REINHOLD ENVIRONMENTAL Ltd.

2010 APC Round Table & Expo Presentation

July 18-20, 2010, in Concord, NC / Hosted by Duke Energy

Combustion and SCR Effects on ESPs and FFs

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Reinhold APC Round Table

July 19-20, 2010

Agenda

- Combustion Effects
  - Particulate: Loading, size
  - Flue gas: Volume, temperature, composition
  - Carbon content

- SCR
  - SO_2 to SO_3 conversion
  - NH_3 slip

Particle Loading

- HHV of coal (Btu/#)
  - Bituminous: 10,000 – 14,000
  - Sub: 8,000 – 10,000
  - Lignite: 3,000 - 8,000

- Ash in coal
  - Bituminous: 10 - 17%
  - PRB: 6 - 7%
  - Lignite: 10 - 50%

Particle Loading

Boiler specification:

- **Rating: 240 MWe (240,000 kw)**
- **Heat rate: 10,000 Btu/kw-hr**
- **Coal HHV: 12,000Btu/#**

Fuel use calculation:

- **kw rating x heat rate / HHV**
- **200,000 #/hr = 100 tph**

Ash content:

- **10% ash = 10 tph**

Particle Loading

	Bit	S-bit	Lig
Moisture %	3.1	23.8	45.9
VM %	42.2	36.9	22.7
FC %	45.4	29.5	21.8
Ash %	9.4	9.8	9.6
HHV Btu/#	12,770	8,683	4,469
# /10^6 Btu	7.4	11.3	21.5

Particle Loading

- 20 – 30 % bottom ash
- 80 – 70 % fly ash (entrained in flue gas)
- Ash accumulation (loss) in
  - Economizer
  - SCR
  - Air preheater
- 60 - 75% to PM control device

Particle Loading

- Assume that ESP is a black box
- Assume any efficiency of black box
- 10% increase in inlet loading
- 10% increase in outlet loading
- Example:
  - 10% increase in coal ash = 10% increase in emissions
  - 5% reduction in HHV = 5% increase in emissions
- ESP power reduced = lower efficiency

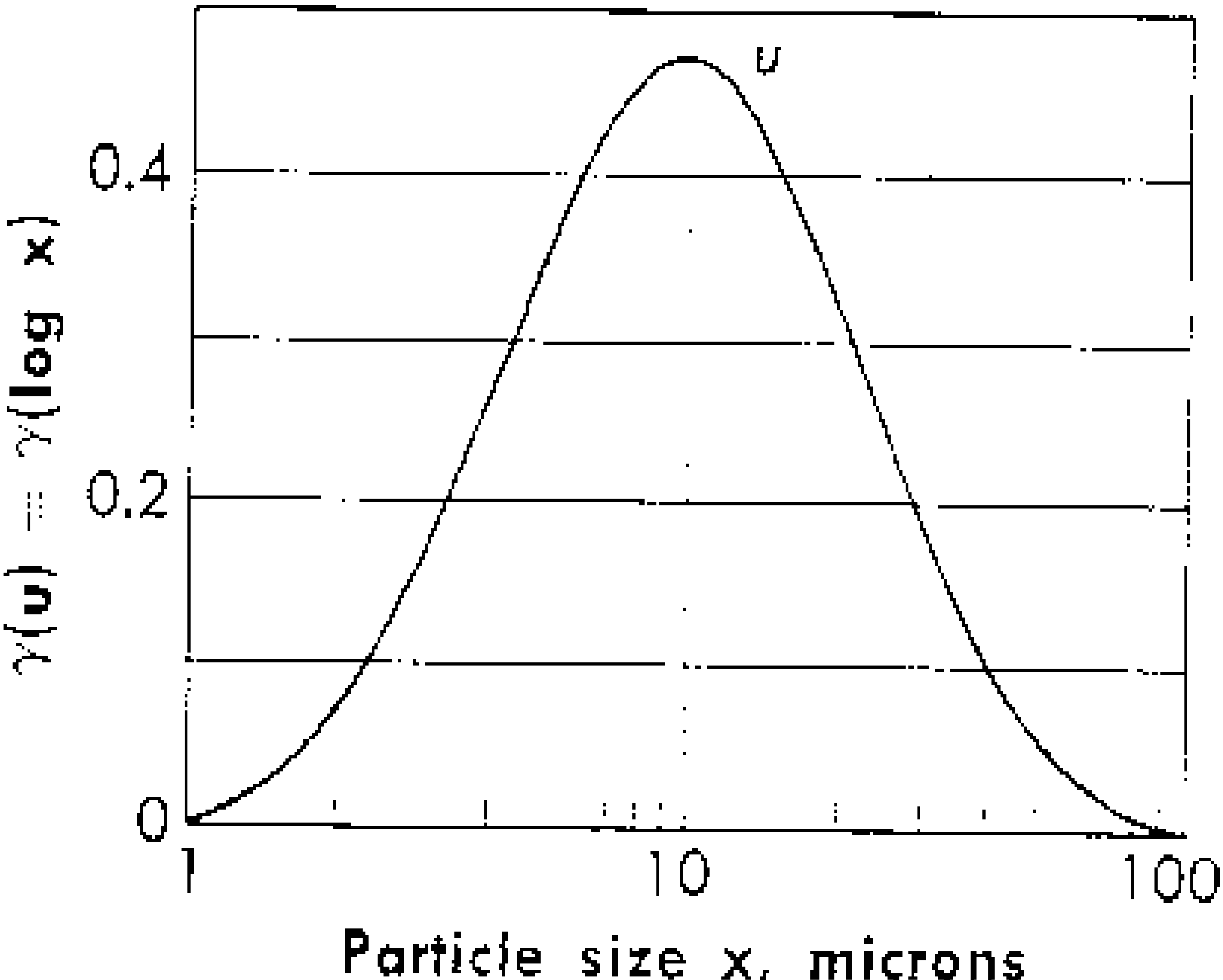
Particle Loading

- FF increase in particle loading means:
  - Higher pressure drop with same cleaning frequency
  - Higher cleaning frequency needed to maintain same pressure loss
  - Perhaps more intense cleaning also needed

