JOURNAL OF THE MINE VENTILATION SOCIETY OF SOUTH AFRICA

Published monthly by the Mine Ventilation Society of South Africa.

Secretaries — ASSOCIATED SCIENTIFIC AND TECHNICAL SOCIETIES OF SOUTH AFRICA, KELVIN HOUSE, 2 HOLLARD STREET, JOHANNESBURG. TELEPHONE 834-1271 P.O. BOX 9426

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VOLUME 22 NO. 5 MAY, 1969 PRICE 60 CENTS (6/-)

ASH AND SILICA CONTENT OF AIRBORNE DUST IN TRANSVAAL AND ORANGE FREE STATE COLLERIES

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SUMMARY

Ash and silica contents of airborne dust are awkward substances to be measured quantitatively when uncertainties are considered as to their importance in the causation of lung diseases. Data obtained by the Collieries Dust and Ventilation Laboratories of the Chamber of Mines of South Africa indicate that there is no correlation between ash content and total silica or quartz content. Loading operations show the lowest ash content, then cutting and drilling operations. The mines in the Witbank area show a lower ash content than those in the Vereeniging area.

INTRODUCTION

The inhalation of excessive quantities of airborne dust on collieries can lead to the development of lung diseases. Most experts differentiate between anthracosis, also called coal miner's pneumoconiosis, which is regarded as being caused by pure coal dust only and anthraco-silicosis, which is caused by the added presence of quartz in coal mine dust in varying quantities.[1] For a number of years the Chamber of Mines Collieries Dust and Ventilation Laboratories have, in the absence of any definite guidance from medical experts as to the relative importance of various minerals, attempted to establish

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in what proportions some minerals appear in the airborne dust of South African collieries. The distinction made had to be a simple one for practical purposes, and is basically as follows:—

1. Water,
2. Volatile matter,
3. Coal,
4. Ash,
5. Total silica, including combined silica,
6. Free silica or quartz.

A typical sample of semi-bituminous coal may consist of 2–8 per cent. water, 22–35 per cent. volatile matter, 40–63 per cent. free coal, 10–27 per cent. ash and 0–8 per cent. quartz by weight.[2, 3] This, of course, does not establish that airborne dust underground is of identical composition to the mother rock and differences are often found, mainly because the components of the coal seam have different grinding characteristics, different specific gravities and different wetting properties. Furthermore, " respirable " contaminants occur in mine air due to the mining process, and these are collected by modern scientific instruments used to sample airborne dust. Blasting fumes and diesel fumes are such typical contaminants. Although the weight of respirable dust is the recommended parameter for coal, surface area is the parameter to be measured for quartz,[4] and the percentages for the various components of airborne dust vary according to whether one parameter or the other is used. The variation is twofold, namely, according to the specific gravity and the power of the particle diameters. The variation according to specific gravity means that for equal weight the coal fraction may have a much greater surface area than the quartz fraction because coal is much lighter than quartz. On the other hand, quartz, being normally of smaller particle diameter than coal, may have a larger surface area than coal for equal weight. Specific gravity and particle diameter counteract each other and it is very difficult to determine which way the trend will be. One should, therefore, not compare percentages measured by weight with those measured by surface area or, for that matter, by number.

Further difficulties arise when sampling instruments and assessment methods are considered. For gravimetric sampling instruments the variations are mainly in the absence of, or efficiency of, elutriation for the larger dust particles and the places and length of time covered by a single sample. The assessment methods of samples obtained gravimetrically vary from various chemical methods to X-ray diffraction and other methods. Even the measurement of weight is not the simple process it is often thought to be in comparison with the measurement of number or area, and considerable knowledge and experience is involved when the extremely small weight differences are to be determined with a satisfactory degree of accuracy. On the other hand, the modified thermal precipitator/photoelectric assessor technique is reliable and rapid [5] but cannot determine the quartz content of coal dust. Even after acid-treatment of the samples we cannot be certain that only quartz is left. More often than not kaolin and mica will still be present in undetermined quantities.[6] If we want to determine the quartz content of coal dust, we are, therefore, bound to the gravimetric collection of airborne dust.

