PUBLICATION ICAC-EP-1
NOVEMBER 2000

TERMINOLOGY FOR ELECTROSTATIC PRECIPITATORS

INSTITUTE OF
CLEAN
AIR
COMPANIES

TERMINOLOGY FOR
ELECTROSTATIC PRECIPITATORS

Publication ICAC-EP-1

Date Adopted: **November 2000**

ICAC

The Institute of Clean Air Companies (ICAC), the nonprofit national association of companies that supply stationary source air pollution monitoring and control systems, equipment, and services, was formed in 1960 to promote the industry and encourage improvement of engineering and technical standards.

The Institute's mission is to assure a strong and workable air quality policy that promotes public health, environmental quality, and industrial progress. As the representative of the air pollution control industry, the Institute seeks to evaluate and respond to regulatory initiatives and establish technical standards to the benefit of all.

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Summary: This document provides definitions of key common terms related to electrostatic precipitators and their operation in the U.S. marketplace, and includes illustrations of common precipitators. The terminology is arranged by major system component areas, and concludes with a section on general and miscellaneous electrostatic precipitator terms. This document is written by and for members of the air pollution control industry as well as for the regulatory community and others seeking to better understand this industry and this particular air pollution control technology. This document is part of an ICAC technical standards series that addresses electrostatic precipitators (see ICAC publications list). As appropriate, terminology specific to dry and wet electrostatic precipitators is listed and defined.

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1.0 BACKGROUND ON ICAC-EP-1

ICAC-EP-1 was originally adopted in 1964 to provide a common definition of terms being used in the electrostatic precipitator industry, which was specific to dry electrostatic precipitators at that time. ICAC-EP-1 was revised and adopted in 1967, 1973 and again in 1984. The ICAC Particulate Control Division prepared the most recent update to ICAC-EP-1 to capture the more extensive terminology that has evolved for both the dry and wet electrostatic precipitator technologies.

2.0 HISTORY OF INDUSTRIAL ELECTROSTATIC PRECIPITATION: The first working industrial electrostatic precipitator (ESP) is generally attributed to the work started in 1907 by Frederick Cottrell. Prior to the availability of the first working ESP, interest in electrostatic effects was confined primarily to laboratory research and public demonstrations. In 1885 Sir Oliver Lodge had attempted an industrial ESP that failed due to the immature nature of power sources available at that time. However, the development of high voltage alternating-current transformers and synchronous mechanical rectifiers allowed Cottrell to develop an actual working ESP. By 1911 Cottrell had developed several successful working installations, and turned his interest and expertise to other research topics. For many years, ESPs were often referred to as "Cottrell collectors".

The first several ESP installations were pipe-type units used to collect acid mist and fine particulate on metal smelters. Pipe diameters of as much as 36 inches were used, with secondary voltages of as high as 220 kV. By 1912, W.A. Schmidt had developed fine wire corona discharge electrodes. By 1916, parallel plate type electrodes had been used successfully. Efficiencies in the 80-90 percent range were possible with these early units.

By the early 1920s, the design of ESPs had improved to allow mathematical modeling of collection efficiency. Anderson (1919) proposed an early model to determine these efficiencies:

$$\text{Efficiency} = 1 - k_a^{\,t}$$

Where; k_a = Precipitation rate parameter
t = ESP treatment time

And Deutsch (1922):

$$\text{Efficiency} = 1 - e^{-(A/V * w)}$$

Where; A = ESP collecting area
V = Flue gas volume
w = Migration velocity

By 1920, the concept of resistivity and conditioning of particulate with water or sulfuric acid had become known (and patented). By the late 1920s, ESPs had also achieved the general form in which they exist today. Over the years, the design and spacing of the electrodes within the ESP have undergone constant revision, but the concept has not changed significantly. However, the performance requirements of the ESPs have changed dramatically from the early years. Where ESPs were installed to recover product or as a "good neighbor policy" in the early years, ESPs are now required to achieve stringent emission requirements. Notably, the size of the ESPs has increased to accommodate these lower particulate emissions requirements. In 1963, Matts and Ohnfeldt proposed a "modified Deutsch equation" to account for particle size distribution effects at higher efficiencies:

$$\text{Efficiency} = 1 - e^{-(A/V * w_k)^N}$$

Where; A = ESP collecting area
V = Flue gas volume
w_k = Precipitation rate parameter
N = typically 0.5-0.8 (depends on particle size distribution)

This equation is still in use today, with modern statistical methods used to determine the exponent (or slope effect). In recent years the size of ESPs is expressed in terms of treatment time (in seconds) or as the ratio of area to volume (A/V). There are several ESP sizing models in use in industry, each a minor variation of the above.

Electrical energization and control of sparking in ESPs has also changed dramatically over the years. The basic concept remains negative DC energization, but specialty means of providing power have developed. Base energization has proceeded from mechanical, to vacuum tube, to saturable core reactors, to silicon controlled rectifiers. In 1950, H.J. White developed and patented pulse energization. More recently (1990s), high frequency transformers have emerged as an alternate to conventional 60 Hz transformer-rectifiers. Controls have also progressed from use of "manual", to analog, to solid state, to microprocessor automatic controls. The most modern controls allow much tighter operation up against the sparking level of the ESP process. Controls are also capable of self-adjusting the current and intermittent energization levels in order to achieve maximum collection efficiency during back-corona conditions.

Collection efficiency of ESPs has improved from 70-90 percent achieved in the early years, to the current levels of 99 percent and higher. Particulate emissions as low or lower than those possible with other air pollution control devices such as scrubbers or fabric filters, have been demonstrated in properly designed and operated ESPs.

3.0 OVERVIEW OF ELECTROSTATIC PRECIPITATORS

An ESP collects and removes particles in flue gas by electrically charging particles. An intense electric field is maintained between high-voltage discharge electrodes, typically wires, rigid electrodes, or rigid frames, and the grounded collecting electrodes, typically plates. A corona discharge from the discharge electrodes ionizes the flue gas passing through the precipitator, and gas ions subsequently ionize fly ash or other particles. The negatively charged particles are then attracted and collected on grounded collecting electrodes (collection plates). Some designs also incorporate high voltage collection surfaces that collect oppositely charged particles. Because precipitators act only on the particulate to be removed, and only minimally hinder flue gas flow, they have very low-pressure drops, and thus low energy requirements and operating costs. The collecting electrodes in dry precipitators are rapped periodically or continuously to dislodge collected particulate, which falls into hoppers for removal. In wet precipitators, a water spray removes the particulate from the collecting plates and discharge electrodes.

Although dry and wet ESP collection systems are conceptually similar, wet precipitators require more corrosion resistant materials. A typical vertical configuration has cylindrical collecting electrodes with discharge electrodes located in the centers of the cylinders. A typical horizontal flow wet configuration is very similar to a dry configuration. Wet precipitators are useful in obtaining low opacities through the removal of acid gases and mists, in addition to fine particulate. Since wet ESPs deal with particulate in liquid form, there are no rapping reentrainment losses or back corona problems. In properly designed wet ESPs there is a minimal water carry-over. Wet ESPs for larger gas flows are common with a horizontal flow design and plate type collecting electrodes, similar to what is used for dry ESPs.

