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A SYMPOSIUM ON RECENT DEVELOPMENTS IN DUST SAMPLING

Continued from January, 1965

THE " CELLOIDIN " TREATMENT OF DUST SAMPLES

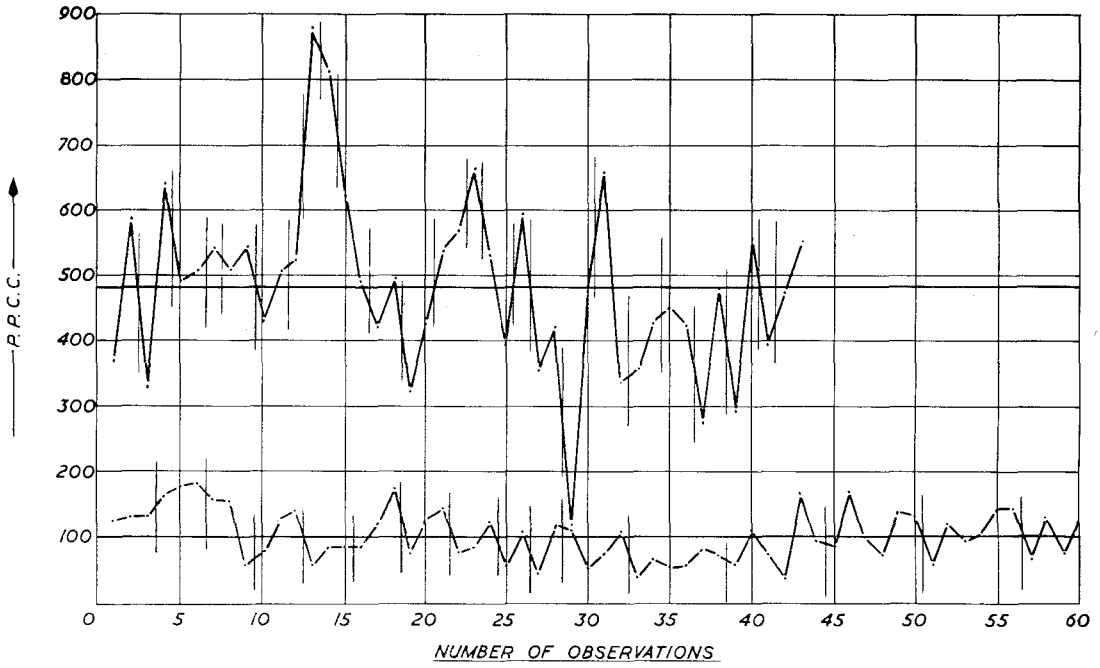
Mrs. F. Coetzee and Miss P. Sandham

It has been known for some time that the standard method of treating dust samples by immersing the slides in hot hydrochloric acid, results not only in the removal of the acid-soluble particles, but also in the mechanical loss of non-soluble, or rock, particles. This loss is particularly heavy amongst the larger size particles, and hence leads to a considerable reduction in the surface area of the rock particles contained in a sample. For some time we have been seeking a method of treating slides which will allow all the acid-soluble particles to be removed, but will prevent the loss of any non-soluble particles.

As a result of a suggestion from the Pathology Division of the Pneumoconiosis Research Unit, such a method has now been found and proved to meet the requirements; it is called the " Celloidin " technique and is now in standard use in the Corner House Laboratories for the treatment of thermal precipitator slides.

The " Celloidin " mixture consists of 1 gram of " Celloidin " dissolved in 100 ml. of alcohol and 100 ml. of ether, with a few drops of a colouring compound added. The slides, containing the dust samples, are first heated in the standard way to remove carbon and organic matter and then cooled. A drop of the " Celloidin " solution is then poured on to the dust strip from a sharply-pointed glass dropper. The slide is held at an angle of approximately 45° during this operation so that the solution runs over the whole strip. The solvents evaporate rapidly

Figure 3 **VARIATIONS IN DUST LEVELS**



and leave a layer of " Celloidin " over the dust particles. This layer has the property that it firmly binds all the dust particles on to the glass slide, but it is highly porous, so that the hot hydrochloric acid can penetrate the pores and reach the dust particles, and thus dissolve the acid-soluble particles. After the solution is applied, the slide must be put under alcohol within a few seconds, otherwise the " Celloidin " film hardens on exposure to the atmosphere and becomes non-porous. The colouring matter is added to the solution so that the operator can see that the whole dust strip has been covered by the layer.

The dust strip, coated by the " Celloidin " layer, is then treated in the immersion cell with hot hydrochloric acid, but the time of treatment must be longer than usual (about 30 seconds) to allow the acid to penetrate the porous layer.

