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A SYMPOSIUM ON RECENT DEVELOPMENTS IN DUST SAMPLING

BACKGROUND

In August, 1963, a symposium was held by the Society at the Chamber of Mines Research Laboratories in Johannesburg on the theme " Recent Developments in Dust Sampling ". Subsequently, in November, 1963, this symposium was repeated in the Orange Free State at the request of the local branch of the Society.

The speakers were from the Chamber of Mines Dust and Ventilation Research Laboratory and from The Corner House Laboratories of Rand Mines, Limited. At the Orange Free State meeting some of the papers were read by other speakers on behalf of the original authors, who could not be present. The discussion leader on each occasion was Mr. D. G. Beadle. Approximately 100 persons attended the Johannesburg meeting and nearly 70 the Orange Free State meeting.

Many of the individual talks were accompanied by actual demonstrations of the instruments or techniques described, and naturally these cannot be given adequately in this report of the proceedings. This report has been prepared by Mr. D. G. Beadle.

Introductory Address

THE NEED FOR DUST SAMPLING

D. G. Beadle

Dust sampling has been carried out in our South African gold mines, by one means or another, for nearly 60 years. Why, after so long a period, do we need to have a symposium to discuss recent developments in this field? Might it not be considered that everything that needs to be known or done in this field is now completed?

But the facts are that, at present, between 2,000 and 3,000 new cases of pneumoconiosis (out of a working population of about 300,000) are found each year; the amount of compensation paid out each year to men with the disease and their dependants is nearly R8,000,000 (£4,000,000), and there has been no significant change in the average dust levels in these mines for about 20 years.

The average dust concentration in these mines, according to published figures, based on konimeter sampling, is about 150 p.p.c.c. This level should not, according to much work published overseas, produce much pneumoconiosis.

The apparently inconsistent statements in the above two paragraphs lead us to pose several questions:—

(i) Are we measuring the true dust levels in the mines, to which men are exposed?

(ii) Are we using adequate dust sampling instruments?

(iii) Are we doing enough dust sampling? By law, each place need be sampled only once per quarter, and our present routine methods cover only a fraction of a second.

(iv) Should we carry out more frequent sampling?

(v) Can we carry out more frequent sampling? Our present methods of assessment of samples are laborious and time-consuming—there is a clear case for automation of methods here.

(vi) Do we treat the dust samples correctly before examining them?

(vii) What is the composition of the dust we sample?

(viii) The 1959 International Pneumoconiosis Conference in Johannesburg specifically recommended that the parameter which should be measured in silicosis studies was the surface area of the respirable dust, i.e. the dust likely to be retained in the human lung during respiration, and that measurements of the dust hazard should extend over a suitable period, e.g. a full working shift. What are we doing to implement these recommendations?

Today's symposium is designed to give you information on these and other points, and to bring you up to date with much of the "back-room" work that is going on in the Chamber of Mines and The Corner House Laboratories on this important subject of dust sampling.

Although dust sampling itself is only one aspect of the wider problem of dust control in mines, it is an important aspect. Unless we can and **do** sample correctly and sufficiently often in order to locate places and operations with unsatisfactory dust conditions, progress to reduce dust levels to satisfactory limits must inevitably be slow.

I hope I have said enough to indicate that it is important that we continue to strive to improve our dust sampling instruments, the techniques of assessing the samples and, perhaps above all, the need to review constantly our dust sampling strategies. My colleagues will now describe to you, in some detail, and often accompanied by actual demonstrations, some of the fields in which they have been, and still are working to improve dust sampling in our gold mines.

LONG SAMPLING THERMAL PRECIPITATORS AND MODIFIED THERMAL PRECIPITATORS

P. J. Blignaut

The thermal precipitator has been found to be one of the most reliable and accurate instruments for the sampling of airborne dust. The operation of the instrument is based on the physical phenomenon of the existence of a dust-free space near a hot body, so that if a cold body, such as a glass slide, is placed close to an electrically heated wire, dust particles which may be present in the space between the wire and the glass will be deposited on the slide as a strip of dust.

The standard thermal precipitator in its present form was first described in 1935 by Green and Watson. Commercial models are in production. There are a number of limitations to this instrument, such as the use of two slides for collecting the dust samples, and the use of a water aspirator for the air. Because of this, the Chamber of Mines has undertaken research into improved instruments.

