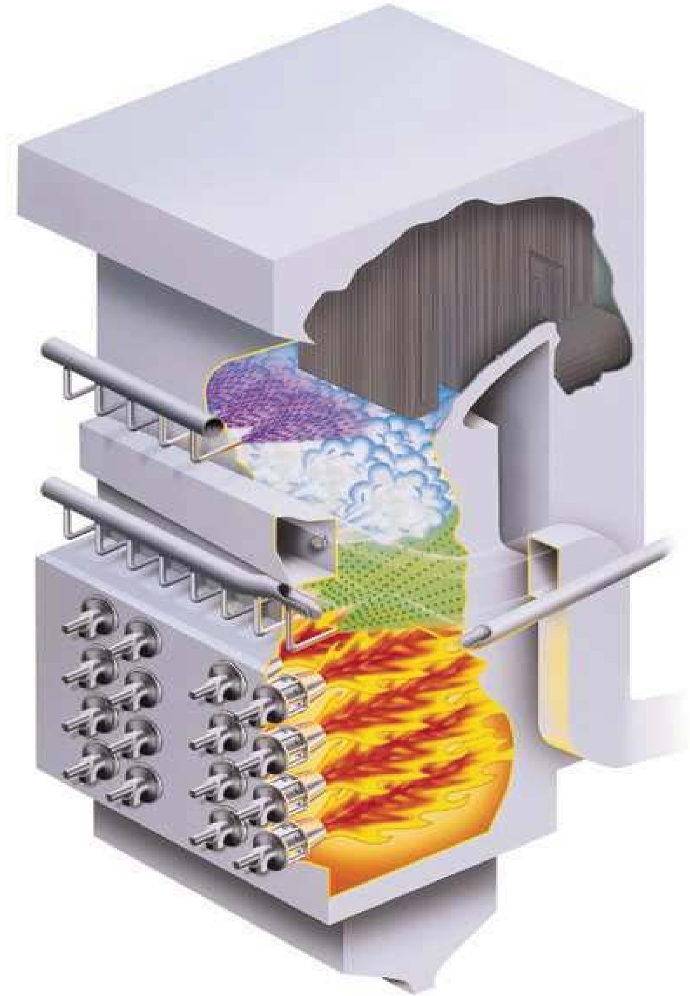
Worldwide Pollution Control Association

WPCA/FirstEnergy Biomass Seminar

Akron, Ohio
December 3, 2009

Particulate Collection Issues
Biomass and External Factors



WPCA Seminar

John Knapik & Easel Roberts

December 2009

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PM Collection – External Factors

- Typically, plant don't seek help until emissions bump against or exceed compliance limits.
- Initial response is to review the operation of the primary PM control device.
- Other than long postponed maintenance issues, the problem is often not the PM control device, but process conditions.
- For this reason, it is critical to consider the whole system when addressing emissions issues.
- Today, we'll start with the affects of burning biomass.

PM Collection – Biomass Basics

- Quickest and cheapest way to generate Renewable Energy.
- Not free and not without issues
- Growing conflict between "Renewable" and "Sustainable"

- Biomass Fuel Desirability – from boiler's perspective
  - > Processed Whole Wood
  - > Wood Residue
  - > Urban Wood Waste
  - > Agricultural Waste

PM Collection – Biomass Basics
Wood & Wood Waste

Pro's

- Burns Good
- Can reduce SO_2 & NO_x beyond simple dilution
- Can bring ~40% Oxygen w/in the fuel
- ~ Fan Neutral
- ~ No additional slagging