Finally, we should bear in mind the results of overseas research which point to the fact that it is not the quartz inherent in coal but the quartz brought in from associated rocks, i.e. quartz with free surfaces, which is the main cause of silicotic lung changes.[7] If samples of coal are examined for quartz content by X-ray diffraction, whether before or after ashing, the amount of quartz determined includes such quartz as may be inherent in individual coal particles and which is potentially harmless. There is at present no reliable method of differentiation between these two conditions. Differentiation by high-power microscopy [8] or phase contrast microscopy [9] has been attempted in other countries, but is also fraught with uncertainties as " free " quartz particles may adhere to, or be covered by, larger particles, and thus pass unnoticed through the field of view.

X-RAY ANALYSIS OF AIRBORNE DUST SAMPLES

The advent of modern portable gravimetric samplers has facilitated the estimation of the amount of dust present in mine air. Concurrent with the introduction of these samplers an X-ray diffraction technique has been developed to enable quartz determinations to be carried out on small samples.[10] A brief description of this technique follows.

Standard X-ray diffraction procedures for quantitative analysis require that the sample be sufficiently thick to prevent the X-ray beam from penetrating it. In this way a "saturated" reflection is obtained. However, if the other extreme is resorted to and the sample is made sufficiently thin so that the reflection is of the order of 10 per cent. of saturated, then a linear relationship between density of deposition and X-ray response is obtained. This simplifies the analytical procedure. Furthermore, calculation shows that, for copper K alpha radiation, a density of deposition of only 0·35 mg quartz/cm^2 is required to give a response of 10 per cent. of saturated. In practice it has been found that specimens with densities of deposition of 0·7 mg/cm^2 and less can be analysed and the limit of detection for quartz is about 0·01 mg/cm^2. For good results the sample must be very fine and must be evenly deposited. A sampling spot as small as 1 cm^2 can be used on the X-ray apparatus.

There are two ways of preparing suitable specimens for analysis. Firstly, the sample can be ground and dispersed in water and then deposited onto a membrane filter using filter apparatus. Better still it can be deposited directly from the air onto a membrane filter installed in a gravimetric sampler. Using this latter procedure many samples have been taken in gold mines by the Corner House Laboratories and analysed jointly with the Chamber of Mines Research Organization. Most coal dusts, however, contain only a small amount of quartz and, furthermore, the gravimetric samplers suitable for use in coal mines use large filters and have low sampling rates. For these reasons it has not been possible to obtain sufficiently high densities of deposition for the quartz to be determined directly on coal mine samples, and the samples were therefore ashed and redeposited on smaller sampling spots. This was the method used for the analysis of the samples in category E below.

ASH CONTENT

Six categories of samples coded from A to F will be presented in these notes, and a brief description of their main characteristics follows.

CATEGORY A: Bulk samples of *in situ* coal: collected from various seams by ventilation observers on different mines. The analysis was carried out by the Physical Sciences Laboratory. Total number: 26, of which 26 analysed for total silica and 10 for quartz content.

CATEGORY B: Bulk dust samples: obtained with a hand-pump and coarse cottonwool filter in a glass-tube during 1958. The analysis was carried out by the Physical Sciences Laboratory. Total number: 14, of which 14 were analysed for total silica and 3 for quartz content.

CATEGORY C: Gravimetric samples taken without elutriator: collected onto filter papers with a gravimetric sampler designed by the Environmental Sciences Laboratory. Total number: 13, of which 5 were analysed for total silica content by the same laboratory.

CATEGORY D: Gravimetric samples taken with a cyclone prefilter: collected onto filter papers as in Category C. Total number: 22, of which 14 were analysed for total silica content.

CATEGORY E: Gravimetric samples collected with an M.R.E. 113A gravimetric sampler onto membrane filters. The samples were analysed by the Physical Sciences Laboratory. Total number: 30, all of which were assessed for quartz content.

