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Project NY 300 010-1
Technical Memorandum M-127

AEROSOL TRAVEL THROUGH VENTILATION SYSTEMS

11 June 1957

U. S. NAVAL CIVIL ENGINEERING
RESEARCH AND EVALUATION
LABORATORY
PORT HUENEME, CALIFORNIA

AD 149991

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Code Sheet for Technical Memorandum M-127
Aerosol Travel Through Ventilation Systems, Project NY 300 010-1

IDENTIFICATION OF COMMERCIAL COMPONENTS

1. Metal viscous-impingement filters at the system intake: Farr Company, type 44, 2-in. thick.

2. Centrifugal blower, System I: Westinghouse, Sturtevant Division, size No. 75, design 10.

3. Heating coil, System I: Refrigeration Engineering Corporation, type AC 603.

4. Spray washer, System I: Air and Refrigeration Corporation, type 1-2, size 1-S.

5. Capillary washer, System I: Air and Refrigeration Corporation, size 1-1H.

6. Filter pad "A", System II: fibrous viscous-impingement type American Air Filter Company, "Amerglas," 2-in. thick.

7. Filter pad "B", System II: metal viscous-impingement type, Air Filter Corporation, "Air-San" model W-2, 2-in. thick.

8. Filter pad "C", System II: metal viscous-impingement type, Air Maze Corporation, type "B", 2-in. thick.

9. Aerosol Generator: Silver Creek Precision Corporation, model 202 microsol fog generator (modified by NRL).

10. Variable transformers, speed control for aerosol generator: General Radio Corporation, Variac, 5 amp capacity, type V-5.

U.S. NAVAL CIVIL ENGINEERING
Research and Evaluation
LABORATORY
Port Hueneme, California

23 January 1958

Errata Sheet

NAVCERELAB Technical Memorandum M-127, "Aerosol Travel Through Ventilation Systems" by Hellberg, Thompson, and Young dated 11 June 1957.

Page 2.	First paragraph, last line. Delete the words "or radiological."
Page 2.	Fifth paragraph, first line. Change the word "in" to "is."
Page 13.	Last paragraph, third line. Change the normalizing factor in quotes to read "100/interpolated raw smoke."
Page 82.	Fourth activity listed. Change the words "Naval Reserve Secretary" to "Naval Research Sections."
Page 82.	Sixth activity listed. Change the words "Naval Marine Reserve Unit No. 1" to "Naval Medical Research Unit No. 1."

Project NY 300 010-1
Technical Memorandum M-127

AEROSOL TRAVEL THROUGH VENTILATION SYSTEMS

11 June 1957

OBJECT OF PROJECT

To develop equipment for the field dissemination of biological warfare decontaminants and to test and evaluate protective devices to prevent personnel contact with airborne pathogens.

OBJECT OF SUBPROJECT

To test and evaluate all types of commercially available ventilation air filters and ventilation air systems to determine their effectiveness in providing personnel protection in the event of a biological warfare aerosol attack.

OBJECT OF THIS REPORT

To show the results of a study of aerosol travel through both a high- and a low-velocity experimental ventilation system to learn what percentages and size ranges of aerosol particles would be removed by the components of the system.

RESULTS

In general, these studies show that aerosol particles larger than 3-μ diameter were removed to varying degrees by the ventilation system components while smaller particles essentially were unaffected.

U. S. NAVAL CIVIL ENGINEERING
Research and Evaluation
LABORATORY
Port Hueneme, California

Project NY 300 010-1
Technical Memorandum M-127

AEROSOL TRAVEL THROUGH VENTILATION SYSTEMS

11 June 1957

E. N. Hellberg, NAVCERELAB, and J. K. Thompson
and J. A. Young, NRL

SUMMARY

Polydisperse aerosols of dioctylphthalate with a particle-size range of approximately 1- to 20-μ diameter were passed into two typical ventilation air systems. The effect on particle-size distribution and concentration was studied at various sampling stations throughout the system by means of a jet-impactor, light-scattering method. In general, aerosol particles larger than 3-μ diameter were removed to varying degrees by the system components while smaller particles were essentially unaffected. It was concluded that building ventilation systems could not be relied upon to provide adequate protection from a biological warfare aerosol attack.

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TABLES

ILLUSTRATIONS

INTRODUCTION

The U. S. Naval Civil Engineering Research and Evaluation Laboratory (NAVCERELAB) and the U. S. Naval Research Laboratory (NRL), Washington, D. C., have conducted a study of aerosol travel through experimental ventilation systems and their components. The purpose of the work was to learn what percentages and size ranges of the aerosol particles would be removed by the components of the systems.

One of the many responsibilities of the Bureau of Yards and Docks is the passive defense of the Naval shore establishments against the hazards of a chemical, biological, and radiological warfare attack. This defense includes the protection of personnel located at these establishments. Personnel protection against an aerosol attack is accomplished in many cases by use of gas masks which are effective against the known warfare agents, but for only short periods of time. In cases where personnel have to be protected for long periods of time, the Army Chemical Corps standard collective protector is used to furnish pressurized filtered-air to sealed buildings or special purpose shelters, such as control centers, hospitals, and communication centers. The collective protectors are self-contained, and have a motor and blower for forcing air through an "absolute" filter which removes better than 99.9 per cent of the particulate aerosols in the $0.3\text{-}\mu$ size range and an activated charcoal filter for adsorbing all of the known chemical warfare agents. Because of the extremely high cost of providing this "absolute" filtration of air, and the possible need for large volumes of air, the Bureau asked the Laboratory to investigate ventilation air filters and mechanical air systems. This project was initiated by the Passive Defense Division of the Bureau to determine whether the less expensive commercially available ventilation air filters and existing ventilation systems in buildings would offer any measure of protection to personnel in the event of a warfare aerosol attack.

Since the activated charcoal filters are the only filters which can remove the chemical warfare gases from ventilation air, the studies reported here on ventilation system components apply only to biological or radiological aerosols. An extensive investigation[1] has been concluded on most of the commercially available makes and types of ventilation air filters using 0-5 u test dust as the warfare aerosol simulant. This investigation shows that none of the filters tested removed sufficient quantities of the test dust to be considered reliable for use in biological or radiological warfare defense.

HISTORICAL

The possibility that the components of a ventilation system might remove some of the particles from an incident aerosol is a matter of interest to the Navy in considering ways to protect personnel and material against chemical, biological, and radiological warfare agents. If a substantial portion of the aerosol particles were removed by passage through a ventilation system, the system would afford a degree of protection which might reduce the need for special air cleaning apparatus. At the same time, however, there would be a problem of contamination of the system by the material which would be retained.

A study[2] has been made of the travel of dioctylphthalate aerosols through a ventilation system aboard the USS GRANVILLE S. HALL (YAG-40) at sea. Particle-size distribution and concentration measurements were made using a jet-impactor, light-scattering technique which will be described later in this report. Experimental difficulties encountered in doing this work aboard a moving ship, plus the fact that the arrangement of the system could not be varied, strongly suggested a more extensive laboratory study.

A study[3] has been made of the travel of biological warfare simulants through a building ventilation system. In this study, conventional biological techniques were used for collecting and analyzing samples.

A program for studying ventilation problems in underway at the Laboratory which has facilities for setting up and studying experimental ventilating systems. Skills and instrumentation have been developed[4,5,6] for making various kinds of aerosol studies. Accordingly, it was logical that NAVCERELAB and NRL carry out a cooperative study of aerosol travel through an experimental ventilation system operated under carefully controlled conditions. A program[7] of study was proposed and approved.[8] BUSHIPS (Code 549) also became interested in the project and offered financial support plus the loan of some shipboard ventilation components. It was mutually agreed to study two ventilation systems. One was to be a low-velocity system such as would be used in a building; the other a high-velocity system such as would be found on a ship. These were not necessarily to be prototype systems, but they were to be arranged so that each component could be studied under typical conditions. The work was to be done at Port Hueneme.

PROCEDURE

Two ventilation systems were set up at NAVCERELAB, with most of the components and duct-work mounted on stands about 3 ft from the floor. This arrangement provided easy access to the system for aerosol sampling and for making necessary changes to the system. Both systems drew fresh air from outside the building through a small room used as a plenum. The system exhausted the air to the outside through a cupola in the roof at a sufficient distance from the intake to prevent aerosol short-circuiting. Before and after each test component,sampling holes 1 in. in diameter were drilled in the ducts in which aerosol sampling probes were inserted through rubber stoppers.

Method

A polydisperse aerosol of dioctylphthalate was generated near the intake of the system being studied; the travel of the aerosol through the system was observed by measuring the particle-size distribution and the total concentration at sampling stations before and after each component in the system. The aerosol measurements were made by a technique using single jet-impactors together with a light-scattering meter. Air flow rates in the ventilation system were measured by means of a draft gage connected across a calibrated orifice plate in the duct.

TEST SETUP

System I

This was a low-velocity system composed of commercially available components such as might be used in a building ventilation system. The duct-work consisted of about 60 ft of 12-in. by 12-in. galvanized sheet metal. A centrifugal blower was installed near the inlet and provided air at velocities varying between 267 and 400 ft per min in a 16-in. by 24-in. inlet duct section. The components of System I, in order of placement from the intake, were as follows:

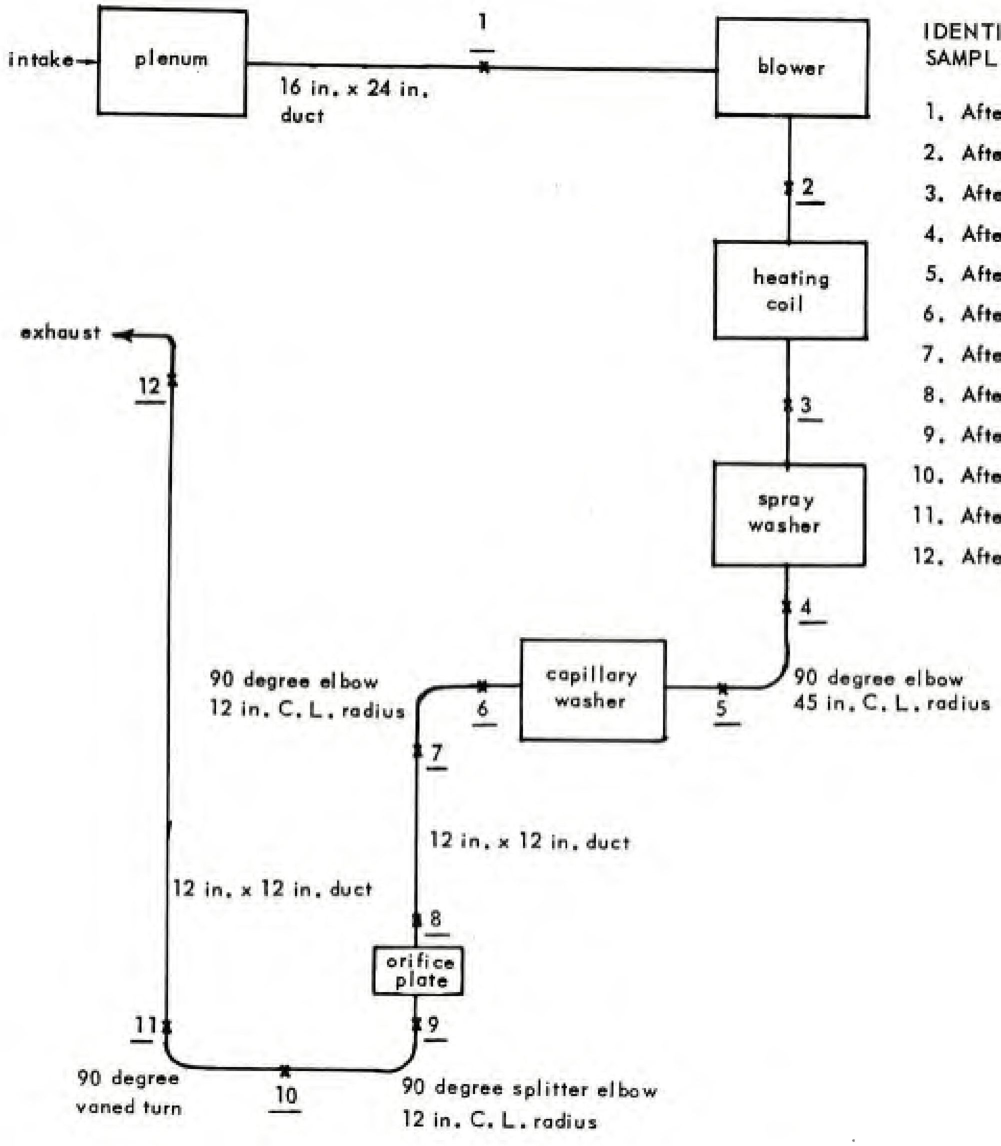
1. Blower, centrifugal, 800 to 1200 cu ft per minute,
2. Coil, heating, hot-water, 2-sq ft cross section,
3. Spray-type air washer,
4. Ninety degree plain elbow, 45-in. radius, 16-in. by 24-in. cross section,
5. Capillary-type air washer,
6. Ninety degree plain elbow, 12-in. radius, 12-in. by 12-in. cross section,
7. Orifice plate for air flow measurement,
8. Ninety degree splitter elbow, 3-vane, 12-in. radius, 12-in. by 12-in. cross section,
9. Ninety degree vaned turn, 5-vane, 12-in. by 12-in. cross section.

The plenum intake was covered by viscous-impingement filters of the wire-mesh type to reduce outside contaminants. Twelve sampling ports were located to permit sampling before and after each component in the system. System I diagrammatically is shown in Figure 1. The aerosol generators were set in the plenum for studies on this system.

System I was permanently assembled; therefore, the components could not be rearranged conveniently. This proved to be a disadvantage since the blower was first in line, and so altered the aerosol that the performance of subsequent components could not be evaluated with the desired accuracy.

System II

This was a high-velocity system composed of shipboard-type heating and ventilation components and about 80 ft of 12-in. by 12-in. duct. It was a modification to System I in that approximately the first



IDENTIFICATION OF SAMPLING STATIONS

1. After plenum
2. After blower
3. After heating coil
4. After spray washer
5. After 18 in. elbow
6. After capillary washer
7. After 12 in. elbow
8. After 8 ft. straight duc
9. After orifice plate
10. After splitter elbow
11. After vaned turn
12. After entire system

Figure 1. Diagram of System I.

half was substituted with duct-work divided into 4-ft long removable sections. Any section of duct could be removed and a ventilation system component inserted in its place. The components were transitioned to facilitate interchangeability, thus allowing them to be placed in any position in the system with respect to the other components. More important, however, was that each test component could be positioned directly after the aerosol generator so the full effect of that component on aerosol reduction could be observed and measured. Vaneaxial blowers were used to give air speeds of 1250 fpm and 2500 fpm in the 1-sq ft duct section. System II consisted of components as follows:

1. Mushroom type air inlet, throat diameter 13-1/2 inches,
2. Blower, vaneaxial, BUSHIPS type A-1, 1250 cfm dc or blower, vaneaxial, BUSHIPS type A-2, 2500 cfm direct current,
3. Coil, preheating, steam, BUSHIPS type 26H, 1250 cu ft per minute,
4. Coil, reheating, steam, BUSHIPS type 27M, 1250 cfm (winter), 2500 cfm (summer),
5. Coil, cooling Freon, BUSHIPS type 44DF, 1250 cu ft per minute,
6. Elbow, 90-degree plain, 12-in. radius, 12-in. by 12-in. cross section,
7. Elbow, 90-degrees plain, 18-in. radius, 12-in. by 12-in. cross section,
8. Elbow, 90-degrees splitter, single vane, 12-in. radius, 12-in. by 12-in. cross section,
9. Elbow, 90-degree vaned turn, 10-vane, 12-in. by 12-in. cross section,
10. Filter pad "A", fibrous viscous-impingement type (glass wool), 20-in. by 20-in. by 2-in. thick,
11. Filter pad "B", metal viscous-impingement type (multiple layers of crimped metal screen), 20-in. by 20-in. by 2-in. thick,
12. Filter pad "C", metal viscous-impingement type (multiple layers of crimped metal screen), 20-in. by 20-in. by 2-in. thick

The above components were not necessarily tested in the order listed.

The three viscous-impingement air filters which were to be evaluated in connection with the tests on System II were selected as being representative of the various commercial types available. Previous filter studies[1] with an aerosol of 0-5-μ test dust had shown that filter pad "A" could be expected to give the best over-all efficiency of the viscous-impingement type, pad "B" would give medium results, and pad "C" would give the poorest performance. The evaluation of the three filters was to be conducted to learn whether the efficiency of the filters as determined with the test dust would prove to be of the same relative order of magnitude when tested with the lighter aerosol dioctylphthalate smoke. Subsequent testing showed this to be true. System II diagrammatically is shown in Figure 2.

In the tests on System II, the aerosol generators were placed in the air intake tunnel to permit mixing of the aerosol before it entered the plenum. This was to provide a uniform cloud for studies on the mushroom-type air inlet, the preheater, and the test filters, which were mounted and tested individually in the plenum. In this series of studies each of the components was studied alone near the intake end of the system. There was insufficient time available to assemble and study the complete system.

Aerosol Generation

The polydisperse aerosol used for these studies was diotylphthalate with a particle-size range of 1- to 20-μ diameter. The aerosol was produced by four spinning-disk atomizers. These atomizers were modified versions of a commercial spinning-disk atomizer designed for spraying insecticides as shown in Figure 3. The modifications, made by NRL, were as follows:

A. Removal of one of the two rotating disks,
B. Removal of the fan and provision for a gravity liquid feed system,
C. The device was mounted upright in a plywood box which served both as an operating stand and a shipping case.

The aerosol generators were run at speeds of about 5000 rpm and were controlled by means of variable transformers. These modifications to the commercial atomizer served to increase the liquid feed rate and to

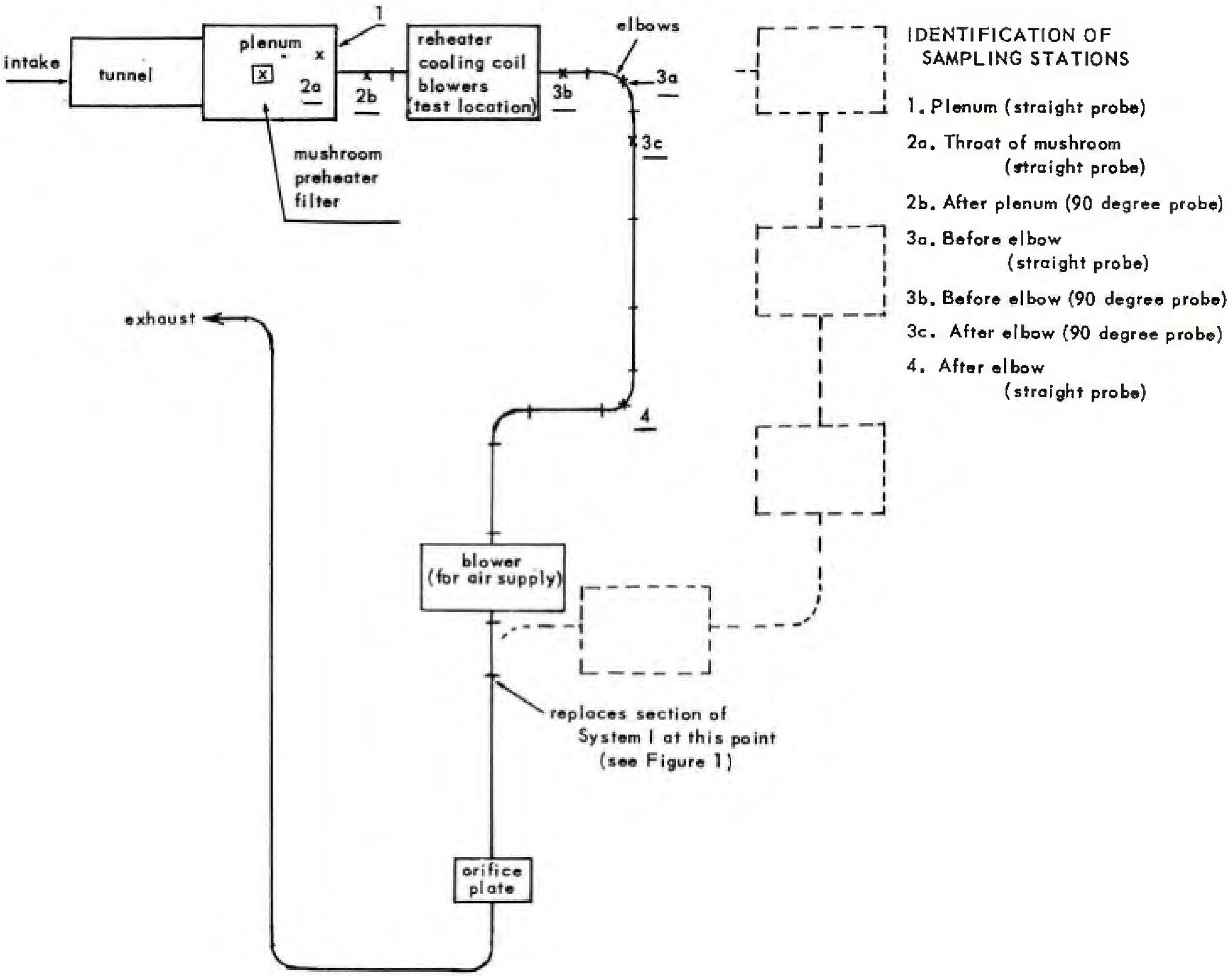


Figure 2. Diagram of System II (modification to System I).

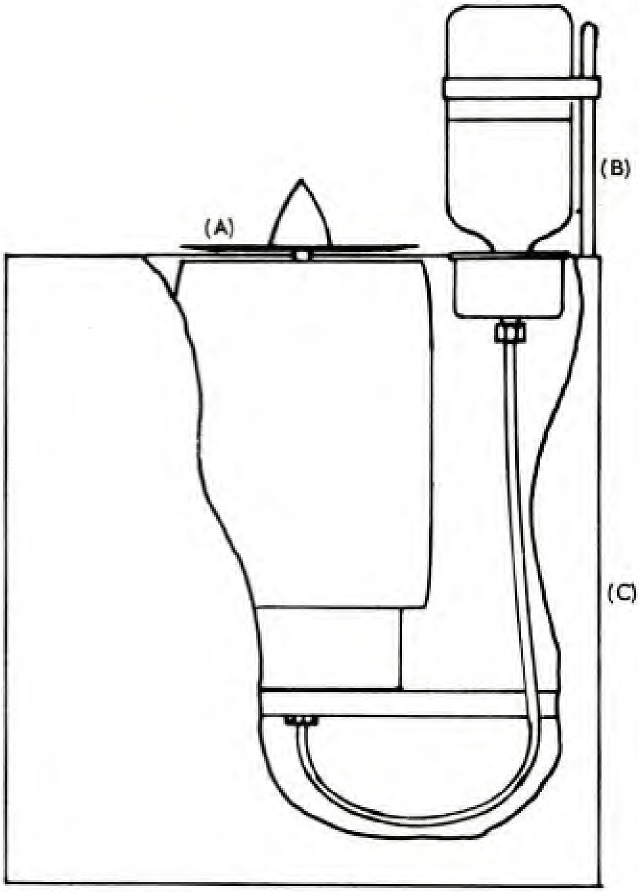


Figure 3. Aerosol generator (cutaway view).

decrease the air blast at the edge of the rotating disk. The effect was to minimize the formation of very small (submicron) particles which would obscure the light-scattering effects of the larger particles. Some droplets larger than 20-μ diameter were produced, but most of these were lost by settling or impaction before entering the system.

Sampling Probes

The sampling probes were made from 5/8-in. copper tubing. For all studies on System I, and for some on System II, the probes had 3-in. radius 90-degree bends at the inlet end. The probes were inserted through rubber stoppers into holes in the side of the duct. The probes were oriented so that the open end faced upstream.

Whenever possible in the System II studies, the probes were straight tubes and were inserted into the side of a 90-degree turn to minimize loss of aerosol particles because of bends in the sampling line.

The sampling rate was 4.8 liters per min in all cases; this corresponded to a velocity of 3800 cm per min at the sampling tube inlet. The air velocities in the duct, expressed in metric units, were approximately 8000 and 12,000 cm per min for the System I studies, and those for System II were approximately 38,000 and 76,000 cm per minute. Therefore, the sampling rate was less than isokinetic; the effect of this condition would be to increase the apparent proportion of large particles in a sample. According to the literature,[4, 5] one might expect a possible error as high as 10 per cent on this account. It is believed that this much error is within the limits of accuracy of the technique as a whole. The 4.8 liters per min sampling rate was chosen in order to cover the desired particle-size range with the particular set of jet-impactors which was available for these studies.

Technique of Measurement

The particle-size distribution and the concentration of the aerosol were determined at the various sampling stations by using single jet-impactors together with a light-scattering meter. The apparatus was arranged as shown in Figure 4.

The jet-impactor is a device[6] for the inertial removal of aerosol particles nominally larger than a certain size, which is called the characteristic diameter of the impactor. The light-scattering

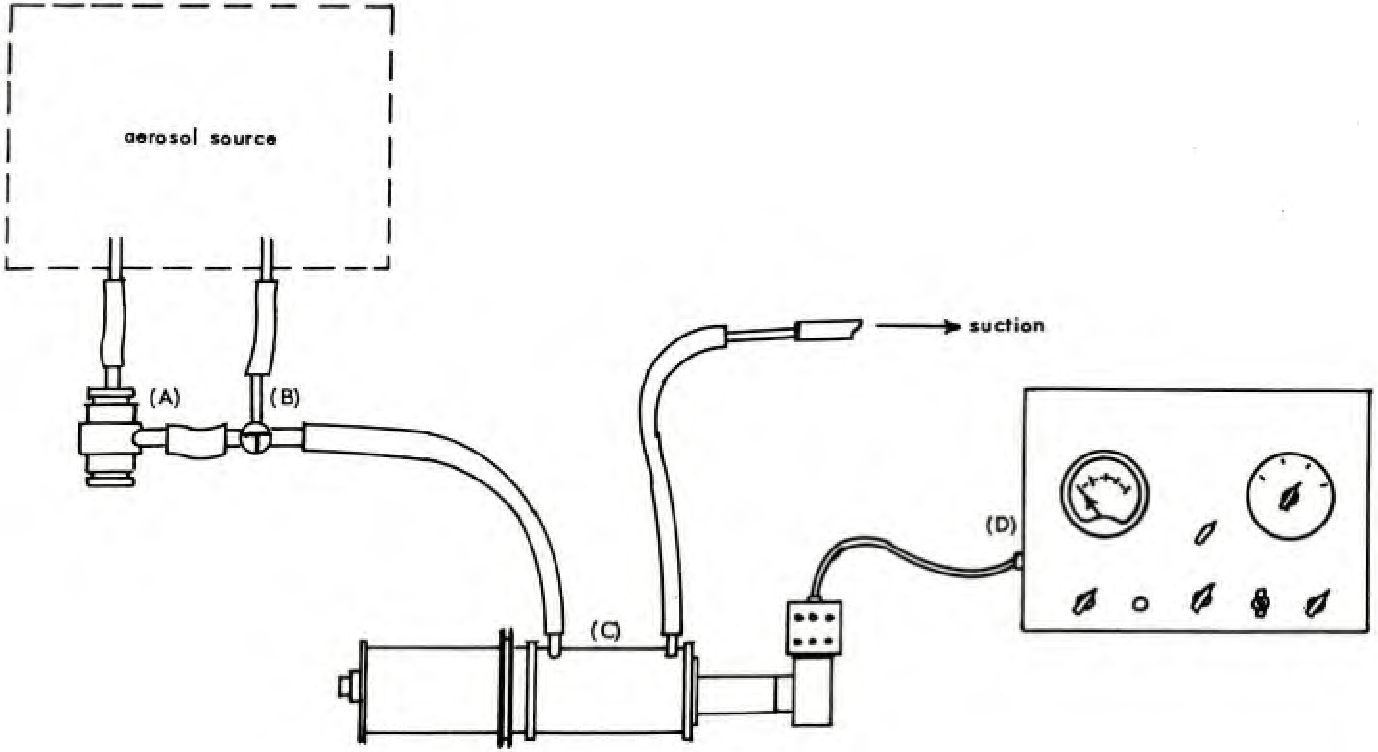


Figure 4. Arrangement of apparatus for aerosol studies.

measurements were made with a light-scattering meter, which has been described.[9] This instrument measures the intensity of scattered light; it has a limiting sensitivity of about 10^4 particles per liter for dioctylphthalate aerosols of 0.3-μ diameter. The aerosol being sampled was drawn at a measured rate either through, (A) the jet-impactor, or through, (B) the open tube, then through, (C) the light-scattering cell, and, (D) the intensity of scattered light was indicated by the meter unit. The meter was first adjusted to read some arbitrary reference value on the sample from the open tube. Then a sample was drawn through the jet-impactor, and the light-scattering meter indicated the fraction of the aerosol that escaped impaction. The difference between the two meter readings corresponded to the fraction of the aerosol that was impacted. The process was repeated for each of a series of jet-impactors whose characteristic diameters divided the total range of particle-sizes into suitable steps. The jet-impactors used here had characteristic diameters of 7.2, 5.8, 4.2, 3.0, 1.6, and 0.8 μ at the sampling rate of 4.8 liters per minute. The resulting series of light-scattering meter readings on the samples from the jet-impactors represented the particle-size distribution as "per cent less than stated size" in terms of light-scattering power.

In the particle-size range concerned here (1- to 20-μ diameter), the light-scattering intensity is a continuous function of the square of the particle diameter and can be used as a measure of particle concentration. Since the light-scattering intensity varies with the square of the diameter, it is proportional to the total surface area of the particles, and the concentration so measured is the surface area concentration, i.e., the amount of surface area in a given volume of aerosol. The corresponding particle-size distribution, therefore, is the distribution of surface area with particle-size.

The median diameter in a distribution of particle-sizes is that diameter which divides the whole group into two equally weighted segments. In a surface area distribution, the median diameter is the surface area median diameter; it divides the whole group into two segments containing equal surface area. The surface area median diameter can be translated into the mass median diameter or the arithmetic median diameter by the use of conversion formulas such as those described in the literature.[10]

Experimental Procedure

The experimental procedure and the subsequent treatment of data will be described in detail for one run; the blower of System I at 800 cfm was the component chosen for illustration. Aerosol samples were taken from Stations 1 and 2 (see Figure 1). Station 1 was upstream from the blower; Station 2 was downstream. The light-scattering meter was placed within reach of both stations so aerosol samples could be drawn alternately from each station. One run consisted of a complete round of light-scattering meter readings on aerosol samples from the six jet-impactors and from the open tube (raw smoke) at the two sampling stations. The order of sampling was as follows:

1. Raw smoke, Station 1
2. Raw smoke, Station 2
3. Impactor 1, Station 1
4. Impactor 1, Station 2
5. Impactor 2, Station 1
6. Impactor 2, Station 2
7. Raw smoke, Station 1
8. Raw smoke, Station 2

and this method was continued for the remaining impactors.

Samples were drawn alternately from Stations 1 and 2 in order to minimize the effect of long-term variations in the aerosol concentration or size distribution. A light-scattering measurement was made on a raw smoke sample between each pair of jet-impactor samples, and an interpolated value for raw smoke concentration was calculated for each meter reading on an impactor sample. A complete round of 20 readings was made in about 10 minutes. In most cases each round was checked by at least one repeat round. The data for this run are given in Table I. The light-scattering meter readings for impactor samples taken from the two stations are given in Columns 1 and 3 along with the raw smoke values.

