Coal Combustion Inc.
Understanding the business of coal

# Coal Combustion Chemistry
# Sulfur 101

or why rocket scientists have it easy

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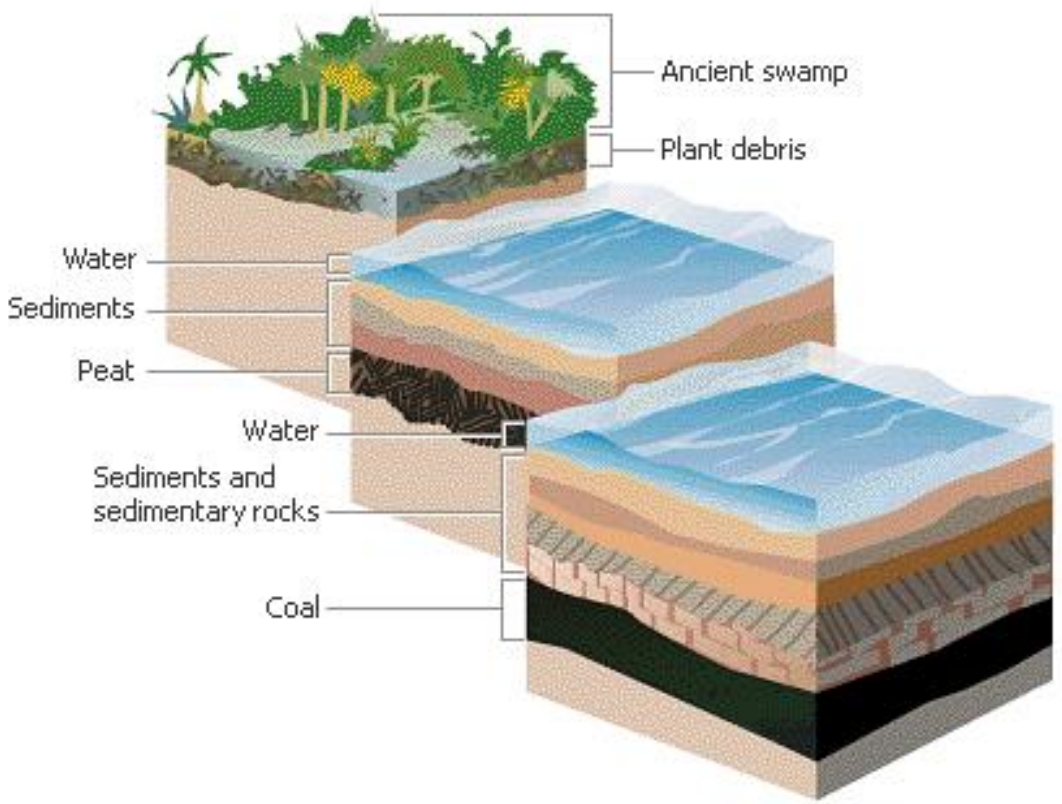
# Sulfur in Coal –

**Bad to the bone**

- **Slag**
- **Fouling deposits**
- **Pluggage**
- **Corrosion**
- **Pollution**
- **Money $**

