

# **REINHOLD ENVIRONMENTAL Ltd.**



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# **Dry ESP Performance and Operating Issues Related to Switching to High Sulfur Coals**

2010 APC/PCUG Conference

By

Ron Triscori

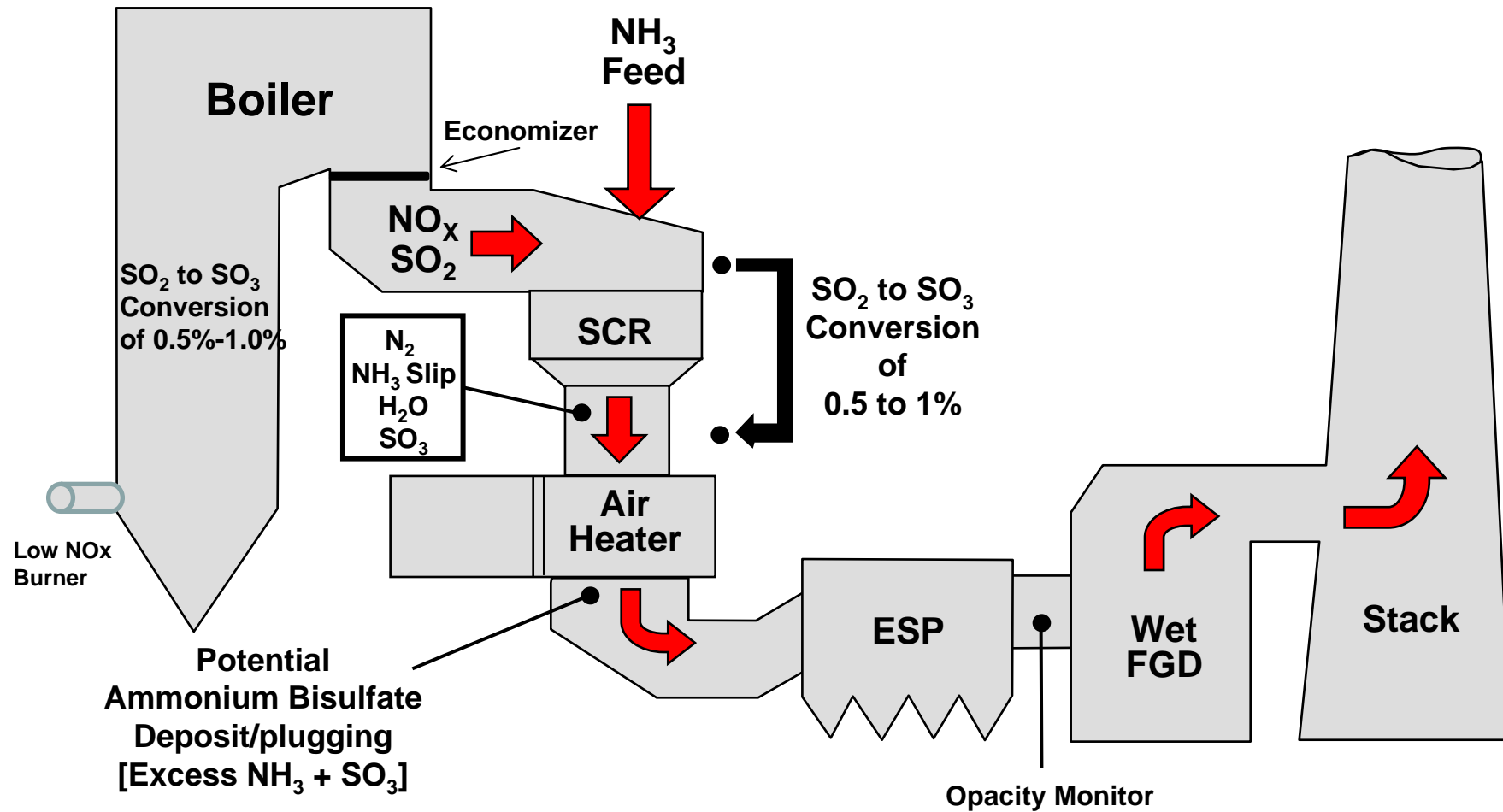


# Presentation Agenda

- Potential changes to Air Quality Control Systems that can impact ESP performance when switching fuels
- Discussion of changes to Fly Ash Resistivity due to fuel switching
- Operational issues related to fuel switching
- Mitigation technology overview



# Back to the 1970's - Only Worse!!





# Coal Combustion Chemistry

## Fuel Constituent

Carbon

Hydrogen

Sulfur

Nitrogen

## Major ash components

Iron

Silicon

Aluminum

## Others:

Sodium

Chlorine

## Trace metals

Mercury

Arsenic, lead, etc.