In a typical electrostatic precipitator, collecting plates are arranged parallel to the flue gas flow with discharge electrodes between them. Most precipitators have multiple independent electrical sections. Each independent section removes a fraction of the particulate in the gas stream. This arrangement generates higher voltages in the first sections of the precipitator, where there is more particulate to be removed. Lower voltages will result in the final, cleaner precipitator sections when the same electrode geometries are used as in the front sections. By contrast, precipitator current (measured in milliamps) increases from the inlet to the outlet sections. Excessive sparking between the discharge and collecting electrodes should be avoided in all fields.

Precipitator size and the operating voltage are key factors in determining electrostatic precipitator removal efficiency. Higher treatment times lead to better removal efficiencies. Maximizing operating voltage (i.e. with automatic voltage controllers) ensures maximum particle charging and better removal efficiencies. Controllers detect spark onset, and maintain voltages just below the level at which sparking would occur. For high resistivity conditions the control strategy may be slightly different: to avoid back-corona and the subsequent loss in collection efficiency the current input can be optimized while at the same time maximizing the operating voltage. Electrostatic precipitators can achieve overall (mass) collection efficiencies exceeding 99.9 percent, so that excellent control of PM-10 and PM-2.5 will be achieved with well-designed and operated electrostatic precipitators.

4.0 TERMINOLOGY FOR ELECTROSTATIC PRECIPITATORS

(Note: The following applies to both dry and wet electrostatic precipitators unless otherwise noted)

4.1 ENVELOPING STRUCTURE

A. Casing (see illustrations 4.1-1, 4.1-2, 4.1-3, 4.1-4)

Casing is the enveloping structure to enclose the internal components of the precipitator. Rectangular or cylindrical configurations are used. The casing includes the gas-tight roof, sidewalls, end walls and hoppers and/or bottoms. A gas-tight dividing wall is used to separate chambers. A non-gas-tight load-bearing wall is used to separate bus sections. The casing is sometimes called the housing or shell.

1. Rectangular Configuration

a. Gas-tight or hot roof (top of gas compartment)

b. Side wall

c. Gas inlet and outlet transitions
   i. Nozzles (pyramidal)
   ii. Plenum (rectangular)

d. Dividing wall (gas-tight)

e. Load bearing wall (non-gas-tight) and/or bayline partition (support structure only)

f. Expansion joints

g. Slide bearing

h. End wall (Dry ESP)

i. Hopper(s) (pyramidal or trough dust receptacle(s)) and/or pan bottoms at bottom of ESP to gather collected dust (Dry ESP)

j. External cold (non-gas-tight) roof (Dry ESP)

k. Internal longitudinal bracing (Dry ESP)

l. Internal transverse bracing (Dry ESP)

m. Bottom or sump (Wet ESP)

n. Drain (Wet ESP)

o. Overflow (Wet ESP)

p. Integral recycling tank (Wet ESP)

q. Bottom or top fog sprays (Wet ESP)

2. Cylindrical Configuration

a. Gas inlet

b. Gas outlet

c. Head

d. Shell

e. Hoppers and/or bottom (Dry ESP)

f. Bottom or sump (Wet ESP)

B. Auxiliary Items

1. Insulator Enclosures

a. Insulator compartment - Enclosure for the insulator(s) supporting the high voltage system (may contain one or more insulators, but not enclosing the roof as a whole).

b. Penthouse – A weatherproof, gas-tight or pressurized enclosure over the entire precipitator that contains the high voltage insulators.

c. Insulator tunnel (Dry ESP) – A weatherproof, gas–tight enclosure, transverse or longitudinal to the precipitator, to contain a row of high voltage insulators.

2. Weather Enclosures

a. Upper weather enclosure - A non-air-tight enclosure on the roof of the precipitator to shelter external equipment (T-R sets, rappers, purge air fans, etc.) and maintenance personnel.

b. Lower weather enclosure - A non-air-tight enclosure at the base of the precipitator to protect hoppers from wind and/or other detrimental weather conditions.

3. Access

a. Doors - A hinged or detachable cover provided with a hand-operated fastening device where accessibility is required.

b. Bolted plate - A cover provided with sufficient bolts to insure tight closure where occasional accessibility is required.

4. Dampers

a. Control - A device installed in a duct to regulate the gas flow by degree of closure. Examples: Butterfly, multi-louver types, etc.

b. Isolation - A device installed in a duct to isolate a precipitator chamber from process gas. Examples:

Single-or double-blade guillotine (with or without air purge/seal system). Also referred to as tight shut-off dampers.

5. Safety Grounding Device - A device for physically grounding the high voltage system prior to personnel entering the precipitator. The most common type consists of a conductor, one end that is grounded to the casing, the other end that is attached to the high voltage system using an insulated operating lever or rod.

6. Key Interlock System – A system of personnel protection to ensure T-R de-energization prior to allowing entry into an otherwise energized precipitator unit.

7. Ductwork Transition - Inlet or outlet duct connection to the precipitator spanning a change in shape or cross-sectional area. Transitions are normally included as part of the precipitator. Examples: Nozzles or plenums.

8. Gas Distribution Devices - Internal elements in the transition or ductwork designed to produce the desired velocity contour at the inlet and outlet face of the precipitator. Examples: Turning or ladder vanes, perforated plates or distribution channels.

   a. Turning vanes – Devices (i.e. a flat or curved thin plate) installed in the ductwork or in a transition to guide the gas and dust flow through the ductwork in order to minimize pressure drop and to control the velocity distribution and dust concentration contours.

   b. Perforated plate – A sheet metal or steel plate with either round or square holes of various diameters located at and used to distribute and balance gas flow at the ESP inlet and outlet faces.

   c. Anti-sneakage baffles - Internal baffle elements within the precipitator to prevent the gas from bypassing the active zone or field of the ESP. These are typically located along the vertical walls of the casing. Typically, the baffle surface is normal to the direction of gas flow.

   d. Hopper baffles – Internal baffle elements within the precipitator hopper to prevent hopper sweepage.

   e. Gas distribution device rapper - A device used to prevent dust buildup on the gas distribution device by dislodging dust from a perforated flow distribution plate. Fouling or buildup on the plates can cause significant distortion of the gas flow patterns.

4.2 COLLECTING ELECTRODE SYSTEM

Dry ESP: (see illustrations 4.2-5, 4.2-6)

The Collecting System: The portion of the precipitator to which the charged ash/dust particles are driven and to which they adhere.

A. Collecting Surface

The individual elements that make up the collecting system and which in total provide the surface area of the precipitator for the deposition of dust particles. Collecting surfaces may be panel type, made up of several panels (4–10) loosely held within support and rapping bars; or, shop assembled type, where panels are physically joined by crimping or welding into larger plate assemblies.

B. Collecting Surface Rapper

A device for imparting vibration or impact to the collecting surface to dislodge the deposited ash/dust particles. The impact is generally achieved by electrical or mechanical means.