# All coal has sulfur
# It comes from sea water vs. fresh water environment



# Sulfur in Coal

Coal typically
is 0.3 to 4.0%
Sulfur

# Sulfur can be in two main forms:

## Organic

## Pyritic

# Organic

# H-C-C-S-C-C-H

# sulfur is attached to coal carbon

# Pyritic

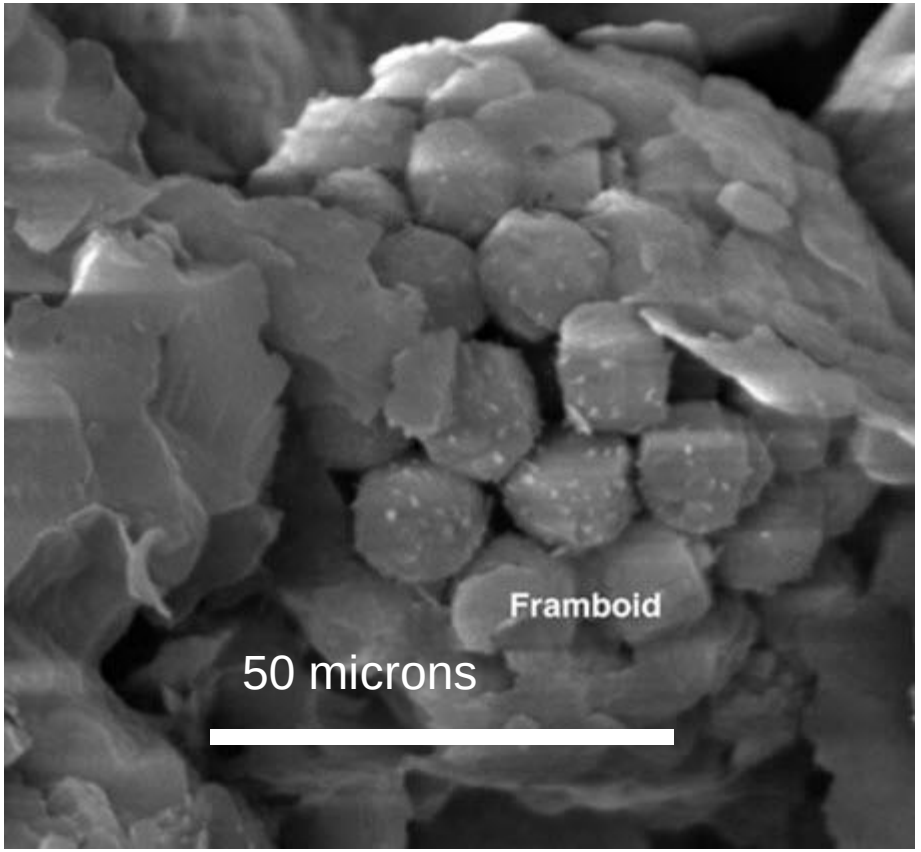
# $FeS_2$

# sulfur is attached to iron in fool's gold


$FeS_2$

**Large sulfur balls can be washed out or rejected by pulverizers**

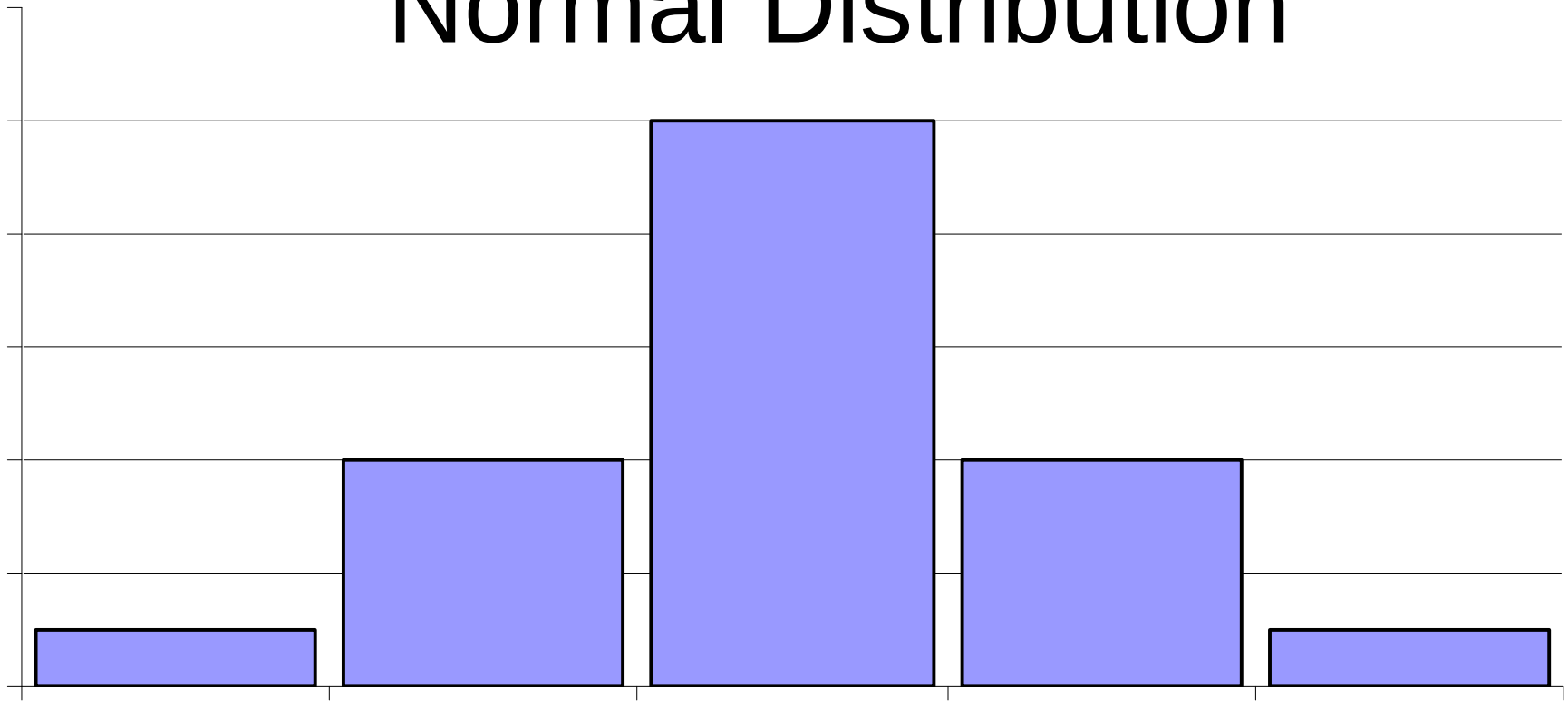
**Small framboids (raspberries) of pyrite are mixed in with the coal**



