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

2010 WPCA Illinois Regional Technical Seminar

By

Ron Triscori

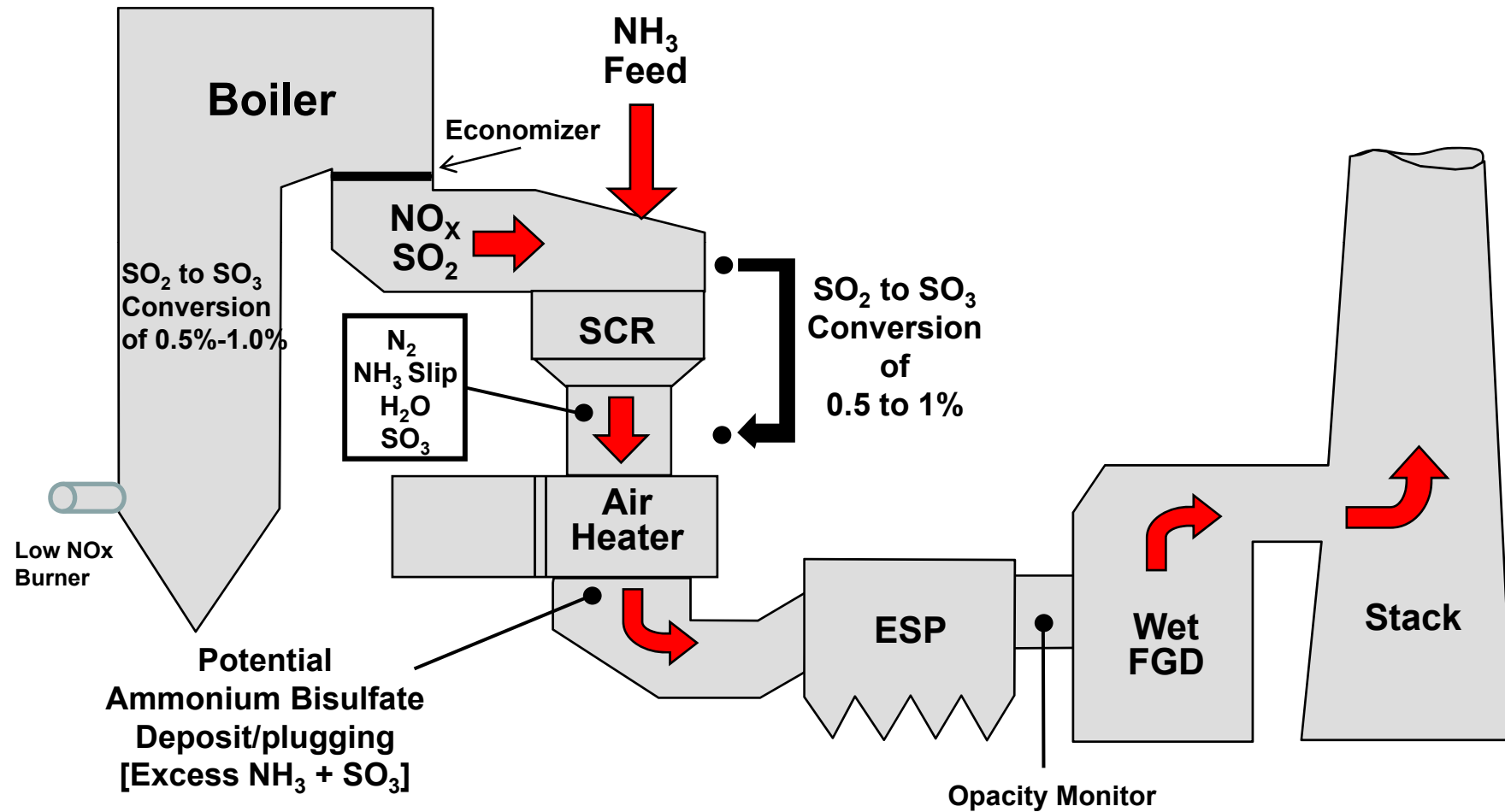


Presentation Agenda

- 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!!



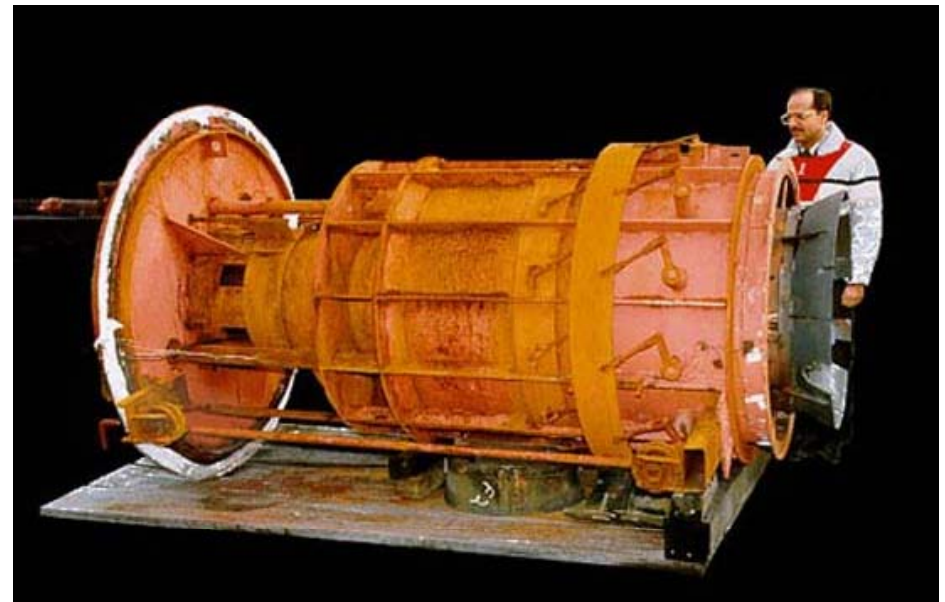


Coal Combustion Chemistry

Fuel Constituent	Combustion (Oxidation) Product
Carbon	Carbon dioxide, CO ₂
Hydrogen	Water, H ₂ O
Sulfur	Sulfur dioxide, SO ₂ Sulfur trioxide, SO ₃
Nitrogen	Nitric oxide, NO Nitrogen dioxide, NO ₂
Major ash components	Bottom ash and fly ash
Iron	Iron oxides, Fe ₂ O ₃ , Fe ₃ O ₄
Silicon	Silica, SiO ₂
Aluminum	Aluminum oxides, Al ₂ O ₃
Others:	Various salts
Sodium	Sodium chloride, NaCl
Chlorine	Various oxides
Trace metals	Trace elements and compounds
Mercury	Elemental mercury, Hg Mercuric oxides and chlorides
Arsenic, lead, etc.	Various chemical salts

