R1649

COAL DUST CONTROL BY CONDENSATION ENLARGEMENT

Terminal Progress Report

Grant No. 5 R01 OH 00822-02

June 30, 1982

F.D. Schowengerdt and J.T. Brown, Jr.

Physics Department

Particulate Science Laboratory

Colorado School of Mines

Golden, Colorado 80401

Prepared for the National Institute for Occupational Safety and Health,
Department of Health and Human Services,
under research grant 5 R01 OH 00822-02

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. PB88-248679
4. Title and Subtitle Coal Dust Control by Condensation Enlargement			5. Report Date 82/06/30
			6.
7. Author(s) Schowengerdt, F. D., and J. T. Brown, Jr.			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Particulate Science Laboratory, Colorado School of Mines, Golden, Colorado, Terminal Progress Report			10. Project/Task/Work Unit No.
			11. Contract(C) or Grant(G) No. (C) (G) OH-00822-02
12. Sponsoring Organization Name and Address			13. Type of Report & Period Covered
			14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

A prototype dust conditioning system for control of coal dust was designed, constructed, and evaluated based on the concept of condensation enlargement. The volume of the device was 0.74 cubic feet and it was designed to handle up to 50 cubic feet per minute (cfm) of dust laden air. The performance of the device was evaluated for both naturally occurring aerosols and laboratory generated coal dust. Both these samples nucleated and grew readily in the conditioner with output droplet sizes ranging up to 10 microns and a large fraction of these falling out inside the conditioner. Nucleation efficiencies of 95 percent were measured, resulting in overall mass removal efficiencies greater than 99 percent at flow rates of 10cfm. At 50cfm, the efficiency dropped to 80 percent. The conditioner consumed 10 gallons of water per hour. Various engineering problems encountered included heat transfer, plate wetting and temperature stability. The device was able to be scaled to a capacity of 3000cfm, sufficient for a full scale mining application. The authors suggest that a geometric configuration of a concentric cylindrical shape with the outer cylinder being cooled and heat introduced along the inner cylinder should be examined as this would have some advantages over the present plane geometry used in the prototype.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

NIOSH-Publication, NIOSH-Grant, Grant-Number-OH-00822-02, Mining-industry, Dust-control, Dust-collectors, Dust-control-equipment, Mineral-dusts, Air-quality-control

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages 37
	20. Security Class (This Page)	22. Price A03 12.95

(See ANSI-Z39.18) *See Instructions on Reverse* OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

I. SUMMARY STATEMENT OF PROGRESS

This is the final report of progress on NIOSH Grant No. 5 R01 OH 00822-02 titled "Coal Dust Control by Condensation Enlargement". The total project period was 5/1/79 through 6/30/82.

A. Objectives

The objectives of the research were to design, construct, and evaluate a prototype dust conditioning system based on the concept of condensation enlargement. The concept had been previously proven in this laboratory through basic studies on the nucleation properties of respirable coal dust (NIOSH Grant No. R01 OH 00565). The results of those studies are reported in detail in References 1 through 4. The overall long-range goal of the research is the improvement of dust control technology for use in coal mines.

B. Results

The results of the project are reported below in summary form and are discussed in Sections II through IV.

1. The prototype condensation conditioner was designed along the general lines described in the original proposal. Total volume is 0.74 ft^3, designed to handle up to 50 ft^3/min of dust-laden air.
2. The prototype was constructed and given a series of preliminary tests. Based on these tests, modifications were made, resulting in the final design upon which the performance tests were conducted.
3. The performance of the final version of the prototype was evaluated for both naturally occurring aerosol and laboratory generated coal dust. Operating plate temperature differences in the 10 - 20^{0}C range were achieved. Both lab aerosol and

coal dust were observed to nucleate and grow readily in the conditioner. Output droplet sizes ranging up to 10 microns were observed, with a large fraction of these falling out inside the conditioner. Nucleation efficiencies of 95% were measured, resulting in overall mass removal efficiencies greater than 99% at flow rates of 10 ft^3/min. The efficiency dropped to 80% at 50 ft^3/min. Water consumption in the conditioner was 10 gal/hr. Power consumption was 6 kW.

4. For the most part, design goals were achieved in the final version of the laboratory prototype. Many engineering problems were encountered, including heat transfer, plate wetting and temperature stability. These problems were more substantial than had been anticipated and their solutions placed limitations on the capacity and portability of this laboratory model. Nevertheless, these tests indicated that the device is scalable to a capacity of 3000 ft^3/min, which would be sufficient for a full-scale mining application.

II. DESIGN

A sketch of the original design concept is reproduced in Figure 1. Hot water flowing down heated plates evaporates and diffuses across a moving air stream to adjacent cold plates. Dust particles in the air stream (moving perpendicular to the paper in Fig. 1) nucleate water droplets, which grow to collectable sizes before leaving the conditioner. Droplets which fall out inside the conditioner add to the condensate flowing down the plates to form a coal-water slurry which drains out the bottom of the conditioner.

In the first model of the prototype, the plates were constructed of perforated aluminum and were heated by means of hot water flowing directly onto them from a reservoir at the top of the plates. The plates proved to be almost non-wettable in this configuration and many subsequent modifications were made to improve their wettability. Among these modifications were etching of the plate surfaces, anodizing, and adding wetting agents. The plates were finally covered with canvas.

Heat transfer was also a difficult problem from the beginning. In order for the device to work as planned, it was necessary to maintain the hot plates at $40^{o}C$ while substantial quantities of water were evaporating off the hot plates and condensing onto the cold plates. This transfer of latent heat presented a major design problem.

Because of the heat-transfer problem, the original concept of heating the plates with the same water that was being evaporated had to be abandoned in favor of direct heating of the plates and the water separately. Also, both the hot and the cold plates had to be reconstructed using copper sheets clamped to rather massive heat sinks. Heating strips were imbedded into the high temperature heat sink and cooling coils were soldered directly to the low temperature heat sink. In the initial version the cold plates were

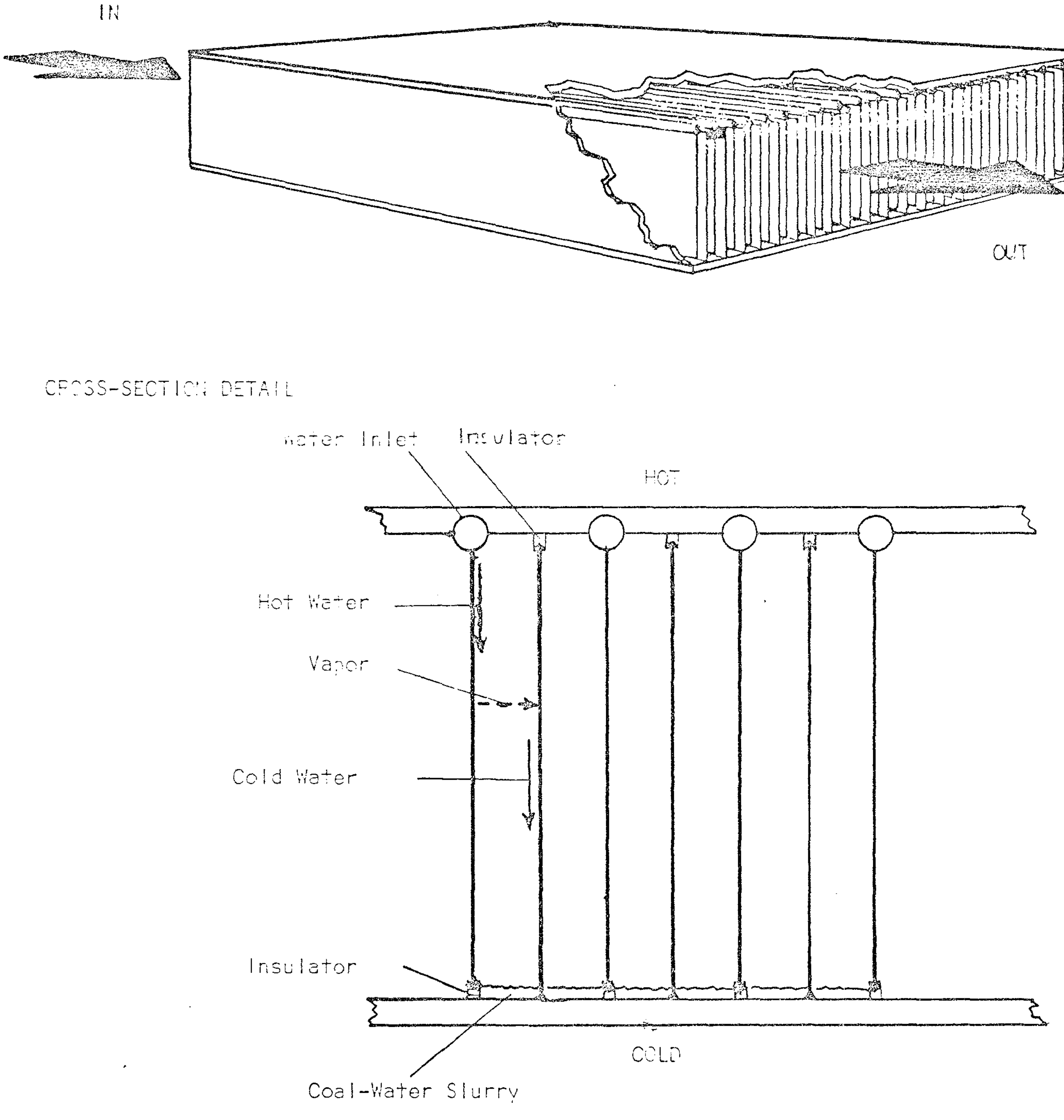

FIGURE 1. Condensation Conditioner - Design Concept.

cooled by circulating refrigerated water. In the final version freon was pumped directly through the cold plate cooling coils.

Other changes from the original design included the addition of plastic strips beneath each hot plate between the adjacent cold plates to keep hot water from dripping on the cold plate heat sink, pre-humidification of the input air, pre-heating of the makeup water for the hot-water reservoir and addition of a water softener for the hot water.

A detailed drawing of the final version of the condensation conditioner is shown in Fig. 2. This is the version on which all of the performance tests reported here were conducted.

