SECTION 5.0

ELECTROSTATIC PRECIPITATORS

Electrostatic precipitators (ESPs) are widely used for controlling particulate emissions from boilers and industrial process sources. To ensure continued operation of the ESPs at the maximum emission control efficiency levels, source specific routine and preventive O&M measures must be identified and implemented. This section provides O&M guidelines for ESPs. A brief description of different types of ESPs is followed by identification of key operating parameters that impact the operation of ESPs. Major operating problems and malfunctions are discussed followed by routine maintenance needs and procedures. Recommendations for operator training and frequency are included.

The information presented in this section has been extracted from the published reports and references presented at the end of this section. These sources also contain additional information regarding operation and maintenance of ESPs.

5.1 Description

5.1.1 Theory of Operation and ESP Types

An electrostatic precipitator uses electrical forces to capture particles in an incoming gas. The particles are given an electrical charge by forcing them to pass through a corona, a region in which gaseous ions flow. The electrical field that forces the charged particles to the walls comes from electrodes maintained at high voltage in the center of the flow path. Figure 5-1 illustrates the basic processes involved in electrostatic precipitation.

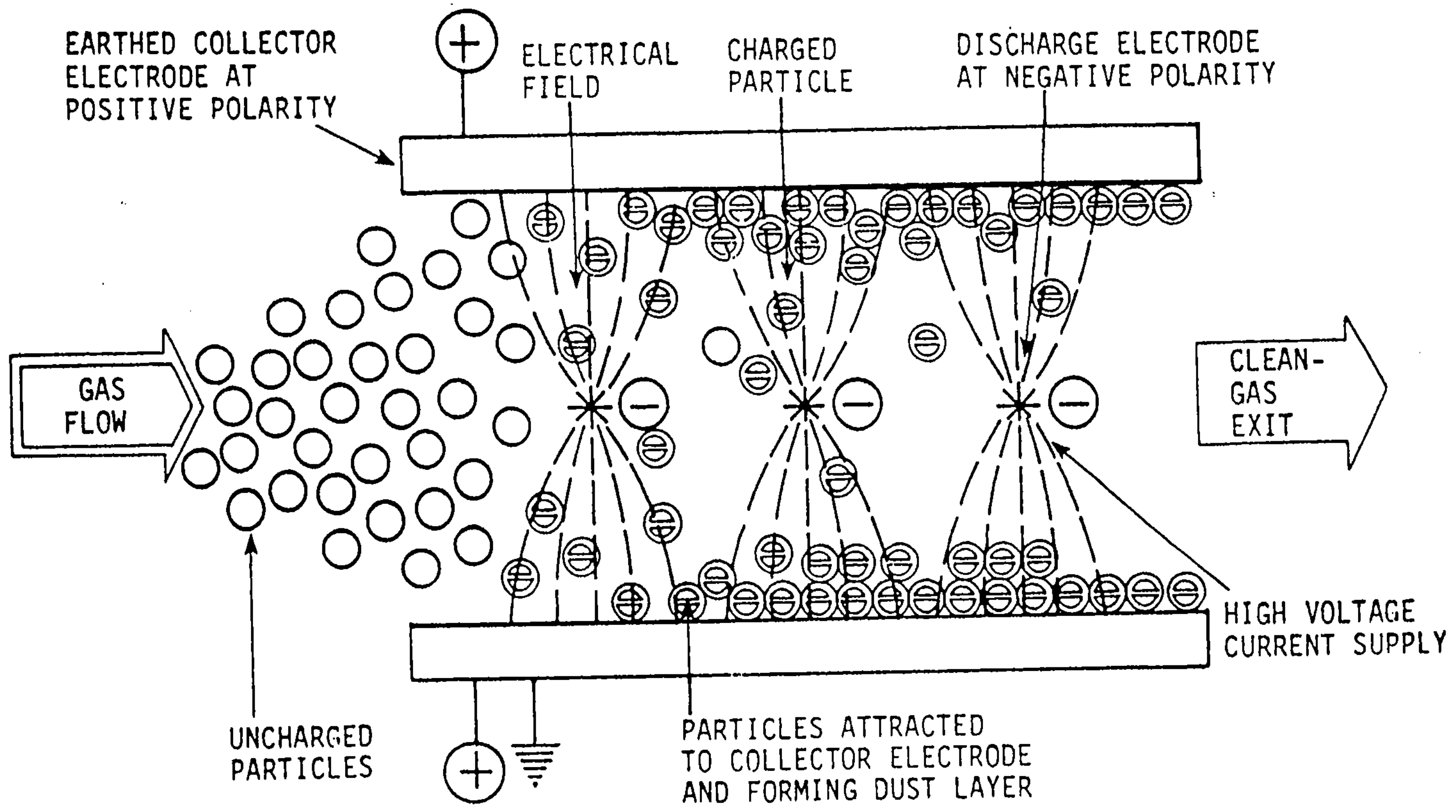

Figure 5-1. Basic processes involved in electrostatic precipitation (Lodge Cottrell)

In a full size ESP, several auxiliaries and support systems are required to effectively implement the electrostatic precipitation principle. Electrical equipment for producing high-voltage supply is necessary for the ESP. A high-voltage transformer (to step up the line voltage) and a rectifier (to convert AC voltage to DC) provide the power necessary for the precipitation process.

The particulate matter collected on the collection plates must be removed by use of a rapping mechanism (or water flushing in case of a wet ESP). The particulate-laden gas stream must travel through the ESP unit at acceptable velocities for effective collection of particulate matter and a fan and ductwork system must be designed and configured to ensure a steady flow of gas through the system.

Figure 5-2 shows an ESP and its main components.

Plate-wire ESPs are used in a wide variety of industrial applications, including coal-fired boilers, cement kilns, solid waste incinerators, paper mill recovery boilers, petroleum refining catalytic cracking units, sinter plants, basic oxygen furnaces, open hearth furnaces, electric arc furnaces, coke oven batteries, and glass furnaces.

5.1.2 ESP Types

Various types of ESP designs are used for a wide range of particulate application. The primary ESP types used in industrial emission control applications are:

- Plate-wire precipitator
- Flat-plate precipitator
- Tubular precipitator, and
- Wet precipitator

Plate-Wire Precipitator--

In a plate-wire ESP, gas flows between parallel plates of sheet metal and high-voltage electrodes. These electrodes are long wires weighted and hanging between the plates or are supported there by mastlike structures (rigid frames). Within each flow path, gas flow must pass each wire in sequence as it flows through the unit.

The plate-wire ESP allows many flow lanes to operate in parallel, and each lane can be quite tall. As a result, this type of precipitator is well-suited for handling large

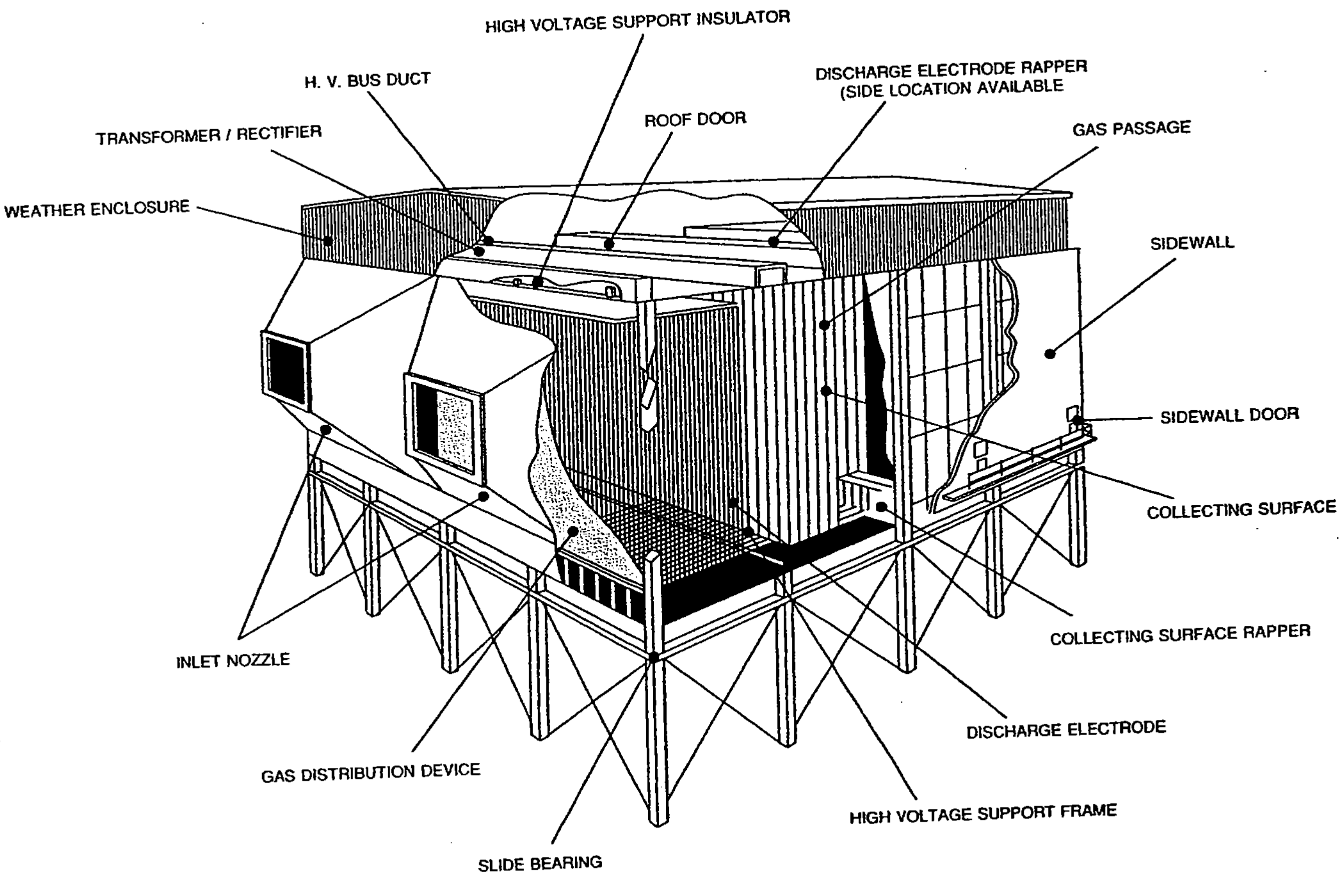

Figure 5-2. Electrostatic precipitator components (Industrial Gas Cleaning Institute).

volumes of gas. The need for rapping the plates to dislodge the collected material has caused the plate to be divided into sections, often three or four in series with one another, which can be rapped independently. The power supplies are often sectionalized in the same way to obtain higher operating voltages, and further electrical sectionalization may be used for increased reliability. Dust also deposits on the discharge electrode wires and must be periodically removed similarly to the collector plate.

