the greater is the "total dust" production of the machine. When such a machine is altered to the "sealed-spline" type its dust production is greatly reduced — the "before acid treatment" count being reduced by well over 50%. Exact quantitative results cannot be given until the statistical analysis of our results is complete. The performance of the drill in other respects, i.e. penetration speed, is not affected by this modification. In this respect our work has confirmed that of other workers, notably Hildick-Smith (Ref. 8).

We have also investigated the effect on dust production and drilling speed of different air pressures, different water pressures and the quality of the water used, i.e. its dust content. The latter factor has a pronounced effect on dust production as measured by counts before acid treatment — "dirty" water producing counts ranging from 3 to 8 times higher than with "clean water."

There is often a considerable difference in the dust production of machine drills of the same type. To investigate possible reasons for this, many of the machines used have been stripped after use and the wear and clearances of all important parts measured. The total air consumption, the volume of air leaking down the jumper and the performance in terms of blows per minute and foot pounds of work per minute are also measured. From a study of these measurements it is hoped to determine the effect these various parameters have on the dust production.

We have also shown that the dust produced at the front-head release ports ("machine dust") often accounts for about 90% of the "total dust," measured before acid treatment. Another experiment showed that this source of dust can be greatly reduced by fitting "Baffle plates" in front of the release ports. The fog of fine water particles emerging from the release ports strikes this plate, and runs off it as a stream of water before it evaporates.

Some preliminary tests have shown that a new type of "external water feed" machine produces far less dust than standard machines. In such machines the water is fed into the borer in such a way that it cannot come into contact with the compressed air; all fogging at front-head release ports and flow of compressed air down the borer is therefore eliminated. Unfortunately, hitherto, such machines have always failed to stand up mechanically to normal use underground, the most common failing being excessive breakages at the side hole drilled in the borer.

The effect of adding two different substances to the water has been investigated. A so-called " soluble oil " increased the penetration speed significantly but neither this substance nor a proprietary soap compound reduced the dust production of the various machine drills in which they were tried.

Detailed results, giving actual figures of dust production under all the conditions mentioned above, will be published in due course when the statistical analysis of the data has been completed.

4. Occupational Dust Sampling

I will now deal, rather more briefly because it is still in its early stages, with the other major project we are undertaking for P.R.U.

No valid data has ever been published, based on strict scientific observation, which shows the relationship between the average dust breathed by a worker throughout his working life, and the time it takes the man to contract a given stage of a dust disease.

The National Coal Board, in Great Britain, has set out to obtain this important relationship in what is known as the "Pneumoconiosis Field Research " project, or more popularly as the "25-pit scheme." Mr. Kitson and I both referred to it briefly (Refs. 9 and 10) on this same occasion last year. Since then I have had the opportunity of studying it in more detail on a P.R.U.-sponsored study tour last September-October. It is a gigantic research project, employing over 100 men full time on it, and scheduled to last for at least 10 years. The annual running cost is about £150,000.

Here in South Africa we are starting a similar scheme, but on more modest lines. Briefly the object is to follow certain randomly selected underground workers throughout their working shifts, taking continuous dust samples from the time each man leaves the surface until he returns there at the end of his shift.

The field observer, taking the dust samples, is instructed to keep as close as possible to the selected worker throughout the shift. The worker is encouraged to carry out his normal days work, even if that may, in some respects, be not quite according to regutions or managements ideas! Our observers do not make any notes of his habits and we scrupulously avoid any comment, either to the man, or the mine officials on the man's work — literally we " see no evil, hear no evil, speak no evil." Generally we are satisfied that we do obtain a fair measure of the true dust to which the men are typically exposed. To date we have had excellent co-operation from the miners themselves, and from the Mine Workers' Union, who are in full sympathy with the scheme.

We take three types of dust samples—(a) two or three standard thermal precipitator samples covering the whole shift, these are assessed before and after acid treatment, and a full size distribution measurement is made of each slide. From this we can calculate such parameters as the number or surface area or mass of the particles in any desired size range. (b) Successive modified thermal precipitator samples which cover 10 minutes each (Ref. 11). These are assessed photoelectrically (Ref. 12). It is my belief that these measurements give a better measure of the danger to health of dust than any other method of dust sampling (Ref. 13). These observations, which amount usually to about 40–50 per shift also give valuable information on the variations in dust level during the shift, a factor which may be significant. (c) Konimeter samples, on the basis of one every 10 minutes throughout the shift. Although the konimeter is believed to be inaccurate (Ref. 14), there are so much data based on its measurements over the past 30 years or more, that it was decided to include it in the survey.