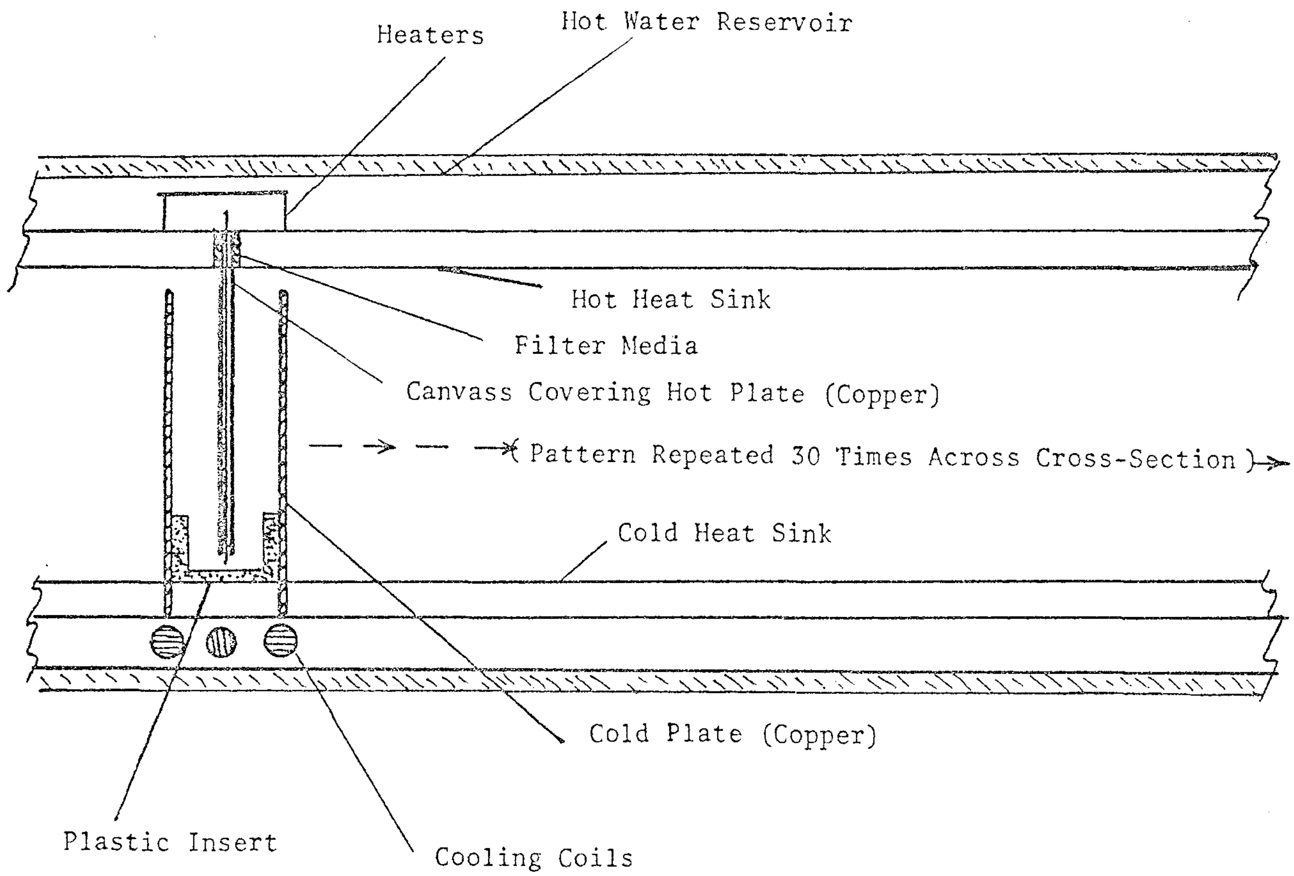

FIGURE 2. Construction Detail - End View of Conditioner Cross-Section, Final Version.

III. CONSTRUCTION

Construction materials are indicated in Fig. 2. All inlet and outlet tubing was 6-inch clear plastic sewer pipe. The walls of the conditioner were made of 1/2 inch clear plastic and all plates and heat sinks were made of copper. The hot plates were covered on both sides with 20-mil canvas.

Heat was supplied by 3 600-watt heaters imbedded in the hot plate heat sink. The water was preheated by 2 600-watt immersible heaters. Heat was removed by means of a 14,000 BTU/hr. refrigeration unit.

A complete system drawing showing all peripherals is given in Fig. 3. Water was pumped by small laboratory units. Air supply was provided by variable speed fans blowing laboratory air through Cambridge absolute filters having an upper size cutoff of 0.2 microns. Air speeds were measured by a Sierra air velocity meter with a maximum sensitivity of 3 feet per minute.

Particle sizing and counting were done with a Climet Instruments white-light optical particle counter and a laser-fired aerosol analyzer (Particle Measurement Systems).

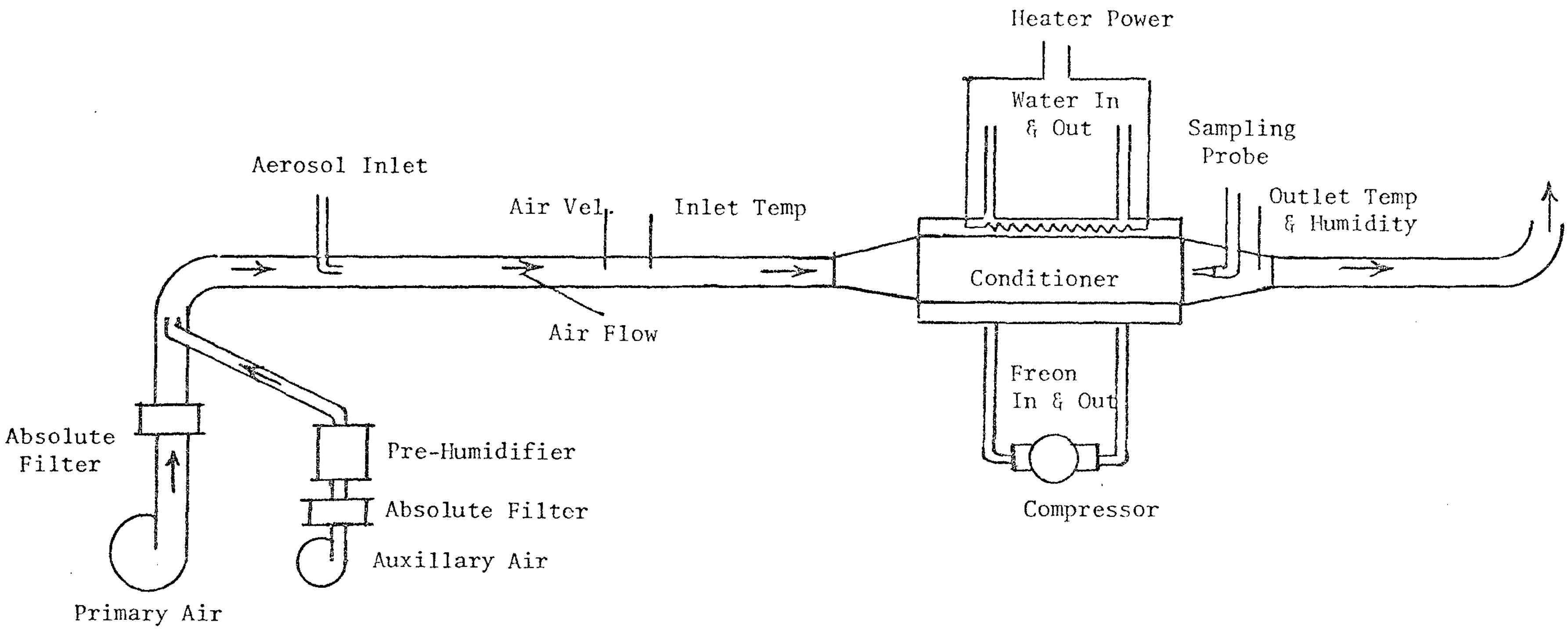

FIGURE 3. Complete System Drawing.

IV. TESTS AND EVALUATION

Two general types of tests were conducted to evaluate the performance of the conditioner: (1) growth measurements were made to determine final droplet sizes and (2) transmission experiments were done to determine the particulate removal efficiency of the device. Before these tests could be run, it was necessary to attain the design temperature differences of $10^{o}C$ - $20^{o}C$ between the hot and cold plates.

A. Temperatures

The total surface area of the plates (40 ft^2) and the small plate separation distance (1/8 inch) between hot and cold plates resulted in very high water vapor diffusion rates (which, however, were essential to the successful operation of the device). The resulting large heat transfer rate made the attainment of the required temperature quite difficult.

In the earlier configurations, temperature differences of only $5^{o}C$ to $10^{o}C$ could be attained. A further complication was that the temperature differences gradually decreased with time as the canvas-covered hot plates became wetter and the vapor diffusion and associated heat transfer increased accordingly. With the modifications discussed earlier, and the installation of a larger refrigeration unit, steady-state temperature differences in the $10^{o}C$ to $20^{o}C$ range were attained.

Plate temperatures recorded during a typical performance test run are shown in Fig. 4. Evaporative cooling by the input air was a significant factor, as can be seen from the large temperature differences at the inlet. Also, heat conduction across the plates can be seen to cause a significant drop in temperature differences near the center of the plates. The best temperature differences are at the top and bottom of the plates, near the heat source and sink, as one would expect. All temperatures were measured with iron constantan thermocouples, fastened to the plates.

