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University of Washington Electrostatic Scrubber Tests: Combined Particulate and SO_2 Control

Interagency Energy/Environment R&D Program Report

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EPA REVIEW NOTICE

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University of Washington Electrostatic Scrubber Tests: Combined Particulate and SO_2 Control

by

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Abstract

A 1700 am^3/hr (1000 acfm) University of Washington Electrostatic Spray Scrubber pilot plant was tested on the coal-fired boiler unit no. 2 at Centralia Power Plant to demonstrate its effectiveness for controlling fine particle and sulfur dioxide emissions. The multiple pass, portable pilot plant operates by combining oppositely charged aerosol particles and water droplets in two spray towers. Aerosol charging sections at a negative polarity precede each spray tower. The pilot plant was operated utilizing only one corona section and one spray tower. A liquor recycle system was constructed, giving the pilot plant the capability to operate in an open-loop or closed-loop mode. All sulfur dioxide tests were run in an open-loop operating mode using either water or Na_2CO_3 solution as a scrubbing liquor.

Simultaneous inlet and outlet source tests using the UW mark 10 and Mark 20 Cascade Impactors provided size dependent and overall mass basis particle collection efficiency data. Measured overall particle collection efficiencies ranged from 98.99% to 99.80% depending upon scrubbing operating conditions. Particle mass concentrations measured at the scrubber outlet ranged from 0.0074 gm/sdm^3 (0.00324 gr/sdcf) to 0.0015 gm/sdm^3 (0.00065 gr/sdcf).

Sulfur dioxide concentrations at the inlet and outlet of the pilot plant were measured with a Thermo Electron Model 40 Sulfur Dioxide Analyzer. Sulfur dioxide collection efficiencies ranged from 8.02% to 97.41% depending on the scrubber operating conditions, inlet sulfur dioxide concentration and the type of scrubbing liquor used.

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ABBREVIATIONS AND SYMBOLS USED

acfm	Actual cubic feet per minute
akm^3	Actual 1,000 cubic meters
C	Cunningham slip correction factor
d_{50}	Particle aerodynamic cut diameter of cascade impactor jet stage
D_j	Diameter of jet in cascade impactor stage
fps	Feet per second
gm/sdm^3	Grams per standard dry cubic meter
gpm	Gallons per minute
KV	Kilovolts
ℓ	Liters
L/G	Liquid to gas flow rate ratio
MPa	Pressure 1,000,000 pascals
psig	Pounds per square inch
SCA	Specific collection plate area
sm^3	Standard cubic meter
SR	Stoichiometric ratio (moles of sodium carbonate per mole of inlet sulfur dioxide)
V_j	Gas velocity in jet
W	Watts

GREEK SYMBOLS

μ	Gas viscosity
μ	Micron
Ψ_{50}	Inertial impaction parameter at 50% collection efficiency for particles of aerodynamic diameter d_{50}

ACKNOWLEDGEMENTS

The assistance, cooperation, and advice of our Project Officer, Dale L. Harmon, Chemical Engineer, Particle Technology Branch, Industrial Environmental Research Laboratory at the Environmental Protection Agency is greatly appreciated. The cooperation of Ted Phillips, Tom White, Pete Steinbrenner, and Bob Werner of the Pacific Power & Light Company was very helpful. The assistance of University of Washington staff and students including Terrell Gault, Gary Raemhild, Tracey Steig, Phil Ayers, Steve Plotkin, Eric Piehl, and Jim Wilder is acknowledged. Terrell Gault wrote his MSE thesis on sulfur dioxide collection with the UW Electrostatic Scrubber. After receiving his MSE degree, Terrell served as Project Engineer doing much of the combined sulfur dioxide and particulate collection study at the Centralia Power Plant.

Section I

SUMMARY AND CONCLUSIONS

The University of Washington Electrostatic Spray Scrubber portable pilot plant was tested at the Pacific Power and Light Steam Generating Plant in Centralia, Washington on coal fired boiler no. 2 to demonstrate its effectiveness in simultaneous control of particulate and sulfur dioxide emissions. The pilot plant consists of a cooling tower, two corona sections which charge the particles to a negative polarity, two spray towers into which positively charged water droplets are sprayed and an electrostatic mist eliminator. A liquor recycle system that gives the capability of open-loop or closed-loop modes has four tanks and two pumps.

The unit was operated using only one corona section and one spray tower and the liquor system in an open loop mode. Overall particle collection efficiencies ranged from 98.99% to 99.80% depending upon the scrubber operating conditions. Using UW Mark 10 and Mark 20 Cascade Impactors, particle size distributions from 0.05μ to 30. μ aerodynamic diameter were measured at the inlet and outlet of the electrostatic scrubber.

Inlet and outlet sulfur dioxide concentrations were measured with a Thermo Electron Model 40 SO_2 Analyzer. SO_2 collection efficiencies ranged from 8.0% to 97.4% for various operating conditions. The efficiency was seen to increase with an increase in spray voltage, liquor-to-gas ratio, stoichiometric ratio, and inlet SO_2 concentration.

In conclusion it appears that the UW Electrostatic Spray Scrubber can effectively collect particulate emissions from a coal fired boiler with relatively low water usage and low corona section plate area. Further, enhanced SO_2 collection efficiencies with electrostatic charging of the scrubbing liquor implies that less alkaline material would be needed with a charged scrubbing system for the same SO_2 collection efficiency.

Section II

RECOMMENDATIONS

To better evaluate the effectiveness of the UW Electrostatic Scrubber for control of particulate and SO_2 emissions, it is recommended that additional testing should be done with the closed loop liquor recycle system using lime scrubbing liquor. Extended field tests of 24 hours or more are recommended to test the chemical and flow characteristics of the effluent sludge, to check the capability of the pilot plant to electrostatically charge liquor droplets that contain a high level of solids, and to optimize operating conditions for minimum scaling.

After this year's testing of the scrubber at a coal-fired boiler, additional testing at field sites is recommended to optimize the design and operating parameters of the pilot plant for simultaneous control of particulate and SO_2 emissions. A field source with a continuous high level of sulfur dioxide would result in greater gas concentrations at the scrubber outlet. A higher SO_2 concentration would allow a broader range of scrubber operating conditions to be tested and increase the statistical reliability of the data.

Section III

RESEARCH OBJECTIVES

The objectives of the research performed under the auspices of Environmental Protection Agency Research Grant Number R803278-01 were to:

1. Demonstrate the effectiveness of the University of Washington Electrostatic Scrubber for simultaneously controlling the emissions of sulfur oxide and particulates emitted from coal-fired power plants.

2. Determine the effect of electrostatic charging of the scrubbing liquor on the sulfur oxide absorption rate and collection efficiency.

3. Use the 1,700 m^3/hr (1000 acfm) portable pilot plant of the UW Electrostatic Scrubber to obtain the data needed to design larger control systems.

Section IV

DESCRIPTION OF THE SOURCE

The Centralia Steam-Electric Project located near Centralia, Washington is a coal-fired electric power generating station owned by eight Northwest utilities and operated by Pacific Power and Light Company personnel. The plant contains two units which have a combined generating capacity of 1,330,000 kilowatts of electricity (665,000 kilowatts per unit). The two boilers, manufactured by Combustion Engineering, are pulverized coal fired type, each with a designed steam rate of 2,400,000 kilograms (5,200,000 pounds) per hour at 16.6 MPa (2400 psig) at the turbine inlet. The two turbine generators were manufactured by Westinghouse Electric Corporation, each with a guaranteed rating of 664,898 kilowatts. The primary fuel is sub-bituminous C coal which comes from a strip mine adjacent to the plant. The coal has a design heating value of 18,100 joules/gm.(8100 BTU's per pound). Fly ash particulate emission is controlled by two electrostatic precipitators.

In October 1977, the U of W Electrostatic Spray Scrubber was transported to the Centralia Power Plant. The sample gas stream (approximately 1500 acfm) was tapped from the outlet of boiler unit number 2. A .3m (12 inch) sampling scoop was installed (facing upstream) at the center point of the transition duct between the air preheater and the precipitator. .25m (10 inch) diameter aluminum ducting connects the sampling scoop to the scrubber, which is located approximately 18 m (60 feet) below on the ground level. Due to the high negative static pressure in the main duct, a Dayton centrifugal blower was installed at the scrubber inlet to boost the air flow capabilities. Fig.IV-1 shows the location of the scrubber trailer (on the right) and the laboratory trailer (on the left). The liquor recycle trailer is located at the back end of the scrubber trailer as shown in Fig. IV-2. A schematic of the ducting arrangement showing the lengths of duct from the sampling scoop to the inlet of the pilot plant is shown in Fig. IV-3.

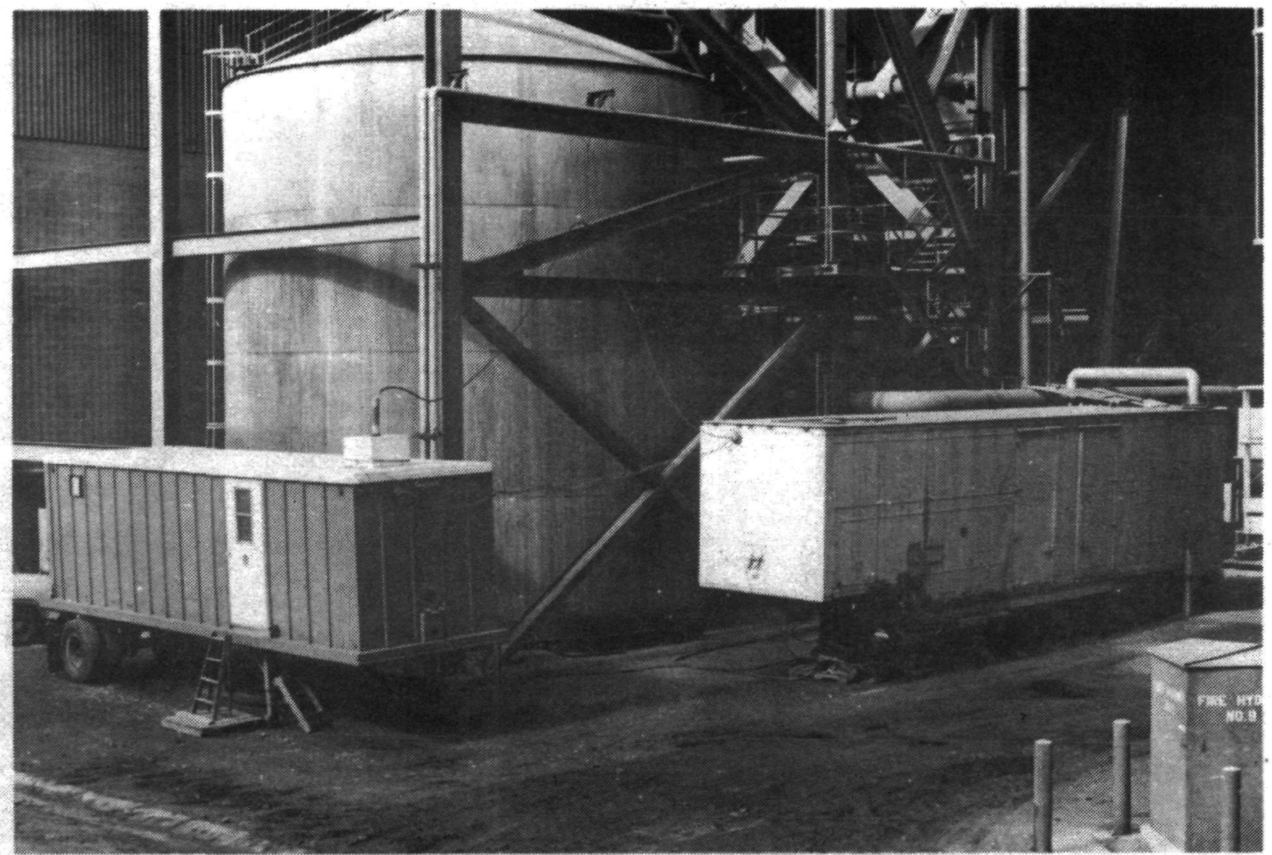

Fig. IV-1. Photograph of UW Electrostatic Spray Scrubber Located at Boiler Unit No. 2, Centralia Power Plant

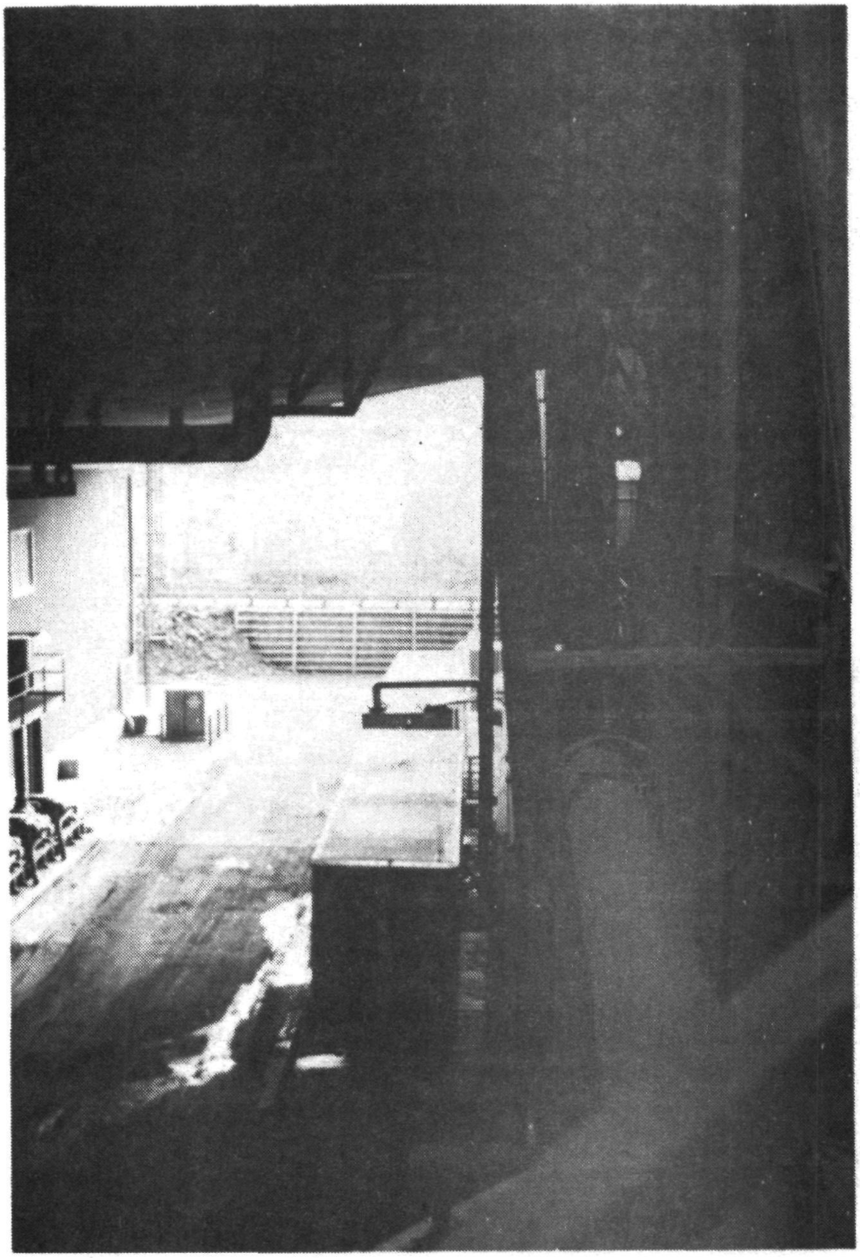

Fig. IV-2. Photograph of Liquor Recycle Trailer at Centralia Power Plant

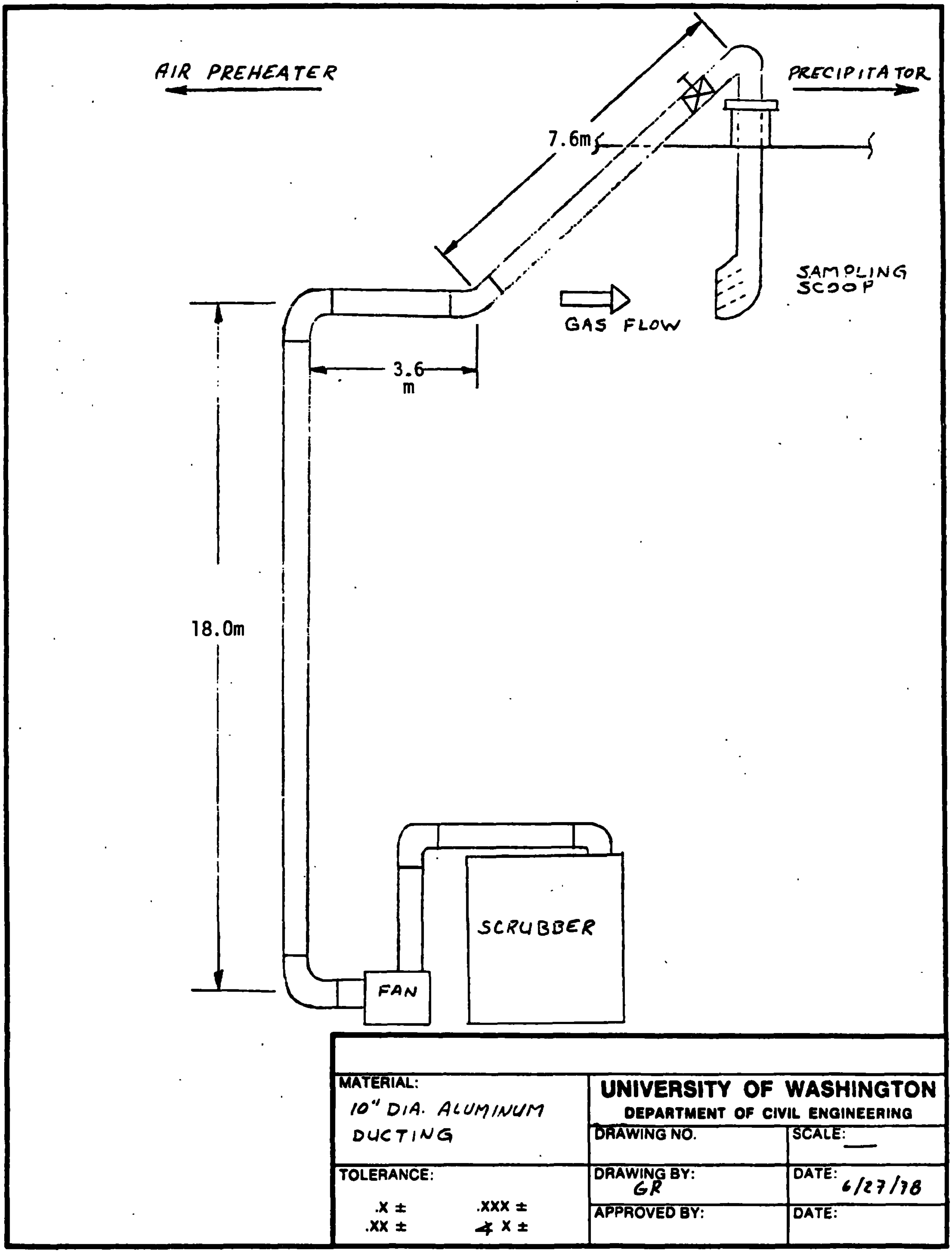

Fig. IV-3. Schematic of Ducting Arrangement to UW Electrostatic Spray Scrubber Pilot Plant at Centralia Power Station

Section V

DESCRIPTION OF UW ELECTROSTATIC SCRUBBER APPARATUS

A. Review of Previous Work

Penney (1944) patented an electrified liquid spray test precipitator involving particle charging by corona discharge and droplet charging by either ion impaction or induction. Penney's system consisted of a spray scrubber with electrostatically charged water droplets collecting aerosol particles charged to the opposite polarity. Kraemer and Johnstone (1955) reported theoretically calculated single droplet (50 micron diameter droplet charged negatively to 5,000 volts) collection efficiencies of 332,000% for 0.05 micron diameter particles (4 electron unit positive charges per particle). Pilat, Jaasund, and Sparks (1974) reported on theoretical calculation results and laboratory tests with an electrostatic spray scrubber apparatus. Pilat (1975) reported on field testing during 1973-74 with a 1,700 am^3/hr (1000 acfm) UW Electrostatic Scrubber (Mark 1P model) funded by the Northwest Pulp and Paper Association. Pilat and Meyer (1976) reported on the design and testing of a newer 1700 am^3/hr (1000 acfm) UW Electrostatic Scrubber (Mark 2P model) portable pilot plant. Pilat, Raemhild, and Prem (1978) reported on tests of the UW Electrostatic Scrubber at a steel plant. Pilat and Raemhild (1978) reported on tests of the UW Electrostatic Scrubber at a coal-fired plant. The UW Electrostatic Scrubber (patent pending) has been licensed to the Pollution Control Systems Corporation (of Renton and Seattle, Washington) for production and sales.

