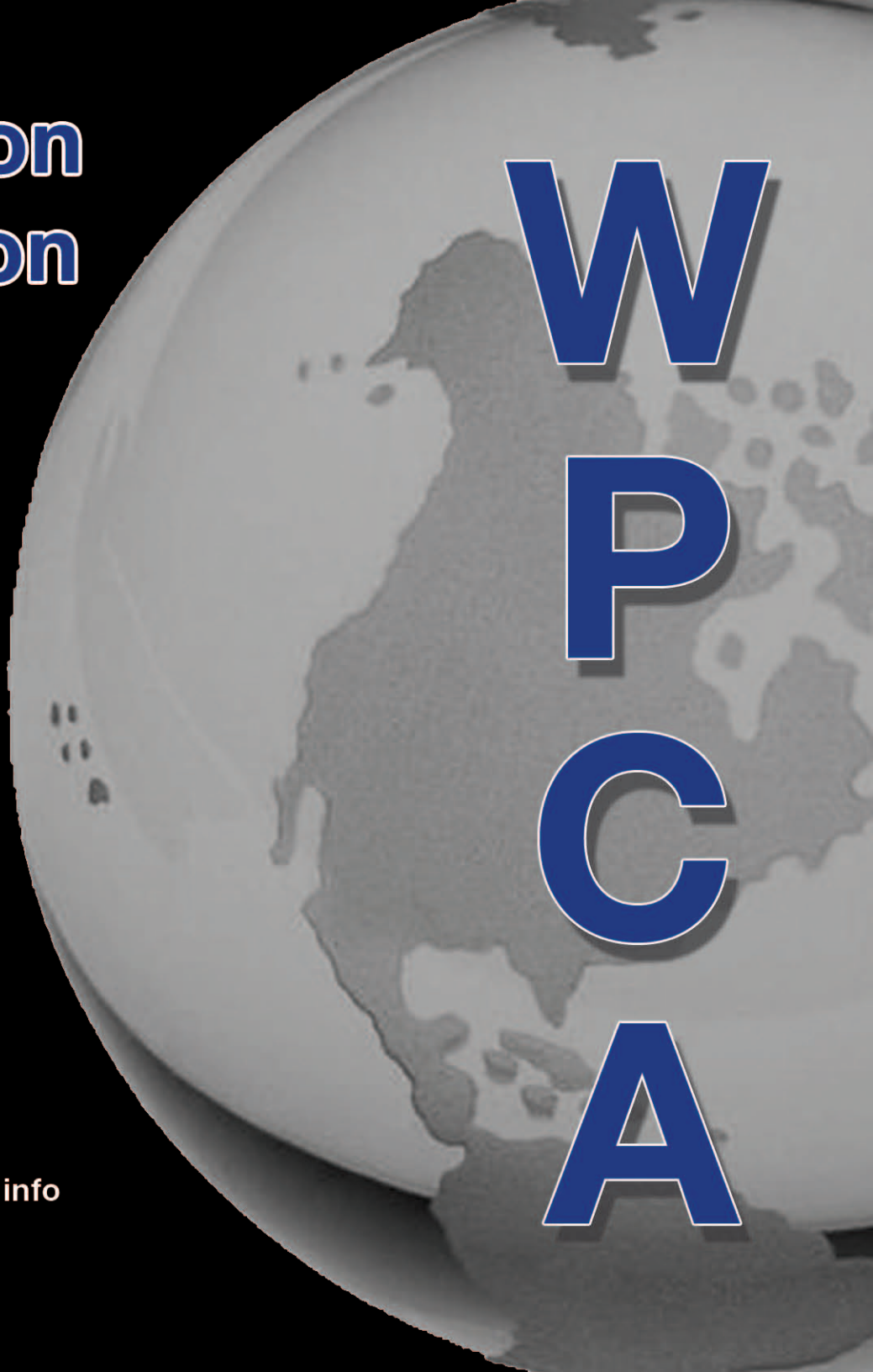
Worldwide Pollution Control Association



Particulate Control O&M Training

APC/PCUG Conference
July 12-16, 2009
The Woodlands, TX

WPCA

Visit our website at www.wpca.info

Electrostatic Precipitator (ESP) Operation & Maintenance

John Caine

Southern Environmental, Inc.

ESP Operation & Maintenance

- ESP Operation – a collection device that removes particles from the gas stream using the force of an induced electrostatic charge.
- Maintenance – "*Just who to assign to the precipitator system should be given much thought. The value of the initial check-out and contacts with the manufacturer can be lost if the user representative is moved to another assignment. A person who can be assigned long term to oversee the precipitator system and monitor the process ... is the best investment a company can make.*"
  J. Katz

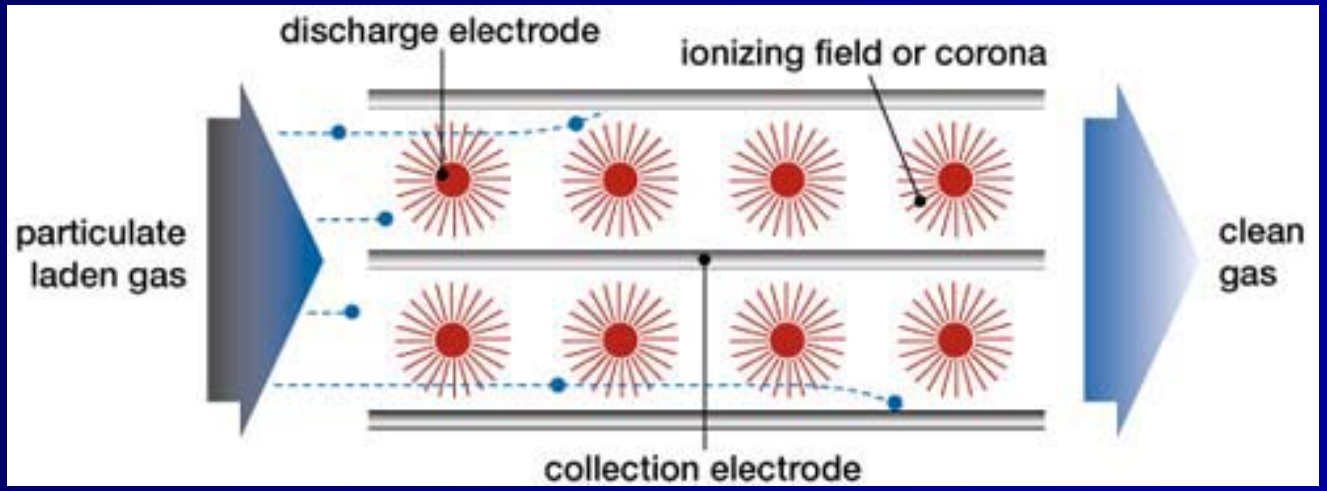
ESP Theory, Process, & Electrical/Mechanical Factors

- Principles of Operation
  - Design Theory
- Process Factors Affecting Migration Velocity & ESP Performance
- Electrical/Mechanical Factors Affecting Performance

Operating Principle

- Dirty Gas In
- Electric Power In
  - Ionization of flue gas
  - Corona field generation
- Dust Out (Hopefully, in the Hoppers!)
- Clean Gas Out

The Basics:


discharge electrode
ionizing field or corona
particulate laden gas
clean gas
collection electrode

ESP Design Theory

In designing a high efficiency ESP, a smaller drift velocity is used.

Matts-Ohnfeldt Equation

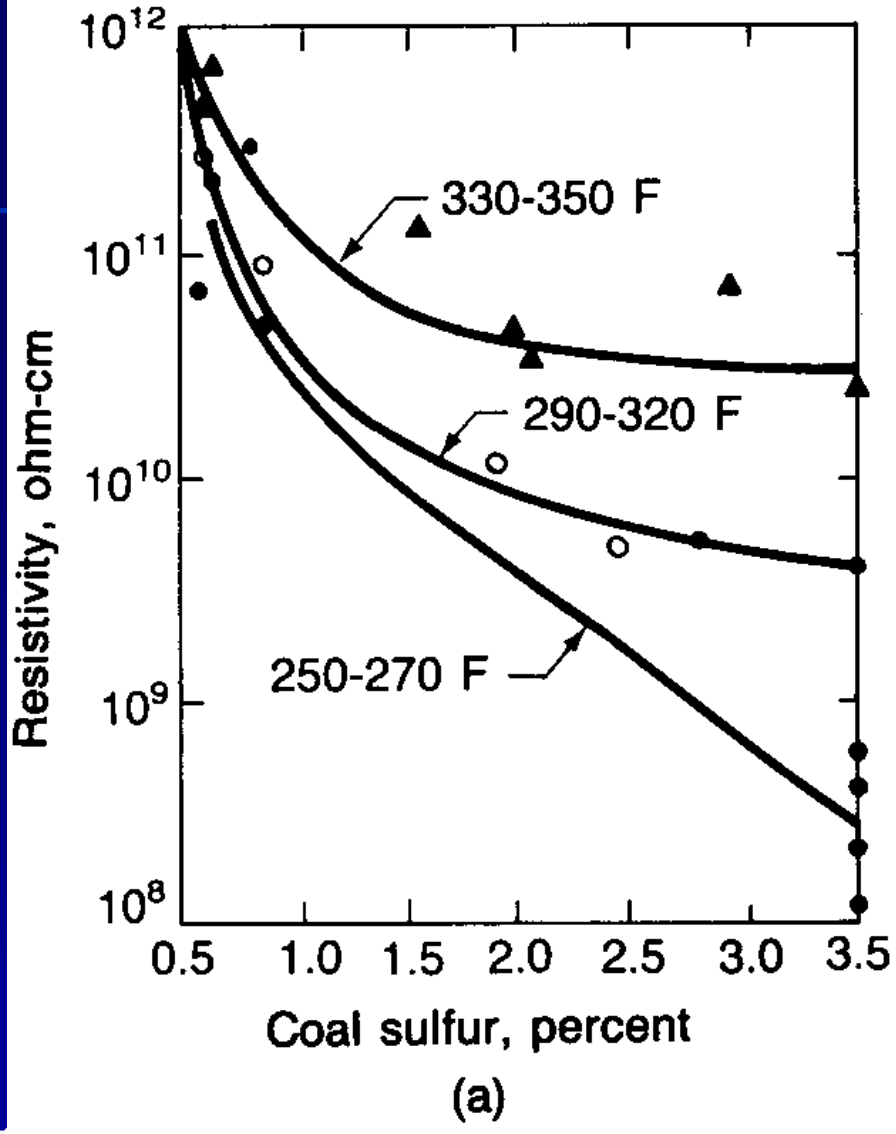
$$\eta = 1 - \exp\left[-\left(\frac{A_C}{Q} w_e\right)^k\right]$$

