ESP Hot TOPICS

By

Tom Lugar

BUELL DIVISION OF FISHER-KLOSTERMAN, INC.

TOPICS:

Present ESP Performance Issues

Future Considerations

Present ESP Performance Issues:

- **Cycling Operation**
- **Hot-Side Operation**
- **Opacity Spikes**
- **Excessive Wire Breakage**
- **Unacceptable Carryover of Ash to a Scrubber**

Future Considerations:

- **Adding a Scrubber Downstream**
- **Control Of Mercury Emissions**
- **Fuel Switching**
- **Control of PM2.5**

Performance Issues

Precipitator performance is dependent on the following parameters:

Ash Particle Size
Ash Loading
Ash Resistivity

These parameters vary depending on the type of boiler, fuel, flue gas temperature and constituents.

Particle Size Considerations

Fine particles, especially those less than 1 micron in diameter, require more treatment time for charging and collection.

The particulate removal efficiency of the outlet electrical fields of an ESP will be less than that of the inlet fields.

Ash Loading Considerations

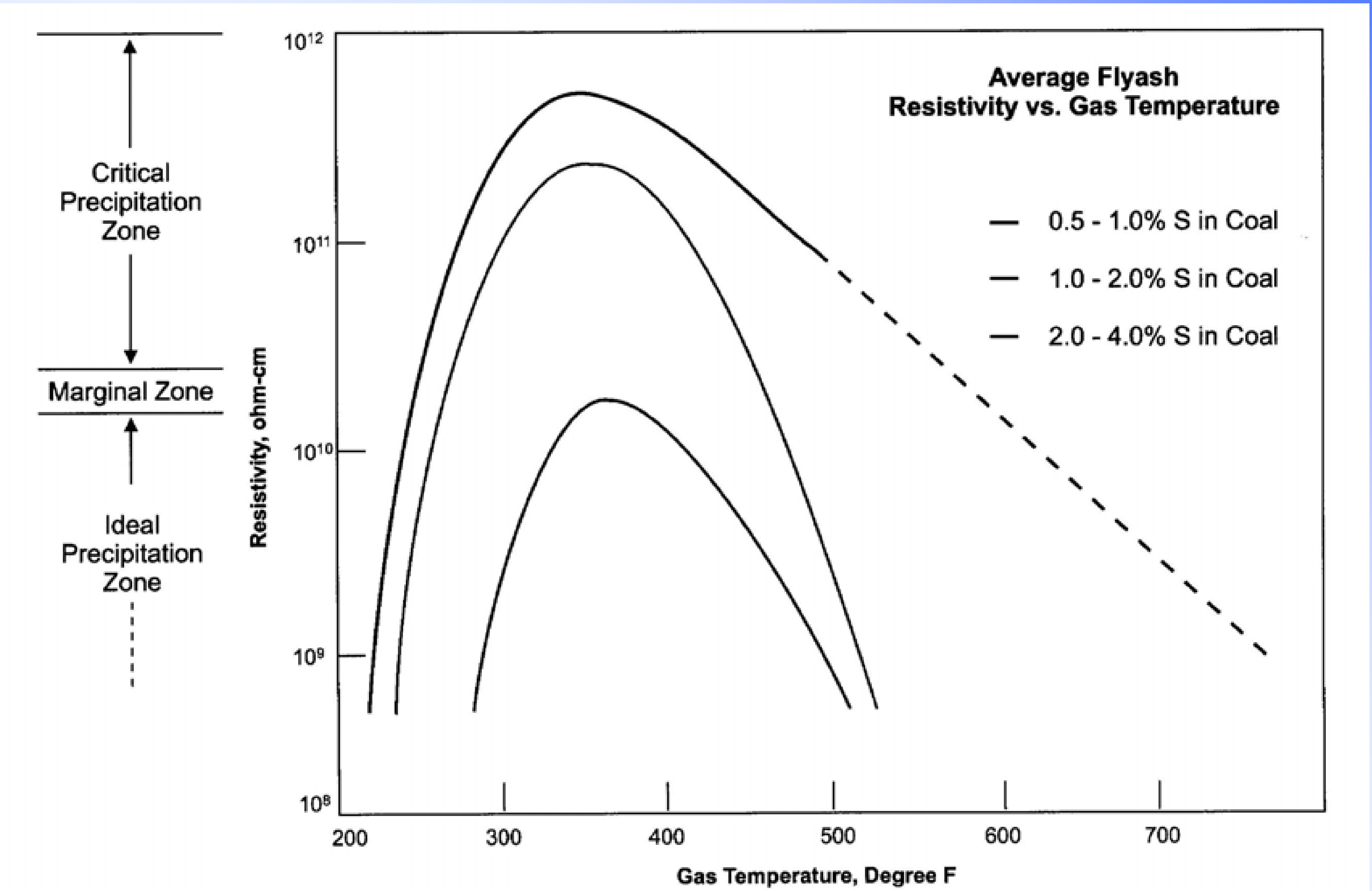
High ash loadings interfere with particle charging by suppressing the corona from the emitters and thus the negative ions generated for charging.