# Cleat

**pyrite has to be ground up**

# Normal Distribution



Quality Parameter

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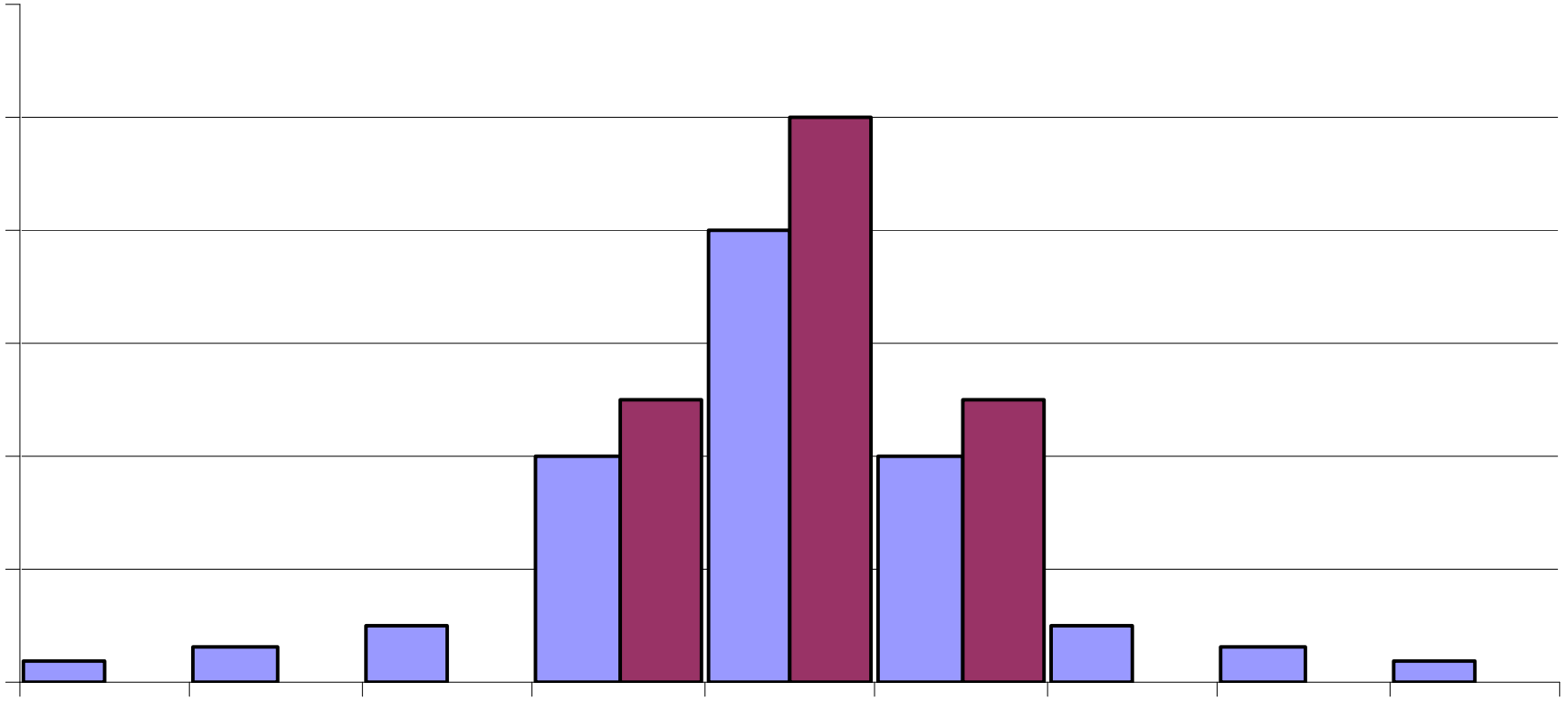
# Small and Large Variability