C. Gas Passage (plate spacing)

The horizontal space between two adjacent rows of grounded collecting surfaces measured from collecting surface centerline to collecting surface centerline and stated in inches or mm.

Wet ESP: (see illustrations 4.2-7, 4.2-8)

Collecting System: The portion of the precipitator to which the charged dust particles and liquid droplets are collected and are washed off. There are no rappers utilized for Wet ESPs. Instead water sprays are used.

A. Collecting Surface

The individual elements that make up the collecting system and which collectively provide the total surface area of the precipitator for the deposition of dust particles and liquid droplets. These could be plate type or tubular.

B. Bottom or Top Fog Sprays

C. Wash Sprays

D. Gas Flow Orientation

There are several commercial wet ESP designs that are of horizontal-flow, up-flow and down-flow (vertical-flow) orientation.

4.3 HIGH VOLTAGE SYSTEM

All parts of the precipitator that are maintained at a high electrical potential under normal operating conditions.

A. High Voltage Structure

The structural elements necessary to support the high voltage discharge electrodes in relation to the grounded collecting surface. High voltage insulators are used to electrically isolate and support this system.

B. Discharge Electrode

The component that is installed in the high voltage system to perform the function of ionizing the gas and creating the electric field. Typical configurations are:

Rigid Discharge Electrode (RDE)
Rigid Frame (RF)
Weighted Wire (W/W)

C. Discharge Electrode Rapper (Dry ESP)

A device for imparting vibration or impact to the discharge electrodes in order to dislodge ash/dust accumulation.

D. High Voltage System Support Insulator (Dry ESP)

A device to physically support and electrically isolate the high voltage system from ground.

E. Anti-Sway Insulators (Dry ESP)

To prevent the high voltage system from swinging due either to high velocity or electrical forces. Not necessary in four-point high voltage suspension designs.

F. Rapper Insulator (Dry ESP)

A device to electrically isolate discharge electrode rappers, yet transmit mechanically forces necessary to create vibration or shock in the high voltage system.

G. Four Point Suspension (Dry ESP)

Method of supporting a high voltage bus section from four support insulators.

H. Two Point Suspension (Dry ESP)

Method of supporting a high voltage bus section from two support insulators.

4.4 PRECIPITATOR ARRANGEMENTS

(See illustrations for dry and wet ESPs)

A. Precipitator

A precipitator is any number of collecting surfaces arrangements or devices using mechanical, electrical or chemical means contained within one independent casing. A precipitator is considered as a single unit contained in a mechanically independent casing. A precipitator contains one or more chambers or fields as described below.

B. Chamber (contained within an ESP)

A longitudinal mechanical subdivision of a precipitator. A precipitator may contain one or more chambers in parallel. The number of chambers is equal to the number of longitudinal structural partitions within the precipitator, plus one (an ESP with a single partition wall is referred to as a two-chamber precipitator). The spacing between the partition walls sets the width of each chamber. Typically, the spacing is about equal. The partition may be gas-tight or an open truss.

Note: Very wide precipitator chambers are frequently equipped with non-gas-tight load bearing walls (baylines) for structural considerations. These precipitators, by definition, are single chamber precipitators.

C. Bus Section

The smallest electrical portion of the precipitator that can be independently de-energized (by sub-division of the high voltage system and arrangement of support insulators). Bus sections may be of different sizes within a given casing.

D. Electrical Field

A singular group of discharge electrodes in the direction of gas flow supported and energized by the bus sections. The field is typically energized by only one power supply in the direction of gas flow, but may have more than one high voltage power supply perpendicular to flow.

E. Mechanical Field

A singular group of parallel collecting plates in the direction of gas flow. Each field is an assemblage of a number of collecting plate panels typically supported at the top and guided at the bottom. A mechanical field may be divided into two electrical fields.

F. Field or Pass:

Number of consecutive treatments with one or more independent power supply in the direction of the gas flow.

4.5 ELECTRICAL

A. High Voltage Power Supply

An electrical supply unit that produces the high voltage DC required for the precipitation process to occur. The supply system consists of a transformer-rectifier (T-R) combination and associated controls. Multiple bus sections can be energized by one power supply.

1. Transformer-Rectifier (T-R)

A unit comprised of a transformer for stepping up normal service to voltages in the kilovolt range, and a full wave bridge rectifier operating at high voltage to convert alternating current (AC) to unidirectional current (DC).

a. Types of rectifiers

i. (Solid state) Silicon rectifier - A rectifier "stack" consisting of multiple silicon diodes, arranged in series with either resistance/capacitance (RC) or metal oxide varistor (MOV) transient compensation, immersed along with the transformer core in mineral oil, silicone or R-Temp fluid.

ii. High frequency switching transformer rectifier – A power supply with built-in power and control electronics and generates a ripple free DC voltage (e.g. operating frequency of 50 kHz).

iii. Pulsed power supply - Generates pulses of high amplitude (kV) in between a base voltage (may be equal to corona onset voltage). Pulse width can be in the range of 1 to 200 µs. A separate conventional T/R set may be necessary for the base voltage.

iv. Other - Older precipitator installations may be equipped with electronic tubes, selenium rectifiers or mechanical rectifiers; however these types are now obsolete.

B. Impedance Devices

1. A linear inductor or current limiting reactor (CLR) is required with silicon controlled rectifier (SCR) controllers to limit current surges and waveform rise time.

2. A transformer with a specially designed high impedance core and coils that performs the same function as a CLR.

3. A saturable core reactor that limits the amount of power to a T-R based on an analog signal fed to its primary winding (becoming obsolete).

4. Resistors.

C. Control Equipment

1. High Voltage Power Supply Control Equipment

Electrical components required to protect, monitor, and regulate the power supplied to the precipitator high voltage system. Regulation of the primary voltage of the high voltage transformer-rectifier is accomplished by one of the following devices:

a. Saturable core reactor - A variable impedance device for automatic operation. By current standards, a very slow device that is now obsolete.

b. Variable "auto-transformer" control – A manual type of system that is now obsolete.

c. Silicon-controlled rectifier

(SCR) – A fast-acting electronic switch for voltage regulation.

The above can be:

i. Automatic power supply control - Automatic regulation of high voltage power that follows changes in precipitator operating conditions utilizing feedback signal(s). Modern controls are microprocessor based with remote control and data acquisition systems. Older controls were solid state and tube-type.

ii. Manual power supply control - Manual regulation of high voltage power based on precipitator operating conditions as observed by plant operators.

d. SE control (pulsar) – Equipment for intermittent energization. This feature is a common build-in for modern microprocessors.

2. Auxiliary Control Equipment

Electrical components required to protect, monitor, and control the operation of precipitator rappers, heaters, and other associated equipment.

D. High Voltage Conductor

Conductor to transmit the high voltage from the transformer-rectifier to the precipitator high voltage system.

1. High Voltage Bus

An electrical conductor (generally copper, aluminum or steel) enclosed within a grounded metal duct.