The light-scattering meter readings for the impactor samples were normalized to a basis of 100 per cent raw smoke by multiplying them by the factor "100 interpolated raw smoke." These normalized values are given in Columns 2 and 4. In addition, the meter readings on samples from Station 2 were normalized relative to Station 1 to show the effect of the loss in gross concentration between Stations 1 and 2. This was done by multiplying the data of Column 4 by the factor "raw smoke Station 2/raw smoke Station 1." These data are given in Column 5.

TABLE 1. Effect of Centrifugal Blower on Particle-Size Distribution at 800 cfm.

Fraction sampled	1 Station 1 Scattered-light Intensity, %	2 Station 1 Normalized for 100% raw smoke	3 Station 2 Scattered-light Intensity, %	4 Station 2 Normalized for 100% raw smoke	5 Station 2 Relation to Station 1
RS	85	100	56	100	70
Imp 1 CD = 7.2 μ	70	82	53	91	63
Imp 2 CD = 5.8 μ	60	71	46	77	54
RS	85	100	62	100	70
Imp 3 CD = 4.3 μ	52	60	43	69	48
Imp 4 CD = 3.0 μ	43	49	38	61	43
RS	90	100	62	100	70
Imp 5 CD = 1.6 μ	20	22	18	28	20
Imp 6 CD = 0.8 μ	4	4	4	6	4
RS	98	100	69	100	70

RS = Raw smoke
Imp = Impactor
CD = Characteristic diameter

The impactor data given in Columns 2 and 4 represent the particle-size distribution of the aerosol (in terms of surface area) at Stations 1 and 2, respectively, as per cent less than stated size. The "stated size" in each case is the characteristic diameter for that jet-impactor. These data are given as a log-probability plot in Figure 5. The solid line represents the particle-size distribution at Station 1; the dotted line represents the particle-size distribution at Station 2. The surface area median diameter of the aerosol is indicated for each station by the ordinate corresponding to 50 per cent probability.

At Station 1, the surface area median diameter was 3.5 microns; at Station 2 it was 2.7 microns. This means that there was a shift of the particle-size distribution toward the smaller sizes. A comparison of the data of Columns 2 and 5 will show not only the change in size distribution but also the change in gross concentration. The gross concentration was reduced 30 per cent from Station 1 to Station 2 as shown by the average raw smoke values.

The relative change in size distribution for each size interval can be shown by the method illustrated in Table II and Figure 6. The differences between successive light-scattering meter readings of Columns 2 and 5 of Table I are shown in Columns 2 and 4, respectively, of Table II. These differences are the percentages of the total light-scattering power of the aerosol particles in each interval between characteristic diameters of successive jet-impactors over the range of 0 to 20 microns. The corresponding size intervals are given in Column 1. Columns 2 and 4 represent of total surface area in each size interval. Dividing by the respective size intervals gives the "per cent surface area per micron size range." The values are given in Columns 3 and 5, respectively, and are used for the ordinates in the block diagram of Figure 6. The unshaded blocks represent the size distribution of the aerosol at Station 1; the superimposed shaded blocks represent that at Station 2.

RESULTS: SYSTEM I COMPONENTS

System I, 800 cu ft per minute

The results of this study are given in Tables III and IV and are shown in the graphs of Figures 7 through 13.

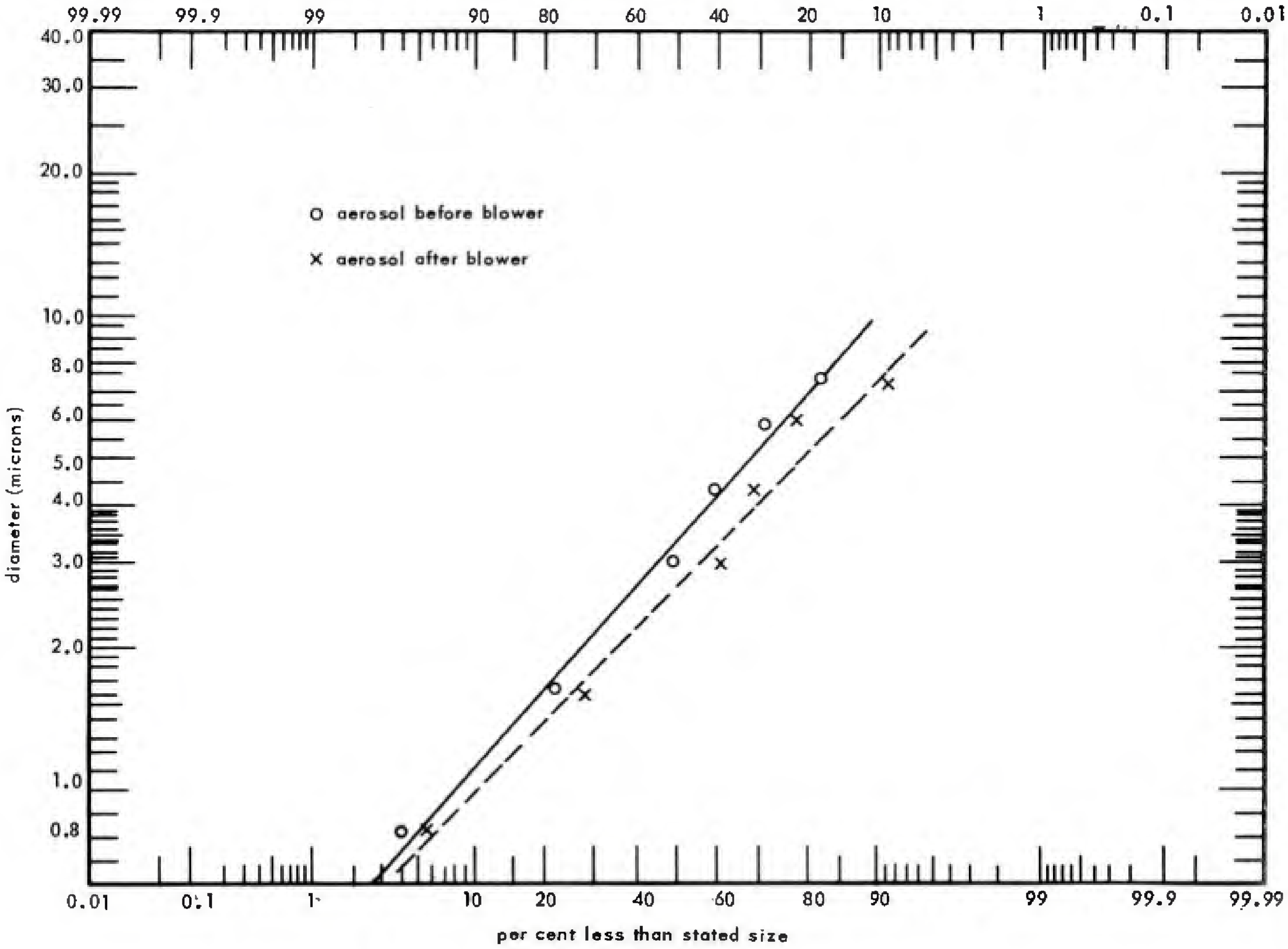


Figure 5. Effect of centrifugal blower on particle-size distribution (800 cfm).

TABLE II. Effect of Centrifugal Blower on Particle-Size Distribution and Concentration at 800 cfm.

1	2	3	4	5
Particle-size interval (microns)	Station 1		Station 2	
	Scattered-light int (rel surface area)	Rel surface area per micron size range	Scattered-light int (rel surface area)	Rel surface area per micron size range
20-7.2	18	1.4	7	0.5
7.2-5.8	11	7.9	9	6.4
5.8-4.2	11	6.9	6	3.8
4.2-3.0	11	9.2	5	4.2
3.0-1.6	27	19.3	23	16.5
1.6-0.8	18	22.5	16	20.0
0.8-0	4	5.0	4	5.0

Int = Intensity
Rel = Relative

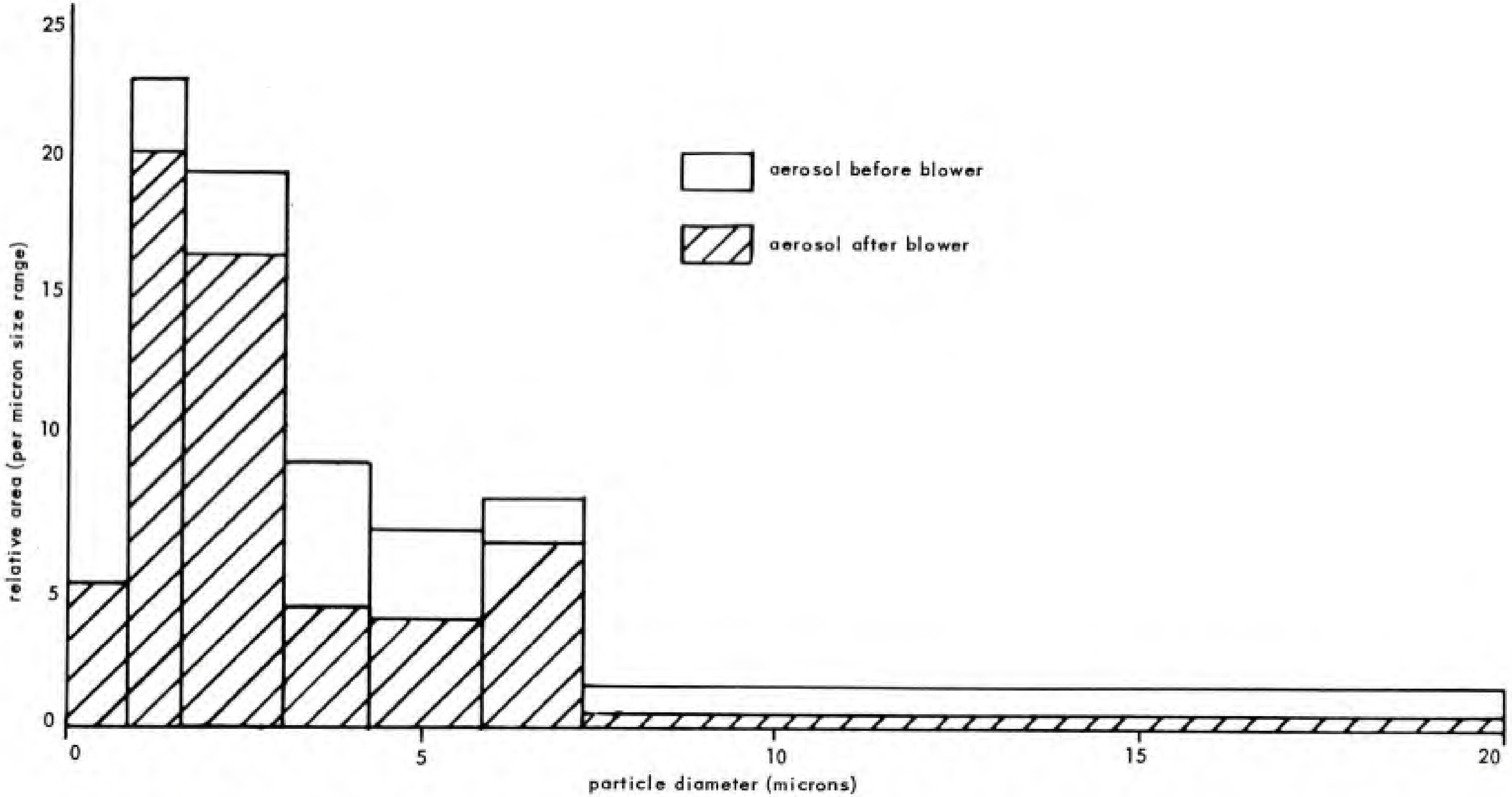


Figure 6. Effect of centrifugal blower on particle-size distribution and concentration (800 cfm).

TABLE III. System I, 800 cfm: Effect of Components on Particle-Size Distribution (Normalized for 100 per cent, Raw Smoke).

Station	Raw Smoke	Imp 1	Imp 2	Imp 3	Imp 4	Imp 5	Imp 6	Station location and condition
1	100	78	68	57	45	21	4	Incoming aerosol
2	100	89	75	62	59	26	5	After blower
2	100	93	82	73	62	29	4	After blower, (dummy heater)
3	100	94	91	78	66	30	7	After blower plus heater (cold) 60 degrees Fahrenheit
3	100	96	89	78	66	29	7	After blower plus heater (hot) 112 degrees Fahrenheit
3	100	93	82	73	62	29	4	After blower plus dummy heater
4	100	95	89	79	68	30	7	After spray washer dry
4	100	91	88	76	69	29	7	After spray washer filled, no spray
4	100	92	88	90	78	36	8	After spray washer, spray on
5	100	95	93	83	71	34	7	After elbow after spray washer
6	100	96	95	92	80	37	8	After capillary washer, dry
6	100	94	88	88	74	39	7	After capillary washer, wet
7	100	97	96	87	73	37	7	After elbow
8	100	97	97	90	80	39	8	After straight duct, 8 ft
9	100	99	95	90	77	39	8	After orifice plate
10	100	98	96	90	82	41	8	After splitter elbow
11	100	96	97	90	80	39	7	After vaned turn
12	100	99	97	93	79	38	7	After entire system

Imp = Impactor

TABLE IV. System I, 800 cfm: Effect of Components on Particle-Size Distribution (Relative to Original Aerosol).

Station	Raw Smoke	Imp 1	Imp 2	Imp 3	Imp 4	Imp 5	Imp 6	Station location and condition
1	100	78	68	57	45	21	4	Incoming aerosol
2	78	68	58	50	44	20	4	After blower
2	78	71	65	56	44	22	3	After blower (dummy heater)
3	66	63	60	52	44	20	5	After blower plus heater (cold) 60 degrees Fahrenheit
3	66	63	58	52	43	19	5	After blower plus heater (hot) 112 degrees Fahrenheit
3	78	73	64	57	49	23	3	After blower plus dummy heater
4	69	65	62	55	47	21	5	After spray washer, dry
4	73	70	67	61	53	23	5	After spray washer filled, no spray
4	72	70	64	56	46	20	6	After spray washer, spray on
5	70	65	64	58	50	25	5	After elbow after spray washer
6	63	61	60	58	50	23	5	After capillary washer dry
6	69	64	60	60	50	27	4	After capillary washer wet
7	66	65	64	58	48	24	5	After elbow after capillary washer
8	62	61	60	56	50	24	5	After straight duct, 8 ft
9	64	63	61	58	50	25	5	After orifice plate
10	61	60	58	54	50	25	5	After splitter elbow
11	62	59	60	56	49	24	4	After vaned turn
12	55	55	53	52	44	21	3	After entire system

Imp = Impactor

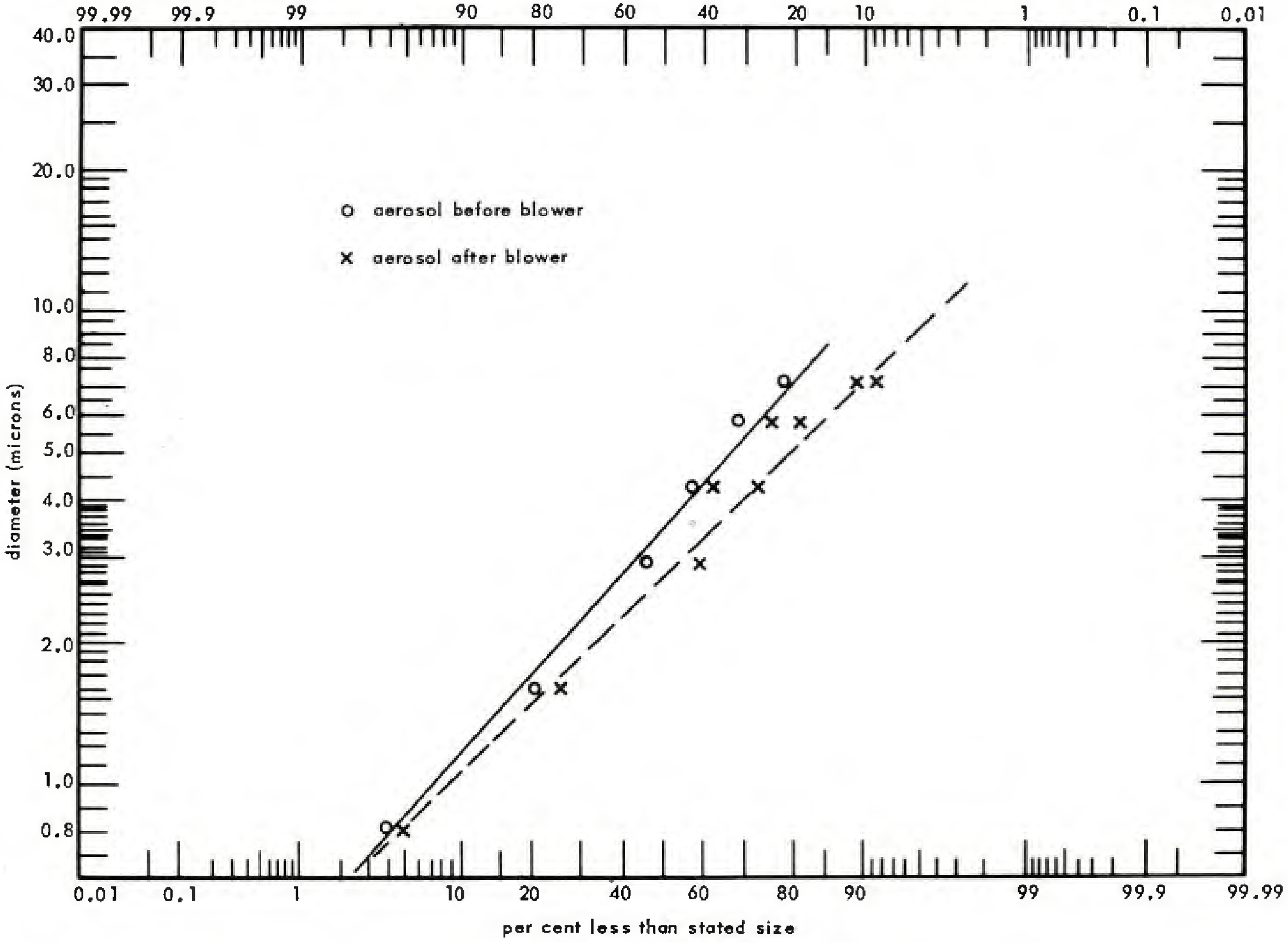


Figure 7. Effect of centrifugal blower on particle-size distribution (800 cfm).

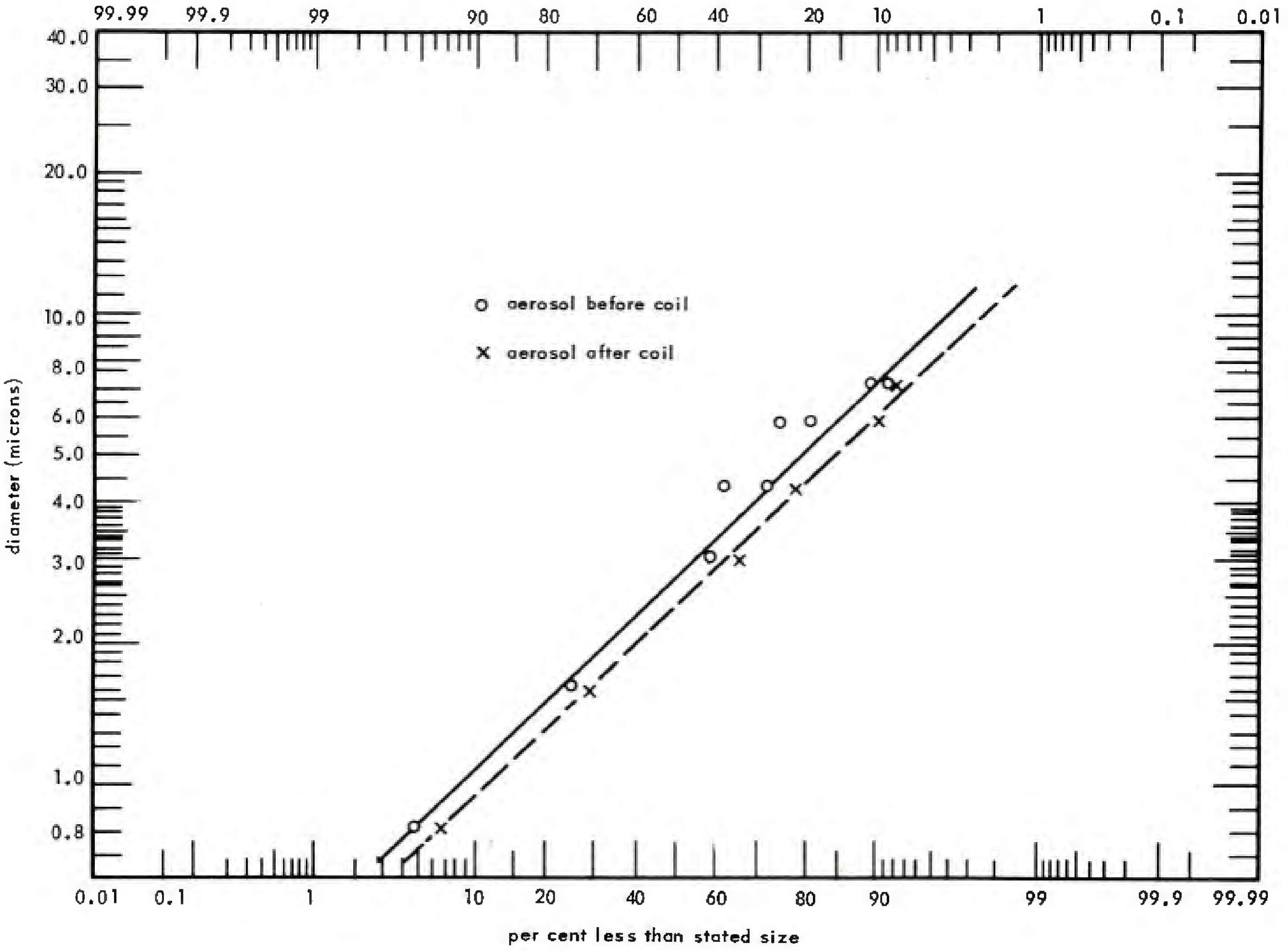


Figure 8. Effect of heating coil on particle-size distribution (800 cfm).

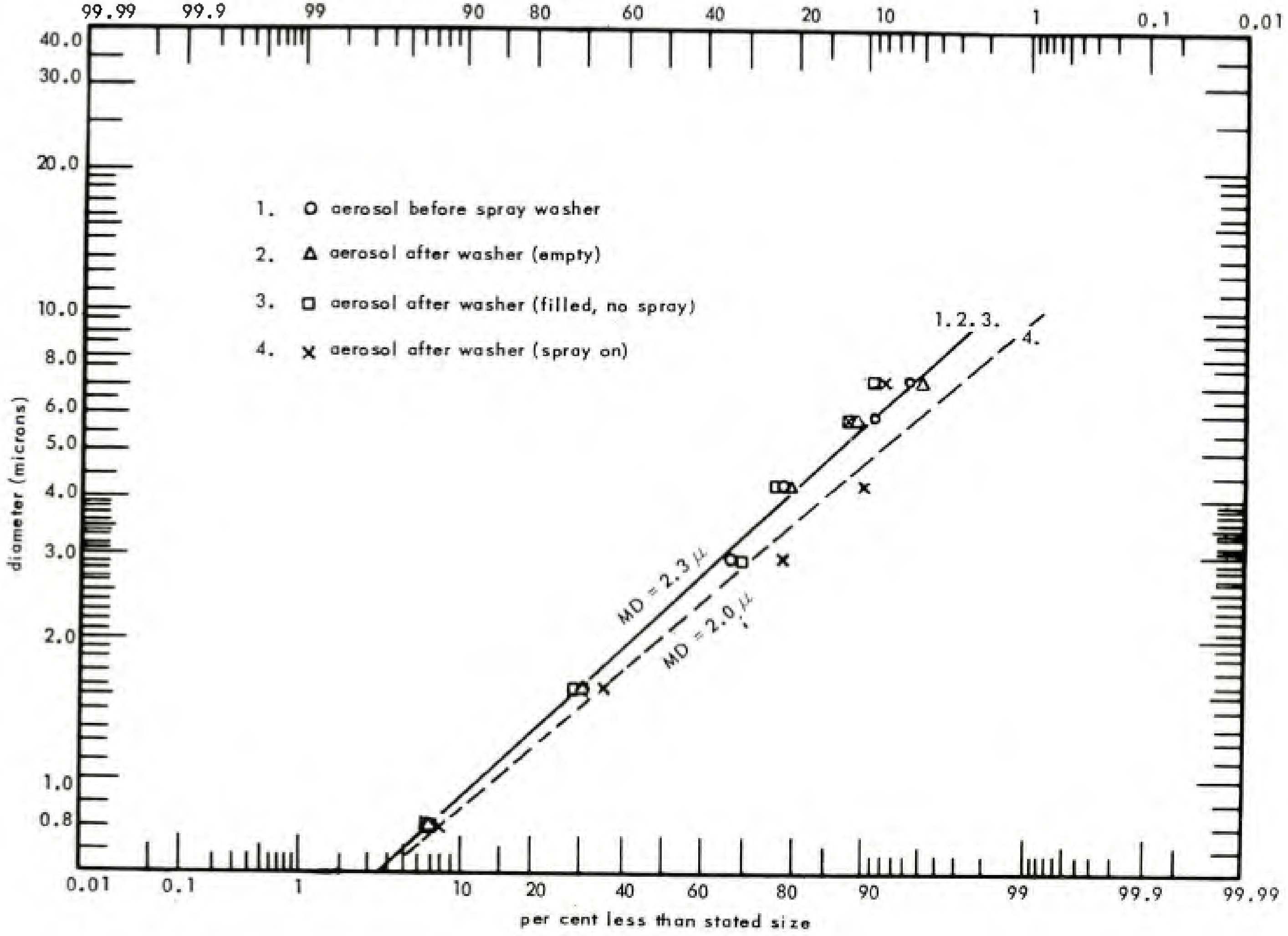


Figure 9. Effect of spray washer on particle-size distribution (800 cfm).

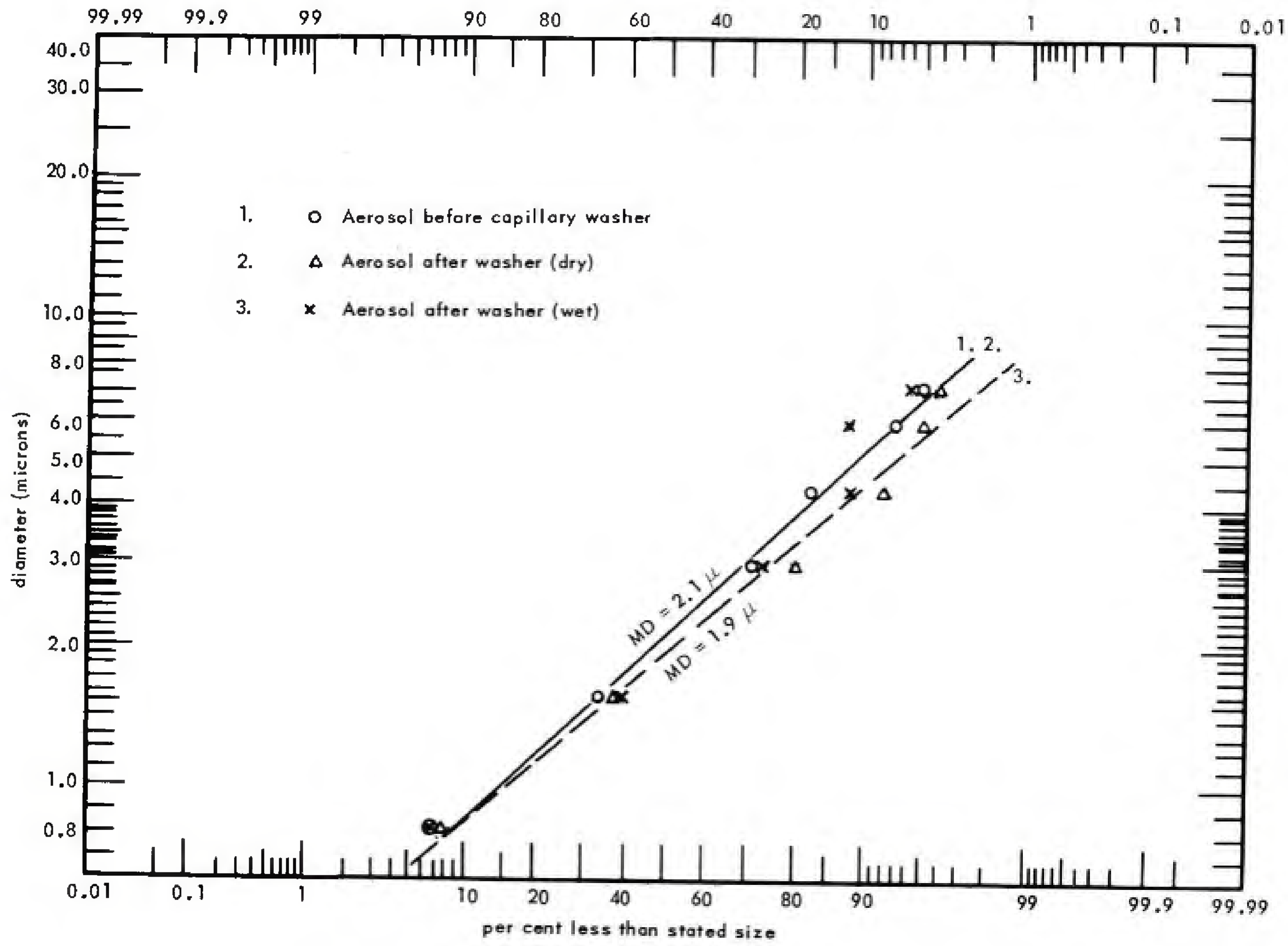


Figure 10. Effect of capillary washer on particle-size distribution (800 cfm).