Addition of Low NO_x Burners

- Altered Particle Shape
- Changed Particle Density



B&W Low NO_x 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 SO_2 to SO_3 conversion across the catalyst



AH Changes due to Inlet Temperature

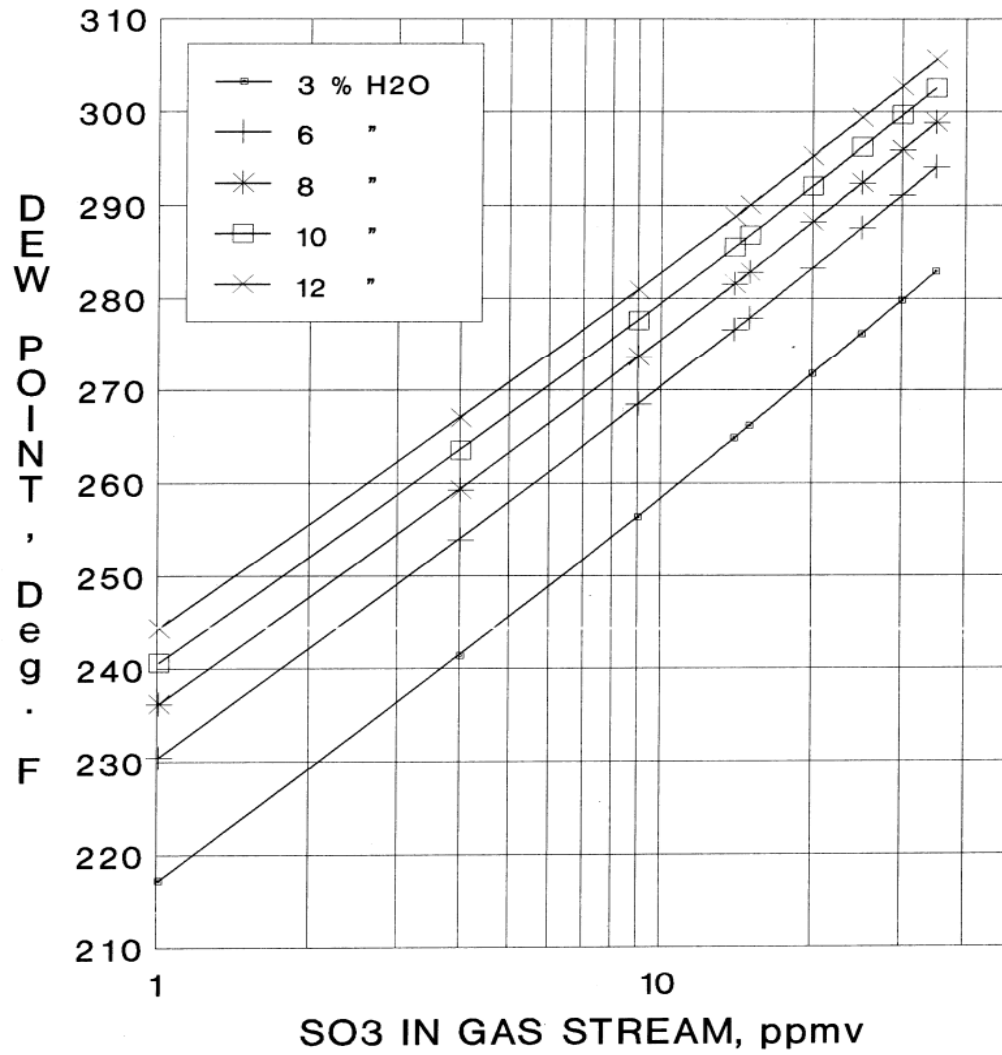
- Effects on A/H Outlet Temperature
- Potential A/H buildup due to Ammonia Salt formation from NH_3 and SO_3 in the flue gas
- Potential corrosion issues due to operation near or at the acid dewpoint temperature