In 1948 P. H. Kitto, of the Chamber of Mines, published his work on a long sampling thermal precipitator in which a single 3x1 inch slide was traversed by clockwork over a heater wire and slot system. A water aspirator was used. In 1952 Kitto and Beadle published a paper on the first modified thermal precipitator, again using a single 3x1 inch slide which could be moved over the wire and slot system by means of an external knob to give twelve separate samples on one slide. A bellows aspirator of 100 c.c. capacity aspirating at 10 c.c. per minute, driven by a small electric motor, battery-operated, was used. The heater wire consumed 2 amperes from a caplamp battery, the current being set by a potentiometer. This type of instrument is used in the gold mining industry for research purposes and in the South African coal mines as the routine dust sampling instrument.

It was found that the bellows aspirating mechanism was not entirely satisfactory and further research resulted in a new aspirating device, described by Kitto and Nunlist in 1959, which consisted of a diaphragm pump driven by a small electric motor to give an aspirating volume of 10 c.c.p.m. A new research thermal precipitator was designed which provided adjustable sampling time using this pump and the modified thermal precipitator head. The instrument has an aluminium carrying case containing a silver-zinc battery and controls consisting of a combined on-off switch and current setting potentiometer, together with an ammeter to indicate heater current. The silver-zinc battery was adopted because of its greater power efficiency compared to that of the caplamp battery. This instrument has an intrinsically safe electrical circuit.

The silver-zinc batteries have been found to be unreliable, so that another version of this instrument using nickel-cadmium batteries of greater reliability, but poorer efficiency, has been developed to prototype form. This instrument uses a governed aspirating and timing motor with a more sophisticated intrinsically safe electrical circuit.

The long sampling thermal precipitator is being further developed and a prototype model is at present being tested. The instrument samples continuously over 24 hours using a voltage controlled governed motor to achieve timing accuracy. The slide is traversed over the heater by a screw mechanism in the head. This type of thermal precipitator will have many applications as a dust monitor in the mines.

It will be seen that there has been much progress in the application of the principle of thermal precipitation for dust sampling. The Chamber of Mines Laboratory, together with The Corner House Laboratory, are now jointly designing a thermal precipitator using the basic techniques of head design and aspiration used in the latest version of the modified thermal precipitator. This is intended for use in routine dust sampling in mines. It will be discussed in the next paper.

A NEW FORM OF MODIFIED THERMAL PRECIPITATOR

D. J. Vermeulen

The generally accepted opinion, especially in the Rand Mines Group, is that thermal precipitator samples taken with a suitable particle size selector offer the most satisfactory basis for dust sampling in our gold mines.

You have just been shown the latest available form of the modified thermal precipitator by Mr. Blignaut; there are several reasons why we should not be satisfied with this present form of the instrument. These are chiefly concerned with its suitability for routine sampling in our mines. The apparatus is too bulky, heavy and complicated for such use. A further objection is that if more than ten samples are required in one shift, it is, in general, necessary to change the microscope slide underground with the consequent serious risk of contamination.

Since a new instrument should be of general usefulness in the mining industry, the Corner House Laboratories and the Chamber of Mines have combined to form a joint committee to design an improved version incorporating the main features of the existing instrument.

The agreed requirements of the new instrument are as follows:—

(1) It should be simple to operate.

(2) Its weight and size should be kept to a minimum.

(3) Slides should not be changed underground.

(4) The instrument should be suitable for operation while a man is moving or crawling in a stope.

(5) The instrument should be intrinsically safe, i.e. able to pass the Government Mining Engineer's Departmental tests for proving electrical instruments safe for use in fiery mines.

The aim is to produce an instrument at least as simple and reliable as the present konimeter. If possible a foolproof interlocked slide transport and timing mechanism will be incorporated, rather after the fashion of the modern single action lever rewind camera. This will be so arranged as to prevent double exposure. There will probably be no need to adjust the current flowing through the wire, thus eliminating a further control, as the nickel-cadmium battery keeps a practically constant voltage until it becomes almost completely discharged.

It is estimated that where an instrument is to be used by a ventilation official in addition to his other ventilation measurements, he will only require ten dust measurements in one shift and will therefore only have to carry one instrument with him. However, if he intends to take only dust measurements, he might take up to 30 samples during one shift (i.e. five hours of sampling time); in such cases he will be obliged to carry up to three complete instruments underground with him, in order to avoid changing slides in a dusty atmosphere. It is therefore important that the instrument should be both light and small. It is hoped that each instrument will not weigh more than 2 lb including batteries and occupy a space say $6'' \times 5'' \times 2''$.