B. Description and Overall System

The major components of the pilot plant include a gas cooling tower, an inlet and outlet test duct, two particle charging corona sections, two charged water droplet spray towers, and a mist eliminator. Auxiliary equipment includes transition ductwork between major components and a fan. The pilot plant is housed in a 12.2 m (40 feet) long trailer and can be transported easily to different emission sources.

The general layout of the pilot plant is shown in Fig. V-1. Incoming gases enter the top of the trailer to be treated in the vertical gas cooling tower and then turn vertically upward to enter the inlet test duct. After moving down through the inlet test duct, the gases enter the first of three horizontal passes.

The first pass contains both particle charging corona sections and the first of two water spray towers. The two coronas are at either end of this pass and are separated by spray tower #1. Spray tower #2 comprises the entire second horizontal pass and the last (third) pass contains the mist eliminator. Due to the extremely high collection efficiencies when both coronas and towers were used, during this testing only corona #2 and spray tower #2 were used.

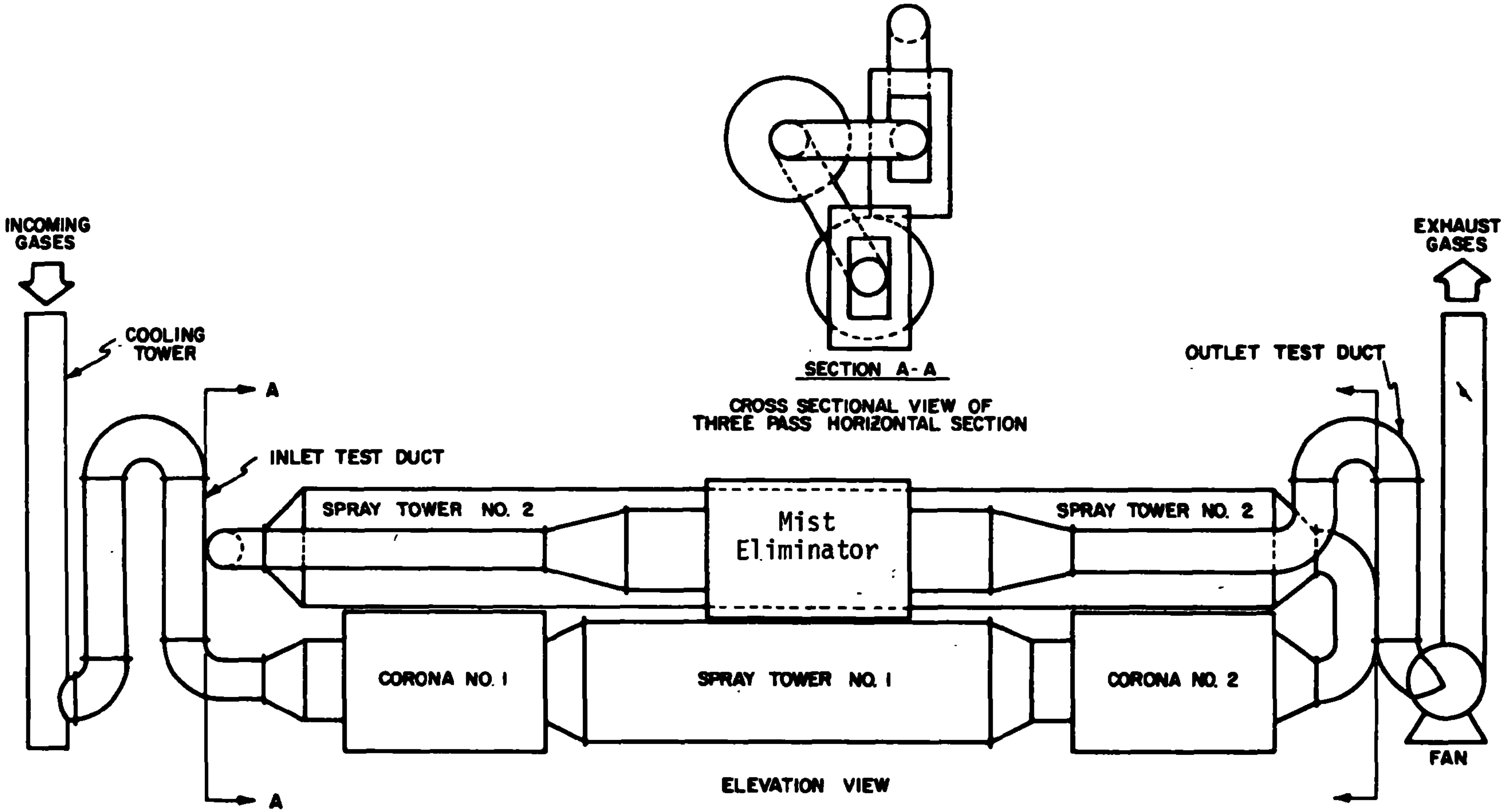

Fig. V-1. General Layout of Electrostatic Scrubber Pilot Plant

At the outlet of the third horizontal pass, the gases enter the top of the outlet test duct and are then directed to the fan before being exhausted through the trailer roof.

C. Cooling Tower

The cooling tower is designed to lower the gas temperature to below 121°C (250°F) in order to maintain structural integrity of the system, which is constructed of steel and fiberglass reinforced plastic. The cooling tower, as shown in Fig. V-2, is .36 m (1 ft. 2 in.) in diameter x 2.98 m (9 ft. 8 in.) in height and is constructed of 21 gage T. 304 stainless steel. Cooling water is introduced through four ports spaced at .61 m (2 ft.) intervals on one side of the tower and is sprayed vertically upward from the tower's centerline. Four Bete Model W 10080 F full cone stainless steel nozzles used for spraying are capable of delivering up to 11.4 ℓm (3.0 gpm) at .45 mPa (50 psig). A funnel built into the bottom of the spray tower extends throught the trailer floor for cooling water removal.

D. Particle Charging Corona Section

Only the corona section at the downstream end of the first horizontal gas passage (corona #2) was used. The corona shell is constructed from 4.8 mm (3/16 in.) wall thickness fiberglass reinforced plastic (FRP) with interior dimensions of .61 m wide x 1.07 m high x 1.52 m long (2 ft. x 3 ft. 6 in. x 5 ft.) in the direction of gas flow. Access to a corona interior is through removable FRP end plates which are normally bolted to 5.1 cm (2 in.) full perimeter 3.2 mm (1/8 in.) thick face glanges on either end of a corona.

The corona is designed to operate in either a single or double lane gas passage mode. Switching from one to another requires rearrangement of the adjustable collection plates and discharge frame(s). The width of individual gas lane(s) for either mode is maintained at .3 m (1 ft.) and the discharge frame to collection plate spacing is therefore .15 m (6 in.). Fig. V-3 shows a cutaway schematic of a corona set up for single lane operation. The testing at Centralia Power Plant was performed with a single lane corona section.

The overall dimensions of the discharge frame shown in Fig. V-3 are .70 m high x 1.14 m long (27½ in. x 3 ft. 9 in.). The frame is constructed of 6.4 mm x 1.91 cm (¼ in. x 3/4 in.) T. 304 stainless steel rectangular bar stock members. Prior to the Centralia test program these frames were modified by welding 3.2 mm (1/8 in.) diameter stainless steel rods in 4.45 cm (1-3/4 in.) lengths perpendicular to the vertical members of each discharge frame. The spikes have sharp points on both ends and are welded at 5.0 cm (2 in.) intervals. This modification has decreased the plate to frame spacing by 6.4 mm (1/4 in.).

The collection plates shown in Fig. V-3 are 1.05 m high x 1.5 m long (41-1/4 in x 59 in.), giving each plate a cross sectional area of 1.58 m^3, which is used in the calculations for SCA. They are constructed from 11 gage T. 316 stainless steel. The plates serve as full chamber baffles to keep the gases within the confines of the single lane passages.

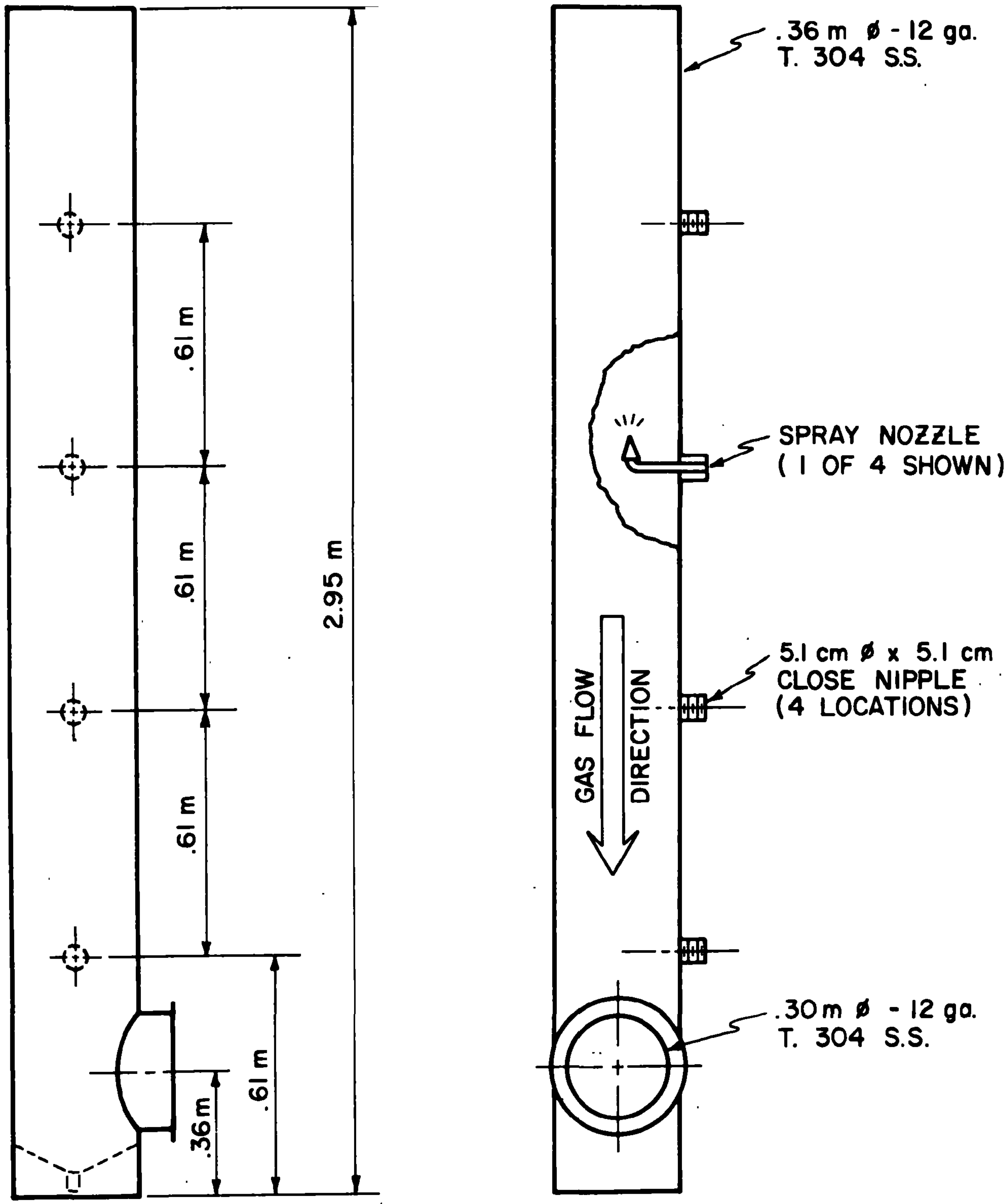

Fig. V-2. Cooling Tower Schematic

A negative corona is used to charge the particles negatively. This is accomplished by maintaining the discharge frame(s) at a high negative potential and the collection plates at a neutral or ground potential. Field strengths generated in corona #2 is 6.15 KV/cm (15.61 KV/in.) Corona power supplies are discussed in all other components inside the corona. This isolation is provided by suspending the frame on two 2.5 cm (1 in.) diameter T. 303 stainless steel rods which are connected to porcelain insulators. The Ceramaseal Model 902B1353-6 insulators are housed in .3 m diameter x .61 m long x 6.4 mm wall thickness (1 ft. x 2 ft. x 1/4 in.) plexiglass tubes which are centered 1.07 m (3 ft. 6 in.) apart and are located on top of the corona shells. Two .30 m to .36 m x 7.6 cm (1 ft. to 1 ft. 2 in. x 3 in.) FRP reducing flanges are used to join the plexiglass tubes to the corona top.

The insultators are continually flushed with a supply of heated purge air. The temperature of the purge air is maintained at about 49°C (120°F) and an even flow across a plexiglass tube section is obtained by introducing the purge air through a distribution plate having approximately 10% hole area. The flushing face velocity of the purge air is set at about .18 m/sec. (0.6 fps). This same purge air distribution flange also serves as a support flange in that an insulator is bolted directly to it. The high voltage lead-in to the discharge frame is through a feed-through type insulator.

The collection plate and discharge frame flush system is shown schematically in Fig. V-4. A continuous wall wash is supplied to the collection plates through 2.5 cm (1 in.) FRP square tube which had 3.2 mm (1/8 in.) diameter holes drilled diagonally into the corner adjacent to the collection plate. The discharge frame flush is an intermittent spray supplied by two Bete 80° fan nozzles. The corona section and the mist eliminator are equipped with this flushing system.

At the nominal gas flow rate of 1,700 am^3/hr. (1000 acfm) the gas velocity in the corona is 1.45 m/sec (4.76 fps) for single lane operation and .72 m/sec. (2.36 fps) for double lane operation. The corresponding gas residence times are 1.05 and 2.10 seconds. By varying the volume of air flow through the system, however, the gas residence time can range from 0.70 seconds (single lane operation at 2550 am^3/hr. (1,500 acfm)) to 4.20 seconds (double lane operation at 850 am^3/hr. (500 acfm)).

E. Water Spray Towers

The only spray tower used in the pilot plant during these tests comprises the entire second horizontal gas passage. The spray tower is .91 m in diameter x 4.8 mm wall thickness (3 ft. x 3/16 in.) and is constructed from FRP. The length of the spray tower is 7.32 m (24 ft.). Gas velocity in the spray tower at a nominal gas flow of 1700 am^3/hr. (1000 acfm) is 0.72 m/sec. (2.36 fps). The corresponding gas residence time is 10.17 seconds.

Utilizing a single spray header in the tower, a maximum of 12 nozzles can be used in the tower. The total number of nozzles used can vary depending on the type of nozzle, the total water flow rate and the pressure head

