American Industrial Hygiene Association Journal

ISSN: 0002-8894 (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/aiha20

Design, Construction and Evaluation of a Multi-Stage "Cassette" Impactor

WILLIAM JONES , JOHN JANKOVIC & PAUL BARON

To cite this article: WILLIAM JONES , JOHN JANKOVIC & PAUL BARON (1983) Design, Construction and Evaluation of a Multi-Stage "Cassette" Impactor, American Industrial Hygiene Association Journal, 44:6, 409-418, DOI: 10.1080/15298668391405058

To link to this article: https://doi.org/10.1080/15298668391405058

Am. Ind. Hyg. Assoc. J. 44(6):409-418 (1983)

Design, Construction and Evaluation of a Multi-Stage "Cassette" Impactor

WILLIAM JONES, JOHN JANKOVIC and PAUL BARON[A]
National Institute for Occupational Safety and Health, 944 Chestnut Ridge Rd., Morgantown, WV 26505;
[A]National Institute for Occupational Safety and Health, 4676 Columbia Parkway, Cincinnati, OH 45226

A cascade impactor, (fabricated from 37-mm cassette pieces) is described. The sampler can be built in a few hours using simple machining operations. Construction details are provided. The unit is small and light enough to be used for personal as well as area sampling. The impactor has been compared with commercially available units under a variety of laboratory and field conditions and agreement has been good. Precision of replicate samples has also been good. The unit was calibrated using the TSI aerodynamic particle sizer and results are in general agreement with theoretical 50% cut points using three different collection substrates.

Introduction

Cascade impactors are used extensively in the field of industrial hygiene for the sizing of solid and liquid aerosols. In these samplers all collected particles regardless of size, shape or density are sized aerodynamically and can therefore be equated to reference particles (unit density spheres). Since human lung penetration characteristics are known for spherical aerosols of unit density,[(1)] data from these samplers can be used to estimate respiratory deposition.

Several definitions exist for respirable, inhaled and total dust. These definitions arose out of health considerations related to the mechanism of toxicity of a particular type of aerosol and to the size dependent deposition of the aerosol in the various parts of the human respiratory tract. Legal and historic considerations have also played a part in the development of these definitions.

Sampling with a cascade impactor allows the estimation of the entire size distribution and calculation of the fraction relevant to a particular legal or health requirement. Also, with the availability of impactor data, the fractions can be recalculated according to new or changed definitions.

A variety of cascade impactors are commercially available using several different designs. Most of these impactors are too large for personal sampling; however, there are at least two exceptions. Andersen Samplers, Inc. at one time made a small four-stage impactor which operated at 1.4 L/min with 50% cut points ranging from .65 to 4.5 μm. Sierra Instruments, Inc. has recently developed a multi-stage radial slot impactor that is small enough for personal sampling. This unit is sold in four, six and eight-stage versions and at 2 L/min the 50% cut points range from .5 to 21 μm. Commercially available impactors are typically expensive with costs ranging from around $500-$3000 per unit.

Mention of company name or product does not constitute endorsement by the National Institute for Occupational Safety and Health.

This paper describes the construction, calibration and laboratory and field testing of a relatively low cost cascade impactor which is small and light enough for personal as well as area sampling.

Sampler Design and Construction

Plastic 37-mm filter cassette tops were chosen as the basic structure of the impactor since they are inexpensive and available from at least 3 sources: Glasrock, Millipore Corp. and Gelman Instrument Co. The cassette tops and bottoms are sometimes collectively referred to as 37-mm field monitors. In order to allow the cassette tops to be stacked one on top of another, the inside surface was machined out as shown in Figure 1. This was accomplished by mounting the cassette on a horizontally rotating shaft and machining out the plastic material using a cutting tool. A lathe with a boring bar is recommended for this operation. If a lathe is not available, however, a small electric drill mounted in a vise with a 1/4" wood chisel used as the cutting tool will work, but is more difficult, and the finished surface is much rougher. To hold the cassette in place, a tight fitting bolt was pushed through the cassette port. A nut was then used to hold the cassette tightly on the bolt. The bolt shaft was then

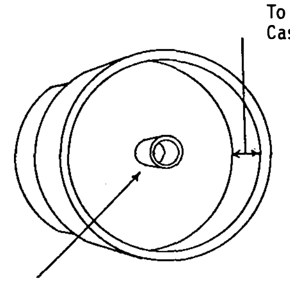

Figure 1 — Cassette top preparation.

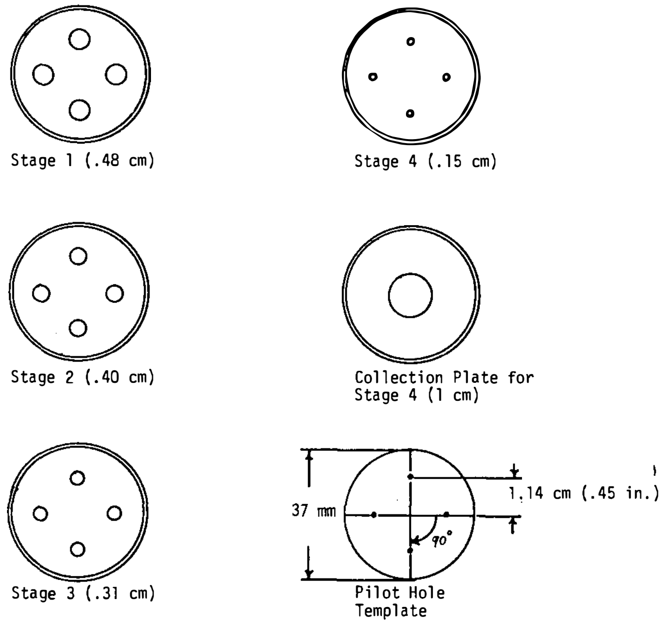

Figure 2 — Jet drilling specifications.

placed in either the lathe or drill chuck. An alternative approach is to mount a cassette bottom in the chuck which allows the individual cassette tops to be easily and quickly mounted for machining. Enough material was removed to allow the cassette tops to be easily stacked. It is important to keep the fit somewhat loose since a tight fit leads to cracking after extended use of the impactor. The next step was to machine down the inlet nozzle of the cassette using an end mill or drill bit. When using an end mill, the inlet port should be machined down to be flush with the top surface of the cassette piece. If a drill bit is used for this operation, it is better not to drill completely through since this leaves a large hole that later must be sealed. Clear casting plastic or epoxy is used to seal the remaining inlet hole. Filling this hole gives the sampler a neater appearance and is more permanent; however, simply taping the hole is probably adequate.

