MANUAL SAMPLING AND MICROSCOPIC MEASUREMENT OF GENERATED AEROSOLS

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Abstract The methods of manual sampling and microsopic size measurement of aerosols generated by atomizing a solution of DOP (dioctyl phthalate) in ethyl alcohol have been described. Larger aerosol particles have been separated in the aerosol generator and these desired particles exit through an outlet pipe of the generator. Samples were collected on petroleum jelly treated glass slides and their diameters were observed under an optical microscope. It has been found that several factors related to collection of samples, such as, collection device, nature and treatment of surfactant used on slide, sample flow rate, sample collection time and sampling location had profound effect on collection of a representative sample and also on diameter of particles sampled. Obtained size distribution of particles sampled are also presented.

INTRODUCTION

Various methods have been developed for sampling and size measurement of aerosol particles, but special difficulties arise in their applications due to the large number of particles with wide size range and varying velocity. Also, droplet and particle size change with time through evaporation and coalescence, posing additional problems.

Particle sampling and size measurement techniques should ideally have the following characteristics (Lefebvre, 1989):

1. Create no disturbance to flow field:
2. Have a size range capability of at least 10, although a factor closer to 30 is desirable in some applications;
3. Have the ability to measure both spatial and temporal distributions;
4. Provide large representative samplers;
5. Tolerate wide variations in the liquid and ambient gas properties;
6. Provide rapid means of sampling and counting.

However, all sampling and measuring techniques, are characterized by various errors and ambiguities, the nature and importance of which depend on the particular method used. The common sources of error are: sampling method (spatial and temporal), sample size, sampling location, drop saturation, particle evaporation and coalescence. To get a representative sample of particulates in a moving airstream, isokinetic sampling is done. As shown in Fig. 1, when the inlet of the sampling probe is aligned parallel to the airstream and if the air velocity (V_r) inside the sampling probe is equal to the air velocity (V_s) in the source from which the sample is being taken, the sampling is said to be isokinetic (V_p=V_s). In this cae, the measured

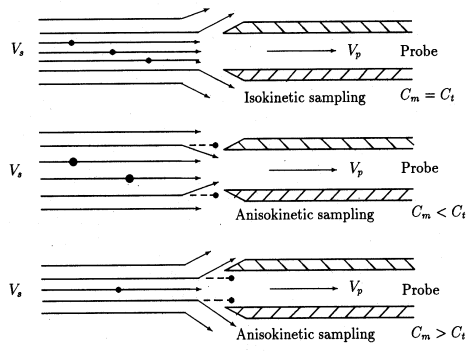

Fig. 1: Isokinetic and anisokinetic sampling for particulates

concentration (C_m) will equal the true concentration (C_t). However, if V_p becomes less or greater than V_s, the measured concentration will be respectively greater or less than the true concentration and the sampling will be called anisokinetic sampling. When V_p>V_s, the air streamlines will bend into the probe and the inertia of the particles in those streamlines will carry some of them past the probe and if V_p<Vs, the air streamlines

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will bend away from the probe and some particles in these streamlines will enter into the probe due to inertia (Nevers, 1996).

Fairly precise measurements of drop size distributions can be obtained if accurate and reliable instrumentation and data reduction procedures are employed. As emphasized by Tate (1982), the ability to recognize and challenge questionable data is extremely important. Experience and judgement are valuable attributes for those who measure particle sizes and use the information in the design and application of various systems.

For examination of aerosol particles in the range above 0.3μm, an optical microscope is a valuable tool. Particle size distributions measured by an optical microscope are very tedious and need tolerance, skill and careful sampling by the operator. However, there are several merits of this method. It not only gives the shape and size of the particle under study, but can also provide more information regarding the physical state of particles being monitored. In most other methods of particle size measurements, such as, sedimentation, impaction, mobility analysis and light scattering techniques, particle size is estimated indirectly from the measurement of a property related to size. Thus, microscopic measurements of particle size form primary measurements upon which most other aerosol sizing methods are based because linear measurements taken by a microscope can be calibrated accurately (Hinds, 1982).

