PREPARATION OF RADIOACTIVELY LABELLED CONDENSATION AEROSOLS. III.*

EQUIPMENT FOR FILTER EFFICIENCY MEASUREMENT BY MEANS OF RADIOACTIVELY LABELLED AEROSOLS

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Received June 1st, 1970

Measurement of the efficiency of the so called highly efficient aerosol filters (penetration factors smaller than $10^{-3}\%$) is difficult and not very accurate if the present measurement techniques are used. Modern technology demands the use of aerosol filters with penetration factors smaller than $10^{-3}\%$, and filters of these parameters (filters made of glass or plastic microfibers) have been recently manufactured. Measurement of their efficiency by the light scattering methods[1] — generally used at present — is difficult. In order to measure penetrations smaller than $10^{-3}\%$, concentration of the testing aerosol in front of the filter has to be larger than 10^5 cm^{-3}. Under these conditions, however, a pronounced coagulation of particles takes place, and the measurements are inaccurate.

The most convenient methods that may be used to measure these low penetrations appear to be the methods of chemical microanalysis, activation analysis[1], and radioactively labelled aerosols.

This communication deals with the use of radioactively labelled aerosols and with the equipment suitable for this type of measurement. Methods of preparation of the labelled aerosols were described in the preceding papers[2-4].

EXPERIMENTAL

Model aerosols: The most suitable radioactively labelled model aerosols proved themselves to be — as reported in our earlier communications[2-4] — the aerosols of silver, gold, platinum oxides, selenium oxides, and rhenium oxide. All these aerosols have been prepared by condensation of vapours of the radioactively labelled metals. As far as the oxides are concerned, they are formed by oxidation processes on the metal surfaces when the metals are heated at normal atmospheric conditions. The dispersity and the methods of radioactive labelling were described earlier, too[2-4].

Apparatus for determination of filter efficiency: The schematics in Fig. 1 shows the basic idea and the entire experimental arrangement. A suitable radioactively labelled aerosol is prepared in the generator G which is placed in a lead screen to minimize penetration of radiation into the laboratory. Air introduced into the generator is purified by passing it through the filter F_1 (a glass fiber filter) and the sorbent S consisting of active charcoal and the molecular sieve A 4. The rate of flow of the gas through the generator is measured by means of the flow meter D_1 and by means of the manometer M_1. The aerosol then enters the 650 l spherical reservoir K. Dilution of the aerosol occurs by introducing filtered air L through the filter F_2. A constant concentration of the

* Part II: This Journal *32*, 4190 (1967).

** This work was supported by IAEA, Contract No 411.

aerosol is obtained after about 30—60 minutes by adjusting the conditions of a "dynamic" equilibrium: the volume of air introduced through the generator and through the filter F_2 equals the volume pumped away by the pump P and measured by the flow meter D_3. After a constant concentration was reached (this is checked by sampling and by measuring the radioactivity of the samples), the determination of the filter efficiency can begin.

The filters *1* and *2* of an area about 10 cm^2 are placed into a special filter-holder[5]. The filter *1* is that one whose efficiency is to be determined. The filter *2* ist the "absolute filter", *i.e.* a filter with an efficiency higher or equal to that one of the filter *1* (if the measurement concerns highly efficient filters). As the absolute filters the highly efficient membrane filters are used[6,7]. The pressure drop Δp of the filter *1* is measured by means of the manometer M_2. Thus the aerosol from the reservoir *K* passes through the filters *1* and *2*. The flow through the filters is measured by means of the flow meter D_2 and by means of the manometer M_3. The filter F_3 serves as the safety filter to collect the radioactivity. The filter-holder is located in a lead case to decrease the background of the Geiger-Müller counters. These counters are placed above the both filters and thus they measure the radioactivity of each of them. By means of this measurement the efficiency of the filter *1* can be determined. An electronic evaluating set-up is used for this purpose. It consists of the divider *DI*, the pulse rate meter *IZ*, the recorder *R*, and of the two amplifiers *Z* and *V* which may be equipped with the automatic time preselector *ST*.

Electrical evaluation of the measured radioactivity: If the radioactivity of the filters *1* and *2* is denoted by *A* and *B*, respectively, then the efficiency of the filter *1* $E = A/A + B$ and the penetration $1 - E = B/A + B$. Therefore, it was aimed at arranging the components in such a way that the multiline recorder might write values of *A*, *B*, $A/A + B$, and possibly $B/A + B$ as a function of time. For this purpose, conventional equipment available in Czechoslovakia was used: the pulse rate meter unit NUZ 614 T *IZ*, the recorder Metra DRg 140 *R*, the voltage stabili-

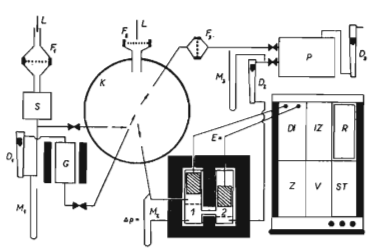

FIG. 1

Schematics of the Experimental Arrangement for Measuring Filter Efficiency by Means of Radioactively Labelled Aerosols (for description see text)

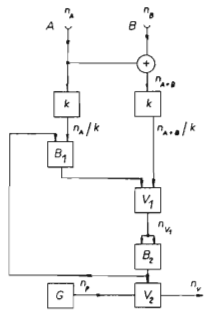

FIG. 2

Diagram of the Ratio-Forming Circuit (for description see text)

zers NBZ 615 T *V*, and NBZ 618 T *Z*, the GM counter probes NAQ 211, and the GM counters 30/30 AB. A new electronic unit of the set-up was the divider *DI* which forms the ratio of the two measured signals, *i.e.* the ration of the pulse rates n_A and n_B.