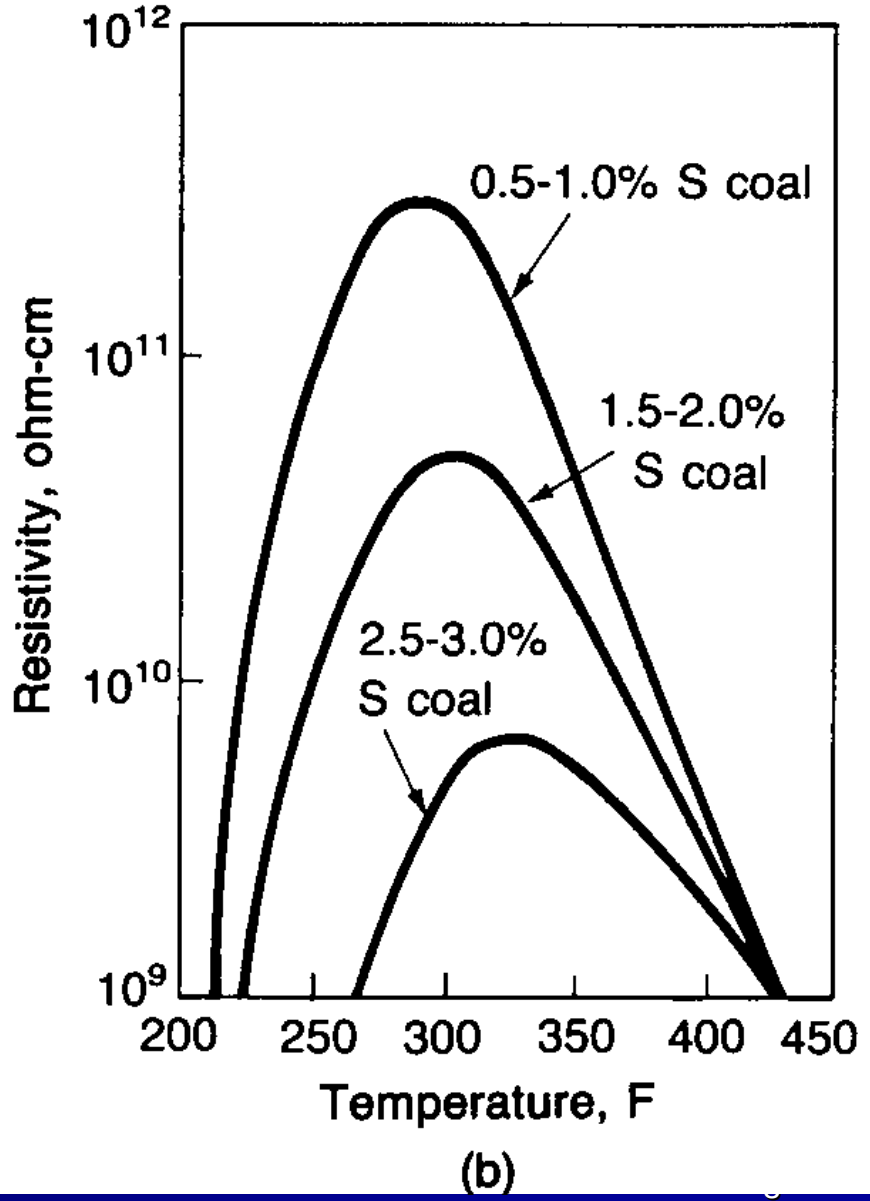
N = Efficiency = (Inlet – Outlet)/Inlet
A = Collecting Area
Q = Gas Volume
W = Migration velocity
K = “experience” factor

Process Factors Affecting Migration Velocity

- Fuel Characteristics
- Fly Ash Concentration
- Particle Size Distribution
- Fly Ash Chemical Composition
- Ash Resistivity
- Acid Dew point Conditions
- Space Charge Effect

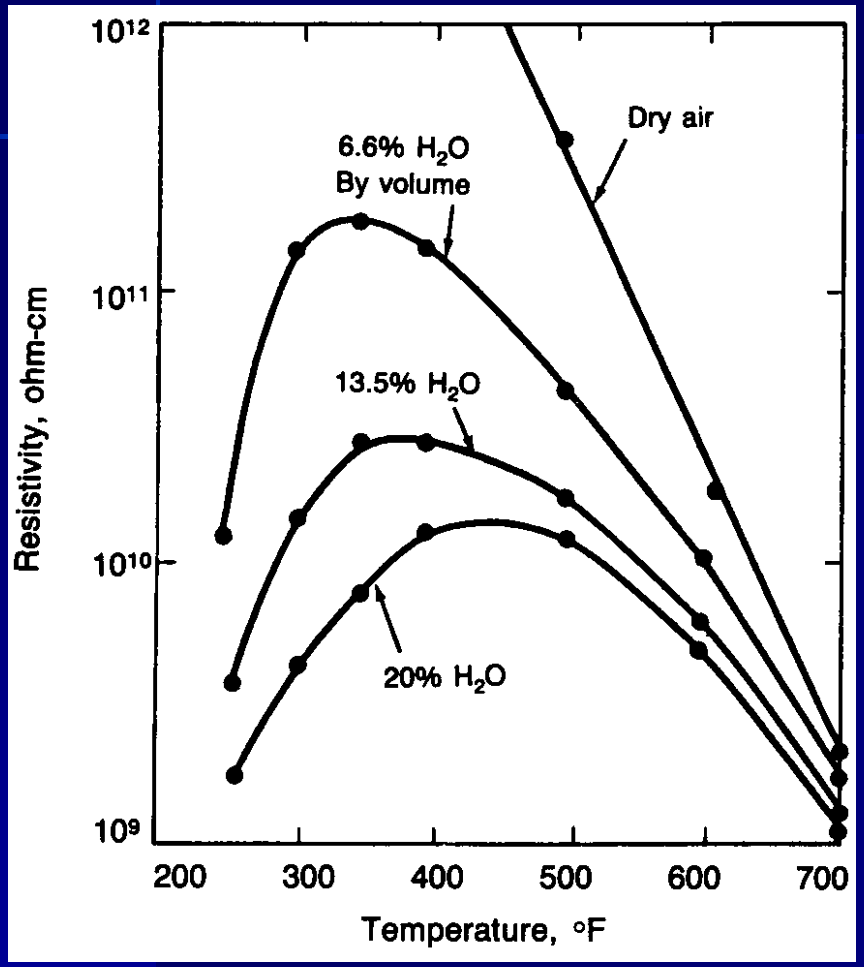
Effects of sulfur content and temperature on resistivity



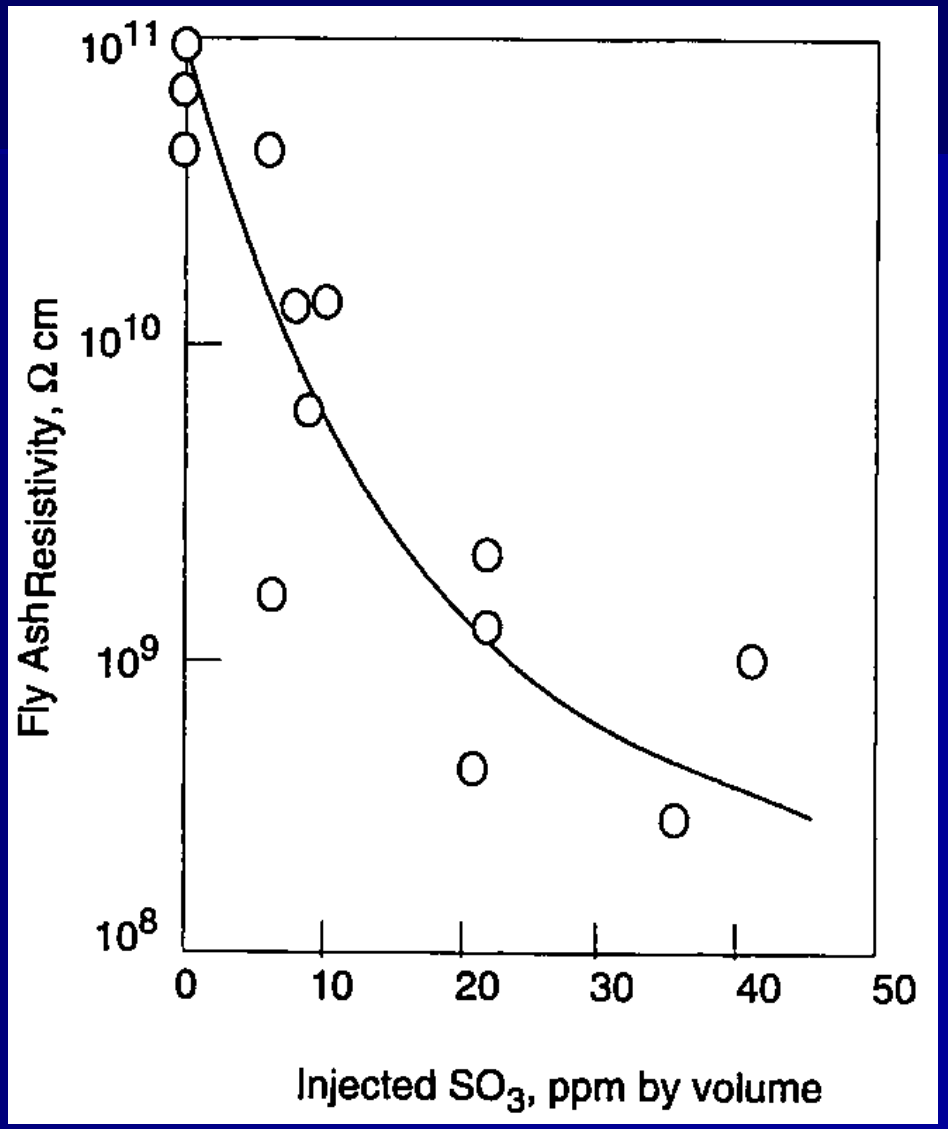


Q: Is S in coal good or bad?

