Changing Basins Changing Expectations

By Rod Hatt

Coal Combustion Inc.

Understanding the business of coal

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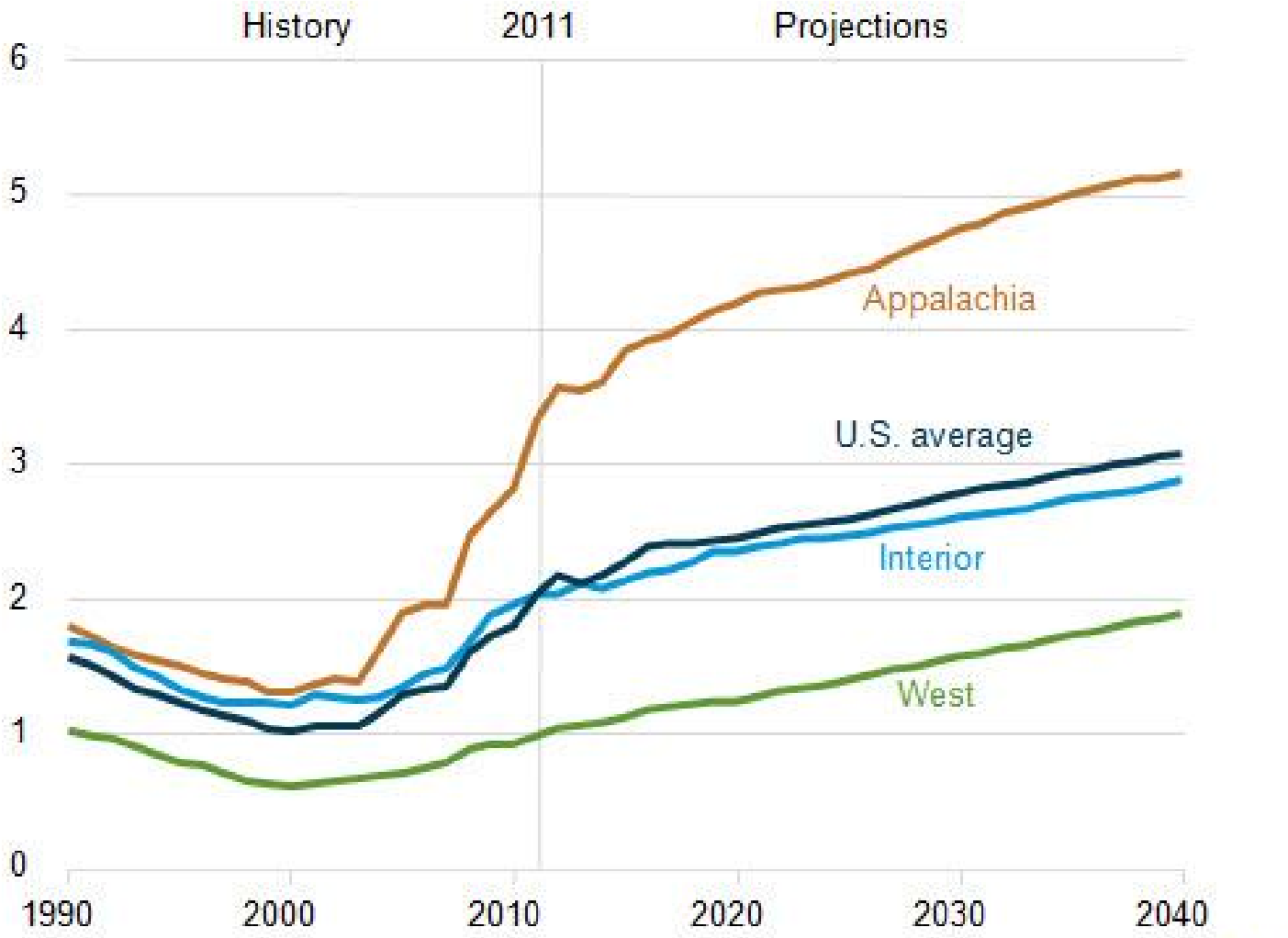
Contacts:

Rod Hatt

859-873-0188

rod_hatt@coalcombustion.com

Figure 106. Average annual minemouth coal prices by region, 1990-2040 (2011 dollars per million Btu)



Why Change?

- Pollution
- Economics
- Deals

Every one else is doing it

Major US Coal Fields

Changing Expectations

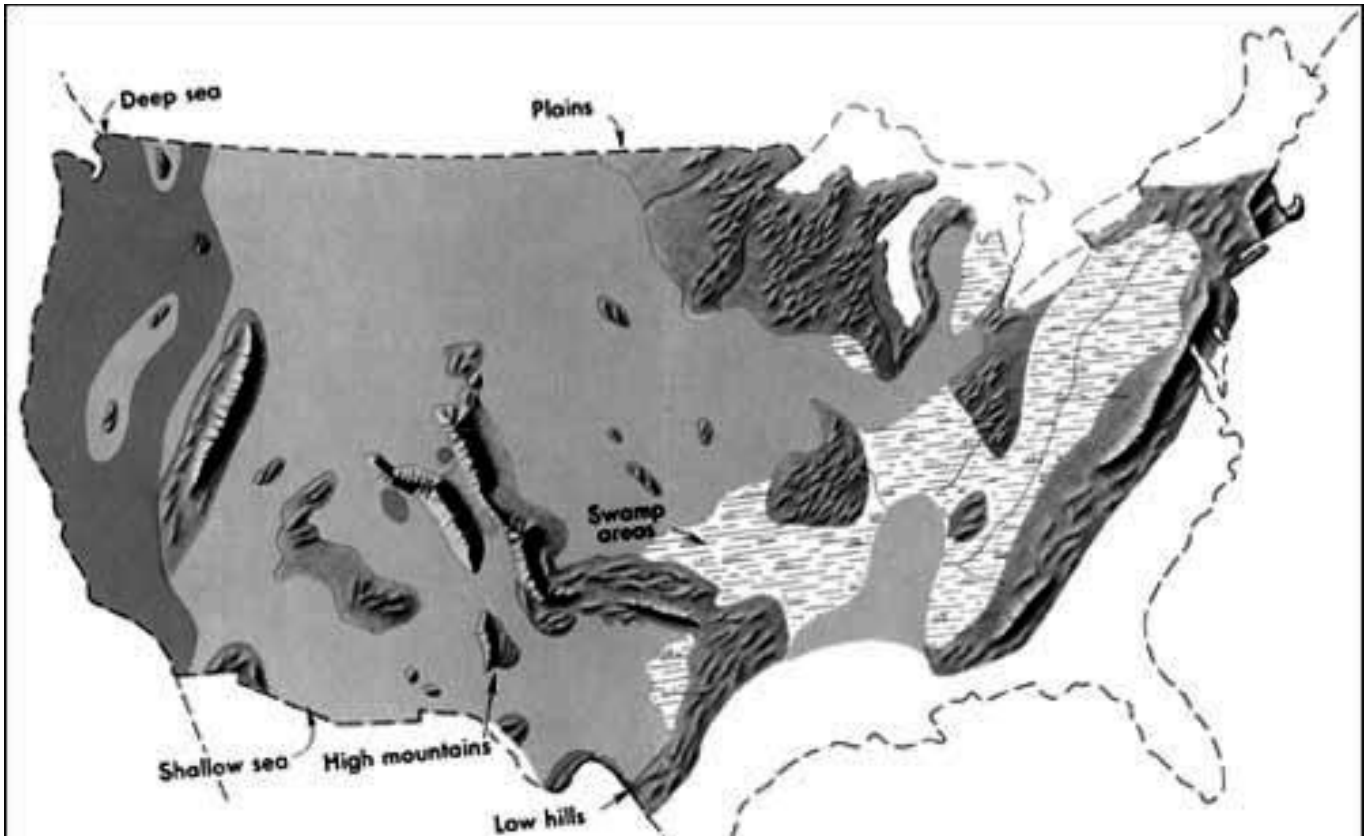
What can Change

- Heat rate / Efficiency
- Aux Load / Net Power
- Coal Handling – Wet Coal, Dust,
  - Spontaneous Combustion,
  - Total Tons
- Pollution Levels
- Ash characteristics
- Slagging and Ash Deposits
- Tube leaks
- Derates and Forced Outages
- ect.ect....

Geology

The world was different when Eastern US coal was growing:

- CO_2 levels were high ~7000 ppm.
- Most of America was under water.
- The Appalachian Mountains were up to 30,000 feet high.
- There was a big swamp from New York to Texas.