Divider: First, this device makes the sum of the pulse rates $n_A + n_B$ (coincidence effects may be neglected in the measured range under question), and then it evaluates the ratio $n_A/n_A + n_B$ or $n_B/n_A + n_B$. In actual measurements this ratio was multiplied by an auxiliary pulse rate n_p, which was supplied by an auxiliary generator and gave impulses uniformly distributed in time. The set-up is shown schematically in Fig. 2. The equipment works in the digital mode. The output rate n_v which carries the information on the instantaneous ratio of the pulse rates, *e.g.* $n_A/n_A + n_B$, if formed by groups of pulses withan uniform pulse rate n_p obtained from the auxiliary generator *G*. The pulse rate n_v is then introduced into the pulse rate meter the output of which is connected with the recorder.

The function of the dividing circuit consists in introducing impulses from the channel *A* into the pulse rate divider with a certain dividing ratio *k*. Each k-th impuls flips over the bistable circuit B_1, and this causes opening of the gate V_1. Impulses with the frequency n_{A+B}/k then pass through V_1. The first impuls that passes through the gate V_1 flips over the bistable circuit B_2. This opens the gate V_2 for impulses from the auxiliary generator *G* which pass with the frequency n_p to the output of the entire set-up. The second impuls that passes through the gate V_2 returns the flip-flop circuit B_2 into its original position. This closes the gate V_2, flips over the bistable circuit B_2 into the idle position, and closes V_1. Impulses from the generator *G* thus cannot reach the output of the set-up any more and the whole system waits for another *k*-th impuls from the channel *A* to repeat the cycle again. The divider treats also pulses from the Geiger-Müller counters 30/30 AB. The block diagram of the divider is in Fig. 3.

The recording galvanometer shows then the increase of activity on the filters *1* and *2*, as well as the changes of the efficiency or the penetration of the filter *1* with time. The equipment is suitable for measuring filter efficiencies and was used in these studies accordingly[5,6].

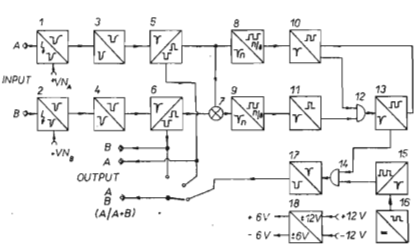

FIG. 3

Block Diagram of the Divider

1, *2* Buffer circuits; *3*, *4* Smitt discriminator; *5*, *6* monostable flip-flop circuits; *7* adding circuit; *8*, *9* dividing circuit consisting of bistable flip-flop circuits; *10* bistable flip-flop circuit; *11* monostable flip-flop circuit; *12* gate; *13* bistable flip-flop circuit; *14* gate; *15*, *16* monostable flip-flop circuit; *17* pulse generator ($f = 10$ kHz); *18* power supplies.

DISCUSSION

The described method and the measuring equipment have several important advantages: *1.* a higher sensitivity in comparison with the contemporary optical methods; *2.* an automatic recording of the dependence of the efficiency (or the penetration) on time; *3.* a possibility of using a wide range of model aerosols; *4.* a possibility of using a comparatively low input concentration of aerosols (*e.g.*, 10^4 to 10^5 cm^{-3}).

On the other hand, high cost of the apparatus and the necessity of using radioactively labelled aerosols — and therefore the necessity of observing strict regulations for handling radioactive materials — represent disadvantages of the method. However, the total cost of the equipment is not higher than the cost of the commercially produced aerosol counters (*e.g.*, Royco, Lomb and Bausch, Sartorius *etc.*).

As far as the sensitivity of the measurements is concerned, it surpasses the above mentioned commercial counters by three to four orders of magnitude[1]. This advantage can be demonstrated in the following example: let us assume that a testing aerosol with the mean diameter of particles 0·1 μm is used; 1 cm^2 of the tested filter may be covered by about 10 μg of the material without influencing the pressure drop over the filter. If the entire filtration area of the tested filter is 10 cm^2, the amount of the radioactively labelled aerosol collected on it is approximately 100 μg. If the penetration is, *e.g.*, 10^{-6}, the total weight of the particles that passed through the filter is 10^{-4} μg. Using specific activity 5 Ci/g this means $5 . 10^{-4}$ μCi. This amount can be easily measured.

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Translated by Z. Herman.