The effect of suppression becomes significant if the higher ash loading has a large population of fines.

Ash Resistivity

The degree of electrical conductivity of the ash expressed in ohms-cm.

The value of resistivity depends on the flue gas temperature, gas constituents, and chemical composition of the ash.

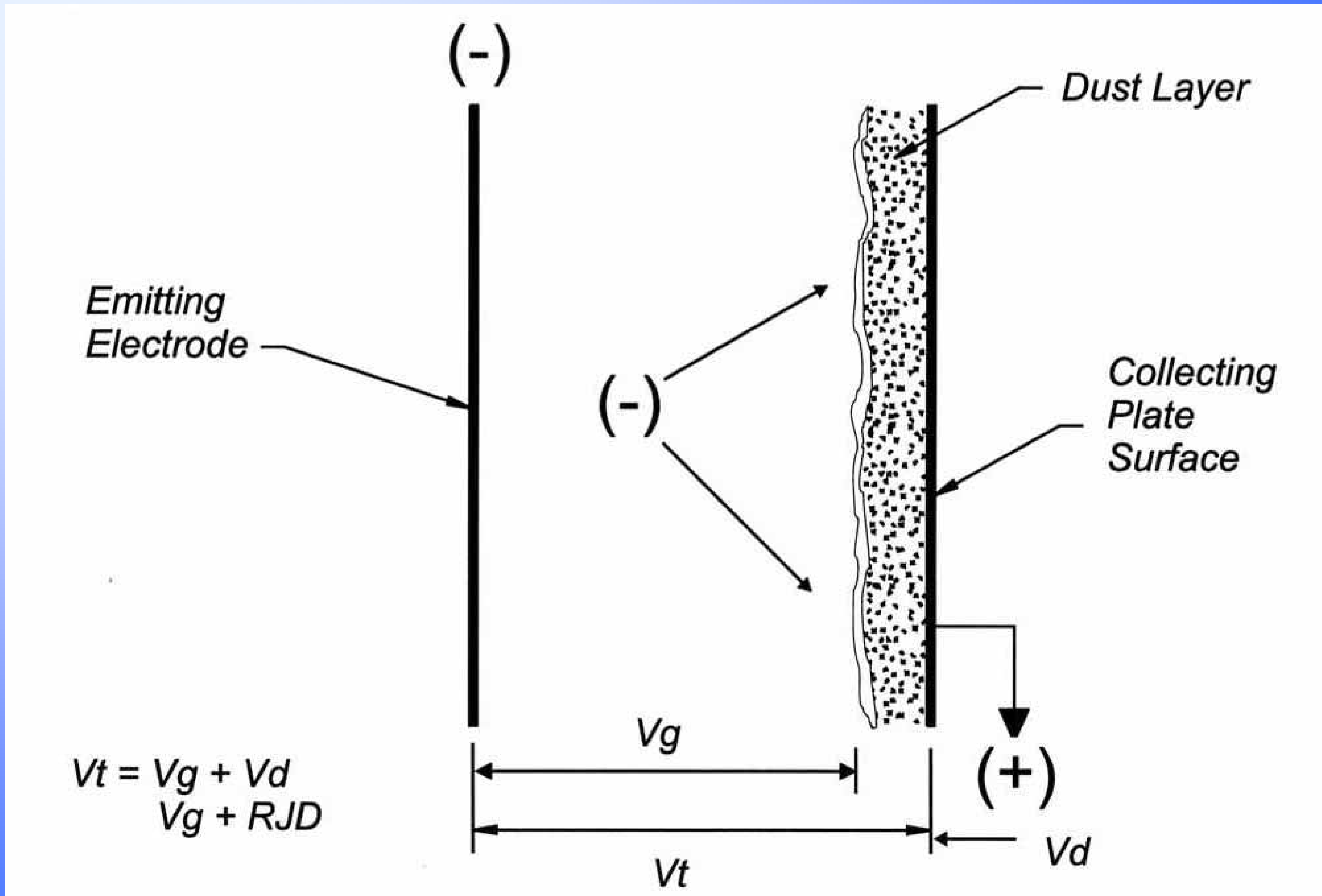

Critical Precipitation Zone
Marginal Zone
Ideal Precipitation Zone
Average Flyash
Resistivity vs. Gas Temperature
0.5 - 1.0% S in Coal
1.0 - 2.0% S in Coal
2.0 - 4.0% S in Coal
Resistivity, ohm-cm
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
200
300
400
500
600
700
Gas Temperature, Degree F

Low Resistivity Effect

- Collected ash particles lose their charge quickly and become reentrained into the gas stream

High Resisivity Effect

- Ionic charge is stored on the dust layer surface and relatively small current flows through the layer to the plate
- Low power levels, low voltage level sparking, back corona formation


(-)
Dust Layer
Emitting
Electrode
(-)
Collecting
Plate
Surface
Vg
(+)
Vt
Vd
Vt = Vg + Vd
Vg + RJD

Present ESP Performance Issues

Cycling Operation

- With Cycling operation, changing inlet conditions can cause performance problems and adversely affect long term reliability.