Flue Gas Conditioning with H2O & SO3



Water spray for cement kiln dust



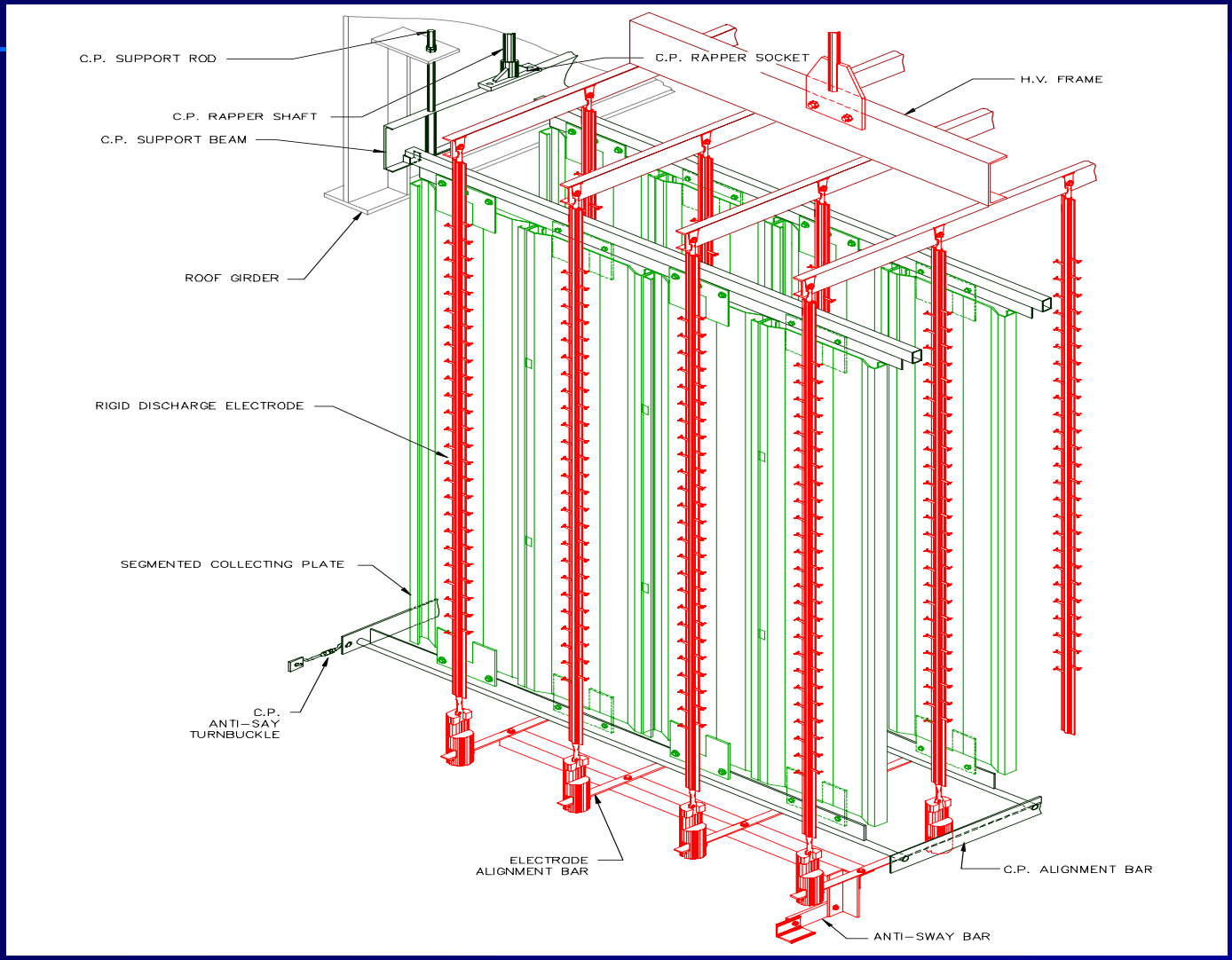
Electrical / Mechanical Factors Affecting Performance

- Collecting Plate Area
  - Precipitator Aspect – L/H - Ratio
  - Number of Fields and Bus Sections
- Corona Power
  - Electrical Controls
  - Internal Clearances
- Gas Velocity and Velocity Distribution
  - Gas Distribution Devices
  - Gas Sneakage
  - Air In-Leakage
- Rappers
  - Dust build-up on CE's & DE's

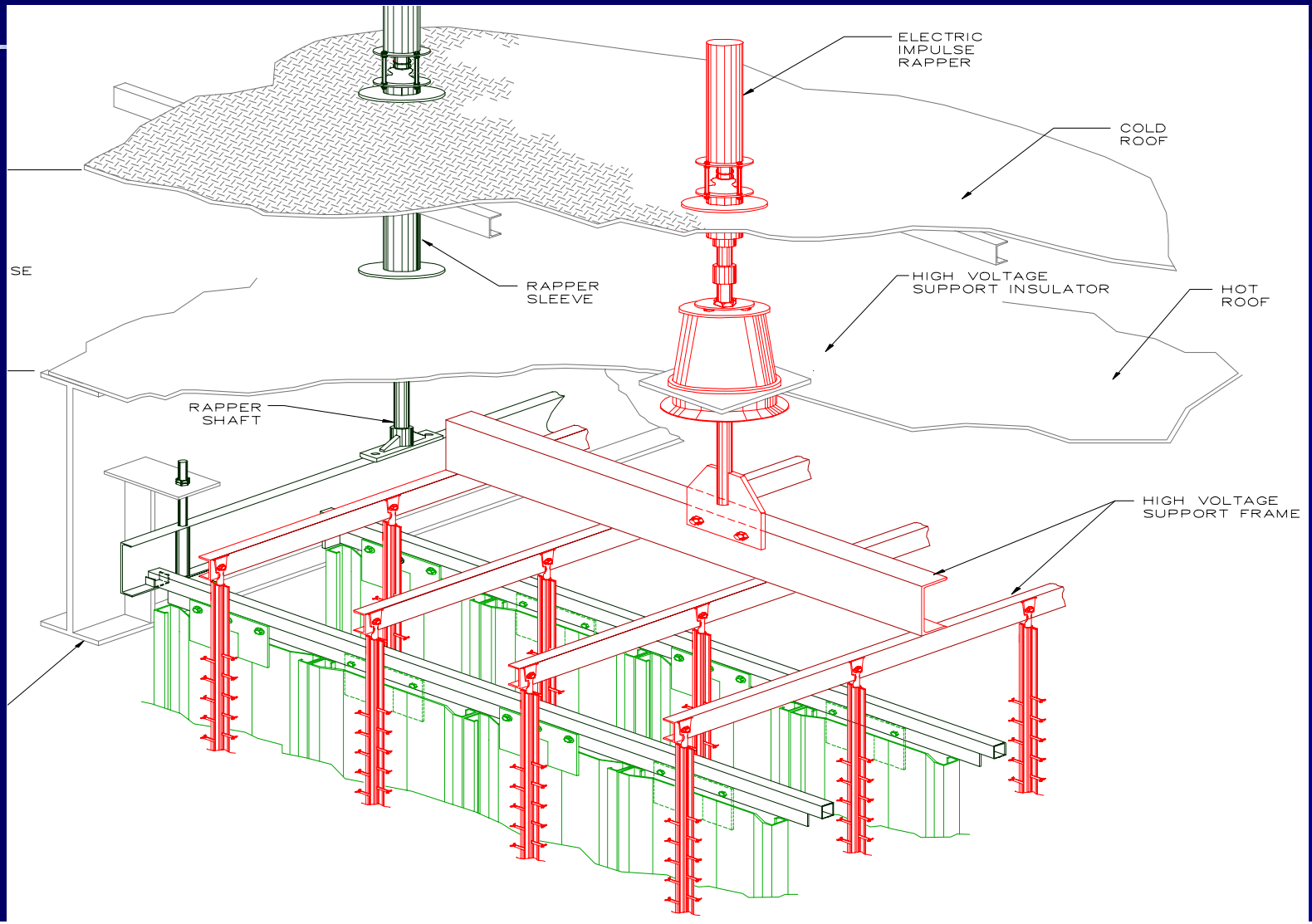
Basic ESP Components:

- ESP Casing
- Collecting Electrodes
- RDEs
- T/R sets
- AVCs
- Rappers
- Rapper Controller
- Purge Air System
- Key Interlocks
- Hoppers
- Etc.

