Notes on the Modification and Use of a Cascade Impactor for Sampling in Ducts

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Although the cascade impactor has been widely applied to the sampling of gently moving air streams as found in mine shafts or in the open atmosphere, only limited use has been made of it in ducts and stacks. An earlier duct probe design for the cascade impactor has been redeveloped, and a method has been found to prevent deposition of aerosol on the first stage prior to the actual sampling period. A control system has been devised which permits reproducible sampling periods as brief as 0.6 second.

Introduction

SINCE THE cascade impactor was first introduced and described by May,[1] it has enjoyed an ever-increasing utilization in industrial hygiene and in related fields where a knowledge of aerosol size distribution and concentration is of interest. Many investigators have designed instruments based on the cascaded impaction principle. However, almost all impactor designs, both commercial and experimental, have been limited to gently moving air streams as found in mine shafts, factories, and the open atmosphere and have not, with the exception of two attempts,[2,3] been directed toward use in sampling from ducts or stacks. The design of a cascade impactor that would be adaptable to a confined, rapidly moving aerosol was initially provided by First *et al.*[4] The salient feature of their design was the construction of a special sampling probe, wherein the first impaction stage was contained in the probe elbow so that the aerosol entered the probe through an isokinetic nozzle, and the particulates that would ordinarily have been lost in making the turn to leave the duct were deposited on the first stage. The balance of the impactor was the first commercial adaptation of May's design (G. F. Casella and Company, Ltd., London). First *et al.*[4] reported moderate satisfaction with this design, and we have adopted it with one major modification. A system has been developed that prevents the impaction of large particulates on the first stage when the sampling pump is not operating.

Method

The need arose in our own laboratory to characterize, under a series of operating conditions, the output of a spray nozzle. Currently employed methods would have required setting the nozzle in a vertical or horizontal position, and making a microscopic evaluation of the spray liquid as trapped in fallout cells or deposited on slides. Although this technique is well developed and has proven generally reliable, it is quite tedious in that it requires microscopic evaluation of multiple samples for each run. Since the particulate diameters were expected to be less than 50 microns, which is well within the capacity of the cascade impactor, an instrument was modified for use in our horizontal aerosol tunnel (Figure 1). This tunnel has been demonstrated to yield a flat velocity profile at 2870 fpm, which corresponds to the isokinetic conditions for the probe tip diameter and flow rate.

The impactor is shown segmented in Figure 2 and pictorially in Figure 3. Mechani-

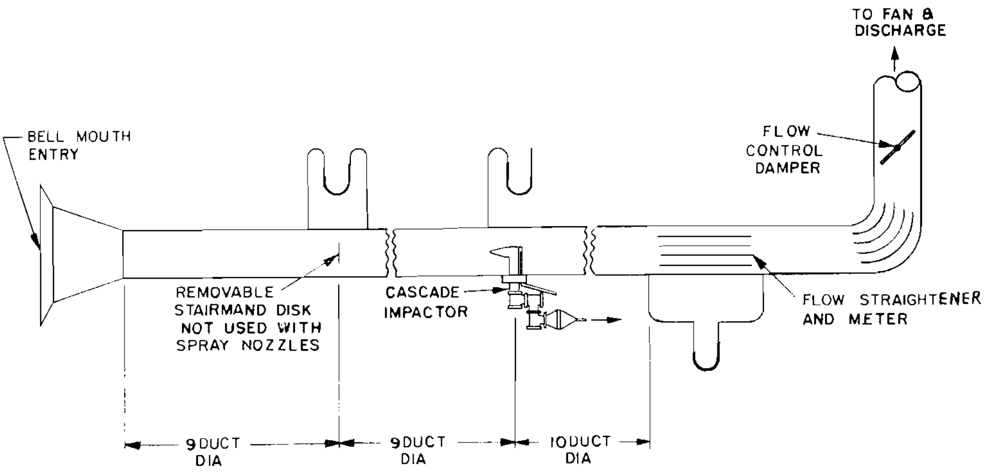

FIGURE 1. Eight-inch horizontal aerosol tunnel.

