Transforming the
Future of Power Technology

ESP
Controls & Electrical Systems
Troubleshooting Guide

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Transforming the Future of Power Technology

Introduction

A Portable Informational Resource on ESP Controls and Electrical Systems

Competitive pressures on the utility industry mandate doing more with less—fewer (and younger) maintenance personnel, tighter budgets and less time to effect solutions to electrostatic precipitator control system problems. Yet, in the utility industry, pollution control remains as critical as ever. While there are a number of good resources available on the theory and operation of electrostatic precipitators (ESPs)—*The Art of Electrostatic Precipitation*, first published November 1, 1979, immediately comes to mind—there has not been a good book that provides helpful diagnostic sequences one can use to deal with day-to-day ESP electrical control problems.

Until now.

Welcome to NWL's *ESP Controls & Electrical Systems Troubleshooting Guide*. Organized into four sections, this handbook is designed to give maintenance essential, critical troubleshooting information in an easy to read and understand format. Toward that end it contains:

- Quick overviews of key terms and concepts

along with descriptions of two critical components: the Current Limiting Reactor (CLR) and Transformer Rectifier (T/R).
- Practical, easy to use troubleshooting tips.
- Equipment diagnostic "decision trees" for determining the cause of malfunctions among such equipment as T/R Sets, T/R Controllers, and Rapper Controllers and poor electrical performance indicated by low meter readings, back corona and opacity spikes.

The troubleshooting decision trees follow a simple "yes-no" question format to make getting to the root causes of problems quickly. In short, whether you are new to the field or an old hand, the *Troubleshooting Guide* offers a wealth of information right at your fingertips—including a helpful index. The index contains important ESP terminology, glossary of air-pollution control terms, listing of Clean Air Act Amendments as well as useful metric and altitude-pressure temperature density tables, along with a listing of Title III hazardous air pollutants.

As you can well imagine, it would be impossible to cover every imaginable potential problem within the confines of a short pocket book such as this one. As a result, we have only focused on those our experience shows to be most common and critical.

Please feel free to call our technical staff if you have troubleshooting issues not covered in the confines of this guide—whether the equipment was made by NWL or not. If required, we can also offer expert field-service diagnostics, repair and replacement equipment.

Having designed and built more than 10,000 T/Rs over the past ten years, NWL can provide both field service and shop repair of almost any ESP T/R. Our repair group—with dedicated facilities and inventory—is extraordinarily responsive to equipment-repair needs, providing one-to-four week turnaround on most repairs.

Preventive maintenance is, of course, the most cost-effective way to deal with problems—before they occur. In fact, many T/R failures are often caused by process and system changes that can only be truly evaluated on-site. Our trained technicians and engineers may also be called upon to evaluate T/R and control-system performance under actual operating conditions.

Finally, if you have questions you would like answered in future editions of this Guide, please contact us. We stand ready to help meet your pollution control equipment diagnostic and preventive maintenance needs.

SECTION I

Transforming the
Future of Power Technology

CONCEPTS AND TERMINOLOGY:

Power Sources For Electrostatic Precipitators

- **Abstract**
- **Overview**
- **The Current Limiting Reactor (CLR)**
- **The Transformer Rectifier (T/R)**
- **The T/R Controller**

Abstract

The purpose of this section is to provide a summary of technical terms and concepts that are generally employed in the field of commercial electrostatic precipitation. The descriptions provided are limited to the components and concepts associated with providing electrical energy to the precipitator. This system of components shall be referred to as the ESP Power Supply.

Overview

The purpose of the power supply for an electrostatic precipitator (ESP) is to provide a source of high voltage for the discharge electrodes of the system. The power supply must accept incoming voltage that is available from the plant; typically 380VAC to 690VAC single phase and output voltage levels from 45KVDC to over 100 KVDC. The amount of electrical current delivered by the power supply is a function of the size and load of the ESP field. Current levels from 500 maDC to 1500 maDC are typical for industrial applications.

The dynamic nature of the ESP load imposes severe stress on the power supply system due to the requisite sparking and arcing that occurs within the ESP field. The power supply must be capable of sensing these disruptions and then be capable of altering its output to clear these disruptions while maximizing the efficiency of the ESP field.

The four major components of the system include: the Control Cabinet, the Current Limiting Reactor (CLR), the Transformer Rectifier (T/R) and

the Voltage Control System which is a major subassembly of the control cabinet. The term Automatic Voltage Controller or AVC is commonly used when referring to the control electronics of the system.

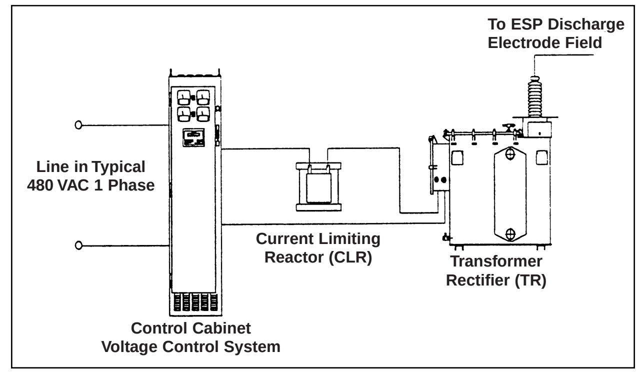


Figure 1 ESP power supply main components

The control cabinet accepts a line feed that is typically 480AVC and provides an output that is a phase angle controlled power source for the system. Phase angle control is established through the use of silicon controlled rectifiers (SCRs). The level of power delivered to the system is a complex function of set points and feedback signals.

The major components of a typical control cabinet include the Automatic Voltage Control System, the SCR system, panel meters, illuminated indicators and a circuit breaker.

The current limiting reactor is an iron core inductor that serves to limit current surges in the system and to provide “wave shaping” of the T/R primary current. The electrical rating and physical size for the CLR varies widely for different size systems and varied applications. For smaller systems, the CLR may be either mounted inside the control cabinet, in an attached enclosure to the T/R, or inside the T/R oil tank. Large systems usually include a separate stand-alone enclosure for the CLR.

The Transformer Rectifier accepts a phase angle control feed signal typically up to 575VAC and delivers a high voltage Direct Current (DC) voltage to the ESP. Average output voltages for T/Rs range from 55KVDC to over 100KVDC. T/Rs are oil filled assemblies that house a step-up transformer and a high voltage rectifier system. In addition, the T/R provides feedback signals to the control electronics (AVC) to permit spark detection, waveform analysis and metering for operator readout. The T/R assemblies are usually mounted on the top of the ESP and use pipe and guard systems for distributing the high voltage power to the emitter electrodes.

The Automatic Voltage Controller (AVC) mounts inside or on the door of the control cabinet. Modern AVCs are microprocessor based systems available from a variety of vendors. The AVC accepts feedback signals from the T/R as well as feedback signals from components in the control cabinet. The primary output signal of the AVC is a signal that is used to control the firing angle for the SCRs within the control cabinet. The AVC continuously adjusts the firing angle to achieve the desired performance for the ESP field. Modern AVCs are usually equipped with digital readout, keypad operator entry system and a communication link for remote control and monitoring.

The Current Limiting Reactor (CLR)

A. Physical Location

The Current Limiting Reactor (CLR) is a large inductor that is used in the primary circuit of the T/R. The purpose of the CLR is to limit the maximum current in the T/R primary and to provide a means of shaping the wave form of the Power Supply output. The CLR can be physically located inside the T/R tank, inside the T/R junction box or in a separate free standing enclosure. The choices for locating the CLR are primarily economically driven for systems below 200 amps. At currents above 200 amps, the heat generated by the CLR usually makes the choice of a separate enclosure mandatory.

B. Inductance

The unit of measure for reactors is the henry. The ability of a reactor to impede the flow of AC current is termed inductance. The inductance of CLRs is usually from 5 to 20 millihenries (.005H to .020H). The CLR value that is required is based upon the total system impedance that is desired for the power supply. This system impedance limits the maximum amount of current that can flow in the primary circuit and is usually specified as percent impedance. A value of from 30% to 50% is usually employed. The impedance of the reactor can be calculated by:

$$\mathbf{Z_{clr} = L \times (2 \times \pi \times f) = L \times 377}$$

where Z_{clr} = impedance in ohms
L = inductance in henries
π = 3.1415

f = frequency in hertz

The percent impedance that the CLR provides is calculated by:

$$\%Z = \frac{L \times 377 \times I \times 100}{V}$$

where

%Z = percent impedance
L = inductance in henries
I = rated primary current
V = system voltage (typically 480 or 575 VAC)

The same formula can be used for calculating the inductance required for a desired % impedance by:

$$L = \frac{V \times \%Z}{I \times 377 \times 100}$$

The system impedance also includes the reactance of the transformer which is typically 5% to 10%. A system impedance of 50% limits the maximum AC current to twice the rated current. At 33% the limit is three times the rated current. When specifying the CLR, the inductance in henries, the primary rated current, and the anticipated spark rate must be given. Since the ESP will periodically spark, the actual average current that the CLR will need to withstand is greater than the T/R rated current.

C. Limiting Peak Current

The term Current Limiting Reactor is somewhat misleading. Although a system impedance of 50% will limit AC current to twice its rating, this is of limited value in light of the fact that neither the

CLR nor the T/R can withstand such current for any length of time before failing. The current limiting characteristic of the CLR that is most important is the ability to limit the rate of rise of current over a half line cycle (8.3 milliseconds). When a severe arc occurs in the ESP, the voltage at the point of the arc drops to near zero. The amount of current that will flow through the arc is limited by impedance of the various feed components, including the transformer, CLR as well as the inductance of the ACR and HV buss work.

In addition, the peak current through the arc is increased by the capacitive discharge of the ESP. As the current through the arc increases, the CLR will be subject to the full line voltage. A 50% impedance system will limit the peak current through the primary to about two times the rated current. In addition, the rate of rise in current through the primary circuit and the SCR controller will be limited to remain within the rating of the SCR devices.

The peak current that accompanies arcs imposes a severe stress on the CLR. The CLR must be capable of withstanding repeated arcing with the resultant two times rated current without adverse effect. To accomplish this, both conductor size and core size must preclude magnetic saturation during peak current conditions. If the core of the CLR were to saturate, then the inductance would diminish to near zero and the CLR would cease to contribute to limiting fault currents.

D. CLR Wave Shaping

The second function of the CLR is to smooth out the pulsating waveform to the ESP. The full wave rectified signal that is supplied to the ESP is actually a pulse train at 120 pulses per second. If the system was permitted to run at full conduction, then the output signal would tend to be a sinusoidal. In reality, however, the waveform of the primary current as well as the secondary voltage (KV) is affected by the conduction angle of the controller, the system inductance, the capacitance of the ESP and the secondary current level.

The wave shape of the T/R primary current is affected by the amount of reactance in the primary circuit. This wave shaping results in several benefits to the overall system. These benefits become particularly important for systems that are running at conduction angles of 90 degrees or less (50% conduction or less). As the inductance of the primary circuit is increased, the percent conductance at a particular load level can be significantly increased. The benefit that is realized is the ability to increase the average current to the ESP before sparking occurs. In many instances, this increased current level results in better collection efficiency for the ESP.

The Transformer Rectifier (T/R)

The T/R is a critical component of the ESP power supply. The purpose of the T/R is to accept an AC power feed from the SCR/CLR control system and convert the 0 to 480VAC (nominal) signal to the required level of high voltage. Transformer Rectifiers are oil filled tanks with a low voltage junction box and one or two high voltage bushings. Single bushing T/Rs are referred to as full wave units and dual busing T/Rs are referred to as double half wave units.

Figures 2 and 3 show the electrical configuration of a full wave and a double half wave unit. T/Rs are usually mounted on the roof of the ESP. Large ESPs may require 50 or more T/Rs. The electrical components of a T/R include the high voltage transformer, the diode assembly, the air core reactor (ACR), the feedback voltage divider and a ground switch which may be integral with the T/R or mounted in the bus duct.

A critical component of the T/R, that is not shown in the electrical drawing, is the dielectric fluid that fills the T/R tank. This fluid provides a means for electrically insulating the internal components as well as a means for dissipating internally generated heat.

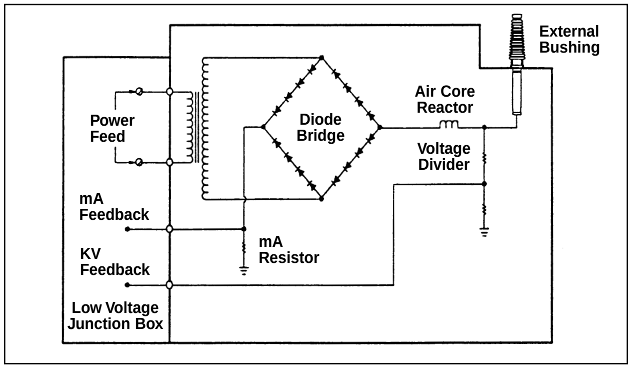


Figure 2 Electrical drawing single bushing full wave transformer

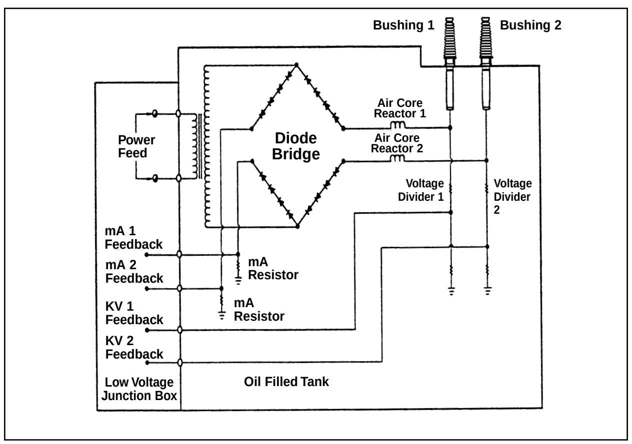


Figure 3 Electrical drawing dual bushing (double half wave) transformer rectifier (TR)

A. T/R Dielectric Fluids

Three types of fluid are presently used for T/R dielectric fluid.

1. Petroleum Based Oil: also known as "transformer oil" or mineral oil. This oil is obtained from

the fractional distillation of crude petroleum. Mineral oil is the most commonly used dielectric fluid for T/Rs.

2. Silicone Oil: a linear polymer liquid termed polydimethyl siloxane or PDMS. This fluid has a higher fire point than mineral oil. Silicone fluid is normally used for indoor applications or when decreased flammability is deemed necessary. Silicone fluid costs considerably more than does mineral oil. Silicone fluid is slightly more viscous than mineral oil for temperatures above 10 degrees Celsius and sometimes requires additional measures be taken to facilitate heat transfer (additional radiator or bigger tank). Usually, however, this is not a critical parameter if tank size is conservatively designed.

3. High Molecular Weight Hydrocarbon: This dielectric fluid is a less costly alternative to silicone fluid for installations needing reduced flammability. HTH fluid is a petroleum based product. Since HTH is significantly more viscous than both silicone and mineral oil at temperatures below 100 degrees Celsius, heat transfer characteristics at lower temperatures require extra consideration in the T/R tank and radiator sizing. The use of this dielectric could be a problem when used in a cold environment where T/Rs are allowed to cool off. This problem is overcome by gradually bringing the T/Rs up to full power to allow the fluid to heat up.

B. The Transformer

The step-up transformer is the major component of the T/R system. Transformers designed for ESP applications employ design techniques specifically developed for this use. ESP transformer coils must be capable of withstanding repeated sparking and arcing of the load. Disruptions such as these, along with occasional shorted fields, cause current surges well above the system ratings. These surges cause the windings of the transformer to exert considerable physical force on the system insulation and support mechanism. If not properly accounted for, these forces will eventually cause premature destruction of the insulation and system failure. The transformer design must integrate the many specified requirements of the system. Included are

1. Turns ratio of the transformer (A 400 VAC to 40 KVAC transformer requires a ratio of 400 to 40,000 or 1 to 100).
2. The peak secondary voltage to determine the internal insulation and clearances.
3. The average/peak secondary current required.
4. The voltage and current "form factors" as determined by the impedance of the load. These form factors define the relationship between the average and RMS values of the output waveforms. There is a separate form factor for the load voltage and load current. These form factors are used to size the transformer to provide the desired average output voltage and current for a specific load impedance.
5. The maximum temperature rise allowed as determined by the ambient air temperature extremes.
6. The maximum available primary voltage as determined by the feed voltage and the primary reactance of the system.
7. The KVA rating of the system to determine conductor sizes as will as core size.