The slides are then given a second ignition, which removes the " Celloidin " layer, and are then ready for examination under the microscope.

With an experienced operator, each slide takes only a few seconds extra to treat in this way, compared with the traditional method, and all our tests show that this improved method of treatment fulfils the requirements mentioned above.

VARIATIONS IN DUST LEVELS

C. D. Williams

It is well known that the amount of dust produced underground in any mine does not remain constant. Dust concentrations differ from time to time during a shift and from one shift to another. It is important to know something about these variations in dust levels if dust sampling is to be satisfactorily carried out.

Obviously if the dust levels are always the same in a given place, a sampling tech-

nique which involves making only one measurement there, will provide adequate information on the general average dust levels in that place. On the other hand, if the dust levels vary considerably either during a single shift or from one shift to another, then a single sample will often fail to provide a reliable value of the average or typical dust levels at that place.

There was no information available on the magnitude of the variation of dust levels underground in South African gold mines and so a number of investigations were carried out in order to determine this variation.

More than one hundred different working places on different mines were sampled using thermal precipitators. A number of samples were taken at each working place per day for a number of days. These samples were of at least one hour's duration. The results obtained at two typical working places are shown in a graph. (Fig. 3.)

These graphs represent two different working places. As can be seen up to 60 observations were taken. The small vertical lines indicate different days. The average dust levels of these places are represented by the horizontal lines. It can be seen from the top graph that a single sample could give results as high as 900 p.p.c.c. or as low as 100 p.p.c.c. The second place was better in that the variation was not as great, but here again a single sample could give a result of between 30 and 190 p.p.c.c.

All the results obtained in this series of experiments have been analysed statistically and it has been found that the typical coefficient of variation for a particular place was of the order of 50 per cent. However, in 5 per cent. of the places sampled, the coefficient of variation exceeded 100 per cent. Had the konimeter been used for this investigation, it is likely that the variation would have been greater due to its very short sampling time.

Finally, I think it is important that attention be given to these results, if we want to get accurate and meaningful results from dust sampling.

SEQUENTIAL CONTROL CHARTS

D. G. Beadle

Mr. Williams has drawn attention to the relatively large variations which commonly occur in dust levels in the same working place. The question which now arises is what should be done to obtain dust measurements which are representative of typical conditions in a given working place, seeing that a single sample may obviously not give a typical result.

Obviously if a large number of samples are taken at the same place, preferably on a number of different days, their average result is far more likely to be representative than any single sample. But we do not have the time and labour to take a large number of samples at each working place. How then can we make sure we have taken enough samples to give a representative mean, without wasting time taking more than the minimum number of samples required to give this representative figure?

After considering several ways in which this might be done, we have developed, in collaboration with Dr. H. S. Sichel, the use of "Sequential Control Charts". An example is shown in Fig. 4.

They are used as follows. At least two samples are taken at the selected working place on different working days; the mean of these two samples is plotted on the chart. As will be seen in the example, this mean result, based on the two samples taken so far, falls within the two curved control lines. This means that, at this stage of the tests, no decision can be made as to whether this particular working place has a typical dust level above or below the arbitrary standard of 300, accepted as marking the border zone between "satisfactory" and "unsatisfactory" conditions.

A third sample is then taken, and the average of all three samples taken to date is plotted. Again it will be seen that the mean, so far, is still inside the control lines, and so again, no valid statement can be made regarding the true dust conditions in that place.