## Combustion (Oxidation) Product

Carbon dioxide,  $\text{CO}_2$

Water,  $\text{H}_2\text{O}$

Sulfur dioxide,  $\text{SO}_2$

Sulfur trioxide,  $\text{SO}_3$

Nitric oxide,  $\text{NO}$

Nitrogen dioxide,  $\text{NO}_2$

## Bottom ash and fly ash

Iron oxides,  $\text{Fe}_2\text{O}_3$ ,  $\text{Fe}_3\text{O}_4$

Silica,  $\text{SiO}_2$

Aluminum oxides,  $\text{Al}_2\text{O}_3$

## Various salts

Sodium chloride,  $\text{NaCl}$

Various oxides

## Trace elements and compounds

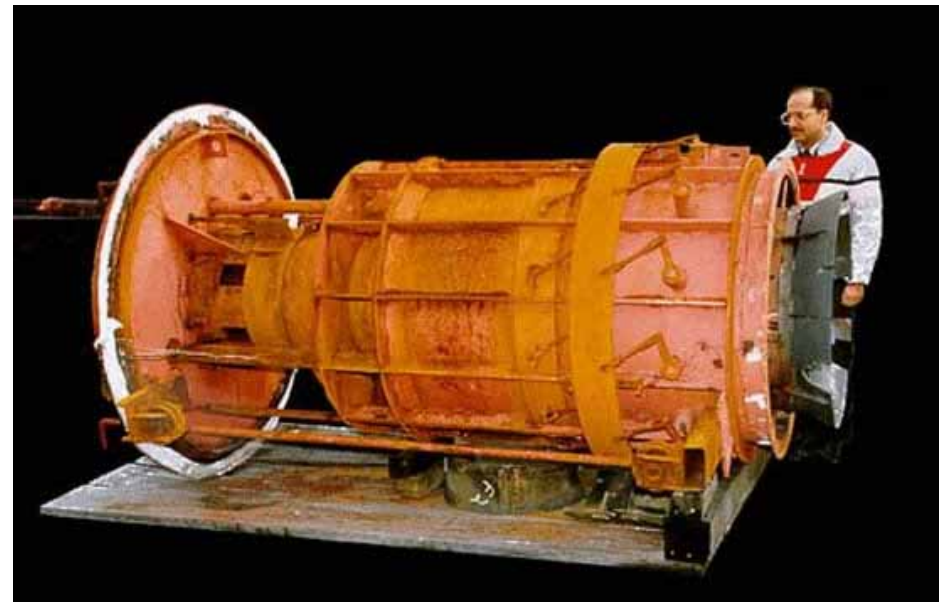
Elemental mercury,  $\text{Hg}$

Mercuric oxides and chlorides

Various chemical salts

# Addition of Low NO<sub>x</sub> Burners

- Altered Particle Shape
- Changed Particle Density



B&W Low NO<sub>x</sub> Burner

# Economizer Outlet Gas Temperature Differences for Various Coals

- PRB units have temperatures typically between 715-800°F prior to SCR
- Eastern Coal units have temperatures typically between 650-700°F prior to SCR
- The above temperature differences could create performance changes when switching to High Sulfur Fuels (i.e. SCR, A/H, etc)
- These changes need to be evaluated on a project by project basis to determine effect on overall system

# SCR Operation

- Potential change in activity of catalyst due to less than optimum inlet temperature
- Potential change in ash constituents and resultant effect on activity
- Potential changes to  $\text{SO}_2$  to  $\text{SO}_3$  conversion across the catalyst