The transformer is typically the most reliable component in the system. Failures of transformers, however, do occur and can often be placed in two general categories. The first is degenerative failure that is caused by the long term breakdown of a component part. If the transformer is used within its rated parameters, then degenerative failure is most likely due to a defect of material or workmanship. the second failure category is overstress failure. Overstress failure is caused by subjecting the transformer to either excessive voltage or excessive current. Overstress failure is usually the case for transformers that fail between five and twenty years of operation.

Degenerative Failure

Of the components and materials used on T/Rs, the layer insulation on the transformer winding determines the life expectancy of the system. Modern designs use Kraft insulation. The life expectancy of the insulation is a function of stress level (voltage across the insulation) and temperature of the insulation material. The operating temperature of the insulation is usually assumed to be 10˚ (C) higher than the overall temperature rise of the winding. The 10˚ margin is based upon the assumption that heat transfer between the coils and the oil can never be absolutely uniform. The expected life of the insulation for modern designs is 34 years if the unit is continuously subjected to rated current and rated voltage (REF ANSI C57.91.1981). Degenerative insulation failure after less than 15 years, although possible is statistically very unlikely, unless there are other contributing factors.

Degenerative insulation failure can be caused by abrasion caused by excessive vibration and physical movement of the transformer windings. Vibration is induced by the 60 cycle AC current while coil movement is induced by current surges. ESPs by nature present a harsh load for transformers due to the sparks and arcs that are expected. T/Rs designed for such applications must therefore employ extraordinary measures to tolerate such conditions. If such measures are not employed or improperly employed, then the abrasion of the coils will occur.

Stress Failure

Stress failure of the T/R occurs when the unit is subjected to either overvoltage or overcurrent conditions. Operators should be suspicious of overstress failure mode if a T/R failure was preceeded by some change that effected operating levels. Common causes for such changes include change in the fuel in use and change out of the T/R controller. But a change in fuel and the resultant change in ESP operating conditions should not cause overstress of the T/Rs. The task of operating the T/R within their design limits is accomplished by the T/R controller. The controller should limit both the KV level and the current level as well as the spark rate to safe limits. The potential for problems with overstress of

the T/R become greater when controls are not properly calibrated and/or if the system feedback does not include the KV signal.

C. The Diode Assembly

1. Function in T/R

The diode assembly of the T/R converts the high voltage AC output of the transformer to a DC signal. The diodes are configured as a full wave bridge with the positive output of the bridge connected to earth ground. The negative output is routed through an air core reactor and then to the high voltage bushing. The diode assembly is made up of a series string of many diode junctions. This series string of diodes should be capable of blocking at least twice the peak output voltage of the T/R. A typical 45 KV T/R will have a peak output voltage in excess of 75 KV. The diode assembly must, therefore, have an effective PIV (peak inverse voltage) of at least 150 KV.

The use of a series string of diodes to obtain high blocking voltage requires that special measures be employed to assure proper voltage sharing. Improper voltage sharing is caused by variation of the reverse leakage of individual diode junctions. This variation results in an uneven distribution of the PIV among the diodes. The wide tolerance that is characteristic of standard silicon diodes will cause the devices with the lowest leakage to accept a disproportionate share of the total voltage. If this phenomenon is permitted to occur, then the diodes will fail in a “domino” fashion.

2. Types Used
Prior to 1980, T/R manufacturers employed the use of RC (Resistor-Capacitor) compensation to address the voltage sharing problem. This approach provided a means of using standard 1000 volt diodes in a string with each diode connected in parallel with a resistor and capacitor. The resistor serves to limit the DC reverse voltage to be shared, while the capacitor distributes high frequency AC voltages caused by sparking and/or “ringing” of the ESP system.

Since 1980, several T/R manufacturers have employed “controlled avalanche” diodes and eliminated the need for the RC compensation. These diodes are now available with ratings exceeding 10,000 volts PIV for each device. Avalanche diodes are screened to insure closely matched reverse leakage characteristics. Because of this, they can be relied upon to properly share the total reverse voltage without the need for parallel RC compensators.

T/R bridge assemblies that use such diodes can usually be assembled on a single circuit board that is mounted in the T/R tank. The RC compensated technology required large assemblies that are populated with many small circuit boards to make up the diode bridge network. Such assemblies consume considerable space in the tank, are prone to mechanical failure and are difficult to replace in the event of failure.

3. Failure Modes
The two common causes for diode failure are excessive electrical stress due to either overcurrent or to overvoltage. Diode failure from overcurrent may

occur if the power supply is allowed to exceed its rated current output for an extended period of time. Since most T/Rs in service have a source impedance of about 50%, the T/R can actually deliver twice its rated current.

In cases of disruptions such as severe arcs or shorted output, the system relies upon the controller to maintain the output current to a safe level. When such disruptions occur, the current may instantly rise to twice rating but must be quickly reduced by the controller to preclude damage to the T/R. If an overcurrent condition is permitted to continue, excessive heat is generated by the diodes. As the diode junctions heat to beyond their rated temperature, the bridge will fail.

Heat Related Failures. In many cases of T/R overcurrent, the heat generated by the diodes cause the diode junctions to exceed their maximum operating temperature. When this occurs the diodes will fail. Occasionally the heat generated will be sufficient to cause the solder that fastens the diodes to the PC board to melt away. As the solder melts and is displaced with dielectric fluid, arcing occurs between the diode lead and the PC board. This arcing results in the breakdown of the dielectric fluid. Carbon and cyanide gas are two of the resultant components of this breakdown. If the internal arcing continues, then the generated carbon will eventually be attracted to the transformer windings and cause failure of the transformer. If excessive cyanide gas is generated, then the air space between the tank lid and the oil will become explosive.

In some cases of overcurrent the diode junction fails to an open condition prior to melting the solder. In such cases, the open circuit diode will be subjected to the entire output voltage of the T/R. This voltage is sufficient to permit arcing around the failed diode creating carbon and cyanide. In addition, the remaining diodes will be subject to excessive voltage and in turn fail. In some cases this process may take place within a few minutes after which the T/R will cease to perform. Such rapid failure modes are less catastrophic because the oil is usually not severely contaminated and the T/R can be repaired on-site. If the failure, however, takes days, then the oil will be severely contaminated and the T/R will require major rebuild in order to be put back in service.

Voltage Related Failures. The second cause of failure of the diode bridge is an overvoltage condition. The diode bridge must be rated for a PIV of at least twice the peak output voltage of the T/R. Intuitively it could be assumed that such a condition could not occur. There are, however, two ways that T/Rs are subject to overvoltage. The most common cause of overvoltage is a malfunctioning or misused controller. A less common cause of overvoltage is voltage "ringing" of the T/R and the ESP.

The provision for KV limitation of the T/R output is a standard feature of most controllers. To accomplish this, a KV feedback is needed. This feedback signal is sometimes either not available because of a lack of voltage dividers in the T/R system or because of a feedback failure. Some controllers use

the primary voltage in conjunction with the turns ratio to calculate the KV value. This calculated value, however, can never be truly accurate because of the unknown load characteristics of the ESP.

When T/Rs are specified, the primary voltage rating is usually 10% to 20% lower than the actual feed voltage. This primary voltage rating (usually 400 VAC for a 480 VAC feed) is specified so that full KV output can be supported under full current conditions. A 480 VAC system with 50% impedance can only deliver about 400 VAC to the transformer primary under full current conditions because of the voltage drop in the reactor (CLR). If, however, the T/R is under no load conditions (i.e. open circuited), then entire feed voltage of 480 VAC can be impressed upon the primary. This 20% overvoltage on the primary results in a similar overvoltage on the secondary. In addition, under open circuit conditions the output bushing will charge to the peak voltage of the secondary voltage waveform. A 55 KV, T/R will charge to approximately 92 KV. Bridge failure under such conditions depends upon the bridge rating. Its ability to survive such stress depends upon the amount of safety factor designed into the T/R.

High Voltage "Ringing." The second cause of overvoltage condition is "ringing" of the secondary circuit. This phenomenon is fairly unusual but does occur under some conditions. Ringing is a term that denotes resonant oscillation of the secondary circuit. An important element of the T/R secondary circuit is the ESP box itself. A resonant circuit is created whenever a capacitor and an inductor are connected together. The plates and wires of an ESP have both a resistive and a capacitive component. Prior to the onset of corona, the ESP is essentially a capacitive load to the T/R. As corona current increases, the resistive component of the ESP increases.

"Ringing" or resonant oscillation is more likely to occur when sparking occurs under light load conditions. Under such conditions, a tank circuit is made up of the ESP acting as a capacitor and a combination of the transformer, the ACR and the high voltage bus work as an inductor. Oscillation will occur at the resonant frequency of this system which is typically a few KHz.

The existence of ringing can be observed through use of an oscilloscope on the secondary feedback. Ringing can be detected by monitoring KV feedback using an ESP spark as a scope trigger. If a problem exists, then a damped oscillation at 1–5 KHz will be observed with peak voltages in excess of T/R ratings.

D. The Voltage Divider

1. Function*:* The voltage divider provides a means for supplying a low voltage feedback signal that is proportionate to the KV output of the T/R. This signal is used for both metering and for control purposes. Most modern T/Rs include a voltage divider that is mounted under fluid within the T/R tank. Many of the older systems, however, did not use KV feedback as a control or metering parameter. In many such installations, external voltage dividers may be mounted outside the T/R near the high voltage bush-

ing to obtain KV feedback.

The voltage divider is a resistor network connected to the high voltage bushing. This divider is made up of a series string of many resistors. Divider values of 50 megohm, 80 megohm and 120 megohm are typically used. The high resistance is used to create a current source that is typically a 0–1 milliamp that is proportionate to the full scale voltage of the T/R. A 50 meg divider provides 0–1 ma feedback signal that corresponds to 0–50 KV output. The output of the voltage divider could be used to directly drive a 1 ma meter with an appropriate scale or it could be converted to a voltage signal. A 10 K ohm resistor is commonly used to provide a 0–10 volt feedback signal. This approach permits the physical location of the resistor to be close to the T/R and reduce the possibility of high voltage signals in the control area. Many of the modern digital controllers use a 0–5V or 0–10V signal for KV feedback for metering and for spark detection. This low voltage feedback can be used to drive an analog voltmeter with an appropriate scale that is wired in parallel with controller.

2. External Dividers: The external voltage divider network is usually mounted in a protective insulating tube of PVC or fiberglass. The divider must be capable of dissipating the heat that is caused by the maximum voltage (KV) output of the T/R. For a 50 meg divider, the power at 50KV is 50 watts. The physical configuration of the external divider must provide a means of dissipating this energy (heat) at a rate sufficient to maintain the resistor temperature within its rated maximum.

Voltage dividers are simple devices and are easily maintained. Failure of the divider is often caused by mechanical or thermal stress. The testing and replacement of dividers is usually a task well within the skills of plant personnel. The testing of dividers for proper resistance could be accomplished through the use of a general purpose digital meter although the use of a "Megger" is preferred. If a general purpose multimeter is used, then the divider should be disconnected from the T/R; connections should be made through use of high voltage clip leads. Any stray charge or capacitance that may exist will affect readings in the 50 meg+ range.

E. The Air Core Reactor (ACR)

1. Function: The Air Core Reactor (ACR) provides a means for protecting the diode bridge from high voltage "transients" that occur within the ESP. ACRs used in modern T/Rs are rated from 20 to 50 millihenries. As the ESP sparks and arcs, the full ESP voltage will be impressed across the ACR. ACR design must provide sufficient layer insulation and clearance to accommodate such voltage. Typical failure mode for ACRs is a sparkover of the layer insulation. Since the ACR is physically much smaller than the transformer secondary coil, it is subject to extreme voltage stress. In the event of any contamination of the dielectric fluid, the ACR is often the first component to fail.

2. Double Halfwave: The "Double Half Wave" use of T/Rs results in severe stress of ACRs. The Double Half Wave system provides a means of exciting two isolated electrode fields from one T/R. Each field is energized by half of the DC output to provide a 60 Hz pulse train, with 8.3 milliseconds on and 8.3 milliseconds off. While seldom used today, this configuration was often employed during the late 1960s. During that period, several installations achieved increased efficiency through the use of the pulsing effect of the split output.

In addition, this approach provided the benefit of isolating a faulty field through the use of the HV switch that is provided. Potential problems for the power supply of the DHW include: unbalanced load for the transformer, complex spark reaction for the controller and capacitor dumping and ringing through the ACR. The ACR problem occurs when one of the fields sparks and discharges both fields through the ACRs and the switch. Many installations that featured the DHW configuration now connect the two bushings together to avoid excessive stress of the T/R components.

The T/R Controller

The purpose of the T/R controller is to accept the incoming line voltage from the power source (typically 480 VAC) and provide a variable voltage to the T/R set. Modern day controllers utilize fast acting Silicon Controlled Rectifiers (SCRs) to phase angle control the primary voltage. Older controllers utilized much slower saturable core reactors to vary the voltage. The exact voltage that the controller will output to the T/R is a function of a number of variables that are dependent upon the precipitator load and the T/R set being used. The controller will try to maintain the highest possible voltage on the precipitator field for varying load conditions. The highest possible voltage is typically the sparkover voltage of the field. The controller must also protect the T/R set from sparks or arcs that occur in the field. It must also make sure that the system is not operating at any current or voltage levels that exceed the design ratings of the T/R set.

Modern controllers utilize microprocessor circuits to analyze feedbacks and operating setpoints to determine the proper output levels. These microprocessors also provide data acquisition, graphical trending of metering values, graphical V-I curve of the precipitator field and an assortment of other features. Most control enclosures contain the following major components.

A. Circuit Breaker

The circuit breaker is used to protect the system from short circuits that occur primarily on the 480 VAC line. It also acts as a lockable disconnect device for removing power from the controller for maintenance purposes.

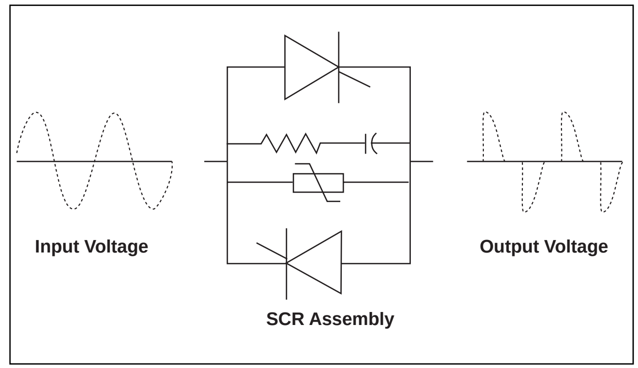
B. Contactor

The contactor is the main device for energizing and de-energizing the primary power to the T/R set. The control circuits open the contactor to remove power if an system alarm occurs. Some controllers use a

shunt trip circuit breaker instead of a contactor.

C. SCR Assembly

The SCR assembly is the main device used to regulate the primary voltage to the T/R set. The assembly is made up of two SCRs connected in a reverse polarity parallel configuration.



One SCR controls the positive half cycles while the other controls the negative. The SCRs are protected from dv/dt damage by a resistor capacitor snubber network and a metal oxide varistor. They are also fused to protect against overcurrent conditions.

The SCR will turn on when two conditions are simultaneously met. The SCR must be forward biased and the gate must be given a trigger signal. By varying the time delay between when these two conditions occur, the amount of time that the SCR is on will also vary. The amount of time that an SCR is on is called the conduction time. It is more commonly referred to as the conduction angle and expressed in terms of degrees. Zero degrees conduction means that the SCR is not gated on, and 180 degrees conduction means the SCR is fully gated on.

D. Metering Circuits

Most control enclosures also contain analog meters in addition to the digital metering displays of the microprocessor circuits. The analog meters provide a better visual trend of the readings under sparking conditions of the precipitator.