However, the example shows that after taking a fourth sample in this working

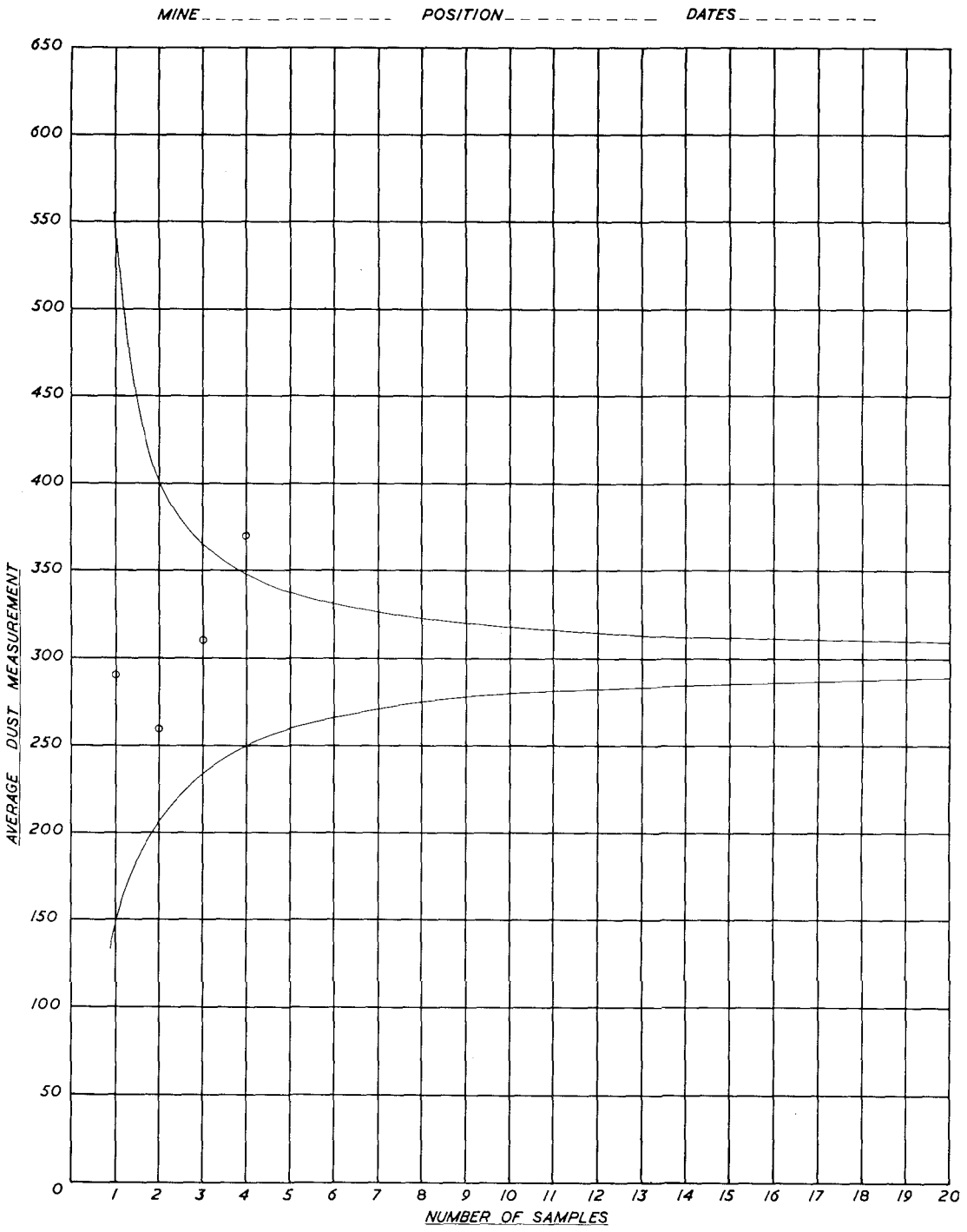

SEQUENTIAL DUST SAMPLING CHART
MINE
POSITION
DATES
AVERAGE DUST MEASUREMENT
650
600
550
500
450
400
350
300
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
NUMBER OF SAMPLES

Figure 4

place, and plotting the mean of all four samples, the plotted point is now above the upper control line, and this means that, based on statistical evidence, this working place can confidently be classified as " unsatisfactory ". Note that if a decision had been made based only on the first two samples, the place would wrongly have been classified as " satisfactory ".

The data on which this example is based are given below:—

Sample Number	*Result of this sample*	*Total of all results so far*	*Average result so far*
1	290	290	290
2	230	520	260
3	410	930	310
4	550	1,480	370

So far, we have only applied this technique to sampling for research purposes; here it has shown itself to be an excellent way of determining if our results are, in fact, statistically valid. We have not considered its application to routine dust sampling, where the need to go back to sample a given place perhaps several times over, until a valid result is obtained, will make heavy demands on time and labour. At the same time the evidence is quite clear that the blind acceptance of a single sampling period as necessarily being truly representative of the true average conditions in that place, is obviously often grossly misleading.

For the statistically-minded, it can be stated that these sequential control charts have been drawn for a co-efficient of variation of 50 per cent in the dust conditions, and that they give the stated result with 95 per cent confidence level. The full statistical reasoning on which they are based is obviously beyond the purpose of this symposium.

GRAVIMETRIC DUST SAMPLING

S. R. Rabson

Gravimetric sampling, as its name implies, is carried out for the assessment of dust concentration by mass or weight.

Gravimetric sampling consists basically of two steps:—

(a) *sampling*, i.e. collecting a representative portion of the dust from the air, followed by

(b) *assessment* of the collected material, by weighing or by chemical analysis or a related method.

A common method of sampling is to filter the dust by drawing the air through a suitable filter. Samples can, however, also be taken by separating the dust by means of electrostatic precipitation, or by a small cyclone or other apparatus operating on the centrifugal principle, or by bubbling or impinging the air through a suitable liquid.

