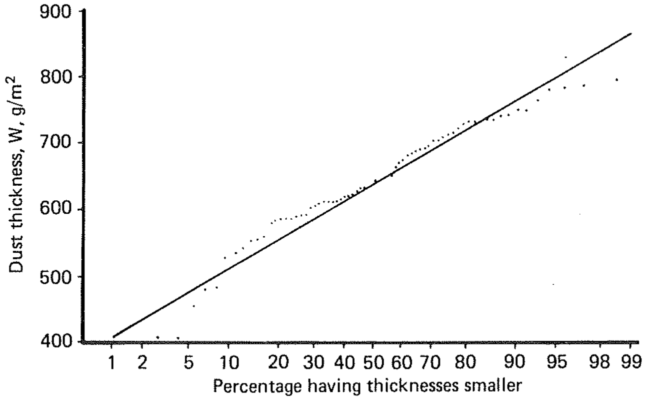

Figure 1. Distribution of dust layer thicknesses (g/m^2) from Ellenbecker's experiments (central bag cleaned last, face velocity of 75 mm/s).

checked. Predicting volume rate of flow from mean dust thickness or inferring cake thickness from pressure drop would be affected by a factor equal the ratio $\overline{W^{-1}}/\overline{W}^{-1}$, which would have introduced less than a 10% error in the two examples studied.

Conclusions

Failure to take inhomogeneity into account in predicting flow rate or pressure drop through filters or in using flow rate or pressure drop to infer cake thickness or pore size can lead to substantial errors, as the formulas and calculations reported here indicate. For the pulse-jet experiments[2] used as real examples, the error would have been less than 10%, but greater heterogeneity would lead to larger effects.

Acknowledgment

The assistance of our colleague Dr. Michael J. Ellenbecker is appreciated.

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Technique for Elevated Release of Sulfur Hexafluoride Tracer

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Study of the dispersion of atmospheric pollutants has benefited greatly in the past from the use of artificial tracers. Such air motion tracers are released into the atmosphere and are then sampled and measured at distances downstream from the source, thus providing direct information on atmospheric transport and diffusion processes. In the past it has been difficult to conduct elevated tracer releases except where smokestacks or other elevated structures already exist. A number of experiments[1-3] have been conducted with sulfur hexafluoride (SF_6) releases from existing structures. Other experiments used aircraft[4] for elevated SF_6 releases. These releases are generally made while the aircraft is executing tight turns over the location desired. This method cannot simulate a point source well, due to the finite size of the flight circle and the difficulty of maintaining a position over the desired site. In recent years, a number of investigators[5,6] have used tethered balloons which carry one end of a hose aloft, through which gaseous tracer can be dispensed. One such method which has recently undergone field tests is described in this paper. The method relies on lightweight tethered balloons that are now available commercially and can be handled easily by two or three people. The operating characteristics of this system are described and several modifications are suggested to meet the needs of other experimenters. The tracer release system can be used to simulate pollutant releases from industrial smokestacks or other elevated sources and could be used to release other gaseous tracers that are dispensed from high pressure cylinders. This paper is written to document the results of field tests in a form that is readily available to other investigators who may wish to use the tracer release system.

Equipment

A diagram for the manifold layout of the SF_6 release system is shown in Figure 1. The system consists of three "K" size pressurized SF_6 cylinders which are connected to a heated and insulated manifold. Flow from the manifold is controlled by a valve and regulator. The operator of the release system adjusts the flow to obtain the desired flow rate using a flow meter that has been calibrated with SF_6. At the completion of the release, the valves on the SF_6 cylinders are closed and a compressed air flush tank is used to force the remaining SF_6 from the release system.

Other ground based components of the release system include a wooden wire storage spool for the ½ inch O.D. polyethylene hose through which the tracer is released and an army surplus, level wind, hand operated winch used for the tether line.