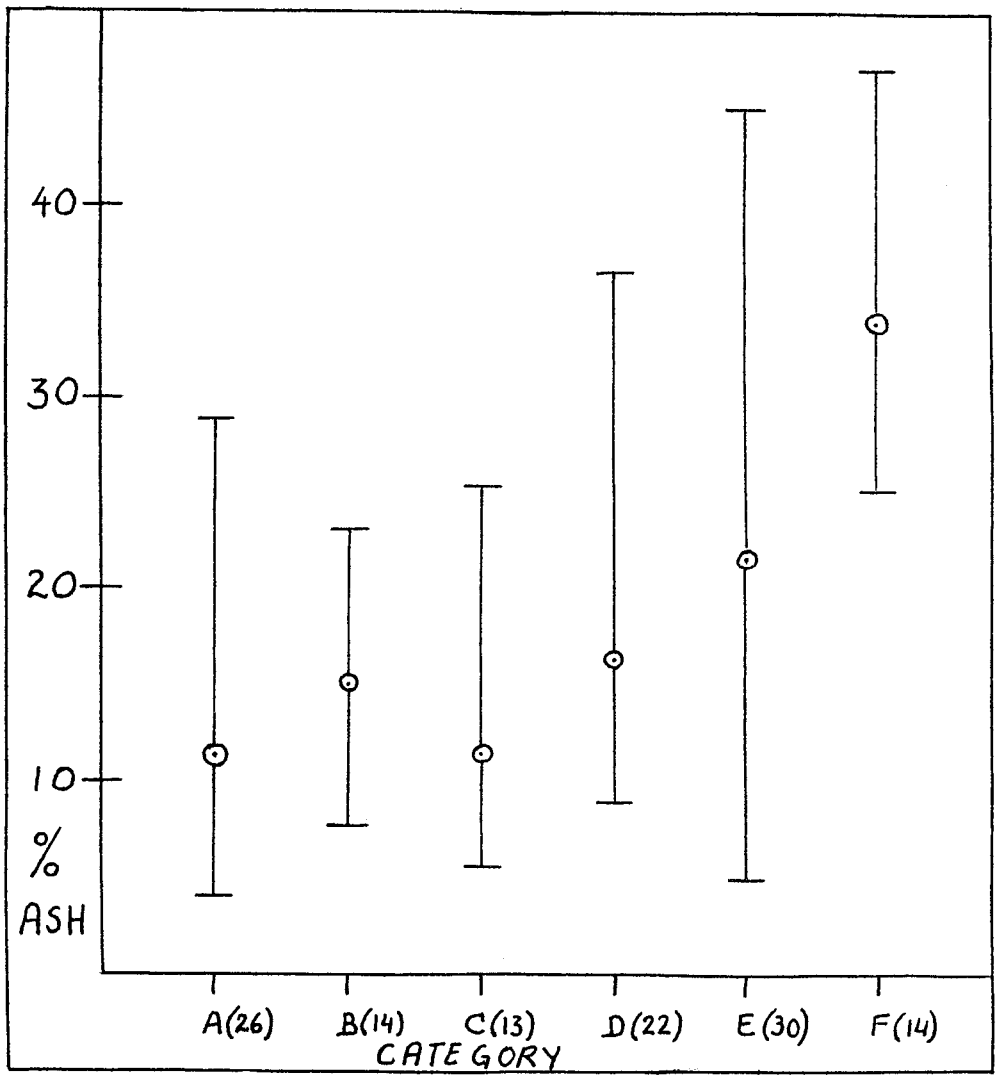

Fig. 1: Mean Percentage Ash with Individual Lowest and Highest per Category
[A-E: Weight, F: P.E.R. Values]