Gravimetric sampling can be divided into two characteristic types:—

(1) Exposure or environmental sampling.

(2) Stack sampling, i.e. sampling of the dust effluent leaving a process in a stack or a duct.

(1) Exposure or environmental sampling

The purpose of this type of sampling is to assess the dust concentrations in the air to which personnel are exposed—in other words, to measure the dust hazard.

Gravimetric methods as distinct from particle number estimates are applied particularly where the dust is of a toxic nature. In such cases, it is the dose or weight of dust absorbed in the system that decides the extent of the harmful effect. Mass determination rather than number is also indicated in all cases where the material is relatively soluble and would therefore be completely dissolved in the system on a short-term basis. Gravimetric methods are used in the mining industry for uranium dust sampling, for manganese and lime dusts, for lead dust and fumes, and for welding fumes. Gravimetric sampling can also on occasion be used for siliceous dust to supplement the results of number determinations.

The characteristic features of the conditions that usually exist are the relatively small quantities of dust, ranging from less than 1/10 milligram per cubic metre (mg/M^3) to say 100 mg/M^3, the normal temperature and quality conditions of the air, and the relatively static nature of the air, velocities being generally less than

100 f.p.m. Consequently, sampling is comparatively simple since ordinary filter materials may be used, no difficulties arise from undue increase in resistance as the dust collects on the filter, and there are no complications from kinetic effects due to the velocity of the dust particles.

A suitable method of sampling is to draw air at a measured rate of say 25 litres per minute through a filter paper of convenient diameter, say 55mm. clamped in a holder, and connected to a pump of suitable capacity. The sampling period may vary from, say, 20 minutes to an hour or more.

The methods of assessment after collection of the dust vary according to the type of dust and other conditions. Apparently the simplest method would be to collect the dust on a weighed filter paper and to weigh the paper after sampling. In actual practice this method is not applicable for small quantities since it is difficult to bring filter paper to constant weight due to moisture absorption and loss in weight during drying. With siliceous and other incombustible dusts, the filter paper may be ignited and the residue weighed.

For dusts containing substances such as lead which tend to volatilize only at high temperatures, the filter paper may be burnt off by heating at a controlled temperature, say 500°C, without material loss of the substance.

Alternative types of filters are available with special properties. " Membrane " or " millipore " filters are highly efficient and more constant in weight than cellulose filters, but cannot be heated as high as 100°C without loss; they can be removed by ignition or by solution in suitable solvents. Similarly " Microsorban " filters are effective, but cannot be heated above 50°C. Glass-fibre filters have been found to be constant in weight and withstand temperatures up to 500°C and are frequently used.

For the determination of uranium, lead and other toxic dusts, e.g. manganese and lime, the collected material is dissolved in a suitable reagent, usually after removing the filter material by combustion, but sometimes directly from the paper, and the amount of contaminant determined by chemical analysis.

The following figures for the accepted MAC values (maximum allowable concentrations for 8 hours' continuous exposure) give an indication of the type of concentrations likely to be met in environmental sampling:

Uranium, Lead: 150 micrograms/M^3 (= 0·15 mg/M^3)

Manganese 5 mg/M^3
Iron Oxide 15 mg/M^3.

Silica dust concentrations in mines range commonly from about 0·1 to 1 or 2 mg/M^3.

(2) Stack sampling

The purpose of this type of sampling is to assess the amount of dust produced by a process, or leaving a process or plant through a stack, or the amount approaching and leaving a dust collector in order to determine its efficiency. In all cases, the emphasis is on the recovery or the loss in terms of weight of material. (Under these circumstances number determinations have no significance.)

The characteristic features of the conditions that usually occur are the high concentrations, the high velocities of the dust-laden air in the duct or stack, and the frequently severe temperature and corrosive conditions. These conditions often make stack sampling quite a complicated matter and place it in a different category from exposure sampling.

Concentrations may vary commonly from 0·01 to 1 grains per cu. ft., i.e. approximately 0·5 to 50 mg. per cu. ft.

(NOTE: For convenience connected with the assessment the mixed unit " mg/cu. ft." is commonly used in this type of work.)

Such concentrations rapidly cause high resistance to be built up on the collecting filter, with resulting drop in flow necessitating frequent adjustment and extensive correction for density at the measuring apparatus.

The usual method of sampling is to insert a probe into the air stream and withdraw a sample of the air by suction using a suitable pump downstream of the filter. The following requirements are essential in this type of sampling: —

(a) The probe must face the air stream.
(b) The sample must be withdrawn at the same velocity as the air stream, i.e. sampling must be isokinetic.