Quality Parameter

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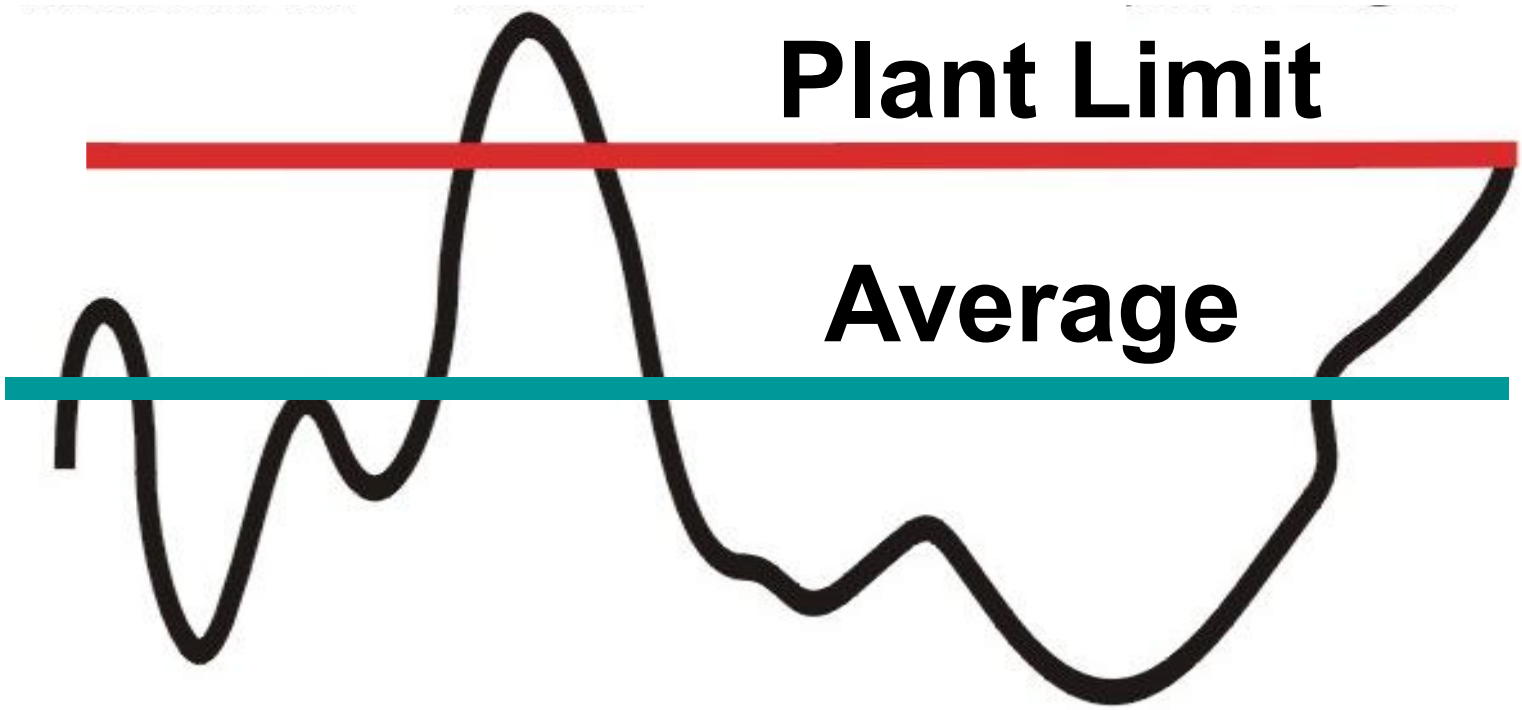
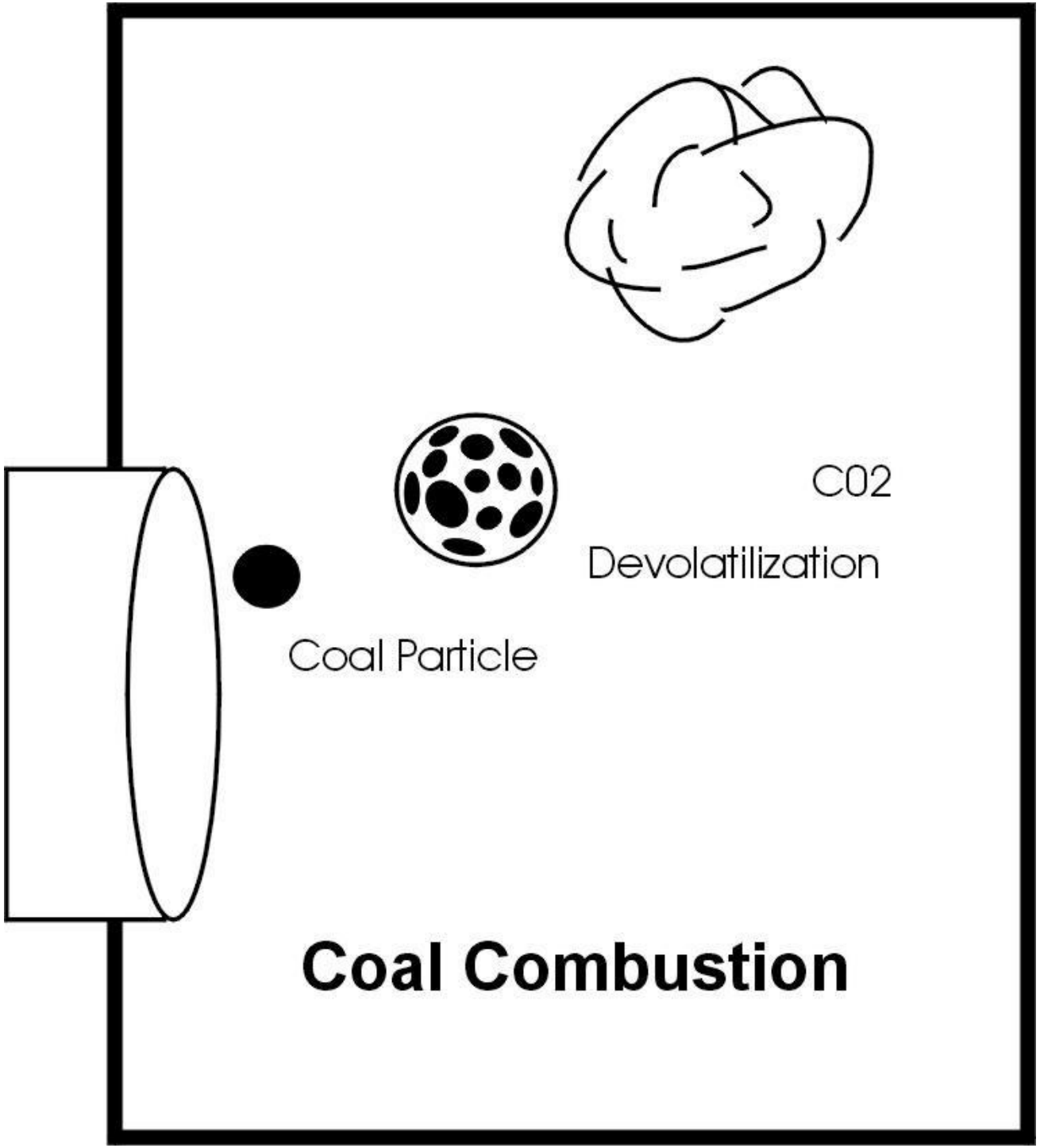
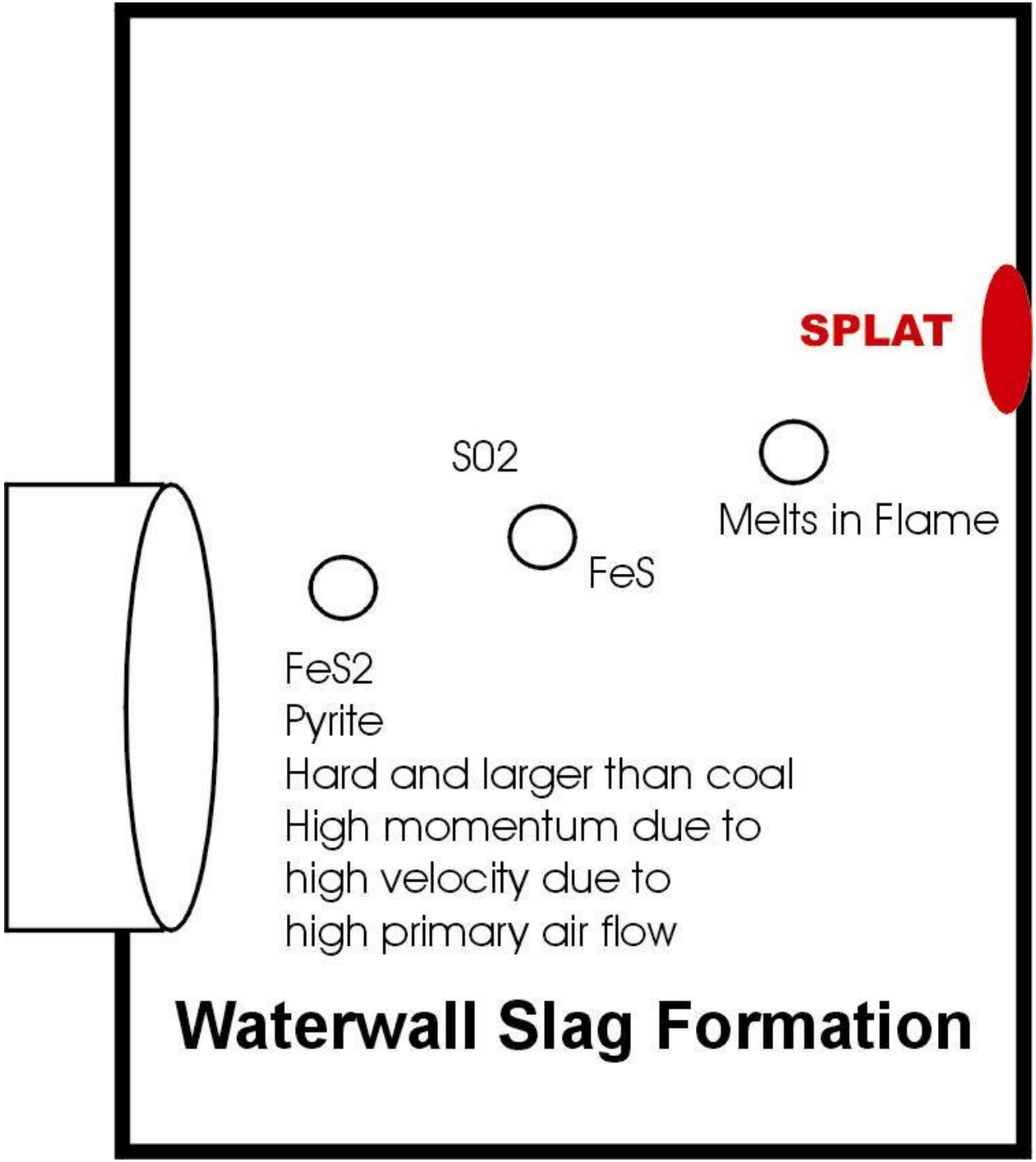