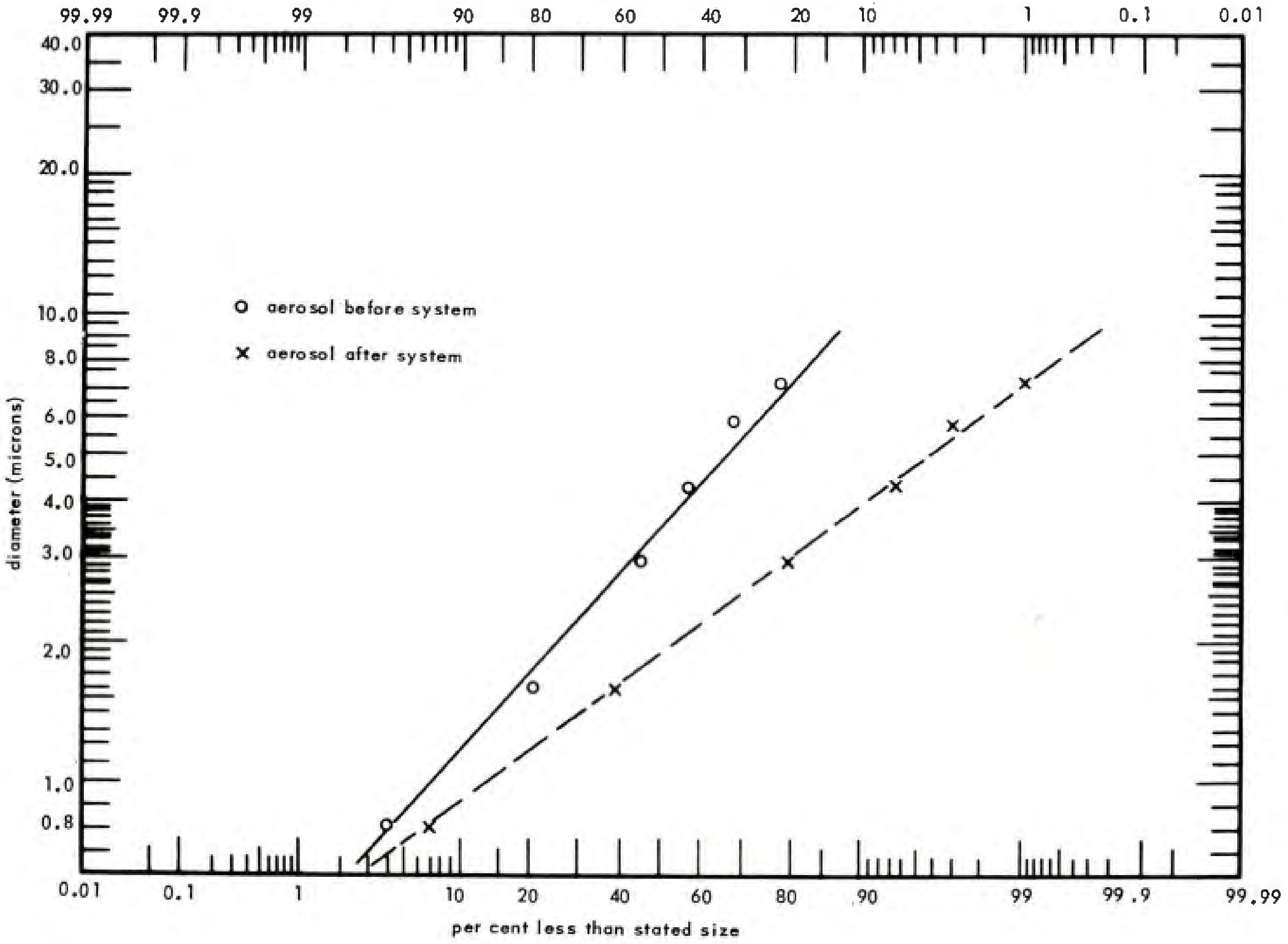


Figure 11. Effect of entire system (1) on particle-size distribution (800 cfm).

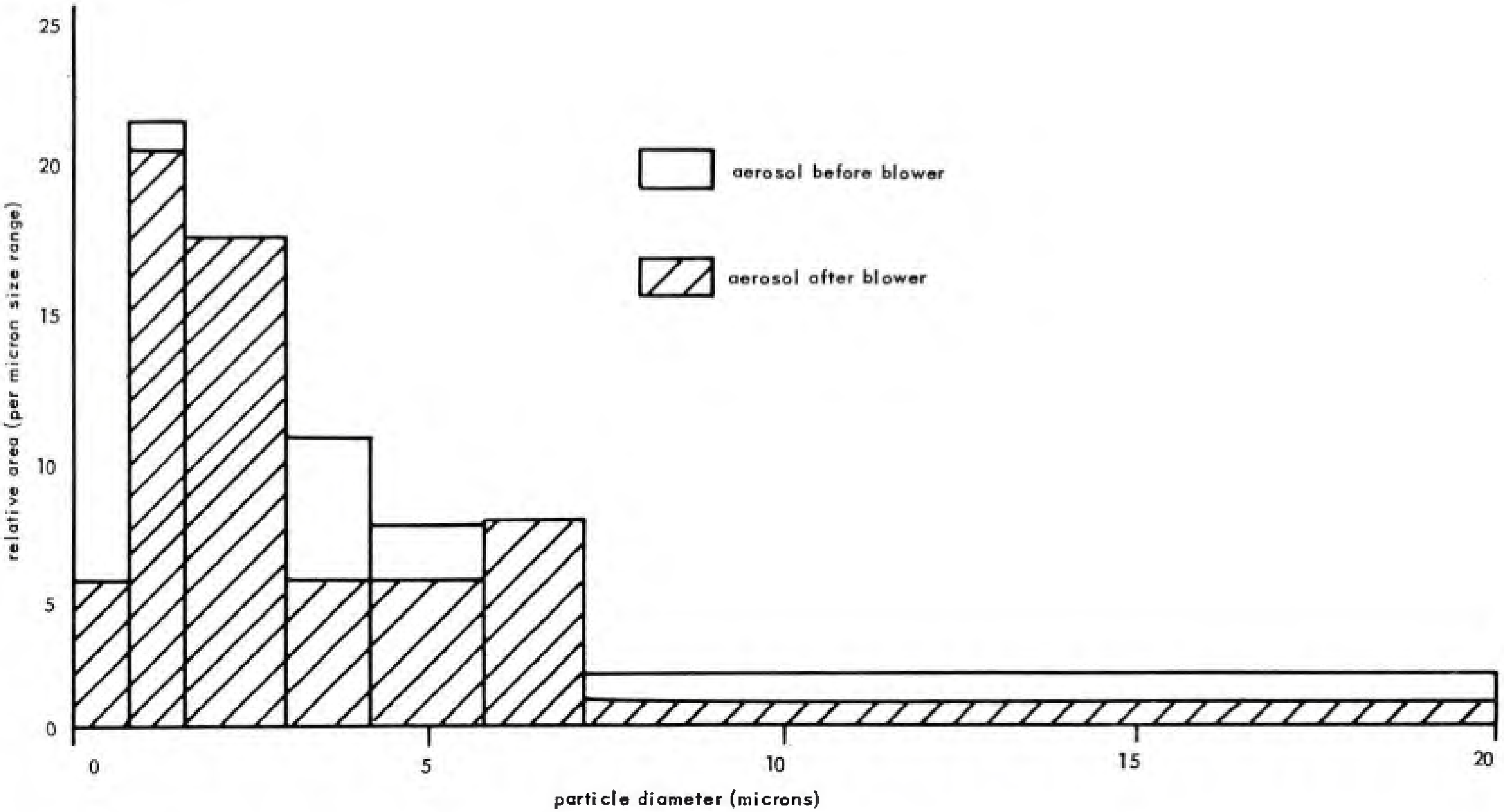


Figure 12. Effect of centrifugal blower on particle-size distribution and concentration (800 cfm).

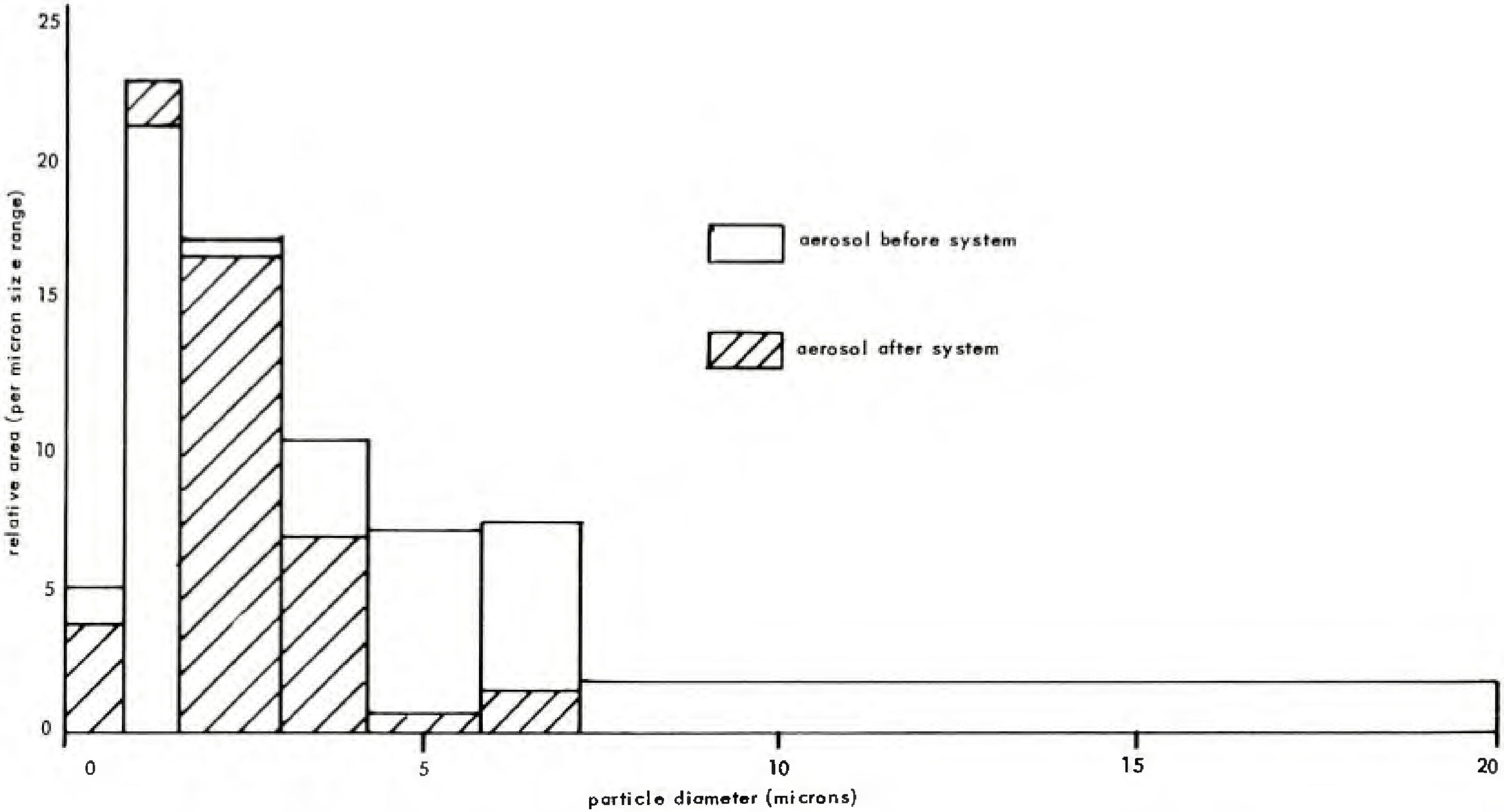


Figure 13. Effect of entire system (1) on particle-size distribution and concentration (800 cfm).

Table III gives the averages of light-scattering meter readings for samples from each of the six impactors normalized to a basis of 100 per cent for raw smoke at the 12 sampling stations. Each figure is an average of a number of individual values. The estimated precisions of the results is 5 to 10 per cent. The notes in the last column in Table III indicate the component and its operating condition corresponding to each set of data.

The data of Table III show the particle-size distribution of the aerosol at each station as per cent less than stated size. The particle-size distribution on each side of the blower, the heating coil, the spray washer, the capillary washer, and the entire system are plotted as log-probability graphs in Figures 7 through 11.

Table IV gives the average of light-scattering meter readings for samples from each impactor adjusted to show the change in gross concentration from one station to the next.

The data of Table IV were used to plot the block diagrams in Figures 12 and 13. These block diagrams show the change in particle-size distribution and concentration caused by the blower and by the entire system. Graphs were drawn only for the components which had a pronounced effect on the aerosol.

System I, 1200 cu ft per minute

The results of this study are given in Tables V and VI and in the graphs of Figures 14 through 20. In general, the results are similar to the corresponding results for the 800 cfm study, but the effects are more pronounced.

Table V gives the averages of the light-scattering meter readings normalized to a basis of 100 per cent for the raw smoke. As before, the data show the particle-size distributions at the various stations as per cent less than stated size. Figures 14 through 18 show the change in size distribution caused by the blower, the heating coil, the spray washer, the capillary washer, and the entire system.

Table VI gives the averages of the light-scattering meter readings adjusted to show the change in gross concentration from one station to the next. These data were used to plot the block diagrams of Figures 19 and 20. These block diagrams show the change in particle-size distribution and concentration caused by the blower and by the entire system.

TABLE V. System I, 1200 cfm: Effect of Components on Particle-Size Distribution (Normalized for 100 per cent Raw Smoke).

Station	Raw Smoke	Imp 1	Imp 2	Imp 3	Imp 4	Imp 5	Imp 6	Station location and condition
1	100	80	71	60	49	22	4	Incoming aerosol
2	100	90	82	74	63	28	5	After blower
3	100	94	92	86	74	39	5	After blower plus heater (cold) 62 degrees Fahrenheit
3	100	94	89	88	72	33	6	After blower plus heater (hot) 119 degrees Fahrenheit
3	100	84	80	72	66	28	4	After blower plus dummy heater
4	100	98	92	86	71	34	4	After spray washer, dry
4	100	90	88	83	73	46	5	After spray washer, filled, no spray
4	100	87	89	82	71	35	5	After spray washer, spray on
5	100	97	93	88	80	39	7	After elbow after spray washer
6	100	98	100	99	94	48	10	After capillary washer, dry
6	100	96	96	96	90	54	12	After capillary washer, wet
7	100	98	96	100	94	45	7	After elbow after capillary washer
8	100	100	100	98	95	47	10	After straight duct, 8 ft
9	100	98	94	93	89	44	10	After orifice plate
10	100	98	98	98	94	48	10	After splitter elbow
11	100	93	90	95	100	50	8	After vaned turn
12	100	98	95	98	90	44	8	After entire system

Imp = Impactor

TABLE VI. System I, 1200 cfm: Effect of Components on Particle-Size Distribution (Relative to Original Aerosol).

Station	Raw Smoke	Imp 1	Imp 2	Imp 3	Imp 4	Imp 5	Imp 6	Station location and condition
1	100	80	71	60	49	22	4	Incoming aerosol
2	70	64	58	52	44	20	4	After blower
2	70	63	56	50	42	19	4	After blower (dummy heater)
3	56	52	51	48	41	21	3	After blower plus heater (cold) 62 degrees Fahrenheit
3	58	55	52	51	42	19	4	After blower plus heater (hot) 119 degrees Fahrenheit
3	73	61	58	52	48	20	3	After blower plus dummy heater
4	52	50	47	44	36	17	2	After spray washer, dry
4	57	51	50	47	41	26	3	After spray washer, filled, no spray
4	50	44	45	41	36	18	3	After spray washer, spray on
5	51	49	47	45	40	20	4	After elbow after spray washer
6	42	42	42	42	40	20	4	After capillary washer, dry
6	43	41	41	41	38	24	4	After capillary washer, wet
7	47	46	46	47	44	21	4	After elbow after capillary washer
8	49	49	49	48	47	23	5	After straight duct, 8 ft
9	53	52	50	49	48	24	5	After orifice plate
10	49	48	48	48	46	23	5	After splitter elbow
11	49	46	44	47	49	25	4	After vaned turn
12	46	45	44	45	41	20	4	After entire system

Imp = Impactor

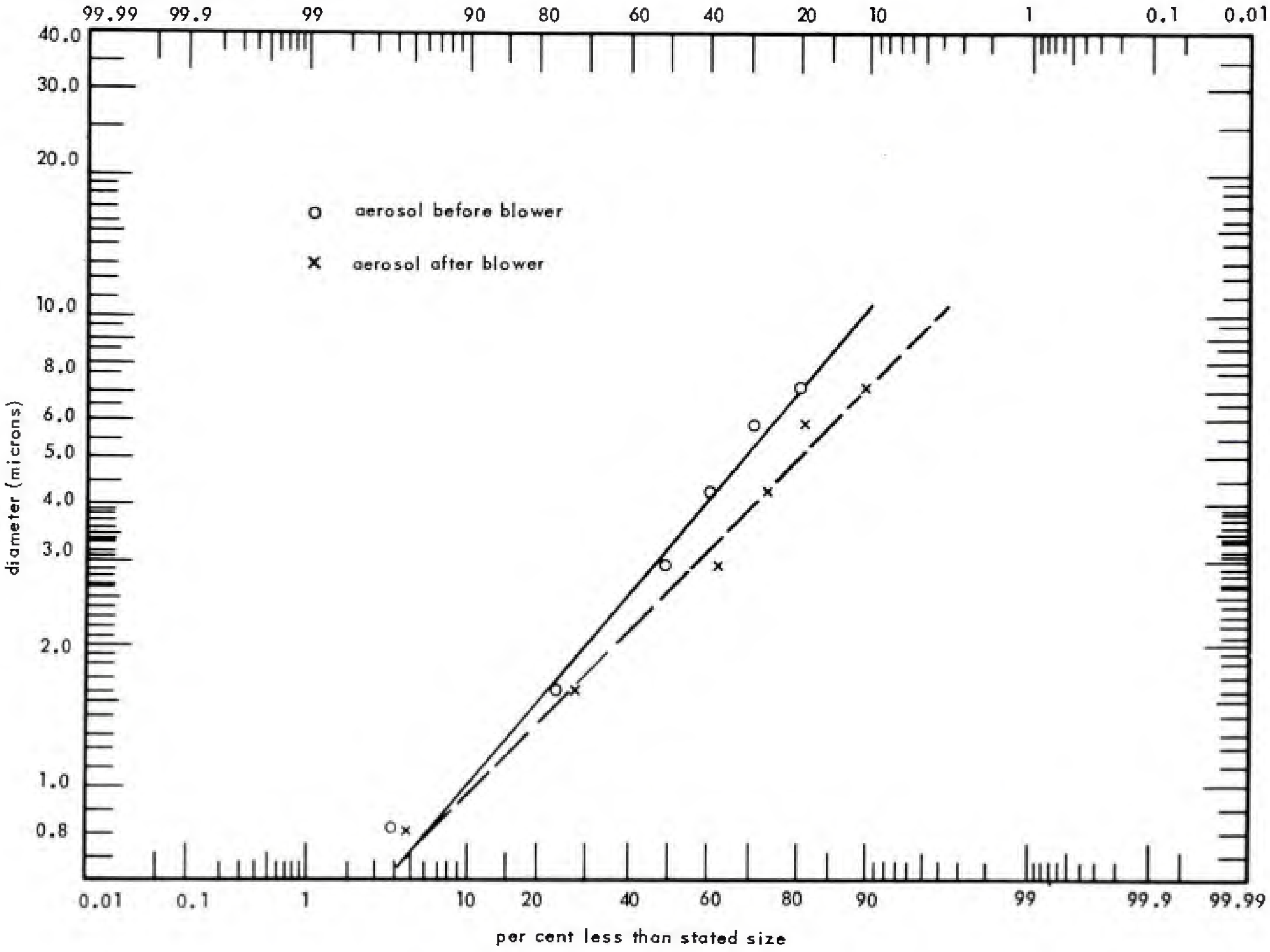


Figure 14. Effect of centrifugal blower on particle-size distribution (1200 cfm).

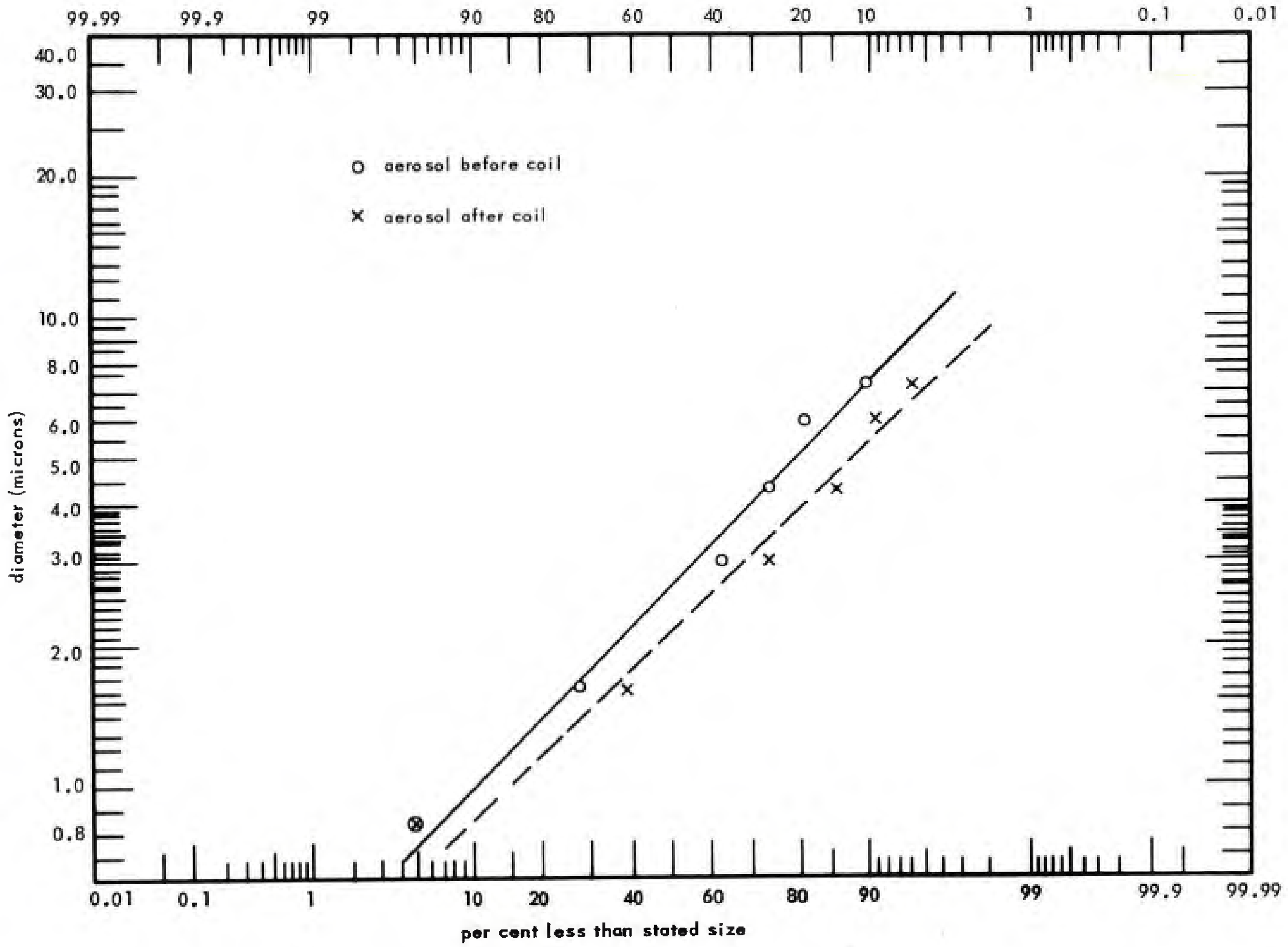


Figure 15. Effect of heating coil on particle-size distribution (1200 cfm).

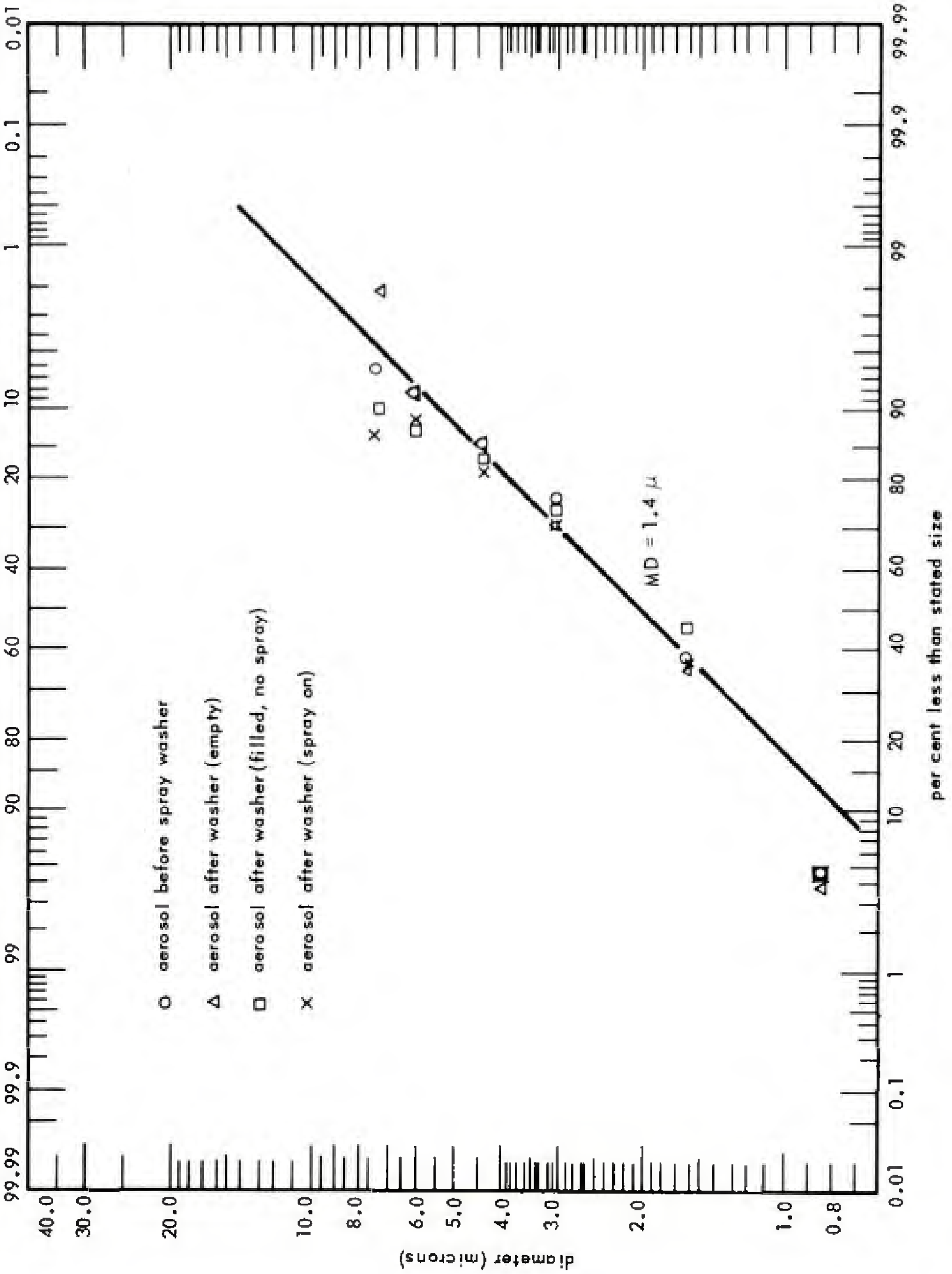


Figure 16. Effect of spray washer on particle-size distribution (1200 cfm).

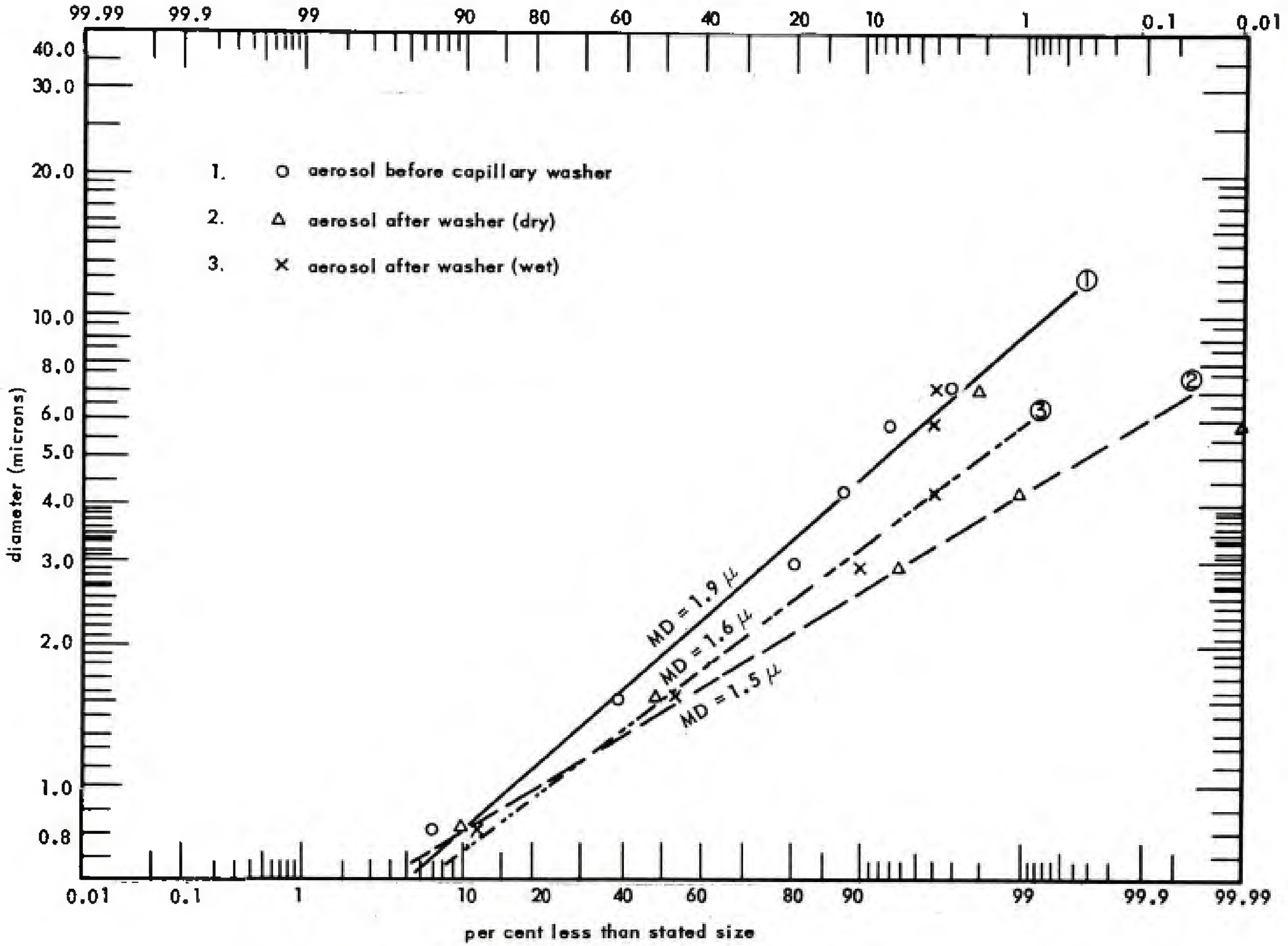


Figure 17. Effect of capillary washer on particle-size distribution (1200 cfm).