These requirements are necessary because of the high air stream velocities (typically 1,000 to 3,000 f.p.m.) and the resultant inertial effects of the dust. Failure to comply with isokinetic sampling results in erroneous figures, and the results can be from as low as $\frac{1}{2}$ of the correct results, if sampling is too rapid, to as high as two or three times the correct result if sampling is too slow. The position is further complicated because the dust profile is seldom uniform across the sampling cross-section, therefore the duct or stack must be traversed at a sufficient number of positions to obtain representative results.

The procedure for stack sampling is therefore broadly as follows:—

(a) Select a suitable sampling station with reasonably even air and dust distribution, i.e. as far from bends and obstruction as possible.
(b) Make a pitot traverse to establish the total volume flow and the velocities at the selected sampling position.
(c) Select a probe or probes of suitable diameter and calculate the sampling volume for each sampling point to ensure isokinetic withdrawal of air.
(d) Traverse the section with the probe at a sufficient number of positions, adjusting the sampling volume at each position.
(e) Adjust and correct the meter reading during operations to allow for build-up in the resistance of the filter.

Typical sampling rates range from 0·2 to 4 c.f.m. with occasionally up to as high as 15 c.f.m. Normal probes are from $\frac{1}{4}''$ to $1''$ in diameter. Filter sizes are generally 55 mm. or 11 cms. in diameter, but for high volumes larger filter areas and special shapes and arrangements are sometimes used.

Special pumps are required to provide the necessary duty and to cope with the increase in pressure, which may reach up to several inches of mercury as the dust deposits on the filter.

The procedure is further complicated if the air is not at normal temperature. For high temperatures, as with air from furnaces (flue gases), corrections must be made for the cooling of the air before it passes through the metering apparatus.

For high temperatures and when the gases are corrosive, the sampling equipment needs to be constructed of special material, and special filtering material must often be used. Usually it is advisable to ensure that the air does not cool below the dew point. Sampling in the moisture laden air from wet scrubbers, etc., often presents an awkward problem.

Almost every stack sampling project represents a problem on its own that requires independent decision as to selection of sampling station, sampling apparatus, filter material and sampling rates.

In order to simplify the procedure, electrostatic sampling has been used to replace the filter methods. This has the advantage that there is no increase in resistance, therefore sampling rate adjustments are easier to make and maintain.

Results are generally worked out on a basis of " lbs. per hour " passing through the stack or duct.

For estimation of collection efficiency, simultaneous samples are taken at the inlet and the outlet of the dust collector under test, over reasonable periods to cover representative conditions, and the percentage dust removed is calculated on a weight basis. Reference is made to all pertinent operating data, e.g. main volume flow, water gauge, etc. In efficiency tests and also where stack sampling is carried out for the purpose of establishing the specifications required for a suitable dust collector, samples are, in addition to weight evaluation, generally subjected to size analysis on a weight basis to complete the necessary information.

INSTRUMENTS FOR GRAVIMETRIC DUST SAMPLING

P. Buckley-Jones

(1) Small Gast Unit

This instrument is used for sampling particulate matter in the air underground, e.g. smoke from diesel engines and also for radioactive dust.

It is also used for conducting gravimetric tests in small diameter pipes.

Sampling rate is generally 10 litres per minute and maximum vacuum at the pump up to 20 inches of mercury.

(2) Gelman Pump Unit

This instrument was designed particularly to determine the weight of particulate matter in uranium plants. (Uranium, total dust, manganese and lime.) It is also applicable generally to all exposure type gravimetric sampling.

The pump is coupled directly to a small 6 volt D.C. motor of 1/20 h.p. which takes just over 10 amperes current.

Maximum vacuum at the pump is 20 inches of mercury. It is used with nickel cadmium rechargeable 6 volt batteries of 30 ampere-hours rated capacity, or with standard lead-acid batteries.

The sampling rate is generally 25 litres per minute. The filter holder is 55 mm. diameter.

The sample holder is specially designed for ease of loading filter papers, with a quick-disconnect arrangement, enabling easy change of holders. Usually a large number of holders are loaded in the laboratory to eliminate handling of filter papers on site. Filters available are ordinary cellulose filters, membrane, glass fibre and other special filters.

The feature of the pump arrangement is the flexibility with which samples can be taken:—

(a) With the unit placed on a bench.
(b) With filter on a stationary support at face level.
(c) Sampling at required position remote from the instrument.
(d) Continuously moving sample (carried over shoulder).

(3) Stack Sampling Unit

This unit is used to determine the mass rate of flow of solids in stacks and ventilation systems.

Features:

Probe and nozzles (stainless steel with cooling fins), Rotameter, vacuum gauge and thermometer, Pitot tube. Uses 11 cm. diameter filter paper, membrane filters or glass fibre filters for high temperature.