Does this coal met spec?


C02
Devolatilization
Coal Particle
Coal Combustion


SPLAT
SO2
Melts in Flame
FeS
FeS2
Pyrite
Hard and larger than coal
High momentum due to
high velocity due to
high primary air flow
Waterwall Slag Formation

# Fusion Spread Ox-Red

| Iron Level | delta Temp. |
|---|---|
| 5 | 20 |
| 10 | 70 |
| 20 | 200 |
| 25 | 300 |

# Role of Iron

| Acid | Base |
| --- | --- |
| $Fe_2O_3$ | FeO |
| | $Fe_3O_4$ |
| Oxidized | Reduced |
| Good | Poor |

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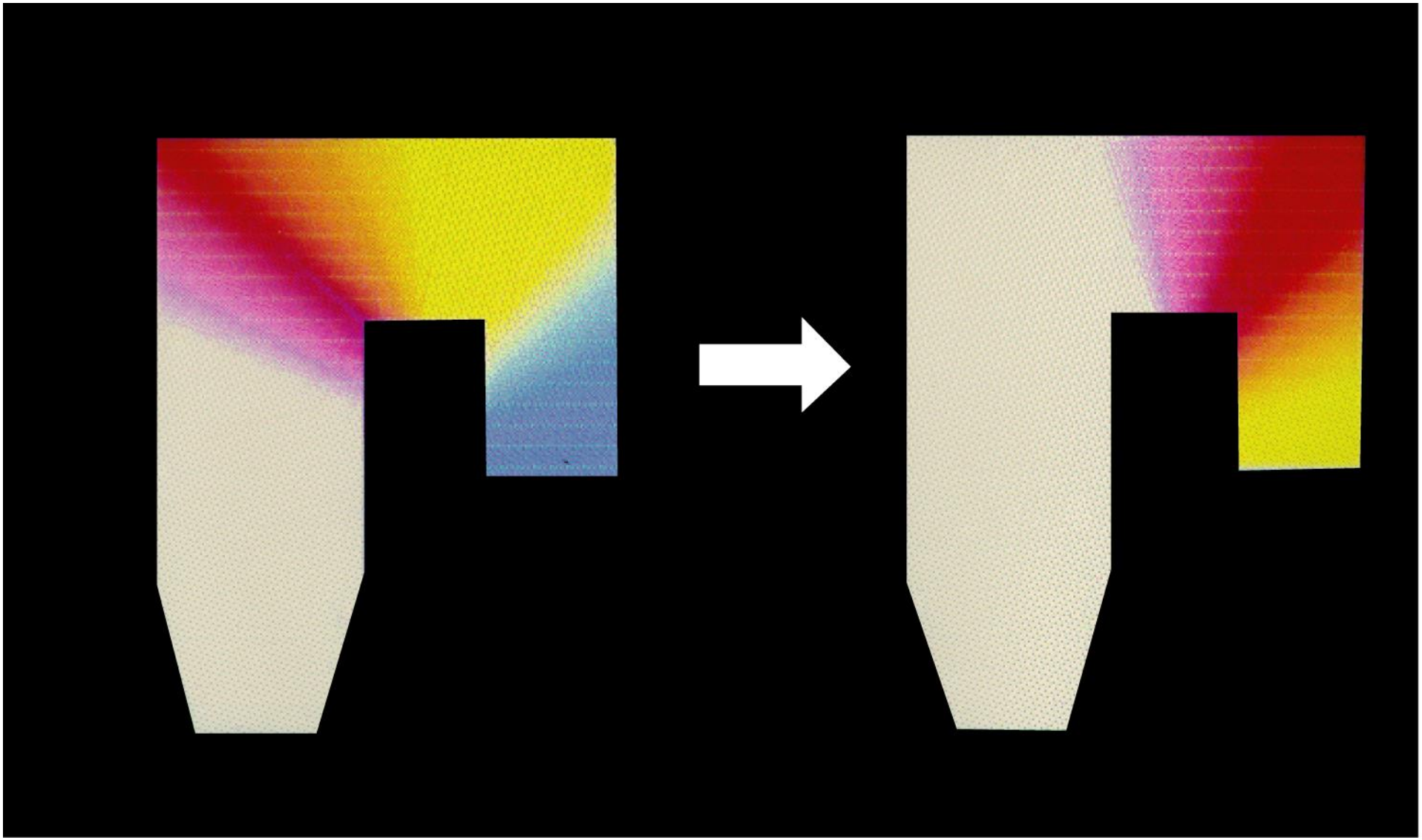