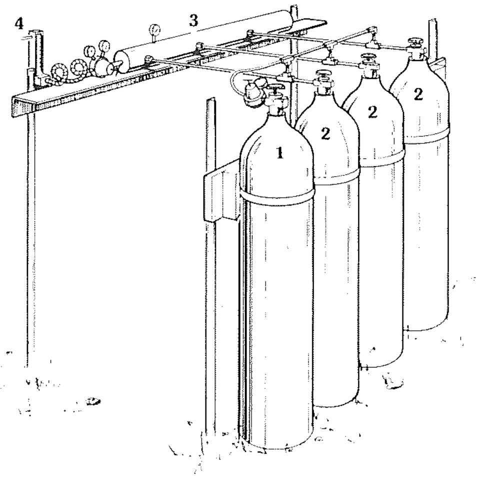

Figure 1. Diagram of the ground based portion of the SF_6 release system. SF_6 is dispensed from 3 "K" size cylinders (2) into a heated, insulated manifold (3). A temperature gage on the manifold monitors the manifold temperature. Tracer is released from the manifold through a two-stage pressure regulator and a heated, insulated coil. The flow rate is adjusted to maintain a constant setting on an accurate flowmeter (4). After release the SF_6 cylinder valves are closed and the release system is purged by opening the pressure regulator on a compressed air cylinder (1).

The airborne portion of the system is illustrated in Figure 2. The lift for the release hose is provided by a tandem balloon system, in which two 7.5 m^3, helium filled urethane plastic balloons (0.038 mm plastic) are connected together (approximately 2 m apart) at the 6 tether points on each balloon. These lightweight balloons have a high free lift to volume ratio. Their small size and mass make them relatively easy to handle—a great advantage over balloons used in some previous investigations. The tandem balloon system is tethered to a winch by a ⅛ inch nylon line attached to the front two tether points of the lower balloon. The release hose is suspended from the four rearmost tether points of the lower balloon and is supported by a light nylon line. The polyethylene hose has hose connectors at 30 m intervals. A sufficient length of hose is suspended directly from the rear tether points to cause the tail of the balloon to sink slightly relative to the nose, thus providing an angle of attack which produces additional aerodynamic lift in moderate or strong ambient wind conditions. The remaining hose is attached to the tether line by nylon wire ties.

Operation

The tethered balloon release system can be operated by two people at a remote site. A source of electrical power is necessary, however, to heat the SF_6 manifold. This can be provided by a portable gasoline or propane powered 115V AC generator.

The most labor intensive operation is the inflation and handling of the tandem balloon system. Under gusty wind conditions or in darkness this may require more than two people. When the balloon system is at altitude, a single operator can monitor and adjust the manifold temperature and SF_6 flow rate, and can purge the hose and manifold of SF_6 before the balloons are retrieved. At the beginning and completion of each release the SF_6 cylinders must be weighed to determine the actual mass of SF_6 released.

Performance

The described SF_6 release system was used in an atmospheric tracer experiment conducted in the Brush Creek Valley of Western Colorado in August 1982. In these experiments, SF_6 was released in down-valley drainage flows within the deep, narrow valley (base elevation, 1700 m MSL) from near sunrise to the time of temperature inversion destruction (approximately 0930 MST). Winds at balloon height ranged up to 8 m/s. SF_6 manifold temperatures were adjusted over the range of 25–40°C during the course of the experiments. Release rates were varied from experiment to experiment within the range of 2.9–9 kg/h. Higher release rates could be attained with the system described. Where relatively low release rates are desired, a smaller diameter hose may be used. Since the maximum achievable height depends primarily on the cumulative weight of the hose and tether line, a higher elevation release should then be possible. Similarly, a higher elevation release should be possible at lower altitudes where the free lift of the balloon is greater.

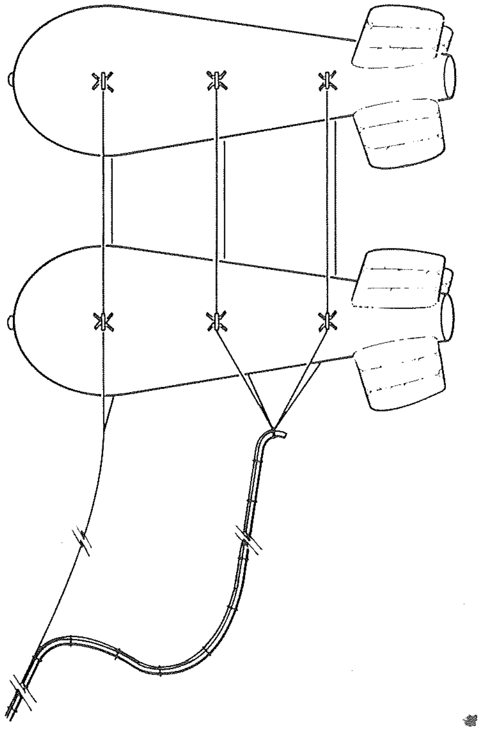

Figure 2. Diagram of the airborne portion of the SF_6 release system. The balloons are approximately 7 m long and 2 m in diameter. The SF_6 hose falls about 60 m before being attached to the tetherline by plastic wire ties.