The whole construction will be sturdy and must be capable of supporting a man's weight. (As one ventilation official put it, " We require an instrument which we can use as a walking stick whilst crawling down a stope ".) The shape must be such that it will be convenient to carry and will not topple easily when placed on a rough surface.

(At this stage, the speaker demonstrated a wooden " mock-up " of the proposed instrument.)

It is possible that we shall incorporate a removable size selecting head having omnidirectional sampling characteristics and capable of operating satisfactorily irrespective of air direction. Another improvement being investigated concerns the design of the heating wire support. It is our desire to devise a means of mounting this in a manner easier and cheaper to produce than at present.

AN IMPROVED KONIMETER MICROSCOPE

C. Hoffman

I think that most present here are conversant with the fact that considerable eye-strain and concentration is involved in assessing dust samples by means of a microscope.

It was with this knowledge in mind that the Gold Fields Research Bureau decided to investigate the possibility of using a binocular microscope for making dust assessments, as it was felt that this would be a means of reducing eye-strain and attendant fatigue.

At the time of taking this decision, I was employed at the New Consolidated Gold Fields Research Bureau and I was assigned the task of counting thermal precipitator slides with a microscope equipped with a binocular eye-piece. I will not go into detail about my findings; let it suffice to say that I very much favour the binocular eye-piece.

As a result of a favourable report on this microscope, it was decided to further extend this experiment and use binocular eye-pieces on the konimeter microscopes. Two mines in the Gold Fields Group purchased microscopes fitted with binocular eye-pieces. Very favourable reports were received from these mines.

In the Chamber of Mines Laboratory we also have binocular microscopes for thermal precipitator counting. Here again there is a very distinct preference shown for the binocular microscopes and members of the staff claim that they can do considerably more counting with these microscopes than is possible with the microscopes equipped with monocular eye-pieces.

We have on view here this afternoon one of these microscopes for counting konimeter samples and there is also a monocular microscope. Both these instruments have slides on the stage and you are invited to examine the samples on each microscope.

The cost of this microscope is R400 when fitted with a Neofluar objective and will be approximately R60 less with an ordinary Achromatic objective.

THE AUTOMATIC PARTICLE COUNTER

J. Thompson

Introduction

Because of the labour involved in the counting and sizing of dust particles by optical methods, a machine that can count and size dust samples simply and easily would be a great asset.

Different machines have been developed in an attempt to automate dust counting. The Chamber of Mines some years ago bought a commercially available automatic particle counter. The cost of the machine was R6,000. The reasons for acquiring the machine were as follows:—

(1) The information available indicated that it would provide satisfactory results.

(2) The machine was in commercial production.

(3) The information and experience to be gained from the machine would indicate whether the machine would in fact count and size correctly and, if not, based on the experience gained, a suitable machine might be developed to meet our requirements.

Description of the machine

A magnified image of the dust particles is projected on a screen in which is situated an adjustable slit. The slide containing the dust sample can be moved by a scanning mechanism which causes the images of the dust particles to pass over the slit.

Behind the slit is a photo-multiplier tube which generates an electrical pulse as each image passes across the slit. The height of the pulse is proportional to the particle size. Each pulse is amplified and passed on to five pulse height discriminators. A discriminator will generate an output if the pulse at its input exceeds a predetermined height. Associated with each discriminator is a counter bank which counts the pulses generated by the discriminator.

How the machine is operated

The slide is placed in position and the stage is adjusted to ensure that the particles will always be in focus when the slide is moved. The slit height is set according to a predetermined programme. The amplifier gain is adjusted to calibrate the pulses. The discriminator's settings are checked. A key is pressed to start the slide traversing mechanism. At the completion of the scanning cycle, which is entirely automatic, a count is displayed on each bank of counters and recorded.

The slit is then set for another particle size and another count is made. The process continues until sufficient information has been obtained.

The counts are then plotted on a graph. From the graph one is able to compute the number of particles of a particular size occurring per unit area of sample.

Limitations of the machine

Factors influencing the operation are:—

(a) *Frequency Bandwidth*
The required bandwidth depends on particle size, slide speed, the number of particles per unit area and the accuracy desired.