Coal Properties

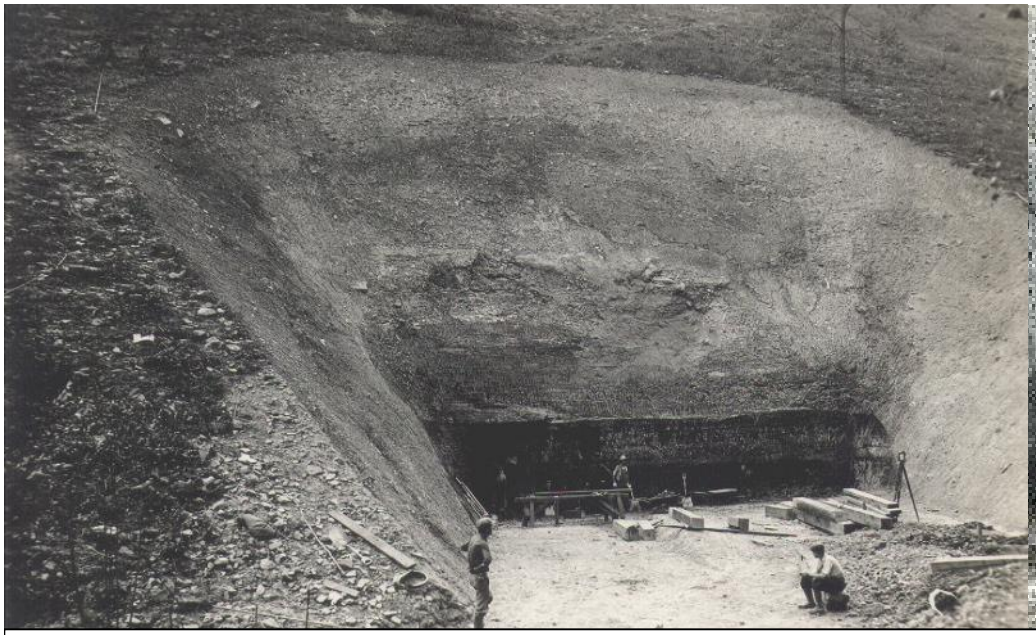
Coal Geology

High Btu, older more mature coal

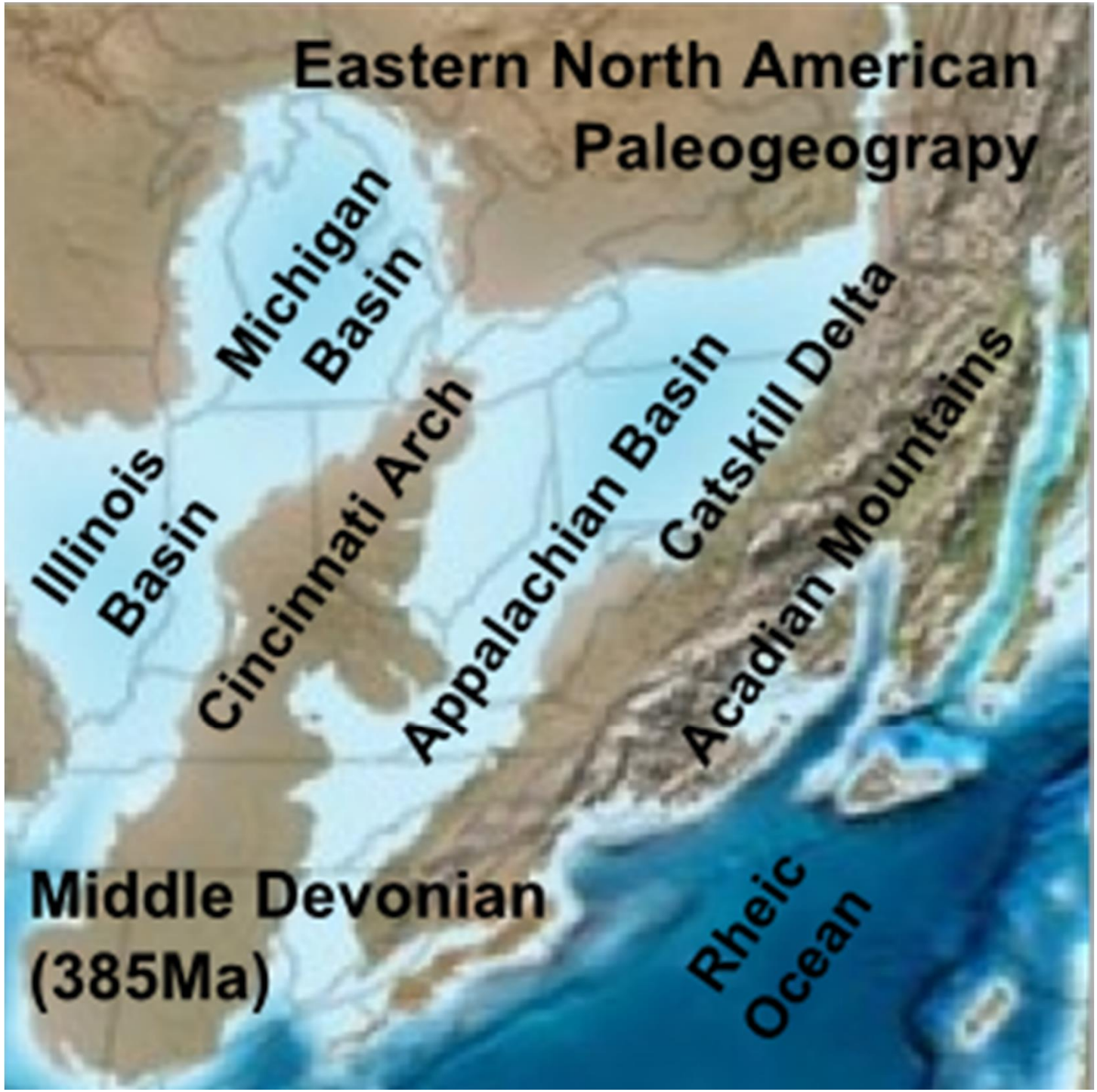
Thin compressed = higher $

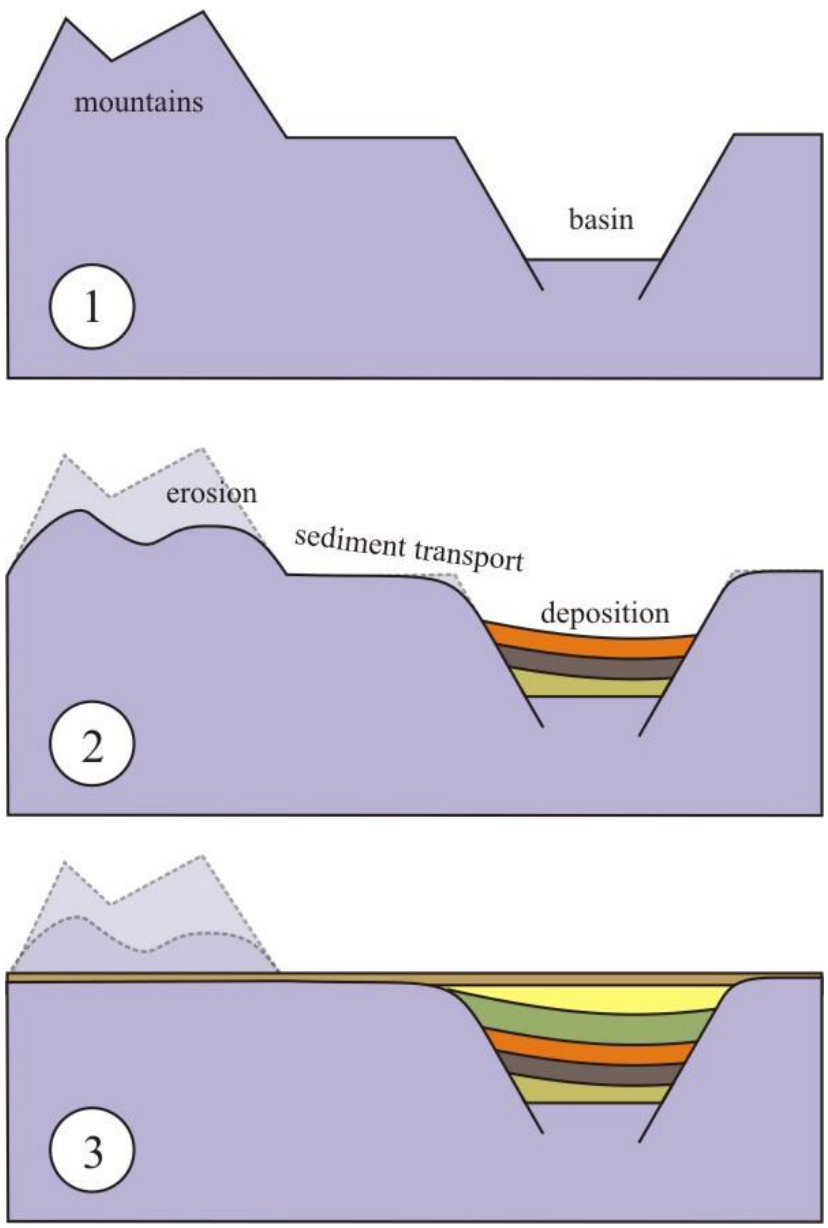
Low Btu more like teenager coal

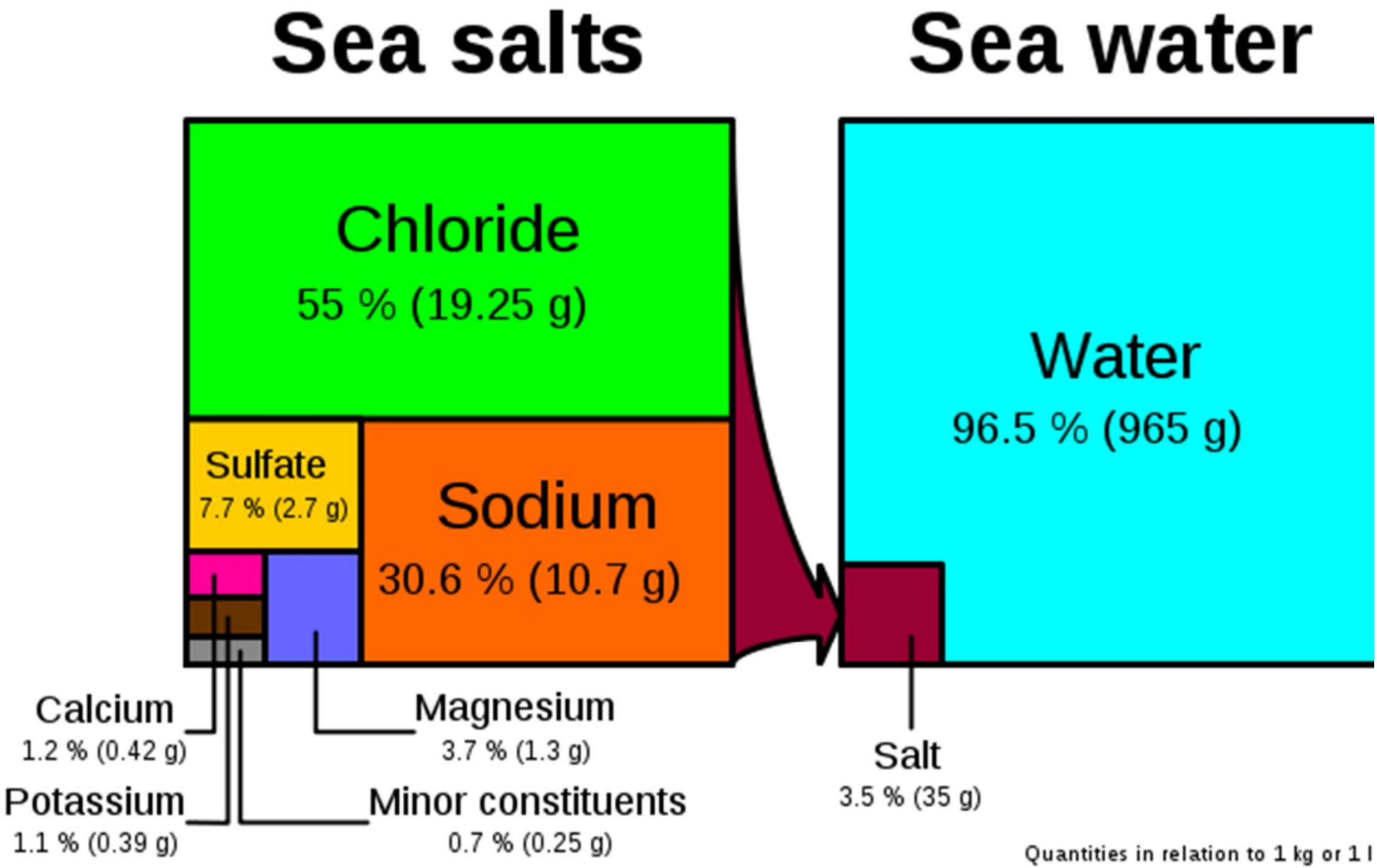
Thicker coal = lower $

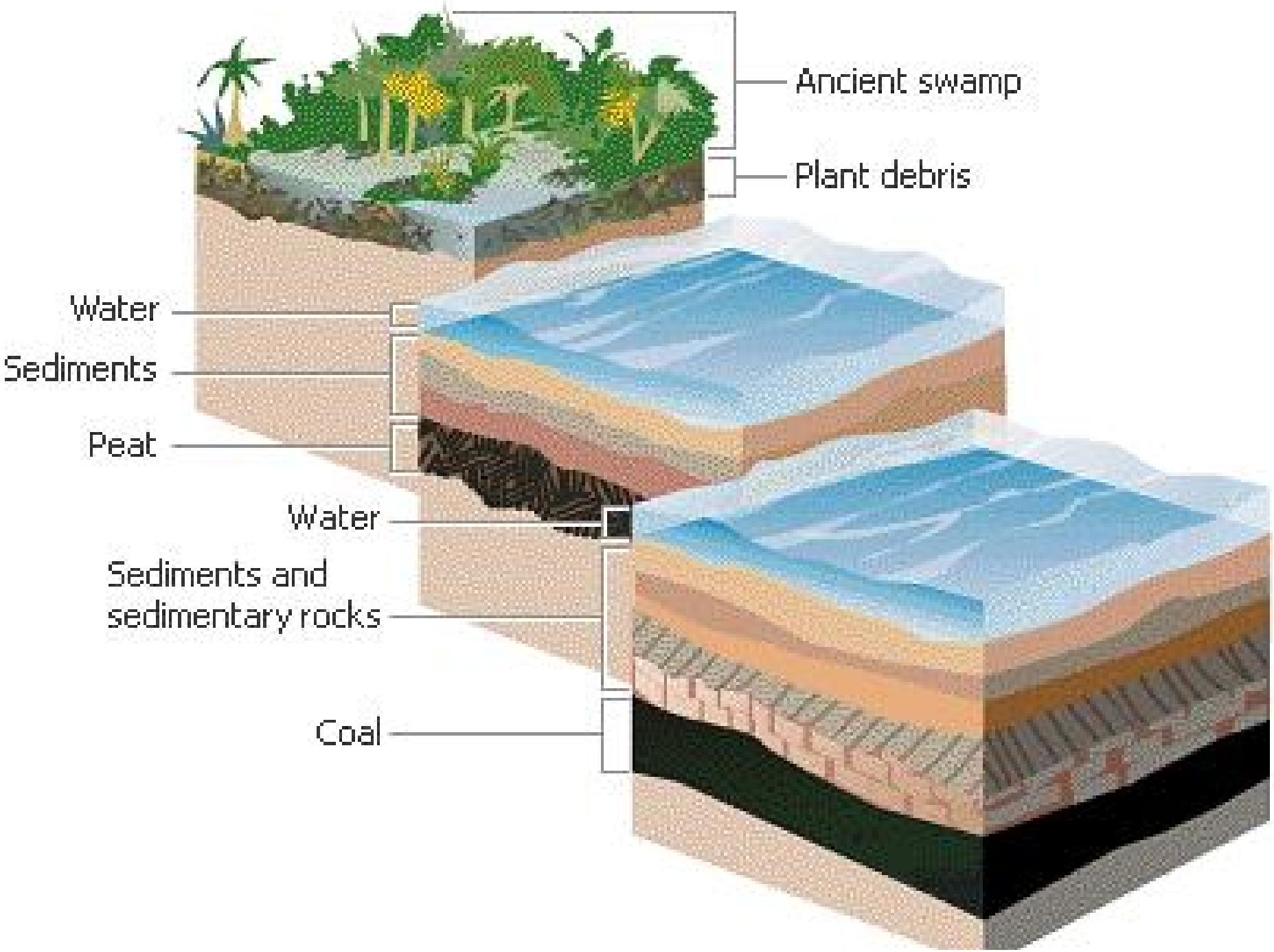


This is where coal comes from.


Eastern North American
Paleogeograpy
Michigan
Basin
Illinois
Basin
Cincinnati Arch
Appalachian Basin
Catskill Delta
Acadian Mountains
Middle Devonian
(385Ma)
Rheic
Ocean


mountains
basin
1
erosion
sediment transport
deposition
2
3


Sea salts
Sea water
Chloride
55 % (19.25 g)
Sulfate
7.7 % (2.7 g)
Sodium
30.6 % (10.7 g)
Water
96.5 % (965 g)
Calcium
1.2 % (0.42 g)
Potassium
1.1 % (0.39 g)
Magnesium
3.7 % (1.3 g)
Minor constituents
0.7 % (0.25 g)
Salt
3.5 % (35 g)
Quantities in relation to 1 kg or 1 l


Ancient swamp
Plant debris
Water
Sediments
Peat
Water
Sediments and
sedimentary rocks
Coal

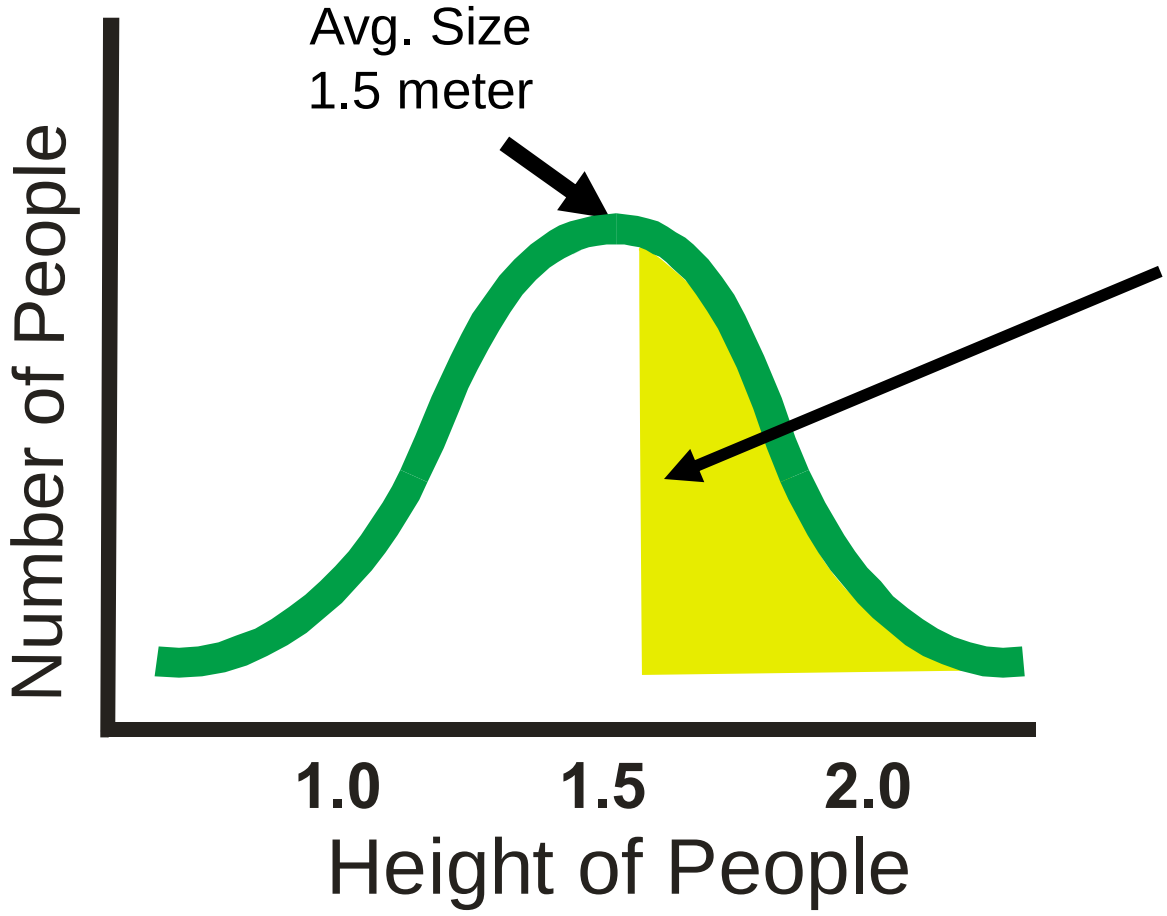
Engineering

1.5 meter desk

1.55 meter door

Fits through every time

Coal Quality



1.55 Meter
Door

Only about 1/2 people fit

Coalification

Wood

Peat

Lignite

Sub-bituminous

Bituminous

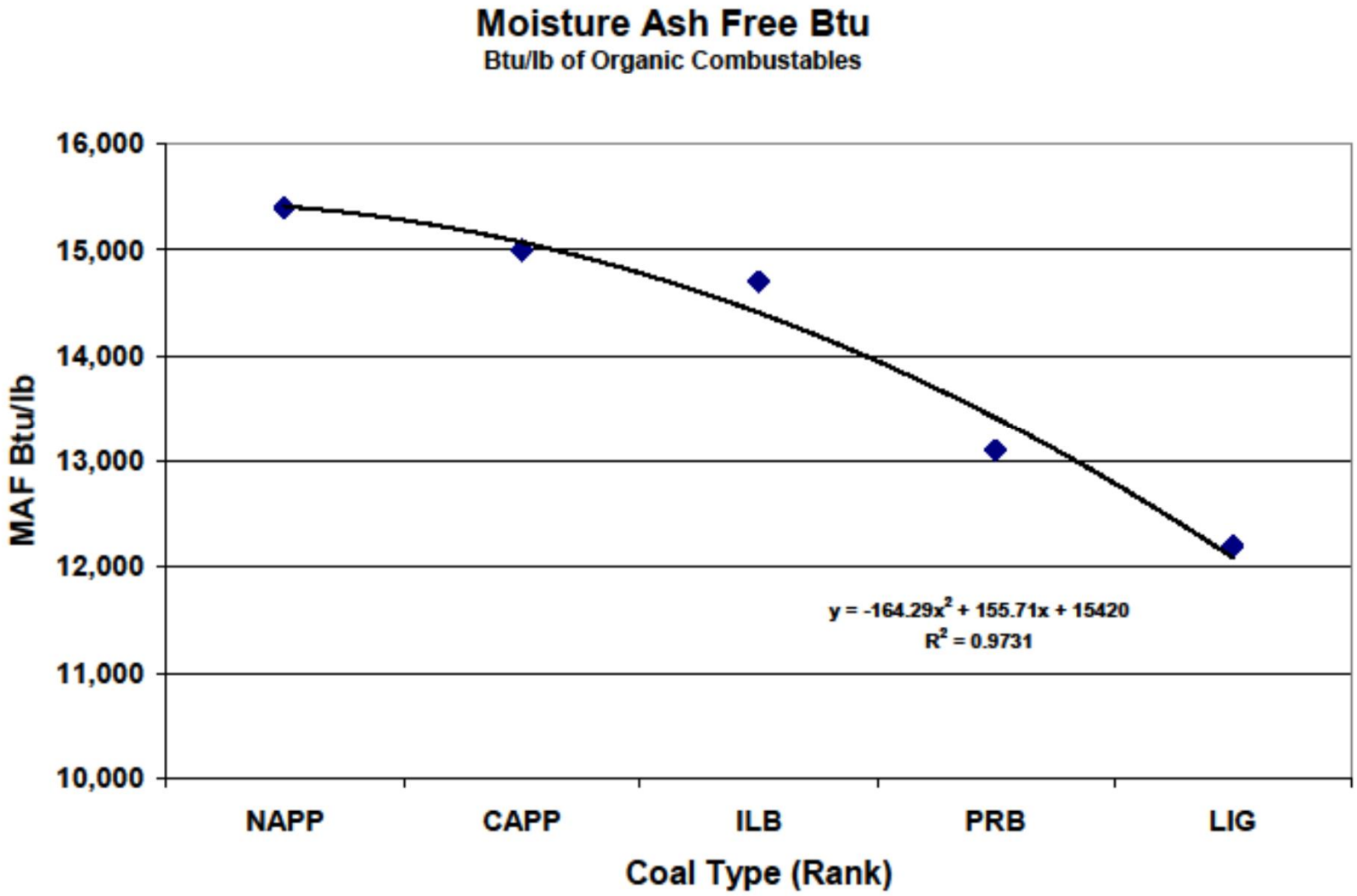
Anthracite

PRESSURE

TIME

Generally:

- Lose Moisture
- Lose Volatile
- Lose Oxygen
- Gain Btu/lb


Moisture Ash Free Btu
Btu/lb of Organic Combustables
MAF Btu/lb
16,000
15,000
14,000
13,000
12,000
11,000
10,000
y = -164.29x² + 155.71x + 15420
R² = 0.9731
NAPP
CAPP
ILB
PRB
LIG
Coal Type (Rank)

Coal Basics

CAPP, NAPP-High rank (Btu) Coals are low moisture and high MAF Btu/lb
Oil like and do not mix with water

PRB-Low rank coals are low MAF Btu/lb due to high oxygen in ultimate test
High oxygen attracts water,
Whiskey and water

