United States
Environmental Protection
Agency

Industrial Environmental Research
Laboratory
Research Triangle Park NC 27711

EPA-600 7-79-078
March 1979

EPA

Fugitive and Fine Particle Control Using Electrostatically Charged Fog

Interagency Energy/Environment R&D Program Report

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EPA-600/7-79-078

March 1979

Fugitive and Fine Particle Control Using Electrostatically Charged Fog

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Grant No. R805228
Program Element No. EHE624

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Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
Washington, DC 20460

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ABSTRACT

We have demonstrated that most industrial pollutants acquire an electrostatic charge as they are dispersed into the air. If this charged, airborne material is exposed to an oppositely charged water fog there is enhanced contact between the particulates and the fog droplets. After contact is made the wetted particulates agglomerate rapidly and fall out of the atmosphere.

This technique has been tested on a wide variety of industrial pollutants ranging from silica flour to sulfur dioxide and fly ash. In general, there has been significant suppression of pollution with a minimum of water fog. The system is therefore well suited to control of moving fugitive dust sources where the usual duct and baghouse systems are ineffective or too costly.

We have also been able to develop electrostatic hoods and screens that can be used to push or direct pollutants to the proper area for collection. Another area of interest has been the control of diesel engine particulates and modifications to cyclone systems for collection of fine particulates. In both cases improvements on the order of 70% have been achieved with relatively simple apparatus.

The charged fog systems are now being tested in various industrial applications with generally good results. All of the work to date including industrial applications that have been released by the companies involved will be discussed in this report.

This paper covers the work done under EPA grant on development of new charged fog systems for control of fugitive dust; demonstration testing of the systems in industrial locations; investigation of the use of charged fog for control of sulfur dioxide; design and construction of a high temperature stack simulator for fog gun testing; development of new electrostatic hoods and screens for pollution control and a discussion of new methods for improvement of dry cyclones.

This report was submitted in fulfillment of Grant No. R805228020 by Professor Stuart A. Hoenig under the sponsorship of the U. S. Environmental Protection Agency. This report covers a period from 1 September 1977 through 30 September 1978 and work was completed as of 30 November 1978.

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INTRODUCTION

In an earlier report [1] we discussed the first two-and-one-half years of the Fugitive Dust Control program and reviewed the technology that had been developed. At that time there were still many questions about the use of charged fog in actual industrial applications and it was by no means clear just what the effects of temperature and contact time would be. Since that report was written the program has developed in a number of directions that will be discussed below. In most cases the applications we had looked for have developed and a number of new and interesting areas of research have been opened.

CONCLUSIONS AND RECOMMENDATIONS

We suggest that the charged fog technique has been demonstrated as an effective control technique for a number of fugitive dust problems. In some cases it is possible to suppress sulfur dioxide and diesel exhaust particulates by the same technique indicating that the charged fog system will enjoy wide use in industry and transportation. We have also begun to investigate specialized techniques for pushing or drawing industrial fumes from the area where they are generated to locations where control techniques can be applied. Again we feel that these systems will see wide industrial use.

We recommend that the present program be continued and that some thought be given to expansion so that more work can be done with industrial organizations to demonstrate the control systems in-the-plant.

I. LABORATORY INVESTIGATIONS

A. IMPROVEMENT OF DRY CYCLONES

Cyclones are widely used in industry for control of dust and fibrous particulates. They are simple, have no moving parts and require relatively little energy to operate. The problem with these systems has been their inability to "catch" the respirable particles in an air stream without significant added complexity and pressure drop. An examination of the literature [2] suggested that the problem was twofold. First, much of the dust emitted from the "clean air" outlet consisted of "fines" that had been deposited in the dust box and then "picked up" again by the vortex. The second problem was the escape of fine dust particles from the boundary layer at the inside of the cyclone. Here the suggestion was that the centrifugal forces on these small particles were not large enough to overcome the aerodynamic forces causing boundary layer breakaway [2].

We felt that the dust box "pick up" problem might well be solved by some sort of cone or cone and plate system that would allow dust to fall into the box but would prevent the vortex from picking the fines back out again. In Figure 1 we show a typical cyclone, of the type used for our experiments, with a cone in place just above the dust box discharge. Results with this system have been most satisfactory and will be shown in Figures 3 and 4.

To solve the centrifugal problem we felt that the most appropriate system would be a simple charged fog generator to induce agglomeration with the hope that the agglomerates would be heavier and therefore more subject to centrifugal effects. This may be an oversimplification of a complex problem in that one author [3] has demonstrated that electrostatic effects are important even in "normal" dry cyclone operations where the dust is charged by triboelectric effects. It may well be that this phenomenon will have to be investigated in some detail as part of our future program.

For the first series of experiments we purchased a twelve inch nominal diameter high efficiency cyclone. The charged fog generator was located on the cyclone centerline as shown in Figure 1. The fogger was brought in through the clean air outlet with the idea that if the system were used in industry this would be the simplest type of retrofit system. (We have found that industrial managers are quite willing to try new devices as long as there is no requirement for modification of equipment that is currently operating well.)

For experimental purposes the cyclone was driven at a flow rate of 410 SCFM (11.6 m^3/min) by a centrifugal blower. The cotton trash was poured into the air stream from paper cups that were dumped into the air intake of the blower every thirty seconds. This system is somewhat inelegant but we were unable to find any sort of feeding system that would work with cotton trash and, in fact, the paper cup system was suggested by Mr. Marvis N. Gillium of the U. S. Department of Agriculture Cotton Research Laboratory in Mesilla, New Mexico.

The fog generator for this system was designed to be simple and not subject to clogging by fibrous particulates. The system used is shown in Figure 2. The corona is generated between the grounded nozzle and the high voltage wire; typical operating voltages have been some 17 kV. To date this system has been most satisfactory. We have been able to operate the fogger at various levels in the cyclone without trouble.

The fine emissions from the cyclone were measured by means of a GCA Corporation RDM-101 Beta Ray system. Periodic tests with an Anderson-2000 impaction sampler indicated that the emissions were entirely in the respirable range (below ten micrometers aerodynamic diameter).

The results with this system are shown in Figure 3 where we show the dust emission from the "clean air" outlet of the cyclone over some twenty "runs" (each run represents a test with the GCA unit). As the dust box filled up the emissions increased due to dust box pickup, as Stairmand has suggested [2]. The next lower curve, taken after the cone had been installed, showed a reduction in emissions of about twenty percent corresponding to Stairmand's theory. Once again the emissions rose as the dust box was filled, suggesting that some pickup was still occurring. The lower curves show the effect of added water fog and it is apparent that the fog performs two separate functions: first, it induces agglomeration and thereby improves cyclone operation; second, it dampens the dust in the dust box so that pickup is made more difficult. The effect of this "wetting" was quite apparent when a window was installed in the dust box; without the cone or the fog the cyclone vortex entered the box and created a storm of dust particles.

The greatest reduction in dust (71%) occurred with (+) charged fog and we feel that this is a most satisfactory result for such a limited program. To appreciate how this will affect cyclone operations we have plotted, in Figure 4, the usual cyclone efficiency curve and the University of Arizona data. We feel that this technique has "pushed" the cyclone system into a new area without the usual complexities and costs associated with highly efficient cyclones. It should be noted that the quantity of water involved was quite small (20 ml/min) and in no case were the walls of the cyclone wetted. There was no apparent buildup of corrosion or deposits on the walls of the cyclone after many hours of operation. We plan to continue this work by developing some improved forms of the cone system that will be easier to install in existing cyclones.

Another area of interest involves testing with other dusts. The Donaldson Company of Minneapolis, Minnesota has provided a quantity of AC fine dust (the standard material used for tests of industrial filters). The whole question of triboelectric charging and its effect on cyclone operation and the use of charged fog remains to be investigated. At the moment we have data on just one material, cotton trash, whose characteristics are completely undefined.

Another question relates to the industrial application of the system on large 36" cyclones of the type used by the cotton industry. It is well known that large cyclones are not as efficient as small ones and in many cases manufacturers have been forced to use a multiplicity of small cyclones rather than a single large unit. This results in higher costs, complexity and frequent clogging on fibrous dusts, e.g., cotton lint. We have received funding to install a charged fogger on a 40" cyclone handling cotton lint at the Marana, Arizona gin of the Producers Cotton Oil Company. We hope to demonstrate that large cyclones can operate efficiently if certain modifications and additions are made. This industrial application will have the added advantage of demonstrating the following system on a large scale apparatus.

B. LABORATORY STUDIES OF CHARGED FOG FOR SO_2 AND DUST CONTROL AT ELEVATED TEMPERATURES

One of the questions raised about the charged fog dust control system is the application in high temperature environments where some of the fog might be lost to evaporation. In previous reports [1] we suggested that most of the fog would be captured by dust and therefore be available for agglomeration, even at high temperatures. At that time there was only a limited amount of data to support this idea. Further data has been obtained with the system shown in Figure 5 where temperatures up to 370°C can be generated. The first results are shown in Figure 6 for a typical copper smelter fly ash. It is clear that the fog was effective in suppressing the respirable dust and that the presence of significant levels of SO_2 did not affect the process.

In another series of tests, with the system of Figure 5*, we held the initial level of dust (copper company fly ash) and SO_2 constant and observed the effect of charged fog on the reduction of SO_2 and fly ash. Typical results over a range of temperatures are shown in Figure 7. It is clear that the charged fog was effective in reducing both the SO_2 and the dust level. The effect of the charged fog on the dust did not vary appreciably with temperature but maximum SO_2 reduction was at about 250°C. This was observed consistently and we suggest that below 250°C most of the SO_2 has not converted to SO_3 and is relatively insoluble in the fog. At 250°C the conversion was almost complete and the effect was large, while at higher temperatures the SO_3 becomes less soluble in the fog and the effect falls off. At present we have no apparatus for measurement of SO_3 versus SO_2 so this is mere speculation. We hope to continue these tests and develop apparatus that will allow continuous monitoring of both SO_2 and SO_3 concentrations.

In future high temperature tests we plan to make use of the Anaconda Stack Simulator to be discussed in Section C.

In another series of tests we have investigated the use of charged fog in suppression of fly ash from a western power plant burning low sulfur coal. The first results are shown in Figure 8 where we have plotted the initial and final dust levels as a function of the operating temperature. It is clear that there was a significant dust reduction, especially at 100° and 150°C which is close to the operating temperatures of many power plant electrostatic precipitators. This suggests that the charged fog system might be used to pre-agglomerate the fly ash, thereby improving the collection efficiency of the ESP. This might be particularly important with older ESP units where the efficiency for fine (one micrometer) particulates is low.

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*It should be noted that the metal box shown in Figure 5 was quite small and that the air velocity in the system was only a few feet per second. This suggests that wall effects could be most important in this system, and it was in recognition of this problem that we built the Anaconda Stack Simulator.

Tests at higher temperatures (200°C and 250°C) yielded somewhat conflicting results and we suggest that this was due to desorption of water from the fly ash. For future studies we will precondition the fly ash to remove adsorbed water before running the experiments.

The initial studies were done without added SO_2 because of a breakdown in SO_2 system. Some very limited, high temperature SO_2 data is shown in Figure 8 and we did not see the large reduction in SO_2 that was observed with copper company B precipitator dust. We suggest that with the metallic copper company dust there was significant conversion of SO_2 to SO_3 and that the SO_3 reacted very quickly with the injected fog. In the case of the nonmetallic fly ash this SO_2 to SO_3 conversion did not occur.

SO_2 is not very soluble in water and we suggest that this is the reason that little reduction in SO_2 was observed. We propose to repeat this experiment with water that has been charged with $Ca(OH)_2$ with the expectation that the SO_2 will react rapidly to form $CaSO_3$.

Another possible improvement involves the use of additives to reduce surface tension and improve dust water contact. In Figure 9 we show the effects of adding Johnson Marsh Company compound MR to the water; there was a significant improvement and we propose to investigate this effect further. In this connection it is worth noting that the addition of detergent materials to water used for scrubbing or fogging is quite controversial in that the lowering of surface tension will reduce the maximum charge that the droplets can hold while at the same time a lower surface tension might well enhance particulate wetting when the droplet actually contacts one or more dust particles. Resolution of this question will require a series of rather detailed experiments which we hope to schedule as time is available.

In view of the discussion above where we indicated that the existing in-the-furnace test system is subject to a number of errors we plan to do all future testing in the Anaconda system shown in Figure 10. This will allow accurate measurements of contact times and the effects of a heated environment.

C. TESTS WITH THE ANACONDA STACK SIMULATOR

In earlier reports [1] we discussed design and construction of the Anaconda funded stack simulator. This unit provides for heat input, addition of dust and gases, a controlled air flow, plus appropriate fogging and sampling systems. To date all tests have made use of precipitator dust provided by a local copper smelter.

Typical results at ambient temperature are shown in Figure 11. The upper curve shows the typical dust density profile measured in some three successive runs. We consider this to be excellent uniformity in a practical system that can simulate industrial conditions. The lower curves show the effect of added water fog; with (-) fog there was a significant reduction in respirable dust. This is most encouraging especially in view of the fact that in this system the total contact time between dust and fog was relatively short (1.5 seconds). It appears from Figure 11 that successful dust-fog interaction did take place in times as short as two seconds, suggesting that the system might well be used in ducts leading to a precipitator or cyclone system. In this connection it is worth noting that we have been contacted by a major manufacturer of ESP systems to propose experiments that would demonstrate how the charged fog system might be applied to improving ESP operation.

In the next contract period we expect to begin high temperature tests with this system and to investigate the effects of added SO_2. Previous laboratory studies have indicated that charged fog can be used to induce absorption of SO_2 on dust and then serve as a binder for the resultant agglomerates. As such this method offers the opportunity to control both dust and SO_2 in a single operation.

D. NEW APPARATUS DEVELOPMENT

One barrier to the wider use of charged fog is the limited size of the units commercially available. The commercial Fogger I (Figure 12) was first developed and sold by the Ransburg Corporation of Indianapolis, Indiana. In November 1978 the fog gun line was purchased by the Ritten Corporation, Ltd. of Ardmore, Pennsylvania. Ritten will be marketing the Fogger I and II along with the other air pollution systems discussed below.

Fogger I is inherently a rather small system with a limiting flow rate of 1 gal/hr (3.78 L/hr) and is intended for small or highly concentrated dust sources. In view of this limitation we appreciated the need for larger systems and began the development of the units to be marketed as Fogger II, III, etc.

The problem here is not simply generating more fog. The fog must be charged and this may be difficult to do with electrostatic induction when the fog flow is very heavy. In a heavy fog flow only the outer layer of fog, that is nearest the induction charging ring, will be charged. We have found it possible to charge such flows directly by holding the nozzle at a high voltage. This does present the problem of electrical leakage down the water supply line, but we have found it possible to eliminate this leakage by the use of plastic tubing and injecting air bubbles into the water stream close to the nozzle. The bubbles provide a barrier to the flow of electricity without interfering with the operation of the fog nozzle.

Another type of charging system, where the nozzle is grounded and the fog is forced to flow through a corona discharge, was shown in Figure 2. We have found this system to be most reliable and expect to use it on some of the new fogging systems. It has the added advantage that there is no inherent voltage limitation as there is with inductive charging. The electrostatic field and the corona discharge can be shaped for most efficient charging of the fog pattern appropriate to the problem. We expect to use this system on the high temperature fogger being designed and tested for the Anaconda Stack Simulator.

To generate large quantities of fog we have made use of the Swirl Air nozzles sold by the Delevan Manufacturing Company of West Des Moines, Iowa. These units are effective at high flow rates and have the added advantage that there are no small orifices to be plugged if the water is contaminated. (We have found that the industrial water provided for spraying is frequently contaminated by rust and nonsoluble particulates; clogging with conventional nozzles is a serious problem.) The Delavan Company has provided data on the droplet size generated by their units. Typical mean diameters of fifty micrometers can be expected with the existing systems.

Another problem with large scale use of charged fog is the "projection" of the fog some distance, i.e., as far as 25 feet (7.62 m). If fog droplets are thrown into still air they will travel some three feet (0.91 m) before being "stopped" by aerodynamic drag. The best way to extend this range is to provide a "sheath" of moving air around the fog. This moving air will carry the fog with it to the target. The Swirl Air nozzles do provide some sheath air naturally but we have found it practical to increase the effect with devices called Transvectors manufactured by the Vortec Corporation of Cincinnati, Ohio.

These units make use of the Coanda effect to generate a large flow of low pressure air with a small input of high pressure air. Typical multiplication ratios, i.e., induced flow/input flow, are as large as 40 and there are no moving parts to require maintenance. We suggest that the Swirl Air nozzles be mounted inside an appropriately sized Transvector, as shown in Figure 13, in order to project the fog to the greatest possible distance. A photograph of a system of this type in action is shown in Figure 14. Typical fog water flows with this unit are 11 to 15 gal/hr (41.6 to 56.8 l/hr) and charge collection tests have indicated that we are charging <u>all</u> of the fog rather than the outer shell as would be the case with induction charging.

To demonstrate the effect of this dust control system on a "large" dust source we set up the dust generation system shown in Figure 15. Figure 16 shows the effect of the charged fog in reducing this pollution. The dust in this case was gypsum which we have found to be a low cost material for these large scale tests. Typical numerical data with a system of this type is shown in Figure 17.

We have made some industrial tests of these large units and that data will be discussed in Section II.

Another area of interest has been the development of special fog guns for extremely dusty environments. There have been some cases where dust build-up on the usual Fogger I units has resulted in short circuits and burn up. One modification to prevent this is an air blown plastic shield that fits around the grounded nozzle and prevents dust build-up. A drawing of this modified Fogger I system (suggested by Mr. Werner

Alchenberger) is shown in Figure 18. We have tested this unit on a Fogger I in the Anaconda dust tunnel with excellent results. We anticipate that fog guns used in very dusty locations will be modified accordingly.

The Anaconda test facility discussed above will allow us to test the charged fog system at high temperatures. This will require a fog gun that can operate at temperatures as high as 200°C, which precludes the use of plastic insulators. The first system for this purpose is much like that shown in Figure 2. Preliminary tests indicate that this unit will allow us to generate charged fog at the high temperatures achieved in the Anaconda system.

E. DEVELOPMENT OF A HAND GRINDER WITH AN INTEGRAL DUST CONTROL SYSTEM

Industrial grinding, sanding and chipping are known to generate copious amounts of dust. In many cases the dust contains large quantities of silica or other hazardous materials and as such presents a problemm to industries concerned with industrial health. There have been attempts to attach various types of dust collectors to grinders but in most cases they have failed because the high velocity of the grinding wheel or sanding disc propels the dust out of the collection region. It is possible to provide overhead collectors to prevent the dust from entering other parts of the plant but this is of little help to the operator who handles the grinder since he is exposed to the dust before it can get to the collection hood.

Under these circumstances we felt it was important to develop a dust control system that was an integral part of the grinder but did not upset the normal weight, balance or appearance of the system. The final technique is shown in Figure 19. Water is passed down the shaft of the grinder and dispensed to the working area of the cup grinder by centrifugal force. (This system is the subject of a patent application by the Ransburg Corporation.) This added water not only suppresses dust, it also serves as a coolant to prevent "burning" the metal by excessive grinding pressure. There has been some observation that water cooled grinding is faster than dry grinding but these are only auxiliary factors to the major purpose of the study, which was control of dust.

Typical results with the dust controlled grinder are shown in Figure 20. There was a significant reduction in respirable dust with a minimal quantity of water, suggesting that this system may have important industrial applications. The ARO Company of Bryan, Ohio is test marketing this system at the present time and commercial versions should be available in the early part of 1979.

F. THE MECHANISMS OF PARTICULATE CHARGING

In earlier reports [1] we suggested that the anomalous charging of certain particulates might be due to the diffusion of ions to the surface during some sort of heating process. The candidate ion was sodium since it is a common contaminant and is well known to have a rapid rate of diffusion in solids. The idea was that when a material was heated sodium would diffuse to the surface and produce a layer of positive charge that would reduce or even reverse the normal negative charge found in particulates.

To test this assumption a specimen of pure powdered quartz, provided by the International Minerals and Chemical Corporation of Libertyville, Illinois, was ground with mortar and pestle and then vacuumed into the special Anderson 2000 sampler and Trek voltmeter system discussed in our first report [1]. The charge was measured as a voltage and is shown in the open bars on the histogram of Figure 21. All of the dust was negatively charged but the larger particulates had the highest level of charge.

We should note here that this type of graph may be deceptive. What is plotted is effectively total charge for the particles size range of interest. If the plates had been weighed after collection the ratio of charge to weight of material collected would probably yield bars of approximately equal height. The interest here was in the effect of temperature and for these first experiments no weighing was done.

We plan to repeat this experiment with pure quartz, desert sand and other particulates, at a series of increasing temperatures, to see if the sodium diffusion effect can be confirmed.

G. MEASUREMENT OF THE QUANTITY OF WATER NEEDED TO SUPPRESS A GIVEN DUST LEVEL

This is obviously important information for planning of a dust control system but until recently our dust feeding apparatus could not provide a constant dust level to permit comparative experiments over some period of time. Recently, we have made use of a Vibra Screw feeder (Vibra Screw Incorporated, Totowa, New Jersey 07511) to produce a relatively constant level of dust in the 2' x 2' dust tunnel. This dust was exposed to increasingly higher levels of (-) charged fog (this polarity had been found to be most effective in earlier experiments) and the change in dust level measured with the Anderson 2000 impaction sampler. The data is shown in Figure 22. At a water flow rate of 40 ml/min the dust density at the four micrometer size level was reduced by some 86% We suggest that further increases in flow rate would be of little value. The flow rate for optimum control was 8.7 ml/g. This value will be used for design purposes in future studies.

We plan to extend these tests to other industrial particulates as time permits. The work is tedious and there are a number of other topics that are of more pressing interest.

H. DEVELOPMENT OF NEW NON-FOG DUST CONTROL SYSTEMS

In discussions with industrial managers it has become clear that control of fugitive dust will require more than a series of fog guns. In many cases the fog guns cannot be used in the area where the dust and smoke are generated. In some cases the pollutants must be collected and moved into an area where appropriate control techniques can be used. For some situations, i.e., diesel exhaust particulates, the control system must be designed to fit on the vehicle itself, preferably as part of the regular exhaust muffler unit.

All of these problems suggst that we look into techniques for containing and moving fugitive dust or smoke so that proper control techniques can be used. The results of this work to date will be discussed in this section. In every case the necessary patent disclosures have been filed with the University Research Office.

1. Control of Diesel Engine Particulates by Means of an Electrostatic Technique

One major objection to the diesel engine is the visible plume of carbon particulates. Another, and potentially more serious problem, is the respirable particles that have been suspected of being mutagenic [4]. In view of the increasing use of diesels for automobiles and their potential for underground application in mines, it seems important to develop some method for control of exhaust particulates.

The particles are essentially carbon flakes some 0.1 to 10 micrometers in diameter; they cannot be removed by conventional filters because of the associated flow of engine exhaust gases, while cyclones are of little value because of the size and weight of the particles.

The book by Lawton and Weinberg [5] suggests that these particles are electrostatically charged. In view of this charging we suggested that electrostatic forces be used to draw the carbon dust out of the gas flow. A typical system is shown schematically in Figure 23, where we have added a swirler system to induce flow rotation. The rotation was expected to encourage large particles to move outward toward the wall. The diesel smoke simulation system involved the partial combustion of C_2H_2 with limited air (personnel at the Donaldson Company in Minneapolis, Minnesota suggested that this was the best method for generating diesel type particulates). The only other element in the system was a corona wire on the axis of the pipe. Typical operating conditions were: air velocity, 335.5 m/min (1100 ft/min); temperature, 23C; corona voltage -20kV. The simulated diesel smoke was injected at the intake port of the driving blower.

Initial results were observed visually and a photograph is shown in Figure 24 with the electrostatic field "off" and "on". The reduction in particulate level is very apparent. To obtain quantitative data the experiment was repeated with an Anderson impaction sampler at the outlet of the plastic tube. Typical results are shown in Figure 25; there was a significant reduction in fine particulates, and we suggest that this may be a low cost method for controlling diesel engine emissions. After continued operation one would expect emission of larger agglomerates but these clumps of carbon would fall out quickly and be too large for consideration as respirable particles.

We hope to improve this system further to achieve higher efficiency and possibly develop some way of permanently capturing the collected particles to preclude reemission. Tests on an operating diesel engine in the University Mechanical Engineering Department will be run as soon as the necessary apparatus is finished.

2. The Electrostatic Hood and Curtain

One of the major problems with fugitive dust and fume systems is that in many cases they cannot be installed at the point of generation because of the need to bring in a crane or front loader. A copper converter is a perfect example of this problem; the need to move cranes and ladles in and out of the area precludes the installation of a permanent hood at the most effective location. In some cases hoods have been installed above in back of the converter, in the hope of catching some of the emission, but in most situations this has not been very satisfactory and converters are a major source of smelter fugitive emissions.

A somewhat similar problem exists in smelter matt-tap areas where personnel movement and crane operations preclude the use of fixed hoods; as a result, there is significant fugitive emission that is hard to control once it has mixed with a large quantity of air.

We have been developing two types of devices that we feel will help alleviate these problems. The first is an electrostatic hood to collect dust and smoke for ultimate disposal. The second is an electrostatic curtain that might be used to "push" dust and smoke sideways toward a hood.

a. The Electrostatic Hood

This device is shown schematically in Figure 26. The objective here was to allow the dust and fume from a hot area to move upward by means of natural buoyancy, while at the same time containing and compressing the smoke to prevent escape and allow the use of a small overhead hood for eventual collection. The operational smelter system would be based on chain mail mesh supported by appropriate metal rings. The system would be light, easy to move or fold up when not needed and relatively immune from damage by moving objects, i.e., the crane. The outer shell would be held at ground potential and thus provide a significant personnel safety factor.

During operation the inner cone would be held at a high negative potential (25 kV) to draw smoke, fume, etc., up between the inner and outer cones. There is extensive experimental evidence that most dust and smoke from "hot" sources are positively charged [5], but for uncharged smoke we have designed a smoke charger.

A working model of the experimental hood is shown in Figure 27 with the voltage "off" on the left. The smoke is provided by partial combustion of C_2H_2, a reaction that is known to produce positively charged smoke [5]. With the field "off" the smoke rises through the cone in the normal manner. With the field "on" (Figure 27, right side) the smoke is drawn into the space between the cones and carried out the top of the system. In actual practice there would be a small conventional hood in this position to draw off and suppress this emission.

The smoke that does not emerge from the top of the electrostatic hood system is deposited on the inner cone, and in practice we would expect that the entire hood system would be washed or shaken periodically to remove the deposited material. Our experiments have indicated that the deposits are highly agglomerated and can be shaken off without breakup into respirable dust particles. This should simplify the cleaning process.

The smoke charging system was designed and tested after we tried to use the electrostatic hood on uncharged oil vapor smoke and found that it did not work. The unit is a simple modification of the improved electrostatic curtain to be described below. The uncharged smoke is drawn in at the bottom of the system and as it passes the corona points it is charged. Some of the smoke is deposited on the grounded screen, but any smoke that passes through the screen is drawn up to the electrostatic hood in the normal manner. In either case the smoke is removed from the ambient air and is no longer a pollutant. Periodically, the system may have to be washed down or shaken to remove agglomerates, but this should not be a severe problem.

We feel that the addition of a smoke charger will make the hood system useful on a wide variety of pollution control problems. We hope to test a similar system on lead fume where control by charged fog has not yet been successful. We expect that lead fume will be intensely charged by the corona ion current, and that the charged fume will be agglomerated by oppositely charged fog.

b. The Electrostatic Curtain

The electrostatic curtain is a dual purpose device. On one hand it provides a significant flow of molecular ions that can be used to charge dust, smoke or fume. This might be especially appropriate for dusts or fumes, e.g., lead, that are difficult to charge by ordinary means because of back corona effects. A second advantage of this system is that it produces an electric wind that can be used to "push" smoke, dust or fume to the proper area for control. Electrostatic devices have a number of advantages over conventional fans or blowers; there are no moving parts to corrode, a steady pushing effect can be produced over a wide area with a relatively small expenditure of power and the systems are light and can be flexible enough to roll up or swing out of the way. When contamination does occur they can be simply shaken clean or even washed with a hose. If inadvertent contact occurs the flexible format will minimize damage and the design is such that no high voltage components are exposed to cause injury.

Our designs have gone through several modifications over a period of time. The first systems used steel phonograph needles inserted by hand in a brass plate to demonstrate the effect. This system was quite effective. In Figure 28 we show the application to uncharged aluminum chloride smoke. In the upper photograph the electric curtain is "off"; in the lower photograph the curtain is "on" and the smoke is pushed backwards. Typical air velocities with this system are 1-2 m/sec, strong enough to push smoke or dust rising by thermal convection.

We felt this design was inappropriate for large scale manufacture and after some experimental studies settled on the system shown schematically in Figure 29. Here the phonograph needles have been replaced by wire brushes that are low in cost and available in a wide variety of sizes and shapes. For our application the brushes would be mounted end to end with the insulators between every two or four brushes as needed. (The initial batch of insulators was made to our design by Professor M. K. Grossman of the University of Arizona Department of Art, Ceramics Group. For large scale purchases we will go to a commercial ceramics manufacturer.) In front of the brushes there will be a grounded metal screen to serve as the corona counterelectrode.

Behind the brushes we propose to mount a porous plastic material to permit airflow and another grounded screen as a safety element. With this system every exposed surface is electrically grounded so that there is no danger of personnel injury due to inadvertent contact. The whole system can be swung out of the way or rolled up like a window shade when not needed.

One possible application for the system is shown in Figure 30 on a copper smelter converter. During times of heavy fume emissions the curtain would serve to "push" the smoke toward the hood for more efficient collection.

These applications of the electrostatic curtain imply a significant "scale up" in size over the laboratory systems tested to date and it is appropriate to comment on what changes in performance might be expected from this vast change in size. In general we suggest that the "pushing velocity" of some 1 to 2 m/sec observed above would not change to any significant degree with a larger curtain. The distance that this flow will "push" the pollution is harder to estimate but since normal rates of rise for heated smoke are less than 1 m/sec we would expect that the curtain might push the smoke at least 2 or 2-1/2 meters in the horizontal direction. Unfortunately the present laboratory space is not suitable for larger scale tests. We have discussed this problem with some of the local copper companies and hope to make use of their experimental smelter facilities in the Spring of 1979.

One interesting application of this system is control of smoke from burning sodium. Sodium is converted to sodium oxide by burning in air and to date it has not been practical to completely suppress the submicron particulates by fogging or wet scrubbers. We suggested to the company involved that the electrostatic curtain be used for this purpose and a typical experiment where the smoke from burning sodium is drawn into the curtain and deposited on the brushes and the grounded screen is shown in Figure 31. For industrial application we would anticipate a series of brushes and screens to insure that every particle of sodium oxide is collected. When the brushes and screens are "full" the system can be washed down with water to remove the deposits.

We feel that this system will solve the immediate problems and improvements will allow the same type of unit to be used on a semipermanent basis. A similar system may well be effective on lead fume which again has been traditionally hard to collect with conventional ESP systems.

I. IMPROVING THE PERFORMANCE OF ELECTROSTATIC PRECIPITATORS

Electrostatic precipitators (ESP) are widely used in industry for control of dust, fume and smoke. In general their operation is quite satisfactory with three exceptions. First, charging of one micrometer particles is relatively inefficient and the collection efficiency in this size range may be rather low. A second problem with ESP units is boil-up during rapping. As the dust falls into the hoppers there is air entrainment and the fine particles are picked up by the air stream where they can appear at the outlet. A last ESP problem, of particular concern to the non-ferrous metal industry, is corrosion. This leads to rapid failure of ESP wires and side plates with excessive inleakage (300% inleakage is not unknown) that results in a loss of stack draft.

We have been discussing the idea of fogging ahead of a precipitator with a large manufacturer of these units and hope to begin tests in the near future. The data of Figure 11 indicate that rapid agglomeration can be achieved by means of charged fog, suggesting that this technique can be used ahead of an ESP.

The boil-up problem has been simulated on campus with the system shown in Figure 32. In Figure 33 we show the boil-up that occurs when the dust drops down the pipe. In Figure 34 we show the effect of charged fog. There was a significant decrease in dust, suggesting that this method could be used with ESP hoppers especially in the last stages where any re-entrained dust is very likely to be carried out of the system.

The ESP corrosion problem is particularly serious for industries that have significant levels of H_2O and SO_2 in the ESP feed gas. There will always be some SO_3 present and this can bring the dew point of the gas down from 350°F to as low as 200°F. Under these conditions any cold spot, e.g., a hopper, can be a point of H_2SO_4 formation. The acid eats away at side plates resulting in still more leakage, cooling, and acid formation. In many cases the ESP units purchased by the copper industry are "down" more than they are operating and corrosion is the major problem.

We have begun looking into this problem with the hope of finding an epoxy or ceramic coating that might be used in corrosion prone areas of an ESP. The requirements are severe; 800°F and H_2SO_4 exposure, and to date it appears that flame sprayed ceramic coatings will be most effective for this purpose. We have talked to two companies that handle flame sprayed ceramics, and small scale tests of mild steel coupons coated with appropriate materials may be done in the near future.

J. CONTROL OF DUST AND SMOKE DEPOSITION ON OPTICAL SURFACES

This is a secondary application of the electrostatic curtain technique and as such presents some topics of general interest.

This study originated with a request from the National Aeronautics and Space Administration to look at techniques that might be used to reduce dust deposition on the optical surfaces of a comet survey satellite. Calculations indicated that passage through the comet tail would coat the optical surfaces within a few minutes.

The electrostatic curtain was one approach to a control technique for this problem and present indications are that a system of this type might well be used on mirrors and lenses exposed to atmospheric contamination on earth. One such application involves the optical system for the SHIVA nuclear fusion system being developed by Lawrence Livermore Laboratory and discussions with that group have begun.

Another approach, developed by Mr. Merwyn G. Utter, is shown in Figure 35. Here the lens is surrounded by two metal rings mounted outside the field of view. When the lower ring is driven at about -10 kV the falling dust moves outward rather than falling on the lens. Similar results were observed with cigarette smoke, suggesting that this system could be used at least with small (10 cm diameter) lenses. This system has the advantage that there is no corona discharge to produce electrical interference or stray light that might interfere with optical studies.

Another protection technique involves the use of a corona sprayer to produce a layer of charge on the lens surface itself. If the lens is charged negatively and the falling dust is also charged negatively by an electric curtain, the dust will be repelled by the lens. We have observed this effect in the laboratory but found it difficult to photograph. It appears that a combined technique of this type would be most effective in controlling dust fall onto optical surfaces.

K. DEVELOPMENT OF HIGH VOLTAGE INSULATORS FOR USE IN INDUSTRIAL ENVIRONMENTS

In the first developments of the electrostatic curtain and hood it became clear that a major problem would be short-circuiting of insulators by deposits of dust and H_2SO_4 fume. This is particularly the case in a high voltage environment where the voltage gradient across the insulator will actually "draw" dust to that area.

In commercial electrostatic precipitators it is common to blow air over insulators or actually plan for periodic shutdowns to physically clean the insulators. We felt that these solutions were not appropriate for our application and Mr. Utter undertook the design and testing of several insulator systems that would be largely independent of dust in the environment. One such design is shown in Figure 36. Here the electric wind generated by the phonograph needles was quite effective in keeping the insulator clean even at 30,000 volts in an atmosphere of carbon smoke produced by partial combustion of C_2H_2. This system has the advantage that the cleaning effect is produced by the same high voltage that drives the curtain or screen.

Another system that is suitable for locations where high voltage or compressed air is not always available is shown in Figure 37. We have tested this system in a water droplet environment at over 35,000 volts without the slightest evidence of contamination or arc-over. We expect to make use of one or both of these systems in a variety of areas.

L. APPLICATION OF CHARGED FOG TO THE SUPPRESSION OF VARIOUS INDUSTRIAL PARTICULATES

These laboratory studies have been done in support of various field tests that the Ritten Corporation either has proposed or has under way. The general procedure involves the use of the 2' x 2' x 16' dust tunnel to expose a flow of dust to charged fog and determine the degree of suppression. Data on grain dust, cotton dust, trona, sandblasting grit, red lead battery dust, aluminum oxide, turkey barn floor sweepings, cotton brack, carbon black, bauxite, gypsum, and calcuium propionate are shown in Figures 38 through 49.