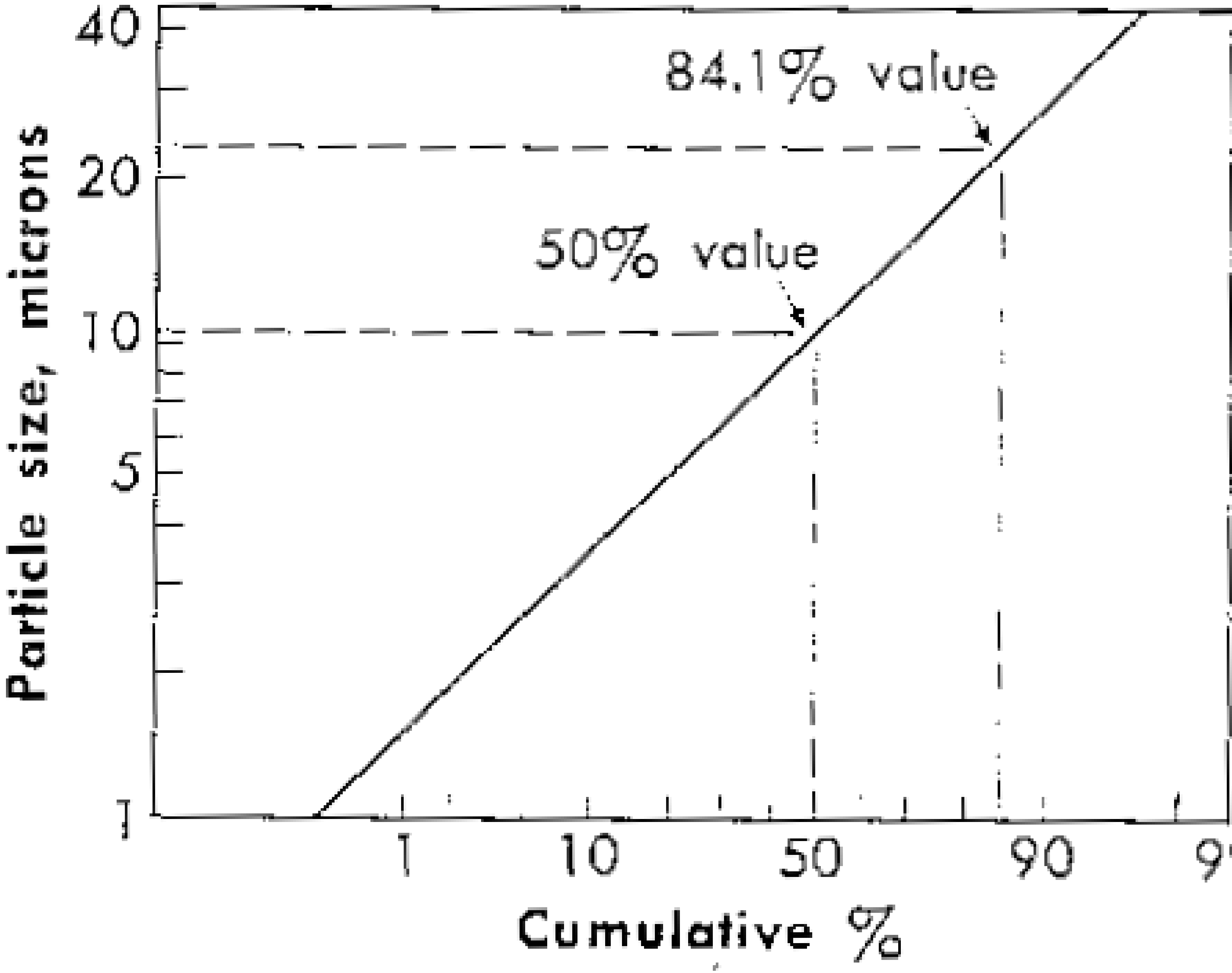
Particle Size

- Characterization of particle size
  - Assume a “normal distribution”
  - Mean particle diameter (μ) – microns or um
  - Standard deviation (σ)
  - Usually calculated by mass

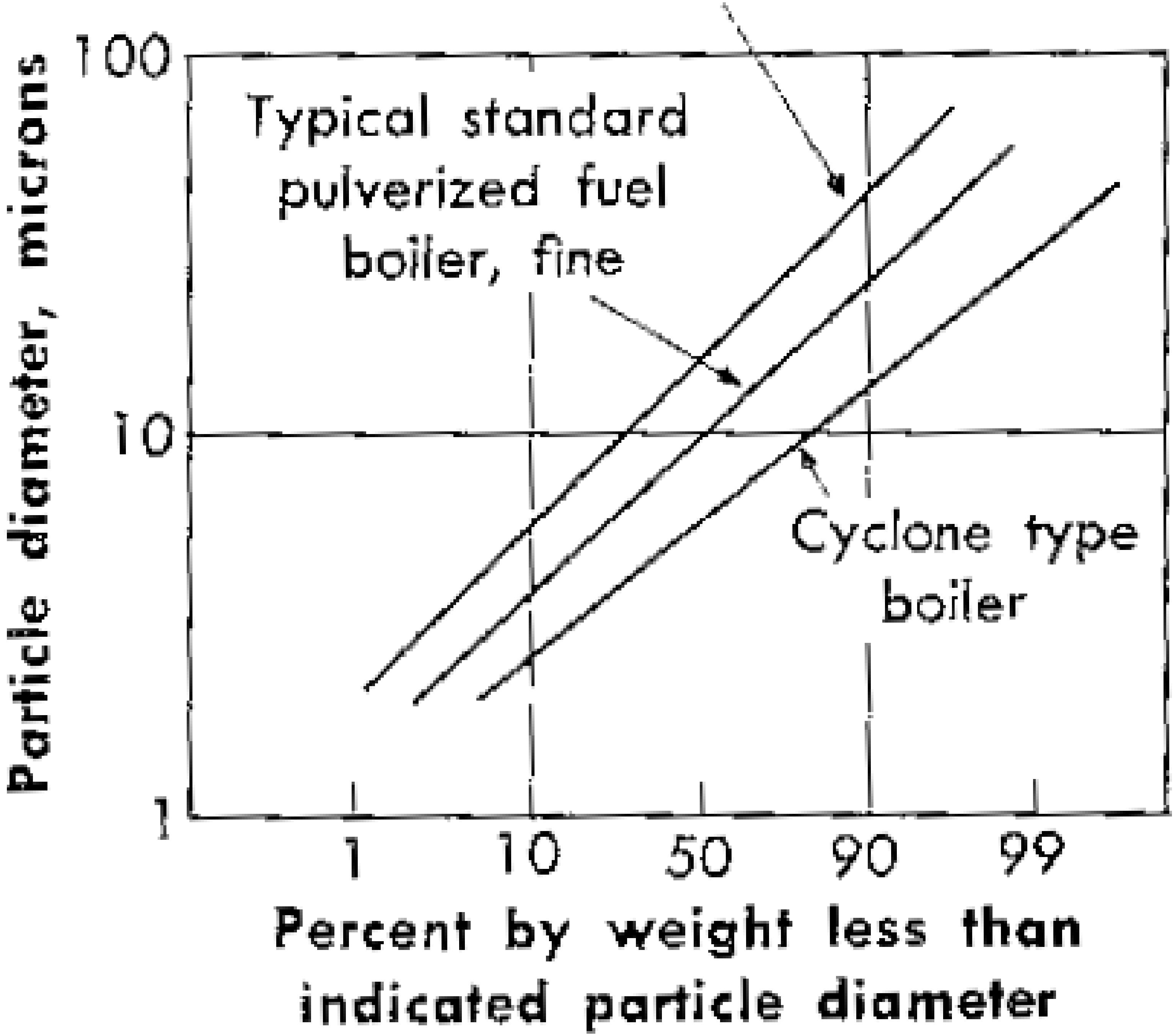
- Typical particle size
  - μ = 5 - 15 um
  - σ = 2 - 5