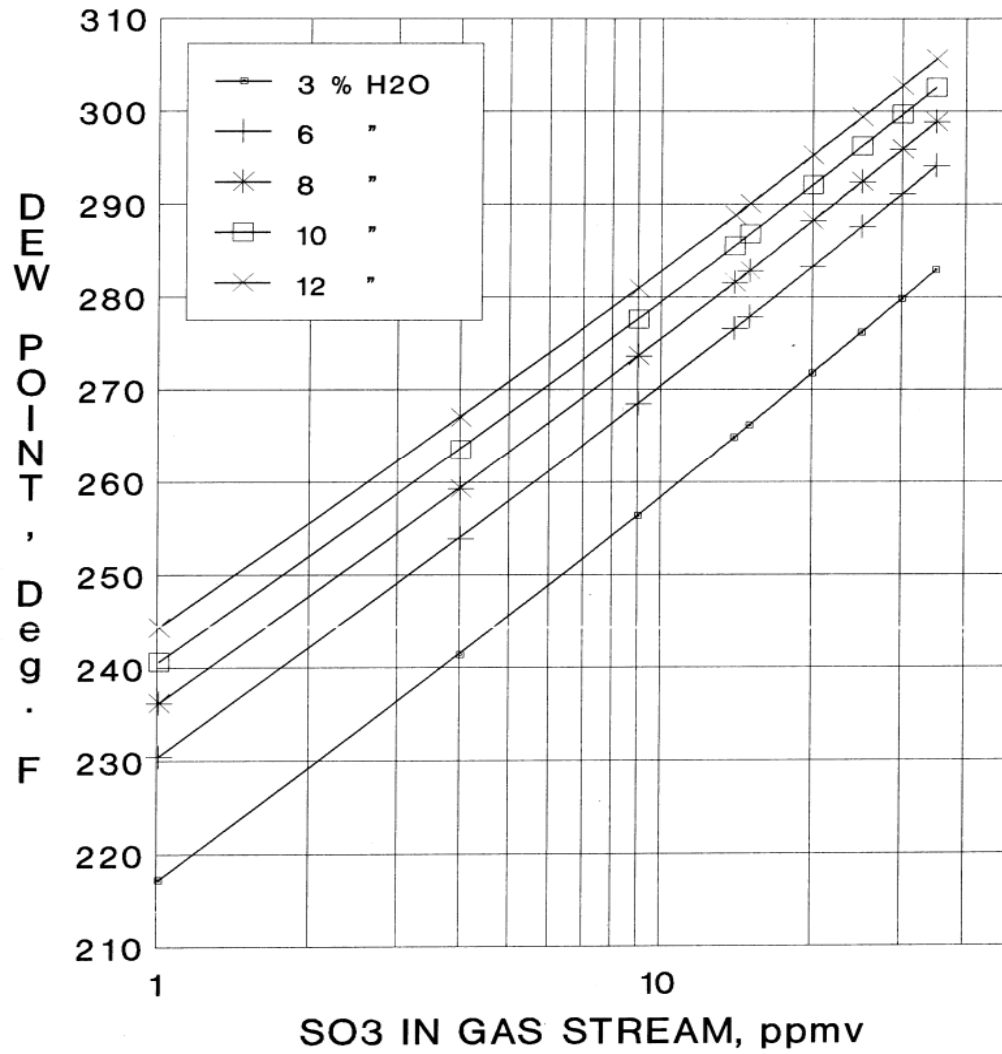
# AH Changes due to Inlet Temperature

- Effects on A/H Outlet Temperature
- Potential A/H buildup due to Ammonia Salt formation from  $\text{NH}_3$  and  $\text{SO}_3$  in the flue gas
- Potential corrosion issues due to operation near or at the acid dewpoint temperature

## Acid Dewpoint Temperature Curve

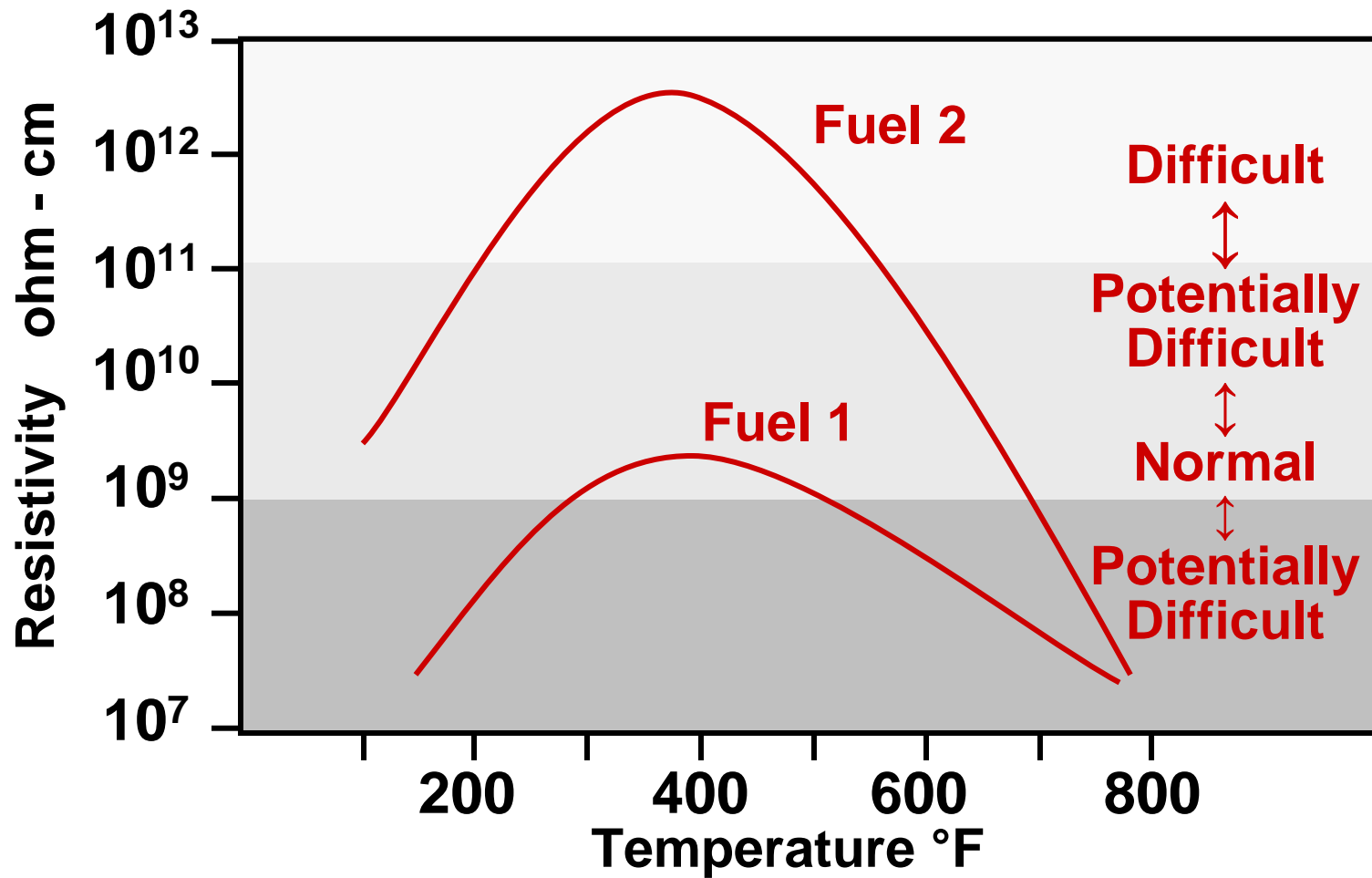
- The following slide shows the relationship between operating temperature, moisture and  $\text{SO}_3$  concentration on acid dewpoint temperature
- The margin between acid dewpoint temperature and operating temperatures are important for optimum ash removal and minimized downstream corrosion