Pump:

Large Gast pump, duty up to 6 c.f.m. (generally 4 c.f.m.). Belt drive by $\frac{1}{3}$ h.p. motor.

Maximum vacuum 20 inches of mercury.

Graphs are used for rapid velocity estimates and selection of probe size/sampling rate for isokinetic sampling.

(4) General Purpose Air Mover

This unit can be used for general gravimetric sampling purposes, particularly where large volumes of air are required.

The volume required is regulated by using a variable transformer and measured by calibrated orifice plates from $\frac{1}{8}''$ diameter to $1\frac{1}{2}''$ giving 0·2 c.f.m. to 25 c.f.m. at a meter reading up to 4·0 inches W.G. using a dial gauge.

Maximum vacuum at the pump is 3 inches of mercury.

AN IMPROVED VERSION OF A GRAVIMETRIC DUST SAMPLER

E. Reinhardt

Amongst the gravimetric sampling units which Mr. Buckley-Jones demonstrated to you was the Gelman pump unit. We have borrowed this unit on occasions from the Chamber of Mines, and find it very useful, particularly for sampling in the lime and manganese sections of uranium plants. We recently decided to construct a number of these samplers for ourselves, and took the opportunity of redesigning it somewhat to make it more convenient to use and to carry. It is different in appearance to the instrument Mr. Buckley-Jones demonstrated, but however different it may look, it is basically the same instrument—it has the same motor, pump, sampling heads and flowmeter. A major difference, however, is that all the components are enclosed in one box which makes it easier to carry.

Incorporated in the electric circuit is a timer-clock, which can be pre-set to switch the motor off after any desired interval up to an hour. Thus it is easy for one operator to supervise several instruments distributed

at various points of the plant and sampling simultaneously.

Nickel-cadmium batteries are used as standard. A battery of five cells gives a sampling time of approximately $1\frac{1}{2}$ hours, after which they must be changed if further samples are to be taken. The battery contacts are built into the lid of the sampler box, and make contact automatically when the lid is closed. There is thus no need to make connections from loose wires on to the batteries.

The plug-in rods fulfil two purposes. They support the sampling head and flowmeter at any desired height; and they form the air passage connection between the pump and sampling head. They are made of hollow aluminium rod, with stainless steel bayonet fitting joints and rubber seals.

The flowmeter (of the "Rotameter" type) was modified to allow air to be drawn through it directly into the supporting rods below it. This was done by drilling a hole in the perspex casing of the flowmeter from the bayonet fitting through to the original outlet passage and then blocking off the original outlet.

We have also designed special carrying boxes consisting of trays each holding six sampling heads, which can be stacked one above the other to enable any desired number of heads to be carried. The top box contains the support rods, the flowmeter and other ancillary equipment.

Experience in recent months has indicated that this improved design is very suitable for our purposes, and it appears to have the following advantages over the original model:—

(i) The stability of the instrument is increased; as it has a larger base area, it is less likely to be knocked over accidentally.

(ii) The motor is isolated from the dusty atmospheres, which the apparatus is commonly used to sample. The motor is ventilated by the filtered air which has passed through the sampling head.

(iii) There are no external plastic or rubber tubes connecting the sampling head and the pump.

(iv) There are no loose wires, with crocodile clips, etc., to be connected to the battery.

(v) The incorporation of the automatic timer switch.

ELECTROSTATIC DUST SAMPLERS

P. J. Blignaut

Electrostatic dust samples fall under the heading of gravimetric samplers discussed in the contribution by Mr. S. R. Rabson. The purpose of my contribution to this discussion is to describe some of the instruments in use and their applications.

The electrostatic sampler works on the principle of electrically charging the dust particles in the air or gas being sampled and collecting the charged dust particles in an intense electric field on to a tube or plate.

The samplers are of two types:—

(1) Those which are used to obtain a mass concentration measurement of dust in a gas.

(2) Those which are used to collect bulk quantities of airborne dust for chemical or physical analysis.

In the first type of instrument the dust is usually collected on a tubular collecting electrode, as in the M.S.A. air sampler. The corona discharge electrode is placed on the central axis of the collecting tube and a potential of 12 kV is applied between the electrodes to provide the charging and collecting fields. The M.S.A. instrument has a small aspirating fan built into the head providing a sampling rate of about 3 c.f.m. The instrument is operated from a mains power supply.