The power supplies for the ESP convert the industrial ac voltage (220-480 volts) to pulsating dc voltage in the range of 20,000-100,000 volts as needed. The supply consists of a step-up transformer, high-voltage rectifiers, and sometimes filter capacitors. The unit may supply either half-wave or full-wave rectified dc voltage. There are auxiliary components and controls to allow the voltage to be adjusted to the highest level possible without excessive sparking and to protect the supply and electrodes in the event a heavy arc or short circuit occurs.

The voltage applied to the electrodes causes the gas between the electrodes to break down electrically, an action known as a "corona." The electrodes usually are given a negative polarity because a negative corona supports a higher voltage than does a positive corona before sparking occurs. The ions generated in the corona follow electric field lines from the wires to the collecting plates. Therefore, each wire establishes a charging zone through which the particles must pass.

Particles passing through the charging zone intercept some of the ions, which become attached. Small aerosol particles (<1 μm diameter) can absorb tens of ions before their total charge becomes large enough to repel further ions, and large particles (>10 μm diameter) can absorb tens of thousands. The electrical forces are therefore much stronger on the large particles.

As the particles pass each successive wire, they are driven closer and closer to the collecting walls. The turbulence in the gas, however, tends to keep them uniformly mixed with the gas. The collection process is therefore a competition between the electrical and dispersive forces. Eventually, the particles approach close enough to the walls so that the turbulence drops to low levels and the particles are collected.

If the collected particles could be dislodged into the hopper without losses, the ESP would be extremely efficient. The rapping that dislodges the accumulated layer also projects some of the particles (typically 12% for coal fly ash) back into the gas stream. These reentrained particles are then processed again by later sections, but the particles reentrained in the last section of the ESP have no chance to be recaptured and so escape the unit.

Practical considerations of passing the high voltage into the space between the lanes and allowing for some clearance above the hoppers to support and align electrodes leave room for part of the gas to flow around the charging zones. This is called "sneakage" and amounts to 5-10% of the total flow. Antisneakage baffles usually are placed to force the sneakage flow to mix with the main gas stream for collection in later sections. But, again, the sneakage flow around the last section has no opportunity to be collected.

These losses play a significant role in the overall performance of an ESP. Another major factor is the resistivity of the collected material. Because the particles form a continuous layer on the ESP plates, all the ion current must pass through the layer to reach the ground plates. This current creates an electric field in the layer, and it can become large enough to cause local electrical breakdown. When this occurs, new ions of the wrong polarity are injected into the wire-plate gap where they reduce the charge on the particles and may cause sparking. This breakdown condition is called "back corona."

Back corona is prevalent when the resistivity of the layer is high, usually above 2×10^{11} ohm-cm. For lower resistivities, the operation of the ESP is not impaired by back corona, but resistivities much higher than 2×10^{11} ohm-cm considerably reduce the collection ability of the unit because the severe back corona causes difficulties in charging the particles. At resistivities below 10^8 ohm-cm, the particles are held on the plates so loosely that rapping and nonrapping reentrainment become much more severe. Care must be taken in measuring or estimating resistivity because it is strongly affected by such variables as temperature, moisture, gas composition, particle composition, and surface characteristics.

Flat-Plate Precipitators--

A significant number of smaller precipitators (100,000-200,000 acfm) use flat plates instead of wires for the high-voltage electrodes. The flat plates (United McGill Corp. patents) increase the average electric field that can be used to collect the particles, and they provide an increased surface area for the collection of particles. Corona cannot be generated on flat plates by themselves, so corona-generating electrodes are placed ahead of and sometimes behind the flat-plate collecting zones. These electrodes may be sharp-pointed needles attached to the edges of the plates or independent corona wires. Unlike plate-wire or tubular ESPs, this design operates equally well with either negative or positive polarity. The manufacturer has chosen to use positive polarity to reduce ozone generation. A flat-plate ESP operates with little or no corona current flowing through the collected dust, except directly under the corona needles or wires. This has two consequences. The first is that the unit is somewhat less susceptible to back corona than conventional units are because no back corona is generated in the collected dust, and particles charged with both polarities of ions have large collection surfaces available. The second consequence is that the lack of current in the collected layer causes an electrical force that tends to remove the layer from the collecting surface; this can lead to high rapping losses.

Flat-plate ESPs seem to have wide application for high-resistivity particles with small (1-2 μm) mass median diameters (MMDs). These applications especially emphasize the strengths of the design because the electrical dislodging forces are weaker for small particles than for large ones. Fly ash has been successfully collected with this type of ESP, but low-flow velocity appears to be critical for avoiding high rapping losses.

Tubular Precipitators--

The original ESPs were tubular, like the smokestacks on which they were placed, with the high-voltage electrode running along the axis of the tube. Tubular precipitators have typical applications in sulfuric acid plants, coke oven by-product gas cleaning (tar removal), and iron and steel sinter plants. Such tubular units are still used for some applications, with many tubes operating in parallel to handle increased gas flows. The tubes may be formed as a circular, square, or hexagonal honeycomb with gas flowing upward or downward. The length of the tubes can be selected to fit conditions. A tubular ESP can be tightly sealed to prevent leaks of material, especially valuable or hazardous material.

A tubular ESP is essentially a one-stage unit and is unique in having all the gas pass through the electrode region. The high-voltage electrode operates at one voltage for the entire length of the tube, and the current varies along the length as the particles are removed from the system. No sneakage parts are around the collecting region, but corona nonuniformities may allow some particles to avoid charging for a considerable fraction of the tube length.

Tubular ESPs make up only a small portion of the ESP population and are most commonly applied where the particulate is either wet or sticky. These ESPs, usually cleaned with water, have reentrainment losses of a lower magnitude than do the dry particulate precipitators.

Wet ESPs--

The major differences in the types of wet ESP's available today are as follows: the shape of the collector, whether treatment of the gas stream is vertical or horizontal, whether incoming gas is preconditioned with water sprays, and whether the entire ESP is operated wet. Figures 5-3 through 5-6 show four different types of wet ESPs. Casing can be constructed of steel or FRP, and discharge electrodes can be carbon steel or special alloys, depending on the corrosiveness of the gas stream.

In circular-plate wet ESPs, the circular plates are irrigated continuously; this provides the electrical ground for attracting the particles and also removes them from the plate. It can generally handle flow rates of 30,000 to 100,000 cfm. Preconditioning sprays remove a significant amount of particulate by impaction. Pressure drop through these units usually ranges from 1 to 3 inches of water.

Rectangular flat-plate units operate in basically the same manner as the circular-plate wet ESPs. Water sprays precondition the incoming gas and provide some initial particulate removal. Because the water sprays are located over the top of the