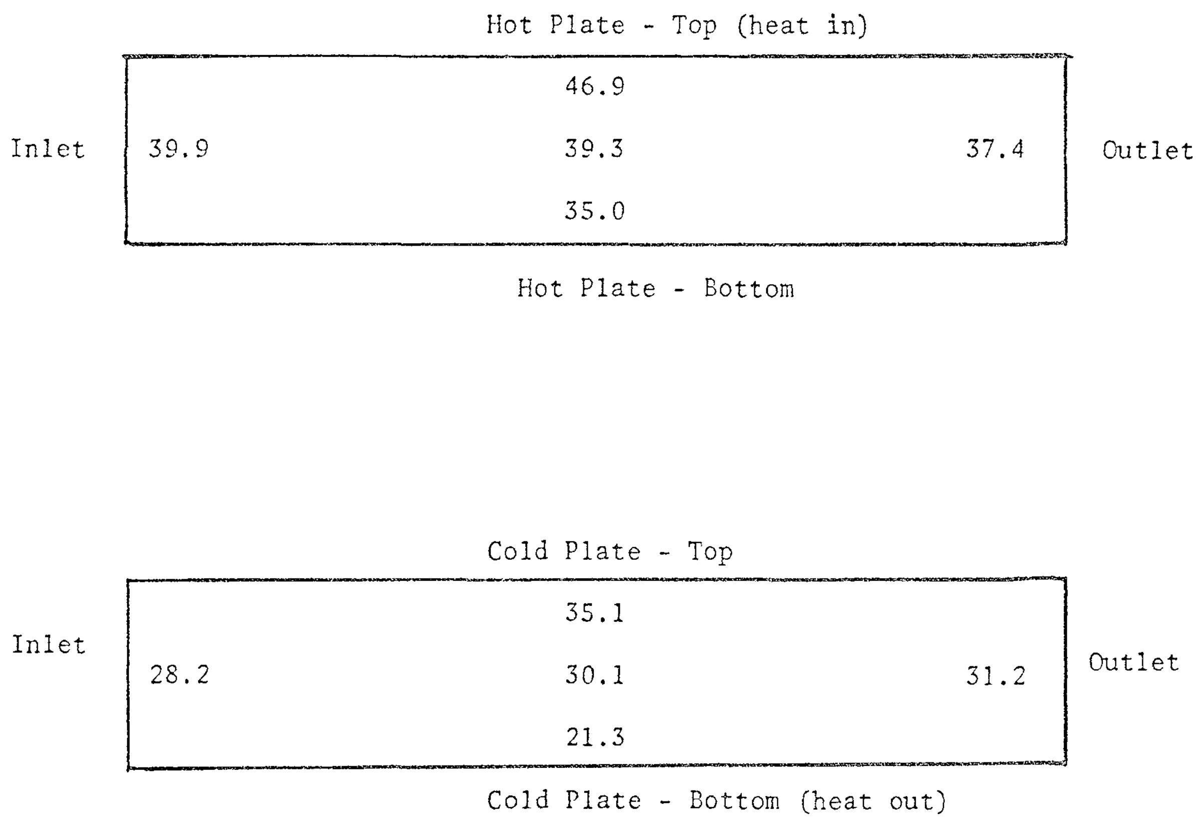

FIGURE 4. Representative Conditioner Plate Temperatures. Side View of One Pair of Plates - All Temperatures in Degrees Centigrade

B. Growth Measurments on Laboratory Aerosol

The growth of naturally-occurring aerosol taken from the laboratory air was studied in order to determine the nucleation and growth characteristics of the device and the trajectories of growing droplets inside the device. For these studies, laboratory air was injected into a filtered air stream at a point approximately 6 feet from the inlet to the conditioner. The resulting droplet size distribution at the outlet was then measured with the white-light optical particle counter (Climet Instruments).

Pulses taken from the counter preamplifier were counted, sized, and stored in a multi-channel pulse-height analyzer. In this way real-time particle size spectra could be obtained.

The sampling probe was in the shape of a flat horn, with inlet dimensions of 1.5 inches by 1/32 inch. The sampling probe could be positioned reproducibly at 5 vertical locations and 7 horizontal locations at the outlet of the conditioner. The probe was 2 inches from the exit end of the conditioner plates.

Air velocity could be adjusted continuously from 30 ft/min to 600 ft/min as measured inside the 6-inch diameter inlet tube. This corresponded to air velocities inside the conditioner of 18 ft/min to 360 ft/min and volume-flow rates of 6.6 ft^3/min to 132 ft^3/min. Corresponding residence times inside the conditioner were 3.3 sec. to 0.17 sec.

Typical output droplet size distributions as obtained by the methods just described are shown in Fig. 5. Air flow rates through the conditioner are indicated on the plots.

The first point to be noted in the plots in Fig. 5 is that several peaks appear at each air flow value. The phonomenon of peak formation in the growth process is best understood by referring to the measured growth-rate curves (see Figs. 11-14, Ref. 1). Smaller particles grow at a higher initial

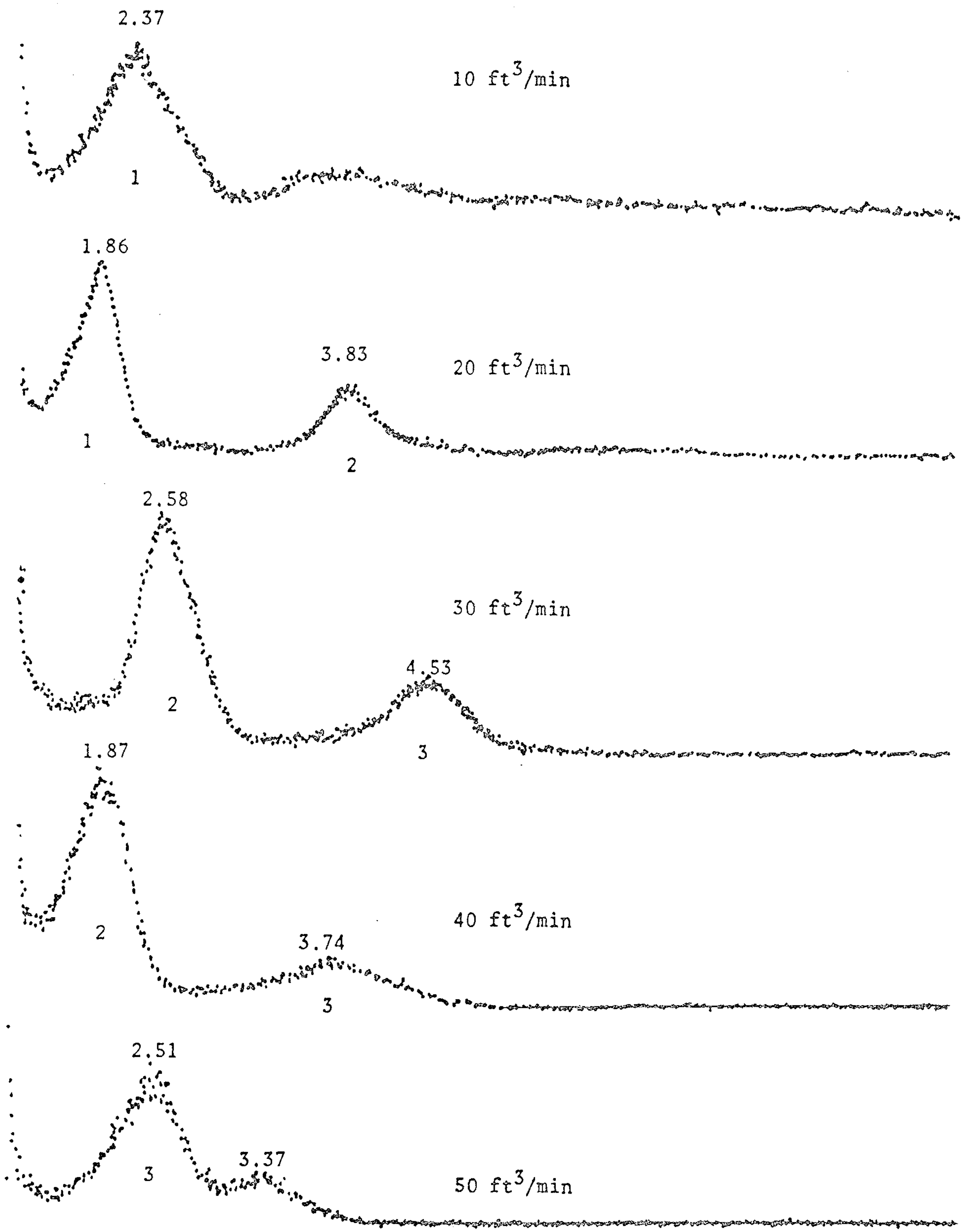

FIGURE 5. Output Droplet Size Distributions for Laboratory Aerosol Input. (Numbers of Droplets vs. MCA Channel Number, or Size) Numbers above peaks are droplet diameters in microns. Those below the peaks are indexing numbers referred to in the text.

rate than larger ones, so that an initially broad distribution, such as the input aerosol distribution, evolves into a narrow distribution as droplet growth proceeds.

The occurence of multiple growth peaks in the present apparatus is not fully understood. In our previous cloud chamber (see Ref. 1), only single peaks were observed, but the geometry was somewhat different there and the supersaturations not nearly so high. The structure we're seeing could be due to coagulation of the growing droplets, to multiple aerosol components with differing hygroscopic material content, or to multiple, but discrete, paths for the growing droplets inside the conditioner.

The presence of these multiple growth peaks poses no serious problem for the operation of the device as a condensation conditioner. The aim of the conditioning is nucleation and growth of particles so that they may ultimately be removed with much higher efficiency than is now possible. Thus any growth peak represents particles that have nucleated water droplets and grown to the indicated size. All particles in the peaks appearing in Fig. 5 can be considered collectable, as will be shown in a later section.

The distributions in Fig. 5 show evidence of droplet fallout inside the conditioner. To see this, the peaks have been numbered so that the evolution of a given peak can be followed as the air velocity is changed. For each peak, the number of particles in the peak increases and the mean size decreases, as the air velocity is increased. This behavior is consistent with the interpretation that the larger droplets are falling enough inside the conditioner so that some of them miss the sampling probe, resulting in a growth peak of reduced height. This would of course occur most effectively at the lower velocities, as can be seen in Fig. 5.

Further evidence of droplet fallout inside the conditioner can be seen in Fig. 6. Here two different droplet size distributions are plotted