ESP Internals



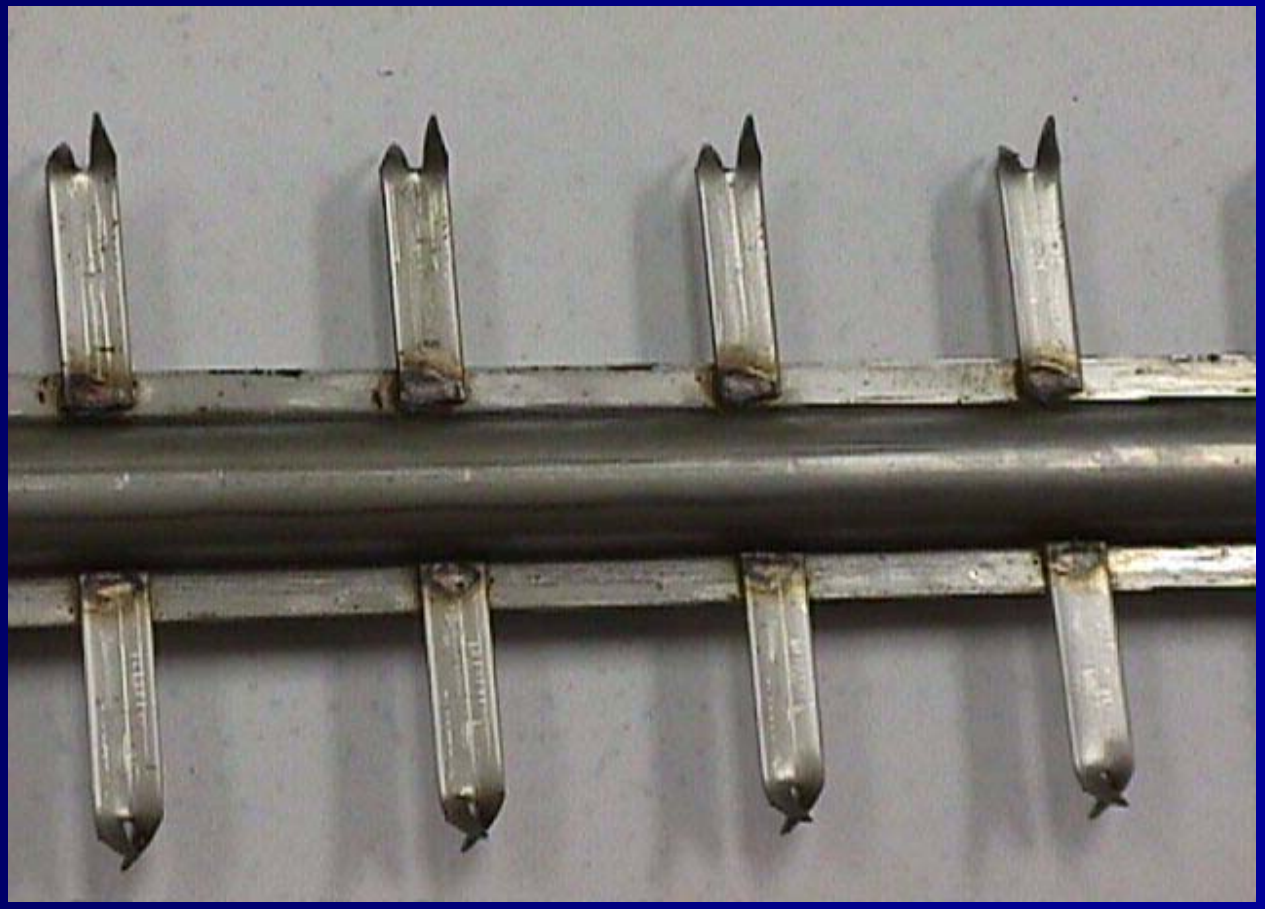
Internal Support Structure



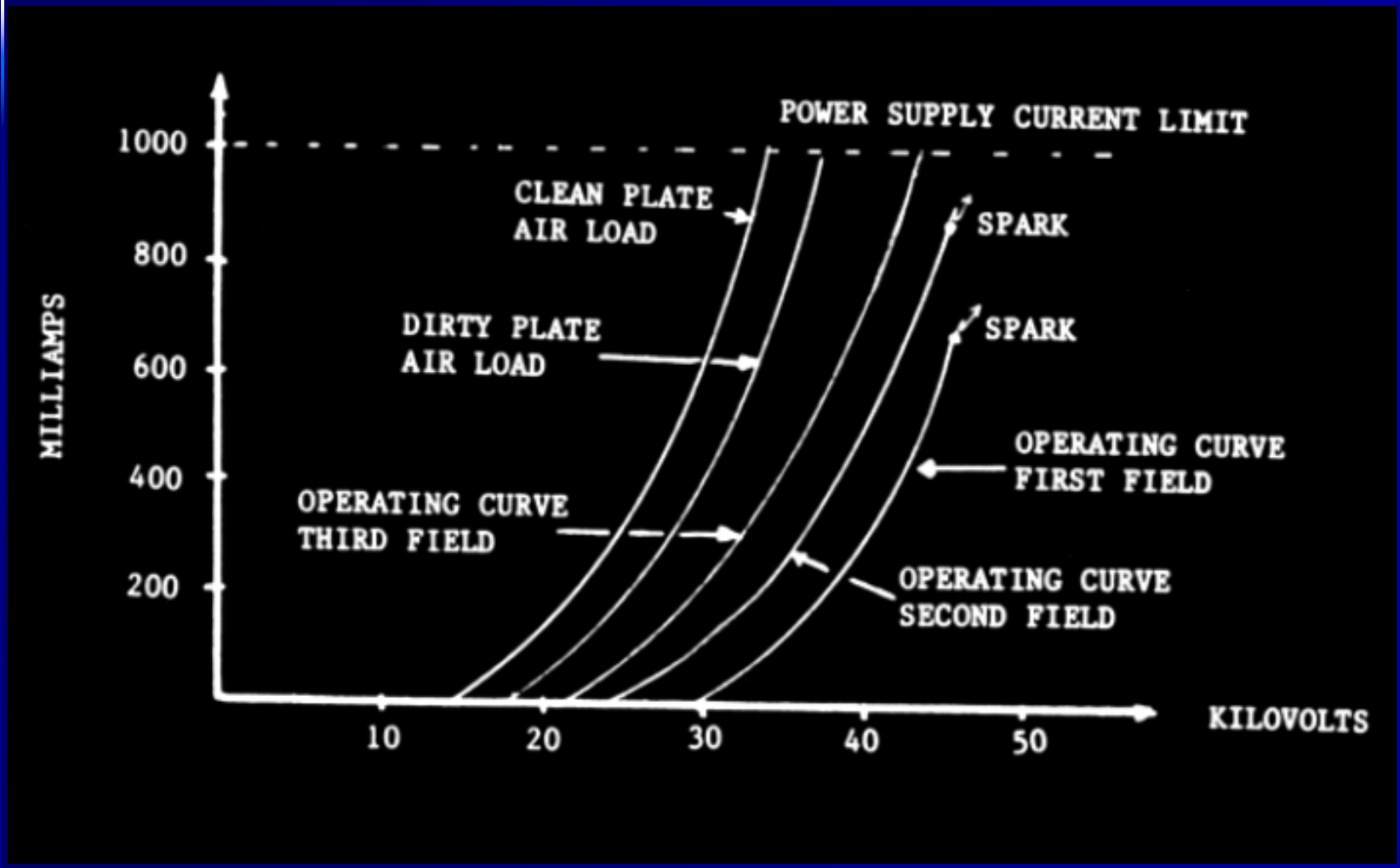
Rigid Discharge Electrode

- "Unbreakable" Rigid Electrode Design
- Low Corona Onset Voltage
- Modify/Customize current/voltage characteristics
  - Number of points per linear foot
  - Geometry of points
- Uniform Current Distribution to Plates
  - Reduce "Shadow Effects"

RIGID DISCHARGE ELECTRODE



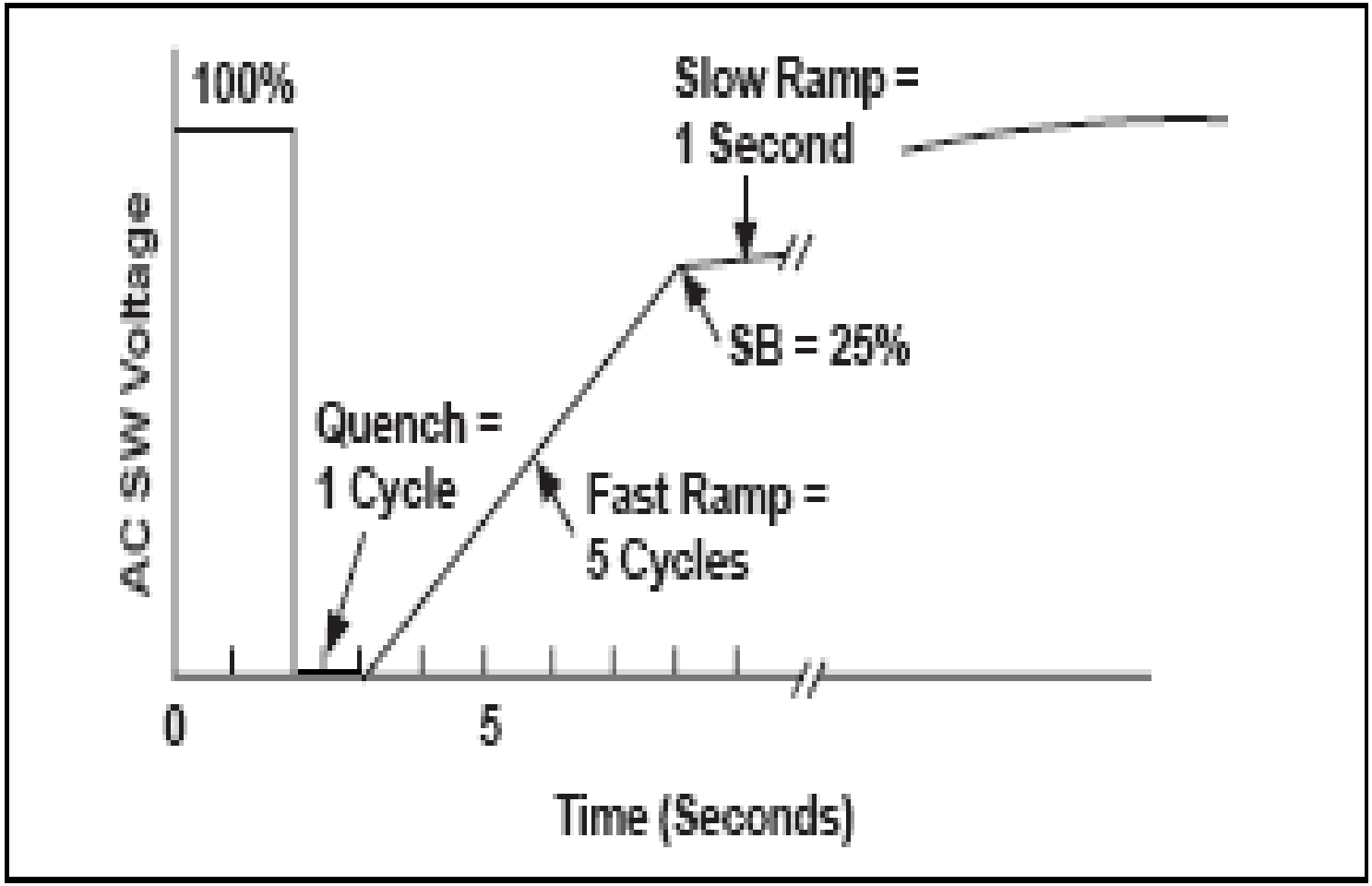
Typical Precipitator Voltage/Current Curves



Max applied voltage = Max Performance

- ESP collecting efficiency increases rapidly as the applied voltage increases
- ESP voltage should be kept at a point which produces a light sparking condition
- The applied voltage is influenced by:
  - Type of T/R set and Discharge Electrode design
  - The electrical conductivity of the gas and the particles in the gas stream.
  - The gas temperature
  - The concentration of suspended matter in the gas stream.
  - The gas pressure.
  - The amount of moisture (water vapor).
  - The degree of cleanliness of the collecting surfaces and discharge electrodes.