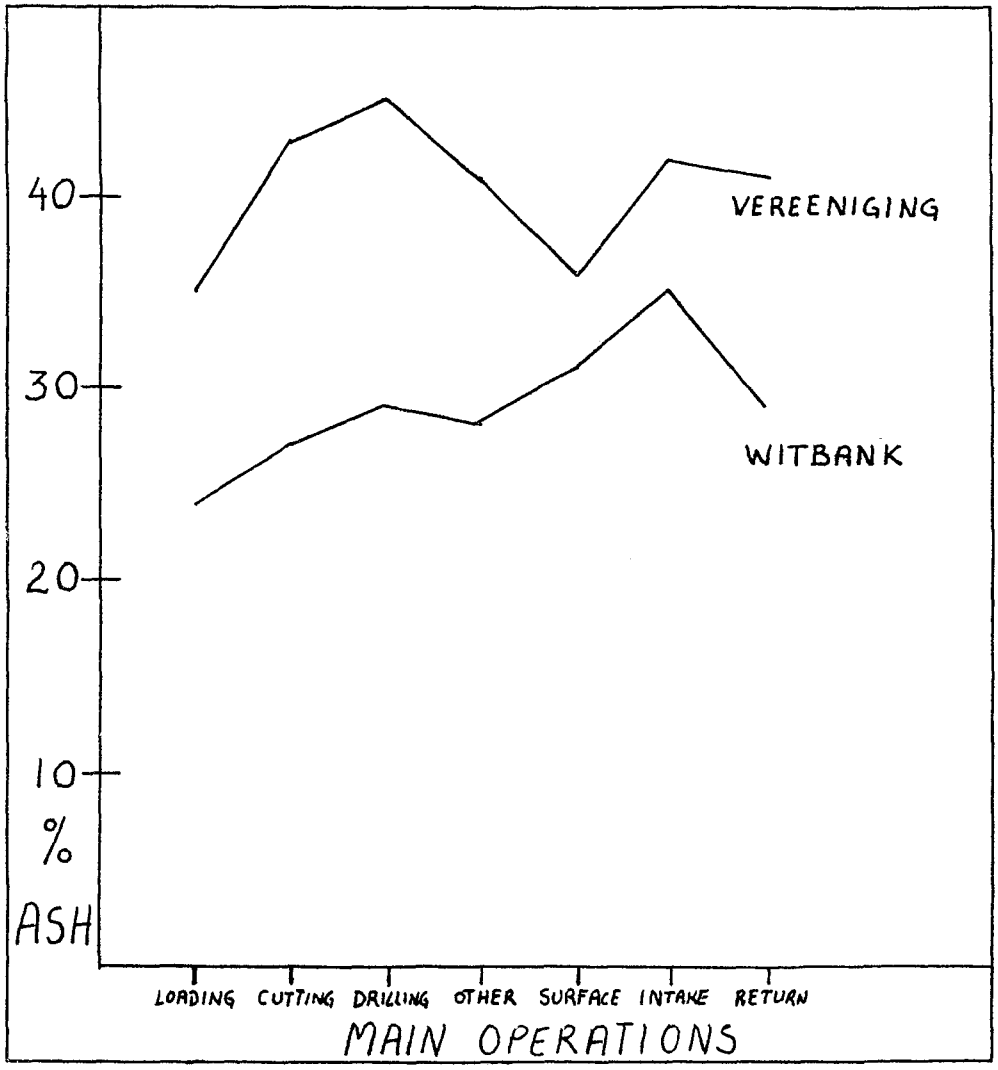

Fig. 2: Mean Percentage Ash per Operation: Witbank and Vereeniging. [P.E.R. Values]

CATEGORY F: Modified thermal precipitator samples assessed photoelectrically before and after ashing at 550°C for one hour. During the period 1962 to 1968 a total of 9,154 samples were ashed. Fourteen yearly means were calculated, 7 each for the Witbank area and the Vereeniging area.

Fig. 1 shows the percentages ash for each category. Categories A, B and C are coarse, and all results are obtained on a weight basis. Categories D and E are "respirable" dust results obtained on a weight basis. Category F is also "respirable" dust but obtained photoelectrically, i.e. on a surface area basis. "Respirable" dust seems to have a higher ash content than total airborne dust.

Fig. 2 shows the percentages ash in more detail for Category F. These are the combined results per operation for the years 1962 to 1968, but given separately for the Witbank area (5,600 samples) and the Vereeniging area (3,500 samples). It is clear that, firstly, collieries from the Vereeniging area have, on average, an airborne dust ash content 55 per cent. higher than the ones from the Witbank area and secondly, the percentage ash in airborne dust increases from loading to cutting to drilling operations.