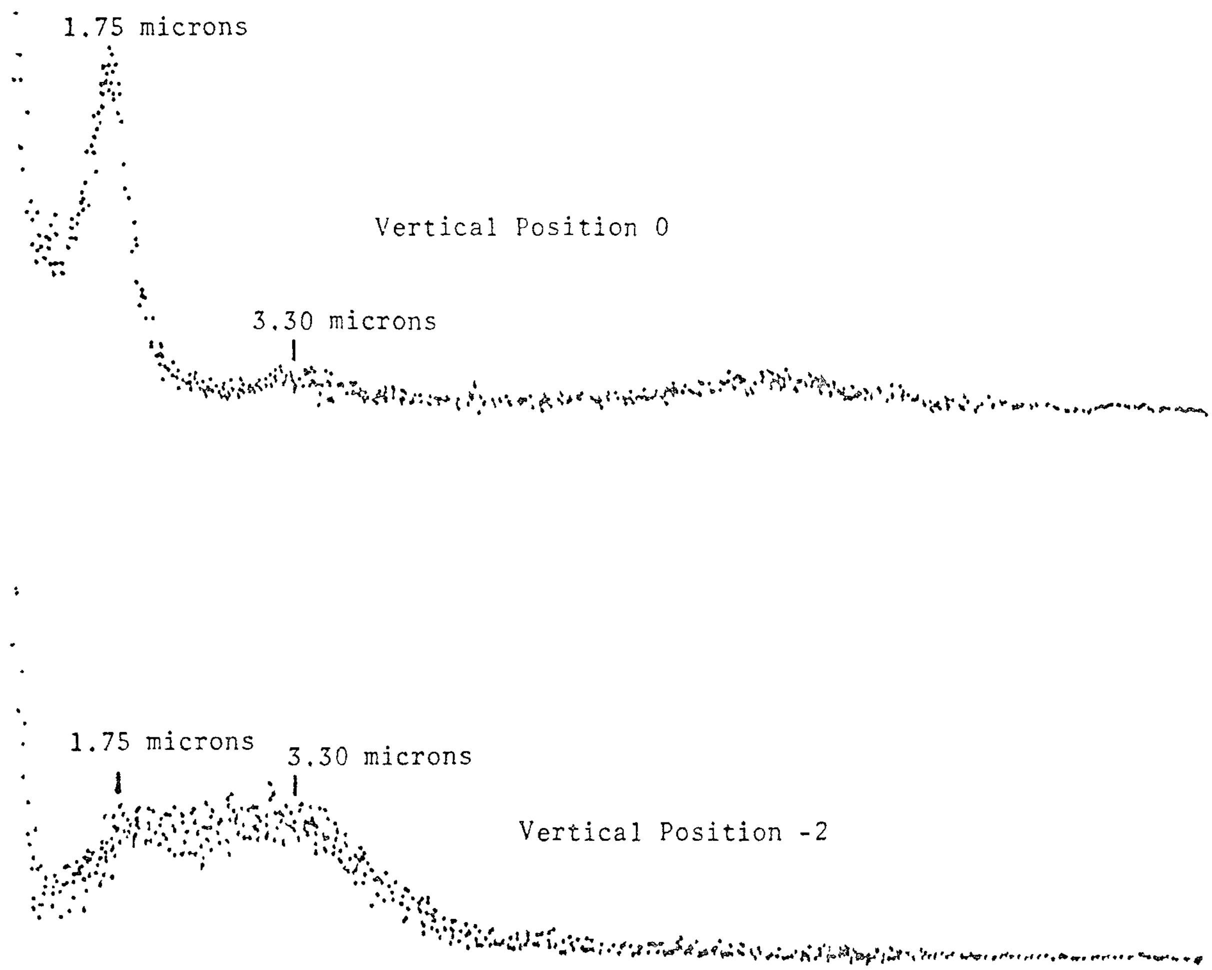

FIGURE 6. Showing the Effect of Droplet Fallout Inside Conditioner on Output Droplet Size Distributions for Laboratory Aerosol Input. Vertical position -2 is approximately 2 cm below vertical position 0.

with the sampling probe in two different vertical positions. These positions differed by approximately 2 cm. Both distributions were taken at an air speed of 90 ft/min. Two major peaks can be seen in each plot. In the plot taken at the lower position, many more droplets are present in the 3.3-micron peak than are present in the distribution taken at the upper position. Thus the larger droplets are falling and more of them are being detected at the lower position.

C. Growth Measurements on Coal Dust

The growth of coal dust in the condensation conditioner was studied under the same operating conditions as were used for the lab aerosol studies. Coal dust generated in a ball mill was passed through a settling chamber to remove the larger particles, then through an ullage tank to damp out fluctuations in the concentration, and finally into a 150 ft^3 plastic storage bag. The bag was kept inflated by filling with filtered air and could thus be purged of laboratory aerosol before filling with coal dust. Colorado coal from Midcontinent Resources, Inc. Redstone Mines, was used for the tests.

Coal dust so produced was injected at the same point as was the lab aerosol, 6 ft. from the conditioner inlet, and the resulting aerosol was analyzed. Output size distributions for several air flow rates through the conditioner are shown in Fig. 7. As can be seen, these size distributions do not differ in any essential way from those observed for the lab aerosol. This observation is consistent with our earlier findings that coal dust in the micron size range behaves much the same as the naturally occurring aerosol in its interaction with supersaturated water vapor.

Here as in Fig. 6 one can see the evolution of the distributions as the air flow rate is increased and the residence time decreased. The effects of droplet fallout inside the conditioner can also be seen in the fact that the total numbers are less at the lower flow rates.

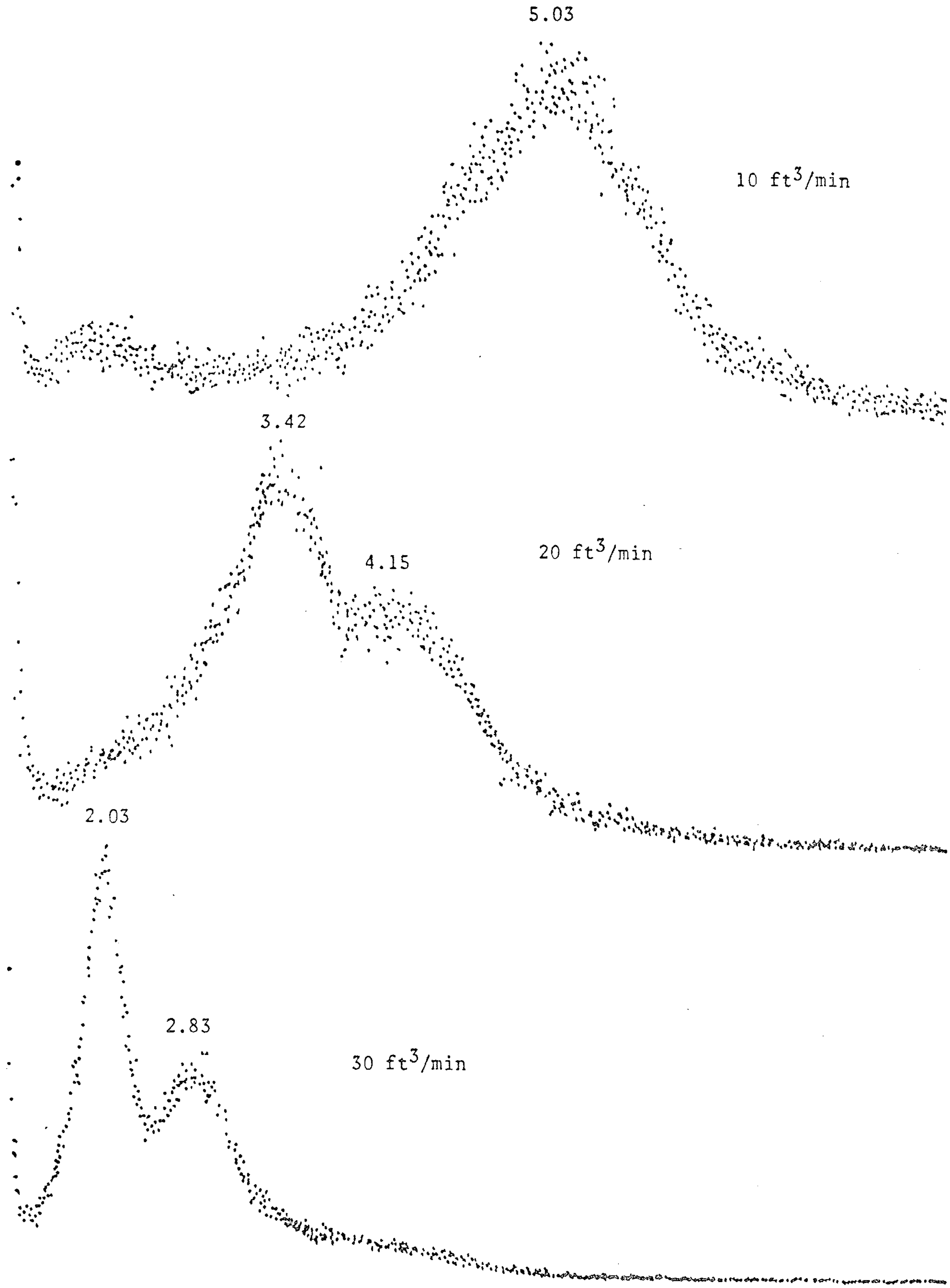

FIGURE 7 (PART A). Output Droplet Size Distributions for Coal Dust Input. (Numbers of Droplets vs. MCA Channel Number, or Size). Numbers above peaks are droplet diameters in microns.

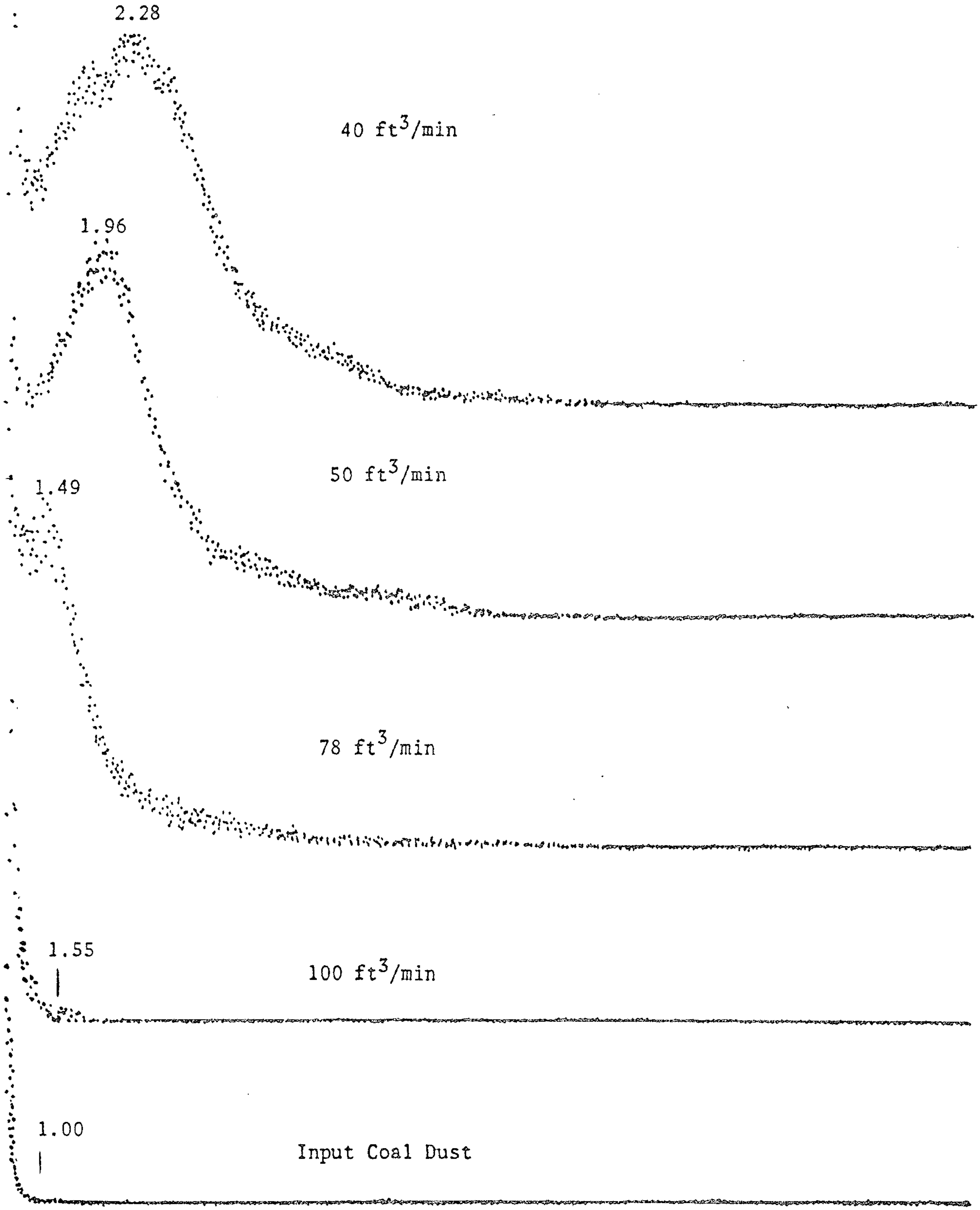

FIGURE 7 (PART B). Output Droplet Size Distributions for Coal Dust Input. (Numbers of Droplets vs. Channel Number, or Size). Numbers above peaks are droplet diameters in microns.

