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FOR THE PERIOD
September 1 - November 30, 1990

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PULSED ELECTRON BEAM PRECHARGER

Submitted by

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PULSED ELECTRON BEAM PRECHARGER

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I. INTRODUCTION AND CURRENT STATUS OF THE PROJECT

Electrostatic collection of a high resistivity aerosol using the Electron Beam Precipitator (EBP) collecting section was demonstrated during this reporting period (Quarter Five). Collection efficiency experiments were designed to confirm and extend some of the work performed under the previous contract. The reason for doing this was to attempt to improve upon the collection efficiency of the precipitator alone when testing with a very high resistivity, moderate-to-high concentration dust load. From the collector shakedown runs, a set of suitable operational parameters were determined for the downstream electrostatic collecting sections of the Electron Beam Precipitator wind tunnel. These parameters, along with those for the MINACC electron beam, will generally be held constant while the numerous precharging parameters are varied to produce an optimum particle charge.

The electrostatic collector experiments were part of a larger, comprehensive investigation on electron beam precharging of high resistivity aerosol particles performed during the period covered by Quarters Five, Six, and Seven. This body of work used the same experimental apparatus and procedures and the experimental run period lasted nearly continuously for six months. A summary of the Quarter Five work is presented in the following paragraphs.

Section II-A of TPR 5 contains a report on the continuing effort which was expended on the modification and upgrade of the pulsed power supply and the monitoring systems prior to the initiation of the electron beam precharging experimental work. During earlier tests of the previously described rotating spark gap pulsed power supply, it was found that a large amount of electromagnetic noise was emitted from the firing spark gap. This

RF emission interfered with the proper operation of the electronics of the optical particle counter and other on-line sensing equipment.

Despite numerous attempts to totally eliminate the emitted noise, only partial success in this endeavor was achieved. The optical particle counter was presently used in some of the tests using only dc energization of the precharger. For preliminary runs using pulsed power, however, the optical particle counter was abandoned in favor of a non-electronic filtering system for use in determining the wind tunnel particle concentration under high loading conditions. Shakedown runs with this filter holder proved its effectiveness in sampling the particle-laden gas passing through the E-beam precharger and collector.

One of the most important tasks of the present contract is to measure in-situ the charge and mass of individual particles exiting the electron beam precharger. Although this capability has been demonstrated during earlier experiments, there were recurring problems with the procedure which included the inability to remotely focus the microscope objective lens while running an experiment. Operation of the FSU-developed charge vs. radius (Q/A) apparatus was greatly improved with the addition of a synchronous motor and gear train which now allows very fine control of the particle image on the video screen.

Section II-B contains a review of the layout and operation of the entire FSU Electron Beam Precipitator (EBP) test system. The EBP is basically an instrumented wind tunnel in the form of a closed circuit loop of ductwork. Various functional modules are interspersed along the length of the wind tunnel, including specialized sections for aerosol generation, electron beam particle precharging, electrostatic dust collection, and gas and particle monitoring. Monodisperse (1.0 μm mean diameter) hydrated alumina "Hydral" dust or polydisperse fly ash aerosols are circulated in the wind tunnel using a high capacity blower; the particles are completely filtered out of the gas stream after passing through a large absolute filter.

Electron beam precipitation is a two-stage procedure, and, as such, different operational requirements are found in each of the two modules. The Mk. III electron beam precharger is located downstream from the aerosol entrainment module. It is composed of a length of insulated ductwork bounded on either side by a set of electrodes. A 100 keV electron accelerator produces a region of bipolar ionization within an annex adjacent to the precharger proper. DC or pulsed electric fields can be applied to the precharger electrodes, extracting a monopolar charge fraction from the ionization zone. Aerosols passing through the precharger are charged to very high levels, and then are transported downstream to the collector. The collecting section just downstream from the precharger is configured like a conventional electrostatic precipitator in order to test electron beam precharging in a "retrofit" situation. Together, the intense charging capability of the precharger and the high efficiency of the collector constitute an effective two-stage particle removal system.

<u>Section II-C</u> presents the results of a series of tests of the electrostatic collector section of the EBP wind tunnel. Normally, the collector forms the downstream half of the precharger/collector two-stage system, but no precharging was used in this particular investigation. The collector is usually operated in a low current mode in order to reduce the formation of back corona. These tests were designed to check the accuracy of

the Micromac current measurement system, to ascertain the efficiency of the collector under high dust loading conditions, and to check the operation of the absolute filter holder bulk dust sampling system. This mechanical sampling device replaced the Climet optical particle counter in this study because of the aforementioned problems with electromagnetic interference from the pulsed power supply.

Collector electrode voltage was incrementally varied from 3.0 kV/cm to 5.0 kV/cm, and ion current was monitored by three methods. Particle collection efficiencies were high even at the corona onset point (approximately 3.0 kV/cm). At 4.5 kV/cm electric field, a large increase in ion current caused a jump in particle collection efficiency to a value of 97.4%. The operational limit of the collector was determined to be approximately 6.0 kV/cm at which point back corona begins to be evidenced. However, because of the high particle collection efficiencies that can be achieved at only moderate voltages, the collector can be run at electric fields of between 3 and 5 kV/cm. Furthermore, because particle charging duties are more effectively handled by the E-beam precharger, the collector can be run in a low current condition which provides energy savings as well as freedom from back corona.

Section III of this TPR reports on the visit of Dr. Kanko Janka, who represented the Tampella Company, Finland. The Tampella Company is a very large, diversified organization involved in a wide variety of activities including power generation and the pulp and paper industry, and Dr. Janka visited the Aerosol Physics Group at FSU with the purpose of learning more about the electron beam precipitator and the PEER pulsed streamer corona treatment method of treating SO_2 and NO_x gases. Finally, Section IV lists the personnel affiliated with the project during Quarter Five.

II. CONTRACT PROGRESS DURING QUARTER FIVE

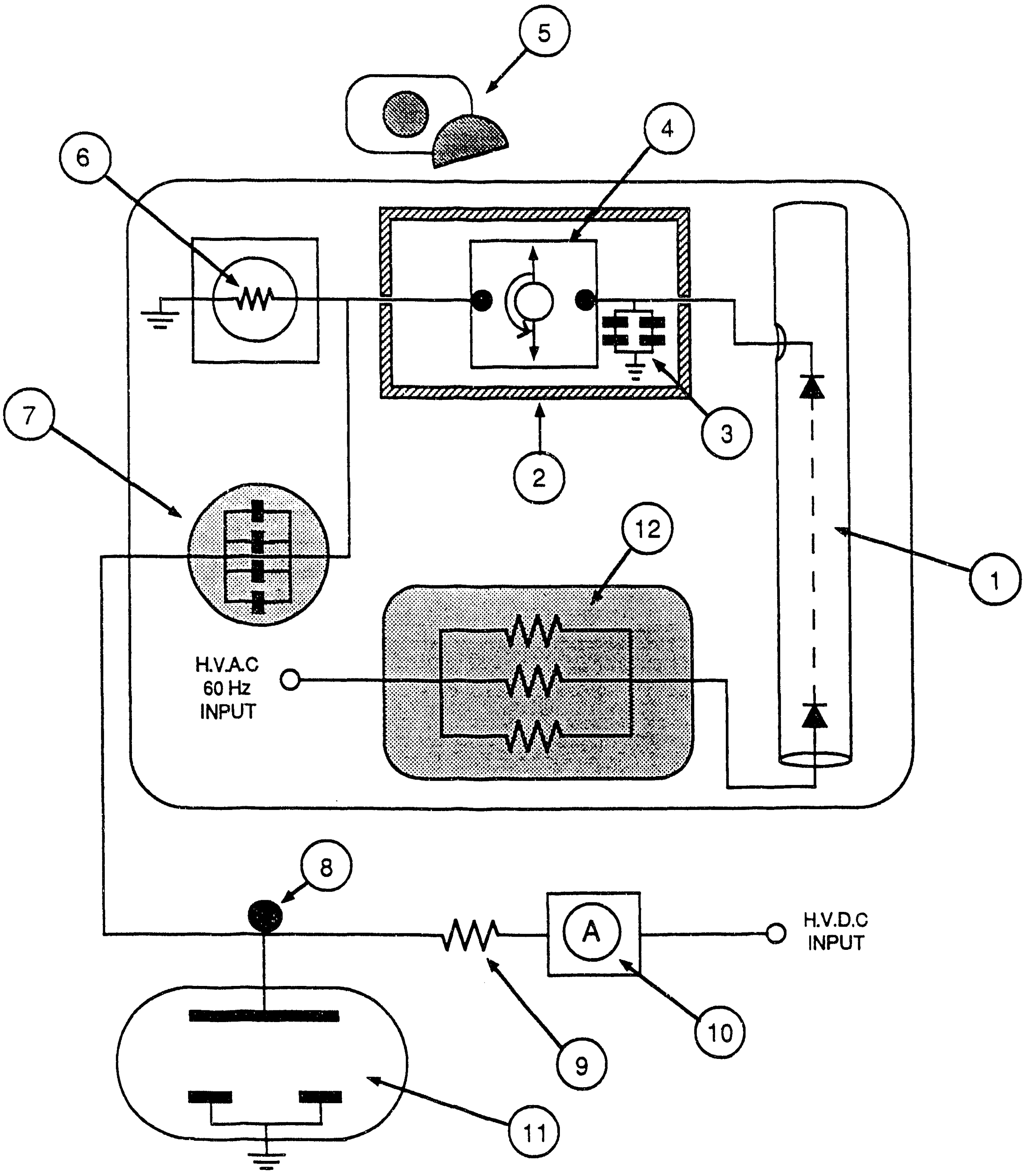
A. Modification of Power Supply and Monitoring Apparatus

1. Pulsed Power Supply - Electromagnetic Noise Reduction

The main objective of the project during this reporting period was to begin running electron beam precharging experiments. However, due to the electromagnetic noise emitted by the pulsed power supply, and problems with the Climet multi-channel analyzer, this seemingly simple objective became difficult to attain without substantial electronic and mechanical modifications. To mitigate and hopefully overcome the problems associated with the noise generated by the pulsed power supply (Figure 1), the group worked on basically two fronts: 1) reduce noise emissions from the pulser itself, and 2) improve the shielding and grounding around the affected monitoring systems in order to enhance their noise immunity.