**Waterwall deposits force heat to convection pass.**

# Waterwall Corrosion ï  Tube Leaks

# SO2 to SO3

Conversion
is excess
oxygen sensitive

# Sulfur burns to $SO_2$

# Then some $SO_2$ burns

$Fe_2O_3$ – pyrite, boiler, slag

$$SO_2 + \tfrac{1}{2}\, O_2 \longrightarrow SO_3$$

$V_2O_5$ – Oil, Petcoke, SCR

# More Reactants ?

**Sulfur in Coal --- SO2**

**Excess Oxygen (helps slag)**

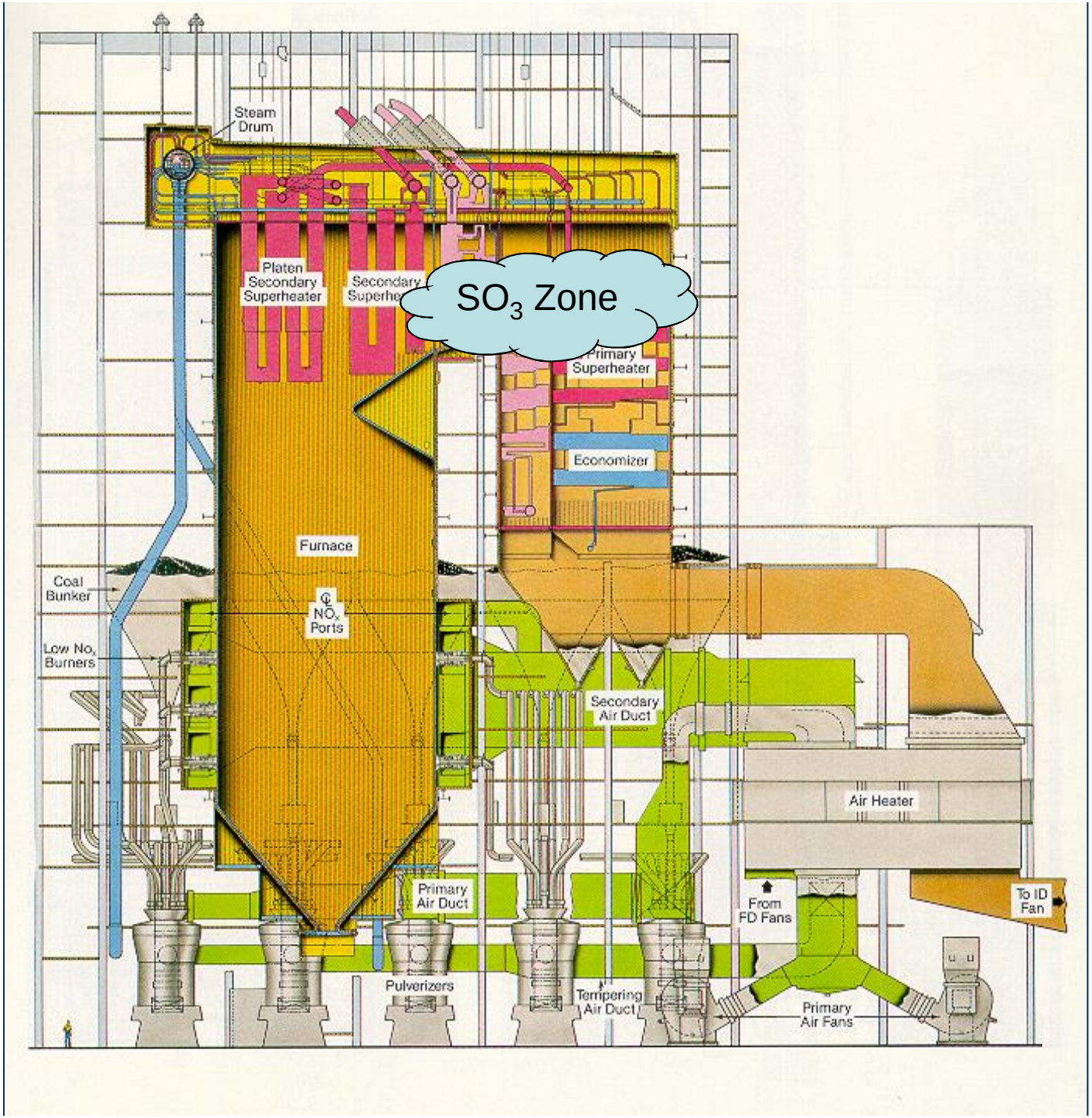
# More catalyst?