Fig. 8 shows the differences in the coal dust output size distributions for different vertical positions of the sampling probe. Again, fallout is evident here as larger droplets are observed at the lower position.

D. Nucleation Efficiency Measurements on Coal Dust

The results presented in B and C above show that for both natural aerosol and coal dust the laboratory prototype condensation conditioner performs its design function of growing particles to collectable sizes. The question of what fraction of those particles entering the conditioner actually participate in this growth process of course relates to the efficiency of the device.

In order to achieve self-consistent results, efficiency measurements were made by taking ratios of the number of particles in a given size range to the total number detected both with the conditioner off and with it on. By taking ratios, fluctuations in the total dust concentration in the storage bag are automatically compensated for.

The size ranges chosen for these measurements were from the lower limit of detection (approximately 0.1 micron) to 1 micron and from 1 micron to the upper limit of detection (approximately 10 microns). The number of particles detected within these size ranges can be determined directly from the multichannel analyzer readouts and compared with the total number of counts. Ratios thus obtained are shown as a function of air flow through the conditioner in Fig. 9. The important point to note here is that the nucleation efficiency as determined this way goes through a decrease as the air flow is increased beyond the point where the dust just has time to nucleate water droplets in its traversal of the conditioner. This "nucleation transient" was the subject of one of our earlier studies, the details of which are reported in Ref. 2. The onset of this effect can be considered a fundamental limitation on the air flow rate possible in a conditioner of a given size.

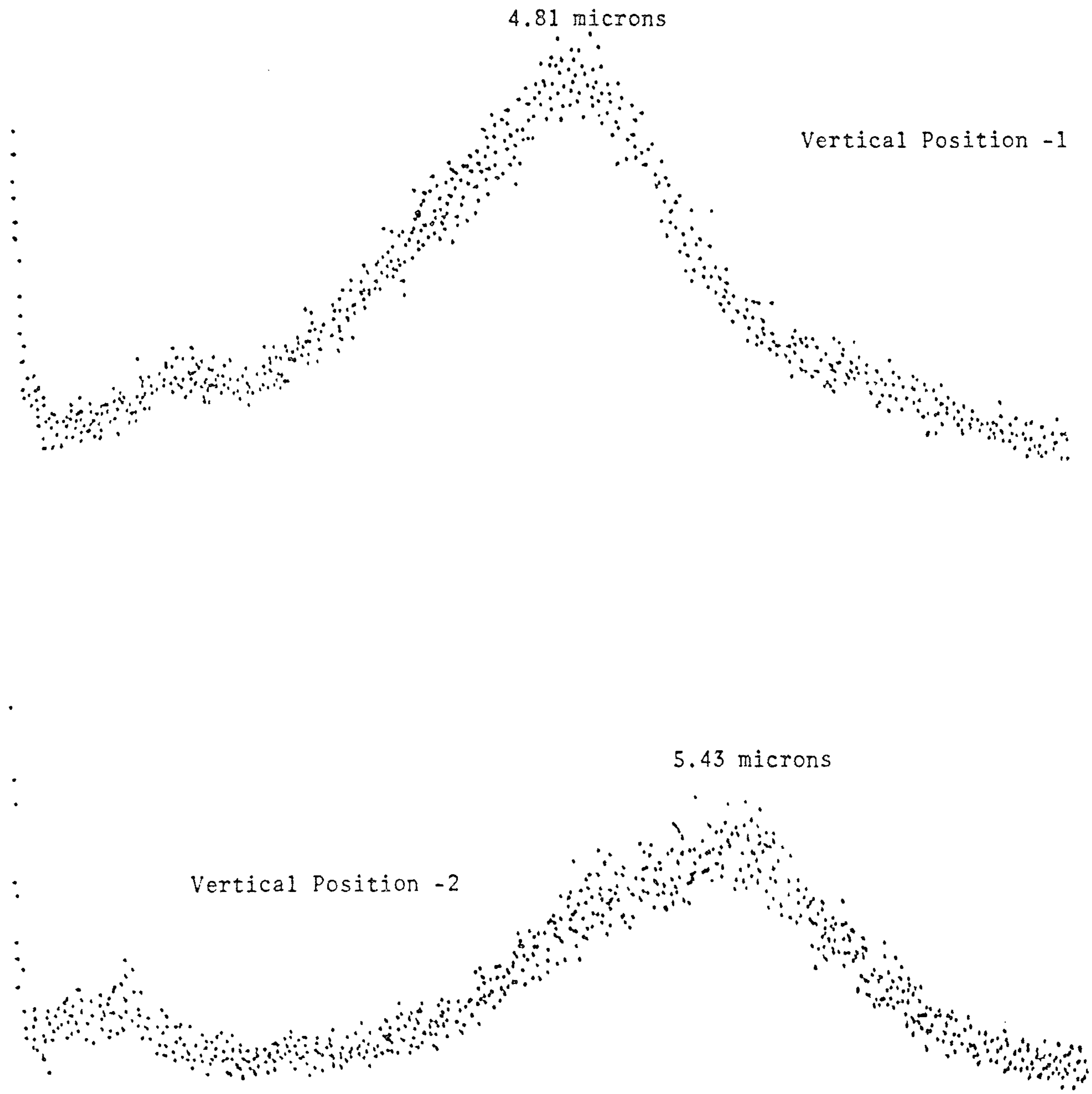

FIGURE 8. Showing the Effect of Droplet Fallout Inside Conditioner on Output Droplet Size Distributions for Coal Dust Input. Vertical position -2 is approximately 1 cm below vertical position -1.

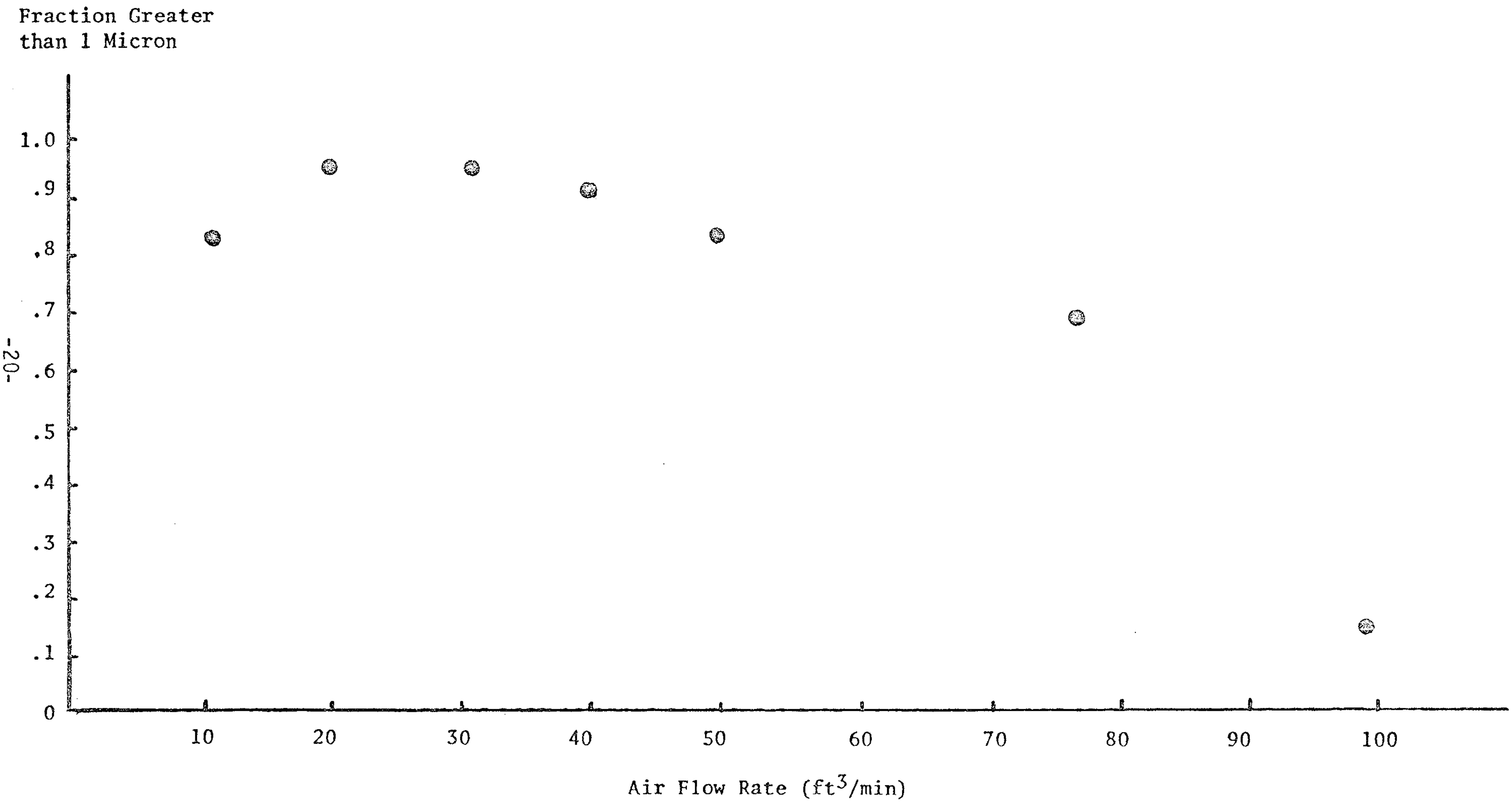

FIGURE 9. Nucleation Efficiency vs. Air Flow Rate for Coal Dust Input. (Note: The drop off at lower flow rates is due to fallout of grown droplets inside the conditioner and does not represent a true drop in efficiency.)