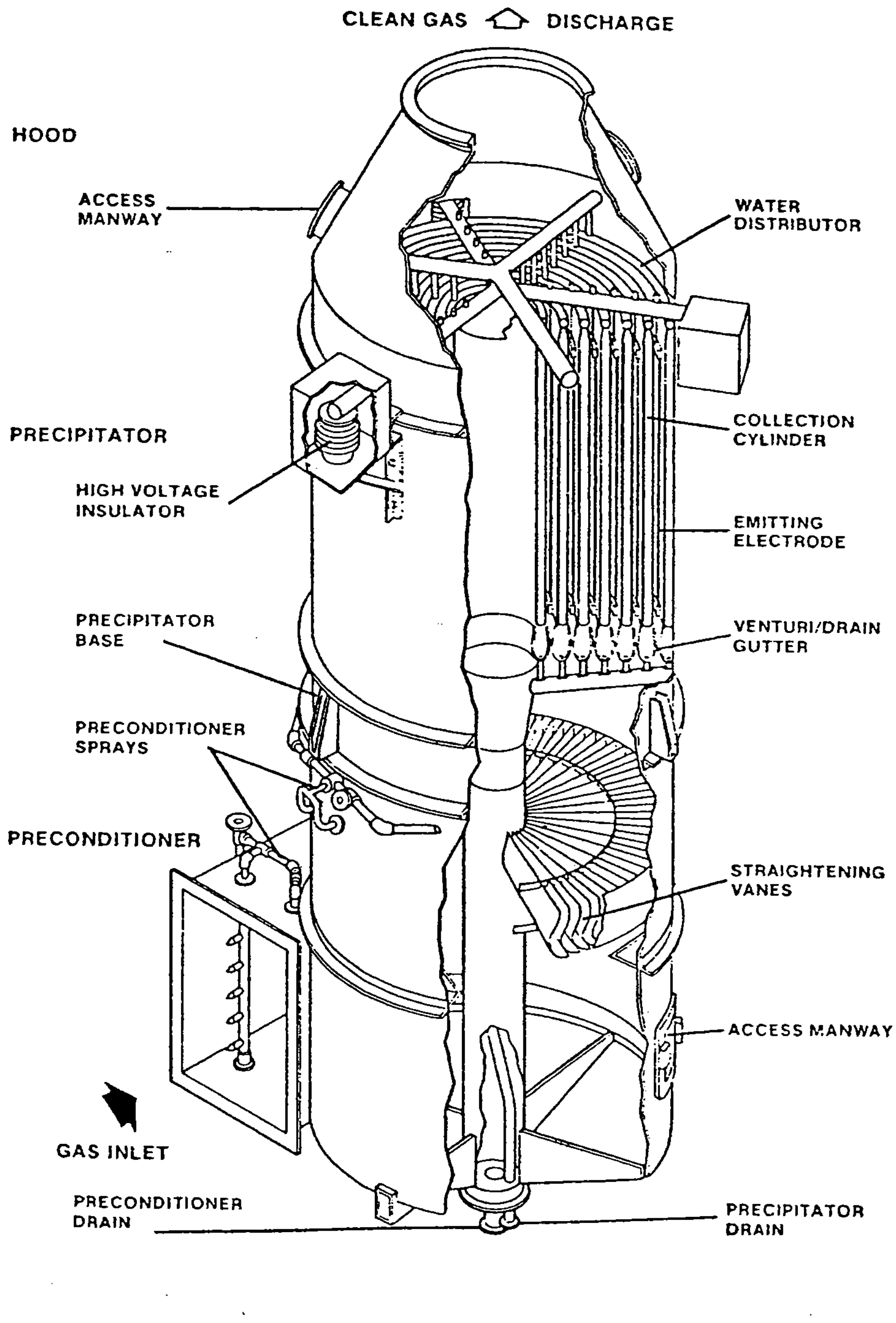

Figure 5-3. Concentric-plate wet ESP (Fluid Ionics, Inc.).

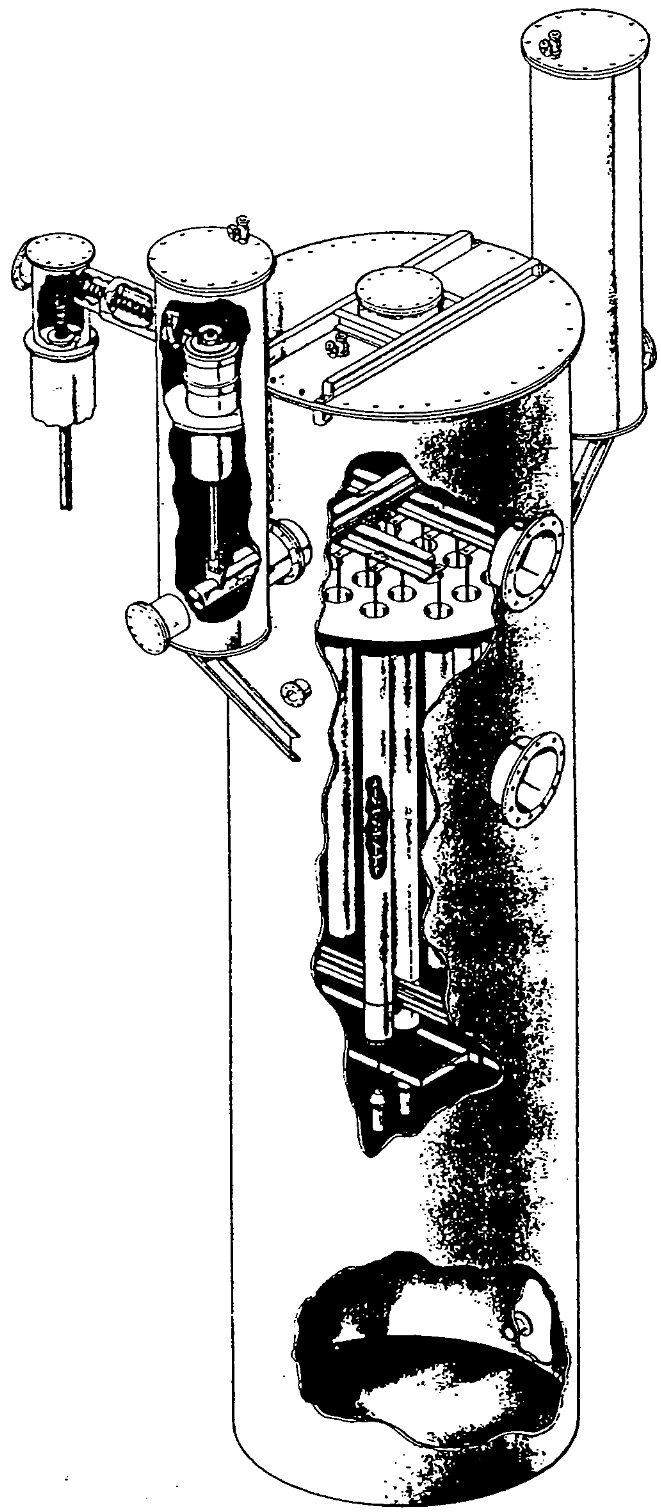

Figure 5-4. Circular-plate wet ESP (Detarring Operations)
(Environmental Elements, Inc.)

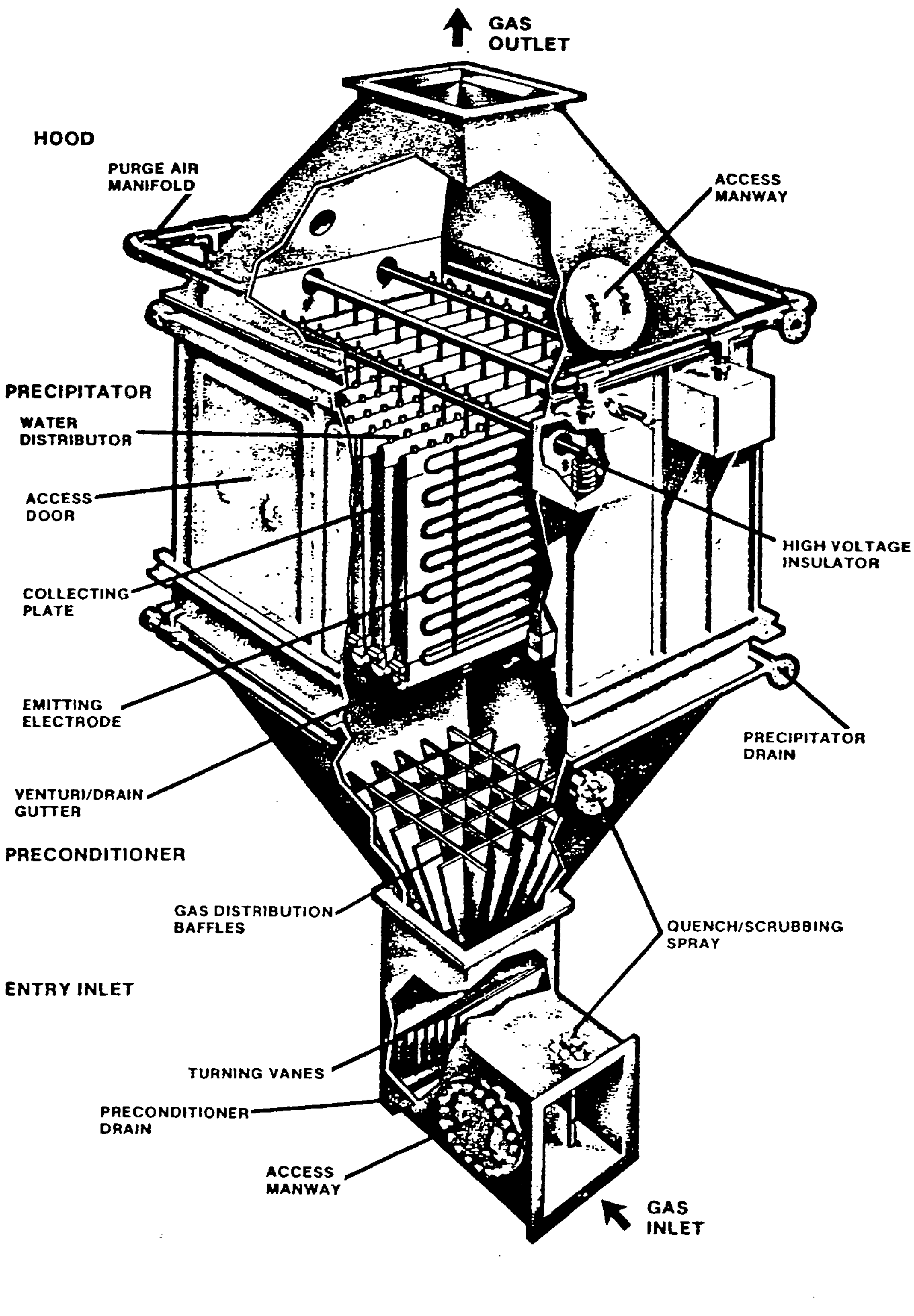

Figure 5-5. Flat-plate-type wet ESP (Fluid Ionics, Inc.)