As this instrument is not suitable for sampling from ducts or stacks, a task for which the electrostatic sampler is well suited, a sampler was engineered in the laboratory for this application. This sampler can be coupled to a sampling tube in a duct or stack. Air is drawn through the sampler by an external aspirator and a power supply provides 18 kV for its electrodes. The insulating body of the unit supporting the electrodes is provided with an electrical heater to prevent condensation of vapours which can lead to electrical failure. This

sampler has a theoretical collecting efficiency of 99·5 per cent at a sampling rate of 6 c.f.m. At 10 c.f.m. the sampling efficiency is still greater than 95 per cent. This sampler is at present operated from a rather bulky mains power supply. A compact battery supply is however under consideration.

These small tube samplers are not able to provide the bulk sampling necessary to collect a large sample in a practical length of time in a low dust area, so that a parallel plate sampler with a large collecting surface area capable of processing larger volumes of air was developed in the laboratory. A paper published in 1954 by Messrs. Kitto, Beadle and myself gave details of an early instrument which was in many ways rather crude. Subsequently, the instrument was re-designed in the laboratory to a much improved design. This instrument is powered by a battery power pack, providing 14 kV, processing the air at a rate of 100 c.f.m. The efficiency is not very high, being of the order of 75—80 per cent for 1 micron particles. The instrument is a compromise between high efficiency and weight and bulk. An instrument which is more efficient would be larger in dimensions. The instrument is designed to provide its own airflow from the energy of discharge from the ionizing wires.

It appears from our experience that it would be desirable to develop this instrument to operate so that it can be used as a true gravimetric instrument to determine mass concentration of dust in the air.

DETERMINATION OF THE COMPOSITION OF DUST BY X-RAY DIFFRACTION

A. Bradley

By way of introduction I should like to explain briefly how X-ray diffraction analysis is done. This method applies only to crystalline solids, whose distinguishing feature is the regular arrangement of their atoms in what can be regarded as planes. Many such planes will exist in a single crystal and the distances between planes parallel to one another (i.e. the lattice spacings) constitute a fundamental property of any particular crystalline substance, which can be identified if the lattice spacings can be measured. Most of the X-rays pass right through the crystal, but a small fraction is reflected by each plane. Now if the wavelength of the X-rays is of the same order as the spacing between the planes, a phenomenon known as interference takes place. This is caused by the fact that the second reflected ray has taken a longer path to the detector and, depending on the angle of the arrangement, it will either counteract or aid the first reflected ray. The effect of all this is that the X-rays are concentrated into certain directions by such multiple reflections. The procedure used in practice is to pulverise the sample to a fine powder so that we have millions of fragments, hence the term " X-ray Powder Analysis ". This powder is packed into a suitable sample holder, which, together with the detector, is rotated so that we scan the X-rays reflected by the powder. Our fragments are usually 5 to 10 microns in diameter and would have approximately 5,000 planes. The intensity of the reflected X-rays is recorded on a chart against the angle of the detector. The trace obtained is then like a fingerprint of the substance being tested, each peak representing the spacing between a particular set of planes.

Before going on to underground mine dust proper, there are two items of interest I should like to present briefly.

Table I shows some results obtained for two samples of airborne dust taken in the vicinity of sand dumps and slimes dams. It will be noted that the percentage of quartz is lower for the finer fractions.

Some eleven samples of soot were collected from a diesel engine during an investigation into slide contamination. The residue obtained from this soot after ignition amounted to 5·4 per cent where old lubricating oil was used, 1 per cent for new oil and 0·7 per cent for new additive-free oil. The main constituents of the residue were found to be quartz, $BaSO_4$ and Fe_2O_3 (haematite). The insoluble residue after acid treatment as well as ignition, was found to consist of quartz, $BaSO_4$ and a little non-crystalline material. No $BaSO_4$ was present when an additive-free oil was used, barium compounds apparently being commonly used

TABLE I

AIRBORNE DUST FROM SAND DUMPS AND SLIMES DAMS

	% *by Wt.*	% *Quartz*
Sample 1		
Greater than 325 mesh	41	87
Greater than 5 microns and less than 325 mesh	54	55
Less than 5 microns ...	5	32
Sample 2		
Greater than 325 mesh	30	74
Greater than 5 microns and less than 325 mesh	49	61
Less than 5 microns ...	21	45

as additives. It also seems likely that quartz, $BaSO_4$ and possibly iron tend to accumulate in engine lubricating oil.

So far we have collected 56 samples of underground airborne mine dust using electrostatic precipitator samplers, which are capable of sampling 6,000 cu. ft. of air per hour. Bearing in mind the limitations of these samplers for gravimetric sampling, the average or standard mine air was found to contain 166 mg. of dust per 6,000 cu. ft. Of this dust 86 per cent remained after ignition and 75 per cent after ignition and acid treatment. Of the residue 64 per cent was quartz, i.e. 48 per cent in the untreated sample. Expressed in the metric system we have 0·98 mg. of dust per cubic metre, of which 0·47 mg. would be quartz. A large variation, however, was found from sample to sample, the heaviest concentration being over 5·0 mg. per cubic metre and the smallest 0·094 mg. per cubic metre. The greatest loss after ignition was 70 per cent and the smallest 2·8 per cent. The greatest loss after acid treatment was 23 per cent. The highest percentage of quartz in the residue was 87 per cent and the lowest 41 per cent. Some sericite was usually present, the largest amount we encountered being approximately 40 per cent (in the residue).