The nucleation efficiency measurements shown in Fig. 9 should not be confused with mass removal efficiencies. The former refer to numbers of particles, the latter to mass. The two are related through the initial size distribution and the probability of nucleation as a function of size.

Mass removal efficiencies, to be discussed in the next section, can be expected to be higher than the nucleation efficiencies measured here. The reason for this is that the probability of nucleation is greater for the larger particles in the initial size distribution and these particles contain more mass. The mass distribution of typical coal dust aerosols in mines show maxima around two microns and particles of this size are nucleated with nearly 100% efficiency even at low supersaturations (see Ref. 2).

Finally, it should be noted that, while for dry coal dust both at the inlet and transmitted through the dry conditioner (see Fig. 7), the number of particles greater than one micron in size is less than 1% of the total, after the dust has traversed the operating conditioner this number has been increased to 95% of the total. Thus there can be no doubt that the conditioner is performing its design function of growing nearly all of the sub-micron coal dust particles into a size range where they can be collected by conventional means.

"Conventional means" here refers to either inertial separation, such as a cyclone "de-mister", or ordinary water sprays. As a demonstration of the collection of coal dust following condensation enlargement in the prototype conditioner, we have fitted the conditioner with a water spray at the output and have run performance tests on the conditioner-spray sequence. The results of these tests are reported in the next section.

E. Performance of Conditioner-Water Spray Sequence

The design of the water spray and its positioning relative to the conditioner and sampling probe is shown in Fig. 10. A total of 15 nozzles

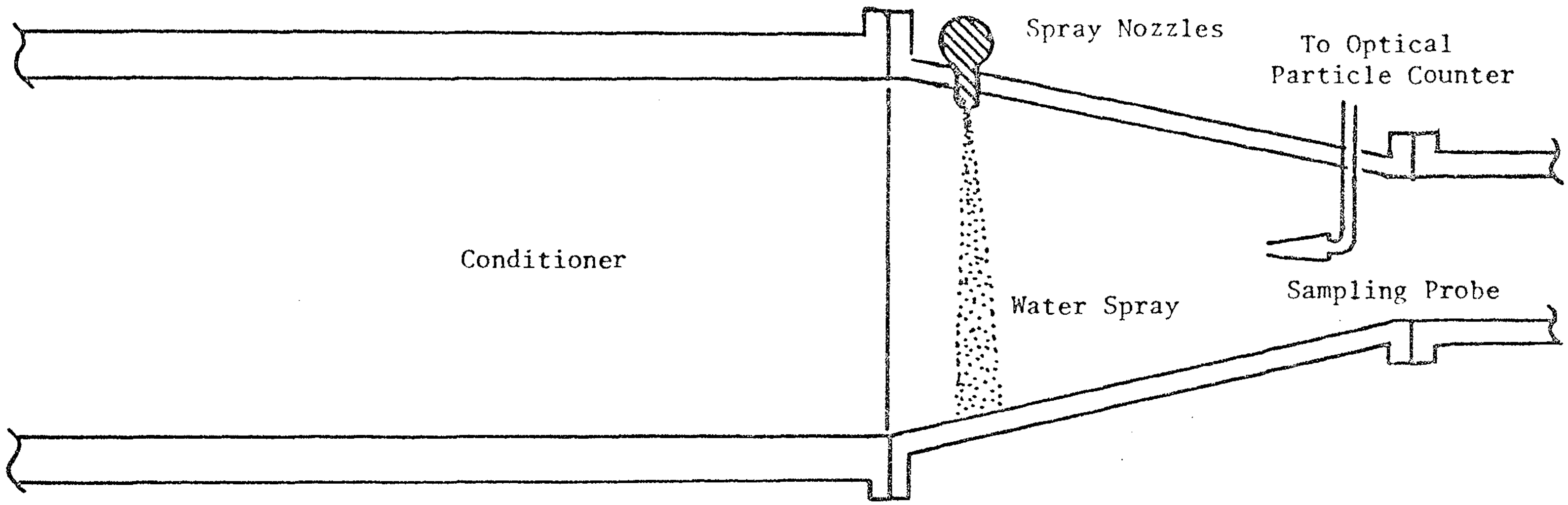

FIGURE 10. Conditioner-Water Spray Sequence.

were available, but only 9 nozzles in the center area were actullay used in order to take advantage of the maximum spray uniformity there. For the conditioner-spray tests, the sampling probe was positioned at the extreme rear of the conditioner exit horn so as to avoid droplets entering the probe directly from the spray. With this arrangement, true transmission experiments could be done with various combinations of conditioner and spray, on and off.

Coal dust generated in the ball mill was injected directly into the inlet airstream approximately 6 ft. upstream from the conditioner. The plastic storage bag was not used for these tests in order that a more realistic simulation of a mine dust atmosphere could be achieved.

Results of the conditioner-spray tests are shown in Figs. 11-15. In Fig. 11 input and output distributions are shown on linear scales for a flow rate of 10 ft^3/min. With the spray only on, the total number of particles transmitted through the apparatus is decreased only slightly as can be seen by comparing Fig. 11 (A) and (B). With the spray off and the conditioner on (C), the condensational growth discussed in the previous sections is evident. Finally, in Fig. 11 (D), the effect of applying the water spray to the output distribution (C) can be seen to be quite dramatic. The total number of particles transmitted has been reduced by roughly 96% and there are virtually no particles in the output larger than one micron or so.

A more relevant measure of the performance of the prototype in terms of current dust control problems in coal mines is its effect on the mass distribution of the coal dust. Figs. 12 and 13 show input and output mass distributions as obtained by taking number distributions measured by the optical particle counter and converting them to calculated mass distributions, assuming a constant mass density throughout the particle distribution.

To speed the analysis, the distribution was divided into 12 intervals, each spanning a size range of equal length and the counts in each of these

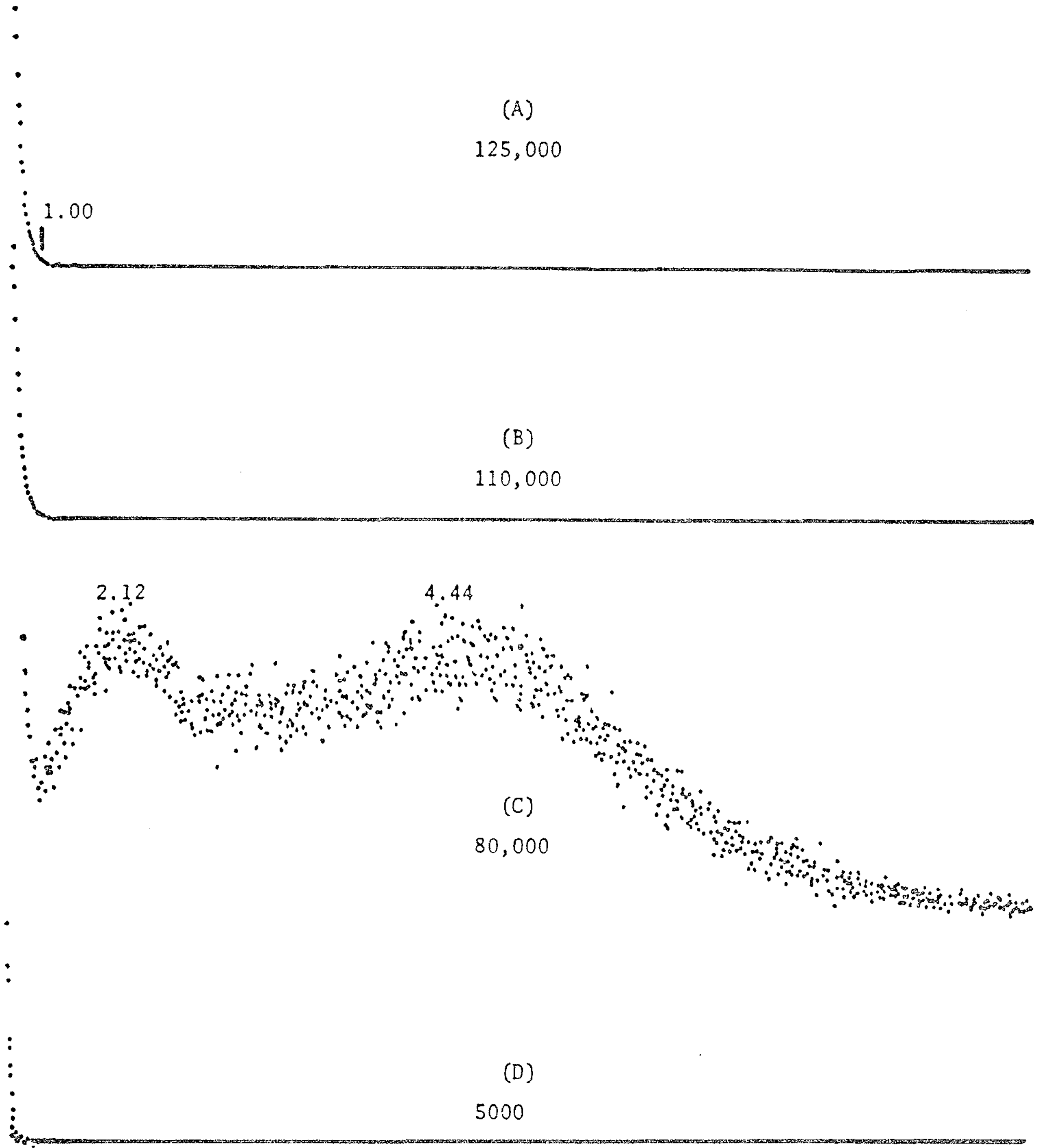

FIGURE 11. Size Distributions for: (A) Coal Dust Transmitted through Apparatus with Conditioner Off and Spray Off; (B) Coal Dust Transmitted with Conditioner Off and Spray On; (C) Coal Dust (Nucleated and Grown) Transmitted with Conditioner On and Spray Off; and (D) Coal Dust Transmitted with Conditioner On and Spray On. (Numbers of Particles or Droplets vs. MCA Channel Number, or Size). Numbers below letters are total counts registered in 10 seconds. Numbers above peaks are droplet diameters in microns.

ranges were accumulated automatically by the MCA. The lower limit of each range was the particle diameter used in calculating volumes and hence masses.

The results shown in Fig. 12 are for the water spray only, while those shown in Fig. 13 are for the water spray and the conditioner. As can be seen in Fig. 12 the total distribution is lowered by about 35% and shifted slightly to lower sizes. This observation is consistent with measurements done by the U.S. Bureau of Mines (see Ref. 5) which have shown typical water sprays to be 30-50% efficient on coal dust.