u
0.4
0.2
0
γ(u) = γ(log x)
1
10
100
Particle size x, microns

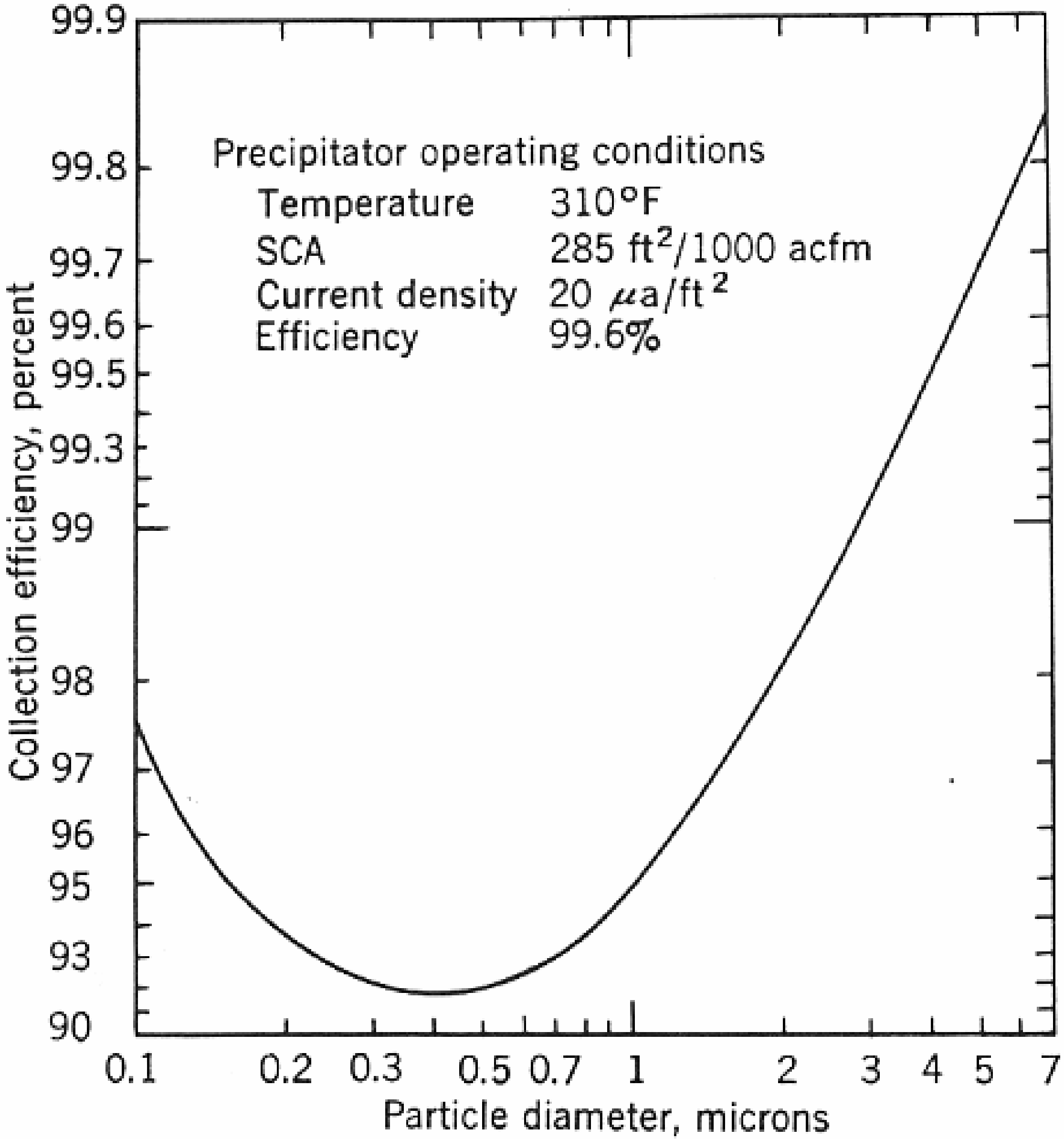


40
20
10
5
1
Particle size, microns
84.1% value
50% value
1
10
50
90
99
Cumulative %

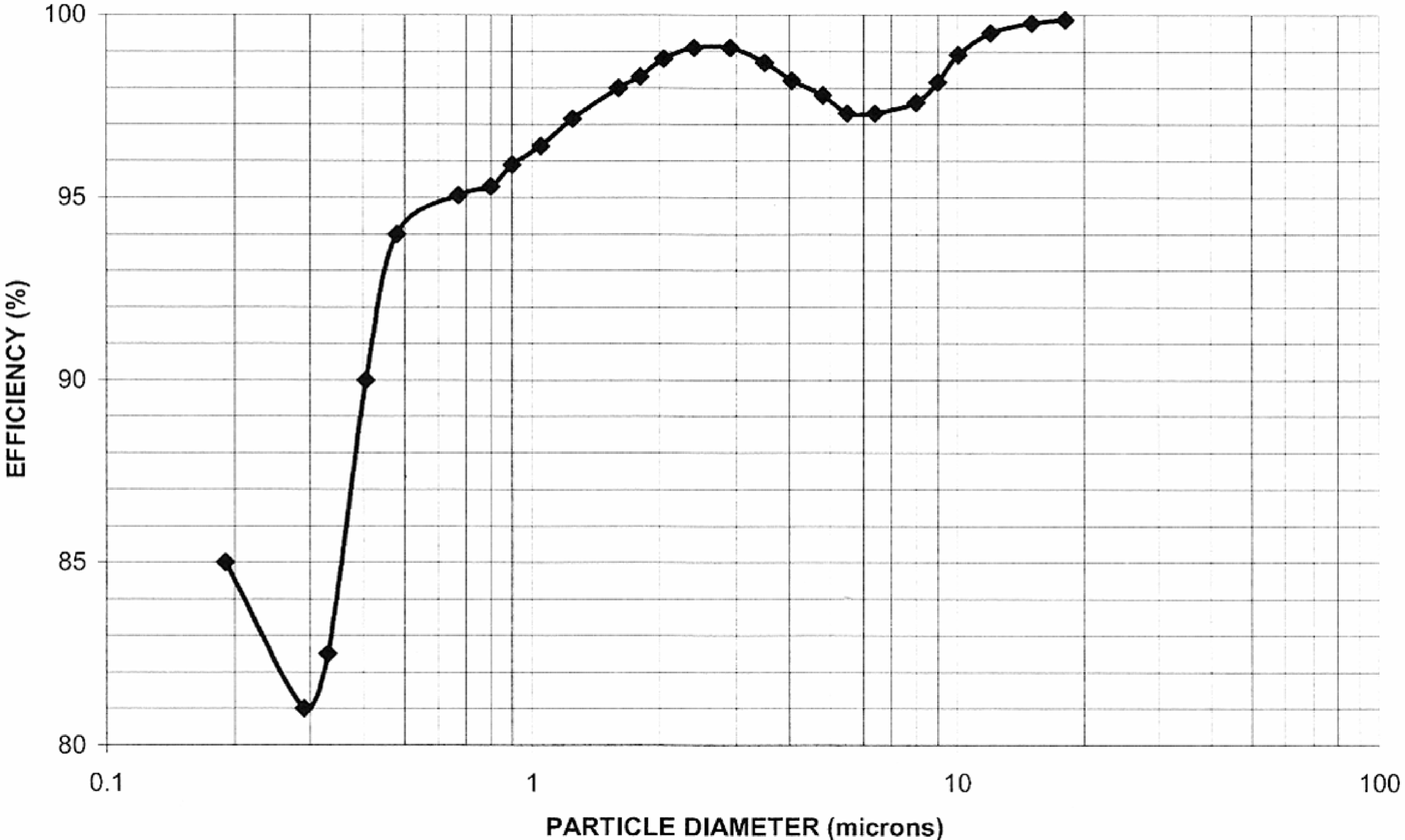


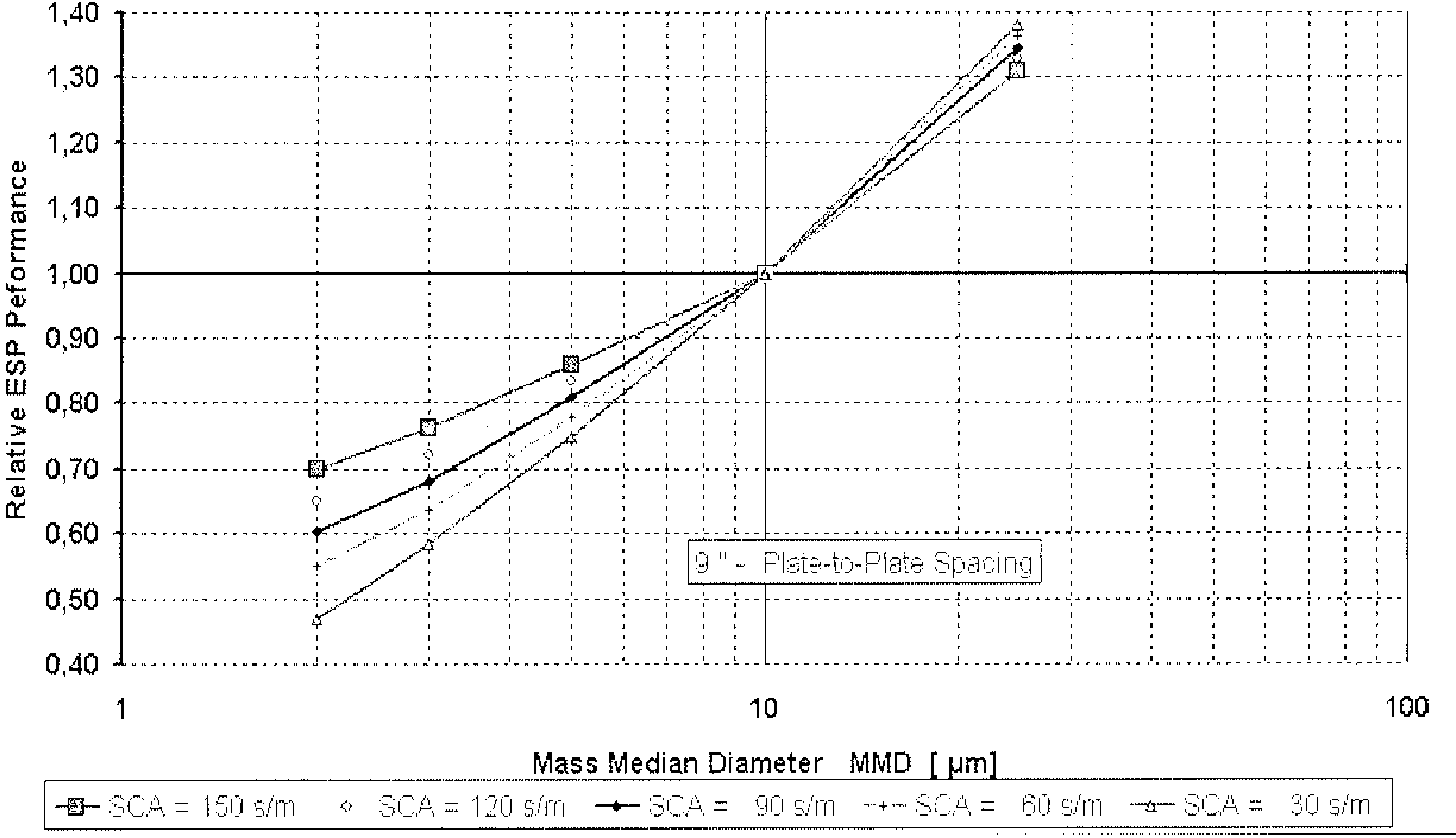
Particle diameter, microns
100
10
1
Typical standard pulverized fuel boiler, fine
Cyclone type boiler
1
10
50
90
99
Percent by weight less than indicated particle diameter