Although, microscopic size distribution measurements appear to be simple and are typically done with a calibrated eyepiece, it is laborious and time consuming because the distribution will not be statistically valid unless about 1000 particles are measured (Sem, 1984). If labour costs are considered, microscopy is often the most expensive particle size measuring method, even if the equipment is already present.

For actual size measurements of liquid particles, which are usually spherical, a flattening coefficient should be employed to the observed size of the particle. For volatile airborne liquid particles, the size of the particles may vary. Solid particles are usually irregular in shape and an equivalent diameter must be estimated for these particles. Projected area diameter, defined as the diameter of the circle that has the same projected area as the particle silhouette, is the most commonly used equivalent diameter. In optical microscopy, projected area diameter is measured using a set of standard area circles printed.
In this experiment work, methodologies have been developed to collect manually a representative sample in terms of sample flow rate, sampling time, sampling location, sample collection device etc. for microscopic measurement of particle size.

EXPERIMENTAL PROCEDURE

In the beginning of this study, an aerosol generator as shown in Fig. 2 was designed, fabricated and operated to generate desired size narrowly distributed particles. An atomizer, mounted at the bottom of the generation chamber of the generator, produced polydisperse aerosols from a solution of DOP in ethyl alcohol. Larger particles in the polydisperse aerosols were subsequently separated in the virtual impactor with a central clean air core of the aerosol generator. Minor flow (about 10% of total flow) of the generator contained the desired size larger aerosol particles. For maximum aerosol generation rate, atomization air and liquid pressures were selected at 206 kPa and - 22cm of alcohol respectively based on the results of nozzle test.

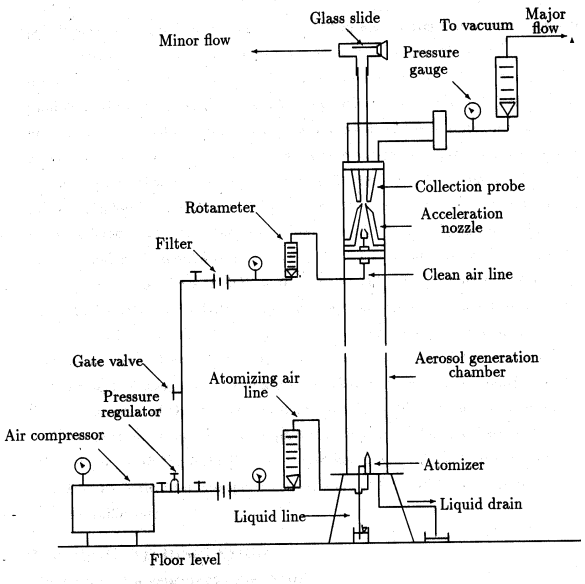

Fig. 2: Experimental set up to generate narrowly distributed aerosol

At this operating pressure, the aerosol flow rate through the generation chamber was measured to be 55 lpm. Clean air flow at the rate of 11 lpm was provided through the centre of acceleration nozzle for better separation of larger particles in the virtual impactor of the aerosol generator. The minor flow rate containing the desired larger particles was 5 lpm. After evaporation of ethyl alcohol, particles of DOP were formed finally. The concentrations of liquid solution (DOP in ethyl alcohol) were so selected that the final narrow distributed particles size varied from 2 μm to 10 μm aerodynamic diameters. Sampling was done to collect the particles of minor flow on slides for subsequent microscopic measurement of their sizes and to ascertain whether they were narrowly distributed. As a trial, the concentration of DOP in ethyl alcohol was taken as 10%

and the solution was atomized in the generation chamber. The particles in the minor flow were sampled using the technique mentioned below. Their size distribution was determined by an optical microscope (Neomet, Union-84332, Bi20-1777, Tokyo, Japan) with 500X magnification and their mean sizes were compared with those measured by LASAIR 2500 optical particle counter.

RESULTS AND DISCUSSION

Collection of a representative sample

No complete method for collecting a representative sample has been described in the literature. Rather, it has been mentioned (Lefebvre, 1989) that collection of a suitable representative sample is laborious and depends on experience. In this study, the protocol for collecting a representative sample has been identified through several trials and logically concluding from the results thereof.