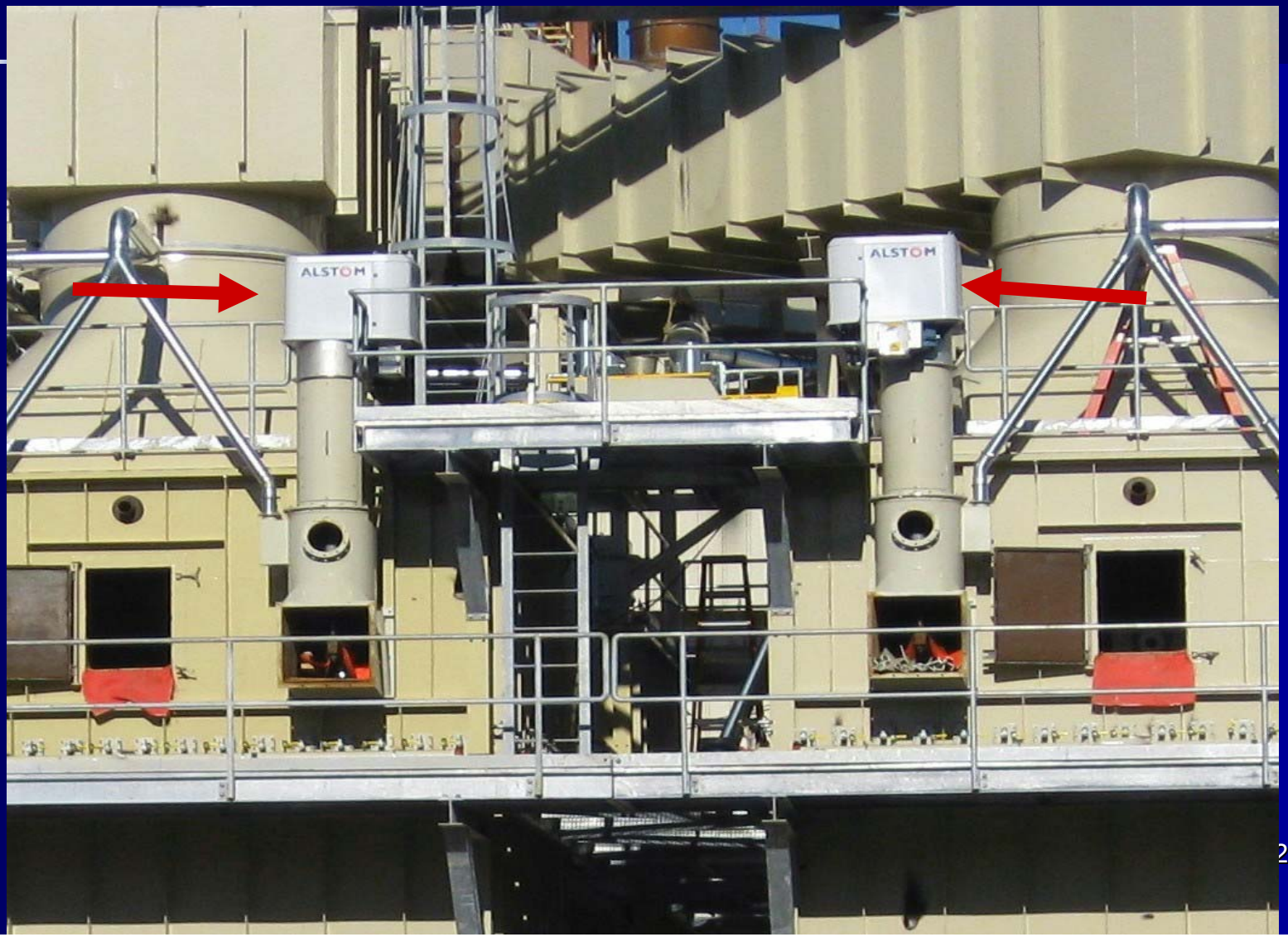
Automatic Voltage Control



Modern High Frequency Transformer Rectifier Set

- Combines T/R, controller, splitter switch and ground switch in one package
- Three phase power
- Less input current – 30% higher power factor
- Easier to install/replace
- Smaller and lighter
- Field serviceable
- Less bus duct required
- High frequency
- Solid-state switch mode (IGBT) design
- Greater collection efficiency (up to 30% more power)
- Better control

Two High Frequency T/R Sets



Modern T/R SET Automatic Voltage Control

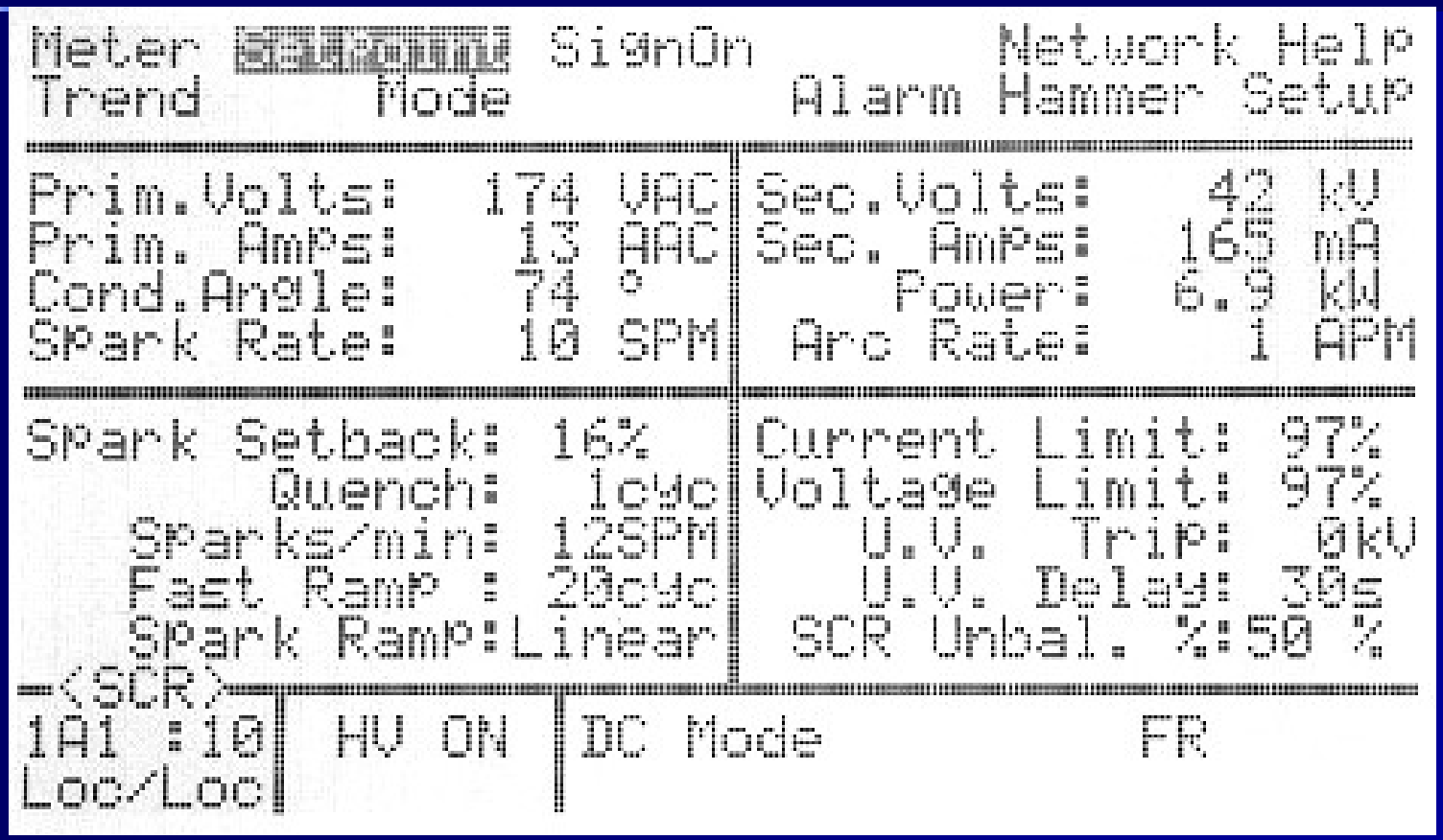
- The AVC is integrated in the TR Set
- The controller is a Graphic Voltage Controller (GVC)
- Operating parameters:
  - Spark Setback
  - Quench
  - Sparks per minute
  - Current Limit
  - Voltage Limit
  - Under Voltage Trip
  - U.V. Delay

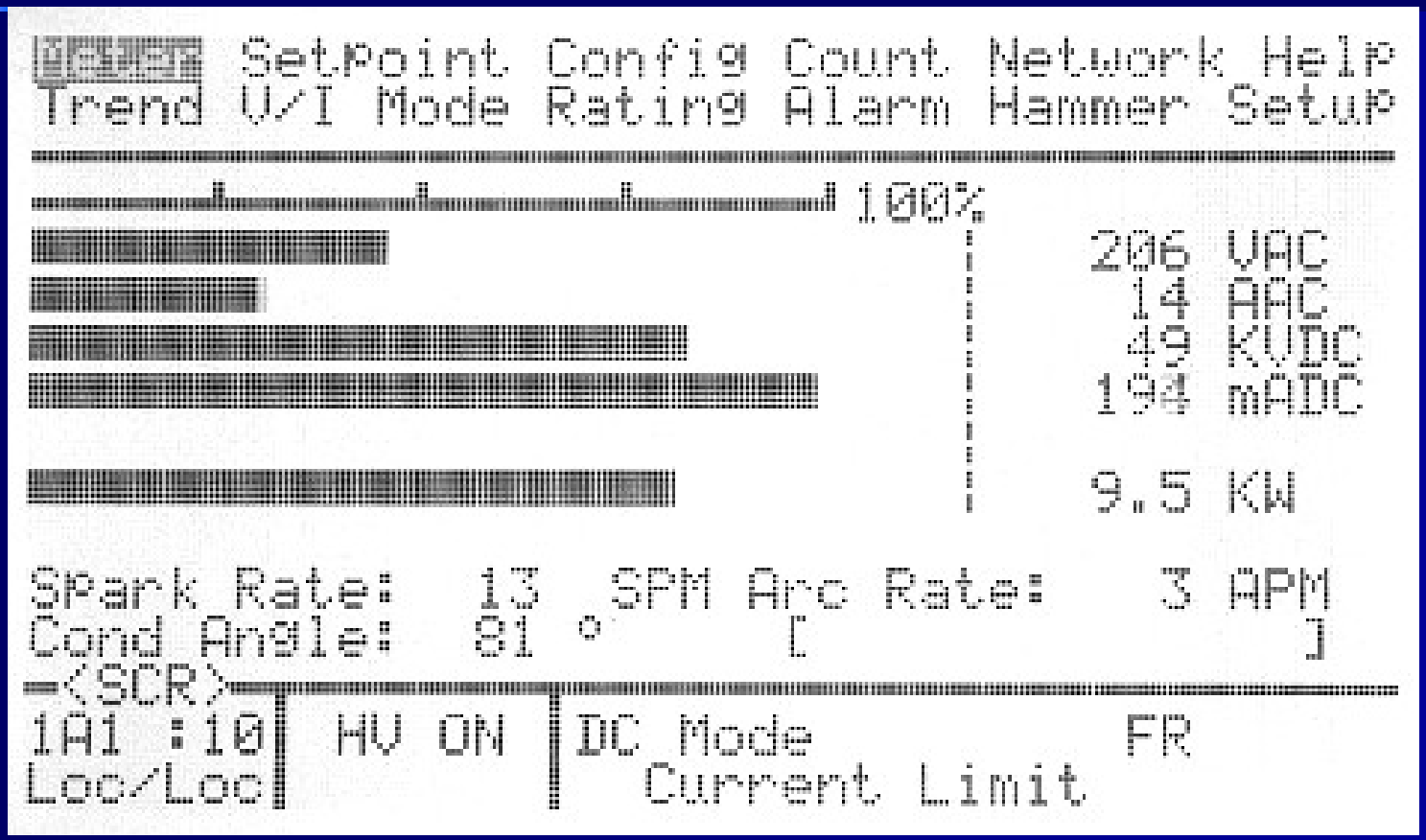
GVC Configuration & Mode Parameters

- Configuration parameters:
  - Setback Offset
  - Max. Duty Cycle
  - Max. Current Limit
  - Spark Sensitivity
  - Arc Sensitivity
- Mode Parameters:
  - Manual
  - Auto-tune
  - Set point
  - Intermittent Energization