To reduce emission production from the power supply itself, the Faraday cage surrounding the rotating spark gap (Figure 2) was regrounded using a 6 inch wide copper strip rather than a heavy braid. This was done because the copper strip has a much higher surface area and a much lower surge impedance than the braid. In addition, the pulser grounding connections and interconnections were inspected and similarly improved wherever possible. Even after the completion of the new grounding system, the pulsed power supply was still saddled with E.M. noise radiation problems, most of which stem from the relatively long cable runs between pulser components. At this point we have learned a great deal about the behavior of pulsed power supplies from working with the present system. With this increased understanding, it is becoming apparent

Pulsed Power Supply



1 - High Voltage Rectifier
2 - Faraday Cage
3 - Capacitor Bank
4 - Mechanical Spark Gap
5 - Strobe Lamp
6 - Tail Resistor
7 - D.C. Isolation Capacitor
8 - Corona Ball
9 - Current Limiting Resistor
10 - D.C. Ammeter
11 - Precharger Electrodes
12 - Current Limiting Resistor

FINNEY 003 MP

Figure 1. Top View of the High Voltage Pulsed Power Supply, showing the Rectifier Network, the Capacitor Bank, the Rotating Spark Gap, and other components.

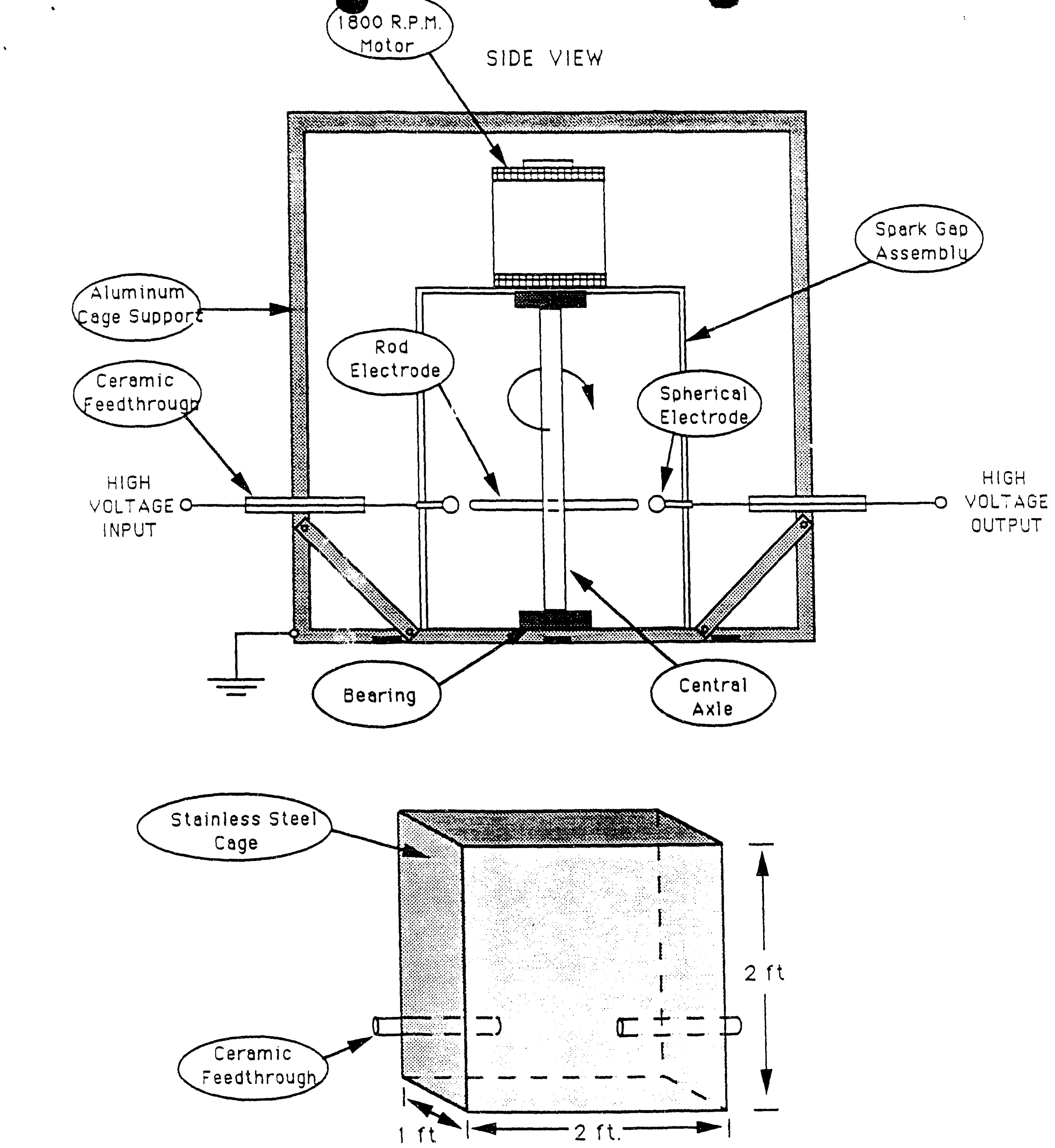


Figure 2. Side View Schematic of the Rotating Spark Gap portion of the Pulsed Power Supply showing the support framework (top), and the Grounded Faraday Cage (bottom).

that the only permanent, long term solution to the noise problem is a complete redesign of the pulsed power supply.

To improve the noise immunity of the affected computer and monitoring systems, we first constructed a tightly shielded case for the MicroMac analog/digital data collection system (Figure 3). This measure allowed the operation of the MicroMac at low pulsed voltages of around 30 kV. However, fatal MicroMac system errors still occurred, and periodically they occurred with greater frequency as the pulse voltage was increased above 30 kV.

Next, we turned our attention yet again to the Climet optical particle sampling and counting system (Figure 4). Various grounding schemes utilizing the sampling unit, the dilution system, and the multichannel analyzer were tried with no success. The possibility of buying or constructing a balanced data transmission system was even investigated. Finally, E and H-field probes were acquired from the department technical staff. These probes, along with expertise from outside of our group, showed that the magnitude of the noise being emitted from the pulsed power supply was such that the operation of any electronically-based data collection system in the vicinity of the pulsed power supply would be nearly impossible without resorting to expensive and exotic shielding methods.

The conclusion of the effort to reduce the E.M. noise emanating from the pulsed power supply was that all electronically-based instrumentation systems would be temporarily abandoned in favor of using mechanically-based aerosol sampling systems for the E-Beam precharger runs. Until such time as adequate resources and expertise can be made available for the task of properly shielding the monitors and pulser, other methods will be used to collect

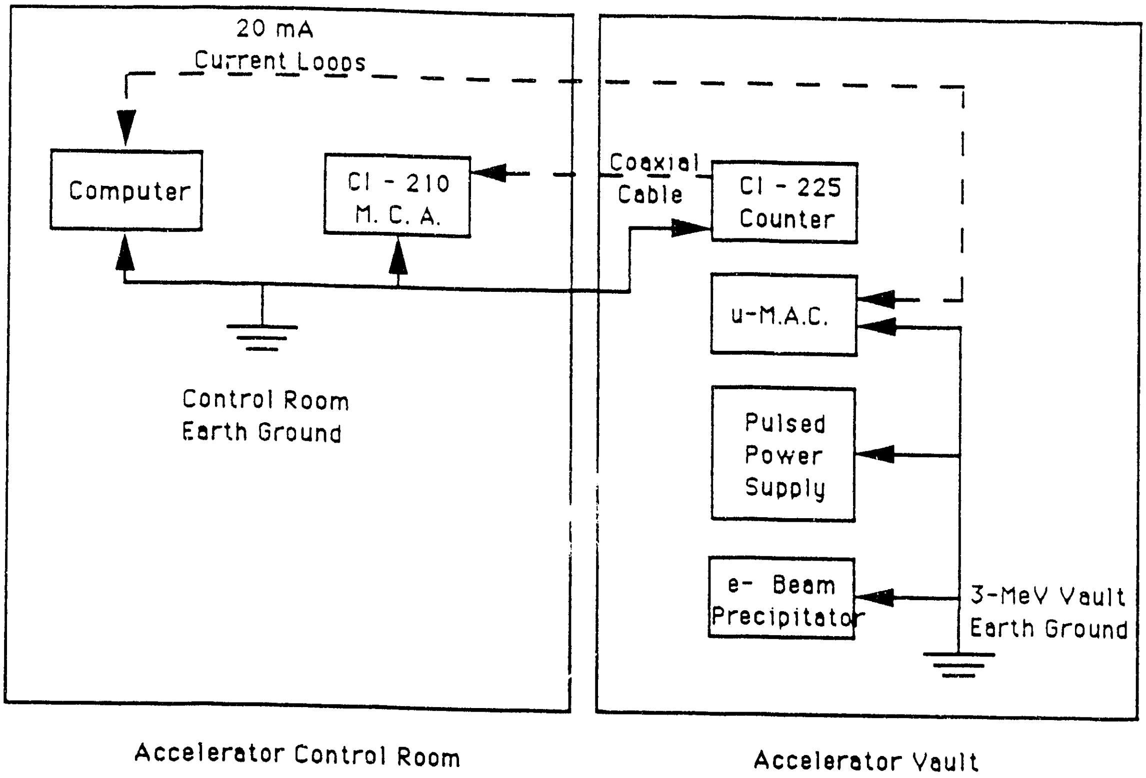
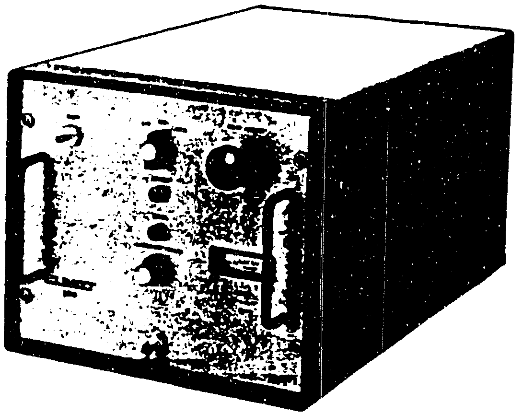


Figure 3. Grounding Layout between the Microcomputer and Multichannel Analyzer (located in the control room), and the Particle Counter, MicroMac Current Converter, Pulsed Power Supply, and E-Beam Precipitator (located in the Accelerator Vault).