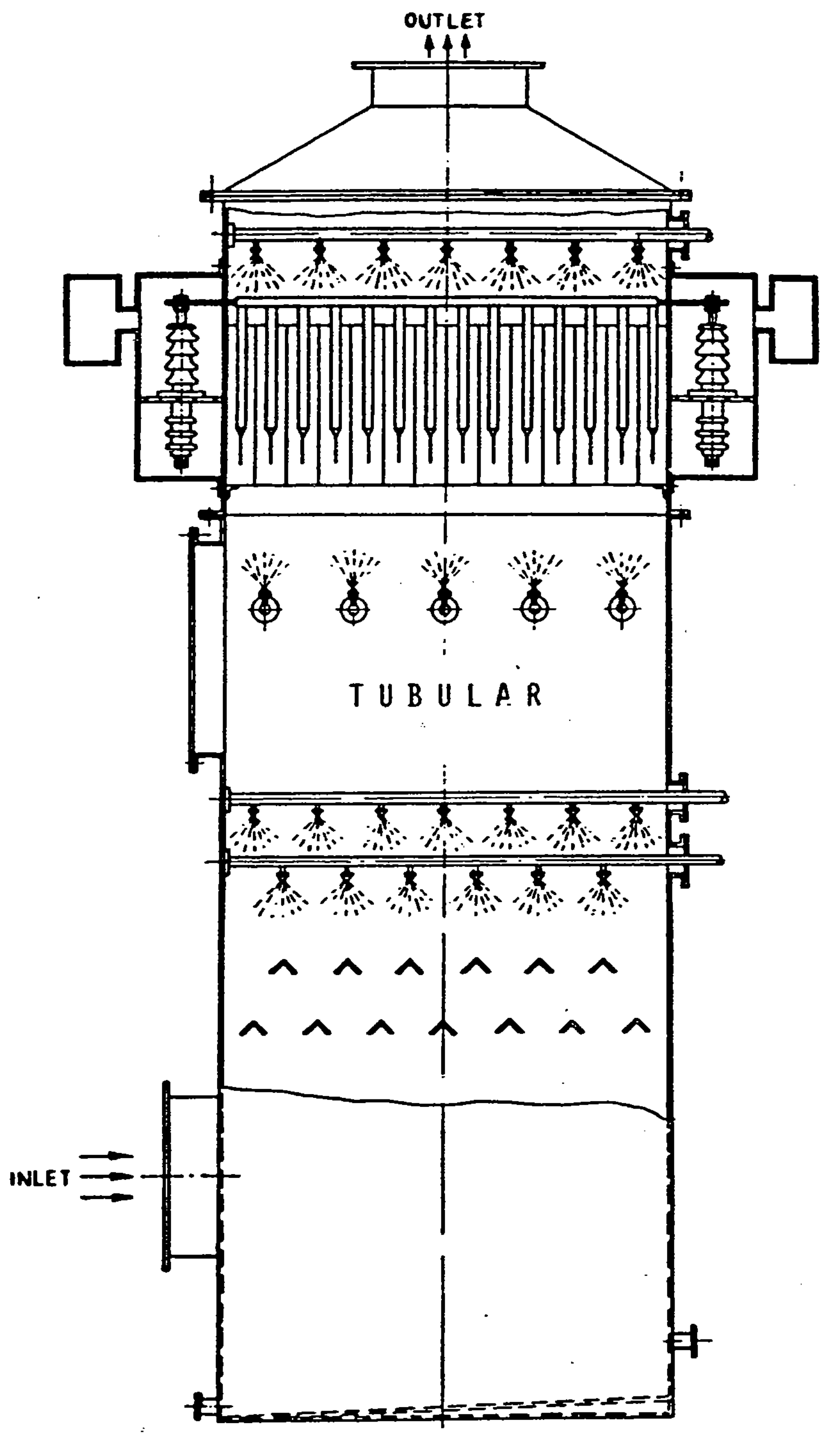

Figure 5-6. Tubular wet ESP
(Beltran)

electrostatic fields and the collection plates are continuously irrigated, the collected particulates flow downward into a trough that is sloped to a drain for treatment. The last section of this type of wet ESP is sometimes operated dry to remove entrained water droplets from the gas stream.

The preconditioner liquor and the ESP liquor are generally treated separately so that the cleanest liquor can be returned to the ESP after treatment.

5.1.3 ESP System Components

The emission control performance of an ESP depends upon the design and operating status of its system components. The primary system areas that are common to different ESP types are:

- Sectionalization and energization
- Rapping techniques
- High voltage frame insulators
- Hoppers and solids discharge equipment
- Gas distribution
- Instrumentation

Sectionalization and Energization--

High efficiency precipitators have more than one electrical field. Two or more fields are normally provided in the direction of the gas flow. For large incinerators, the gas flow can be split into two or more chambers each of which has several fields in series. The sectionalization of the precipitators improves both precipitator performance and reliability.

One of the underlying reasons for sectionalization is the significant particle concentration gradient and dust layer thickness gradients between the inlet and outlet of the precipitator. At the inlet of the precipitator, the dust layer accumulates rapidly since 60 to 80 percent of the mass is collected rapidly. This makes this field more prone to electrical sparking due to the nonuniformities in the dust layer electrical fields. Also, the fine particles which are initially charged in the inlet field but not collected create a space charge in the interelectrode zone. This space charge inhibits current flow from the discharge electrodes and collection plates. By sectionalizing the precipitator, the inherent electrical disturbances in the inlet field do not affect the downstream fields.

Another reason for sectionalization is the differences in electrical sparking which are normally moderate-to-frequent in the inlet fields and low-to-negligible in the outlet fields. The automatic voltage controllers used on precipitators are designed to quench the electrical spark by reducing the applied voltage to zero for milliseconds. Then the voltage is increased in several steps to a voltage close to the one at which sparking occurred. When sparking rates increase in a field, the net effect is to lower the peak voltages and to lower the applied time of the electrical power. By using a number of independent power supplies, the electrical disturbances in one field are isolated.

Rapping Techniques--

For dry type electrostatic precipitators, there are two major approaches to rapping: (1) external roof-mounted rappers, and (2) internal rotating hammer rappers. The external rappers are connected to groups of collection plates or an individual high voltage frame by means of rapper shafts, insulators, and shaft seals. The advantage of these roof-mounted rappers is that there is access to the rapper during operation and the intensities can be adjusted for variations in dust layer resistivity. The disadvantage is that the large number of rapper shaft components can attenuate rapping energy and become bound to the hot or cold decks.

The internal rotating hammer rappers have individual rappers for each collection plate. Due to the greater rapping forces possible, these can be used for moderately high resistivity dusts. The disadvantages of these rappers are the inability to adjust the frequency and intensity in various portions of the precipitator and the inaccessibility for maintenance. Also, the internal rotating hammer rappers can be vulnerable to maintenance problems such as shearing of the hammer bolts, distortion of the hammer anvils, bowing of the support shafts, and failure of the linkages.

High Voltage Frame Insulators--

In both wet and dry types of electrostatic precipitators, there are two different types of high voltage frame insulators: high voltage frame support insulators and bus line post insulators. The frames are supported at the top by means of a set of cylindrical or post insulators.

There are either 2 or 4 cylindrical high voltage frame support insulators per frame depending on the manufacturer's design approach. They are usually 1 inch thick and rest on a gasket to reduce the risk of cracking. The high voltage frame is suspended from the top cover on the cylindrical insulator. There are a set of holes or nozzles through the cover to allow heated purge air to flow downward into the precipitator and thereby reduce dust and moisture build-up on the interior surfaces. For further insulator protection, tubular heaters are often mounted near the external bases of the insulators.

The post type insulators are kept clean and dry using a heated purge air flow into the insulator compartment or penthouse. Typical temperatures are 150 to 200 degrees Fahrenheit.

There are insulators at the bottom of the precipitator to stabilize the high voltage frames. These insulators are necessary to maintain proper collection plate-to-discharge electrodes even during times of gas flow rate and gas pressure variations. The anti-sway insulators must be mounted so that they allow free movement of the lower high voltage frame assemblies during thermal expansion and contraction. Also, they must be oriented to minimize dust accumulation. In their location directly above the hoppers, it is not possible to supply a dry, heated air stream for protection against moisture and solids build-up.

Hoppers and Solids Discharge Equipment--

For dry type electrostatic precipitators, proper design of the hopper and solids discharge equipment is especially important. These units handle high mass loading and some of the reaction products are hygroscopic and prone to bridging. Hopper heaters and thermal insulation are important to avoid the hopper overflow conditions which could cause an undervoltage trip of a field and which could possibly cause serious collection plate-to-discharge electrode alignment problems.

Hopper insulation generally consists of 2 to 4 inches of mineral wood insulation mounted one or more inches away from the side of the hopper wall. The insulation includes a weather proof outer lagging and air stops at regular intervals to prevent any chimney effect convective cooling. Hopper heaters located on the bottom one-third of the hopper are used to reduce the possibility of solids bridging.

Electrostatic precipitator hoppers normally have a hopper center baffle to reduce gas sneakage around the fields. This baffle should extend well into the bottom area of the hopper. However, there should be some clearance around the entry to the discharge valve throat so that the baffle does not inadvertently contribute to the solids bridging problems.

Precipitator hoppers often include capacitance or nuclear level detectors, electrical vibrators, poke holes, and strike plates.

Gas Distribution--

One of the most important steps in ensuring adequate gas distribution is to allow sufficient space for gradual inlet and outlet transition sections. Units with very sharp duct turns before and after the transition are also prone to gas distribution problems.

Proper gas distribution is achieved by the use of one or more perforated gas distribution screens at the inlet and outlet of the precipitator. These are generally hung from the top and cleaned by means of externally mounted rappers. Location of the gas distribution screens (and ductwork turning vanes) is usually based on either 1/16th scale flow models or gas distribution computer models.