One interesting application of charged fog involves the control of welding fume. This fume is a mixture of chemical particles from the flux and metallic particles from the arc itself. Welding requires close operator control and as a result the metal fumes go past the welder before they can be captured by hoods and exhaust systems. We hoped that the charged fog would be effective in suppressing the fume at the actual source. Another advantage of this type of test is that it generates information about the interaction of charged fog with metal fume and this is of interest in the lead, zinc, and iron industries.

The experimental set up for this first test is shown in Figure 50. The continuous wire welder (Miller Electric Company, Model 35S) was loaned to the University by T. M. Caid and Sons of Tucson, Arizona. This welder was a bare wire, CO_2 shielded system and operated without flux. For this reason there was no flux smoke and the fume was primarily finely divided metal particles. To see the effects, if any, of added flux we placed the flux (Linde Company type AWS-A5.17-69) in the welding area by hand and sampled the emissions with glass fiber filters. The analytical data, provided by the University Analytical Laboratory, are given in Table 1; Blank 1 and Blank 2 were clean filters. The data indicates little difference between the flux and no-flux results except for somewhat higher levels of Ca, Sr, K, and Mg when flux was used. We do not consider these differences significant in terms of pollution emitted during welding.

Table 1. Welding Fume Data With and Without Flux (All data reported as mg/filter)

Sample I.D.	Fe	Na	Cu	Mn	Zn	Ca	Pb	Cr
Blank 1	15.1	893	<.6	<.15	1.9	172	2.23	0.23
Blank 2	14.6	523	1.48	<.15	6.8	55.6	2.23	0.15
With Flux	988	1610	26.3	162	7.5	398	2.43	<.08
No Flux	1820	1760	31.0	170	10.2	277	3.54	0.27

Sample I.D.	Sr	Li	Rb	K	Mg	Ni	Co	Be	Ba	V	Cd
Blank 1	4.24	0.3	0.68	60.6	52.4	<.03	<.13	<.025	<20	<.4	<.25
Blank 2	<.5	0.08	0.78	141	9.08	<.03	<.13	<.025	<20	<.4	<.25
With Flux	3.63	0.8	1.18	152	108	<.03	<.13	<.025	<20	<.4	<.25
No Flux	5.25	0.62	0.84	115	77.4	<.03	<.13	<.025	<20	<.4	<.25

The first experimental results in terms of the reduction in metal fume with charged fog are shown in Figures 51 and 52.

In general there was about a 50% reduction in captured particulates, but the data was subject to wide variations. An attempt was made to run at two different water flows in the hope of demonstrating that there would be an enhanced effect with lower water flows. In one case (Figure 51) this effect was observed but in another series of tests (Figure 52) just the opposite results were obtained. There were wide variations in the data from day to day for reasons which are not clear at the moment. We are planning some tests with a heated source of lead or zinc in the hope of gaining more understanding of the metal fume/water fog interaction.

The variations in the experimental results may have been due to changes in the welding process itself. The Miller unit was a small one and our technician is not a trained welder. Another problem may have been changes in the position of the welding head with respect to the stove pipe used to draw off the smoke and fume. The welding head had to be moved about to prevent the build up of a mound of weld material and this did change the induction characteristics of the system. We tried adding a 10" diameter funnel to the welding end of the system in order to improve the "draw" of the stove pipe and provide a more uniform flow of fume but this did not improve matters. We suggest that the problem was due primarily to variations in the welding process itself. In spite of these difficulties there was a general reduction in the fume from welding when charged fog was used.

In this connection we might note that this test system does not allow all of the fume produced by the welder to be exposed to the charged fog. We estimate that some 20% of the fume was pulled into the pipe (Figure 50) before the charged fog could get at it. This suggests that under actual industrial conditions where all of the fume is exposed to charged fog, the effectiveness of the system might rise from some 58% to 75%.

II. INDUSTRIAL TESTS

The available data from industry is limited to what we can obtain at local mines, smelters, cement plants, etc., and most of the results in 1977 were discussed in our last report [1]. Since then tests have been run at the Tucson plant of the Gates Learjet Corporation where the dust source was a belt sander.

The physical layout is shown in Figure 53. The irregular nature of the sander operation and the movement of workmen, lift trucks, etc., in the area precluded numerical measurements of the dust level. It was decided to look for "visual results" with charged fog. Typical before and after photographs are shown in the attached Figure 54. It was very apparent that the charged fog reduced visible dust generated by the sander and Company management has made arrangements for installation of one or more fog guns.

Other industrial results, at a local sandblasting operation, are shown in Figures 55 and 56. Here again, the irregular nature of the operation and the ambient winds precluded the use of conventional dust samplers. The fact that the man running the sandblaster was protected by a White Cap System and the need to keep the fog off sandblasted surfaces made it impractical to use personnel samplers. We chose to photograph the operation with and without the fog as shown in Figures 55 and 56. There was a significant reduction in visible dust and the company involved is rebuilding their sandblast booth to accommodate a fog gun.

Other commercial installations of eight or more Fogger I units have been reported by the Ritten Company with excellent results at a Midwestern foundry and a West Coast cement plant.

In the Southwest we have been working with several copper smelters on the application of charged fog units for control of dust and SO_2. In one case a Fogger I mounted above the silica belt has been most effective in suppressing the dust from the operation.

In another area of the same plant we have made use of the experimental Fogger II to suppress dust from a furnace clean-out operation. The dust normally blows from the unloading area into the smelter as shown in the upper part of Figure 57. The effect of charged fog is shown in the lower photograph of Figure 57; the offensive dust has been entirely eliminated.

In connection with these industrial tests there is always the question of how much of the observed dust reduction was due to the charged fog versus the simple "blow away" effect of the air aspirated by the fog gun itself. It is impossible to give a general rule for every case but we have attempted to test for these effects by first operating the fog gun with the air "on" and the water "off" to check on the blow-away effects. Another technique involved actually testing downwind of the fog gun as was done in connection with the test set up of Figure 17. In the sawdust tests of Figure 54 the agglomerated dust was quite visible on the floor under the fog gun. In the test of Figure 57 it was "impossible" to stand down wind of the dust source with the fogger "off"; with the fogger "on" the only noticable effect was an occasional spray of fine mist. We expect to continue these industrial tests and to make arrangements for quantitative testing whenever possible; however we have found that many industrial managers are "only" interested in visible effects. If they "see" the system work they do not want to waste time on a lot of measurements unless they are required to "meet" an OSHA or EPA citation.

Another series of tests with the fogging units were done in a local cotton gin where fibrous particulates were a problem. In this case it was possible to obtain numerical data and in Figures 58 and 59 we show data taken in three areas of an operating cotton gin. In every case there was significant reduction of dust and we anticipate working more closely with the cotton industry in the future.

III. DEVELOPMENT OF A HANDBOOK FOR USERS OF THE CHARGED FOG DUST CONTROL SYSTEM

The application of charged fog to the control of fugitive dust is quite new and we recognized the need for some sort of handbook that would help engineers in applying this technique. We have been able to do some work in this area but new applications seem to occur so rapidly that it has been difficult to stop and simply finish the material. Under these circumstances it seems appropriate to include Figures 60 through 64 showing typical applications of the fog guns in industrial situations. In general the first rule seems to be "suit the fog guns to the dust source." If the dust source is very large or diffuse the small Fogger I will not be effective unless many units are mounted in the same area. For large dust sources it may be more effective to obtain a Fogger II from the Ritten Corporation (contact Mr. F. A. Sando, President, The Ritten Corporation, Ltd., 40 Rittenhouse Place, Ardmore, Pennsylvania 19003 (215) 896-0900) or the author.

Dust testing is another problem. If the GCA Corporation RDM-101 unit is used there may be significant changes in the way the dust deposits under "dry" and "moist" conditions. This is shown in Figure 65. In some cases we have observed that a smaller quantity of dust will yield a larger reading on the RDM-101 because of the "pile up" effect. In these cases we suggest the use of filters for evaluation.

Another problem has been observed with personnel dust samplers. They vary widely in the amount of dust they collect and users are urged to take a large number of readings before drawing any conclusions.

One last problem that may arise is due to aspiration of ambient air through the Fogger I. In some cases this may give indications that the quantity of dust in the area has actually "increased" when the fog guns were on. This is obviously impossible: the fog guns cannot "make" dust. If aspiration is a problem or if aspirated dust causes short circuits in the fogger, the author or Mr. F. A. Sando at the Ritten Corporation should be contacted for appropriate modification systems.

IV. DEVELOPMENT OF SPECIALIZED DUST TESTING EQUIPMENT

In view of the difficulties in dust testing discussed above we have developed a simple dust monitor that can be used to give rapid qualitative estimates of the dust density in an area before and after fogging. The system makes use of a hand operated pump (the Bachrach Instrument Company, Mountain View, California 94043) and a Nuclepore 0.8 micrometer filter (Nuclepore Corporation, Pleasanton, California 94566). Dust laden air is drawn through the filter and the dust density is evaluated by a hand held optical reflection test system. This system is a portable version of the tape samplers used in automatic smoke evaluation systems.

The optical data can be converted to actual dust loading in mg by means of a calibration curve such as that shown in Figure 66. For precise dust measurements a calibration curve for each type of dust would be needed. For demonstration purposes where only the relative decrease in dust density with charged fog is required, no calibration curve is needed.

It is worth noting that if a calibration curve is available, a knowledge of the number of pump strokes and the air flow per stroke allows the operator to calculate the dust density in mg/m^3.

Another mode of operation would involve the use of several filters, of decreasing pore size, in series. This would allow the dust to be separated into fractional sizes before the optical evaluation.

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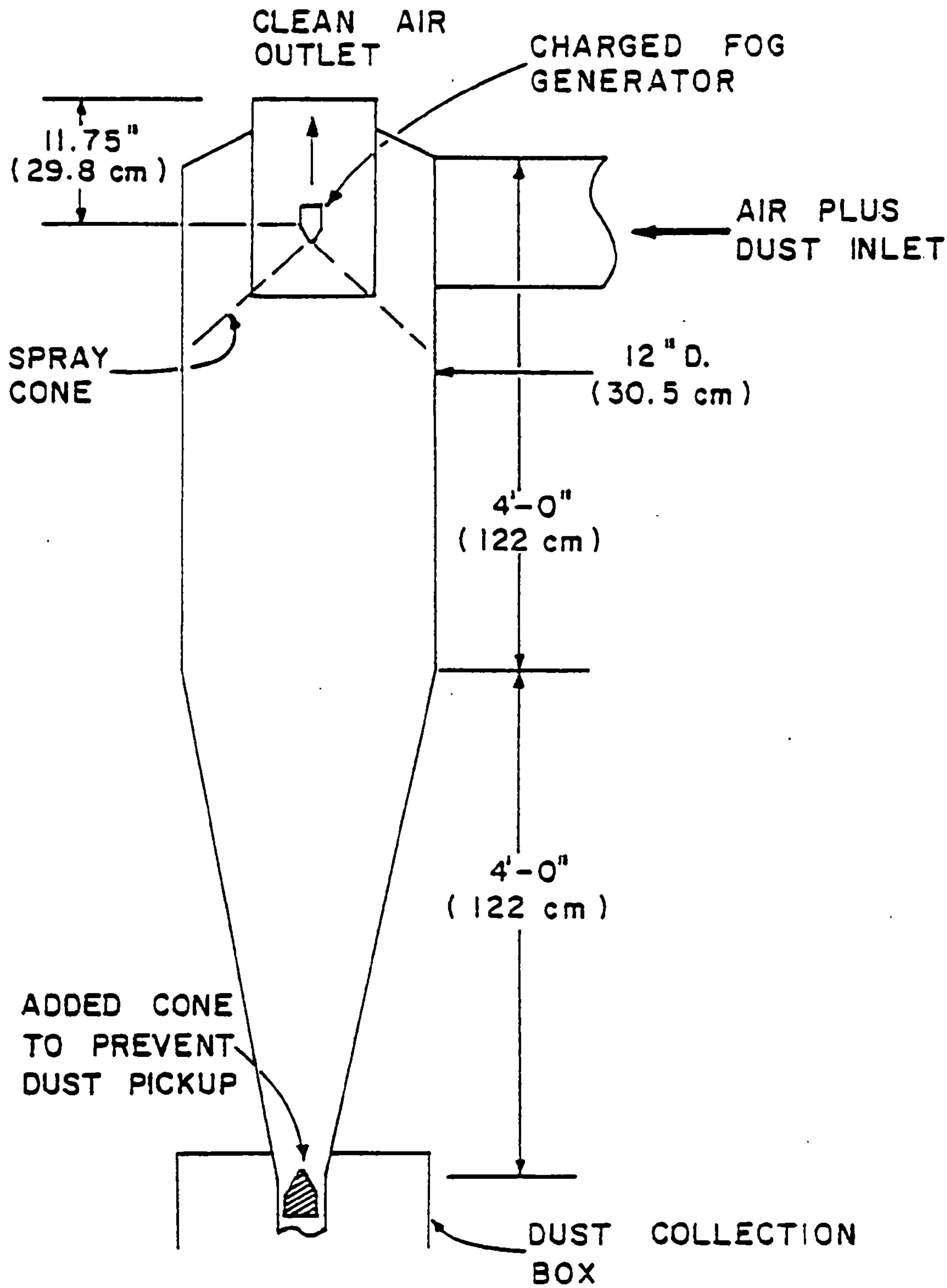


Figure 1. Dust cyclone modified for improved fine particulate collection.

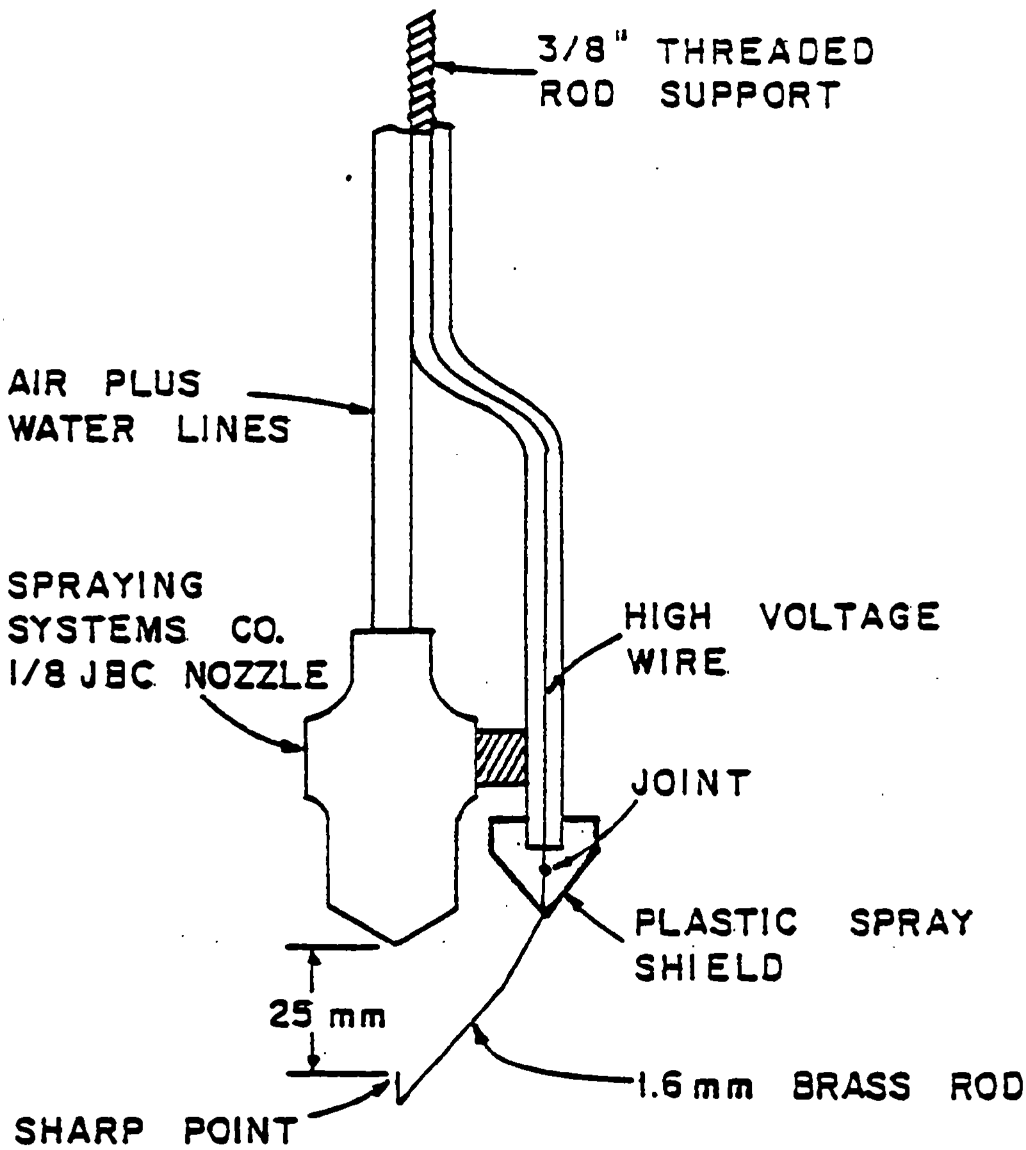


Figure 2. Fog generator for dust cyclone (scale: full).

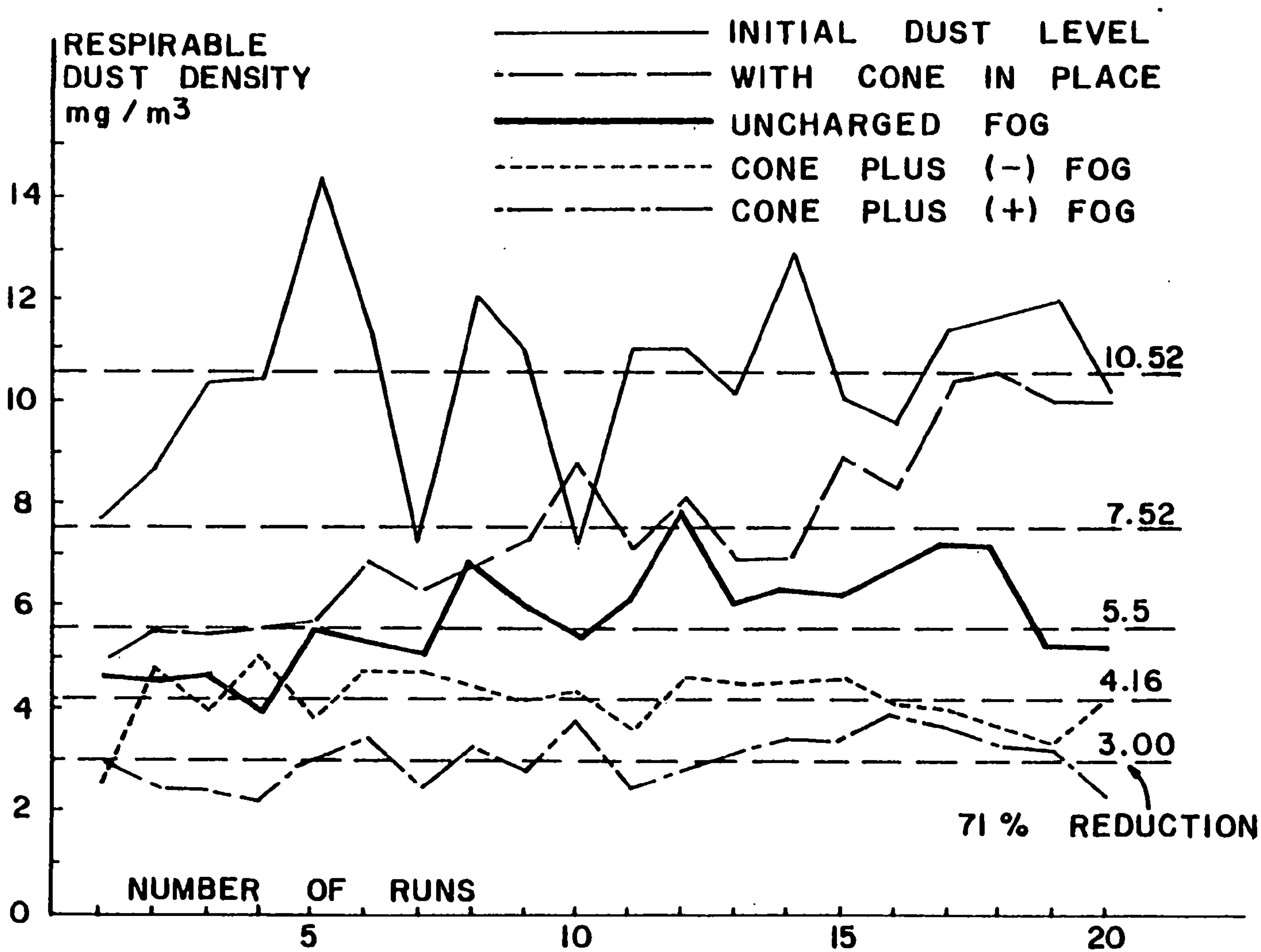


Figure 3. Improvement of control of fine particle emissions for dry cyclone operating on cotton trash. Air flow 12.2 m^3/min; water flow 20 ml/min; dust flow 190 g/min.

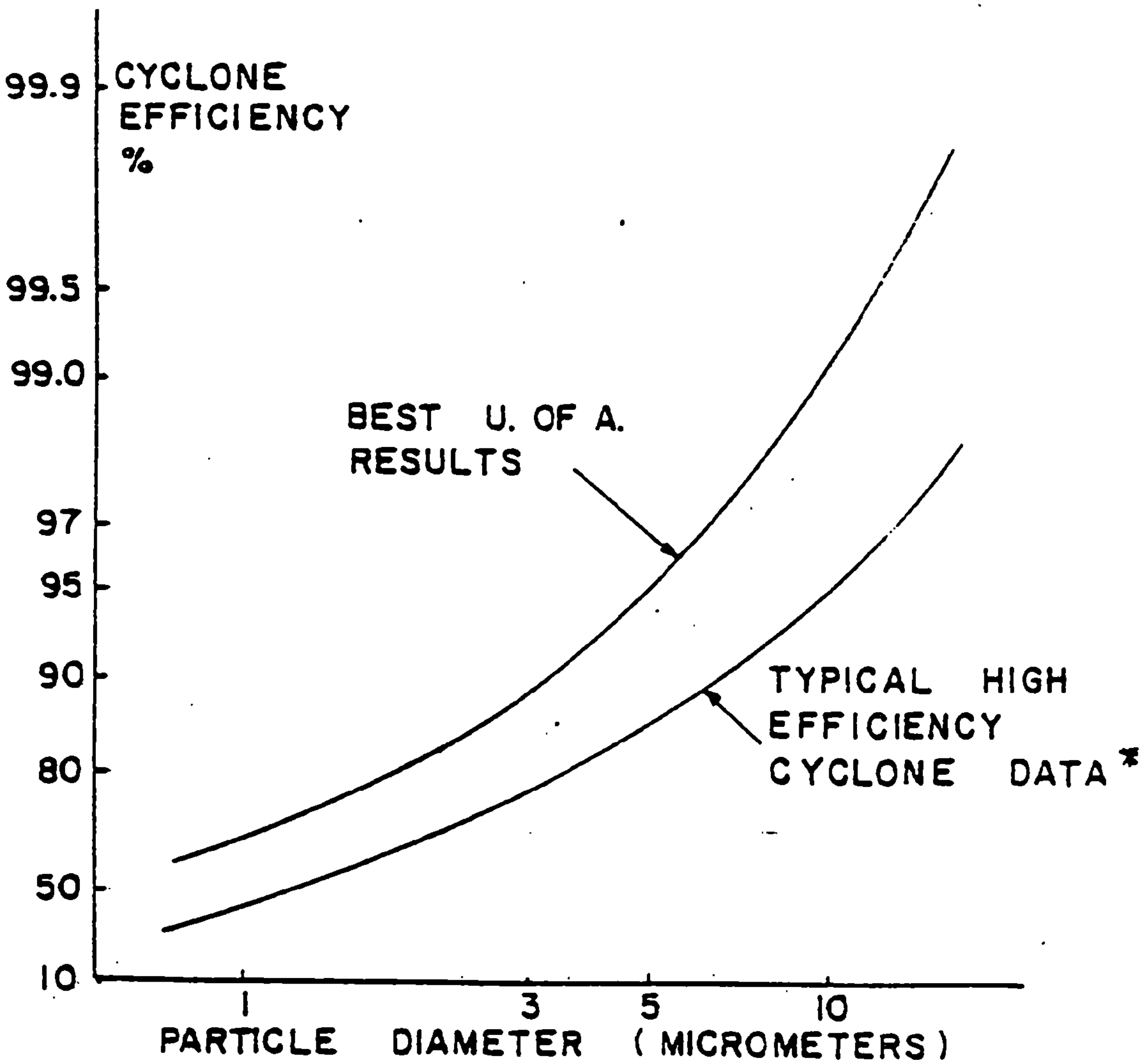


Figure 4. Improvement of cyclone efficiency with cone and charged fog, operating on cotton trash.

*W. Strauss, Industrial Gas Cleaning, Pergamon Press, 1975.

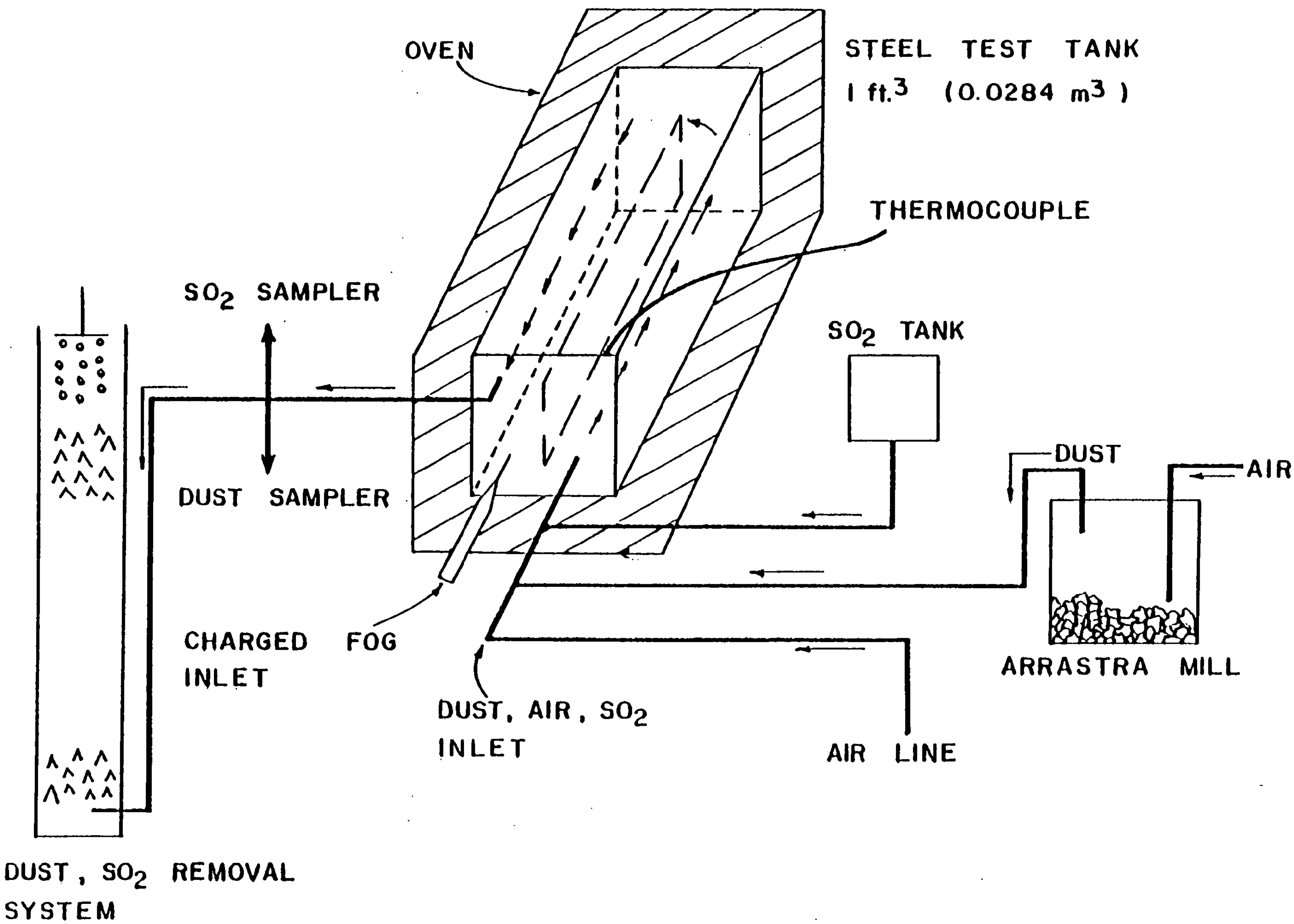


Figure 5. System for high temperature tests of the effect of charged fog on sulfur dioxide and selected dust materials.

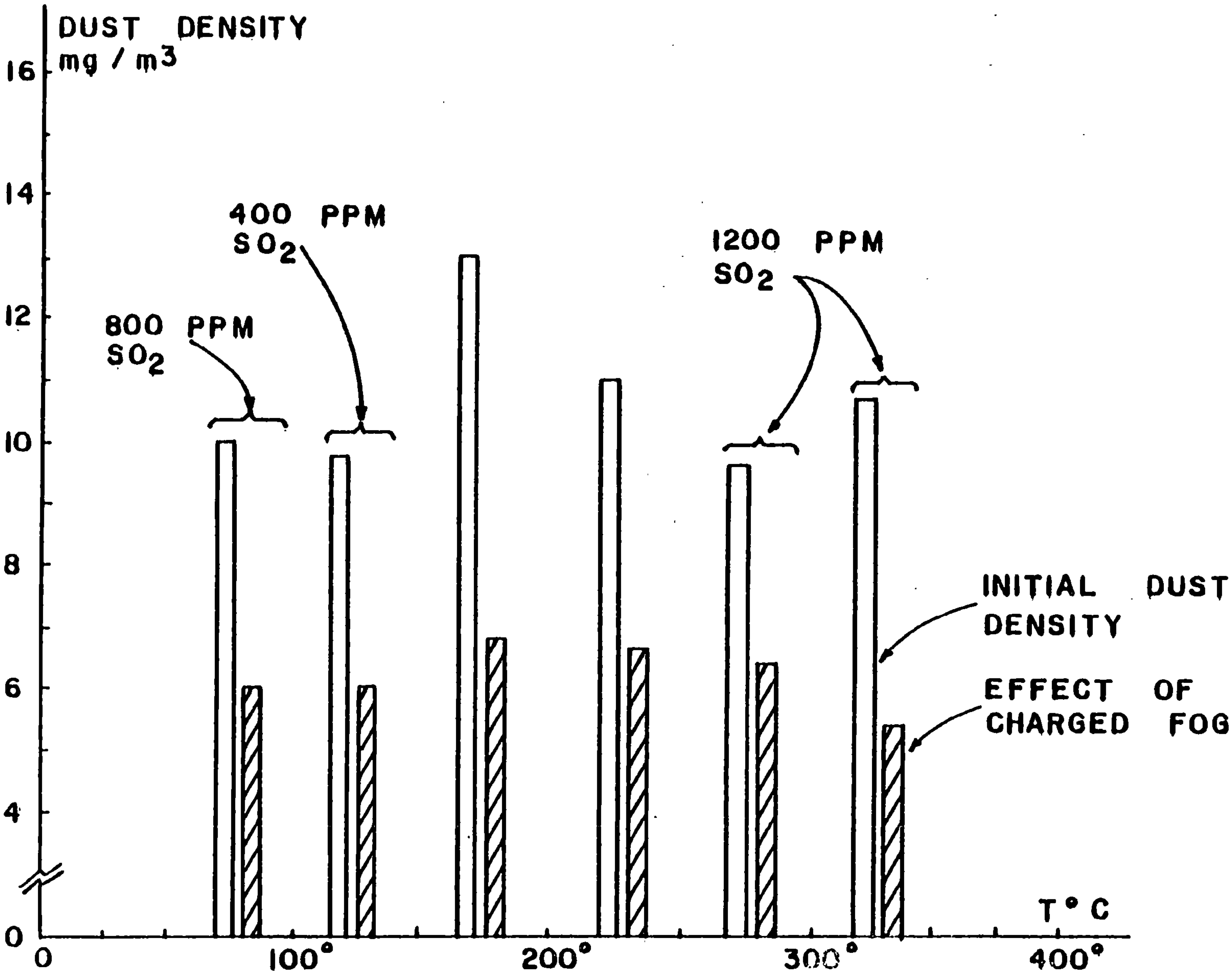


Figure 6. Control of copper company fly ash by means of charged water fog. Water flow 3 ml/min; air flow 0.58 m^3/hr.; fog charging voltage +6000 volts. Each column represents the average of at least eight runs.

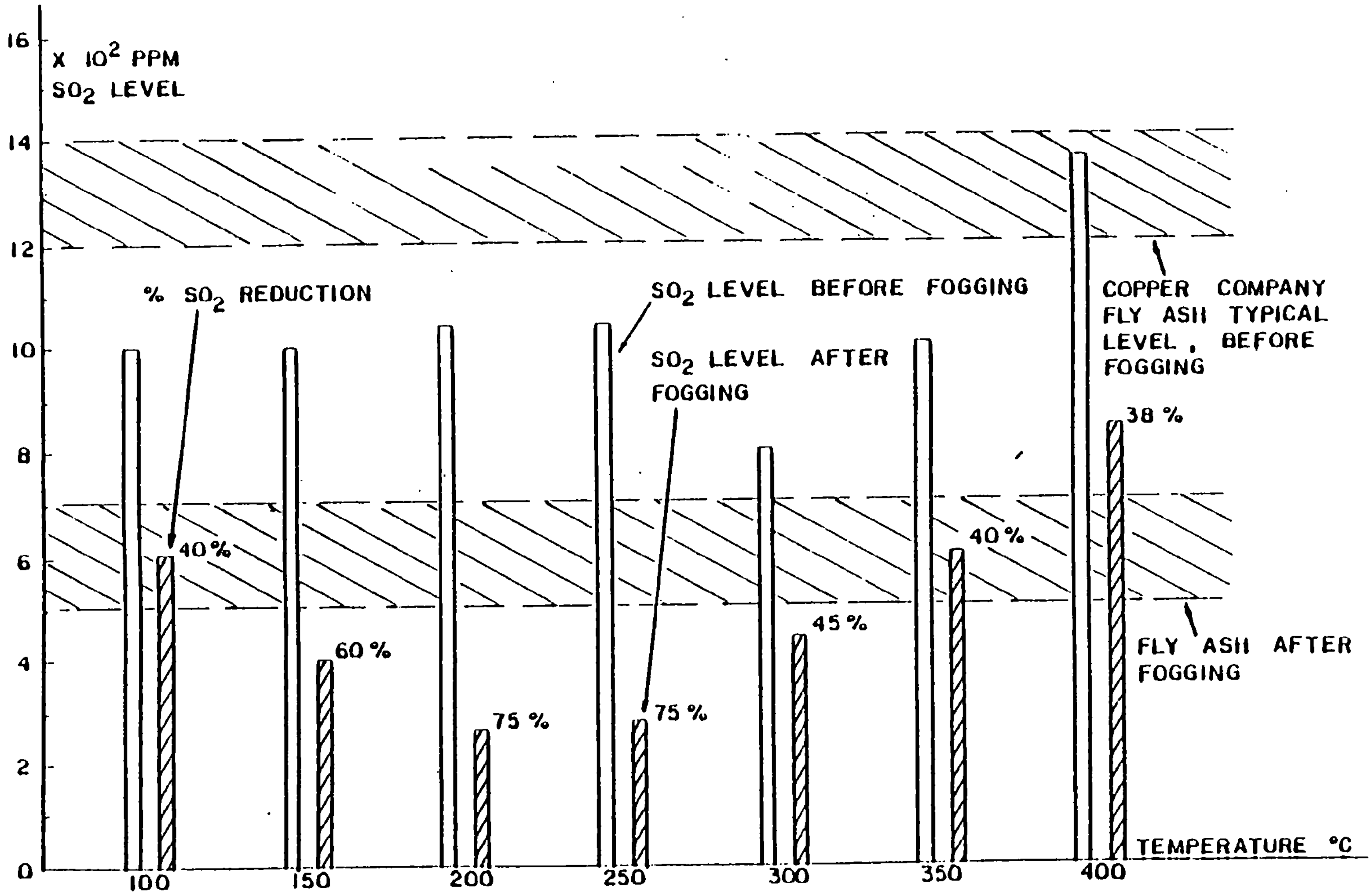


Figure 7. Control of SO_2 with positively charged water fog. Horizontal shaded bars show levels of fly ash. SO_2 flow 12 ml/min; water flow 3 ml/min; air flow 0.7 m^3/hr.