Acid Dewpoint Temperature Curve

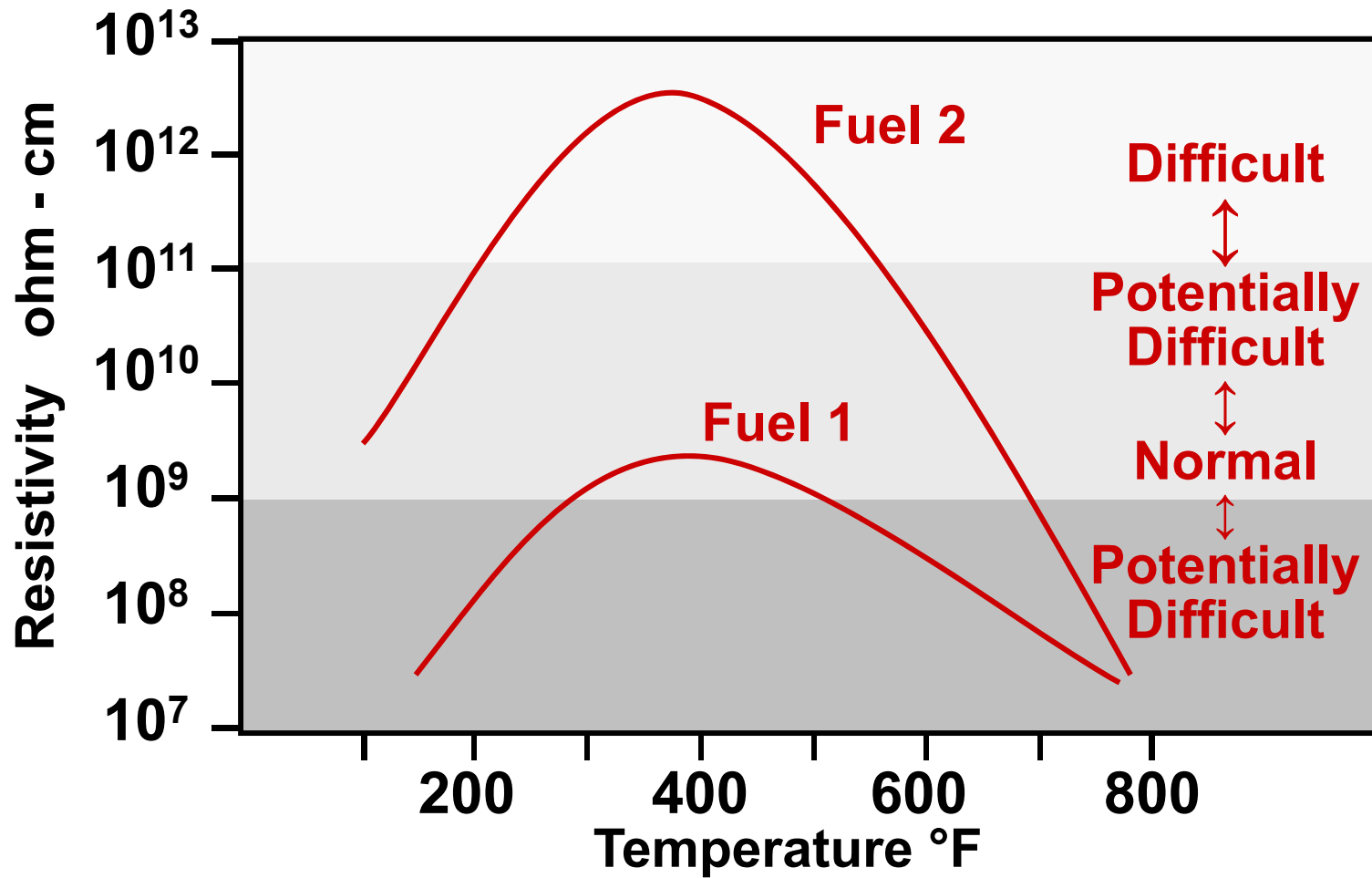
- The following slide shows the relationship between operating temperature, moisture and SO_3 concentration on acid dewpoint temperature
- The margin between acid dewpoint temperature and operating temperatures are important for optimum ash removal and minimized downstream corrosion

ACID DEW POINT IN FLUE GAS (SULFUR TRIOXIDE)



Analysis of Resistivity Curve

- The resistivity curve shows expected resistivity values at various SO_3 levels and temperatures
- 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 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 **Optimum**

$10^{12} - 10^{13}$ ohm-cm High

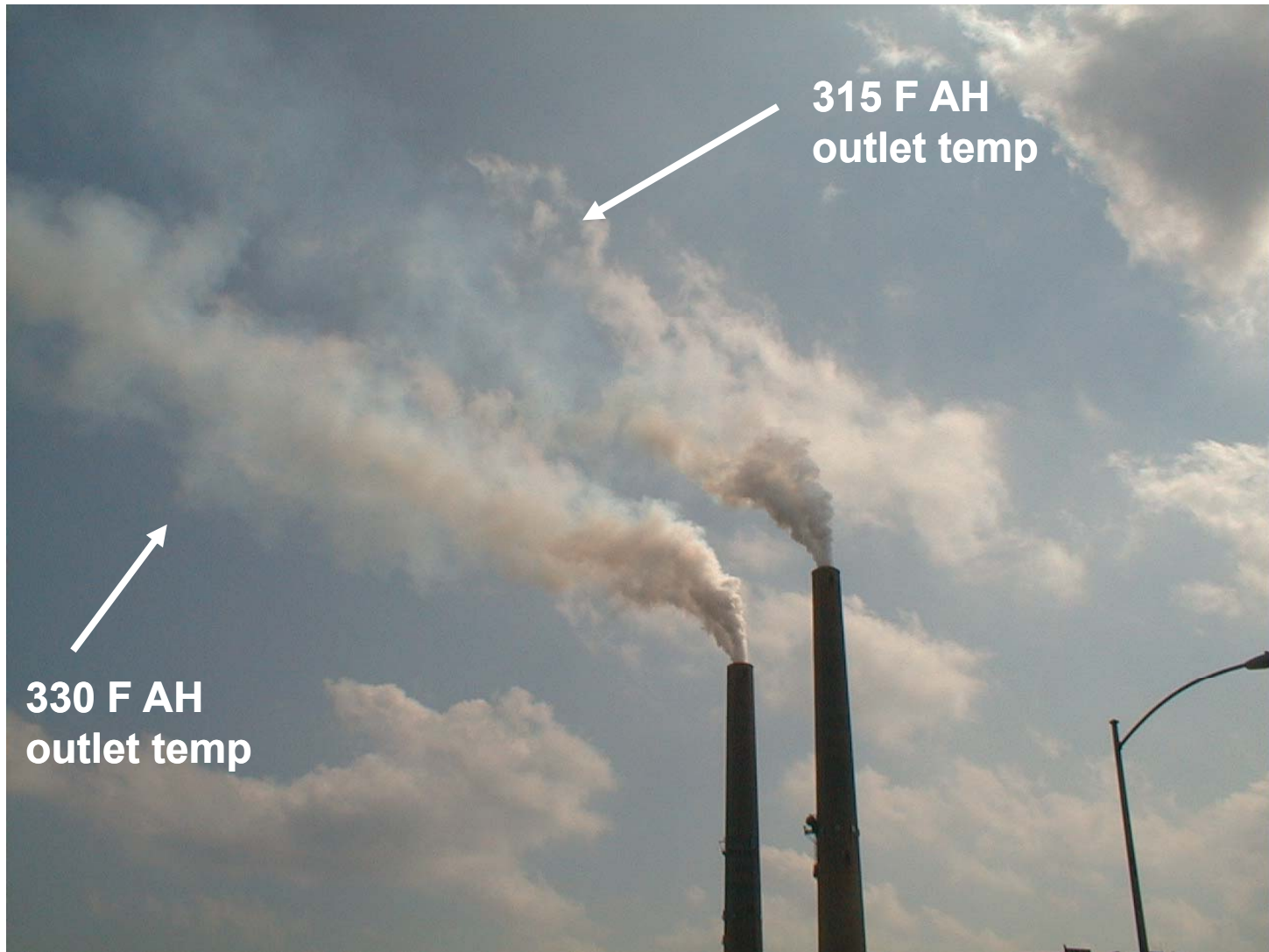
Major factors:

- ash chemistry
- SO_3
- temperature
- moisture

Reduction of SO₃ in Boiler Gas by Lowered Temperature and Electrical Precipitation (After Archbold)

Temperature °F	Average SO ₃ 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 SO₃, Acid Dewpoint Temperature, and Resistivity

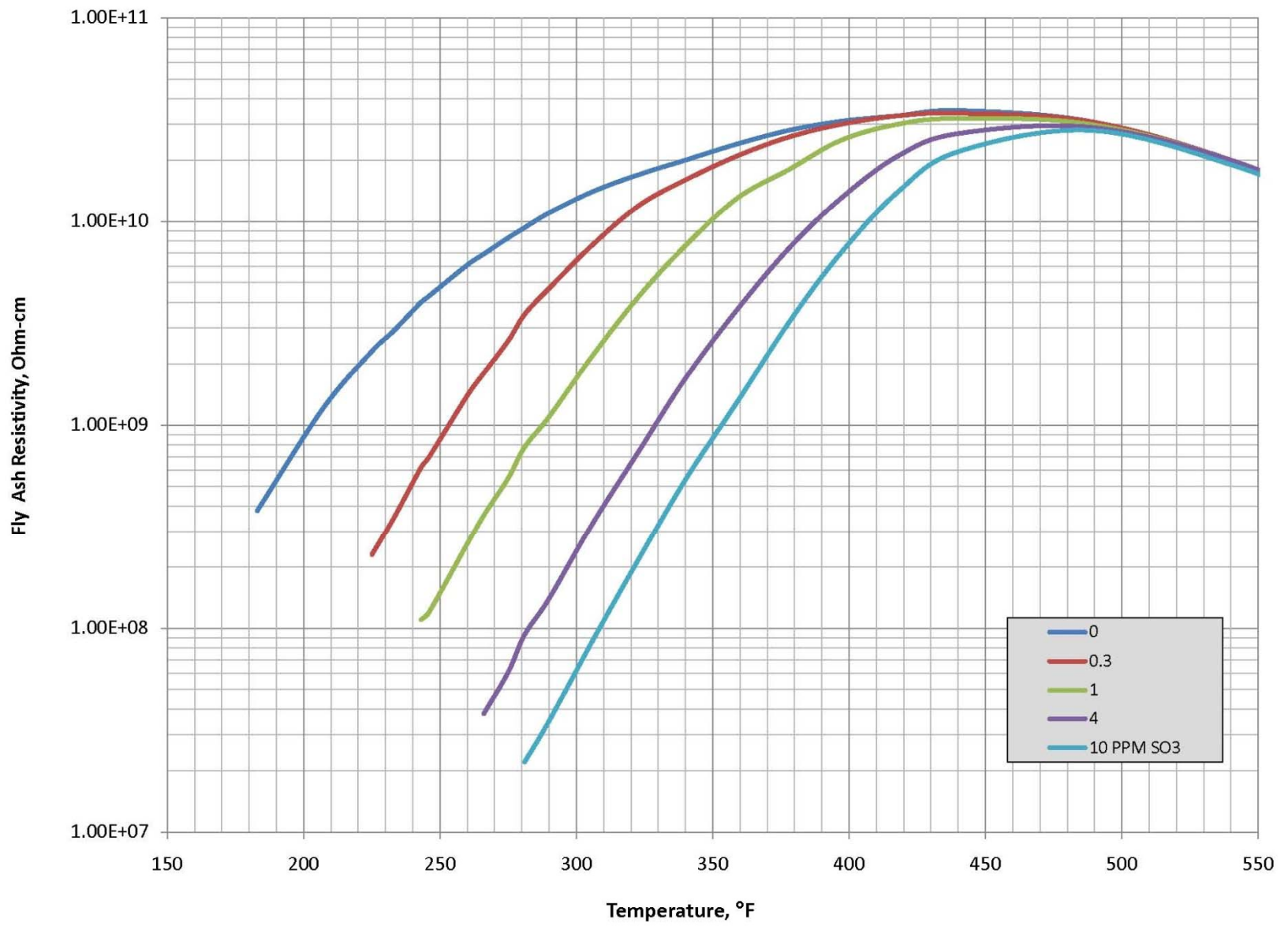
PRB Ash Analysis

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

Analysis

- Testing suggests that due to the high amount of CaO in the ash, the inlet SO₃ expected at the DESP inlet will be between 3 and 4 ppm.
- Acid dewpoint temperature is approximately 262 F
- Approximately 30% of the SO₃ is removed in the DESP leaving and approximately 2 – 3 ppm is in the exiting flue gas