Collection device

wo collection devices, one at a time as shown in Fig. 3, were used to collect samples. One was a 3.2 cm PVC tee having a constant cross-sectional area throughout (Fig. 3a) and the other was also a 3.2 cm PVC tee but fitted with a nozzle (impactor) having 0.013m outlet diameter at the entering point of aerosols (Fig. 3b). It had been found that in the later case, a thin film of aerosols formed on glass slides due to reduced cross-sectional area and higher velocity of impaction.

After impaction the aerosols disintegrated again and that was revealed by viewing many nuclei of aerosols accumulated at certain parts of the slides. A third type of sampling device (Fig. 3c) was also used to collect samples of aerosols from minor flow. It was also a PVC tee but the perpendicular sampling leg having reduced cross-sectional area and was positioned into the outlet pipe as shown in Fig. 3c. The diameter of the sampling leg was calculated to be about 1.2 cm so that the flow rate through the leg was about 8 lpm sampling isokinetically from the minor flow rate of 5 lpm. The isokinetic sampling was confirmed by measuring the velocities of aerosol inside both the outlet pipe and sampling leg of the tee by a precision hotwire annenometer. The diameter of straight leg of the tee was 3.2 m, so that the velocity of aerosol when striking the glass slide was about 1.68 cm/s. It was observed that due to this lower striking velocity, shape of samples collected on the glass slide were undeformed and best in quality.

Slide coating

As the commercially manufactured coatings reported in literature were not available locally, several types of coatings were used on glass slides for collecting the samples. Firstly, a thin coat of carbon soot, generated by burning a wick of kerosene, was deposited on glass slides and samples were collected on them. It was found that very dark impressions of particles were formed on carbon soot due to low velocity of very small particles striking the slides when the samples were collected without the impactor. The boundaries of such type of impressions were too illegible to identify. Secondly, the slide surface was coated with petroleum jelly. A very thin and uniform film was formed on slides by heating the coated slides to about 100^0C for about 5 see and then cooled slowly to stabilize the coating. It was observed that due to the sticky nature of the coating, aerosol collecting capability of this type of slides was superior. Their shapes also remained undeformed. When sampling was done without heating the coated slides, the aerosol

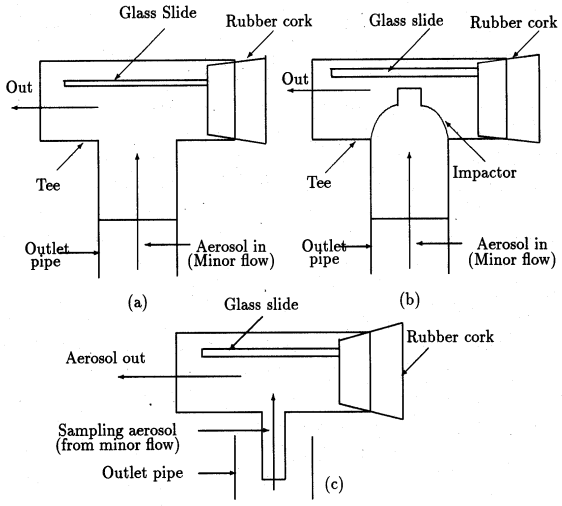

Fig. 3: Sample collection devices used

particles could not be identified due to the uneven film thickness of the coating. Bare glass slides were also tried to collect sample of aerosol particles but with negative result. In this case, the droplet boundary smeared over the slide resulting in erroneous estimation of the droplet diameter.

Sample flow rate / Impaction velocity

Sample flow rate or impaction velocity should not be higher to flat or bouce the particle. Various flow rates were used to collect samples on slides. The flow rates were varied from 5 lpm to about 15 lpm. Very good results were obtained with flow rate between 5 to 6 lpm on petroleum jelly coated glass slides. On carbon coated glass slides, very ill-defined impressions were formed on slides with lower flow rates but higher collection time and with higher flow rates but lower collection time.