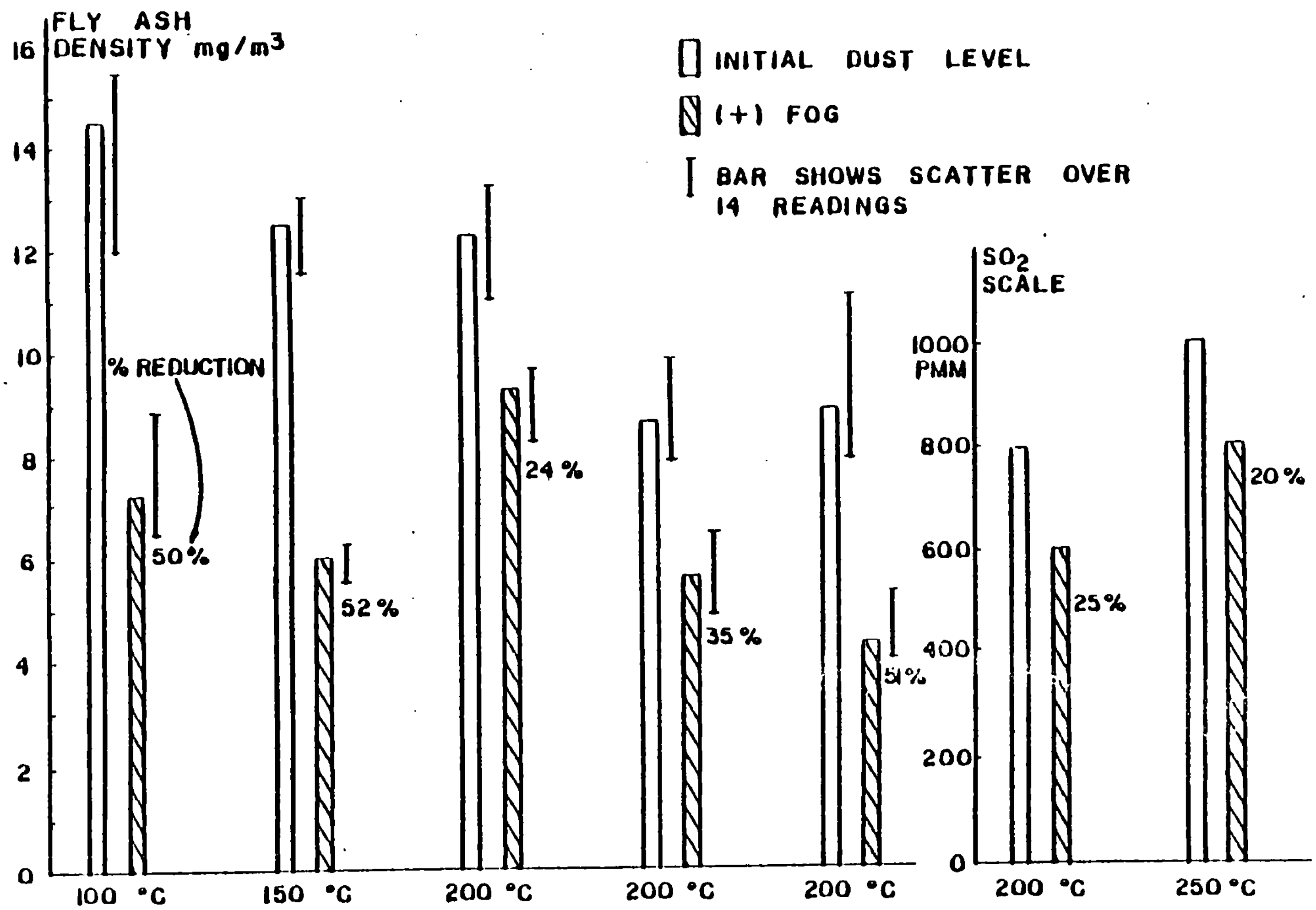


Figure 8. Control of power plant fly ash with positively charged fog. Water flow 3 ml/min; air flow 0.564 m^3/hr.

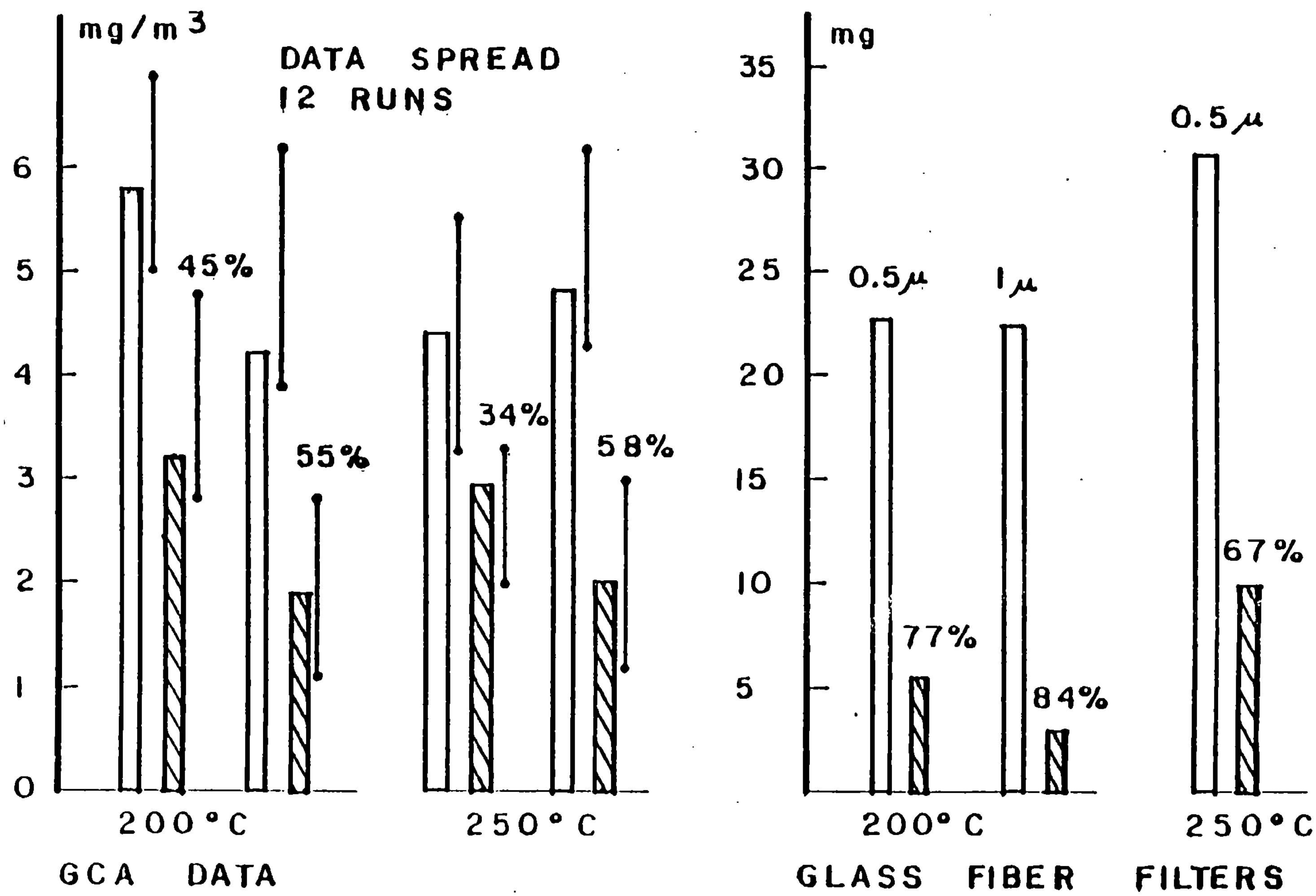


Figure 9. Control of power plant fly ash with positively charged water fog and 1% MR compound (Johnson March Co.) Water flow 1.5 ml/min.

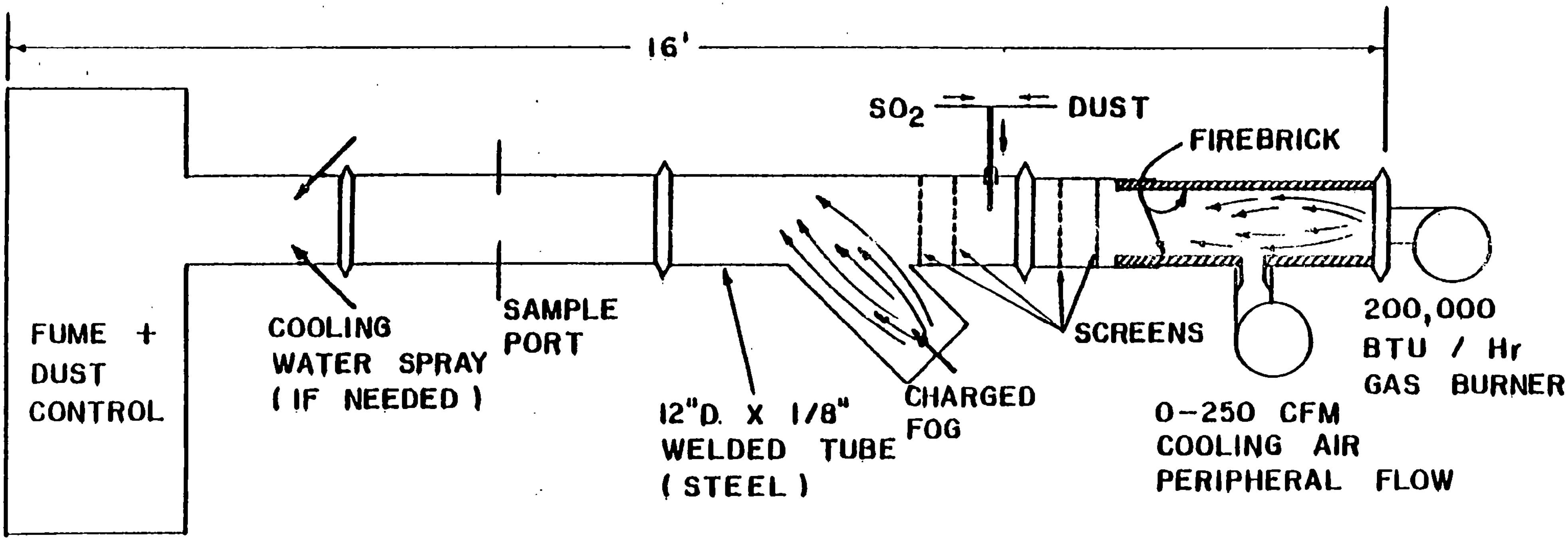


Figure 10. Schematic drawing of stack simulator apparatus funded by Anaconda Company.

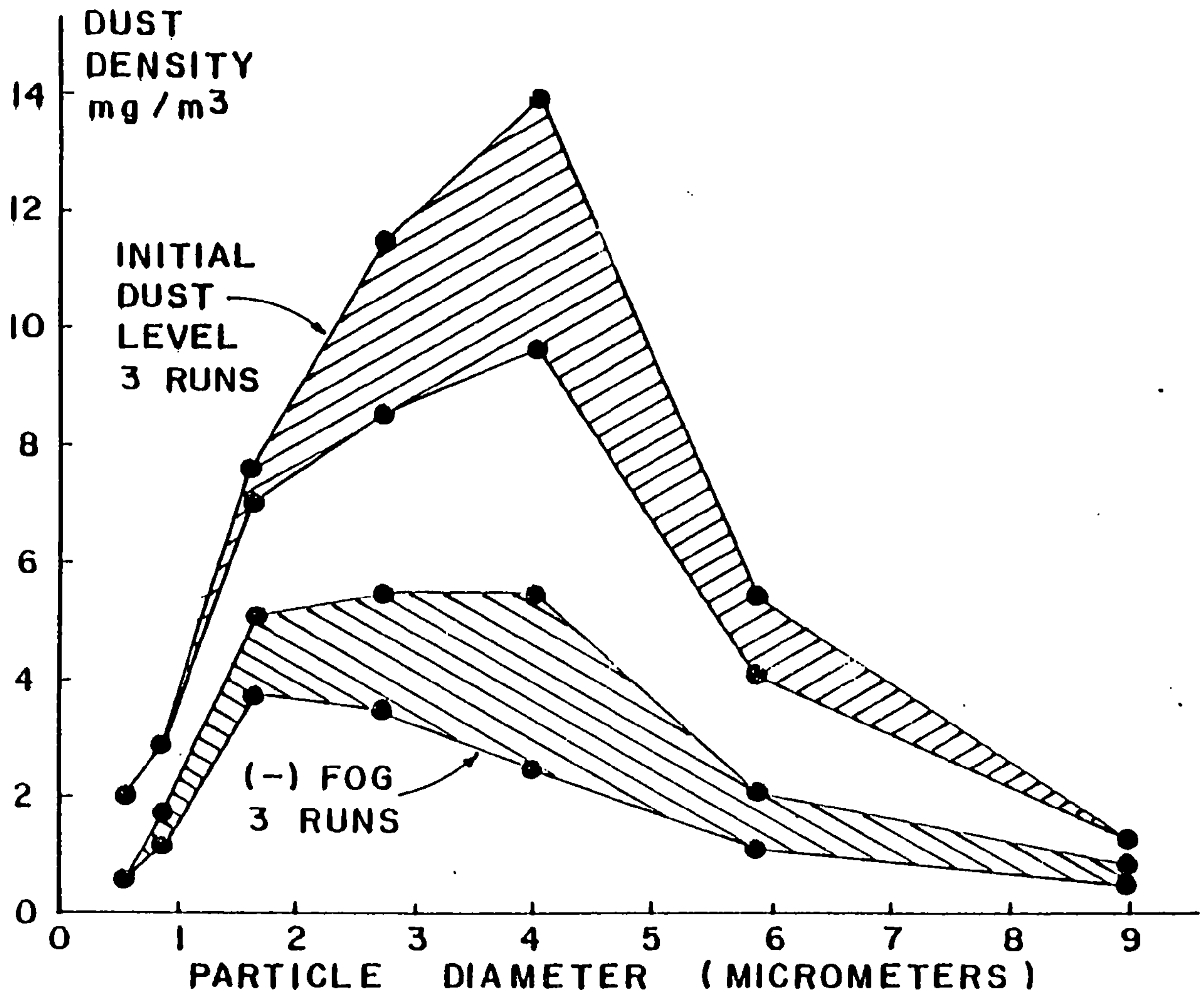


Figure 11. Control of smelter fly ash with charged water fog, tested in Anaconda stack simulator. Water flow 100 ml/min; air velocity 106.4 m/min; temperature 23°C; contact time 2 seconds.

Figure 12. Electrostatic fogger manufactured by Ritten Corporation, Ltd.

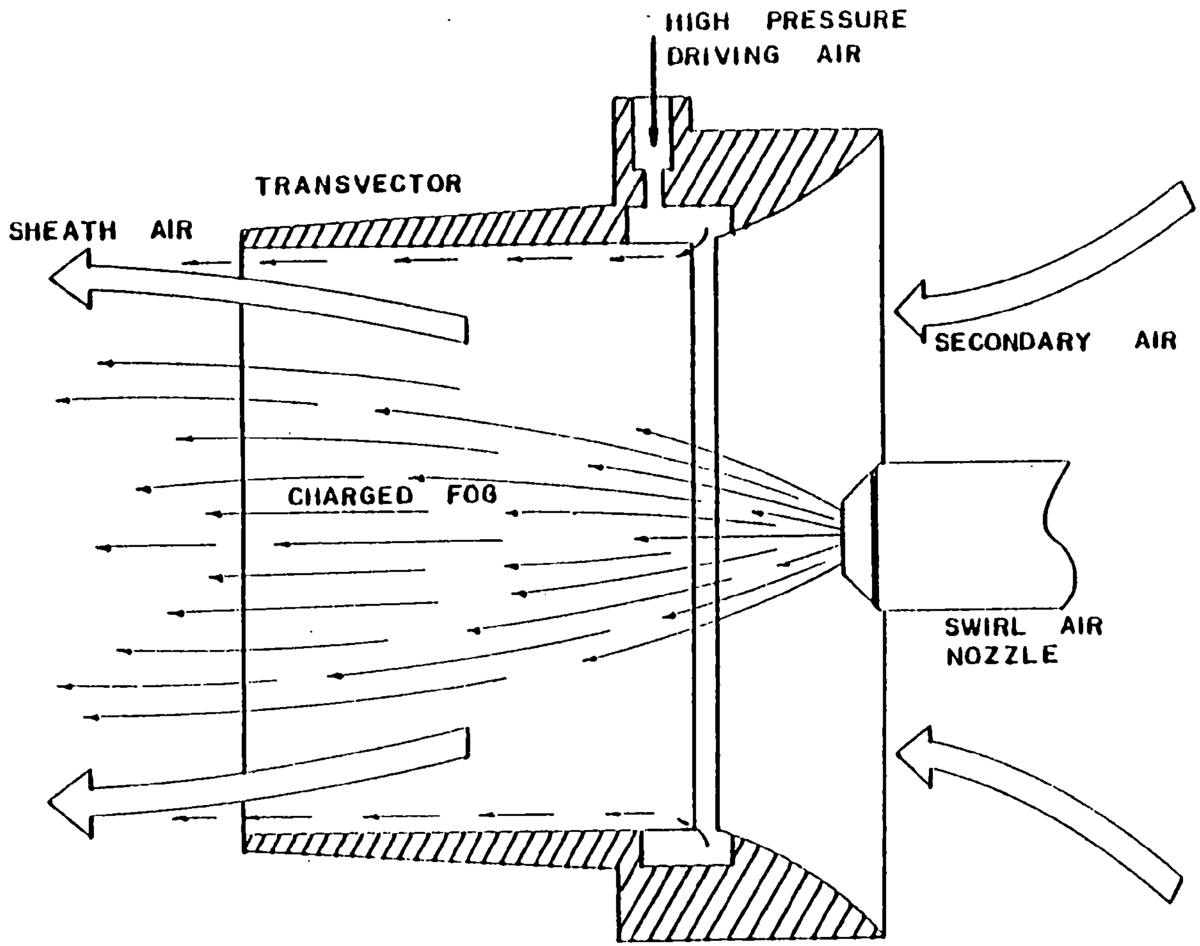


Figure 13. Schematic drawing of Transvector and Swirl Air fog nozzle system for projection of charged fog.

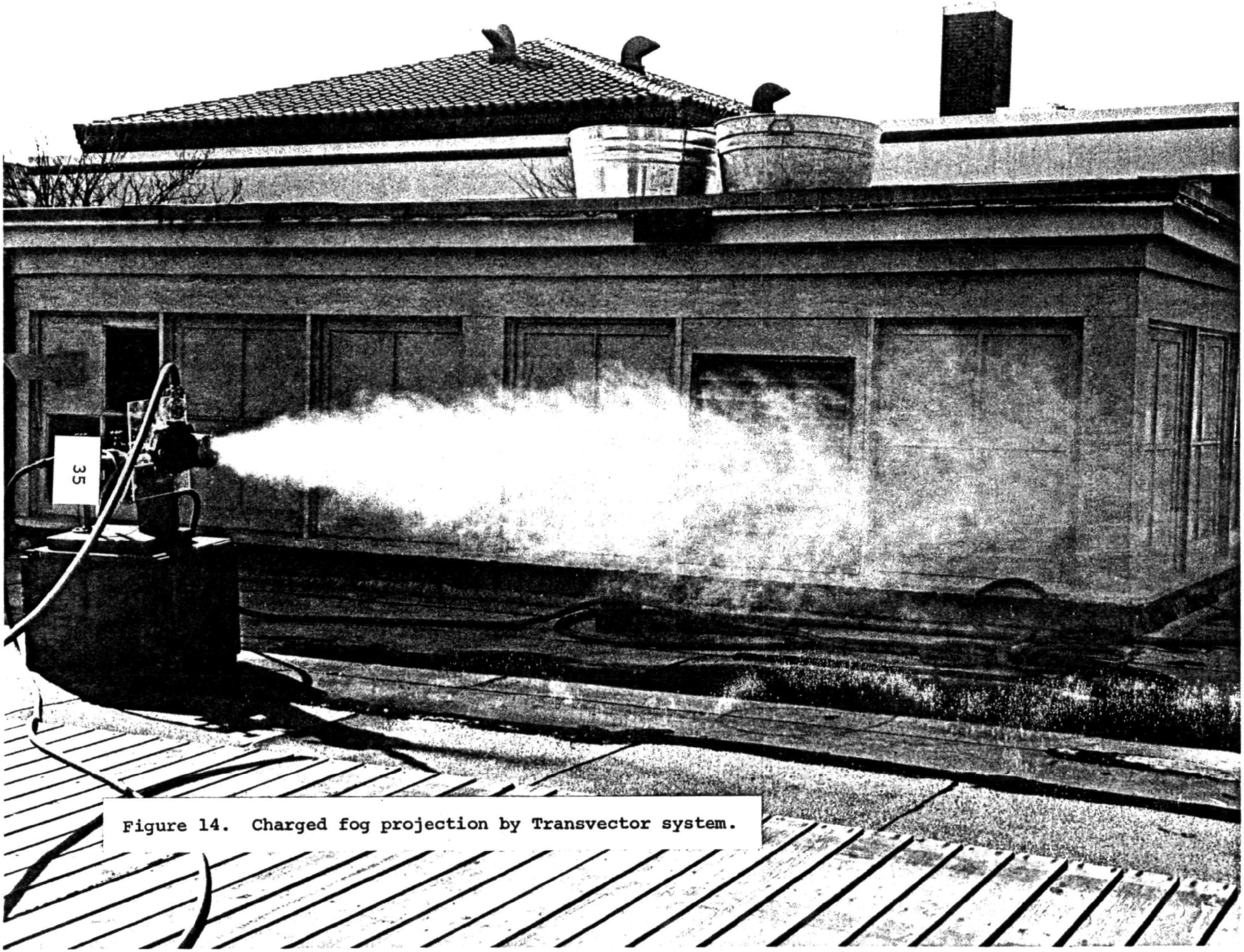


Figure 14. Charged fog projection by Transvector system.

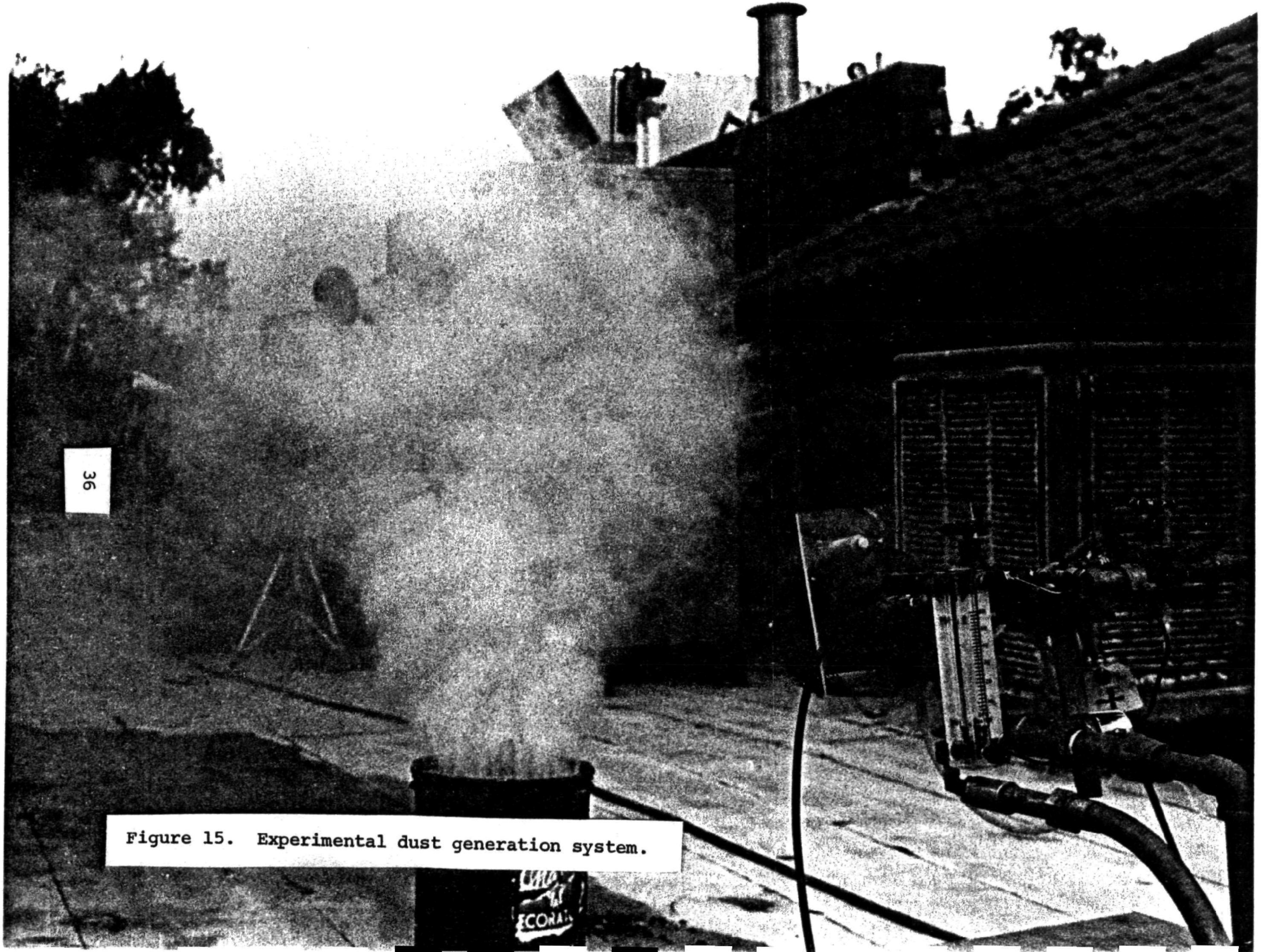


Figure 15. Experimental dust generation system.

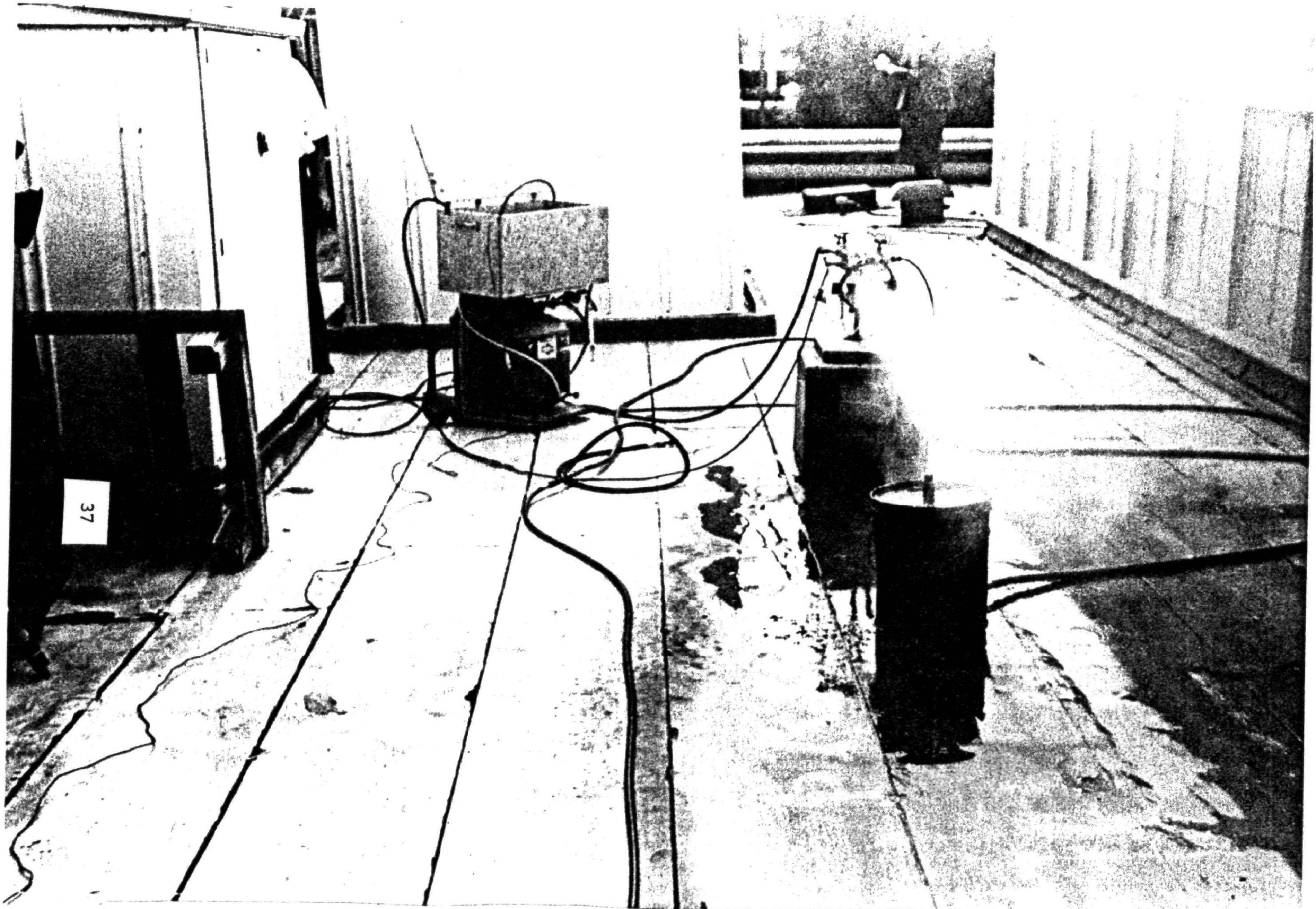
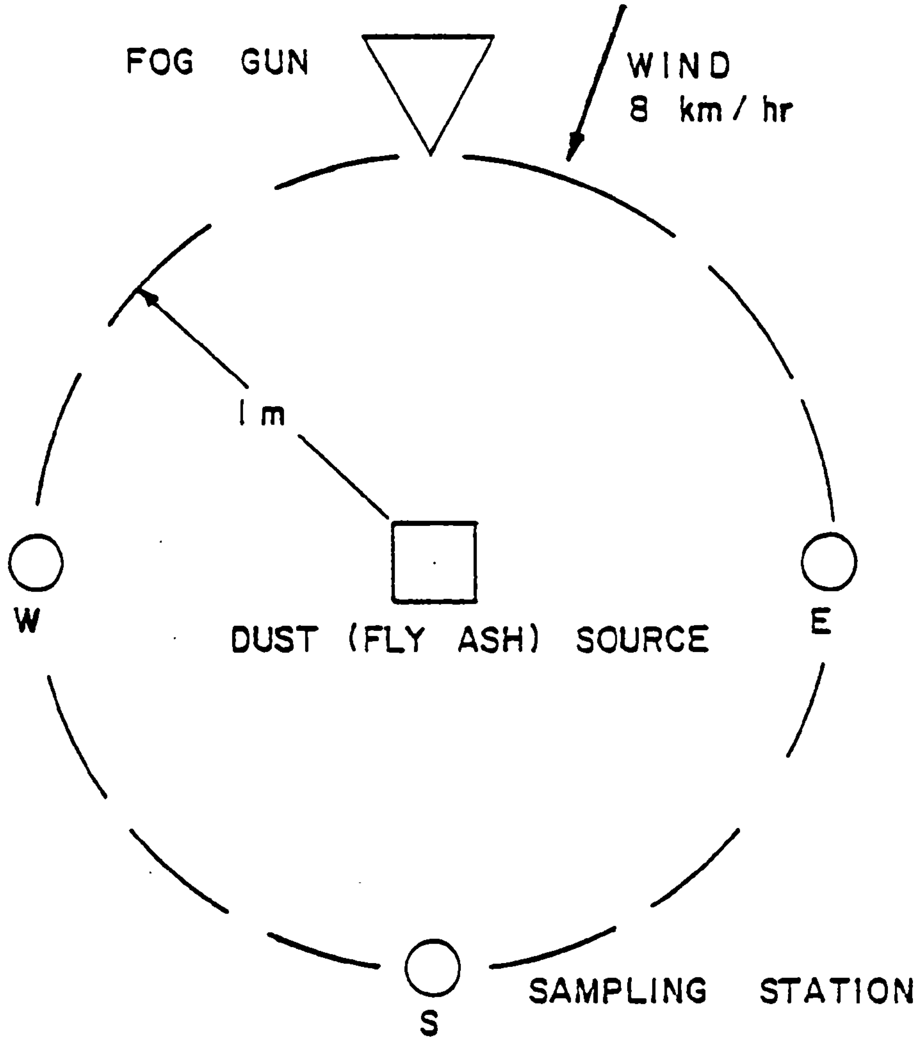


Figure 16. Effect of charged fog in reducing dust pollution shown in Figure 15.



STATION	E	W	S
DUST LOADING AVERAGE OF 4 RUNS	2.23 mg/m^3	2.0 mg/m^3	3.48 mg/m^3
DUST LOADING WITH (+) FOG 3 GAL./min	0.2	0.0	1.1
NET REDUCTION	91 %	100 %	68.4 %

Figure 17. Results of outdoor test of dust reduction by charged fog.

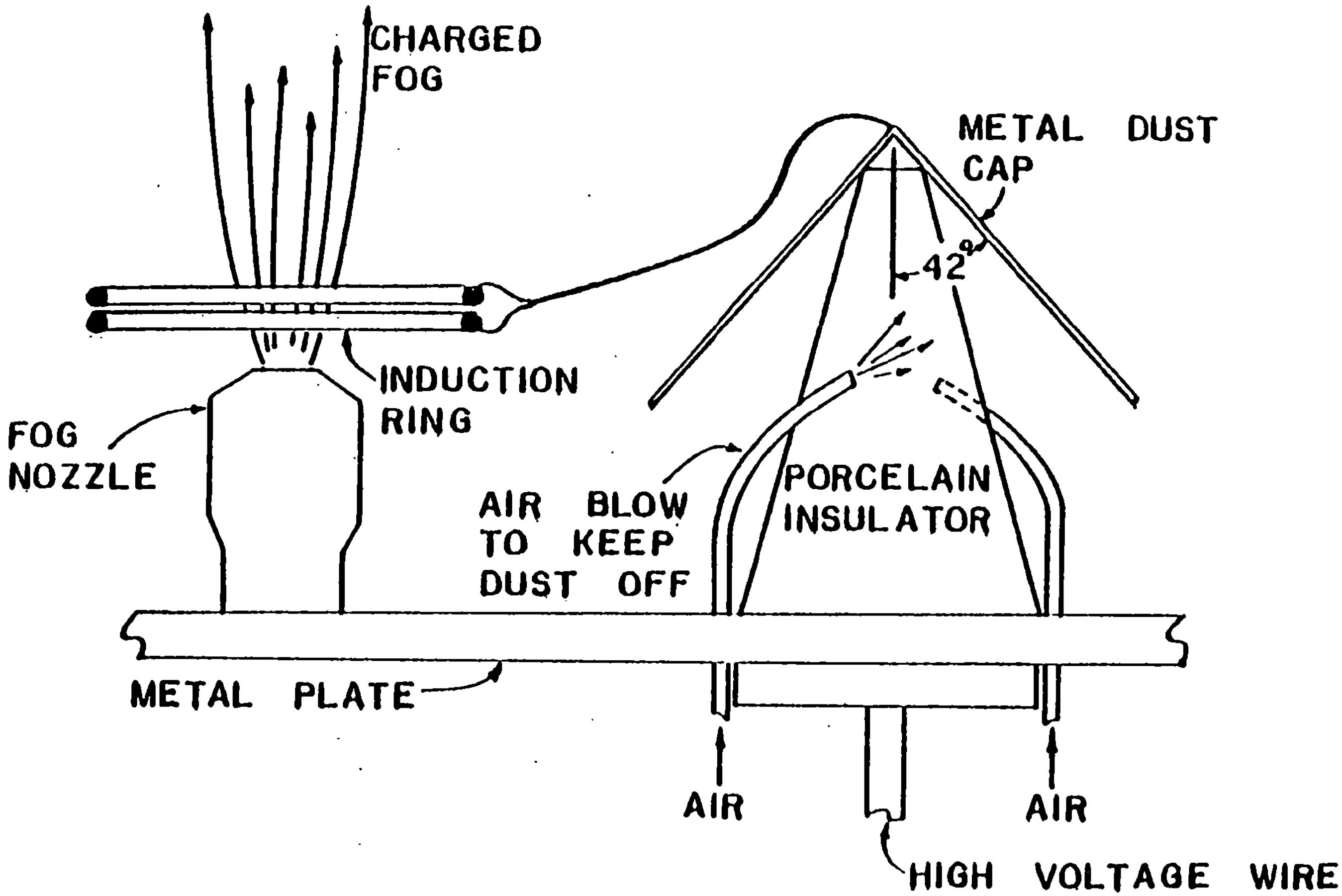


Figure 18. Schematic drawing of special fog generator for dusty or high-temperature environments (scale: full).