PRB



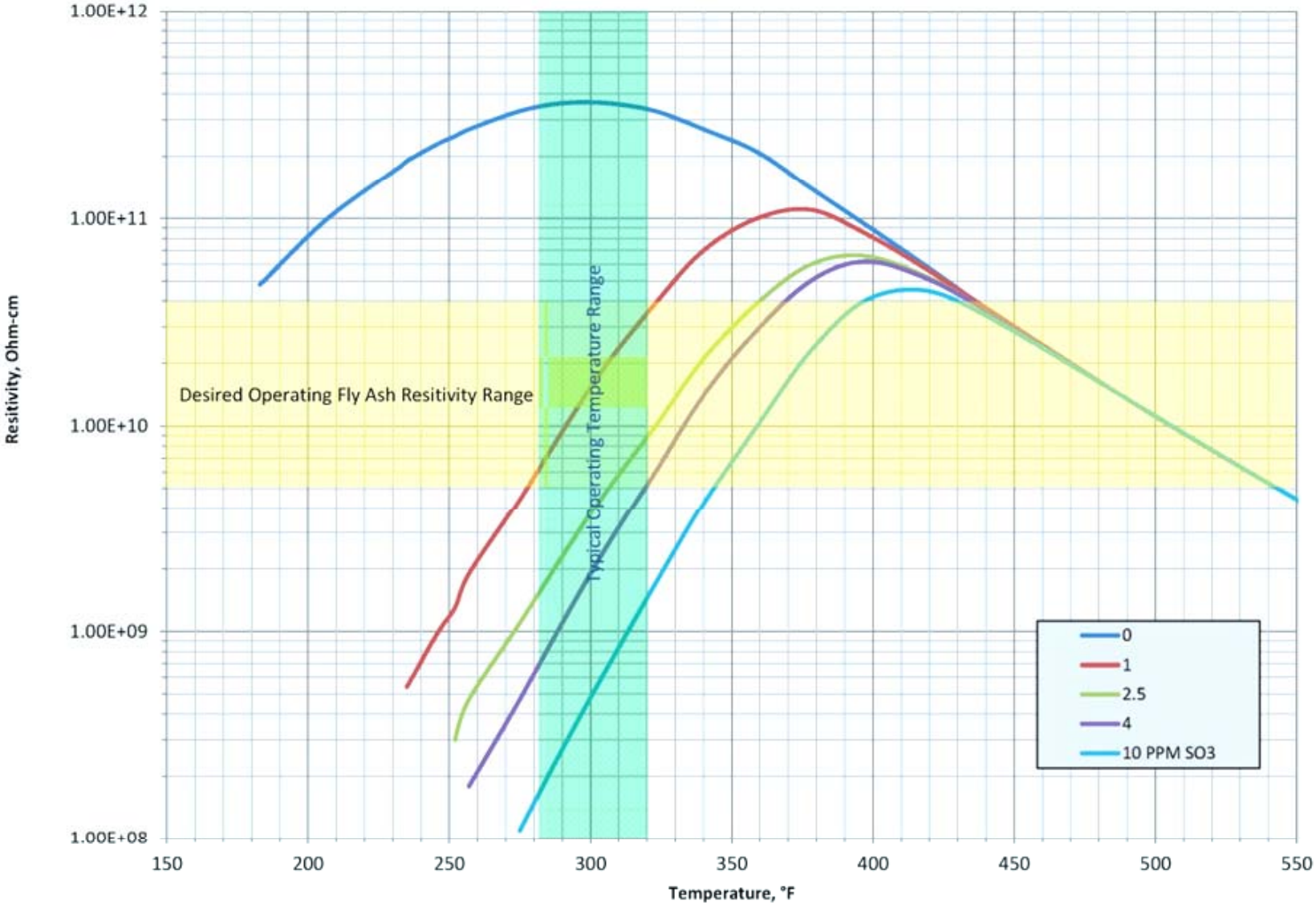
Eastern Low Sulfur Coal Ash Analysis

Coal case	CA1
Proximate Analysis (As Received)	
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 SO ₂	1.99
Ash Mineral Analysis	
Silica (SiO ₂) - %	56.33
Alumina (Al ₂ O ₃) - %	26.54
Titania (TiO ₂) - %	1.54
Iron Oxide (Fe ₂ O ₃) - %	6.68
Magnesia (MgO) - %	0.83
Lime (CaO) - %	1.17
Potassium Oxide (K ₂ O) - %	2.19
Sodium Oxide (Na ₂ O) - %	0.23
Phosphorous Pentoxide (P ₂ O ₅) - %	0.23
Sulfur Trioxide (SO ₃) - %	0.76

Analysis

- Using a 1% conversion in the boiler and 1% conversion in the SCR results in a value of 14.4 ppm SO_3 at the inlet of the Air Heater
- Estimated SO_3 capture in the Air Heater is approximately 30%.
- Therefore 10.1 ppm SO_3 is expected at the DESP inlet
- Acid dewpoint temperature is approximately 280 F
- Approximately 30% of the 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

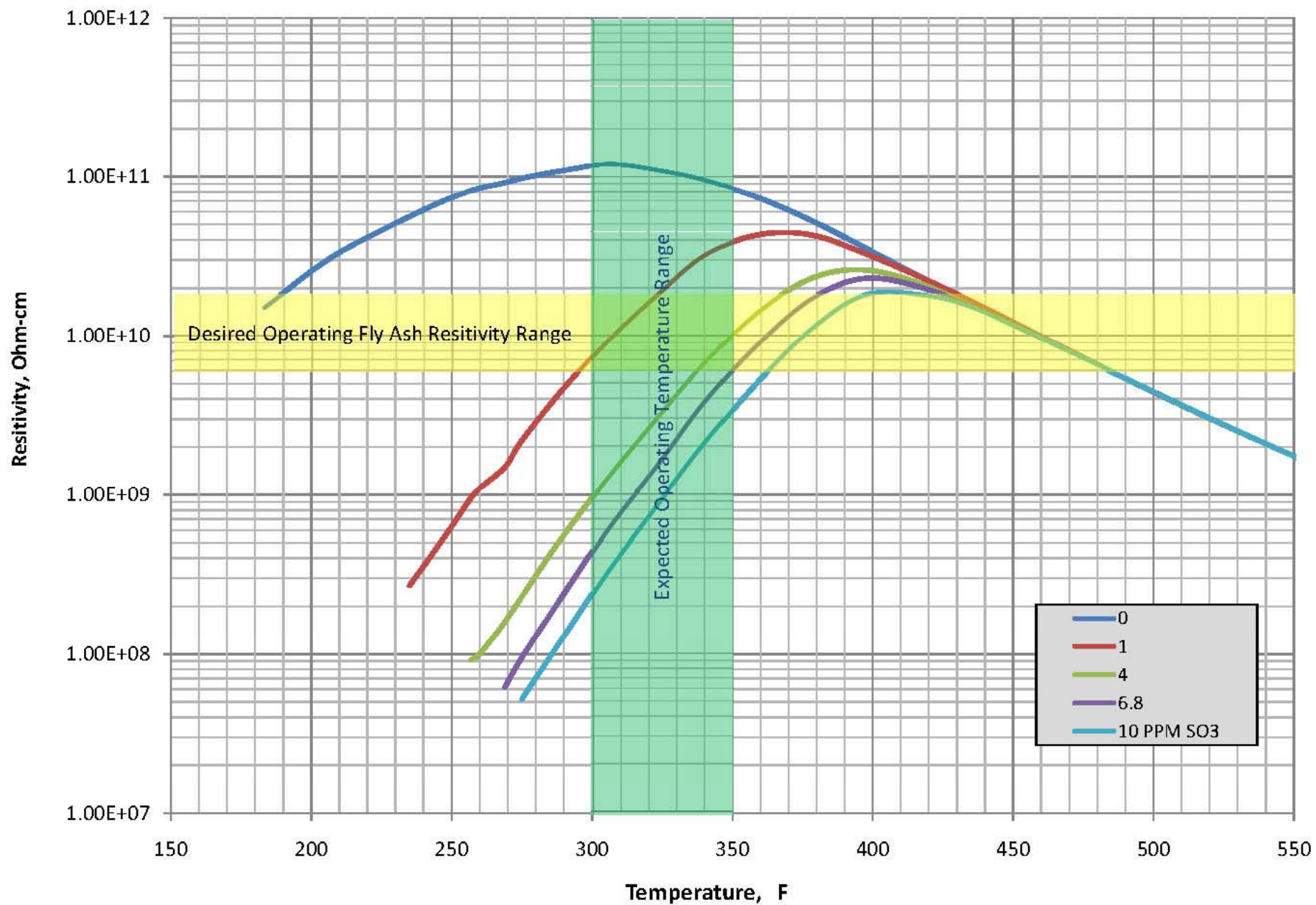
Parameter	Performance
Ultimate Analysis	
Ash, % weight	7.73
Moisture, % weight	5.71
Carbon, % weight	72.67
Hydrogen, % weight	4.89
Oxygen, % weight	4.96
Nitrogen, % weight	1.38
Sulfur, % weight	2.56
Chlorine, % weight	0.10
Total, % weight	100.0
HHV, Btu/lb	13,100
Proximate Analysis	
Ash, wt. %	7.73
Volatiles,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