A special harness carrying the above equipment has been designed to make it as easy as possible for the field observers to follow the miner wherever he goes. The standard thermal precipitator head is mounted on a mechanical aspirator which replaces the water aspirator. A spare thermal precipitator head is carried already loaded with slides so that when a new sample is to be started, slides can be exchanged with a minimum of delay.

The electrical controls for both the standard thermal precipitator and modified thermal precipitator are mounted on a common panel in front of the observer. A special warning light indicates when the modified thermal precipitator has reached the end of its run. The batteries to operate both thermal precipitators and the investigator's cap lamp are carried on his back.

Although no one would claim that while carrying this apparatus it is easy to follow an energetic worker, so far our field observers have not often failed to keep close to the man throughout the whole shift.

From these sampling shifts we shall build up records which show us the range of dust concentration to which various occupational groups of underground workers are exposed throughout their daily shifts.

When we have obtained sufficient data, the results will be compared with the development of lung disease in these same classes of workers; this work will be undertaken by the Statistical Unit of P.R.U. As a result of these investigations we should obtain a great deal of useful information in reply to the following questions.

(i) What are the relative dangers of different categories of mining work? This answer would spotlight the type of working place at which immediate and urgent efforts should be made to improve dust conditions.

(ii) Which method of dust sampling and assessment correlates best with the health hazard of dust? When this answer is obtained, consideration should be given to the practicability of adopting this method for routine dust sampling.

(iii) What is the true relationship between dust and disease? Once this relationship is obtained, it will be possible to specify the maximum dust levels which can be tolerated without causing dust diseases in any stated time.

This last point warrants some amplification. Suppose we plot a hypothetical graph showing the relationship between dust and disease. This is shown in Figure VIII. Note that no units or methods of measurement are specified — this does not affect the argument.

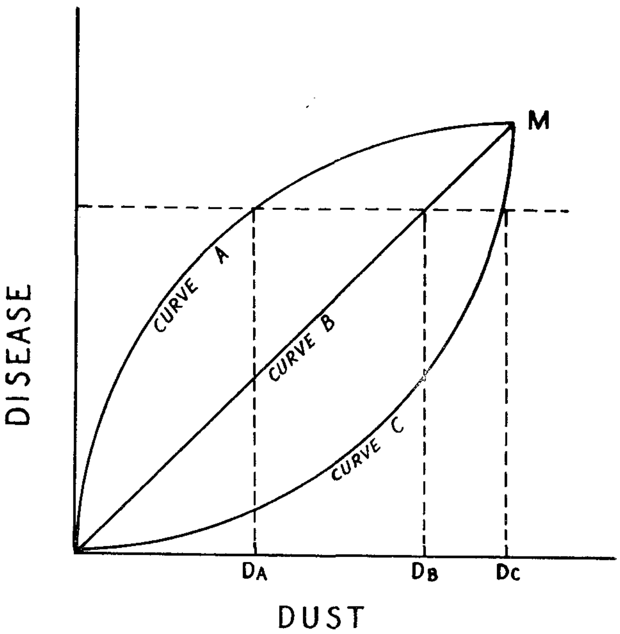

Figure VIII.

The average relationship between the two parameters may be as in curve A, or as in curve B, or as in curve C, or, of course, any other shape.

Let us also postulate that the level at which the disease becomes detectable, disabling or compensatable (i.e. the level below which we wish to keep it under given conditions) is shown by the horizontal dotted line.

The first useful result we get from having the true relationship between dust and disease, is the maximum level of dust which is permissible if disease is not to occur. That is, if the relationship is as in curve A, the maximum dust level is D_A; if the relationship is as in curve B, the maximum dust level is D_B, and similarly for D_C. This alone will be extremely useful information.

But there is a second important use we can make of this result. Suppose present day average dust levels are at point M. If curve A is the true relationship between dust and disease, it indicates that very great reductions must be made in dust levels before disease incidence is reduced appreciably. The effort and cost would need to be enormous, but at least we would know the facts.

If on the other hand, curve C is the true relationship, even a small general reduction in dust levels would produce a large decrease in disease. If this could be shown to be the case, surely everyone concerned would be prepared to put in that little extra effort required? When we get these facts — and it is the basic object of our research to get get them — we will know where we stand in regard to dust control. At present no one can give an answer based on scientific grounds to this question which might well be asked — "If we reduce the dust in our mines by, say, 25%, what effect will it have on the incidence of pneumoconiosis?" It should not be impossible to reduce dust levels by any reasonable specified amount, if we know for certain that this would produce a sufficient decrease in disease to make the effort worth while.

I hope I have said enough to satisfy you that the investigations we are making for P.R.U. are well worth making, that they will add to our knowledge on this important problem of dust, and that when the results are known and applied, we shall have helped to some extent to combat this enemy.

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