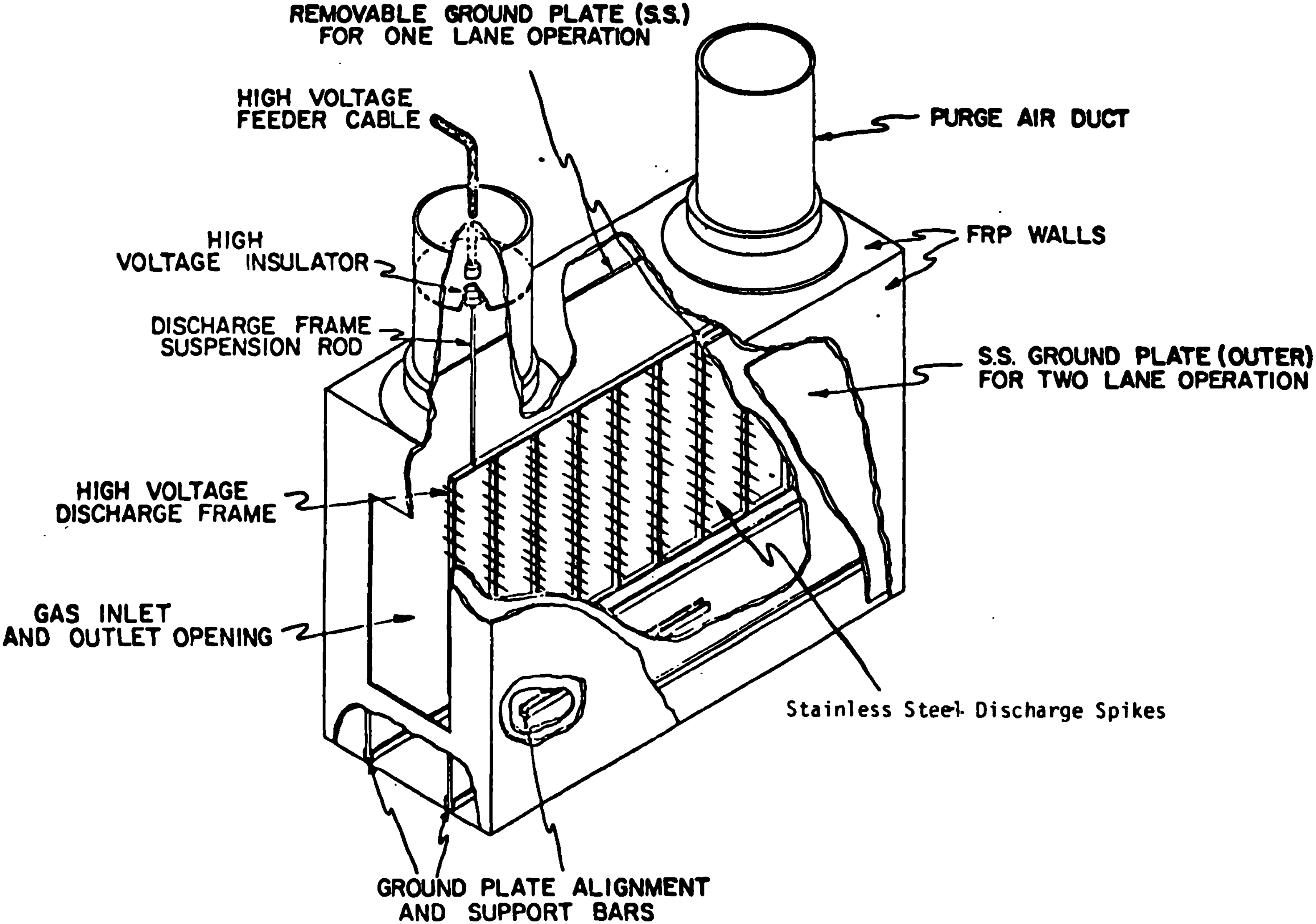

Fig. V-3. Particle Charging Corona Section

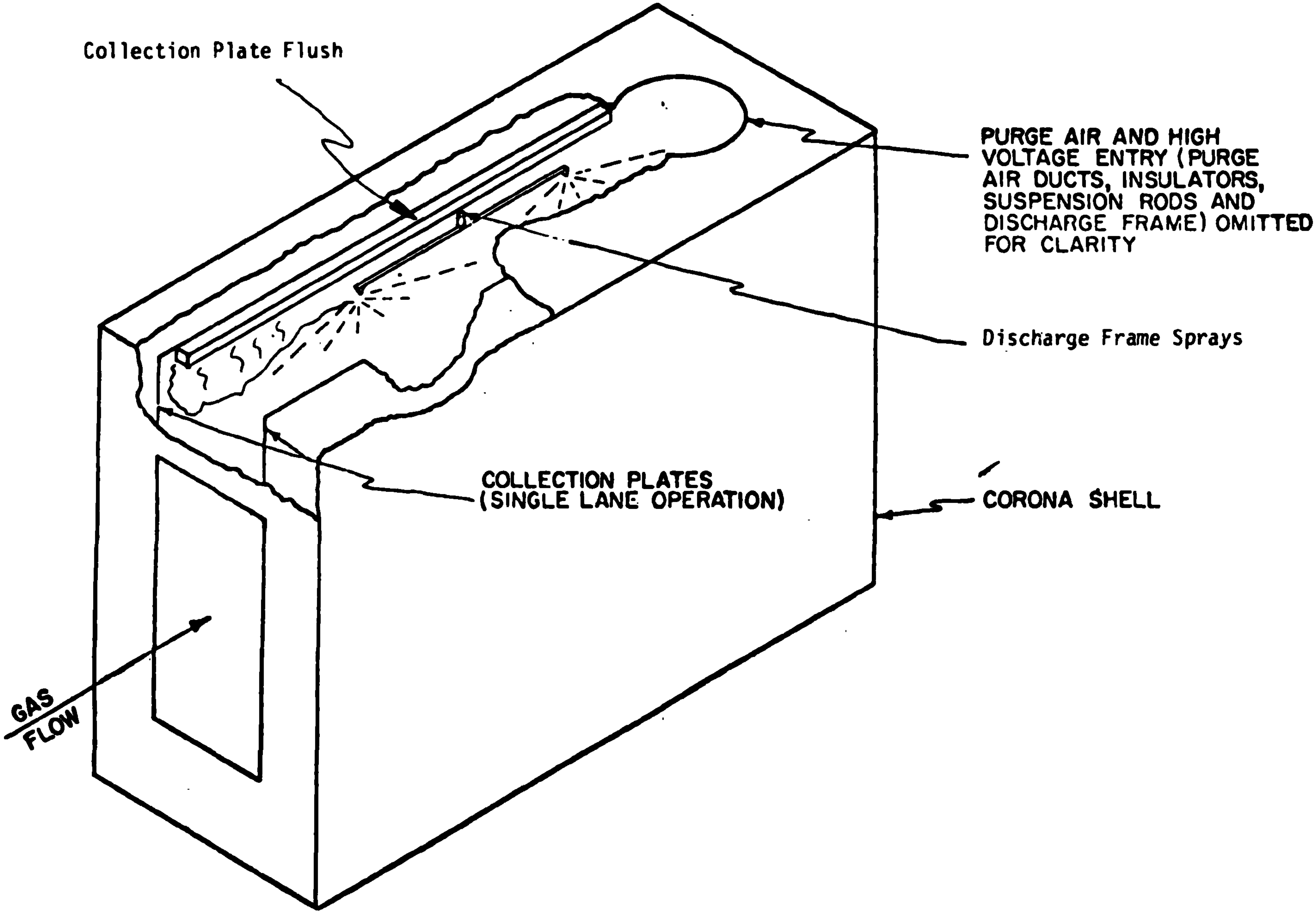

Fig. V-4. Collection Plate Flushing System desired. All nozzles spray in the direction of gas flow (co-currently). A total of 5 to 7 nozzles were used in the Centralia tests, depending on the desired flow rate. Bete TF6FCN full cone fog nozzle/header arrangement typical for the spray tower is shown schematically in Fig. V-5.

A positive charge is imparted to the water droplets by maintaining the nozzles at a positive potential (direct charging). The nozzles are electrically isolated from the spray tower walls by introducing heated purge air through 7.6 cm diameter x 10.2 cm long (3 in. x 4 in.) polyvinyl chloride (PVC) entry caps which are situated on top of the two spray towers (see Fig. V-5). Both the water and the high voltage lead-in cable enter through a 6.4 mm (1/4 in.) diameter street tee fitting connected to the middle of each entry cap.

F. Mist Eliminator

The mist eliminator is situated in the middle of the third and last horizontal pass and is used to remove entrained water droplets from the airstream. The mist eliminator is identical to the corona sections, with the exception of the discharge frame being maintained at a positive potential and the total height being 5.1 cm (2 in.) shorter (necessitating an equivalent shortening of the discharge frame and collection plates).

G. Test Ducts

The inlet and outlet test ducts are located immediately before the first corona and immediately after the mist eliminator, respectively (see Fig. V-1). Both test ducts are constructed from 4.8 mm wall thickness (3/16 in.) FRP and are .30 m in diameter x 1.22 m long (1 ft. x 4 ft.). Vertical gas flow in a downward direction is employed because it allows the most convenient positioning of the particle sizing source test equipment used and described in Section VI, "Particulate Sampling Apparatus." The particle sizing source test equipment also dictated the size of the test ports which are .15 m wide x .46 m high (6 in. x 1 ft. 6 in.). The test ports are located three duct diameters downstream and one duct diameter upstream from flow disturbances.

H. Fan

The fan used to induce the air flow (i.e., clean side) through the pilot plant is a New York Blower Model RFE-12. The straight-bladed fanwheel and housing are constructed from FRP. The fan is driven through a split pulley belt drive by a Westinghouse 3.7 kW (5 hp), 208 volt, 3-phase motor turning at 1,800 rpm and is capable of delivering up to 2550 am^3/hr. (1500 acfm) at 20.3 cm (8 in.) water colume (WC) static pressure. The fan has a horizontal inlet and vertical outlet. A 4.8 mm (3/16 in.) FRP wall thickness x .30 m (1 ft.) diameter exhaust duct containing an adjustable damper extends up through the trailer roof.

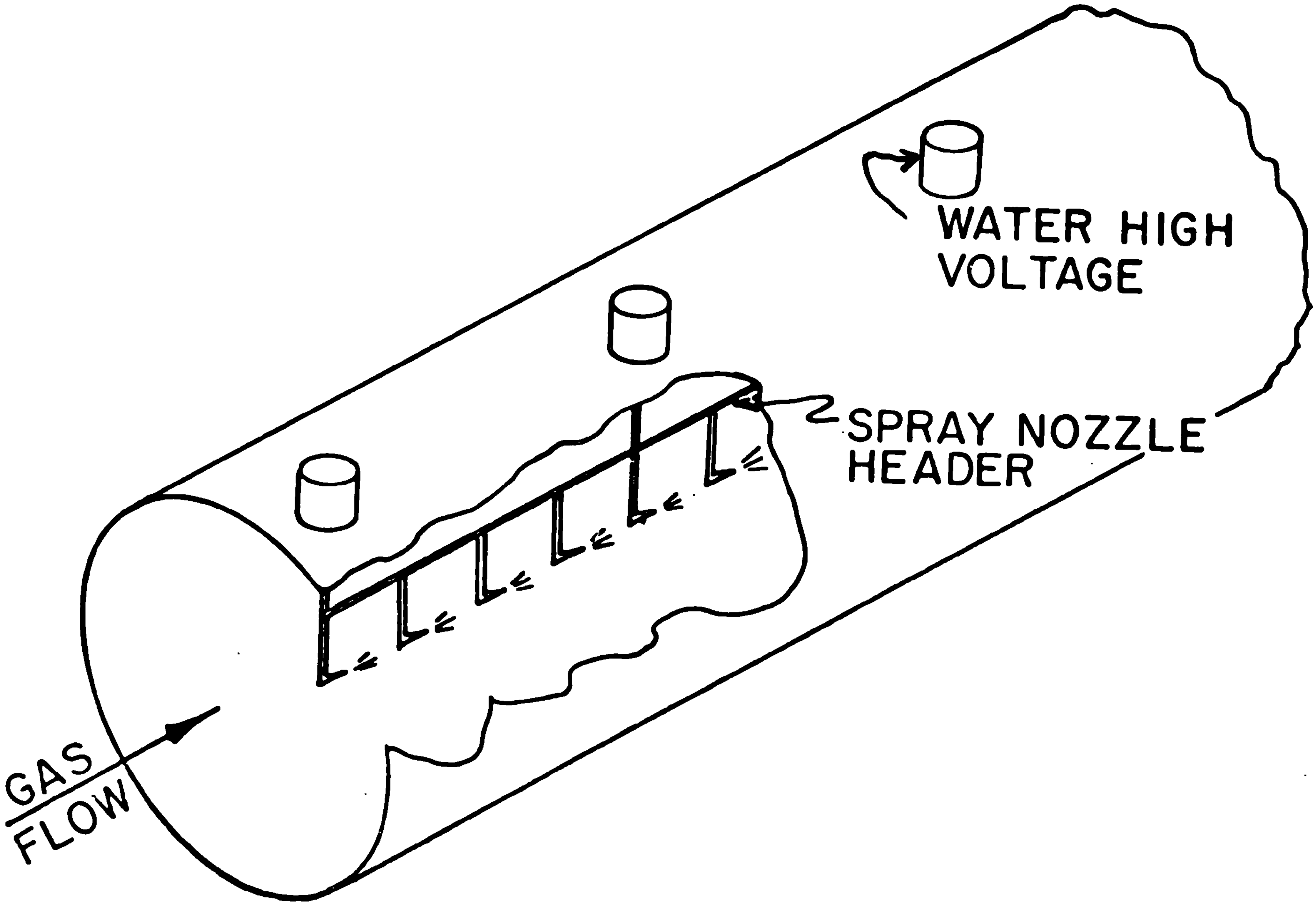

Fig. V-5. Spray Header and Nozzle Arrangement Typical to Spray Towers #1 and #2.

As previously mentioned, a Dayton centrifugal blower was installed at the scrubber inlet to increase the air flow capabilities at the Centralia Power Plant.

I. High Voltage Power Supplies

Three high voltage power supply units used in the pilot plant serve the corona, mist eliminator, and water droplet charging. All three units operate off a 110 volt, 50 Hz, 1 Ø supply and are equipped with multi-range voltage and current meters on the high voltage output side. The units are also equipped with overvoltage and overcurrent surge protection.

The power supplies used for the corona section and the mist eliminator are equipped with spark rate controllers. The Universal Voltronics unit which energizes the mist eliminator has a L.L. Little P-30 automatic voltage control and the NWL unit for corona #2 has an integrated NWL spark rate controller. The three power supplies are described in the following table.

Table V-1. High Voltage Power Supply Units

Source	Model	Polarity	Rated Peak Output	
			KV	mA
Corona #2	NWL	Negative	90	30
Mist Eliminator	Universal Voltronics	Negative	70	25
Droplet Charging	Hipotronics #825-40	Positive	25	40

J. Liquor Control Panel in the Scrubber Trailer

The water supply system for the cooling tower, spray tower and corona flushing system is controlled at a single control panel situated near the inlet sampling port. Two different sources supply water to the control panel: charged water (either recycled or fresh) and uncharged fresh water.

The charged liquor is used in the spray tower. It is pumped from a sump tank in the liquor recycle trailer by a Gould centrifugal pump model 3196ST. This pump provides the necessary liquor flow requirements of .79 MPa (100 psig) and a maximum of 45.4 ℓ/min. (12 gpm) to the spray tower. Since the spray charging is achieved by applying from 0 to 30 KV at the throat of each nozzle, the pump will also be at an elevated potential. It is therefore electrically isolated on a micarda base with a FRP cover.

The uncharged fresh water is used in the gas cooling tower (approximately 11.4 ℓ/min. (3 gpm) and the corona section flushing system (the flow rate is unmonitored).

K. Purge Air Heating System

The purge air heating system is schematically illustrated in Fig. V-6. The system consists of both commercially available and custom built components. The fan is a Barry Blower model BUF-90 Junior Fan employing a 248.3W (1/3 hp) motor with a maximum capacity of 850 cubic meter per hour (500 acfm). The discharge air then passes through a custom design Nelco Duct Heater. It is a 9 Kw heating unit with 4 stages to regulate the degree of heating required. The duct heater operated on 208V, 3Ø power with a 110V control source which is external of the heater. A custom designed distribution plenum follows the heater and provides an adjustable purge air supply to the high voltage access points on the corona section, the mist eliminator section and the spray header in the tower.

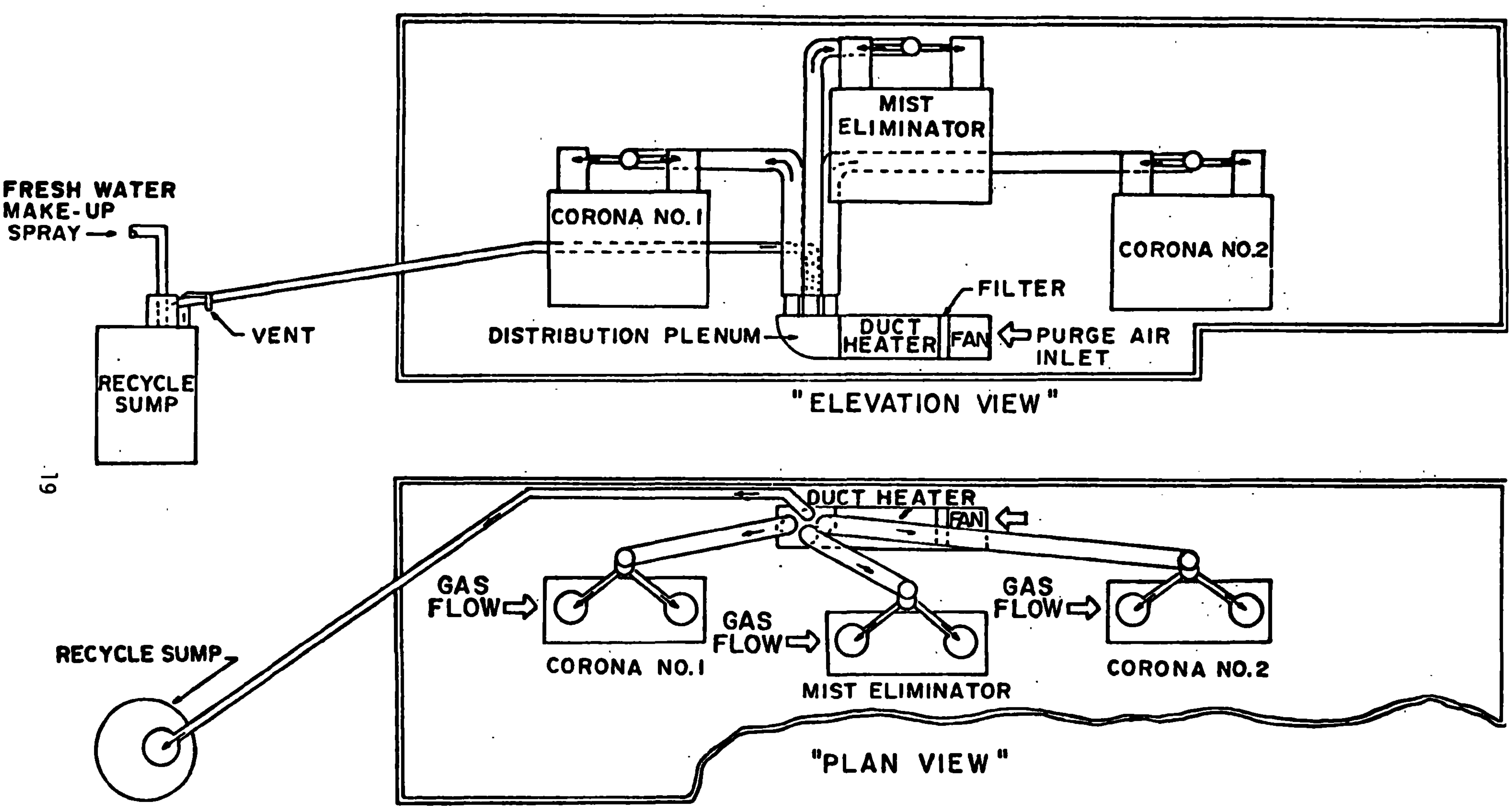

Fig. V-6. Heated Purge Air System

Section VI

DESCRIPTION OF THE LIQUOR RECYCLE SYSTEM

A. Description of Overall System

In order to use the Electrostatic Scrubber Pilot Plant to obtain data needed to design larger control systems, the design of the liquor recycle system was to enable the scrubber to operate in a "closed loop" mode. The design was to be flexible so different scrubbing liquors could be used with minimum modification to the system. The system has been built in a moving van trailer so it is portable. The design also makes the recycle system integrable with the present system; i.e., the same electrical isolation system is used.

The major components of the recycle system include a mix tank, two alkaline slurry mixing tanks, two clarifying tanks, a sump tank and two pumps. All plumbing between the equipment is done with PVC Schedule 80 pipe. The system is housed in a 12.2 m (40 ft.) long trailer and can be easily transported to different emissions sources with the other parts of the UW Electrostatic Scrubber Pilot Plant.

Fig. VI-1 shows the layout of the liquor recycle system. The effluent of the scrubber goes first into a mix tank which is outside the back door of the trailer. Alkaline slurry such as lime or Na_2CO_3 is mixed in the 208 liter (55 gal.) drums above the mix tank and then added as a liquid solution to this tank. From the mix tank the liquid passes a flow control panel where it is divided into two streams.

One stream is directly recycled into the sump tank, and the other is bled into the clarifying tanks. The latter stream then joins the recycling stream before being pumped into the sump tank. From this tank the liquor is pumped into the scrubber.

When operating in an "open-loop" liquor recycle mode the 7.6 cm (3 in.) drain to the mix tank was disconnected and ducted to the power plant water treatment system. Fresh water was then supplied to the mix tank at the same consumption rate as supplied to the spray tower.