ESP Instrumentation--

The principal instruments used to monitor electrostatic precipitator performance are generally included on the primary control cabinet for each transformer-rectifier set. Table 5-1 summarizes the types of instruments often used.

5.2 Monitoring ESP Operation

For a continued optimum performance of ESPs, several key parameters must be monitored regularly and necessary corrective actions must be taken to rectify any deviations from acceptable parameter ranges.

TABLE 5-1. ELECTROSTATIC PRECIPITATOR SYSTEM INSTRUMENTS

Parameter Measured	Process/Equipment Controlled	Portable Instrument Port or Sampling Tap
Inlet gas temperature	Precipitator trip	Yes
Outlet gas temperature	-	Yes
Inlet static pressure	Induced draft fan	Yes
Combustibles monitor	Precipitator trip	-
T/R set electrical meters for each field:		
Primary voltage	Undervoltage trip	-
Primary current	Overcurrent trip	-
Secondary voltage	-	-
Secondary current	Overcurrent trip	-
Spark rate	Spark rate limit	-
Rapper frequency	-	-
Penthouse air temperature	Purge air fan	-
Penthouse static pressure	-	-

Performance monitoring includes measurement of key operating parameters by both continuous and intermittent methods, comparison of these parameters with baseline and/or design values, and the establishment of recordkeeping practices. These monitoring data are useful in performance evaluation and problem diagnosis.

5.2.1 Key Operating Parameters and Their Measurement

The typical ESP parameters that must be monitored are: gas volume and gas velocity through the ESP; temperature, moisture, and chemical composition of the gas; particle size distribution and concentration; resistivity of the particulate; and power input. Many of these factors are interrelated.

Gas Volume and Temperature--

According to predictive equations and models, a decrease in gas volume results in an increase in collection efficiency and vice versa. A decrease in gas volume results in an increase of the specific collection area or SCA (ft^2 of plate area/1000 acfm), a decrease in gas velocity through the ESP, an increase in the treatment time (during which the particulate is subjected to the electric field charging and collecting mechanisms), and hence, improved performance. A decrease in velocity may also reduce rapping reentrainment and enhance the collection of the fine particles in the 0.1 to 1.0 µm range, which are exceptionally difficult for most ESPs to collect.

For industrial applications, the ESP is normally designed for maximum expected flow and it will generally not be exceeded. The facility should not perform any major source modifications without evaluating their impacts on the flow rate.

Monitoring the temperature of the gas stream can provide useful information about the performance of an ESP and can provide useful clues for diagnosing both ESP performance and process operating conditions. The effect of temperature is most important as it relates to the resistivity of the particulate and is an indicator of excessive inleakage into the gas stream.

Temperature can also affect gas properties to such an extent that they will change the relative levels of voltage and current and the density and viscosity of the gas stream, which affect particle migration parameters.

Lastly, comparison of inlet and outlet temperatures may be useful in the diagnosis of excessive inleakage into the ESP. Even the best constructed and insulated ESP will experience some temperature drop, which can range from 1° to 2°F on smaller ESPs or up to 25°F on very large ESPs. In any case, some acceptable difference or maximum differential should be set, and when exceeded, this should be an indicator of improper operation or a maintenance problem that must be corrected.

Chemical Composition and Moisture--

The chemical composition of both the particulate entering the ESP and the flue gas can affect ESP performance, although in somewhat different ways. In many process applications, either the gas composition or key indicators of gas composition are usually available on a continuous or real-time basis. Chemical composition of the particulate matter, however, is often not available except on an intermittent, grab-sample basis.

The chemical composition of the particulate matter influences ESP performance. Specifically, it greatly influences the range of resistivity with which the ESP will have to operate. The presence of certain compounds such as alkalies, calcium, or other components can be used to predict resistivity problems. In addition, chemical composition can change with particle size, which may change ESP performance at the inlet, mid, and outlet sections and further complicate prediction of ESP performance on a day-to-day basis.

The presence of water vapor and/or acid gases may prove useful as resistivity modifiers or conditioners, and they may be necessary for proper ESP performance. On the other hand, they may cause a sticky particulate that is difficult to remove.

Particle Concentrations and Size Distribution--

Electrostatic precipitators can be designed for a wide range of mass loadings to provide satisfactory performance when combined with other operating and design parameters. Within limitations, changes in the mass loading do not seriously affect an ESPs performance, although some changes in outlet concentration can occur. However, any source modifications must be evaluated for their impact on the mass loading and ESP performance.

Particle size distribution is usually determined through the use of cascade impactors. Various types of cascade impactors are available with different particle cut sizes and for different loadings. The cascade impactor is usually placed on a standard sampling probe and inserted into the gas stream for isokinetic sampling of the particulate. After sampling is completed, each stage of the impactor is weighed in the lab and compared against its initial weight to determine distribution.

Power Input--

The power input to the ESP can be a useful parameter in monitoring ESP performance. The value of power input for each field and for the total ESP indicates how much work is being done to collect the particulate. In most situations, the use of power input as a monitoring parameter can help in the evaluation of ESP performance, but some caution must be exercised.

The transformer/rectifiers (T-R's) of most modern ESPs are equipped with primary voltage and current meters on the low-voltage (a.c.) side of the transformer and secondary voltage and current meters on the high-voltage rectified (d.c.) side of the transformer. The terms primary and secondary refer to the side of the transformer that is being monitored; the input side is the primary side of the transformer. Older models may have only primary meters and, perhaps, secondary current meters. When both voltage and current meters are available on the T-R control cabinet, the power input can be estimated. Each T-R meter reading must be recorded.

When only the primary meters are available, the values for a.c. voltage and current are recorded and multiplied; however, when secondary meters are available, d.c. kilovolts and milliamps also should be recorded and multiplied. When both primary meters and secondary meters are available, the products of voltage and current should be compared. These values represent the number of watts being drawn by the ESP; in all cases, the secondary power output (in watts) is less than the primary power input to the T-R. The primary and secondary meter values should not be multiplied; however, this is done occasionally to aid in the evaluation of the ESP performance (e.g., primary voltage to secondary current).

The power inputs calculated for each T-R set and for the ESP do not represent the true power entering the T-R or the effective power entering the ESP; however, they are sufficiently accurate for the purpose of monitoring and evaluating ESP performance. These values indicate just how well each of the sections is working when compared with the actual voltage and current characteristics. The ratio of secondary power (obtained from the product of the secondary meter readings) to the primary power input will usually range from 0.5 to 0.9; the overall average for most ESPs is between 0.70 and 0.75. In general, as the operating current approaches the rated current of the T-R it appears to be more efficient in its utilization of power. This is due to a number of factors, including semiconductor controlled rectifier (SCR) conduction time, resistance of the dust layer, and capacitance of the ESP. The actual voltage and current readings that are used to calculate power will be controlled by the gas composition, dust composition, gas temperature, and physical arrangement within the ESP. Thus, as one moves from inlet fields towards outlet fields, the apparent secondary power/primary power ratio increases in most ESPs because the ESPs tend to operate to their rated current output. When ESPs only have primary voltage and current meters, the power input may be estimated by obtaining the multiplication product.

5.2.2 Parameter Monitoring

Parameter monitoring usually plays a key role in an overall operation and maintenance plan, particularly one that stresses preventive maintenance. Such monitoring also forms the basis for a recordkeeping program that places emphasis on diagnostics. Typically, daily operating data are reduced to the data on a few key parameters that are monitored. Acceptable ranges may be established for various parameters (by use of baseline test data) that require further data analysis or perhaps some other action if the values fall outside a given range. Care must be taken not to rely on just one parameter as an indicator, as other factors, both design- and operation-related, usually must be considered. Typical parameters that can be monitored daily include opacity, corona power input sparking, fan operation, gas temperature, process operating rates, and conditioning systems (if used).

Many sources use opacity levels as the first indicator of performance changes. In general, opacity is relatively easy to monitor daily or continuously and is a good indicator and tool for this purpose. If used in conjunction with mass/opacity correlations, it can help in the scheduling of maintenance and in the reduction or optimization of ESP power input. It is not wise to rely on opacity data alone, however, as such reliance can cause one to overlook problems that can affect long-term performance (e.g., hopper pluggage may not significantly increase opacity at reduced load, but it may misalign the affected fields and reduce their performance at full load or in other difficult operating situations).

Another useful parameter that can be monitored daily is the corona power input to the ESP, which can be thought of as a measure of the work done to remove the particulate. Corona power input can be obtained by multiplying the voltage and current values of either the primary or secondary side of the transformer. As noted earlier, the apparent power input on the primary and secondary side will differ because of circuitry and the metering of these values. Values from the secondary meters are preferred. As a general rule, performance improves as the total power input increases. This is normally the case when resistivity is normal to moderately high, assuming most other factors are "normal" and components are in a state of good repair. One should not rely solely on power input, however. The pattern or trends in power input throughout the ESP are important in a performance evaluation. Also, in some cases, although the apparent power input is high, the performance is poor. For example, when dust resistivity is low or very high or when spark rates are very high, corrective measures will usually lower power input, but will also substantially improve performance.

Some ESPs are relatively insensitive to power input changes. This condition is usually limited to high-efficiency ESPs that are generously sized and sectionalized. The normal power input of some of these ESPs may be reduced by one-half to two-thirds without causing any substantial change in performance. The emissions from the ESPs are caused primarily by rapping reentrainment and gas sneakage, both of which are relatively unaffected by the level of power input. In this case, power reduction for energy conservation is probably a useful option.