# ACID DEW POINT IN FLUE GAS (SULFUR TRIOXIDE)



# Analysis of Resistivity Curve

- The resistivity curve shows expected resistivity values at various  $\text{SO}_3$  levels and temperatures
- $\text{SO}_3$  levels follow the temperature gradient across the DESP inlet
- Therefore, a potential cause of higher opacity levels downstream maybe related to low resistivity in some or all sections of the DESP and can be the result of not only  $\text{SO}_3$  but higher particulate emissions due to poor DESP performance



## Ash Resistivity

# *Particulate Resistivity*

*How poorly/how well the particle conducts:*

$10^4 - 10^8$ ohm-cm	Low
$10^9 - 10^{11}$ ohm-cm	<b>Optimum</b>
$10^{12} - 10^{13}$ ohm-cm	High

## **Major factors:**

- ash chemistry
- $\text{SO}_3$
- temperature
- moisture

## Reduction of SO<sub>3</sub> in Boiler Gas by Lowered Temperature and Electrical Precipitation (After Archbold)

Temperature °F	Average SO <sub>3</sub> by volume, ppm			Comments
	Air Heater Inlet	Air Heater Outlet	Precipitator Outlet	
650-700	22.9	-	-	Results are averages of many readings taken over a period of six days
325-335	-	21.9	12.0	
290-300	-	9.4	4.3	
280-285	-	7.1	2.0	

From Industrial Electrostatic Precipitation by Harry J. White



**In this section, three (3) coals will be analyzed for SO<sub>3</sub>, Acid Dewpoint Temperature, and Resistivity**



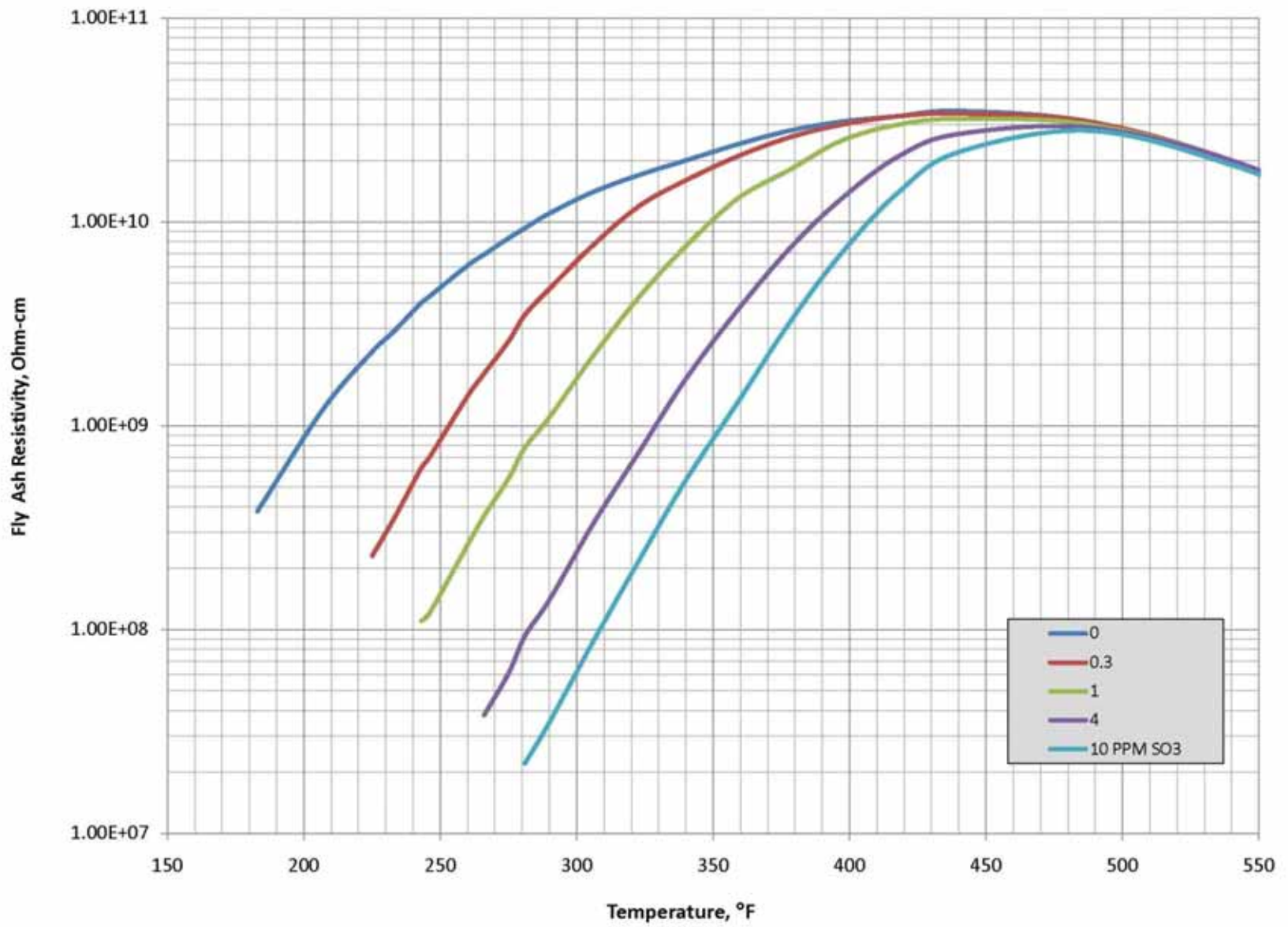
# PRB Ash Analysis

Coal Case	PRB
<b><u>Proximate Analysis</u></b>	
Fixed Carbon	34.87
Volatiles	32.85
Sulfur	0.28
Moisture	27.52
Ash	4.77
<b><u>Ash Mineral Analysis</u></b>	
Li <sub>2</sub> O	0.01
Na <sub>2</sub> O	1.6
K <sub>2</sub> O	0.29
MgO	5.6
CaO	22.4
Fe <sub>2</sub> O <sub>3</sub>	5.3
Al <sub>2</sub> O <sub>3</sub>	15.95
SiO <sub>2</sub>	32.2
TiO <sub>2</sub>	1.35
P <sub>2</sub> O <sub>5</sub>	1.05
SO <sub>3</sub>	13.1