Fig. 3 shows the percentages ash for Category F, this time per year for each area. All operations are included in these results. The number of samples ashed for each operation remains about constant relative to other operations. Again, results for the Vereeniging area are consistently higher than those for the Witbank area, but while the latter appear to increase slightly at a steady rate, the former results seem to vary appreciably from year to year.

One explanation for this appreciable variation is the changing number of ashed samples taken each year in sections where diesels are in use. A typical result from one " diesel " section showed an average of only 12 per cent. ash for 62 airborne dust samples. It was calculated that, if the ash content for that section was assumed to be the average for the rest of the colliery, 70 per cent. of the airborne dust concentration in P.E.R. consisted of extremely fine diesel fumes, i.e. carbon particles of approximately $\frac{1}{2}$ micron diam.[11] Such extreme case only serves to explain why caution must be observed in attaching a certain significance to ash content values.[12] Certainty only exists if they are considered as representative of airborne matter. What portion of such airborne matter is completely harmless is difficult to assess, but it may sometimes amount to a large portion by weight or surface area.

SILICA CONTENT

Total silica and quartz contents for the Categories A to E are shown in *Fig. 4*. Total silica was obtained by chemical analysis, weight parameter, for Categories A to D. Quartz content was obtained by X-ray diffraction, also weight parameter, for Categories A, B and E only. Neither total silica nor quartz content are very different *in situ* or in the airborne dust or in the " respirable " dust, acording to these results. Percentage results indicate the relative content of certain minerals in the total dust. Most samples collected in the past came from dust sources higher than average for the express purpose of obtaining enough dust to analyse. Their absolute concentrations are therefore not really representative of normal conditions on the mines. Nevertheless, the composition of these samples would not have been much different if the absolute concentrations had been lower. It should be realized that total silica includes such silica combined with other minerals in various compounds present in the ash. Quartz, with certain reservations as stated in the introduction above, is the more important mineral. Naturally, if it is assumed that a certain dust contains 5 per cent. quartz, there is still the total dust concentration to be considered before one concludes that such amount of quartz in the dust is dangerous to health. It is obvious that a person breathing 50 mg/m^3 of such dust will also inhale 2·5 mg/m^3 of quartz, and this is considered harmful. On the other hand, a person breathing 5 mg/m^3 of mixed dust will only inhale quartz at a rate of 0·25 mg/m^3, and one should then consider seriously whether it is at all worthwhile to take the quartz content into account during routine airborne dust sampling.

PICTORIAL ESSAY

Fig. 5 is an attempt at a better understanding of a coal dust particle, excluding foreign airborne matter. This attempt is really a question: Which assumption is to be considered correct and which measurement is nearest the correct relative toxic values of coal and quartz? [13] If it was answered, dust measurement could become much more precise and relevant. The figure is self-explanatory.