CI-225

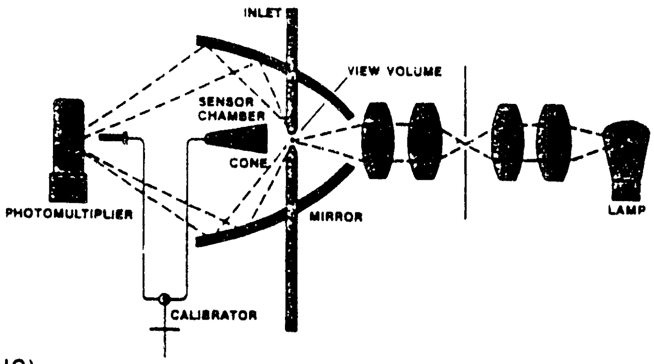
FEATURES:

- ☐ 0.3 MICRON SENSITIVITY
- ☐ LONG DISTANCE DATA TRANSMISSION
- ☐ COMPACT DESIGN WITHOUT SACRIFICING VERSATILITY OR PERFORMANCE
- ☐ ELLIPTICAL MIRROR OPTICS



MODEL CI-225 OPTICAL SYSTEM:

The patented elliptical mirror light collection system is recognized as the finest in the world, gathering the greatest amount of scattered light for any given particle.



SPECIFICATIONS:

Power: 115/230 volt, 60/50 Hz.

Signals: (1) Digital Output, BNC Connector (J3)
(2) Analog Output for Particle Size Analysis, BNC Connector (J4)

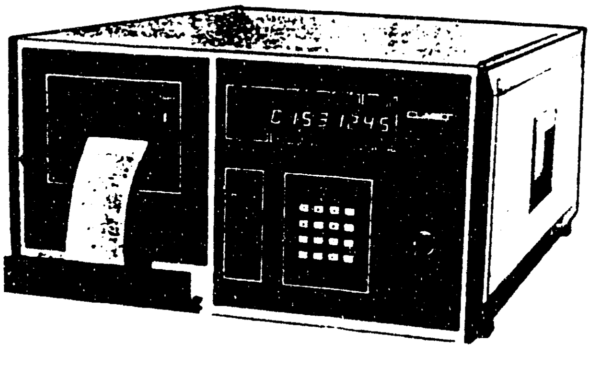
Standard Particle Size Range: .3 to 10 microns and above

Flow Rate: .25 cubic feet per minute

Weight: 40 lbs.

Size: 9½" H, 11½" W, 19¾" L

CI-210 MULTI-CHANNEL ANALYZER



The Climet CI-210 Multi-Channel Analyzer is a microprocessor-controlled multiple pulse discriminator which receives pulses representing particle sizes from one to forty Climet Particle Sensors simultaneously. Pulses are continuously discriminated, accumulated, displayed, and recorded in the CI-210 according to the unit's ten internally stored programs. Most any <u>number of sensors</u> x <u>size ranges per sensor</u> combination ≤ forty can be specified. Alarms, data summaries, and computer interfaces are optional and available upon request.

Figure 4. The Climet Optical Particle Size/Number Measurement System, showing the CI-225 Counting Unit and the CI-210 Multichannel Analyzer.

particle size and number data from the electron beam precipitator when pulsed power is used. Consultation with other groups employing pulsed power in close proximity with electronic monitors has revealed that our problem is far from uncommon, but nevertheless resolvable.

2. Particle Charge vs. Radius Apparatus

The charge vs. radius (Q/A) measurement apparatus (Figure 5), which has been detailed in TPR No. 2, is a highly modified Millikan Oil Drop apparatus which is used to measure particle size and charge in an airborne medium. These measurements are made possible by making video recordings of the laser-illuminated particles as they are passed into an airtight cell. The cell chamber contains a set of parallel plates which generate an ac electric field, causing particles in the field to oscillate in a known and calculable manner. By using the magnitude of particle oscillation and the rate of fall of the particles in computer spreadsheet and graphing programs, a Q/A ratio can be obtained. Thus, for each experimental run, the particle charge provided by electron beam precharging can be compared with the particle collection efficiency of the system in order to establish a cause and effect relationship.

The main goal of this reporting period was to complete the upgrade of the Q/A focusing system. As parts for the upgrade began to arrive from orders placed during Quarter 4, a completely dimensioned draft sketch was made of the exact system design. A synchronous ac stepping motor and an adjustable gear train assembly was developed in order to provide for finer control of the optical components and to allow the focusing speeds to be changed as desired.

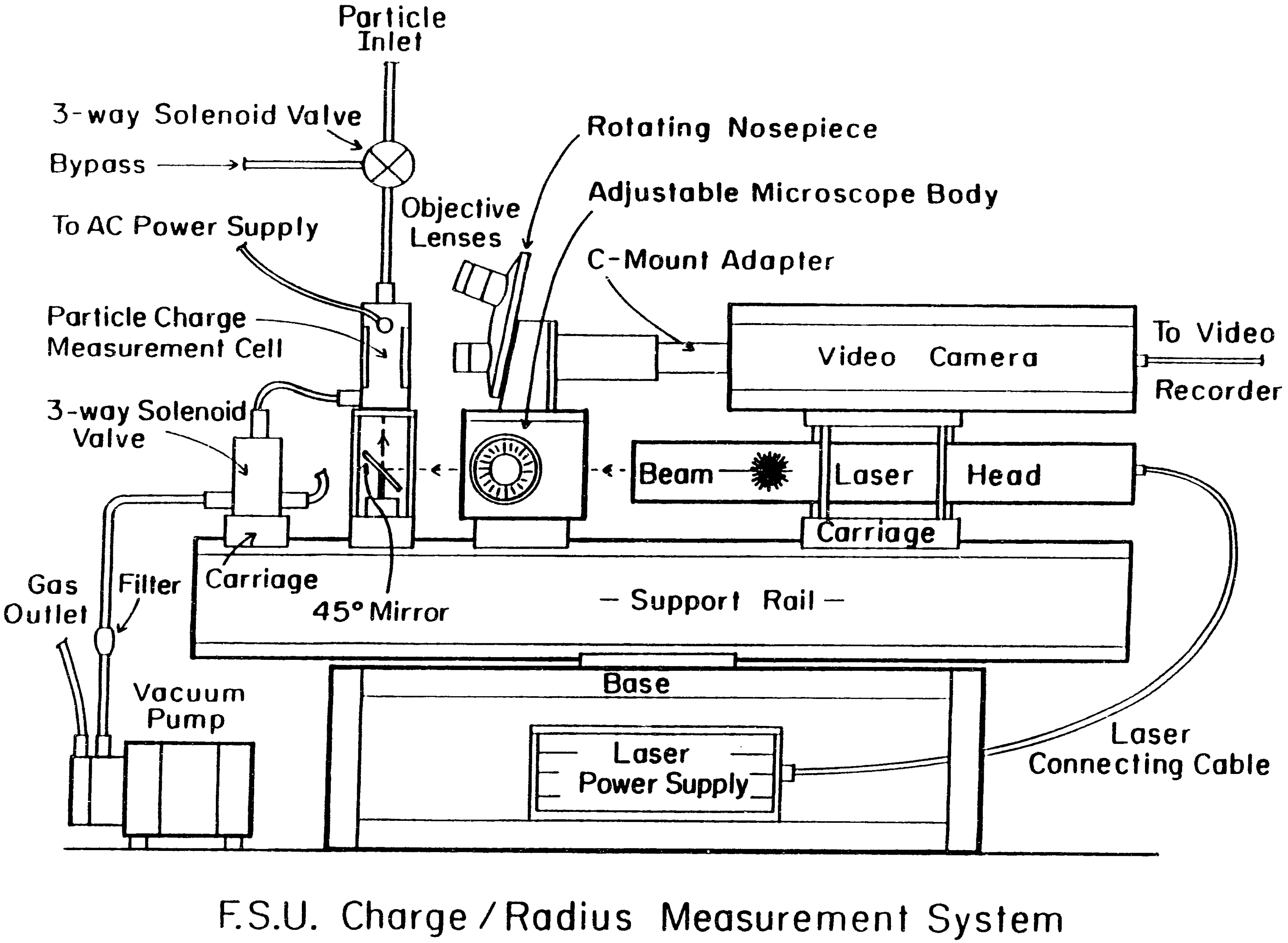


Figure 5. The FSU Particle Charge vs. Radius (Q/A) Monitoring Apparatus, showing the Laser Beam, the Video Recording System, and the Particle Charge Measurement Cell.

The first task of constructing the focus system frame proved to be a labor-intensive job due to the fact that many of the pieces necessary for assembly had to be machined by hand. Another step consisted of wiring the motor control switching circuitry into a grounded metal box with standard AC input line. Additional time was allocated for rewiring the external focus control system to be compatible with the new motor and, in addition, replacing the control pushbuttons with a single toggle switch.

The final Q/A focusing system design consisted of a V-shaped apparatus with slots milled in either side. These slots were used to secure the motor and gear train, and allowed the assembly to be moved to accommodate different gear ratios. Changing gear ratios adjusts focusing speed and torque of the apparatus as deemed necessary for various experimental conditions. The gear train consists of four gears, three of which are fixed ratio gears, and a removable fourth gear which provides providing the output speed. Any gear out of a set of variable sized gears (current set includes three) can act as the fourth gear, thereby changing the gear train ratio and speed. Input to output ratios range from 1:24 to 1:12 to 1:8, giving output speeds of 3, 6, and 9 RPM (as reduced from the fixed motor speed of 72 RPM). This fourth gear is attached to a shaft which runs to the focus control knob; this knob moves the lens focus carriage located on the structural beam forward or in reverse. In addition, a set of safety microswitches was installed on the carriage and wired to the motor control lines. The microswitches prevent the focus control from overshooting the carriage stops by turning off the motor when the carriage reaches a certain point. Without this safety failure, the gears could possibly "strip" if the focusing system locked up.