ILB coals are medium rank with moderate moisture

Low sulfur coals are low in pyrite

Mechanical sampling is best, but

+/-10% of 30% moisture
+/-3%

8500 Btu/lb at 30%
8136 Btu/lb at 33%

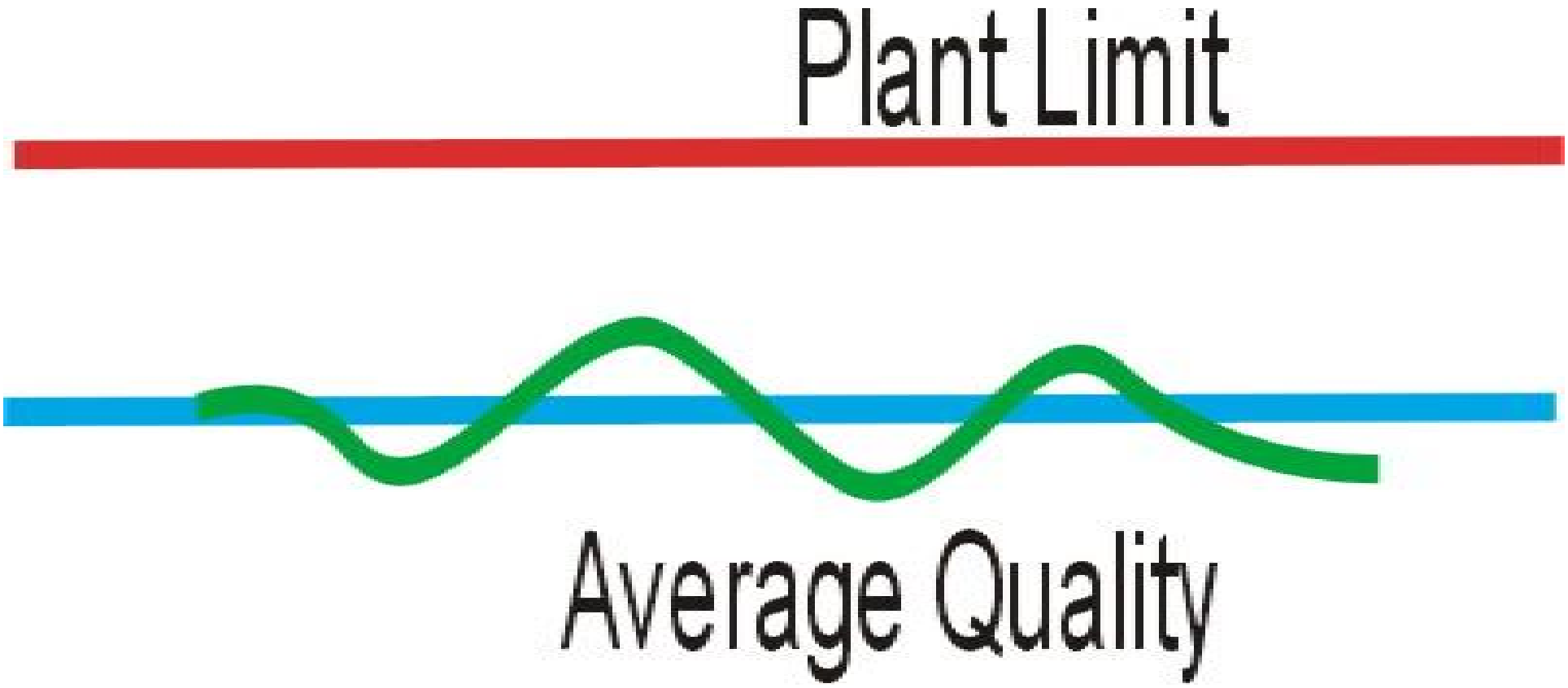
+/- 364

just on moisture sampling variability

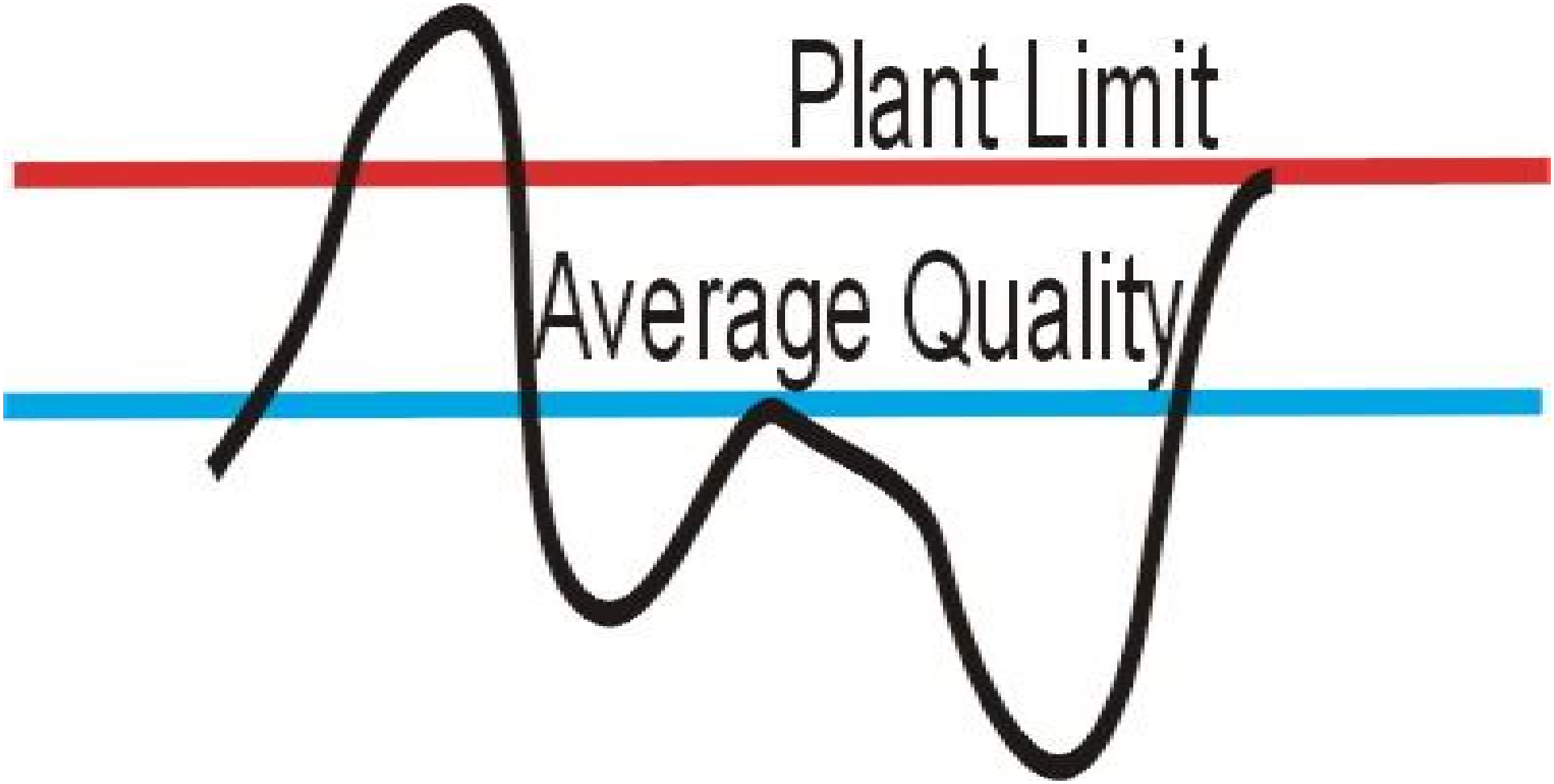
Measuring Coal Quality

ASTM only produces average data

Power plants respond to swings in quality



Coal Combustion Inc.
Understanding the business of coal



CCI

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Understanding the business of coal

One step over the line...

How we look at coal quality

ASTM

- Proximate
- Ultimate
- HGI
- Fusion
- Ash Chemistry
- Trace Elements
- EQ Moisture
- Forms of Sulfur

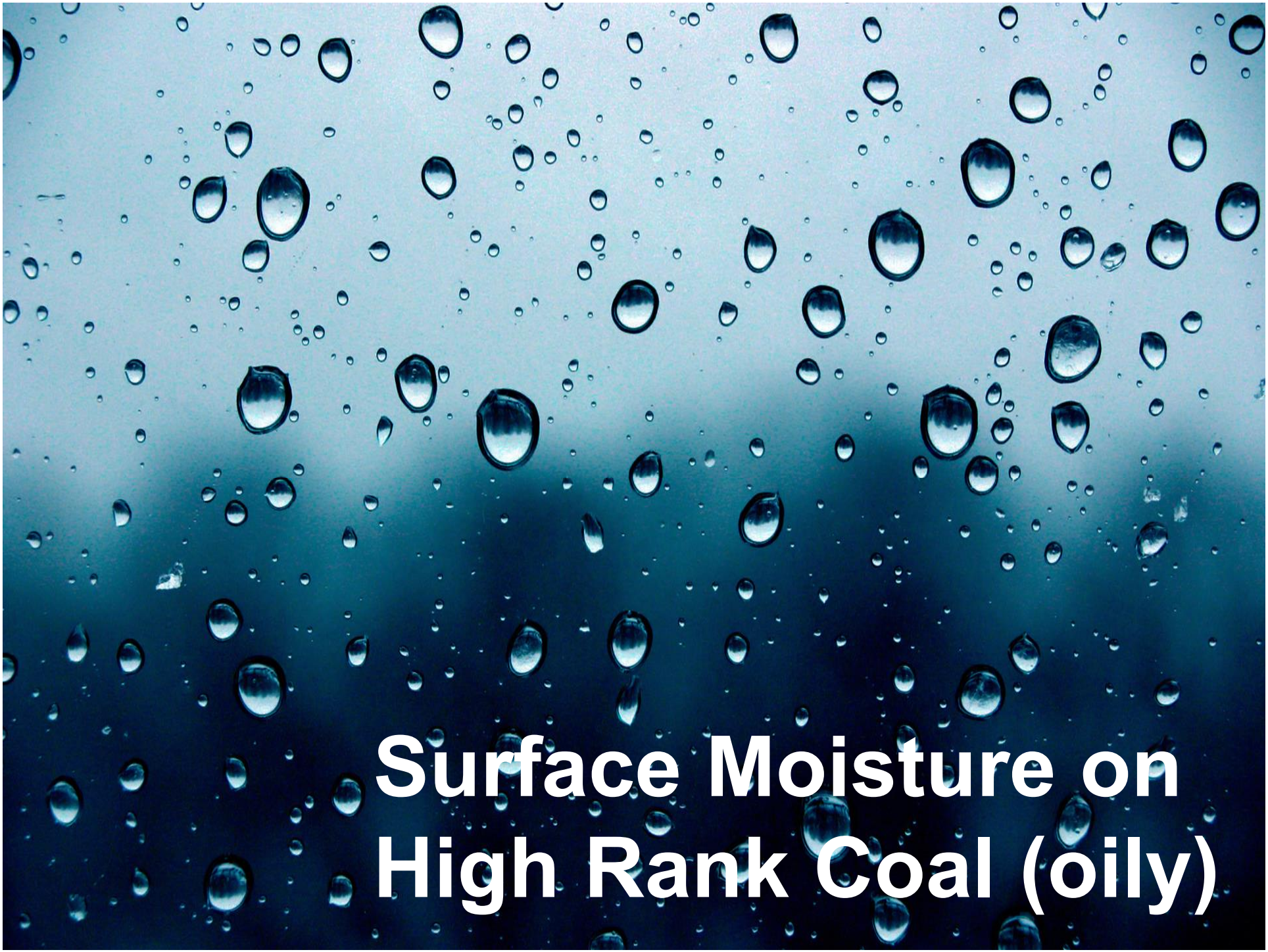
% Moisture

Moisture can be in two forms in coal:

1. inherent or residual or bed moisture

2. surface or the moisture found on the outside of the coal

The sum of these or TOTAL Moisture is reported in the Prox test

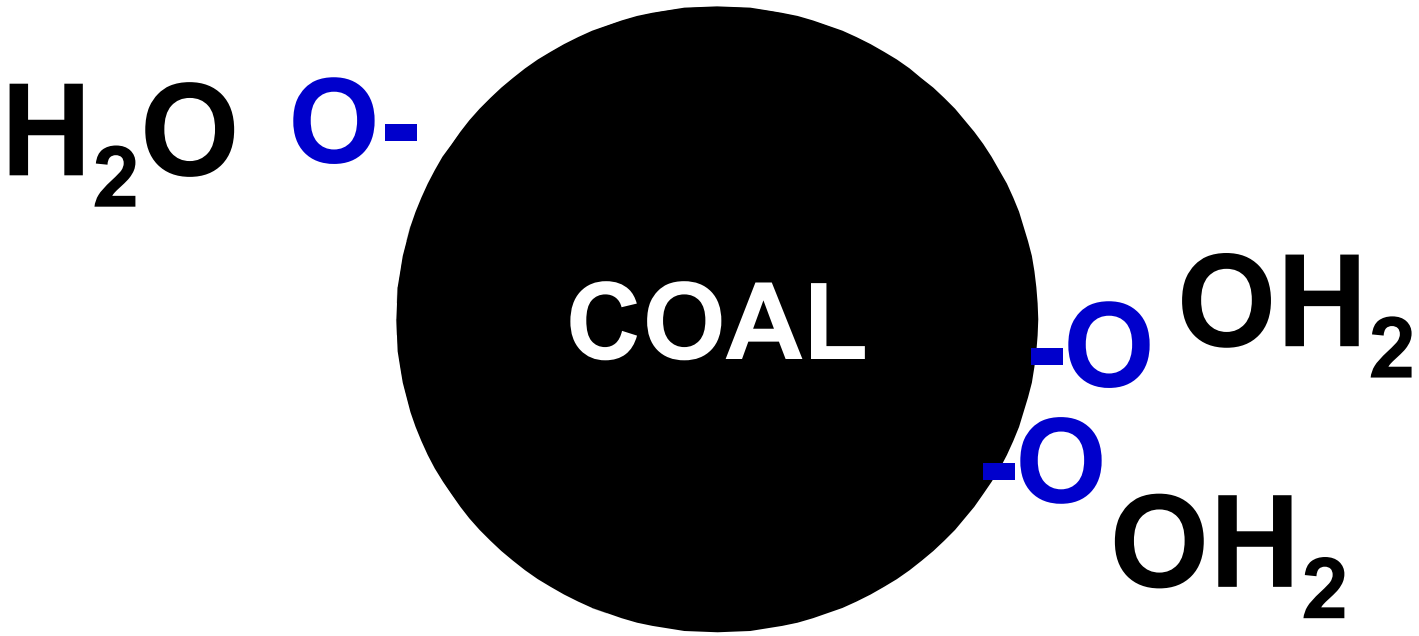

Surface Moisture on
High Rank Coal (oily)

Chemistry

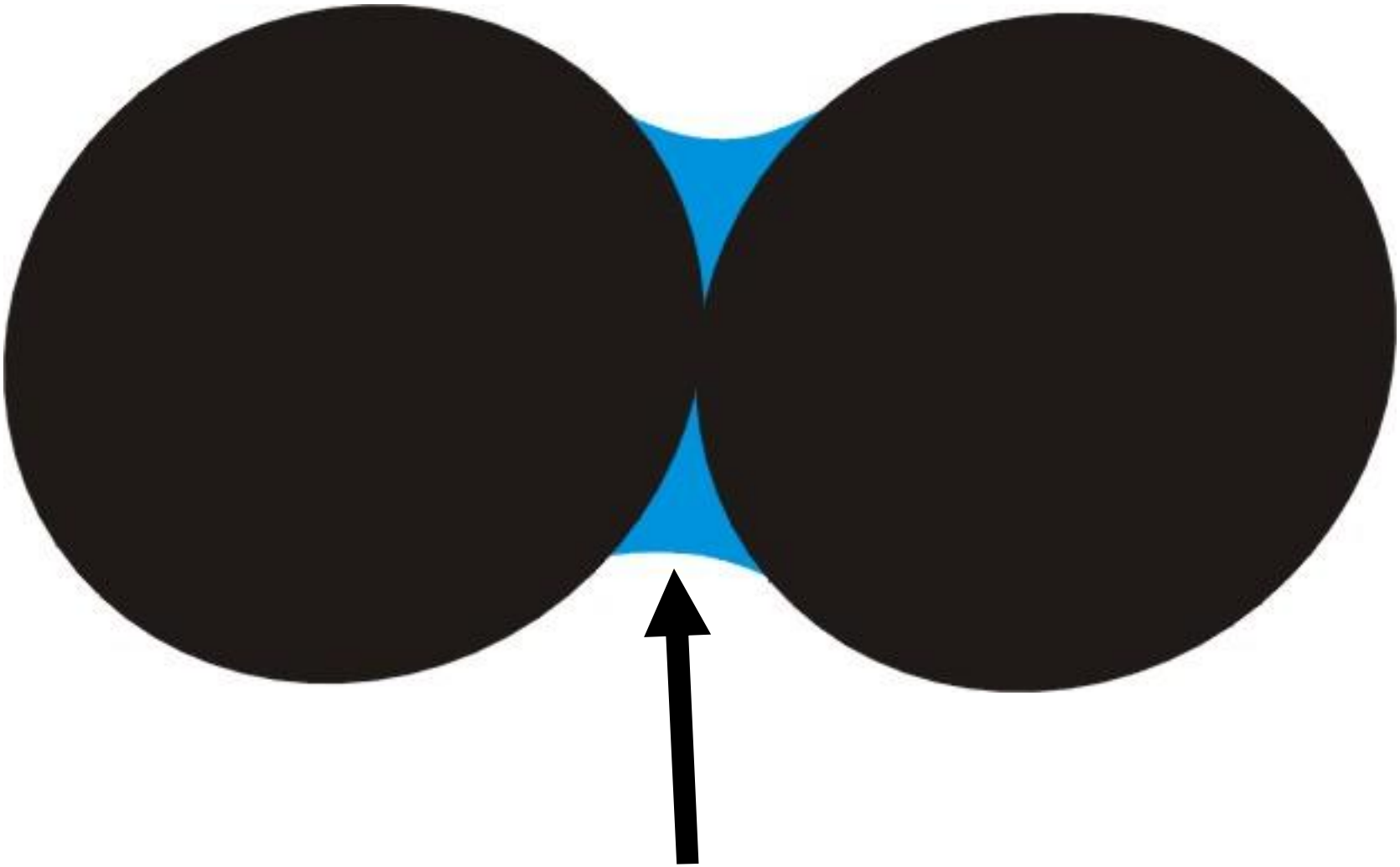
Like Likes Like

Chemistry

Like Likes Like



Low rank coals (low MAF, high Ox) have higher moisture levels



Surface Moisture

% Ash

Like Moisture, Ash can be in two forms in coal:

1. intimately mixed with the coal

2. rocks not in the coal seam
(out of seam dilution, OSD, $)

The sum of these or TOTAL Ash is reported in the Prox test


Coal 6-8% ash
Profit $
100% rock

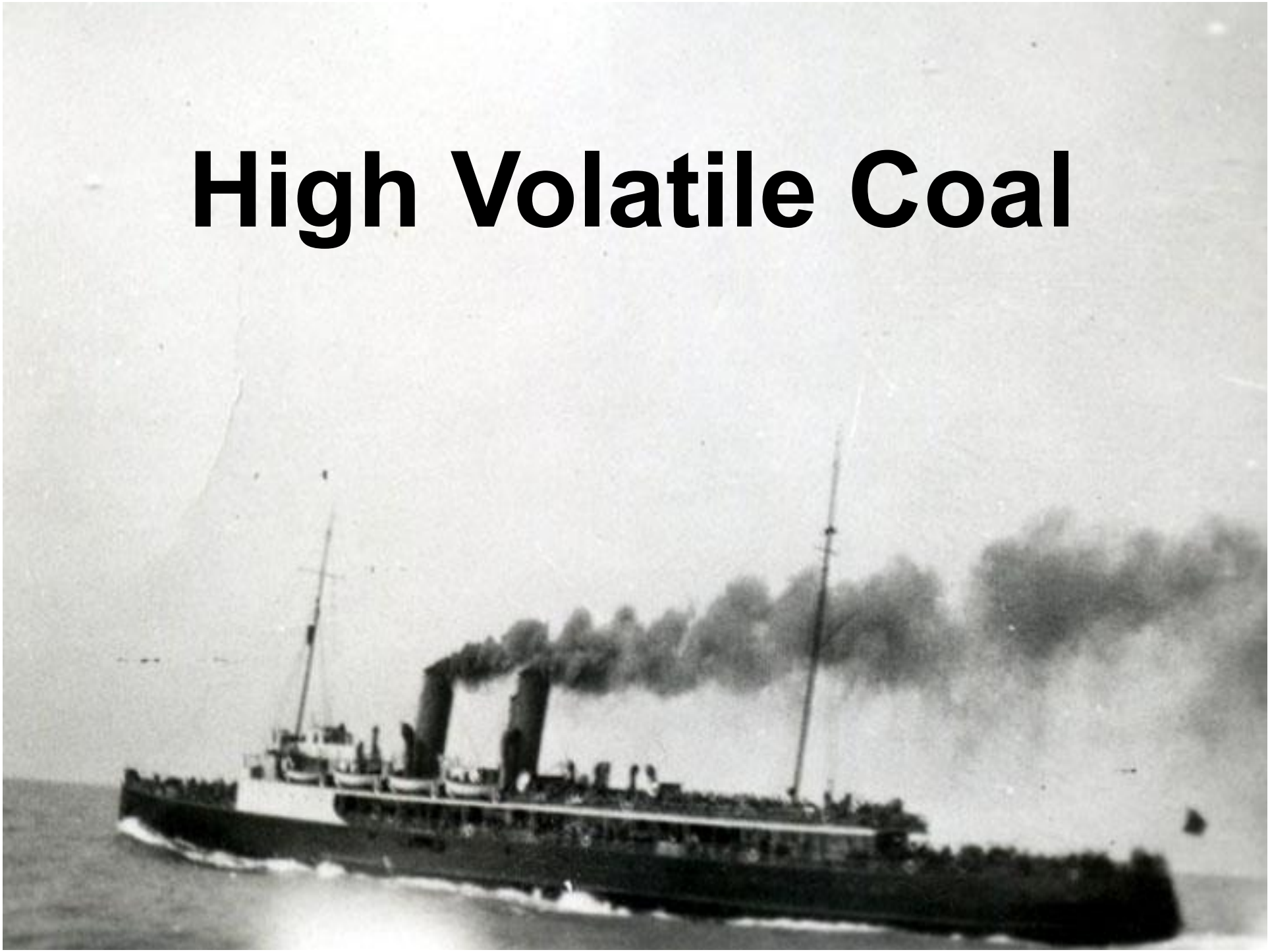
% Volatile

Smoke or no smoke

Coke or Less Coke

Cooked coal with no air at 950 C.