ESP Particle Size Performance



ESP EFF vs. Particle Size - EPRI





1,40
1,30
1,20
1,10
1,00
0,90
0,80
0,70
0,60
0,50
0,40
Relative ESP Peformance
1
10
100
Mass Median Diameter MMD [µm]
9 " - Plate-to-Plate Spacing
SCA = 150 s/m
SCA = 120 s/m
SCA = 90 s/m
SCA = 60 s/m
SCA = 30 s/m

Gas Volume

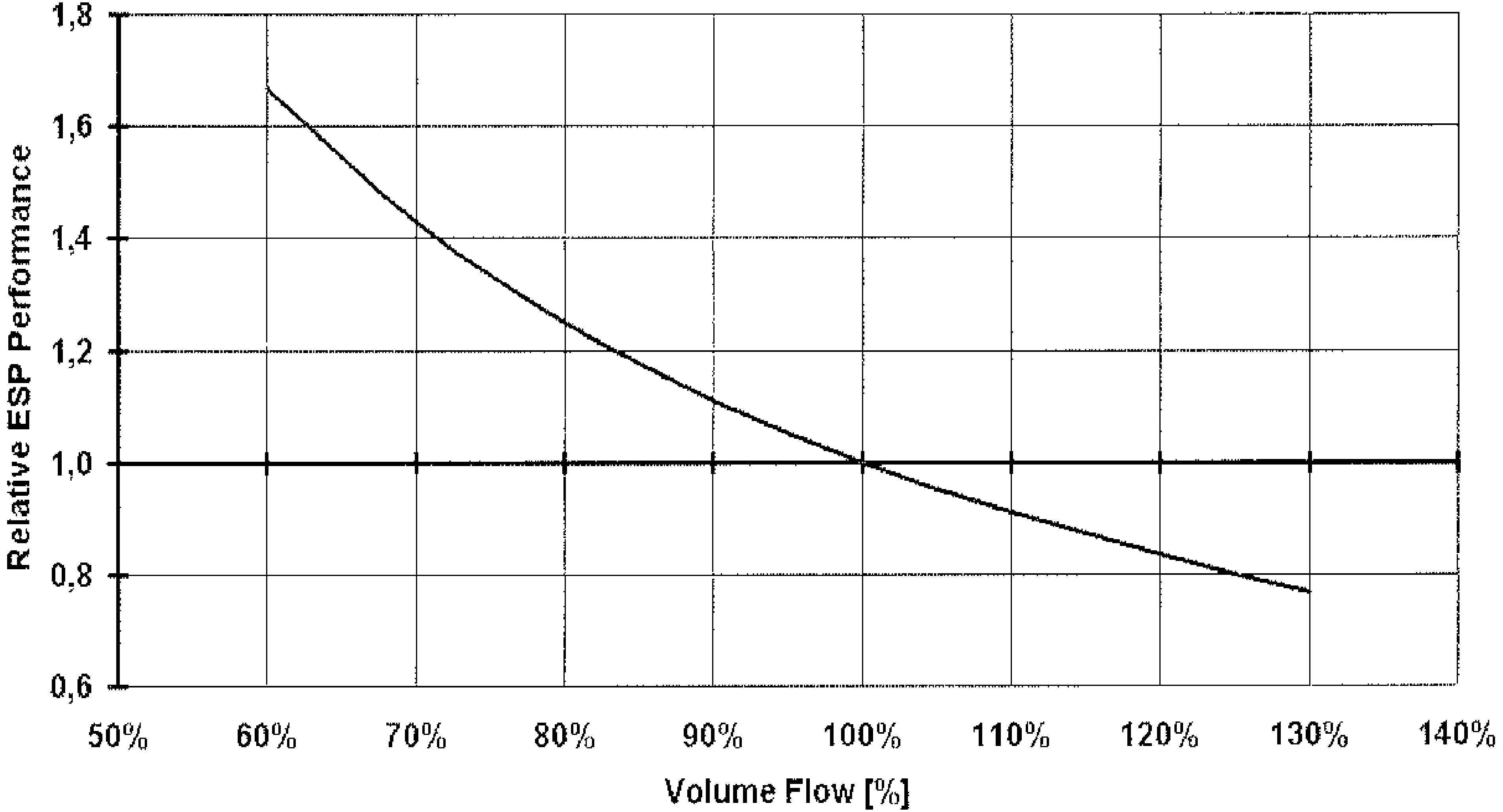
- **Gas volume determined by**
  - **Stoichiometric (theoretical) air required to burn coal based on its ultimate chemistry (C, H, N, O, H20)**
  - **Excess air – not a perfect world**
  - **Air inleakage**
    - **Expansion joints**
    - **Air preheated**
    - **Seals**
    - **Valves**

Ultimate Coal Analysis

Component	% by wt
Moisture	2.5
Carbon	75.0
Hydrogen	5.0
Sulfur	2.3
Nitrogen	1.5
Oxygen	6.7
Ash	7.0
Total	100.0

Flue Gas Volume - ESP

- Higher velocity through ESP
- Shorter treatment time
- More ash re-entrainment
- Lower efficiency


1,8
1,6
1,4
1,2
1,0
0,8
0,6
Relative ESP Performance
50%
60%
70%
80%
90%
100%
110%
120%
130%
140%
Volume Flow [%]

Flue Gas Volume - FF

- Higher A/C (air to cloth) ratio
- Higher filtration velocity
- Higher pressure loss
- More frequent cleaning
- Shorter bag life
- May drive finer particles through cloth and filter cake resulting in higher emissions