2. Cable (high voltage transmitting)

a. Dry cable

b. Oil-filled cable (obsolete)

E. General Electrical Terms

1. Primary Current

The current in the primary winding of a transformer as measured by an analog AC ammeter or signal conditioning circuit that feeds a digital display or microprocessor control/display system.

2. Primary Voltage

The voltage across the primary winding of a transformer as measured by an analog AC voltmeter or signal conditioning circuit that feeds a digital display or microprocessor control/display system.

3. Precipitator Current

The rectified or unidirectional (DC) average charging current to the precipitator measured by an analog milliamp meter or signal conditioning circuit located in the ground leg of the rectifier that feeds a digital display or microprocessor control/display system. Average charging current is equal to average corona current.

4. Precipitator Voltage

The rectified or unidirectional (DC) average voltage to the (high voltage) precipitator measured by an analog voltmeter or signal conditioning circuit located in the ground leg of the rectifier that feeds a digital display or microprocessor control/display system. Most modern controls distinguish between peak, average, and valley voltage.

5. Spark

A discharge from the high voltage system to the grounded system, self-extinguishing and of short duration.

6. Arc

An electrical discharge of substantial magnitude from the high voltage system to the grounded system, of relatively long duration and not tending to be immediately self-extinguishing.

7. Pulsing

"Intermittent Energization (IE)", "Semi Pulsing," and "Pulse Blocking" are terms commonly used to define 60 Hertz pulsing of precipitator electrical sections. In these systems some of the half-waves are blocked to create a more pronounced ripple. Charging ratio (CR) is a term that normally gives the repetition rate of half cycles. (e.g. CR 1:5 means one pulse out of five half waves are used for charging the ESP.)

4.6 GENERAL AND MISCELLANEOUS

Aerosol—Particle of solid or liquid matter that can remain suspended in the air because of its small size. Particulates under 1 micron in diameter are generally called aerosols. A specific definition of aerosol may be needed for a particular specification.

Air Core Reactor (ACR)—Protects the T/R diode bridge from high voltage transients that occur within the ESP.

Air Leakage—Unwanted air entering into an exhaust system (holes in ducts, missing and ineffective seals, etc.).

Aspect Ratio---The ratio obtained by dividing the length of the precipitator by the effective height.

Automatic Power Supply—Automatic regulation of high voltage power for changes in precipitator operating conditions utilizing feedback signal(s). Sometimes referred to as AVC (automatic voltage control).

Automatic Voltage Control (AVC)--- Monitors secondary current and voltages to assist an operator in determining optimum power levels and spark rates of each field (Note: "optimum" settings need to account for process variables (e.g. fuel or temperature changes).

Back Corona—A phenomenon that occurs when the gas within a high resistivity dust layer becomes ionized, which causes heavy positive ion backflow, which neutralizes negative ion current and reduces voltage levels. This impact on the dust layer can result in reentrainment of collected particles.

Baghouse---An air pollution control device that traps particulates by forcing gas streams through large permeable bags usually made of glass fibers.

Bridge—Material building across an opening (such as a hopper opening) and blocking off that opening.

Bushing—Alternate term for high voltage insulator.

Capture Velocity—The air velocity at any point in front of a hood or at a hood opening necessary to overcome opposing air currents and to capture the contaminated air at the point by causing it to flow into the hood.

Carrying Velocity—The gas velocity that is necessary to keep the dust airborne (usually 3500 to 4599 ft/min in ductwork depending upon the nature of the dust).

Cold Roof—The casing section that serves as the penthouse ceiling/ESP roof-walking surface.

Collection Efficiency---The weight of particulate collected per unit time divided by the weight of particulate entering the precipitator during the same unit time expressed as a percentage. The computation is as follows:

$$\text{Efficiency} = \frac{(\text{Part. In}) - (\text{Part. Out})}{\text{Particulate In}} * 100$$

Concentration—The amount of dust or mist in gas. Usually expressed in terms of particulate weight per volume of gas (grains per cubic foot, pounds per 1000 pounds of gas, parts per million or milligrams per cubic meter).

Current Density---The amount of secondary current per unit of precipitator collecting surface or discharge electrode. Common units are mA/m^2, mA/ft^2 and nA/cm^2.

Collecting Surface Area---The total flat projected area of collecting surface exposed to the active electrical field (effective length * effective height * 2 * number of collection plates).

Corona Power (KW)---The product of secondary current and secondary voltage. Power density is generally expressed in terms of: (1) watts per square foot of collecting surface, or (2) watts per 1000 acfm of gas flow. A multiplier of approximately 1.07 can be applied to adjust for a ripple of high voltage.

Current Limiting Reactor (CLR)—An impedance device used to protect T/R diode bridge by limiting the current during an arc/spark. It also provides a means of wave shaping voltage to provide higher average values.

Dew Point—The temperature at which the equilibrium vapor pressure of a liquid is equal to the partial pressure of the respective vapor. For air containing water vapor, it is the temperature at which liquid water begins to condense for a given state of humidity and pressure. For flue gas containing water vapor and SO_3, it is the set of conditions at which liquid sulfuric acid begins to condense as the temperature is reduced.

Dielectric Fluid—A substance used to keep the transformer operating at moderate temperature levels, and as a dielectric where space is concerned.

Diode Assembly—Converts high voltage AC output of the transformer to a DC signal.

Drag Conveyor—Chain type scraper installed in a pan bottom on the ESP to gather dust (in lieu of hoppers). Typically used on black liquor recovery boilers.

Dust—A dispersion aerosol formed by the grinding or atomizing of a solid, or the transfer of a powder into a state of suspension through the action of air currents or by vibration.

Dust Collector Efficiency-See Collection Efficiency.

Dust or Mist Concentration—The weight of dust or mist contained in a unit of gas.

Effective Length---Total projected length of collecting surface measured in the direction of gas flow. Length between fields is to be excluded.

Electro Filter— German terminology for electrostatic precipitator.

Electrostatic Attraction—Mutual attraction, caused by static electricity, by which particles tend to draw together or adhere.

Electrostatic Precipitator (ESP)—An air pollution control device that removes particulate matter from an air or gas stream by imparting an electrical charge to the particles allowing electrostatic forces to attract the particles to oppositely charged collection surfaces.

Emission Control Equipment—Machinery used to remove air contaminants from the discharge of industrial exhaust streams.

EP or ESP—Abbreviation for electrostatic precipitator.

Fly Ash—The particulate impurities resulting from the burning of coal and other material.

Fossil Fuels—Coal, oil and natural gas, so called because they are the remains of ancient plant and animal life.

Gas Flow Rate—The volume of process gas at any point of the plant exhaust system measured in terms of time. Typical units of measurement are:

acfm—Actual Cubic Feet per Minute
am^3/hr—Actual Cubic Meters per Hour
scfm—Standard Cubic Feet per Minute (Flow corrected to standard temperature (70 F) and pressure (one-atmosphere))
dscfm— Dry Standard Cubic Feet per Minute

Grain—A dust weight unit commonly used in air pollution control. One grain = 1/7000 lb.