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

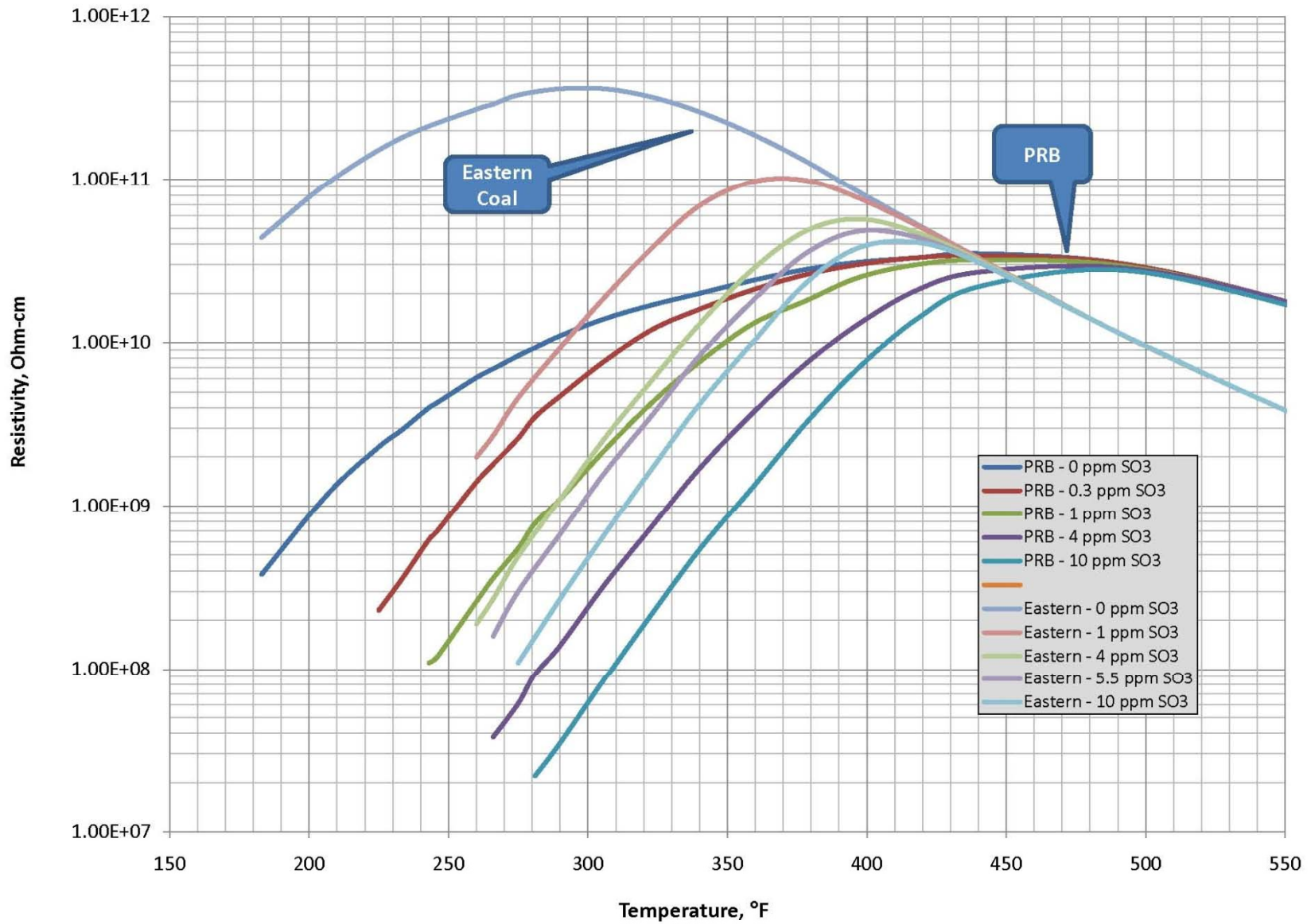
Analysis

- Using a 1% conversion in the boiler and 1% conversion in the SCR results in a value of 32 ppm SO_3 at the inlet of the Air Heater
- Estimated SO_3 capture in the Air Heater is approximately 30%.
- Therefore 22 ppm SO_3 is expected at the DESP inlet
- Acid dewpoint temperature is approximately 298 F
- Approximately 30% of the SO_3 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 SO_3 can be expected downstream of the DESP when burning higher and higher sulfur coals
- Without limiting 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