An operating flow rate of 2 L/min was chosen for this design since there are a variety of small pumps available with this flow capacity. A 4-stage impactor was built with 50% cuts of 20, 15, 10, and 3.5 μm. These points were selected since there were three commercially available impactors on hand with similar cut points for comparison. These units were the Sierra Series 216 ambient sampler, the Sierra Series 260 impactor and the Sierra Series 290 personal cascade impactor. The hole sizes necessary for the above cut points were then calculated, (based on 4 jets per stage) using the Model 201 Impactor Calculator prepared by Virgil Marple (University of Minnesota), and available from Sierra Instruments, Inc. The hole sizes were calculated to be .48, .40, .31, and .15 cm for 50% cut points of 20, 15, 10, and 3.5 μm, respectively. A template was made to mark the hole positions and a soldering iron, (with a pointed tip) was used to mark the hole centers in the plastic for easy drill alignment. The holes were drilled according to the specifications on Figure 2. Note that the centers for the 4 jets are the same for each impactor stage. The holes in the template should be made just large enough to allow marking with the soldering iron tip. Stages 2, 3 and 4 serve also as the collection plates for stages 1, 2 and 3, respectively. The collection plate for stage 4 is simply a cassette top (machined out as described above) with a 1-cm hole drilled out in the center. The particles that are able to penetrate the final stage are then collected on a back-up filter which is mounted in an unmodified standard cassette bottom. After the holes were drilled, they were bevelled to a vertical depth of 0.7 mm using a 27/64" drill bit with a 118° included angle. All of the machining operations involved in building the cassette impactor are best done at very low machine speeds.

Two types of collection media, (Gelman type E glass fiber filter paper and greased aluminum foil) were developed for use in the impactor. Both types of media were cut out as shown in Figure 3. The hole centers for stage 1-3 collection media are identical to the jet hole centers for stages 1-4. After making a template, the glass fiber filters were cut using a cork borer. The holes for the aluminum foil media were cut using a 1/4" paper punch. Standard 37-mm glass fiber filters were used as back-up filters for the impactor. Each complete set of sampling media therefore includes three of the four hole media, one single hole substrate, and one plain filter. When using the aluminum foil collection media a light coating of grease (Apiezon H or L) was applied in the area indicated on Figure 3. The Apiezon L grease was applied directly; the H grease was mixed with toluene and applied with a brush. The collection media are loaded for sampling starting with the back-up filter. The four-hole filters are lined up such that the holes are directly over the jets. Also it is important to align stages 1, 2 and 3, such that the impaction points fall directly between the filter holes. After the impactor is initially aligned, a straight line can be marked down the length of the impactor. This facilitates subsequent alignment of the impactor stages. The sampler is then sealed with tape. A two-inch wide specialty labeling tape available from American Scientific Products is recommended. Electrical tape also works well although it is more difficult to apply. The tape must be carefully smoothed over the outer surfaces of the impactor to prevent leaks. A standard cassette top is then placed on top of stage 1 to seal the sampler prior to use. Figure 4 is an exploded diagram of the impactor that shows how the pieces fit together.

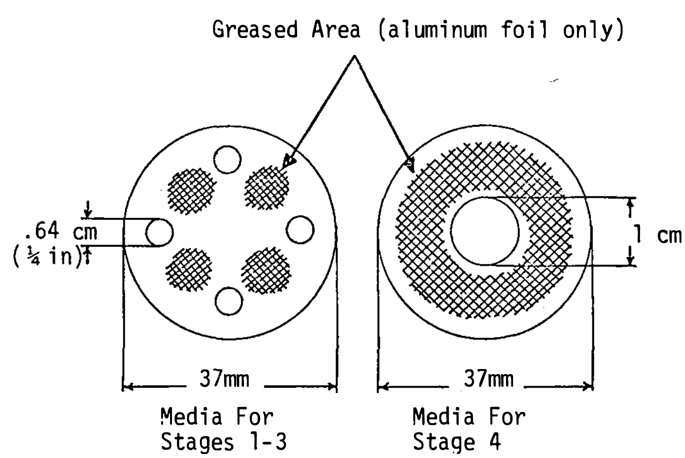

Figure 3 — Collection media specifications.

Evaluation Methods

Calibration

The penetration curves for the cassette impactor stages were measured separately in order to determine the 50% cut points for comparison with those theoretically determined. The penetration curve for each stage was obtained by measuring the size spectrum penetrating the impactor and dividing it by the size spectrum of the challenge aerosol using a prototype TSI Aerodynamic Particle Sizer (APS).[2]

The challenge aerosol was generated from a stirred water suspension of polydisperse latex spheres or aluminum oxide powder with a Retec nebulizer. For successful calibration each impactor stage had to be challenged with an adequate number of particles both smaller and larger than the estimated 50% cut point. Thus, the size distribution of the suspension was chosen to be optimal for each stage. The nebulized aerosol passed through a heated drying tube into the calibration chamber. The aerosol was then mixed with the dilution flow and passed through a flow straightener. The test chamber was horizontal with dimensions 0.4 m × 0.4 m × 4 m and the air velocity was approximately 20 M/min. The flow through the impactor was effected by a needle valve controlled vacuum pump. During calibration, the inlets were facing the horizontal air flow. Care was taken to minimize interaction effects between the exhaust of the impaction stages and the inlet of the APS. Typically, the bottom part of each stage was used as the inlet to measure the challenge aerosol distribution. The nozzle section of that stage was then inserted to measure the preselected distribution.

Since the first two stages of the cassette impactor had cut points designed to be at 15 and 20 μm (above the range of the APS), only the two lower stages were calibrated at 2 L/min. In order to get an estimate of the accuracy of the first two stages, the calibration of all four impactor stages was also carried out at 5 L/min which lowered the cut points of all stages to within the range of the APS. Calibration of the stages was carried out using Apiezon L greased aluminum foil substrates. Penetration curves were also measured using Apiezon H grease and glass fiber filter substrates.

Laboratory Evaluation

The initial laboratory evaluation was conducted in a dust chamber developed under contract for NIOSH for coal dust

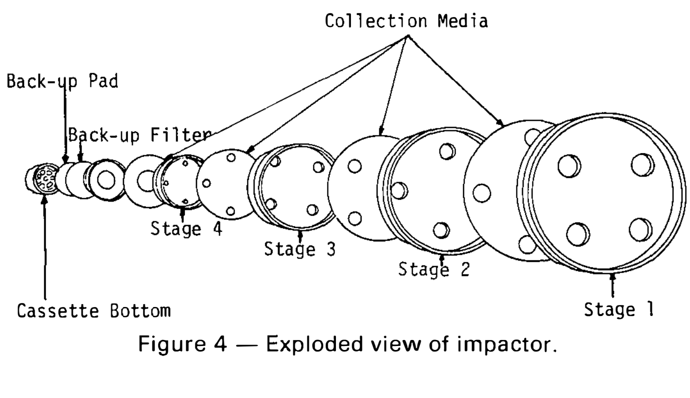

Figure 4 — Exploded view of impactor.