Flue Gas Composition

- CO_2
- H_2O
- O_2
- SO_2
- N_2

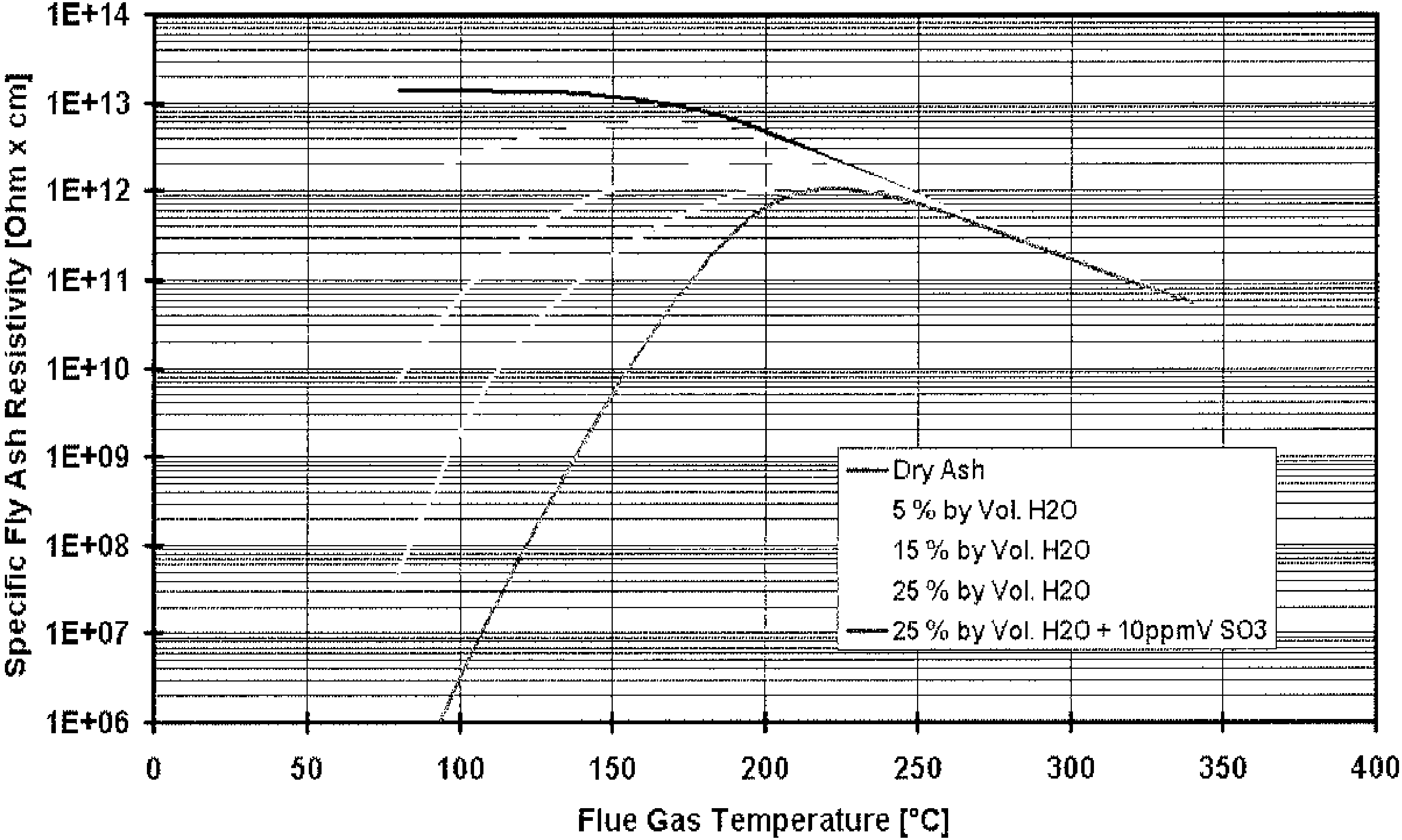
Flue Gas Composition

- **Moisture (H2O)**
  - **Inherent moisture in coal**
  - **Excess moisture: rain, snow**

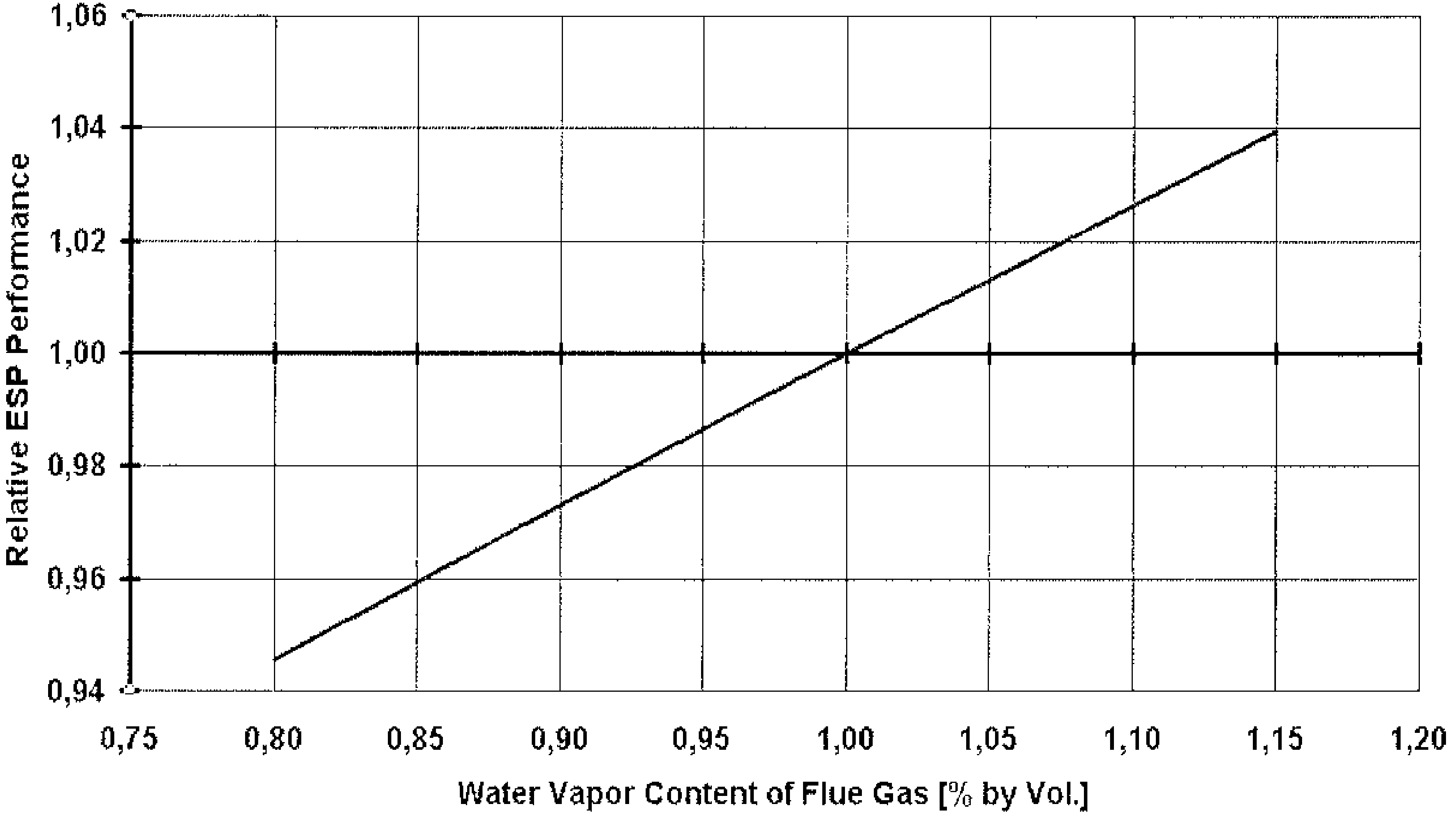
Gas Composition – H20

- ESP
  - Operate at higher KV, increased efficiency
  - Lower resistivity = higher efficiency
  - Ash more difficult to rap off electrodes
  - Potential hopper pluggage
- FF
  - May need more intense or more frequent cleaning of bags
  - Potential hopper pluggage