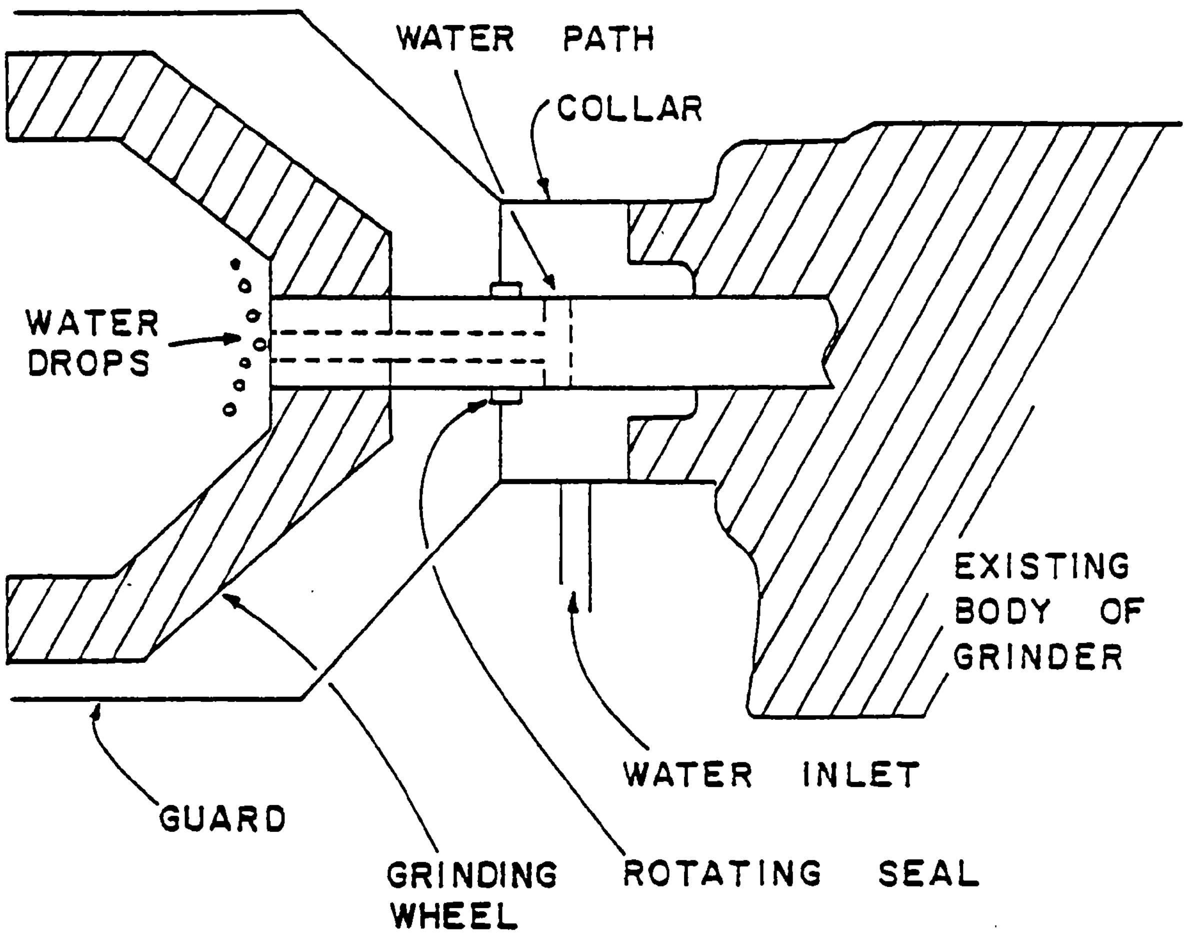


Figure 19. Modification of typical hand cup grinder to provide for dust control by water addition.

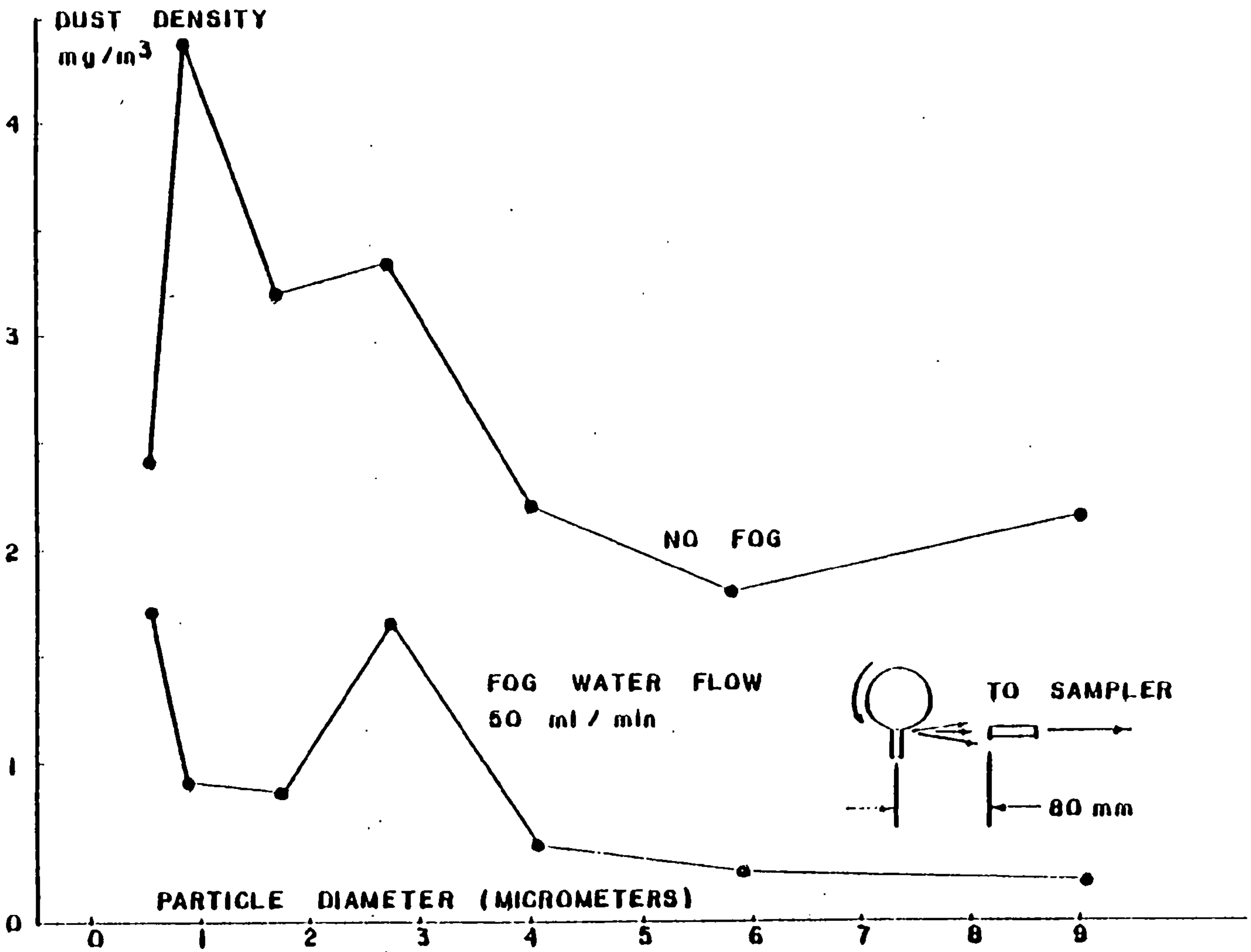


Figure 20. Reduction of dust from an air driven grinder by water fog. ARO Corporation Model 7025 KH5C at 5000 RPM grinding cast iron.

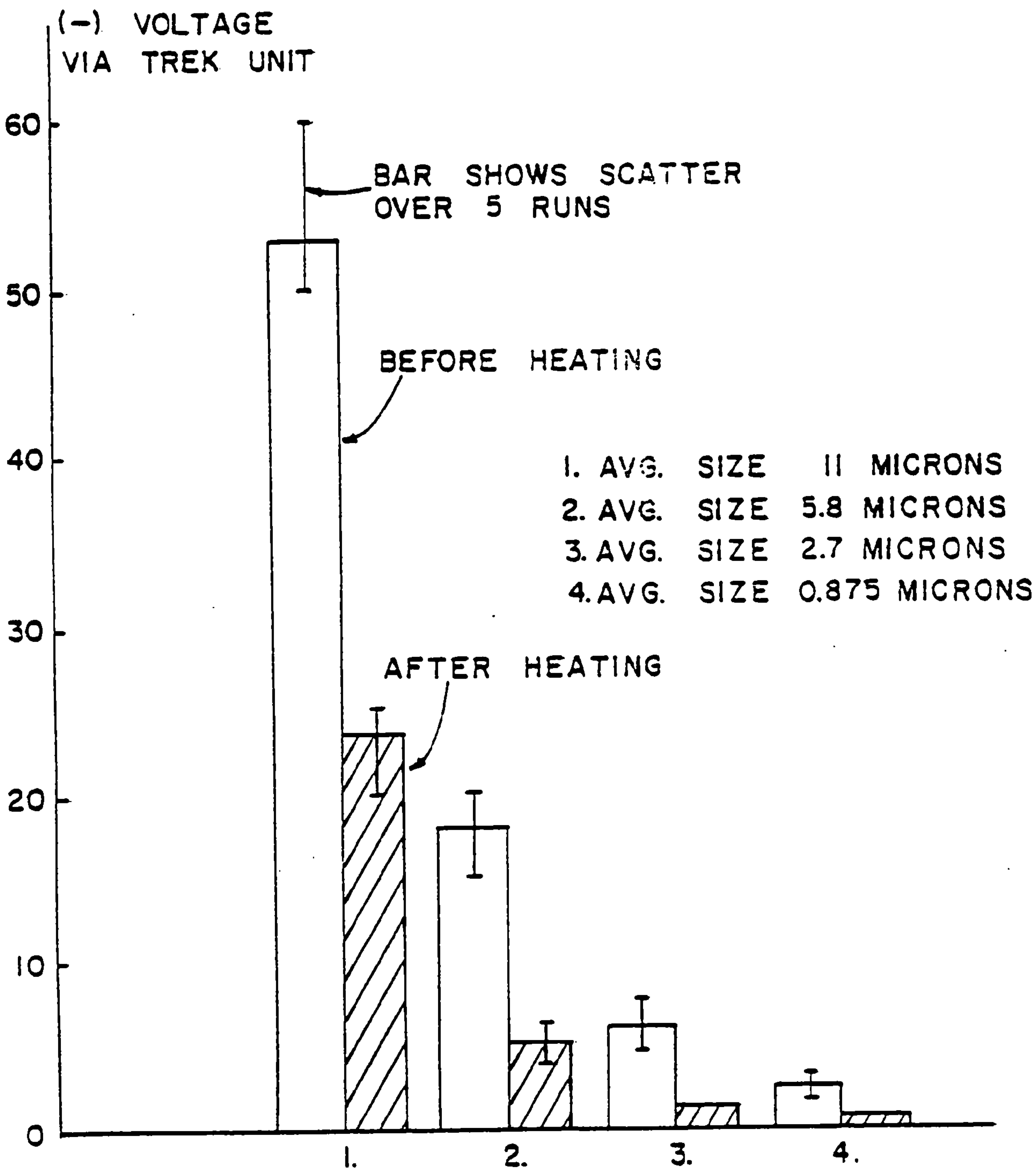


Figure 21. Effect of heating to 250°C on the charging behavior of ultra-pure quartz.

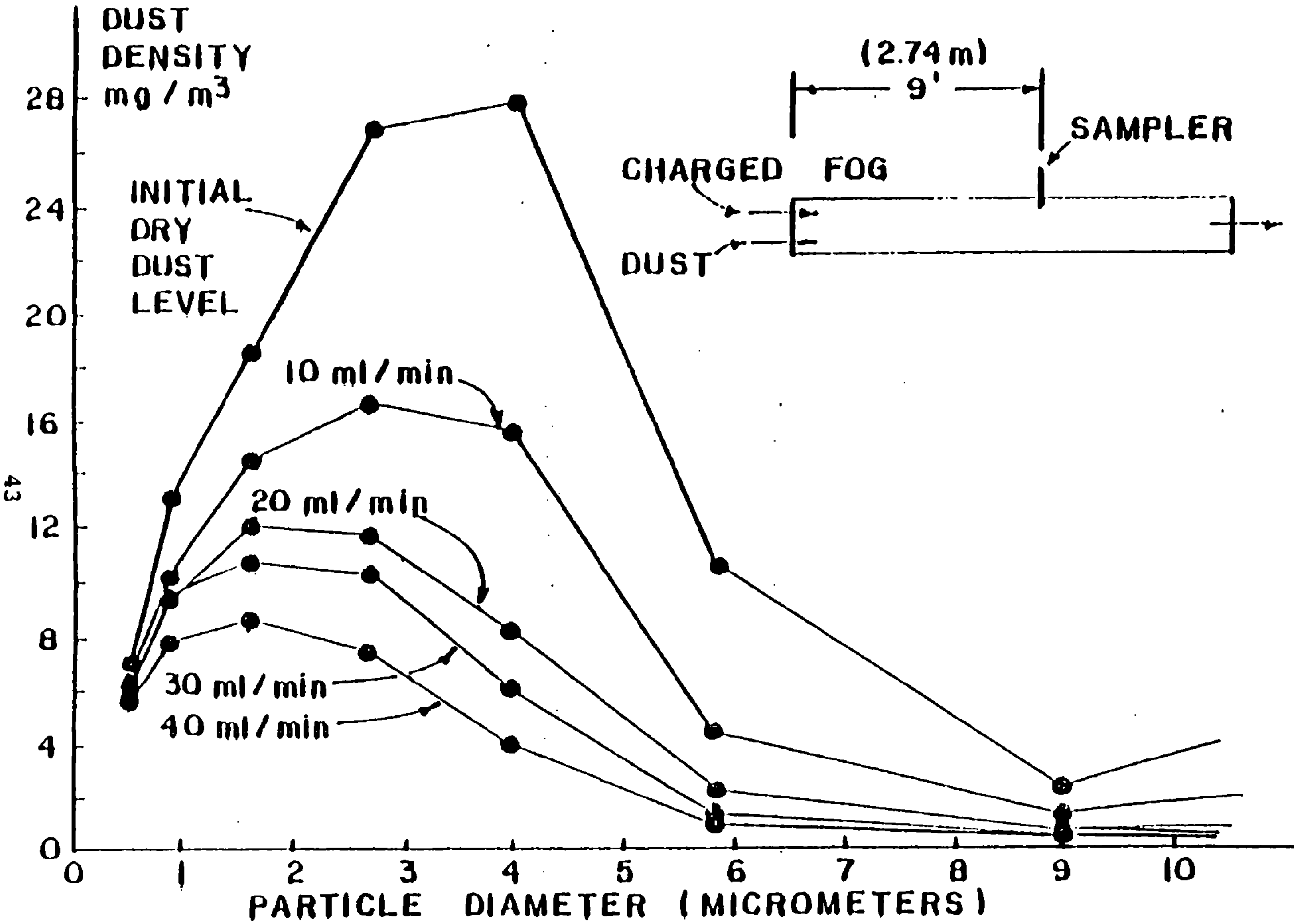


Figure 22. Control of iron foundry dust from cyclone area with negatively charged water fog at various flow rates. Dust flow to tunnel 4.6 g/min; air flow 5.1 m^3/hr.

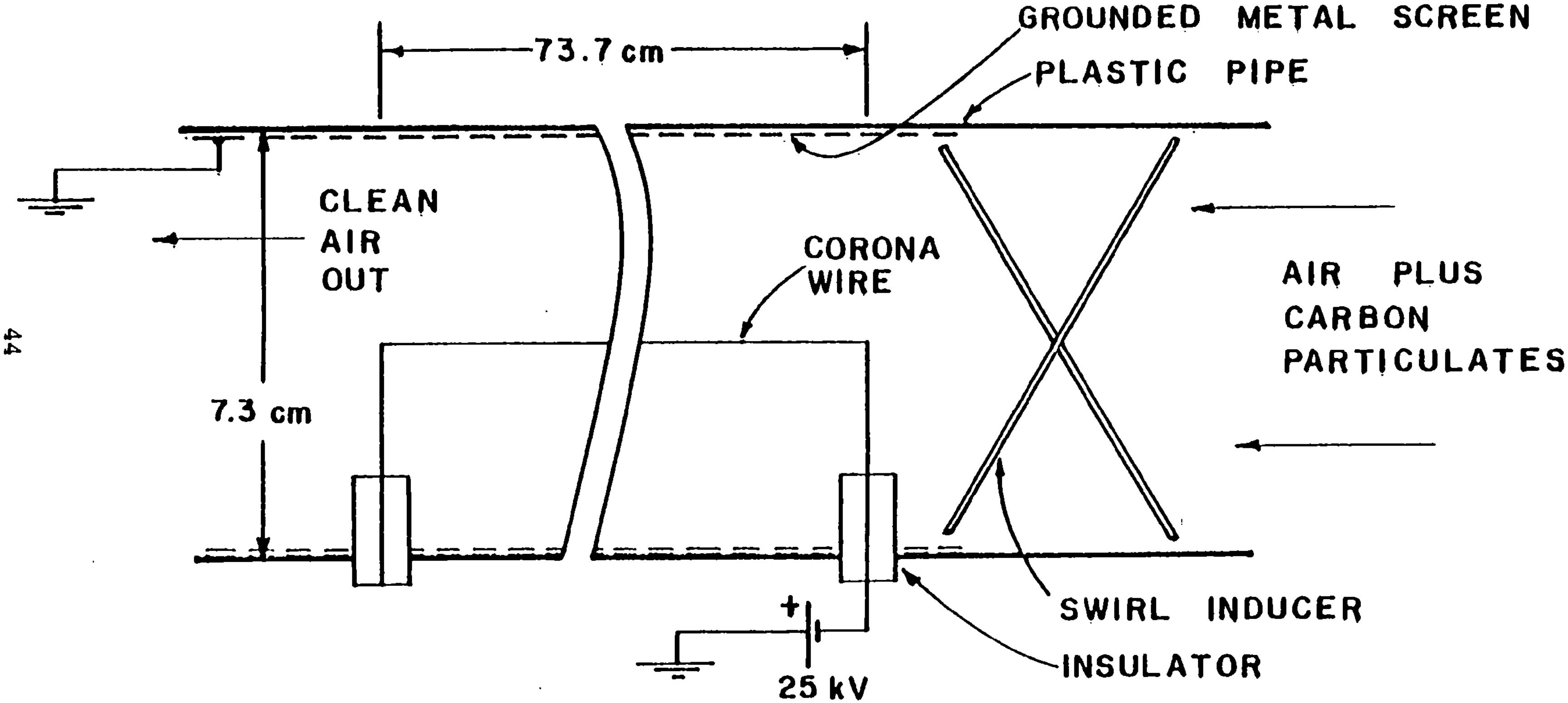


Figure 23. Schematic drawing of a diesel particulate control system with swirler to induce flow rotation.

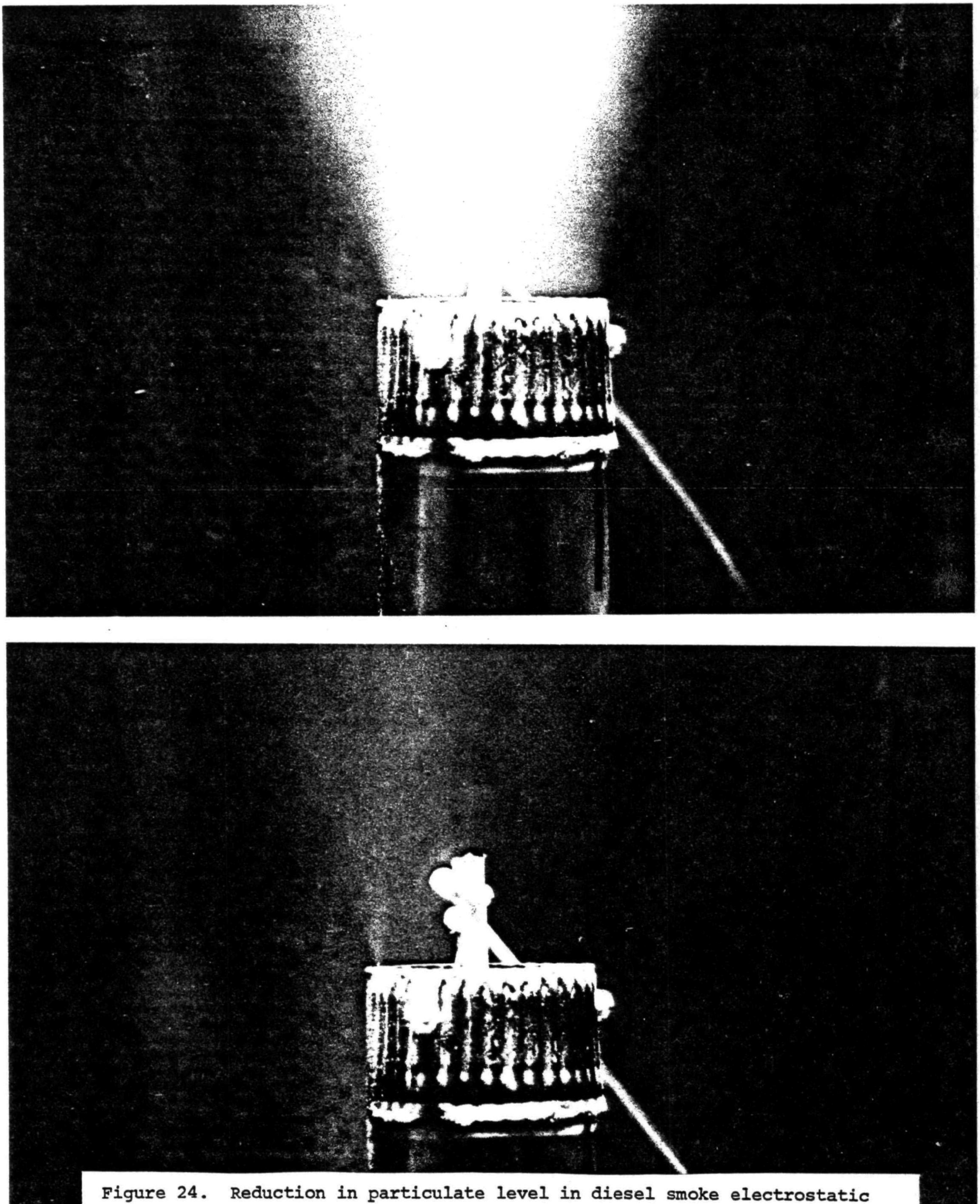


Figure 24. Reduction in particulate level in diesel smoke electrostatic precipitator. Above: electrostatic field off; below: electrostatic field on.

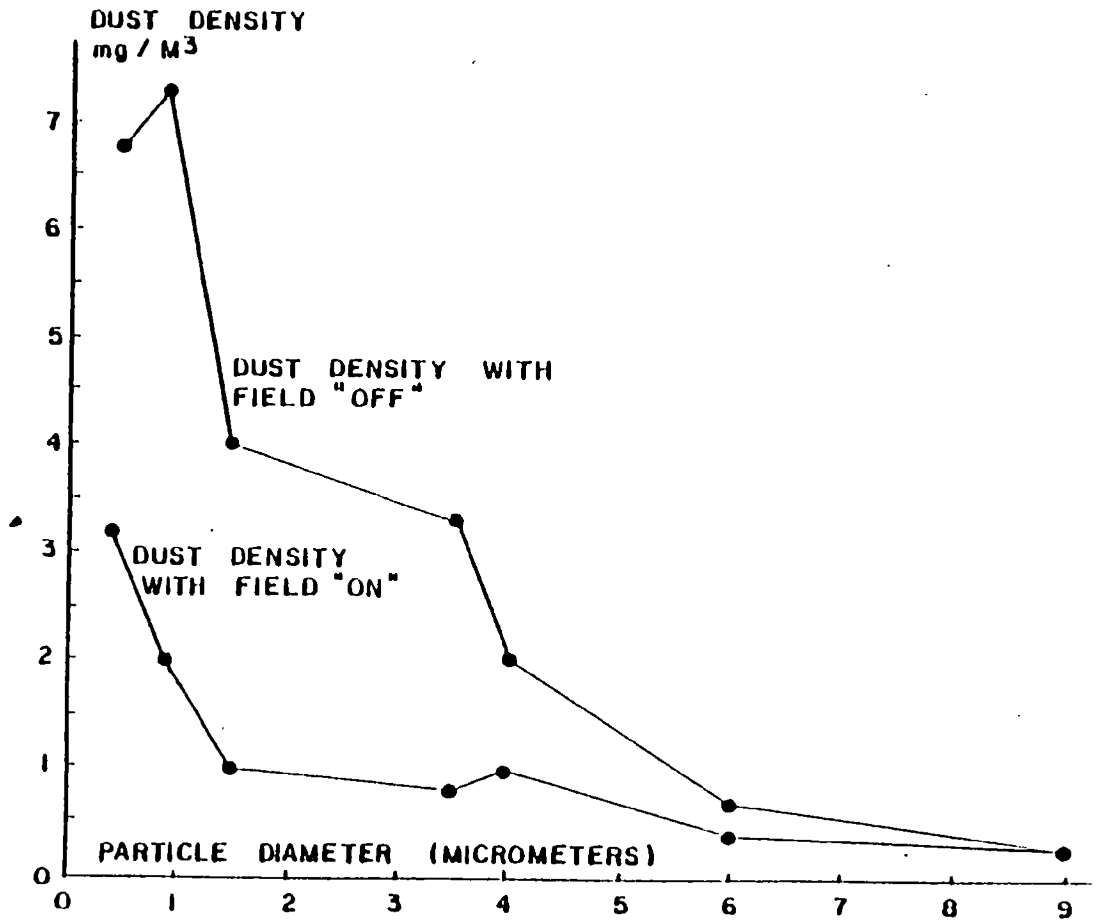


Figure 25. Control of simulated diesel smoke by means of a swirling flow electrostatic precipitator. Air velocity 1100 ft/min (335.5 m/min); corona voltage -20,000; test time 1 hour.

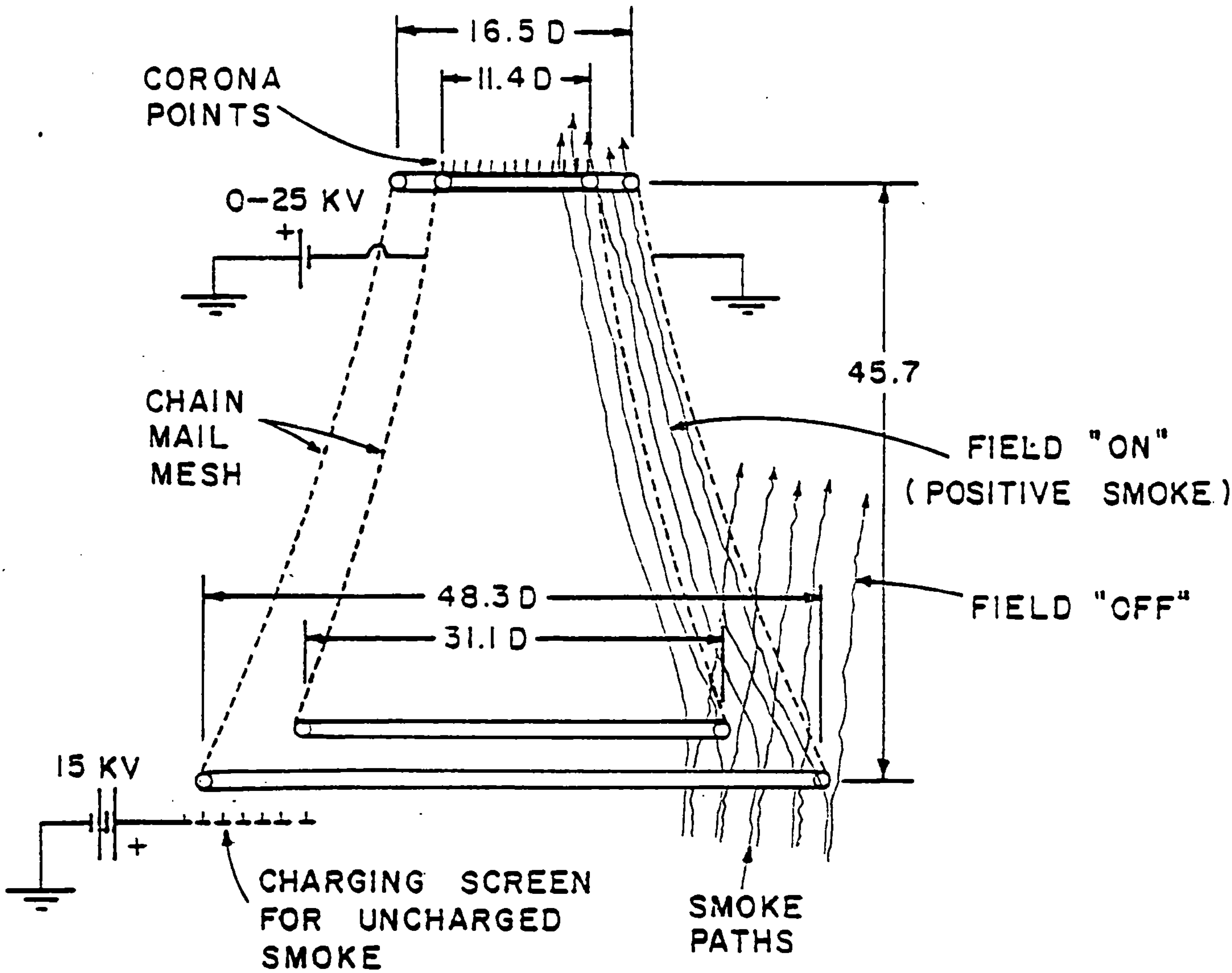


Figure 26. Schematic drawing of electrostatic hood system.

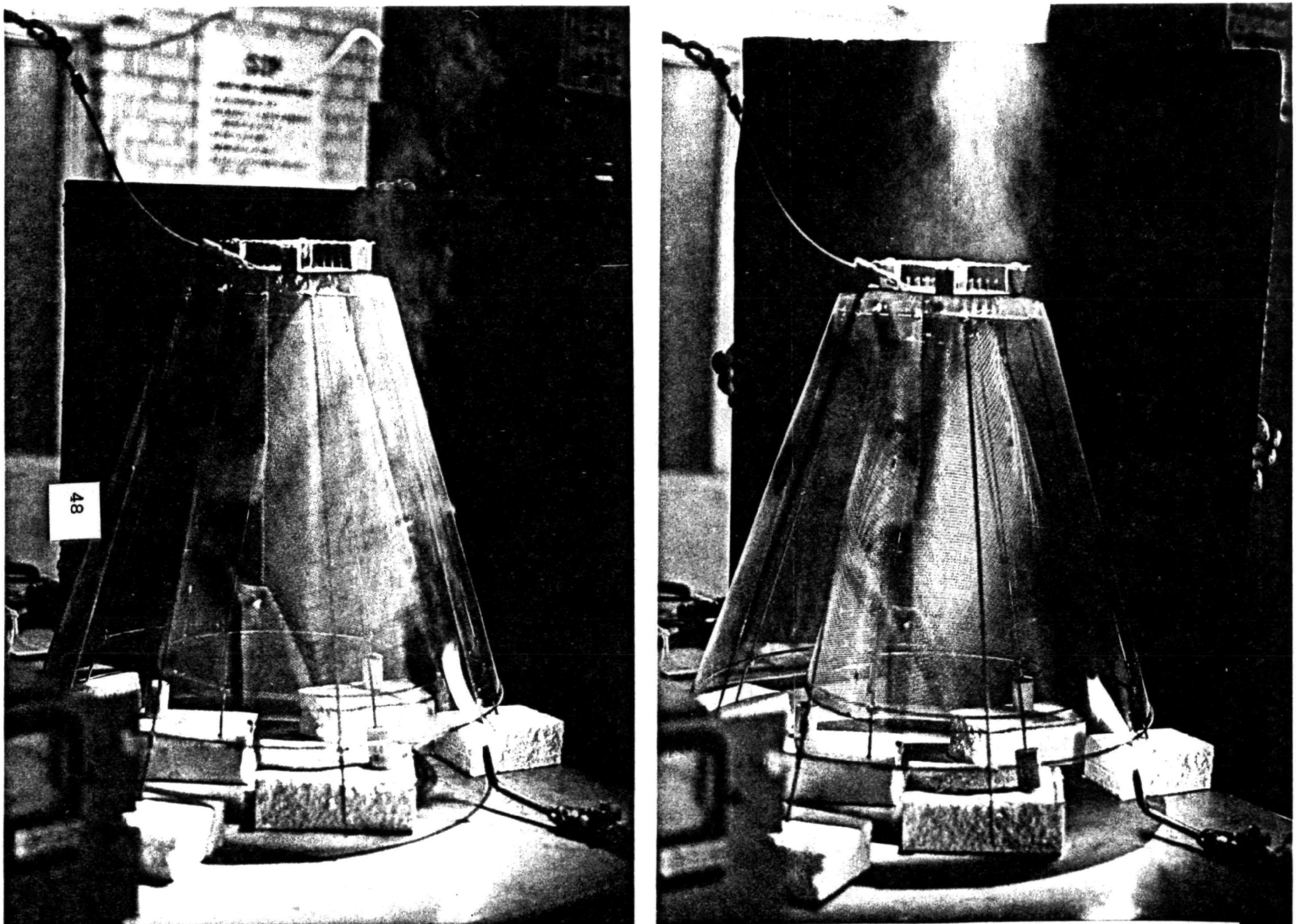


Figure 27. Model of experimental electrostatic hood in operation. Left: With electrostatic field "off", the smoke rises <u>through</u> the cones. Right: With field "on", the smoke is drawn into the space <u>between</u> the cones and carried out the top of the system.