- Operating below the acid dewpoint during Cold Start may cause damp deposits on the ESP electrodes and hopper walls forming hard, crusty deposits on the collecting plates and emitting electrodes

Cycling Operation

Recommended Cold Start Procedure

- Energize insulator and hopper heaters at least 6 hours before startup or leave energized if cycling on a daily basis
- Energize rappers and ash evacuation systems 2 hours before startup
- Increase rapper force and frequency until normal operating temperature is reached to limit adhesion of damp ash on electrodes
- Energize TRs one at a time as needed to maintain opacity limit and maintain power levels below maximum to minimize sparking
- At normal operating temperature, switch TR controllers to automatic and rapper settings to standard settings

Cycling Operation

Point of Contention: Should the inlet or outlet electrical fields be energized first?

- Energize TRs Inlet to Outlet

  Minimizes Power Consumption

  Limits Damp Ash Collection to Inlet Fields

- Energize TRs Outlet to Inlet

  Limits Collection of Damp Ash on Electrodes by Allowing Dropout in Non-Energized Front Electrical Fields

Shutdown Procedure

The ESP Shutdown Procedure is just as important as the Startup Procedure to the operating integrity of the ESP

- De-energize the electrical fields one at a time as required to maintain opacity limit.

Again, **Two Approaches**:

- De-energize outlet TRs first, outlet to inlet: Power savings since outlet fields tend to operate near rated power levels

- De-energize Inlet TRs first, inlet to outlet: Avoids opacity spikes due to rapper reentrainment since downstream fields are energized to recharge and recollect reentrained ash.

Shutdown Procedure (cont.)

- After ESP Shutdown, maintain operation of rappers, hopper evacuation system, and hopper heaters for at least 2 hours following purge procedure.

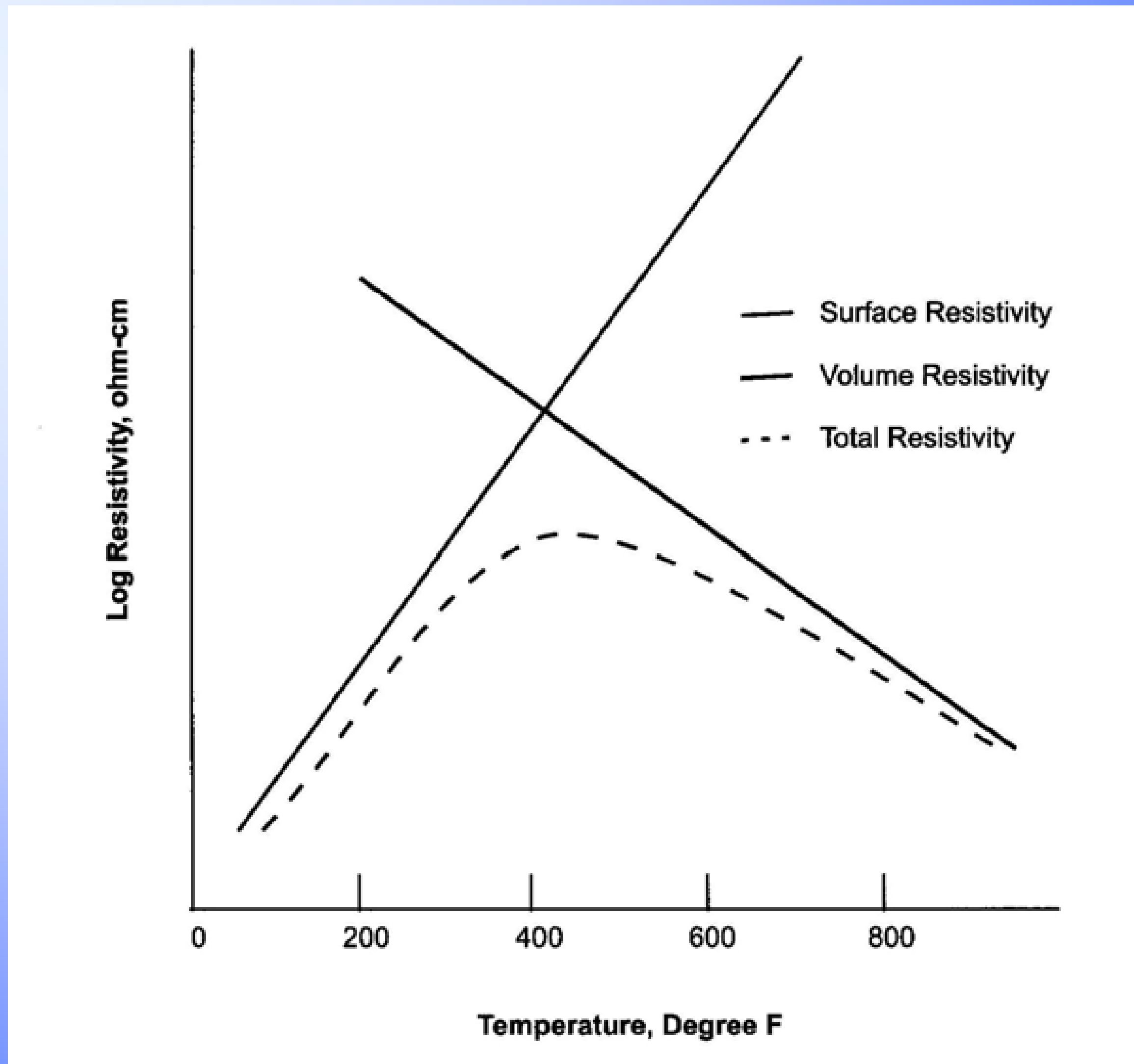
  This will ensure the ESP remains in an operational ‘clean state’ to the best extent possible for subsequent startup.