(b) *Sensitivity*
The limit is set by the brightness of the light source, the sensitivity of the photo-multiplier and the smallest slit opening required. The constancy of the light source is also important.

(c) *Sharpness of projected image*
The mechanism which moves the slide must be accurate enough to keep the particles in focus. As the particles become smaller and the magnification becomes greater, so the difficulty of keeping the particles in focus increases.

If one considers a particle 1 micron in diameter and a sample density of 4 per cent projected area, the following tentative specification arises:—

(a) Minimum counter speed for evenly distributed particles 12,000 cycles per second.

(b) Minimum amplifier bandwidth D.C. to 500,000 cycles per second.

(c) Flatness of slide and error in slide moving mechanism $\pm 0{\cdot}3$ micron.

It was found that the machine as purchased did not meet our requirements. Modifications have already been made to the counters, the light source power supply and the amplifier. It is felt that the machine, with certain modifications, ought to be able to count particles down to 1 micron in diameter at the expected sample densities with reasonable accuracy.

COUNTING CONTROL CHARTS

Mrs. M. van der Walt

To maintain a certain standard of accuracy in dust counting, periodic check counting is carried out in the Corner House Dust Laboratory. In order to decide if the counts by two different microscopists agree within satisfactory limits, the "Counting Control Chart" (see Fig. 1) has been introduced.

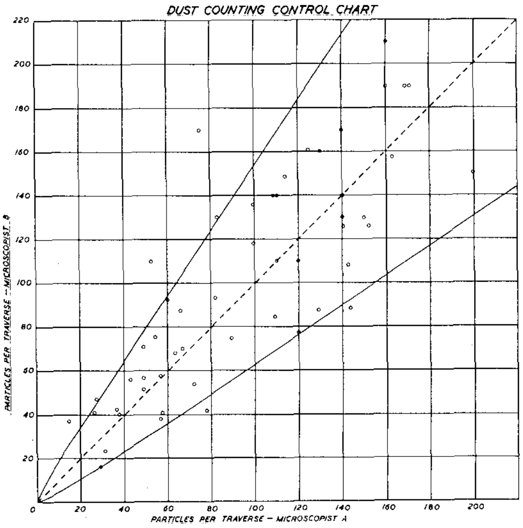

Figure 1

These charts were compiled as follows: Hundreds of slides were each counted by two or more experienced microscopists. They knew that their results were to be compared with each other, and presumably took special care to obtain the most accurate possible results. These results were then given to the Consultant Statistician (Dr. H. S. Sichel) who calculated the limits within which (at the 99 per cent level) all counts could be expected to agree when great care is taken in the counting. These limits are the solid lines on the chart, and it will be noted that they are not straight lines. The dotted line is at 45° and if two microscopists obtained exactly the same count, the plotted point would lie on this line.

In our routine counting, a microscopist does not know when one of her counts is to be checked by another microscopist. During the course of routine counting, a senior laboratory assistant will decide, at random intervals, that a check count must be made on a slide which one microscopist has just completed. The check count is made by either the senior assistant herself or another assistant. The two counts of the same slide are then plotted on the control chart. A separate chart is maintained for each pair of microscopists in the laboratory.

Even though we do not expect exact agreement between the counts of the same slide by two different microscopists, we do know that, when a microscopist is properly trained and experienced, her counts should fall within the specified limits when compared with another microscopist's. It is expected that 99 per cent of all comparison counts should fall within the control lines. If it is found that a given microscopist's counts are consistently higher or lower than the general average, or that the same person has too many points falling outside the control lines, she will be relieved of her duties!

RECENT IMPROVEMENTS IN PHOTOELECTRIC ASSESSORS

D. J. Vermeulen

The work I am about to describe to you does not concern any fundamental work to produce a new instrument. We have been concerned with certain improvements and extensions of the present double beam photoelectric assessor, originally developed by D. G. Beadle, with which you are presumably all familiar.

It has been noticed that on several of our existing instruments there was a serious zero drift which occurred when first switching on, and which re-appeared after each operation of the read/calibrate switch through the "off" position. This drift decayed exponentially with time, but it nevertheless took up to ½-hour for the instrument to reach usable stability. This slowed the operation of the instrument enormously, especially when the drift was re-established after each successive calibration.