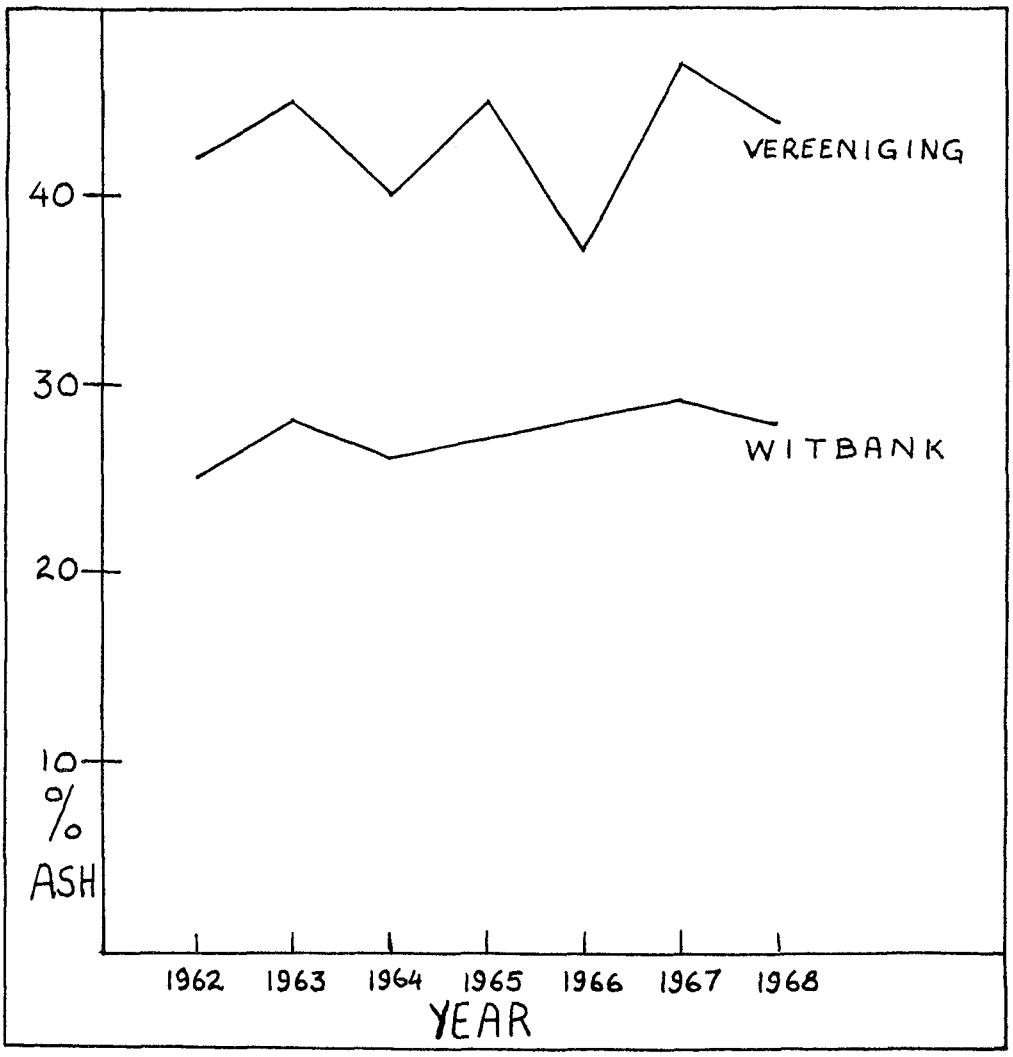

Fig. 3: Mean Percentage Ash per year: Witbank and Vereeniging. [P.E.R. Values]

CONCLUSION

Present methods of analysis determine, with a high degree of accuracy, the quality and quantity of certain minerals in airborne matter, which includes airborne coal dust. Before deductions are made from such analysis as to the relative and absolute value of each mineral component, it will be necessary to obtain a clearer picture of the relationship between such airborne matter and the fraction of it that is detrimentally active in the human lung. There is, however, one important conclusion to be drawn: As long as the total quantity of " respirable " dust is reduced methodically