Grain Loading—The concentration of particles contained in the gas emitted from a pollution source. The measurement is specified as grains of dust per volume of gas emitted.

Heat Jacket—Second "skin" installed over ESP casing with heated air blown through the intermediate space. Serves to replace insulation in preventing condensation or corrosion.

Hopper Capacity (Dry ESP)---Total volumetric capacity of the hopper(s) measured from the hopper ridge plane or a plane 10 to 12 inches below the high voltage system or plates, whichever is lower.

Hot Roof—The ESP top casing that separates the hot gas on one side and insulator compartment on the other.

Insulation—Any method that will retard the flow of heat through a wall.

Insulator—Material (i.e. ceramic, alumina) used to separate high voltage components from grounded parts.

Liquid to gas (L/G) ratio (Wet ESP)--- Common unit is gpm/1000cfm (gallons per minute per 1000 cubic feet per minute). This is the amount of liquid introduced in the Wet ESP in order to keep it clean.

Manometer—A u-shaped device for measuring the static pressure at a point relative to some other point; the pressure difference causes water to rise or fall. The difference in the level of the water columns is equivalent to the pressure differential.

Manual Power Supply—Manual regulation of high voltage power based on precipitator operating conditions as observed by plant operators.

Mechanical Collector—Devices to remove particulate from gas streams and are functionally dependent on the laws of mechanics governing the motion of bodies in space. Devices can be operated dry or wet. When operated wet, devices are generally called scrubbers. Examples of mechanical collectors are cyclones, settling chambers and various types of impingement collectors.

MIGI—Magnetic impulse gravity impact rapper.

Modeling—An investigative technique using computer, mathematical or physical representation of a system that accounts for all or some of its known properties. Typically used to define flow characteristics and distribution.

Nozzle---Ductwork transition at ESP inlet or outlet.

Opacity—The amount of light obscured by particulate contained in the gas. Opacity is typically used as an indicator of performance for a particulate control device.

Precipitator Gas Velocity--- Generally expressed in terms of ft/sec or m/sec and computed as follows:

$$\text{Velocity} = \frac{\text{Gas Volume (ft}^3\text{/sec)}}{\text{ESP Effective Cross-Section Area (ft}^2\text{)}}$$

Where effective cross-section is effective field height * width of gas passage * number of passages.

Particulate—A particle of solid matter.

Particulate Concentration (Ash, Dust or Mist)---The weight of particulate or mist contained in a unit of gas (grams per normal cubic meter, pounds per thousand pounds of gas, pounds per million Btu heat input, grains per actual cubic foot of gas or grains per standard dry cubic foot). Note: The temperature and pressure of the gas must be specified if stated as volume.

Particulate Matter—Any solid in the atmosphere.

Penthouse—A weatherproof, gas-tight enclosure over the precipitator that shelters the high voltage insulators.

Pitot Tube—A specially constructed probe for taking velocity pressure readings in a duct.

Plenum—Pressure equalizing chamber.

PM_{10}—Particulate matter with an aerodynamic diameter less than or equal to a nominal diameter of 10 microns.

$PM_{2.5}$—Particulate matter with an aerodynamic diameter less than or equal to a nominal 2.5 microns.

PPM (Parts per Million)—The number of parts of a given pollutant in a million parts of air. Units are expressed by weight or volume.

Pressure Drop (ΔP)—The differential pressure between two points in a system. The resistance to flow between the two points.

Primary Collector—A dry or wet collector that is followed by a secondary collector with greater filtering efficiency for collection of smaller diameter particles.

Pulsed Power Supply--- Superimposes high voltage pulses on base voltage to enhance performance in presence of high resistivity dust.

Rapper---Mechanical or electrical hammer used to vibrate ESP internals.

Rapping Intensity (Dry ESP)**---**The “g” force measured at various points on the collecting or discharge electrodes. Measured forces should be specified as longitudinal or transverse.

Reentrainment—The phenomenon whereby dust is collected from the air stream and then is returned to the air stream. This occurs when dust is rapped from a collector plate and then caught up by the moving gas stream.

Resistivity—Reciprocal of conductance. The primary electrical property used in evaluation of collection efficiency of ESPs (expressed in units of ohm-centimeter).

Ringlemann Chart—A series of charts, numbered from 0 to 5, that simulate various smoke densities by defining various percentages of black. These charts were developed and used to measure the opacity of gas leaving a stack. A Ringlemann Number 1 is equal to 20 percent opacity with a Ringlemann Number 5 equal to 100 percent.

Secondary Collector—A dust collector that is preceded by primary collector(s). The secondary filter normally has a higher filtering efficiency.

Settling Chamber—A dry collection device that removes particulate matter from the gas stream by slowing down the exhaust gas velocity.

Specific Collecting Area (SCA)---A figure obtained by dividing total effective collecting surface of the precipitator by gas volume, expressed in $ft^2/1000$ acfm or $m^2/m^3/s$. SCA should always relate to well defined plate spacing.

Stabilizer—Slang term for lower stabilizing insulator.

Stack—A smokestack; a vertical pipe or flue designed to exhaust gases.

Stack Opacity Monitors---USEPA approved monitors utilized to measure the light obscured by particulate contained in the gas at the stack location.

System Gas Volume—All gases flowing through the exhaust gas system including excess air, scavenger air and leakage air).

Transition—An aerodynamically designed inlet or outlet duct connection to the precipitator. Transitions are normally included as part of the precipitator, sometimes referred to as inlet/outlet nozzles.

Traverse—A method of sampling points in a duct where pressure readings will be taken to determine velocity. A traverse divides the duct into equal, evenly distributed areas that are each tested, compensating for errors caused by uneven gas flow in the duct.

Treatment Time--- A figure obtained by dividing the length of a precipitator by the precipitator gas velocity.

Tumbling Hammer—Rotating shaft type internal rapping system.

Turbulent Flow—Fluid flow in which the velocity of a given particle changes constantly both in magnitude and direction.

USEPA---U.S. Environmental Protection Agency

Voltage Divider—A means for supplying a low voltage feedback signal that is proportional to the kV output of the T-R.