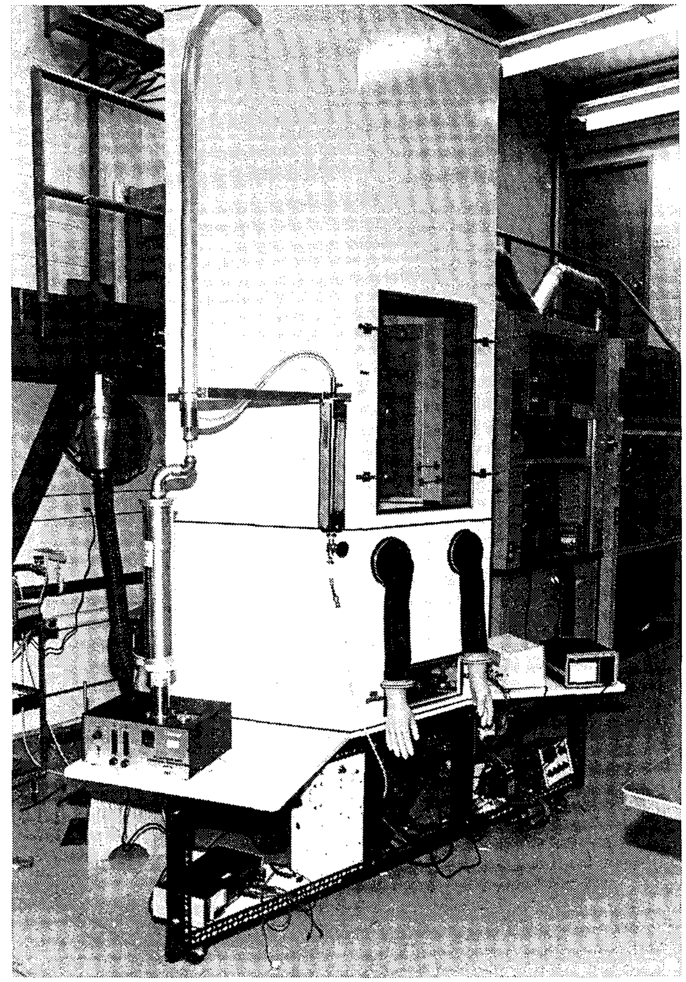
Figure 5 — Coal dust chamber.

sampler testing.[3] The chamber utilizes a TSI Model 3400 fluidized bed aerosol generator. Coal dust plus dilution air enters the top of the chamber and is mixed by the energy of the aerosol jet. The aerosol then flows through a 10-cm thick honeycomb structure to provide a low velocity, low turbulence, downward flow through the test section of the chamber. The chamber is hexagonal in cross section and is about 2.4 m high and 1.2 m wide.[3] Figure 5 is a picture of the chamber.

The cassette impactor was compared in this chamber to the Sierra 260 and a prototype Sierra Series 290 impactor. The 260 is a single jet multi-stage impactor which was designed according to revised impaction theory.[4] Greased glass cover slips are used as collection media. In these tests a flow rate of 2 L/min was used which resulted in 50% cut points in the range of 0.95 to 21 μm. Constant flow Dupont P-4000 pumps were used for all impactor tests. The Sierra 290 sampler was also run at 2 L/min and sticky tape "Sierra-Film" collection media were used. In the coal dust test, two of the Sierra model 260 samplers, two cassette impactors, and one Sierra 290 sampler were placed side by side. Sampling time was approximately 2 hours.

The cassette impactor was also evaluated in a silica dust chamber. This is a rather large (1.5 m × 1.5 m × 2.2 m) chamber which is usually used by NIOSH for respirator certification.[5] In this test three cassette impactors (with

TABLE I
Cassette Impactor Dp50's (μm)

Stage	Theoretical 2L/min	Theoretical 5L/min	Experimental (Greased Foil) 2L/min	Experimental (Greased Foil) 5L/min	Experimental (Glass Fiber) 2L/min	Experimental (Glass Fiber) 5L/min
1	20.	12.8	-	15.0 (±1.5)	-	14.8 (±1.5)
2	15.	9.6	-	10.7 (±.8)	-	9.8 (±.6)
3	10.	6.7	12.5 (±1.0)	6.52 (±.1)	11.9 (±1.0)	6.1 (±.1)
4	3.5	2.3	3.7 (±.05)	2.31 (±.05)	3.55 (±.05)	2.1 (±.05)

Apiezon H greased aluminum foil) were compared side by side with three Sierra model 260 samplers and one Sierra 216 impactor. The Model 216 is a slotted cascade impactor designed for area sampling. Glass fiber collection media were used and the flow rate was held constant at 7 L/min using three Dupont P-4000 pumps. At this flow rate the 50% cut points ranged from 0.95 to 18 μm. Sampling time in this chamber was approximately 1 hour.

Field Evaluation

The greased glass cover slips for the Sierra 260 were found to be difficult to work with under field conditions and collection media were unavailable for further tests with the Sierra 290. Therefore, the Sierra 216 was chosen for the field comparisons. The first field test was conducted in a small woodshop. Samplers were placed on a table approximately 1.5 m from a band saw cutting operation. In this evaluation six cassette impactors (three with glass fiber media and three with Apiezon H greased foil media), were compared side by side with one Sierra 216.

In an additional test in the woodshop, two cassette impactors (one with glass fiber and one with Apiezon H greased foil) were mounted side by side on a worker who spent time working both at a band saw and at a lathe.

The second field evaluation was conducted at a pilot scale peanut processing facility. Samplers were set up near a pilot scale peanut sheller. As in the woodshop, the cassette impactor (using Apiezon H greased foil and glass fiber collection media) was compared against the Sierra 216. During these field tests the cassette impactors were simply taped to the side of the sampling pumps.

Results

Calibration

The calibration results are given in Table I. As previously mentioned the theoretical Dp50 values were calculated using the Model 201 impactor calculator. The experimentally derived Dp50 values are in good agreement with theory for the lower (3,4) stages. For stages 1 and 2 at 5 L/min, and stage 3 at 2 L/min, the trend is for the experimental values to be somewhat higher than theory. This is true for both glass fiber and greased foil collecting media. The error limits noted on the table are based on replicate measurements as well as estimates of biases due to interaction between the impactor exhaust and the APS inlet.

Figure 6 shows the measured penetration curves for stages 1-4 using the Apiezon L grease substrate. Figure 7 shows the penetration curves under the same conditions, except that a glass fiber substrate was used. Stage 1 penetration data for the glass fiber substrate was not included because of poor statistical precision of the data. The 50% cut points for stage 1 were estimated with relatively poor precision as indicated in Table I.