E. Alarm Circuits

Alarm circuits are used to monitor the system and de-energize the T/R set if certain conditions occur. The common alarm conditions are:

Overcurrent—Protects the T/R and controller from operating at current levels above the T/R ratings.

Undervoltage DC—This occurs if the output voltage of the T/R remains low (typically under 10 KVDC) for more than a short period of time (typically 30 seconds). Undervoltage alarms usually indicate a shorted field, a shorted T/R, or a malfunction in the controller.

Overvoltage DC—This occurs if the output voltage of the T/R set goes above the rating of the set. This alarm usually indicates a problem with the power system or an open circuit in the precipitator field.

SCR Unbalance—If both SCRs are not operating at the same conduction angle, a DC voltage will be fed to the T/R primary. This can cause the T/R core to saturate and draw a large amount of DC current. This type of alarm usually indicates a problem with the SCRs or the triggering of the SCRs.

T/R Overtemperature—This monitors the temperature switch on the T/R set. If the oil gets too hot (typically 95˚ C) the unit will shutdown. This alarm indicates that the system may be operating at too high a current, or that there is a problem in the T/R set.

T/R Liquid Level—This monitors the level switch on the T/R set. If the dielectric fluid gets too low, the unit will shutdown. This alarm usually indicates a lead in the T/R set. Not all T/Rs have this feature.

SCR Overtemperature—This monitors the temperature switch on the SCR heatsink. If the heatsink gets too hot, it indicates either a problem with the SCRs, or the ventilation system in the enclosure. Not all SCR assemblies have this feature.

F. Limit Circuits

There are certain conditions that occur within the system that require some type of corrective action, but not necessarily turning the T/R off. With limit circuits, the conduction angle of the SCRs will automatically change to try to correct the condition. The most common limit circuits are:

Current Limit—If the current starts to exceed a preset level, the controller will reduce the conduction angle of the SCRs to whatever is required to maintain that level. Because of this, a T/R set can operate a shorted precipitator field and never exceed the current rating of the T/R.

Voltage Limit—If the output voltage starts to exceed a preset level, the controller will reduce the conduction angle of the SCRs to whatever is required to maintain that level. This is used to protect a T/R set from operating at too high a KVDC output.

Conduction Angle Limit—This is used to place the unit in manual operation or to limit the conduction angle from exceeding a certain value.

G. Process Control

The controller must perform certain process control also. The efficiency of the precipitator is directly related to the voltage applied to it. The higher the average voltage on the fields, the better they will perform. The controller must find the optimum voltage to operate at. The highest voltage that can be applied to any field is the voltage at which that field sparks. The controller will continually increase the output of the T/R until one of the following conditions occurs:

a. A spark or arc occurs
b. Current limit is reached
c. Voltage limit is reached
d. Maximum conduction angle is reached

By continually searching for the highest possible operating voltage, the controller is able to optimize the collection process for any load variations.

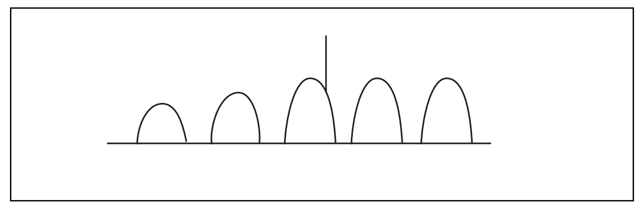
H. Spark/Arc Response

The controller's search for the maximum voltage

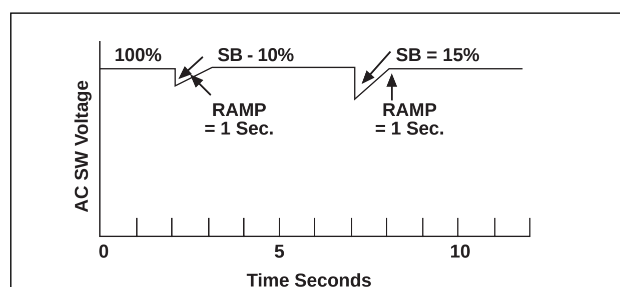
that can be applied to a field, actually causes the field to spark. The controller must also protect the system from the effects of this sparking. There are two different types of sparkovers that occur, a spark and an arc. The controller should recognize when each type occurs and respond accordingly.

Spark—A spark is a relatively small discharge within the precipitator that self-extinguishes with no increase in the base waveform current.

Since the spark is gone by next half cycle, the controller really doesn't have to protect against any large fault currents. But if it takes no control action,

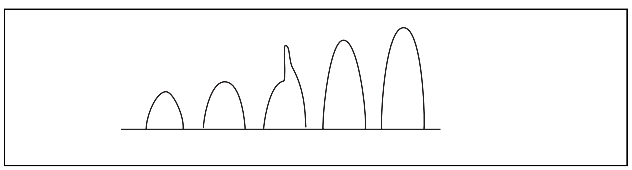


another spark will occur on the next half cycle. Each time a spark occurs the electrostatic field is discharged. If the field is rapidly sparking in this manner, it will never reach its optimum voltage. The

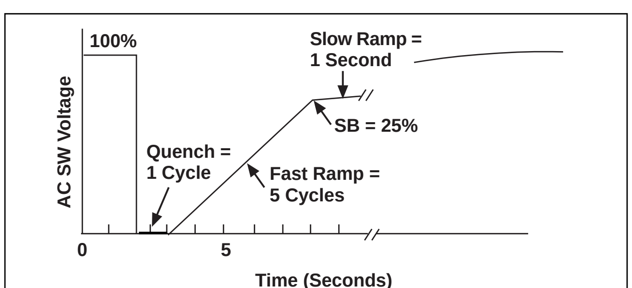


proper control response is to reduce the conduction angle of the SCRs a small amount on the next half cycle. This "setback" will reduce the KVDC in the precipitator so as to stop another spark from occurring. A "slow ramp" then increases the voltage back to the original sparkover point.

Arc—An arc is a large disruptive discharge within the precipitator that will not self-extinguish. During an arc large levels of fault current continually flow. The level of that current is determined by the system impedance but is usually high enough to damage the SCRs or the T/R rectifiers.



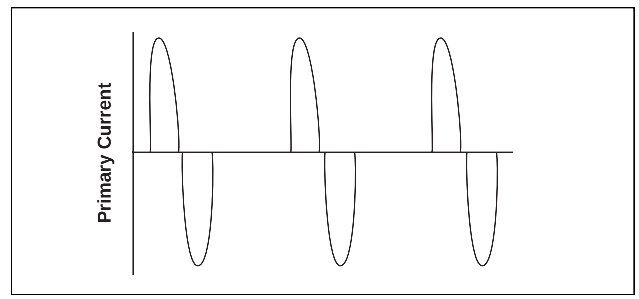
To stop this from happening the controller turns the SCRs off during the next half cycle. They will stay off for a certain duration of time. This reduces the KVDC to zero allowing the arc to extinguish or "quench" itself. The period of time that the SCRs



are off is called the "quench time". A "fast ramp" then quickly increases the voltage to the "spark setback" level where the "slow ramp" then increases it back to the arc over voltage.

I. Intermittent Energization

This mode allows the primary voltage to the T/R to be pulsed a variable number of half cycles on and a variable number of full cycles off. This pulsing may be helpful for back corona conditions or for power savings.



Care must be taken that the off time is always configured in full cycles of voltage. If half cycles are used the voltage being applied to the transformer when it turns on would be the same polarity as the voltage that was applied when it turned off. This could possibly cause the transformer core to saturate.

J. Back Corona

Back corona is a condition that occurs primarily with high resistivity ash loads and is usually associated with low sulfur coals. The resistivity of the ash determines the voltage drop across the dust layer on the collecting and electrode surfaces. If the resistivity of the dust is high enough, the voltages will be high enough to cause a back corona to be generated in the dust layer. This back corona generates positive ions that neutralize the negative charge from the electrodes. The loss of the space charge also causes a loss in the precipitator efficiency. Back corona can be diagnosed by performing a V-I curve. If the curve goes vertical, meaning small changes in KV cause large changes in mADC, back corona is present. If the curve bends backwards, meaning the KV actually decreases and the MADC increases, there is a severe back corona condition present.

Troubleshooting Tips

- **The "Lamp Test"—A Simple Means for Testing T/Rs**
- **What Meter Readings Can Tell You When Troubleshooting Transformer Rectifiers (T/Rs)**

Recommended Practice:

- **Oil Integrity Testing**
- **Mineral Oil Filtering Procedure for Transformer Rectifier (T/R) Sets**

TROUBLESHOOTING TIP

The "Lamp Test"— A Simple Means For Testing T/Rs

Often, the functional "health" of a T/R needs to be determined. The "T/R Lamp Test" can be performed on T/Rs that are already installed as well as on T/Rs that are disconnected.

When testing an installed T/R, the T/R Lamp Test can be performed either at the T/R location or at the Controller location. While the Lamp Test should by no means be considered a complete T/R test, it does provide a means of ruling out many common failure modes. In addition, the test provides a high confidence level that the T/R system is "safe" to energize with a fully powered control system (typical 480 VAC).

But before you proceed with this test, several warnings are in order:

1. The tests described *results in high-voltage output on the T/R high-voltage bushing* as well as the possibility of *high voltage on feedback connection points*.
2. This test should *ONLY be performed by persons familiar with high-voltage systems*.

Summary

The lamp test uses an ordinary incandescent light bulb to permit low level energization of a T/R. This technique can provide excellent information about the unit's functionality. The test setup consists of:

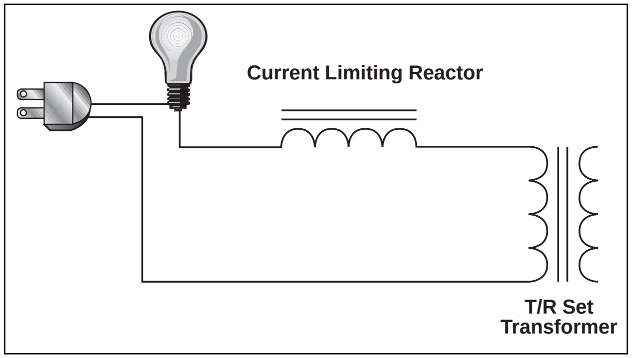
- A light bulb that is wired in series with the T/R primary winding
- Connected to 120VAC power source available as a standard wall plug

A recommended lamp size of 60 to 100 watts will limit the maximum current draw to about 1 ampere under a short circuit condition. The test operator can draw various conclusions by simply observing the brightness of the light bulb. In addition, if the test operator has the skill to use other instruments such as a volt/ammeter and/or an oscilloscope, significant additional information can be assessed as well.

The basic indicator of the lamp test is the observation of a dull glow of the light bulb. In general, this will indicate that the T/R is in operable condition (a bright illumination or no illumination indicates an abnormal condition). If an abnormal condition is suspected then this hookup can provide a configuration for further testing.

Test rig assembly

1. **Connect a wire of desired length** between the "hot side" of the wall plug and one terminal (or wire) of the lamp socket (the "hot side" is normally the smaller prong).
2. **Connect a wire to the return side of the wall plug long enough to reach the test connection point.** The loose end of this wire should be suitably dressed (lug or clip) to hook up to the T/R connection point. This is the "Return Wire."
3. **Connect a wire to the second terminal** or wire of the lamp socket long enough to reach the connection point (same as wire in step 2). This is the "Hot" wire.
4. **Install the light bulb.**



5. **Verify proper connections** by connecting the "Hot" wire to a ground point, plugging in the wall plug and observing the lamp illuminating brightly.

Configuration for Installed T/R

1. **The hookup to the system may be either at the T/R junction box or at the controller output terminals.** In all cases the circuit breaker feed to the T/R must be opened.
2. **The High Voltage connection (bushing) to the ESP field may be open or connected at the operators option.** Upon conducting the test, High Voltage in excess of 20,000 volts will be present on the T/R output. All interlocks and safety precautions for the ESP and High Voltage duct work MUST BE OBSERVED!

   If the ESP field is connected, then a shorted field will give the same results as will a shorted secondary in the T/R.
3. **If the hookup is at the Controller output then the CLR will also be in the primary circuit.** The impedance of the CLR will have negligible impact on the test indications since the current draw is so low.
4. **If the system is equipped with a KV feedback capability** the operator must be mindful of the high voltage that will be present on the high voltage bushing as well as on the KV feedback system. Verify that the KV feedback signal has an appropriate resistance path to ground. This path may be through the KV indicator meter or through an external resistor. IF THE KV FEEDBACK WIRE IS OPEN CIRCUIT TO GROUND THEN HIGH VOLTAGE WILL BE PRESENT ON THIS WIRE! IF THERE IS ANY DOUBT OF THIS THEN CONNECT THE KV FEEDBACK TERMINAL TO GROUND!
5. **Connect the test fixture "Hot" wire** (the wire from the lamp) to the "hot side" (the terminal that connects the SCRs to the CLR and then to the T/R). If the connection is to be made at the T/R junction box then the "hot side" of the system is the connection point between the T/R and the CLR.
6. **Connect the test fixture "Return Wire"** (the wire from the plug) to the "Return Side" of the system under test.
7. **Plug the fixture into a wall socket** and observe the lamp. A dull glow indicates a basically "Healthy System"; a bright illumination or no illumination indicates trouble. The choice of lamp size, either 60 or 100 watt, should be a function of the T/R size. For units under 700 ma the smaller lamp is more effective.

Interpreting the results

VERY DULL GLOW

Normal indications from a very dull glow:

- The T/R does not have any shorted turns in either the Primary or Secondary windings.
- There are no direct shorts in the “hot side” feed to the T/R nor shorts to ground in the transformer winding.
- There are no shorts to ground in the CLR if connected during test.
- The T/R Rectifier bridge does not have a shorted leg.
- The output, High Voltage feed system and ESP field (if connected) are not shorted to ground.

BRIGHTER THAN DULL GLOW

A brighter than dull glow indicates potential for:

- Shorted turns in transformer
- Shorted High Voltage bushing or ESP field or HV duct
- Shorted rectifier bridge
- Short in primary voltage feed system

NO GLOW

No glow from the bulb indicates an open circuit on the 480 VAC system. The open circuit may be in the interconnection wiring, in the CLR (if present), or in the T/R primary winding or connections.

This T/R Lamp Test is an abbreviated version of but one test that can be used to determine T/R

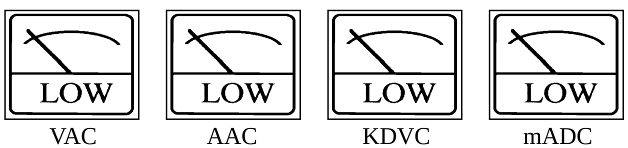
functionality. If you would like more information on this and other tests you can use in T/R troubleshooting—let us know on the reply card attached to this issue. Or better still, call 1-800-PICK NWL—and talk with one of our service people who have long-term experience in performing on-site ESP equipment diagnostics.

TROUBLESHOOTING TIP

What Meter Readings Can Tell You When Troubleshooting Transformer Rectifiers (T/Rs)

You pass by them dozens of times in the course of a work week—meters. They're designed to give you information about the performance of specific components of your clean-air system.

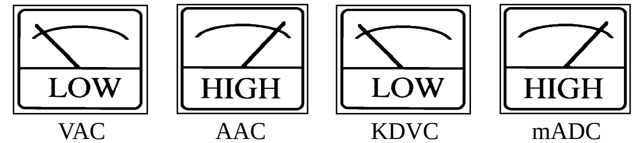
Analyzed collectively, however, they can also help perform an important diagnostic function. The following are four problems indicated by T/R meters—along with tests you may want to perform in resolving those problems.