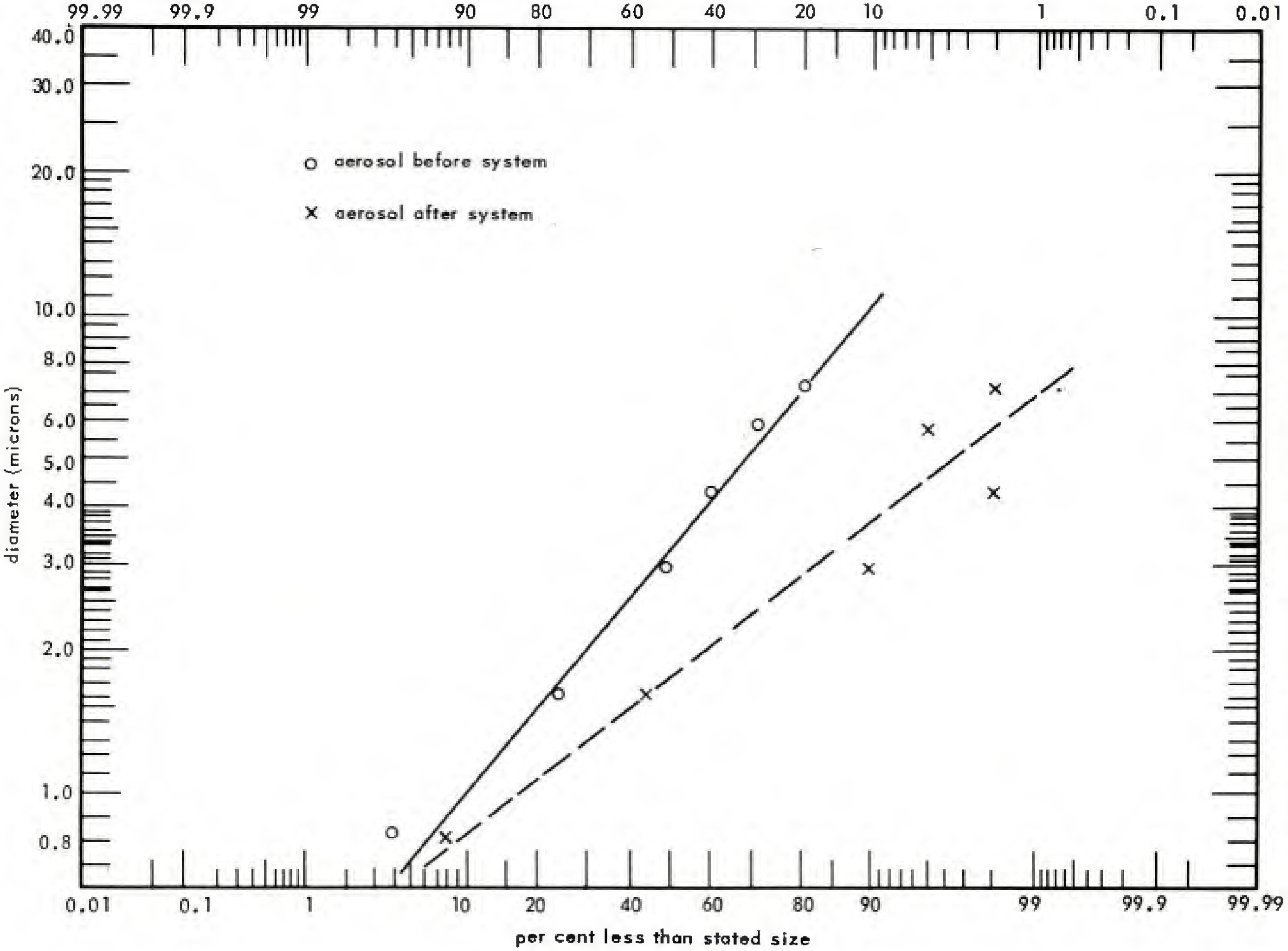


Figure 18. Effect of entire system (1) on particle-size distribution (1200 cfm).

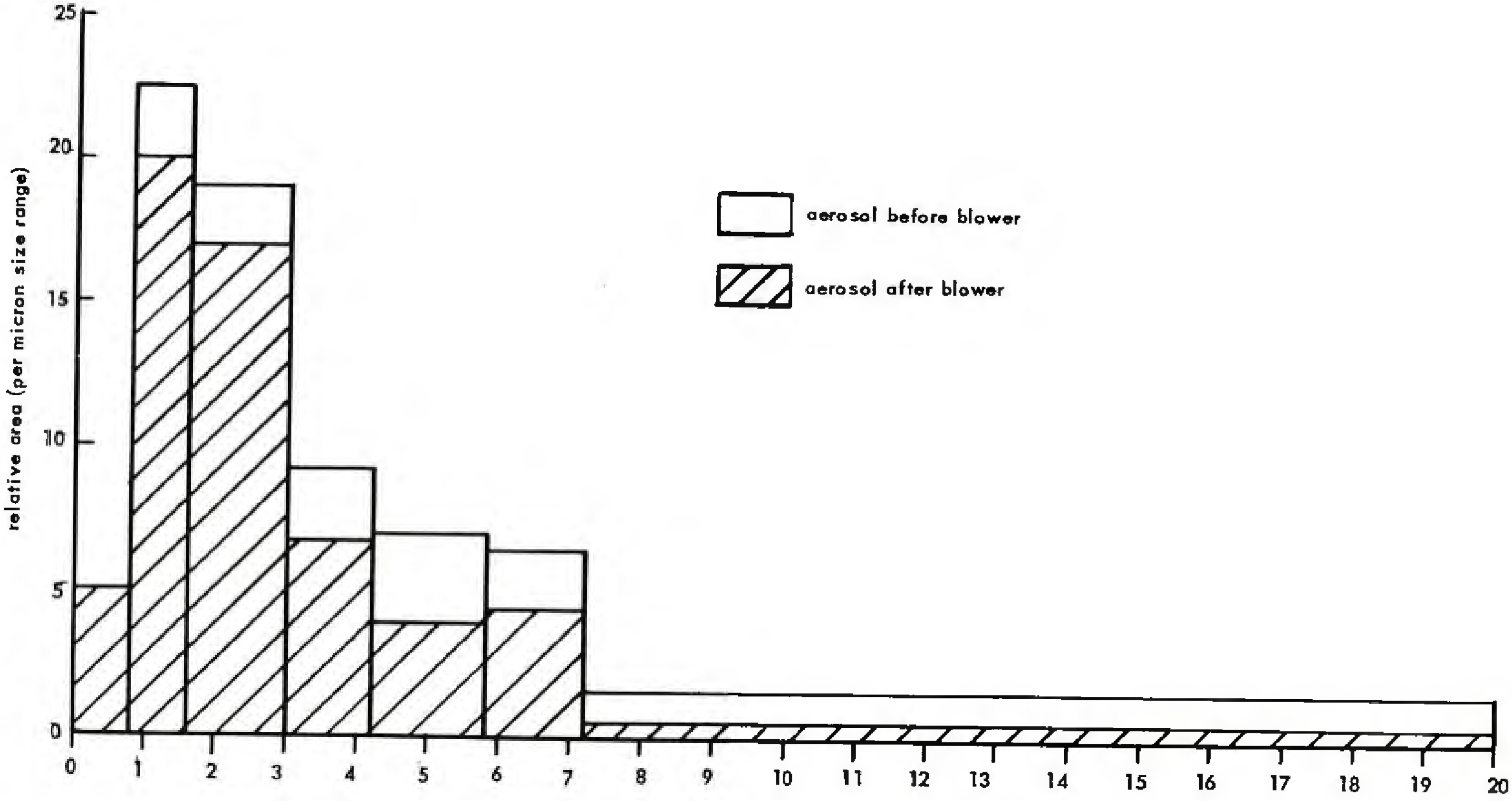


Figure 19. Effect of centrifugal blower on particle-size distribution and concentration (1200 cfm).

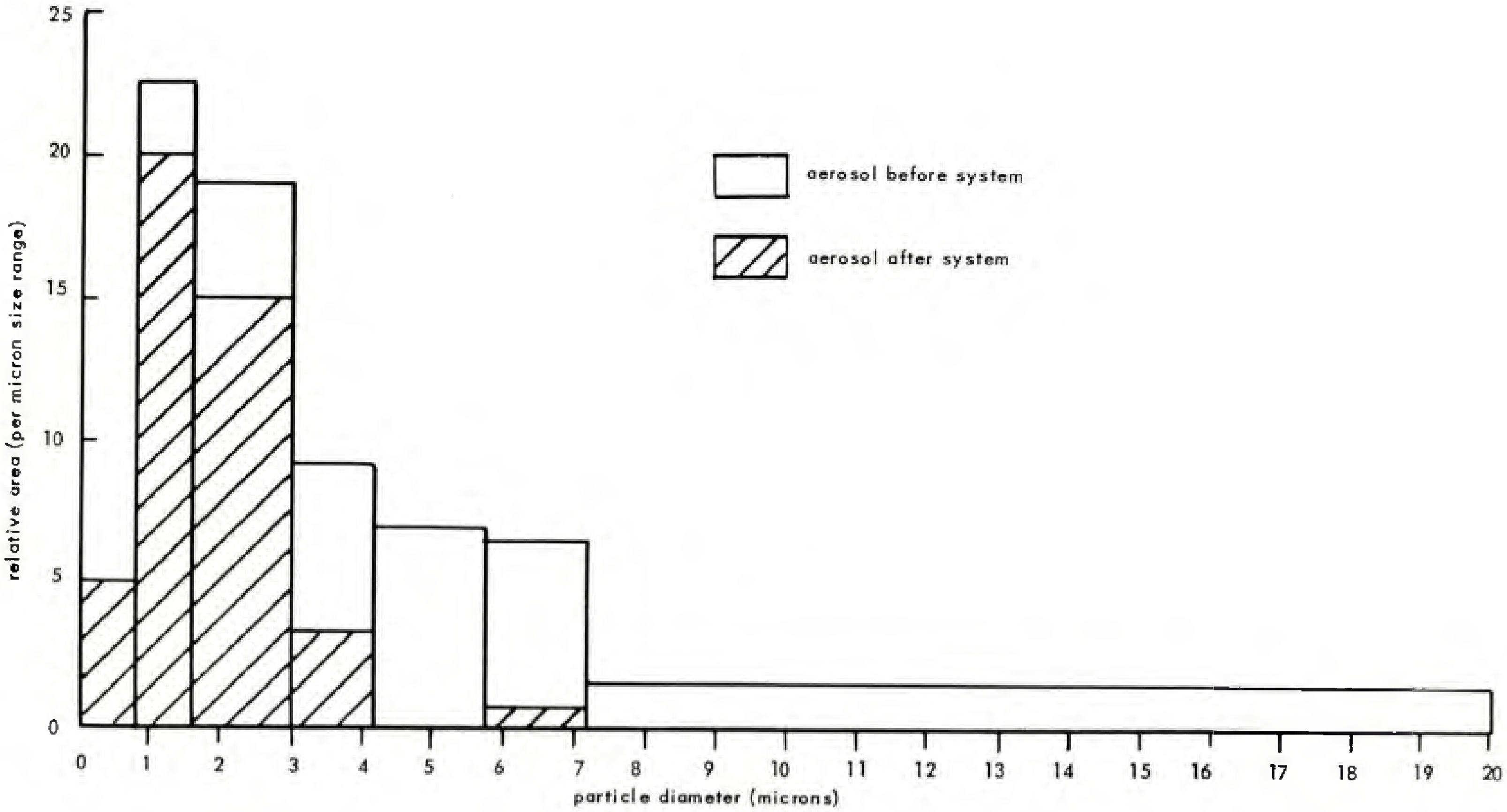


Figure 20. Effect of entire system (1) on particle-size distribution and concentration (1200 cfm).

The results of the studies at 800 and 1200 cfm were similar; the effects noted at 1200 cfm were more pronounced, however, than those at 800 cu ft per minute.

At both air speeds there was a progressive lowering of the median diameter of the aerosol. In both cases, the blower had the greatest effect; it removed 22 per cent of the total at 800 cfm and 30 per cent at 1200 cu ft per minute. This was attributed both to the centrifuging action and to the 90 degree turn in the air path. The heating coil removed 15 per cent at 800 cfm and 20 per cent at 1200 cu ft per minute. It made no difference whether or not the coil was heated. The spray washer removed none at 800 cfm and 10 per cent at 1200 cu ft per minute. The capillary washer removed 10 per cent at 800 cfm and 16 per cent at 1200 cu ft per minute. The system as a whole, including the blower, removed 45 per cent of the total at 800 cfm and 54 per cent at 1200 cu ft per minute. The median diameter of the original aerosol was 3.4 microns; passing through the system lowered the median diameter to 1.9 microns.

No measurable effects were noted for the other components of this system. The blower, being first in the system, so altered the aerosol that there were few large particles left to test the subsequent components.

RESULTS: SYSTEM II COMPONENTS

The results of the study on the System II components are given in Tables VII and VIII and are shown in the graphs of Figures 21 through 50. Each test component under study was inserted into the system near the intake, where it would be free from interference by other components.

Table VII gives the averages of the light-scattering meter readings for samples from each of the six impactors normalized to a basis of 100 per cent for the raw smoke. The last column indicates the location of the sampling stations and the conditions of operation.

The data of Table VII show the particle-size distributions as per cent less than stated size; the particle-size distributions are shown as log-probability plots in Figures 21 through 41.

Table VIII gives the averages of the light-scattering meter readings for the samples from each impactor adjusted for the change in gross concentration from one station to the next.

TABLE VII. System II: Effect of Components on Particle-Size Distribution (Normalized for 100 per cent Raw Smoke).

Station	Raw Smoke	Imp 1	Imp 2	Imp 3	Imp 4	Imp 5	Imp 6	Station location and condition
(Mushroom inlet at 1250 cfm)								
1	100	83	75	59	49	23	5	Incoming aerosol (plenum)
2a	100	81	72	60	45	22	4	After mushroom (straight probe)
3	100	84	74	57	46	22	4	After mushroom plus elbow (straight probe)
2b	100	72	67	53	40	--	--	After mushroom plus elbow (90 degrees probe)
(Mushroom inlet at 2500 cfm)								
1	100	83	75	62	49	24	4	Incoming aerosol (plenum)
2a	100	74	64	51	40	19	4	After mushroom (straight probe)
2b	100	70	60	48	36	21	2	After mushroom plus elbow (90 degrees probe)
2b	100	76	67	55	43	--	--	After elbow only, mushroom removed (90 degrees probe)
(27M Reheater coil 1250 cfm)								
2b	100	71	61	48	42	21	3	Incoming aerosol
3	100	81	71	56	49	23	3	After coil, no heat, 61 degrees Fahrenheit
3	100	86	85	94	71	47	18	After coil, heated to 99 degrees Fahrenheit

TABLE VII. System II: Effect of Components on Particle-Size Distribution (Normalized for 100 per cent Raw Smoke). (Continued)

Station	Raw Smoke	Imp 1	Imp 2	Imp 3	Imp 4	Imp 5	Imp 6	Station location and condition
(27M Reheater coil, 2500 cfm)								
2b	100	61	52	38	34	19	2	Incoming aerosol
3	100	80	74	55	46	26	2	After coil, no heat, 60 degrees Fahrenheit
3	100	83	76	68	52	26	5	After coil, heated to 88 degrees Fahrenheit
(26H Preheater coil, 1250 cfm)								
1	100	82	75	65	50	23	3	Incoming aerosol (plenum)
2b	100	72	69	58	44	20	3	After coil, no heat
(A-1 Blower, 1250 cfm)								
2b	100	71	63	50	39	16	2	Incoming aerosol
3	100	94	88	74	66	27	3	After blower
(A-2 Blower, 2500 cfm)								
2b	100	64	53	43	34	13	2	Incoming aerosol
3	100	86	80	71	55	23	3	After blower
(44DF cooling coil, 1250 cfm)								
2b	100	75	68	51	41	17	3	Incoming aerosol
3	100	92	89	74	62	23	3	After coil, no cooling, 54 degrees Fahrenheit
3	100	93	89	77	63	24	6	After coil, cool to 40 degrees Fahrenheit

TABLE VII. System II: Effect of Components on Particle-Size Distribution (Normalized for 100 per cent Raw Smoke). (Continued)

Station	Raw Smoke	Imp 1	Imp 2	Imp 3	Imp 4	Imp 5	Imp 6	Station location and condition
(44DF cooling coil, 2500 cfm)								
2b	100	64	57	43	33	12	1	Incoming aerosol
3	100	96	94	86	66	28	3	After coil, no cooling 56 degrees Fahrenheit
3	100	96	92	89	74	29	3	After coil, cool to 48 degrees Fahrenheit
(Elbows at 1250 cfm, straight probes)								
3	100	82	74	61	50	23	5	Incoming aerosol
4	100	87	77	61	50	22	4	After 18 in. plain elbow
4	100	88	74	59	46	21	2	After 12 in. plain elbow
4	100	83	77	62	53	24	7	After 12 in. splitter elbow
4	100	87	77	65	54	26	6	After vaned turn
(Elbows at 2500 cfm, straight probes)								
3	100	77	70	57	45	29	6	Incoming aerosol
4	100	80	70	62	48	28	5	After 18 in. plain elbow
4	100	82	72	60	47	32	6	After 12 in. plain elbow
4	100	80	70	56	45	31	6	After 12 in. splitter elbow
4	100	81	72	61	48	29	6	After vaned turn

TABLE VII. System II: Effect of Components on Particle-Size Distribution (Normalized for 100 per cent Raw Smoke). (Continued)

Station	Raw Smoke	Imp 1	Imp 2	Imp 3	Imp 4	Imp 5	Imp 6	Station location and condition
(Elbows at 2500 cfm, 90 degree probes)								
3b	100	71	61	48	38	19	2	Incoming aerosol
3c	100	68	61	44	38	18	2	After 18 in. plain elbow
3c	100	72	66	52	40	21	1	After 12 in. plain elbow
3c	100	75	64	48	38	20	1	After 12 in. splitter elbow
3c	100	65	54	44	34	17	2	After vaned turn
(Filters at 1070 cfm)								
1	100	82	75	65	50	23	3	Incoming aerosol (plenum)
2b	100	100	97	98	92	45	6	After filter pad "A" Pressure drop: 0.15 in. H_2O
2b	100	93	98	83	69	32	2	After filter pad "B" Pressure drop: .09 in. H_2O
2b	100	97	98	88	74	34	5	After filter pad "C" Pressure drop: 0.28 in. H_2O

Imp = Impactor

TABLE VIII. System II: Effect of Components on Particle-Size Distribution (Relative to Original Aerosol).

Station	Raw Smoke	Imp 1	Imp 2	Imp 3	Imp 4	Imp 5	Imp 6	Station location and condition
(Mushroom inlet at 1250 cfm)								
1	100	83	75	59	49	23	5	Incoming aerosol (plenum)
2a	98	79	70	59	44	22	4	After mushroom (straight probe)
3	107	90	79	61	49	23	4	After mushroom plus elbow (straight probe)
2b	130	94	87	69	52	--	--	After mushroom plus elbow (90 degree probe)
(Mushroom inlet at 2500 cfm)								
1	100	83	75	62	49	24	4	Incoming aerosol (plenum)
2a	124	92	80	64	50	24	5	After mushroom (straight probe)
2b	100	70	60	48	36	21	2	After mushroom plus elbow (90 degree probe)
2b	100	76	67	55	43	--	--	After elbow only, mushroom removed (90 degree probe)
(27M reheater coil at 1250 cfm)								
2b	100	71	61	48	42	21	3	Incoming aerosol
3	81	66	57	45	40	19	2	After coil, no heat, 61 degrees Fahrenheit
3	125	110	110	112	89	59	23	After coil, heat on, 99 degrees Fahrenheit

TABLE VIII. System II: Effect of Components on Particle-Size Distribution (Relative to Original Aerosol). (Continued)

Station	Raw Smoke	Imp 1	Imp 2	Imp 3	Imp 4	Imp 5	Imp 6	Station location and condition
(27M reheater coil at 2500 cfm)								
2b	100	61	52	38	34	19	2	Incoming aerosol
3	78	63	58	43	36	20	2	After coil, no heat, 60 degrees Fahrenheit
3	71	59	54	48	37	26	4	After coil heated to 88 degrees Fahrenheit
(26H Preheater coil at 1250 cfm)								
1	100	82	75	65	50	23	3	Incoming aerosol (plenum)
2b	117	84	81	68	52	23	4	After coil, heat off
(A-1 Blower at 1250 cfm)								
2b	100	71	63	50	39	16	2	Incoming aerosol
3	54	51	47	40	36	15	2	After blower
(A-2 Blower at 2500 cfm)								
2b	100	64	53	43	34	13	2	Incoming aerosol
3	61	52	49	43	34	14	2	After blower
(44DF cooling coil at 1250 cfm)								
2b	100	75	68	51	41	17	3	Incoming aerosol
3	64	59	57	47	40	15	2	After coil, no cooling, 54 degrees Fahrenheit
3	64	60	57	49	40	15	4	After coil, cooled, 40 degrees Fahrenheit

TABLE VIII. System II: Effect of Components on Particle-Size Distribution (Relative to Original Aerosol). (Continued)

Station	Raw Smoke	Imp 1	Imp 2	Imp 3	Imp 4	Imp 5	Imp 6	Station location and condition
(44DF cooling coil at 2500 cfm)								
2b	100	64	57	43	33	12	1	Incoming aerosol
3	44	42	41	38	29	12	1	After coil, no cooling, 56 degrees Fahrenheit
3	44	42	40	39	33	13	1	After coil, cooled, 48 degrees Fahrenheit
(Elbows at 1250 cfm, straight probes)								
3	100	82	74	61	50	23	5	Incoming aerosol
4	101	88	78	62	51	22	4	After 18 in. plain elbow
4	98	86	72	58	45	21	2	After 12 in. plain elbow
4	100	83	77	62	53	24	7	After 12 in. splitter
4	100	87	77	65	54	26	6	After vaned turn
(Elbows at 2500 cfm, straight probes)								
3	100	77	70	57	45	29	6	Incoming aerosol
4	84	67	59	52	40	24	4	After 18 in. plain elbow
4	97	79	70	58	46	31	6	After 12 in. plain elbow
4	112	90	78	63	50	35	7	After 12 in. splitter elbow
4	106	86	76	65	51	31	6	After vaned turn

TABLE VIII. System II: Effect of Components on Particle-Size Distribution (Relative to Original Aerosol). (Continued)

Station	Raw Smoke	Imp 1	Imp 2	Imp 3	Imp 4	Imp 5	Imp 6	Station location and condition
(Elbows at 2500 cfm, 90 degree probes)								
3	100	71	61	48	38	19	2	Incoming aerosol
4	95	65	58	42	36	17	2	After 18 in. plain elbow
4	98	70	65	51	39	21	1	After 12 in. plain elbow
4	102	77	66	49	39	20	1	After 12 in. splitter elbow
4	100	65	54	44	34	17	2	After vaned turn
(Filters at 1070 cfm)								
1	100	82	75	65	50	23	3	Incoming aerosol (plenum)
2b	48	48	47	47	44	22	3	After filter pad "A"
2b	68	63	67	56	47	22	1	After filter pad "B"
2b	63	61	62	55	47	21	3	After filter pad "C"

Imp = Impactor

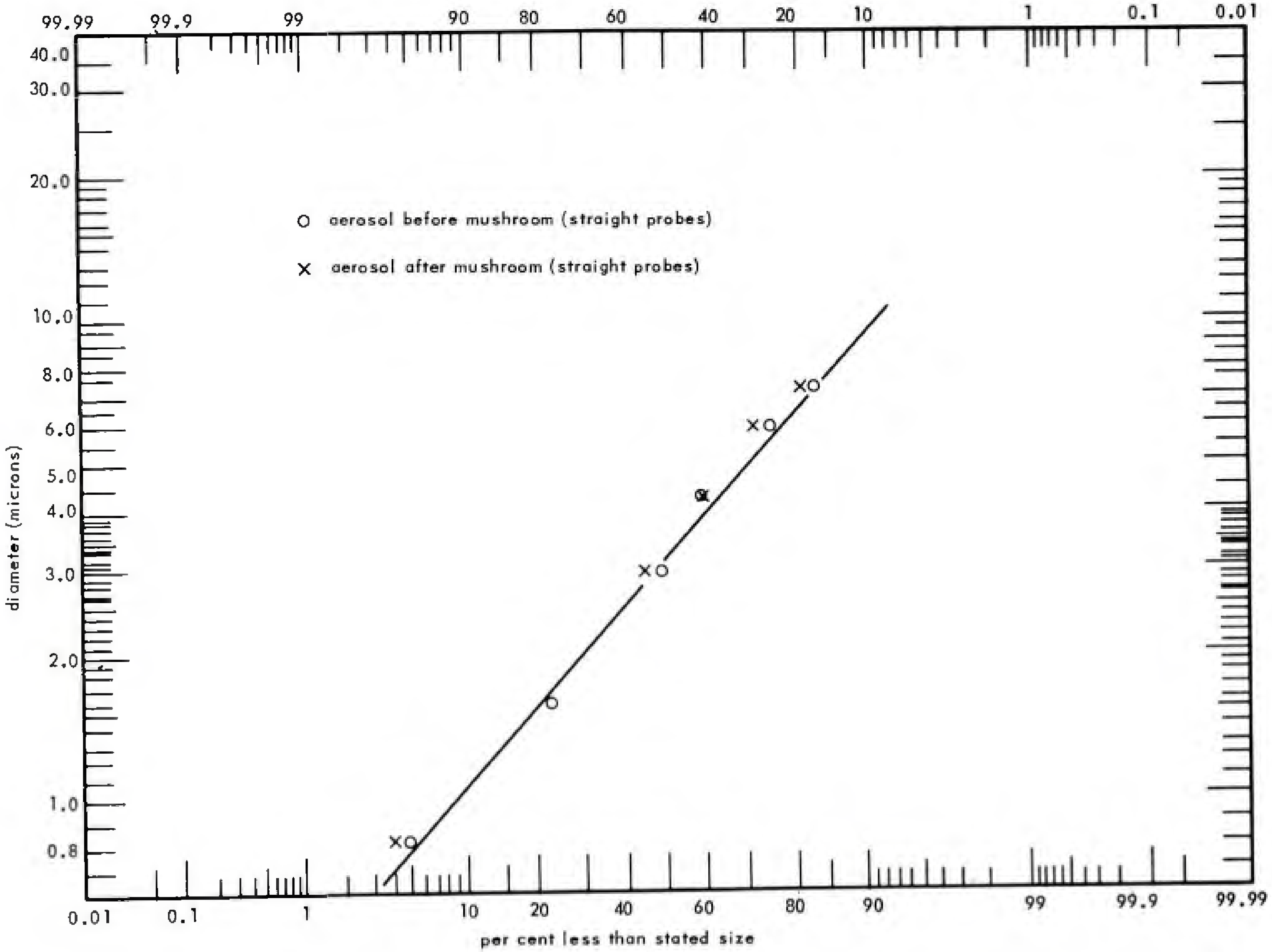


Figure 21. Effect of mushroom inlet on particle-size distribution (1250 cfm).

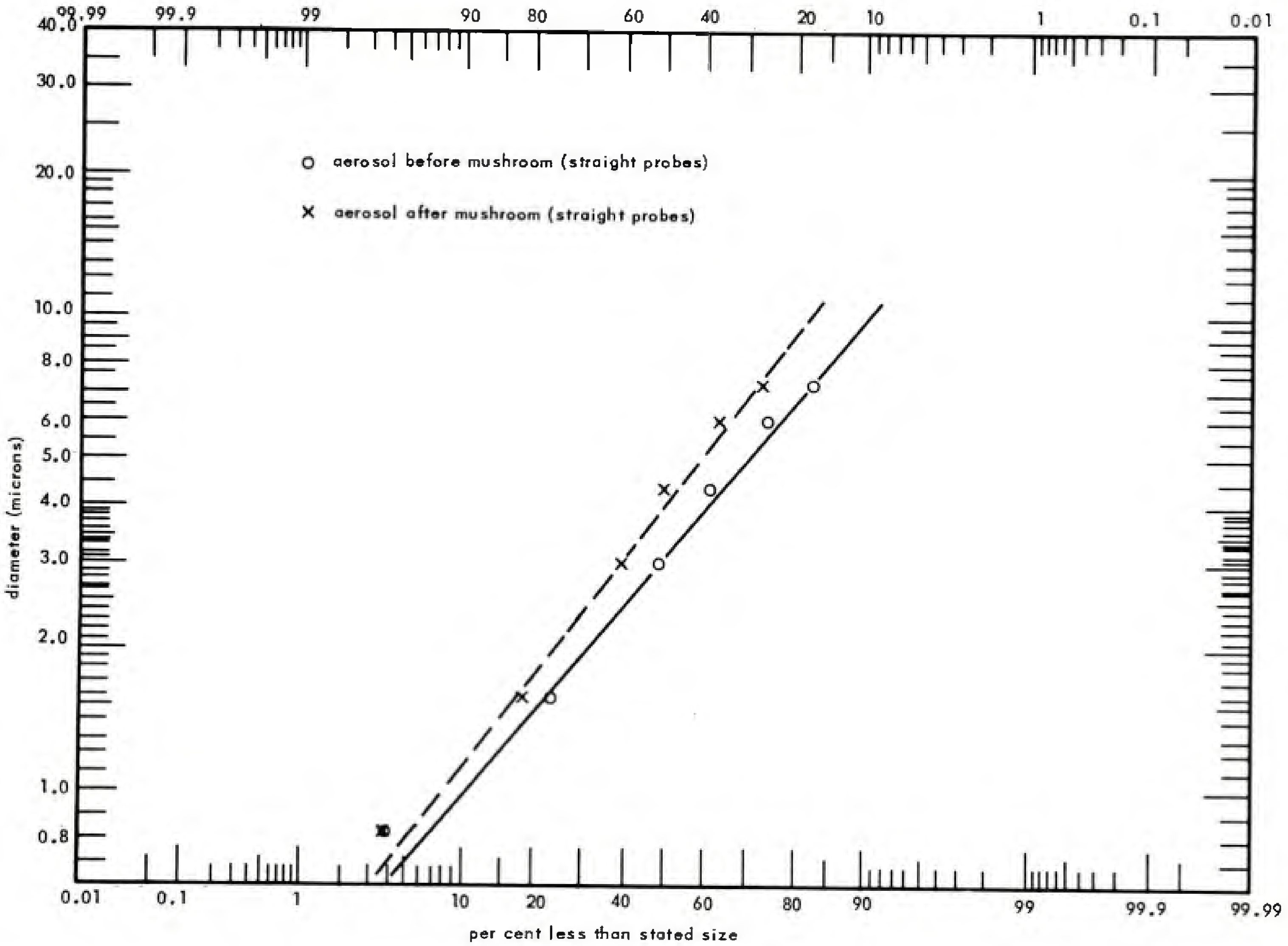


Figure 22. Effect of mushroom inlet on particle-size distribution (2500 cfm).