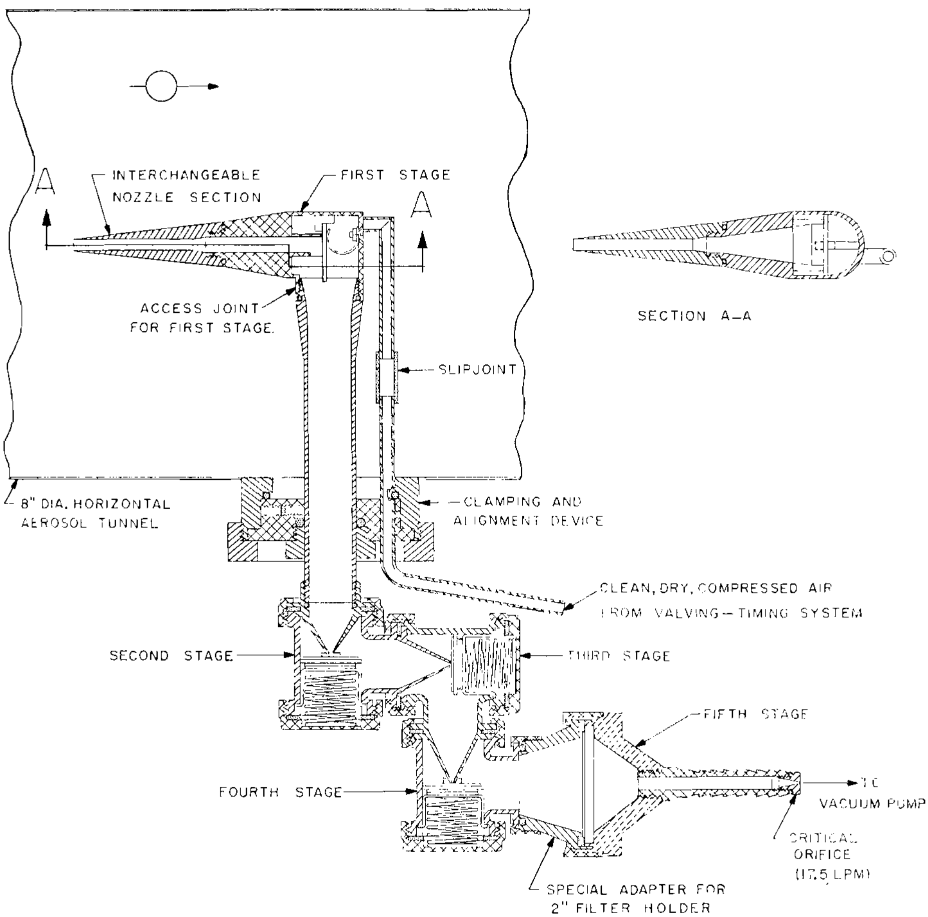

FIGURE 2. Sectional view of cascade impactor modified for duct sampling.

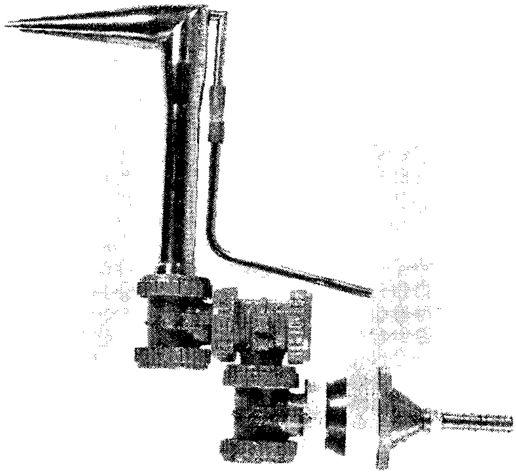

FIGURE 3. Photograph of modified cascade impactor shown with clamping and alignment apparatus removed.

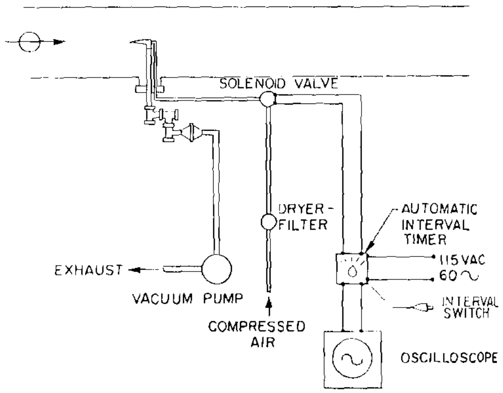

FIGURE 4. Schematic diagram of cascade impactor valving-timing apparatus.

cal features of the design include a clamping and alignment arrangement (Figure 2) whereby the impactor can quickly and simply be installed or removed from the duct. This procedure is necessary because the first stage slide is inserted by removing the nozzle section of the probe. The fifth (filter) stage of the impactor was replaced with a unit of our own design. All gaskets in the impactor were replaced with ones made of silicone rubber 1/16 inch thick.