Fly Ash Resistivity vs. H2O



Effect of H2O on ESP



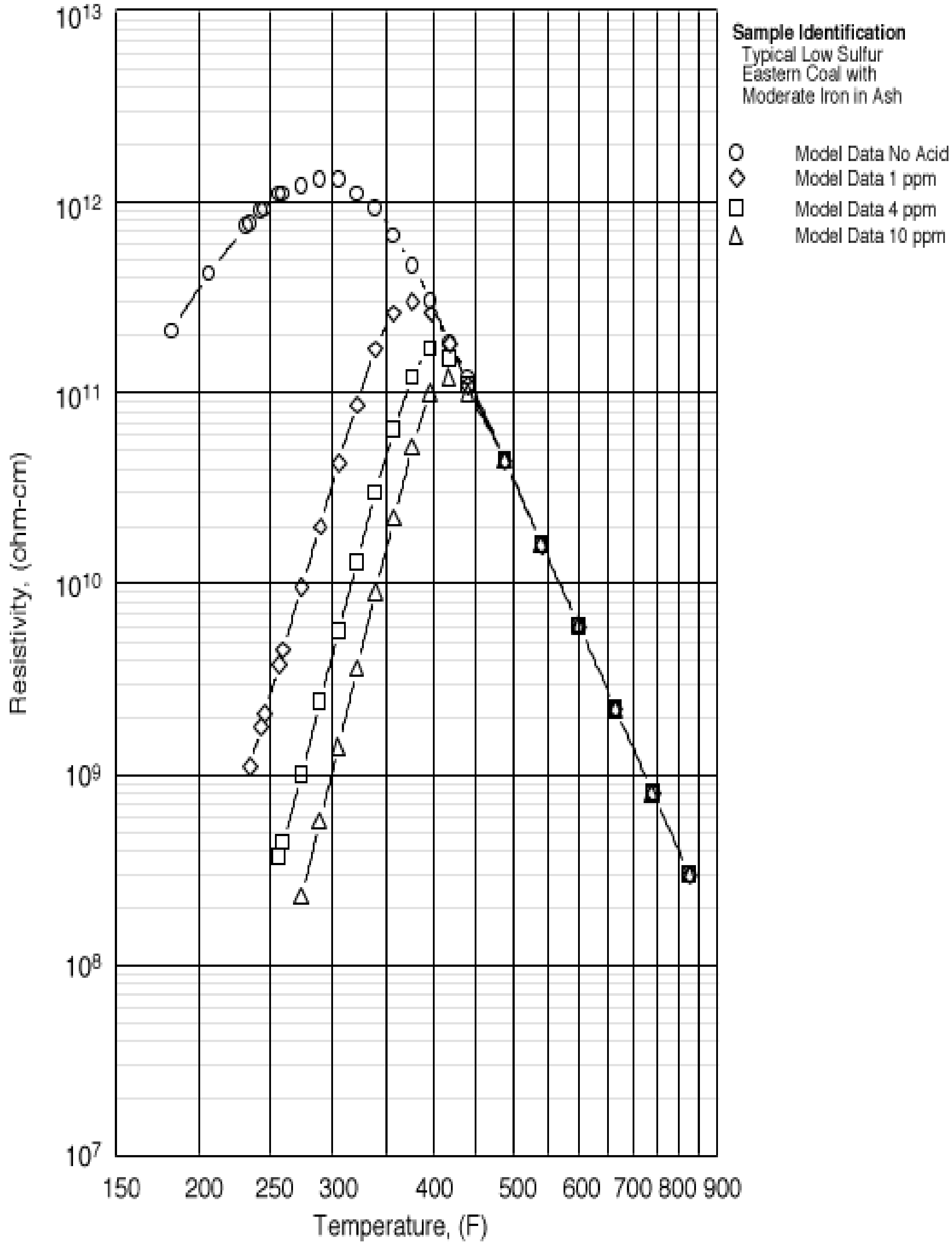
Flue Gas Composition

- SO_2 and SO_3
  - %S in coal
  - Formation on SO_2 (~700-900 PPM SO_2 / % S)
  - Conversion of SO_2 to SO_3
    - 0.4% rule of thumb
    - More with higher Fe content in ash
    - More with SCR due to catalyst

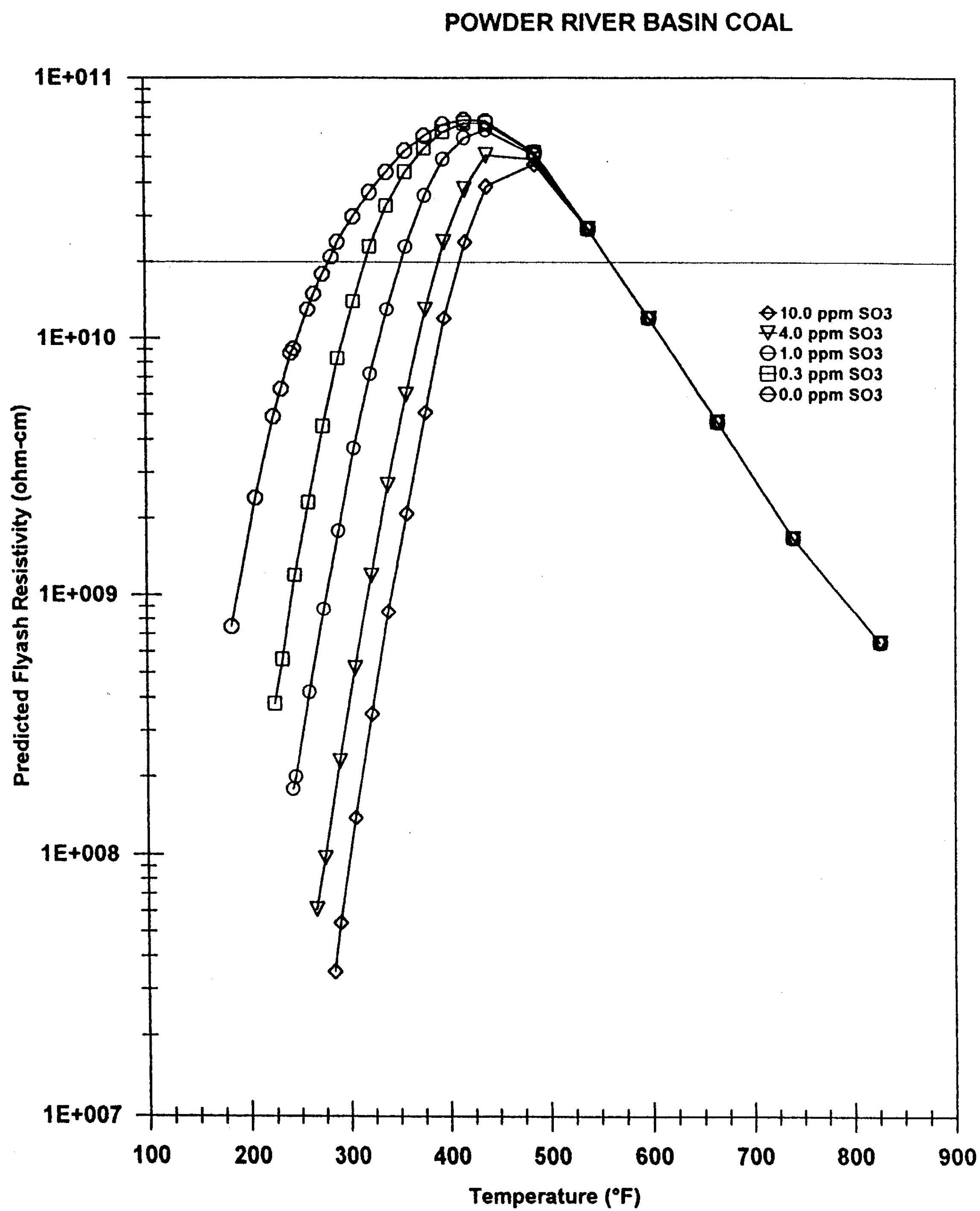
Gas Composition – SO_3

- **ESP**
  - **Higher SO_3**
  - **Lower Resistivity (ρ)**
  - **Higher efficiency**

- **FF**
  - **No significant effect**



Sample Identification
Typical Low Sulfur
Eastern Coal with
Moderate Iron in Ash
Model Data No Acid
Model Data 1 ppm
Model Data 4 ppm
Model Data 10 ppm
Resistivity, (ohm-cm)
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
150
200
250
300
400
500
600
700
800
900
Temperature, (F)


POWDER RIVER BASIN COAL
1E+011
1E+010
1E+009
1E+008
1E+007
Predicted Flyash Resistivity (ohm-cm)
100
200
300
400
500
600
700
800
900
Temperature (°F)
10.0 ppm SO3
4.0 ppm SO3
1.0 ppm SO3
0.3 ppm SO3
0.0 ppm SO3