# Analysis

- Testing suggests that due to the high amount of CaO in the ash, the inlet  $\text{SO}_3$  expected at the DESP inlet will be between 3 and 4 ppm.
- Acid dewpoint temperature is approximately 262 F
- Approximately 30% of the  $\text{SO}_3$  is removed in the DESP leaving and approximately 2 – 3 ppm is in the exiting flue gas

# PRB



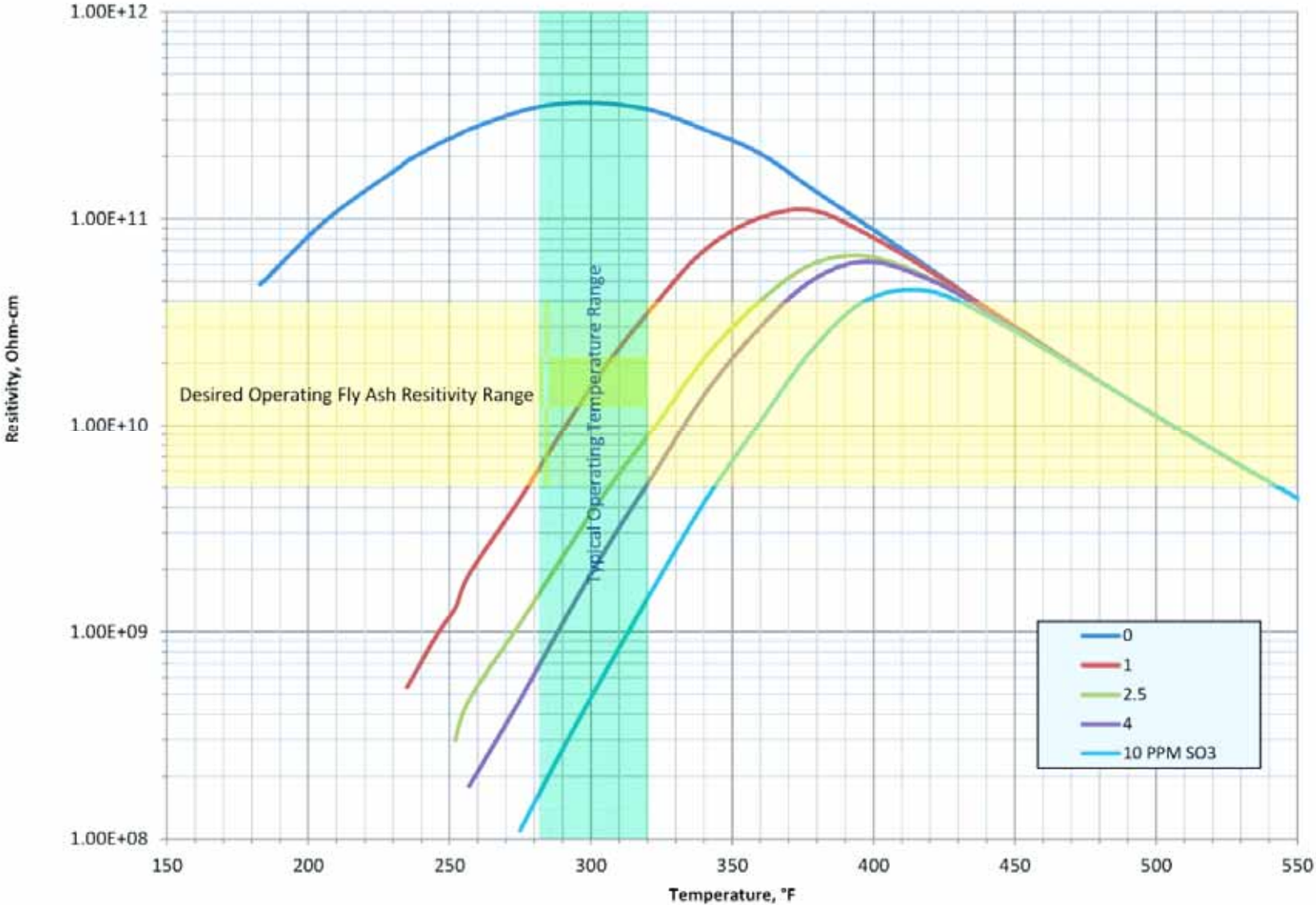
# Eastern Low Sulfur Coal Ash Analysis

Coal case	CA1
<b>Proximate Analysis (As Received)</b>	
HHV (Btu/lb)	11,676
Moisture (%)	7.69
Ash (%)	12.61
Sulfur (%)	1.16
Volatile Matter (%)	32.67
Fixed Carbon (%)	47.03
Ash Loading (lbm/Mbtu)	10.80
Calculated SO2	1.99
<b>Ash Mineral Analysis</b>	
Silica (SiO2) - %	56.33
Alumina (Al2O3) - %	26.54
Titania (TiO2) - %	1.54
Iron Oxide (Fe2O3) - %	6.68
Magnesia (MgO) - %	0.83
Lime (CaO) - %	1.17
Potassium Oxide (K2O) - %	2.19
Sodium Oxide (Na2O) - %	0.23
Phosphorous Pentoxide (P2O5) - %	0.23
Sulfur Trioxide (SO3) - %	0.76