Figure 8 shows the effect of the different substrates on stage 4 at 5 L/min. Similar effects were noted for the other stages. The Apiezon H and L greases had very similar 50%

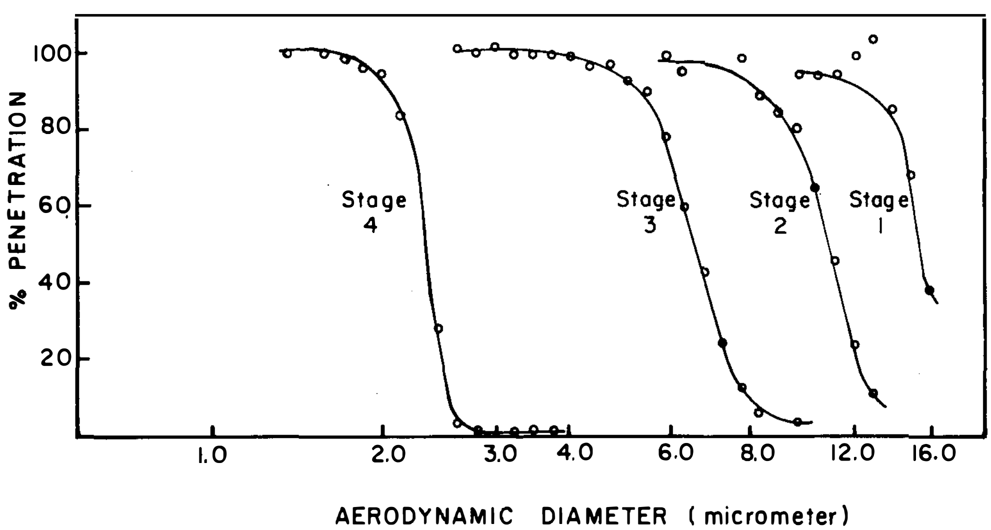

Figure 6 — Penetration curves of cassette impactor with Apiezon L grease substrate (5 L/min).

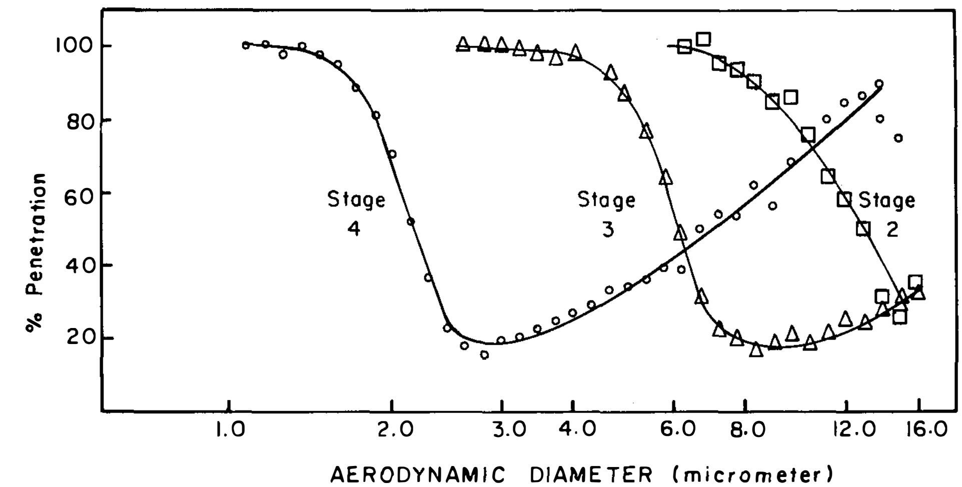

Figure 7 — Penetration curves of cassette impactor with glass fiber filter substrate (5 L/min).

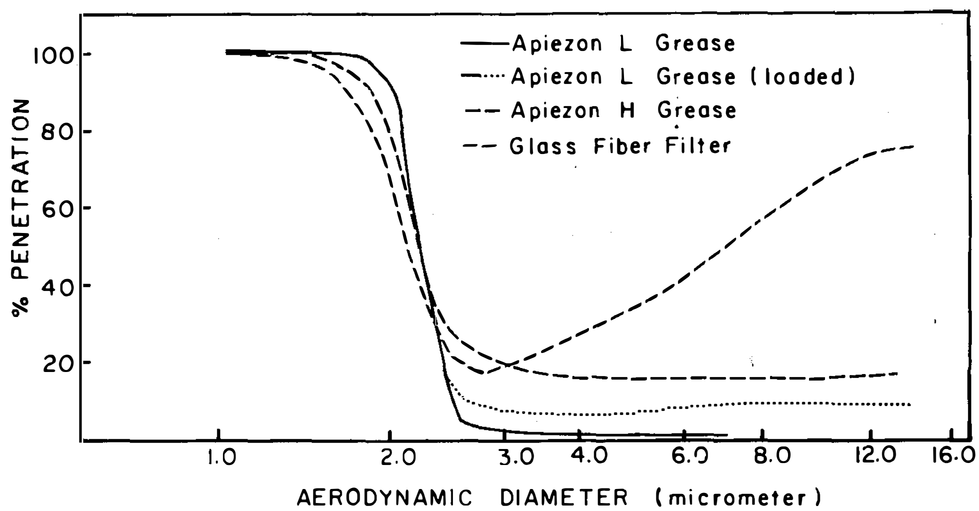

Figure 8 — Penetration curves of stage 4 of cassette impactor with different substrates (5 L/min).

cut points, but the H grease produced 15-20% particle bounce above the cut point. This degree of bounce did not change significantly with loading. A clean L greased surface exhibited virtually no bounce, while a dust laden L surface approached the degree of bounce of the H surface. The glass fiber surface exhibited penetration above the cut point increasing to about 70% penetration at 15 μm. It is important to point out that these stages were calibrated separately. In practice, stage 4 would not be exposed to many of these larger particles since during sampling this stage is preceded by three additional impactor stages. The error due to penetration is therefore probably less severe than is visually suggested by the graph.

Laboratory Evaluation

Figures 9 and 10 are log probability plots of the coal dust and silica dust chamber results respectively. The precision of replicate samples using the Sierra 260 and cassette impactor was quite good. Replicate sampling was not possible with the Sierra 216 and Sierra 290 since only one of each was available for our tests. Agreement between all four impactors was also good in both chamber runs. The mass median aerodynamic diameter (MMAD) for the silica dust was about 2 μm, which is actually smaller than the final stage cut point of the cassette impactor (3.5 μm). Obviously this size distribution is best measured with an impactor with better resolution of the smaller particle sizes. The cassette impactor was still able to reasonably estimate this distribution and, in fact, the 3.5-μm point agreed well with the other impactors.

Field Evaluations

Figures 11 and 12 give the results of wood dust sampling using the cassette impactor (with filter and greased foil media), and the Sierra 216. Agreement between the two impactors was excellent as was the precision of replicate samples using the cassette impactor with both collection surfaces. Figure 13 gives the results of personal sampling using two cassette impactors (with both media) and again good agreement was achieved.