The fundamental cause of this drift has not been established, but we know that it occurs only when two cells are connected as in the photoelectric assessor circuit, and then only occasionally. Cells displaying this drift show no tendency to drift when checked individually.

The drift is initiated when the resistance in the circuit is changed from a low value to a high value and this occurred every time the instrument was switched from "read" to "calibrate" through the "off" position.

The remedy has been simple—we have eliminated the "off" position. The photoelectric assessor is then much more stable once it has settled down and remains so throughout its operation.

The second improvement concerns the reading of the instrument. You may have had the experience of trying to use one of these instruments and have realized how necessary it is to take care in setting the slide exactly in the right position to obtain a maximum galvanometer reading. This usually involves moving the slide backwards and forwards through the maximum to be quite sure of catching the peak.

To a large extent this is due to the rather sluggish action of the galvanometer in the circuit which we have been using; by that I mean it is slow to respond to changes in the circuit current. However, even with a fast acting galvanometer, the process of taking photoelectric assessor readings is slow and if consistent results are to be obtained, the work is exacting. We have therefore been considering the use of an electric motor to drive the slide across the light beam, and a rapid-response recorder to record the peak readings. In recent years it has become possible to obtain recorders of the same order of sensitivity as the spot galvanometer, whilst at the same time being robust and reliable.

The apparatus demonstrated here merely illustrates the recording of photoelectric assessor samples and is not the best suited to the problem.

We do not at this stage envisage using the instrument in this form; this is merely an experimental stage to prove the worth of recording photoelectric assessor results in this manner.

Apart from the more rapid assessment of slides, this method gives a permanent record which can be referred to at any time afterwards.

The recorder which we envisage will have a response time better than ½ second, whilst the spot galvanometer has a response between 5 seconds and 1 second.

A DIFFRACTION APPARATUS FOR ASSESSING DUST SAMPLES

J. H. Talbot

The modern trend in dust sample assessment is towards instruments capable of rapid, accurate and automatic operation. Such instruments have many advantages. They relieve microscopists of their tedious duties, eliminate errors due to fatigue and differences between individuals, and minimize the time and costs required to obtain results. Two instruments intended for this purpose have already been mentioned in the addresses by Messrs. Thompson and Vermeulen. A further two at present being developed in the Chamber of Mines Dust and Ventilation Laboratory will now be described.

The first is a particularly simple instrument intended only for the measurement of projected area. The second is a more elaborate instrument which, in addition to the projected area, gives complete information about the size distribution. Both instruments make use of the phenomenon of diffraction.

Determination of projected area by measuring the diffracted light is a comparatively new method; earlier instruments measured the extinction of the primary light beam. The method of obtaining the diffracted light separately was discovered quite recently. This is achieved by aluminizing the slide with the dust sample on it. (The technique is similar to that for making surface replicas described in Part II of my series on electron microscopy recently published in the Society's Journal.) The dust particles are then removed from the slide by washing. In their place are left holes in the aluminium film of the same size and shape as the dust particles which they replace. The light transmitted by these holes is accurately proportional to their area for diameters down to at least 0·3 micron. This provides us with the most accurate method known (apart from electron microscopy) for measuring the projected area of dust samples. It is superior to the extinction method in two respects. The first is the accurately linear relationship between the signal and the projected area for particles larger than 0·3 micron. The second is the large improvement in signal-to-noise ratio resulting from the elimination of light scattered by the glass slide.

An instrument based on these principles is at present being developed in this laboratory. Like that just described by Mr. Vermeulen it uses a recording potentiometer to give a permanent record of the projected area. Except for slide changing, operation is entirely automatic. The instrument is intended for routine use for measuring dust on mines. It is difficult at this stage to give an estimate of the cost of such an instrument, but it could probably be built for between R600 and R1,000 depending largely on the quality of the recorder used.

Tests have shown that the aluminizing technique is a practical proposition for routine use, a junior laboratory assistant becoming proficient in about three days.