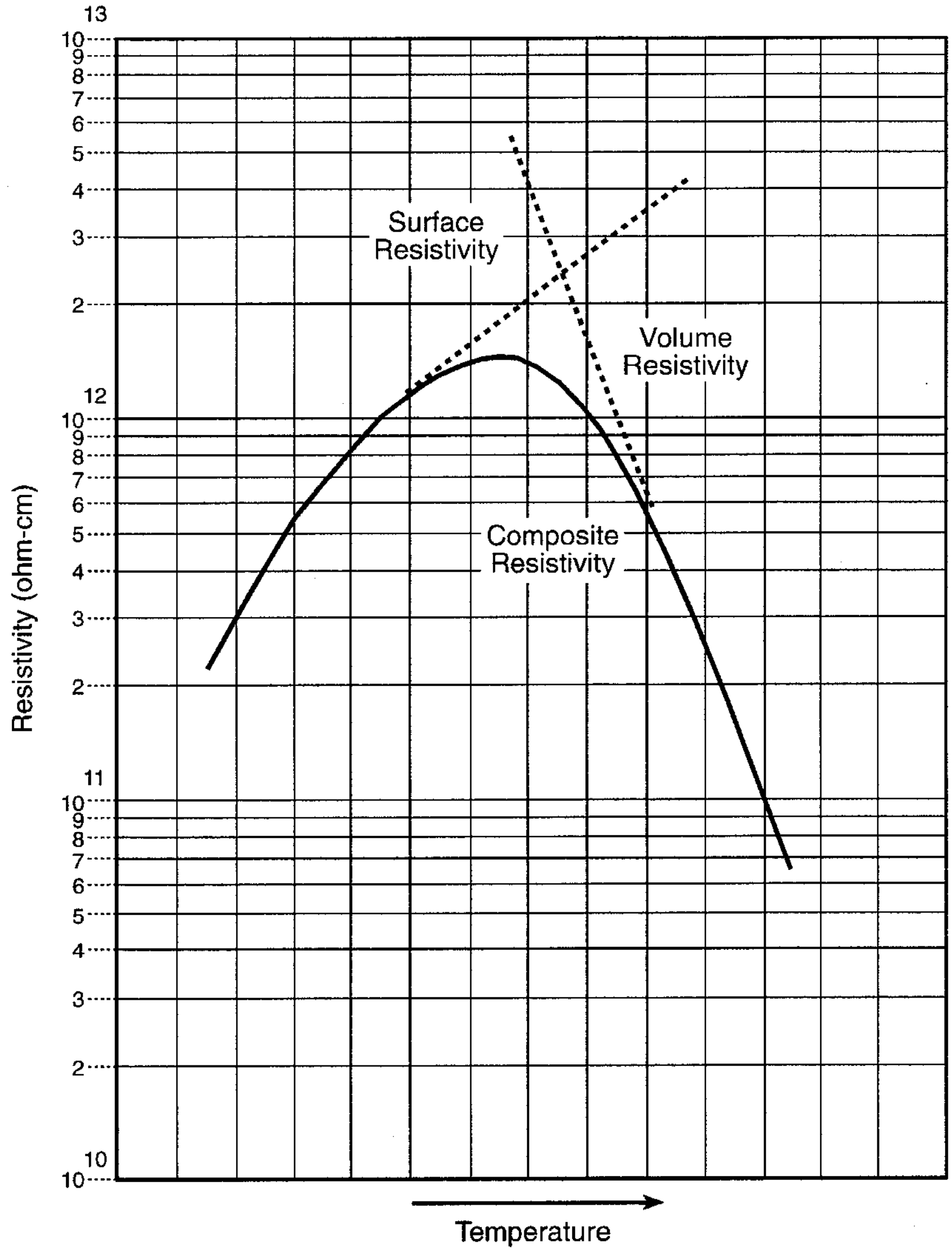
H_2O and SO_3

- Determine acid dew point
- Potential of additional corrosion
- Potential for heavier, stickier ash
- Potential cleaning problems
- Potential hopper evacuation problems

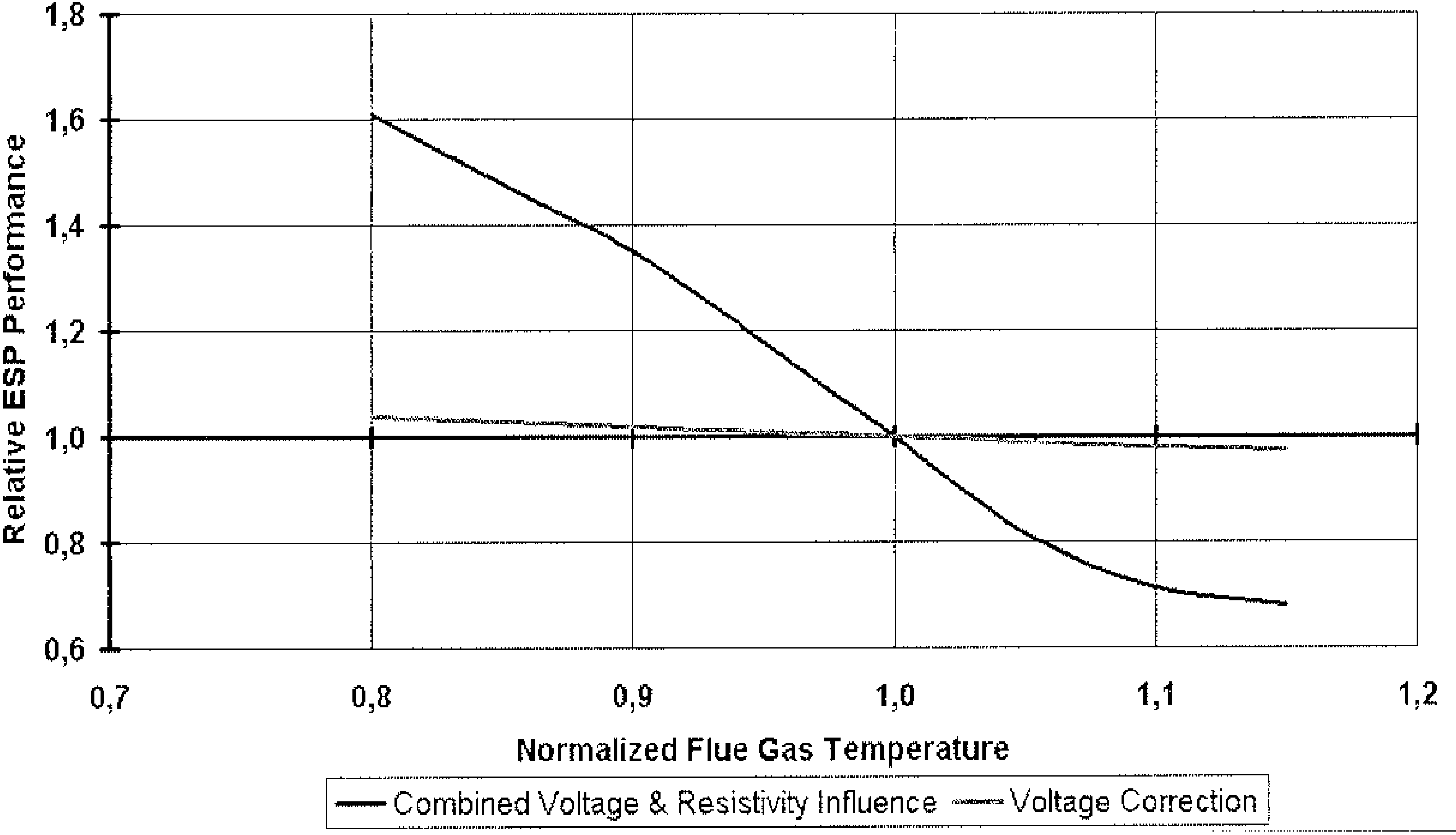
Gas Temperature

- ESP
  - Affects ash resistivity
  - Impacts ESP efficiency

- FF
  - No significant effect


13
10
9
8
7
6
5
4
3
2
12
10
11
10
Resistivity (ohm-cm)
Surface Resistivity
Volume Resistivity
Composite Resistivity
Temperature

Temperature Impact on ESP



Carbon in Ash

- Proximate analysis
  - Volatile matter and fixed carbon
- Volatile matter
  - Rapid oxidation may form soot (unburned carbon)
  - due to local O2 deficiency
- Fixed Carbon
  - Burns by surface reaction – O2 diffusion
  - If coal not ground fine enough, it can result in “char” – unburned carbon