Present ESP Performance Issues

Hot-Side Operation

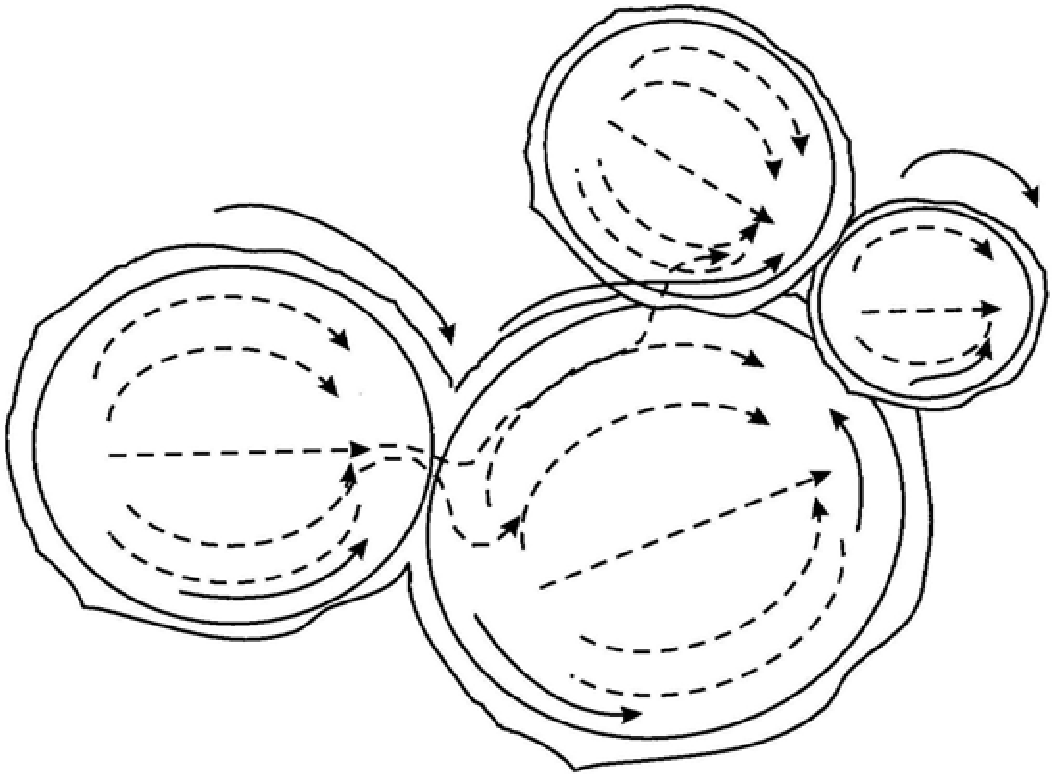
In the late 60's it became apparent that cold-side ESPs were not performing well when fuel switching to western low sulfur coals due to resultant high ash resistivity.

Ash resistivity is temperature dependent.



Log Resistivity, ohm-cm
Surface Resistivity
Volume Resistivity
Total Resistivity
0
200
400
600
800
Temperature, Degree F