Water and Na_2CO_3 solution were the scrubbing liquors for open-loop testing.

B. Liquor Tanks

The mix tank is a 510 liter (135 gal.), .91 m (3 ft.) diameter, 1.22 m (4 ft.) high tank that was purchased on a previous EPA grant. The alkaline slurry mixing tanks are two teflon line 208 liter (55 gal.) drums. Flow out of these tanks can be measured by sight glasses on the side of each tank. From the mix tank the liquor is pumped through a Gould Model 3196 ST pump to the flow control panel.

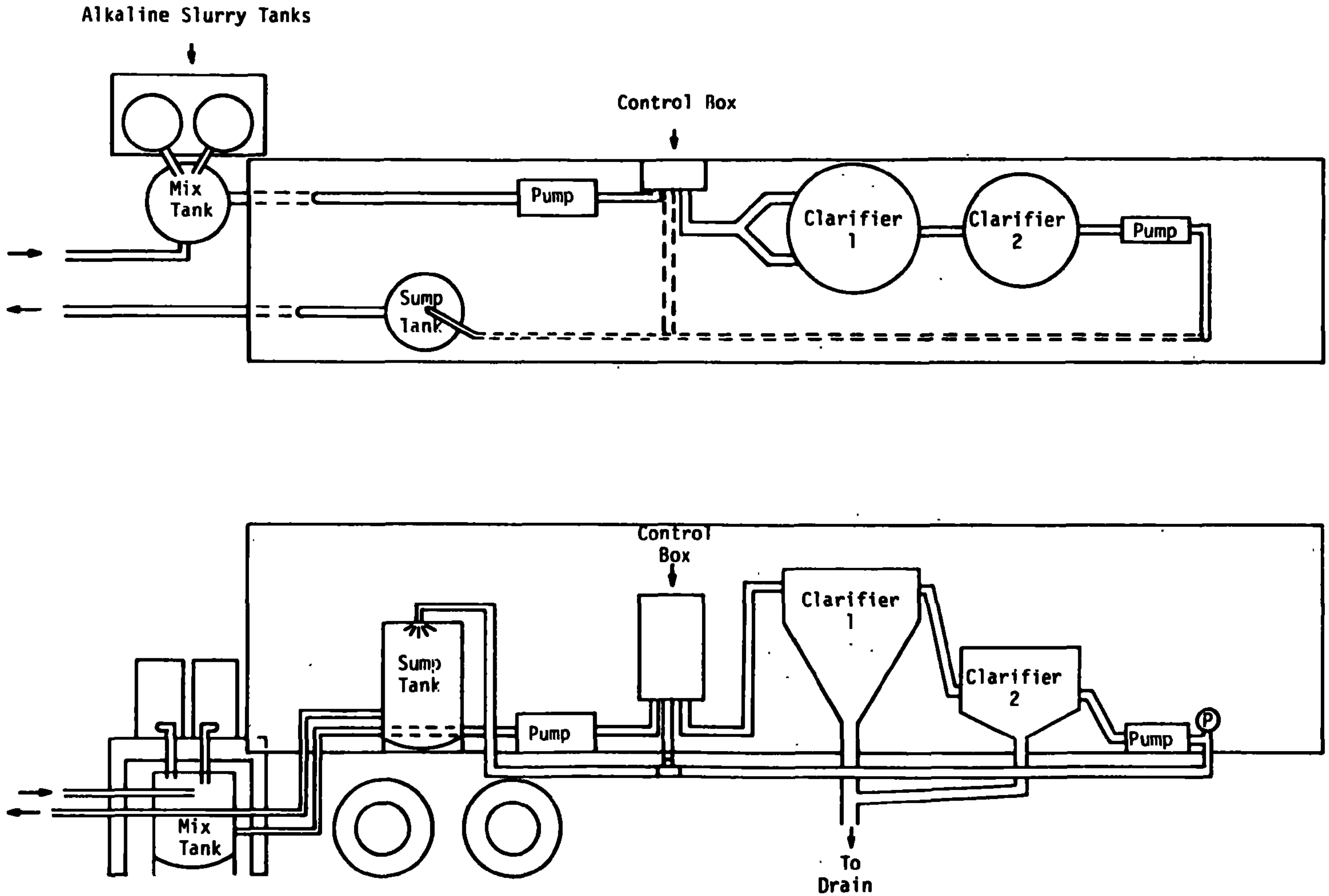

Fig. VI-1. General Layout of the Liquor Recycle System

The first clarifying tank is 2.13 m (7 ft.) high and 1.52 m (5 ft.) wide. The liquor from the control box splits into two streams before entering the tank. This helps minimize the disturbance of the settling material by the incoming stream. A baffle plate is also suspended near these outlets for the solids in the stream to impinge against. The diameter of the tank was experimentally determined by the settling characterisitcs of sludge composed of flyash, lime and calcium carbonate. Knowing the solids flux as a function of suspended solids concentration and assuming a maximum 38 liter influent flowrate of 5% slurry into the tank, the tank must be at least 1.4 m (4.6 ft.) in diameter. Its circular design is to prevent scale formation that could happen in the corners of square tanks. The bottom of the tank has a 60^o angle so the settled sludge can flow to the bottom drain without mechanical assistance.

The second clarifying tank is 1.19 m (4 ft.) high and 1.19 m wide. The feed from the first to the second settling tank is by gravity. Makeup water lost by sludge removal from the first tank as well as Mg if additional alkalinity is needed in the lime/limestone system. A 2.2 kW (3 hp), 3600 rpm, 110 v., 1Ø Deming centrifugal pump transfers the liquor from the second clarifying tank to a point where it mixes with the liquor recycle stream and goes into the sump tank. The sump tank is a .91 m (3 ft.) diameter 1.52 m (5 ft.) high tank also purchased on a previous grant. As discussed in Section V-J (page 17) the Gould Model 3196 St pump, housed in the main pilot plant trailer sprays the liquor into the spray tower from this tank.

Section VII

EXPERIMENTAL PROCEDURES AND TEST EQUIPMENT

The field test measurements for the UW Electrostatic Scrubber are listed in Table VII-I.

A. UW Mark 10-20 Cascade Impactors

The Mark 10 and Mark 20 Cascade Impactors were used to measure both particle size distribution and mass concentration at both the inlet and outlet test ducts, respectively. The impactors provide this information by segregating the aerosol sample into discrete size intervals. The weight on each plate provides size distribution information and the total weight is used to determine the mass concentration. The Mark 10 has been designed for high particle concentrations characteristic of the scrubber's inlet and uses 27 stages plus one final filter to reduce overloading. The Mark 20 is designed for low particle concentrations as exist at the outlet of the scrubber and has 14 stages plus one final filter. Both impactors utilize reduced absolute pressure in the last impactor stages to size particles as small as .05 μ in diameter (aerodynamic).

The basic components of a sampling train utilizing a UW Cascade Impactor as shown schematically in Fig. VII-1. The impingers in the condenser unit are used to collect water vapor in the sample air stream and provide a basis for calculating the moisture content of the gas stream which may be checked against the wet and dry bulb determination. The dry gas meter is used to determine the total sample volume. The absolute pressure gauge measures the pressure on the last stage of the impactor.

By conducting simultaneous particles size distribution tests at both the inlet and outlet test ducts, the size-dependent collection efficiency curve of the pilot plant may be measured.

B. TECO Model 40 SO_2 Analyzer

A Thermo Electron Model 40 Fluorescent SO_2 Analyzer was used to measure SO_2 levels in the gas stream at the inlet and outlet of the pilot plant. The principle of operation of this monitor is based upon the measurement of the fluorescence of SO_2 produced by its absorption of ultraviolet radiation.

A sample gas conditioning unit was designed and fabricated at UW. The unit samples the gases from the inlet or outlet ducts, passes the gases through heated Teflon tubing, through a heated 19 x 90 mm glass fiber thimble filter, through a Greenburg-Smith impinger containing sulfuric acid (for removing excess water vapor), and then through heated Teflon tubing into the TECO instrument.

A strip chart recorder was attached to the SO_2 analyzer. This allowed for continuous monitoring of the SO_2 concentration being measured. Each data point in this report represents a 5 minute average as recorded on the strip chart. By knowing the inlet and outlet SO_2 concentrations and gas flow rates, the SO_2 collection efficiency of the scrubber pilot plant could be calculated.

Table VII-1. Field Test Parameters and Measurement Methods

Parameter	Measurement Methods
1. Gas properties	
- Sulfur dioxide concentration	Continuous instrumentation, batch source tests
- Velocity	Pitot tube
- Volumetric flow rate	Orifice flow meter
- Temperature	Thermometer, thermocouples
- Moisture	Wet-dry bulb, continuous instrument
2. Particle properties	
- Size distribution	UW Mark 10-20 Cascade Impactor
- Mass concentration	UW Mark 10-20 Cascade Impactor
3. Liquor properties	
- pH	pH meter
- Sulfite concentration	Titration with $KI-KIO_3$
- Sulfate concentration	Gravemetric
- Suspended solids	Filtration
- Flow rate	Rotameters
- Pressure	Pressure gauge
4. Scrubber conditions	
- Particle charging voltage	Voltmeter on power supply
- Particle charging current	Ammeter on power supply
- Liquor charging voltage	Voltmeter on power supply
- Liquor charging current	Ammeter on power supply
- Mist eliminator voltage	Voltmeter on power supply
- Mist eliminator current	Ammeter on power supply
- Gas pressure drop	Static pressure taps

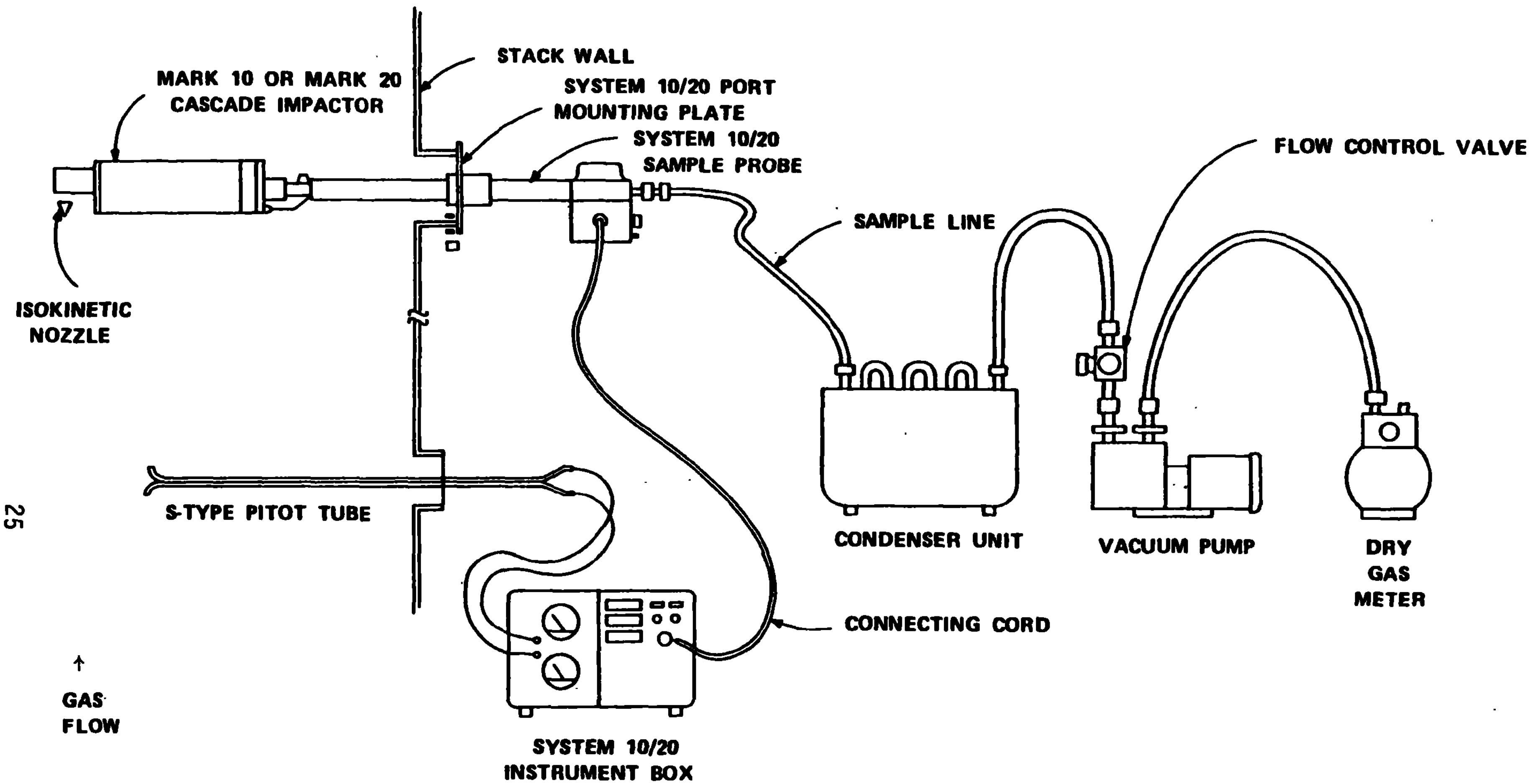

Fig. VII-1. UW Mark 10-20 Cascade Impactor Sampling System Schematic

Section VIII

PARTICULATE COLLECTION EFFICIENCY RESULTS

A. General Test Description

The first series of particulate collection efficiency measurements on the UW Electrostatic Spray Scrubber were performed with the unit in the open-loop mode. The scrubbing liquor for these tests was water.

B. Particulate Collection Efficiency Measurements

Results of inlet-outlet impactor tests 1-4 and 7-8 are shown in Table VIII-1. Scrubber operating parameters (corona voltage, mist eliminator voltage and liquor flow rate) were held constant for tests 1-4 and 7-8 with a variation in spray voltage from 0 to 10 KV. A significant variation in the inlet gas flowrate from 31.2 sdm^3/min. (1101 sdcfm (1449 acfm)) to 36.2 sdm^3.min. (1281 sdcfm (1637 acfm)) was noted. This variation was unavoidable. With both the scrubber I.D. fan and booster fan operating at full capacity, a variation in the negative static at the outlet of the air preheater (due to varying boiler conditions) resulted in subsequent variations in inlet gas flow. This created changes in the parameters L/G, SCA, and gas residence time.

The overall particle collection efficiency for tests 1-4 and 7-8 ranged from 98.99% to 99.80% (0.20% to 1.01% penetration). The particle collection efficiency and penetration as a function of particle size (aerodynamic cut diameter of cascade impactor stages, d_{50}) for these tests are shown in Fig. VIII-1. The symbols on the curves of Figure VIII-1 are computer calculated collection efficiency points and are on the graph only to identify the curves. The aerodynamic cut diameter of the impactor stages is defined as the diameter of the particle of unit density collection with 50% efficiency and is calculated by:

$$d_{50} = \left(\frac{18\mu D_j \Psi_{50}}{CV_j}\right)^{1/2}$$

where μ is the gas viscosity, Dj the jet diameter, Ψ_{50} the inertial impaction parameter at 50% collection efficiency for particles of diameter d_{50}, C the Cunningham correction factor, and Vj the gas velocity in the jet diameter. The collection efficiency particles greater than .3 microns diameter was above 90% for each of these tests.

Figures VIII-2 and VIII-3 are the lognormal approximation and the parabolic fit curve of the actual collection efficiency for test 2 and 3. Test 2 was run with electrostatically charged liquor and test 3 was not. Both tests had approximately the same overall collection efficiency (99.55% for test 2 vs. 99.58% for test 3), and this is reflected by the lognormal approximation. The actual collection efficiency curves show the increase in collection of particles below .5 μ diamaeter.

Test No.	Date	Inlet Gas Flow sdm^3/min (sdcfm)	Outlet Gas Flow sdm^3/min (sdcfm)	Particle Mass Conc. gm/sdm^3 (grains/sdcf)		Overall Coll. Eff. (%)	Penetration (%)	Total Liquor Flow Rate ℓ/min. (gpm)	Corona Voltage (kV)	Spray Voltage (kV)	Demister Voltage (kV)	SCA $m^2/sm^3/min$ ($ft^2/scfm$)	L/G ℓ/aKm^3 (gal/1000 acf)	Gas Residence Time (sec.)		
				Inlet	Outlet									Corona Section	Spray Tower	Mist Eliminator
1	3/01/79	34.6 (1223)	51.7 (1825)	1.0973 (0.47952)	0.0074 (0.00324)	98.99	1.01	60.6 (16)	(-)90	0	(+)60	0.091 (0.028)	1.14 (10.6)	0.86	8.32	0.82
2	3/02/79	34.5 (1219)	50.1 (1769)	0.9185 (0.40142)	0.0029 (0.00126)	99.55	0.45	60.6 (16)	90	(+)10	60	0.091 (0.028)	1.12 (10.4)	0.86	8.35	0.82
3	3/02/79	36.2 (1281)	50.7 (1791)	1.0913 (0.47690)	0.0033 (0.00146)	99.58	0.42	60.6 (16)	90	0	60	0.087 (0.026)	1.05 (9.8)	0.82	7.95	0.78
4	3/14/79	36.0 (1270)	48.8 (1724)	1.2688 (0.55448)	0.0049 (0.00214)	99.48	0.52	60.6 (16)	90	10	60	0.087 (0.027)	1.02 (9.5)	0.83	8.01	0.79
7	5/02/79	33.1 (1168)	44.0 (1553)	1.0198 (0.44566)	0.0016 (0.00069)	99.79	0.21	60.6 (16)	90	10	60	0.095 (0.029)	1.13 (10.5)	0.90	8.71	0.86
8	5/02/79	31.2 (1101)	46.2 (1631)	1.1011 (0.48117)	0.0015 (0.00065)	99.80	0.20	60.6 (16)	90	0	60	0.101 (0.031)	1.18 (11.0)	0.95	9.25	0.91

Table VIII-1. Results of Cascade Impactor Tests 1-4 and 7-8 at Centralia Power Plant.