Another instrument invented and being developed here is the diffraction size-frequency analyser (DISA). Sample preparation is the same as for the simpler instrument just described. By scanning the diffracted light with a photo-multiplier we obtain a curve (called a diffraction pattern) on the chart of a recording potentiometer. By a careful choice of illuminating conditions the area under the curve can be made proportional to the projected area of the dust cample. The size distribution can be obtained from the diffraction pattern by computation (it takes 1½ minutes on an IBM 704 computer) or a distribution of a

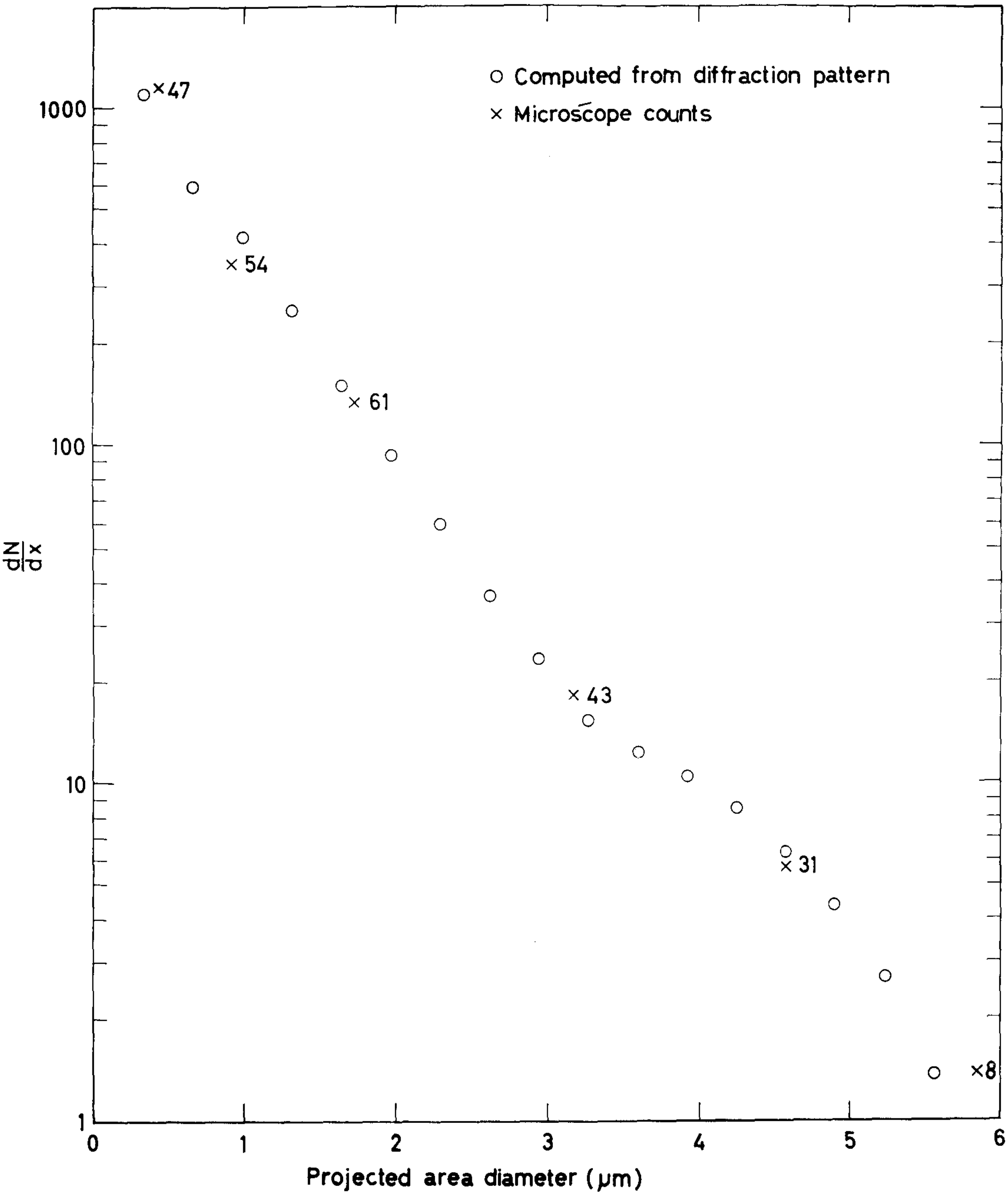

Fig. 2. The size-frequency distribution computed from the diffraction pattern (circles) and the size-frequency distribution obtained by a 40-traverse count on the same sample with a light microscope (crosses).