Surface and Volume Conduction

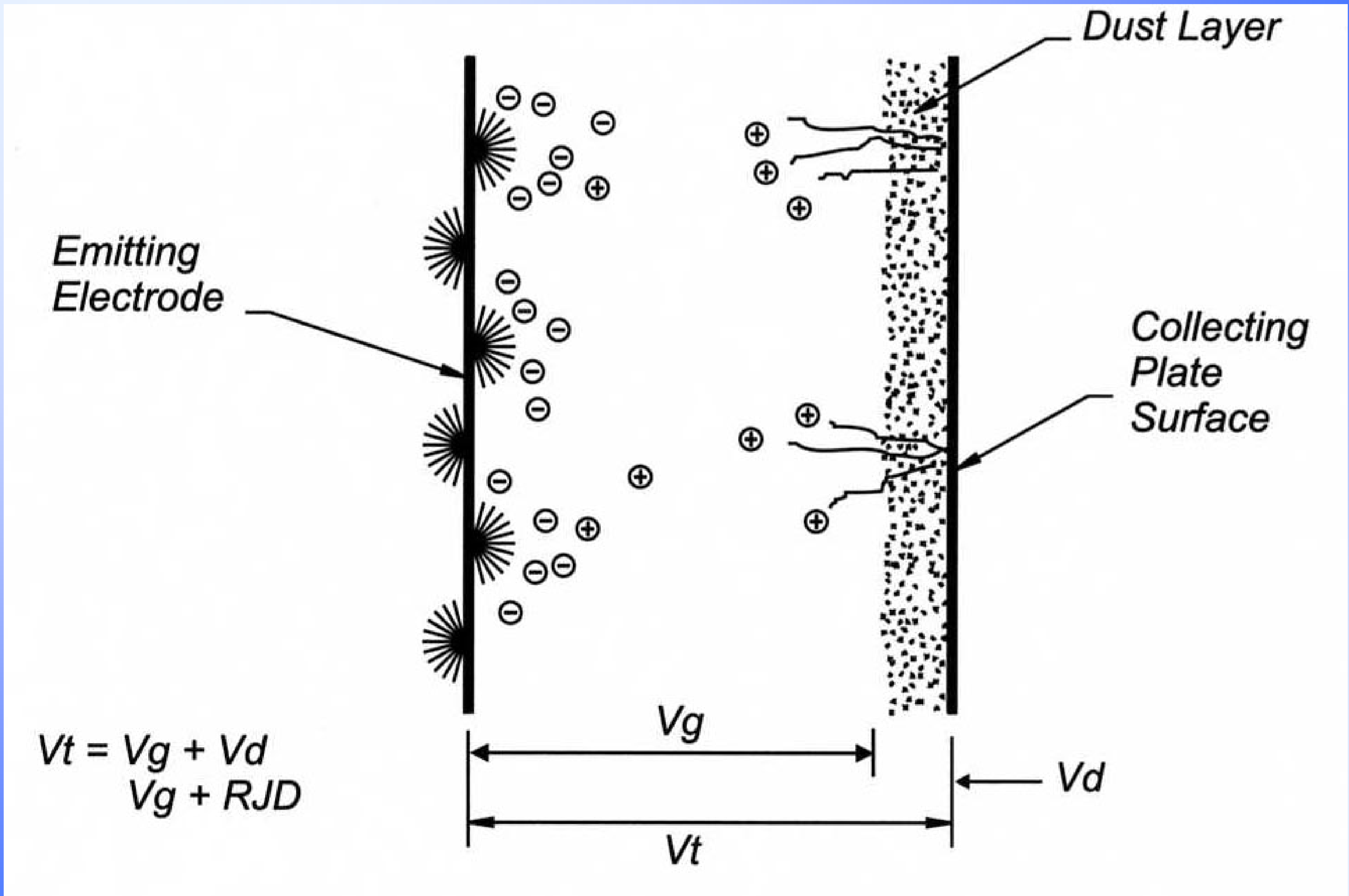


Surface Conduction ⟶ *Volume Conduction* - - - - - - - - →

Surface Conduction Charge Carriers: H^+, OH^-, Na^+, K^+, *Li.,* HSO^-_4, SO^-_4 *Ions*
Volume Conduction Charge Carriers: Na^+, K^+, Li^+ *Ions*

Hot-Side Operation

- With a significant decrease in ash resistivity above 600 ºF, the concept of the Hot-Side ESP was born.
- Along with structural problems, hot-sides experienced time dependent performance deterioration with certain low sodium content western and eastern flyashes.
- The time dependent performance deterioration was determined to be depletion of charge carrying sodium ions in the ash layer resulting in a thin, high resistivity ash layer on the plates.
- Sodium depletion begins 3-4 weeks after startup with clean collecting plates and resistivity reaches a maximum within 2 months typically.



Dust Layer
Emitting Electrode
Collecting Plate Surface
Vt = Vg + Vd
Vg + RJD
Vg
Vd
Vt

Hot-Side Operation

Over the past 20-30 years most structural problems are under control and remedies have been supplied successfully to the sodium depletion problem. So why discuss the hot-side problem now?

- Some hot-sides have not experienced performance degradation in the past while burning high sodium content coals or problems have not been that severe.
- Performance problems can arise with recent fuel switching to lower sodium content coals.