High Volatile Coal



Denbigh - 1863 Blockade runner fueled with low volatile
Did captain use ap**proximate** test?

Short Prox

Moisture
Ash
Sulfur
Heating Value

% Sulfur

Total sulfur includes both pyritic and organic

Sulfur in Coal

Coal typically
is 0.3 to 4.0%
Sulfur

Sulfur can be in two main forms:

Organic

Pyritic

Sulfur in Coal –

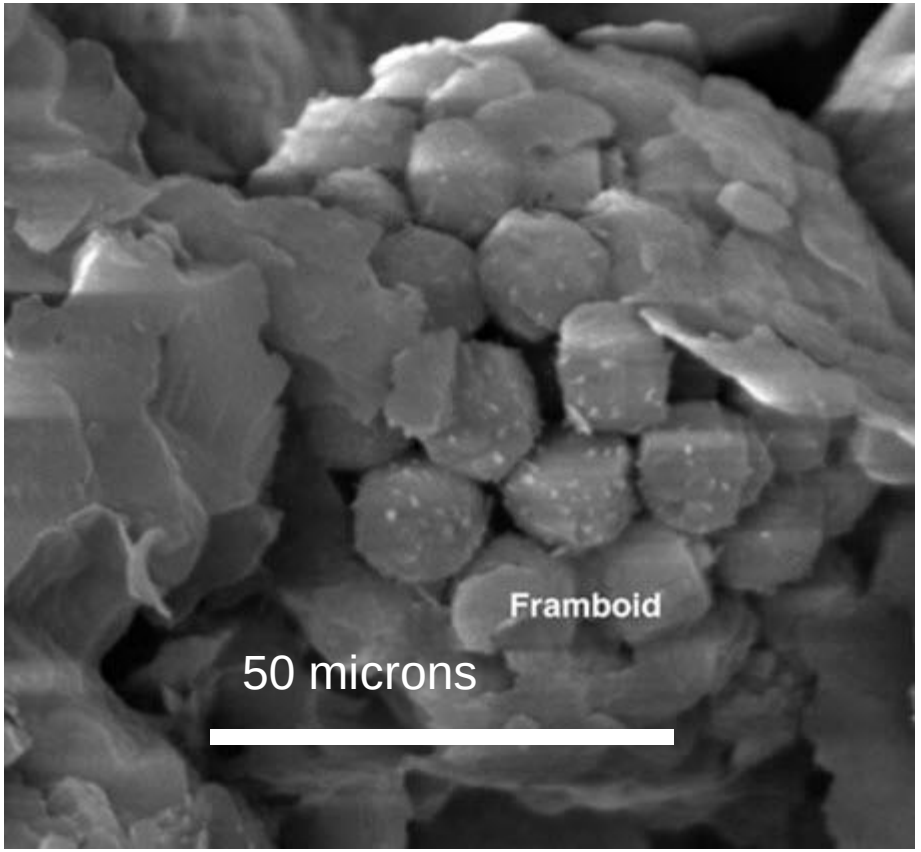
Bad to the bone

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


FeS_2

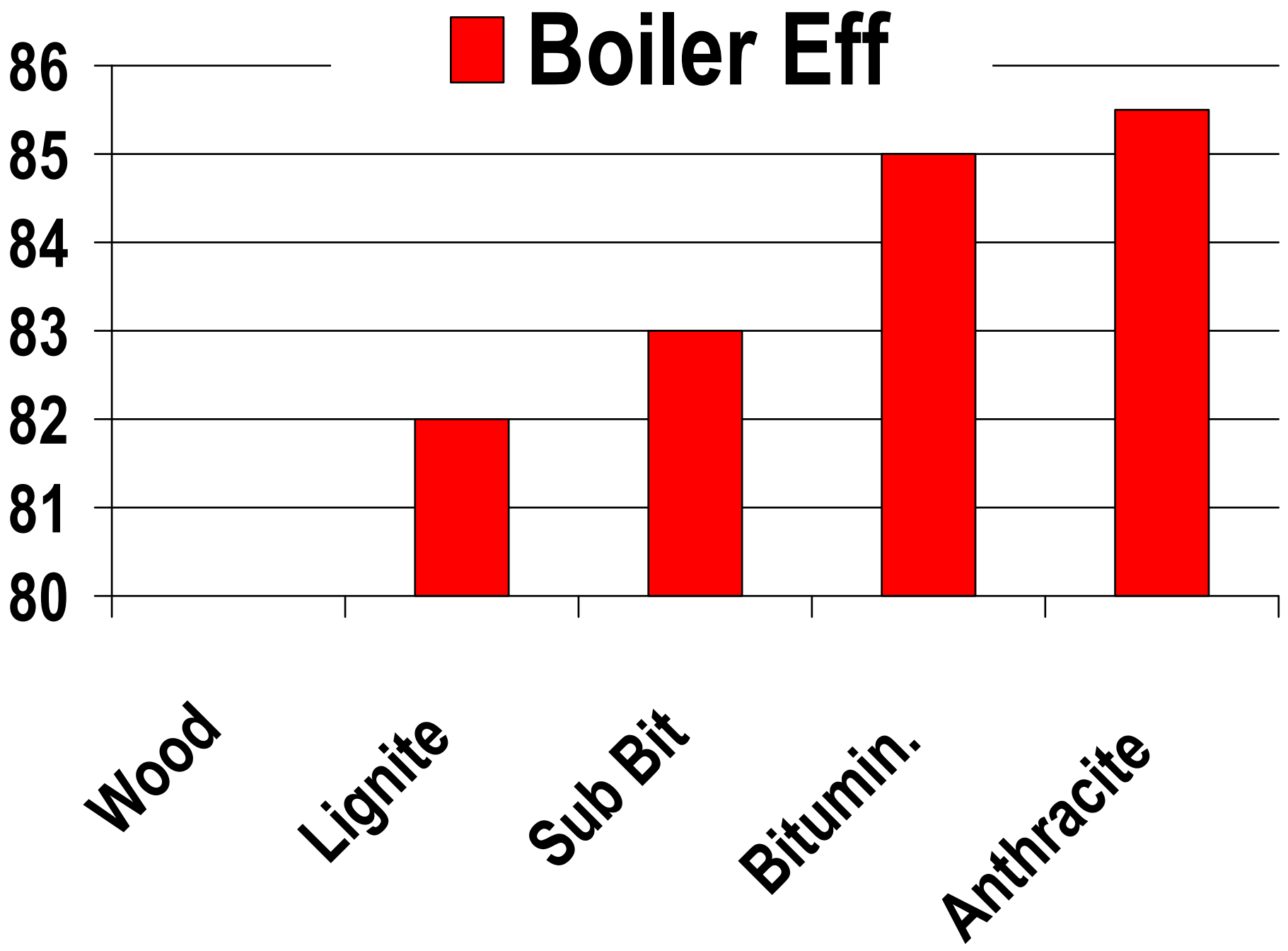
Large sulfur balls can be washed out or rejected by pulverizers

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



Cleat

pyrite has to be ground up


Boiler Eff
86
85
84
83
82
81
80
Wood
Lignite
Sub Bit
Bitumin.
Anthracite

Boiler Efficiency

Moisture and hydrogen impacts
1% change for 10% moisture change
1% change for 1% hydrogen change
Higher vs. Lower heating value
Gross verse Net

Lower Heating Value or Net Calorific Value

LHV =

HHV –

1040 x

(% Moisture/100 +((Hydrogen ï Ox/8) x 8.98))

Compounding Efficiency Losses

Conversion from CAPP to PRB
and operation at partial load

10 to 20 % loss in efficiency
10 to 20 % more CO2 per MW

Ultimate

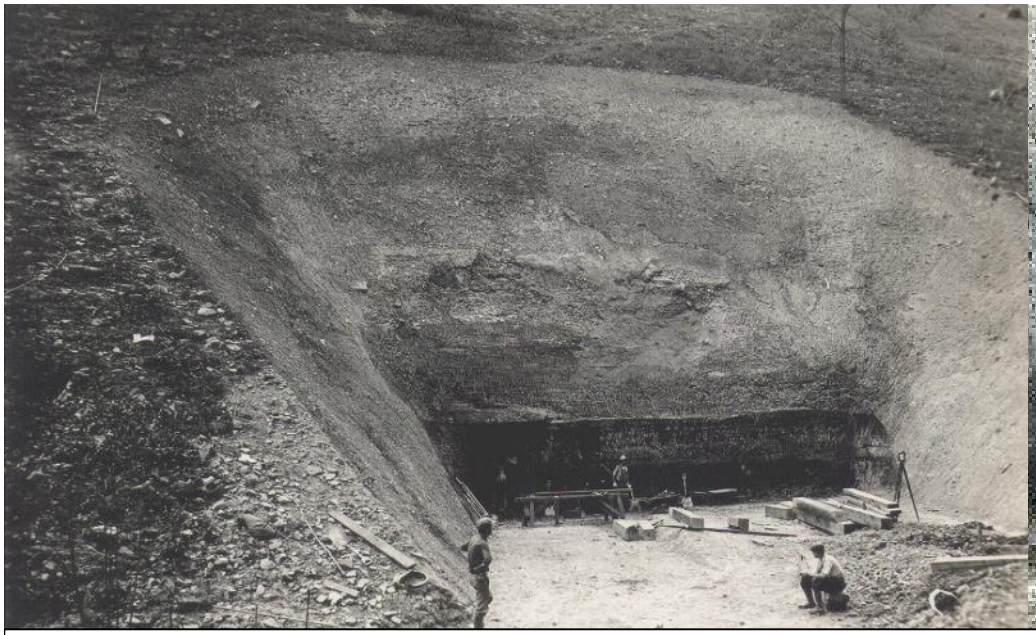
Moisture

Ash

Carbon, Hydrogen,

Nitrogen, Sulfur

Oxygen (by difference)



This is where coal comes from.

We understand the concept of buying Btus by pricing fuels In:

$/MBtu = ($/ton) / 2x(Btu/lb/1,000)

Example:

$40/ton coal 12,500 Btu/lb.

$/MBtu = (40)/2x(12,500/1,000)

$/MBtu = (40)/(2x12.5)

$/MBtu = 40/25 = $1.60 per MBtu

Coal Sizing

Top x Bottom

2 x 0 is top size of 2 inches down to bottom 0 inches, or fines

2 inch coal can have up to 5% over 2.0 inches

Crushed coal specs work same way

1/8 x 0 is coal crushed to meet 95+ % passing 1/8 screen, (square vs. round hole)