RRY
FONRY AVC X-M

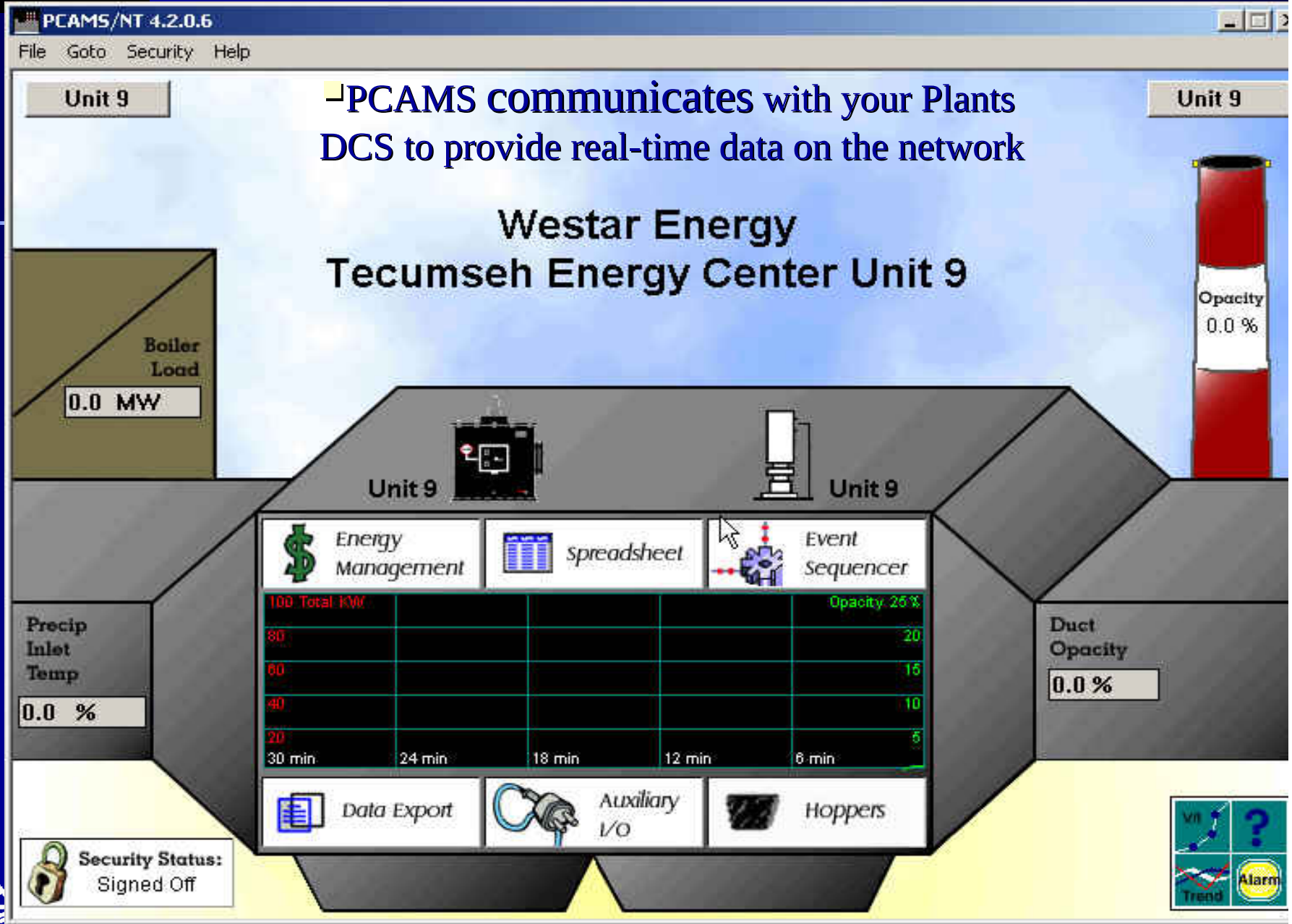

ENVIRONMENTAL
TECHNOLOGIES
45.7 KV
Spark Rate: 10 SPM
Arc Rate: 0 APM
BC
IE


Meter Trend
Mode
SignOn
Network Help
Alarm Hammer Setup
Prim.Volts: 174 VAC
Prim. Amps: 13 AAC
Cond.Angle: 74 °
Spark Rate: 10 SPM
Sec.Volts: 42 kV
Sec. Amps: 165 mA
Power: 6.9 kW
Arc Rate: 1 APM
Spark Setback: 16%
Quench: 1cyc
Sparks/min: 12SPM
Fast Ramp : 20cyc
Spark Ramp: Linear
Current Limit: 97%
Voltage Limit: 97%
U.V. Trip: 0kV
U.V. Delay: 30s
SCR Unbal. %: 50 %
<SCR>
1A1 :10
Loc/Loc
HV ON
DC Mode
FR


SetPoint Config Count Network Help
Trend V/I Mode Rating Alarm Hammer Setup
100%
206 VAC
14 AAC
49 KVDC
194 mADC
9.5 KW
Spark Rate: 13 SPM Arc Rate: 3 APM
Cond Angle: 81 °
<SCR>
1A1 :10
Loc/Loc
HV ON
DC Mode FR
Current Limit

Precipitator Management Controller System

- Option to plant DCS
  - A hardware/software package for monitoring and controlling the TR Sets and rapper controller
  - Remote access and control
  - Start and stop T/R sets and rappers remotely
  - Data Logging & trending
  - Trends historical data and generates reports


PCAMS/NT 4.2.0.6
File Goto Security Help
Unit 9
PCAMS communicates with your Plants DCS to provide real-time data on the network
Unit 9
Westar Energy
Tecumseh Energy Center Unit 9
Opacity
0.0 %
Boiler Load
0.0 MW
Unit 9
Unit 9
Energy Management
Spreadsheet
Event Sequencer
100 Total KW
Opacity 25 %
80
60
40
20
20
15
10
5
30 min
24 min
18 min
12 min
6 min
Precip Inlet Temp
0.0 %
Duct Opacity
0.0 %
Data Export
Auxiliary I/O
Hoppers
Security Status:
Signed Off
Alarm
Trend

CE & DE Rapper Controller Should Contain:

- Multiple programmable variables to maintain optimum rapping for maximum collection efficiency
  - Frequency - Repeat Time
  - Intensity
  - Anti-coincidence groups
- Separate Rapper Programs to Optimize Rapping for the Current Operating Condition
  - Normal operation
  - Heavy dust load
  - During start-up
  - Other unusual condition

Rapping Frequency

- When a collecting surface is rapped, it needs a sufficient dust layer for the dust to shear off and fall into the hoppers. If the dust layer is too thin when rapped, the dust will re-entrain. If the dust layer is too thick, there will be excessive sparking/arcing with subsequent loss of power.
- The time duration for dust to collect on collecting surfaces varies according to the electrical field location. In theory, the inlet field will collect 80-90% of the dust. The second field will collect 80-90% of what's left, and so on.
- Because the inlet field collects most of the dust, its time of optimum dust accumulation is short relative to the other fields.

Rapping Intensity

- An optimum intensity - Rapper Weight Lift Height - is also important in reducing emissions.
  - Too severe intensity can cause re-entrainment as well as CE & DE Support Structure failure.
  - Insufficient rapping intensity may not be capable of shearing the complete dust layer, causing build-up.
- Rapping Rule of Thumb for Collecting Electrodes
  - 1st Field – 5-6 ft. pounds every 1 minutes
  - 2nd Field – 5-6 ft. pounds every 2 minutes
  - 3rd Field – 5-6 ft. pounds every 4-5 minutes
  - 4th Field – 5-6 ft. pounds every 6+ minutes

Roof with Rappers and T/R Sets

Support Insulators & Purge Air System

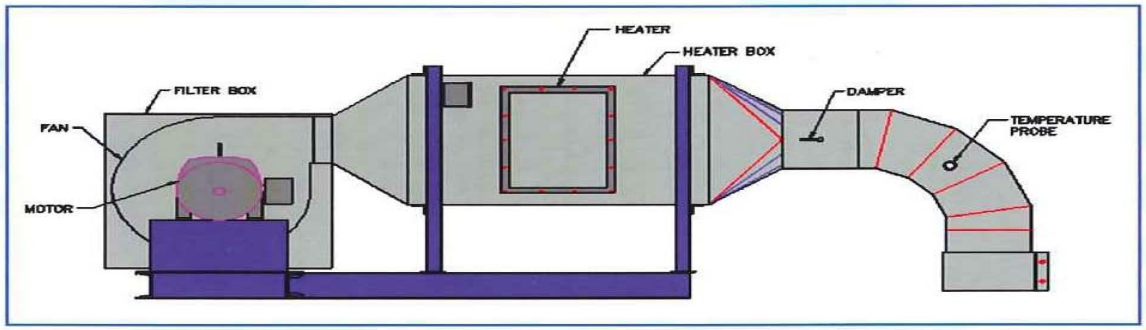
- Support Insulators
  - Provide adequate clearance between high voltage and ground potential
  - Must have strength to support DE system
  - Set on smooth surface to prevent mechanical cracking
- Purge Air System
  - To keep insulators clean and maintain electrical isolation
  - Adequate volume to maintain flow thru/across support insulators
  - Sufficient temperature to prevent acid/H2O condensation
- Always start the Purge Air System at least two hours before energizing the TR Sets
- Backup system is recommended to enhance reliability

PURGE AIR SYSTEMS

Purge Air systems protect high-voltage support insulators from moisture and dust that could accumulate on their surfaces and cause them to fail.