Operation and setup of the new camera focus system is similar to the previous focusing system. The motor control circuitry is connected to a control line which runs inside the accelerator vault to an external panel switch in the control room. The motor is then easily controlled from outside the vault. Moving the switch up or down moves the focus lens in or out; when the switch is placed in the middle position, the motor is almost instantaneously stopped with no noticeable backlash which was a major problem in the previous setup.

In final testing of the completed focus system it was concluded that the new design was more versatile and was extremely effective in solving the problems with the earlier design. The motor control started and stopped with almost no delay while being, fully reversible, and the new system was also easily removable from the Q/A bench as well. An added feature of speed control over the system was also an important benefit, which may prove to be very useful in experiments to come.

3. Absolute Filter Holder Aerosol Sampler

A new method to sample and count aerosol particles was commissioned this term because of the inability of the Climet to function in concert with the pulsed power supply. When an oscilloscope was connected to the communication cable of the Climet, it was found that a voltage with a peak value of as high as 50 volts was induced on the cable by the pulsed power supply. This noise resulted in a distortion of the data transmitted from the sensing unit to the multichannel analyzer, usually causing the entire network to "lock up".

The new particle monitoring protocol involved attaching an "absolute filter holder" (Figure 6) on the side of the monitoring

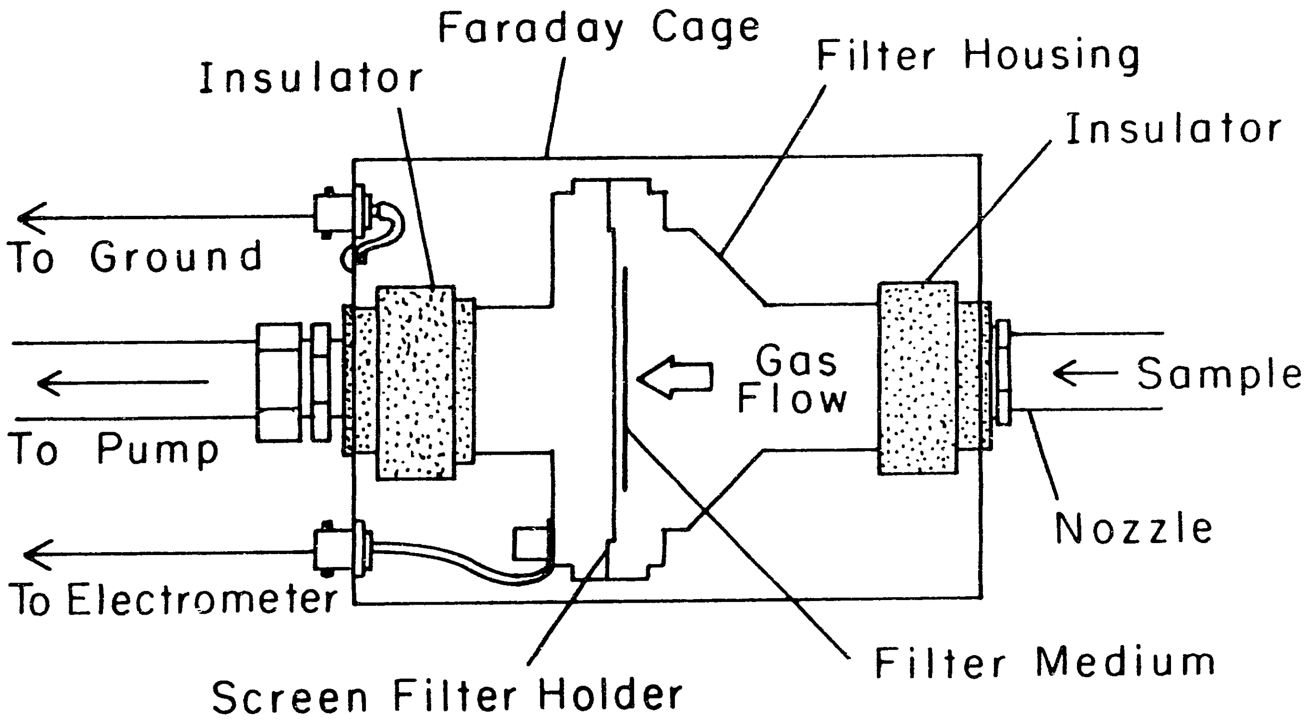


Figure 6. The Absolute Filter Holder Aerosol Sampler, used for determining bulk particle mass in E-Beam experiments having high concentrations of Hydral Dust.

module downstream from the collecting section. Monodisperse aerosol in the wind tunnel was sampled using a nozzle attached to the body of the filter holder which was, in turn, attached to a vacuum pump. The vacuum pump was calibrated to sample the air isokinetically; this isokinetic rate was found to be 3.75 SCFH. Contained within the filter holder was a paper filter which removed 99.9% of all particles of 0.1 μm diameter or greater. The number of individual Hydral particles could then be calculated by weighing the filter paper before and after the sampling period.

A number of test samples of fifteen minutes duration were taken to determine the constancy of this method. The filter paper was weighed before and after an electron beam precharging run, and a change in weight was determined. The change in the filter paper weight was small, within the range of 0.3 mg. This, however, represents a difference of approximately 12,500 particles when using 1.0 μm diameter hydrated alumina dust as the test aerosol. From early indications, the absolute filter holder method of monitoring particle concentration, while not "real time", represents the best available technique which is also immune to noise emitted from the pulsed power supply.

B. Electron Beam Precipitator - Review of Systems

As a prelude to beginning the electron beam particle precharging experiments using a pulsed charging electric field, several shakedown runs using dc power in the electrostatic collector were completed this term. Experiments were conducted using the FSU Electron Beam Precipitator wind tunnel, the Mk. III E-beam precharger, and a moderately high concentration of Hydral test dust. Although the wind tunnel and associated subsystems have been described elsewhere in detail, a review of the experimental apparatus, the mechanics of precharging, and data acquisition and analysis procedures will be reviewed here.

Figure 7 shows the Electron Beam Precipitator (EBP) test system . The closed-circuit or "racetrack" wind tunnel is composed of a continuous loop of square, stainless steel ductwork interspersed with a number of specialized modules. Some approximate dimensions of the system are: length - 19 ft, width - 7 ft, height - 3.5 ft, total path length - 45 ft, duct size - 1 ft x 1 ft. Opening module tops and sides as well as a number of sampling ports allow ready access to the interior of the wind tunnel.

A large squirrel cage blower controlled by an outlet damper circulates room temperature air at gas velocities and volumes of up to 33 ft and 2000 ACFM, respectively. Just upstream from the fan is a large H.E.P.A. high capacity filter capable of removing 99.97% of all particles larger than 0.3 μm diameter. A humidity control and monitoring device is located downstream from the fan. Relative humidity levels during the tests ranged from 30 - 50% but were generally very close to 40% RH. Dry air from a compressed air source can also be added to control humidity.

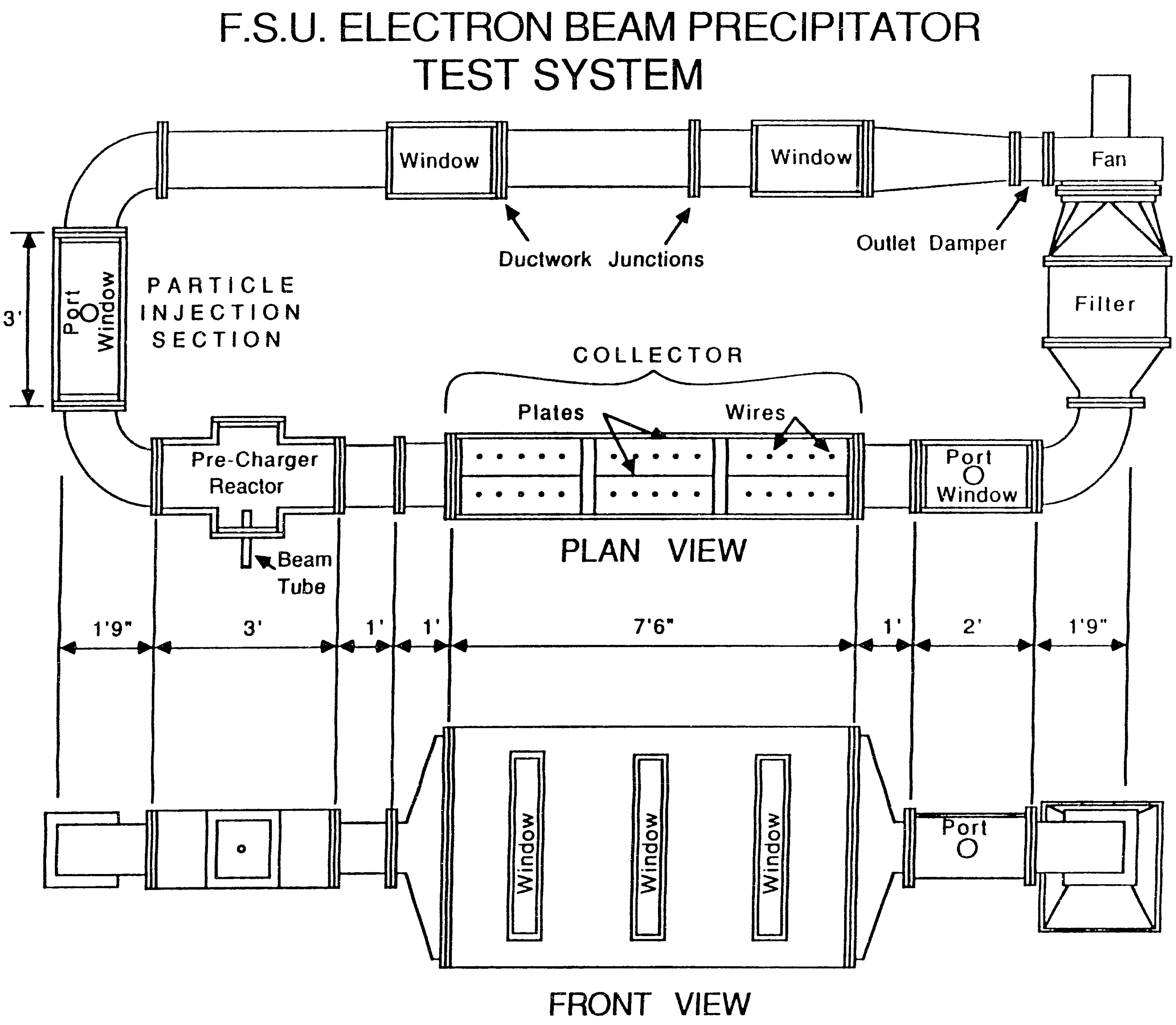


Figure 7. The Two-Stage, Laboratory Scale FSU Electron Beam Precipitator Wind Tunnel, showing the Aerosol Injection, E-Beam Precharger, and Collector Modules.