# Analysis

- Using a 1% conversion in the boiler and 1% conversion in the SCR results in a value of 14.4 ppm  $\text{SO}_3$  at the inlet of the Air Heater
- Estimated  $\text{SO}_3$  capture in the Air Heater is approximately 30%.
- Therefore 10.1 ppm  $\text{SO}_3$  is expected at the DESP inlet
- Acid dewpoint temperature is approximately 280 F
- Approximately 30% of the  $\text{SO}_3$  is removed in the DESP leaving and approximately 7.0 ppm is in the exiting flue gas

### Appalachian Coal - DB #714





# Average Coal and Ash Analysis

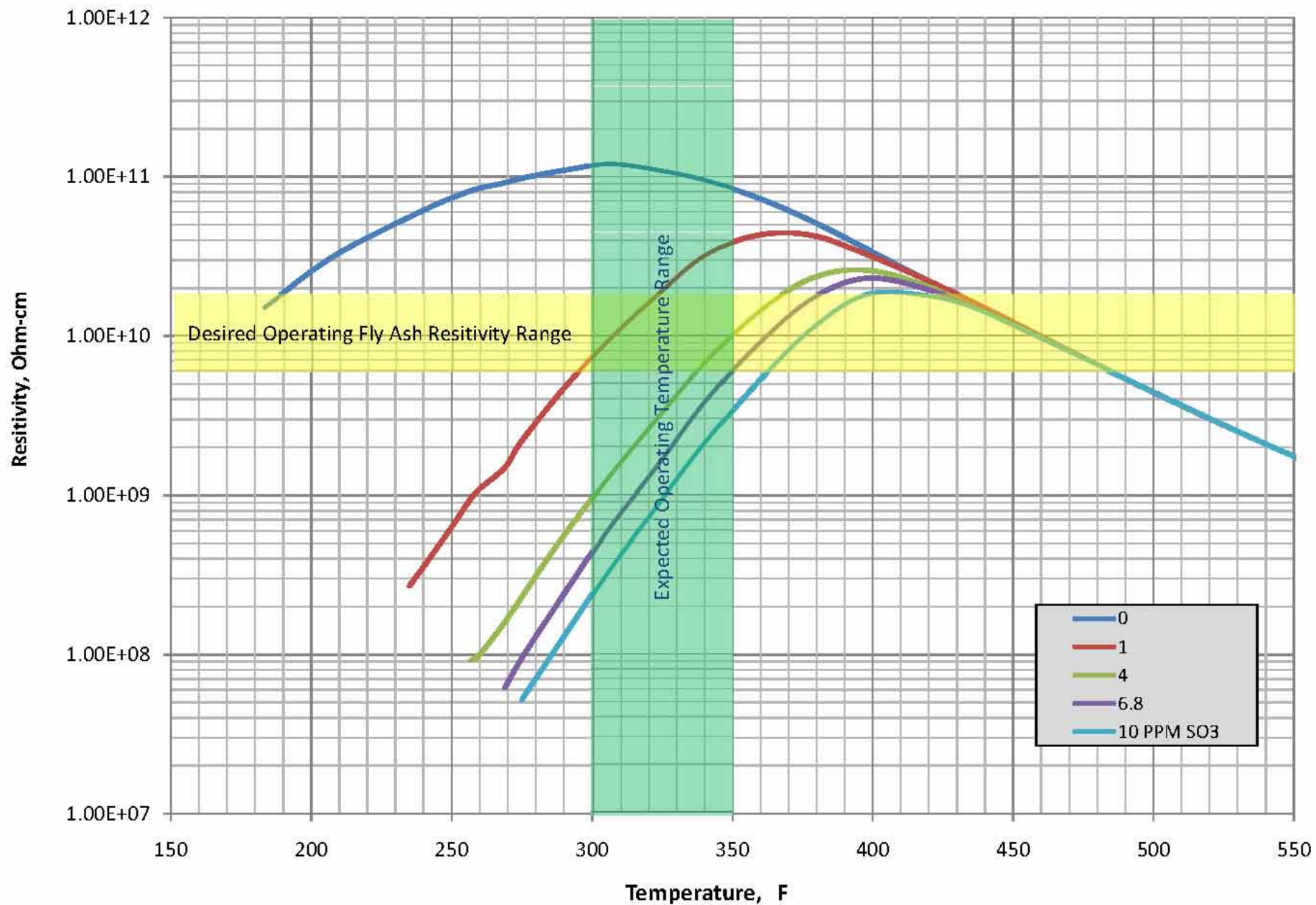
Parameter	Performance
<b>Ultimate Analysis</b>	
Ash, % weight	7.73
Moisture, % weight	5.71
Carbon, % weight	72.67
Hydrogen, % weight	4.89
Oxygen, % weight	4.96
Nitrogen, % weight	1.38
Sulfur, % weight	2.56
Chlorine, % weight	0.10
Total, % weight	100.0
HHV, Btu/lb	13,100
<b>Proximate Analysis</b>	
Ash, wt. %	7.73
Volatiles, wt. %	35.73
Fixed Carbon, wt. %	50.84
Sulfur, wt. %	2.56
Moisture, wt. %	5.71
Lb SO <sub>2</sub> /MMBtu	3.91