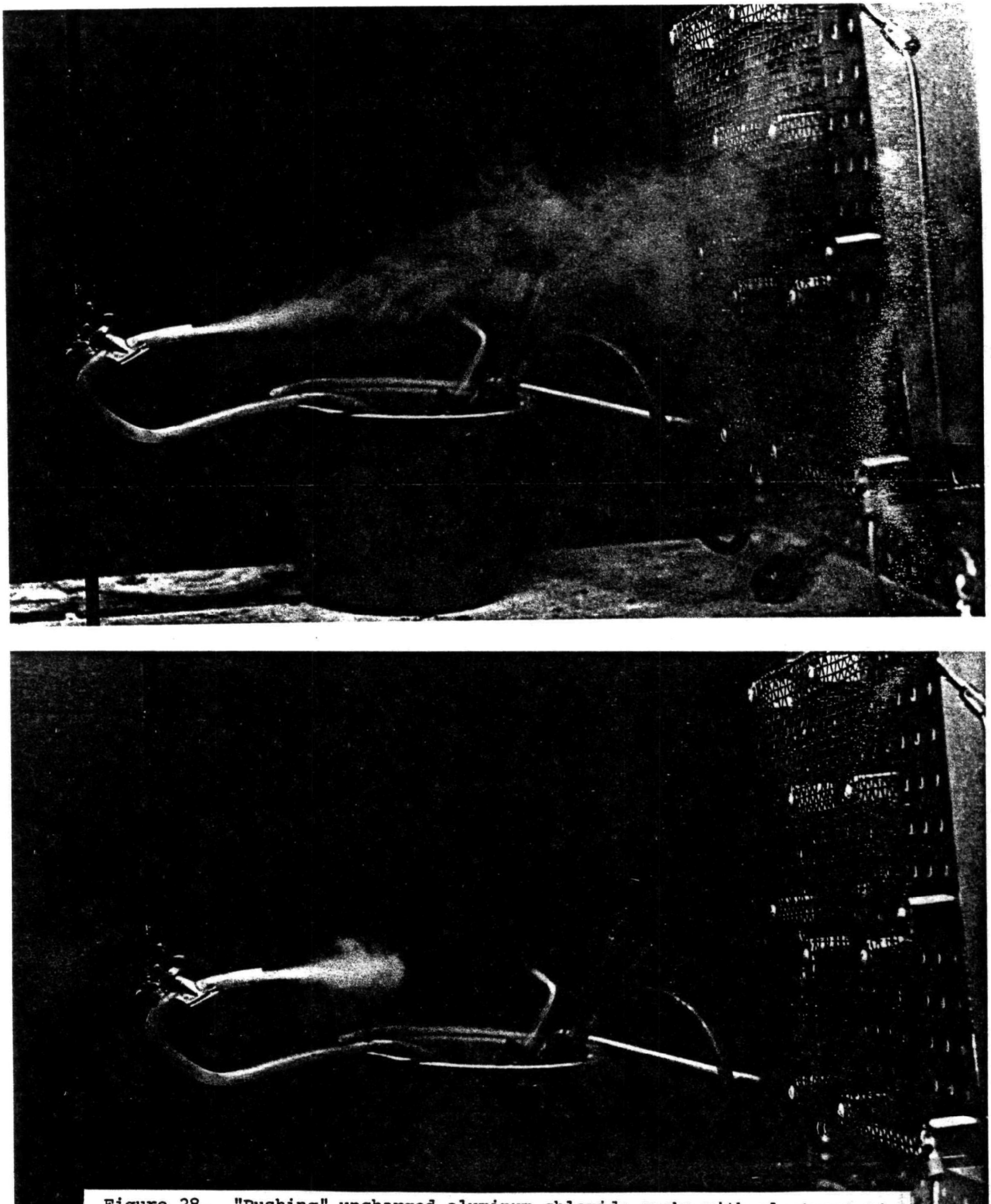


Figure 28. "Pushing" uncharged aluminum chloride smoke with electrostatic curtain. Above: Curtain "off". Below: Curtain "on"; smoke is pushed backwards.

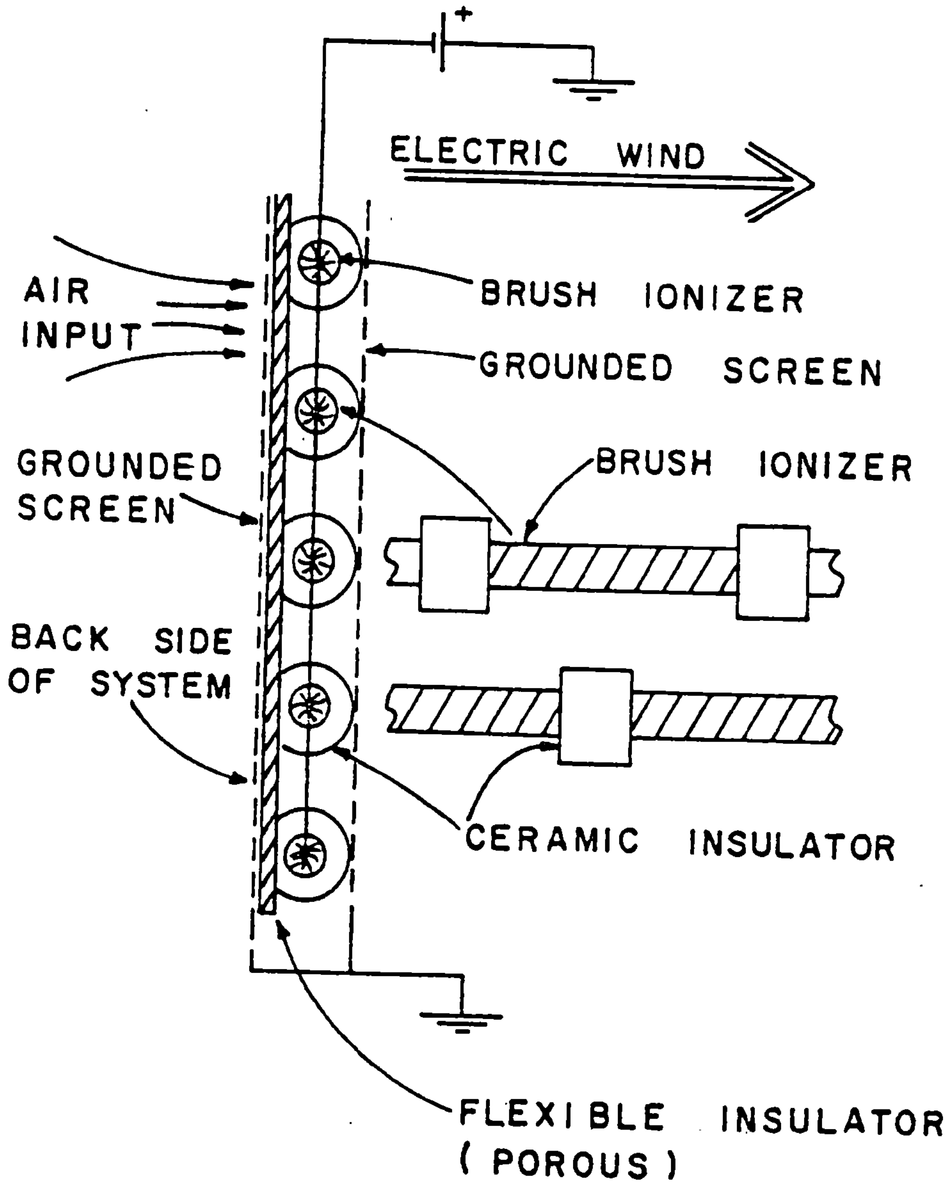


Figure 29. Schematic drawing of electrostatic curtain system with grounded screens on both sides.

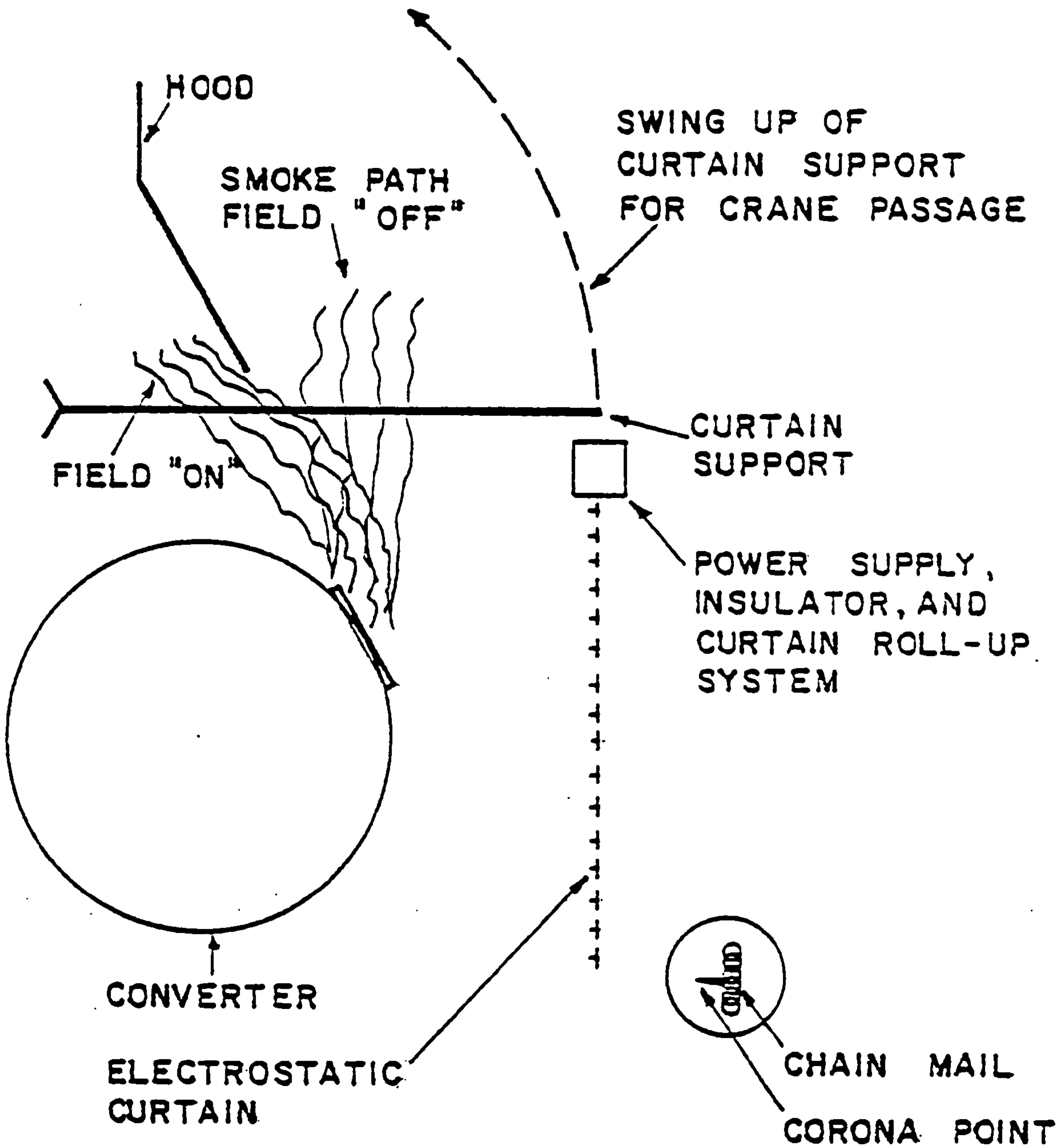


Figure 30. Schematic drawing of electrostatic curtain system on copper smelter converter.

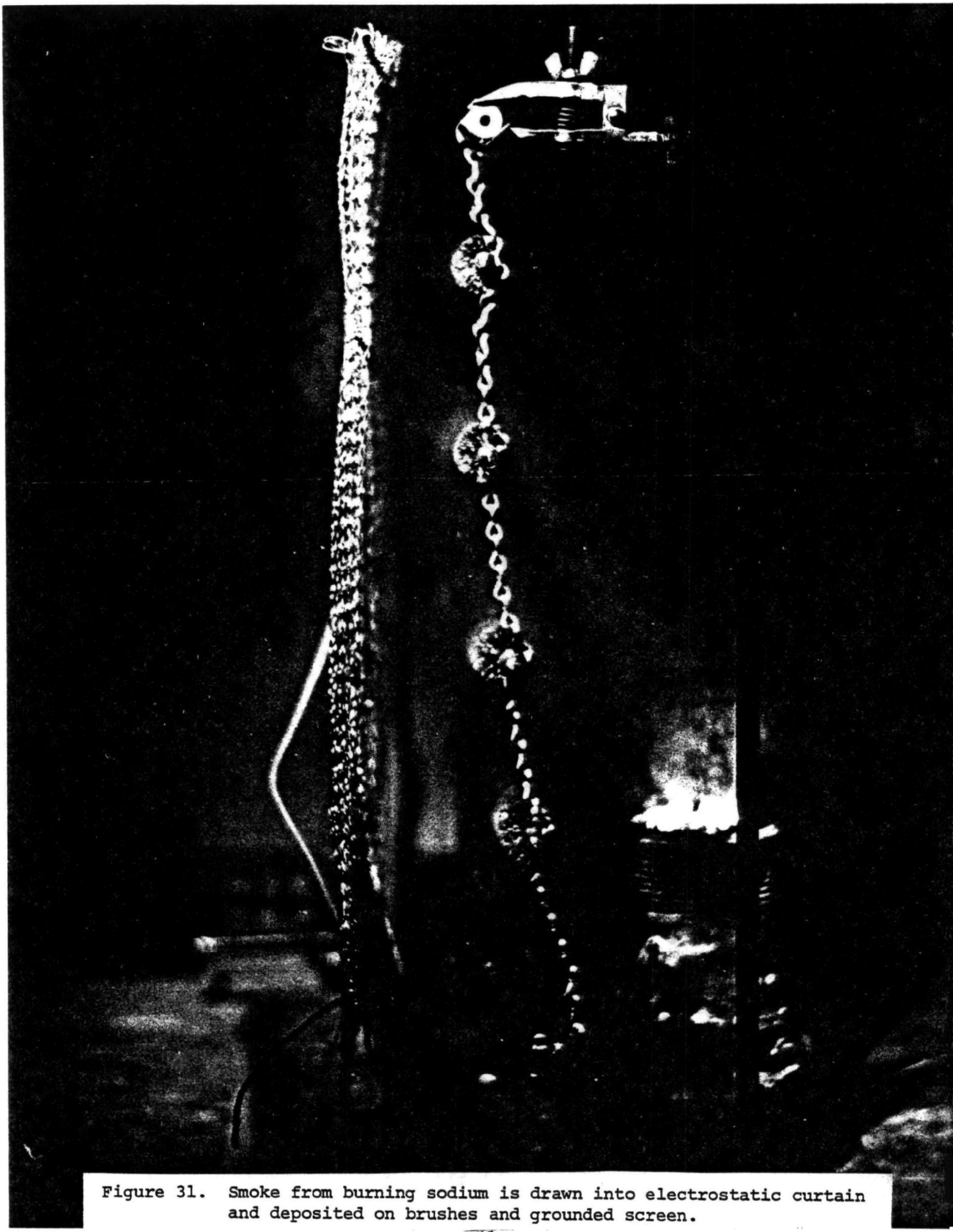


Figure 31. Smoke from burning sodium is drawn into electrostatic curtain and deposited on brushes and grounded screen.

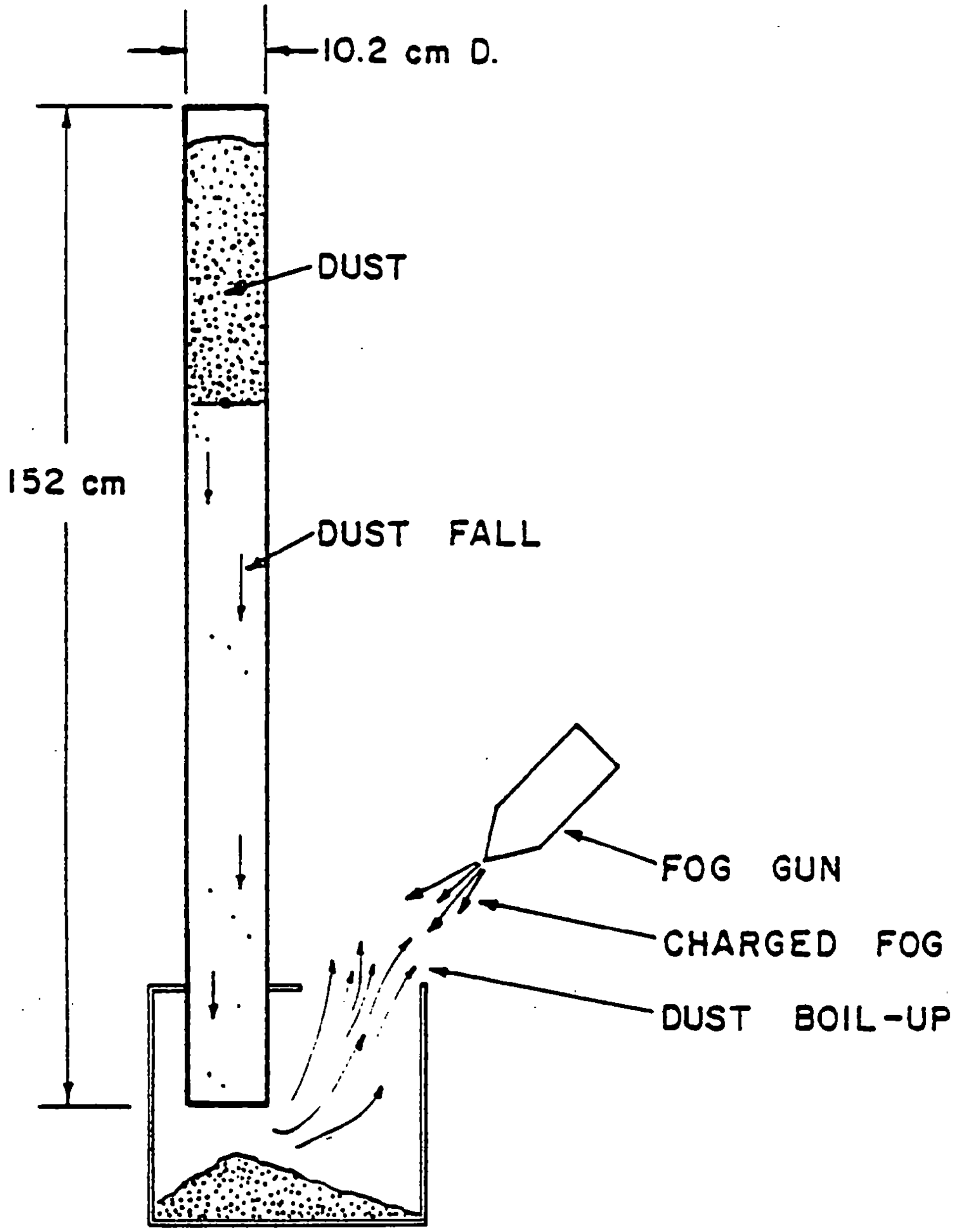


Figure 32. System for control of simulated dust boil-up by charged fog gun.

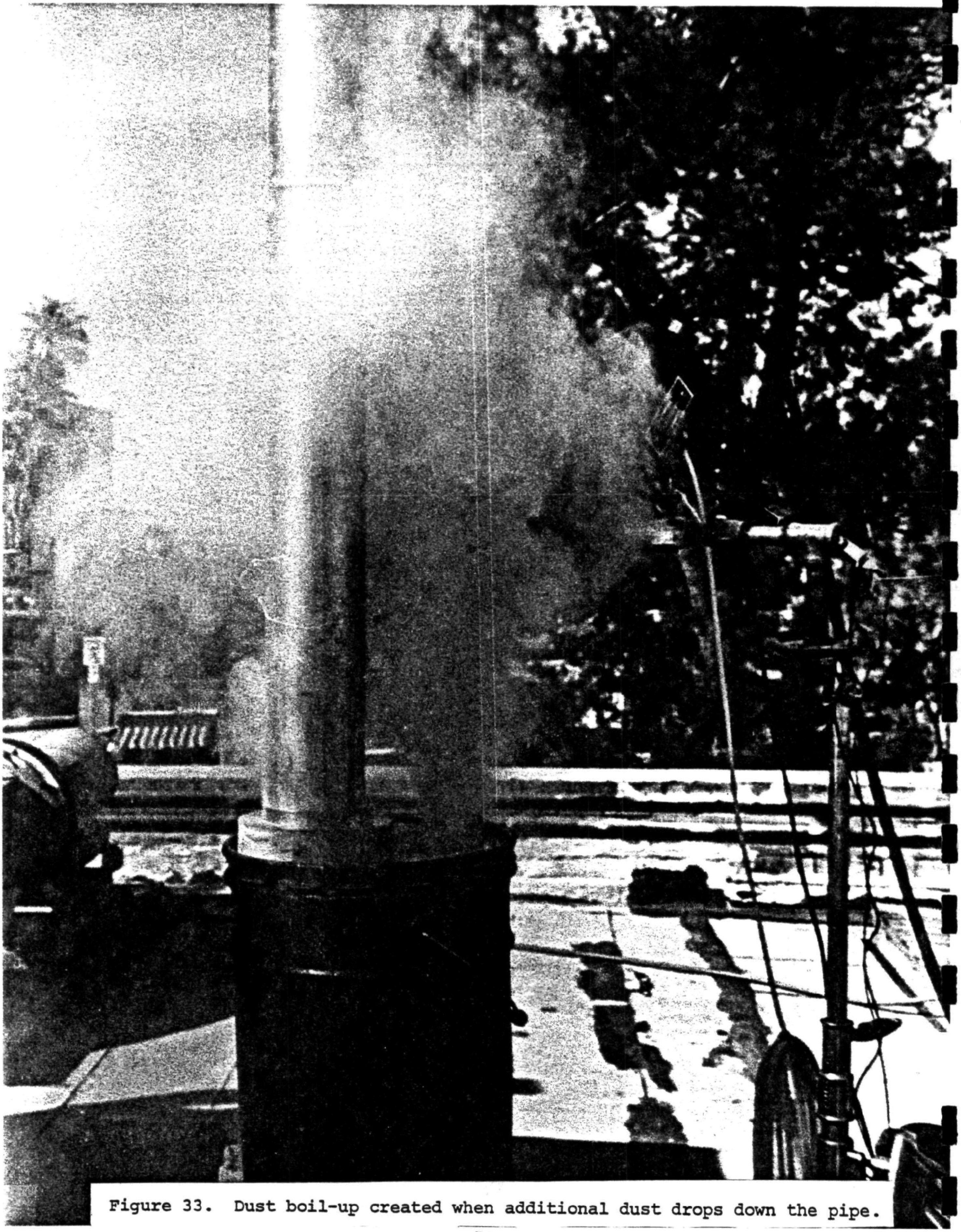


Figure 33. Dust boil-up created when additional dust drops down the pipe.

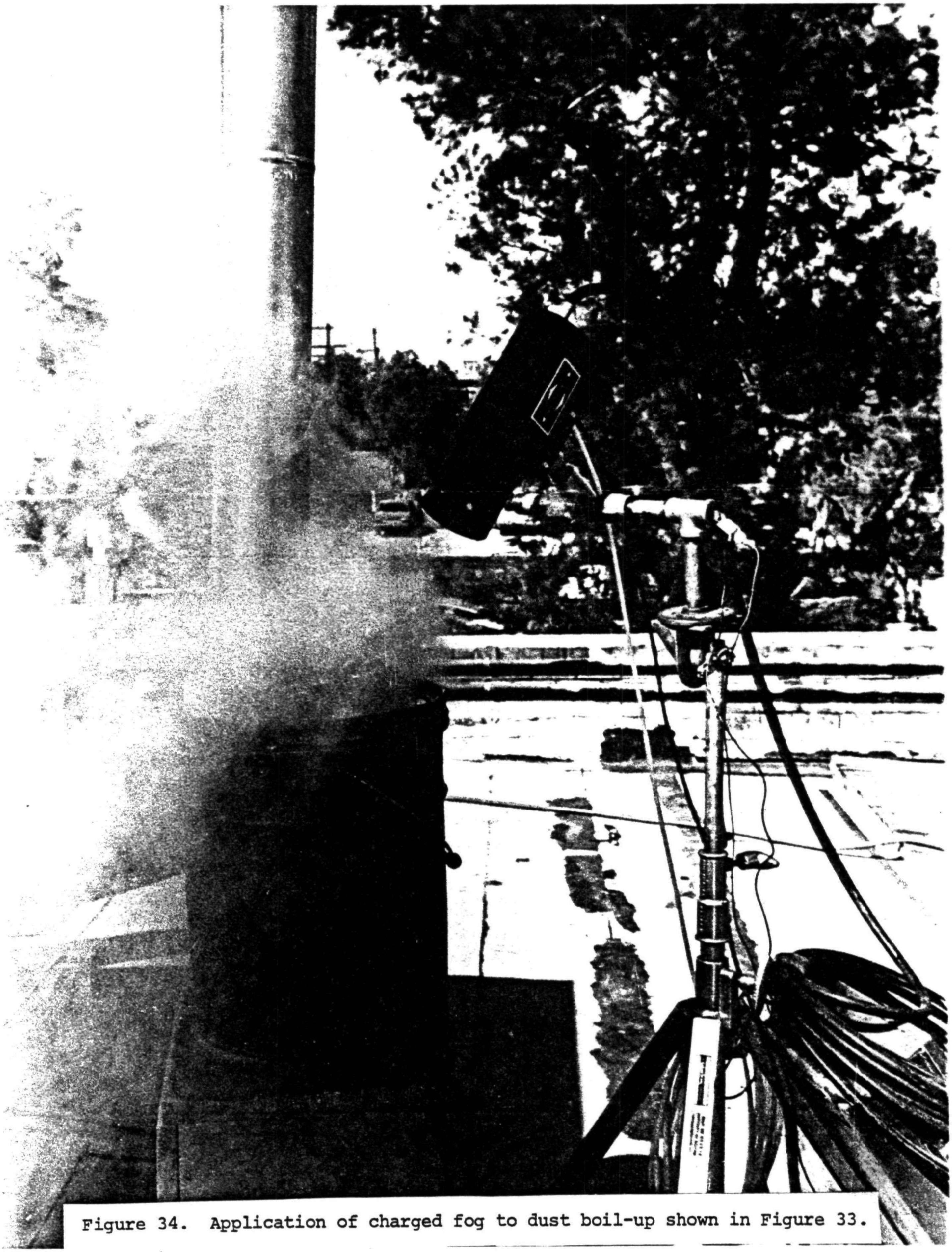


Figure 34. Application of charged fog to dust boil-up shown in Figure 33.

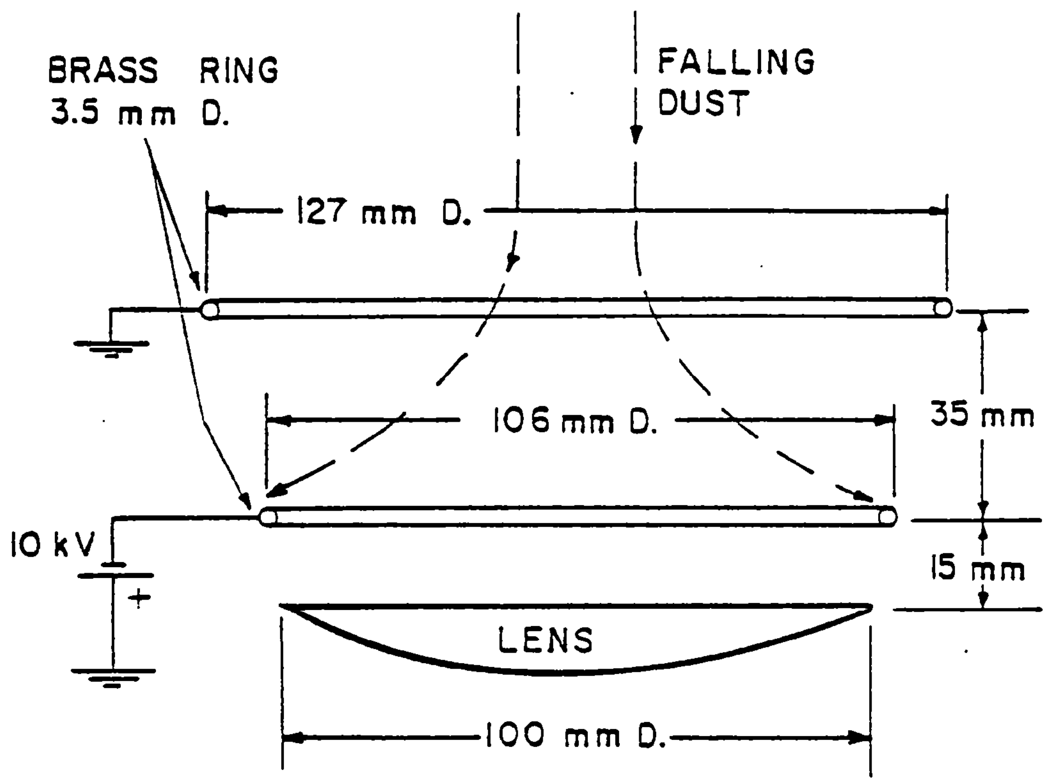


Figure 35. Schematic drawing of optical dust control system.

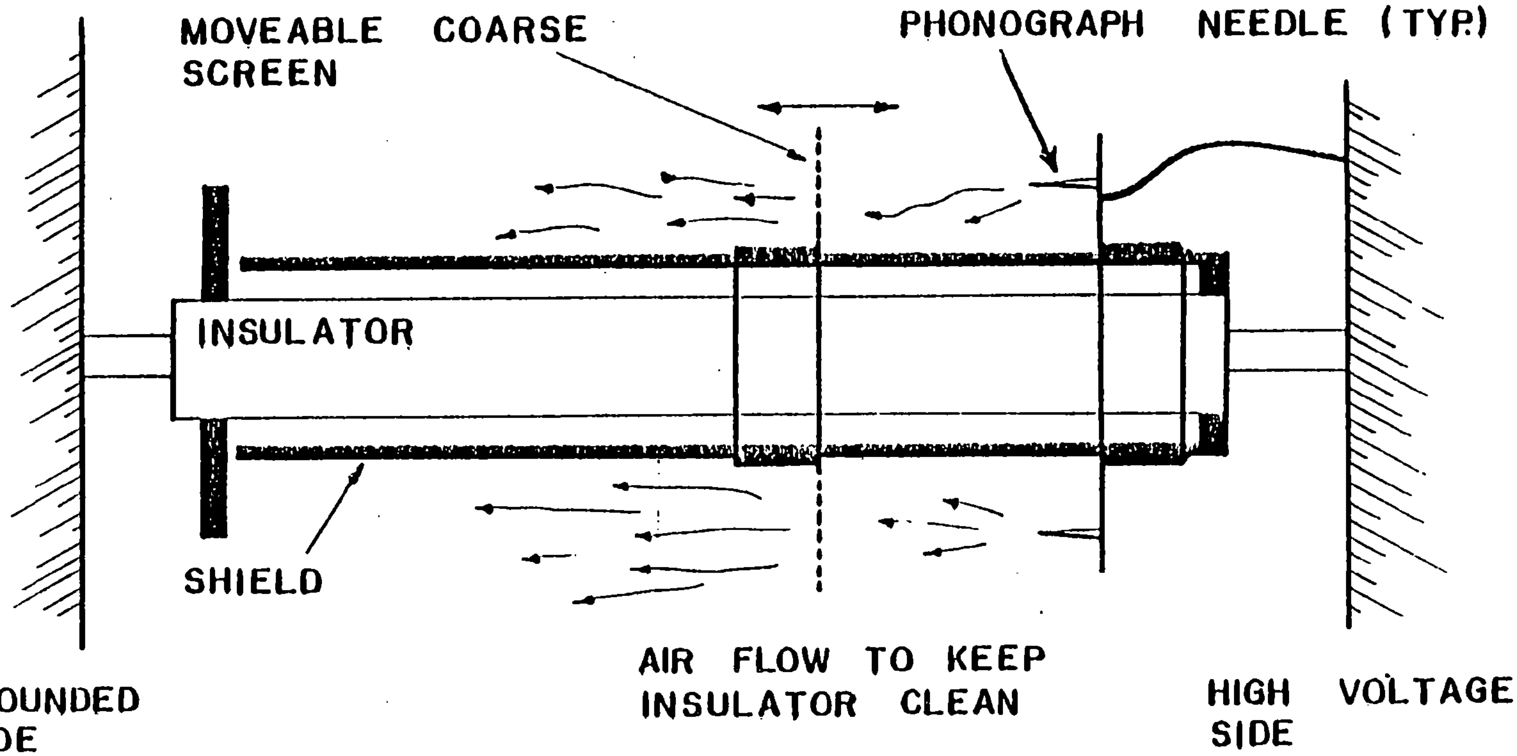


Figure 36. Schematic drawing of electric wind system for cleaning insulating shield; the "wind" generated by the phonograph needles keeps the insulator from building up deposits.

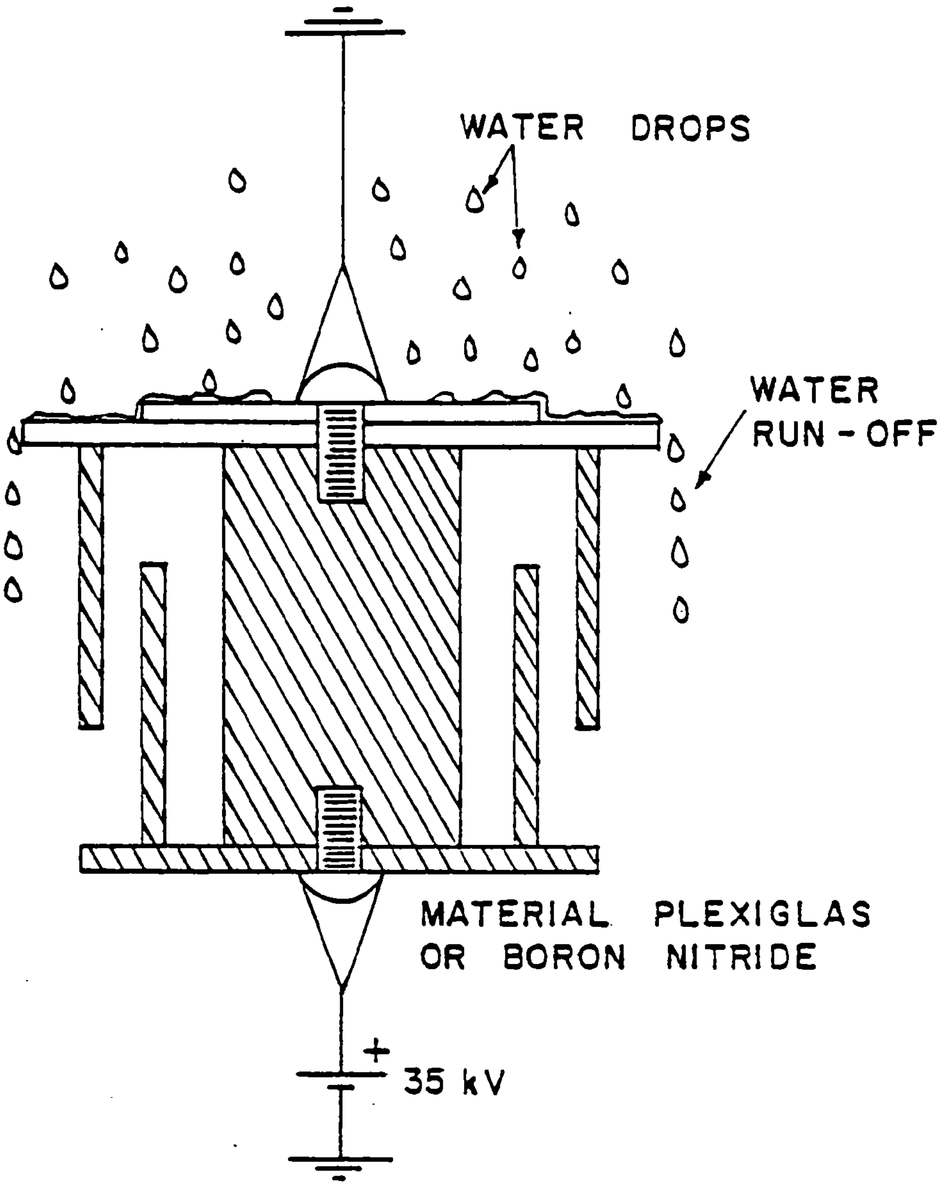


Figure 37. Schematic drawing of high voltage insulator for wet environments (scale: full).