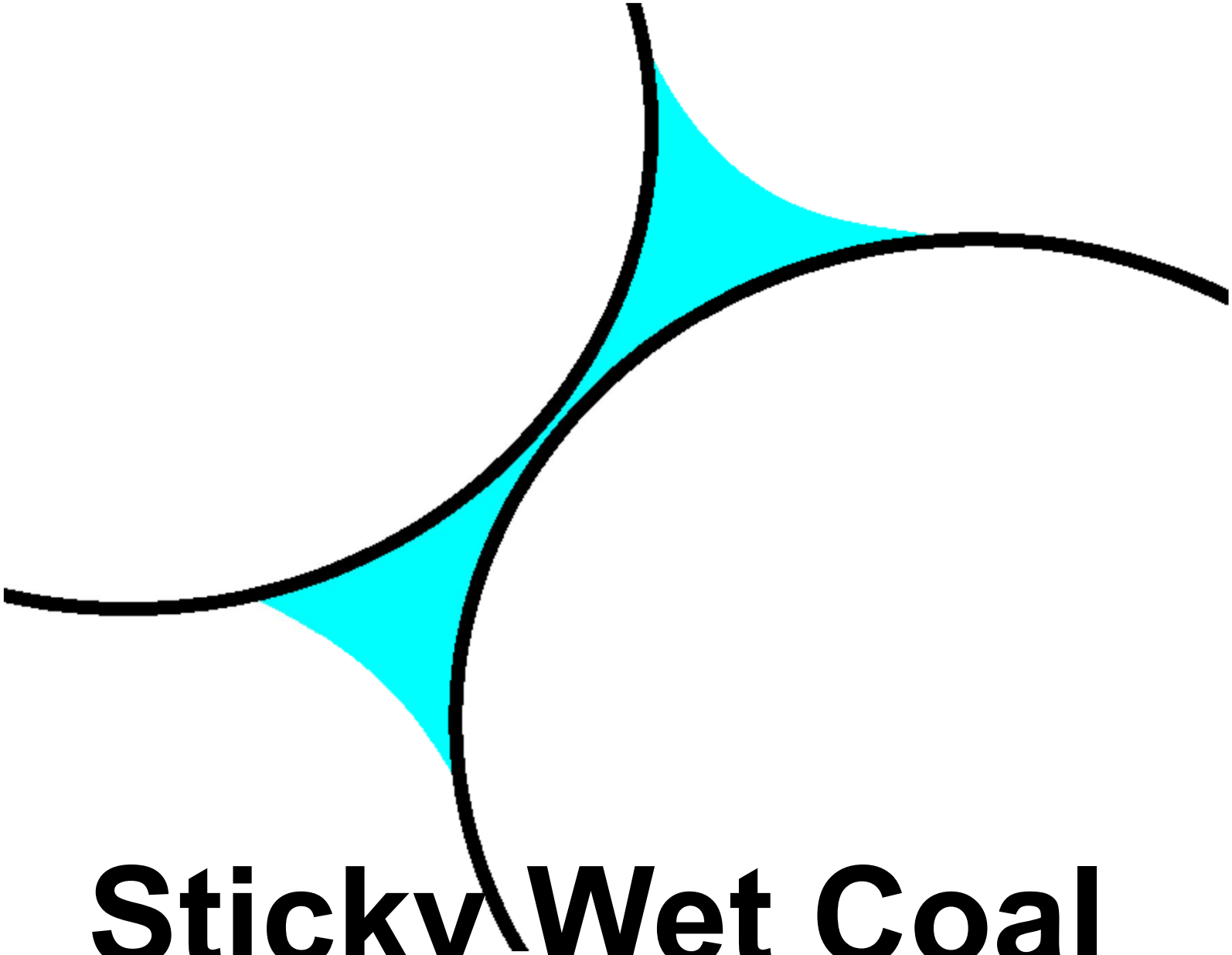
Coal Handling

Moisture

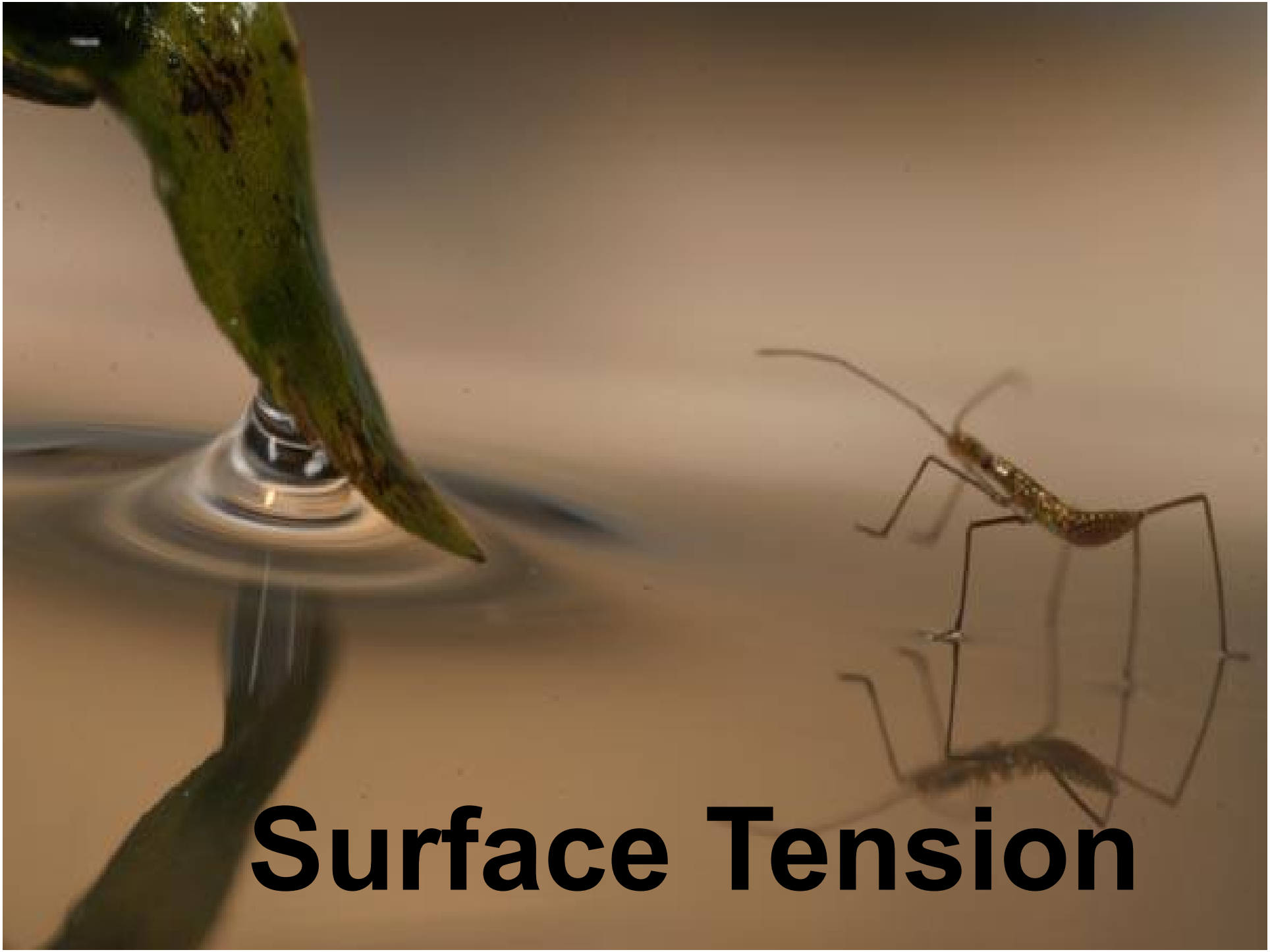
Size

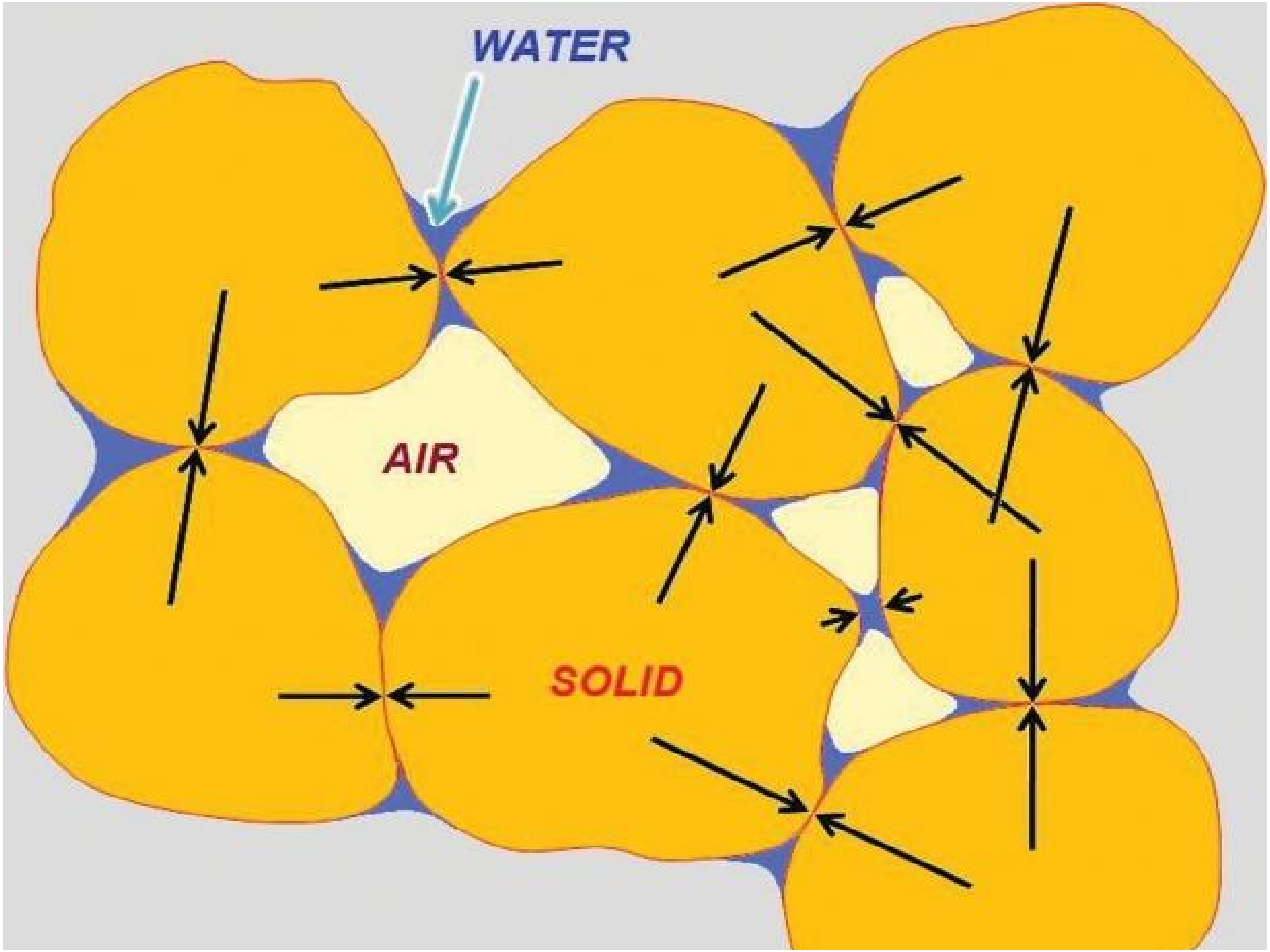
HGI

Clays



Sticky Wet Coal


Surface Tension


WATER
AIR
SOLID

Moisture

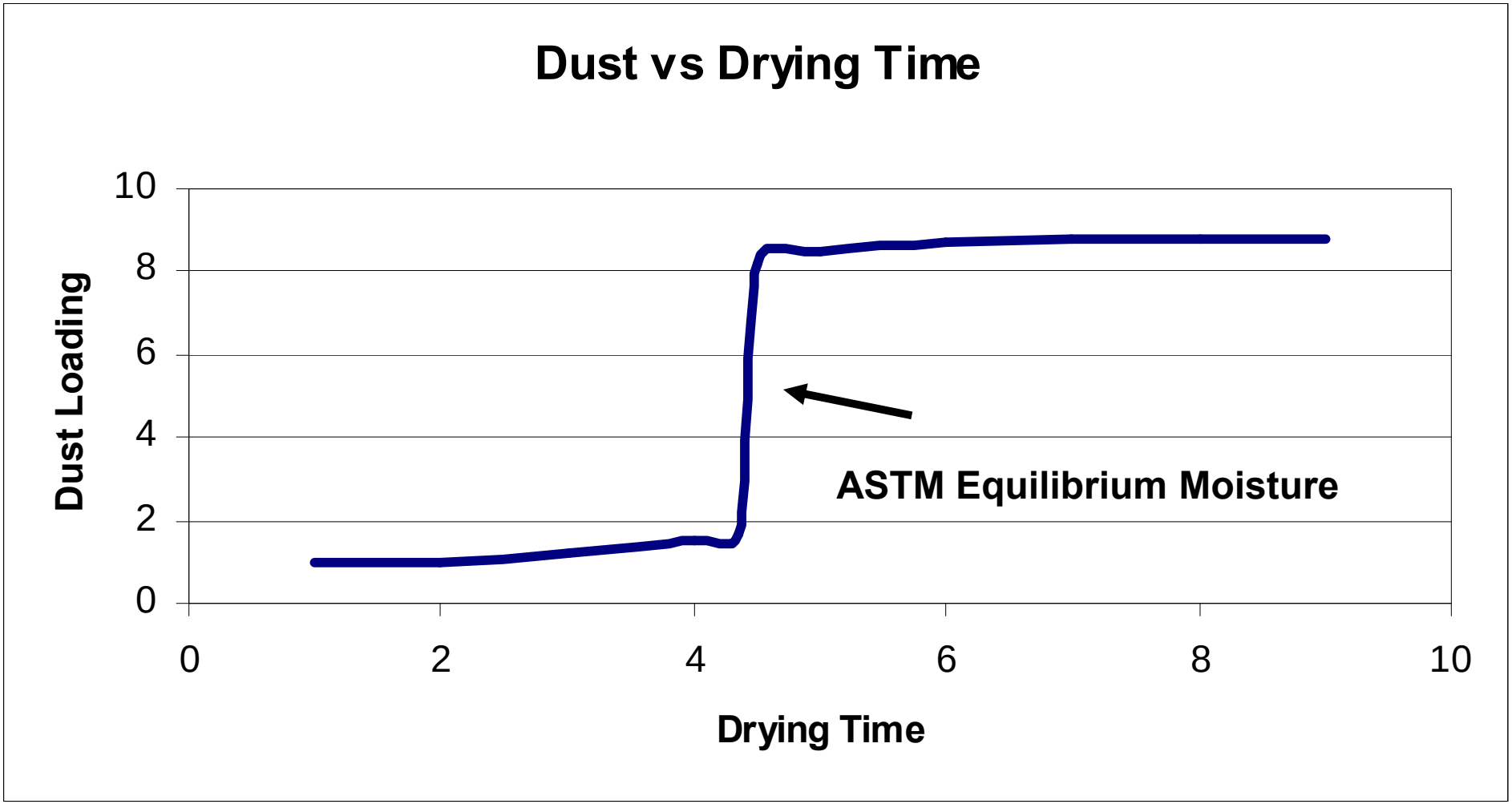
Total

Equilibrium, Bed

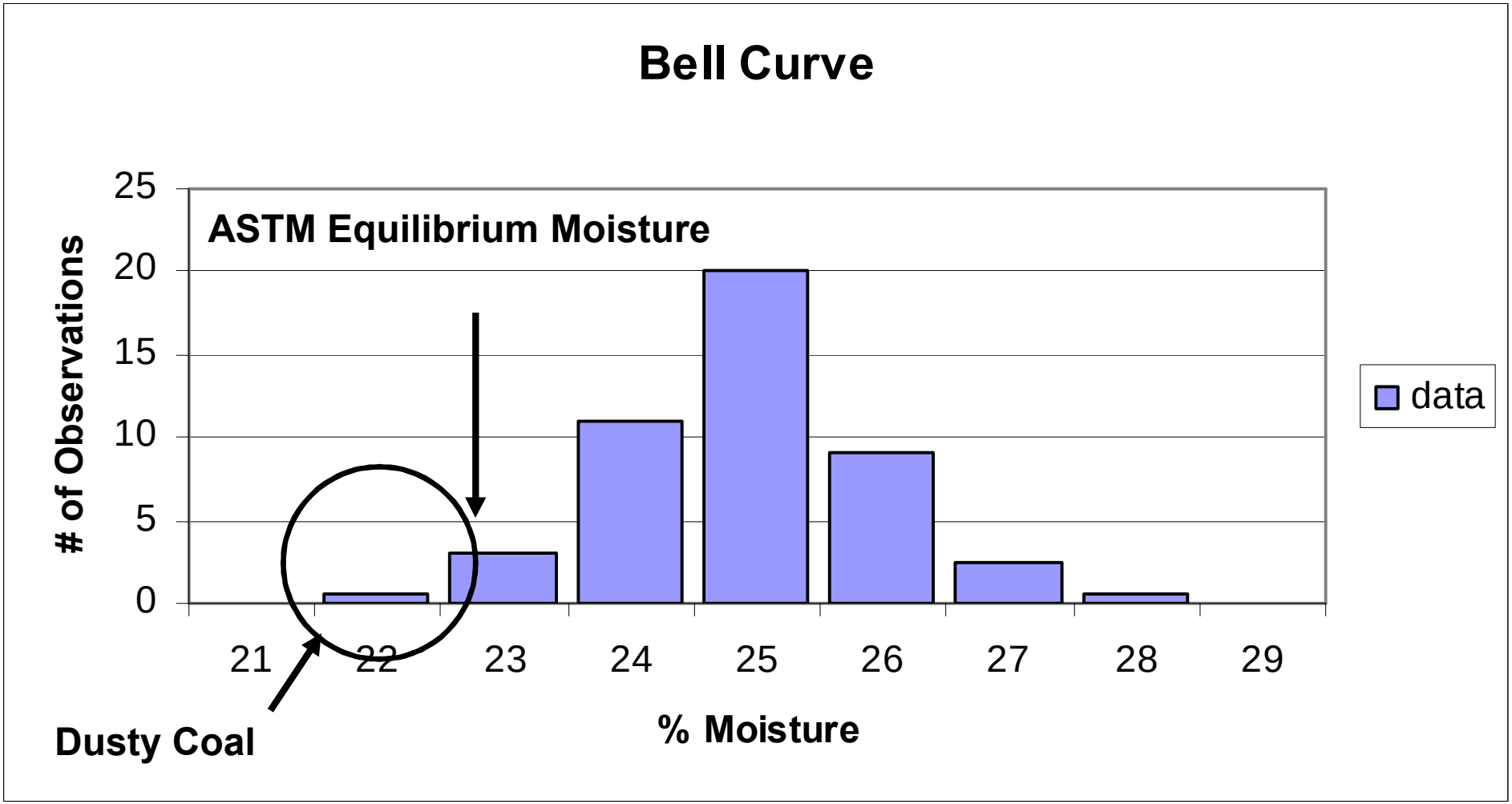
Test results

Air Dry

Residual



KEMA Research


Bell Curve
ASTM Equilibrium Moisture
# of Observations
25
20
15
10
5
0
21
22
23
24
25
26
27
28
29
% Moisture
data
Dusty Coal

PRB Coal
ñfreshò


PRB Coal
ñagedò- 1 hr


PRB Coal
aged - 5 hr

PRB Coal
aged - 1 day

PRB Coal
aged - 2 days


PRB Coal
aged - 4 days

PRB Coal
aged - 6 days


PRB Coal
aged - 6 days
(1)


PRB Coal
aged - 6 days
(2)

PRB Coal
aged - 6 days
(3)