Ash Analysis	Typical
SiO <sub>2</sub> , % wt.	43.17
Al <sub>2</sub> O <sub>3</sub> , % wt.	21.95
Fe <sub>2</sub> O <sub>3</sub> , % wt.	21.17
CaO, % wt.	5.18
MgO, % wt.	0.90
Na <sub>2</sub> O, % wt.	1.06
K <sub>2</sub> O, % wt.	1.45
TiO <sub>2</sub> , % wt.	0.93
P <sub>2</sub> O <sub>5</sub> , % wt.	0.59
SrO, % wt.	
MnO <sub>2</sub> , % wt.	
SO <sub>3</sub> , % wt.	4.28
BaO, % wt.	
Undetermined, % wt	0.0

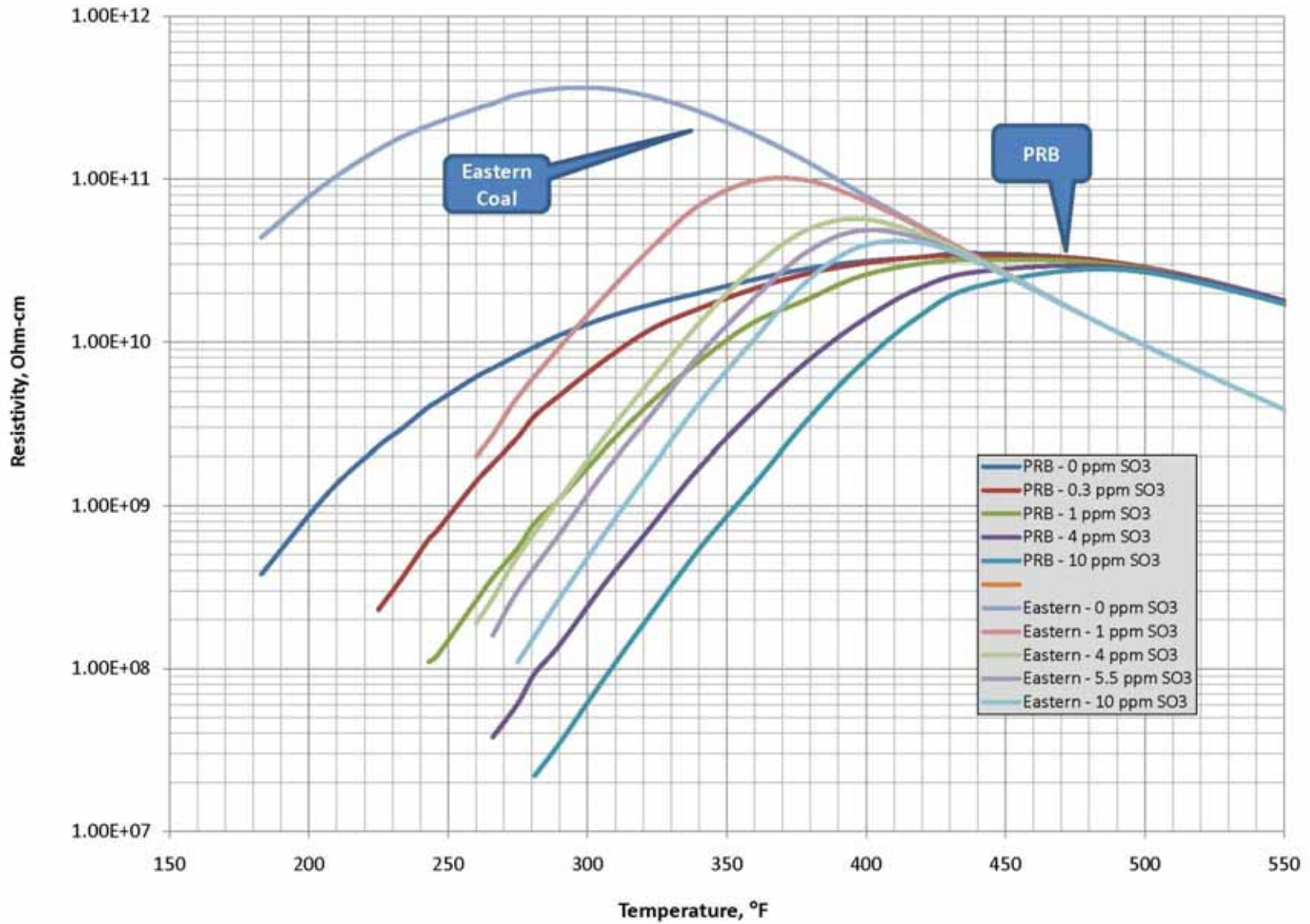
# Analysis

- Using a 1% conversion in the boiler and 1% conversion in the SCR results in a value of 32 ppm SO<sub>3</sub> at the inlet of the Air Heater
- Estimated SO<sub>3</sub> capture in the Air Heater is approximately 30%.
- Therefore 22 ppm SO<sub>3</sub> is expected at the DESP inlet
- Acid dewpoint temperature is approximately 298 F
- Approximately 30% of the SO<sub>3</sub> is removed in the DESP leaving and approximately 15.5 ppm is in the exiting flue gas

### Appalachian - #8 Washed Blacksville Performance/Typical Values



### Fly Ash Resistivity Eastern vs. PRB Coals





## What Low Resistivity Really Means:

- Pith Ball effect
- Results in high power input
- Particulate begins to act like carbon in the ESP
- Velocity implications – high velocities create more reintrainment