Probable Cause: No power to T/R set

Tests

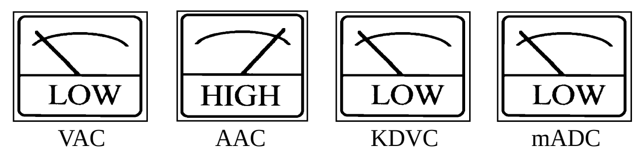
1. Check if controller is responding to sparking. If it is, use a scope to verify that sparks/arcs are occurring. Run T/R with precipitator disconnected to verify that T/R is not sparking internally.
2. Check for open SCR fuses.
3. Verify that SCRs are firing.
4. Check for open CLR.
5. Check for proper operation of controller power components.
  a. circuit breaker
  b. contactor



Problem: Short Circuit—DC Side

Tests

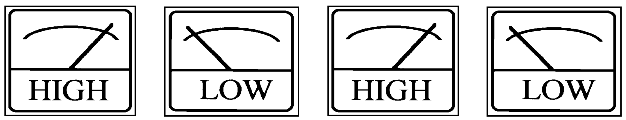
1. Run T/R set with HV bushing disconnected from the precipitator.
  a. If no current flows the short is in the precipitator.
  b. If current still flows the short is in the T/R set.
2. If precipitator is shorted, check electrodes and insulators for shorts.
3. If T/R is shorted, check HV bushing and external switch (if applicable) for shorts.



Problem: Short Circuit T/R set

Tests

1. Megger diodes for shorts.
2. Run T/R without diodes. If AAC still high, transformer is bad.



VAC AAC KDVC mADC

Problem: Open circuit

Tests

1. Run T/R set with HV bushing grounded externally.
   a. If current flows, precipitator field is open.
   b. If no current flows, T/R is open.

2. If precipitator is open, check all HV connections to electrodes.

3. If T/R is open, megger unit. Check for open diodes or connections in T/R tank.

RECOMMENDED PRACTICE

Oil Integrity Testing

To insure continued performance of your power supplies, the following ASTM tests should be performed annually on dielectric fluid sample extractions.

Test 1

Neutralization Number (D664)—The neutralization number for service-aged transformers is, in general, a measure of the acidic constituents of the oil. It may be pertinent, if compared to the value of the new product, in detecting contamination of the oil from substances which have come in contact with the oil. It may also be important in revealing a tendency toward chemical change or deterioration of the oil and its additives. It may be used as a general guide for determining when oil should be replaced or reclaimed, provided suitable rejection limits have been established and confirmation is received from other tests.

Test 2

Dielectric Breakdown Voltage (D877)—The dielectric breakdown voltage of an insulating liquid is of importance as a measure of its ability to withstand electric stress without failure. It is the voltage at which breakdown occurs between two electrodes under prescribed test conditions. It serves primarily to indicate the presence of contaminating agents such as water, dirt or conducting particles in the liquid, one or more of which may be present when low dielectric values are found by test. However, a high dielectric breakdown voltage does not indicate the absence of all contaminants.

Test 3

Interfacial Tension (D971)—The interfacial tension between an electrical insulating oil and water is a measure of the molecular attractive force between their unlike molecules at the interface. It is expressed in dynes per centimeter (millinewtons per meter). This test provides a means of detecting soluble polar contaminants and products of deterioration. Soluble contamination or oil-deterioration products generally decrease the interfacial tension value.

Test 4

Power Factor (D924)—Power factor is the ratio of the power dissipated in the oil in watts to the product of the effective voltage and current in voltamperes, when tested with a sinusoidal field under prescribed conditions. A high value is an indication of the presence of contaminants or deterioration products such as oxidation products, metal soaps, charged colloids, etc.

Test 5

Color (D1500)—The color of an insulating oil is determined by means of transmitted light and is expressed by a numerical value based on comparison with a series of color standards. A rapidly increasing or high color number is an indication of oil deterioration or contamination or both.

Test 6

Water in Insulating Oil, Karl Fisher Method (D1533)—Water contamination of insulating oil may be present in several forms. The presence of free water may be disclosed by visual examination in the form of separated droplets or as a cloud dispersed throughout the oil. This type of water invariably results in decreased dielectric strength, which may be restored by filtration or other suitable means. Water in solution cannot be detected visually and is normally determined by either physical or chemical means.

ASTM methods cited are suitable for the determination of water in insulating oil and, depending upon conditions of sample handling and method of analysis, can be used to estimate total water as well as soluble water content of oil. The unit of measure of the water is in soluble water content of oil in parts per million. These tests are significant in that they will show the presence of water which may not be evident from electrical tests.

The following typical control limits for oil are used for evaluating the conditions of dielectric fluid:

Neutralization Number
ASTM D664 .4 mg XOH/gram Maximum

Dielectric Breakdown
ASTM D877 22 KV Minimum

Interfacial Tension
ASTM D971 18 dynes/DM Minimum

Power Factor
ASTM D924 1.0% (Doble limit)

Color
ASTM D1500 4.0 Maximum

Moisture Content
ASTM D1533 55 ppm Maximum

RECOMMENDED PRACTICE

Mineral Oil Filtering Procedure for Transformer Rectifier (T/R) Sets

One of the best ways to insure continued operation of your T/R set is to insure the proper condition of the mineral oil in it. The mineral oil provides not only a cooling medium but a dielectric medium to handle the voltage stress within the unit. It's not uncommon that as the operational age of the unit increases, the dielectric strength of the oil will decrease. One of the ways to remove any contamination, and restore the dielectric strength, is to filter the mineral oil. Although the filtering process described below will not remove moisture or degasify the oil, it is very effective for particulate removal.

Equipment Required

Filtering should be done with a two-stage filter. The first stage should use a cellulose cartridge designed to remove particles 25 microns or larger. The second stage filter should be designed for removal of particles .5 microns or larger. A pump will also be required to circulate the mineral oil through the filters. The pump should be suitable for use with mineral oil. The flow rate of the pump should not exceed the maximum allowable flow through the filters.

Equipment Hookup

The hookup of the equipment is relatively simple. First you should de-energize the T/R set and properly ground the precipitator field for personnel safety.

Next attach the intake side of the pump to the drain valve located at the bottom of the T/R set. The outlet of the pump will be run through the filter. Remove the T/R set access cover and place the filter outlet hose in a horizontal position just below the oil level. This horizontal position will help eliminate the formation of air bubbles as the oil is returned to the T/R set. Once the hose is in position reinstall the access cover as tightly as possible to reduce any further contamination.

Filtering the Oil

Once the equipment is properly connected the pump should be run for about 8 hours to remove the contaminants from the fluid. It may be necessary to have some additional fluid available to prime the pump or serve as make up for the oil in the filtering system. It is very important that the high voltage coils are not exposed to air during the filtering process. Exposure of the coils to air may result in a failure upon re-energization of the T/R set. After the filtering is complete, remove the access cover and visually inspect the mineral oil. If particles can still be seen, continue filtering until all of the particles have been removed. Once completed, test the oil's dielectric strength. The minimum level should be 28 KV using ASTM test method D877.

Pressure Test

Once the filtering equipment has been disconnected, reinstall the T/R access cover. Next, pressurize the top air space above the oil with dry nitrogen to 4 psi.

Let stand for 2–3 hours, then check for any decrease in the pressure level. The pressure test is performed to insure that the T/R is properly sealed and will not breathe. After the pressure test is completed, bleed off excess nitrogen to .5 psi. The process of applying the nitrogen blanket then bleeding off excess pressure can be repeated several times. This will essentially purge the top air space of any moisture.

Routine Maintenance

The T/R set mineral oil should be tested on a annual basis to insure proper dielectric strength. Additional tests as can also be performed on the oil. They include neutralization number, interfacial tension, power factor, color, and moisture content.

Transforming the Future of Power Technology

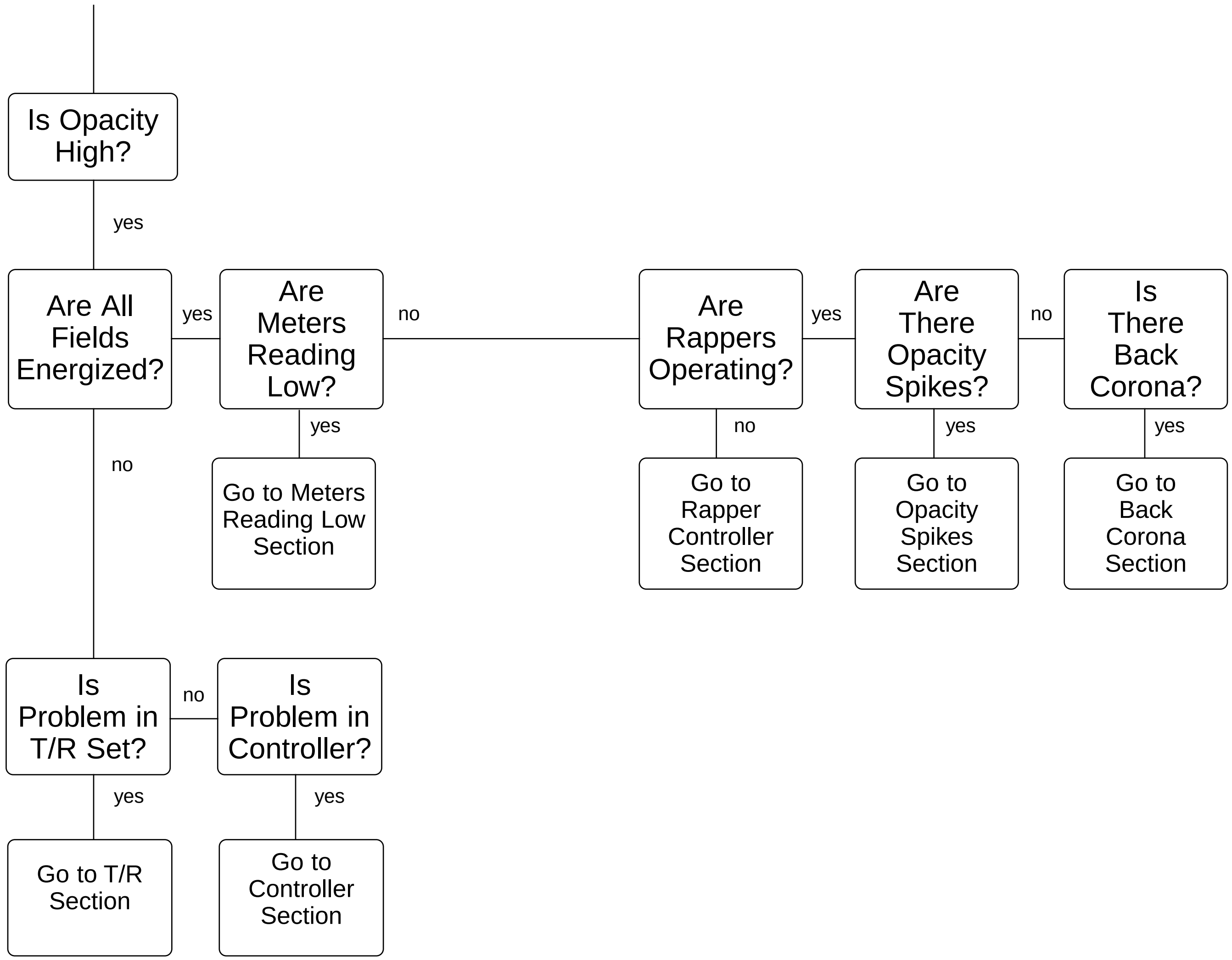
EQUIPMENT TROUBLESHOOTING

NWL Equipment

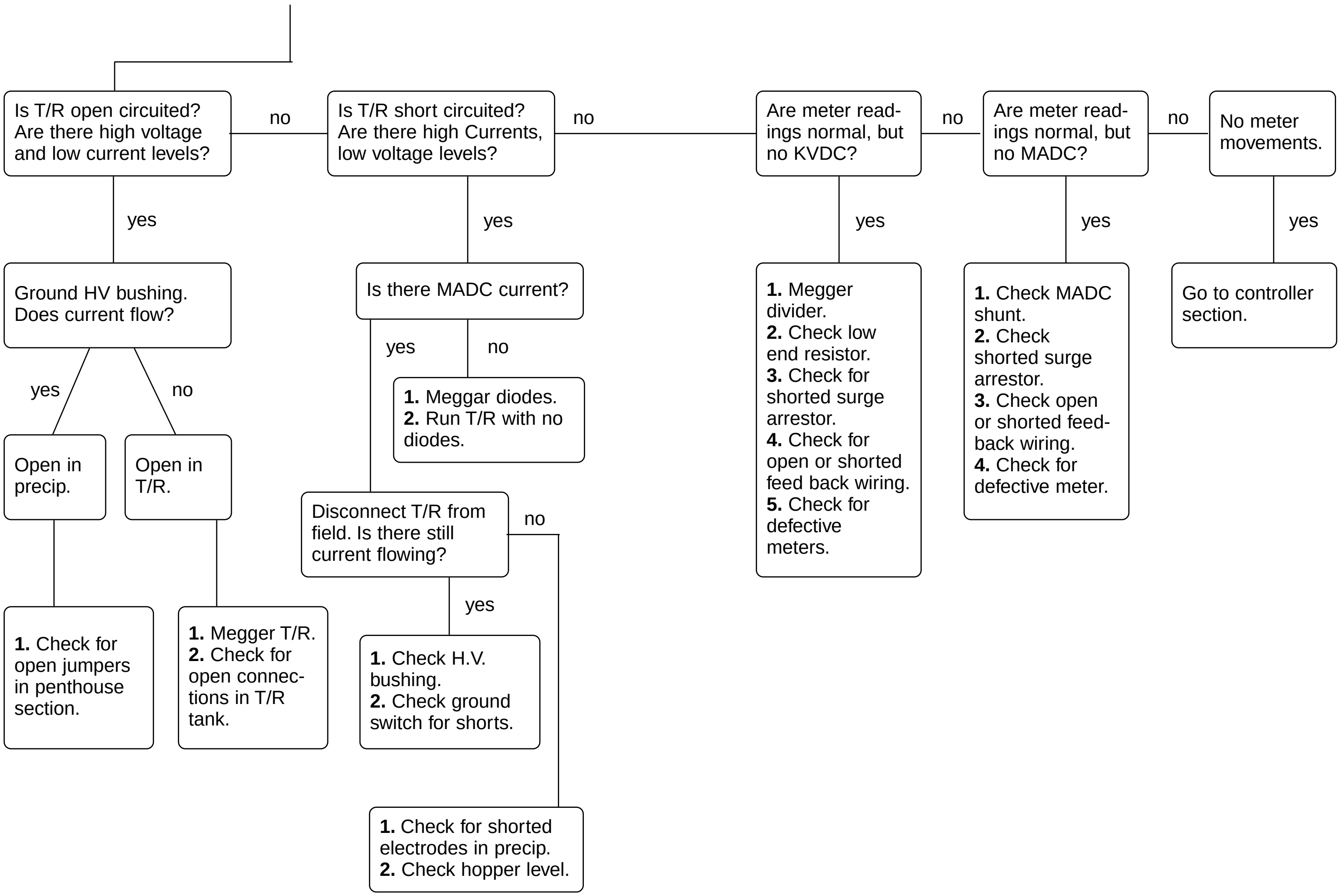
The following decision trees will help you conduct more thorough troubleshooting for the following:

- **Electrical Systems (overall)**
- **T/R Set**
- **T/R Controller**
- **Rapper Controller**
- **Meter Readings Low**
- **Back Corona**
- **Opacity Spikes**