Surface Moisture

0-4 Dusty
3-6 OK
5+ Sticky


PRB Plant of the Year

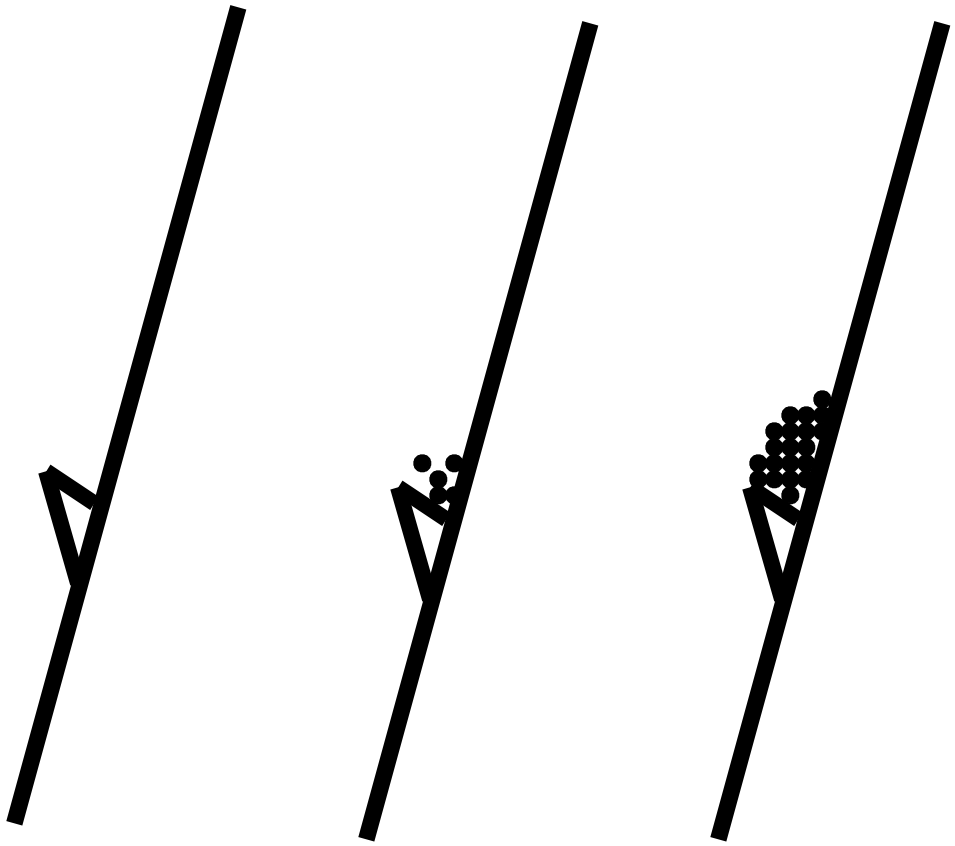
Deposits grow Deposits

Like Likes Like

Small deposits just get bigger

Fine wet coal

Look for drier coal
Make coal larger
Don’t crush wet coal

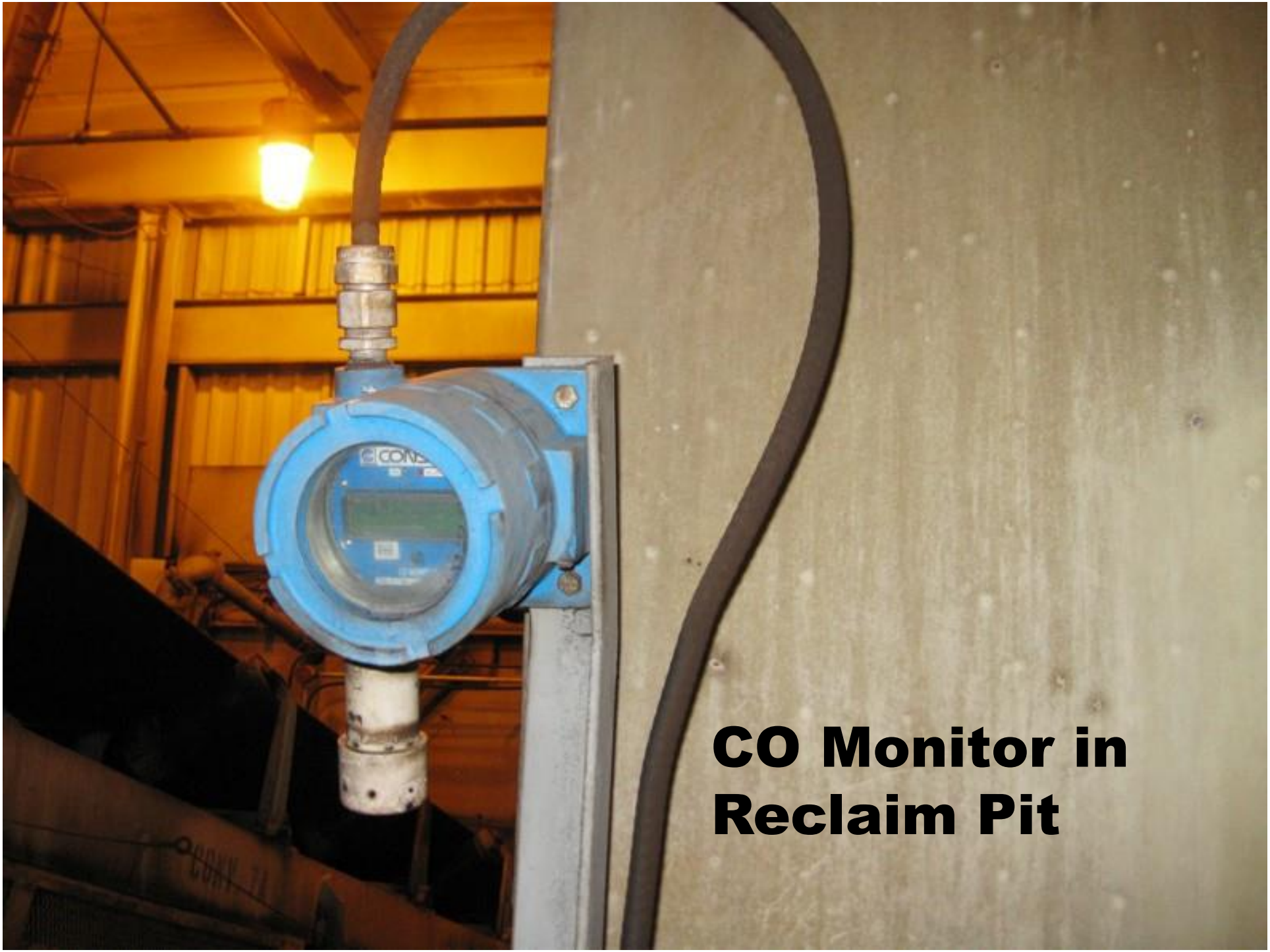


Remove all lips and ledges and obstructions for good flow

Power Plants like Mechanical Fixes

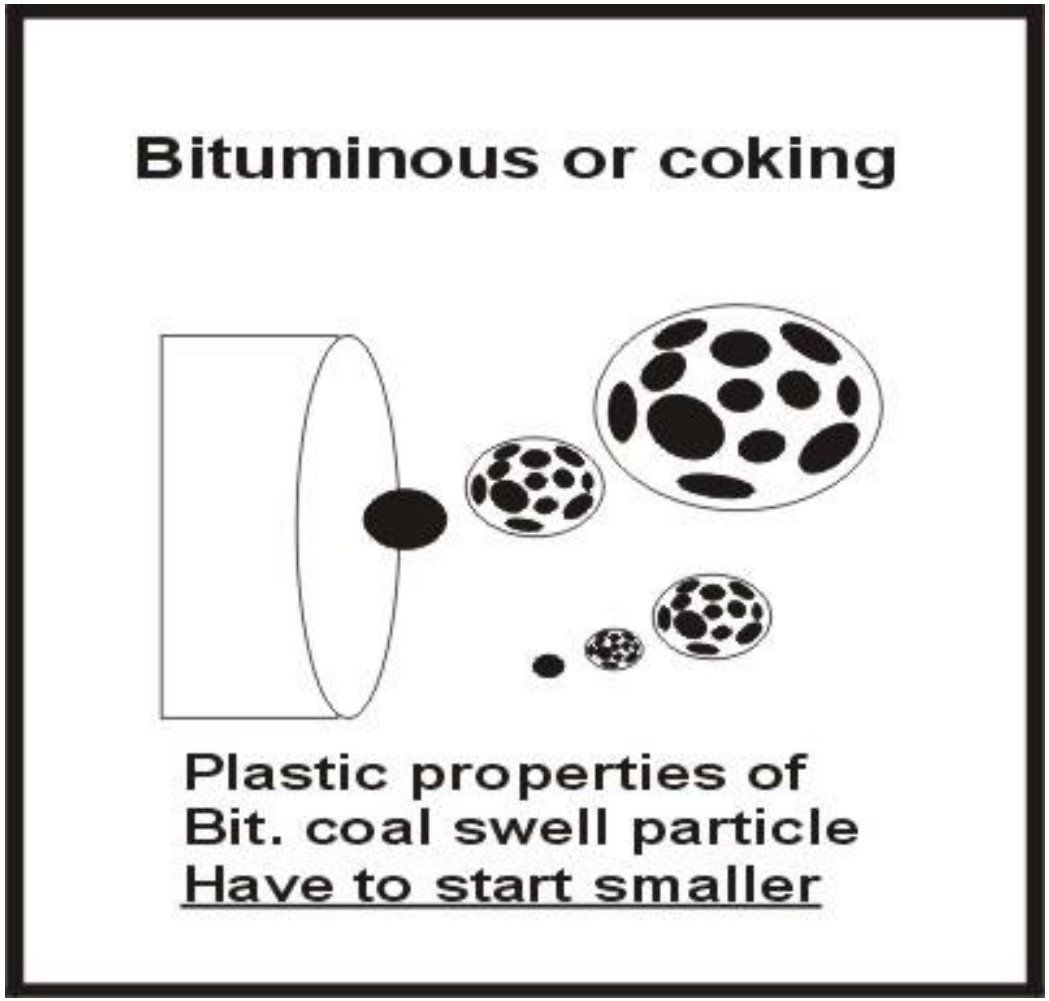

Collection


Wash Down

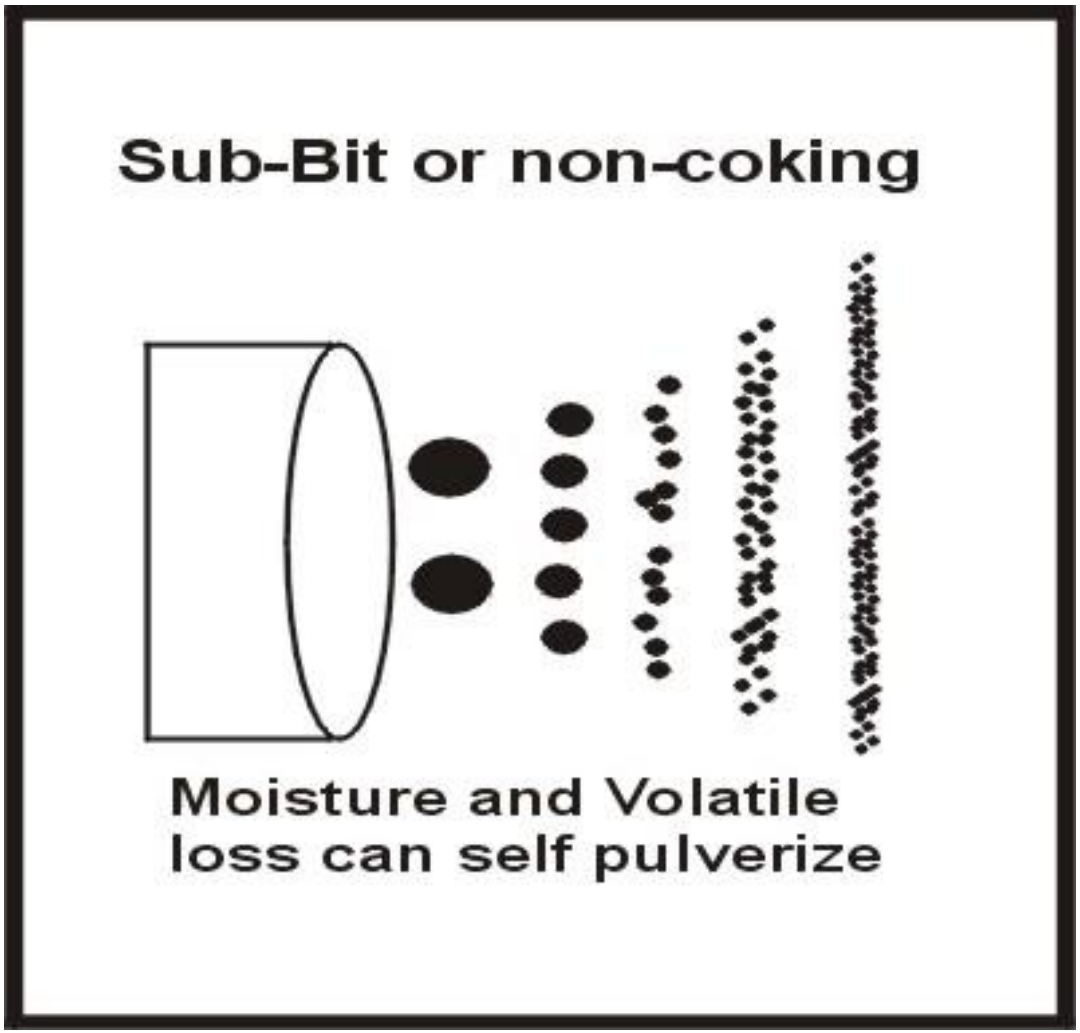

CO Monitor in
Reclaim Pit

Why rocket scientists have it easy!

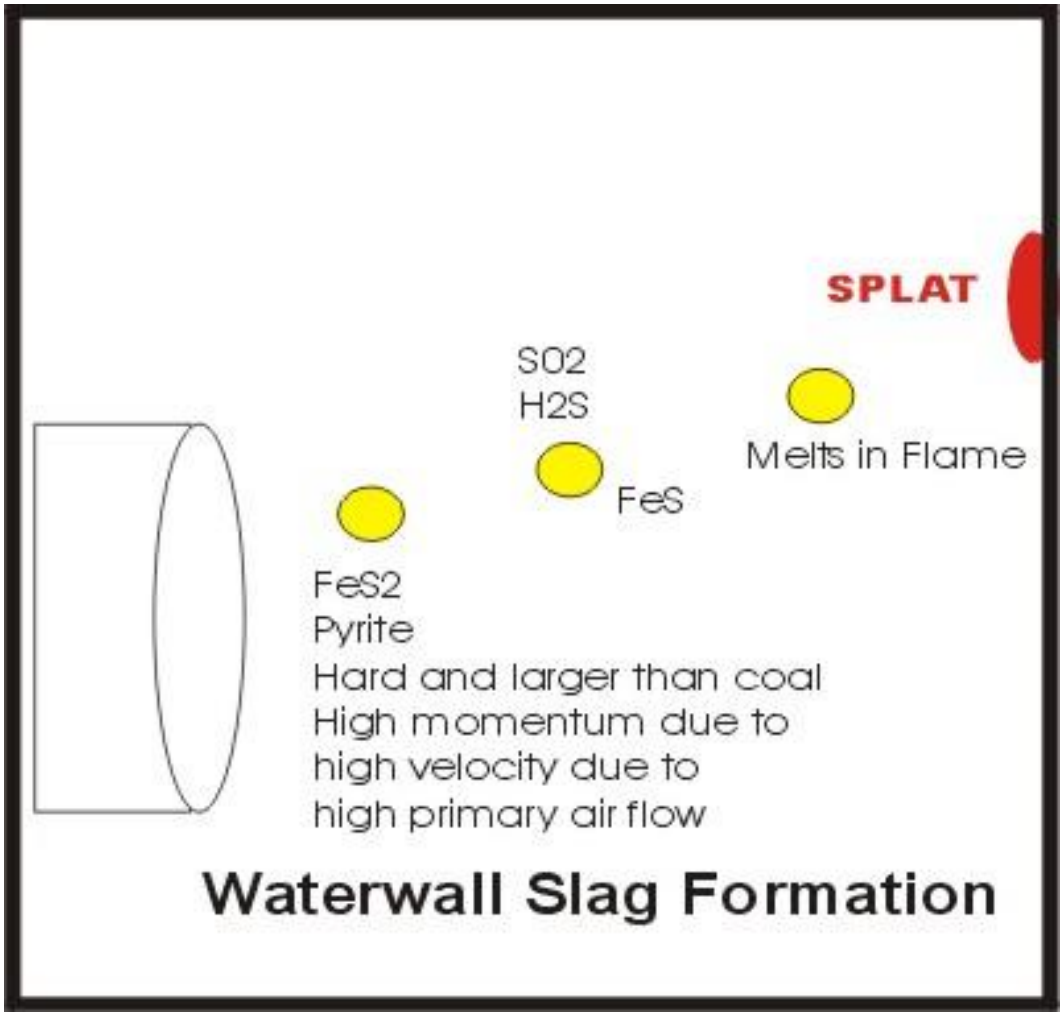
Bit Coal Combustion



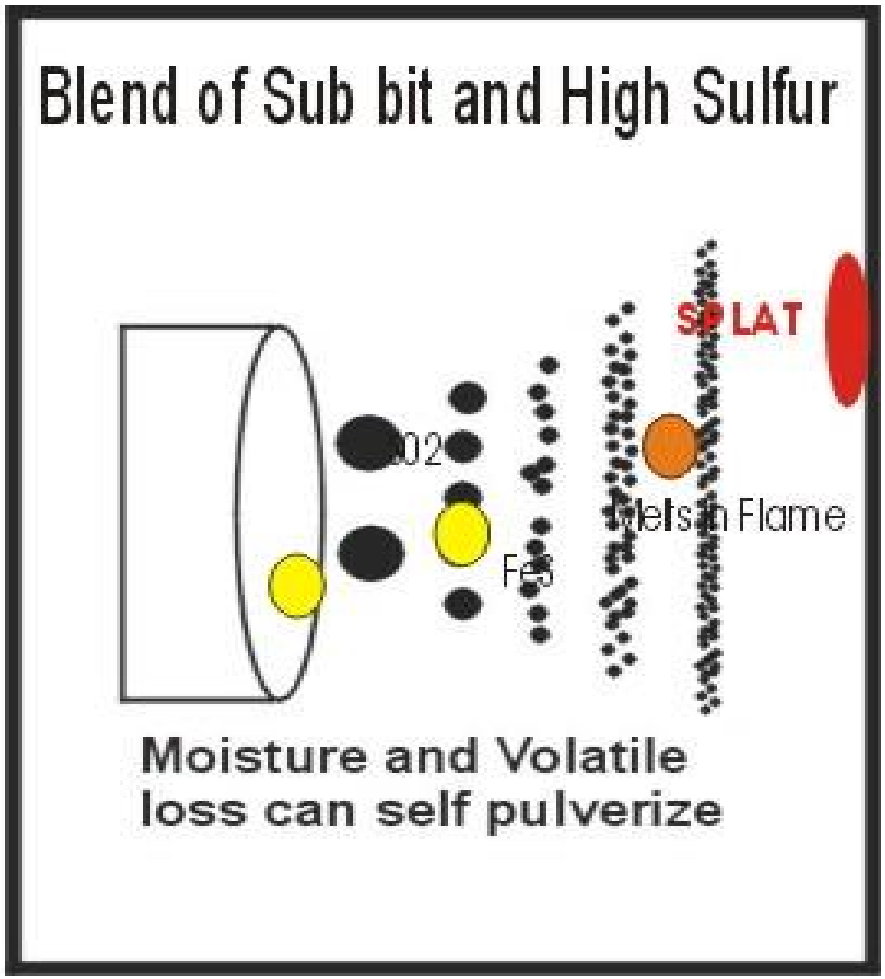
Sub-Bit Coal Combustion



Coal Combustion



Coal Combustion



Advice – Set up plant

1. Pulverize to meet Un-reactive coal
2. Pulverize for slag control-not carbon
3. Maintain CV to take load off mill

or

1. Change Expectation – Load, Forced Outage Rate, Maintenance,

Lets look at all boiler related coal qualities on a heat basis; lets put all percentages on a per million Btu basis

LOADING LEVELS

Coal Reactivity

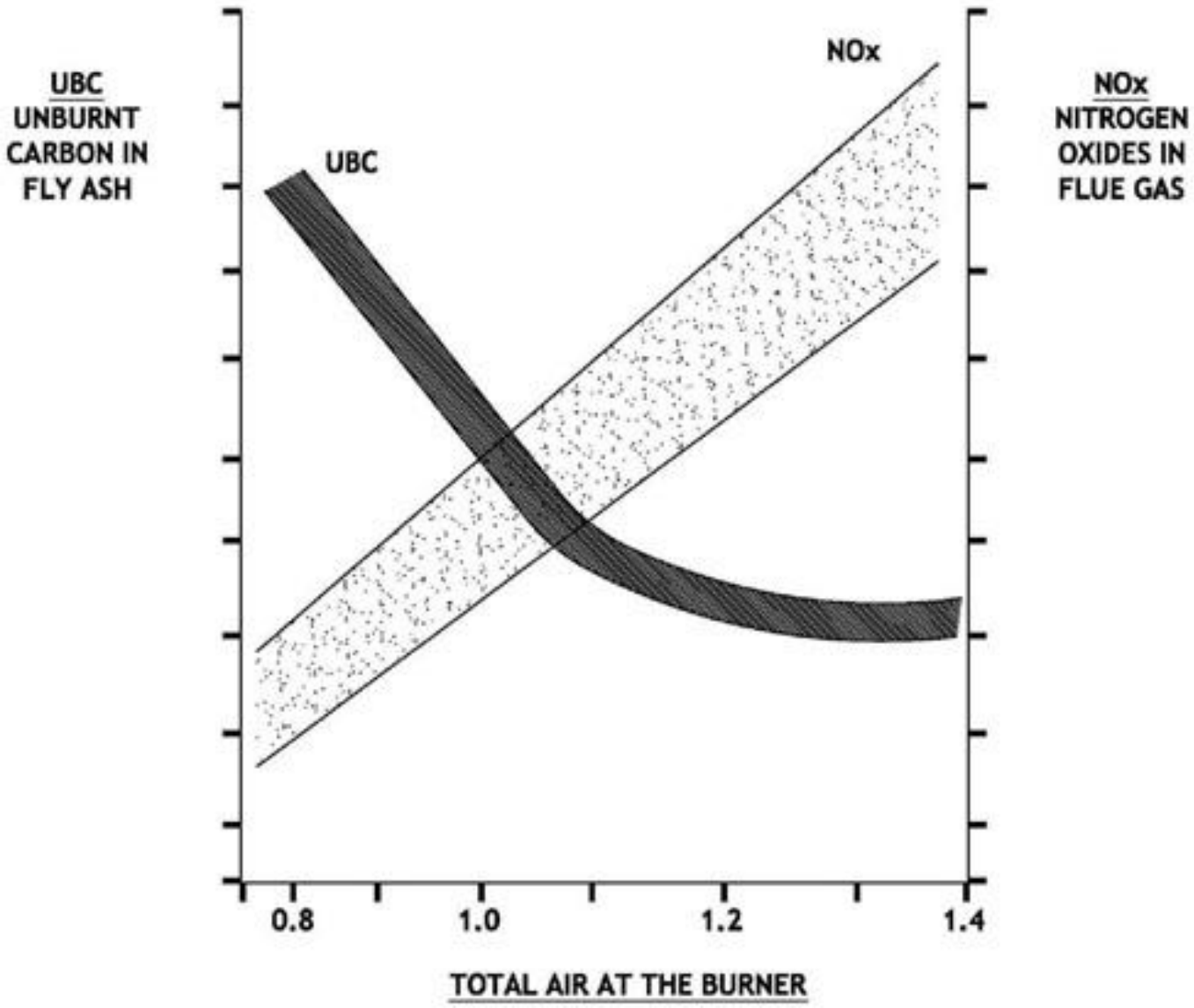
Volatile

Fuel Ratio = FC/Vol

Coal Reactivity

Volatile
Oxygen
per million Btus

	EKY CAPP	WY PRB
Volatile	34	34
FC	50	34
Btu/lb	12,500	8,500
Fuel Ratio	1.5	1.0
Lbs Vol.	27 lbs	40 lbs
MBtu	MBtu	MBtu