standard type can be fitted optically by a method known as pattern recognition. However, much information about the size distribution can be obtained from the diffraction pattern without resorting to either of these techniques. The diffraction pattern is a representation of the size distribution in a distorted space, something like the projection of a spherical earth on to a flat surface, except that the distortion is more severe. With experience, one soon learns that in Mercator's projection areas near the poles of the earth are greatly exaggerated and one quickly learns to make automatic allowance for this. Similarly, to an experienced observer, the diffraction pattern can be almost as meaningful as a plot of the size distribution in ordinary space. By recording the diffraction patterns on transparent paper one can rank samples according to size distribution, projected area, or total number of particles without any calculation by merely superimposing the curves. By comparison with a number of standard distributions one can obtain a very good idea of the size distribution. For ultimate precision either the pattern recognition or the computer method can be used.

The present experimental instrument records the diffraction pattern of one sample every two minutes, the speed being limited by the slow response of the recorder. Using a high speed recorder the time could be reduced to 15 seconds per sample. A prototype, still in the design stages, will be fully automatic and will record diffraction patterns at the rate of two per minute.

Advantages of the diffraction size-frequency analyser over other automatic instruments are:—

(1) It makes use of the entire dust sample.

(2) It is much simpler and cheaper. No high precision work is necessary and there is no need for any focusing.

(3) It is faster.

(4) The results lend themselves to rapid automatic curve-fitting and goodness-of-fit tests.

Its advantages over microscope observations are:—

(1) Speed.

(2) Automatic operation.

(3) Elimination of errors due to fatigue and elimination of differences between observers.

(4) The whole dust sample is used. Compared with a single traverse count on a thermal precipitator sample this results in an improvement by a factor of 35:1 in the statistical uncertainty due to counting a limited number of particles.

(5) The results lend themselves to rapid automatic curve-fitting and goodness-of-fit tests.

Its only disadvantage is the need for aluminizing the slides. However, with modern vacuum equipment this is very easy and samples can be treated in large numbers at a time.

Finally, to convince you of the soundness of the method, the results from a sample of dust taken with a thermal precipitator at an underground tip in the normal course of operations is given in Fig. 2, which shows the size distribution computed from the diffraction pattern (circles) together with the size distribution obtained from microscope observations (crosses). This is one of a number of similar comparisons made on samples of mine dust, all of which show excellent agreement.

CALCULATION OF THE RESPIRABLE SURFACE AREA OF DUST SAMPLES

C. D. Williams

One recommendation made at the 1959 Pneumoconiosis Conference held in Johannesburg was that the surface area of the respirable dust be measured.

As you know, the konimeter, now used for routine dust sampling on the mines, provides a measure of the number concentration of the dust, that is, it gives the result in particles per cubic centimetre, and this, of course, is not a surface area measurement.

The latest medical evidence seems to support the theory that whatever causes the fibrosis or damage in the lungs must come from the surface of the dust particles which have entered the lungs. It has also been shown that the dust is deposited differentially in the lungs, that is, only a specific proportion of the dust which is present in the air will reach the lungs.

It was undoubtedly considerations such as these that resulted in the Pneumoconiosis Conference recommending that the surface area of the respirable dust, that is, the surface area of the dust which would penetrate to the lungs, be measured.

In order to calculate the surface area of a dust sample taken by the thermal precipitator, it is necessary to size the particles during the microscope counting. From this it is possible to draw a size-frequency curve.

Now the recommendations made at the Pneumoconiosis Conference was that 100 per cent of the particles of 1 micron and smaller be measured, that 50 per cent of the particles of 5 microns be measured and that no particles of size 7 microns and greater be measured.

Obviously this correction does not make a very big difference if the result is expressed as a number concentration because most of the particles in our dust are less than 1 micron. However, if we are to heed the recommendation made by the Pneumoconiosis Conference and so measure the surface area, this correction is very important, as the larger particles are responsible for most of the total surface area of the sample.

For the calculation of surface area, the dust particles are considered as spheres.

As can be imagined, the calculation of respirable surface area from first principles, for each slide, will be time-consuming and therefore expensive. The result can be worked out on a computer, but this again is expensive.

Rand Mines, Limited, in asociation with Dr. Sichel and Mr. A. Joffe, have developed a technique whereby all the necessary steps can be done from prepared tables. Hence having obtained the size-frequency for a thermal precipitator sample by counting under the microscope, it takes only approximately two minutes using these tables and charts to calculate respirable surface area.