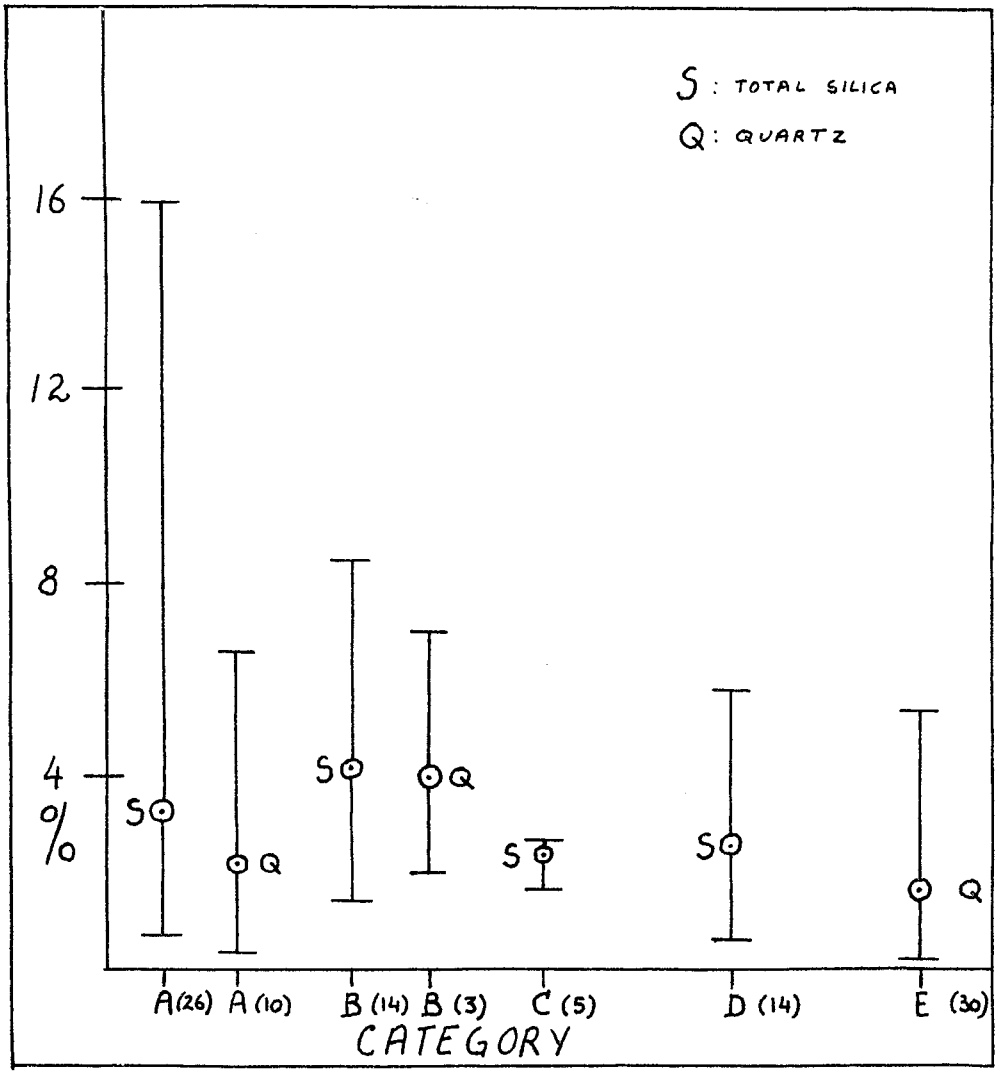

Fig. 4: Mean Percentages of Total Silica and Quartz with Individual Lowest and Highest per Category. [Weight Values]

to a low figure and kept to such a low figure, the industry can look forward to a continuous reduction in the incidence of lung diseases. This is the main objective of routine airborne dust sampling.

Acknowledgement is given to the Chamber of Mines for permission to publish this paper.