Figure 13 shows again the very dramatic effect of the conditioner and the water spray together on the coal dust. The total mass in the distribution of Fig. 13 is reduced by over 99% and the maximum in the distribution is shifted down to the micron region. Thus, while neither the conditioner nor the spray alone can do an effective job of cleaning the input air, both of them together are highly effective.

F. Mass Removal Efficiencies

Mass removal efficiencies of the complete prototype system (conditioner plus water spray) are shown in Fig. 14 and 15. The results in Fig. 14 are shown as a function of input particle size, with air flow rate as a parameter. Above 6 microns the efficiency is 100% within our measurement accuracy (0.1%). For flow rates below 50 ft^3/min, the efficiencies stay in the 90%-plus region all the way down to the sub-micron region. The sudden decrease in efficiency at 50 ft^3/min is due to the nucleation transient discussed earlier. This transient can be reduced, and the efficiency cutoff value increased to higher flow rates by making the conditioner larger (increasing residence time) or by increasing plate temperature differences (increasing supersaturation). We note that the residence time at which the decrease begins is about 0.5 seconds.

Fig. 15 shows the mass removal efficiencies integrated over particle size. Here the drop in efficiency is even more evident and occurs at about 40 ft^3/min. It should be noted, however, that even at 50 ft^3/min the efficiency

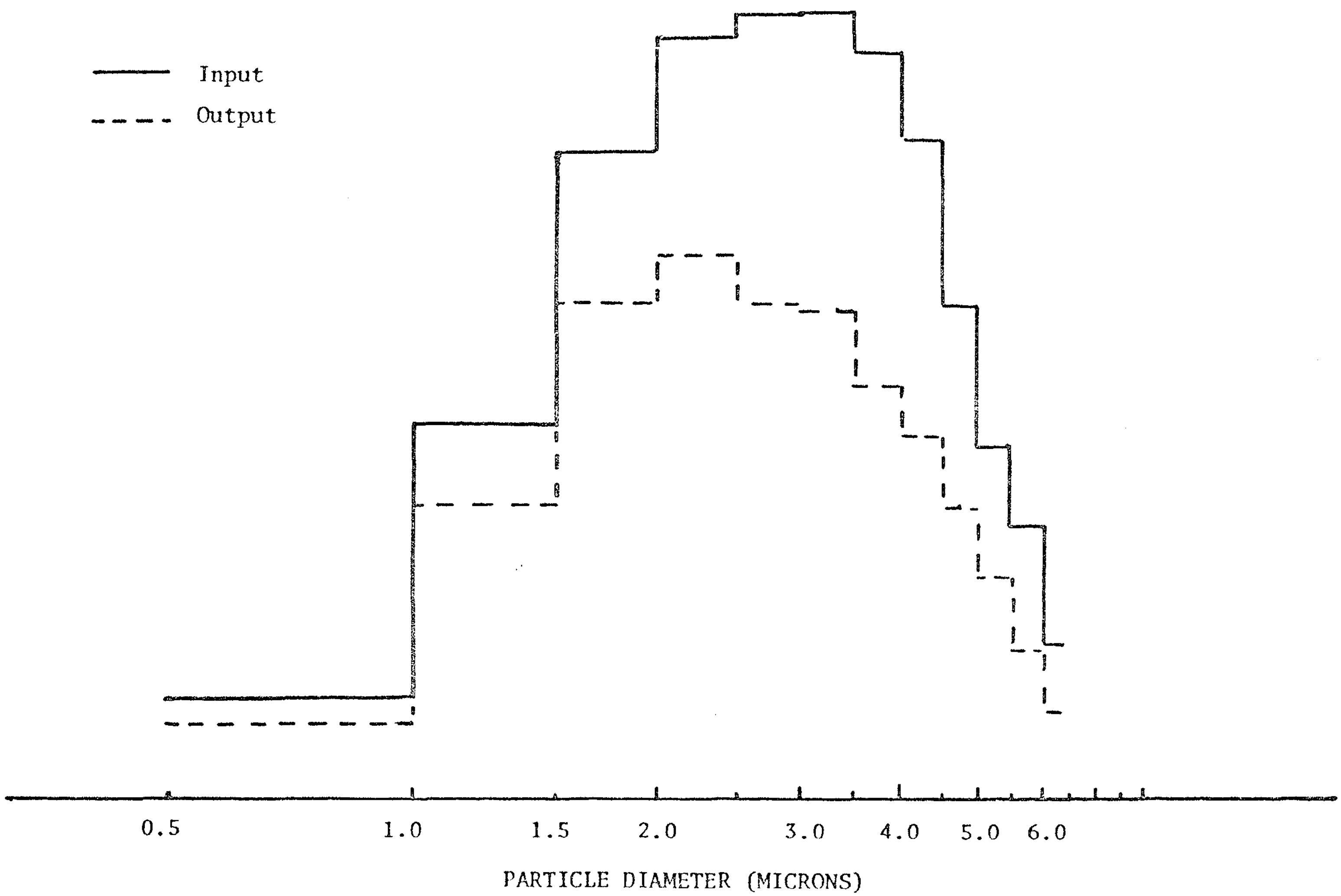

FIGURE 12. Coal Dust Mass Distributions with Conditioner Off and Spray On. (Vertical Scale is relative concentration in arbitrary units.)

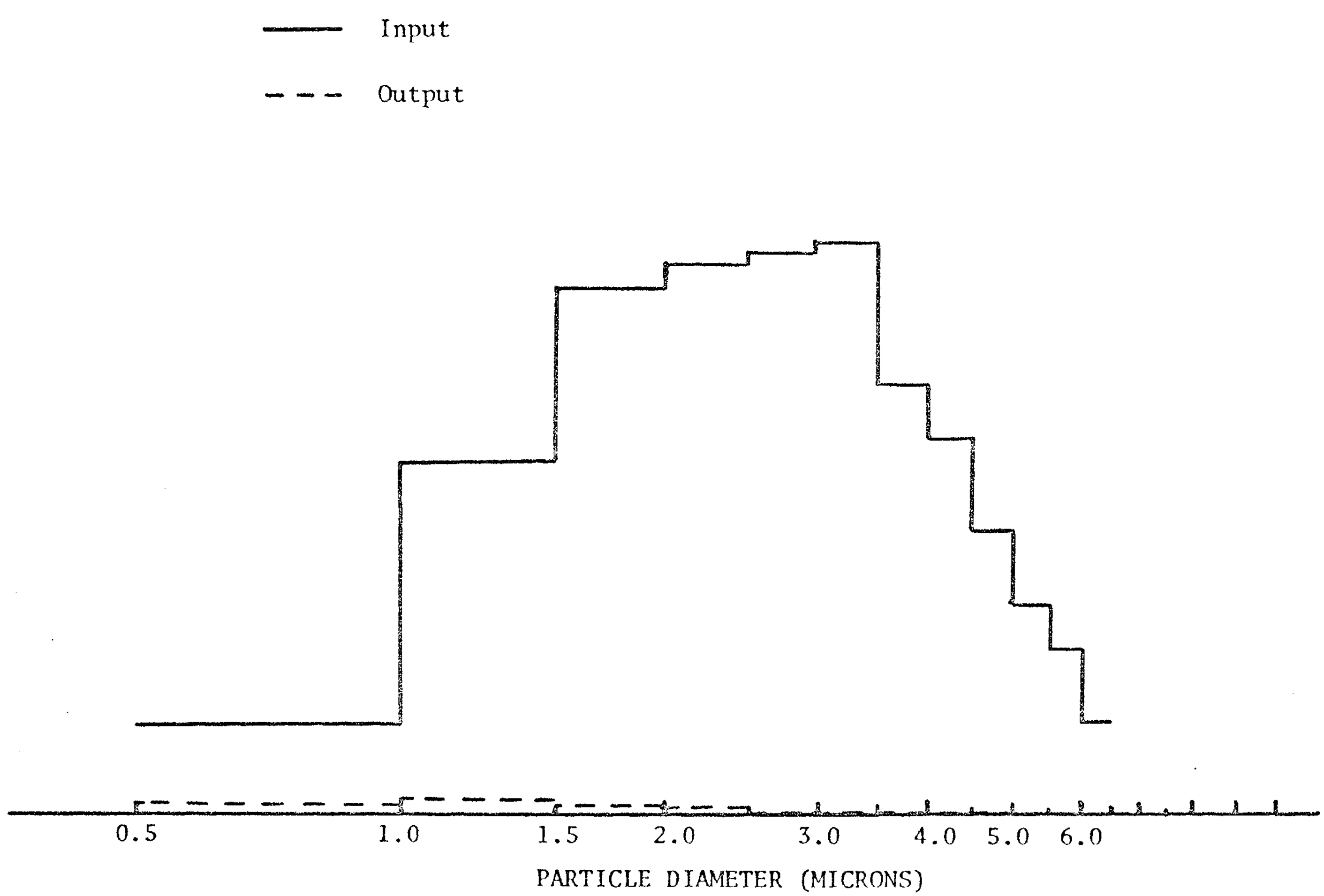

FIGURE 13. Coal Dust Mass Distributions with Conditioner On and Spray On. (Vertical Scale is relative concentration in arbitrary units.)