## Summary of Previous Resistivity/Fuel Analysis

- Reviewed PRB and Low S Eastern Fuels to review how some unit DESP units may have operated prior to adding WFGD Systems.
- Additionally a medium S Eastern fuel was analyzed to provide insight into where operation may start when scrubbers are utilized
- Acid dewpoint temperatures have increased and more  $\text{SO}_3$  can be expected downstream of the DESP when burning higher and higher sulfur coals
- Without limiting  $\text{SO}_3$  at the DESP inlet and/or increasing the Dry ESP inlet temperature, potentially both poor operating performance and corrosion issues can occur as higher sulfur coals are burned



# Effects of High Sulfur Coals on Dry ESP Operation

# *Transformer-Rectifiers (T-Rs) High Voltage Power Supplies*



# T/R Set Differences

- High Sulfur applications are a high current density application
- Due to bus section sizing, new T/Rs may be required
- SMPS power supplies may be advantageous. However, care must be taken due to sizes available
- High corona generating discharge electrodes may be advantageous

# Insulator Heating and Ventilating System Differences

- High Sulfur applications create higher acid dewpoint temperatures
- This normally requires more heating capacity than low sulfur applications
- The air purge/insulator distribution system may need modification to avoid insulator problems
- This system may need to be started earlier than on low Sulfur applications to ensure insulator life and avoid tracking
- Proper flow distribution, air filter cleanliness and piping insulation are essential for trouble free operation
- High Alumina content insulator material is recommended



# *ESP Rappers*





# Rapping Differences

- Due to reduced holding force of dust layer to collecting plate, lighter rapping force is of advantage
- Less frequent rapping - Particularly in last field is required to minimize rapping losses and optimize particulate removal



# Hopper Discharge Difference

- The nature of flyash when firing high sulfur coals can cause pluggage problems
- Stainless steel liners or rounded corners may be used to manage these issues
- Hoppers heaters may need to be modified and more heat may be required
- Throat heaters may be required
- Certain types of hopper baffles could become problematic and may need to be altered
- Hoppers should not be used to store flyash

# Possible Corrosion Issues

- Any location where in-leakage can occur is a potential for acid corrosion (doors, expansion joints, ash removal systems, etc.)
- Cold spots on casing and hoppers are potential problem areas
- Dust free areas in ESP and downstream ductwork are potential problem areas



## To Minimize the Potential for Corrosion

- Check all gaskets and interfaces for leakage – Smoke test may be beneficial
- Infrared photography on ESP casing and ductwork can be used to locate cold spots

# Possible Solutions for Opacity Issues

- ▶ Raise the average inlet temperature for the DESP
  - ▶ Possible mixing of the flue gas maybe possible on some plants to raise the temperature to the DESP
- ▶ Add sorbent injection to reduce the  $\text{SO}_3$  concentration
- ▶ Larger current density T/R sets may be required



# Sorbent Injection Overview

<b>Sorbent</b>	<b>Effectiveness</b>	<b>Relative O&amp;M Costs</b>	<b>Relative Capital Costs</b>	<b>Relative Maintenance</b>
Ammonia	Good for lower SO3 Concentration	Low	Low-NH3 already in use w/SCR	Low
Magnesium Hydroxide	Good Furnance Injection	High	Moderate - Slurry	Moderate
Hydrated Lime	Good Limited by ESP Performance	Low	Low	Moderate to Low
SBS	Excellent	High	Moderate	High
High Surface Area Lime	Good to Excellent	Low	Low	Moderate ESP Concerns
Trona	Excellent	Low	Low	Low

## *Sorbent Utilization*

### *Affected by:*

- ➔ **Sorbent particle size / surface area**
- ➔ **Sorbent residence time**
- ➔ **Sorbent penetration and mixing**
- ➔ **Reagent type**
- ➔ **Temperature of Injection Point**



# Sorbent Selection Based on Overall ESP Size

- If ESP size is small, Na based sorbents may be beneficial
- If ESP size is large, hydrated lime may be cost effective

# Location of Sorbent Injection

- Dry Injection
  - Basic locations are ESP inlet & WFGD inlet
  - Tested injection at SCR inlet and A/H inlet
- Wet Injection
  - Have installations at A/H inlet and ESP inlet
  - Tested at SCR inlet

# Wet vs. Dry Injection

- Degree of  $\text{SO}_3$  removal required
- Cost of Sorbent
- Reliability of system
- Overall cost to operate



# Sorbent Injection

- May be required in the future for Hg control
  - $\text{SO}_3$  competes with Hg for activated carbon sites

# Conclusions

- Additional equipment and/or modifications to the air quality system may present challenges to Dry ESP operation and/or performance when switching to high sulfur coals.
- Low resistivity operation may become as large of an issue now as high resistivity operation has in the past.
- Acid dewpoint temperature after switching may require additional heating on purge system and/or hopper
- Some modification to Dry ESP inlet temperature may be required for system integrity
- Dry ESP performance is critical to scrubber projects producing saleable gypsum

# Conclusions cont.

- Sorbent injection may be required to optimize Dry ESP Performance
- Supplemental sorbent injection may be required down the road if stringent Mercury control regulations are enacted
  - Sorbent injection will most likely be required if activated carbon costs are to be minimized
- One must evaluate the entire plant gas cleaning train to optimize Dry ESP performance and operation when switching to high sulfur coals



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