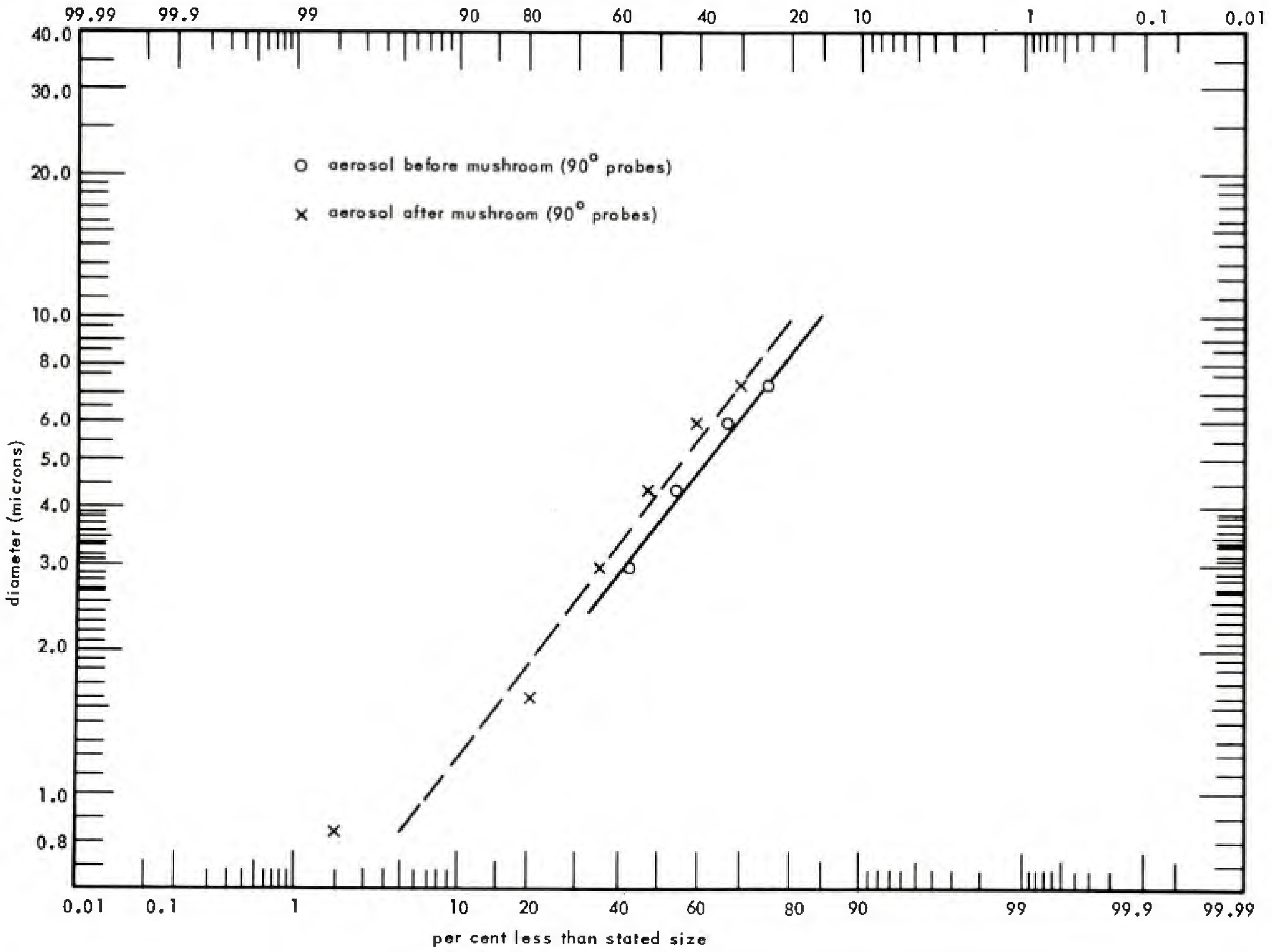


Figure 23. Effect of mushroom inlet on particle-size distribution (2500 cfm).

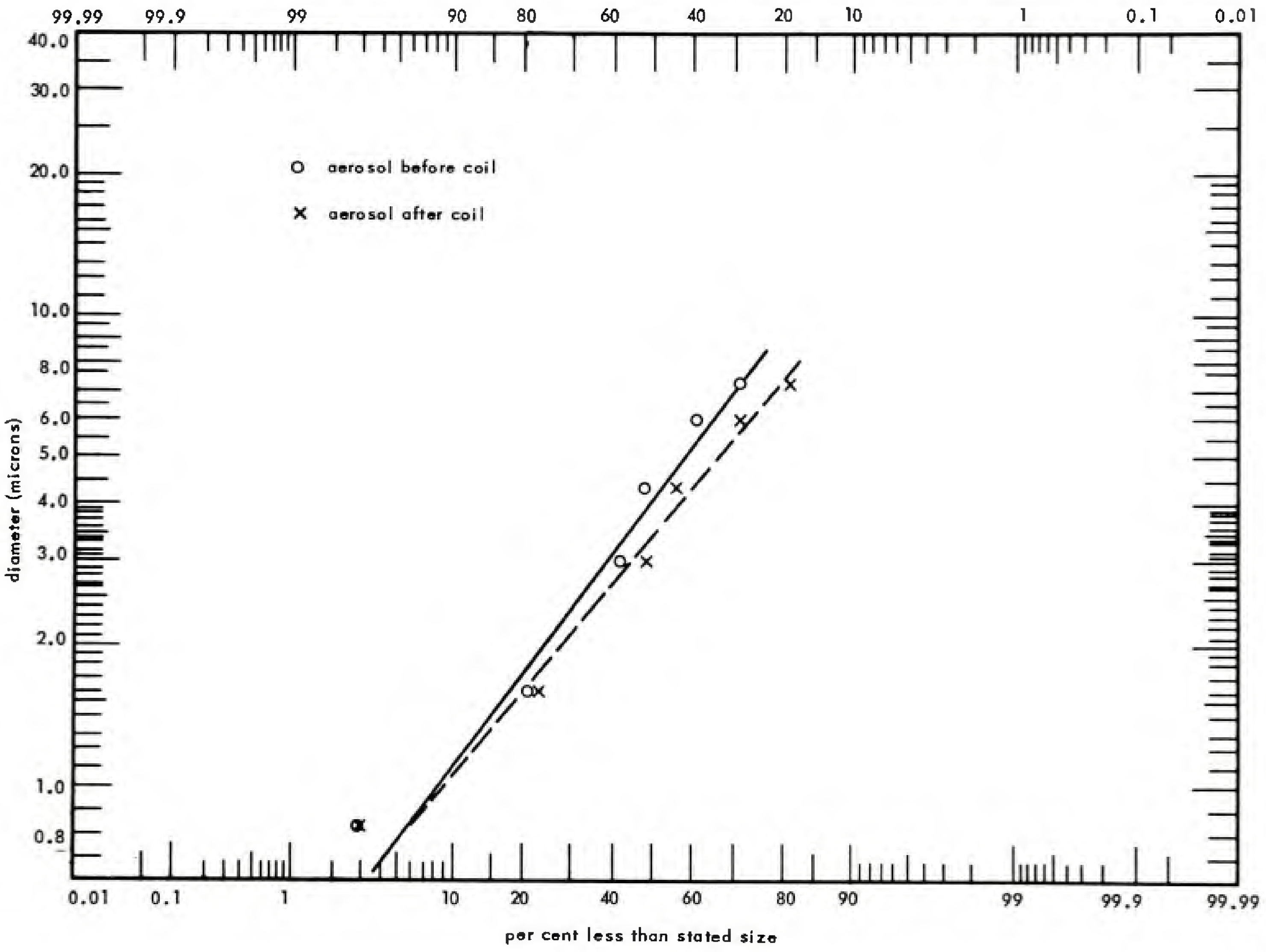


Figure 24. Effect of reheater coil on particle-size distribution (1250 cfm).

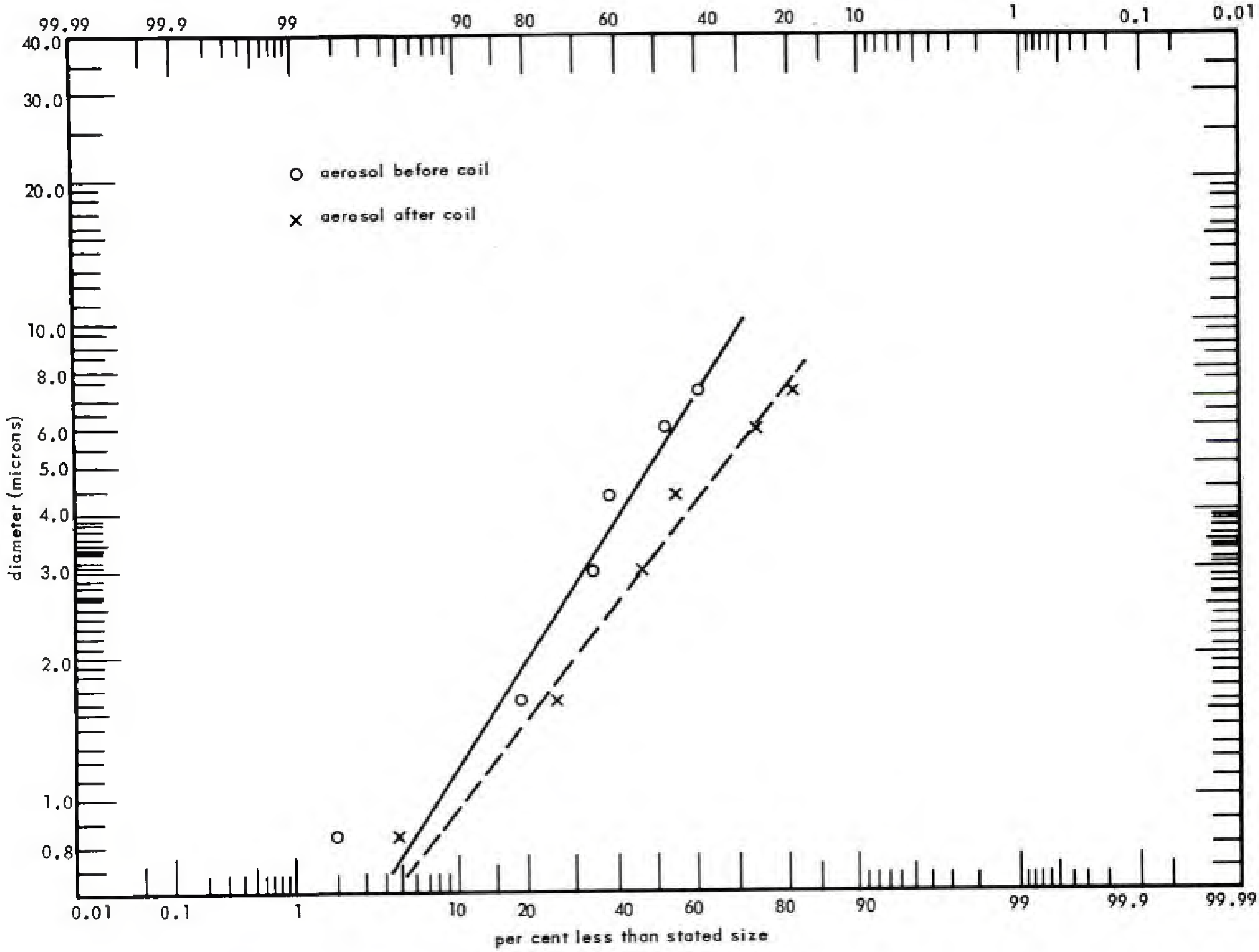


Figure 25. Effect of reheater coil on particle-size distribution (2500 cfm).

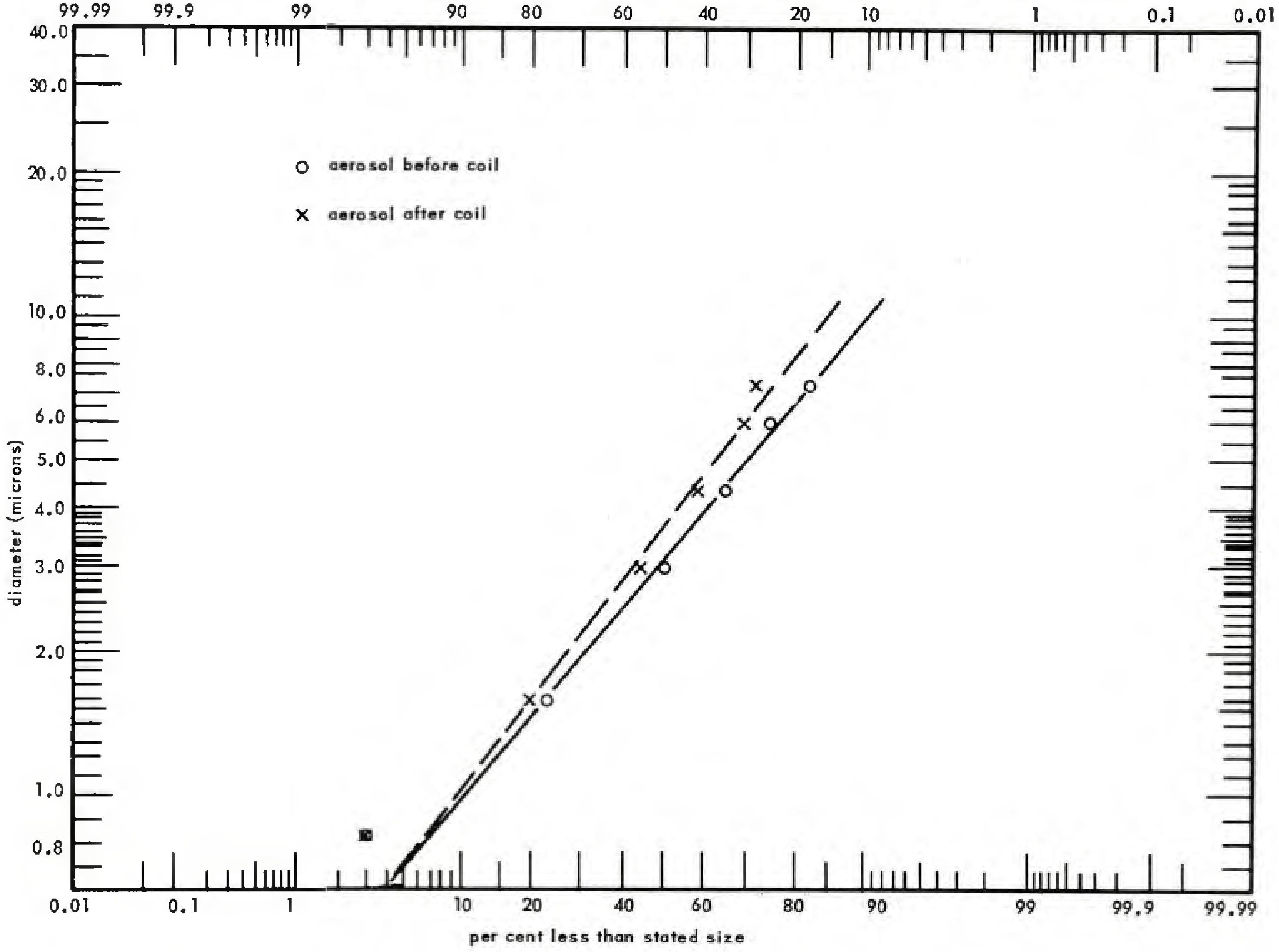


Figure 26. Effect of preheater coil on particle-size distribution (1250 cfm).

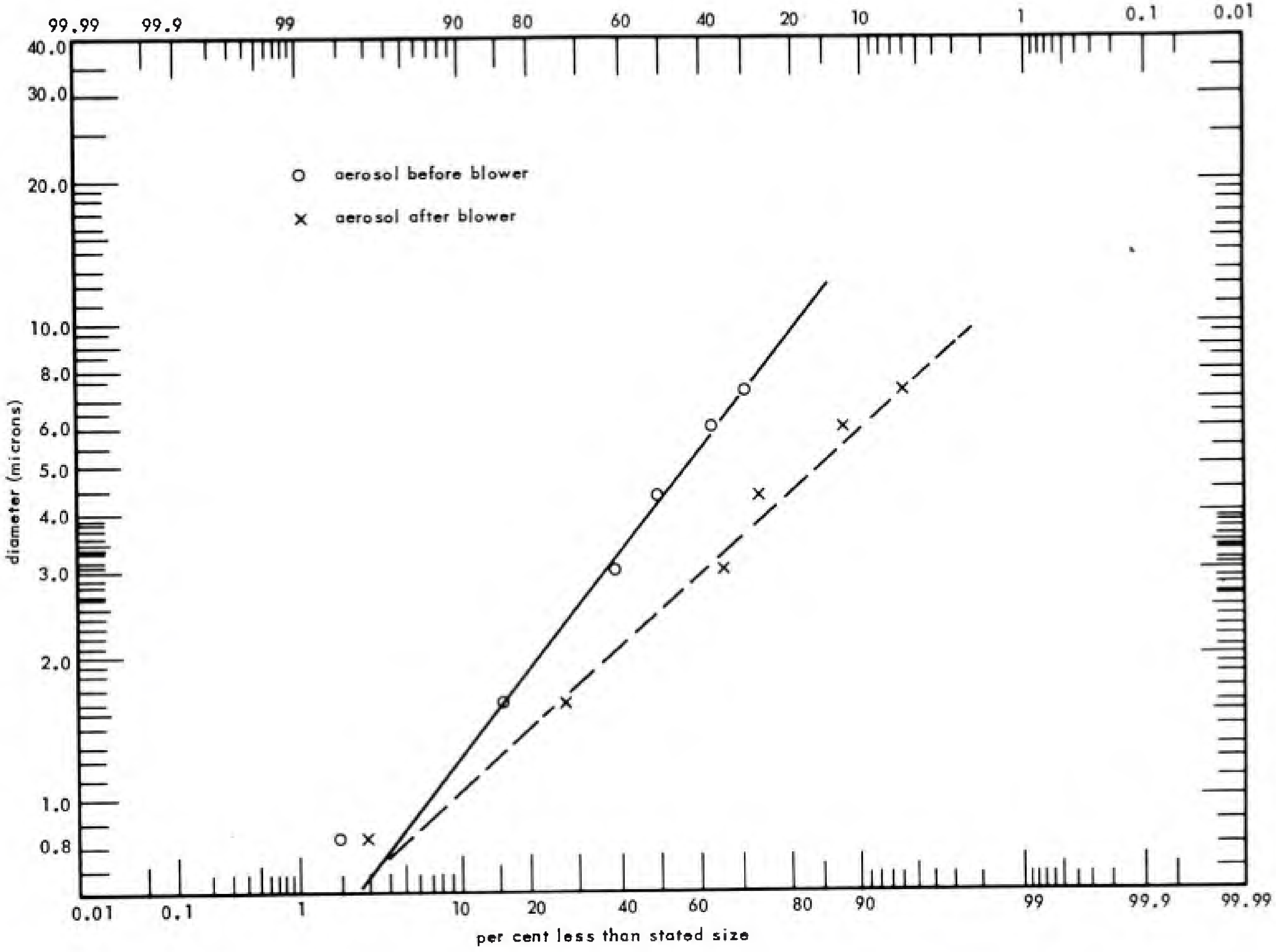


Figure 27. Effect of axivane blower on particle-size distribution (1250 cfm).

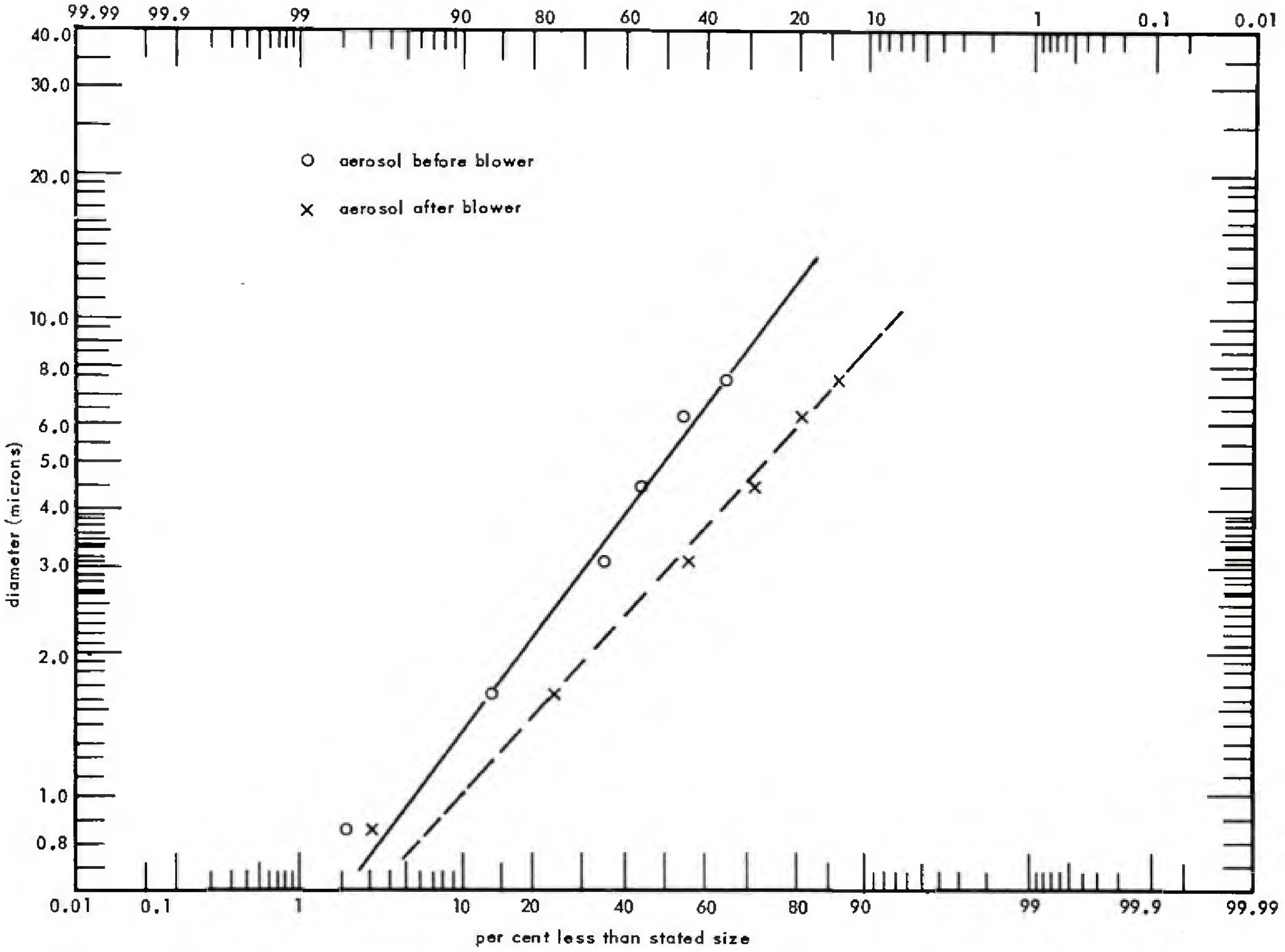


Figure 28. Effect of axivane blower on particle-size distribution (2500 cfm).

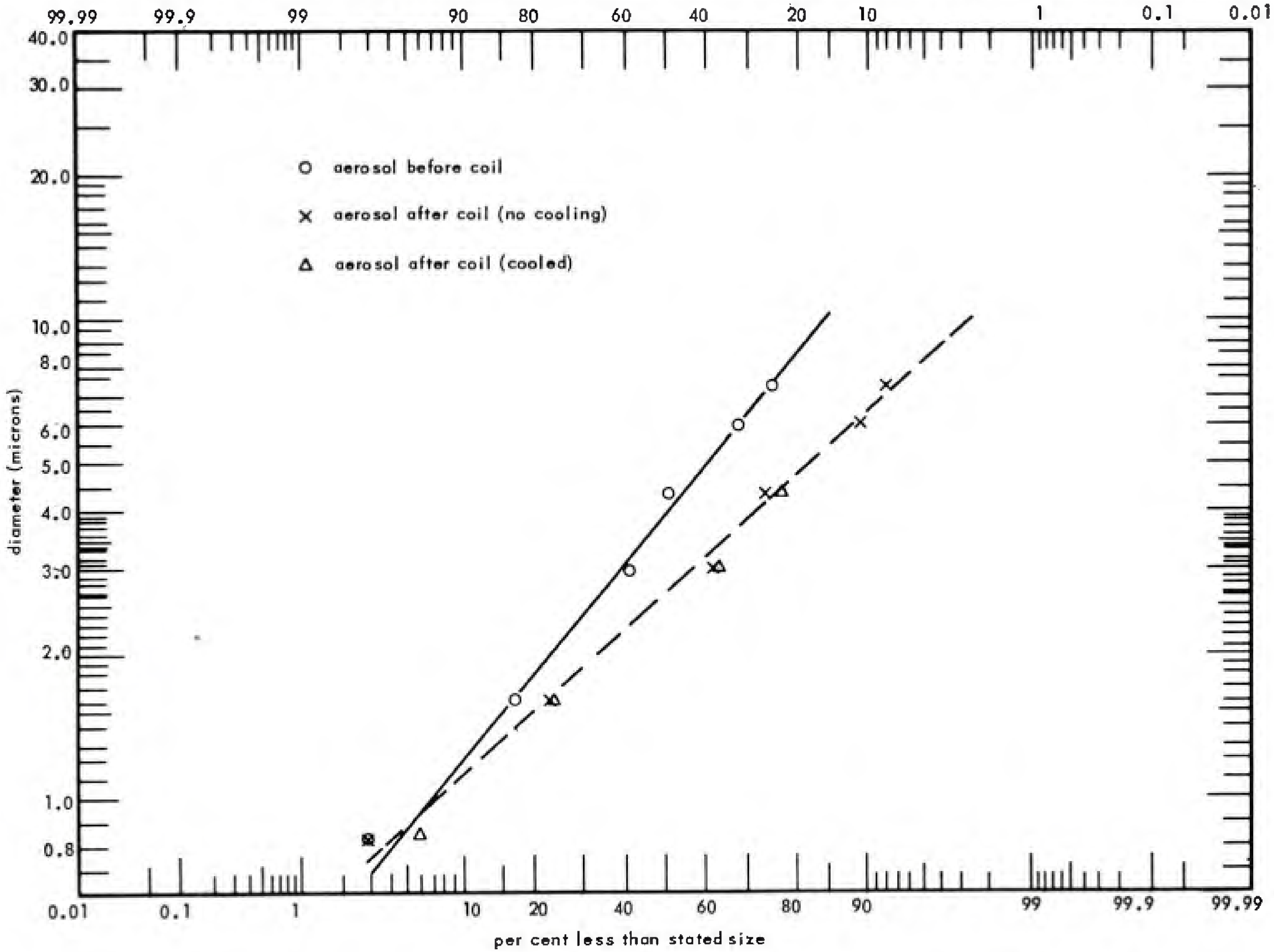


Figure 29. Effect of cooling coil on particle-size distribution (1250 cfm).

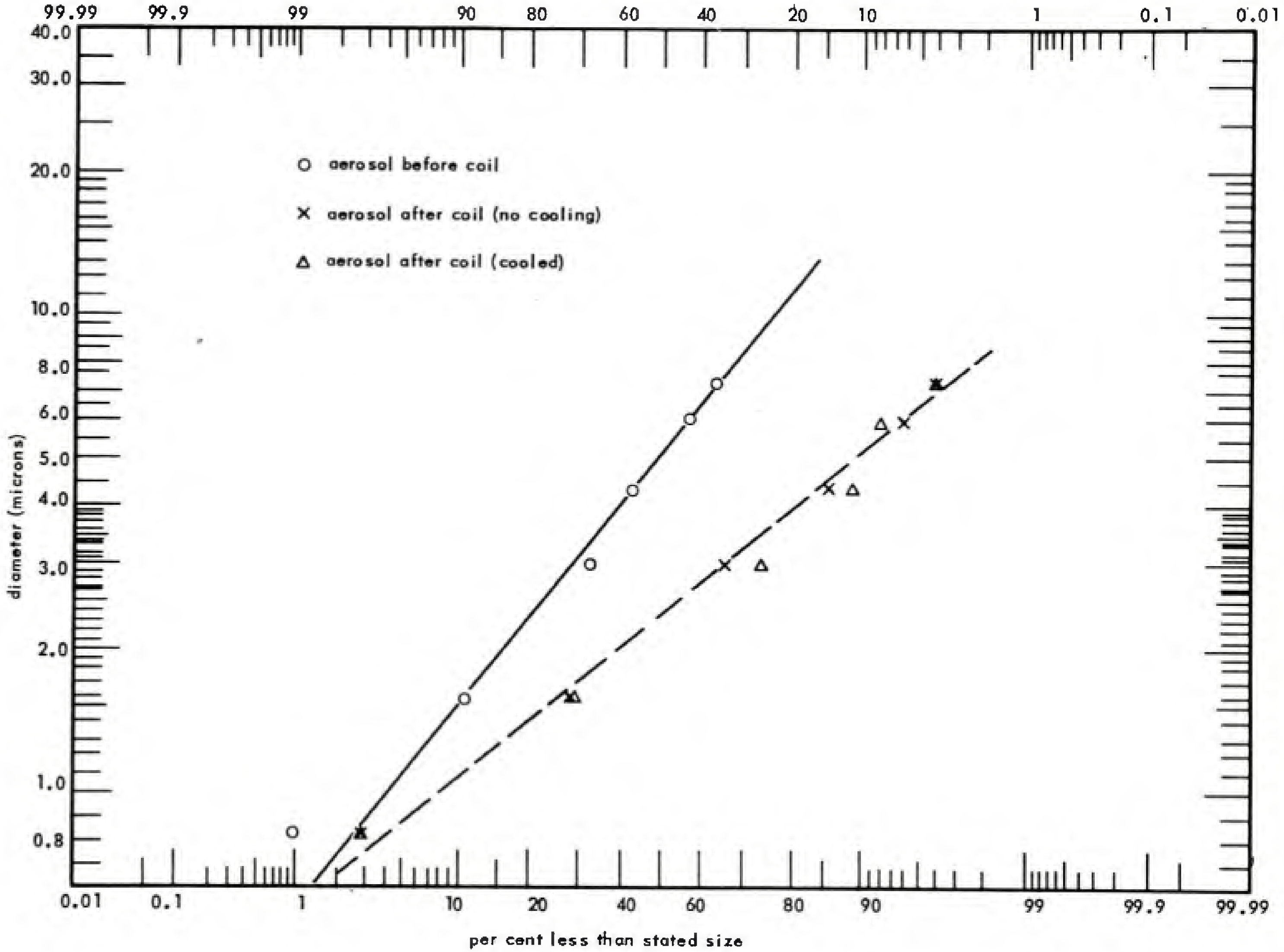


Figure 30. Effect of cooling coil on particle-size distribution (2500 cfm).

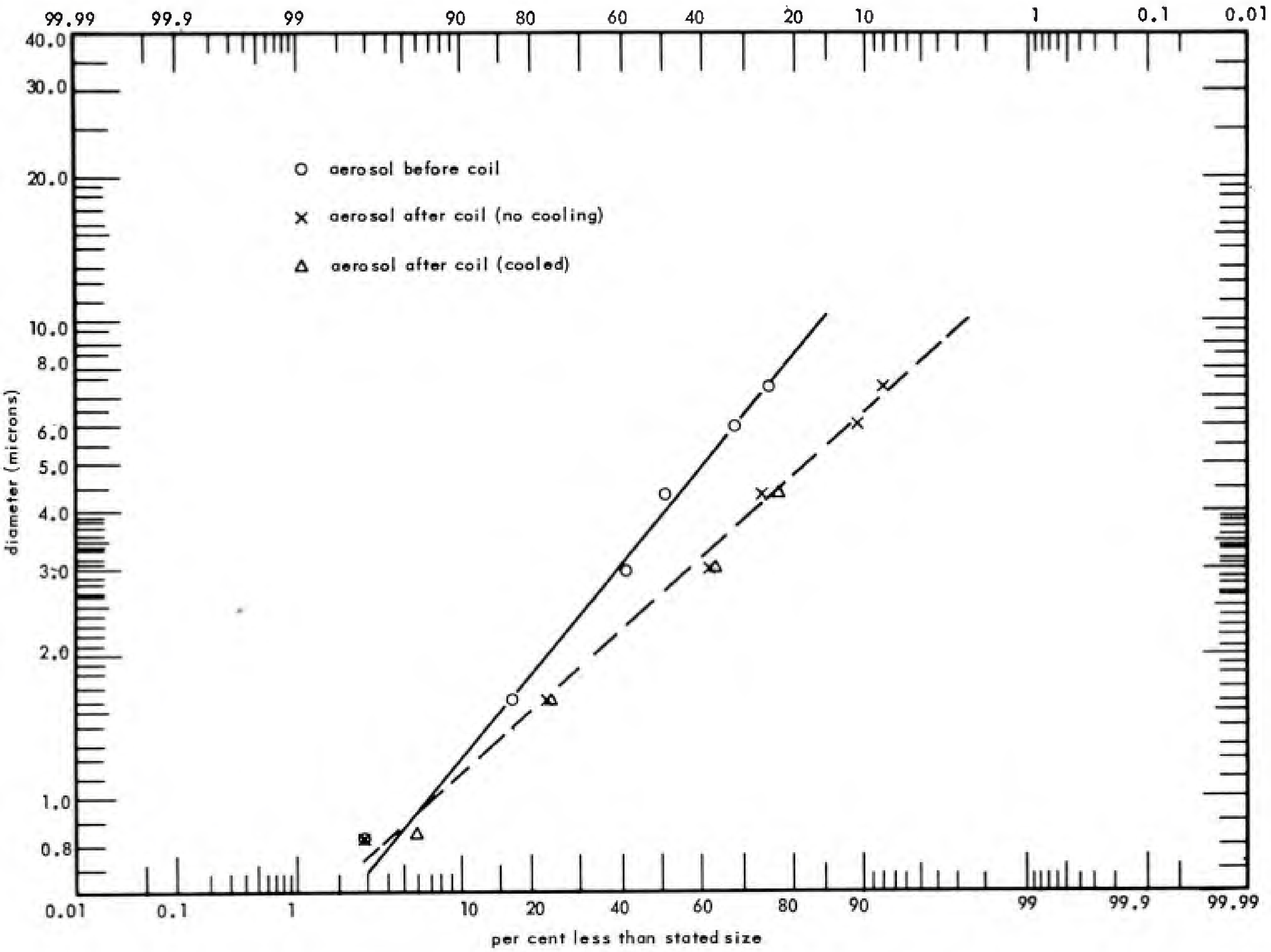


Figure 29. Effect of cooling coil on particle-size distribution (1250 cfm).