RE Consulting

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

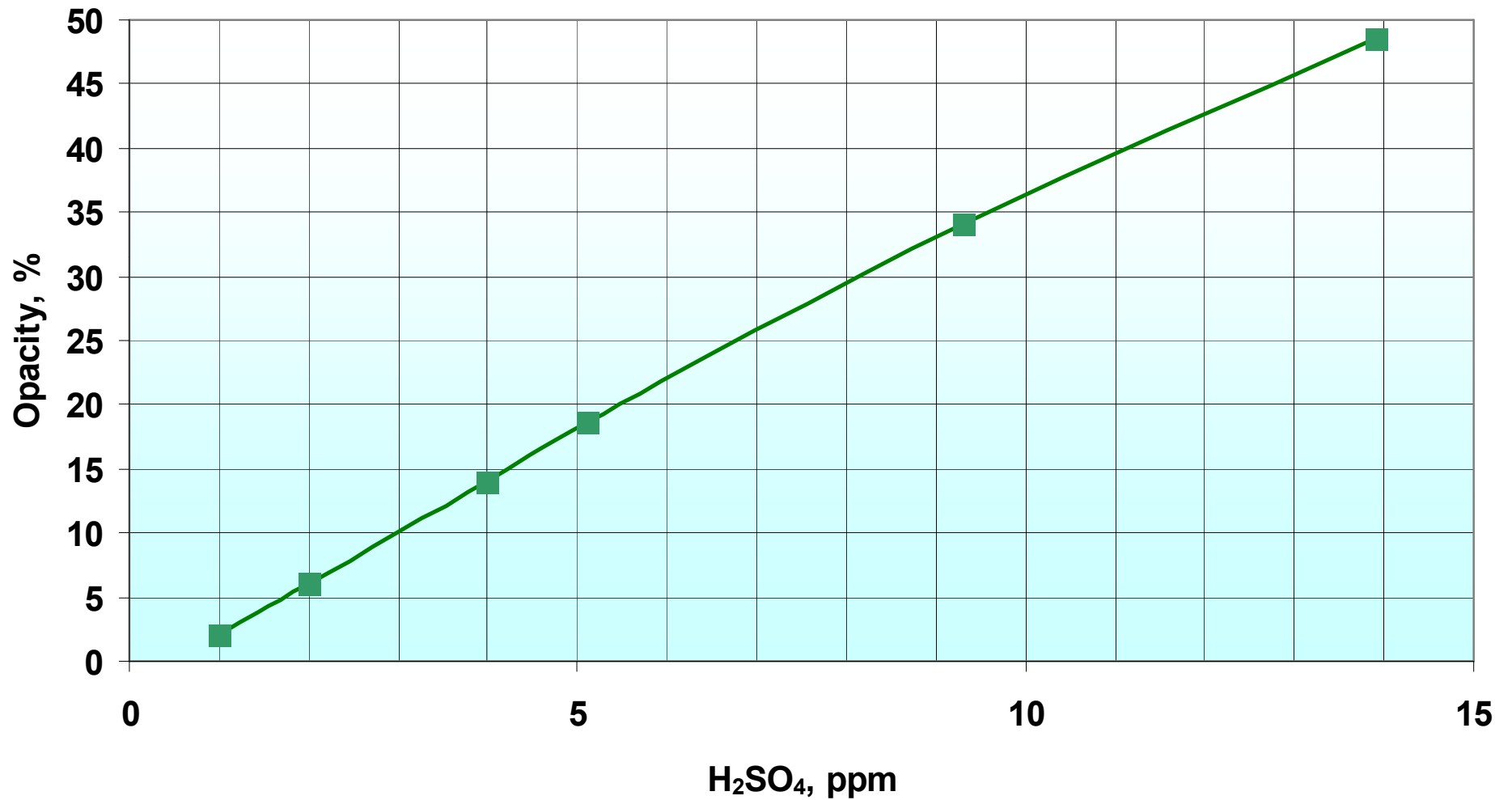
Possible Solutions for Opacity Issues

- ▶ 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 SO_3 concentration
- ▶ Larger current density T/R sets may be required



Sorbent Injection Overview

Predicted plume opacity (after evaporation of water fog) for large unit with DESP & scrubber



Graph presented by Southern Research Institute, APC Expo, SO₃ Mitigation Panel, Tampa, 7/05

Sorbent	Effectiveness	Relative O&M Costs	Relative Capital Costs	Relative Maintenance
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 SO₃ removal required
- Cost of Sorbent
- Reliability of system
- Overall cost to operate