Varying corona power input affects power density (watts/square foot of plate area). This may be tracked two ways: 1) by obtaining an overall value for the ESP, or 2) by checking the power density in each field from inlet to outlet of the ESP. Power density should increase from inlet to outlet as the particulate matter is removed from the gas stream (the maximum value is usually less than 4 watts/ft^2). Power density accounts for the differences or normalizes the values for power input in each field that are caused by different field size. Most normally operating ESPs will show an overall power density of 1 to 2 watts/ft^2; values of 0.10 to 0.50 watt/ft^2 are more common for high-resistivity dusts.

The gas volume passing through the ESP is important to the actual SCA, the superficial velocity, and the treatment time. Normal gas flow to the ESP can be monitored daily using gas temperature, fan operation, and normal process operation as indicators. The temperature of the gas stream, the excess-air values (for combustion sources), and the production rate all influence the gas volume entering the ESP. If gas volume is known or estimated, the specific corona power (watts/1000 acfm) can be calculated. This value tends to account for changes in performance due to different loads and power input because removal efficiency generally increases as the specific corona power increases. The same cautionary remarks that apply to overall power input also apply to specific corona power. The values obtained for specific corona power input may be misleading if other factors are not considered.

5.3 ESP Malfunctions

Other than changes in process conditions, the most common malfunction associated with ESP performance is from broken discharge wires and plugged hoppers. A detailed list of the causes and effects of malfunctions, categorized according to functioning component, is given in the following pages. In some cases, solutions to the problems are provided. Table 5-2 provides a summary of common ESP malfunctions.

Discharge Electrodes--

In a weighted wire design, a broken wire may swing freely and cause shorting between discharge and collector electrodes, usually immobilizing an entire field. Wire breakage results from electrical, mechanical, or chemical problems.

Electrical

Electric erosion (arcing) is the principal cause of failure.

Minimum clearance between electrodes results in repeated sparkover, causing local heating and vaporization of metal. The tension from the suspension weights causes ultimate failure.

Breakage can occur on shroud as well as wire and usually occurs on the lower portion of wire.

Mechanical

Excessive rapping breaks wire.

Crimps and bends are sources of fatigue with rapping and vibration.

TABLE 5-2. SUMMARY OF MALFUNCTIONS ASSOCIATED WITH ELECTROSTATIC PRECIPITATORS

Malfunction	Cause	Effect on ESP Efficiency	Corrective Action	Preventive Measures
Poor electrode alignment	Poor design Ash buildup on frame hoppers Poor gas flow	Can drastically affect performance and lower efficiency	Realign electrodes Correct gas flow	Check hoppers frequently for proper operation
Broken electrodes	Wire not rapped clean, causes an arc which embrittles and burns through the wire. Clinkered wire. Causes: a) poor flow area, distribution through unit is uneven; b) excess free carbon due to excess combustion air or fan capacity insufficient for demand required; c) wires not properly centered; d) ash buildup resulting in bent frame, (same as c); e) clinker bridges the plates and wire shorts out; f) ash buildup, pushes bottle weight up causing sag in the wire; g) J hooks have improper clearances to the hanging wire; h) bottle weight hangs up during cooling, causing a buckled wire; i) ash buildup on bottle weight to the frame forms a clinker and burns off the wire.	Reduction in efficiency due to reduced power input, bus section unavailability	Replace electrode	Inspect hoppers Check electrodes frequently for wear Inspect rappers frequently Check flow distribution
Distorted or skewed electrode plates	Solids buildup in hoppers Gas flow irregularities High temperatures	Reduced efficiency	Repair or replace plates Correct gas flow	Check hoppers frequently for proper operation; Check electrode plates during outages
Vibrating or swinging electrodes	Uneven gas flow Broken electrodes	Decreases in efficiency due to reduced power input	Repair electrodes	Check electrodes frequently for wear
Inadequate level of power input (voltage too low)	High dust resistivity Excessive particulate on electrodes Unusually fine particle size Inadequate power supply Inadequate sectionalization Improper rectifier and control operation Misalignment of electrodes	Reduction in efficiency	Clean electrodes, gas conditioning or alterations in temperature to reduce resistivity; Increase sectionalization	Check range of voltages frequently to make sure it is correct continuous resistivity measurements
Back corona	Particulate accumulated on electrodes causing excessive sparking, requiring reduction in voltage charge	Reduction in efficiency	Same as above	Same as above

(continued)

TABLE 5-2 (continued)

Malfunction	Cause	Effect on ESP Efficiency	Corrective Action	Preventive Measures
Broken or cracked insulator or flower pot bushing leakage	Ash buildup during operation causes leakage to ground Moisture gathered during shut-down or low load operation	Reduction in efficiency	Clean or replace insulators and bushings	Check frequently Clean and dry as needed; Check for adequate pressurization on top housing
Air leaks in through hoppers	From dust conveyor	Lower efficiency; dust reentrained through ESP	Seal leaks	Identify early by increase in ash concentration at bottom of exit to ESP
Air leaks in through ESP shell	Flange expansion	Same as above, also causes intense sparking		
Gas bypass around ESP: - dead passage above plates - around high tension frame	Poor design - improper isolation of active portion of ESP	Only small percentage drop in efficiency unless severe	Baffling to direct gas into active ESP section	Identify early by measurement of gas flow in suspected areas
Corrosion	Temperature goes below dewpoint	Negligible until precipitation causes interior plugs or plates to be eaten away; air leaks may develop, causing significant drops in performance	Maintain flue gas temperature above dewpoint	Energize precipitator after process system has been on line for ample period to raise flue gas temperature above acid dewpoint
Hopper pluggage	Wires, plates, insulators fouled because of low temperatures Inadequate hopper insulation Improper maintenance Boiler leaks causing excess moisture Ash conveying system malfunction: gasket leakage, blow malfunction, or solenoid valves Misadjustment of hopper vibrators Material dropped into hopper from bottle weights Solenoid, timer malfunction Suction blower filter not changed	Reduction in efficiency	Provide proper flow of ash	Frequent checks for adequate operation of hoppers Provide heater and/or thermal insulation to avoid moisture condensation

(continued)

TABLE 5-2 (continued)

Malfunction	Cause	Effect on ESP Efficiency	Corrective Action	Preventive Measures
Inadequate rapping, vibrators fail	Solids buildup Poor design Rappers misadjusted	Resulting buildup on electrodes may reduce efficiency	Adjust rappers	Frequent checks for adequate operation of rappers
Too intense rapping	Poor design Rappers misadjusted Improper rapping force	Reentrains ash, reduces efficiency	Same as above	Same as above Reduce vibrating or impact force
Control failures	Power failure in primary system Transformer or rectifier failure: a) insulation breakdown in transformer b) arcing in transformer between high voltage switch contacts c) leaks or shorts in high voltage structure d) insulating field contamination	Reduced efficiency	Find source of failure and repair or replace	Pay close attention to daily reading of control room instrumentation to spot deviations from normal readings
Sparking	Inspection door ajar System leaks Plugging of hoppers Dirty insulators	Reduced efficiency	Close inspection doors; repair leaks; unplug hoppers; clean insulators	Regular preventive maintenance will alleviate these problems

Poor electrical alignment causes the wire frame to oscillate, fatiguing wires and increasing sparking.

Swinging wire frames can often be detected by listening for the regular snap of the arc-over.

Chemical

Acid gases corrode wires. Material flakes off during rapping, thus exposing new surfaces to additional corrosion attack.

Wire buildup is not usually due to insufficient rapping but to some other factor, such as process change. Uniform buildup can have the effect of creating a larger diameter wire and requiring higher voltage to initiate ground current. A sudden failure or rash of failures can occur from process changes or extreme malfunction in the ESP.

In a rigid frame design, one broken wire does not result in the failure of the entire bus section. High "G" forces in rapping rigid wire frames can lead to premature mechanical failure near the impact point, at connection to support members, sharp bends, and welded connections. High resistivity dusts are very tenacious and need high rapping forces. These conditions require an ESP designed for high resistivity dust.

Rappers (Vibrators/Impulse)--

Impulse electric or pneumatic rappers are more successful in difficult rapping applications than are electric vibrators.

Pneumatic rappers are beneficial in warm, high-moisture ambient environments. If the temperature falls below freezing, however, pneumatic is not recommended because the entrapped moisture in the air lines may freeze unless adequate air dryers are installed.

Rappers (Mechanical Failures)--

Failures occur in the transmission hardware at the interface of a high-strength alloy and mild steel components.

Poor quality of welds from rapper to support frame may result in cracks. Good welding practice is to preheat and postheat.

Rapper binds due to misalignment during installation.

Rapper rod seizure occurs from dust accumulation.

Collector Electrodes--

Plate corrosion results from gas temperature going below dew point and allowing condensation to occur on lower portion of plate. Air leakage into hopper also produces condensation and corrosion on electrodes.

Mechanical failure at supports can occur from poor construction or assembly and overrapping.

Dust Removal System--

Plugging is the main problem and could result from moisture condensation, with its associated dust agglomeration and caking within the hopper. Dust buildup will eventually contact high-voltage electrode frame and short cut high-voltage bus sections, misaligning electrodes, and form clinkers by ash fusion from the high-voltage current. Hoppers and heaters should be operated continuously to avoid buildup.

Housing and Casing--

Air leaks and infiltration (causing corrosion) can occur at expansion joints, slip joints, and inlet/outlet ducts. Should acid/gas temperature go below dew point, condensation can also result in corrosion.

Coupons of aluminum, corten, and stainless steel are often placed inside the unit to study the corrosion resistance of these materials. Coatings such as coal tar epoxy are used to eliminate corrosion.