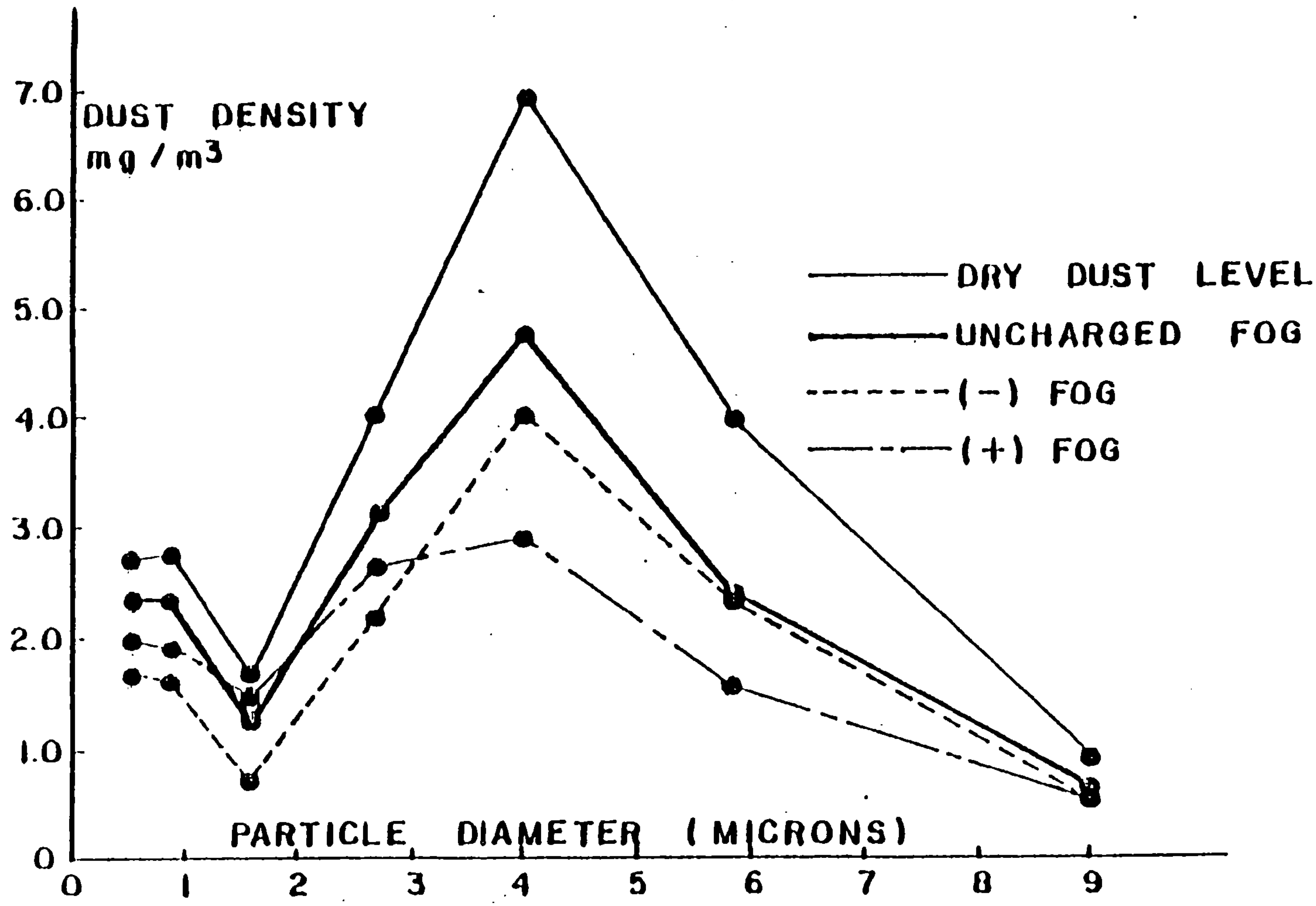


Figure 38. Control of grain dust with water fog. Water flow 10 ml/min; air flow 4.81 m^3/hr.

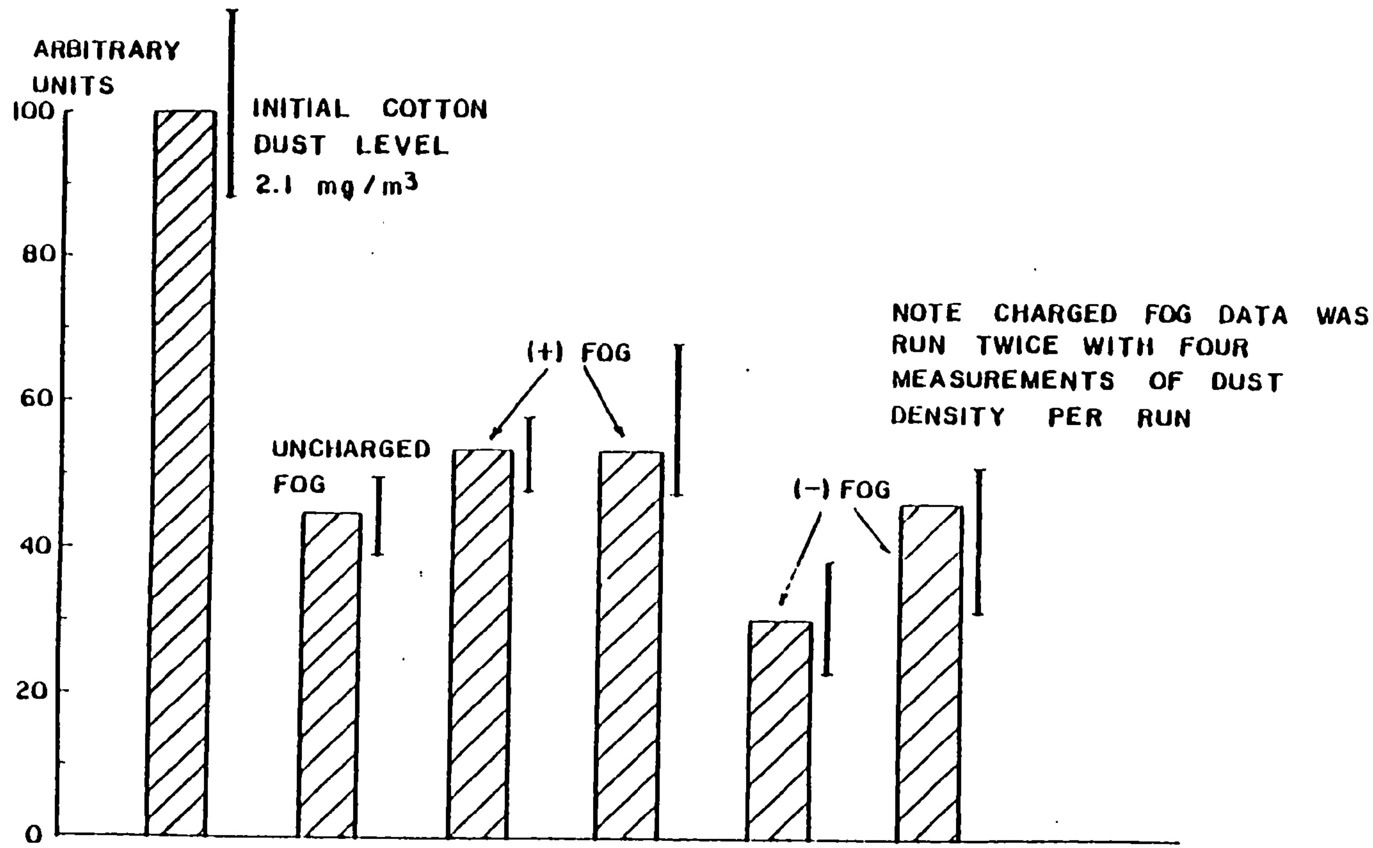


Figure 39. Control of cotton dust (from towel manufacturing area) with water fog. Water flow 15 ml/min; air flow 150 SCFH (4.25 m^3/hr). Data taken with GCA Corp. RDM-101 Beta Ray dust monitor.

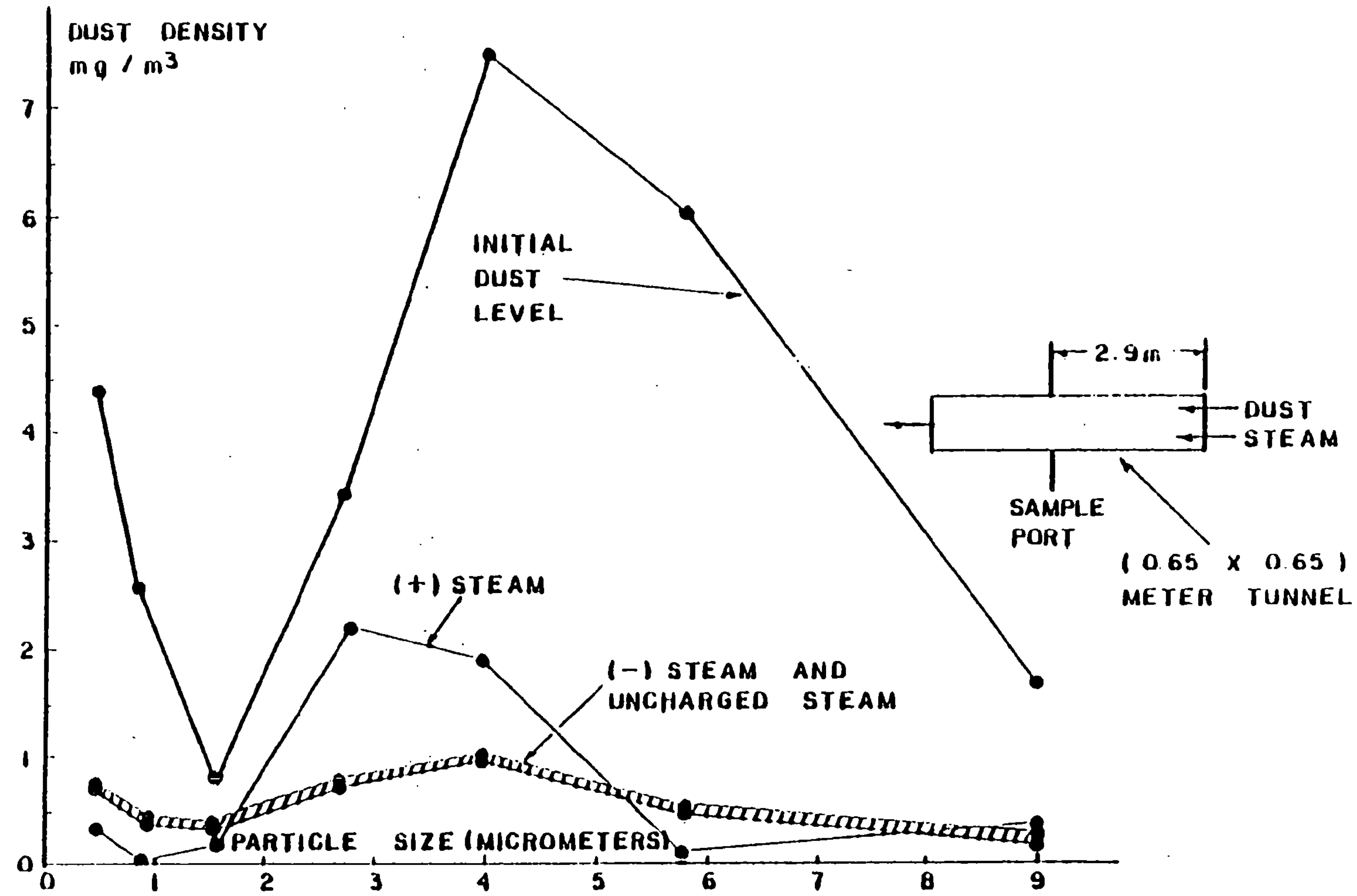


Figure 40. Control of trona dust with charged steam. Air flow 150 SCFH (4.25 m^3/min); steam flow 15 ml/min.

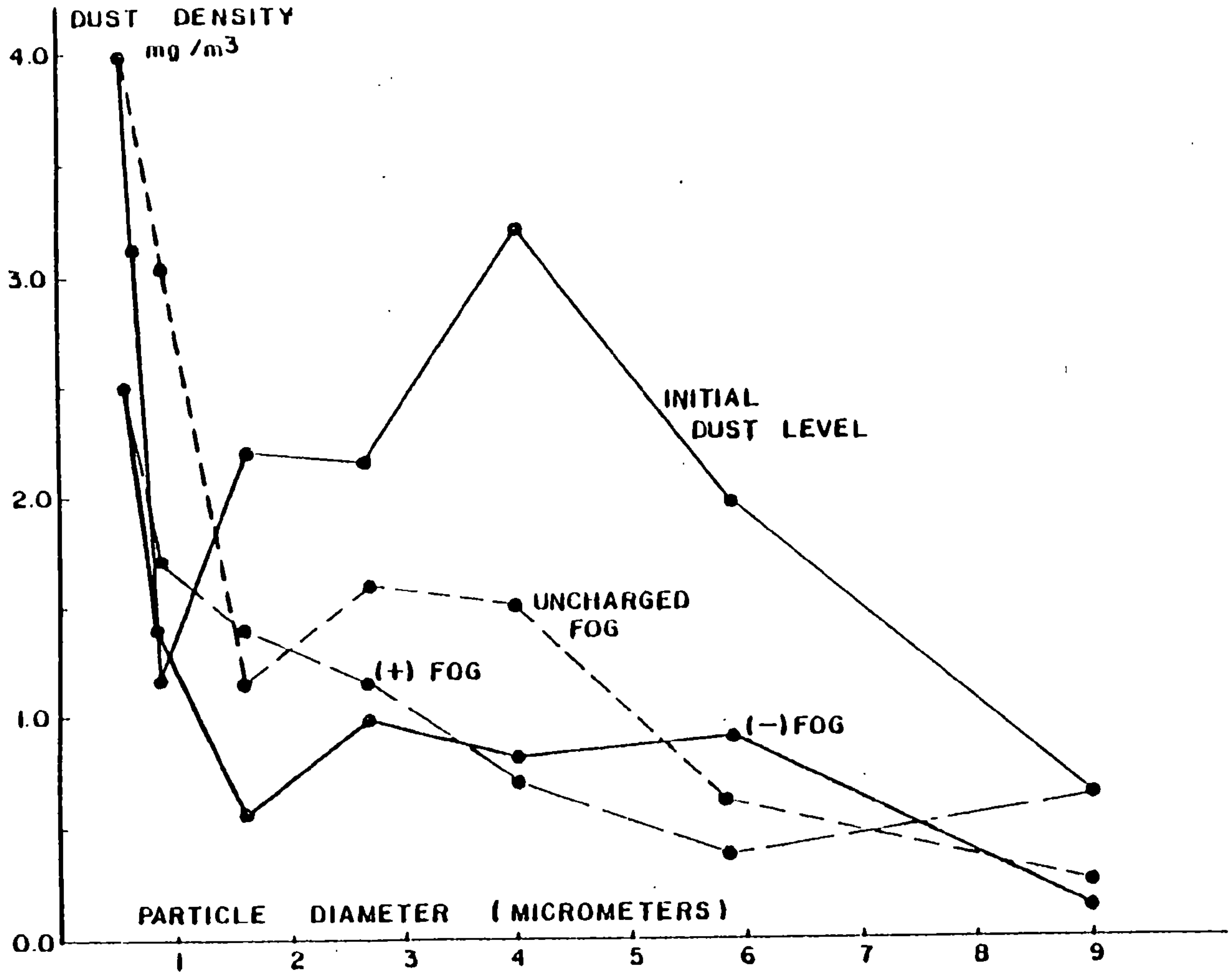


Figure 41. Control of sandblasting grit with charged fog. Water flow 15 ml/min; air flow 210 SCFH (5.94 m^3/hr).

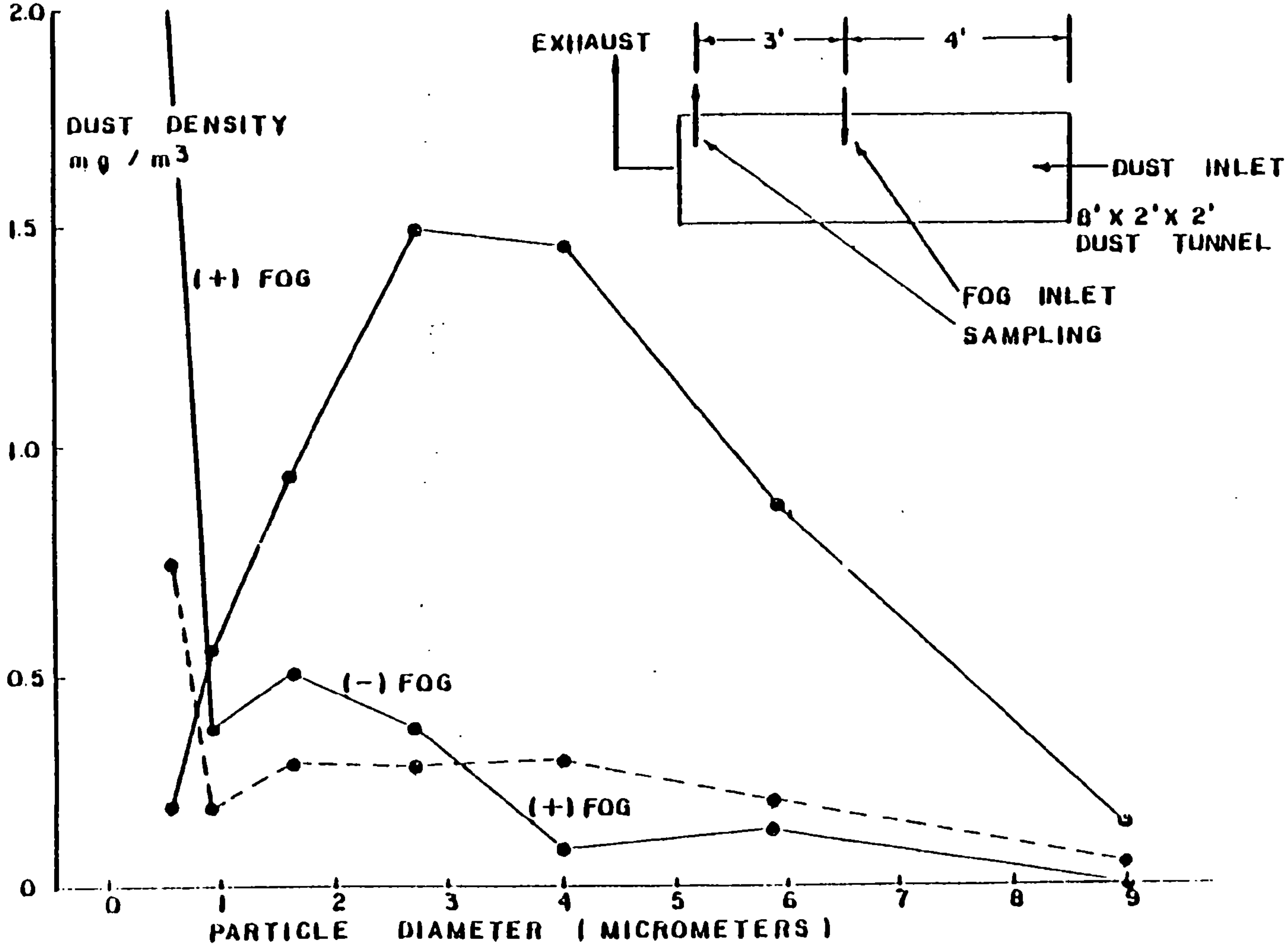


Figure 42. Control of dry red lead battery dust with charged fog. Water flow 15 ml/min; air flow 150 SCFH (4.25 m^3/hr).

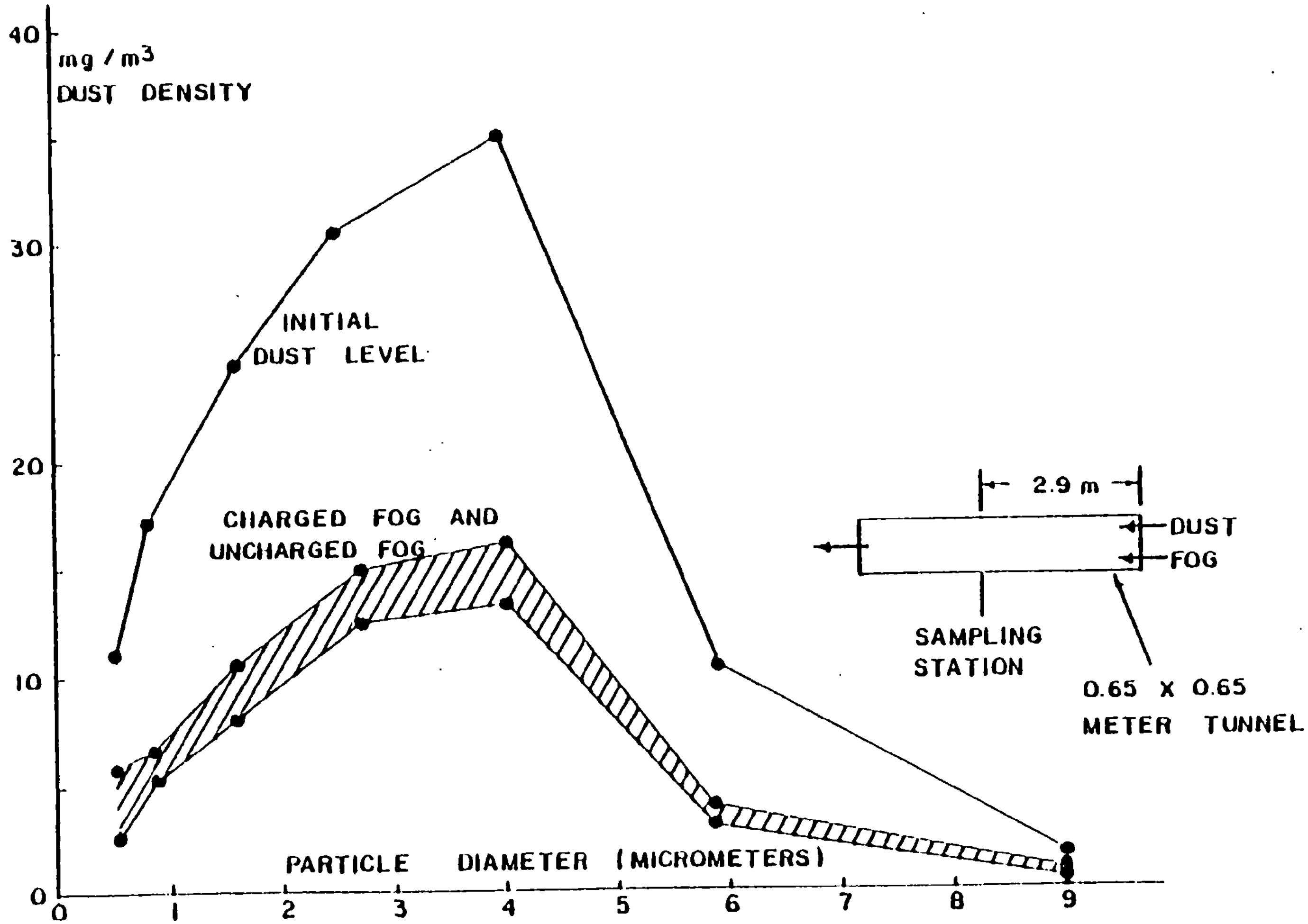


Figure 43. Control of aluminum oxide dust with charged fog. Water flow 15 ml/min; air flow 150 SCFH (4.25 m^3/hr).

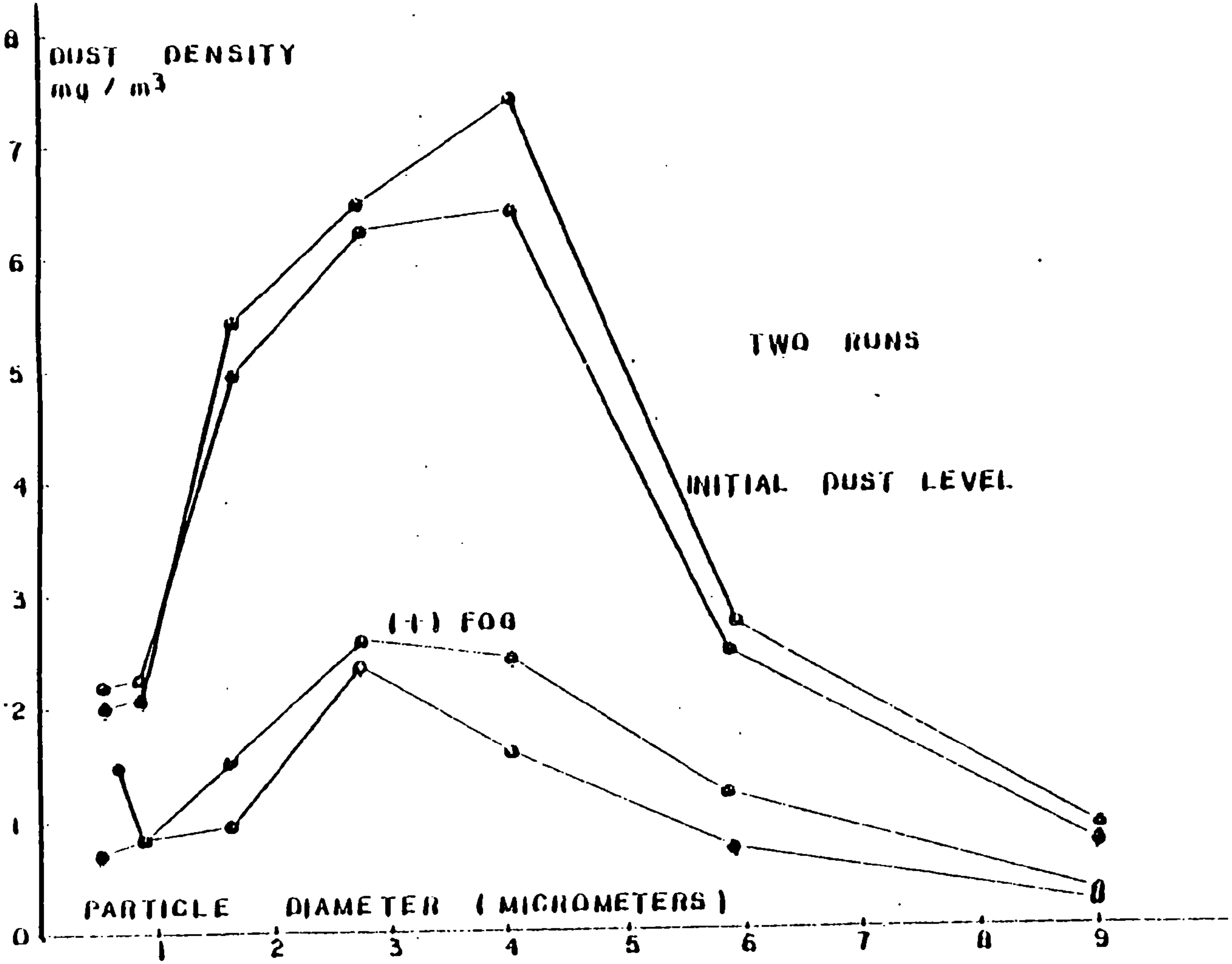


Figure 44. Control of respirable dust (turkey barn floor sweepings) with charged fog. Water flow 15 ml/min; air flow 150 SCFH (4.25 m^3/hr).

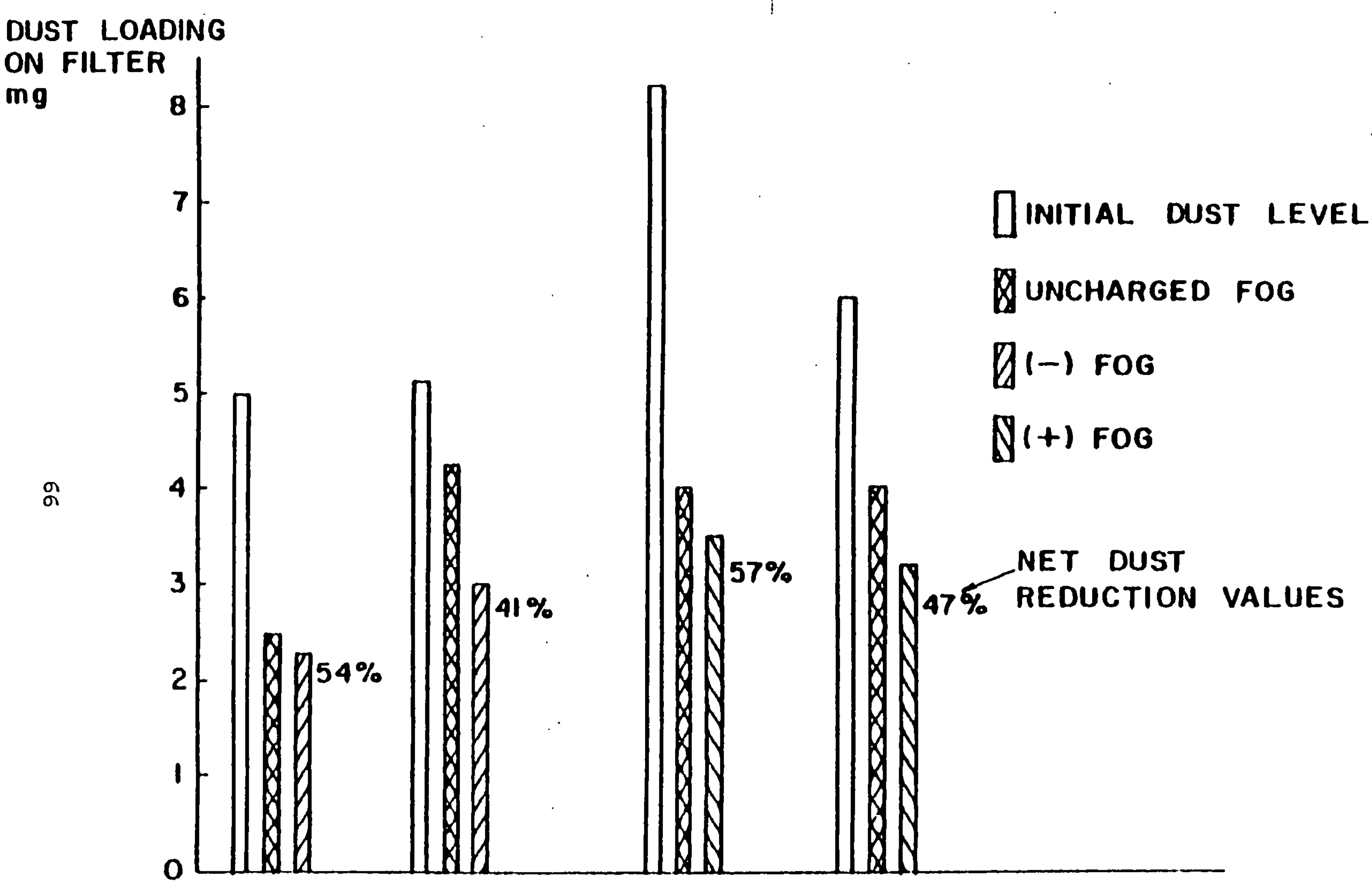


Figure 45. Control of cotton brack dust with charged fog. Water flow 10 ml/min; air flow 5.1 m^3/hr. Reeve Angel 0.1 micron glass filter.

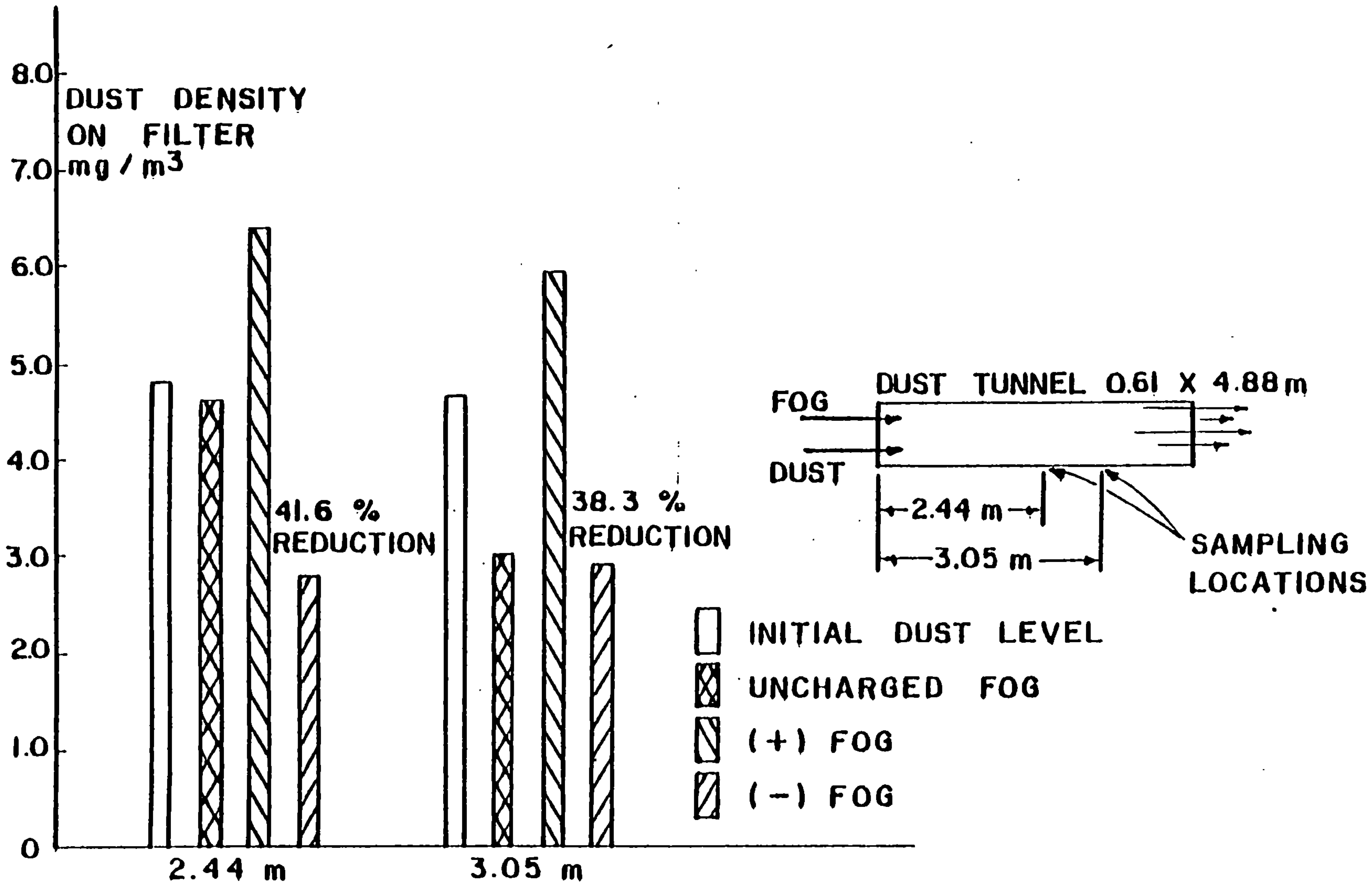


Figure 46. Control of carbon black dust with charged fog. Water flow 12 ml/min; air flow 6.2 m^3/hr; Reeve Angel 0.1 micron glass filter; sampling time 2 min.

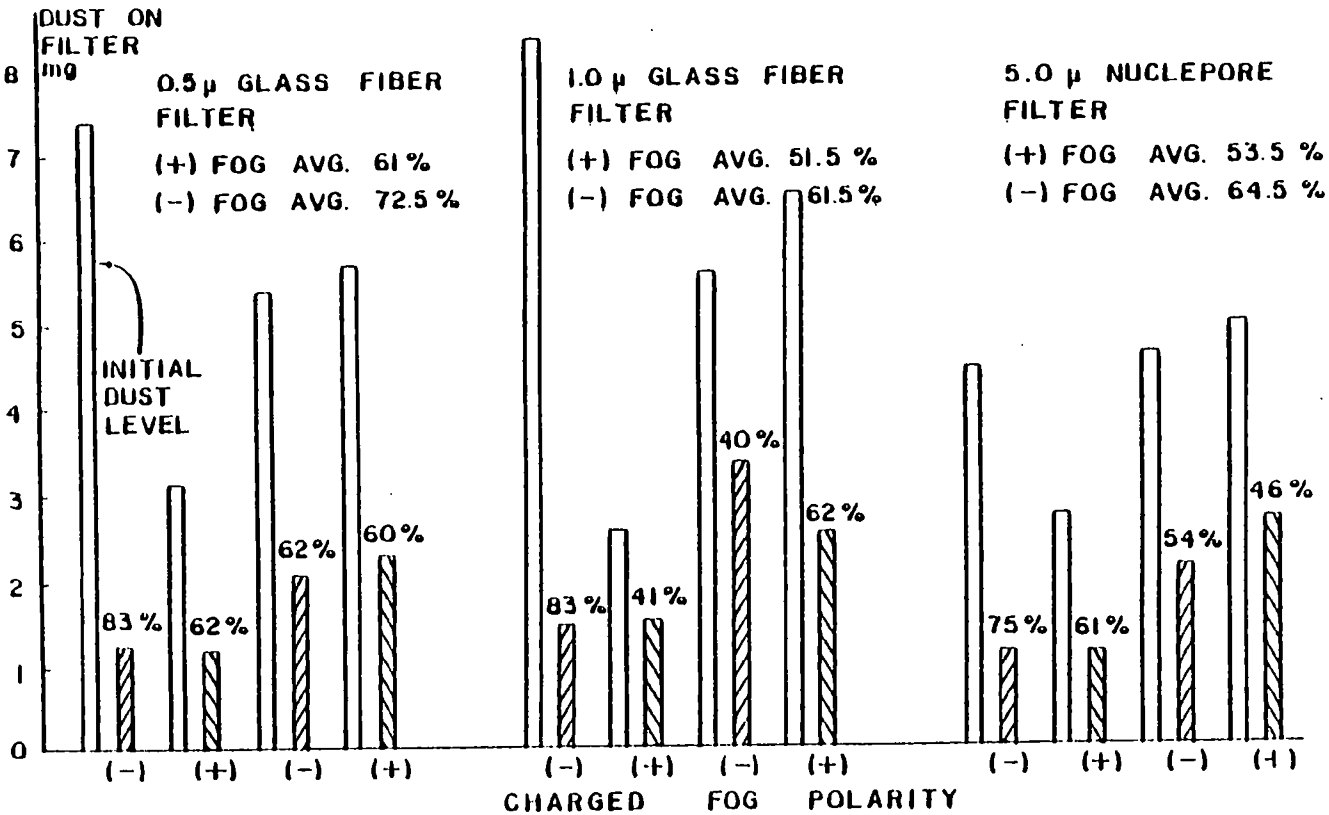


Figure 47. Control of bauxite dust with charged fog. Water flow 20 ml/min; air flow 5.1 m^3/hr.