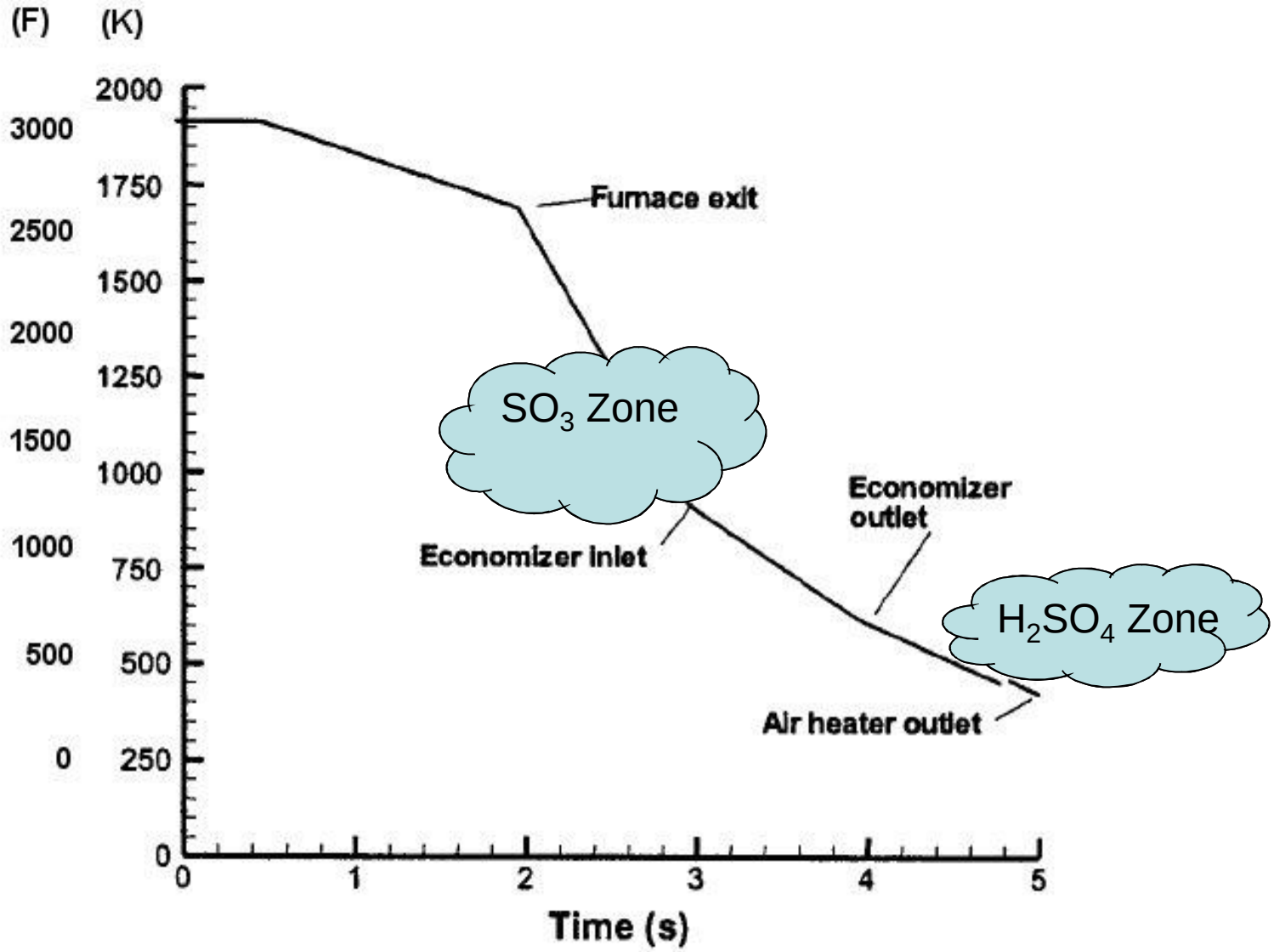
**Pyrite $FeS_2$**

**Slag $Fe_3O_4$, $Fe_2O_3$**

**SCR**

**Vanadium $V_2O_5$ in fuel**


Steam Drum
Platen Secondary Superheater
Secondary Superhe
$SO_3$ Zone
Primary Superheater
Economizer
Furnace
Coal Bunker
$NO_x$ Ports
Low $NO_x$ Burners
Secondary Air Duct
Air Heater
Primary Air Duct
From FD Fans
To ID Fan
Pulverizers
Tempering Air Duct
Primary Air Fans




**Temperature-time history for a coal-fired power plant (from Senior et al., 1999)**

# So

- High Excess Air can make more SO3
- Low Load operation with high Excess air can make more SO3
- High sulfur coals can make more SO3
- Unbalance combustion verses balanced can make more SO3