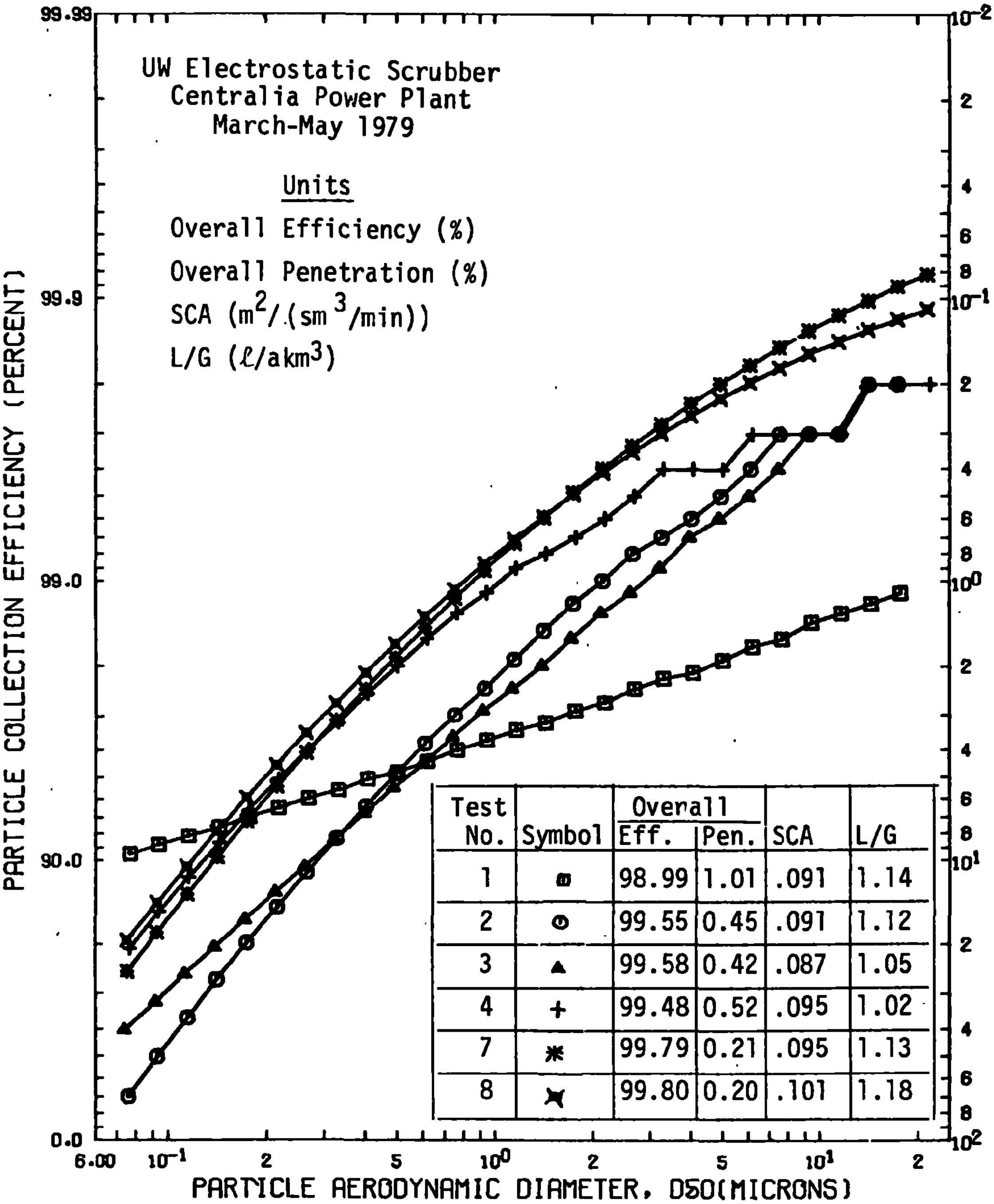

Fig. VIII-1. Particle Collection Efficiency and Penetration vs. Particle Size for Impactor Tests 1-4 and 7-8(Log-Normal Approximation)

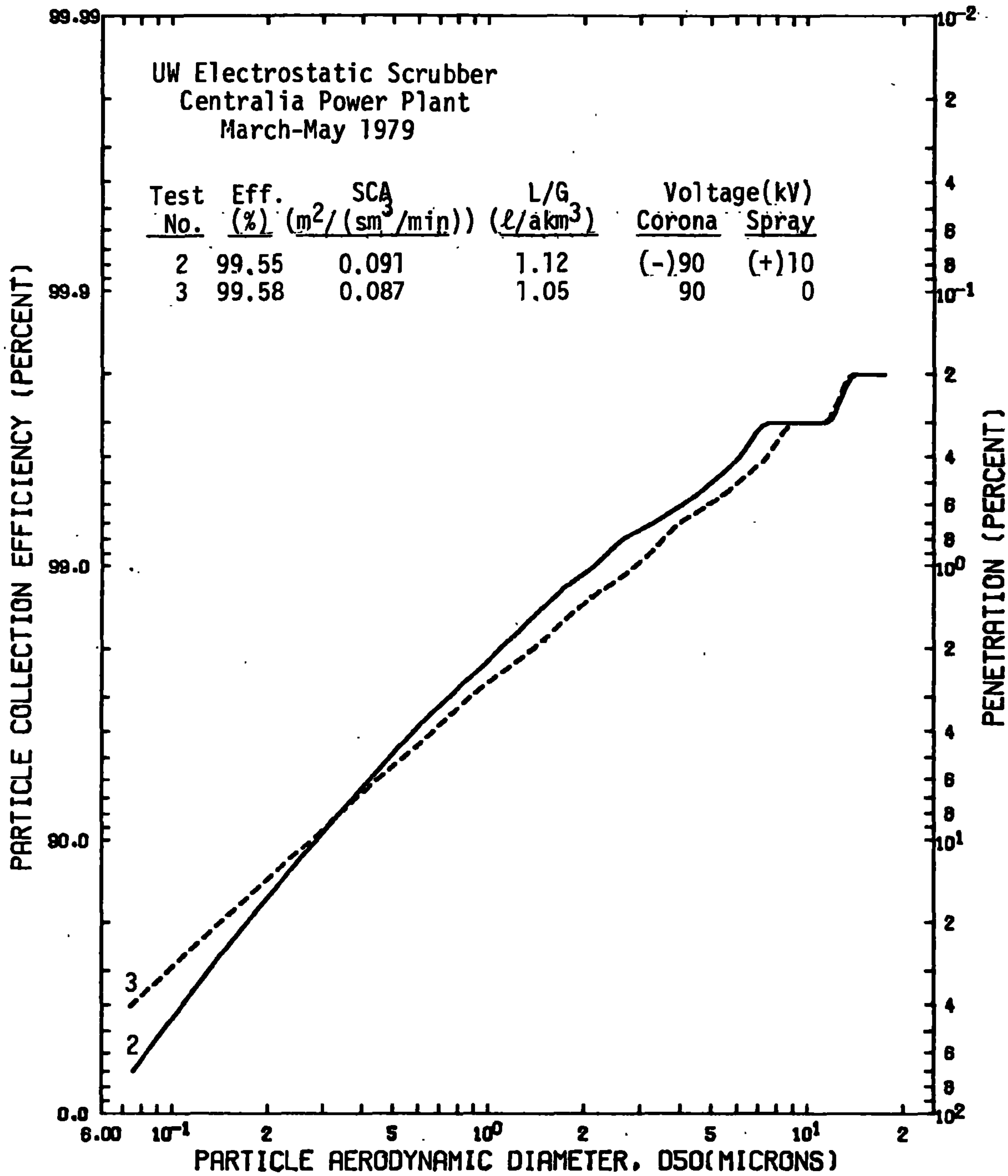

Fig. VIII-2. Particle Collection Efficiency and Penetration vs. Particle Size for Impactor Tests 2 and 3 (Log-Normal Approximation)

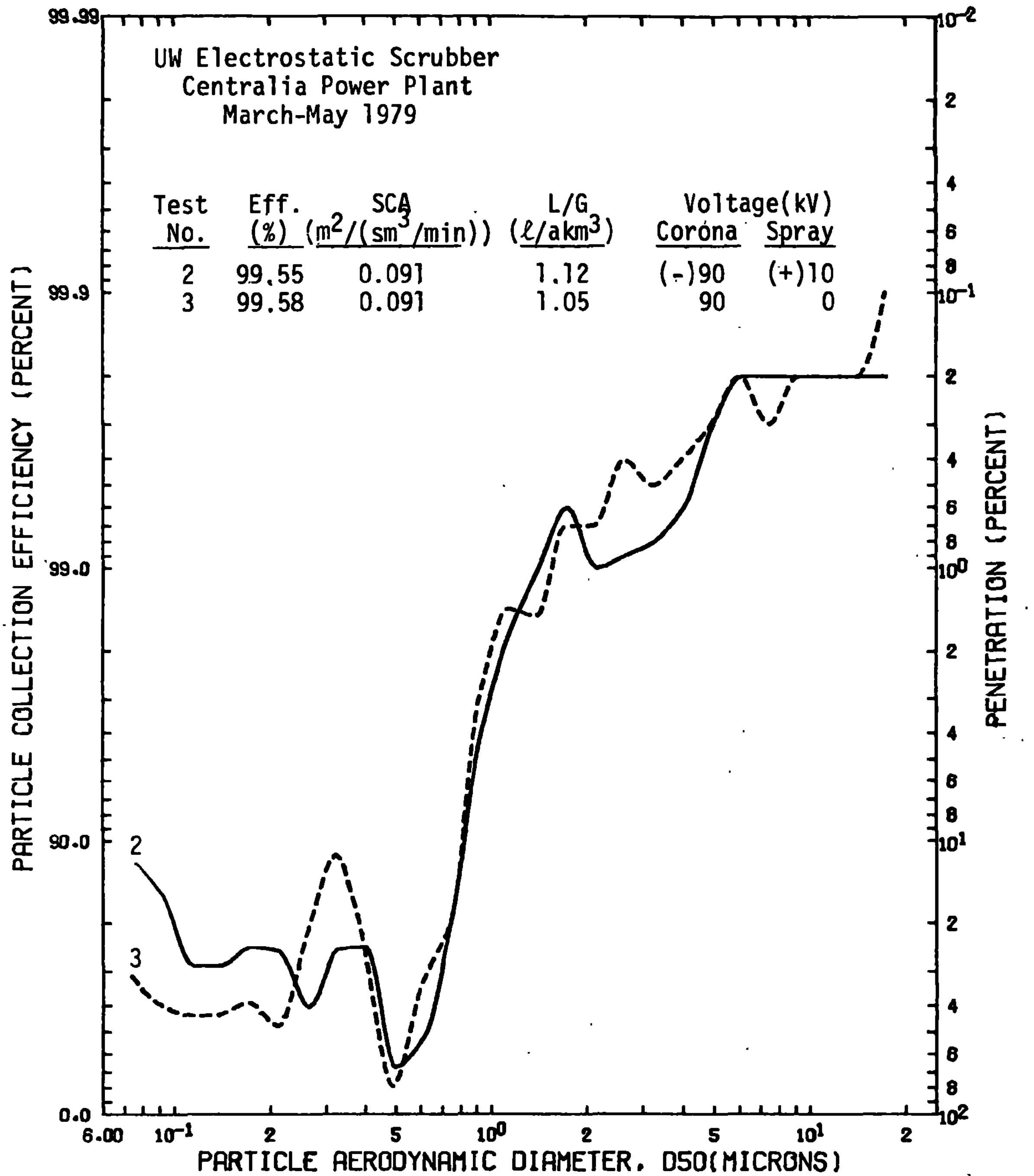

Fig. VIII-3. Particle Collection Efficiency and Penetration vs. Particle Size for Impactor Tests 2 and 3 (Parabolic Curve Fit)

Particle mass distributions for tests 2 and 3 are shown in Figures VIII-4 and VIII-5. On these graphs the particle collection efficiency is the area between the scrubber inlet and outlet mass distribution lines. As with the actual efficiency curve, the maximum removal is measured above 10 μ diameter particles and the minimum with the d_{50} equal to approximately .5 μ.

The cumulative size distribution for tests 1-4 and 7-8 measured at the inlet and outlet of the scrubber are shown in Figures VIII-6 and VIII-7. The particle mass mean diameter (particle diameter at which 50% of the particle mass is greater than this diameter and 50% less) was in the 22.2 to 65.6 micron diameter range at the scrubber inlet and in the 0.74 to 5.91 micron diameter range at the scrubber outlet. There is a good correlation between the actual particle size distribution as measured with the cascade impactors and the straight line (log-normal) approximation as seen with test 3 in Fig. VIII-8, so this report uses the log normal size distribution.

The particle mass concentrations (grains/sdcf) less than the stated particle aerodynamic diameter, d_{50} (microns) for these tests are shown in Fig. VIII-9 and VIII-10. The curves in these graphs illustrate the reduction in particle size range at the inlet and outlet of the scrubber.

Particle mass concentrations measured at the scrubber outlet for tests 1-4 and 7-8 ranged from 0.0015 gm/sdm^3 (.00065 grains/sdcf) to 0.0074 gm/sdm^3 (.00324 grains/sdcf). The difference between the particulate grain loading at the scrubber inlet and outlet prevented simultaneous sampling. Despite sampling times at the outlet as high as 1 hour, low weights on the impactor substrates were experienced.