An aerosol of 1.0 μm median diameter hydrated alumina (Hydral) monodisperse test dust having a resistivity at room temperature of > 10^{12} Ω-cm was generated using the fluidized bed/screw feeder aerosol generator (Figure 8). The highly concentrated dust suspension was dispersed into the circulating gas stream at the particle injection module. Two 50% open area baffle screens downstream form the injection point insure that a completely distributed aerosol will be delivered to the precharger.

Since electron beam precipitation is a two-stage concept, particle charging and collecting occur as two separate functions. Particle charging is accomplished in the electron beam precharger upstream from the collecting stage. Figure 9 shows the precharging module and the associated electron beam source and vacuum station. The outer precharging module is the same cross sectional size (1 ft x 1 ft) as the wind tunnel ductwork although the actual precharger sub-duct is only one-quarter the size (6 in x 6 in). The smaller duct is suspended concentrically within the outer module and is constructed of an insulation material. Within the precharger are three parallel sets of metal plane electrodes across which the charging electric field is applied. The flow of test aerosol passes between two of these electrode sets which delineate the charging zone.

Ions and electrons for the particle charging process are provided by an electron beam source. The source itself is a 100 keV maximum energy electron accelerator constructed at FSU, dubbed the MINACC. Within an evacuated, insulating PVC pipe are a hot filament cathode and a series of accelerating rings at successively lower electric potentials (Figure 10). The electron beam passes down the pipe and through a thin plastic film "window" out into the precharger where the ionization process occurs.

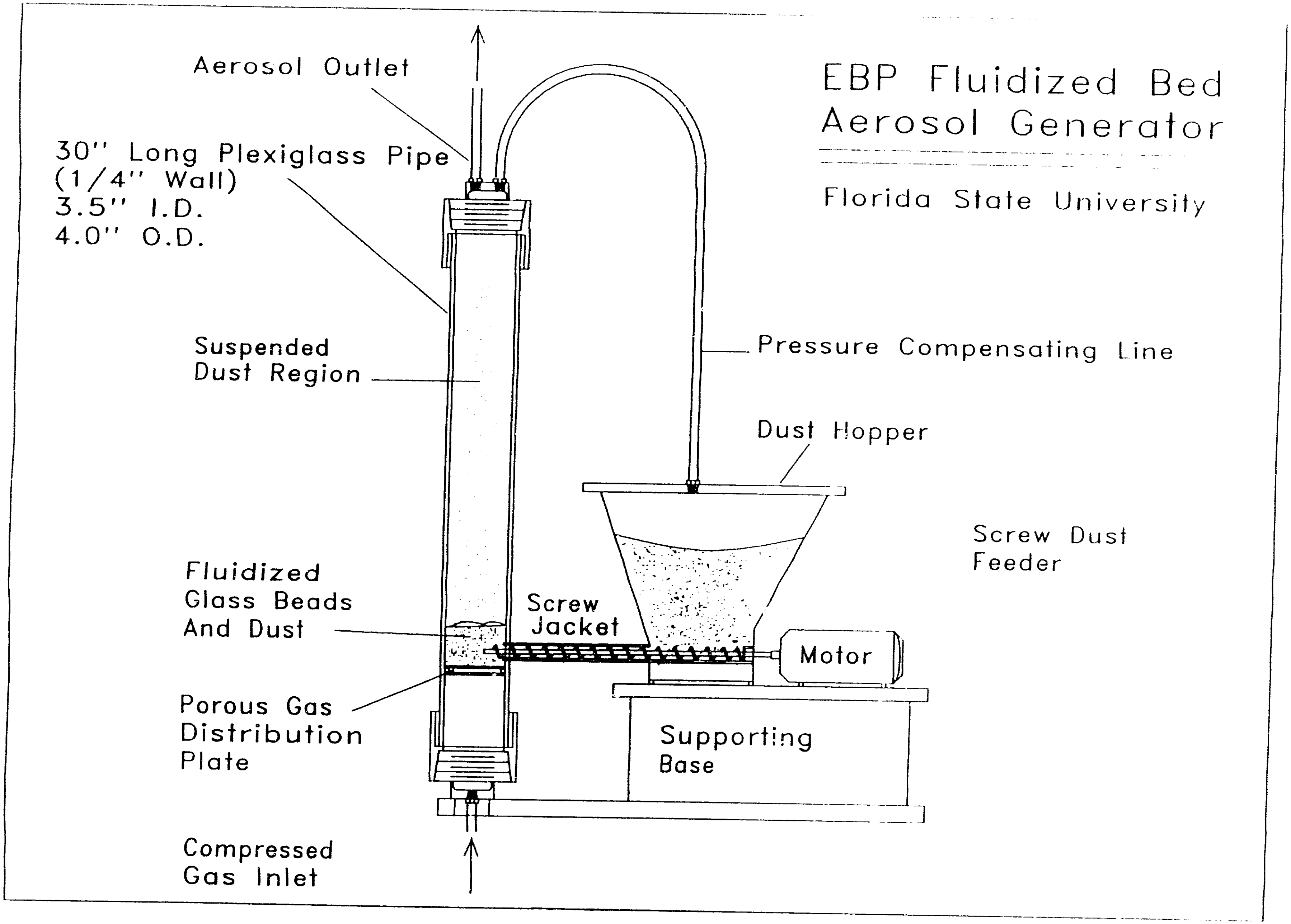


Figure 8. Schematic Diagram of the Fluidized Bed / Screw Feeder Aerosol Generation System, which Deagglomerates and Resuspends Hydral and Fly Ash.

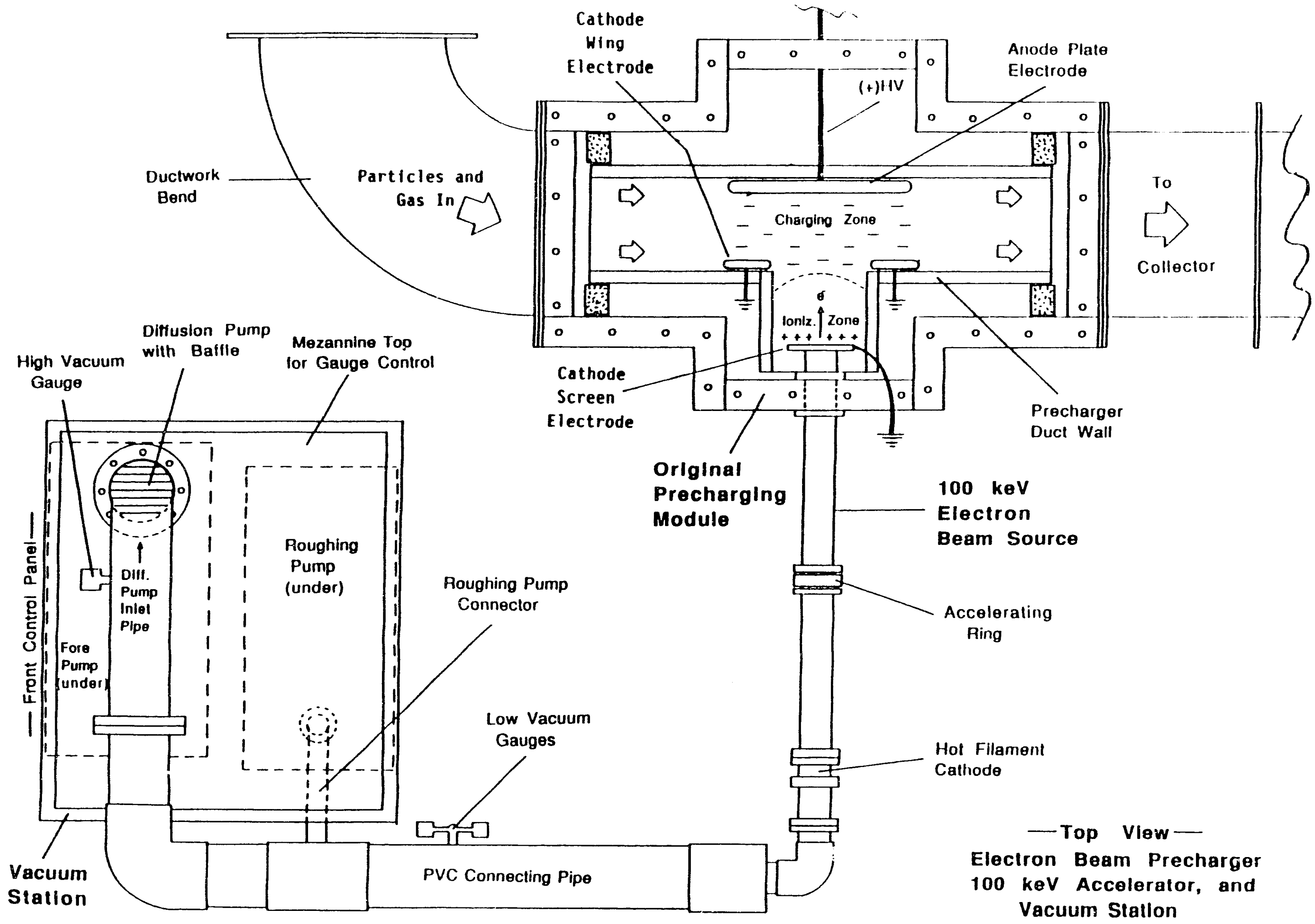


Figure 9. Top View of the BG/CP-2C Vacuum Station, The 100 keV Electron Beam Accelerator (MINACC), and the E-Beam Particle Precharging Module.