For personal sampling a 2 in. cassette extension (available from Glasrock) was used, modified as shown in Figure 14. Although the inlet losses associated with this adaptor were

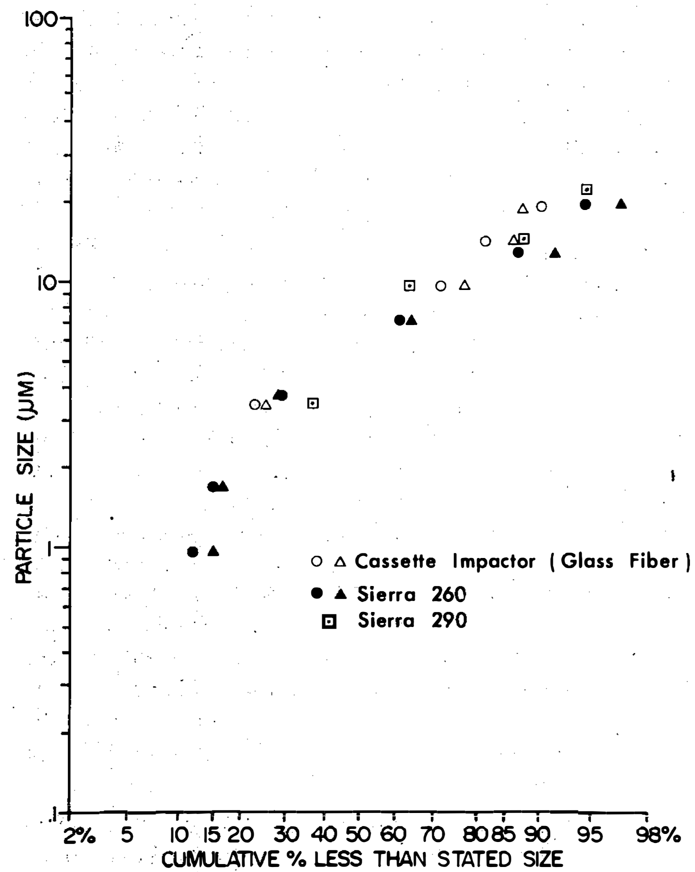

Figure 9 — Coal dust chamber results.

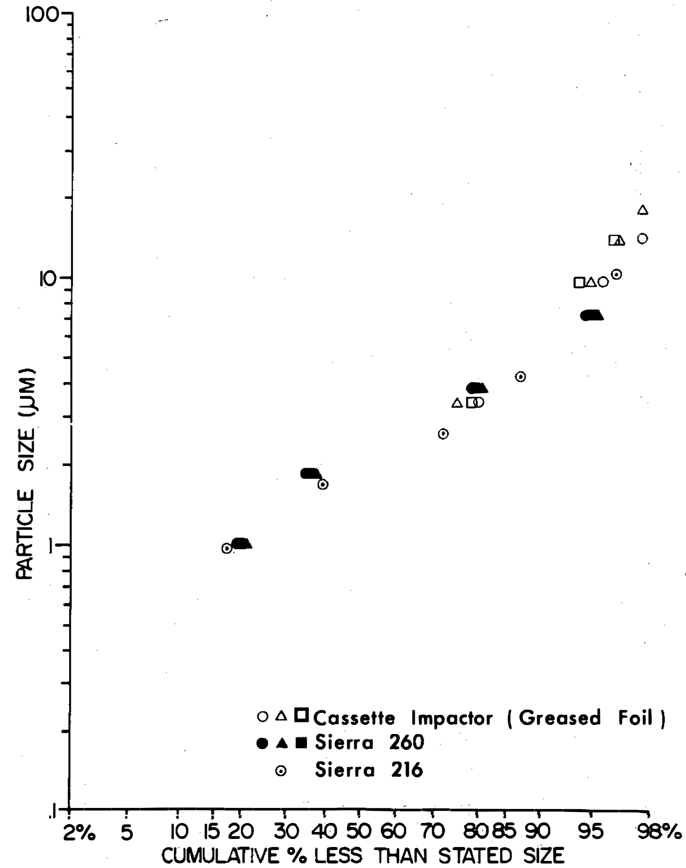

Figure 10 — Silica dust chamber results.

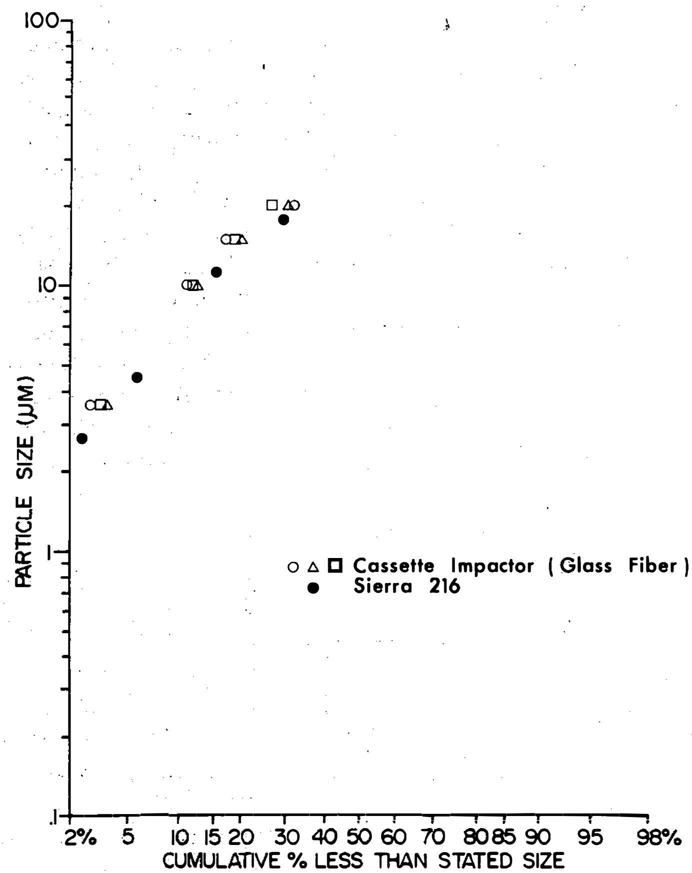

Figure 11 — Woodshop results using glass fiber filter media.