TABLE II

Region	% *Quartz in Residue*	% *Quartz in Original*
East Rand (30 samples) ...	51	31
Central Rand (20 samples) ...	58	40
West Rand (21 samples) ...	58	41
Klerksdorp (8 samples) ...	50	36
Orange Free State (21 samples) ...	53	39

Table II shows the mean percentage of quartz in the residue for each mining region. For this purpose we have used the results obtained for some 44 samples collected by Mr. D. G. Beadle as well as our own figures and each sample has been given equal weight. It will be noted that some difference is shown between the various regions, but due to the large inter-sample variation this has not yet been demonstrated to be significant.

Closing Address

WHERE DO WE GO FROM HERE?

P. H. Kitto

In the first place because I am not in a position to dictate future policy in the mining industry, and in the second place because I am not a prophet, any answers I can give to the question posed in the title of this contribution can only represent my own opinions or suggestions with regard to possible improvements in dust sampling and assessment.

The previous speakers have given you some ideas of the lines along which developments are taking place, but before considering what the next steps should be, it would be as well to remind ourselves as to what the objects of all this dust sampling are. Apart from the obvious one of complying with the regulations, they may be summarized in one sentence as follows:—

To determine the dust concentrations to which men are being exposed at various

places in the mines with the ultimate object of keeping these exposures to a reasonable level.

Bearing this object in mind, why then do we need improvements to our present methods of routine dust sampling and assessment? In my opinion, there are three main reasons why improvements are essential.

(1) Because the amount of sampling being done at present is completely inadequate to enable us to achieve the object given above.

(2) Because present methods of assessment are slow and laborious, making it difficult to increase the amount of sampling without excessive increase in staff.

(3) Because many men are still getting silicosis and general dust levels have not improved for many years.

If we agree that improvements are necessary, let us consider likely ways in which this might be achieved.

At the outset I should like to stress that there is no need to wait for new instruments to be made before any action is taken to improve the position. It is common knowledge now, that the present konimeter returns do not give an unbiased reflection of dust conditions underground and I should like to appeal therefore to all mines to return the dust counts as they are found, whether conditions are improved later or not. Only in this way can we get a statistically valid picture of the trend of dust conditions from year to year.

In addition, more efforts must be made to find dusty places and to improve them, and for this purpose I think every mine should have at least one man whose job it would be to do just this and nothing else. At the same time we must endeavour to make all the workers underground more dust conscious—not an easy task I must admit. A few years ago a book was written by a well-known worker in this field overseas, entitled " Dust is Dangerous ". I should like to see a poster with this title as the caption prominently displayed at numerous places in every mine.

Looking a little further ahead, what next must we aim at in our efforts to reduce dust? Somehow or other we must get much more dust sampling done, but it must be based on a properly designed sampling scheme, putting more effort into sampling those places where high dust concentrations are likely to occur and less effort into places where dust counts are consistently low.

Automatic dust samplers such as the long-sampling thermal precipitator would be of value to act as monitors on the dust production of certain working places or sections, and if the samples could be assessed rapidly it would be easy to see whether conditions had changed to the extent of making further action necessary. If they had, men could be sent in with other instruments to locate the sources of increased dust production.

Still further in the future we may reach the stage where every man wears his own personal dust sampler, so that a permanent record is obtained of his cumulative dust exposure. Limits could then be set after which further dust exposure would not be permitted.

Coming to the assessment of dust samples, some rapid methods have been described by previous speakers. We hope that these, and possibly others as well, can be perfected in the near future. Their operation should, as far as possible, be automatic, even if this makes them costly, because the larger the number of samples that can be dealt with by one machine, the less the number of machines that will be necesssary. Centralized laboratories on a Group or regional basis may be the answer for expensive instruments of this type.

Summing up, therefore, I have endeavoured to show that while the research into, and the development of, dust sampling techniques are even more necessary today than they have been in the past, the practical underground man is still in the vanguard of our campaign against dust. Without your help and without your appreciation of the problems involved, little will be achieved. Let us not go down in history as the generation that merely maintained the " status quo "—let us rather make a real effort to break through the present " dust barrier ". Both morally and physically we shall reap the rewards in time to come.