Hot-Side Operation

Potential Solutions for a Sodium Depletion Problem:

- Water washing of the collecting plates every 3 months to remove the thin residual sodium depleted ash layer.
- Sodium conditioning of the coal as it is transported to the bunkers with sodium sulfate or carbonate, 3-5 lb/ton coal
- Injection of proprietary additives upstream of the ESP
- Cold-side conversion of the ESP with the probable addition of SO_3 flue gas conditioning – always an option but more so when switching to PRB coals

Present ESP Performance Issues

Opacity Spikes

Main cause is ash reentrainment that has become a problem with fuel switching or has been a long term problem

Opacity Spikes

Some Possible Causes:

- Rapper timing and force not optimized to limit reentrainment
- Large number of collecting plates for each rapper may require excessive rapping force to clean outlying plates – Install additional rappers in each section.
- Excessive sparking with short duration power reduction in some electrical fields – slack wires whipping, swinging alignment grids, insulator tracking, loss of spark control with some voltage controllers. Effect more severe for outlet fields

Present ESP Performance Issues

Excessive Emitting Wire Breakage

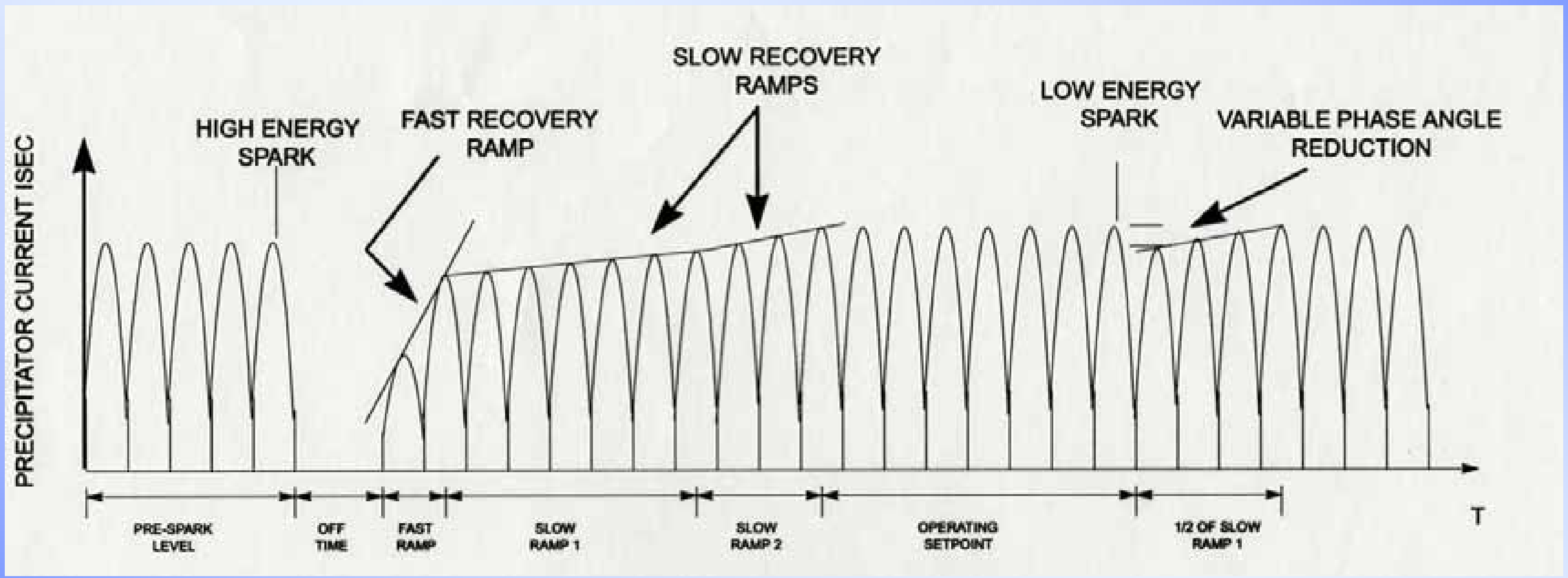
For wire-weight ESP designs, wires can last 15-20 years typically

If wire breakage is now starting to occur with increasing frequency after many years of problem-free operation then it is time to re-wire the ESP.

Excessive Emitting Wire Breakage

Premature Wire Failure Causes:

- Corrosion
- Spark Erosion: Excessive multiple sparking due to close electrical clearances, swinging alignment grids, improper spark response from voltage controllers


PRECIPITATOR CURRENT ISEC
HIGH ENERGY SPARK
FAST RECOVERY RAMP
SLOW RECOVERY RAMPS
LOW ENERGY SPARK
VARIABLE PHASE ANGLE REDUCTION
PRE-SPARK LEVEL
OFF TIME
FAST RAMP
SLOW RAMP 1
SLOW RAMP 2
OPERATING SETPOINT
1/2 OF SLOW RAMP 1
T

Excessive Emitting Wire Breakage

If wire replacements have been frequent and if collecting plates need to be replaced, then it may be time to consider installing rigid discharge electrodes

- A Rigid Discharge Electrode System requires increased plate-to-plate spacing and may require replacement of the high voltage TRs depending on the spacing dimension used.

Present ESP Performance Issues

Unacceptable Carryover of Ash to a Scrubber

Two Scenarios:

- Gradual Performance Deterioration Over Time, ESP Worked Well After Scrubber Installed
- Abrupt Performance Deterioration After Fuel Switch

Unacceptable Carryover of Ash to a Scrubber

- A gradual increase in ash to the scrubber and no change in fuel or process conditions may mean a maintenance overhaul of the ESP may be required.