In an elevated release from a tethered balloon system it is of interest to determine how the release elevation varies with time, since this may have a pronounced effect on the interpretation of data from the tracer experiment. In Figure 3 the height of the tethered balloon system and the wind speed at balloon height are plotted as a function of time for a 1h 40 min period on August 4, 1982. Height data were obtained at 6 s intervals from a sonde, attached to the balloon, which transmitted atmospheric pressure and temperature data to the ground. During the period 0354–0506 MST, the balloon maintained an average altitude of 104.7 m with a standard

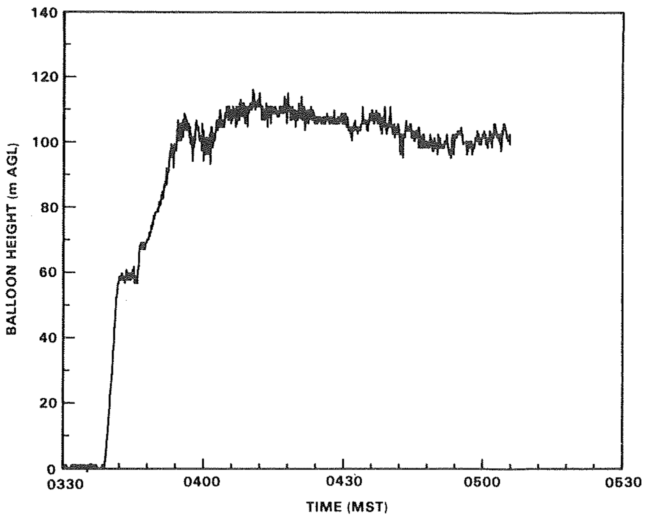

Figure 3. Balloon height versus time for August 4, 1982, Brush Creek, Colorado.

deviation of 4.2 m. The winds at balloon height during this period were measured with an independent tethered balloon sounding system which made four vertical profiles through the elevation of the tandem balloon system. Winds at release height were nearly constant in direction (322–326°) but were decreasing in speed from 7.4–6.4 m/s. Although the data series is rather short, there is some indication that the balloon height decreases as the windspeed at balloon height decreases. This suggests that the aerodynamic lift of the balloon system (as distinct from the free lift) is an appreciable factor in determining balloon performance.

The tandem tethered balloon system described above handled well in the field trials. Experience was also gained with other balloon configurations before the field trials. In one set of dual balloon tests a single balloon was used to lift the hose and tether line and a second balloon was attached to the main tether line when the lift of the first balloon became insufficient to carry additional mass. Difficulties encountered with this system included potential damage to the lower balloon due to collisions with the main tetherline (especially under low wind speed conditions with a short tether line on the lower balloon) and twisting and constriction of the hose when independent wind direction reversals occurred at the lower or upper balloon.

From the field tests it was concluded that the tandem balloon system is useful in atmospheric tracer experiments where a single balloon has insufficient lift to provide a release at the desired elevation. The release system proved to be portable, easy to use, and suitable for simulating continuous elevated pollutant releases. Further field testing should be conducted, however, to determine the maximum dispensing rate of SF_6 and the behavior of the tandem balloon system under turbulent or variable wind conditions.

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Mr. Al Morris of Ambient Analysis, Inc. and Mr. Bob McBeth of the National Center for Atmospheric Research provided helpful suggestions used in testing balloon configurations. Mr. Roger Schreck provided help in operating the balloon system and in collecting supporting meteorological data. The work was supported by the U.S. Environmental Protection Agency through Interagency Agreement AD-89-F-2-097-0 with the U.S. Department of Energy. Comments on the manuscript by Mr. Rich Fisher, EPA Region VIII meteorologist, and Mr. Alan Huber, EPA Project Officer, are appreciated.

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Pollution Variability and the Shape of the Dose-Response Curve

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In a recent issue of *JAPCA*, Adams and Crocker[1] discuss the economic relevance of the dose-response curve in assessing environmental damage. In their discussion they point out that regions which experience more variable air pollution levels will also experience more variable crop yields than areas with less variable air pollution levels. It is also possible to demonstrate that for a given average pollution level, regions which have more variable pollution levels will experience higher (or lower) average damages than regions with less variable pollution levels if the dose-response curve is strictly convex (or concave). This result suggests that models that rely only upon average

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