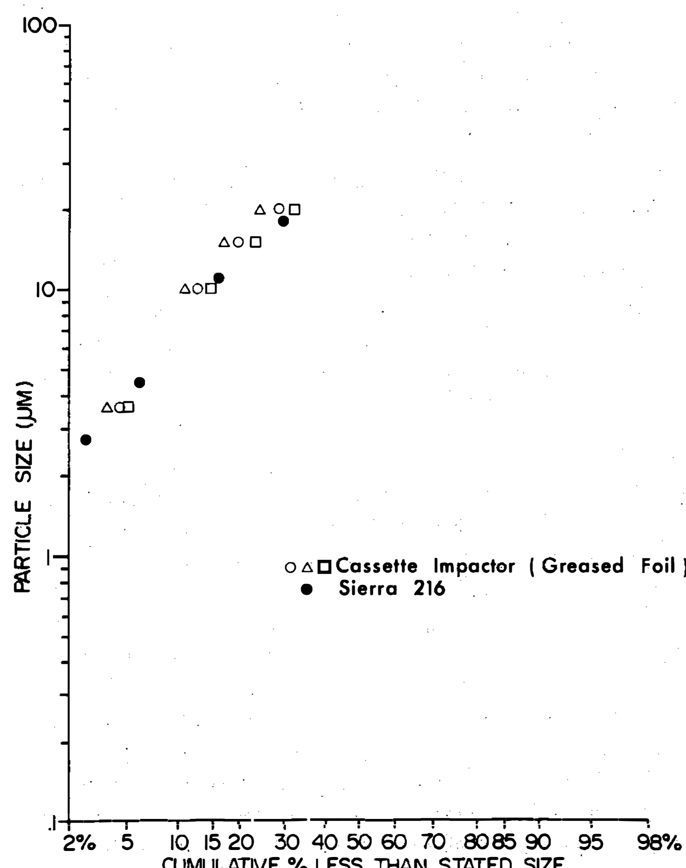

Figure 12 — Woodshop results using greased foil media.

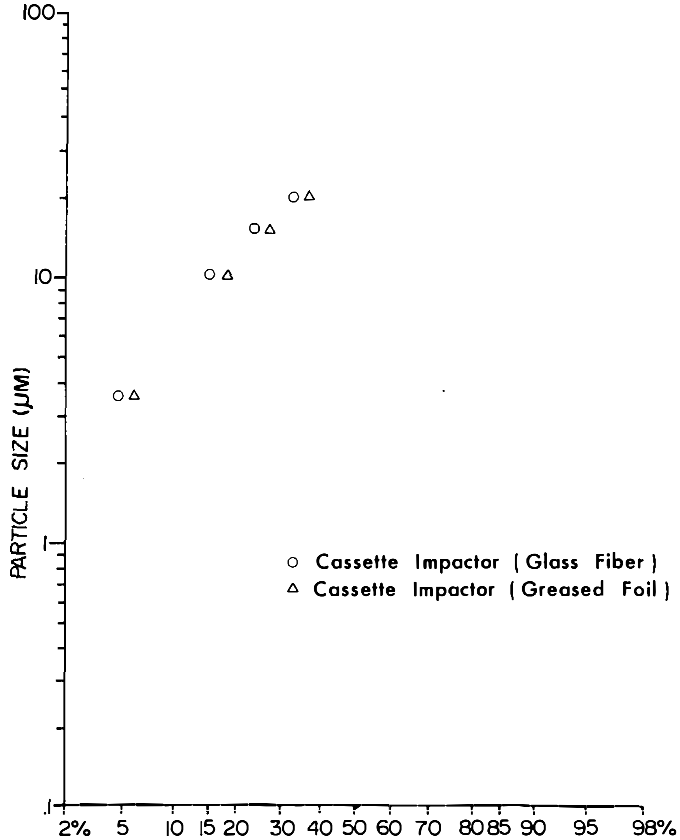

Figure 13 — Personal sampling results from woodshop.

not investigated, it is offered as a suggestion for keeping out large particulate that might otherwise drop onto the first stage during personal sampling. The impactor could also be used for personal sampling without this extension by simply attaching the clip to the top stage.

Figures 15 and 16 are the log probability plots of impactor data collected around the peanut shelling operations and the pattern of good precision and good agreement between impactors is again maintained.

For the laboratory and field comparisons the theoretical cut points for the cassette impactor were used since the experimental penetration data for stages 1 and 2 at 2 L/min were not available.

Discussion

The log probability plots comparing the cassette impactor with other impactors indicate good agreement both in the lab and in the field. MMAD and GSD were estimated from these plots and the average difference between impactors was about 10%. The actual values are not included here since the estimation of MMAD involved extrapolation beyond the data points for some of the plots. Also, the estimation assumes that the data is lognormally distributed; i.e., the points will produce a straight line when plotted on log-probability paper. Actual data typically have some degree of curvature which makes the estimation of a straight line through the points somewhat subjective. Although agreement is good, there is a fairly consistent pattern of the cassette impactor indicating a larger MMAD than the other units. If these comparisons are considered as another type of "calibration" of the cassette impactor, it appears that the theoretical cut point estimates for stages 1 and 2 are too high. At 2 L/min the Reynold's number for stages 1 and 2 are low and therefore the actual cut points may differ significantly from theory. The range of the APS has recently been extended and work is currently in progress to experimentally determine the penetration of stages 1 and 2 at 2 L/min.

It is interesting that there does not appear to be much difference in results using the greased foil and glass fiber collection media even though the experimental data indicated more bounce associated with the use of glass fiber filters. The greased aluminum foil substrates were harder to prepare than the glass fiber filters. There are, however, times when the greased surface was superior. Wood dust, for instance, showed very little affinity for the glass fiber substrate. Any rough handling of the media resulted in some dust loss from the filter. This was especially true for the first stage since the smaller wood dust particles were better able to embed in the filter. There was no such problem with the greased foil substrate. Although it was not tried in these tests, perhaps an acceptable compromise would be to use the greased surface only for the first stage (where it does the most good). This would minimize the work involved in sample preparation.

Note that it is important to use a "strong" variety of glass fiber filter. Gelman Type E worked well since it has a woven structure. Other less sturdy types were tried but were totally unacceptable due to tearing experienced when the filters were squeezed in the cassettes.

Both types of collection substrates for the cassette impactor are light relative to substrates for other impactors. The greased aluminum foil weighs about 50 mg and the glass fiber filters weigh about 80 mg. This has proven to be a real advantage in the gravimetric analysis since it allows better resolution of small weight changes. The weights for the Sierra 260, 216 and 290 media were about 100, 120 and 150 mg, respectively. These are certainly heavier than the cassette impactor media but not nearly as heavy as substrates used with some other impactors. The glass fiber media for the Andersen and Gelman impactors for instance weigh about 400 and 800 mg, respectively. Although these two impactors have higher flow rates which results in more mass collection, it has still been difficult to get precise gravi-

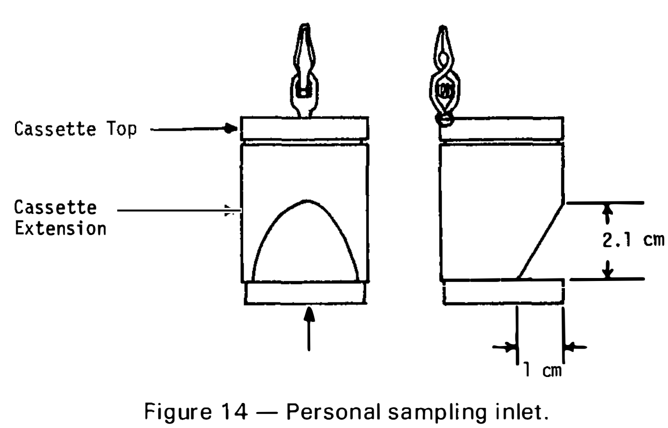

Figure 14 — Personal sampling inlet.

metric results with these impactors in this laboratory. Although this problem may be due to handling/weighing procedures, it is believed that the small sample weight to tare weight ratios are a factor.