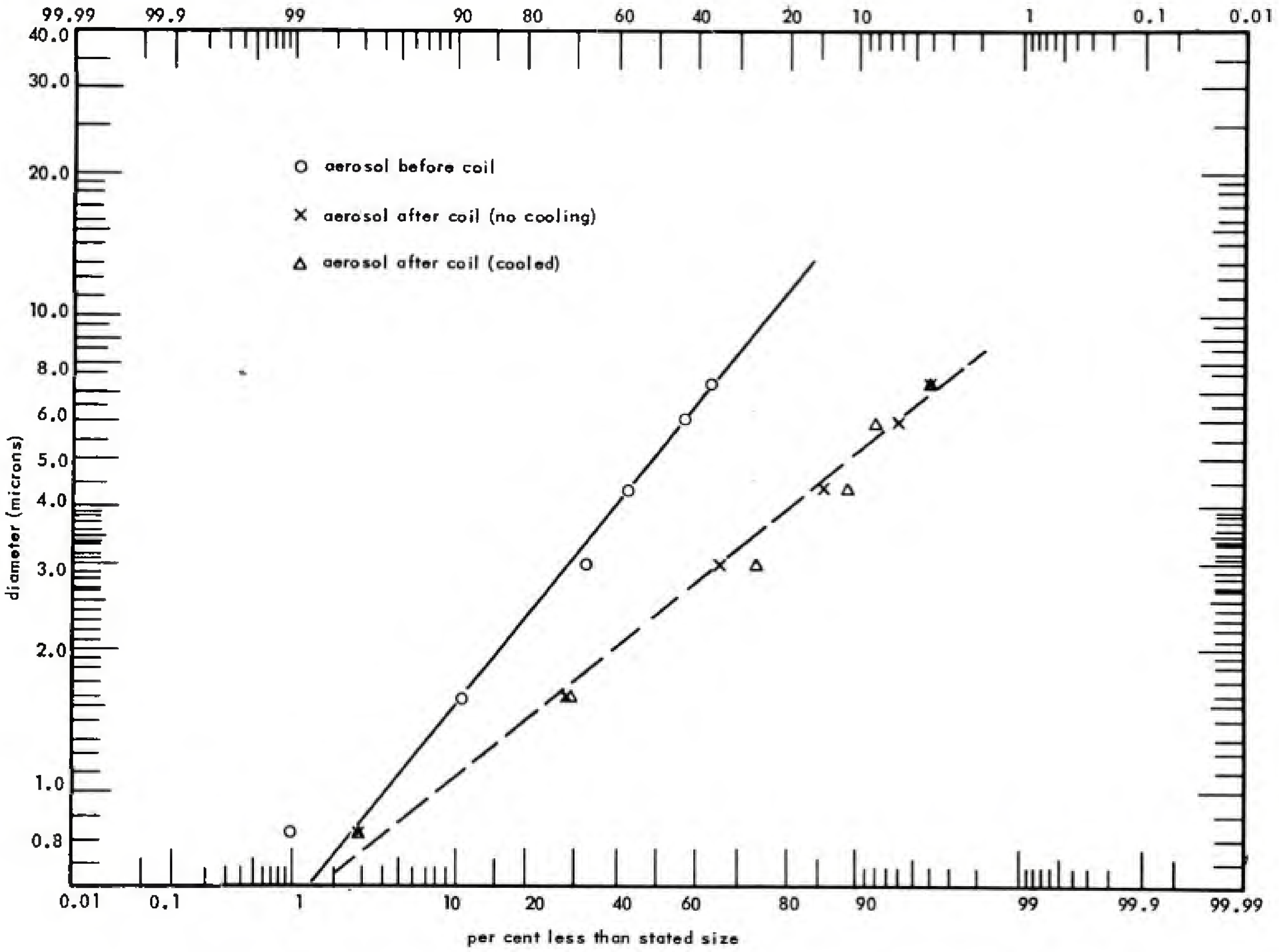


Figure 30. Effect of cooling coil on particle-size distribution (2500 cfm).

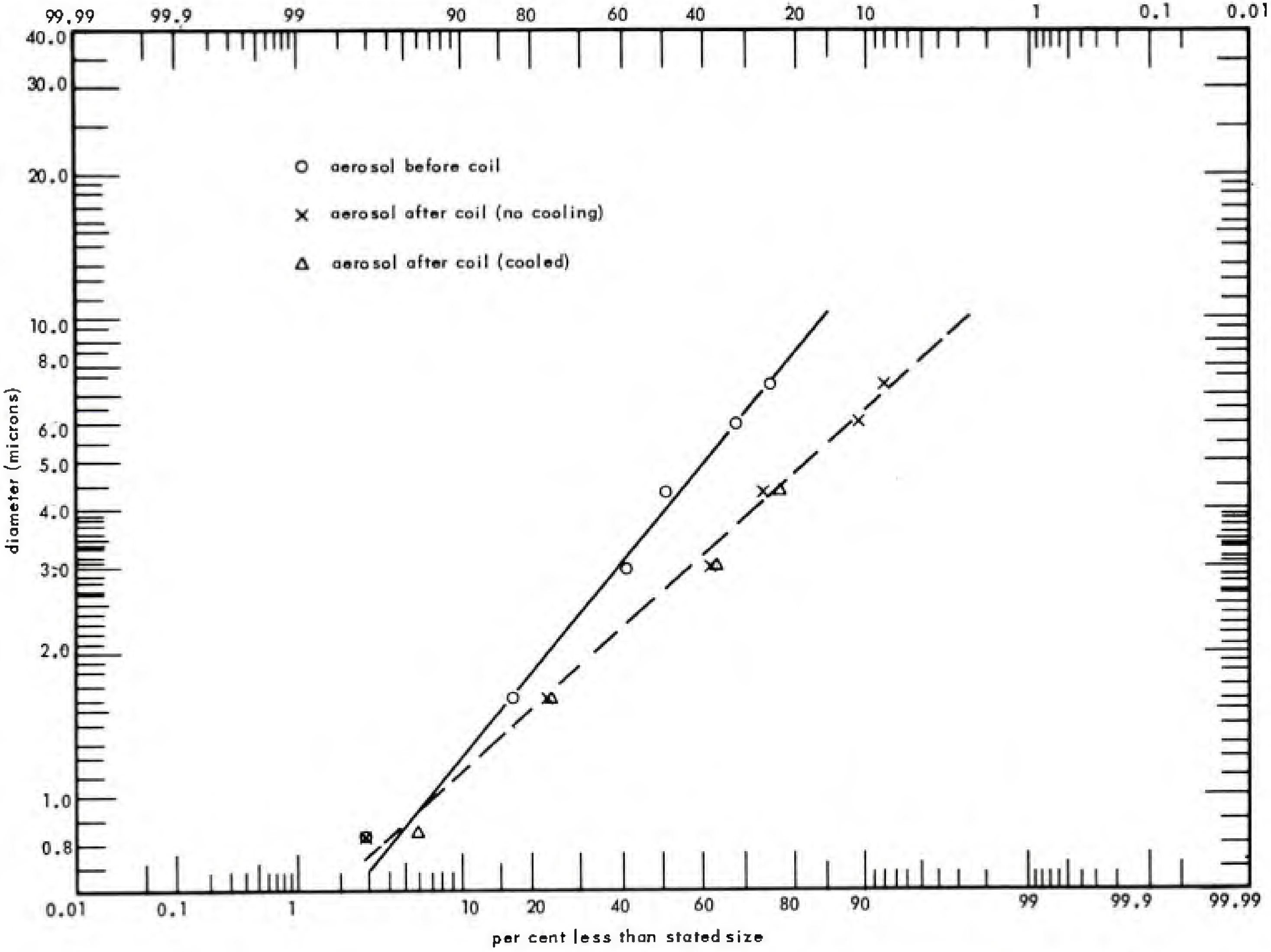


Figure 29. Effect of cooling coil on particle-size distribution (1250 cfm).

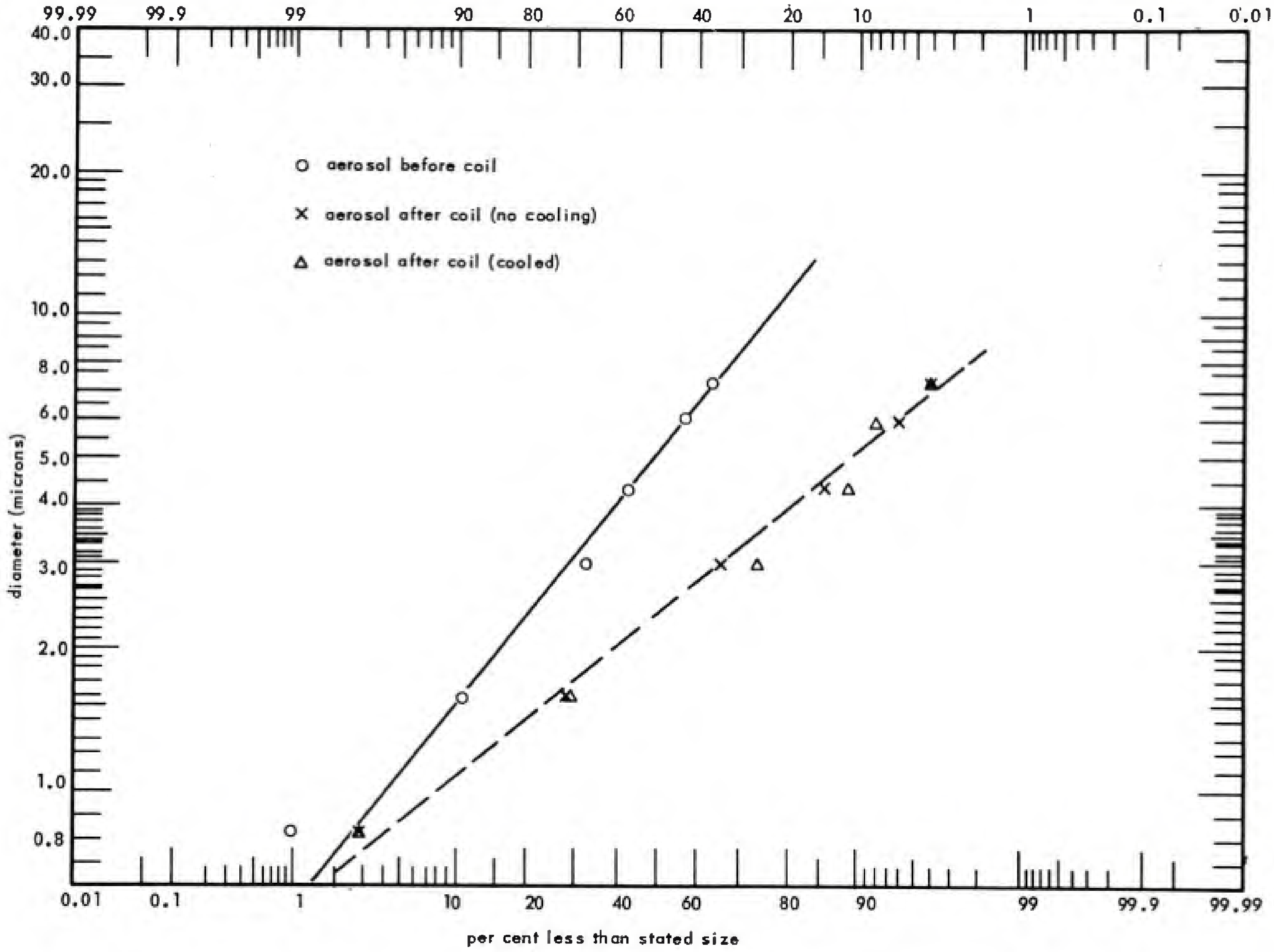


Figure 30. Effect of cooling coil on particle-size distribution (2500 cfm).

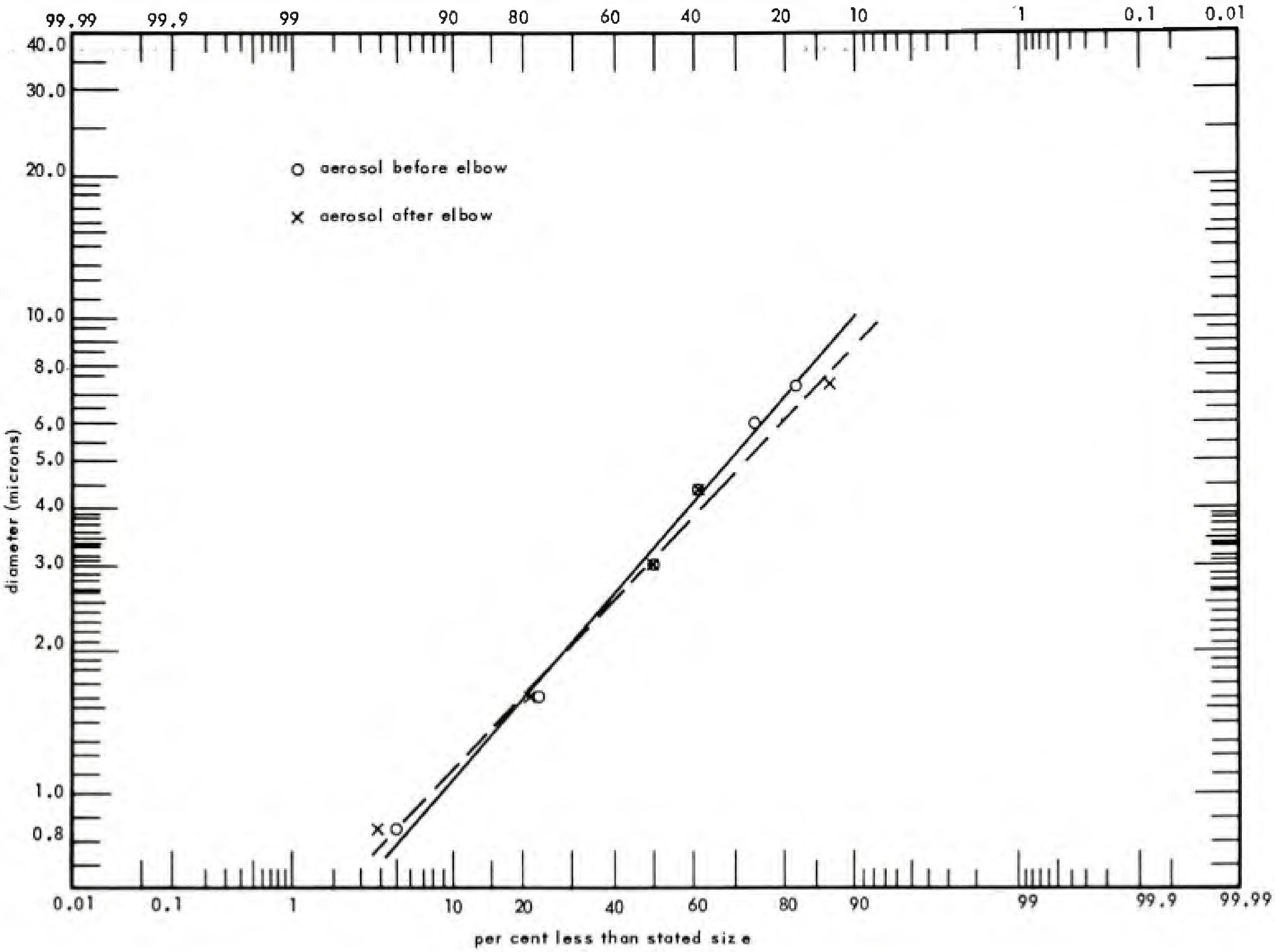


Figure 31. Effect of plain elbow (18-in. radius) on particle-size distribution (1250 cfm).

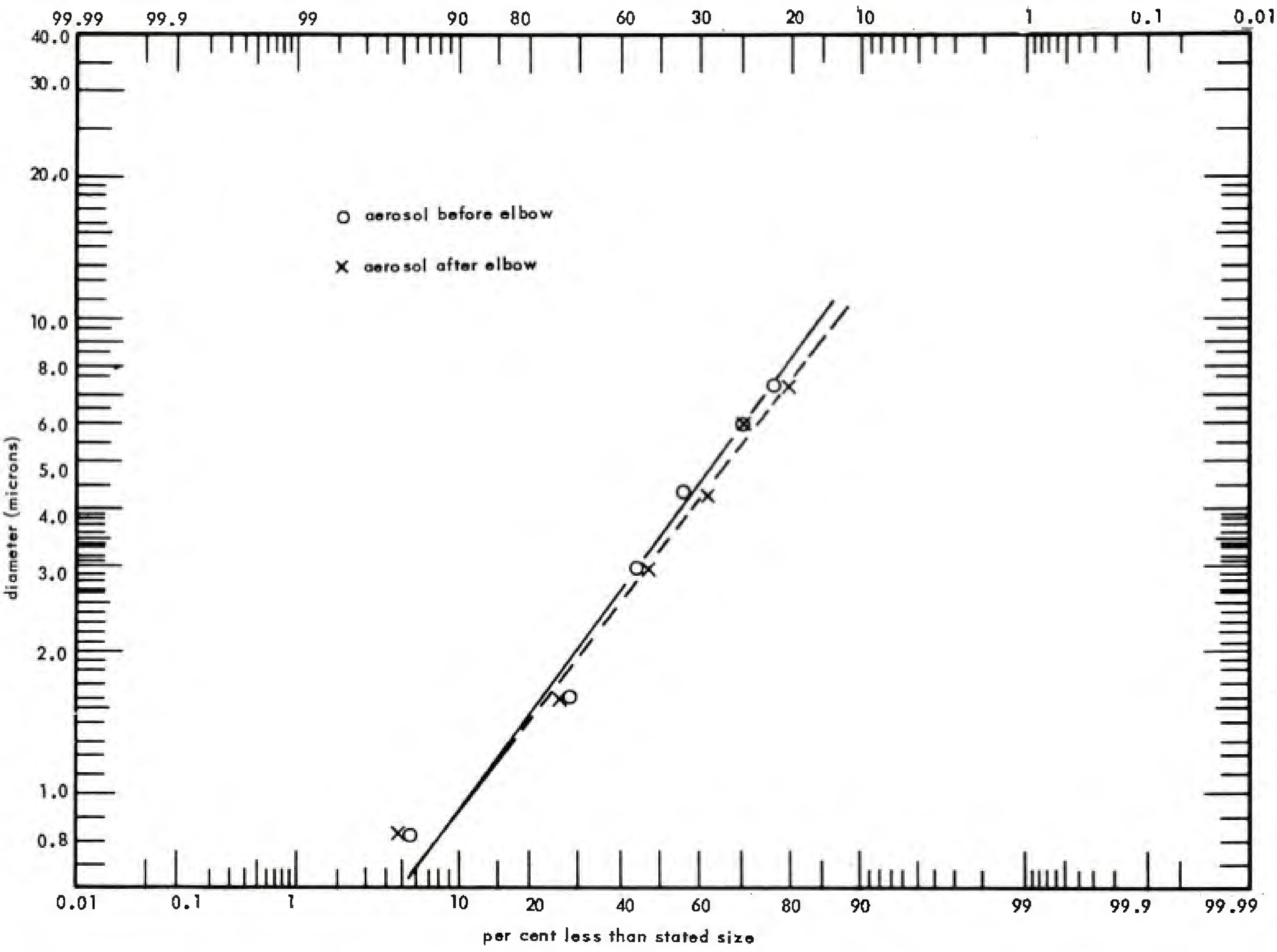


Figure 32. Effect of plain elbow (18-in. radius) on particle-size distribution (2500 cfm).

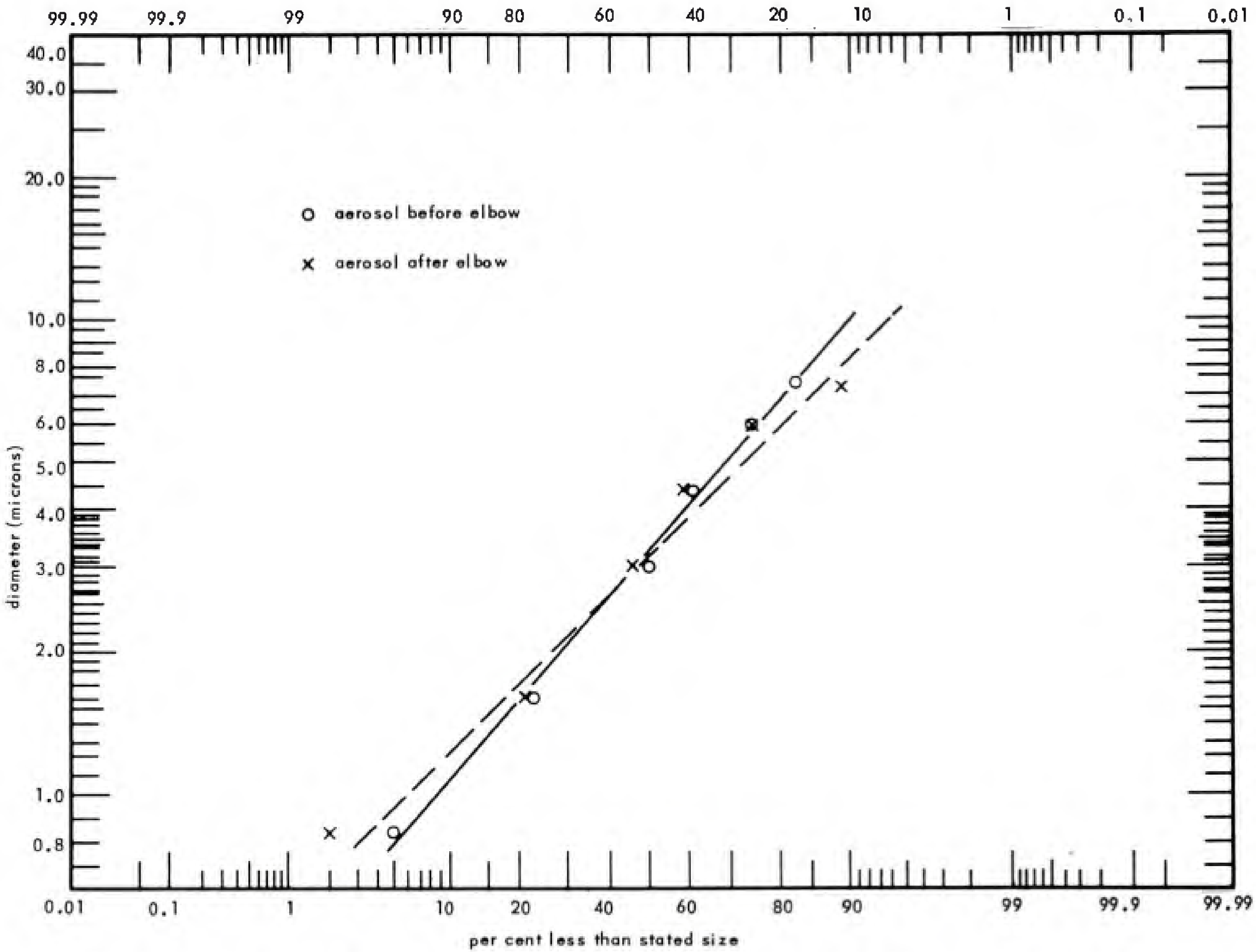


Figure 33. Effect of plain elbow (12-in. radius) on particle-size distribution (1250 cfm).

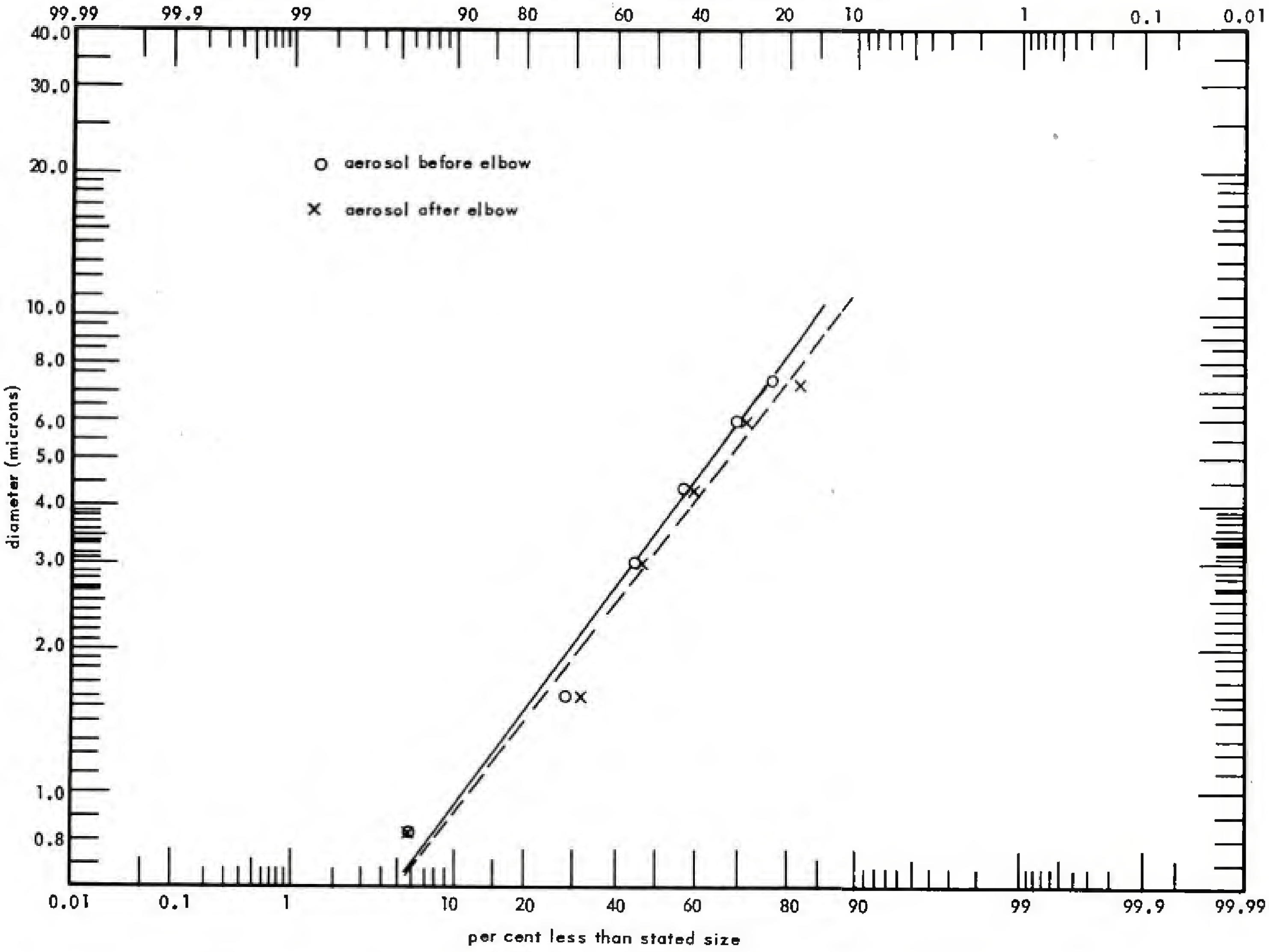


Figure 34. Effect of plain elbow (12-in. radius) on particle-size distribution (2500 cfm).

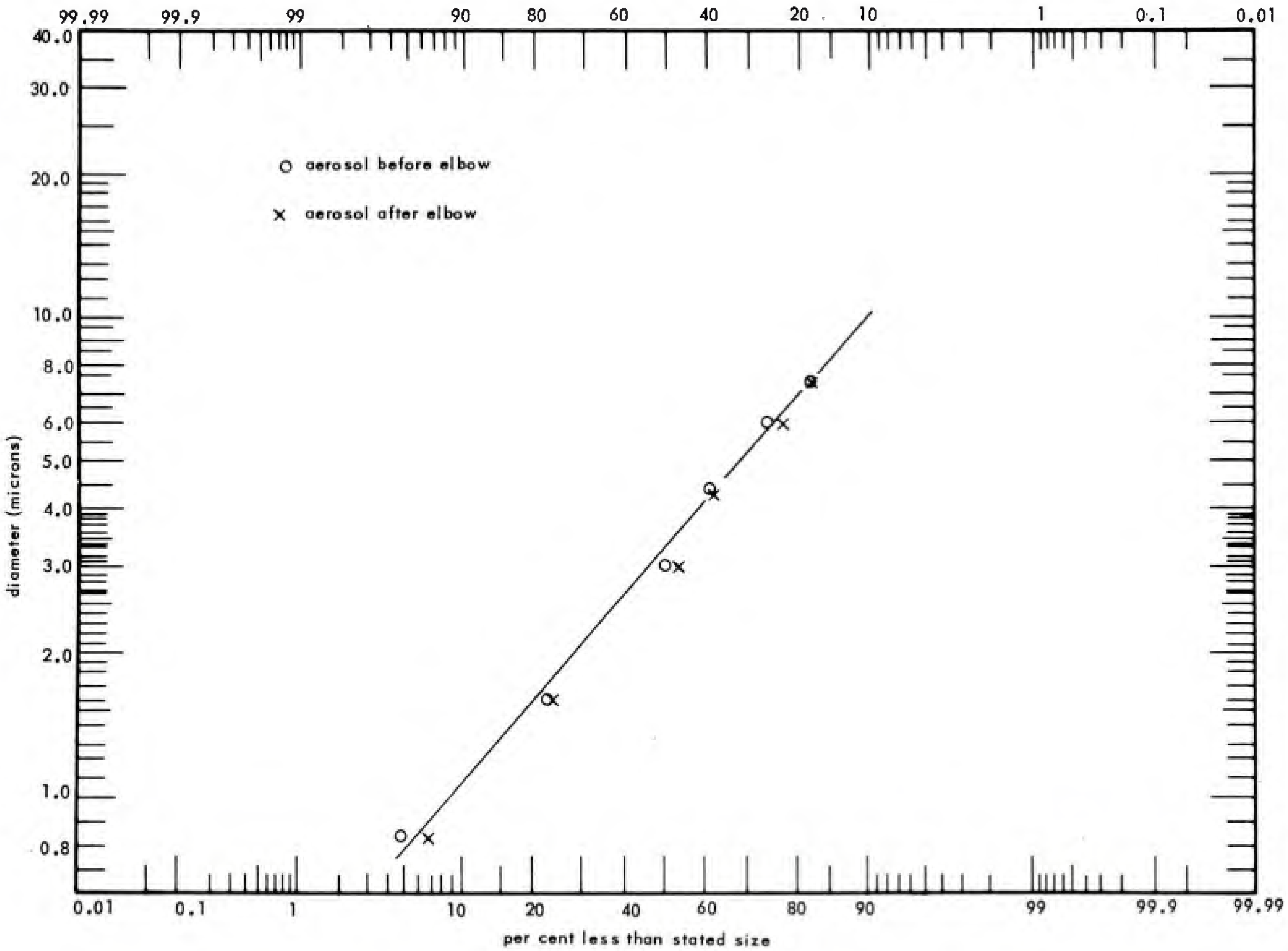


Figure 35. Effect of single-splitter elbow (12-in. radius) on particle-size distribution (1250 cfm).