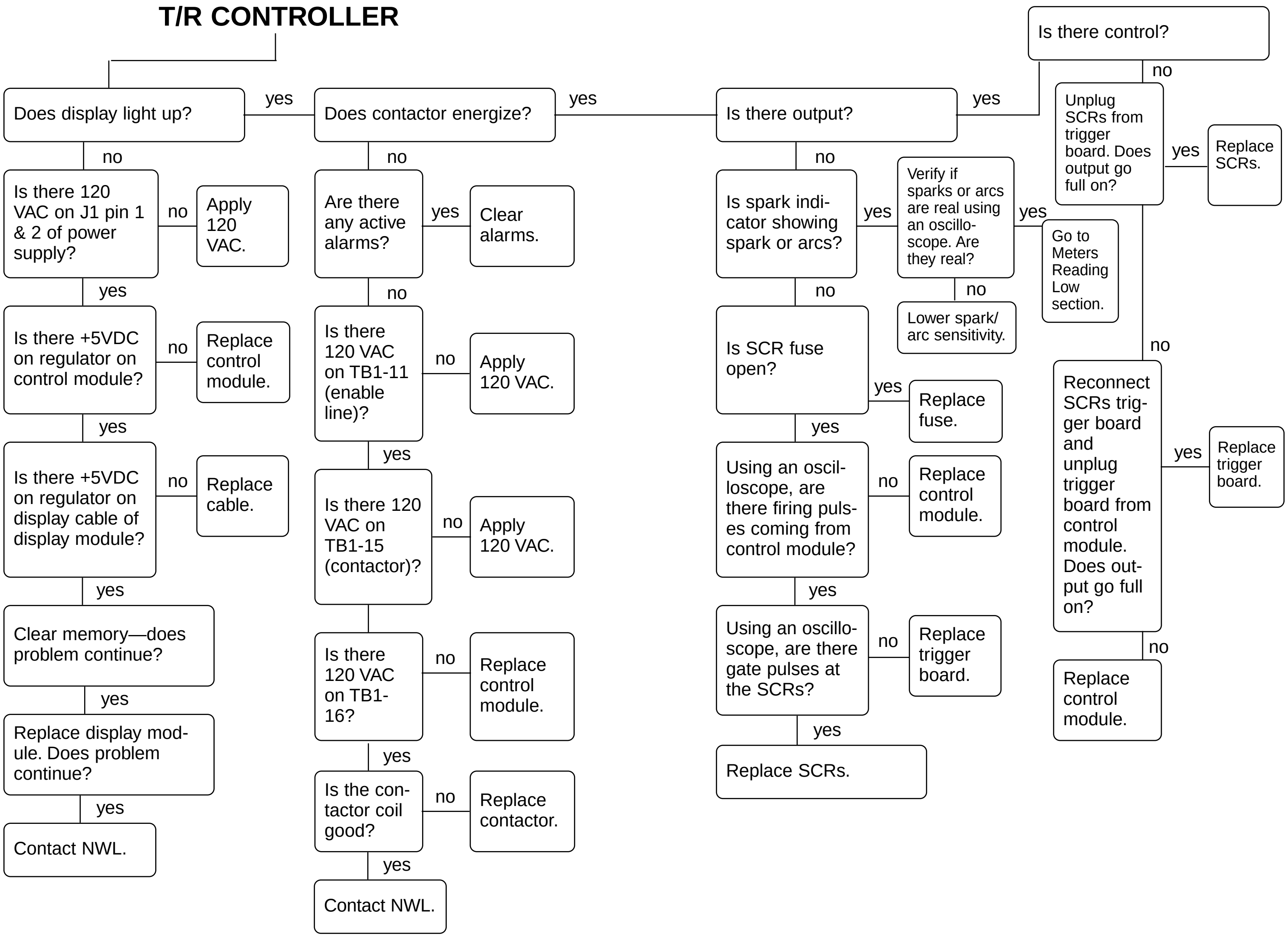
ELECTRICAL SYSTEMS



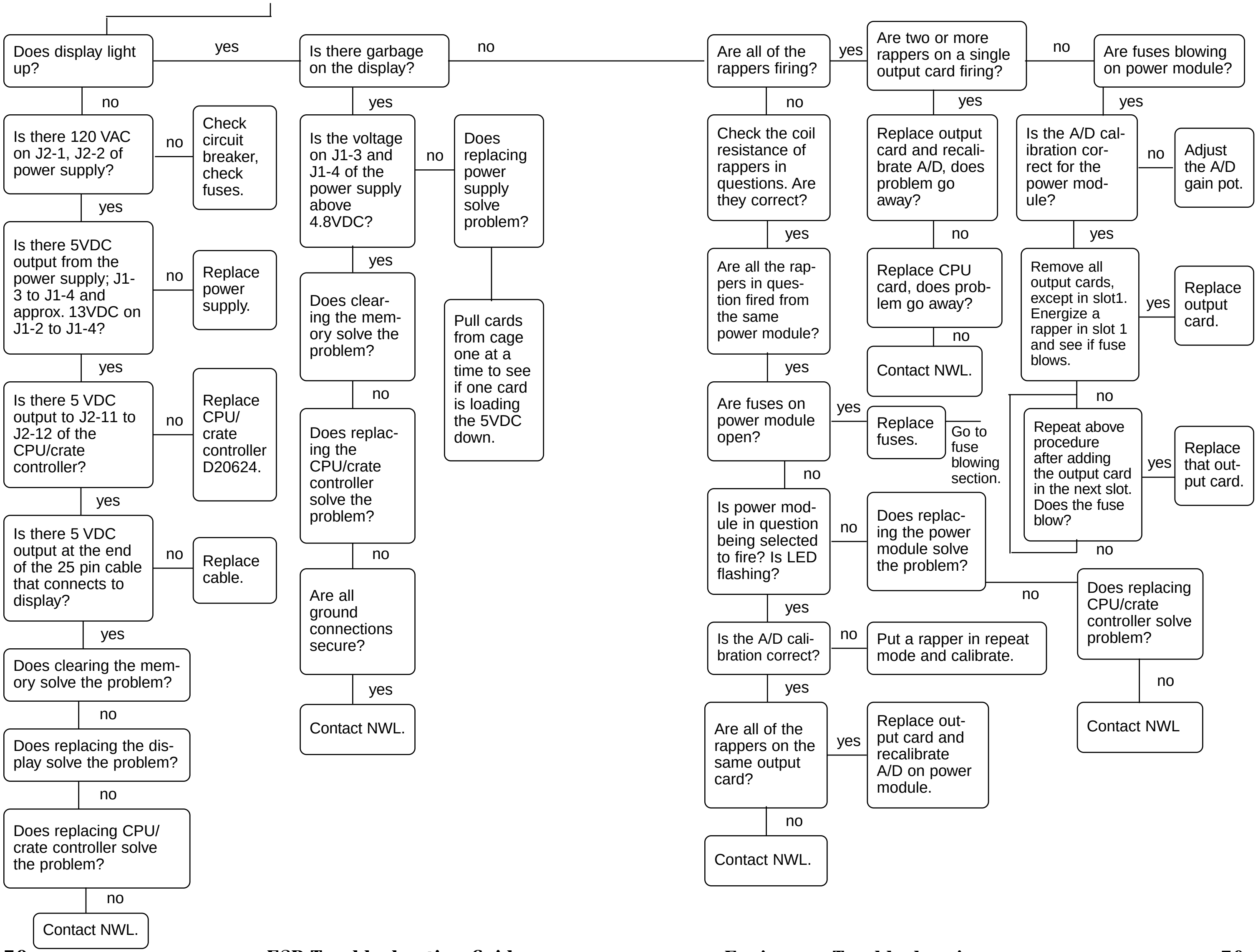
T/R SET


Is T/R open circuited? Are there high voltage and low current levels?
no
Is T/R short circuited? Are there high Currents, low voltage levels?
no
Are meter readings normal, but no KVDC?
no
Are meter readings normal, but no MADC?
no
No meter movements.
yes
Ground HV bushing. Does current flow?
yes
no
Open in precip.
Open in T/R.
1. Check for open jumpers in penthouse section.
1. Megger T/R. 2. Check for open connections in T/R tank.
yes
Is there MADC current?
yes
no
1. Meggar diodes. 2. Run T/R with no diodes.
Disconnect T/R from field. Is there still current flowing?
no
yes
1. Check H.V. bushing. 2. Check ground switch for shorts.
1. Check for shorted electrodes in precip. 2. Check hopper level.
yes
1. Megger divider. 2. Check low end resistor. 3. Check for shorted surge arrestor. 4. Check for open or shorted feed back wiring. 5. Check for defective meters.
yes
1. Check MADC shunt. 2. Check shorted surge arrestor. 3. Check open or shorted feed-back wiring. 4. Check for defective meter.
yes
Go to controller section.

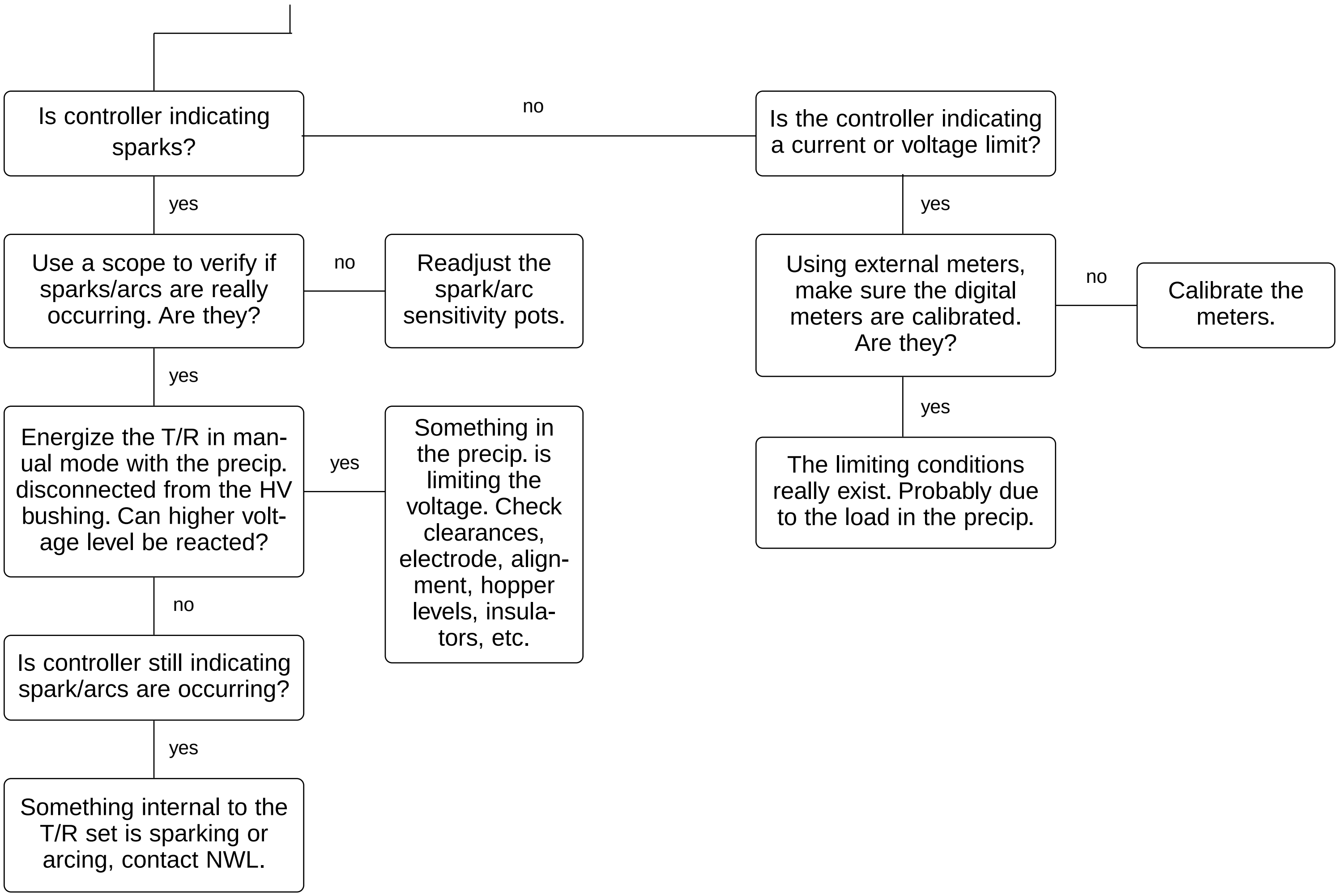
T/R CONTROLLER



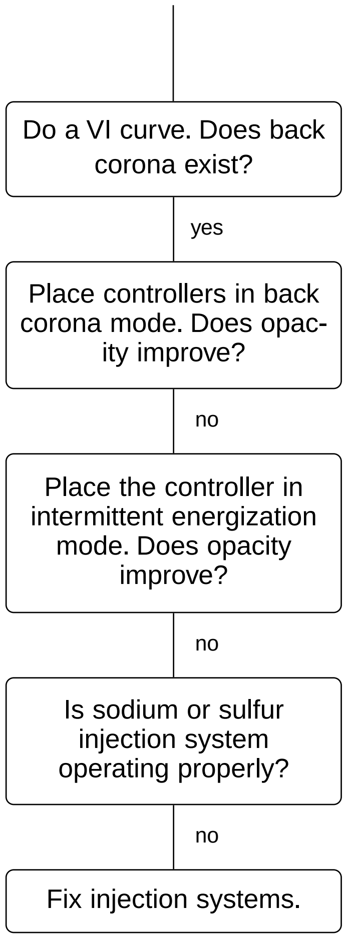
RAPPER CONTROLLER



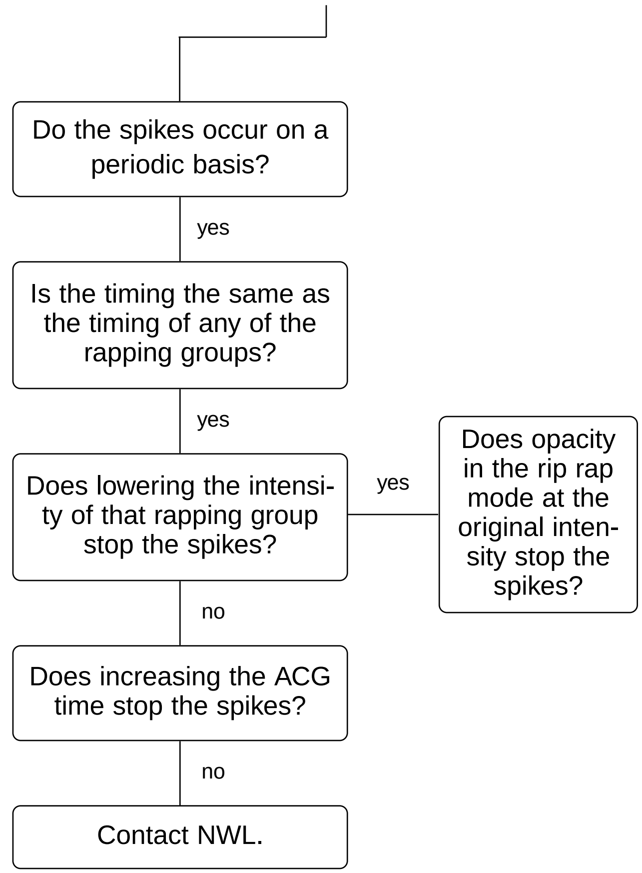
METER READINGS LOW



BACK CORONA



OPACITY SPIKES



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- Glossary of Air Pollution Control and ESP Terminology
- Clean Air Act Amendments
- Conversion Factors Metric Equivalents
- Altitude-Pressure Temperature Density Table of Air
- Title III Hazardous Air Pollutants

Glossary of Air-Pollution Control and ESP Terminology

The terminology for electrostatic precipitators has been standardized by the Institute of Clean Air Companies, Inc. (ICAC). The terms most used are defined below.

Abrasion-Flex—Where cloth has abraded in a creased area by excessive bending.

Absorber—A kind of scrubber.

Absorption—the penetration of a substance into or through another; distinct from adsorption.

ACFM—Actual Cubic Feet per Minute of gas volume at the actual condition temperature, pressure and composition. See gas flow rate.

Acid Deposition—(Acid Rain) A complex chemical and atmospheric phenomenon that occurs when emissions of sulfur and nitrogen compounds and other substances are transformed by chemical processes in the atmosphere, often far from the original sources, and then deposited on earth in either a wet or dry form. The wet forms, popularly called "acid rain," can fall as rain, snow or fog. The dry forms are acidic gases or particulates.

Adsorbent—In addition to the adjectival meaning, the term describes any of several substances that

collect gaseous pollutants. Used both for measurement and control.

Adsorption—The adhesion of a substance to the surface of a solid or liquid.

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.

Air Changes per Hour (ACH)—The movement of a volume of air in a given period of time; if a building has one air change per hour, it means that all of the air in the building will be replaced in a one-hour period.

Air Contaminant—An impurity emitted to the outside air. It can be solid (dust, particulate matter), liquid (vapor/mist), or gas (carbon monoxide, sulfur dioxide).

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

Air Horsepower—The theoretical horse power required to drive a fan if there are no losses in the fan, that is, if its efficiency is 100%.