INVESTIGATION OF SUB-MICROSCOPIC PARTICLES

J. H. Talbot

It is not my intention to describe the results obtained with the electron microscope. These were recently published in the Society's Journal. Instead I wish to mention some lesser known matters relating to dust sampling with the electron microscope. Some of the remarks will be applicable not only to electron microscopy, but to other techniques as well.

Let me state at the outset that I do not consider the electron microscope to be a very suitable instrument for this purpose. At present it is the only well-tried method we have of assessing the submicroscopic dust particles, but I feel that the time is approaching when it should be superseded in this application.

You all know that the electron microscope yields beautiful pictures of even the most minute dust particles with a sharpness and faithfulness unequalled by any other instrument. The accuracy of the results is of a high order. What then is the objection to the electron microscope?

It is the laborious nature of the techniques, making the method costly and slow. You are all aware of the disadvantages of costly methods. I shall, therefore, deal only with the disadvantages of slow methods.

The development and introduction of new mining methods are continually being made. With the mining industry's increasing awareness of the value of research we can expect improvements and innovations in mining methods to take place more rapidly in the future. It is essential that any dust evaluation technique to be of value should be sufficiently rapid to keep abreast of these developments. It is of no use to know the dust production of some method when that method has already been supplanted. To quote one example, the dust production of the exposed spline machine drill was studied by electron microscopy in the years 1953–1956. This study had no sooner been completed when this type of drill was supplanted by the sealed spline machine. To study the dust production of this machine by the same methods would probably occupy two or three years, by the end of which we may find that it is no longer in use.

What then can take the place of the electron microscope?

One possibility is to use an electron diffraction instrument similar in principle to the diffraction size-frequency analyser described in my earlier talk. This I feel is possible but not easy. A more practical approach would seem to be to build up the smaller particles by vacuum coating their edges by the method described in Part III of my recent series of articles on electron microscopy published in the Society's Journal. The light diffraction method could then be used to study the entire particle size range.

If the electron microscope techniques have been slow in producing results, then the statistical analysis of these results has been even slower. The optical pattern recognition method of curve-fitting mentioned in my earlier talk provides a rapid method of performing much of the work at present done in a laborious way by statisticians. In addition to curve-fitting the method provides us with a ready-made goodness-of-fit test. Diffraction size-frequency analysis lends itself to this sort of thing in a way that no other method does.

I would not like to give the impression that the electron microscope is redundant in dust studies. Those of you who have taken the trouble to read my series of articles on electron microscopy will, I hope, agree with me that this instrument has given, and will continue to give, valuable results in dust research quite apart from its use in dust sample assessment.

MINE VENTILATION NOTES FOR BEGINNERS

By W. L. le Roux

(Continued)

NOTE 5:

DENSITY OF HUMID AIR

It has previously been explained how to calculate the density of dry air. Calculating the density of humid air is rather more complicated and is normally avoided by looking up the answer in density tables or charts. However, it is useful to know the principles on which the calculation is based.

In example 4 it was shown that the density of dry air at 26 in. Hg. and 65°F was 0·0657 lb./cu. ft.

Example. What is the density of humid air at 26 in. Hg. and 65°F?

It is impossible to give an answer to this question unless more information is supplied to indicate how humid the air is. Either the wet bulb temperature, the dew point temperature or the relative humidity must be stated.

(*a*) Let us assume that the air is saturated with water vapour.

From tables, the vapour pressure of water at 65°F is found to be 0·62 in. Hg.

The partial pressure of the air is thus $26 - 0 \cdot 62 = 25 \cdot 38$ in. Hg. (see Note 4).

Now, using this pressure.

$$PV = WRT$$

$$25 \cdot 38 \times 70 \cdot 7 \times 1 = W \times 53 \cdot 3 \times 525$$

$$\therefore W = 0 \cdot 0641 \text{ lb./cu. ft.}$$

This is the weight of the air in the mixture.

From the tables 1 cu. ft. of saturated vapour at 65°F weighs 0·00098 lb.

The total weight of air plus water vapour in a cubic foot of the mixture is thus:

$$0 \cdot 0641 + 0 \cdot 00098 = 0 \cdot 06508 \text{ lb.}$$

One cubic foot of air and saturated water vapour thus weighs less than 1 cu. ft. of dry air at the same temperature and barometric pressure.