- A thorough, comprehensive ESP inspection needs to be conducted to identify deficiencies for corrective action. The inspection should also include a pre-outage evaluation of the ESPs electrical parameters and control's spark response as well as an air-load energization to identify close clearances

Unacceptable Carryover of ash to a Scrubber

- If performance has degraded with fuel switching, then the design parameters of the ESP may not be adequate to maintain design removal efficiency in response to new process conditions and ash characteristics.
- A performance evaluation needs to be conducted to determine what upgrades to the ESP are required to restore acceptable performance with the new fuel(s).
- Depending on the severity of the performance deterioration, upgrade requirements may include the addition of sections to the ESP, gas conditioning, or replacement with a new ESP or fabric filter.

Future Considerations

Adding a Scrubber

- It is expected that most FGD retrofits will be wet limestone forced oxidation systems producing commercial grade gypsum

- Depending on the amount of ash from the existing ESP and its chemical composition, potential problems could occur with the gypsum quality byproduct and the chemistry of limestone dissolution and SO_2 removal.

- The role of the existing ESP, when adding an WFGD system, thus extends beyond achieving the traditional 20% opacity.

Adding a Scrubber

Questions to be Answered:

- Can the ESP meet the required flyash loading limitations to the scrubber?
- Can the ESP meet the emissions requirement consistently with enough margin in performance to handle upset conditions in ESP operation such as loss of an electrical field?
- Is the mechanical condition of the ESP and the condition of its auxiliary systems such that an additional operating life of 15-20 years can be expected?

Adding a Scrubber

In Order to Answer These Questions:

- Conduct a thorough inspection of the ESP and evaluate its control system to identify deficiencies for corrective action.
- Conduct performance testing to determine the removal efficiency of the ESP.
- If fuel will be switched for scrubber operation, performance testing should be conducted while conducted a test burn with the future fuel(s).
- Depending on the performance test results, correcting identified deficiencies may be all that is required to restore performance to the required level.

Future Considerations

Mercury Control

EPA’s Clean Air Mercury Rule (CAMR) Limits Mercury Emissions From Coal-Fired Electric Generating Units Nationwide.

Phase I by 2010

Phase II by 2018

Mercury Control

Three Forms of Mercury

Elemental **Hg^o** - Insoluble in Water

Oxidized Form **Hg^{++}** - Solid Form, Water Soluble

Particulate Bound **Hgp** - Elemental or Oxidized Form Adsorbed by Carbon in Ash

Mercury Control

Present Major Mercury Control Option

Adsorption of elemental and oxidized forms on injected sorbents such as powdered activated charcoal and collection downstream along with particulate bound mercury in an ESP or FF.

Mercury Control

ESP Performance

- A number of test programs with injection of various sorbents and enhanced sorbents, injected upstream of an ESP, conducted by various sorbent suppliers and organizations, show mercury removal rates of 30-90% in the ESP.

- Mercury removal efficiency of the ESP was highly dependent on coal type, LOI, flue gas temperature, chlorine in the coal, and SO_3 content in the flue gas.