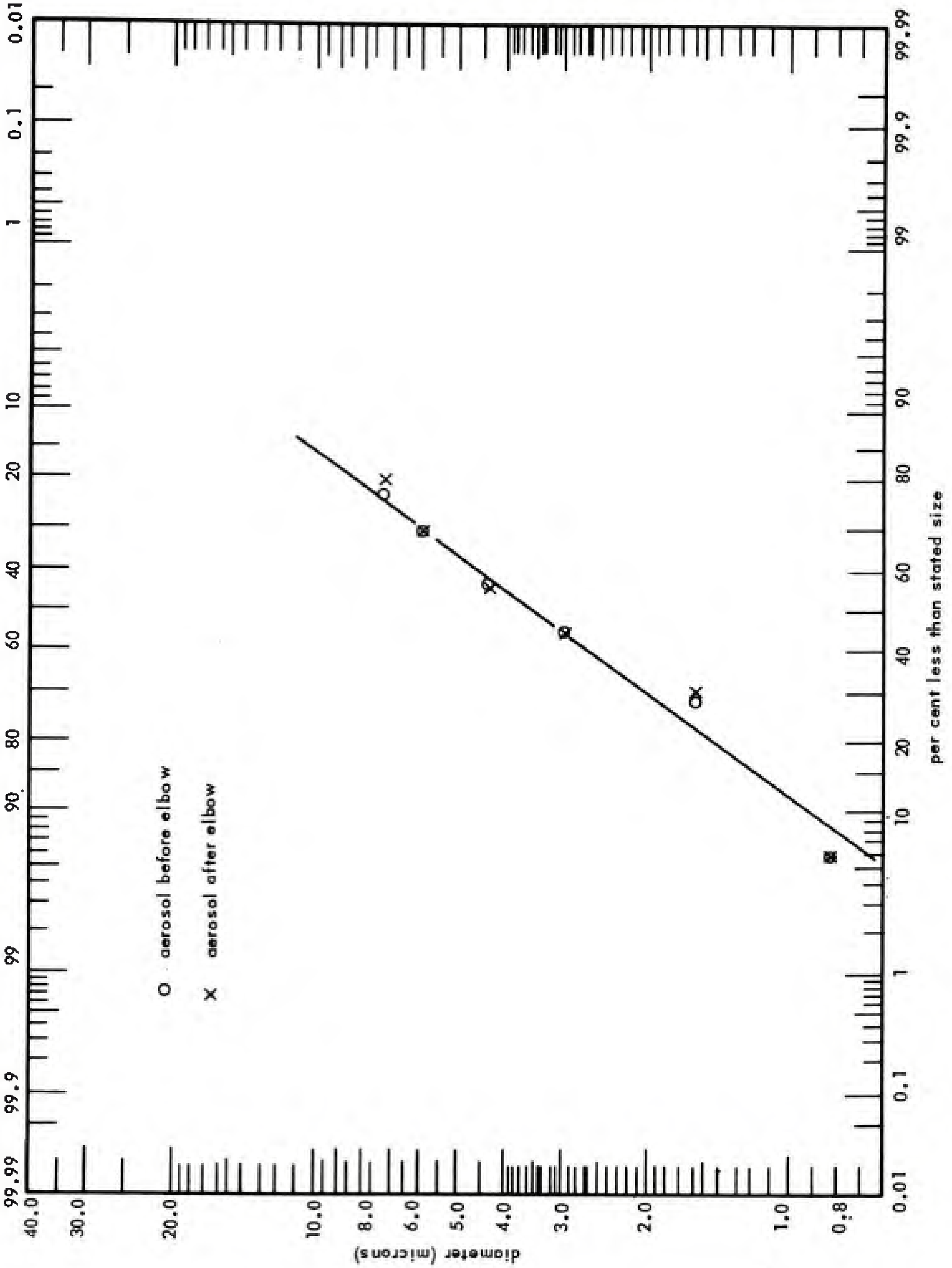


Figure 36. Effect of single-splitter elbow (12-in. radius) on particle-size distribution (2500 cfm).

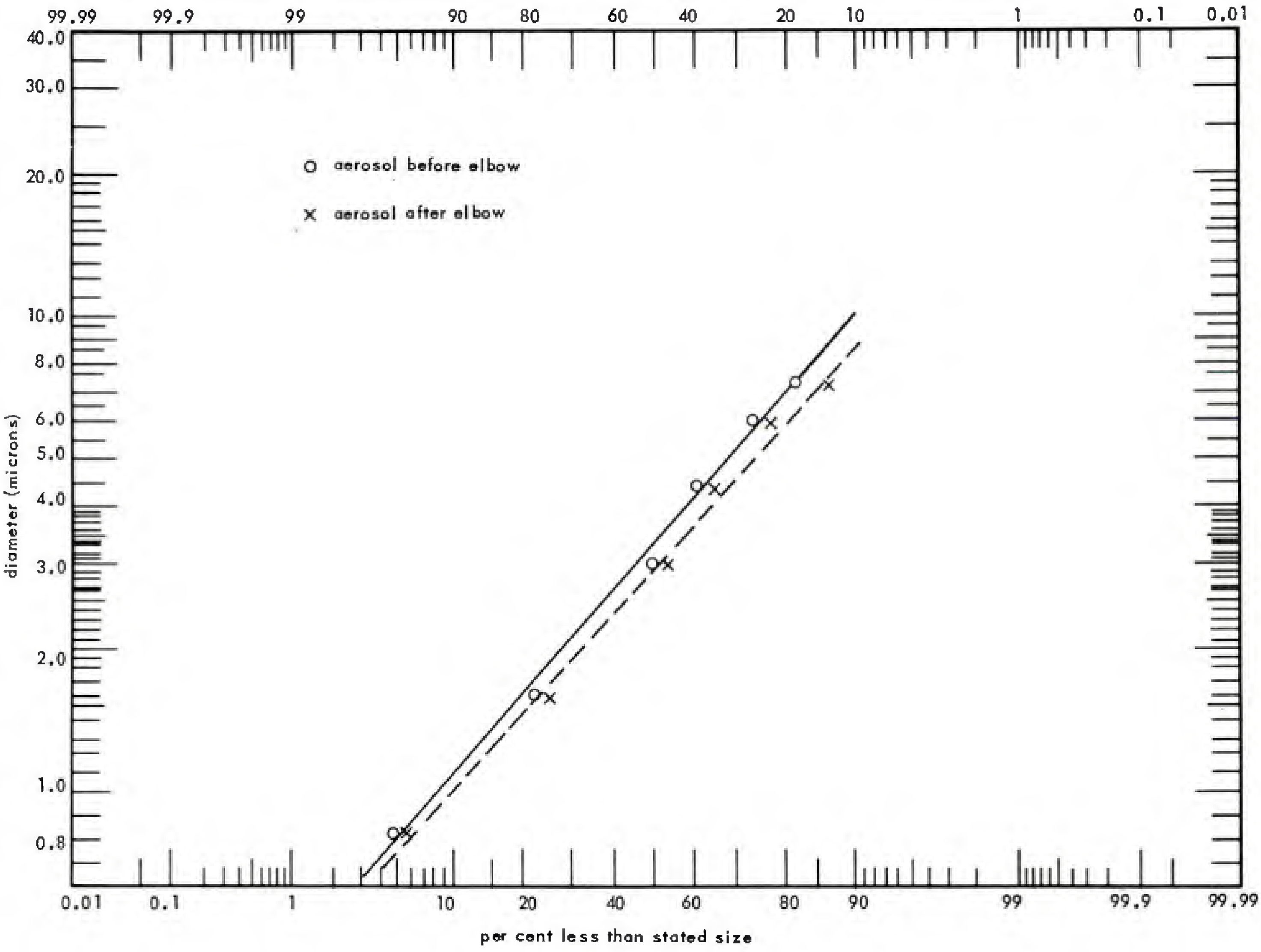


Figure 37. Effect of vaned turn on particle-size distribution (1250 cfm).

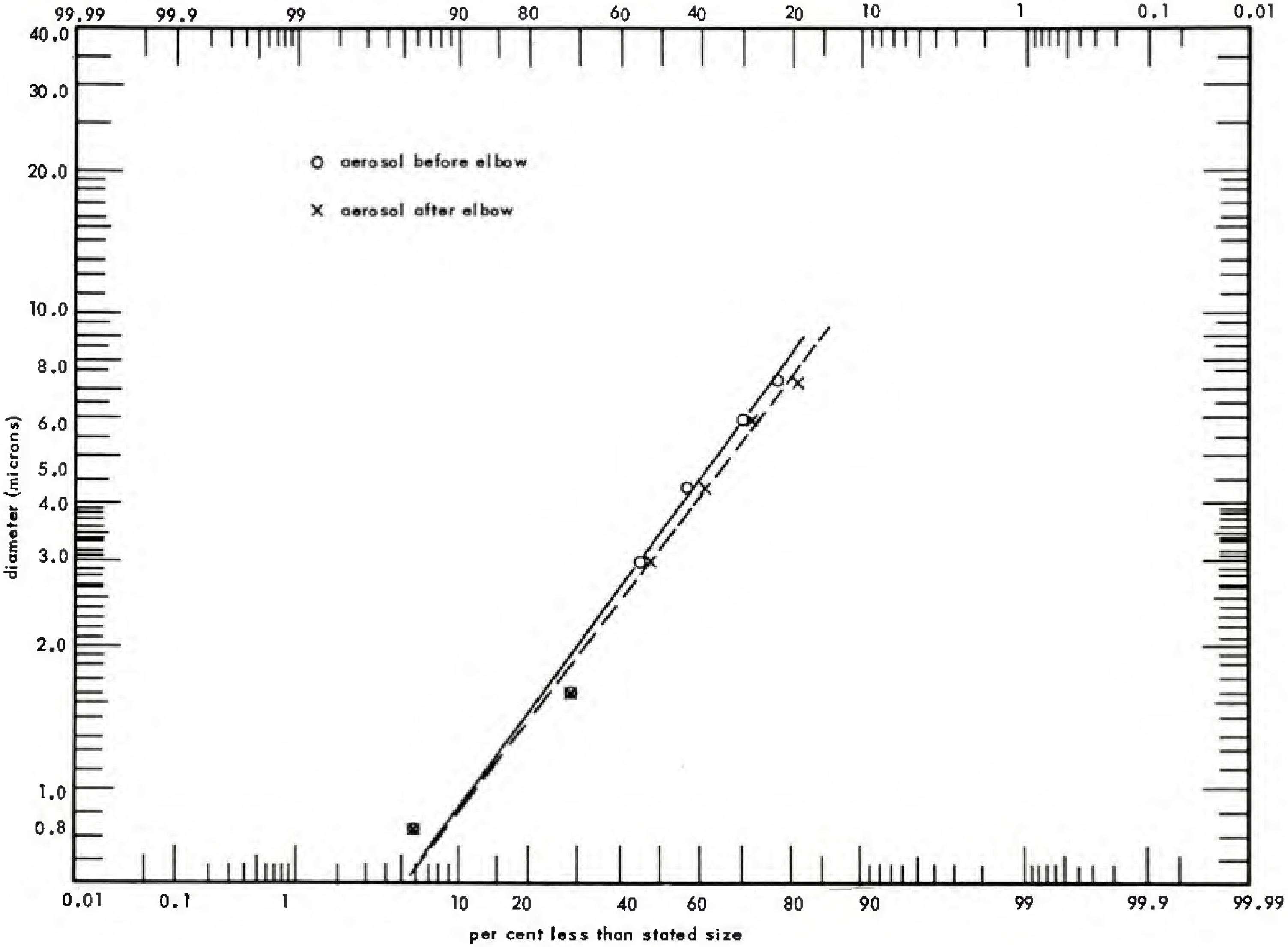


Figure 38. Effect of vaned turn on particle-size distribution (2500 cfm).

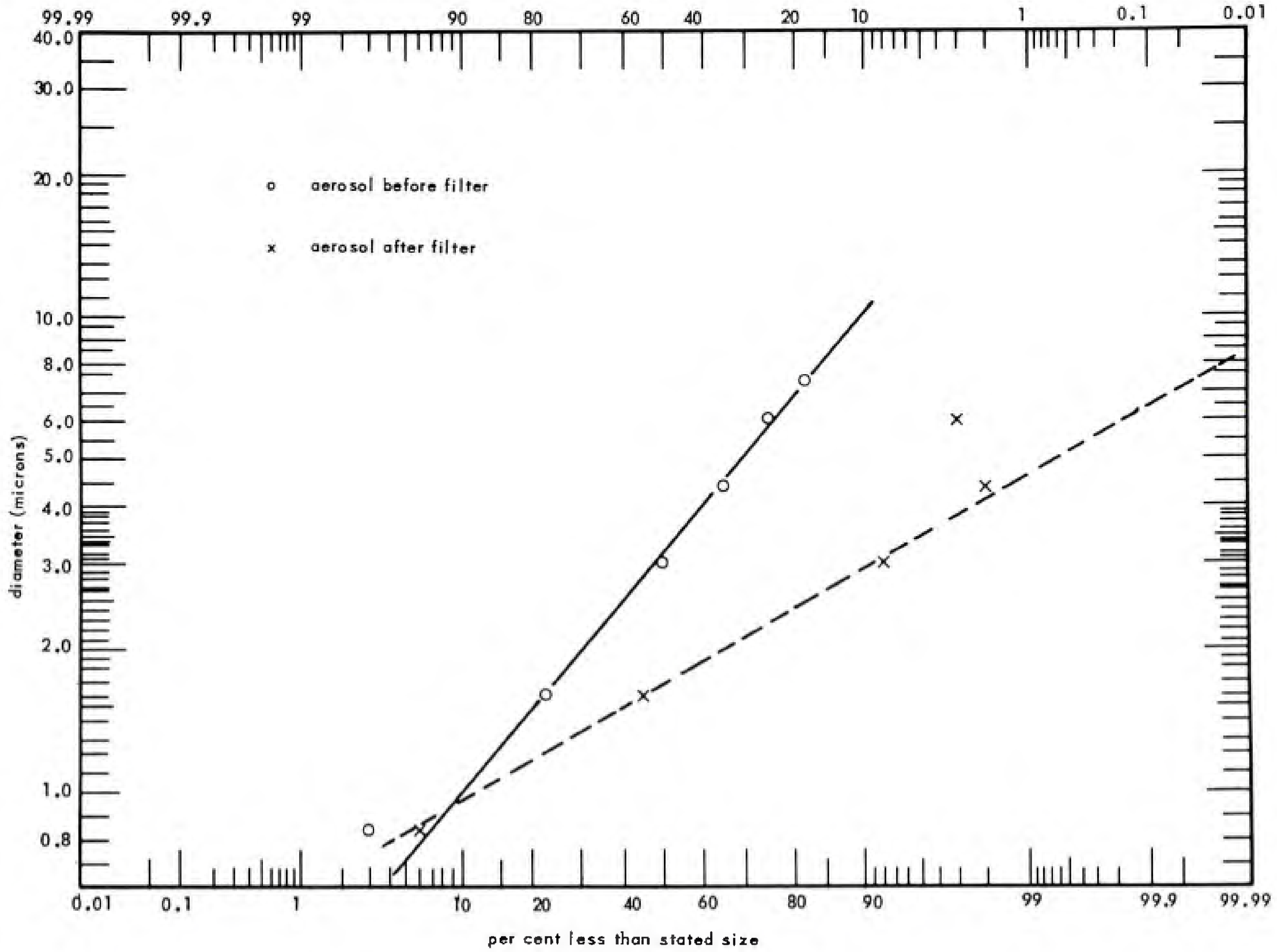


Figure 39. Effect of coarse filter A on particle-size distribution (1070 cfm).

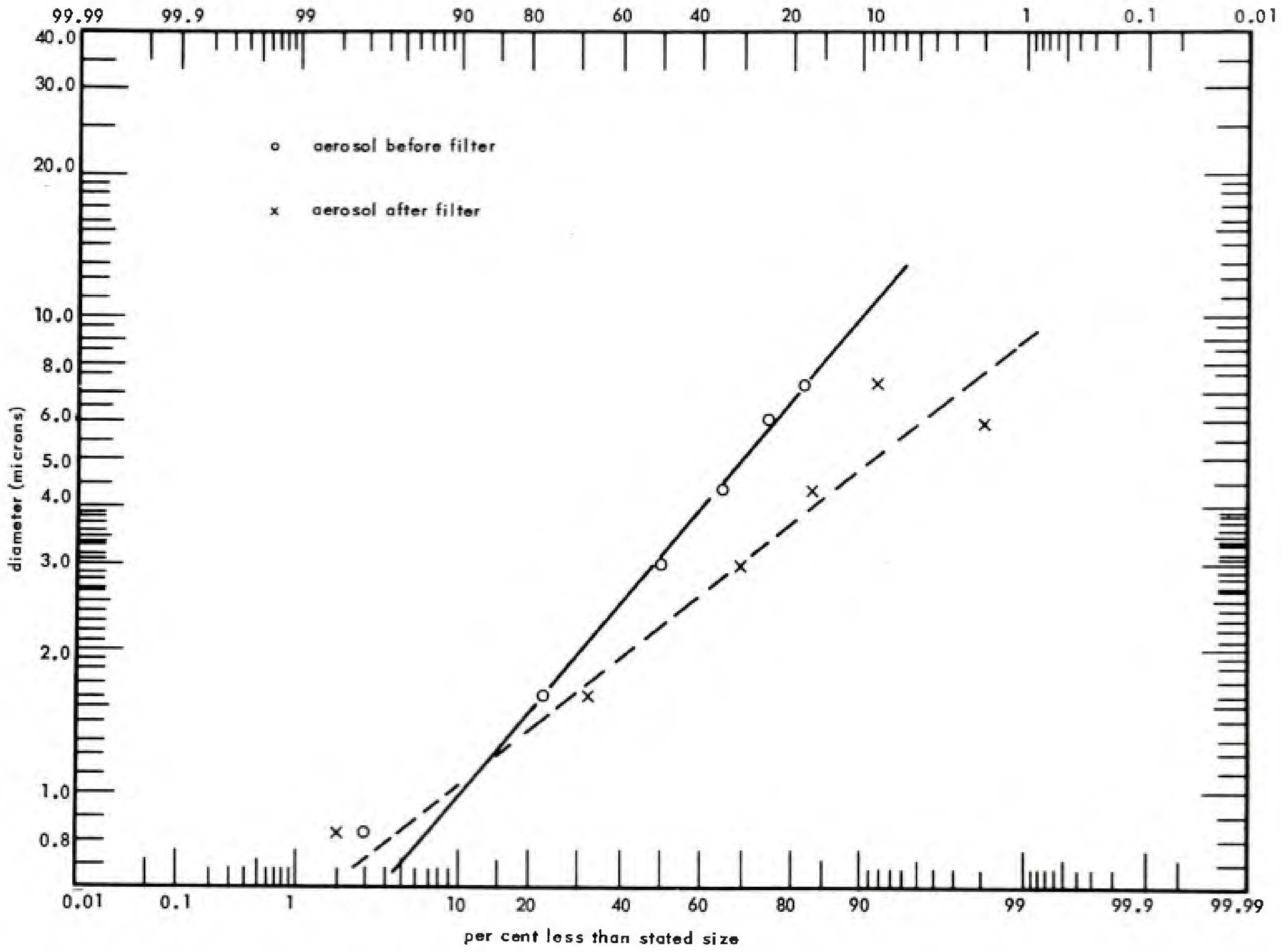


Figure 40. Effect of coarse filter B on particle-size distribution (1070 cfm).

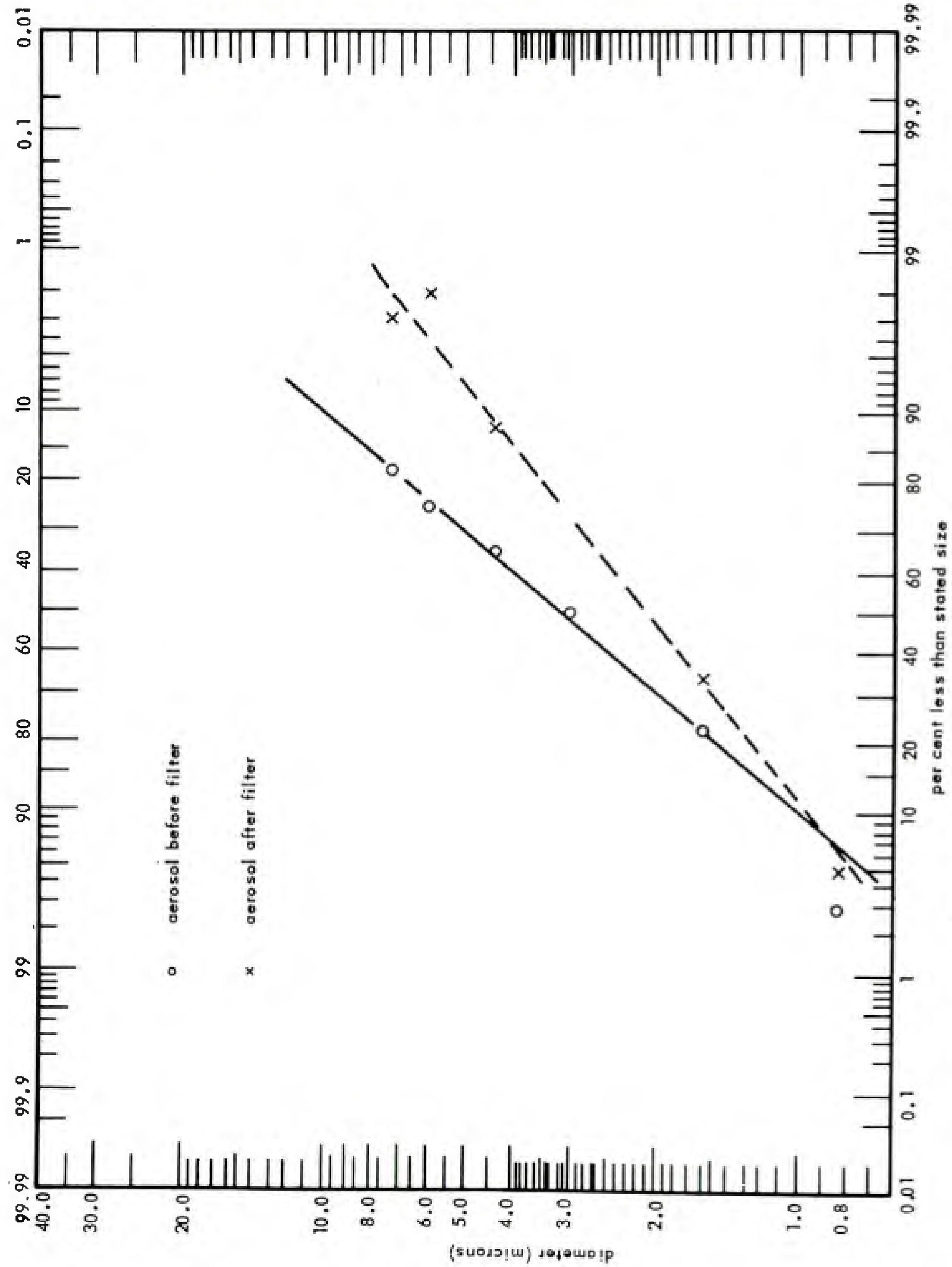


Figure 41. Effect of coarse filter C on particle-size distribution (1070 cfm).

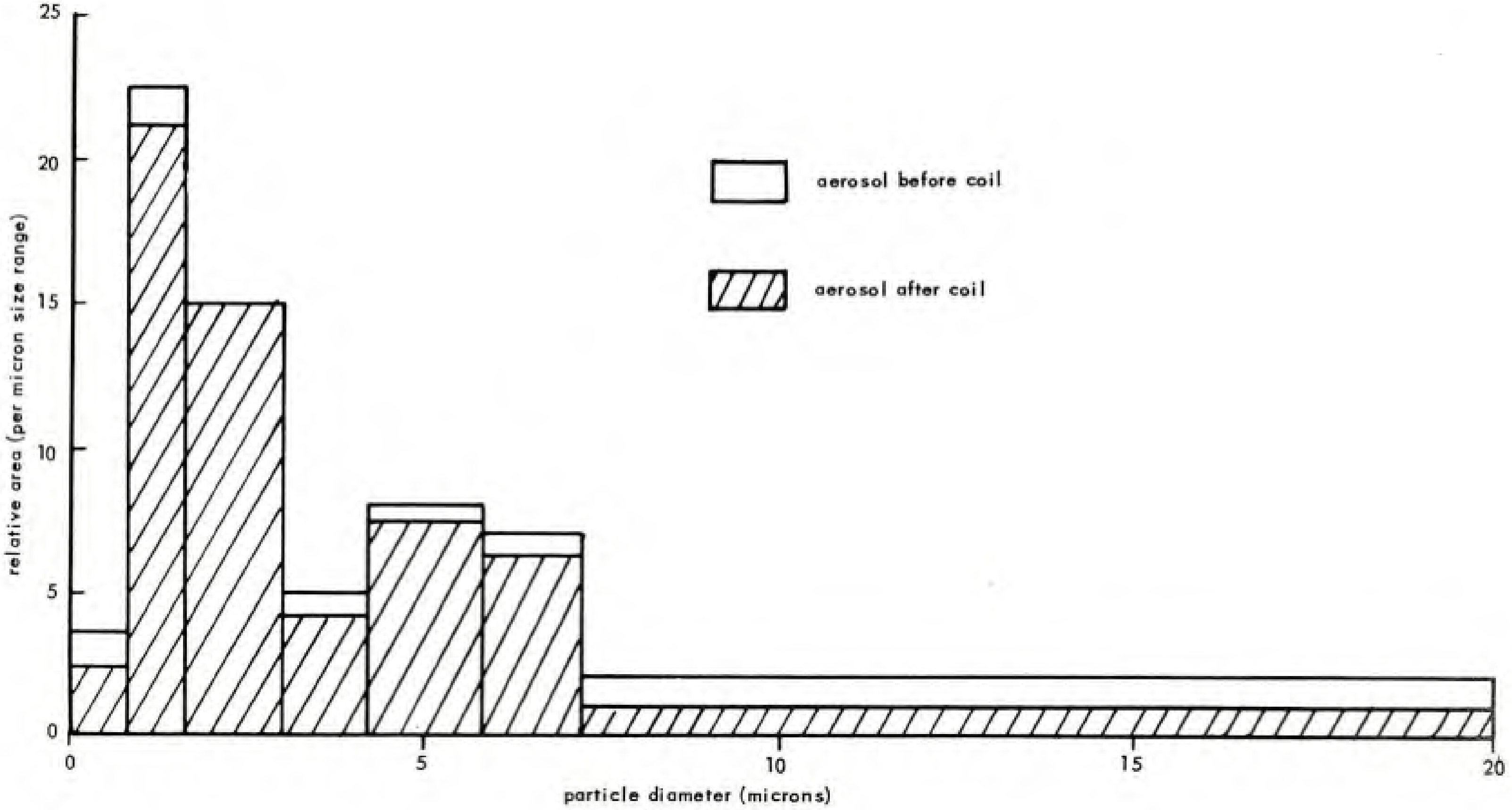


Figure 42. Effect of reheater coil on particle-size distribution and concentration (1250 cfm).

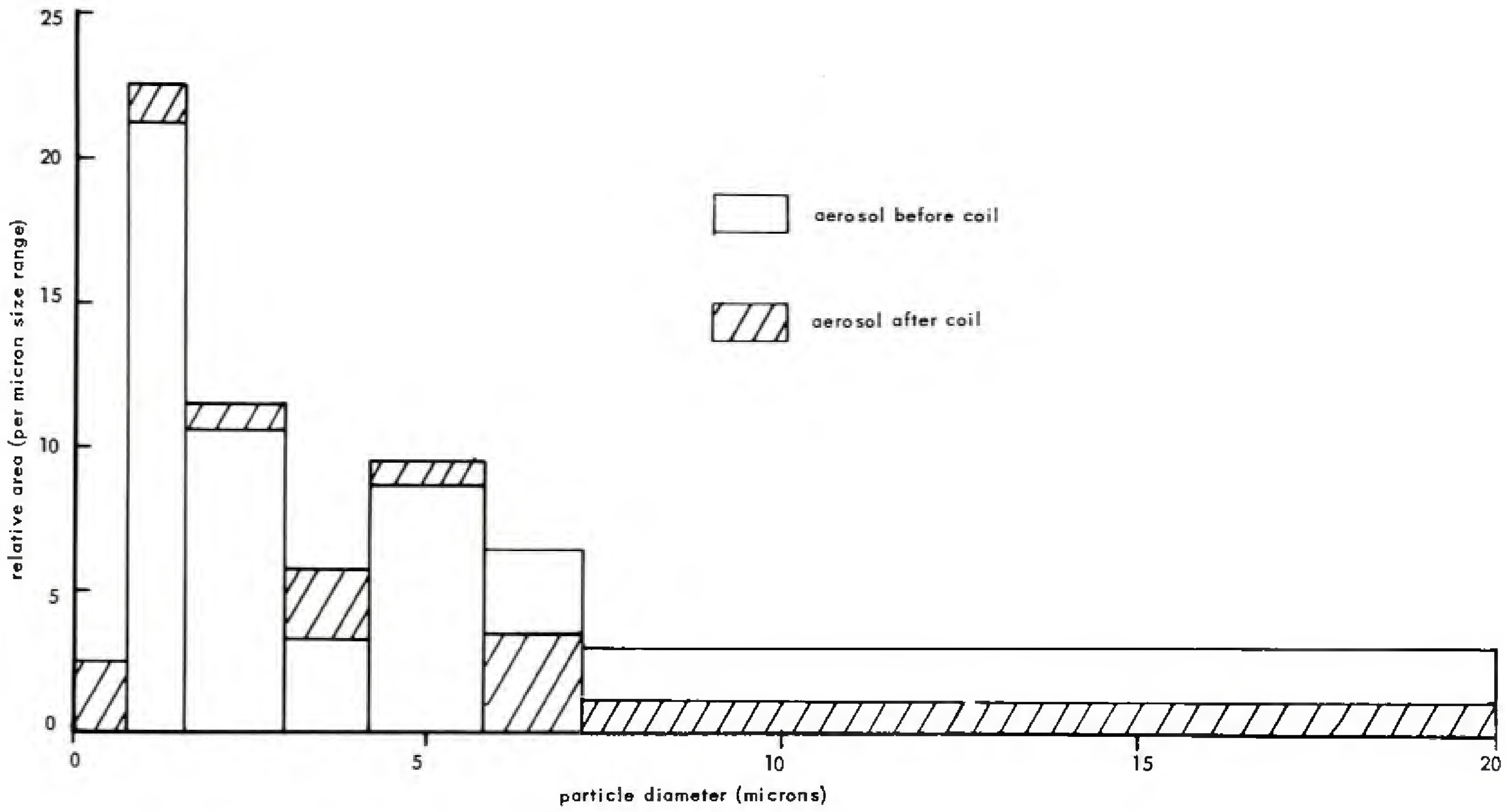


Figure 43. Effect of reheater coil on particle-size distribution and concentration (2500 cfm).