The cassette impactor has other advantages in terms of field handling. Because of the low cost, several can be made for use in a particular survey so that they can essentially be treated like total dust samplers. That is, they can be loaded at the lab, taken into the field and used, and then brought back to the laboratory for final weighing. The samplers do not have to be disassembled in the field. This is important since a significant part of the imprecision in field impactor sampling can be due to handling procedures. As mentioned, the greased glass cover slips (used with the Sierra 260) were found to be awkward to use under field conditions. The sticky tape used on the Sierra 290 was also difficult to handle during the coal dust chamber test. Thin stainless steel collection media are now available for the 290 and work done by others at this laboratory indicate that this is a better substrate.[6] No difficulty was experienced using the Sierra 216 impactor in the field.

The cut points for the cassette impactor were chosen principally to match cut points for commercially available units for purposes of comparison. There is no reason to be restricted to these cut points and in fact, one of the main advantages of this unit is that it provides a simple and inexpensive method of designing an impactor for a particular situation.

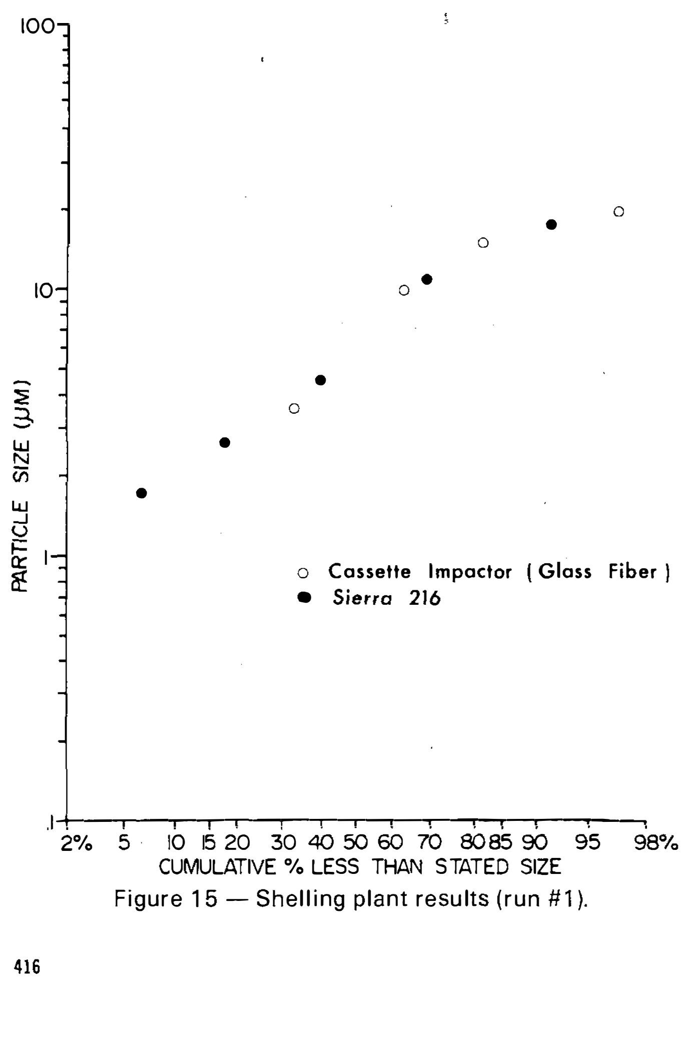

Figure 15 — Shelling plant results (run #1).

Although the cassette impactor can be modified to include stages with different cut sizes, several precautions need to be noted. The nozzle Reynold's number (Re), the impaction plate spacing to nozzle width ratio (S/W), and the nozzle throat length to width ratio (T/W) all need to be kept within certain limits. It has been recommended that the Re be kept within the range 500 to 3 000.[4] However, at 2 L/min, the cassette impactor stages described above have Re's in the range 150 to 500. These low Re values do not seem to affect the field performance relative to the commercial impactors, but may partly explain the discrepancies from theory noted for stages 1 and 2 in the laboratory calibration. The S/W ratio should be kept in the range of 0.5 to 5.[7] Thus, in extending the cassette impactor to smaller cut sizes, the nozzle to plate spacing needs to be reduced. This can be accomplished by machining off the bottom end of the impactor stage. The T/W ratio should be kept in the range of 0.25 to 5 to maintain the same relative sharpness and position of the cut.[4,7] Overall, the upper cut size limitation is largely due to the physical size of the cassette impactor while the lower cut size limit is due to the achievable machining and assembly precision.

The machining operations involved in building cassette impactors are quite simple and it is felt that most people with access to a shop could make them successfully. If one is willing to do the work themselves then the cost is indeed nominal since material cost is approximately $5.00/unit. If the machine work is contracted out then the cost per unit goes up significantly. To get a general idea of outside labor cost a bid to build 10 cassette impactors was requested from a local machine shop.[8] The labor cost estimate per unit was $36.00 (based on 2 hours labor per sampler at $18.00/hr.). The total cost per sampler (approximately $40.00), is still well below the cost of commercial cascade impactors. The estimate of 2 hr labor per sampler (for 10 samplers), may be somewhat high. Floyd Reece (USDA Poultry Research Laboratory, Mississippi State, Mississippi) has built 3 cassette impactors and his estimate of labor time was 1 hr/sampler.

A related issue however is the useful life of the cassette impactor compared to other devices. Since the cassette impactor is plastic, it is obviously more prone to breakage than most commercial impactors. There is, however, at least one plastic cascade impactor on the market (Pixe International Corporation, Tallahassee, Florida).

From the standpoint of corrosion, the cassette impactor is probably more resistant to attack from acids and bases and less resistant to reaction with organic vapors. Erosion of the samplers is not thought to be a problem due to the low air velocity through the sampler and low concentration of dust in most industrial environments. If, however, the impactor is to be used in high concentrations of an abrasive dust, periodic inspection of the jets is recommended.

The most critical factor affecting the life of a cassette impactor is probably cracking which occurs after repeatedly squeezing the cassette pieces together. This was particularly a problem with early prototpyes which were machined to fit very tightly. More recent samplers have been machined for a looser fit and cracking no longer seems to be a problem.