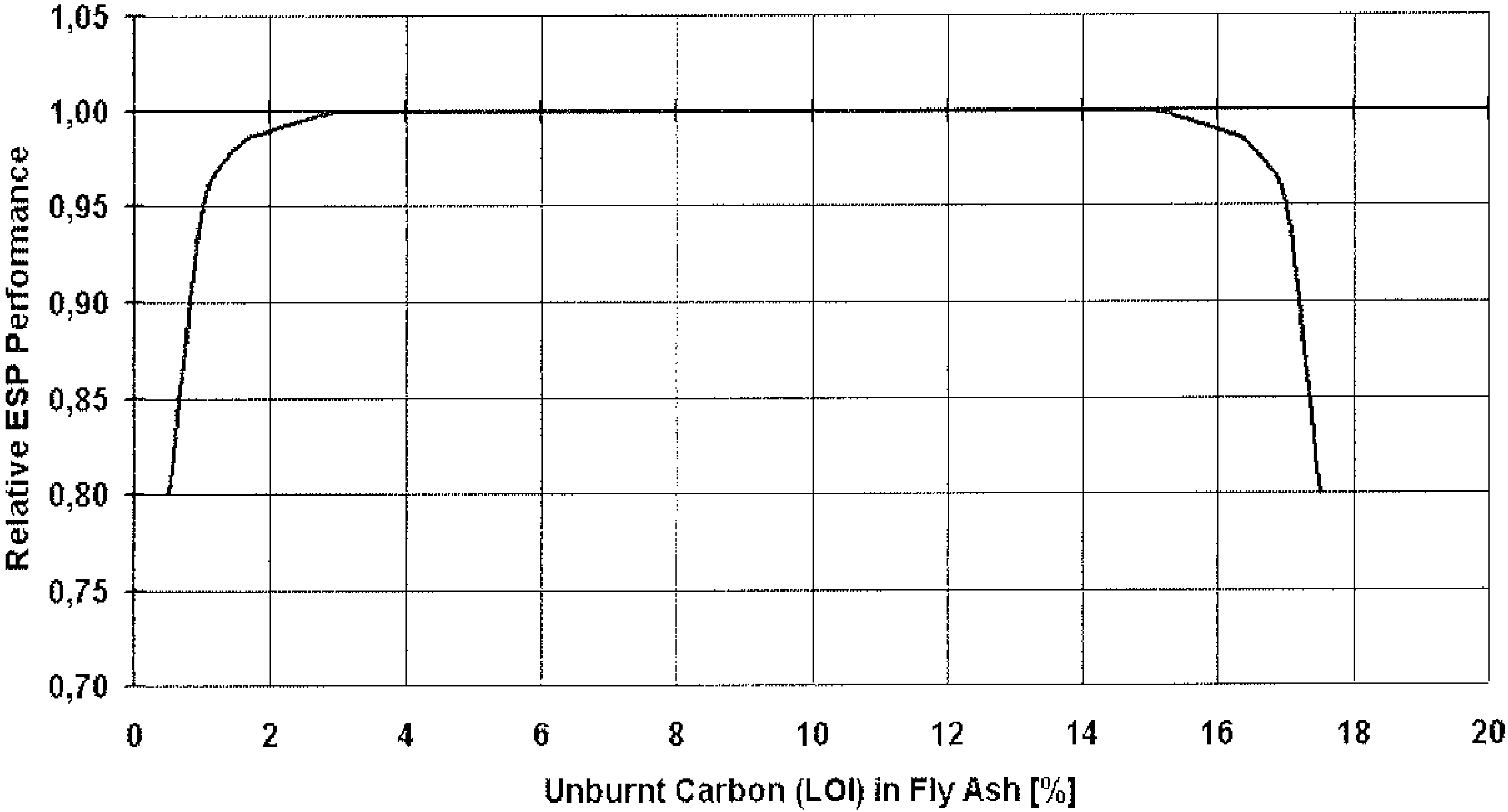
Carbon in Ash

- **Loss on ignition / unburned carbon**
  - **Represents boiler efficiency loss**
  - **1 - 25% in ash**
  - **Soot: finer PM**
  - **Char: larger PM**

Carbon in Ash

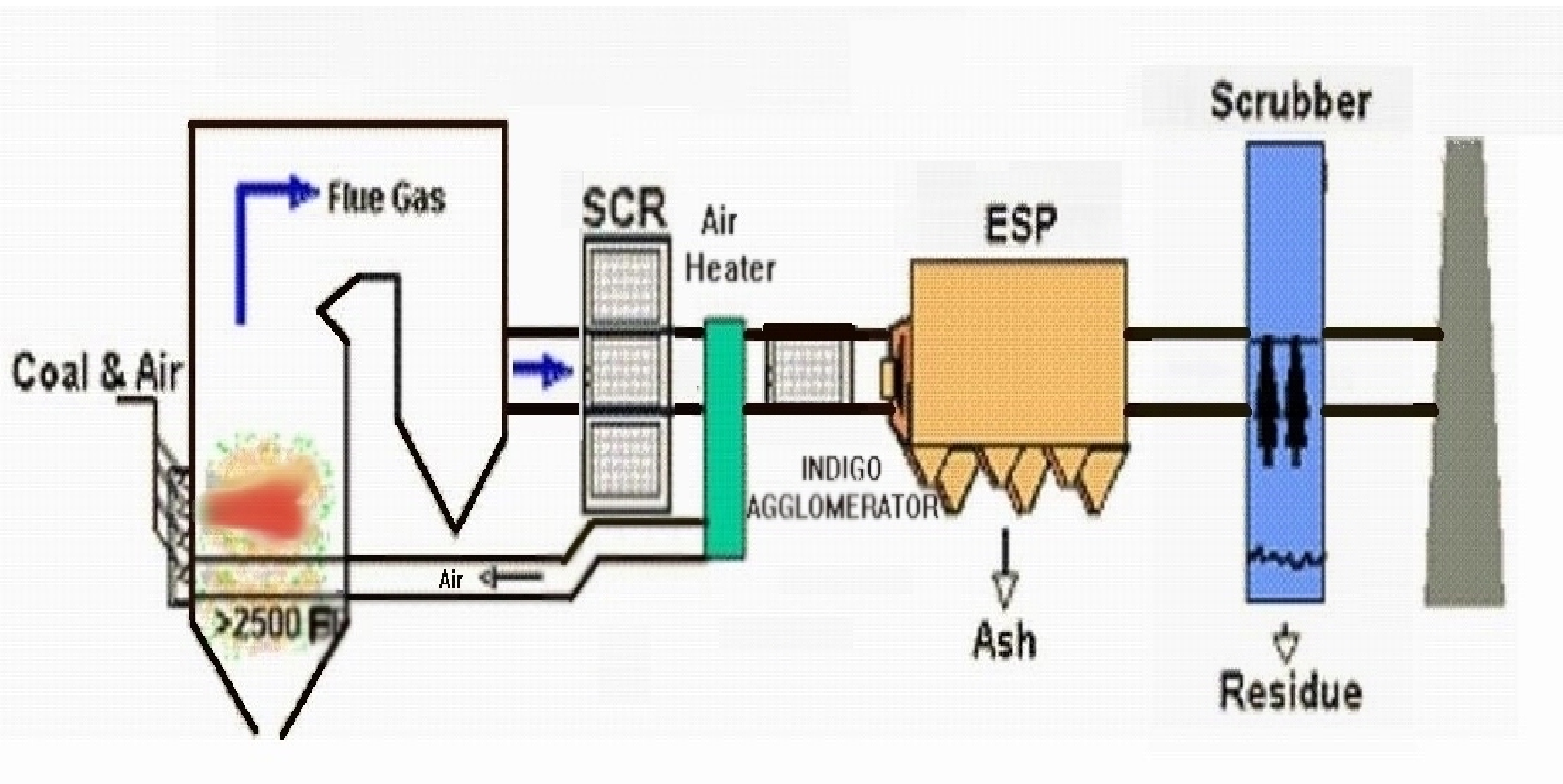
- Potential problems
  - High C in ash can make it unsellable
  - C is difficult for ESP to retain
  - Soot can lead to higher opacity due to fineness and blackness
  - Potential of hopper fires
  - Contamination of ESP insulators

Carbon Effect on ESP



SCR

- **SO_2 to SO_3 conversion**
- **Ammonia (NH_3) slip**


Scrubber
Flue Gas
SCR
Air
Heater
ESP
Coal & Air
INDIGO
AGGLOMERATOR
Air
>2500 F
Ash
Residue

SO_2 to SO_3 Conversion

- Typical conversion: 0.4%
- Fe in ash can more than double that
- SCR can add 0.5 – 2.0% more
- Conversion as high as 3%
- 3% S coal with 1.5% conversion
- 36 ppm SO_3

High SO3

- **Higher acid dew point can lead to corrosion**
- **SO3 emissions – “blue plume”**
- **May need to inject absorbent**
  - **Lime**
  - **Trona**

Ammonia Slip

- Contamination of ash may make it unsellable
- Nuisance odor problem

SO3 and NH3

- Can form sodium bisulfate
- Fine white particulate
- Sticky: makes fly ash stickier
- May result in more difficult electrode cleaning in ESP and bag cleaning in FF
- Small amounts can be beneficial to ESP
- May cause APH pluggage
  - High pressure loss
  - Forced outage for cleaning

Summary

- **Combustion Effects**
  - **Particulate: Loading, size**
  - **Flue gas: Volume, temperature, composition**
  - **Carbon content**

- **SCR**
  - **SO_2 to SO_3 conversion**
  - **NH_3 slip**