# Fouling Deposits

## Think Fluid Bed Boiler

$$CaO + SO_3 = CaSO_4$$

**PRB convection pass fouling**

**and it can be harder to measure SO3 with high alkalis (Na, K) and alkaline earths (Mg, Ca) in coal**

# After the economizer

## $SO_3$ combines with $H_2O$

## $SO3 + H_2O \longrightarrow H_2SO_4$

## to form sulfuric acid

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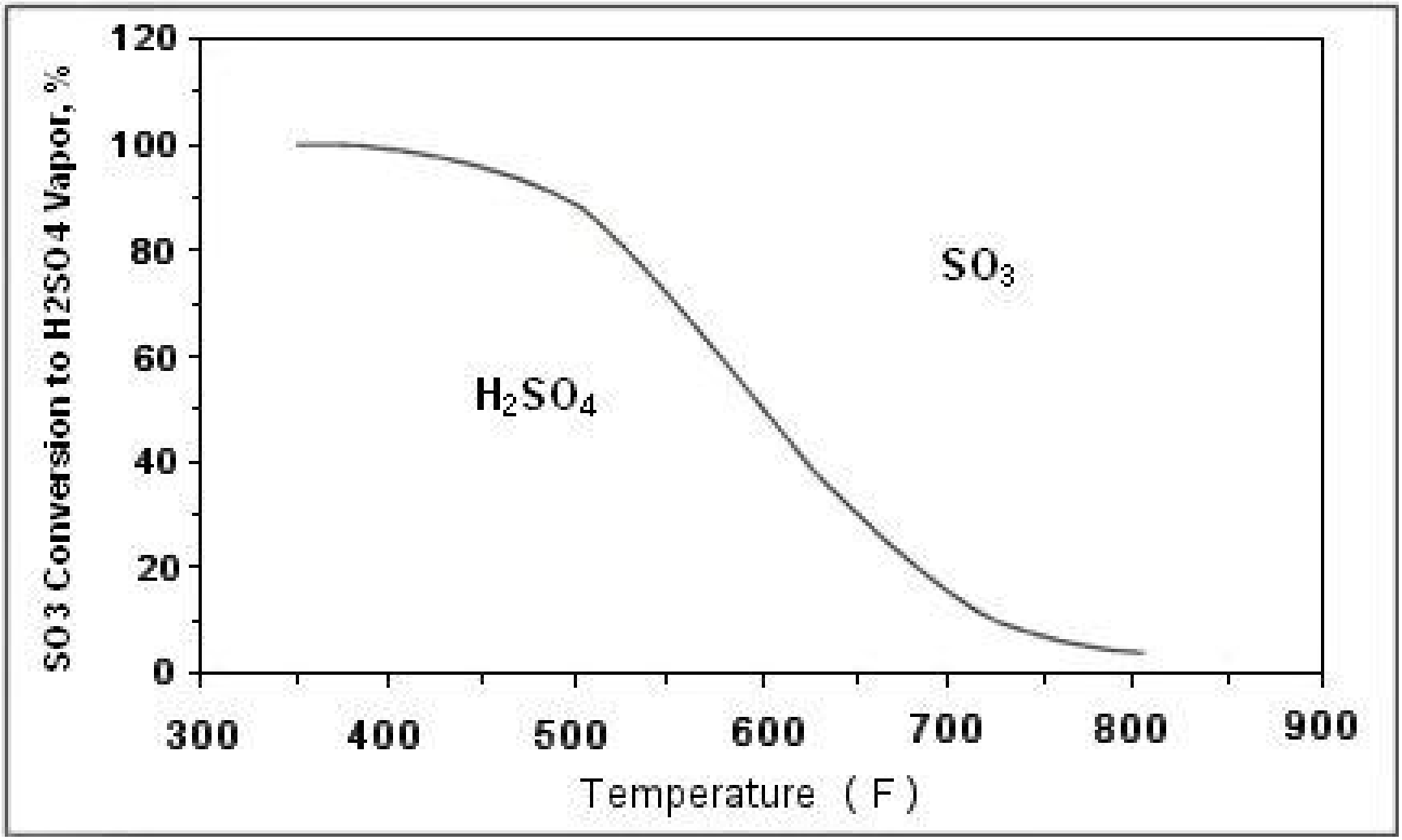
SO3 Conversion to H2SO4 Vapor, %
120
100
80
60
40
20
0
300
400
500
600
700
800
900
Temperature ( F )
$SO_3$
$H_2SO_4$

thanks Cal

$H_2SO_4$ combines with all sorts of stuff to plug, foul, corrode and then it can leave the stack and form a visible plume of smoke

**sulfuric acid mist SAM**

# Industry Examples

Walhco $SO_3$
Orimulsion
Cold End Corrosion

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# SO3 = lbs SO2/MBtu x 4

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## Dynamic Calculation of H2SO4 Vapor Loading

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# Dynamic Calculation of H2SO4 Vapor Loading

- Measure or Estimate typical SO2 to SO3 conversion at typical excess O2 setting
- Typically conversion rate (CR) is 1 to 1.5 %

**base SO3 = SO2 x CR**

**= 1200ppm x 0.012**

**= 14.4ppm SO3**

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# Oxygen Impact on Furnace SO3

- Measure or Estimate typical SO2 to SO3 conversion at several excess O2 settings
- Plot O2 verses SO3 and determine liner or exponential relationship

**Actual SO3 = (base SO3 +excess O2 SO3) or**

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# Oxygen Impact on Furnace $SO_3$

- Determine Nominal Furnace Conversion at Normal $O_2$
  - 0.5% - 1.5% (Variable "X")
- Determine Furnace Conversion at Elevated $O_2$
  - Example: 1% Conversion at 3%
  - 2% Conversion at 6%
- Determine Conversion Rate Sensitivity
  - 0.33% Delta per 1% of $O_2$ (Variable "Y")

- Actual SO3 into the SCR =
  - SO2 * (X + (Y*($O_2$ Delta)))

# Thank you Breen