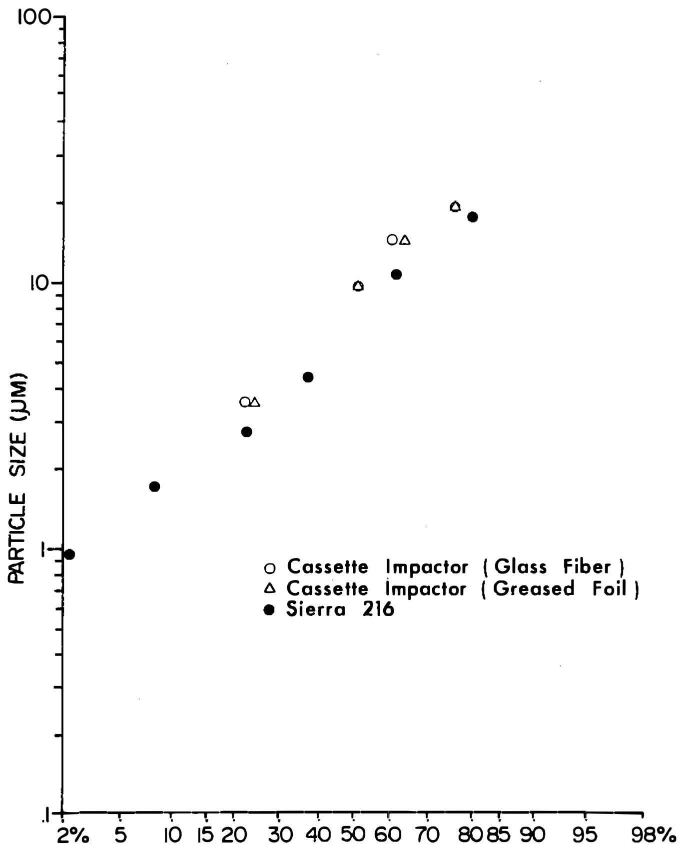

Figure 16 — Shelling plant results (run #2).

Admittedly, these samplers have not been in use long enough to have good information on expected useful life. It is believed however that with proper machining and careful use, differences in the useful life of the cassette impactor relative to commercial devices may become measurable only after years of service.

There have been recent reports indicating that sampling with non-conductive devices can affect the amount and size distribution of dust collected.[9,10] A non-conductive plastic sampling cassette accumulates a high and variable charge level on its surface that can affect the entry of charged aerosol particles. The magnitude of this effect under field sampling conditions is not clear. Measurements were made to determine the electric field around the inlets of various personal sampling devices using a Trek Model 300 Non-contacting Electrostatic Voltmeter. The field in the neighborhood of the inlet of a new polystyrene 37-mm cassette was highly variable in sign and magnitude, with a maximum of about 15 kV/m. When the cassettes were handled or rubbed on various surfaces, an increase in field strength was usually observed. Thus, particles entering the flow field of the inlet are subjected to a variable electric field. The extent to which this field affects the sampled dust depends on the magnitude and relative charges of the dust particles.

A study on conductive vs. non-conductive cyclones indicated that non-conductive cyclones gave slightly more variable results.[11] Another study comparing charged and uncharged open-faced cassettes may have found a mass increase when sampling a sawed polyurethane aerosol under low humidity conditions with a conductive cassette charged to +1 kV. However, for other aerosols (primarily fibrous glass) and conditions, the tests did not detect a significant difference between the different cassettes and voltage levels. Thus, a noticeable effect may occur under conditions considered optimum - namely, low inlet velocity, low humidity, highly charged aerosol and a highly charged cassette.[12]

In the present study, no difference between the non-conductive cassette impactor and the conductive commercial impactors was found that could be attributed to charge effects. It is felt that under most sampling conditions, electrostatic effects will not significantly change the results obtained with the cassette impactor. However, under conditions of low humidity, when measuring a highly charged aerosol, it may be expedient to coat the inlet area of the cassette impactor (or the entire impactor) with a conductive paint. Conducting silver paint (Ladd Research Industries, Inc.) was applied to one of the cassette impactors and this seemed to be a suitable coating in that it made the surface conductive without altering the hole sizes significantly. The easiest and least expensive treatment however was to paint the surface with a colloidal graphite/hexane mixture. Colloidal graphite is also available from Ladd. After treatment, a light buffing seems to increase conductivity.

Conclusion

A relatively low cost cascade impactor has been developed. Experimental determination of penetration curves indicates generally good agreement with theory. Both laboratory and field tests show that the sampler is accurate (*i.e.*., good agreement with other impactors) and precise. The impactor offers some advantage over other designs in terms of field use. The low cost makes impactor sampling a more viable alternative to cyclone sampling providing the industrial hygienist with a more complete characterization of aerosol exposure.

References

1. **Morrow, P.E.:** Evaluation of Inhalation Hazards Based Upon the Respirable Dust Concept and the Philosophy and Application of Selective Sampling. *Am. Ind. Hyg. Assoc. J. 25*: 213-235 (1964).
2. **Remiarz, R.J., J.K. Agarwal, F.R. Quant, and G.J. Sem:** A Real-Time Aerodynamic Particle Size Analyzer. Presented at the International Symposium on Aerosols in the Mining and Industrial Work Environment (1981).
3. **Marple, V.A. and K. Rubow:** Aerosol Test Chamber. Final Report for NIOSH Contract No. 212-81-0010 (1981).
4. **Marple, V.A. and B.Y.H. Liu:** Characteristics of Laminar Jet Impactors, *Env. Sci. Technol. 8*:648-654 (1974).
5. **Myers, W.R.:** Silica Dust Test for Respiratory Protective Devices. *National Institute for Occupational Safety and Health.* Available through NTIS (1977).
6. **McCawley, M.A., J. Burkhart, C. Davidson, and P. Morey:** Personal Impactor: Field Evaluation. Presented at AIH Conference (1982).
7. **Haberman, S.A.:** Experimental Simulation of Respirable Cut-off Characteristics in Inertial Particle Samplers. M.S. Thesis, Dept. of Environmental Health, University of Cincinnati, Cincinnati, OH (1979).

8. **Smith, T.**: Bid to Build 10 Cassette Impactors. Romisch Manufacturing and Metals Inc., Morgantown, West Virginia (1982).
9. **Briant, J.K. and O.R. Moss**: The Influence of Electrostatic Charge on the Performance of 10 mm Nylon Cyclones. Presented at AIH Conference (1982).
10. **Cohen, B.S., N.H. Harley, and M. Lippmann**: Factors Contributing Bias to Estimates of Inhalation Exposure. Presented at AIH Conference (1982).
11. **Almich, B.P. and G.A. Carson**: Some Effects of Charging on 10 mm Nylon Cyclone Performance. *Am. Ind Hyg Assoc. J 35*:603-611 (1974).
12. **Kuusisto, P.**: Measurement with the Filter Method: 1. Investigation into Electrostatic Interference in Sampling of Glass Fiber Dust. Swedish Board of International Safety, Dept. for Industrial Medicine (Translated), (1979).

25 August 1982; Revised 26 January 1983