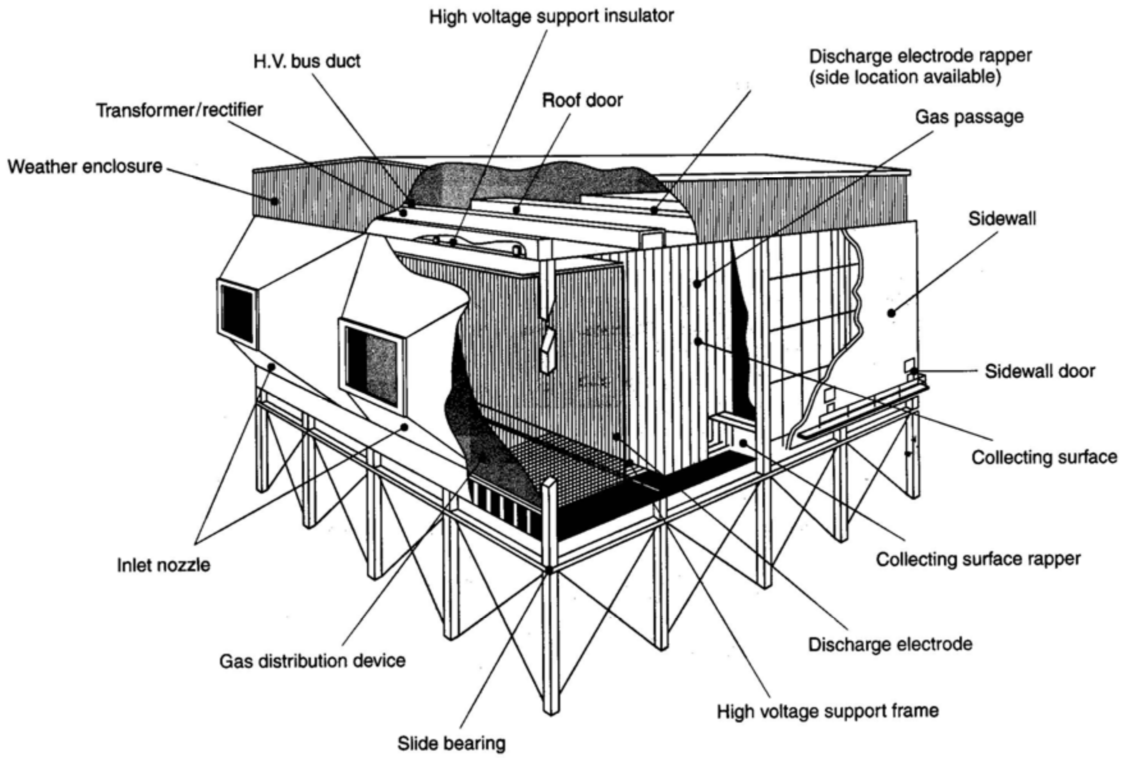
Wet Bottom—An Agitated liquid pan bottom used to gather dust in lieu of hoppers. This system is typically used on black liquor recovery boilers.

Wet Collector—A dust collector that uses water to remove particulate matter from the exhaust gas (wet washers, venturis, wet fans).

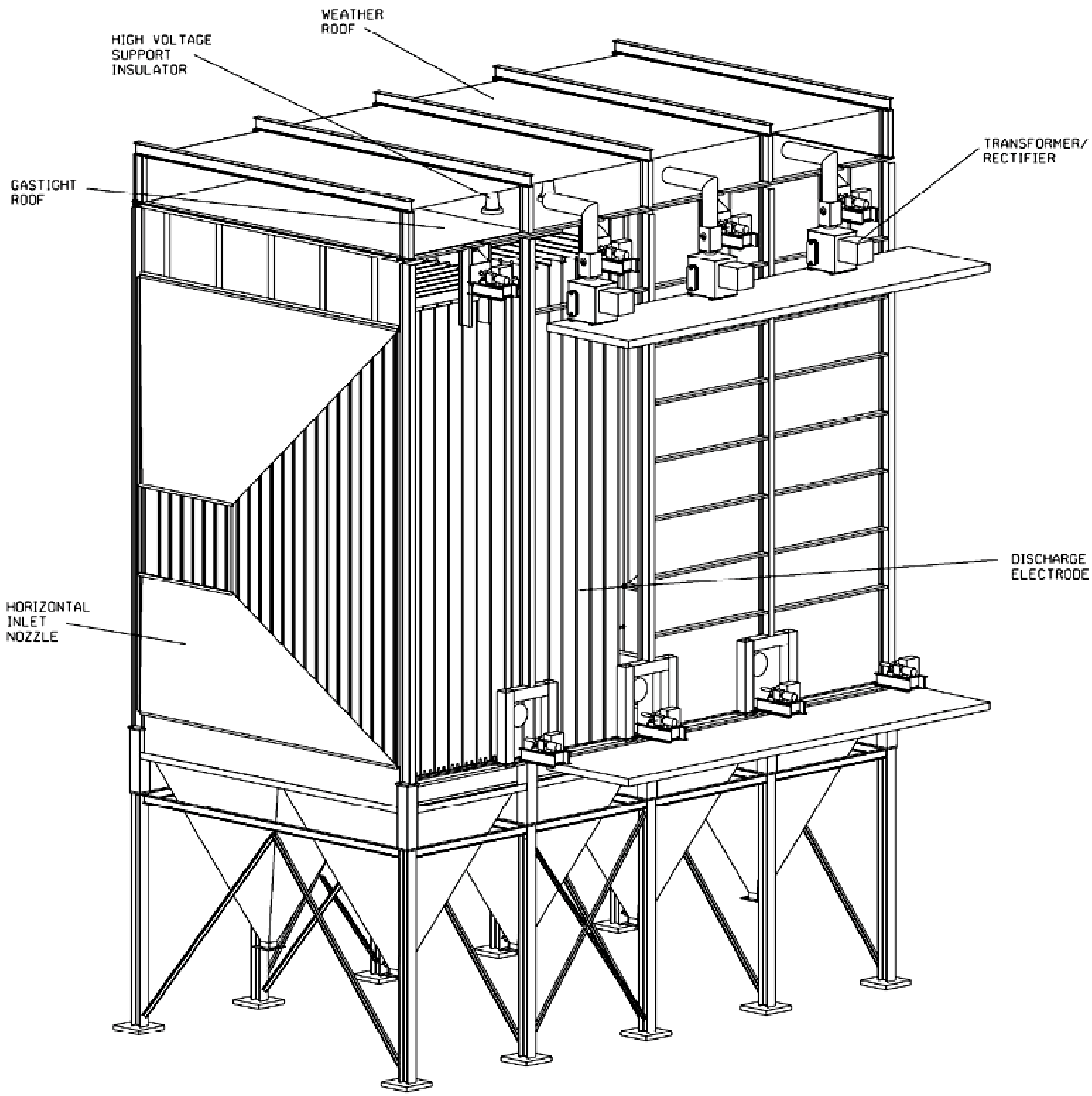
Wet Electrostatic Precipitator (Wet ESP/WESP) ---precipitators for collection of aerosols under saturated conditions.