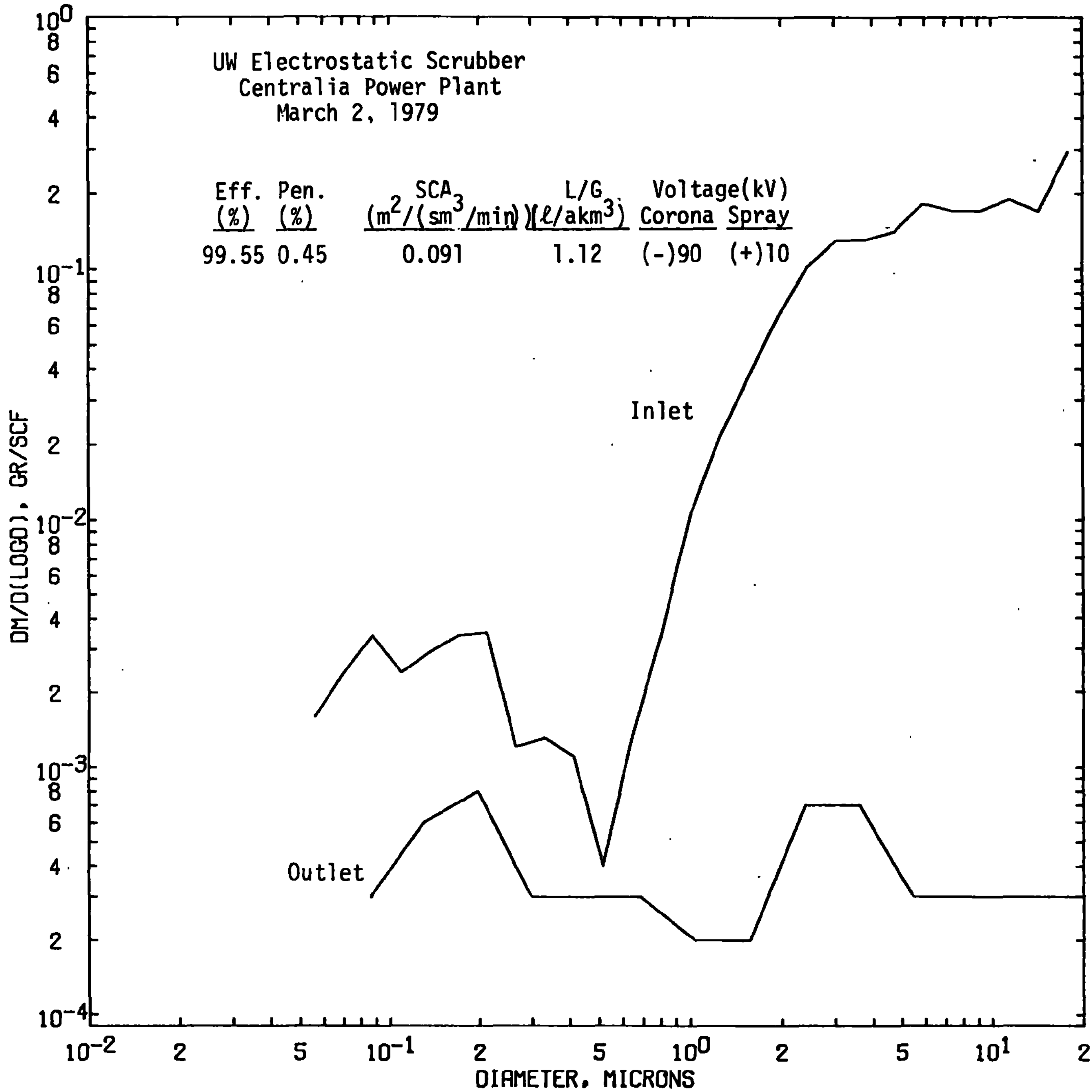

Fig. VIII-4. Particle Mass Distribution vs. Particle Size for Impactor Test 2

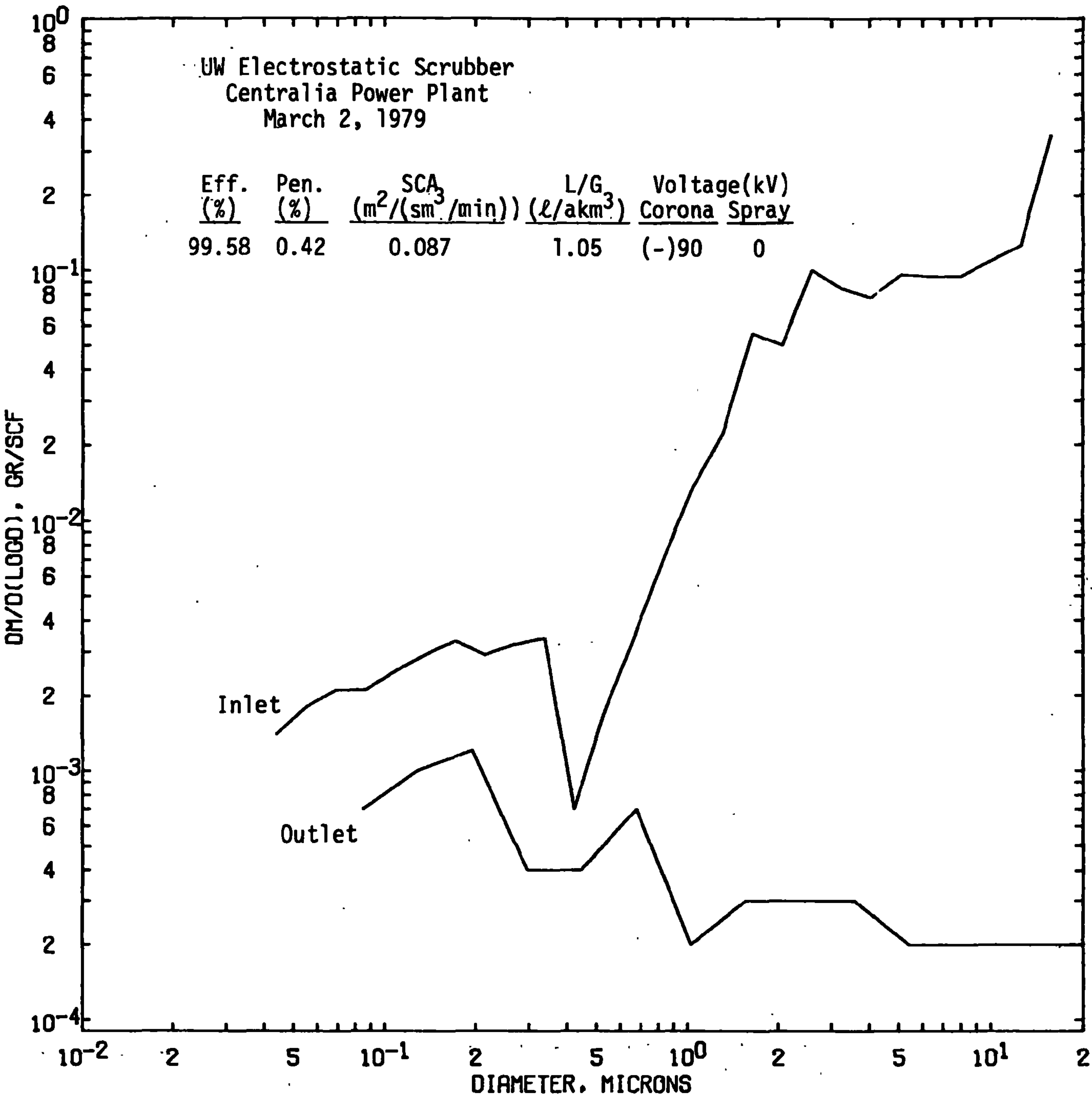

Fig. VIII-5. Particle Mass Distribution vs. Particle Size for Impactor Test 3

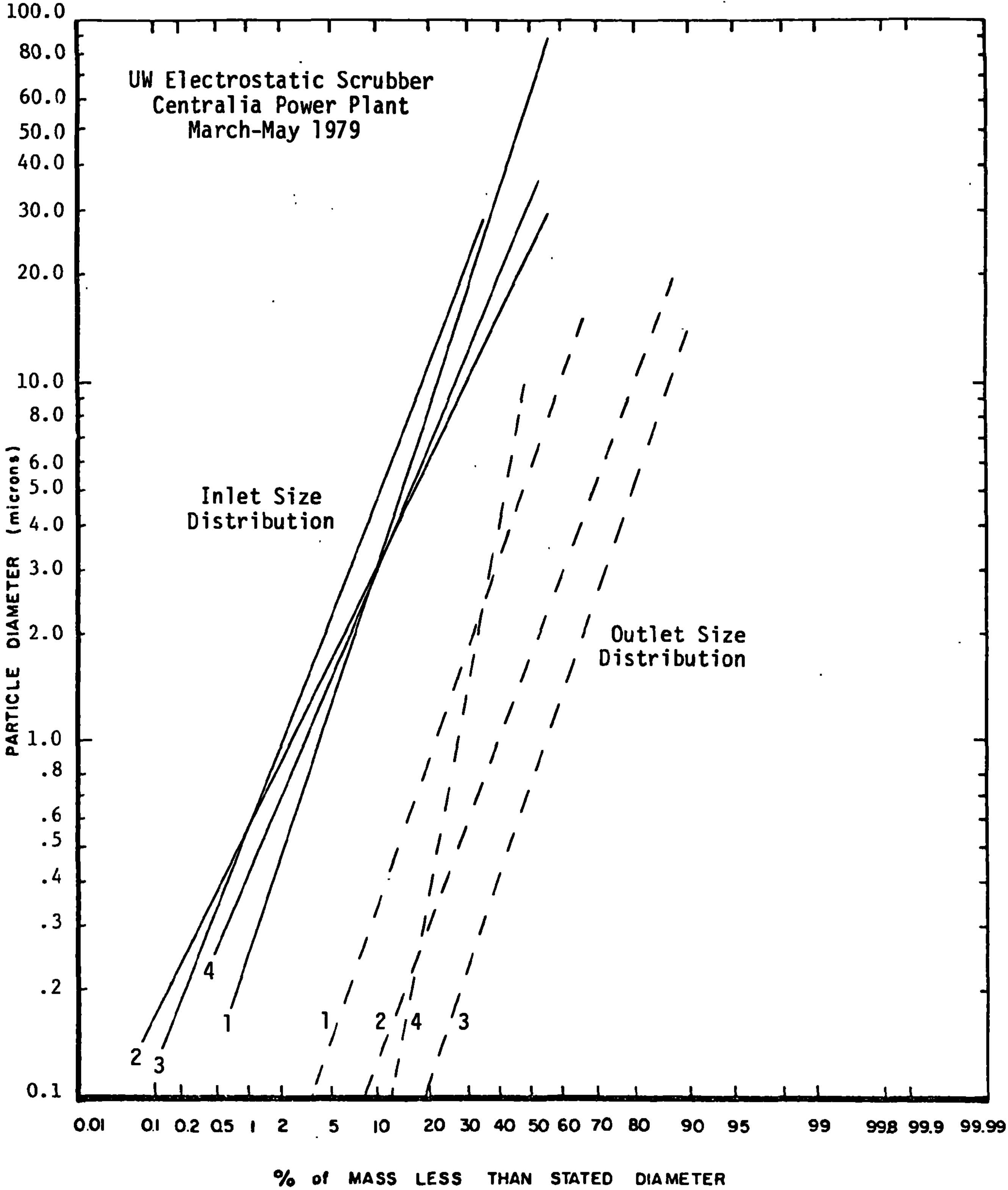

Fig. VIII-6. Inlet and Outlet Particle Size Distributions for Impactor Tests 1-4 (Log-Normal Approximation)

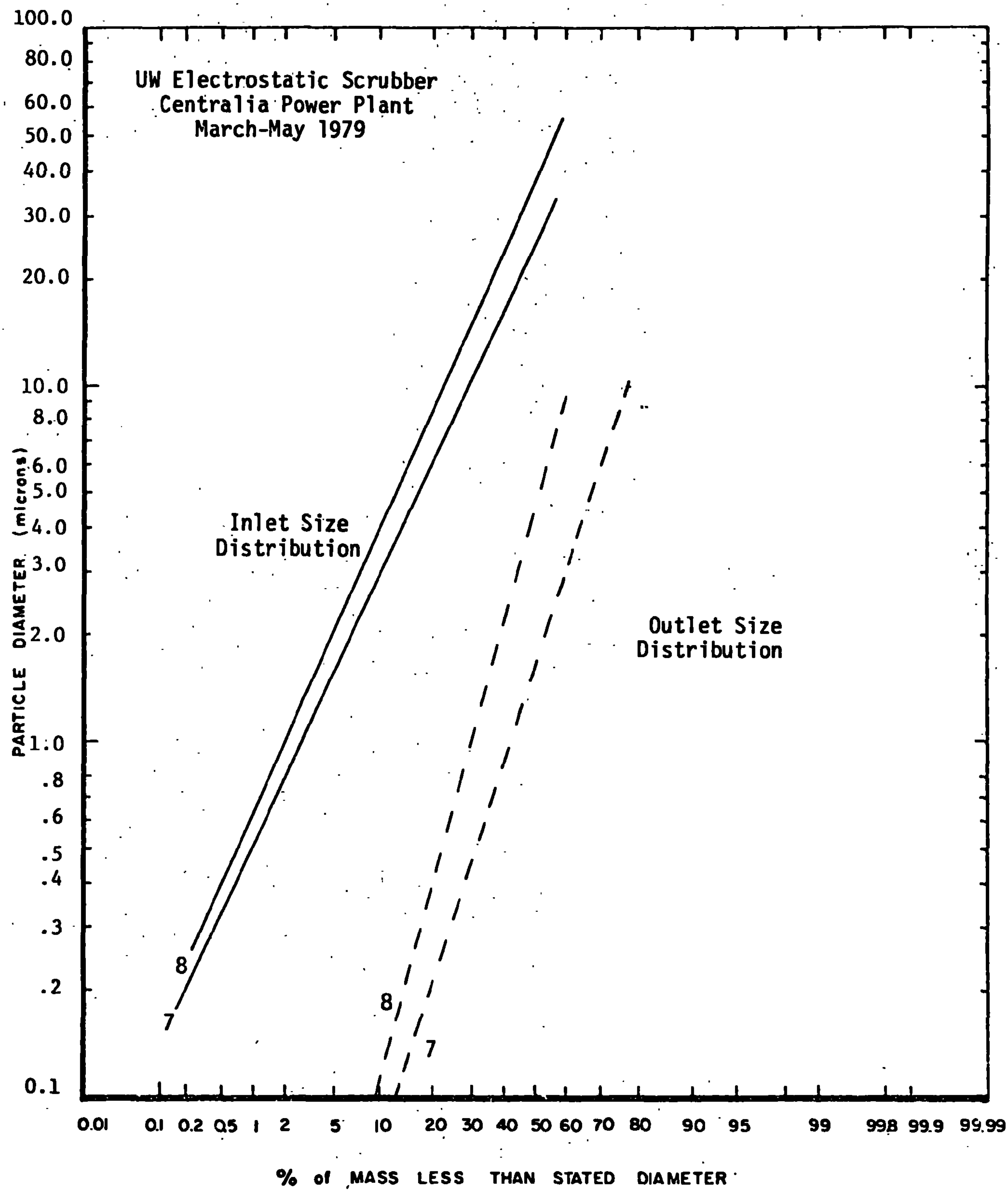

Fig. VIII-7. Inlet and Outlet Particle Size Distributions for Impactor Tests 7-8 (Log-Normal Approximation)

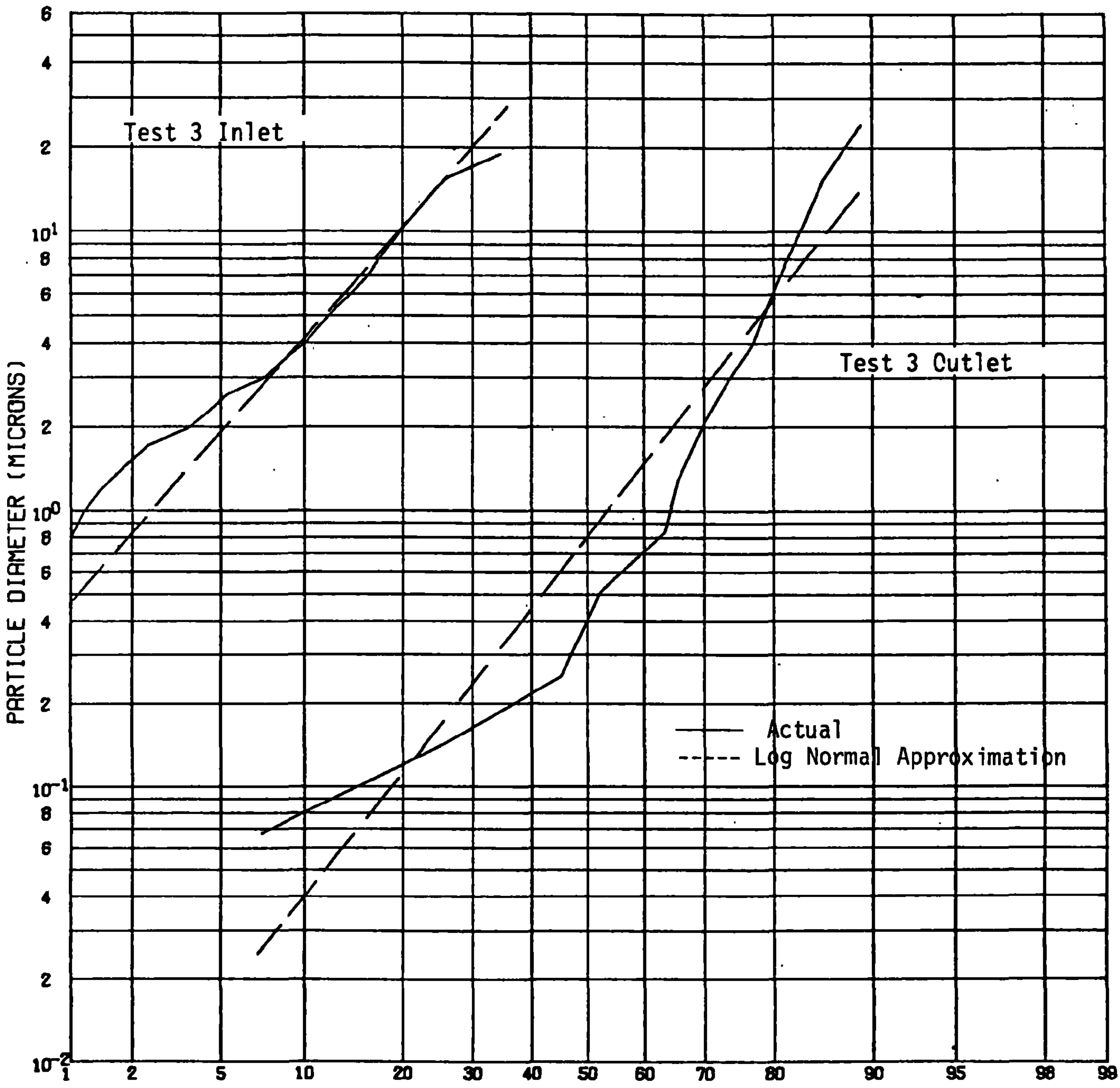

Fig. VIII-8. Inlet and Outlet Particle Size Distributions for Impactor Test 3 (Log-Normal Approximation and Actual Data)

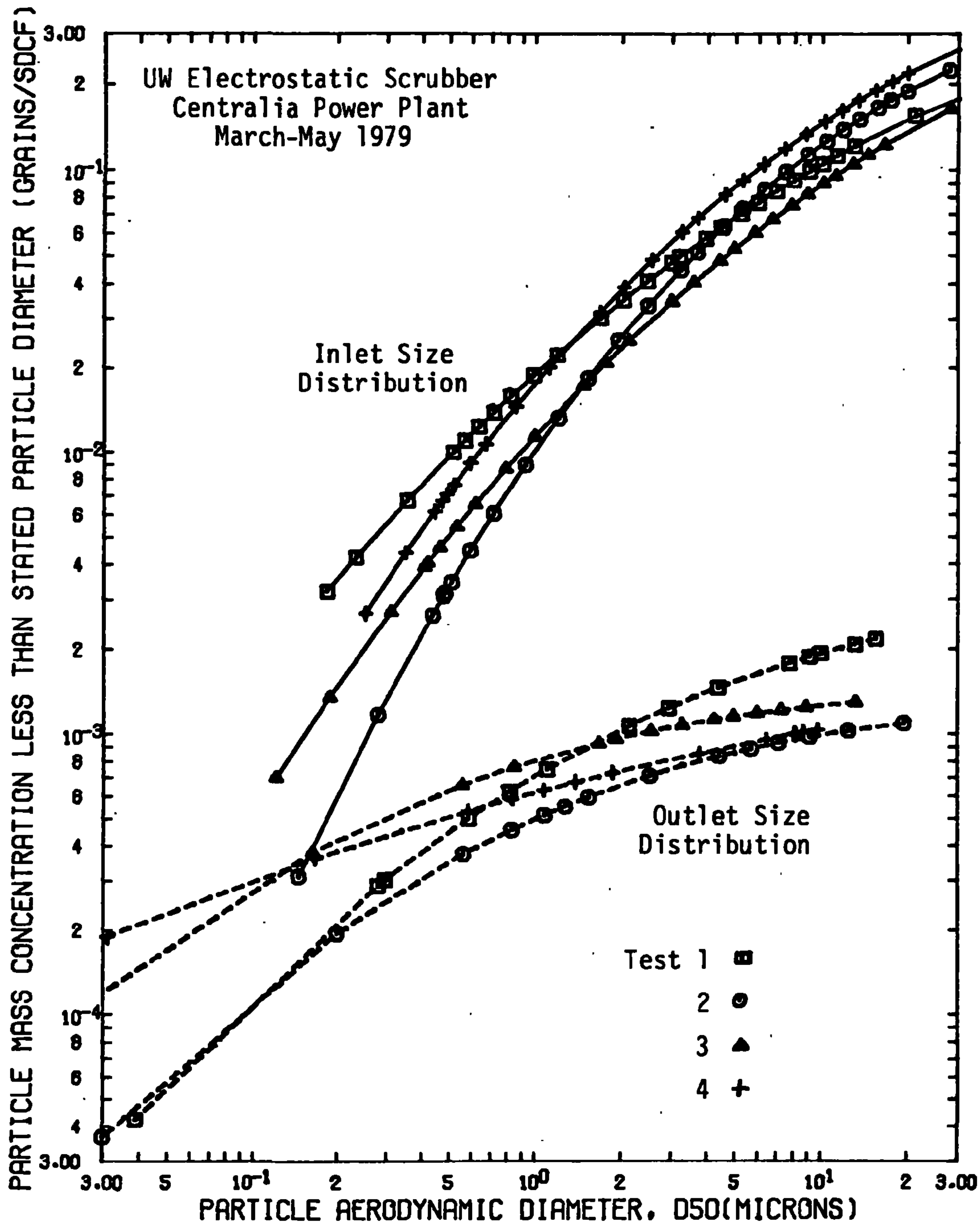

Fig. VIII-9. Particle Mass Concentration for Particle Less Than Stated Diameter for Impactor Tests 1-4.

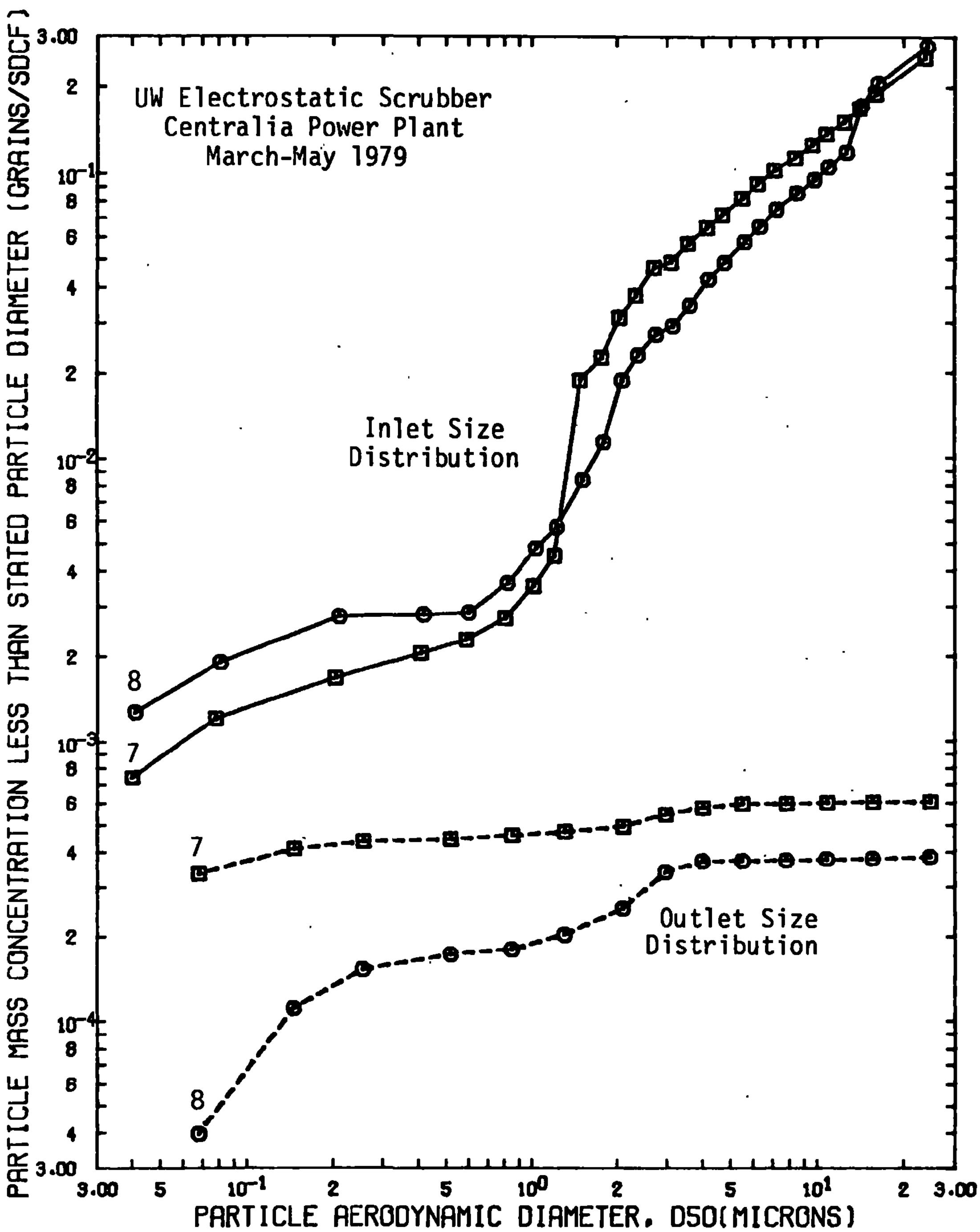

Fig. VIII-10. Particle Mass Concentration for Particles Less Than Stated Diameter for Impactor Tests 7-8.