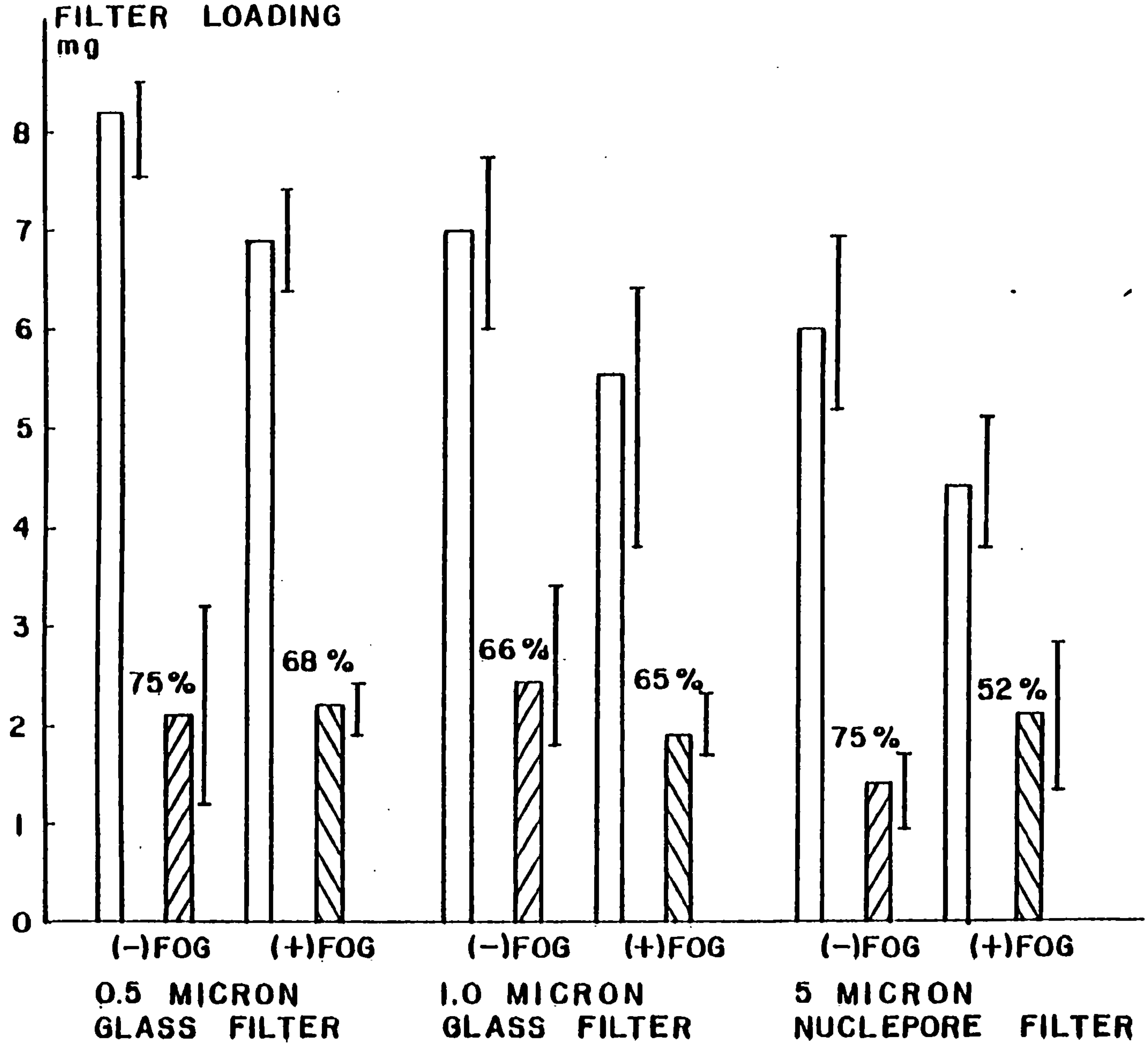


Figure 48. Control of gypsum dust with charged fog. Water flow 20 ml/min; air flow 5.1 m^3/hr.

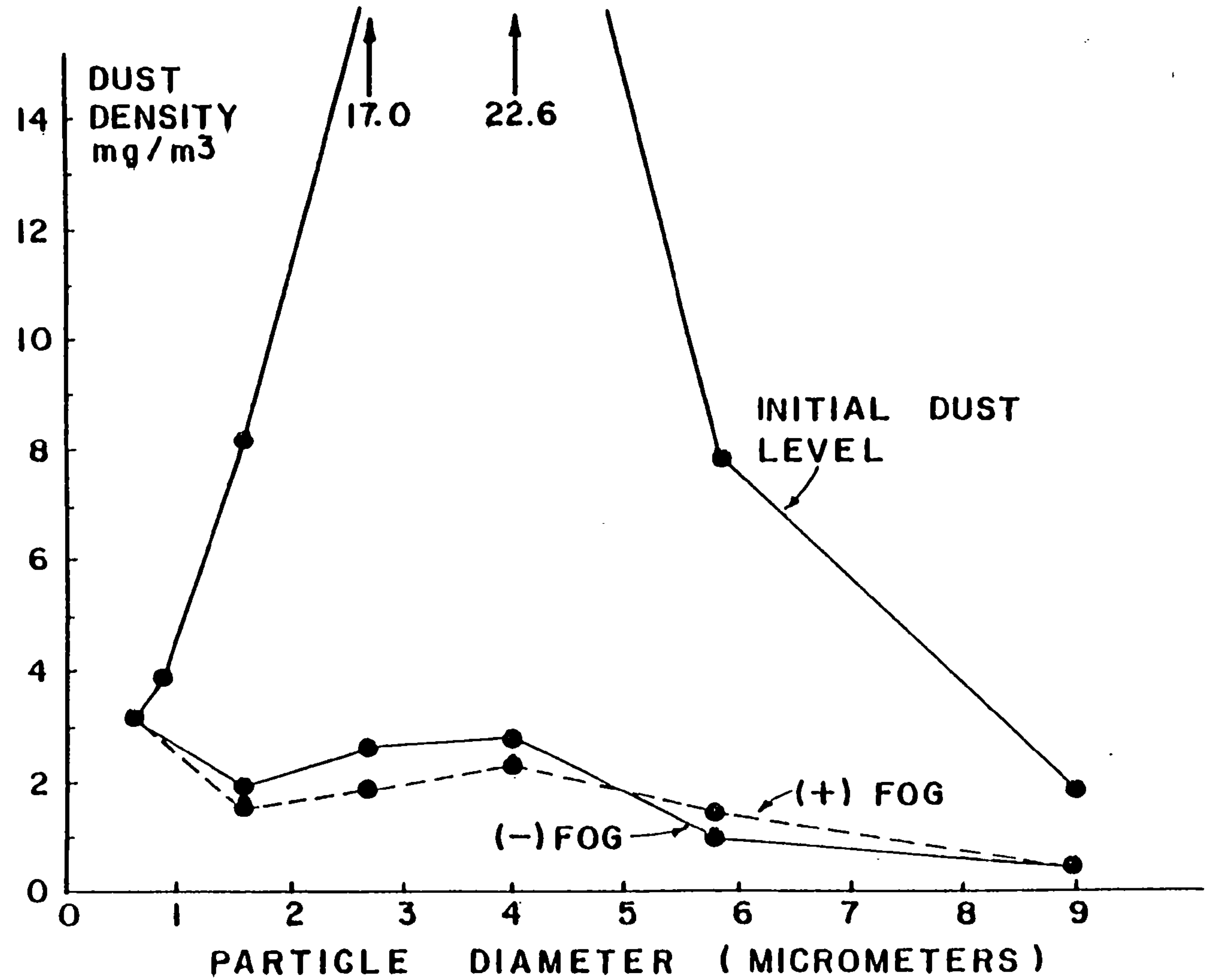


Figure 49. Control of calcium propionate dust with charged fog. Water flow 20 ml/min; air flow 4.24 m^3/hr.

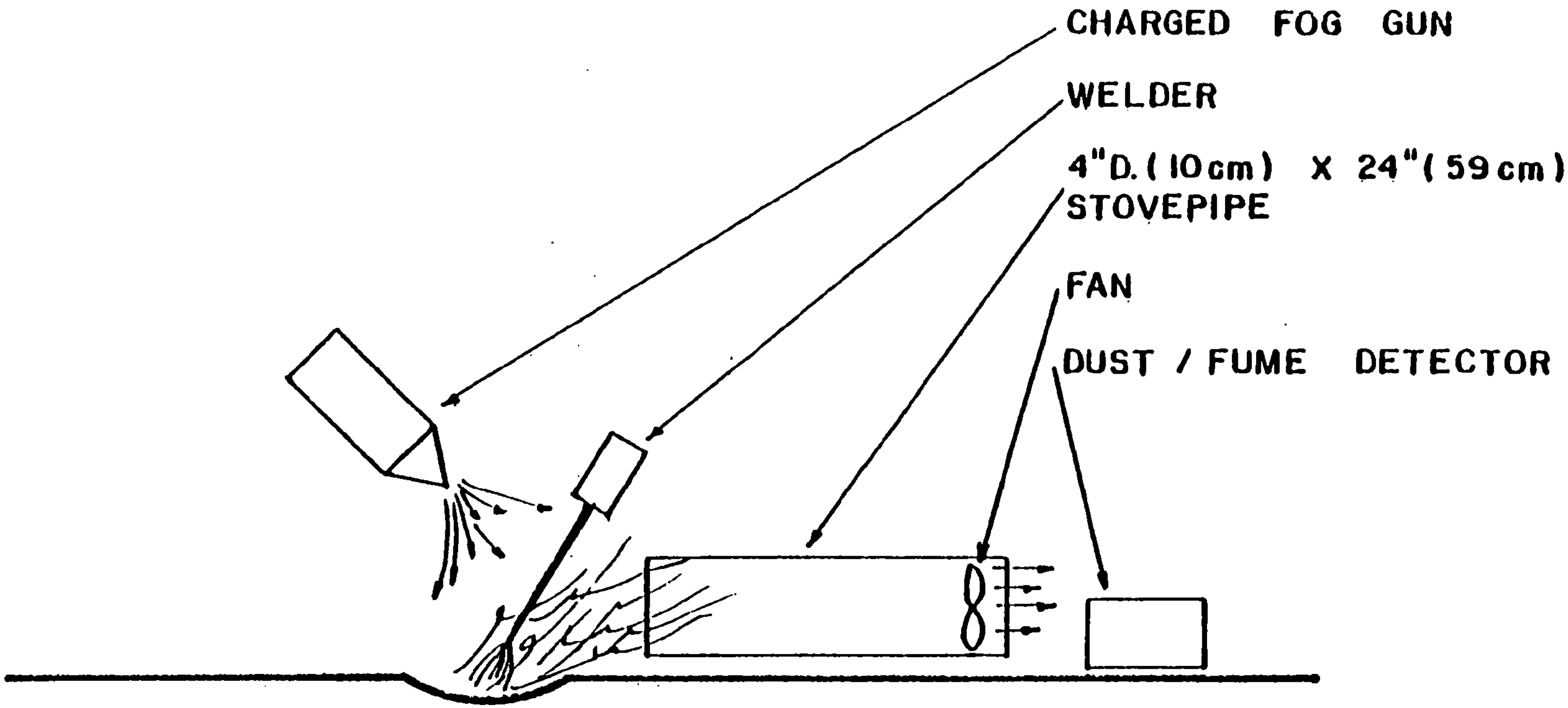


Figure 50. Schematic drawing of experimental test system for control of welding smoke and fumes.

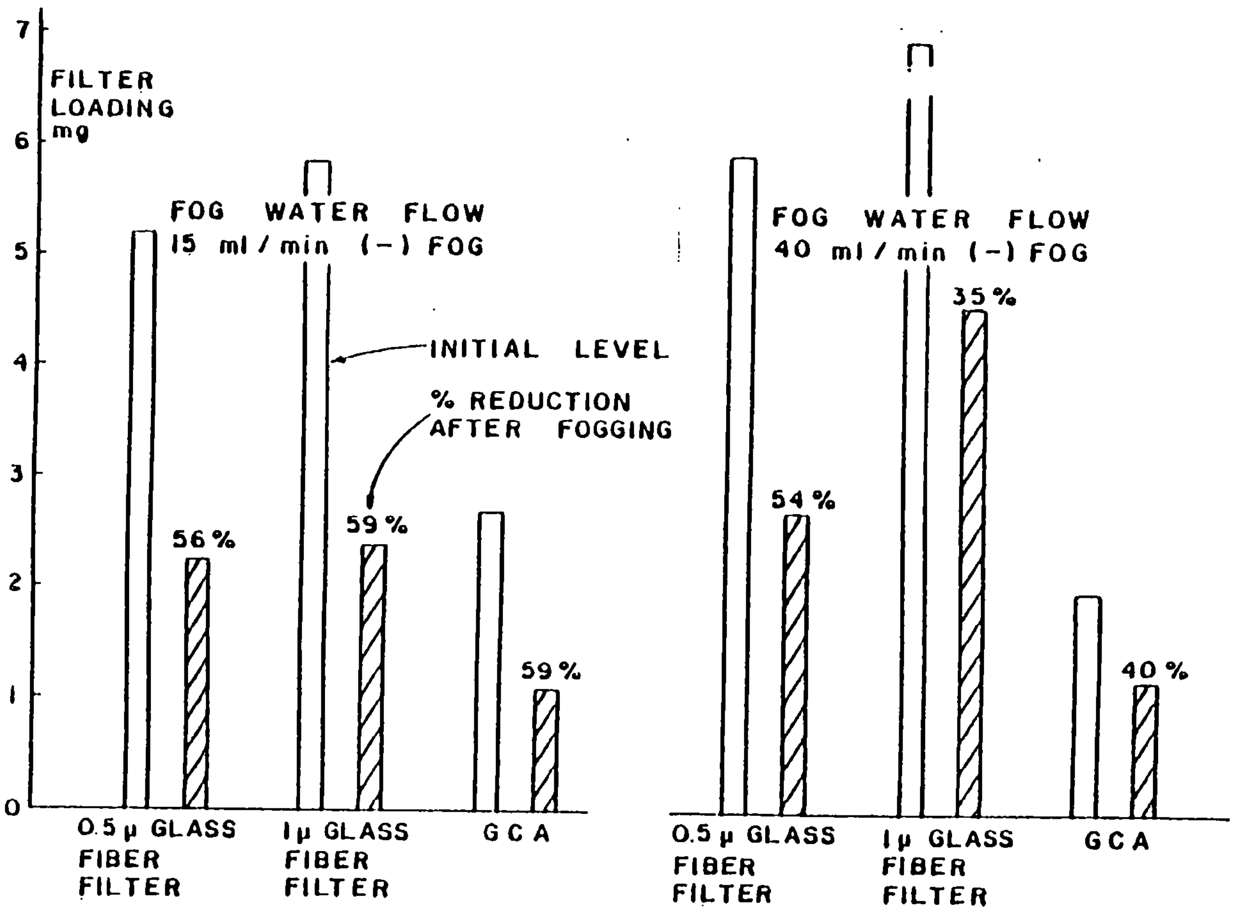


Figure 51. Reduction of metal welding fume with charged fog. Air flow 2.83 m^3/hr. Miller Electrical Mfg. Co., Appleton, Wisconsin, Model 35-S continuous wire welder.

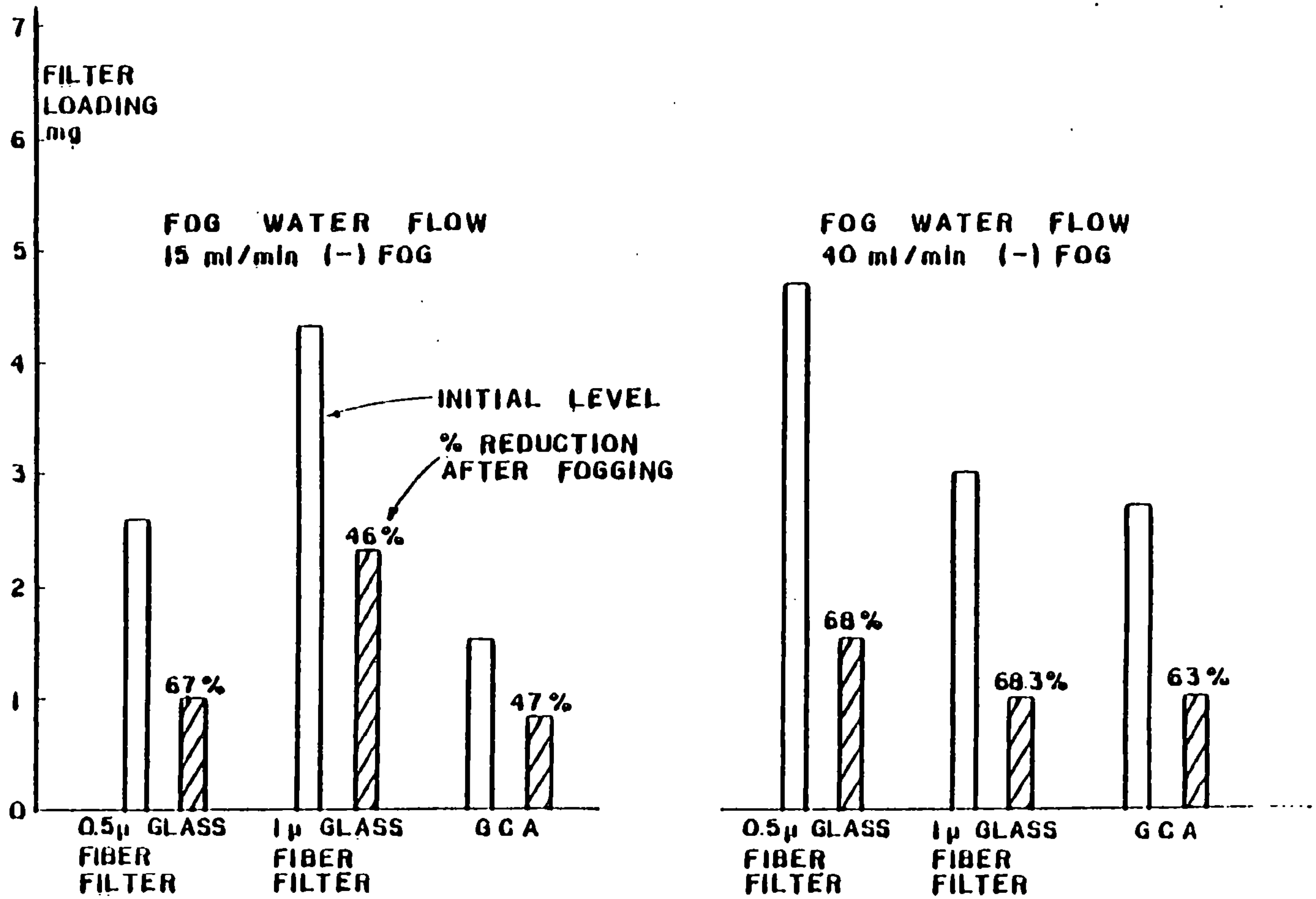


Figure 52. Reduction of metal welding fume with charged fog. Air flow 2.83 m^3/hr. Miller Electrical Mfg. Co., Appleton, Wisconsin, Model 35-S welder.

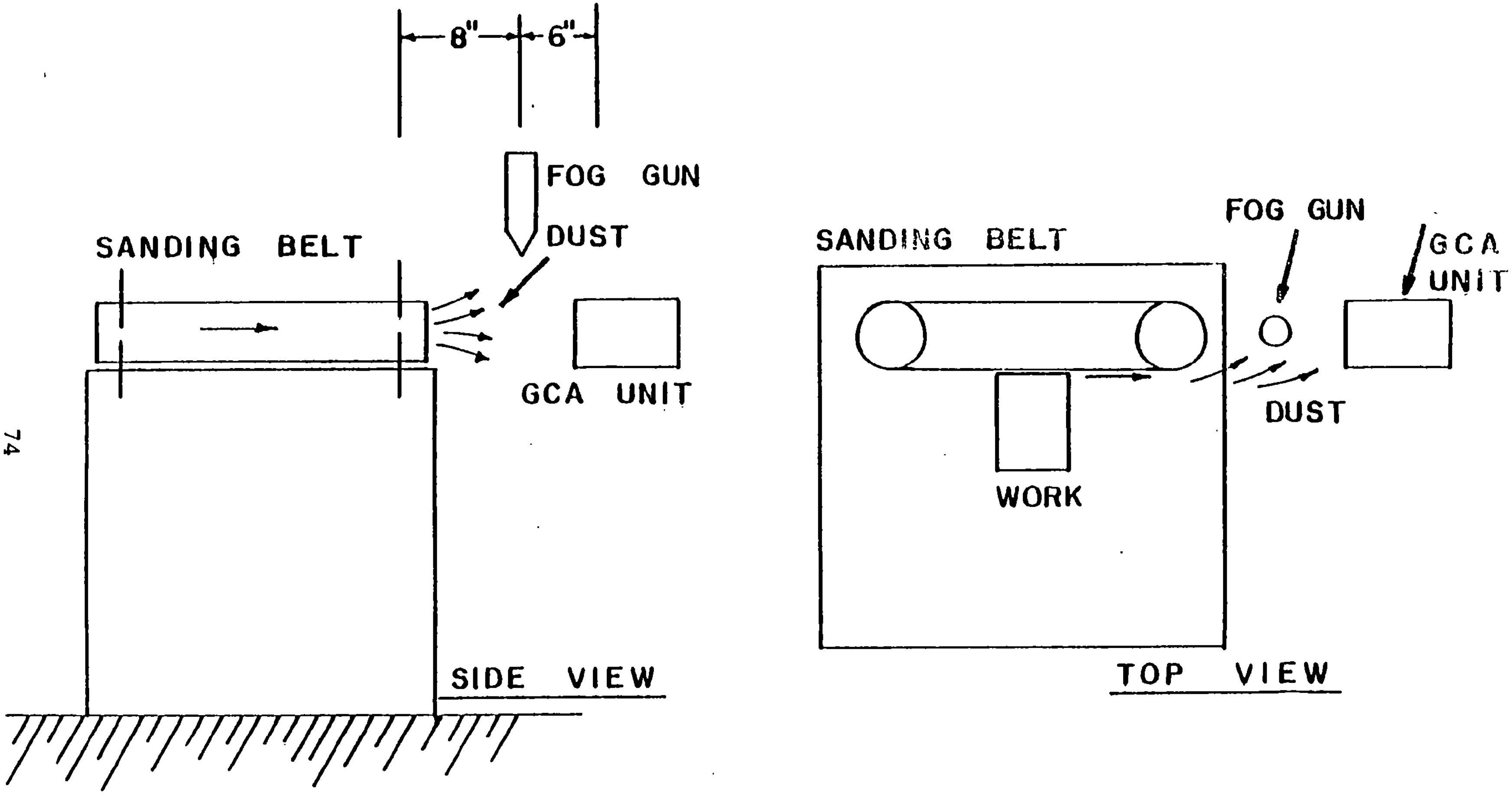


Figure 53. Schematic drawing of dust control system for industrial sander.

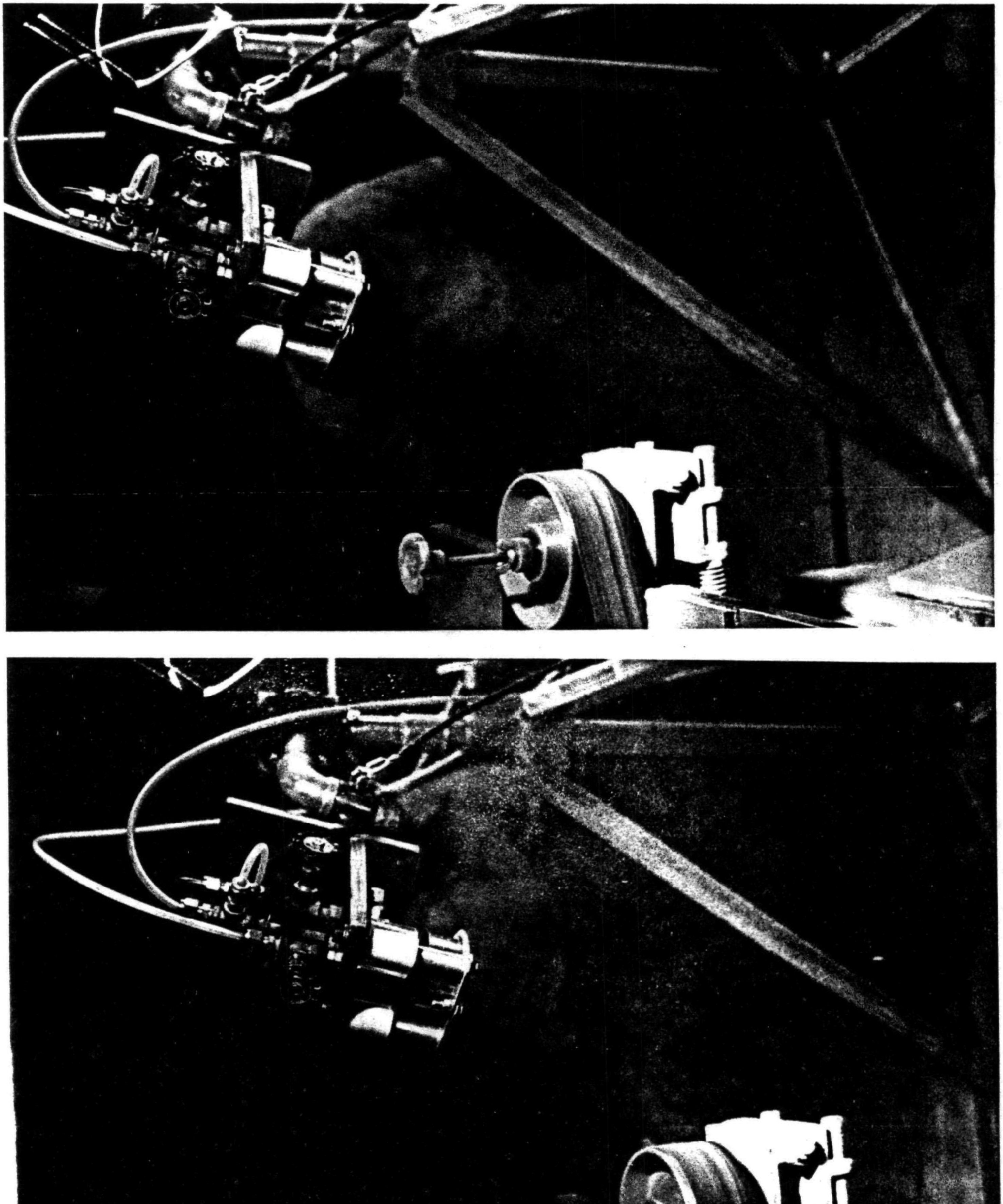


Figure 54. Reduction of dust from sander with charged fog. Left: Dust without charged fog. Right: With charged fog on.

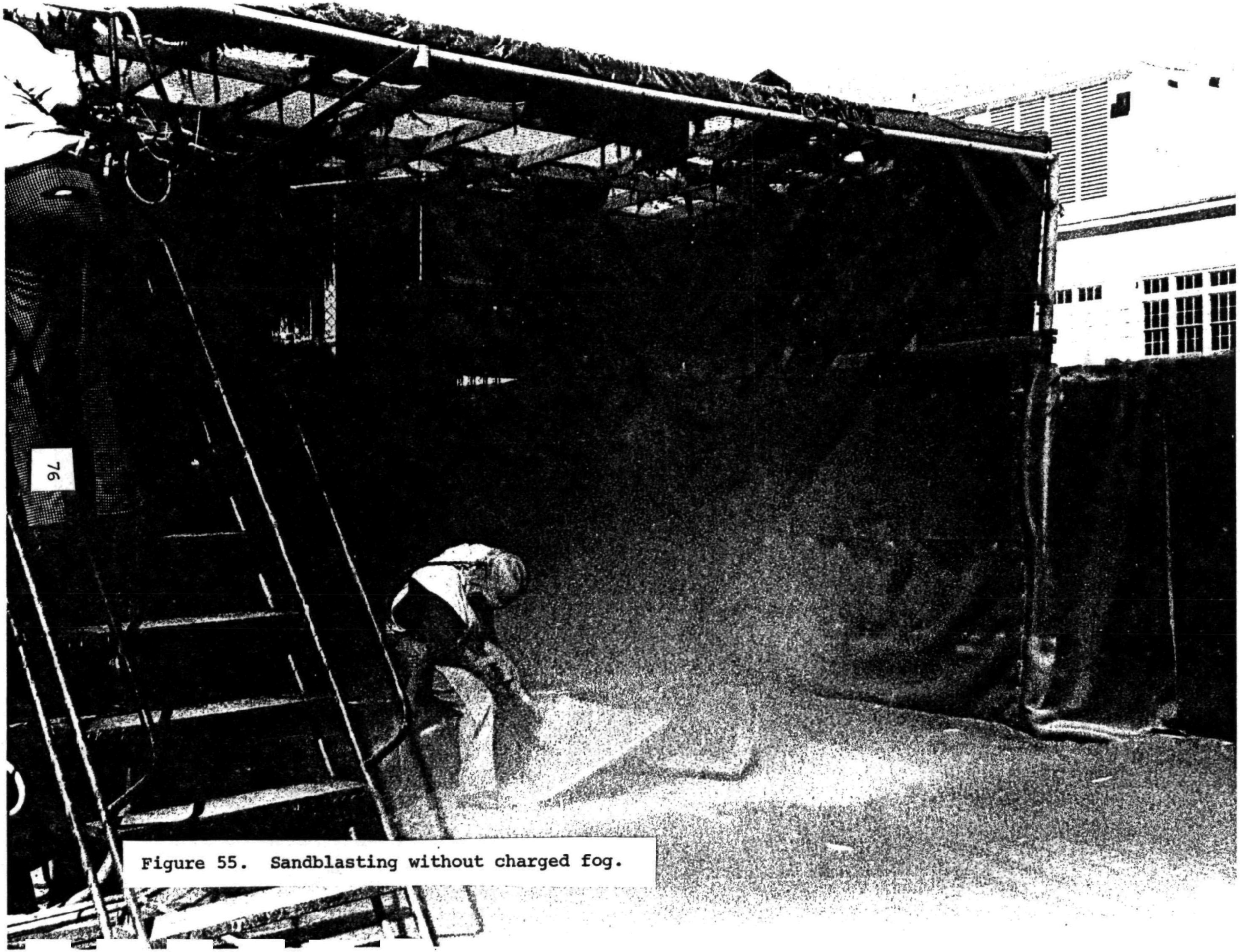


Figure 55. Sandblasting without charged fog.

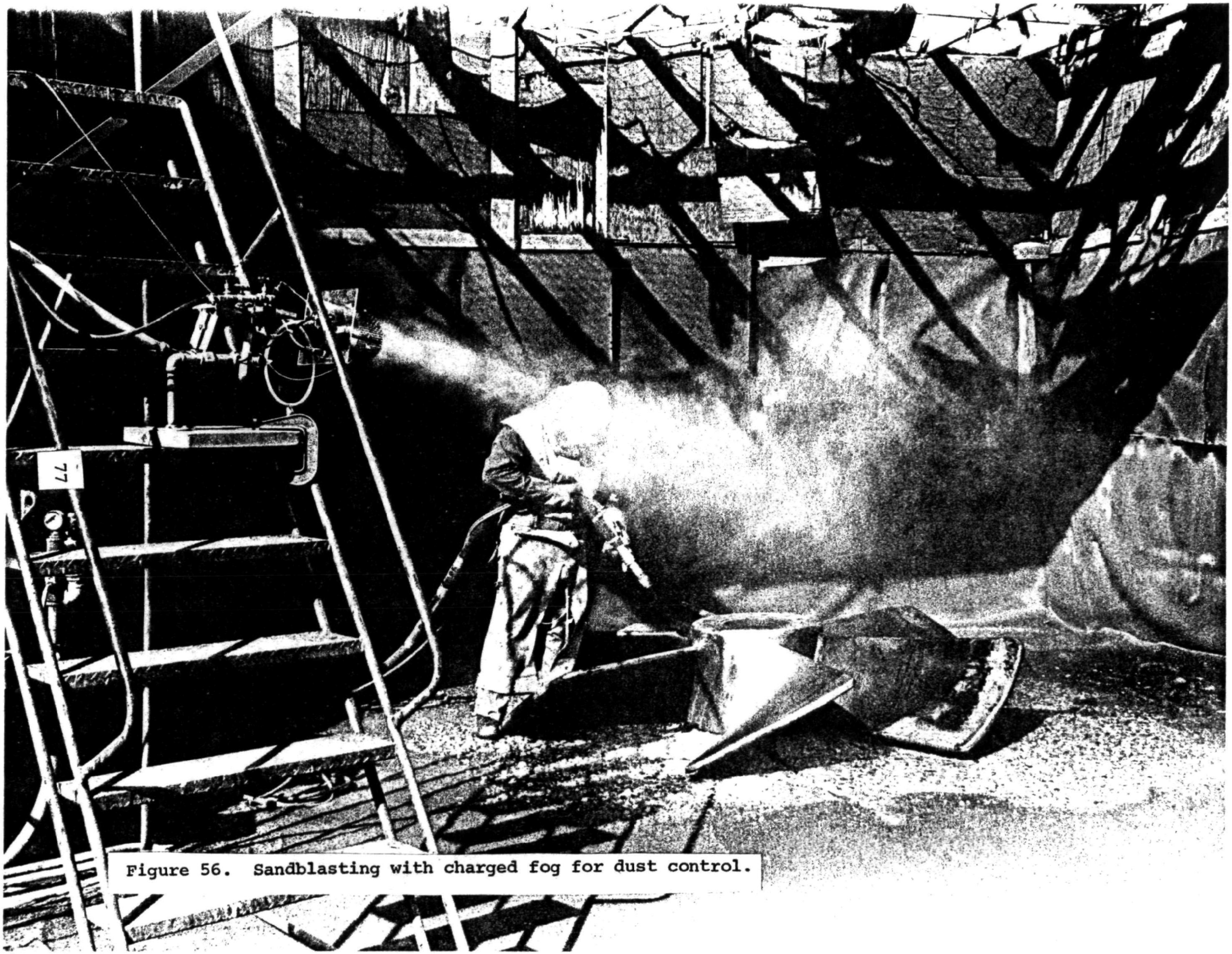


Figure 56. Sandblasting with charged fog for dust control.