Illustrations

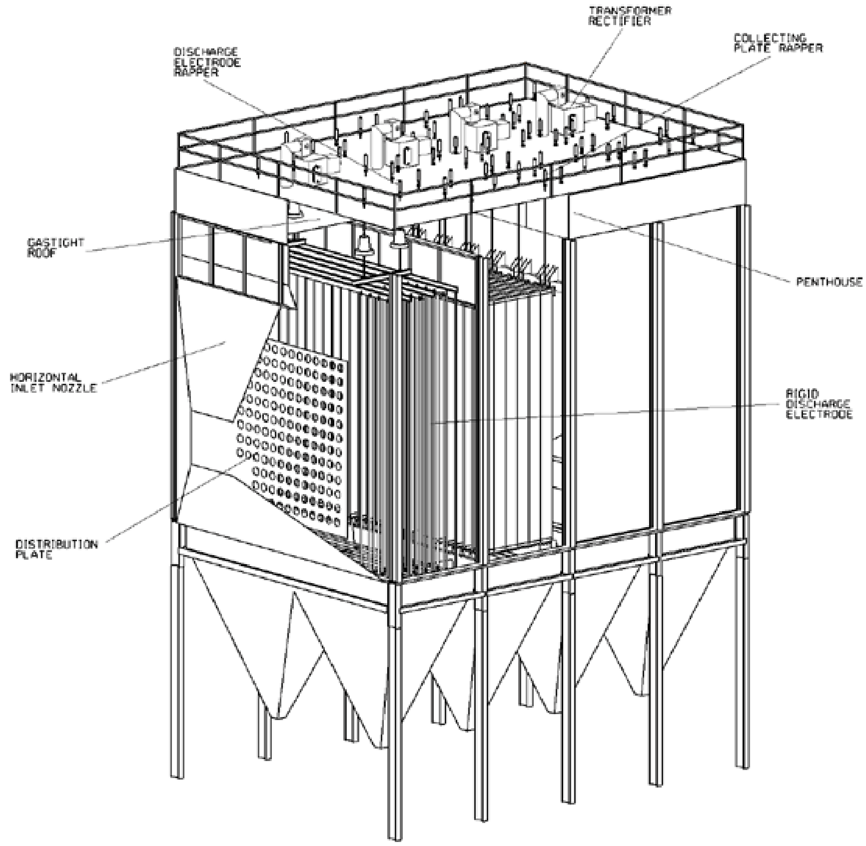
4.1-1 Electrostatic Precipitator Components