Operators Challenge

Plant Basics

Boilers are Btu machines

Pulverizers are ton machines
Pulverizers grind and DRY coal

Higher moisture lower Btu coals
impact pulverizer performance

Sizing

Set for Coal type
Set for Slag control
Set for Maintenance

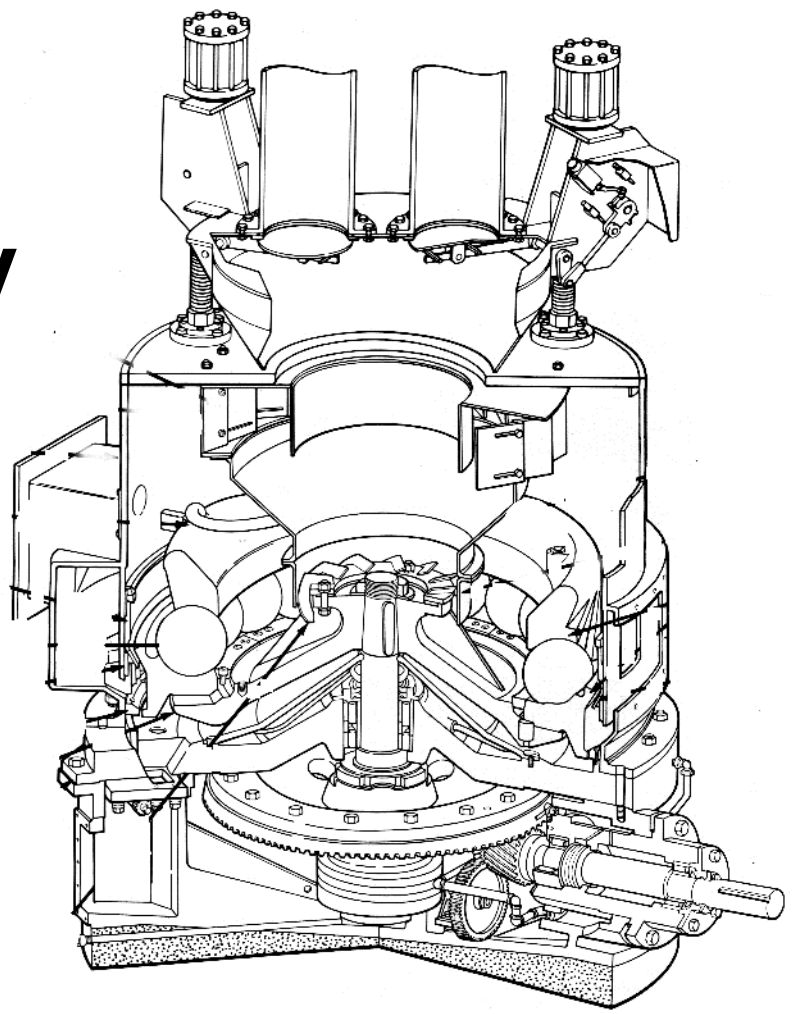
May be opposite directions

Very Important

Ash and High Velocity Wears Them Out

#1 for PC plant

Impacts load
High Maintenance
Performance Testing



Babcock Power

Benefits of Optimized Milling Systems

The benefits of optimizing pulverizer systems can be considerable, generally resulting in overall improved operation, including:

- Reduced levels of LOI/UBC
- Increased coal fineness
- Lower CO emissions from improved fuel balance and fineness
- Lower NOx emissions
- Reduced slagging and fouling
- Balanced O2 profile across unit
- More uniform tube metal temperatures
- Increased boiler efficiency
- Improved plant heat rate

