Recent Advances in Dust Measurement by Diffraction

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SYNOPSIS

Two new diffraction instruments for dust measurement are described, one for evaluating dust samples taken with the konimeter, and the other for continuous real-time measurements at the working place. The instruments measure one or more moments of the size spectrum. The most useful moments are number, linear dimensions, area and volume.

INTRODUCTION

An instrument for evaluating konimeter samples has been described by Talbot.[1] The first instrument described here is, in principle, the same. However, substantial improvements have been made in ergonomics, sensitivity and reliability and these improvements are described.

The second instrument to be described operates according to the same principles but has been designed to give continuous readings at the working place.

THE DUST COUNTER FOR KONIMETER SLIDES

Two views of this model are shown in Fig. 1. The main housing contains a helium-neon laser which sends a beam through the konimeter slide up towards the microscope objective. The slide is supported by a conventional konimeter microscope stage of the most modern design. The operator positions each dust 'spot' centrally in the field of the microscope. Then he rotates the nose-piece of the microscope to what would normally be an adjacent objective lens. But instead of a lens, the nose-piece carries a plane mirror which reflects the laser beam back through the slide and through a spatial filter, thence to the photo-detector.

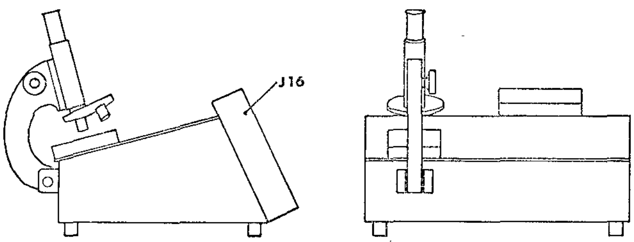

Fig. 1.

This double-pass system effectively doubles the sensitivity for a given power laser.

Two spatial filters are used, one for counting the number of particles, the other for measuring area. The spatial filters are somewhat unusual. They are made by masking the two sides of an optical flat with a mirror surface on both sides. A hole drilled in the centre of the optical flat transmits the primary beam. The optical flat is at 45° to the optical axis. The side facing the slide receives the diffracted light which it reflects into the photo-detector. After the first measurement, the slide is rotated through 180° and the second measurement is made. A knob on the front panel selects the spatial filter.

A Tektronix J16 radiometer measures the filtered diffraction cross-section. While expensive, this instrument represents the highest standards of quality and reliability. It has a 2,5-digit display and a dynamic range of 10^5. It can measure 1 nW of radiant power, which is sufficiently sensitive for a full-scale reading of 19,9 particles cm^{-3}, when measuring number, and 1,99 $\mu m^2\ cm^{-3}$ when measuring area. However, full-scale readings of ten times these figures have been chosen for the most sensitive scales to allow a large margin for power losses. Thus the user is assured of an instrument with a long life without maintenance.

Two independent calibration controls are provided, one each for number and area measurements. The changeover from one to the other is effected automatically when the spatial filter is selected.

THE CONTINUOUS REAL-TIME MONITOR

The continuous monitor is shown in section in Fig. 2. Instead of a laser, it has a tungsten-halogen light source, 1, at the principal focus of a 100 mm diameter Fresnel lens, 2. This produces a parallel beam in the sample volume between the aforementioned Fresnel lens and a second Fresnel lens, 3. The latter lens is 200 mm square and is large enough to collect most of the light diffracted by particles suspended in the sampling volume. An image of the lamp filament is produced on the light and heat sink, 4. The diffraction pattern of the dust particles surrounds this sink concentrically. Spatial filtering of the diffraction pattern is effected by forming a suitable array of photo-cells in the plane of the diffraction patterns. Interchangeable arrays are available to provide a choice of moment (number, linear dimensions, area or volume) being measured.

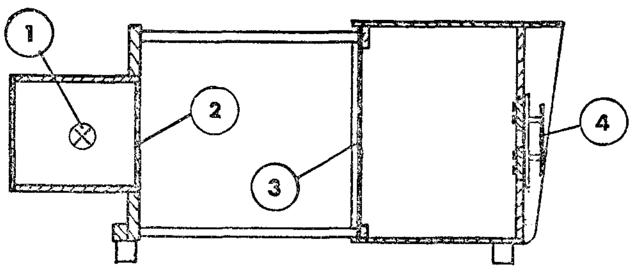

Fig. 2.

The distance between Fresnel lenses is normally 200 mm giving a sample volume of 1,5 l. A choice of read-out equipment is available. If a good-quality meter with digital output is used, a full-scale reading of 199 particles cm^{-3} or 19,9 $\mu m^2\ cm^{-3}$ can be obtained. The sensitivity may be improved by increasing the length of the rods separating the two Fresnel lenses.

Incorporated in the amplifier is a filter for removing the D.C. component of the photo-cell current and modifying the time-varying components in such a way that the square root of the variance of the parameter is measured. Assuming that the particles enter the sampling volume in a random

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sequence, the variance is an estimate of the mean. By incorporating a squaring module, the mean may be measured on a linear scale. The full-scale readings mentioned in the previous paragraph relate to this circumstance. Where a squaring module is not incorporated, the readings are on a square root scale of nearly constant precision. In this case the mid-scale readings correspond to the values mentioned for the full-scales in the linear case.

The use of a filter of this type removes the need for adjusting the zero to offset light diffracted by the Fresnel lenses and dust particles that happen to settle on them. Without the filter, the zero is so unstable as to seriously impair the sensitivity. A 12-V battery is required for operation. Current drain is 4,5 A. Where provision of so much power is a problem, the filter may be used with a lamp of lower power with some loss of sensitivity.

DISCUSSION

The provision of a normal microscope on the first instrument makes it very easy for the operator to position the dust samples. Any unsuitable samples can be identified and rejected. Two reliable measurements from each sample are obtained in quick sequence.

The continuous monitor provides a useful dust control in real time for use in mines and quarries. Its most serious limitation is that it measures the total suspended matter in the atmosphere. When used at the normal power rating, the heat produced is, in most instances, sufficient to evaporate mist.

REFERENCE

1. TALBOT, J. H. *J. Mine Vent. Soc. S. Afr.*, vol. 27, 1974, p. 161.