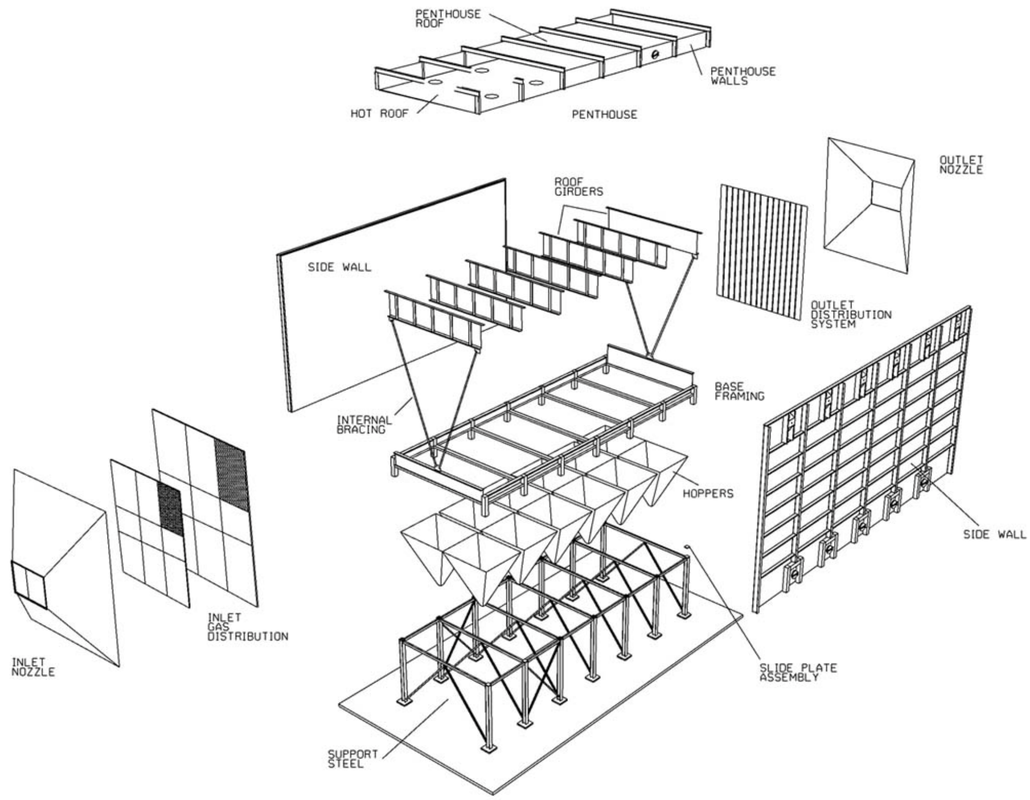
4.1-2 Enveloping Structure



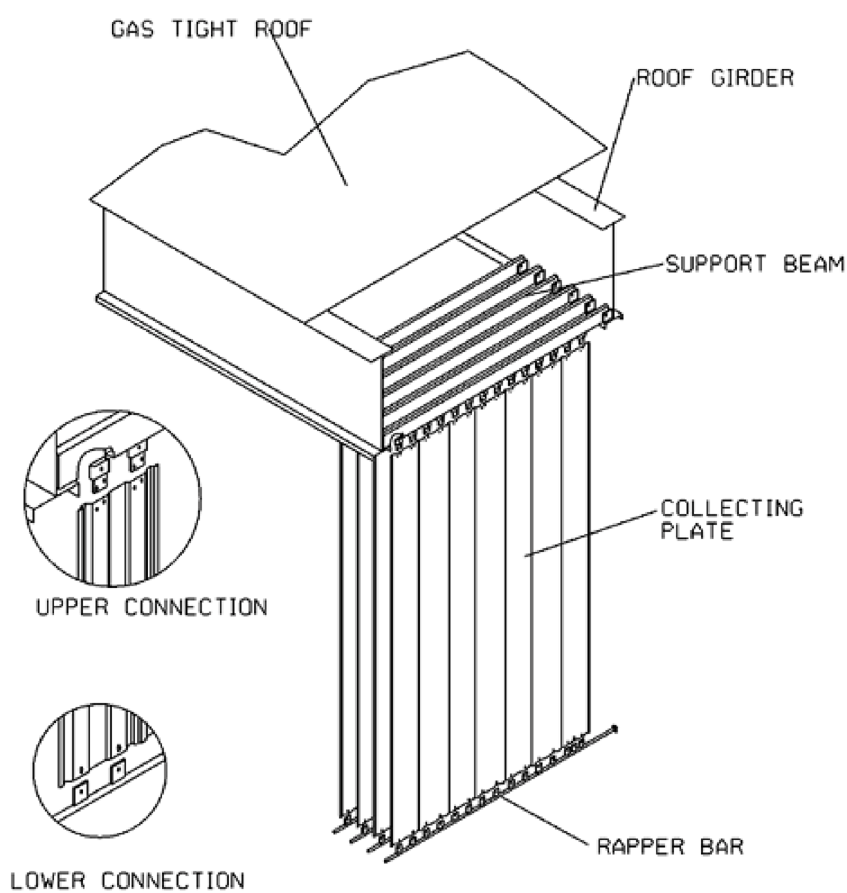
4.1- 3 Enveloping Structure



4.1- 4 Enveloping Structure Components

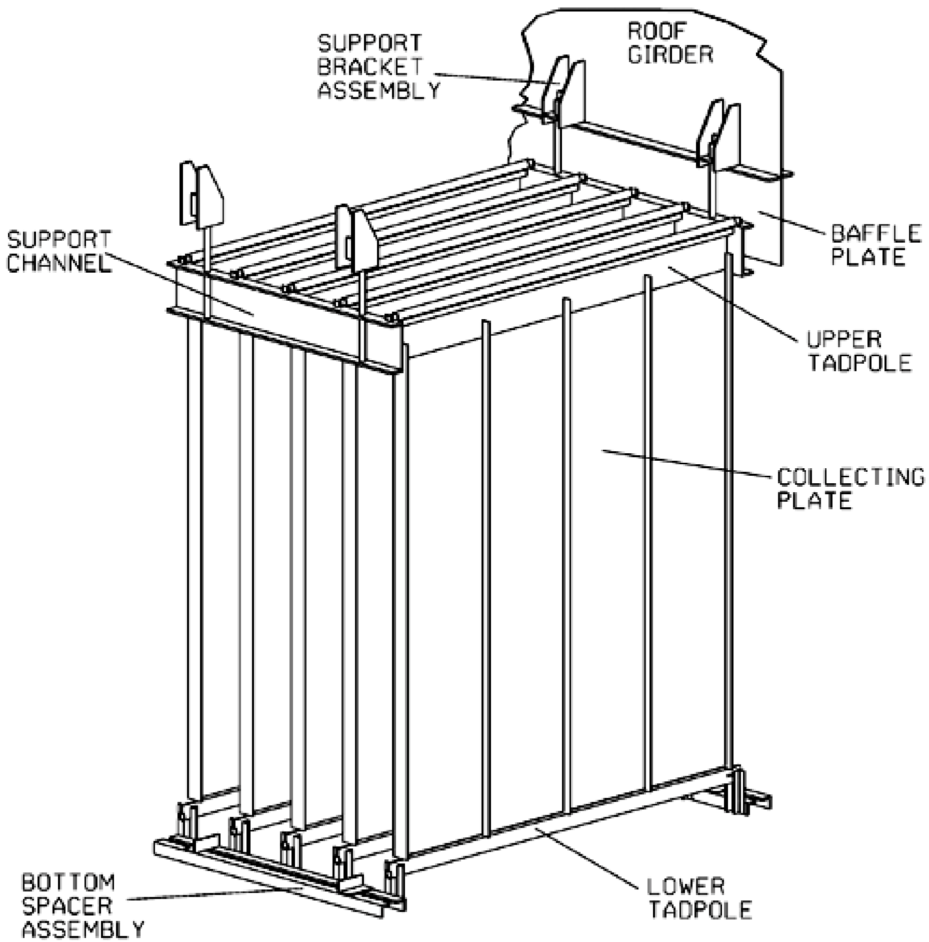


4.2- 5 Collecting Plate Suspension System



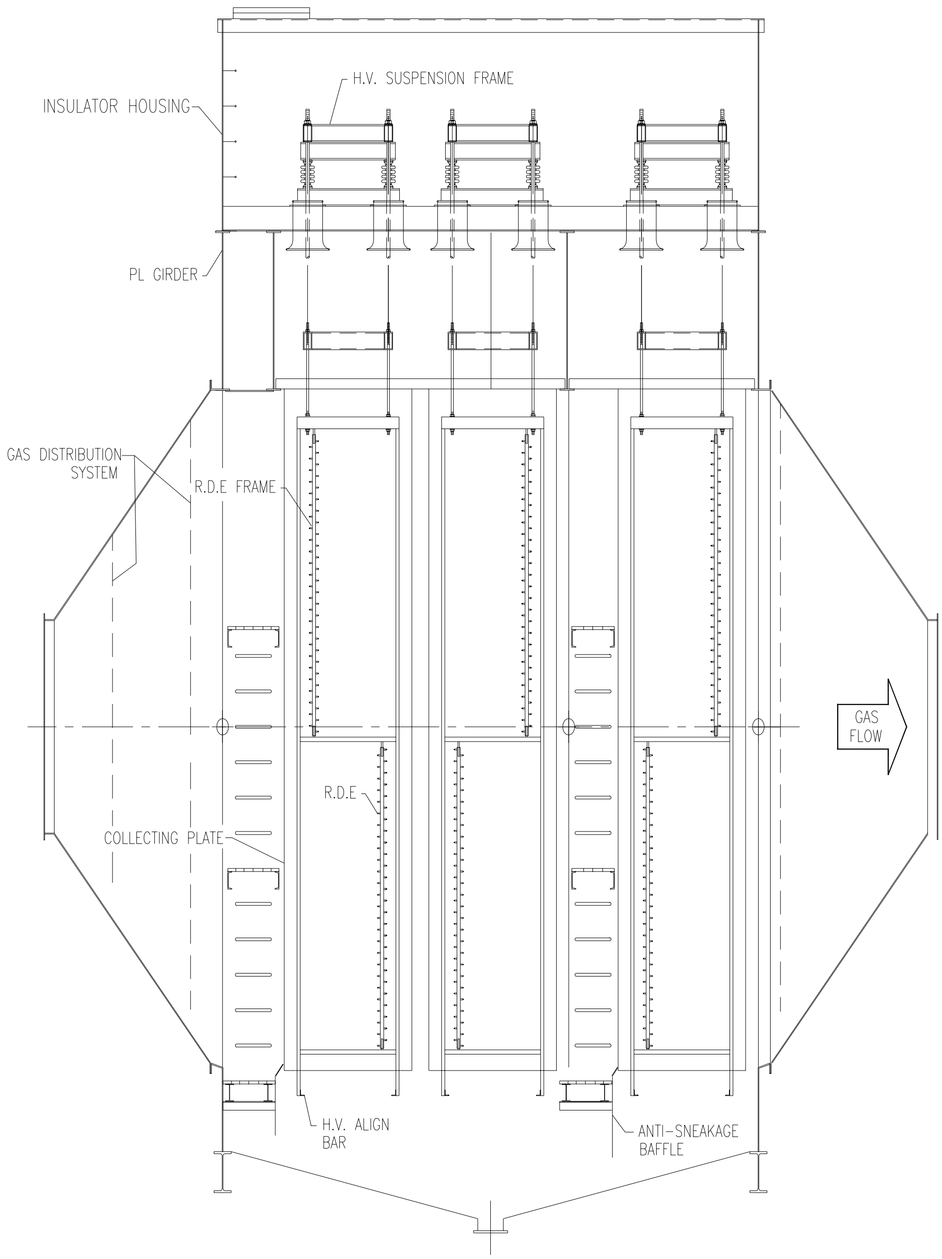
COLLECTING PLATE SUSPENSION SYSTEM

4.2- 6 Collecting Plate Suspension System



COLLECTING PLATE SUSPENSION SYSTEM
5-CURTAINS

4.2-7 Collecting Electrode System (Wet ESP) – horizontal flow, plate type



4.2-8 Collecting Electrode System (Wet ESP) – vertical flow, tubular type