Mercury Control

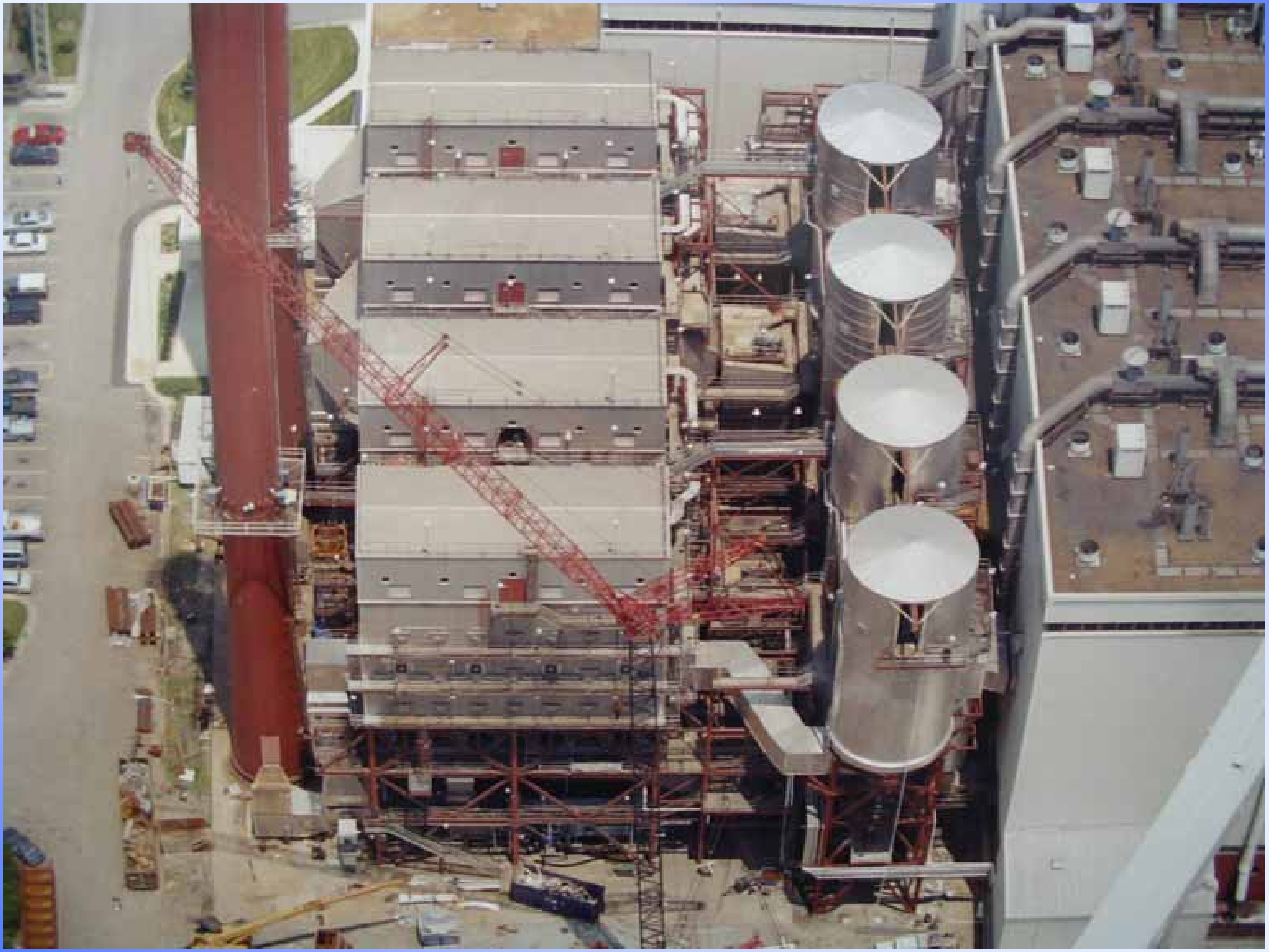
The best option presently for consistent, high mercury removal efficiency ($\geq$ 90%) is sorbent injection followed by a fabric filter

If high mercury removal is required, options are:

- Convert ESP casing to PJFF; if ESP not large enough, replace with a PJFF
- Add PJFF downstream of the ESP: standard A/C ratio or high ratio (EPRI COHPAC)

A fabric filter downstream of the ESP with sorbent injection between the ESP and FF allows ESP collected ash to remain suitable for sale.

Conversion of ESP Casings to PJFF



Mercury Control

Recommendation if Considering Sorbent Injection:

- Many variables affect the performance of sorbents in adsorbing mercury and there are many types of sorbents and enhanced sorbents available.
- Site specific pilot testing is a wise course of action

Future Considerations

Fuel Switching

- Conduct performance testing of the ESP during test burn of the new coal(s)
- If performance degrades, options are as listed previously for fuel switching with addition of a scrubber

Future Considerations

Control of Fine Particulate Emissions PM2.5

Airborne particulate matter 2.5 micron and less in diameter downstream of a stationary source can be in two forms:

- **Solid Particulate**
- **Condensed Gaseous Emissions**

Control of fine particulate would also control many heavy trace metals such as As,Cd,Ni,Se, etc., that nucleate as submicron particulate or condense on the fine fraction of flyash

Control of PM2.5

If standards are enacted for PM2.5 from stationary sources, solid particulate as PM2.5 would likely be limited to 0.01 or 0.015 lb/MMBTU.

For an ESP:

PM2.5	Overall Limit	ESP Removal %
0.015 lb/MMBTU	**0.03 lb/MMBTU**	**99.6%**
0.01 lb/MMBTU	**0.015 lb/MMBTU**	**99.8%**

Control of PM2.5

Most of the newer ESPs installed on utility boilers are achieving >99.5% removal efficiencies.

Options for Newer ESPs:

Reentrainment, mostly due to rapping, is the largest single problem confronting high efficiency ESPs with as much as 80% of emissions attributed to it.

- To limit reentrainment, rapper force and timing must be optimized
- Correct any mechanical, electrical, and control system deficiences

Control of PM2.5

For many older, low SCA (plate area/1000 ACFM) ESPs, performance upgrades required to achieve PM2.5 emission limits could be extensive.

Fine particulate require more treatment time for charging and collection. ESP outlet fields have lower fractional removal efficiencies than the inlet fields.

Control of PM2.5

Options for older ESPs:

ESPs with SCA of <250

- Convert casing to or replace with PJFF
- Add a PJFF downstream
- Addition of wet ESP sections to the ESP

Control of PM2.5

Options for Older ESPs:

ESPs with SCA >250

- Add sections to the ESP to increase SCA and treatment time
- For high resistivity ash, add gas conditioning along with additional sections to the ESP
- Add wet ESP sections to the ESP
- Covert the casing to PJFF
- Add PJFF downstream