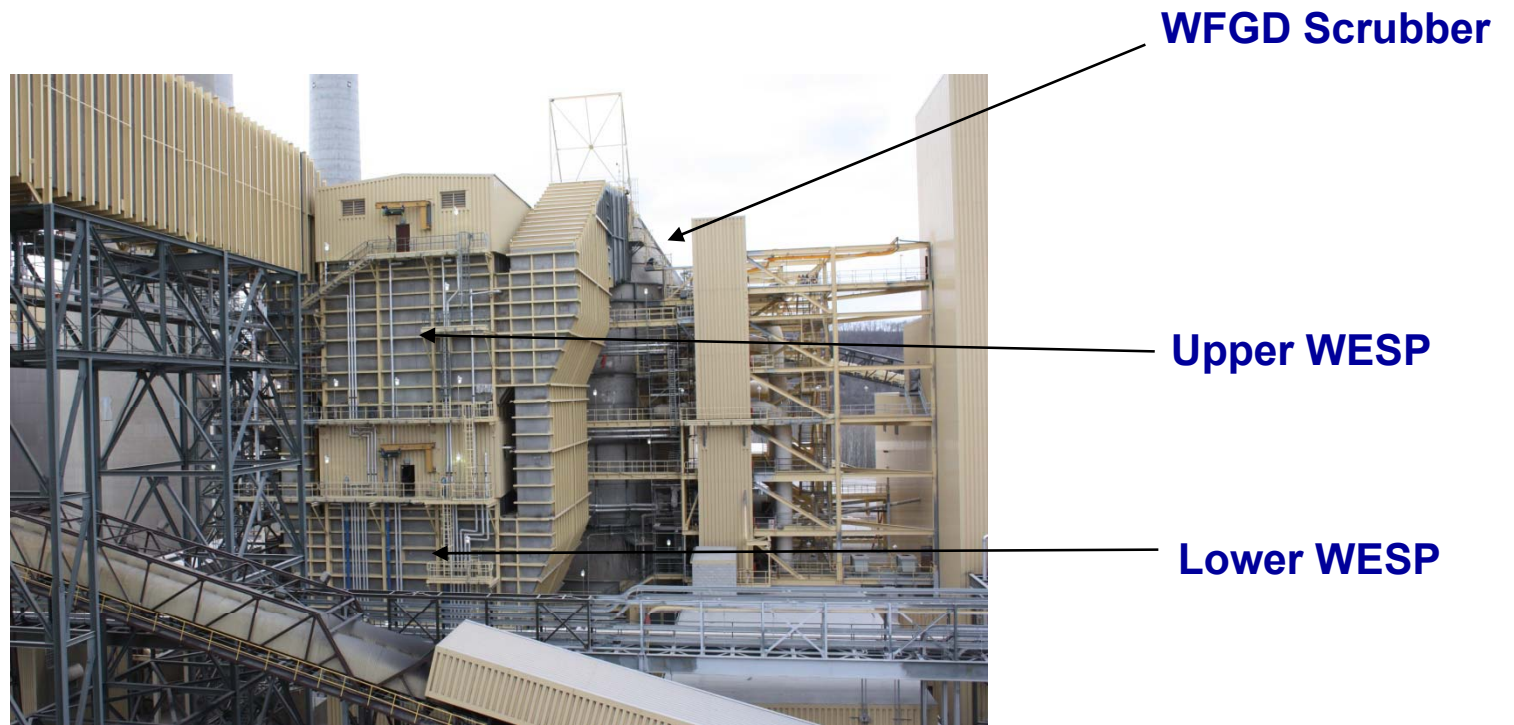
Sorbent Injection

- May be required in the future for Hg control
 - SO_3 competes with Hg for activated carbon sites

AES Deepwater – Pasadena, TX



East Kentucky Power Cooperative (EKPC)



Spurlock Unit #2 Limestone WFGD followed by 3 field WESPs

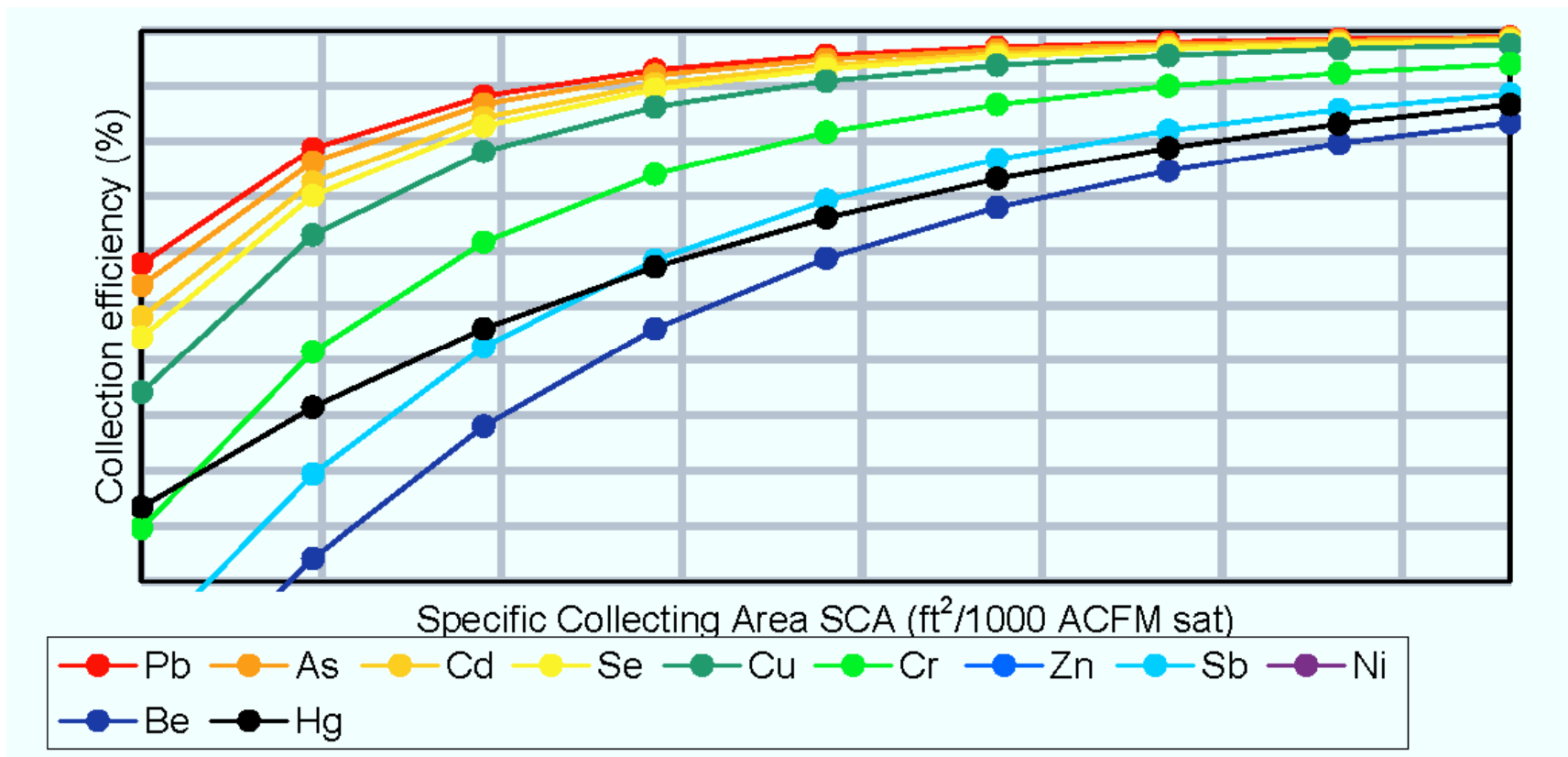
Spurlock Unit #2 WESPs

Project Information:

System Size:	585 MW
Fuel:	4.2% Sulfur Bituminous Coal
WFGD Inlet Gas Flow:	2,110,000 ACFM @ 325°F
WESP Inlet Gas Flow:	1,744,000 ACFM @ 129°F
SO ₂ Removal Efficiency:	98%
SO ₃ Removal Efficiency:	91.2%
Stack Opacity:	<15%
No. of WESP Chambers:	2
Bus Sections Wide per Chamber:	2
Total No. of Bus Sections:	12

The WFGD/WESP System has met the performance requirements of the project!

WESP Fractional Efficiencies for Heavy Metals



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 sealable 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
- WESP may be needed for heavy metal control, More Stringent Total Particulate Requirements, ME carryover from WFGD systems
- 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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