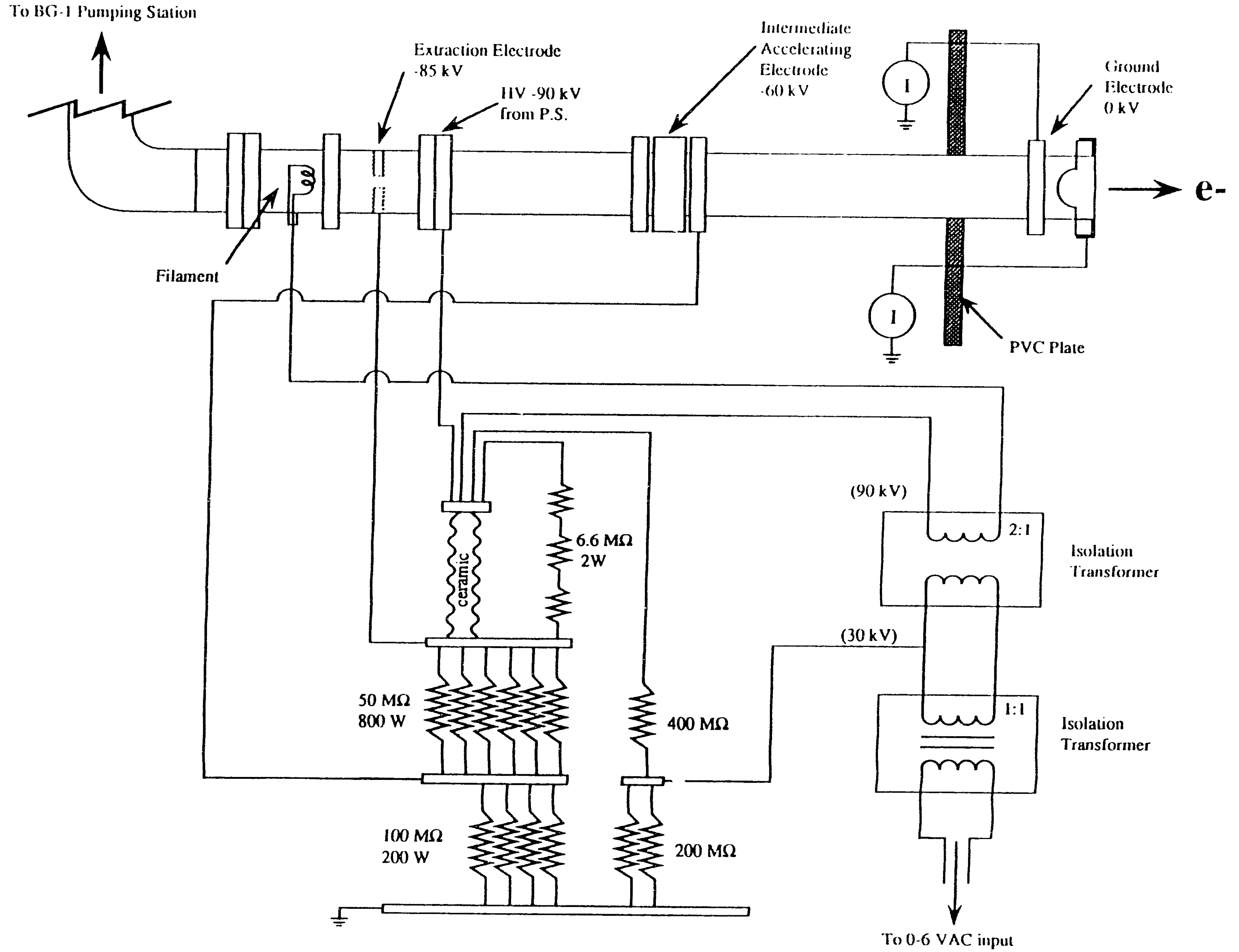


Figure 10. Side View Schematic Diagram of the 100 keV Electron Beam Accelerator (MINACC), showing the Accelerator Column, the thin Window, and the Dropping Resistors.

Maintaining the MINACC at a pressure level of approximately 5 x 10^{-6} torr is a dedicated vacuum station, the BG-2 (Figure 9). Control over the pumping process is exercised by a CVC vacuum gauge controller and a series of solenoid-actuated valves. Protection for the diffusion pump is built into the station circuitry in case of an accelerator window blowout or other major vacuum leak.

The mechanics of electron beam particle precharging have been described elsewhere in detail, but the process will be briefly outlined again. Figure 11 shows the present internal electrode configuration of the Mk. III E-beam precharger. As the high energy electron beam passes from vacuum into air through the "window" on the end of the MINACC, the ionization process commences. Positive and negative ions and secondary electrons are created at a rate dependent upon the initial electron beam energy and current. This zone of ionization is contained within a recessed area out of the flow of aerosol in the precharger.

Along both side walls of the inner precharging module are a set of plate which define the boundary of the charging zone (Figure 11). When an electric field is applied between the anode and cathode electrodes, the charge density is separated into two monopolar fractions (Figure 12). The negative fraction composed of ions and free electrons is drawn out into and maintained in the charging zone, through which particle-laden gas is flowing. High levels of particle charge and fast charging rates result from, respectively, the large electric fields and dense ion currents in the precharger.

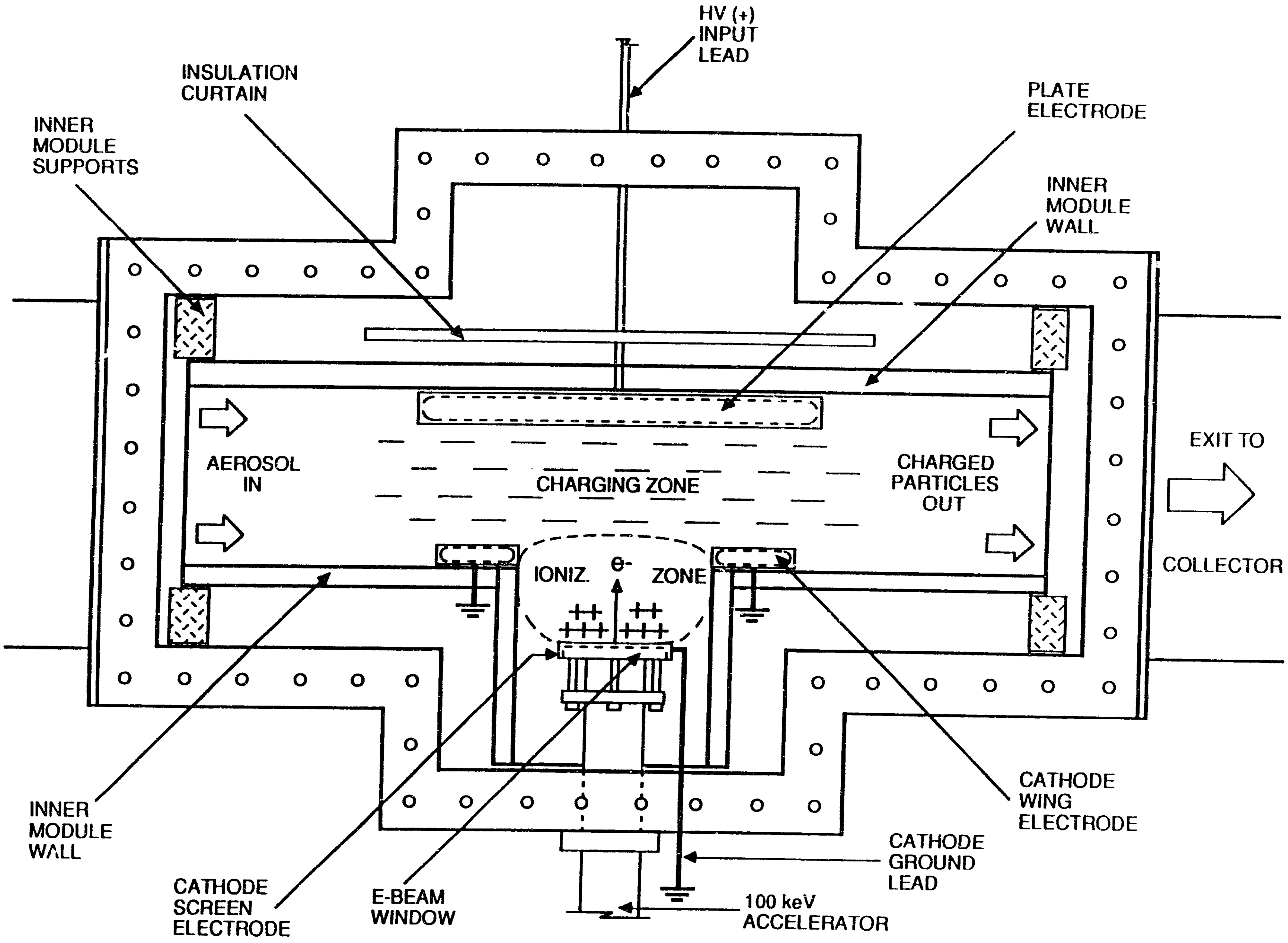


Figure 11. Top View of the Mk. III Electron Beam Precharging Module showing the E-Beam Accelerator, the Cathode and Anode Electrodes, and the Ionization and Charging Regions.