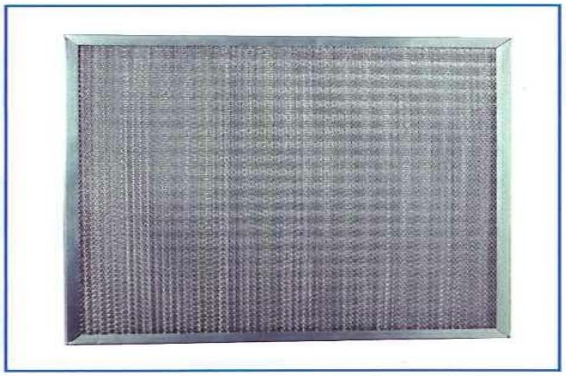
Support insulators provide many years of use when properly maintained such as preheating prior to start-up. The constant flow of dry heated air prevents condensation and prevents flue gas from entering.

Volume, temperature and pressure of the purge air are critical design parameters that vary significantly. Southern Environmental designs each purge air system to satisfy the specific requirements of each application.



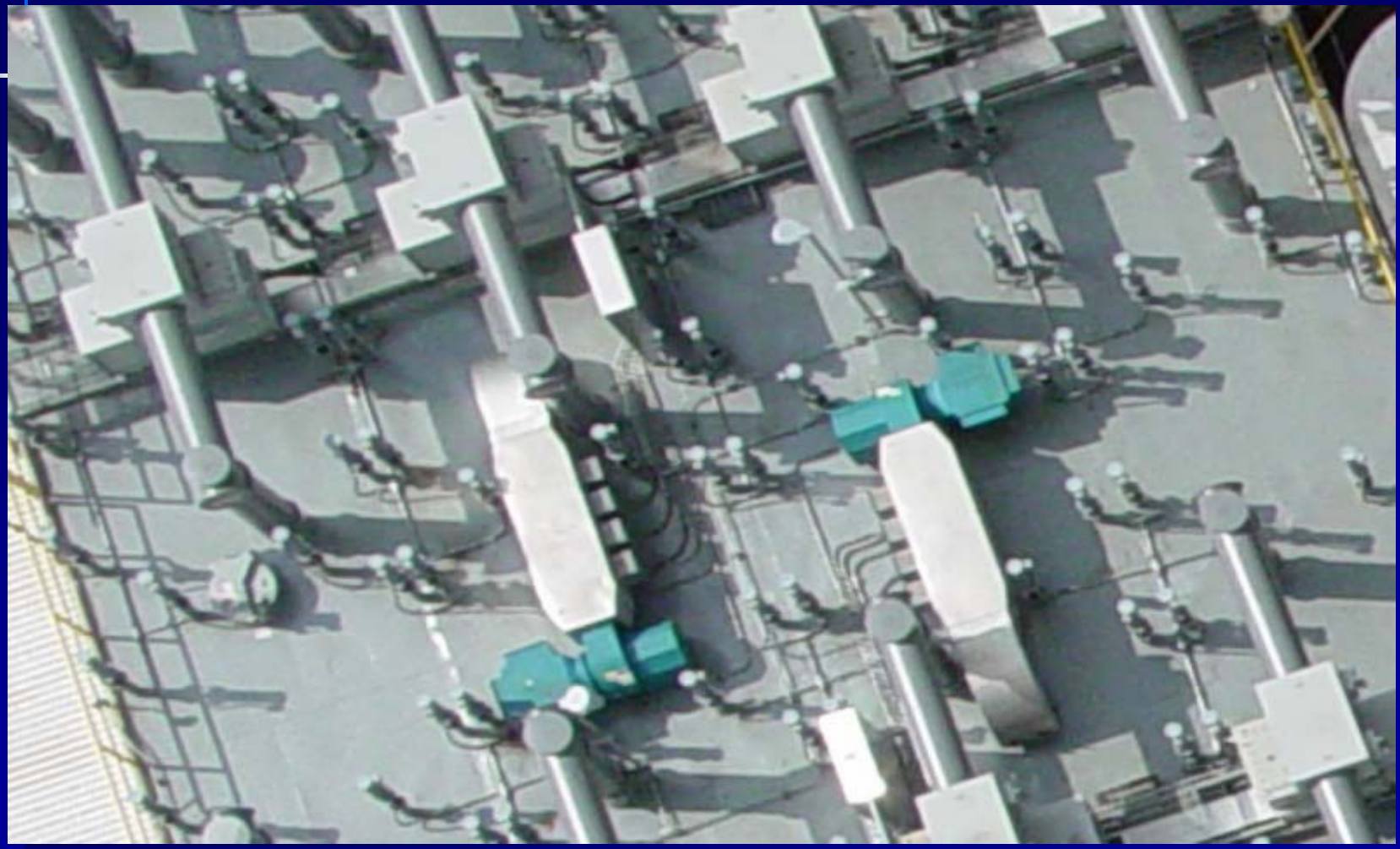
PURGE AIR SYSTEM COMPONENTS:

- Heaters
- Fans
- Box
- Filters
- Purge Air Controller
- Heater Controller



Purge Air System Installed

Two Purge Air Systems Installed



Hopper Design and Maintenance

- Ideal design is one hopper for each field – not shared between two fields
- Hopper baffles - required to prevent gas sneakage and dust reintrainment
- Design with adequate slope and no obstructions to promote smooth ash flow and prevent buildup
- Check hoppers for integrity/corrosion
  - Check all welds
  - Check for leaks
- Check door gaskets

HOPPER HEATERS

- Prevent Fly Ash from cooling down below dew point and condensing causing build up or bridging
- Hopper heaters usually applied to bottom one third of hopper surface
  - Generally 180-200 Watts/ft2
- Hopper Heaters should be turned on two hours before ESP is put on line
- Heaters turn on and off based on a thermostat setting
- Heaters should be operating any time the ESP is in service

Hopper Vibrators and Level Detectors

- Hopper Vibrators
  - Ensure that all ash is removed from the hoppers when the ash is evacuated
  - Pneumatic or electric type are available
  - Vibrators are generally controlled by the ESP PLC

- Hopper Level Detectors
  - The hoppers should be monitored to verify that there is not excessive ash build up
  - A full hopper will ground out the TR Set along with the possibility of causing major damage to the discharge electrodes and other internals

KEY INTERLOCK SYSTEM

- Purpose
  - Protect personnel
  - Avoid injury
  - Prevent damage to equipment
- Maintenance
  - The key interlock system should be keep clean and operational
  - Only lubricate with graphite
  - Never use oil or grease on locks
  - Liability (spare keys)
- Sequence of operating procedure

Avoid Liability

- Never allow Spare keys or master keys which could disable the interlock protection
- Never incorporate padlocks with a key interlock system
- Do not rely entirely on the key interlock system for protection from high voltage (USE GROUND STICKS)

Type F - Flat Mounted

Interlock Transfer Panel

HOPPER ENTRY

- Hot fly ash is fluid – flows like water
- Be careful when opening hopper doors
- Be careful when unplugging hoppers (poke tubes)

Confined Space Entry Requirements

- Always obtain proper entry permits
- Monitor for toxic gases
  - Ozone
  - Lack of O2
  - Sulfur oxides
  - Other
- Lock-out Tag-out Plan
- Always have hole watch

Spare Parts - Keep Recommended quantity on hand or order quickly on-line

Mechanical Spare Parts
Boot Seals with Clamps
Ground Straps
Rapper Donuts
Electromagnetic Rappers
Anti-Sways

Controls
Insulated Shafts
Support Insulators
Insulator Gaskets

Controls

Purge Air System
Purge Air Filter
Purge Air Heater

T/R Sets
T Paks
FDBK Boards
Surge Arrestors

Voltage

Power Cube

Rapper

Display Head
DC S-Rap Cards
Smart CPU

Parts On-Line Over the Internet

- Either Keep Sufficient Parts in Inventory or:
- Order over the Internet

Ordering Parts on Line

SOUTHERN environmental INC.
Our product is ESP's, but our strength is our people.

- ESP Units
  - ESP Unit Summary
  - Place Parts Order
  - Order Status
- User
  - Login Credentials
  - Contact Info
  - Payment Methods
- Company
  - Shipping Addresses
  - Shipping Methods
- Other Info
  - Main Menu
  - Contact Us
  - Log Out

Welcome Back Roland Koomen!
Thanks for using Southern Environmental's Parts On Line

Company ESP Unit Summary For Southern Environmental Parts On Line

Your current ESP Units are shown below.

Southern Environmental
6690 W Nine Mile Road
Pensacola, FL 32526

ESP Unit	Job Number	Date Installed	Parts	Action
		Unit 1 6690 W Nine Mile Road Pensacola, FL 32526		
	4321	5/14/09	Hide	New Order
Rapper Assembly Parts				
Boot Seal		Part No: 1100		
Cover		Part No: 12152		
Rapper Rod		Part No: 1337		
Guide		Part No: 1437		
Rapper Shaft		Part No: 21492		
Shafts				
FRP Insulator Shaft		Part No: 21956		
Steel Shaft		Part No: 2603-200		

ESP NORMAL OPERATING AND MONITORING

- Transformer Rectifier Sets
- Rapper Controller
- Purge Air System
- Hopper Level
- VI Curves
- Startup and Shutdown procedure