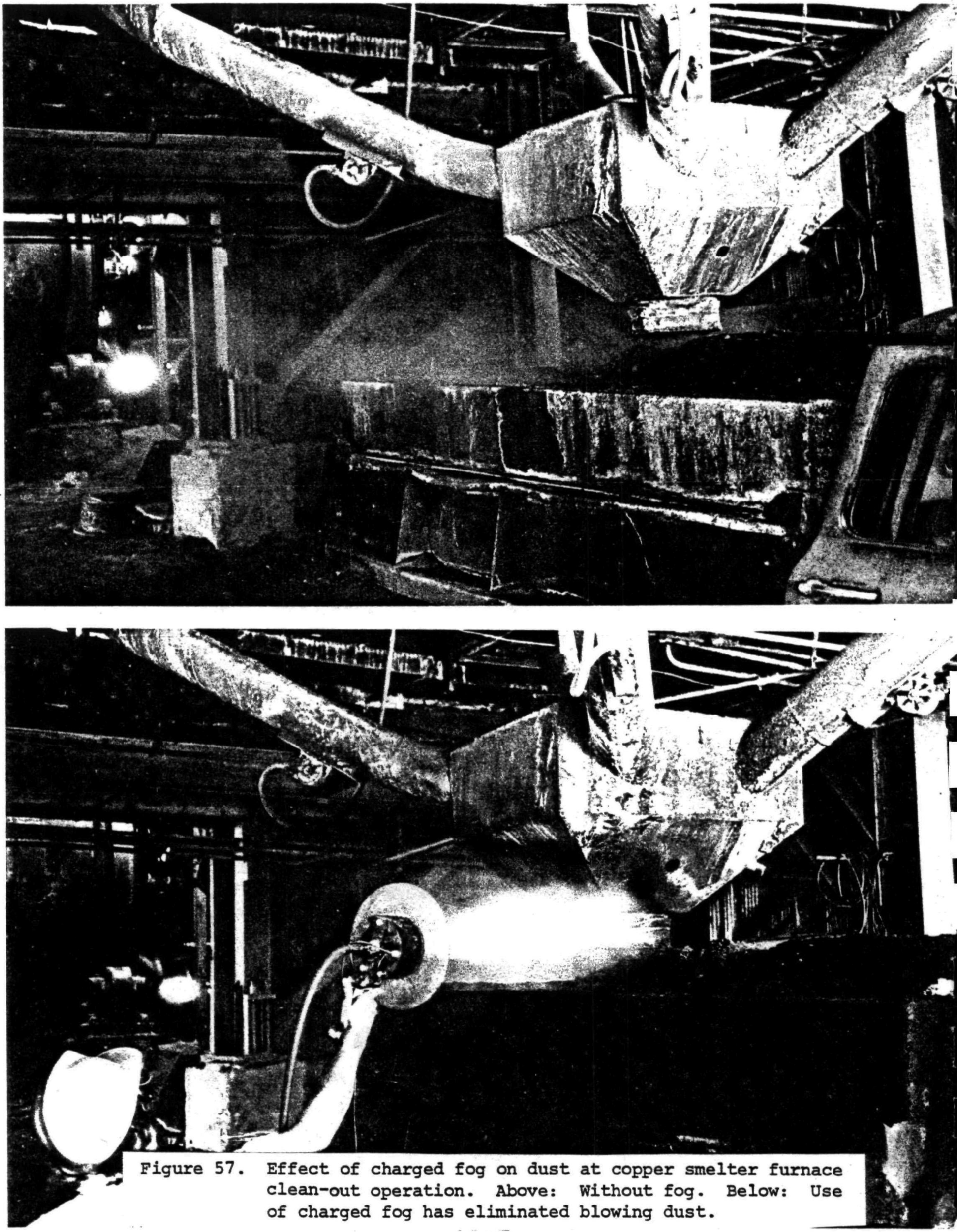


Figure 57. Effect of charged fog on dust at copper smelter furnace clean-out operation. Above: Without fog. Below: Use of charged fog has eliminated blowing dust.

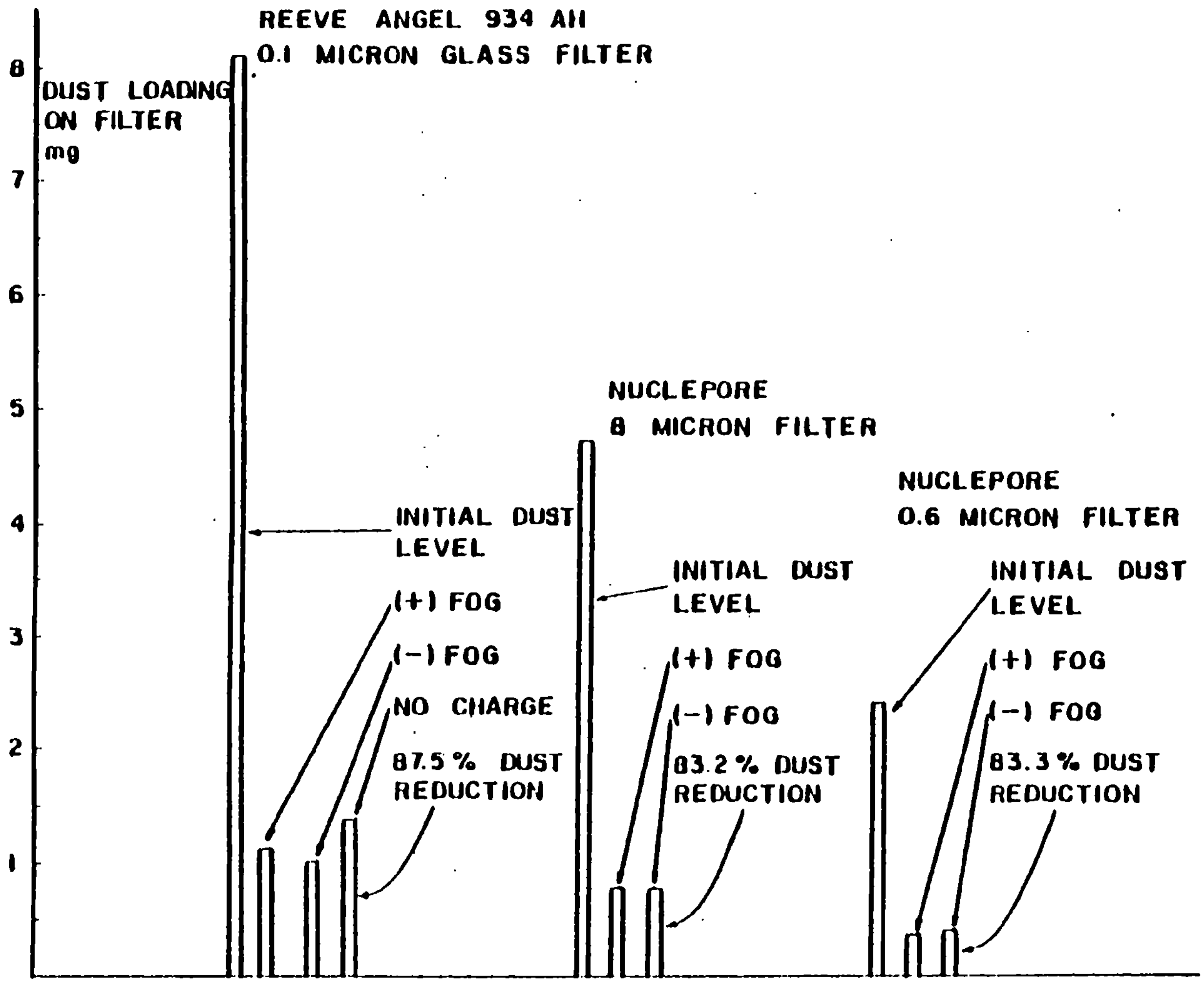


Figure 58. Effect of charged fog on cotton dust in an operating cotton gin. Water flow 50 ml/min; air flow 1.13 m^3/hr; sampling time 4 minutes.

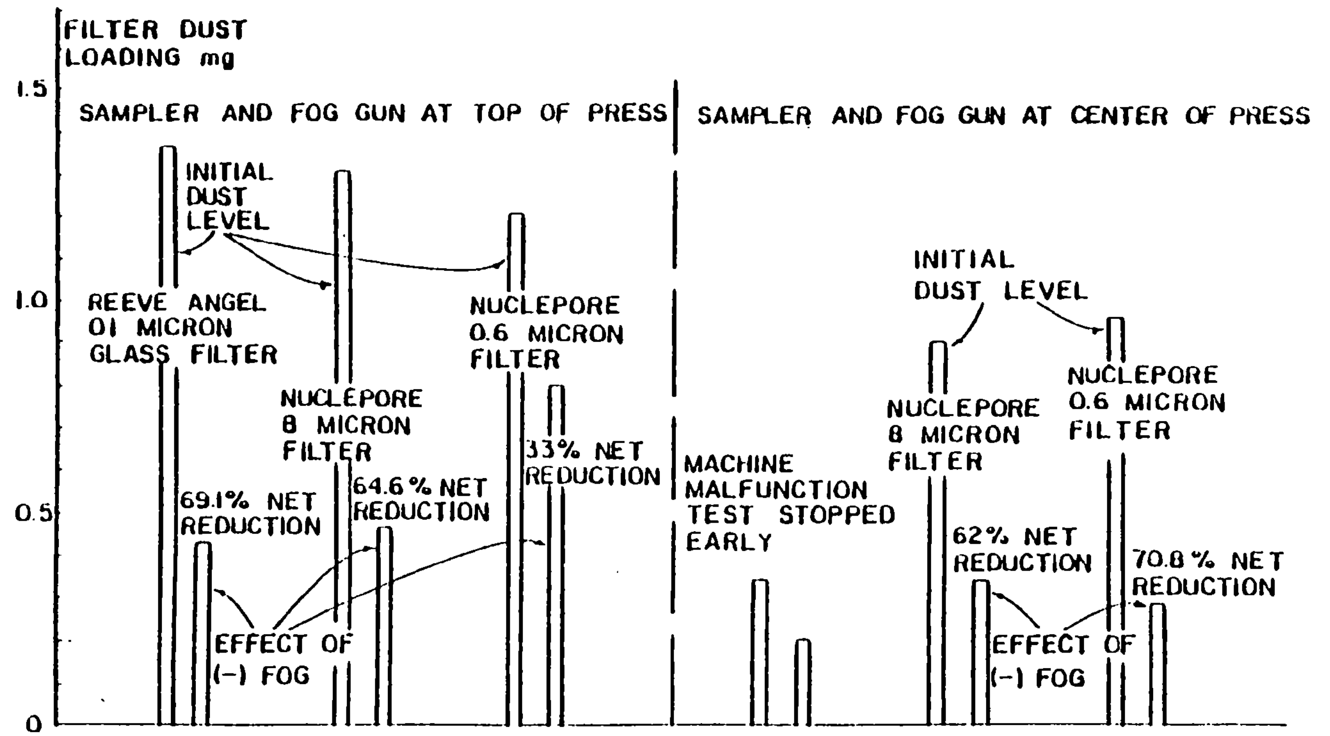


Figure 59. Effect of charged fog on cotton dust with fog gun at two different locations in cotton gin. Water flow 100 ml/min; air flow 4.5 m^3/hr.

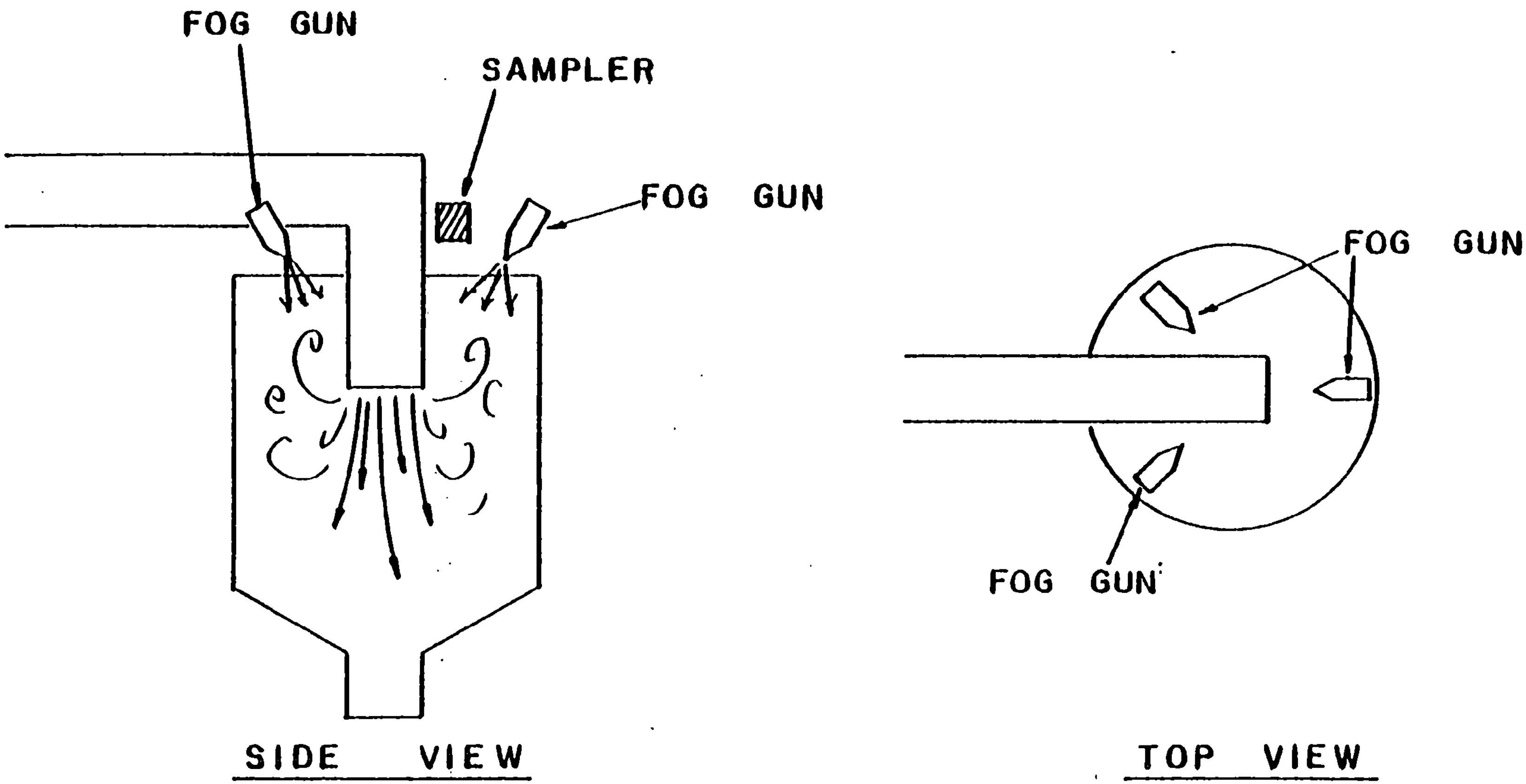


Figure 60. Fog gun system for dust control in duct.

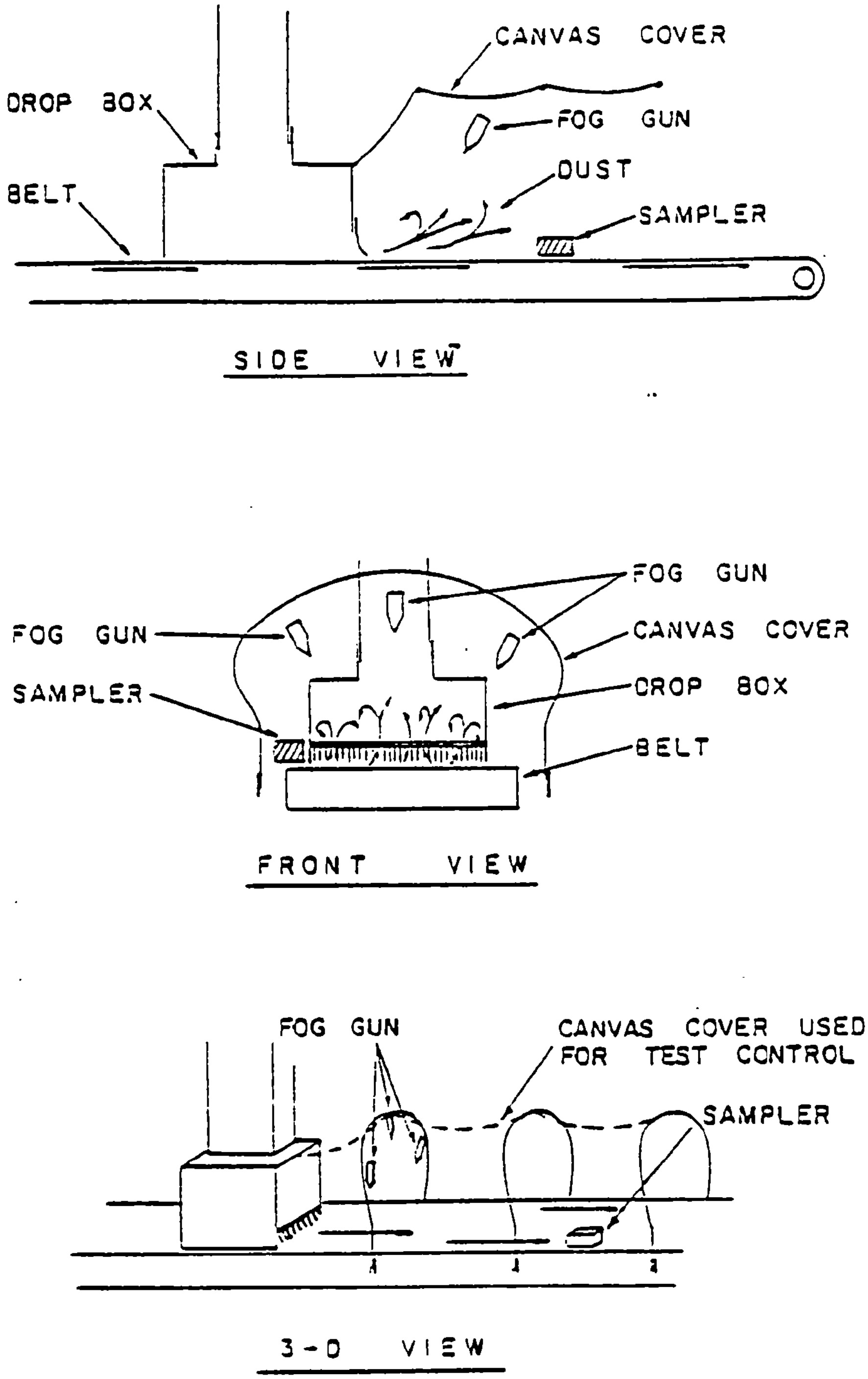


Figure 61. Fog gun system for dust control in a drop box.

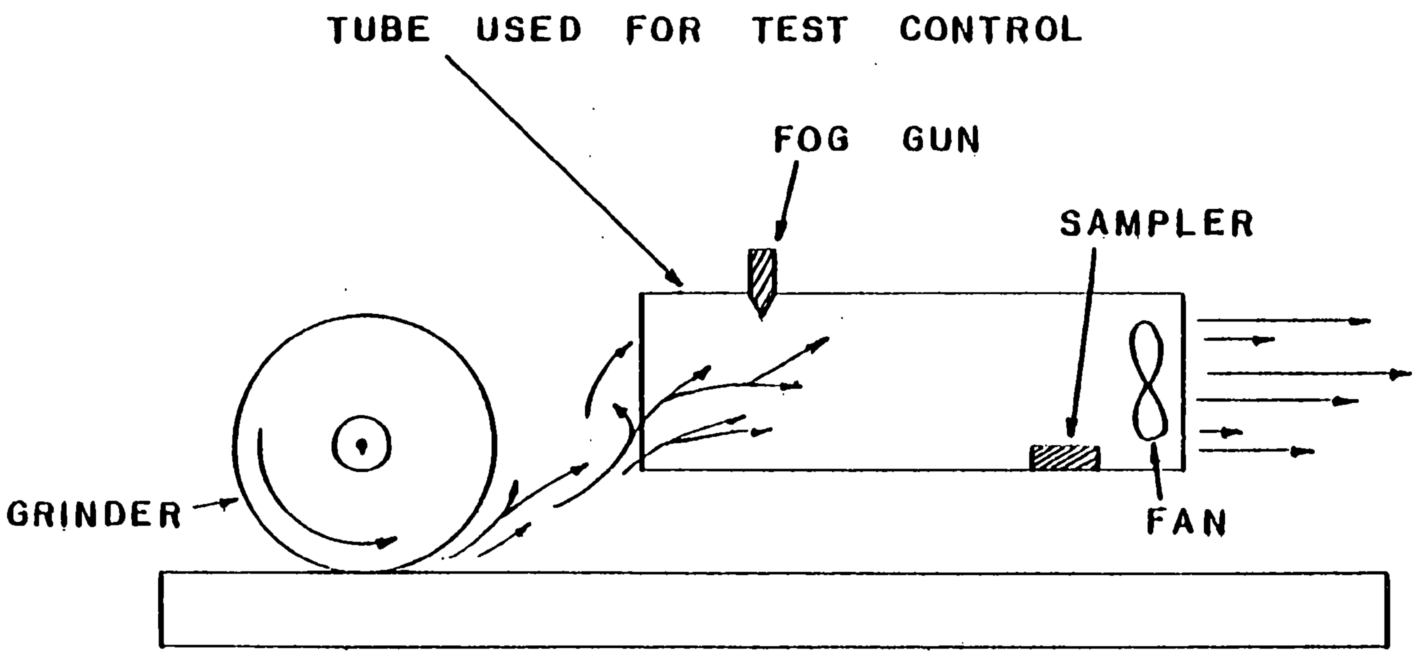


Figure 62. Fog gun system for dust control on grinder.

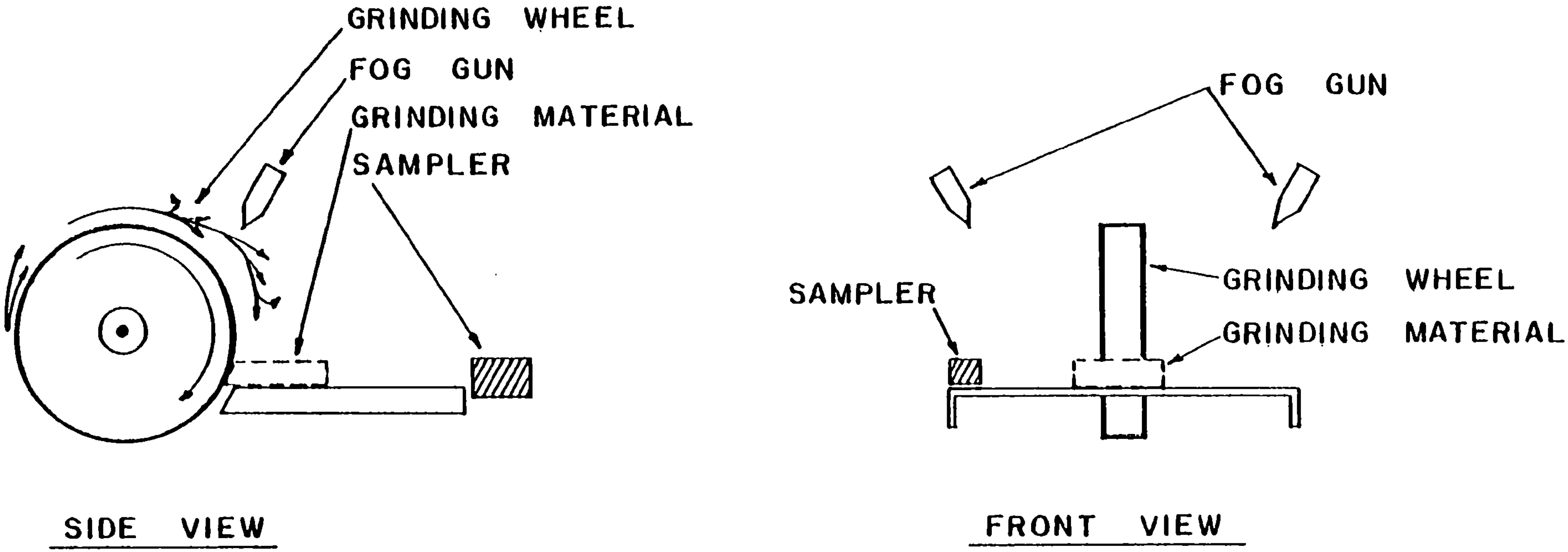


Figure 63. Fog gun system for dust control during grinding.

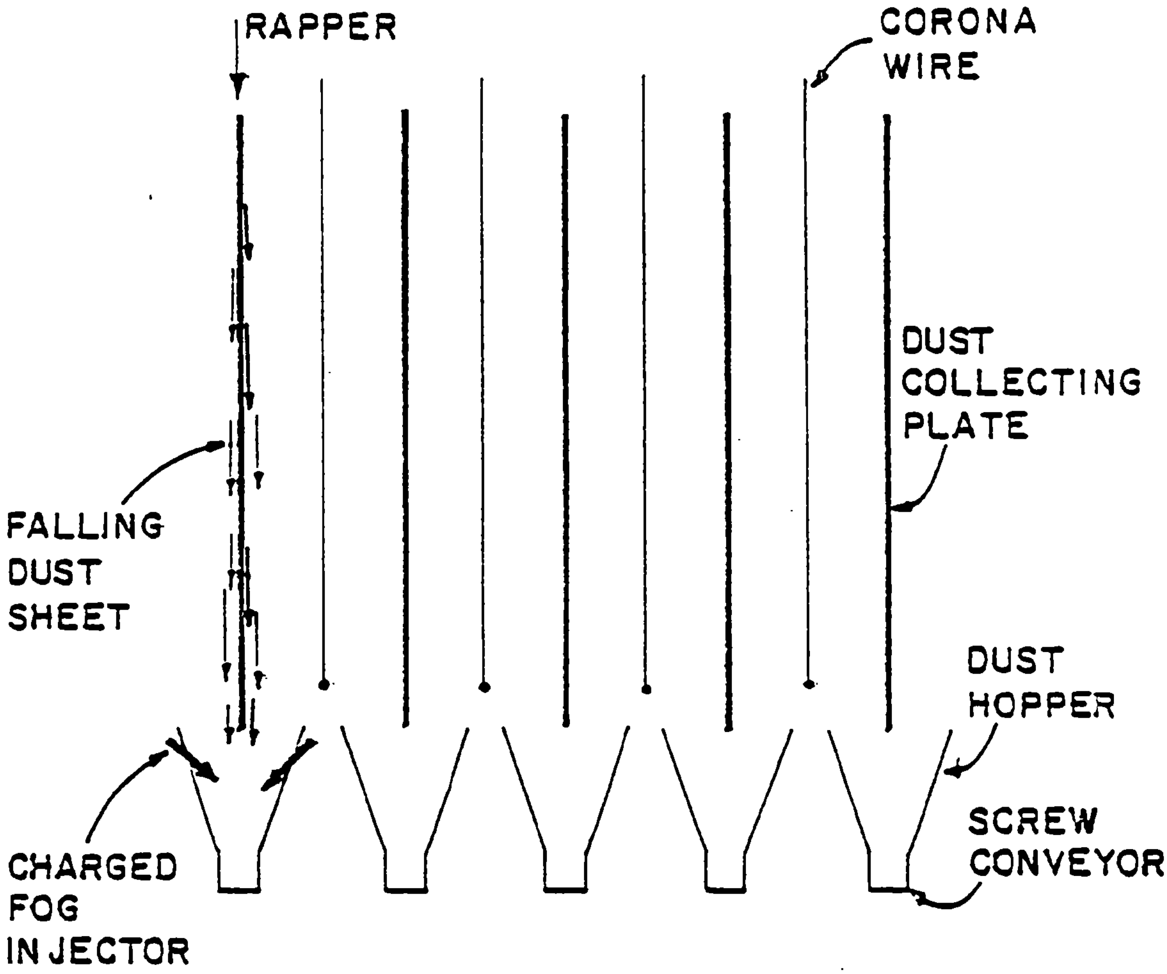


Figure 64. Fog gun system for control of dust boil-up during rapping in an electrostatic precipitator.

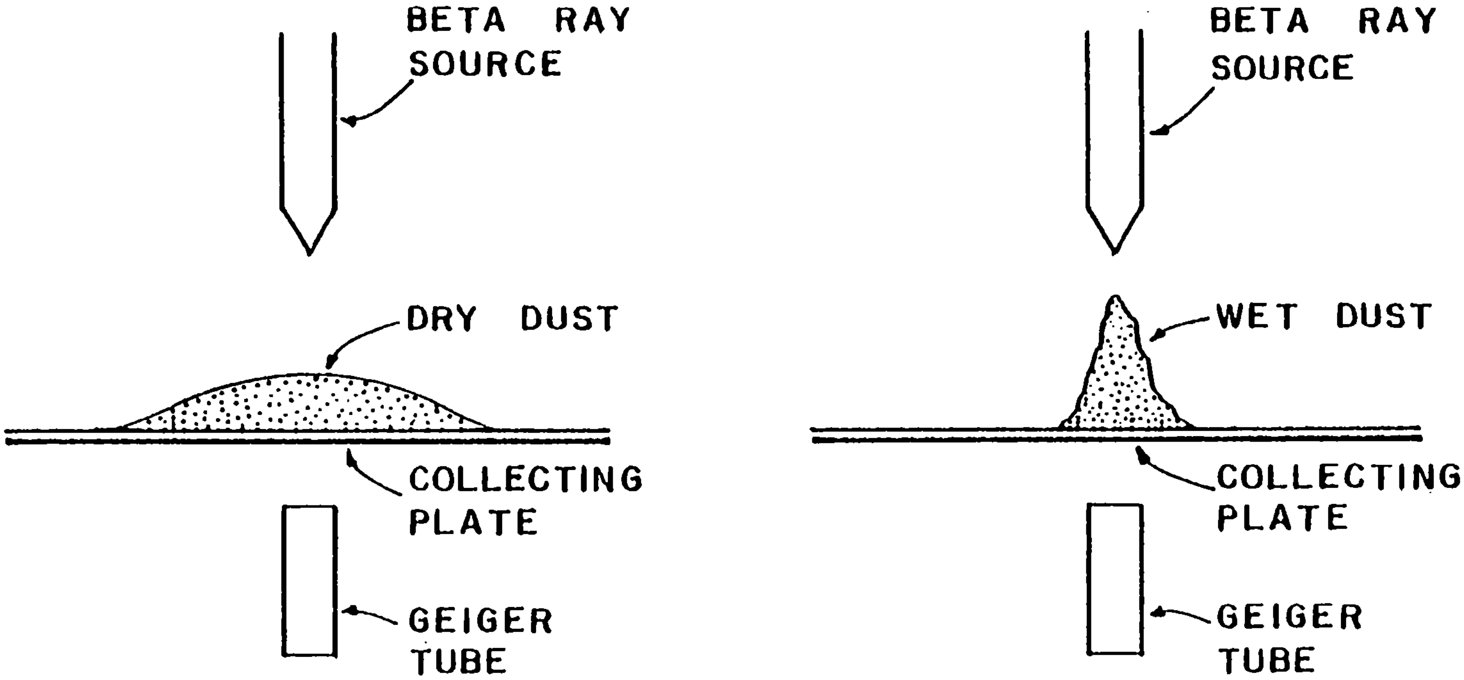


Figure 65. Differences in pile-up of dry and wet dust in GCA RDM-101 dust monitor.

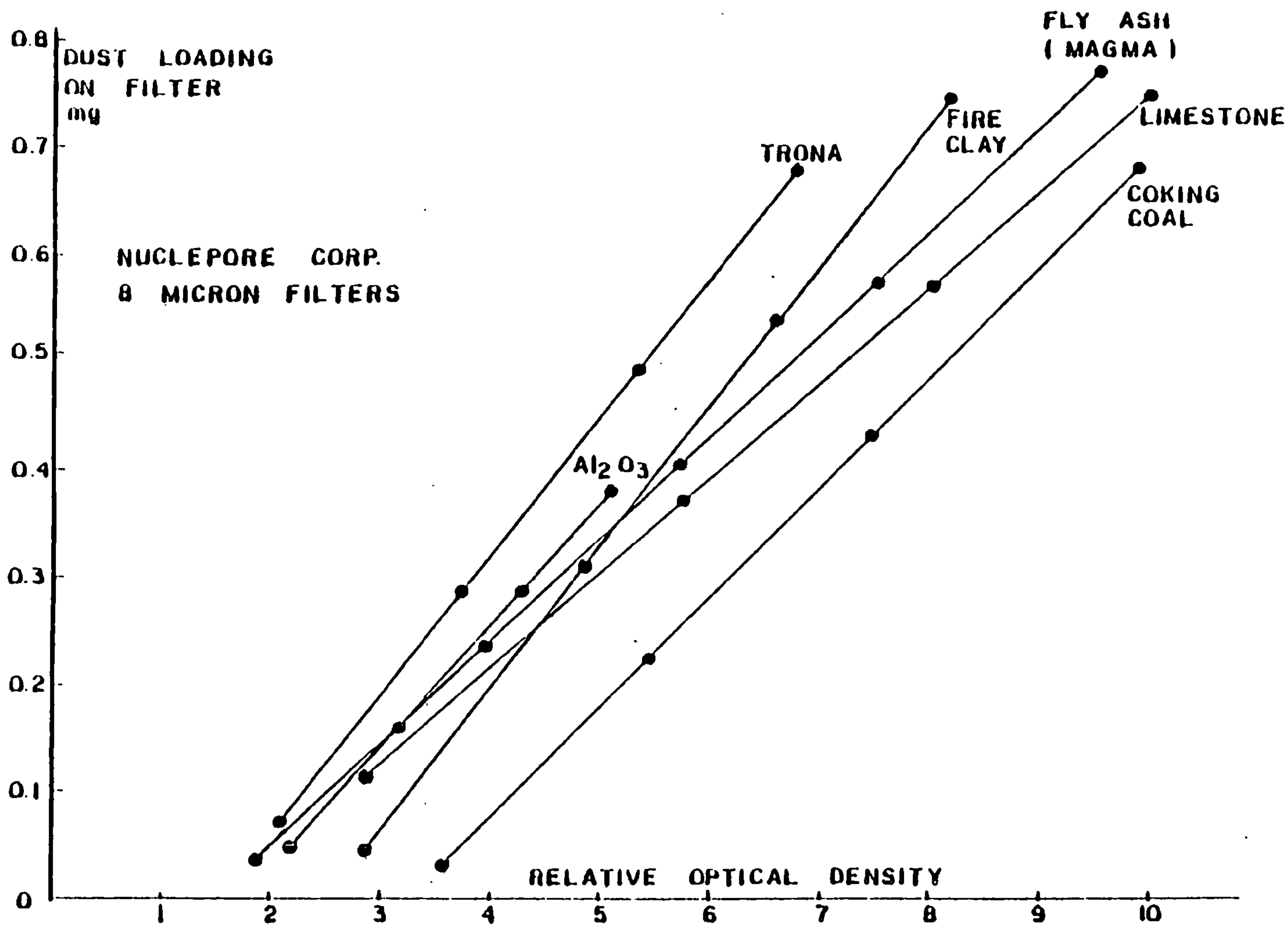


Figure 66. Calibration curve for converting optical data to actual dust loading, assorted dust materials.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/7-79-078	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Fugitive and Fine Particle Control Using Electrostatically Charged Fog		5. REPORT DATE March 1979
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Stuart A. Hoenig		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Arizona Tucson, Arizona 85721		10. PROGRAM ELEMENT NO. EHE624
		11. CONTRACT/GRANT NO. Grant R805228
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Industrial Environmental Research Laboratory Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED Final; 10/77 - 12/78
		14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES IERL-RTP project officer is Dennis C. Drehmel, MD-61, 919/541 2925.

16. ABSTRACT The report gives results of a study of fugitive and fine particle control using electrostatically charged fog. Most industrial pollutants acquire an electrostatic charge as they are dispersed into the air. Exposing this charged airborne material to an oppositely charged water fog enhances contact between the particles and the fog droplets. After contact, the wetted particles agglomerate rapidly and fall out of the atmosphere. This technique has been tested on a wide variety of industrial pollutants ranging from silica flour to SO2 and fly ash. In general, there has been significant suppression of pollution with a minimum of water fog. In addition, electrostatic hoods and screens can be used to push or direct pollutants to the proper area for collection. The system is therefore well suited to control of moving fugitive dust sources where the usual duct and baghouse systems are ineffective or too costly. The charged fog systems are now being tested in various industrial applications with generally good results. All work to date, including industrial applications that have been released by the companies involved, are discussed in the report. The report covers work on: developing new charged fog systems for controlling fugitive dust; demonstration testing of the systems in industrial locations; and designing and constructing a high-temperature stack simulator for fog gun testing.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Leakage	Pollution Control	13B	14B
Dust	Cyclone Separators	Stationary Sources	11G	07A,13I
Aerosols		Particulate	07D	
Fog		Fugitive Emissions	04B	
Electrostatics			20C	
Processing			13H	

18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 99
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)