The probe section is fabricated from stainless steel. This material was selected because the nozzle and first stage are fabricated from a number of machined parts which can be neatly and reliably assembled only by an inert gas-arc welding process. The rectangular cross section of the probe is formed by splitting a bar of steel, milling and finishing the passage, and then welding the two halves back together. The remainder of the constructional details may be discerned from Figure 2.

Because the impactor slides were analyzed by light-field microscopy, it was necessary to provide a method of taking a very brief sample to ensure that none of the stages of the impactor would be overloaded. This was accomplished with the apparatus detailed in Figure 4. A stream of clean, dry compressed air (15 psig) is fed to the impactor backflush tube. This air stream prevents large particles from entering the probe and depositing on the first stage prior to the sampling period. The vacuum pump is left on at all times during operations, but it draws only a portion of the stream of clean compressed air. The solenoid valve in this timing circuit serves only to shut off the supply of compressed air which is fed to the backflush system (Figures 2 and 3).

When it is desired to take a sample of the aerosol flowing in the tunnel, the automatic timer is pulsed, and the supply of compressed air is shut off for a predetermined period, allowing a sample to be drawn directly from the air stream. At the end of this period, the compressed air is switched back on, and no further sampling can take place. When the timer is used, intervals as short as 0.6 second can be utilized with assurance that a representative sample will be captured. For these shorter time periods, an oscilloscope is introduced in the circuit to determine the exact time period.

Although the liquid used for this study (Dow 200 fluid, 10 centistokes) was capable of being dyed for purposes of gravimetric analysis (saturated with DuPont Oil Yellow), a poor agreement with the manufacturer's established impactor calibration was observed, probably owing somewhat to the short sampling times. The effective drop sizes (EDS) found by our own calibration were approximately 50% greater than those given by the manufacturer for the current instrument,[5] and of a different slope. If the mass median diameter (MMD) method of calibration is utilized, as described by several authors and summarized by Mercer,[6] then the results are usually within a ±10% error band from calibrations made from previous runs on the same material and conditions. More important, the slope is usually found to be the same, a parameter that is perhaps more sensitive than the absolute value of the mean diameter. However, because maximum accuracy and reproducibility were desired, all samples were analyzed by light-field microscopy, and the count data for the individual stages were combined and evaluated according to the original method of May.

The fluid used in these studies has a very low surface tension (20 dynes/cm) and tends to spread quite rapidly when deposited on glass slides. This condition, however, was easily overcome by cutting slides from a transparent Teflon sheet 0.005 inch thick. Particulates deposited on this Teflon sheeting remained intact and did not spread for periods of up to two days.

This design would also be adaptable to small-diameter stacks, process stream ducts, and free air streams of known velocity, such as are encountered in sampling from aircraft. From sampling considerations the lower practical limit of nozzle tip diameter is approximately 0.2 inch. To maintain isokinetic sampling conditions, this impactor design is limited to use at velocities above 2800 fpm (~32 mph) if operated at the design flow rate of 17.5 liters/min.

References

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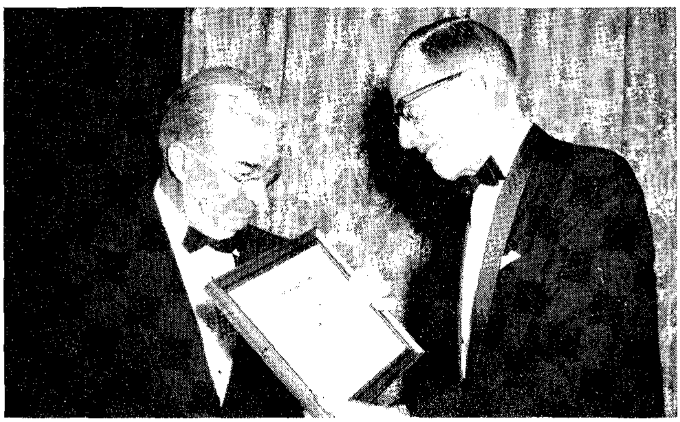

Dr. Robert A. Kehoe Honorary Member

At the 1966 annual banquet of the American Industrial Hygiene Association, Dr. Robert A. Kehoe (left) was presented with the plaque signifying his election to honorary membership in A.I.H.A. This honorary membership was presented to Dr. Kehoe in recognition of his many and varied contributions to the field of industrial hygiene. For many years Dr. Kehoe was the Director of the Institute of Industrial Health, Kettering Laboratory, University of Cincinnati College of Medicine, and although he has recently retired he has not diminished his activities and interest in industrial hygiene and occupational medicine.