Sample collection time

The time for collecting the samples on slides was varied from 3 seconds to 7 seconds. It was found that good

distributed samples were obtained on petroleum jelly coated slides when the sampling time was between 3 to 5 seconds. Beyond that, multiplets of particles were observed to form in proportion with time. About 250 to 300 well distributed particles were found to collect on each slide during the time mentioned above. Number of slides required for sampling was determined as per the number of particles to be measured under microscope during each sampling.

Sampling location

It had been found that measurement of nozzle spray characteristics in a flowing air stream should ideally be carried out well downstream of the nozzle (0.2 to 0.3 m) using air at low temperature (<300 K) in conjunction with liquids of low volatility (Chin, 1986). But the atomizing liquid employed in the present study was a mixture of volatile and non-volatile components. So the sampling location should be at such a place that the volatile component of aerosol droplets evaporate completely keeping the non-volatile part inlact. Collecting samples far away from the source may dry up the non-volatile part of aerosol droplet partly or completely.

Samples were collected at very near (19.5 cm) to the point from where minor flow was emerging (source) and also at a distance of about 1 m from the source. In the former case, very large droplets were observed due to non-evaporation of volatile part (solvent) of the aerosol droplets and also due to coagulation of some droplets. In case of later, it was found that inner portions of some droplets were dried up due to the large distance of sampling location. Good results were obtained by collecting samples at a location of between 30 to 40 cm downstream of the source.

Microscope setting and slide viewing

The samples on slides were viewed in a vertically oriented microscope with 500X total magnification. This magnification was essential because with this magnification, a 10 μm droplet which was our targeted largest size droplet, appeared as 5 mm through the microscope.The sampled slide was placed upside down on the table directly over the objective. After fine focussing, the intensity of incoming beam of light was adjusted to suit to eye-viewing and the colour of the light was varied by various colour glasses mounted on the microscope to identify a droplet distinctly. With the help of traverse screws, the entire slide was scanned through the microscope by longitudinal and cross table movement. The process was repeated until the entire slide was scanned.

EXPERIMENTAL RESULTS

As mentioned earlier, polydisperse aerosols were produced by the atomizer in the generation chamber at an atomizing air pressure of 206 kPa (gauge) and a liquid pressure of -22 cm of alcohol from a solution of DOP and ethyl alcohol having 10% concentration of DOP. Larger aerosol particles were separated in the improved virtual impactor of the aerosol generator and they form the minor flow. Fig. 4 shows the log-normal size distribution of DOP particles sampled from minor flow with the techniques mentioned above. More than 1500 particles were collected on four treated glass slides at a time and their geometric diameters were measured under the microscope. As calculated from the sampling, the sample had the following statistical data:

- Median: 9 μm
- Mode: 10 μm
- Arithmetic mean diameter: 7.41 μm
- Geometric mean diameter: 6.4 μm
- Geometric standard deviation: 1.57

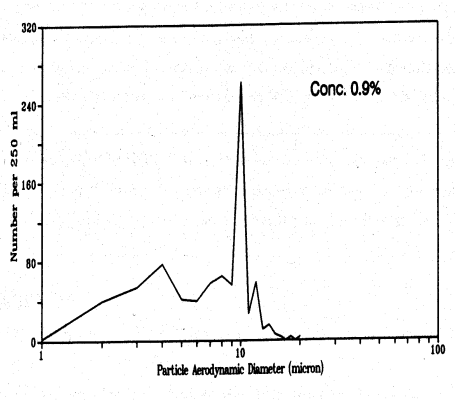

Fig. 4 Number log-normal distribution of DOP particles in minor flow

CONCLUSION

Methodologies have been developed to collect a suitable and representative sample of aerosol particles on petroleum jelly treated glass slides from the minor flow of the improved virtual impactor operated under conditions specified and subsequently microscopic measurement of the particles were carried out. It has been observed that sample collection device, type and treatment of surfactant used on glass slides, sample flow rate, sampling time and sampling location are very important to obtain a truly representative sample. The above factors were carefully analyzed and the optimum conditions of the factors were determined and used. Particle size distribution obtained was satisfactory.

This work was funded by CSIR, New Delhi, India with IIT, Kharagpur, India under contract no. 22(0283)/98/EMR-II. The research described in this paper has not been subjected to review by CSIR and therefore does not necessarily effect the views of the Council.

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