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

Air Monitoring—The continuous sampling for and measuring of pollutants present in the atmosphere.

Air Quality Criteria—As the Federal government uses the term, the varying amounts of pollution and lengths of exposure at which specific adverse effects to health and welfare take place.

Air Quality Standards—The approximate concentration level of a selected pollutant that is permitted in the atmosphere to minimize detrimental effects.

Air Pollution—the presence in the atmosphere of gases, fumes or particulate matter, alone or in combination with each other, in sufficient concentration to disturb the ecological balance; cause objectionable effects, especially sensory offenses; cause transient or chronic illnesses; or impair or destroy property.

Air, Standard—Dry air at 70˚ and 29.92 inches (Hg) barometer. This is substantially equivalent to 0.075 lb/ft^3.

Air Toxics—Any air pollutant for which a national ambient air quality standard (NAAQS) does not exist (i.e., excluding ozone, carbon monoxide, PM-10, sulfur dioxide, nitrogen oxides) that may reasonably be anticipated to cause cancer, developmental effects, reproductive dysfunctions, neurological disorders, heritable gene mutations or other serious or irreversible chronic or acute health effects in humans.

Antisneakage baffles—Internal baffle elements within the precipitator to prevent the gas from bypassing the active field or causing hopper reentrainment.

APC—Air Pollution Control.

Arc—A discharge of substantial magnitude of the high voltage system to the grounded system, of relativity long duration and not tending to be immediately self-extinguishing.

Area Source—Any small source of nonnatural air pollution which is not large enough to be classified as a major source or point source.

Aromatics—A type of hydrocarbon, such as benzene or toluene, added to gasoline in order to increase octane. Some aromatics are toxic.

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

ASTM—American Society of Testing Materials.

Attainment Area—An area considered to have air quality as good as or better than the National Ambient Air Quality Standards as defined by the Clean Air Act. An area may be an attainment area for one pollutant and a nonattainment area for others.

Attrition—Wearing or grinding down by friction.

One of the three basic contributing processes of air pollution, the others being vaporization and combustion.

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).

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

BACM—(Best Available Control Measure) A term used in the CAAA referring to the "best" measures (according to EPA guidance) for controlling emissions.

BACT—(Best Available Control Technology) An emission limitation based on the maximum degree of emission reduction achievable. Under Title I of the CAAA, EPA will establish BACT standards for serious, severe and extreme nonattainment areas.

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.

Blind—(Blinding) Blockage of bag by dust, fume

or liquid entering the filter media and not being discharged by the cleaning mechanism. Once enough material has built up, air flow is severely restricted and the bags have to be cleaned or replaced.

Blow-pipe—See manifold.

Blue Smoke—A descriptive term for the gaseous hydrocarbons that escape from hot asphalt and other sources of VOC.

Bolted Plate—A cover provided with sufficient bolts to insure tight closure where occasional accessibility is required.

Brake Horsepower—The horsepower actually required to drive a fan. This includes the energy losses in the fan and can be determined only by actual tests of the fan (this does not include the drive losses between motor and fan).

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

Bus Section—The smallest portion of the precipitator which can be independently de-energized (by subdivision of the high voltage system and arrangement of support insulators).

CAAA—Clean Air Act Amendments of 1990.

Cable—Oil filled cable or dry cable for transmitting high voltages.

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.

Carbon Monoxide—A colorless, odorless gas which is toxic because of its tendency to reduce the oxygen-carrying capacity of the blood.

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.

CAS (Chemical Abstracts Service)—Registry Number is a numeric designation assigned by the American Chemical Society's Chemical Abstracts Service which uniquely identifies a specific chemical compound.

Casing—Enveloping structure to enclose the internal components of the precipitator. Rectangular or cylindrical configuration are used. The casing includes the gas tight roof, side walls, and end walls and hoppers and/or bottoms. A gastight dividing wall is used to separate chambers. A nongastight load bearing wall is used to separate bus sections. The casing is sometimes called the housing or shell.

Cell (In width)—A cell is an arrangement of bus sections parallel to gas flow. NOTE: Number of cells wide times number of fields deep equals the

total number of bus sections.

Cellplate—See tubesheet.

CFM—Cubic Feet (of any gaseous matter) per Minute. See gas flow rate.

Chamber—A gastight longitudinal subdivision of a precipitator. A precipitator with a single gastight dividing wall is referred to as a two chamber precipitator. NOTE: Very wide precipitator chambers are frequently equipped with nongastight load bearing walls for structural considerations. These precipitators by definition are single chamber precipitators.

Clean Coal Technology—Any technology not in widespread use as of the date of enactment of the Clean Air Act Amendments which will achieve significant reductions.

Clean Fuel—Blends and/or substitutes for gasoline fuels. These include compressed natural gas, methanol, ethanol and others.

COH—Abbreviation for coefficient of haze, unit of measurement of visibility interference.

Coke Oven—An industrial process which converts coal into coke, which is one of the basic materials used in blast furnaces for the conversion of iron ore into iron.

Collecting Surface Area—The total flat projected area of collecting surface exposed to the active electrical field (effective length x effective height x 2 x number of gas passages).

Collecting Surface Rapper—A device for imparting vibration or shock to the collecting surface to dislodge the deposited particles or dust.

Collecting Surfaces—The individual elements which make up the collecting system and which collectively provide the total surface area of the precipitator for the deposition of dust particles.

Collecting System—The grounded portion of the precipitator to which the charged dust particles are driven and to which they adhere.

Collection efficiency—The weight of dust collected per unit time divided by the weight of dust entering the precipitator during the same unit time expressed in percentage. The computation is as follows:

$$\text{Efficiency} = \frac{(\text{Dust in}) - (\text{Dust out})}{(\text{Dust In})} \times 100$$

Combustion—the production of heat and light energy through a chemical process, usually oxidation. One of the three basic contributing processes of air pollution, the others being attrition and vaporization.

Combustion Air—Amount of air necessary to burn the available fuel.

Combustion Products—1) Primarily gaseous matter such as carbon oxides, nitrogen, oxygen and water vapor resulting from the combustion of fossil fuels. 2) In the context of emission control, the gaseous products resulting from the burning of any kind of material containing carbon in a free or combined state. Also referred to as "combustion contaminants."

Concentration—The amount of dust in gas. Usually expressed in terms of grains per ft^3, lbs per 1000 lbs of gas, parts per million or milligrams per cubic meter.

Conduction—The transfer of heat by physical contact between substances.

Control Damper—A device installed in a duct to regulate the gas flow by degree of closure. Examples: Butterfly or Multilouver.

Conversion Factors—See page 109 and 110.

Convection—The transfer of heat through a liquid or gas by the actual movement of the molecules.

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.

Current Density—The amount of secondary current per unit of precipitator collecting surface. Common units are ma/ft.^{2} and mA/cm^2.

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

CTG (Control Techniques Guideline)—Guidance documents issued by EPA which define **Reasonably Available Control Technology** (RACT) to be applied to existing facilities that emit certain threshold quantities of air pollutants; they contain information both on the economic and technological feasibility of available techniques.

Delta P (AP)—Change in pressure, or pressure drop, that occurs across a piece of control equipment.

DNAPLS—Dense nonaqueous phased liquids.

Density Factor—The ratio of actual air density to density of standard air. The product of the density factor and the density of standard air (0.075 lbs/ft^3) will give the actual air density in pounds per cubic foot.

Dew Point—the temperature at which the equilibrium vapor pressure of a liquid is equal to the existing 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 as the temperature is reduced. For flue gaining water vapor and SO 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.

Discharge Electrode—The part which is installed in the high voltage system to perform the function of ionizing the gas and creating the electrical field. Typical configurations are

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

Discharge Electrode Rapper—A device for imparting vibration or shock to the discharge electrodes in order to dislodge dust accumulation.

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

Dry Bulb Temperature—The actual temperature of a gas, taken with a conventional thermometer.

DSCFMT—Dry Standard Cubic Feet per Minute. See gas flow rate.

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, e.g. pounds per thousand: pounds of gas, grains per standard dry cubic foot (the temperature and pressure of the gas must be specified if given as volume).

Early Reduction/Early Compliance—A provision in the CAAA which provides incentives to a company for complying with new standards before they are required to by law.

Effective Cross-Sectional Area—Effective width times effective height.

Effective Height—Total height of collecting surface measured from top to bottom.

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

Effective Stack Height—The height at which a plume becomes essentially level. It is the actual stack height plus the plume rise.

Effective Width—Total number of gas passages multiplied by spacing dimension of the collecting surfaces.

Effluent—A discharge or emission of a fluid (liquid or gaseous).

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

Electrostatic Precipitator—A kind of precipitator that first charges particulate (ESP), allowing electrostatic forces to attract particles to a collection point.

Emission—Release of pollutants into the air from a source.

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

Emission Factor—The statistical average of the amount of a specific pollutant emitted from each type of polluting source in relation to a unit quantity of material handled, processed or burned. Eg. the emission factor of oxides in nitrogen in fuel oil combustion is 119 lbs per 1,000 gallons of fuel oil used. By using the emission factor of a pollutant and specific data regarding quantities of material used by a given source, it is possible to compute emissions for that source—information necessary for an emission inventory.

Emission Inventory—A list of primary air pollutants emitted into a given community's atmosphere, in amounts (commonly tons) per day, by type of source. The emission inventory is basic to the establishment of emission standards. Also see emission factor.

Emission Standard—The maximum amount of a pollutant that is permitted to be discharged from a single polluting source: e.g., the number of pounds of fly ash per cubic foot of gas that may be emitted from a coal-fired boiler. Rule or measurement established to regulate or control the amount of a given pollutant that may be discharged to the outdoor atmosphere from its source.

EPA—Environmental Protection Agency.

Evaporation—The physical transformation of a liquid to a gas at any temperature below its boiling point.

Excess Air—Air in excess of the amount necessary to combust all the available fuel.

Exhaust Gas—The gases emitting from an industrial process, generally a combustion process.

Exhaust Stack Temperature—The temperature of the exhaust gas, measured in the discharge stack.

Exhaust Volume—The amount of exhaust gas (air, products of combustion and water vapor) leaving the exhaust stack, usually measured in ACFM.

Federal Implementation Plan (FIP)—Under current law, a Federally implemented plan to achieve attainment of an air quality standard, used when a State is unable to develop an adequate plan. Under the Senate bill, a plan containing control measures developed and promulgated by EPA in order to fill gaps in a State Implementation Plan (SIP).

Field (in depth)—A field is an arrangement of bus sections perpendicular to gas flow that is energized by one or more high voltage power supplies.

Fines—Fine particulate; aerosol.

Flexing—Bending, or contracting and expanding.

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

Fog—The condensation of water vapor in air. Also see smog.

Forced Draft Burner—A burner which has its secondary air supplied under pressure. This is normally done by surrounding the dryer opening by a plenum or windbox and supplying the air with a low pressure fan.

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

Fugitive Emissions—Emissions not caught by a capture system.

Fume—solid particulates generated by condensation from the gaseous state, generally after volatilization from molten metal, and often accompanied by a chemical reaction, such as oxidation. Fumes flocculate and sometimes coalesce.

GACT—(Generally Available Control Technology) Methods, practices and techniques which are commercially available and appropriate considering economic impacts and the technical capabilities of the firms to operate and maintain the emissions control systems. Under Title III of the CAAA, EPA will establish either GACT or MACT standards for each source of HAPs.

Gas Distribution Devices—Internal elements in the transition or ductwork to produce the desired velocity contour at the inlet and outlet of the precipitator. Example: turning vanes or perforated plates.

Gas Distribution Plate Rapper—A device used to prevent dust buildup on perforated plates.

Gases—Normally, formless fluids which occupy the space of their enclosure and which can be changed to a liquid or solid state only by the combined effect of increased pressure and decreased temperature. Gases diffuse.

Gas Flow Rate, Cubic Feet per Minute (CFM)—

The volume of process gas at any point of the plant exhaust system measured in terms of minutes. There are several units of measurement:

ACFM—The actual gas flow measured (Actual Cubic Feet per Minute)

SCFM—The gas flow volume reduced to 70˚F (standard temperature) by calculation (Standard Cubic Feet per Minute)

DSCFM—The gas flow reduced to 70˚ (standard temperature) and without volume of steam or water vapor contained in the exhaust gas (Dry Standard Cubic Feet per Minute)

Gas Passage—Formed by two adjacent rows of collecting surfaces; measured from collecting surface centerline to collecting surface centerline.

Grain—A dust weight unit commonly used in air pollution control. Equal to one seven thousandth of a pound. One grain = 1/7000 lb.

Grain Loading—The rate at which particles are emitted from a pollution source. Measurement is made by the number of grains per cubic foot of gas emitted.

Halons—A family of compounds containing bromine, fluorine, iodine and chlorine used in fighting fires, that breakdown in the atmosphere depleting stratospheric ozone.

HAPs (Hazardous Air Pollutants)—Any of the 189 chemicals listed under Title III of the CAAA.

All HAP sources will have to comply with GACT or MACT standards.

HCFCs—Chlorofluorocarbons that have been chemically altered by the addition of hydrogen, and which are significantly less damaging to stratospheric ozone than other CFCs.

HEPA Filter (High Efficiency Particulate Air Filter)—Capable of removing at least 99.97% by count of a standard 0.3 micron challenge particulate (DOP test).

High Voltage Conductors—Conductor to transmit the high voltage from the transformer rectifier to the precipitator high voltage system.

High Voltage Power Supply—The supply unit to produce the high voltage required for precipitation, consisting of a transformer rectifier combination and associated controls. Numerous bus sections can be independently energized by one power supply.

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:

1. Saturable Core Reactor—A variable impedance device
2. Variable "Auto-Transformer" control

3. Silicon Controlled Rectifier (SCR)—Electronic switch for voltage regulation

High Voltage Structure—The structural elements necessary to support the discharge electrodes in their relation to the collecting surface by means of high voltage insulators.

High Voltage Systems—All parts of the precipitator which are maintained at a high electrical potential.

High Voltage System—Support Insulator—A device to physically support and electrically isolate the high voltage system from ground.

Hi-Volume Sampler—Also called a Hi-Vol. A device used in the measurement and analysis of suspended particulate pollution.

HON—Hazardous Organic NESHAPs.

Hopper Capacity—Total volumetric capacity of hoppers measured from a plane 10" below high voltage system or plates, whichever is lower.

Humidity, Absolute—The weight of water vapor per unit volume, pounds per cubic foot or grams per cubic centimeter.

Humidity, Relative—The ratio of the actual partial pressure of water vapor in a space to the saturated pressure of pure water vapor in a space to the saturated pressure of pure water at the same temperature.

H.V. Bus—A conductor enclosed within a grounded duct.

Hydrocarbon—Any of the vast family of compounds containing carbon and hydrogen in various combinations: found especially in fossil fuels. Some of the hydrocarbon compounds are major air pollutants; they may be carcinogenic or active participants in the photochemical smog process.

Inch of Water—A unit of pressure equal to the pressure exerted by a column of water one inch high at a standard temperature. (407" WC = 14.7 PSI)

Inches WG (Inches of Water Gauge)—See inch of water.

Incinerator—A device which burns household, industrial, pathological or hazardous solid, liquid or gaseous wastes under controlled conditions.

Inclined Manometer—A testing instrument using a liquid column, set at an incline to increase reading accuracy, to measure pressure. Normally used to read velocity pressure.

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

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).

Isolation Damper—A device installed in a duct to isolate a precipitator chamber from process gas.

Inversion—An atmospheric condition caused by a layer of warm air preventing the rise of cooling air trapped beneath it. This prevents the rise of pollutants that might otherwise be dispersed and results in a concentration of the air pollution.

Impedance Devices—

1. Linear inductor or current limiting reactor required to work with SCR-type controllers
2. A transformer with a specially designed high impedance core and coils
3. Saturable core reactor
4. Resistors

LAER (Lowest Achievable Emission Rate)—The rate of emissions which reflects either the most stringent emission limit contained in the implementation plan of any state (unless it is proved that such limitations are not achievable) or the most stringent emission limit achieved in practice, whichever is most stringent.