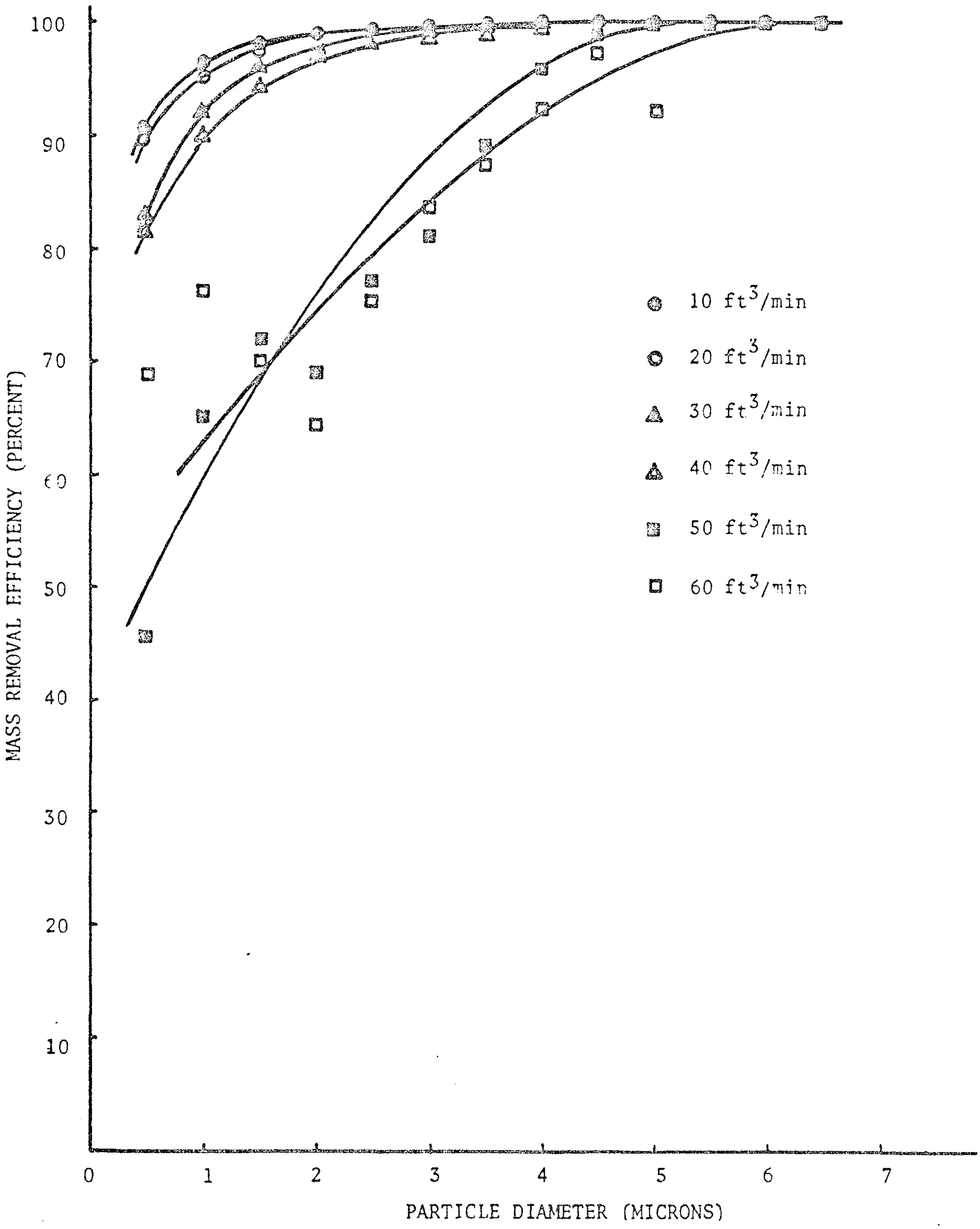

FIGURE 14. Mass Removal Efficiencies for Coal Dust as a Function of Particle Size (Conditioner plus Spray).

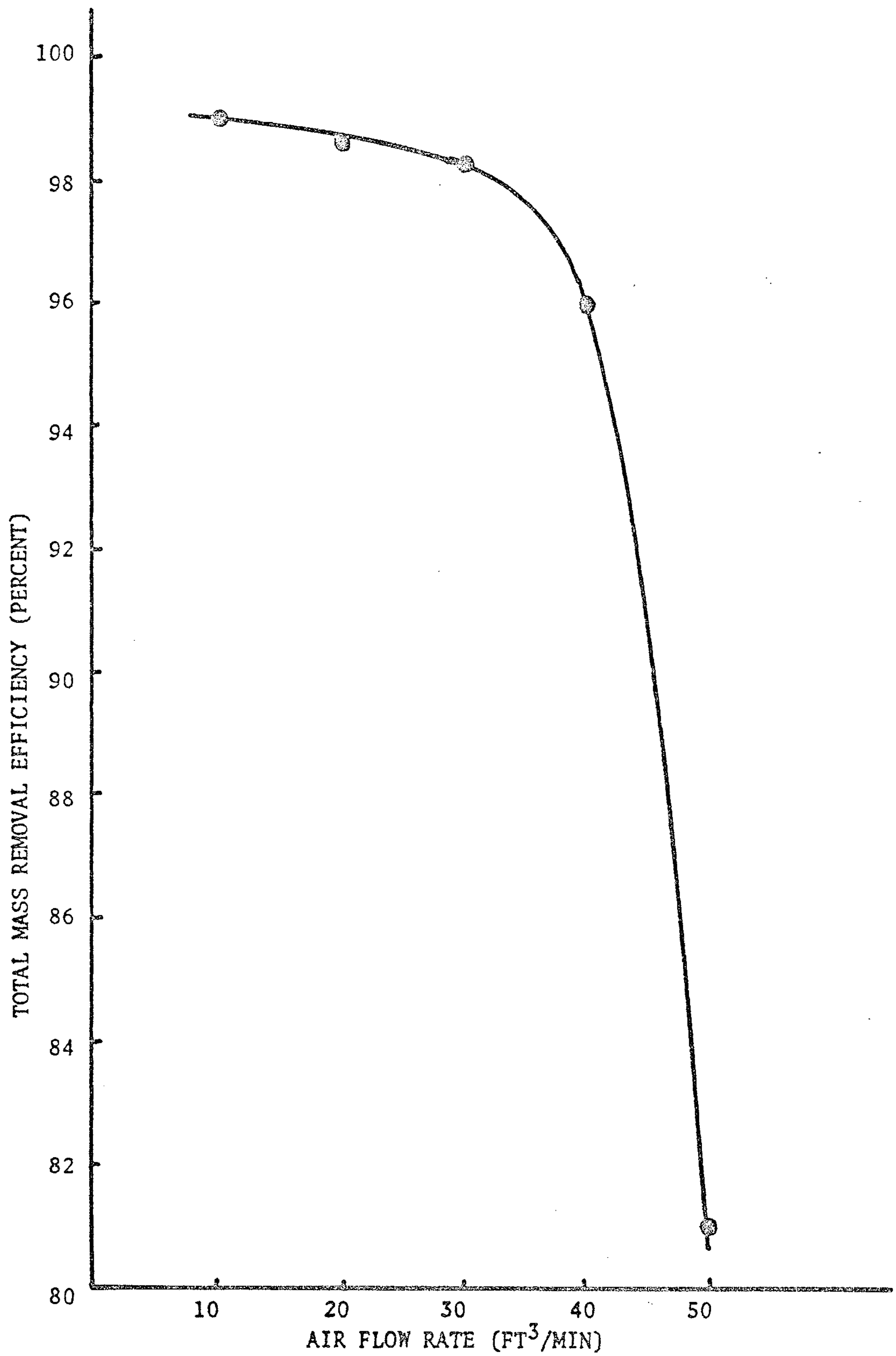

FIGURE 15. Total Mass Removal Efficiency for Coal Dust (Conditioner plus Spray).

of the conditioner-spray sequence is greatly improved over that of the spray alone.

References

1. F.D. Schowengerdt and J.T. Brown, "Nucleation Properties of Respirable Coal Dust", Terminal Progress Report on NIOSH Grant No. 1 R01 OH 00565-03 (1978)

2. F.D. Schowengerdt and J.T. Brown, "Nucleation Properties of Respirable Coal Dust", Terminal Progress Report on NIOSH Grant No. 2 R01 OH 00565-03 (1979)

3. J.T. Brown and F.D. Schowengerdt, "Analysis of a Continuous Flow Thermal Diffusion Cloud Chamber", J. Aerosol Science 10, 515 (1979).

4. J.T. Brown and F.D. Schowengerdt, "Droplet Growth Measurements in a Continuous Flow Thermal Diffusion Cloud Chamber", J. Aerosol Science 10, 339 (1979)

5. T.F. Tomb, J.E. Emmerling, and R.H. Kellner, Am. Ind. Hyg. Assoc. J. 33, 715 (1972)

V. CONCLUSIONS

A. Significance of Results

The main significance of the results of this research is that the concept of condensation enlargement can be made to work as a dust control mechanism in a laboratory prototype conditioner. Although there is a great deal of engineering design necessary before practical application in a coal mine can become a reality, the concept has been proven in this work.

Energy consumption in the laboratory prototype has turned out to be greater than was projected in the original design, but this is believed due to inefficiencies still existing in the heat transfer paths. The energy consumed in actually getting the water vapor to the dust and in getting the dust to nucleate and grow is probably of the order of that originally predicted. Therefore we believe that reductions in the energy consumption can be achieved through better design.

The problem of final size is perhaps more serious. For a specified volume air flow rate given by

$$Q = \frac{dV}{dt} ,$$

the total volume of the conditioner is uniquely determined by the residence time. In the prototype, we designed for a volume of 1 ft^3. Plate thickness and other obstructions reduced this to 0.74 ft^3 in the final version. For residence times below about 0.5 seconds (air flow rates above 50 ft^3/min) we did not get good growth and the efficiency (see Fig.15) started falling off. Taking all these facts into consideration, in order to keep the residence time at about 0.5 seconds the conditioner would have to be about 60 times as large as the prototype in order to handle the nominal flow rate of 3000 ft^3/min needed for mine applications.

Scaling the prototype with volume, we get 44 ft^3 for a 3000 ft^3/min conditioner. Although this is by no means prohibitively large, it is larger than the 25 ft^3 envisioned in the original design. Residence times, and hence overall size, can of course be decreased by increasing plate temperature differences. As pointed out earlier, we have found it to be difficult to maintain further temperature-difference increases in the present design, but again, improvements in heat transfer which would allow increased temperature differences to be achieved should be possible.

B. Recommendations for Future Development

The laboratory phases of the development of this concept for coal dust control are essentially complete with the completion of this project. The concept should be tested on other types of particulates such as fly ash, industrial effluents, and oil shale retort products. Numerous engineering design improvements are possible on the present configuration. These would include better heat transfer design, better methods of getting hot water onto the plates, and improved construction materials.

Other geometric configurations should also be investigated. For example, a concentric cylindrical geometry with the outer cylinder being cooled and heat introduced along the inner cylinder could have some advantages over the present plane geometry. This possibility is being explored in the laboratory at the present time.

VI. PUBLICATIONS

The following paper was published during the report period:

F.D. Schowengerdt and J.T. Brown, "An Electrostatic Size Classifier for Aerosol Particles", Reivew of Scientific Instruments <u>51</u>, 1098 (1980)

VII. PERSONNEL

The following personnel worked on the project during the report period:

F.D. Schowengerdt, P.I.
J.T. Brown, Co-P.I.
Tim Wendelin, Graduate Assistant
Chris Walker, Graduate Assistant
Roger Greer, Undergraduate Assistant
Rick Powell, Undergraduate Assistant
Tom Milner, Undergraduate Assistant
Tom Lookabaugh, Undergraduate Assistant
Joseph Neev, Undergraduate Assistant
Marcus Wichmann, Undergraduate Assistant