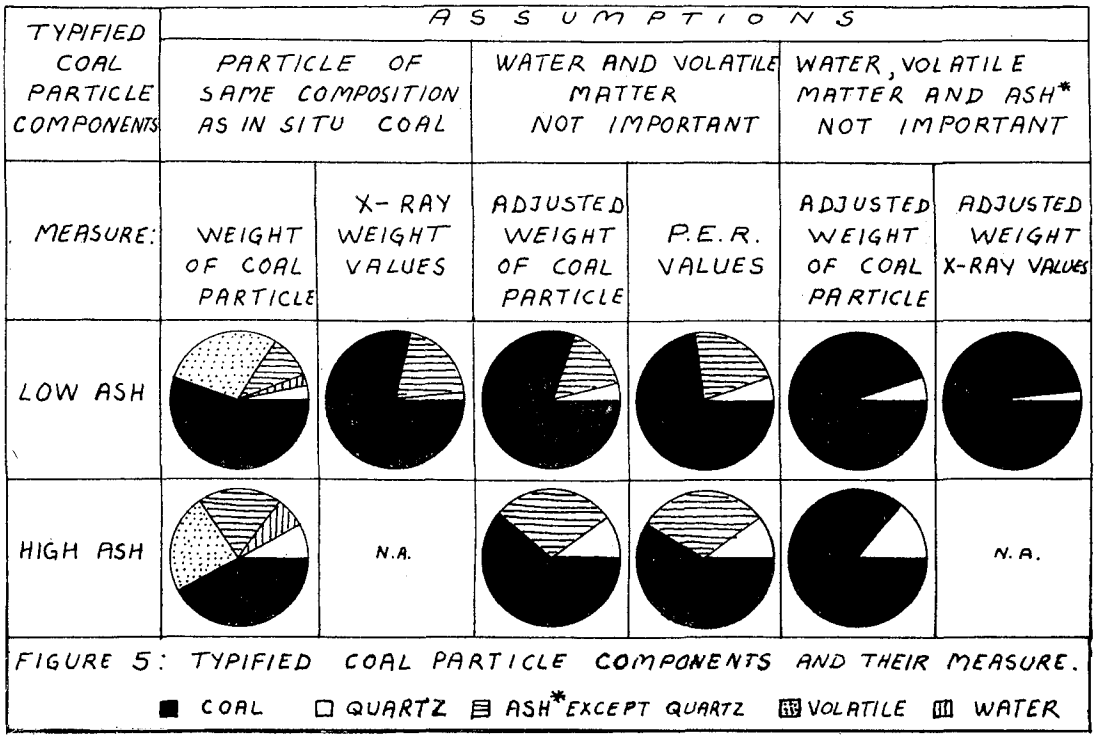

FIGURE 5: TYPIFIED COAL PARTICLE COMPONENTS AND THEIR MEASURE.

References

1. "Guide to the Prevention and Suppression of Dust in Mining, Tunnelling and Quarrying," 1965, p. 9. International Labour Office.
2. SAVAGE, W. H. D.: "Proximate and Ultimate Analyses of Product Samples taken during 1967." Bulletin No. 72, Fuel Research Institute of South Africa.
3. KUNSTMANN, F. H., and KERKOVIUS, H. D. T.: "The Occurrence of Quartz in South African Coals." Report No. 2, 1968, Fuel Research Institute of South Africa.
4. Proceedings of the Pneumoconiosis Conference, 1959, pp. 619–620. South African Council for Scientific and Industrial Research.
5. KITSON, G. H. J., and HAVEN, Y. J. F.: "Photoelectric Readings: Their Significance for Dust Control on Collieries," *Jnl. S.A. Inst. Min. & Mett.*, Oct., 1968.
6. NAGELSCHIMDT, G., GRIFFIN, O. G., and WHEATLEY, K.: "The Composition of Airborne Dusts in Coal Mines." M.R.E. Research Report No. 148, June, 1958.
7. TIMAR, M., SZANDANYI, S., and UJHELYI, A.: "Experimental and Clinical Investigations of the Effect on the Organism of Coal Dusts with Different Quartz Content. *Beitraege Silikose-Forschung*, Heft 76, 1962.
8. Medical Research Council: "Chronic Pulmonary Disease in South Wales Coalminers." H.M. Stationery Office, London, 1943.
9. SCHMIDT, K. G.: "Phase Contrast Microscopy for the Dust Laboratory." *Staub*, Vol. 22, No. 8, August, 1962.
10. BRADLEY, A. A.: "The Determination of Quartz in Small Samples by an X-ray Technique." *Jnl. Sci. Inst.*, 1967, Vol. 44, pp. 287–288.
11. FREY, J. W., and CORN, M.: "Diesel Exhaust Particulates." *Nature*, Vol. 216 1967, No. 5115.
12. MATLA, W. P. M., and TERPSTRA, J.: "Relationship between Quartz Content and Ash Content of Dust in Mine Workings." *Geol. en Mynb.*, December, 1964, Vol. 43, pp. 531–534.
13. THAER, A.: "Investigations into the Chemical Behaviour of Stone and Coal Dust under Physiological Conditions with regard to Dust Lung Disease in Coal Mines." *Bergbau Archiv*, Vol. 16, 1955, pp. 21–39.