Liquid Flowrate—The amount of water or "scrubbing liquid" introduced into a wet collector.

Low NOx Burners—One of several combustion technologies used to reduce emission of NOx.

Lower Explosive Limit—The lower limit of flammability or explosibility of a gas or vapor at ordinary ambient temperature expressed in percent of a gas or a vapor in air by volume.

Lower Weather Enclosure—A nongastight enclosure at base of precipitator to protect hoppers from wind and/or detrimental weather conditions.

MACT (Maximum Achievable Control Technology)—the standard with which sources of HAPs will have to comply; the CAAA defines MACT as “the maximum degree of reduction in emissions... achievable for new or existing sources... taking into account the cost of achieving such reductions.” MACT standards for existing sources must be at least as stringent as the average level of control achieved at the best controlled 12 percent of facilities, and MACT for new sources will have to be even stricter.

Major Source—A stationary source which emits a large amount of pollution. In nonattainment areas, under Title I of the CAAA, a major source is one which emits more than 100, 50, 25 or 10 tons per year depending on whether the area is classified as Marginal or Moderate, Serious, Severe or Extreme, respectively. For hazardous air pollutants, under Title III of the CAAA, a major source is one which can emit more than 10 TPY of any one HAP or 25 TPY of total HAPs.

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 that are functionally dependent on the laws of mechanics governing the motion of bodies in space. 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.

Mega—A prefix meaning 1 million.

Micro—A prefix meaning 1/1,000,000 abbreviated by the Greek letter u.

Micrometer—See micron.

Micron—Symbol um; a unit of length equal to one millionth of a meter. An average human hair is 70 microns in diameter. In general, particles down to 10 microns can be seen without the aid of magnification.

Migration Velocity—A parameter in the Deutch-Anderson equation used to determine the required size of an electrostatic precipitator to meet specified design conditions. Other terminology used: W-value and precipitation rate. Values are generally stated in terms of ft/min or cm/sec.

Milli—A prefix meaning 1/1,000.

Mist—Suspended liquid droplets generated by condensation from the gaseous to the liquid state or by breaking up a liquid into a dispersed state, such as by splashing, foaming and atomizing.

Modeling—An investigative technique using computer mathematical or physical representation of a system that accounts for all or some of its known properties.

Montreal Protocol—An international environmental agreement to control chemicals that deplete the ozone layer. The protocol, which was renegotiated in June 1990, calls for a phaseout of CFCs, halons and carbon tetrachloride by the year 2000, a phaseout of chloroform by 2005, and provides financial assistance to help developing countries make the transition from ozone-depleting substances.

MSDS (Material Safety Data Sheet)—Compilation of data and information on individual hazardous chemicals produced by the manufacturers and importers of that chemical, as required by OSHA's Hazard Communication Standard, 29 CFR 1910.1200.

NEDS—National Emission Data System.

NESHAP—National Emissions Standards for Hazardous Air Pollutants.

New Source—A stationary source, the construction or reconstruction of which is commenced after the proposal date of the standard. Also NSPS (New Source Performance Standard).

NIOSH (National Institute for Occupational Safety and Health)—Created by the Occupational Safety and Health Act of 1970. NIOSH is part of the Centers for Disease Control under the Department of Health and Human Services. Its mandate includes conduction research in developing criteria and/or recommendations to be used in setting occupational exposure standards, identifying and evaluating workplace hazards, measurement techniques and control technologies, and providing professional education as well as health and safety information.

Nonattainment Area—An area which has not achieved air quality as good as the National Ambient Air Quality Standards as defined by the CAAA.

NOx (Nitrogen Oxides)—Chemical compounds containing nitrogen and oxygen; react with volatile organic compounds, in the presence of heat and sunlight, to form ozone. They are also a major precursor to acid rain. Nationwide, approximately 45% of NOx emissions come from mobile sources, 35% from electric utilities and 15% from industrial fuel combustion.

OCIS (OSHA Computerized Information System)—A comprehensive data base that contains information and data on standards interpretation, chemical information, hazardous waste activity 5(a)(1) citations, a health hazard evaluation index, training materials and other information compiled by OSHA on subjects related to occupational safety and health.

Opacity—Refers to the amount of light that can pass through; normally refers to the degree of visibility of an exhaust plume. Normal measurement technique used is by EPA method 9.

Ozone—A compound consisting of three oxygen atoms, that is the primary constituent of smog. It is formed through chemical reactions in the atmosphere involving volatile organic compounds, nitrogen oxides and sunlight. Ozone can initiate damage to the lungs as well as damage to trees, crops and materials. There is a natural layer of ozone in the upper atmosphere which shields the earth from harmful ultraviolet radiation.

Particulate—A particle of solid or liquid matter.

Particulate Matter—Any solid or liquid material in the atmosphere.

PEL (Permissible Exposure Limits)—Limits developed by OSHA to indicate the maximum airborne concentration of a contaminant to which an employee may be exposed.

Penthouse—A weatherproof, gastight enclosure

over the precipitator to contain the high voltage insulators.

Permit—An authorization, license or equivalent control document issued by EPA or an approved state agency to implement the requirements of an environmental regulation; e.g., a permit to operate a facility that may generate harmful emissions.

Photochemical Process—The chemical changes brought about by the radiant energy of the sun acting upon various polluting substances. The products are known as photochemical smog.

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

Plenum—Pressure equalizing chamber.

Plenum Pulse—Type of pulsing collector where entire sections of the clean air plenum are isolated and pulsed with either compressed air or air from a high pressure blower.

PM_{10}—A new standard for measuring the amount of solid or liquid matter suspended in the atmosphere ("particulate matter"). Refers to the amount of particulate matter under 10 micrometers in diameter. The smaller PM_{10} particles penetrate to the deeper portions of the lung, affecting sensitive population groups such as children and people with respiratory diseases.

Point Source—A stationary location or facility from which pollutants are emitted. Also, any single identifiable source of pollution.

Polymerized—A chemical reaction in which two ore more small molecules combine to form larger molecules that contain repeating structural units of the original molecules.

Pounds per 100 Pounds of Gas—A common quantitative definition of pollution concentration.

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.

Precipitator Current—The rectified or unidirectional average current to the precipitator measured by a milliammeter in the ground leg of the rectifier.

Precipitators—Any number of devices using mechanical, electrical or chemical means to collect particulates. Used for measurement, analysis or control. See electrostatic precipitator.

Precipitator Gas Velocity—A figure obtained by dividing the volume rate of gas flow through the precipitator by the effective cross sectional area of the precipitator. Gas velocity is generally expressed in terms of ft./sec. and is computed as follows:

Velocity = Gas Volume (CFM)
Effective cross section area ft^2

Precipitator Voltage—The average DC voltage between the high voltage system and grounded side of the precipitator.

Effective cross section is construed to be the effective field height x width of gas passage x number of passages.

Pressure, Atmospheric—The pressure due to the weight of the atmosphere. It is the pressure indicated by a barometer; standard atmospheric pressure is 29.92 inches of mercury.

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

Pressure, Static—The potential pressure exerted in all directions by fluid at rest. For a fluid in motion it is measured in a direction normal (90˚) to the direction of flow. Usually expressed in inches water gauge when dealing with air.

Pressure, Velocity—The kinetic pressure in the directional flow necessary to cause a fluid at rest to flow at a given velocity. Usually expressed in inches water gauge.

Prevention of Significant Deterioration (PSD)—EPA program in which state and/or federal permits are required that are intended to restrict emissions for new or modified sources in places where air quality is already better than required to meet primary and secondary ambient air quality standards.

Primary Collector—A dry or wet collector which is followed by a secondary collector with greater filtering efficiency.

Primary Current—Current in the transformer primary as measured by an AC ammeter.

Primary Voltage—The voltage as indicated by AC voltmeter across the primary windings of the transformer.

Process Weight—The weight per hour that is run through the process. Commonly used in APC codes to determine the maximum allowable pollution exhausted.

Promulgate—To make a new law known and put it into effect. The EPA promulgates a rule when it issues the final version in the Federal Register.

PSI (Pounds per Square Inch)—A measure of pressure. 1 psi equals 27.7" water gauge.

PSIA (Pounds per Square Inch Absolute)—The absolute pressure without reference to another point. Atmospheric pressure is 14.7 PSIA.

PSIG (Pounds per Square Inch Gauge)—The pressure relative to atmospheric. For instance, 10 PSIG equals 24.7 PSIA. This is the common pressure term.

RACM (Reasonably Available Control Measures)—A broadly defined term referring to technologies and other measures that can be used to control pollution; includes Reasonably Available Control Technology and other measures. In the case of PM_{10}, it refers to approaches for controlling small or dispersed source categories such as road dust, wood stoves and open burning.

RACT (Reasonably Available Control Technology)—An emission limitation on existing sources in nonattainment areas, defined by EPA in a Control Techniques Guideline (CTG) and adopted and implemented by states. Under Title I of the CAAA, EPA will establish RACT standards for marginal, moderate and serious nonattainment areas.

Radionuclide—Radioactive element which can be man-made or naturally occurring. They can have a long life as pollutants, and are believed to have potentially mutagenic effects on the human body.

Radon—A colorless, naturally occurring, radioactive, inert gaseous element formed by radioactive decay of radium atoms in soil or rocks.

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

Reentrainment—The phenomenon whereby dust is collected from the air stream and then is returned to the air stream. Occurs when dust is pulsed from a bag and then caught up by an upward moving air stream.

REL (Recommended Exposure Limits)—Issued by NOISH to aid in controlling hazards in the workplace. These limits are generally expressed as 8- or 10-hour TWAs for a 40-hour work week and/or ceiling levels with time limits ranging from instantaneous to 120 minutes.

Repowering—The replacement of an existing coal-fired boiler with one or more clean coal technologies, in order to achieve significantly greater emission reduction relative to the performance of technology in widespread use as of the enactment of the Clean Air Act Amendments.

Residual Risk—The quantity of health risk remaining after application of the MACT (Maximum Achievable Control Technology).

Resistance—In air flow, it is caused by friction of the air against any surface, or by changing the momentum of the gas.

Ringelman—A measure of the opacity caused by pollution from a stack. Grades opacity from 0 to 5, where 0 is an invisible discharge and 5 is totally opaque.

Ringleman Chart—Actually, a series of charts, numbered from 0 to 5, that simulate various smoke densities, by presenting different percentages of black. A Ringelman No. 1 is equivalent to 20 per-

cent black; a Ringelman No. 5, to 100 percent. They are used for measuring the opacity of smoke arising from stacks and other sources, by matching with the actual effluent, the various numbers, or densities, indicated by the charts. Ringelman numbers were sometimes used in setting emission standards.

RTECS (Registry of Toxic Effects of Chemical Substances)—A data base that lists an identification number, synonyms, Department of Transportation (DOT) hazard label information, EPA Toxic Substances Control Act (TSCA) information, OSHA and Mine Safety and Health Administration (MSHA) air exposure limits, and animal and human toxicologic data.

Sanctions—Actions taken against a state or local government for failure to plan or to implement a SIP, e.g., a ban on construction of new sources.

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 of which is grounded to the casing, the other end attached to the high voltage system using an insulated operating lever.)

SCFM (Standard Cubic Feet per Minute)—The volume that a gas would occupy at standard temperature and pressure conditions (70˚ F and 14.7 PSIA). See gas flow rate.

Scrubber—A device that uses a liquid spray to remove aerosol and gaseous pollutants from an air stream. The gases are removed either by absorption or chemical reaction. Solid and liquid particulates are removed through contact with the spray. Scrubbers are used for both the measurement and control of pollution.

Scrubber, Gas—Any device in which a contaminant, solid or gaseous, is removed from a gas stream by liquid droplets. (Types include spray towers, packed towers, cyclone scrubbers, jet scrubbers, orifice scrubbers, venturi scrubbers, impingement scrubbers and mechanical scrubbers).

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

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

Silicon Rectifier—A rectifier consisting of silicon diodes immersed in mineral oil or silicone oil.

Single Precipitator—An arrangement of collecting surfaces and discharge electrodes contained within one independent casing.

SIP (State Implementation Plan)—Documents prepared by states, and submitted to EPA for approval, which identifies actions and programs to be under-

taken by the State and its subdivisions to implement their responsibilities under the Clean Air Act.

Smog—The irritating haze resulting from the sun's effect on certain pollutants in the air, notably those from automobile exhaust; see photochemical process. Also a mixture of fog and smoke.

Smoke—Carbon or soot particles, less than 0.1 micrometers in size which result from the incomplete combustion of carbonaceous materials such as coal, oil, tar and tobacco.

SO_2—Sulfur dioxide is an invisible, nonflammable acidic gas, formed during combustion of fuel containing sulfur.

SO_3—Sulfur trioxide oxidized from SO_2; combines with atmospheric moisture to form sulfuric acid mist (H_2SO_4).

Soot—Very finely divided carbon particles clustered together in long chains.

Source—Any place or object from which pollutants are released.

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

Specific Collecting Area (SCA)—A figure obtained by dividing total effective collecting surface of the precipitator by gas volume, expressed in thousands of actual cubic feet per minute.

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

Stage II Controls—Systems placed on service station gasoline pumps to control and capture gasoline vapors during an automobile refueling.

Static Pressure (Cold)—The pressure caused by the resistance to air flow through the system if the gas were at standard conditions or colder, if this is a possibility.

Static Pressure (Hot)—The pressure caused by the resistance to air flow through the system at actual conditions. Measured in inches of water (WG).

Streamline Flow—Fluid flow in which the velocity pressure and fluid density of a given particle remains constant with time.

STEL (Short Term Exposure Limit)—The employee's 15 minute time weighted average exposure which cannot be exceeded at any time. STEL is set by OSHA for each pollutant and expressed in terms of ppm or mg/m^3.

Stoichiometric Air—The exact quantity of air required to combine with the given fuel so that the ensuing combustion reaction is perfect and no free oxygen or unburned constituents remain. In reality,

air in excess of the stoichiometric ratio is usually provided to encourage complete combustion of the fuel.

Sulfur Dioxide (SO_2)—A heavy, pungent, colorless air pollutant formed primarily by the combustion of fossil fuels. It is a respiratory irritant, especially for asthmatics, and is the major precursor to the formation of acid rain.

Sulfur Oxides—Pungent, colorless gases formed primarily by the combustion of fossil fuels; considered major air pollutants, sulfur oxides may damage the respiratory tract as well as vegetation.

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

Tape Sampler—A device used in the measurement of both gases and fine particulates. It allows air sampling to be made automatically at predetermined times.

Threshold Limit Values (TLV)—Represents the air concentrations of chemical substances to which it is believed that workers may be exposed daily without adverse effect.

TLV® (Threshold Limit Value)—A registered trademark for an exposure limit developed by the American Conference of Governmental Industrial Hygienists (ACGIH). A listing of TLVs may be found in the ACGIH's "Documentation of the

Threshold Limit Values and Biological Exposure Indices for 1988-1989."

TPY—Tons per year.

Transformer Rectifier—A unit comprised of a transformer for stepping up normal service voltages to voltages in the kilovolt range, and a rectifier operating at high voltage to convert AC to unidirectional current.

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.

Transportation Control Measures (TCMs)—Steps taken by a locality to adjust traffic patterns (e.g., bus lanes, right turn on red) or reduce vehicle use (ridesharing, high-occupancy vehicle lanes) to reduce vehicular emissions of air pollutants.

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, in seconds, obtained by dividing the effective length, in feet, of a precipitator by the precipitator gas velocity figure calculated above.

TSCA (Toxic Substances Control Act)—Administered by the Environmental Protection Agency (EPA), was passed by Congress to protect human health and the environment by requiring testing and necessary use restrictions to regulate the commerce of certain chemical substances.

TSD (Facility)—Treatment, Storage and Disposal.

Turbulent Flow—Fluid flow in which the velocity of a given particle changes constantly both in magnitude and direction—here, uneven gas flow in the exhaust system is caused by obstructions and changes in direction.

Turning Vanes—Vanes in ductwork or transition to guide the gas and dust flow through the ductwork in order to minimize pressure drop and to control the velocity and dust concentration contours.