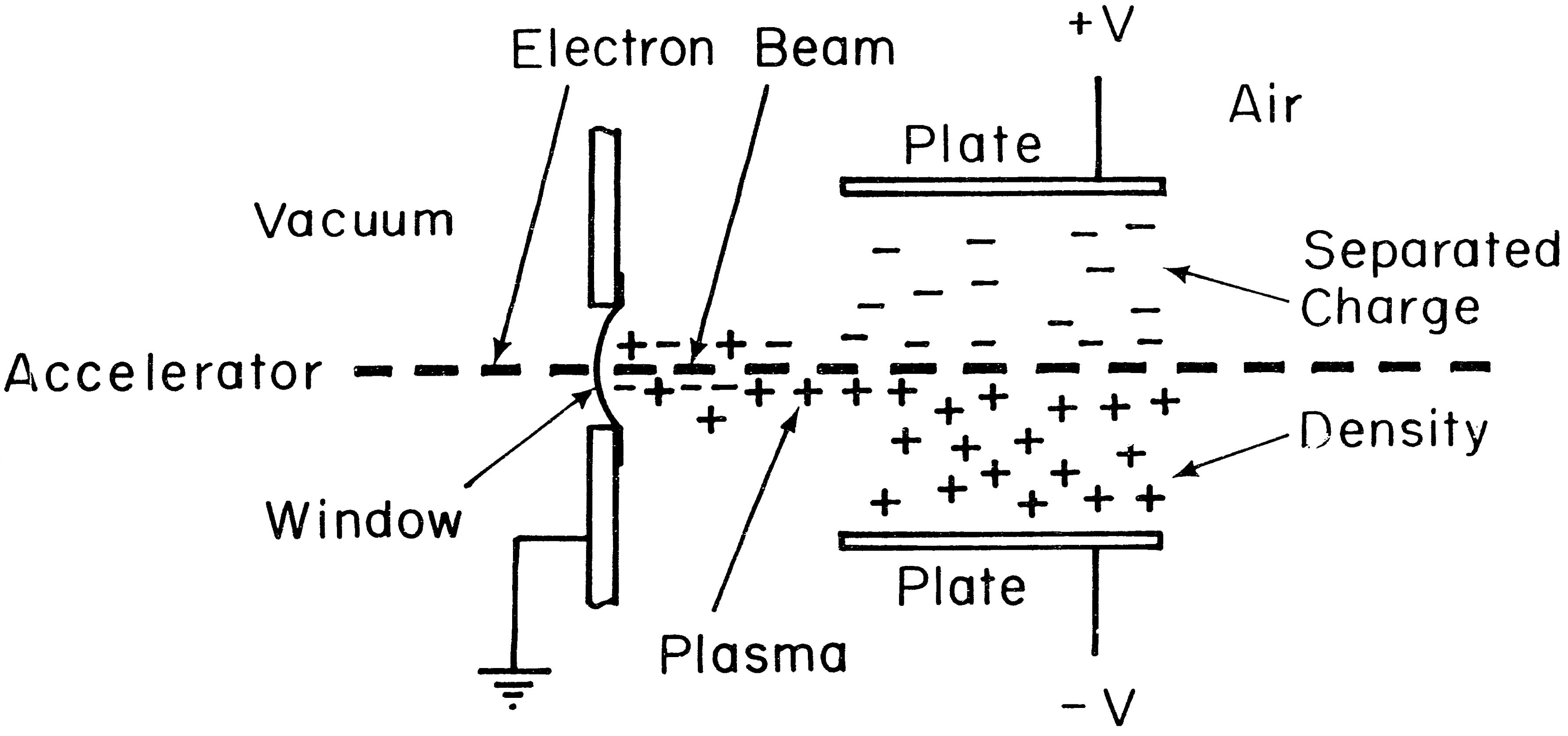


Figure 12. Representation of the process of Electron Beam Ionization of Air Molecules, showing the formation of Secondary Electrons by the Primary Beam, and the Separation of Charge using an intense dc Electric Field.

Highly charged particles pass out of the precharger, into an expansion section, and then into the collector. Baffle screens insure an even flow into and out of the collection module. The electrostatic collector (Figure 13) is of a standard wire-plate precipitator design with two channels, one of which can be blocked off with a baffle plate converting the collector to a higher velocity, lower SCA (Specific Collection Area) device. Each field is composed of two 2.5 ft wide by 4 ft high collecting plates separated by 6 in. Five 0.125 in thick wires spaced at 5 in hang between each set of plates. The gas velocity in the collector varied between 0.6 ft/sec and 2.35 ft/sec, changing the SCA from 833 to 1667 using only one collector channel. Voltage was generally set at either 26.7 kV (3.5 Kv/cm) or 30.5 kV (4.0 kv/cm). Table 1 shows the dimensional relationships between the precharging module, the racetrack ductwork, and the one and two channel collector configurations.

Several monitoring locations are spaced throughout the wind tunnel, with the three main ones being upstream from the precharger, midway between the precharging and collecting modules, and immediately downstream from the collector. The latter monitoring station was used for these experiments. It contains a Climet optical particle counter which measures particle size and number, from which the system collection efficiency can be determined. The previously described absolute filter holder bulk dust sampling device is also located here. A Kurz electronic air velocity probe and a General Eastern relative humidity and temperature sensor completed the array of aerosol monitors.

Figure 14 shows a schematic diagram of the microcomputer-based data acquisition system which ties the above mentioned monitors to a small computer. In addition to the inputs from the Climet

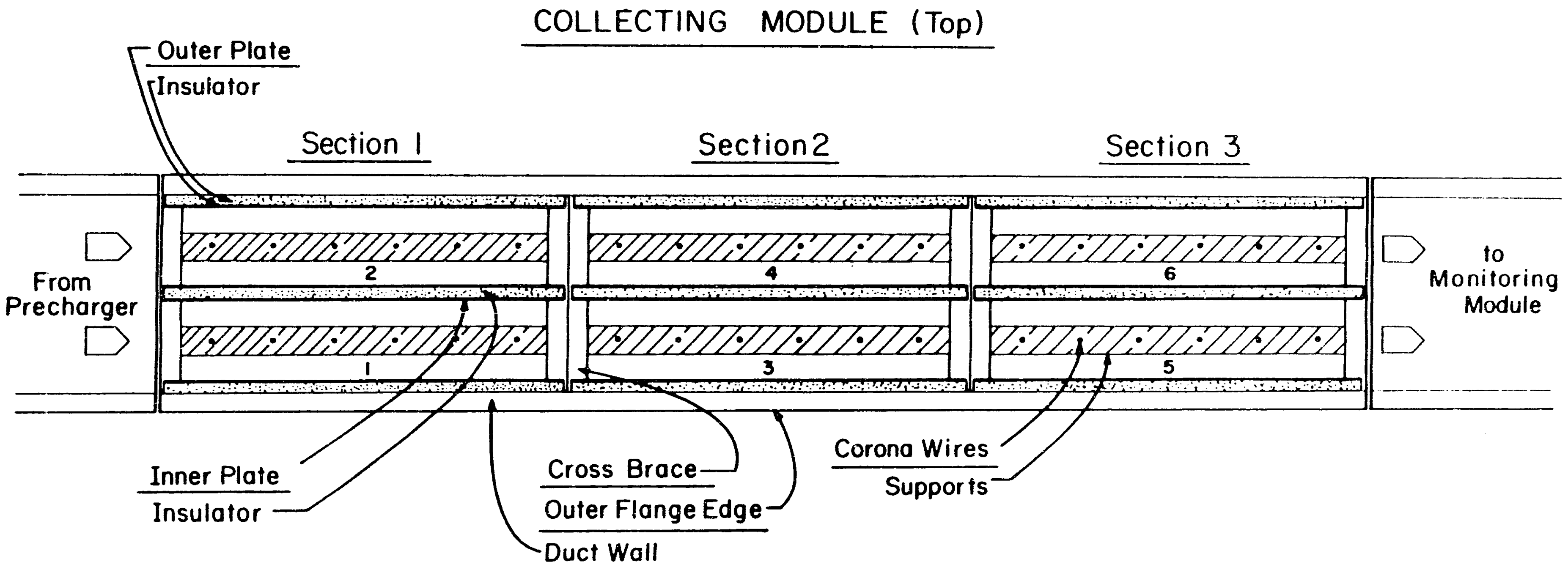


Figure 13. Top View of the Collecting Module within the EBP Wind Tunnel, showing detail of the Six Electric Field Regions composed of Parallel Collection Plates and Central Corona Wires.

Table 1.

DIMENSIONAL RELATIONSHIPS OF THE EBP WIND TUNNEL (EBP)

FSU ELECTRON BEAM PRECIPITATOR

DUCT -- Stainless Steel, Closed Loop, 1 ft^2 Cross Sectional Area, 40 ft. Path Length

PRECHARGER -- Mk. III Version, Charging Zone
Length = 15 cm (0.5 ft)
Width = 14 cm (0.45 ft)

ELECTRICAL PARAMETERS --
Voltage = 0 - 77 kV dc
E - Field = 5.5 kV/cm
Ion Current = 0 - 40 μA
Current Density = 1.25 mA/m^2

ELECTRON BEAM --
Energy = 90 keV
Current = 2 μA

COLLECTING SECTION --
Plate Area = 60 ft^2
Width = 6 in
Wires = 0.109 in (15)

AEROSOLS AND GENERATORS --
PSL (Collision Nebulizer)
Hydrated Alumina, Fly Ash
(Fluidized Bed/Screw Feeder)