Section IX

SULFUR DIOXIDE COLLECTION EFFICIENCY

A. General Test Description

SO_2 collection efficiency measurements on the UW Electrostatic Spray Scrubber were performed with the unit in an open-loop operating mode. In the open loop mode fresh water was added to the mix tank at the same consumption rate as supplied to the tower, and the scrubber effluent sent to the power plant water treatment system. Tests were run with fresh water and with Na_2CO_3 solution. Concentrated Na_2CO_3 liquor was added to the mix tank at a fixed rate during the latter tests. SO_2 collection efficiency measurements, described in Section VII, were performed on the scrubber in both operating modes.

B. SO_2 Collection Efficiency

1. Results Using Water as a Scrubbing Liquor

Initial SO_2 collection efficiency tests were performed with water on March 16th. Also at the beginning of each test day with open-loop system, several tests were run using water as a scrubbing liquor The results of inlet/outlet SO_2 measurements are shown in Table IX-1. As with the particulate tests a significant variation in the inlet gas flow rate from 32.9 sdm^3/min. (1163 sdcfm) to 41.5 sdm^3/min. (1465 sdcfm). This created changes in gas residence time and L/G. Inlet SO_2 concentrations varied from 270 ppm to 1300 ppm. Using water as a scrubbing liquor, the overall SO_2 collection efficiency ranged from 16.21% to 50.82%.

Test series 2 demonstrated the effect of the corona charge and spray voltage charge. With particle charging corona section off the SO_2 removal increased from 17.56% to 20.09% by increasing the spray voltage from 0 to 7.5 KV. With the corona on the collection efficiency was increased to 25.48%. At this condition as with test series 1, the spray voltage did not have a significant effect on the SO_2 collection efficiency.

Test Series 3 demonstrated the effect of L/G on SO_2 removal. With the sprays off, SO_2 collection was 8.02% due to SO_2 absorption by the wet wall corona sections. As the L/G was increased to 1.10 ℓ/akm^3 (10.3 gal/1000 acf), the collection efficiency increased to 23.46%. These results are illustrated in Fig. IX-1.

A comparison of test series 1, 4, 5 and 7 shows the effect of inlet SO_2 concentration on SO_2 collection efficiency. This comparison is plotted on Fig. IX-2. SO_2 removal ranged from 16.21% at 270 ppm inlet SO_2 to 50.82% at 1300 ppm. The reason for this increased

Table IX-1. Results of SO_2 Tests at Centralia Power Plant Using Water as a Scrubbing Liquor.

Test Series No. & Date	Inlet Gas Flow sdm³/min (sdcfm)	Outlet Gas Flow sdm³/min (sdcfm)	SO_2 Concentration (ppm)		Overall Collection Efficiency (%)	Stoichiometric Ratio (moles alkali / mole inlet SO_2)	L/G ℓ/akm³ (gal/1000acf)	Corona Charge (kV)	Spray Voltage (kV)	Demister Voltage (kV)
			Inlet	Outlet						
1 3-16-79	37.2 (1314)	48.9 (1728)	430 430 430	258 249 252	21.05 23.80 22.88	0	1.10 (10.3)	(-)70 70 70	0 (+)5 10	(+)60 60 60
2 3-16-79	37.2 (1314)	48.9 (1728)	415 415 415 415	260 252 235 235	17.56 20.09 25.48 25.48	0	1.10 (10.3)	0 0 90 90	0 7.5 0 7.5	60 60 60 60
3 3-16-79	37.2 (1314)	48.9 (1728)	490 490 490 490	342.5 315 302.5 286	8.02 15.41 18.76 23.46	0	0 0.53 (5.0) 0.80 (7.5) 1.10(10.3)	90 90 90 90	0 0 0 0	60 60 60 60
4 3-30-79	36.9 (1302)	46.2 (1632)	1300	510	50.82	0	1.06 (9.9)	90	0	60
5 4-18-79	41.5 (1465)	50.3 (1777)	615 615	375 365	26.04 28.01	0	0.93 (8.6)	90 90	0 7.5	60 60
6 4-18-79	38.4 (1356)	49.8 (1757)	500 500	310 290	19.67 24.85	0	0.80 (7.5)	90 90	0 15	60 60
7 5-03-79	32.9 (1163)	43.8 (1547)	270 270	170 160	16.21 21.14	0	0.94 (8.8)	90 90	0 10	60 60

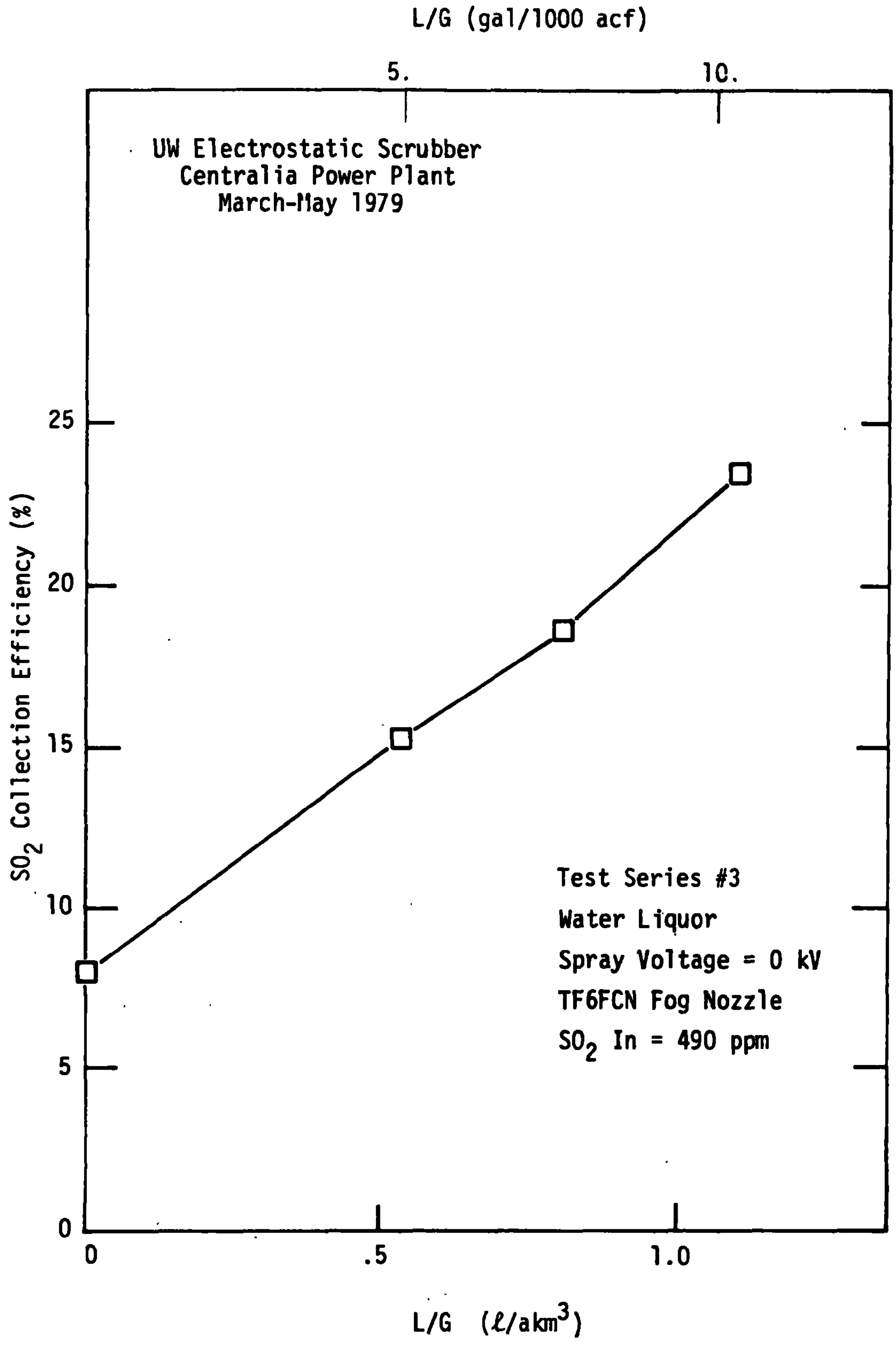

Fig. IX-1. SO_2 Collection Efficiency vs. L/G for Tests Using Water as a Scrubbing Liquor

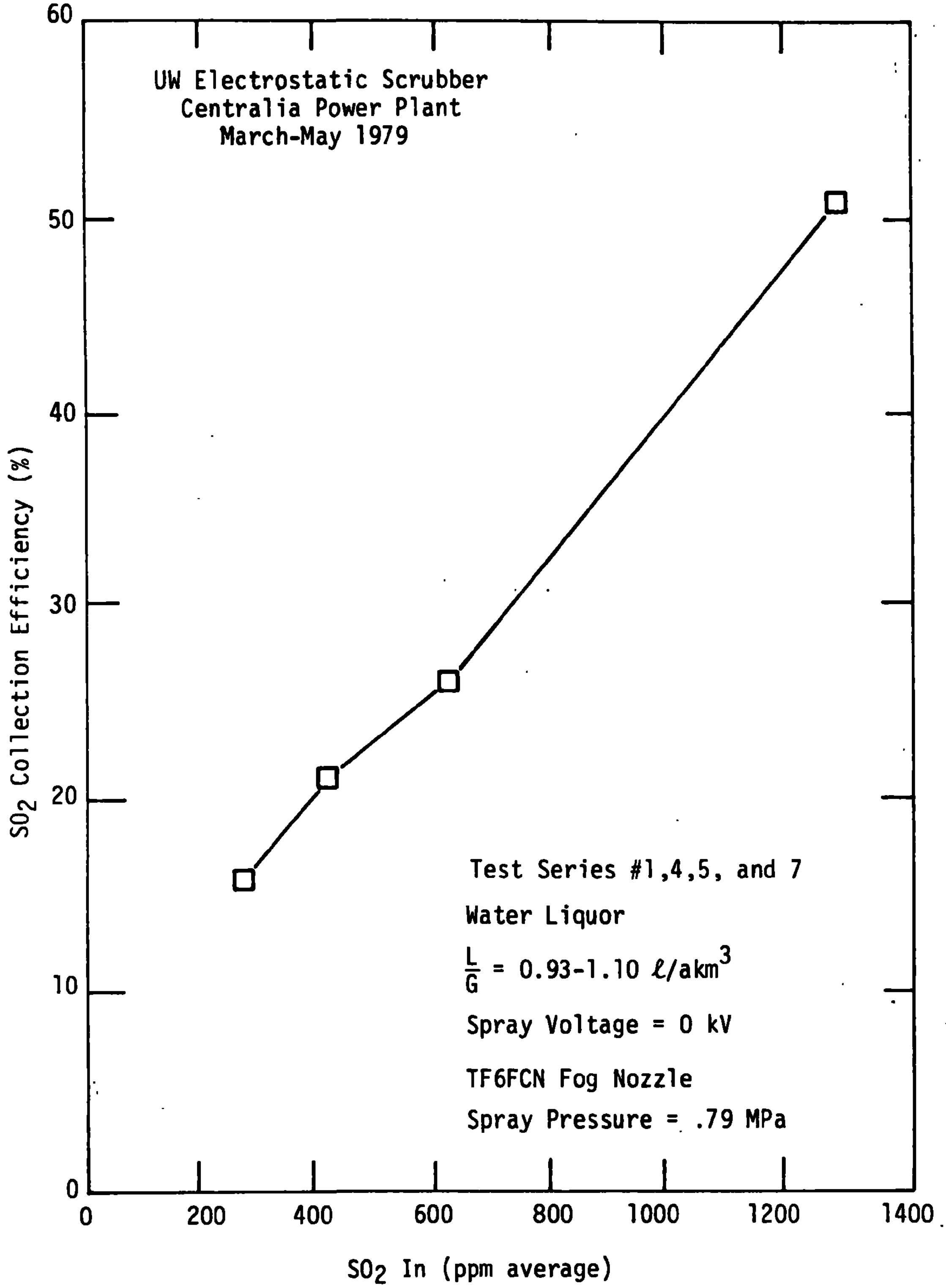

Fig. IX-2. SO_2 Collection Efficiency vs. Inlet SO_2 Concentration for Tests Using Water as a Scrubbing Liquor

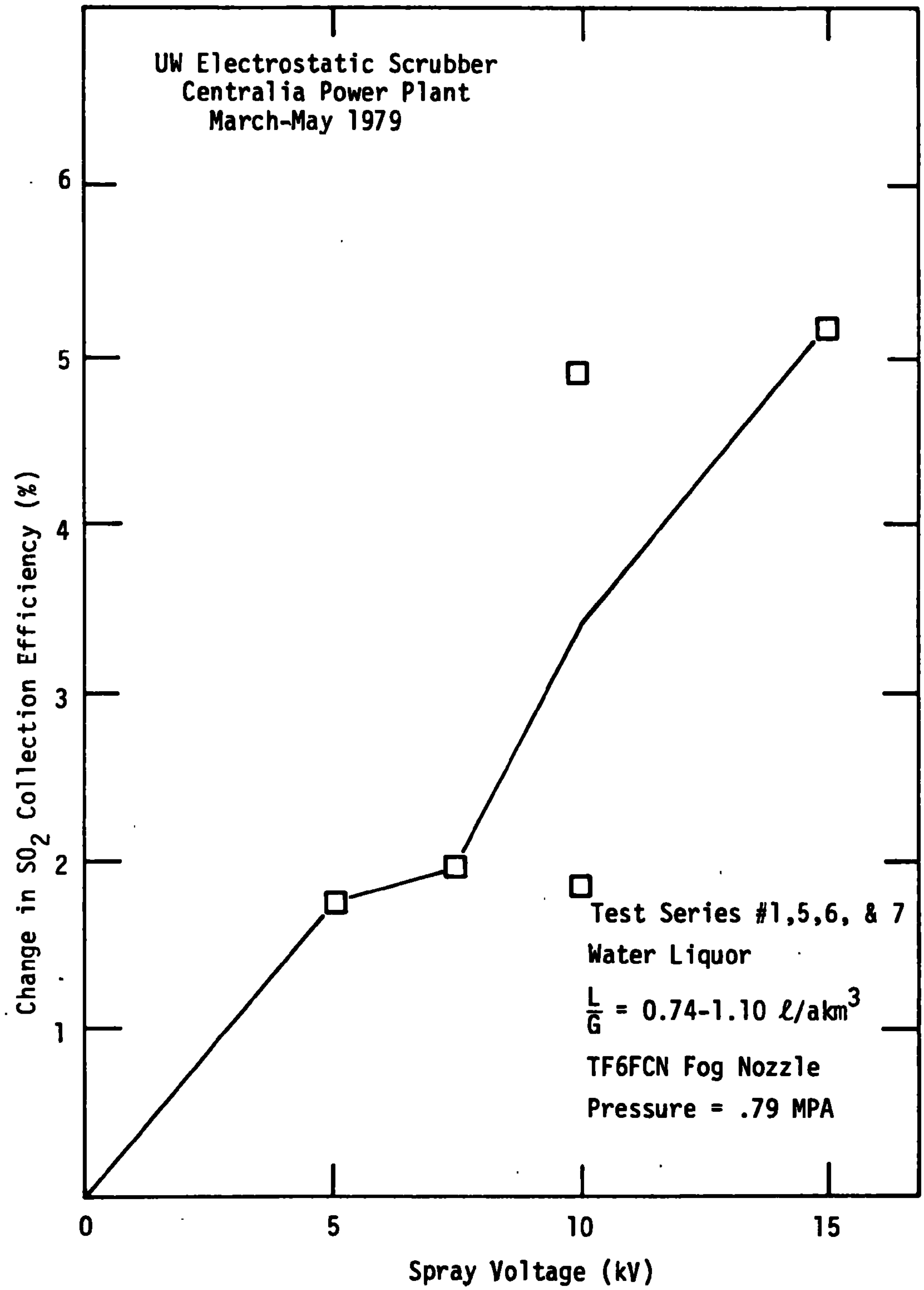

Fig. IX-3. Change in SO_2 Collection Efficiency vs. Spray Voltage for Tests Using Water as a Scrubbing Liquor removal is that a higher inlet SO_2 concentration raises the rate of mass transfer at the gas-liquid interface.

The greatest effect of spray voltage upon SO_2 collection was seen in test series 6. By increasing the spray voltage from 0 to 15KV, the efficiency was raised from 19.67% to 24.85%. Fig. IX-3 illustrates the change in SO_2 collection efficiency vs. the spray voltage change in test series 1, 5, 6, and 7.

2. Tests Using Na_2CO_3 Solution as a Scrubbing Liquor

SO_2 collection efficiency tests were run with Na_2CO_3 liquor in March through May 1979. For these tests, concentrated Na_2CO_3 solution (10% by weight) was metered into the mix tank at a rate designed to give a desired stoichiometric ratio. The pilot plant was run for one half hour prior to each reading to allow the sodium carbonate concentration to equilibrate throughout the entire liquor system.

As shown in Table IX-2 five sets of tests were conducted. The overall results of these tests showed the effect of spray voltage, stoichiometric ratio (SR), liquor-to-gas ratio (L/G), and inlet SO_2 efficiency varied from 38.38% to 97.41% using Na_2CO_3 scrubbing liquor.

During test series 1-N the inlet SO_2 concentration was 1200 ppm, the highest encountered during these tests. Even with the low stoichiometric ratio of .36, a collection efficiency of greater than 71% was realized. By increasing the spray voltage from 0 to 10 KV, the SO_2 efficiency was increased by 2.1% when the SR = .29, and by 1.5% at SR = .36.

Test series 2-N and 3-N demonstrate the effect of L/G upon SO_2 collection efficiency as shown in Fig. IX-4. With inlet SO_2 concentrations approximately the same, raising the L/G from 0.87 to 0.96 ℓ/akm^3 increased the SO_2 removal from 8% to 16%. An increase in collection efficiency was also seen with the application of charge to the sprays, this difference being greater at lower stoichiometric ratios.