Insulators--

Dust and/or moisture accumulation on the insulator surface could lead to electrical arc-over as evidenced by tracking. Excessive arc-over could result in insulator cracking or breakage. Filtered and heated purge air prevents fouling of the insulators, bus bars, and bus ducts.

5.3.1 Troubleshooting Procedures

Guidelines for troubleshooting and correcting ESP malfunctions are provided in Tables 5-2 and 5-3. These charts may be used as diagnostic aids to troubleshoot specific symptoms. A supplementary approach to evaluate operational problems is to interpret abnormal electrical meter readings from the ESP control cabinet. Table 5-3 provides guidance for troubleshooting and correcting ESP electrical malfunctions and Table 5-4 shows how gas parameters and electrical failure impact ESP meter readings.

5.4 Electrostatic Precipitator Operation and Maintenance

Proper operation and maintenance of an ESP requires familiarity with procedures for equipment startup, shutdown, inspection, recognition of common malfunctions, and troubleshooting. Discussion of the cause and effect relationship and the impact on performance is discussed in this section.

5.4.1 Pre-Startup Inspection

The inspection performed before startup is critical to the performance of an ESP. The precipitator may not be operational for one of three reasons:

New installation requiring shakedown and debugging.

Process shutdown resulting in ESP shutdown.

ESP shutdown for maintenance.

Regardless of the reason for shutdown, an opportunity exists while the unit is down to perform a thorough inspection. This inspection should be performed at least annually. An example of a checklist for visual and mechanical inspection during shutdown is provided in Figure 5-7.

5.4.2 Routine Startup

After the precipitator has been thoroughly inspected, the unit should be buttoned up (following all safety procedures). An outline procedure for routine startup is given

TABLE 5-3. TYPICAL TROUBLESHOOTING CHART FOR ELECTROSTATIC PRECIPITATOR ELECTRICAL PROBLEMS

Symptom	Cause	Remedy
No primary voltage No primary current No precipitator current Vent fan on Alarm energized	Overload condition	Check overload relay settings Check wiring components
	Misadjustment of current limit control	Check adjustment of current limit control setting
	Overdrive of SCR's	Check signal from firing circuit module
No primary voltage No primary current No precipitator current Vent fan off Alarm energized	Relay panel fuse blown	Replace
	Circuit breaker tripped	Reset circuit breaker
	Loss of supply power	Check supply to control unit
Control unit trips out on overcurrent when sparking occurs at high currents	Circuit breaker defective or incorrectly sized	Check circuit breaker
	Overload circuit incorrectly set	Reset overload circuit
	Short circuit condition in primary	Check primary power wiring
High primary current No precipitator current	Transformer or rectifier short	Check transformer and rectifiers
No primary voltage No primary current No precipitator current Vent fan on Alarm not energized	SCR and/or diode failure	Replace
	No firing pulse from firing circuit and/or amplifier	Check signal from firing circuit and/or amplifier
Same as above, even after replacing components or subpanels, changing wires, or repair	SCRs being fired out of phase	Reverse input wires
Low primary voltage High secondary current	Short circuit in secondary circuit or precipitator	Check wiring and components in H.V. circuit and pipe and guard. Check precipitator for: Interior dust buildup Full hoppers Broken wires Ground switch left on Ground jumper left on Foreign material on H.V. frame or wires Broken insulators

(continued)

TABLE 5-3. (continued)

Symptom	Cause	Remedy
Abnormally low precipitator current and primary voltage with no sparking	Misadjustment of current and/or voltage limit controls	Check settings of current and voltage limit controls
	Misadjustment of firing circuit control	Turn to maximum (clockwise) and check setting of current and voltage limit controls
Spark meter reads high -- off scale Low primary voltage and current No spark rate indication	Continuous conduction of spark counting circuit	Deenergize, allow integrating capacitor to discharge, and reenergize
	Spark counter counting 60 cycles peak	Readjust
	Failure	Replace
Spark meter reads high; primary voltage and current very unstable	Misadjustment of PC-501	Readjust
	Loss of limiting control	Replace
Neither spark rate, current, nor voltage at maximum	Misadjustment of PC-501	Readjust setting
	Failure	Replace
	Failure of signal circuits	Check signal circuits
No spark rate indication; voltmeter and ammeter unstable, indicating sparking	Failure of spark meter	Replace spark meter
	Failure of integrating capacitor	Replace capacitor
	Spark counter sensitivity too low	Readjust
No response to current limit adjustment; however, does respond to other adjustments	Controlling on spark rate or voltage limit	None needed if unit is operating at maximum spark rate or voltage adjustment. Reset voltage or spark rate if neither is at maximum.
	Failure	Replace
	Current signal defective	Check signal circuit
No response to voltage limit adjustment; however, does respond to current adjustment	Controlling on current limit or spark rate	None needed if unit is operating at maximum current or spark rate. Reset current and spark rate adjustment if neither is at maximum
	Voltage signal defective	Check voltage signal circuit
	Failure	Replace

(continued)

TABLE 5-3. (continued)

Symptom	Cause	Remedy
No response to spark rate adjustment; however, does respond to other adjustment	Controller on voltage or current	None needed if unit is operating at maximum voltage or current. Reset voltage and current adjustment if neither is at maximum
	Failure	Replace
Precipitator current low with respect to primary current	Surge arrestors shorted	Reset or replace surge arrestors
	H.V. rectifiers failed	Replace H.V. rectifiers
Low or no voltage across ground return resistors	H.V. transformer failed	Replace H.V. transformer
	Ground or partial ground in the ground return circuit	Repair ground return circuit

TABLE 5-4. GUIDE FOR INTERPRETING ABNORMAL METER READINGS

1. Increasing gas temperature results in a corresponding voltage increase and current decrease (arcing can develop). Conversely, decreasing gas temperature will result in voltage diminution and current increase.
2. An increase in moisture content at given process conditions results in a relatively small increase in current and voltage levels.
3. Excessive sparkover may result from additional moisture and is indicated by a voltage increase.
4. Grain loading increase somewhat elevates voltages and reduces current.
5. A particle size decrease causes a voltage rise and diminished current.
6. Gas velocity (flow rate) increase tends to increase voltages and depress current.
7. Air leakage may cause additional sparkover and reduced voltage.
8. During normal operation for individual power supplies, the voltage/current ratio decreases in the direction of gas flow.
9. Hopper overflow results in shorting, drastically reduced voltage, and current increase.
10. Broken, swinging discharge electrode wires result in violent arcing and extreme and erratic meter behavior.
11. A T/R short results in zero voltage and high current.
12. Buildup on wires is accompanied by a voltage increase to maintain the same current level.
13. Buildup on plates is accompanied by a voltage decrease to maintain the same current level.

ESP PREOPERATION AND INSPECTION CHECKLIST

Facility Name:	Date of Inspection:
Facility Location:	Time of Inspection:
Process:	Name of Inspector (print):
ESP ID:	Signature of Inspector:

INSPECTION ITEM	CHECKED YES	CHECKED NO	COMMENTS/CORRECTIVE ACTIONS:
DISCHARGE ELECTRODES			
Upper Support Frame	______	______	
Lower Support Frame	______	______	
Hanger Supports	______	______	
Antiswing Supports	______	______	
Weights	______	______	
Wires	______	______	
Alignment	______	______	
Corrosion	______	______	
Buildup	______	______	
COLLECTOR ELECTRODE			
Warpage	______	______	
Support	______	______	
Spacers	______	______	
Guides	______	______	
Alignment	______	______	
Corrosion	______	______	
Buildup	______	______	
GAS SNEAKAGE BAFFLES	______	______	

Figure 5-7. Preoperation and inspection checklist for electrostatic precipitator. (continued)

ESP PREOPERATION AND INSPECTION CHECKLIST

Facility Name:	Date of Inspection:
Facility Location:	Time of Inspection:
Process:	Name of Inspector (print):
ESP ID:	Signature of Inspector:

INSPECTION ITEM	CHECKED YES	CHECKED NO	COMMENTS/CORRECTIVE ACTIONS
RAPPERS(COLLECTOR/DISCHARGE)			
Mechanical/Electrical Connections	______	______	
Buildup	______	______	
Corrosion			
TR SET			
Surge Arrestor Gap	______	______	
Transformer Liquid Level	______	______	
Ground Connections	______	______	
High Tension Bus Duct	______	______	
Conduits	______	______	
Full Wave Switch Box	______	______	
Alarm Connections	______	______	
Ground Switch Operation	______	______	
High Voltage Connections	______	______	
Register Board			

Figure 5-7. Preoperation and inspection checklist for electrostatic precipitator. (continued)

ESP PREOPERATION AND INSPECTION CHECKLIST

Facility Name:	Date of Inspection:
Facility Location:	Time of Inspection:
Process:	Name of Inspector (print):
ESP ID:	Signature of Inspector:

INSPECTION ITEM	CHECKED YES	CHECKED NO	COMMENTS/CORRECTIVE ACTIONS
INSULATOR COMPARTMENT			
Filter Compartment	_____	_____	
Dusts/Insulation			
Flow	_____	_____	
Temperature	_____	_____	
Motor	_____	_____	
Pressure	_____	_____	
Heater	_____	_____	
BLOWER			
Current	_____	_____	
Voltage	_____	_____	
RPM	_____	_____	
Static Pressure	_____	_____	
Belt Tension	_____	_____	
Bearing Lubrication	_____	_____	
Damper	_____	_____	

Figure 5-7. Preoperation and inspection checklist for electrostatic precipitator. (continued)

ESP PREOPERATION AND INSPECTION CHECKLIST	
Facility Name:	Date of Inspection:
Facility Location:	Time of Inspection:
Process:	Name of Inspector (print):
ESP ID:	Signature of Inspector:

INSPECTION ITEM	CHECKED YES	CHECKED NO	COMMENTS/CORRECTIVE ACTIONS
DUCTS (INLET/OUT/STACK)			
Leakage	______	______	
Joints	______	______	
Gasketing	______	______	
Dampers	______	______	
Comments/Corrective Actions			

Figure 5-7. Preoperation and inspection checklist for electrostatic precipitator.

below. Power on/off buttons with green and red lights are usually provided for components.