TWA (Time Weighted Average)—Employee's average airborne exposure which can not be exceeded in any 8-hour work shift. TWA is set by OSHA and expressed in mg/m^3.

Upper Weather Enclosure—A nongastight enclosure on the roof of the precipitator to shelter equipment (T/R sets, rappers, purge air fans, etc.) and maintenance personnel.

Vaporization—The change of a substance from the liquid to a gaseous state. One of the three basic contributing processes of air pollution: the others being attrition and combustion.

Vapors—The gaseous form of substances which are normally in the solid or liquid state and which can be changed to these states, either by increasing the pressure or decreasing the temperature alone. Vapors diffuse.

Variance—Permission granted for a limited time, under stated conditions, for a person or company to operate outside the limits prescribed in a regulation. Usually granted to allow time for engineering and fabrication of abatement equipment to bring the operation into compliance.

Velometer—A simple instrument for determining the velocity of gas in a duct. Its operation is similar to an inclined manometer, except that it automatically converts the reading to velocity.

Venturi—Device used to increase the efficiency of a compressed air pulse. Designed with converging circular sides to a throat and then diverging sides. Designed such that when a pulse is introduced at the top, a negative pressure zone is created outside the top, and secondary air is induced into the venturi, compounding the pulse strength.

Venturi Scrubber—A wet type dust collector that can obtain very high efficiency, but requires large horsepower to do so. The gas and dust particles are accelerated in a throat, where finely atomized water is introduced and water/dust collisions take place.

VOCs (Volatile Organic Compounds)—A group of chemicals that react in the atmosphere with nitrogen oxides in the presence of heat and sunlight to form ozone; does not include methane and other compounds determined by EPA to have negligible photochemical reactivity. Examples of VOCs include gasoline fumes and oil-based paints.

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

Water Gauge—Inches water is a pressure term defined as a pressure equal to that exerted by a column of water of the same height. 27.7" WG equals 1 PSI.

Wet Bulb Temperature—The temperature of a gas stream taken with a wetted thermometer. It is approximately equal to the adiabatic saturation temperature of the gas.

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

Wrapper—Used in electrostatic precipitators, the light gauge steel or aluminum covering put over insulation.

CLEAN AIR ACT AMENDMENTS

1990

Title I:	Nonattainment: Ambient Air Quality
Title II:	Motor Vehicles
Title III:	Hazardous Air Pollutants
Title IV:	Acid Rain
Title V:	Permits
Title VI:	Stratospheric Ozone
Title VII:	Enforcement
Title VIII:	Miscellaneous

CONVERSION FACTORS METRIC EQUIVALENTS

Length

cm = 0.3937 in	in = 2.5400 cm
meter = 3.2808 ft	ft = 0.3048 m
meter = 1.0936 yd	yd = 0.9144 km

Volume

cm^3 = 0.0610 in^3	in^3 = 16.3872 cm^3
m^3 = 35.3145 ft^3	ft^3 = 0.0283 m^3
m^3 = 1.3079 yd^3	yd^3 = 0.7647 m^3

Capacity

liter = 2.2046 lb of pure water at 4C	liter = 0.2642 gal (US)
	in^3 = 0.0164 liter
liter = 61.0250 in^3	ft^3 = 28.3162 liter
liter = 0.0353 ft^3	gal (US) = 3.7853 liter

Weight

gram = 15.4324 grains	grain = 1/7000 lb
gram = 0.0353 oz	grain = 0.0648 g
kg = 2.2046 lb	oz = 28.3495 g
	lb = 0.4536 kg

Concentration

grain/ft^3 = 2288.1 mg/m^3
lb/acre = 0.11208 g/m2
lb/1000 ft^3 = 16,017 mg/m^3
lb/1000 ft^2 = 4.8807 g/m^2
ton/sq mile = 0.35026 g/m^2
grain/ft^2 = 0.69725 g/m^2

Heat & Energy Units

1 boiler HP = 33,475 Btu/hr
1 ton (refrig) = 12,000 Btu/hr
Btu = 0.2520 kg-cal

1 kw-hr=	*1 hp-hr=*
1000 whr	0.7457 kw-hr
1.3410 hp-hr	1,980,000 ft-lb
3413 Btu	2545 Btu

1 lb water evaporated from and at 212 F

Temperature Equivalents

Fahrenheit, ˚F = ˚Ranking - 460 = (˚Cx9/5)+32
Celsius, ˚C = ˚Kelvin - 273 = 5/9 = (˚F-32)x5/9

Pressure Equivalents

1 atmosphere =
14.696 lb/in^2 = 2116.3 lb/ft^2
33.96 ft of water = 407.52 in water
29.92 in mercury = 760 mm mercury
1.01296 bar

1 in water =
0.0361 lb/in^2 = 5.196 lb/ft^2
0.0735 in mercury = 1.876 mm mercury
0.002456 atmosphere = 0.08333 ft water

1 bar =
0.9872 atmosphere
14.5 lb/in^2

ALTITUDE-PRESSURE TEMPERATURE DENSITY TABLE OF AIR

Altitude (feet)	**Pressure** (In Hg Abs)	**Temperature** (Degrees F)	**Density** (lbs/ft^3)
0	29.92	70.0	.0750
500	29.38	68.1	.0740
1000	28.85	66.1	.0730
1500	28.33	64.2	.0719
2000	27.82	62.3	.0709
2500	27.31	60.4	.0698
3000	26.81	58.4	.0687
3500	26.33	56.5	.0676
4000	25.84	54.6	.0666
4500	25.37	52.6	.0657
5000	24.89	50.7	.0648
5500	24.43	48.8	.0638
6000	23.98	46.9	.0628
6500	23.53	45.0	.0619
7000	23.09	43.0	.0610
7500	22.65	41.0	.0600
8000	22.12	39.0	.0590
8500	21.80	37.1	.0581
9000	21.38	35.2	.0573
9500	20.98	33.3	.0564
10000	20.57	31.3	.0555
11000	19.75	28.5	.0538
12000	19.03	23.6	.0521
13000	18.29	19.7	.0505
14000	17.57	15.8	.0488
15000	16.88	12.0	.0473
20000	13.70	-12.6	.0405

Altitude-Pressure Temperature Density Table of Air (continued)

Altitude (feet)	Pressure (In Hg Abs)	Temperature (Degrees F)	Density (lbs/ft^3)
25000	11.10	-30.1	.0337
30000	8.88	-47.5	.0281
35000	7.03	-65.6	.0233
40000	5.54	-69.8	.0185
45000	4.36	-69.8	.0145
50000	3.43	-69.8	.0114

TITLE III
Hazardous Air Pollutants

CAS No.	Chemical Name	Category
75070	Acetaldehyde	OV
60355	Acetamide	OV
75058	Acetonitrile	OV
96862	Acetophenone	OV
53963	2-Acetylaminofluorene	OV
107028	Acrolein	OV
79061	Acrylamide	OV
79107	Acrylic acid	OV
107131	Acrylonitrile	OV
107051	Allyl chloride	HV
92671	4-Aminodiphenyl	OV
62533	Aniline	OV
90040	o-Anisidline	OV
1332214	Asbestos	N
71432	Benzene (including gasoline)	OV
92875	Benzidine	OV
98077	Benzotrichloride	HV
100447	Benzyl chloride	HV
92524	Biphenyl	OV
117817	Bls (2-ethylhexyl)phthalate (DEHP)	OV
542881	Bls(chiromethyl)ether	HV
75252	Bromoform	HV
106990	1,3-Butadiene	OV
156627	Calcium cyanamide	OV
105602	Caprolactarn	
133062	Captan	OV
63252	Carbaryl	OV

Hazardous Air Pollutants (continued)

CAS No.	Chemical Name	Category
75150	Carbon disulfide	OV
56235	Carbon tetrachloride	HV
463581	Carbonyl sulfide	OV
120809	Catechol	OV
133904	Chloramben	HV
57749	Chlordane	HV
7782505	Chlorine	N
79118	Chloroscetic acid	HV
532274	2-Chloroacetophenone	HV
108907	Chlorobenzene	HV
510156	Chlorobenzilate	HV
67663	Chloroform	HV
107302	Chloromethyl methyl ether	HV
126998	Chloroprene	HV
1319773	Cresols/Cresylic acid (isomers/mixer)	OV
95487	o-Cresol	OV
108394	m-Cresol	OV
106445	p-Cresol	OV
98828	Cumene	OV
94757	2,4-D, Salts and Esters	HV
3547044	DDE	
334883	Diazomethane	OV
132649	Dibenzofurans	OV
96128	1,2-Dibromo-3-chloropropane	HV
84742	Dibutylphthalate	OV
106467	1,4-Dichlorobenzene(p)	HV
91941	3,3-Dichlorobenzidene	HV
111444	Dichloroethyl ether (Bls(2-chloroethyl) ether)	HV

Hazardous Air Pollutants (continued)

CAS No.	Chemical Name	Category
542756	1,3-Dichloropropolene	HV
62737	Dichlorovos	HV
111422	Diethanolamine	OV
121697	N,N-Diethyl anilline (N,N-Dimethylaniline)	OV
64675	Dimethyl sulfate	OV
119904	3,3-Dimethoxybenzidine	OV
60117	Dimethyl aminoazobenzene	OV
119937	3,3'-Dimethyl benzidine	OV
79447	Dimethyl Carbamoyl chloride	OV
68112	Dimethyl formamide	
57147	1,1-Dimethyl hydrazine	OV
131113	Dimethyl phthalate	OV
77781	Dimethyl sulfate	OV
534521	4,6-Dinitro-o-cresol, and Salts	OV
51285	2,4-Dinitrophenol	OV
121142	2,4-Dinitrotoluene	OV
123911	1,4-Dioxane (1,4-Diethyleneoxide)	OV
122667	1,2-Diphenythydrazine	OV
106898	Ephichlorohydrin (1-Chloro-2,3-epoxypropane)	HV
106887	1,2-Epoxybutane	OV
140885	Ethyl acrylate	OV
104414	Ethyl benzene	OV
51796	Ethyl carbonate (urethane)	OV
75003	Ethyl chloride (chloroethane)	HV
106934	Ethylene dibromide (dibromoethane)	HV

Hazardous Air Pollutants (continued)

CAS No.	Chemical Name	Category
107062	Ethylene dichloride (1,2-dichloroethane)	HV
107211	Ethylene glycol	OV
151564	Ethylene imine (Aziridine)	OV
75218	Ethylene oxide	OV
96457	Ethylene thlourea	OV
75343	Ethylene dichloride (1,1-Dichloroethane)	OV
50000	Formaldehyde	OV
76448	Heptachlor	HV
118741	Hexachlorobenzene	HV
87683	Hexachlorobutadlene	HV
77474	Hexachlorocyclopentadlene	HV
67721	Hexachloroethane	HV
822060	Hexamethylene-1,6-diisocyanate	
680319	Hexamethylphosphoramide	OV
100543	Hexane	OV
302012	Hydrazine	N
7647010	Hydrochloric acid	A
7664393	Hydrogen fluoride (Hydrofluoric acid)	A
123319	Hydroquinone	OV
78591	Isophorone	
58899	Lindane (all isomers)	HV
108316	Maleic anhydride	OV
67561	Methanol	OV
72435	Methoxychlor	HV
74839	Methyl bromide (Bromethane)	HV
74873	Methyl chloride (Chloromethane)	HV

Hazardous Air Pollutants (continued)

CAS No.	Chemical Name	Category
71556	Methyl chloroform (1,1,1-Trichloroethane)	HV
74884	Methyl iodide (Iodomethane)	HV
108101	Methyl isobutyl ketone (Hexone)	OV
624839	Methyl isocyanate	OV
80626	Methyl methacrylate	OV
1634044	Methyl tert butyl ether	OV
101144	4,4'-Methylene bis (2-chloroardiline)	HV
75092	Methylene chloride (Dichloromethane)	HV
101688	Methylene diphenyl diisocyanate (MDI)	OV
107779	4,4'-Methylenedlaniline	OV
91203	Naphthalene	OV
98953	Nitrobenzene	OV
92933	4-Nitrobiphenyl	OV
100027	4-Nitrophenol	OV
79469	2-Nitropropane	OV
684935	N-Nitroso-N-methylurea	OV
62759	N-Nitrosodimethylamine	OV
59892	N-Nitrosomorpholine	OV
56382	Parathion	OV
82688	Pentachloronitrobenzene	OV
87865	Pentachlorophenol	HV
108952	Phenol	OV
106503	P-Phenylenediamine	OV
75445	Phosgene	HV
7803512	Phosphine	

Hazardous Air Pollutants (continued)

CAS No.	Chemical Name	Category
7723140	Phosphorus	N
85449	Phthalic anhydride	OV
1336363	Polychlorinated biphenyls (Alodors)	HV
1120714	1,3-Propane sultone	OV
57578	beta-Propiolactone	OV
123386	Proplonaldehyde	OV
114261	Propoxur (Baygon)	OV
78875	Propylene dichloride (1,2-Dichloropropane)	HV OV
75569	Propylene oxide	OV
75558	1,2-Propylenimine (2-methyl aziridine)	OV
91225	Quinoline	OV
106514	Quinone	OV
100425	Styrene	OV
96093	Styrene oxide	OV
1746016	2,3,7,8-Tetrachlorodibenzo-p-dioxin	
79345	1,1,2,2-Tetracholoethane	HV
127184	Tetrachloroethylene (Perchloroethylene)	HV
7550450	Titanium tetrachloride	M
106883	Toulene	OV
95807	2,4-Toulene diamine	OV
584849	2,4-Toulene diisocyanate	OV
95534	o-Toluidine	OV
8001352	Toxaphene	HV
120821	1,2,4-Trichlorobenzene	HV
79005	1,1,2-Trichloroethane	HV
79016	Trichloroethylene	HV

Hazardous Air Pollutants (continued)

CAS No.	Chemical Name	Category
95954	2,4,5-Trichlorophenol	HV
88062	2,4,6-Trichlorophenol	HV
121448	Triethylamine	
1582098	Trifluralin	OV
540841	2,2,4-Trimethylpentane	
108054	Vinyl acetate	OV
593602	Vinyl bromide	HV
75014	Vinyl chloride	HV
75354	Vinylidene chloride	HV
1330207	Xylenes (isomers/mixture)	OV
95476	o-Xylenes	OV
108383	m-Xylenes	OV
106423	p-Xylenes	OV
0	Antimony Compounds	M
0	Arsenic Compounds	N
0	Beryllium Compounds	M
0	Cadmium Compounds	M
0	Chromium Compounds	M
0	Cobalt Compounds	M
0	Coke Oven Emissions	
0	Cyanide Compounds[1]	
0	Glycol Ethers[2]	OV
0	Lead Compounds	M
0	Manganese Compounds	M
0	Mercury Compounds	M
0	Fine Mineral Fibers[3]	
0	Nickel Compounds	M
0	Polycylic Organic Matter[4]	O
0	Radionuclides (including Radon)[5]	
0	Selenium Compounds	N

Hazardous Air Pollutants (continued)

V=Volatile
N=Nonmetallic Inorganics
O=Organic
M=Metals and Metal Compounds
A=Acids, Bases and Salts

NOTE: For all listings above which contain the word "compounds" and for glycol ethers, the following applies: Unless otherwise specified, these listings are defined as including any unique chemical substance that contains the named chemical (i.e., antimony, arsenic, etc.) as part of that chemical's infrastructure.

[1] X'CN where X=H' or any other group where a formal dissociation may occur. For example KCN or $Ca(CN)_2$.

[2] Includes mono- and di- ethers of ethylene glycol, diethylene glycol and triethylene glycol R-$(OCH2CH)_n$ - OR' where
n= 1, 2 or 3
R= alkyl or aryl groups
R'= R, H or groups which, when removed, yield glycol ethers with the structure: R-$(OCH2CH)_n$ - OH.
Polymers are excluded from the glycol category.

[3] Includes mineral fiber emissions from facilities manufacturing or processing glass, rock or slag fibers (or other mineral derived fibers) of average diameter 1 micrometer or less.

[4] Includes organic compounds with more than one benzene ring, and which have a boiling point greater than or equal to 100˚ C.

[5] A type of atom which spontaneously undergoes radioactive decay.