Inlet SO_2 concentrations of Runs 4 and 5 were only 265 ppm and 350 ppm, respectively, which resulted in corresponding low SO_2 collection efficiencies. Fig. IX-5 illustrates the effect of inlet SO_2 concentration upon SO_2 efficiency with SR constant. Despite low inlet SO_2 levels test 5-N does show an increase in SO_2 removal from 45% to 78% by increasing the SR from 0.33 to 1.75. Collection efficiency at all stoichiometric ratios was increased by application of a 10 KV spray voltage as seen in Fig. IX-6.

Table IX-2. Results of SO_2 Tests at Centralia Power Plant Using Na_2CO_3 Solution as a Scrubbing Liquor.

Test Series No. & Date	Inlet Gas Flow sdm^3/min (sdcfm)	Outlet Gas flow sdm^3/min (sdcfm)	SO_2 Concentration (ppm)		Overall Collection Efficiency (%)	Stoichiometric Ratio $\left(\frac{\text{moles } Na_2CO_3}{\text{mole inlet } SO_2}\right)$	L/G ℓ/akm^3 (gal/1000acf)	Corona Charge (kV)	Spray Voltage (kV)	Demister Voltage (kV)
			Inlet	Outlet						
1-N 3-30-79	36.9(1302)	46.2(1632)	1200	350	63.44	.29	1.06 (9.9)	(-)90	0	(+)60
	36.9(1302)	46.2(1632)	1200	330	65.53	.29	1.06 (9.9)	90	(+)10	60
	36.9(1302)	46.2(1632)	1200	275	71.27	.36	1.06 (9.9)	90	0	60
	36.9(1302)	46.2(1632)	1200	260	72.84	.36	1.06 (9.9)	90	10	60
2-N 4-18-79	41.5(1465)	50.3(1777)	590	85	81.95	.66	0.93 (8.6)	90	0	60
	41.5(1465	50.3(1777)	590	80	83.01	.66	0.93 (8.6)	90	7.5	60
	38.4(1356)	49.8(1757)	500	14	96.37	1.55	0.98 (9.2)	90	0	60
	38.4(1356)	49.8(1757)	500	10	97.41	1.55	0.98 (9.2)	90	7.5	60
3-N 4-19-79	35.9(1268)	48.0(1695)	600	230	48.76	.37	0.87 (8.1)	90	0	60
	35.9(1268)	48.0(1695)	600	215	52.10	.37	0.87 (8.1)	90	7.5	60
	35.9(1268)	48.0(1695)	540	112	72.27	.82	0.87 (8.1)	90	0	60
	35.9(1268)	48.0(1695)	540	108	73.26	.82	0.87 (8.1)	90	7.5	60
	35.9(1268)	48.0(1695)	480	52	85.52	1.90	0.87 (8.1)	90	0	60
4-N 5-3-79	32.7(1156)	43.8(1547)	255	70	63.26	1.07	0.94 (8.8)	90	0	60
	32.7(1156)	43.8(1547)	255	66	65.36	1.07	0.94 (8.8)	90	7.5	60
	32.7(1156)	43.8(1547)	255	66	65.36	1.07	0.94 (8.8)	90	10	60
	32.7(1156)	43.8(1547)	255	62	67.46	1.07	0.94 (8.8)	90	0	60
	32.7(1156)	43.8(1547)	255	60	68.51	1.07	0.94 (8.8)	90	7.5	60
	32.7(1156)	43.8(1547)	265	52	73.74	1.21	0.94 (8.8)	90	0	60
	32.7(1156)	43.8(1547)	265	55	72.23	1.21	0.94 (8.8)	90	7.5	60
	32.7(1156)	43.8(1547)	265	58	70.71	1.21	0.94 (8.8)	90	0	60
	33.8(1192)	46.4(1637)	265	66	65.80	.82	0.91 (8.5)	90	0	60
	33.8(1192)	46.4(1637)	265	63	67.35	.82	0.91 (8.5)	90	7.5	60
	33.8(1192)	46.4(1637)	265	98	49.21	.60	0.91 (8.5)	90	0	60
	33.8(1192)	46.4(1637)	265	95	50.77	.60	0.91 (8.5)	90	10	60
	33.8(1192)	46.4(1637)	265	115	40.40	.45	0.91 (8.5)	90	0	60
	33.8(1192)	46.4(1637)	265	111	42.48	.45	0.91 (8.5)	90	7.5	60
	33.8(1192)	46.4(1637)	275	115	42.57	.45	0.91 (8.5)	90	15	60
	33.8(1192)	46.4(1637)	275	118	41.07	.45	0.91 (8.5)	90	0	60

Table IX-2 (cont.) Results of SO_2 Tests at Centralia Power Plant Using Na_2CO_3 Solution as a Scrubbing Liquor.

Test Series No. & Date	Inlet Gas Flow sdm^3/min (sdcfm)	Outlet Gas Flow sdm^3/min (scdfm)	SO_2 Concentration (ppm)		Overall Collection Efficiency (%)	Stoichiometric Ratio ($\frac{\text{moles } Na_2CO_3}{\text{mole inlet } SO_2}$)	L/G ℓ/akm^3 (gal/1000acf)	Corona Charge (kV)	Spray Voltage (kV)	Demister Voltage (kV)
			Inlet	Outlet						
5-N 5-17-79	32.3(1142)	45.2(1595)	340	140	42.49	.33	0.88 (8.2)	90	10	60
	32.3(1142)	45.2(1595)	340	142.5	41.46	.33	0.88 (8.2)	90	0	60
	32.3(1142)	45.2(1595)	355	130	48.85	.42	0.88 (8.2)	90	0	60
	32.3(1142)	45.2(1595)	355	122	52.00	.42	0.88 (8.2)	90	10	60
	32.3(1142)	45.2(1595)	355	120	52.79	.42	0.88 (8.2)	90	14.5	60
	36.8(1300)	47.1(1662)	338	110	58.39	.53	0.77 (7.2)	90	0	60
	36.8(1300)	47.1(1662)	338	105	60.28	.53	0.77 (7.2)	90	10	60
	36.8(1300)	47.1(1662)	330	97	62.42	.68	0.77 (7.2)	90	10	60
	36.8(1300)	47.1(1662)	330	103	60.10	.68	0.77 (7.2)	90	0	60
	36.8(1300)	47.1(1662)	360	63	77.63	1.25	0.77 (7.2)	90	0	60
	36.8(1300)	47.1(1662)	360	61	78.34	1.25	0.77 (7.2)	90	10	60

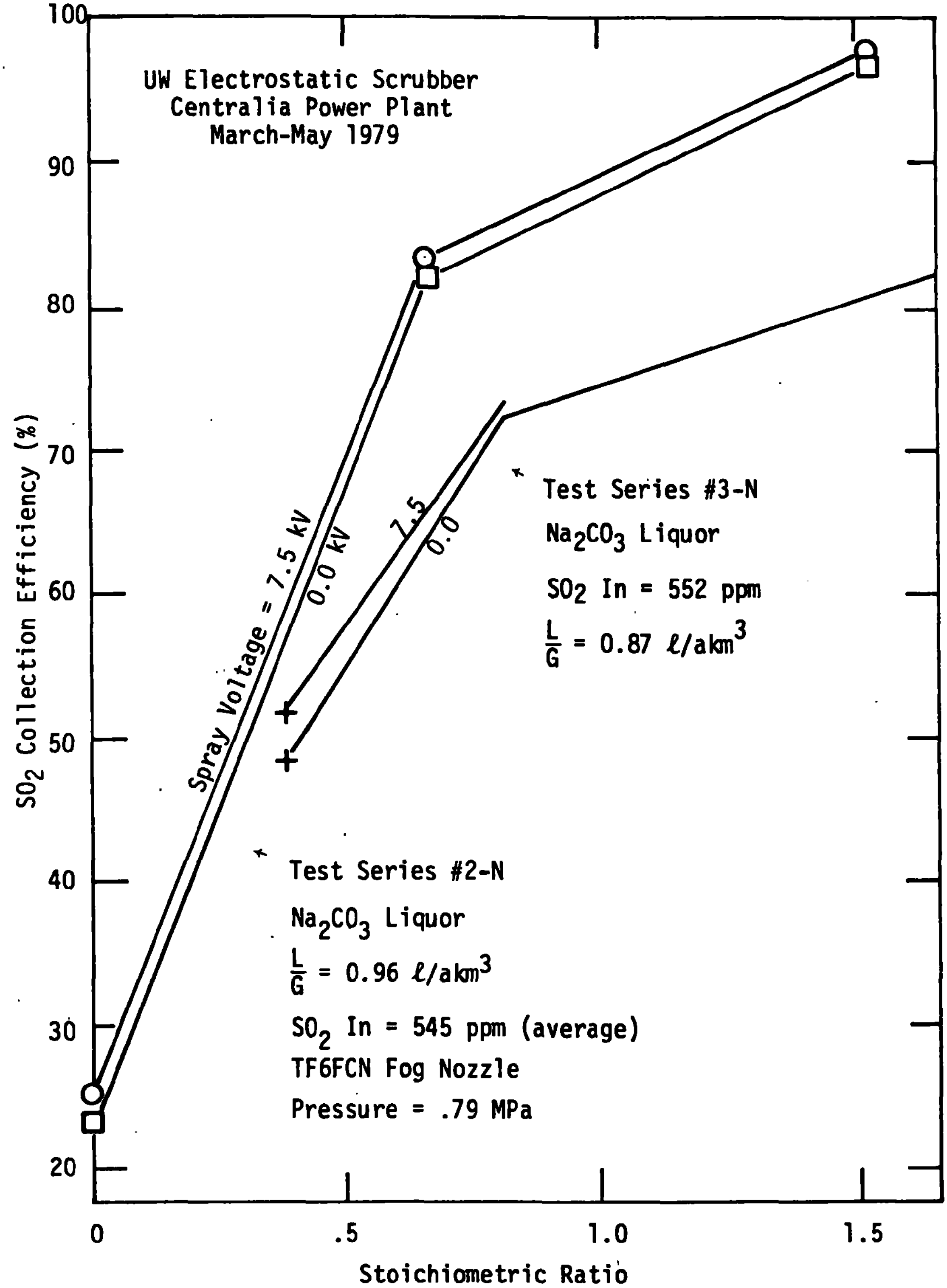

Fig. IX-4. Effect of L/G on SO_2 Collection Efficiency For Tests Using Na_2CO_3 Solution as a Scrubbing Liquor

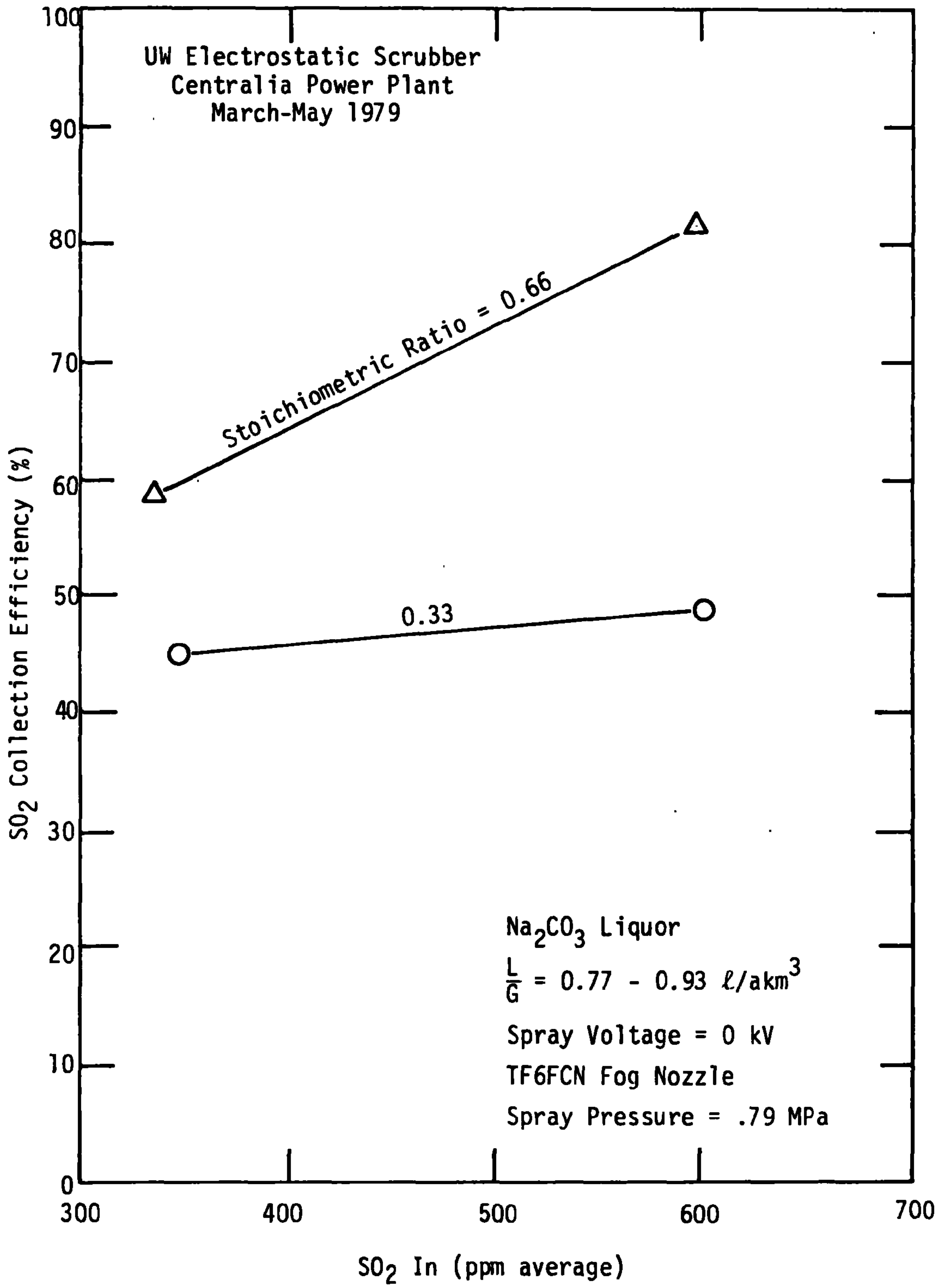

Fig. IX-5. SO_2 Collection Efficiency vs. Inlet SO_2 Concentration at Varying Stoichiometric Ratios

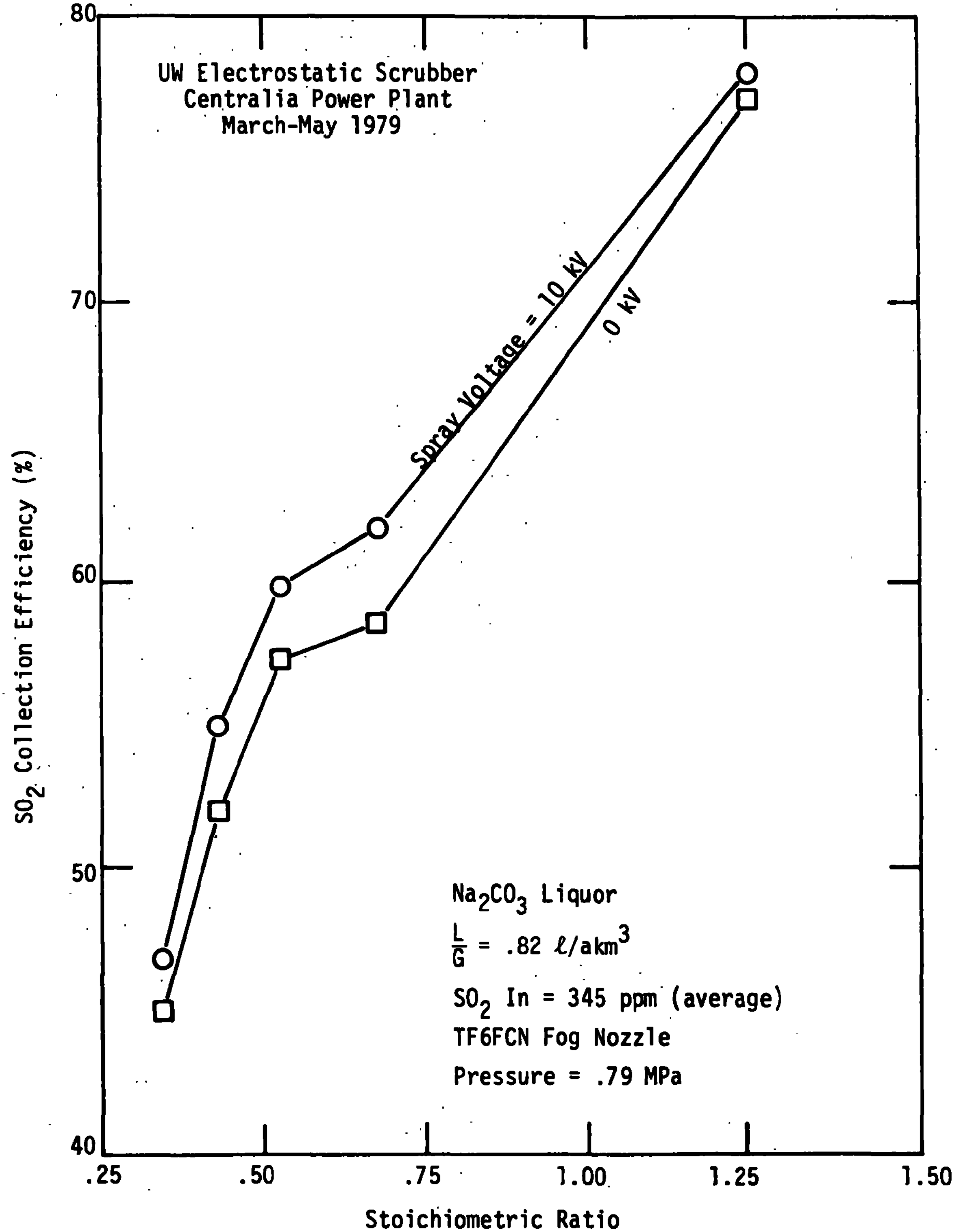

Fig. IX-6. Effect of Stoichiometric Ratio and Spray Voltage on SO_2 Collection Efficiency

Section X

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16. ABSTRACT The report gives results of tests of a 1700 a cu m/hr University of Washington electrostatic spray scrubber pilot plant on a coal-fired boiler to demonstrate its effectiveness for controlling fine particle and SO2 emissions. The multiple-pass portable pilot plant operates by combining oppositely charged aerosol particles and water droplets in two spray towers. Aerosol charging sections at a negative polarity precede each spray tower. For these tests, the pilot plant used only one charging section and one spray tower. A liquor recycle system was constructed, permitting the pilot plant to operate in an open- or closed-loop mode. All SO2 tests were run in an open-loop mode using either water or Na2CO3 solution as the scrubbing liquor. Simultaneous inlet and outlet source tests using cascade impactors provided size-dependent and overall mass basis particle collection efficiency data. Measured overall particle collection efficiencies were 98.99%-99.80%, depending on scrubbing operating conditions. SO2 collection efficiencies were 8.02%-97.41%, depending on the scrubber operating conditions, inlet SO2 concentration, and the type of scrubbing liquor used.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Sodium Carbonates	Pollution Control	13B	07B
Flue Gases		Stationary Sources	21B	
Scrubbers		Particulate	07A,13I	
Electrostatics			20C	
Desulfurization			07D	
Dust			11G	
Aerosols				

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