1. Follow key interlock procedures for closing access doors.

2. Preheat insulator compartments for several hours before energizing system.

3. Activate dust handling system (air lock, screw conveyors, etc.).

4. Operate discharge and collector electrode rapping system.

5. Operate gas distribution baffle plate vibrators.

6. Turn on high voltage (manual mode) for one section only and bring up input voltage slowly (10 percent increments) to rated voltage or rated current while recording panel meter readings. This procedure is commonly referred to as an airload test. The test establishes reference readings and checks operation of electrical equipment, clearances, etc. After these readings are recorded, turn down high voltage on the field and similarly perform an airload test on the next field. If excessive sparking or d.c. readings are obtained, another internal inspection may be necessary.

7. If system operates satisfactorily, turn off T/R sets.

8. Open bypass dampers.

9. Start blower.

10. If possible, preheat the ESP by pulling hot, clean air through the system, thus avoiding condensation of moisture and contaminant gases. Buildup of condensed material on electrodes is difficult to remove. Energize one field only to minimize the effect.

11. Allow contaminant gases to pass through the unit.

12. Record data from monitoring instrumentation (fan motor amperage and voltage; temperatures; a.c. voltage/current; d.c. voltage/current; spark rate).

5.4.3 Routine Inspection and Maintenance During Operation

During routing operation, an inspection procedure that includes a recording of ESP operation data should be used. Samples of a routine daily and weekly inspection form for an ESP are provided in Figures 5-8 and 5-9, respectively. Only visual inspection of

DAILY ESP INSPECTION FORM

Facility Name:	Date of Inspection:
Facility Location:	Time of Inspection:
Process:	Name of Inspector (print):
ESP ID:	Signature of Inspector:

T/R CONTROL SET NO.	PRIMARY VOLTS	PRIMARY AMPS	SECONDARY AMPS 1	SECONDARY AMPS 2	SECONDARY KVOLTS 1	SECONDARY KVOLTS 2	SPARKS PER MINUTE	COMMENTS/CORRECTIVE ACTIONS

HV Bus Duct Noise? YES / NO

Localized Sparking? YES / NO

Transformer-Rectifier Readings OK? YES / NO

Precipitator Hopper Levels OK? YES / NO

Rapper and Vibrator Controller Operating? YES / NO

Gas Temperature ______°F

Opacity ___________%

Figure 5-8. Example daily ESP inspection form.

WEEKLY ESP INSPECTION FORM	
Facility Name:	Date of Inspection:
Facility Location:	Time of Inspection:
Process:	Name of Inspector (print):
ESP ID:	Signature of Inspector:

INSPECTION ITEM	COMMENTS/CORRECTIVE ACTIONS
Check HV Transformer Oil Level and Temperature	
Inspect T/R Control and Purge Air Filters	
Check Access Door Air Inleakage	
Check Purge Air and Heater System Operation	
Rapper System Settings Check	
Vibrator System Settings Check	

Rapper/Vibrator Setting Record	Field 1	Field 2	Field 3	Field 4	COMMENTS/CORRECTIVE ACTION
Rapper Settings - Previous Intensity Frequency					
Rapper Settings - New Intensity Frequency					
Vibrator Settings - Previous Intensity Frequency					
Vibratory Settings - New Intensity Frequency					

Figure 5-9. Example weekly ESP inspection form.

the unit is possible, and therefore only instrumented operational parameters can be obtained. Inspection forms for longer periods of time (e.g., quarterly and annually) are more ESP manufacturer and process specific and should be developed on a site and ESP specific basis. A tailor-made checklist can be prepared by the user based on vendor recommendations and process specific gas parameters. An example maintenance report form is presented as Figure 5-10 to report items requiring maintenance attention and the completed maintenance activities.

5.4.4 Routine Shutdown

An ESP is shut down primarily because of routine or emergency process shutdown, routine ESP maintenance, or emergency ESP malfunction. In these situations, the ESP should continue to be operated until it is purged with clean air. The following steps are then taken:

1. Stop blower.
2. If possible, isolate ESP by closing inlet/outlet dampers.
3. Shut down T/R set.
4. Continue to operate rapping and dust removal system until wires and plates are believed to be clean; then shut down rappers and dust removal system (make sure that hoppers are clean).
5. Open access doors following interlock procedure.

   Note: Hopper access doors should be opened with care because hot dust may be packed against them.
6. Use ground hooks to remove extraneous electric charge buildup.
7. Allow system to cool and dust to settle before entering.
8. Allow insulator compartment vent system to operate.

MAINTENANCE REPORT FORM

Department	Unit	System	Subsystem	Component	Subcomponent

Originator: ____________________ Date: __________ Time: ____________

Assigned To:

1	Mechanical
2	Electrical
3	Instrumentation

Priority:

1	Emergency
2	Same Day
3	Routine

Unit Status:

1	Normal
2	Derated
3	Down

Problem Description: ____

____

____

____

Foreman: ____________________ Date: __________

Job Status:

1	Repairable
	Hold for:
2	Tools
3	Parts
4	Outage

Cause of Problem: ____

____

____

Work Done: ____

____

____

Supervisor: ____________________ Completion Date: ____________

Materials Used: ____

____

____

Labor Requirements: ____

____

Figure 5-10. Example maintenance report form.

5.4.5 Maintenance During Shutdown

When the ESP can be entered, internal inspection can be commenced (Figure 5-7). It is advisable to leave the insulator compartment vent heaters on during shutdown to prevent moisture from condensing on the high-voltage insulators. Generally, the high-maintenance items are:

Discharge electrode breakage
Plugged hoppers
Insufficient rapping
Insulator bushing failure
Electrical component breakdown

5.4.6 Wet Electrostatic Precipitator Operation and Maintenance

As one would expect, the WEP has a high potential for corrosion and scaling and requires a water treatment system. If the wash liquor is to be recycled through the WEP, which in most cases is necessary to save on water consumption, the same water treatment methods used with scrubbers must be applied. Concentration of suspended and dissolved solids must be maintained, in addition to pH control. The clarification of solids must be sufficient to minimize spray nozzle plugging and buildup of recycled materials on the internal members of the precipitator. If condensible materials are being collected, a means for removing them must be provided (such as skimming devices or methods for sludge removal).

The dissolved solids concentration must be maintained at a steady and acceptable level, either by the right amount of purging, by chemical treatment, or both.

Pre-Startup Inspection--

Before starting up the WEP, a thorough inspection of the system is required. The procedure and checklist to follow is provided in Figure 5-7, with the exception of items applying to the water cleaning system.

<u>Water Cleaning System</u>

Turn on water cleaning system and check all pipe connections for leaks.

Check for adequate water flow.

Check individual water line pressure.

Check angles and direction of nozzle spray. Correct nozzle positioning is necessary to obtain coverage of precipitator internals.

Inspect drain system to ensure that wastewater drains freely.

Check for adequate clearance between piping and high voltage system.

WEP inspection checklists can be compiled using Figures 5-7 through 5-9 and equipment supplier maintenance documents.

Routine Startup--

Follow procedure in Section 5.4.2, except replace Items 3, 4, and 5 with activation of spray system.

Routine Inspection and Maintenance During Operation--

Only visual inspection of the external components of the system is possible during operation. Therefore, only instrumented operational parameters can be observed, along with inspection of electromechanical equipment and structural components. A routine daily and weekly inspection checklist for a WEP can be made from Figures 5-8 and 5-9. Since actual inspection and maintenance practices are quite specific to the particular system used, a tailormade checklist should be prepared by the user and vendor.

Common Malfunctions--

Scaling, buildup, and corrosion are commonplace in WEP's. These conditions are prevalent not only within the liquor recirculating system, but also in the electrostatic precipitator housing. Liquor clarification and chemical treatment are critical to WEP performance. Thorough familiarity with scrubber and dry ESP troubleshooting procedures are necessary in order to properly diagnose WEP malfunction and poor performance.

5.5 Operator Training

Proper training of ESP operating staff is necessary to ensure that the system operates at its peak performance level. An ESP system consists of several electrical and mechanical components. The operator must understand the function of each component and should be able to diagnose impacts of any abnormal changes in the operating parameters of the individual system components.

The operators will normally receive initial training from the ESP manufacturer. A manufacturer's representative is on site during the start up of the system to ensure that the system parameters are defined for the source being controlled. Minor and major adjustments will be done during the startup phase and the ESP operator should accompany the vendor representative during this phase.

The operator should also renew the equipment manual provided by the system supplier and highlight key sections of the manual. A ready reference chart of the key parameters and their normal accepted ranges should be prepared to identify any potential problems.

Operator training should be performed when the ESP is initially installed and periodically (e.g., semiannually) for new operators. The operator training should address ESP failure modes and malfunction diagnosis topics. This should include:

- ° Special operating problems
- ° Process startup and shutdown
- ° Wire breakage
- ° Plate alignment
- ° Hopper overflow
- ° Dust handling system

Understanding of the operating parameters of the process discharging to the ESP is also important and the operator should be familiar with the process parameters and their impact on the operator of the ESP system. The operator should be aware of the process upset conditions and necessary ESP remedial measures.

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