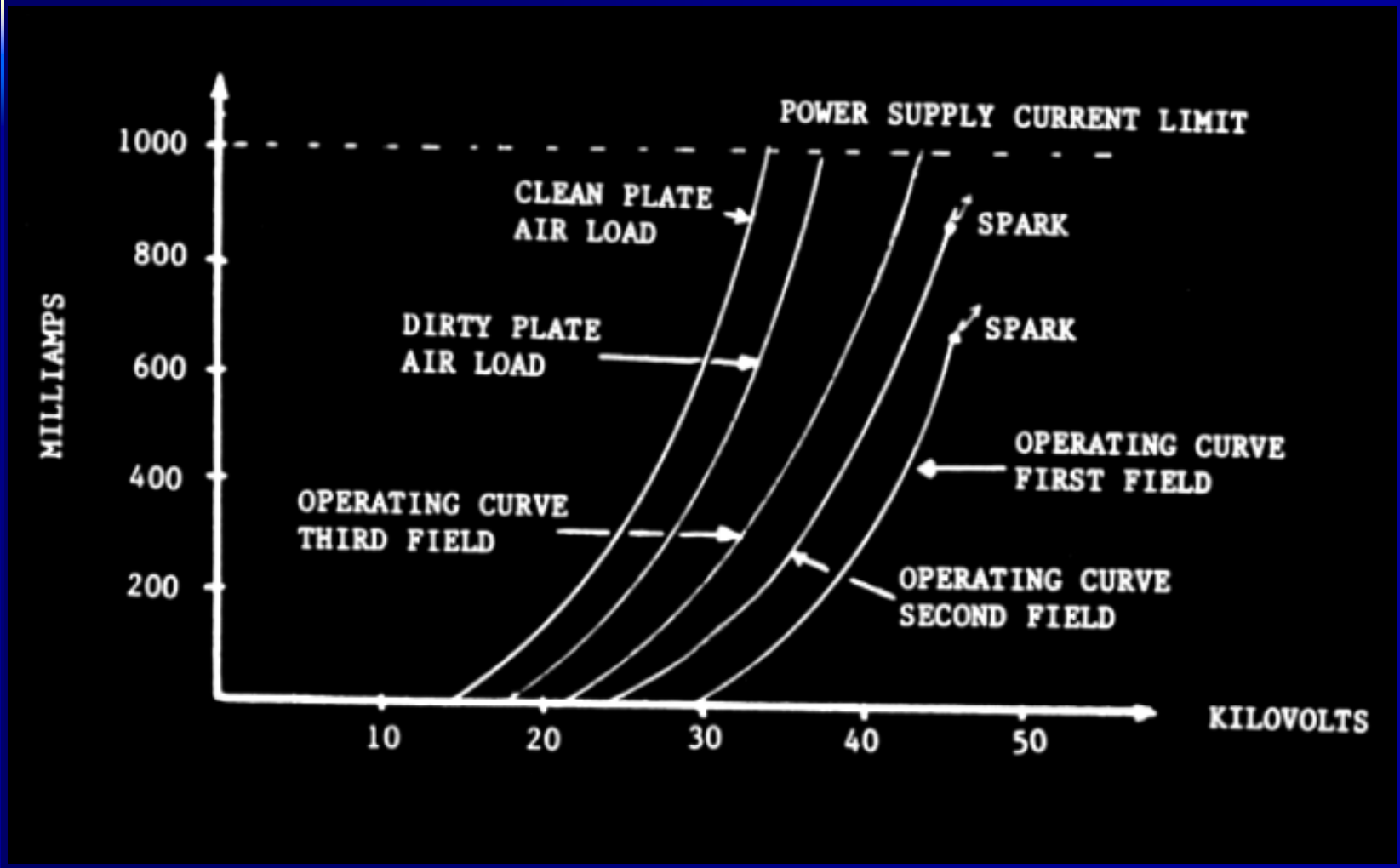
System Checkout and Startup

- System check out and startup process:
  - The Megger Test - With ground switch in the HV position, place the megger between the HV bushing and tank ground. The megger should read infinity.
  - Switch Continuity Test
  - Control System Setup
  - Start Up T/R Set
- Routine Maintenance
  - Clean High Voltage Bushing
  - Check Dielectric Fluid

VI CURVES

- Voltage to Current curves are a good way of monitoring the performance of a TR Set
- At Startup a set of VI curves will be generated for all TR Sets indicating the TR Set performance with a new/clean ESP
- By comparing new VI curves with the initial set of VI curves the deterioration of a TR Set performance can be verified

Typical Precipitator Voltage/Current Curves



Placing the Precipitator In Operation

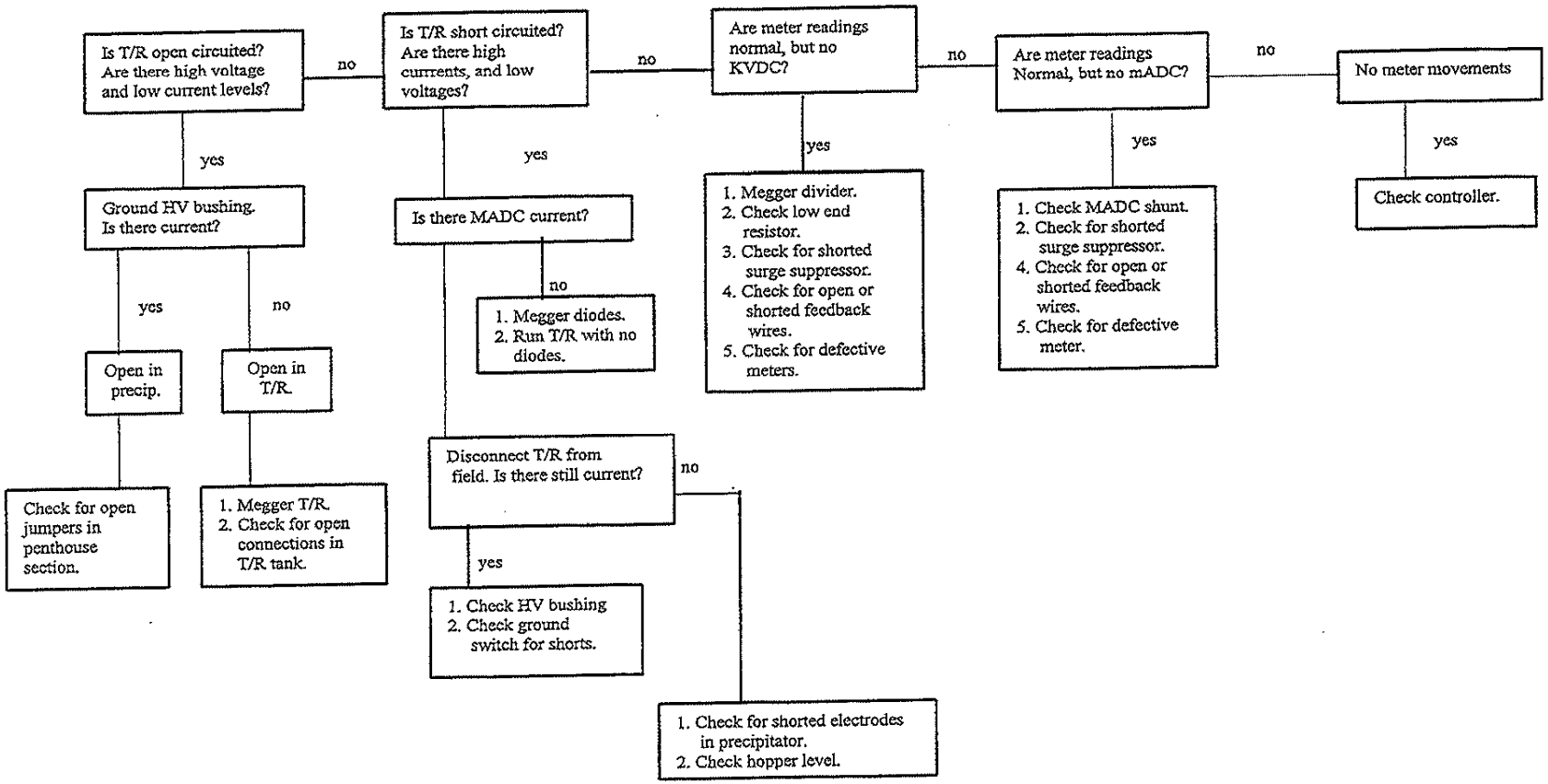
- Physically inspect the internals and the penthouse to assure that all grounds have been removed and that no materials or tools were left behind by workman
- Close and lock all access openings and complete the Key Interlock sequence per the Key Interlock drawing
- Energize the Purge Air System and verify proper operation at least 2 hours before energizing the TR Sets
- Verify that the Ash Removal System is in operation

Placing the Precipitator In Operation CONT.

- Energize the Rapper Controller and verify proper operation
- Admit Gas to the unit and allow it to flow through until the ESP is well above dew point (generally 1 hour)
- Verify that the breakers are closed in the TR Sets
- Turn on the HV at the PCAMS or by using the HHP at each TR set
- If the TR Set controllers have previously been adjusted for automatic operation and the Plant is operating at rated capacity, no further adjustments are necessary

Troubleshooting

Section 9- Troubleshooting Decision Tree
Transformer/Rectifier Sets



Shutting Down the Precipitator

- After flue gas has stop flowing though the ESP, the TR Sets and rappers can be turned off at the PCAMS
- If the shutdown is going to be for a prolonged amount of time, all auxiliary equipment may be turned off (Purge Air System, Ash Handling System, Hopper Heaters, Hopper Vibrators, etc.

Shutting Down the Precipitator CONT.

- Ensure that all Fly Ash is removed from the hoppers before shutting down the Ash Handling System
- If the shutdown is only going to be for a short time the auxiliary equipment may be left on
- If personnel are going to be entering the ESP be sure to ground all high voltage and follow all safety procedures

PERFORMANCE ISSUES AND TROUBLESHOTING

- Performance evaluations
- Record keeping practices
- Problem solutions

INSPECTIONS AND PREVENTIVE MAINTENANCE

- Transformer Rectifier Sets
- Rappers
- Purge Air System
- External Inspection
- Internal Inspection
- Hoppers

Checking T/R Sets

- Check tank for oil leaks
- Clean HV bushing
- Clean feed-thru bushing
- Take oil sample and have it analyzed

RAPPERS

- Check all rappers plumb and tightness
- Check all ground straps
- Test fire all rappers and check for proper lift height
- Verify proper operation of rapper program

Maintenance and Service

- Electrical Equipment
  - General Cleaning of the Electrical Equipment
  - Care of Transformer-Rectifier Unit
    - Automatic Voltage Control
    - Rappers and Control
      - Rapper
      - Rapper Control
- Precipitator
- Annual Maintenance

EXTERNAL INSPECTION

- Check for casing leaks
- Check for leaks around openings
- Check door gaskets
- Check welds
- Check lagging

INTERNAL INSPECTION

- Check entire ESP for corrosion
- Check all welds
- Check Alignment of internals
- Check/clean all insulators (H.V. bushing, feed-thru, support, anti-sway)
- Check for loose bolts
- Check gas distribution devices
- Check for signs of poor gas distribution
- Check for excessive build-up

Access to Capable Companies for the following Services

- Replacement Parts
- Inspections
- Troubleshooting
- Operator Training
- Annual Maintenance
- Determining the right time for a rebuild

Questions??