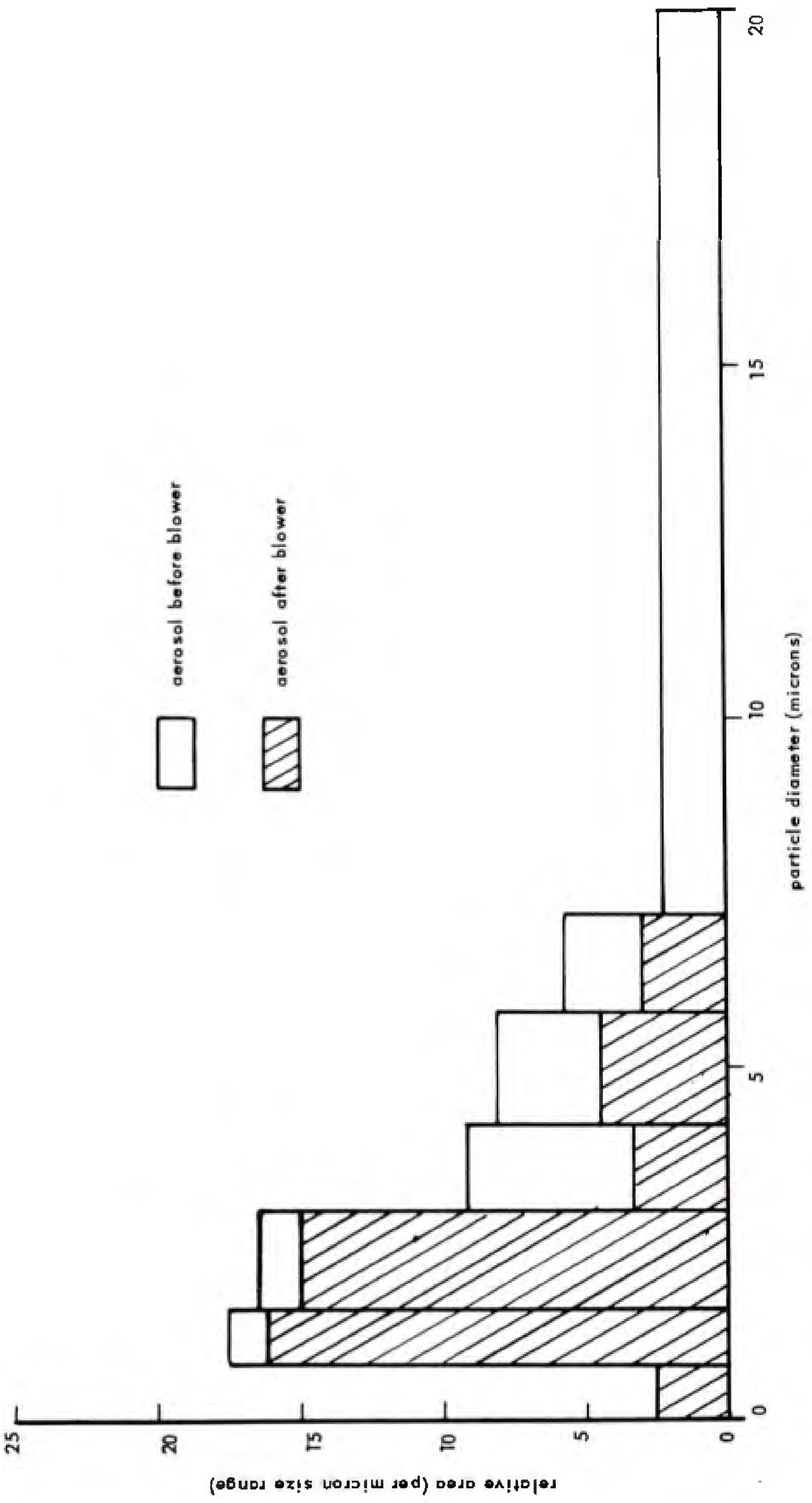


Figure 44. Effect of axivane blower on particle-size distribution and concentration (1250 cfm).

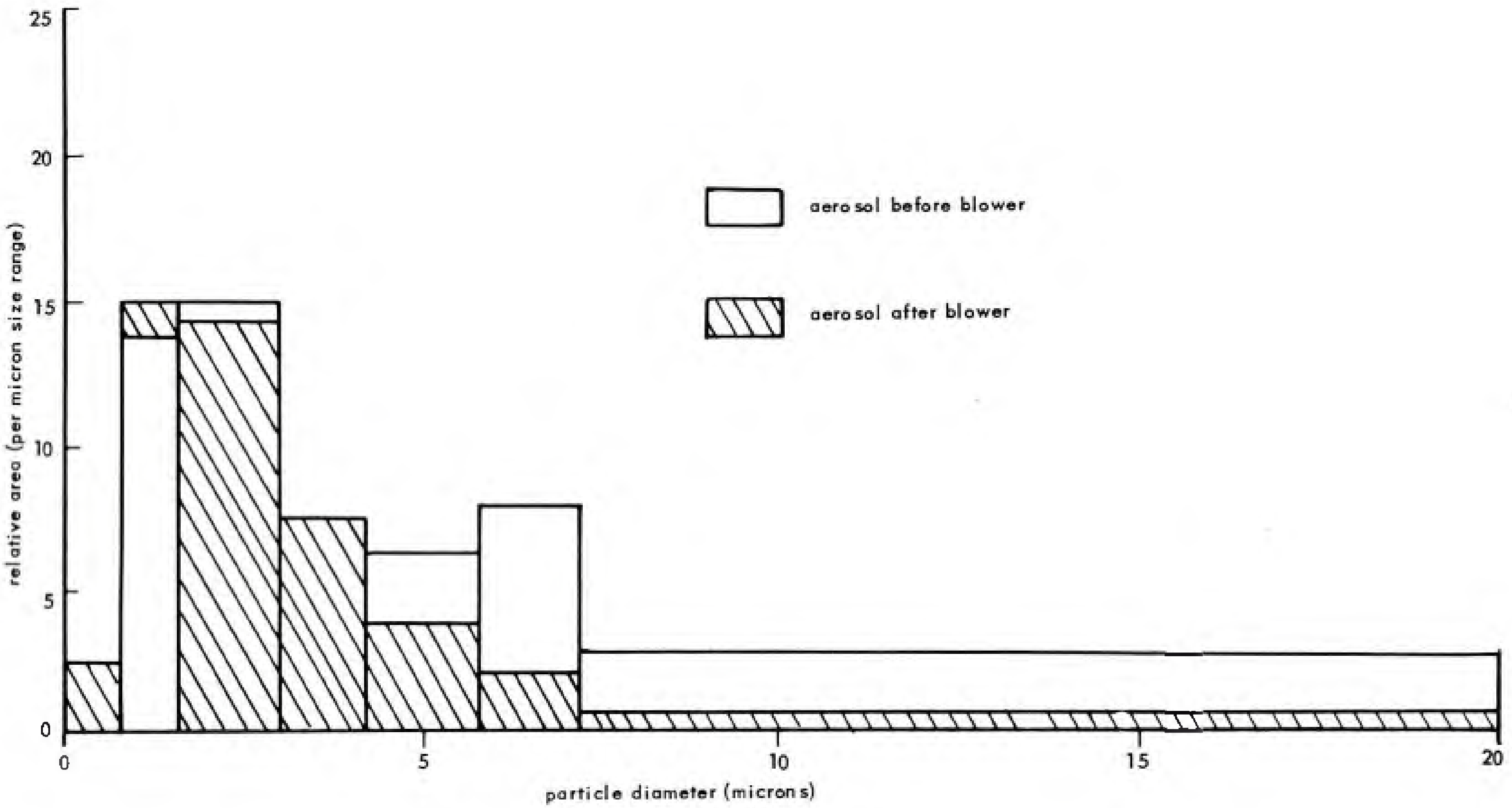


Figure 45. Effect of axivane blower on particle-size distribution and concentration (2500 cfm).

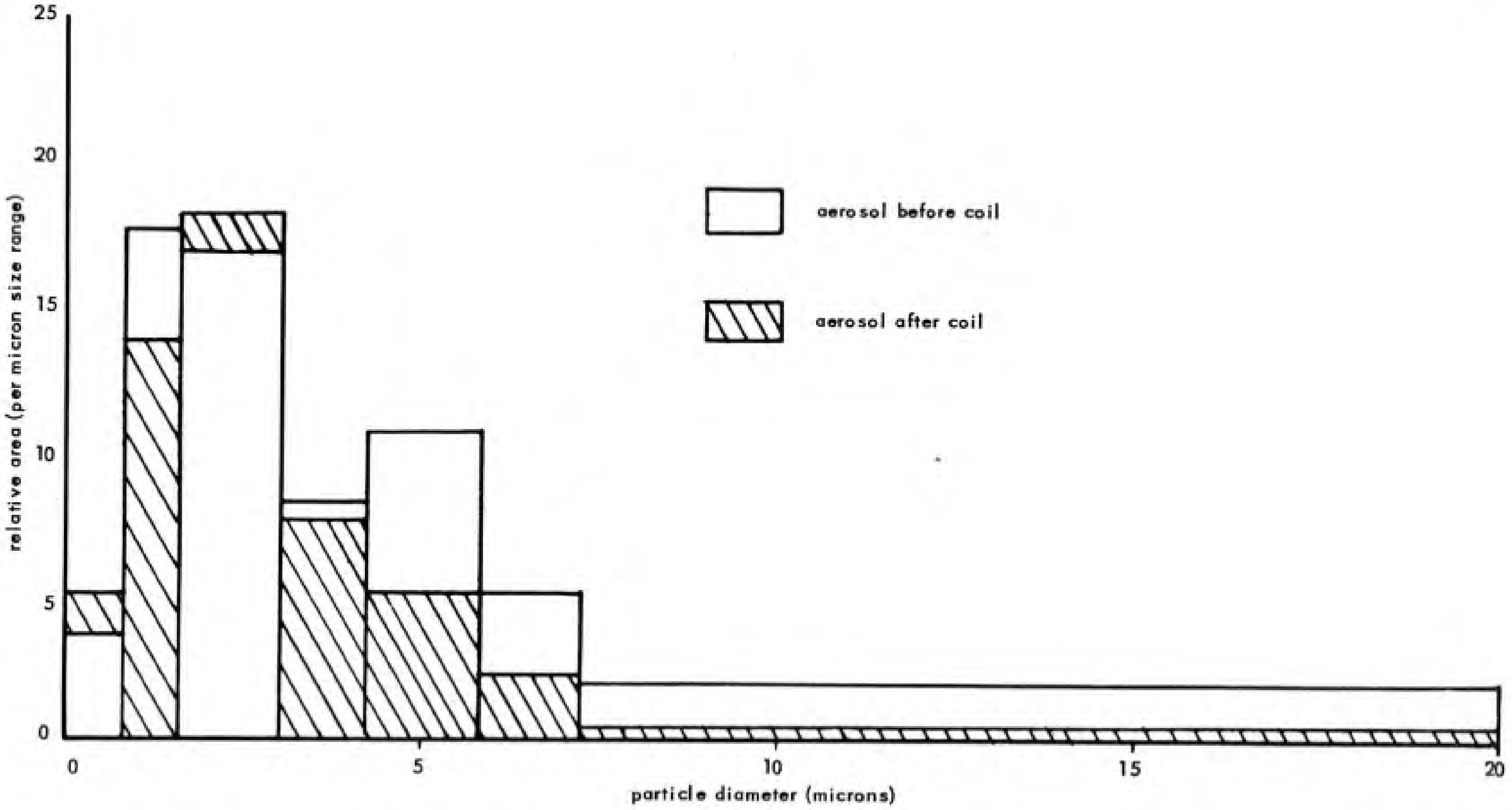


Figure 46. Effect of cooling coil on particle-size distribution and concentration (1250 cfm).

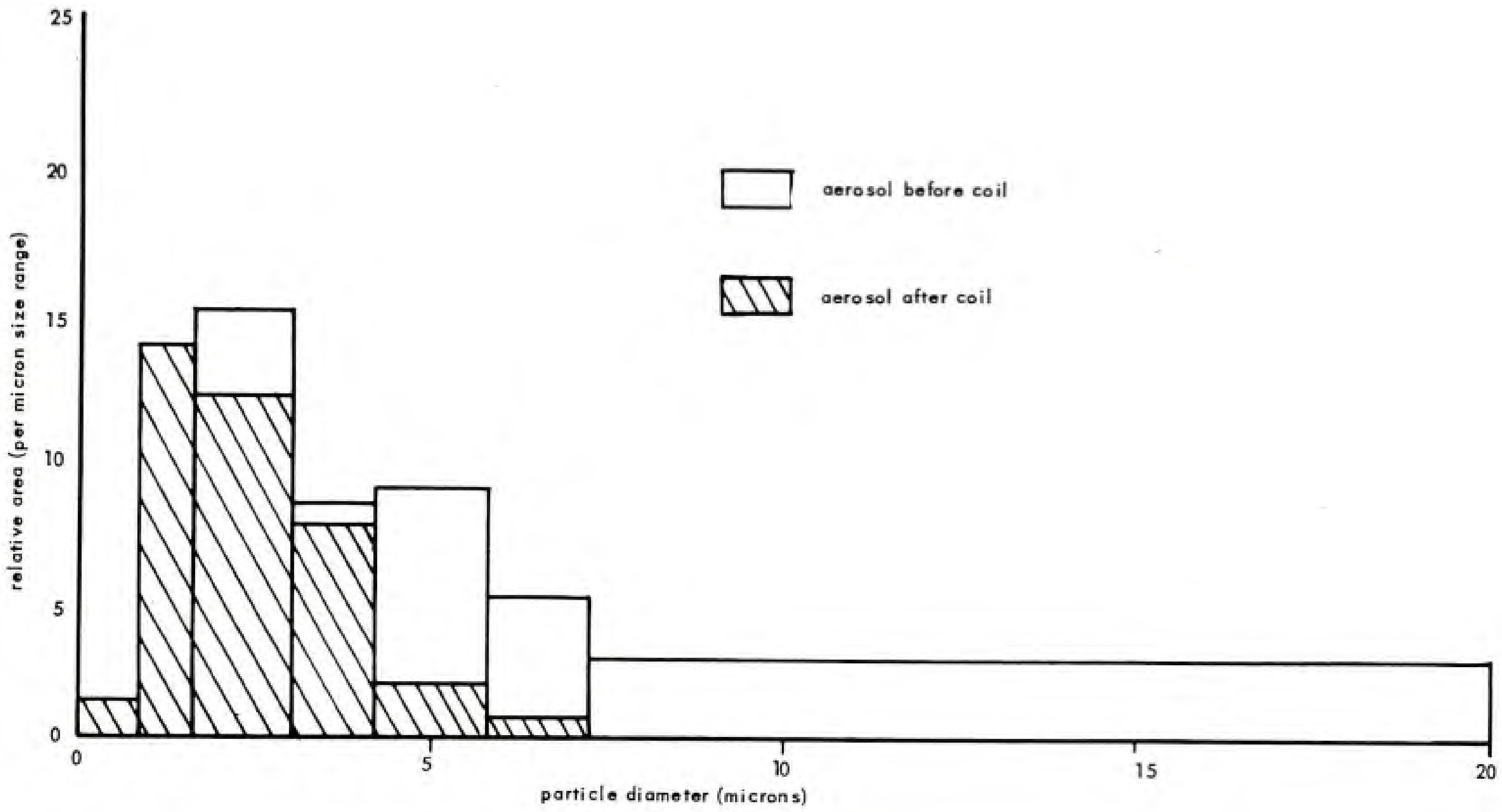


Figure 47. Effect of cooling coil on particle-size distribution and concentration (2500 cfm).

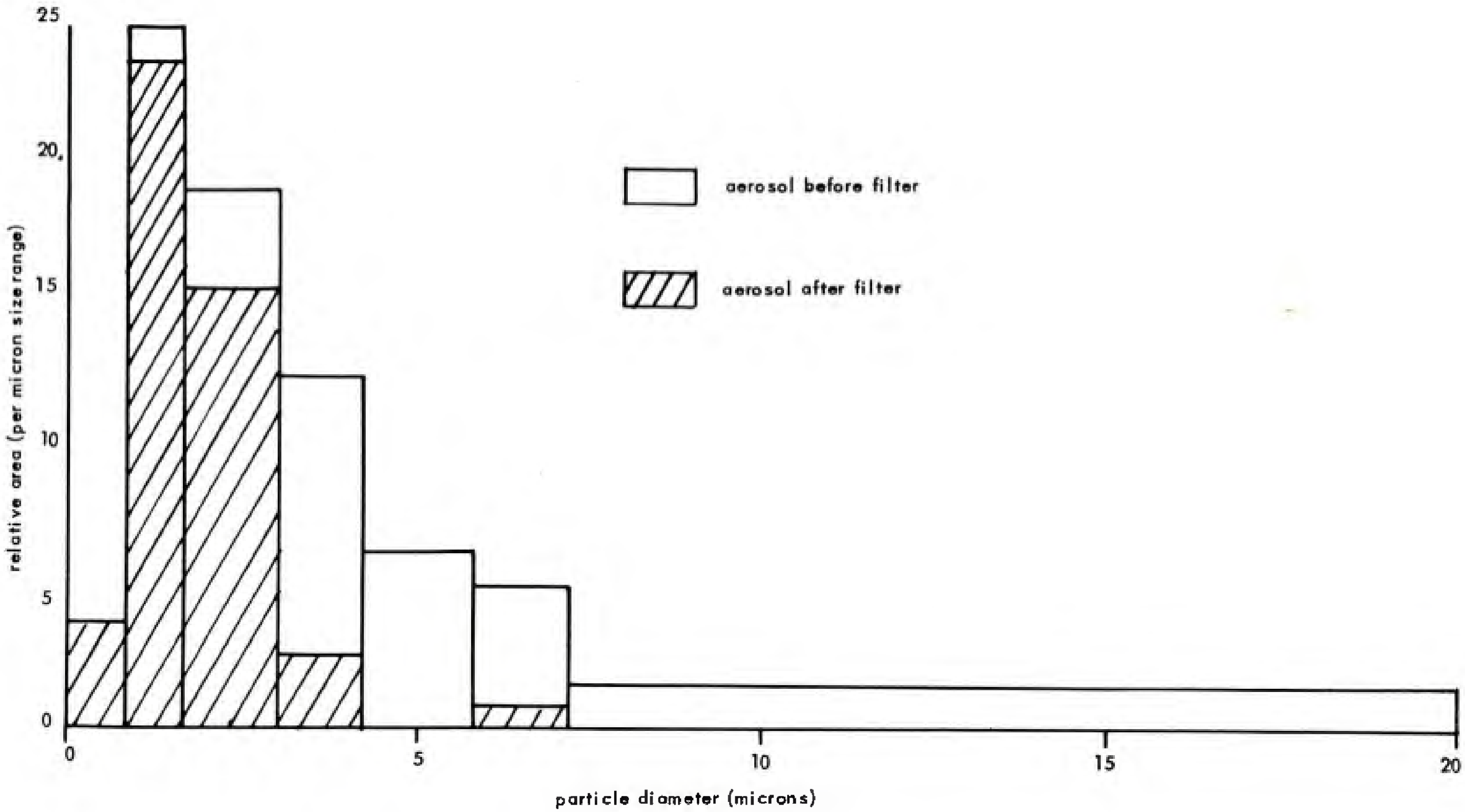


Figure 48. Effect of coarse filter A on particle-size distribution and concentration (1070 cfm).

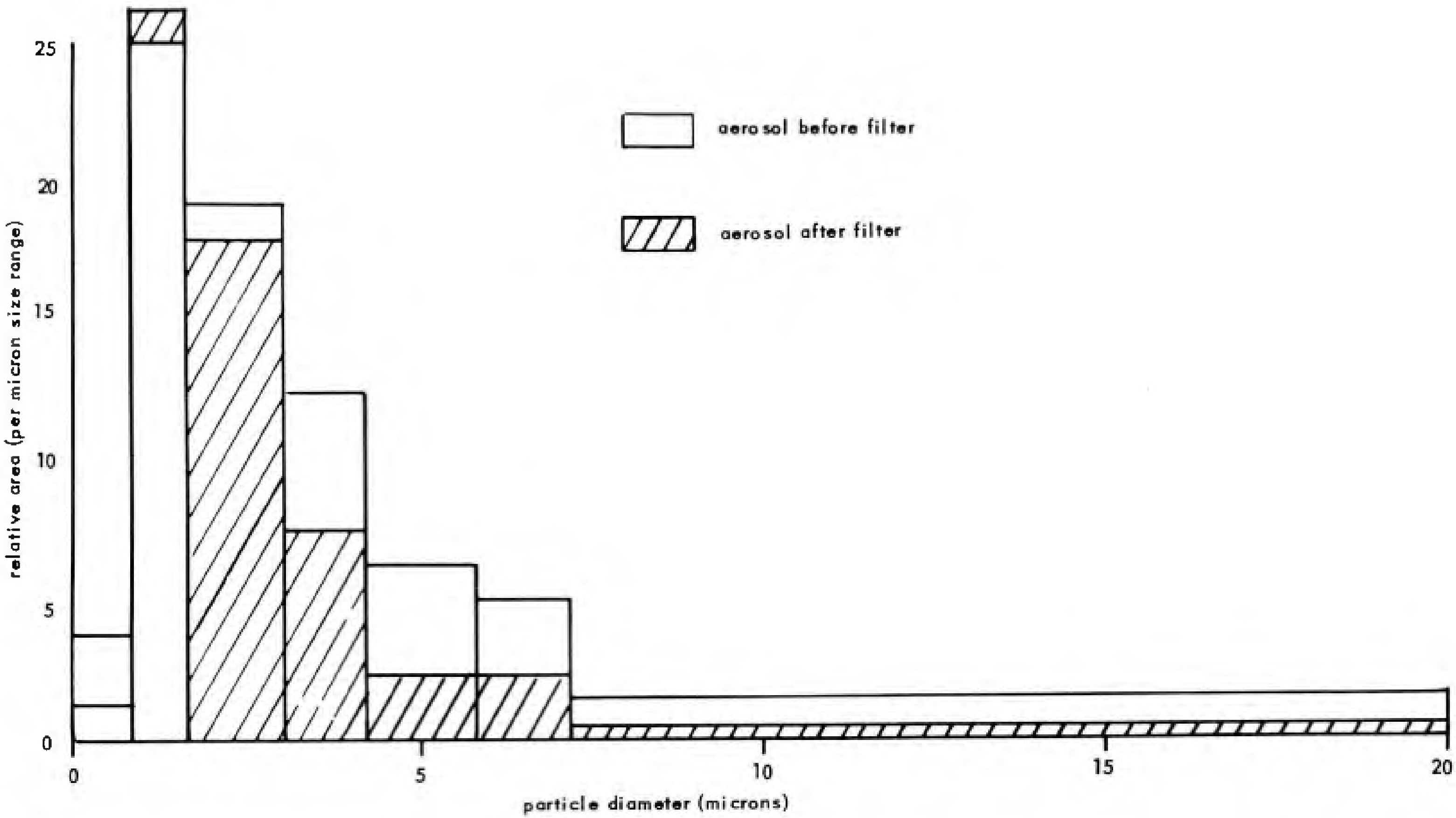


Figure 49. Effect of coarse filter B on particle-size distribution and concentration (1070 cfm).

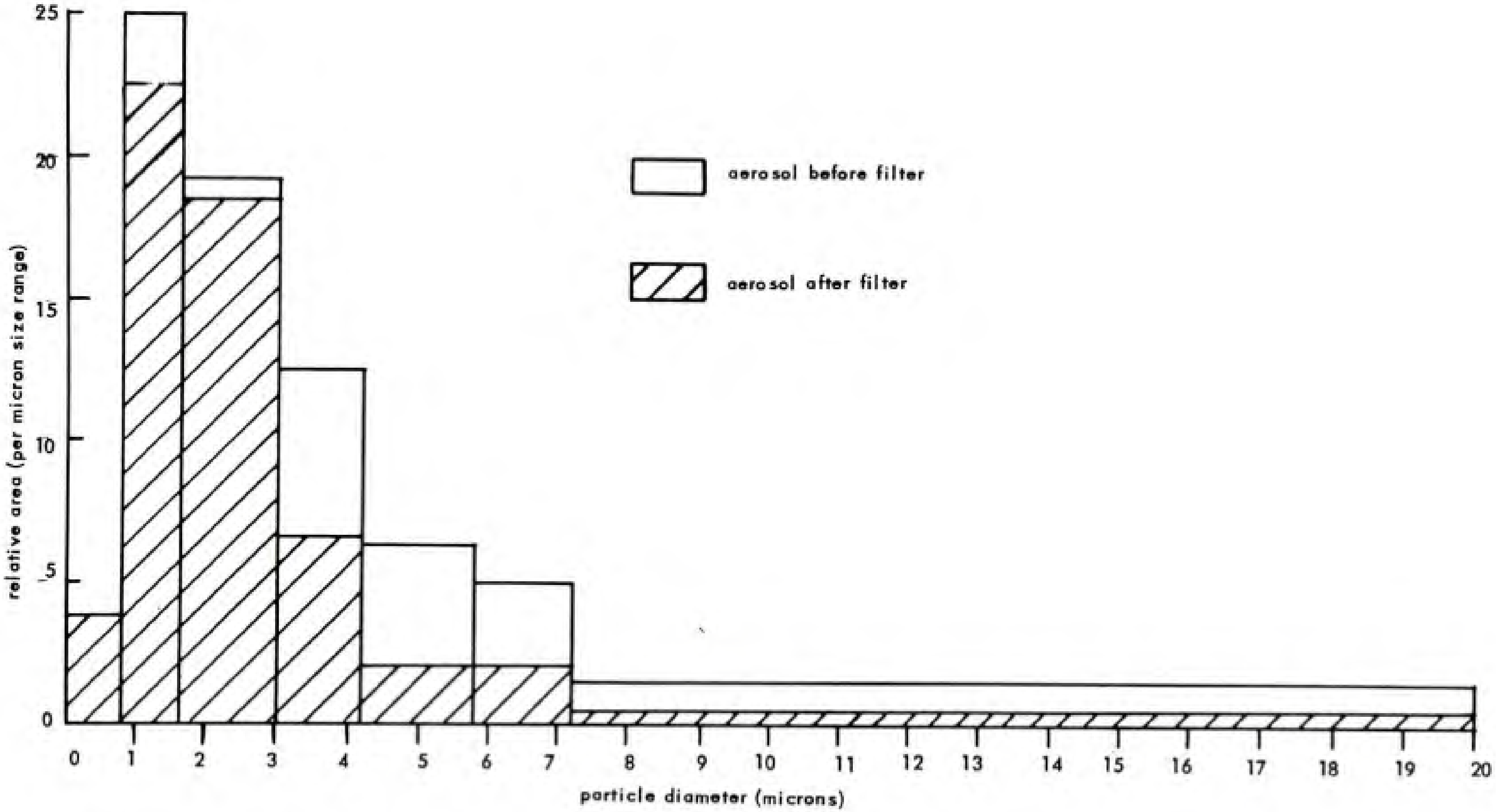


Figure 50. Effect of coarse filter C on particle-size distribution and concentration (1070 cfm).

The data of Table VIII were used to draw the block diagrams of Figures 42 through 50. These block diagrams show the change in both the particle-size distribution and the concentration of the aerosol. Block diagrams were not drawn for the elbows because of their slight effect on the aerosol.

The results obtained with the mushroom inlet were unsatisfactory. The data show an apparent increase in gross concentration caused by the mushroom. This was probably the result of faulty sampling. No way was found to get a reliable aerosol sample at the rim of the mushroom. One cause of this was failure to maintain a uniform cloud all around the mushroom.

The reheater coil acted as a coarse filter, removing about 20 per cent of the aerosol particles. It was most effective on the larger particles; there was a slight lowering of the median diameter of the aerosol. This filtering effect could not be tested while the coil was heated. The heat caused vaporization of dioctylphthalate which had collected on the coil, and this vapor subsequently recondensed to form a dense secondary aerosol which obscured the effects of the original cloud.

The preheater coil showed an apparent increase in aerosol concentration, which again may have been due to faulty sampling in the plenum.

The cooling coil, like the reheating coil, acted as a coarse filter, removing 36 per cent of the aerosol particles at its normal flow rate of 1250 cu ft per minute. At 2500 cfm the cooling coil removed 56 per cent of the aerosol particles. The median diameter of the aerosol was slightly lowered. Refrigeration made no measureable difference in the performance of the coil as a filter.

The 1250 cfm blower (A-1) removed 46 per cent of the aerosol particles and lowered the median diameter of the aerosol from 3.9 to 2.6 microns. The 2500 cfm blower (A-2) removed 39 per cent and lowered the median diameter of the aerosol from 5.0 to 2.8 microns.

The elbows had little effect on the gross concentration; they caused a slight decrease in the median diameter of the aerosol. There was little measurable difference in performance between the various types (18-in. and 12-in. radius plain elbows, single-splitter elbow, and vaned turn). This indicates that at the air speeds of these studies the elbows all gave laminar flow.

The three coarse filters all showed the same effects to different degrees. Filter pad "A" (glass wool) removed 52 per cent of the aerosol particles, filter pad "B" (wire-mesh) removed 37 per cent, and filter pad "C" (wire-mesh) removed 32 per cent. All were more effective against larger particles than against smaller ones. The median diameter of the aerosol was lowered from 3.1*u* to about 2*u* in each case.

In all the studies there was evidence of a considerable amount (not measured) of dioctylphthalate retained in the duct. This material, accumulated during the entire period of test, thoroughly wet the duct walls, and leaked through the joints. The leakage suggested that there would be a potential contamination problem in the case of a hazardous agent.

CONCLUSIONS

In general, the ventilation systems components had little or no effects on aerosol particles smaller than about 3-*u* diameter. The blowers, and the coils were fairly effective "filters" toward particles larger than 3 microns. The commercial air washers and coarse filters were effective only against the larger particles. These facts, plus the possibility of contamination of the ducts by accumulated material, indicate that no effective protection against aerosols should be expected from a ventilation system or its components alone. Dependence, rather, should be upon special protective apparatus, and this should be located as close as possible to the ventilation intakes.

The chief source of variance in the results was the aerosol generator. The aerosol was quite variable in concentration and particle-size distribution.

RECOMMENDATION

It is recommended that a study be made of aerosol generator variance in concentration and particle-size distribution using monodisperse large-size aerosols.

ACKNOWLEDGEMENT

The authors wish to acknowledge the invaluable service of Mr. Harold R. Joerding, engineering aid, NAVCERELAB, whose technical assistance and suggestions aided in the successful completion of the project.

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Polydisperse aerosols of dioctylphthalate with a particle-size range of approximately 1- to 20-μ diameter were passed into two ventilation systems: a high- and a low-velocity. The effect on particle-size distribution and concentration was studied at various sampling stations throughout the system by means of a jet-impactor, light-scattering method. The tests indicated that effective protection can not be expected from ventilation systems against aerosol particles smaller than about 3-μ diameter because of the possibility of duct contamination by accumulated material.

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IV. NY 300 010-1

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