Typical Sizing

200 mesh = 75 microns
55-75 % passing

50 mesh 300 microns
0.1 to 4 % retained

4 / 0.1 = 40 x more oversize

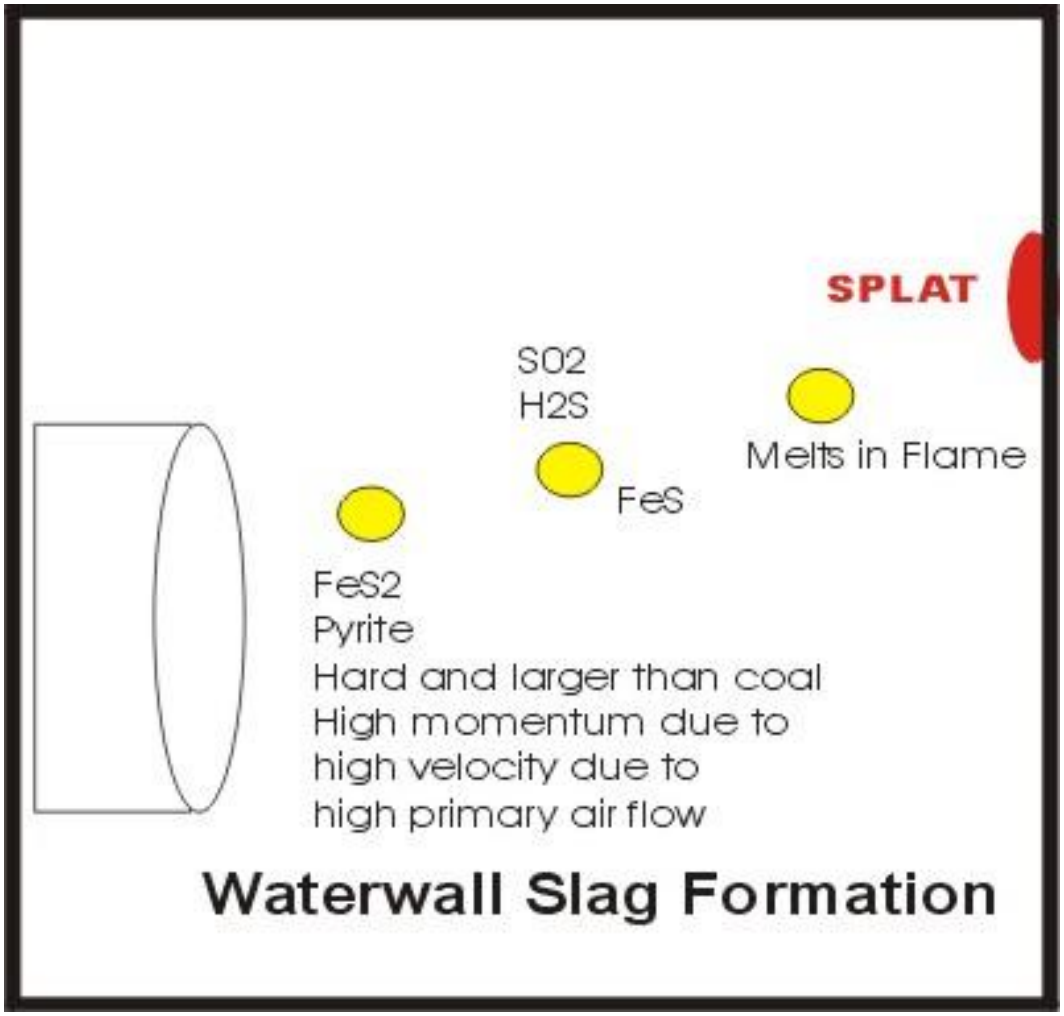
Sizing

200 mesh polish

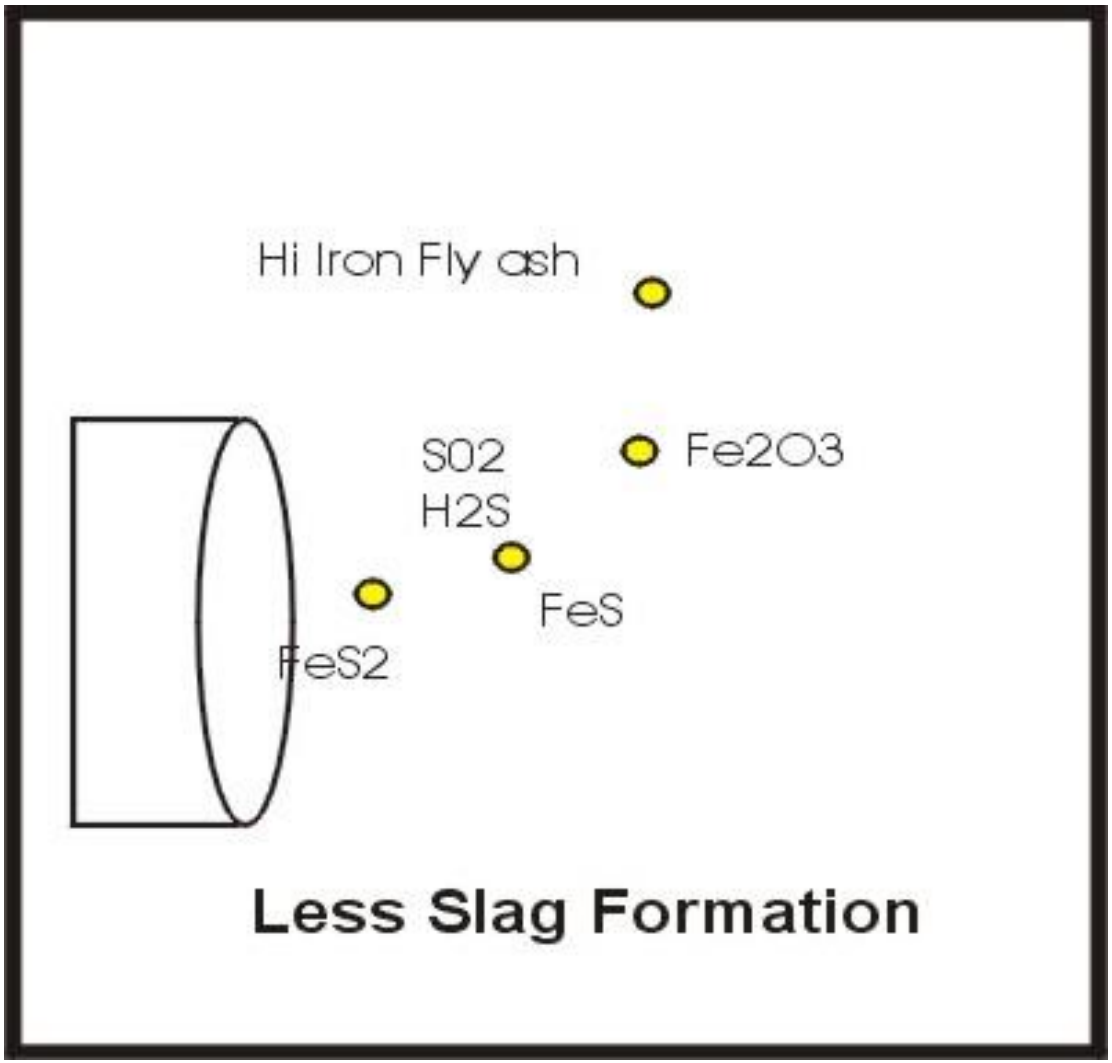
50 mesh grinds

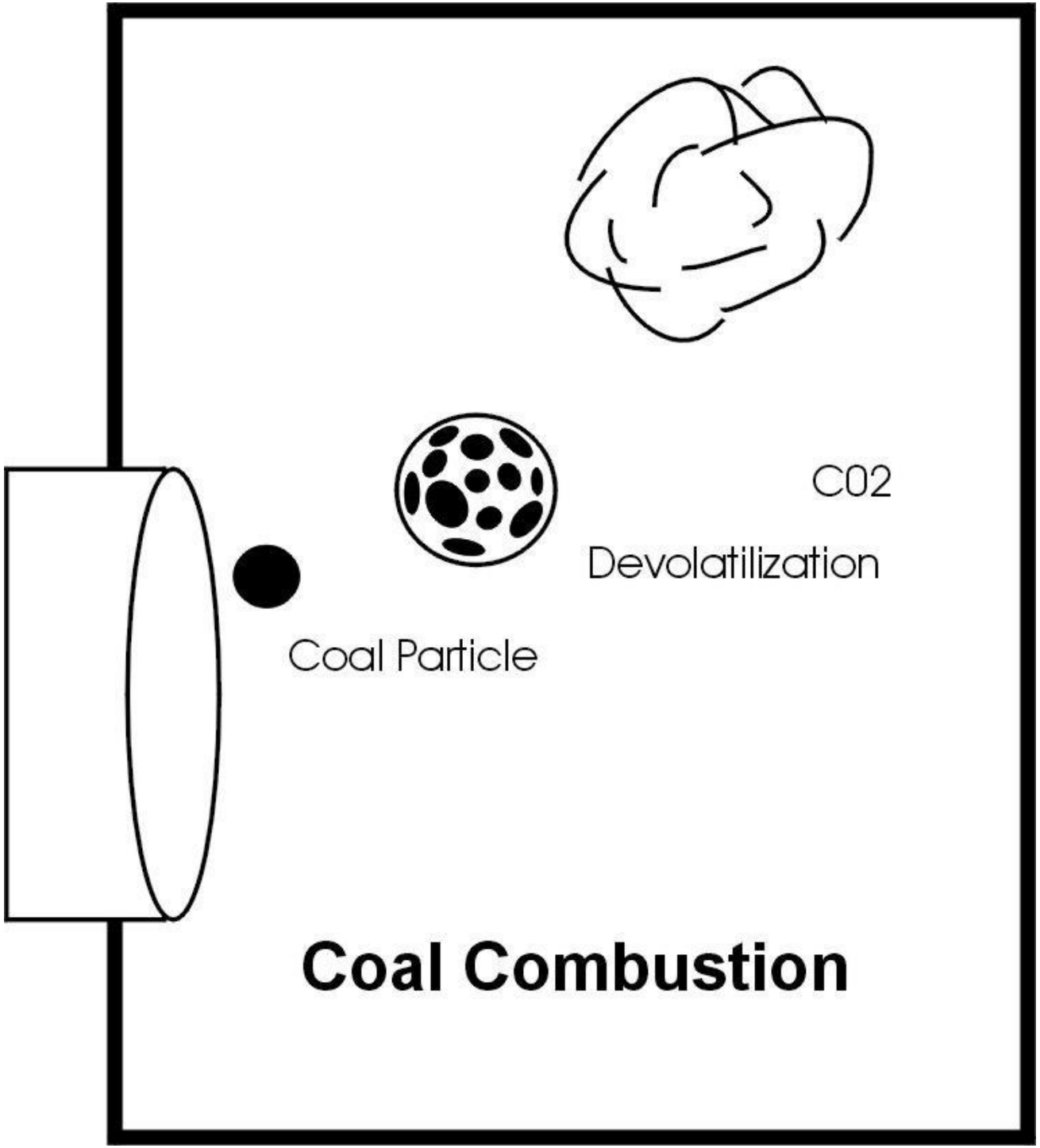

Splat Factor

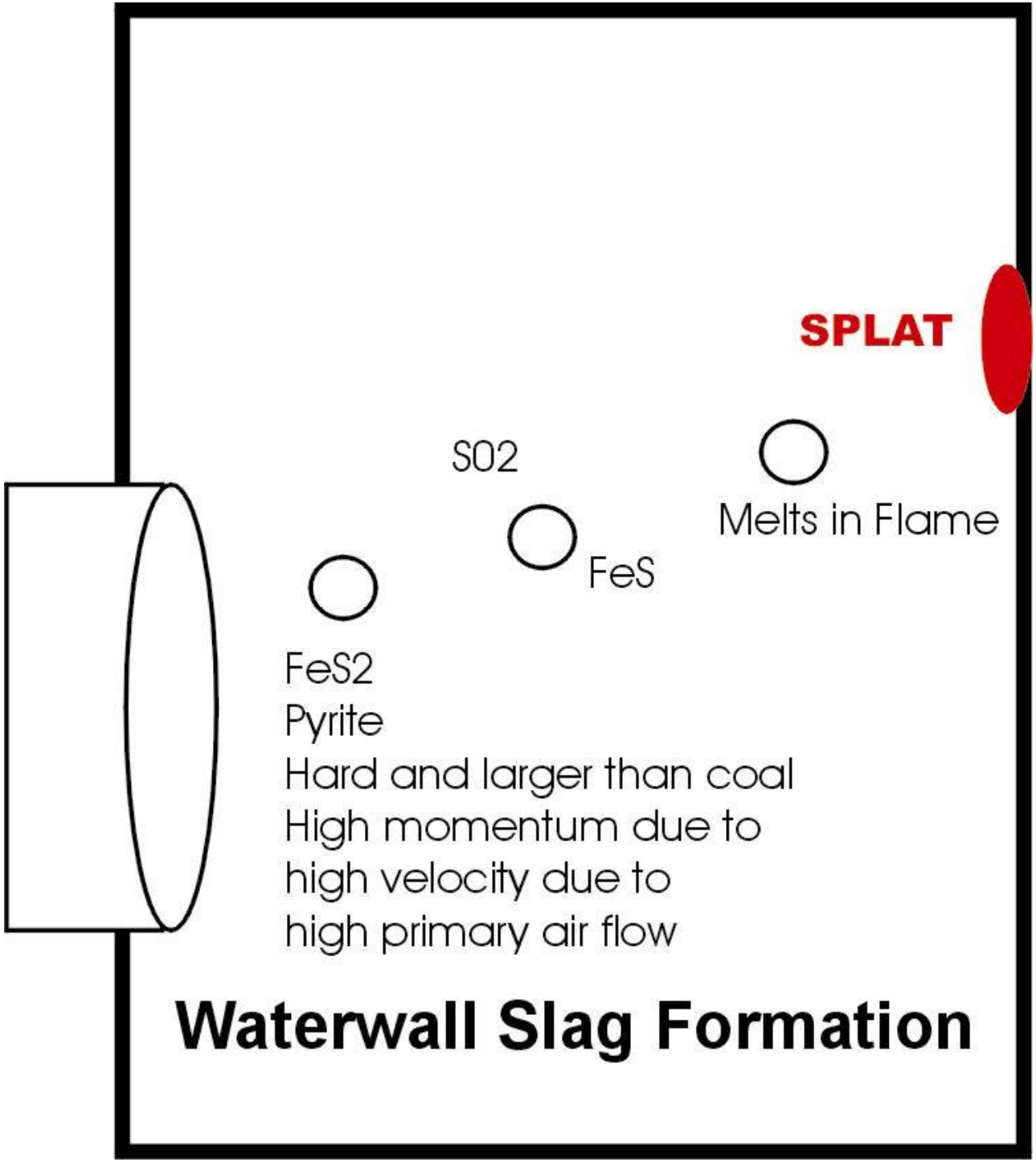
Coal Combustion



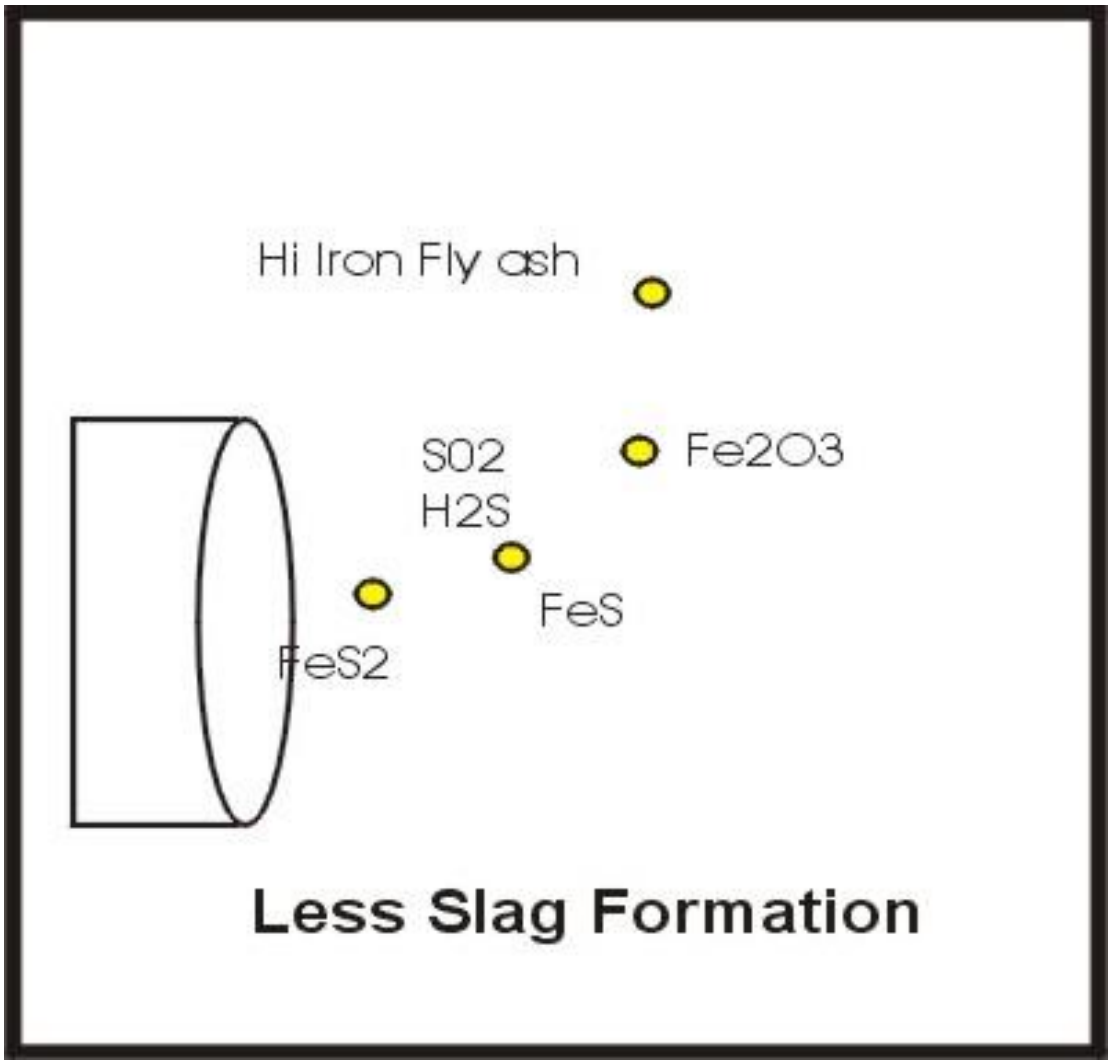
Coal Combustion



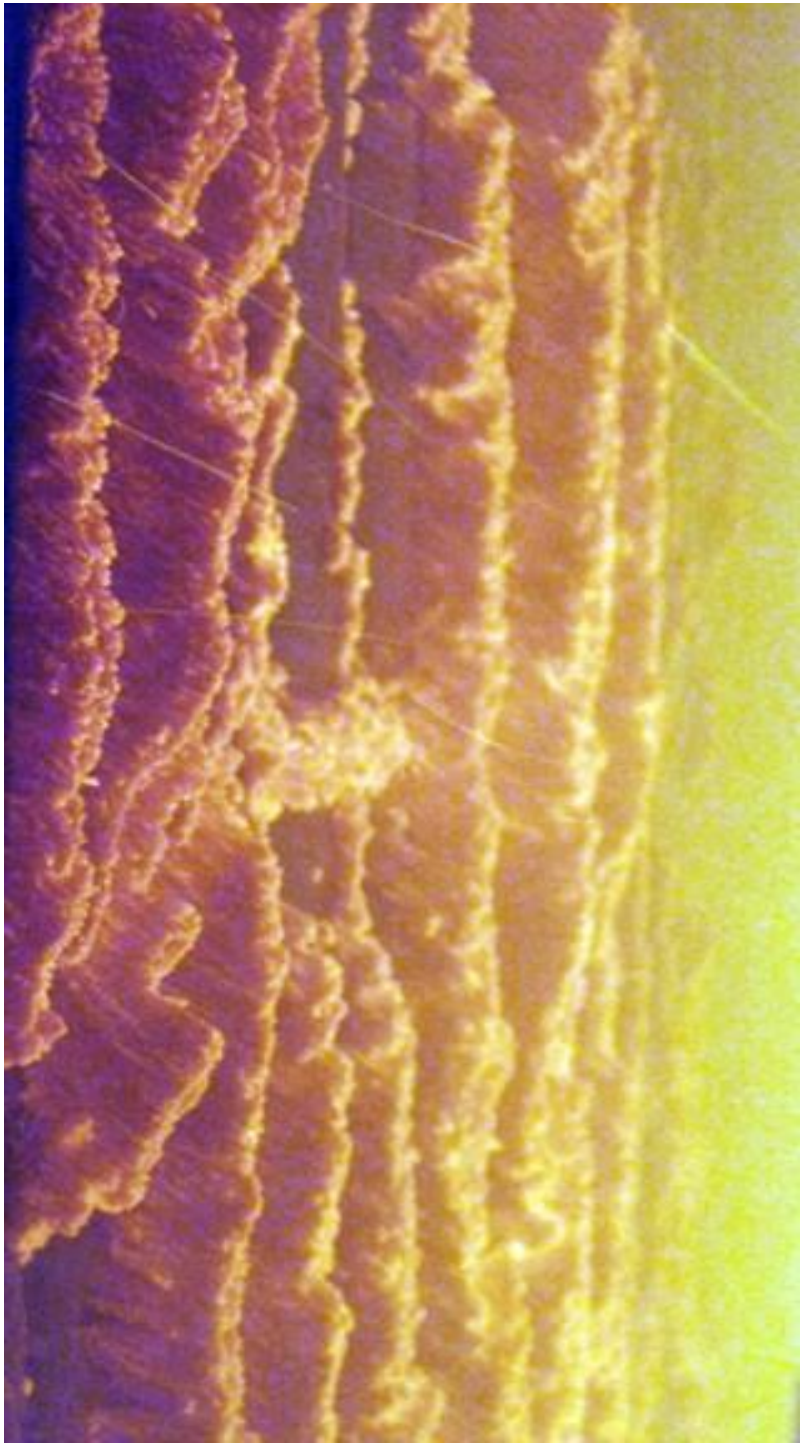

C02
Devolatilization
Coal Particle
Coal Combustion

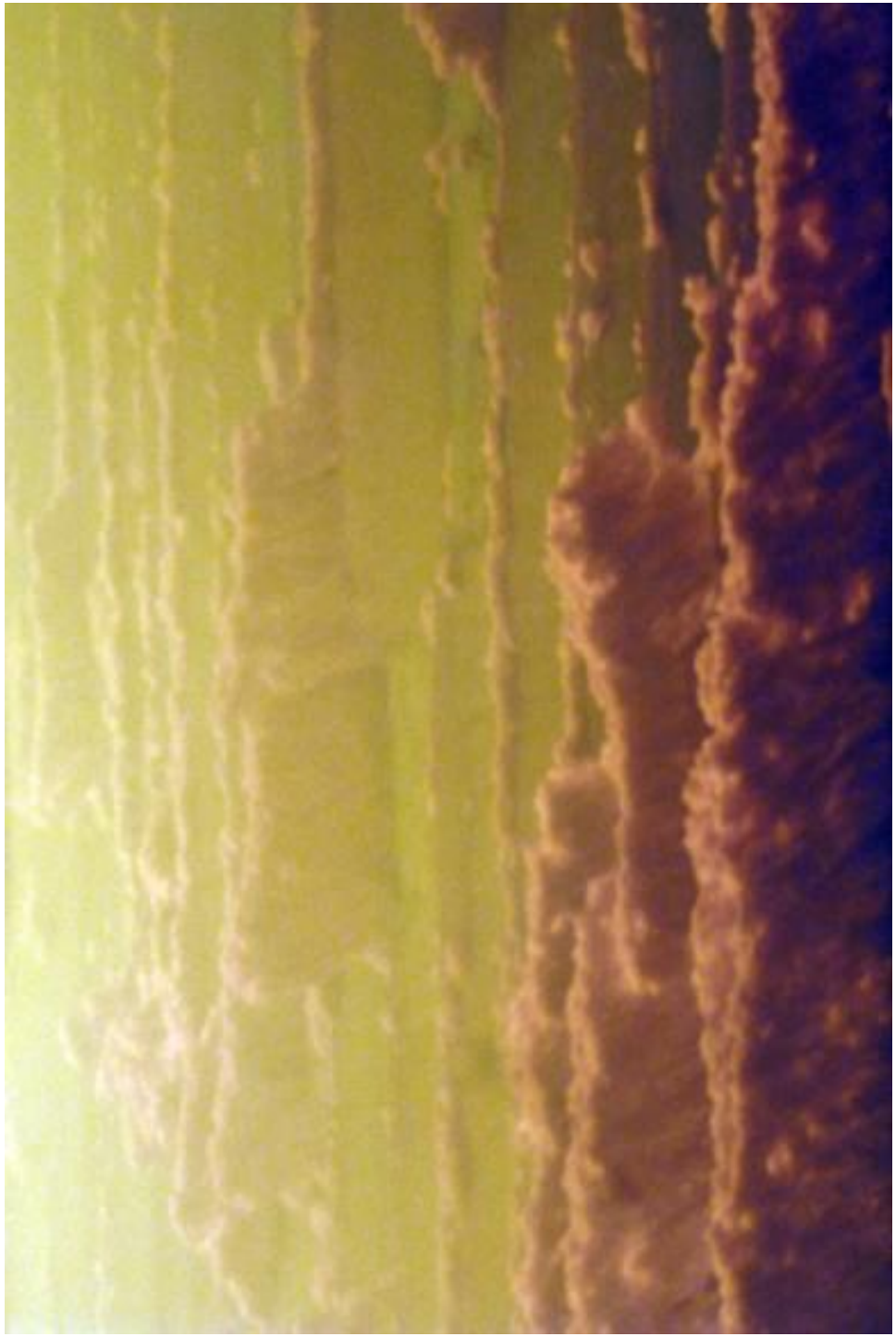

SPLAT
SO2
Melts in Flame
FeS
FeS2
Pyrite
Hard and larger than coal
High momentum due to
high velocity due to
high primary air flow
Waterwall Slag Formation

Coal Combustion




Then goes
To the
Superheater





Fusion Temperatures
or Cone melt down test

Waste of time and money!

Same coal has many fusions?
Washed coal has lower fusion?
Washed coal makes less slag?

Ash Chemistry
Major & Minor Elements

SiO_2
Al_2O_3
TiO_2

Fe_2O_3
CaO
MgO
K_2O
Na_2O

Slag Index = dry S x B/A

= dry S (~1/3 to 2/3 pyrite) x B/A

= dry S (FeS_2)xFe2O3+CaO+…/SiO2+…

Traditional Slagging Index

SI ~ $(Fe)^2$ (iron squared)

This means that as sulfur increases the slagging increases exponentially.

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Slag is a build up of rate process so, the amount of ash should matter.

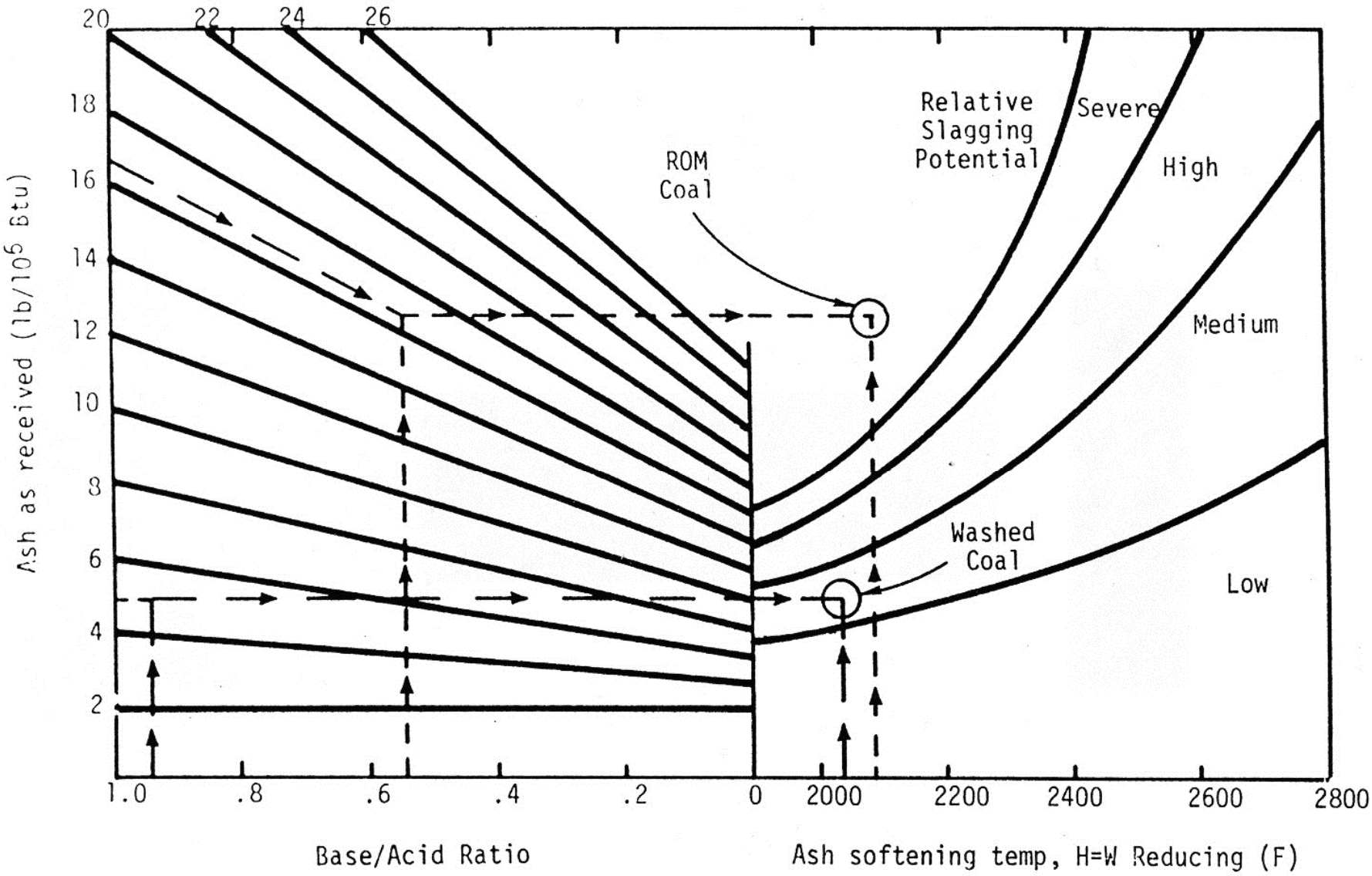


Figure 2-23. AEP slagging index (31).

Lbs. of ash/MBtu

= %ash / (Btu/10,000)

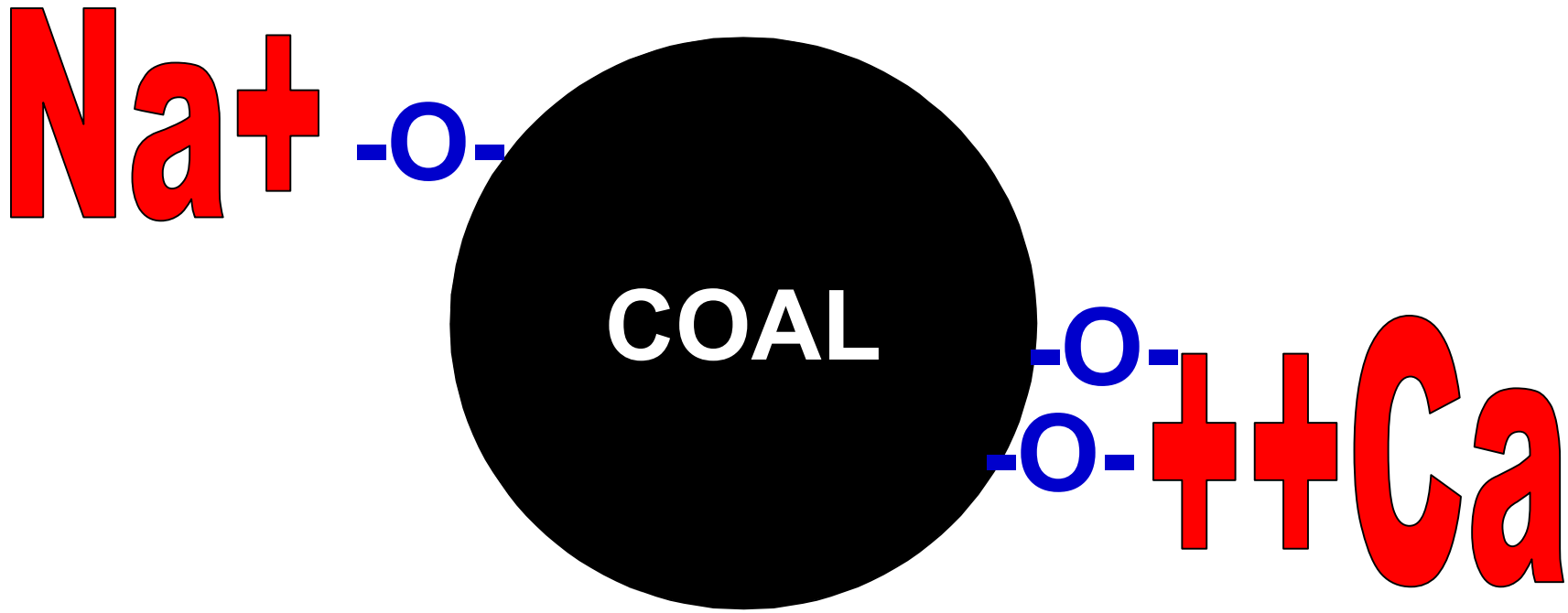
Lbs. of element/MBtu

= %ash / (Btu/10,000)
X (%Element/100)

Test	Hi Na_2O	Low Na_2O
Btu/lb	9,300	9,000
% Ash	4.0	6.5
% Na_2O	8.0	5.0

Test	Hi Na_2O?	Low Na_2O?
lb Ash/MBtu	4.3	7.2
% Na_2O	8.0	5.0
lb Na_2O/MBtu	0.34	0.36

Organically Bound Alkalis



Causes

Fuel Related

Pyrite
Clays
Alluminosilicates
Organic Alkalis

Causes

Equipment

Soot Blowers
Pulverizers
Air to Fuel Ratio
Burners
Changes

Causes

Design

Furnace Size
Tube Material/Spacing
Soot Blower Coverage
Observe/Measure Slag

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Thank you!