PARTICLE MONITORS --
Optical Particle Counter
Absolute Filter Holder

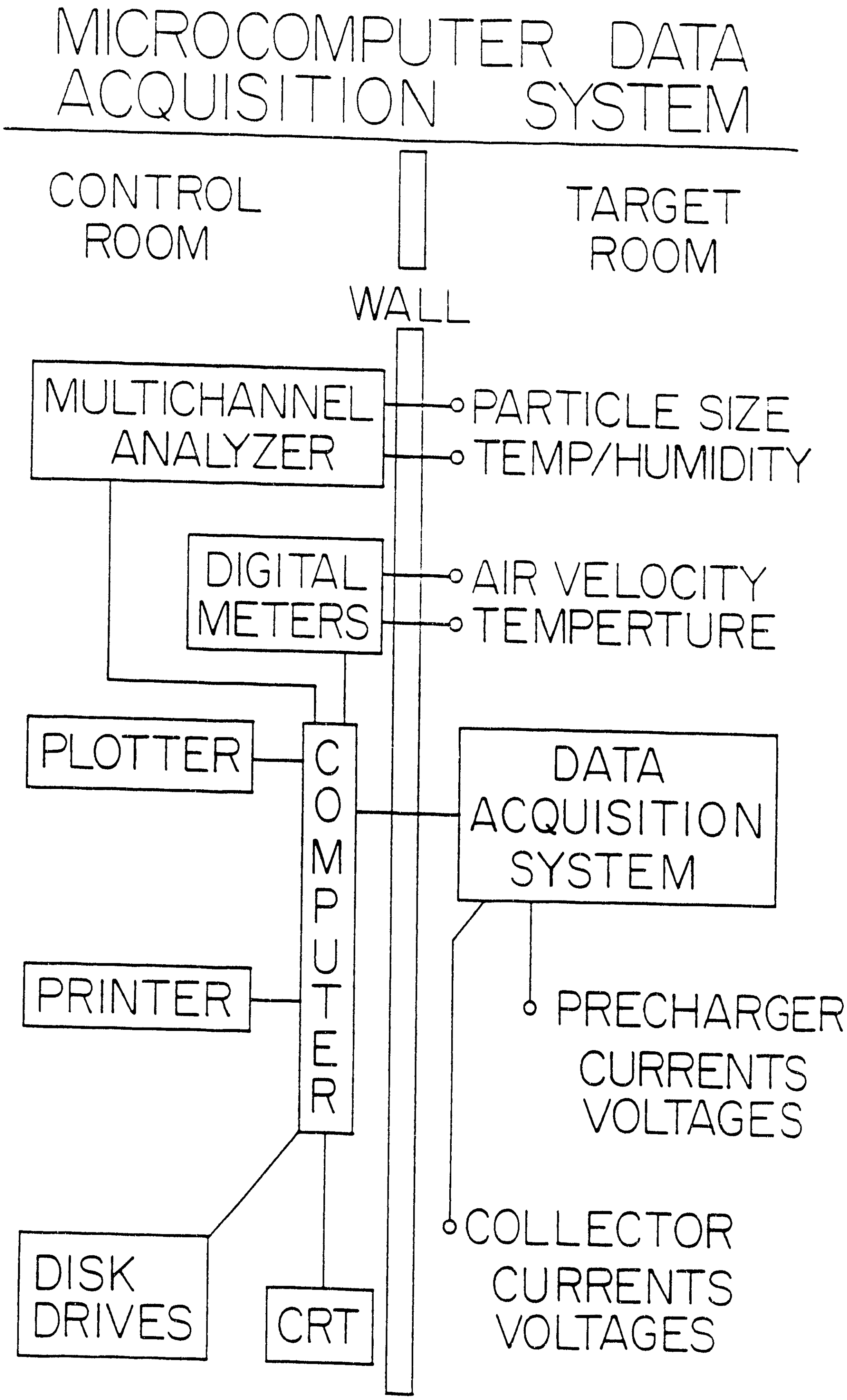


Figure 14. The Microprocessor-based Data Acquisition and Analysis System serving the Electron Beam Precipitator Monitors.

multichannel analyzer and the air velocity and humidity probes, a Micromac data acquisition device measures the precharger and collector voltages and currents and sends the digital data to the computer. A remote controlled, closed circuit TV system is used to visually monitor analog meters measuring the MINACC accelerator vacuum, the electron beam current, and the precharger and collector ion current levels.

C. Experimental Run of Electrostatic Collector

Prior to testing electron beam precharging in conjunction with the low current collecting section, an experiment was run on the collector while operating in a high voltage, high current mode. The collector in the EBP wind tunnel (Figure 13) is configured like a conventional electrostatic precipitator, with two 6 inch wide channels each bisected with a row of centrally located tensioned discharge wires. Wire length and diameter are 4 feet and 0.109 inch, respectively, and plate dimensions for each of the six total fields are 4 feet high and 2.5 feet wide. Only one channel, or three fields in-line, were used in the present experiment in order to raise the gas velocity in the collector without also increasing the total gas volume.

The purpose of this experiment was three-fold. First, a comparison was made between a) the collector ion current reading as recorded by the MicroMac A/D converter and b) the currents obtained from the analog meters in the high voltage input line supplying the discharge wires and in the power supply control circuit. Second, the newly instituted method of taking bulk dust samples with an absolute filter holder which was described earlier was tested under realistic experimental conditions. Third, the dust penetration and collection efficiency was determined for various electric field levels in order to ascertain a suitable collector voltage for the pulsed electron beam precharging experiments. Fine, high resistivity ($> 10^{12}$ Ω-cm) Hydral dust was used for a conservative test of the system.

Procedures for characterizing the collecting section began with obtaining a baseline particle count consisting of a filter sample taken with the absolute filter holder from the EBP wind tunnel while the collector was off. Next, a series of five filter samples were obtained with the collector operating at electric field values of between 3.0 and 5.0 kV/cm. Finally, another baseline sample similar to the first run was taken after the collector was de-energized. Each of the filter samples were weighed before and after each run, yielding a net sample weight. The first and last samples with the collector off were averaged to offset any change in particle concentration which occurred over the two hour duration of the experiment. Run conditions were as follows:

1. Gas Composition : Air
2. Gas Temperature & Humidity: 75°C, 40% RH
3. Gas Volume & Velocity : 1.0 ft^3/sec, 0.5 ft/sec
4. Test Dust Type and Size : Hydral, 1.0 μm mean diam.
5. Fluidized Bed Flow : 0.12 ft^3/sec
6. Screw Feeder Setting : 100
7. Filter Sampler Flow : 3.75 SCFH = isokinetic
8. Sample Time : 10 min (900 sec)

The results of the collector particle removal efficiency experiment are shown in Table 2. An initial voltage level of 23 kV (3.0 kV/cm) was selected because corona onset occurs near this point. Ion current was measured by three methods: 1) the MicroMac A/D converter on the ground side of the precipitator collection plates, 2) an analog milliammeter in the high voltage line leading to the discharge wires, and 3) the output current meter on the front panel of the HV power supply. At corona onset, the measured ion current is very small, only approximately 100 μA for the total of all six collector plates. However, the particle penetration was only 12.99%, meaning that even relatively low electric field and current levels produce a rather high collection efficiency of 87%.

Table 2.

Particle Collection Efficiency of Hydral Dust (Collector Only)

Run #	Voltage (kV)	Electric Field (kV/cm)	MicroMac Current (mA)	Analog Current (mA)	Power Supply Current (mA)	Sample Weight (mg)	Particle Penetration (%)	Collection Efficiency (%)
1	0	0	0	0	0	0.36	-	-
2	23	3.0	>0.01	0.02	>0.01	0.05	12.99	87.01
3	26.5	3.5	0.01	0.02	0.02	0.04	10.39	89.61
4	30.5	4.0	0.03	0.035	0.05	0.04	10.39	89.61
5	34.0	4.5	0.42	0.45	0.44	0.01	2.60	97.40
6	37.5	5.0	1.65	>2.0	1.72	>0.005	<1.30	98.70
7	0	0	0	0	0	0.41	-	-

As the voltage (and thus electric field) level is raised above the corona onset point at about 23 kV, ion current increases slowly at first and then undergoes a sharp rise when 34 kV (4.5 kV/cm electric field) is reached. Concurrently, the decrease in particle penetration with increasing electric field is small (several percent) until a voltage of 34 kV causes a significant decrease in penetration. The jump from 89.6% particle collection efficiency to 97.4% with only a 3.5 kV increase in collector voltage (from 30.5 kV to 34 kV) is heralded by a much larger corona charging current. At 5.0 kV/cm electric field, very little Hydral dust was collected on the filter representing high efficiency for the single channel collector.

Sparkover between the corona wires and the collector plates occurs at between 6 and 8 kV/cm electric field, depending upon the thickness and composition of the high resistivity ash layer coating the plates. With only a moderate dust coating, back corona sets in soon after 6.0 kV/cm is reached, causing particle discharging and dust reentrainment among other ills. As higher, more realistic dust loadings are achieved, the collector will regress into a back corona condition at even lower voltages. In the upcoming experiments, a pulsed electron beam precharger will be used to charge particles to very high levels upstream from the collector. Therefore, the collector will not be required to operate at a high voltage and ion current which induces debilitating back corona. The collector can be run at a relatively low voltage and current while still providing a sufficient electric field strength for collecting the previously precharged particles.

III. PUBLICATIONS, PRESENTATIONS, AND VISITORS

A. Visit of Dr. Kanko Janka, Tampella Company, Finland.

The Aerosol Physics Laboratory was visited this term by Dr. Kanko Janka, Project Manager, Power Industry Division, Tampella Corporation Ltd., Tampere, Finland. The Tampella Corporation is a large, diversified, multinational company involved in the areas of forest products, packaging materials, mining and rock excavation, pulp and paper manufacturing, and, most applicable to FSU, power industries. The Power Industry Division is concentrated in the fields of energy generation, chemical recovery, hydroelectric construction, and air pollution control technology. Specifically, Tampella is interested in advanced techniques for fly ash removal and flue gas desulfurization in coal fired boilers.

An all-day meeting between members of the Aerosol Physics Group (APG) and Dr. Janka took place on Monday, May 7, 1990. Topics of discussion centered on the progress made by the APG in the areas of electron beam aerosol precipitation, free electron particle charging, and pulsed streamer corona treatment of SO_2 and NO_x. Dr. Janka's interest in these technologies was directed towards the possible utilization of the E-beam precharger and the pulse energized electron reactor (PEER) on several Tampella Co. power plant boilers. The APG will keep in contact with Tampella in order to foster the industrial acceptance of these advanced pollution control systems invented at FSU.

IV. PERSONNEL

A. Scientific Investigators

1. Dr. W. Neil Shelton	Principal Investigator
2. Mr. Wright C. Finney	Associate in Research

B. Graduate Student Assistants

1. TBA

C. Undergraduate Student Assistants

1. Chris Oswald
2. Mushtaq Sarwar
3. John Blair

D. Part-Time Secretaries

1. Nancy Lochner
2. Amy Maxey
3. Natalie Duguid

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