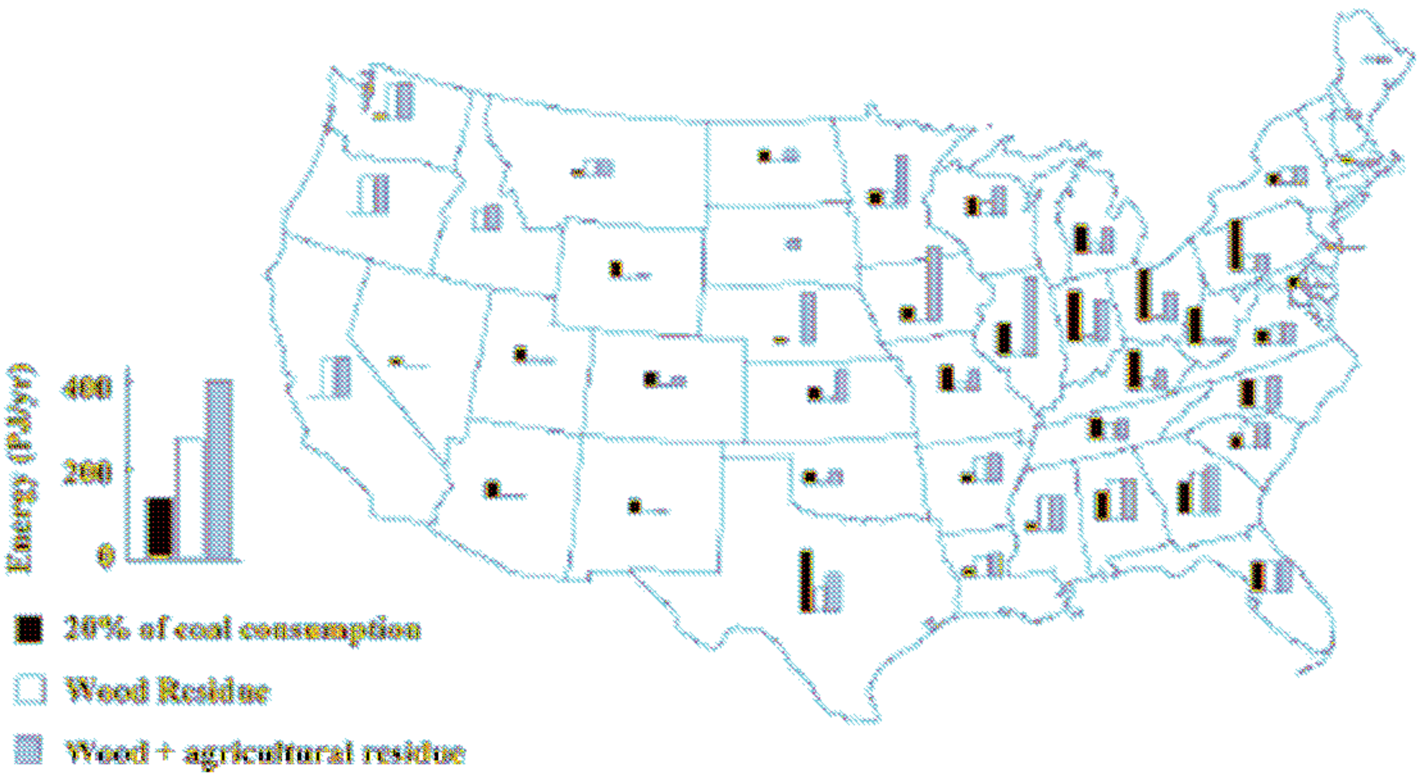
Con's

- Must be processed or **~50% water**
- Material Handling an issue

@ 10% biomass on a btu basis, the volume of fuel is almost equal to the 90% coal volume

- Ohio lacks sufficient supply for state wide implementation

PM Collection – Biomass Basics
Wood & Wood Waste



Robinson, Rhodes & Keith, Vol. 37, No. 22, 2003 / Environmental Sciences & Technology, 5081-5089

PM Collection – Biomass Basics Agricultural Wastes

ONLY consider with your eyes WIDE OPEN

Pro's

- Carbon Neutral
- Reasonable Availability
- Sustainable
- Cheap
- Can and is being done

Con's

- Sodium, Potassium, Chlorine and Silica
- Sodium or Potassium salts
  Liquid at ~1300 °F or ~700 ° C
  Slagging can be rapid and severe
- Sodium + Silica = Na_2SiO_3
  A water soluble, heat resistant cement
- Ion Mobility
  $KCl + CaSO_4 = K_2SO_4 + CaCl_2$
  Accelerates SH Tube corrosion
- SCR Catalyst deactivation may accelerate.

PM Collection – Realities of Biomass Burning

348 *Energy & Fuels, Vol. 16, No. 2, 2002* *Robinson et al.*

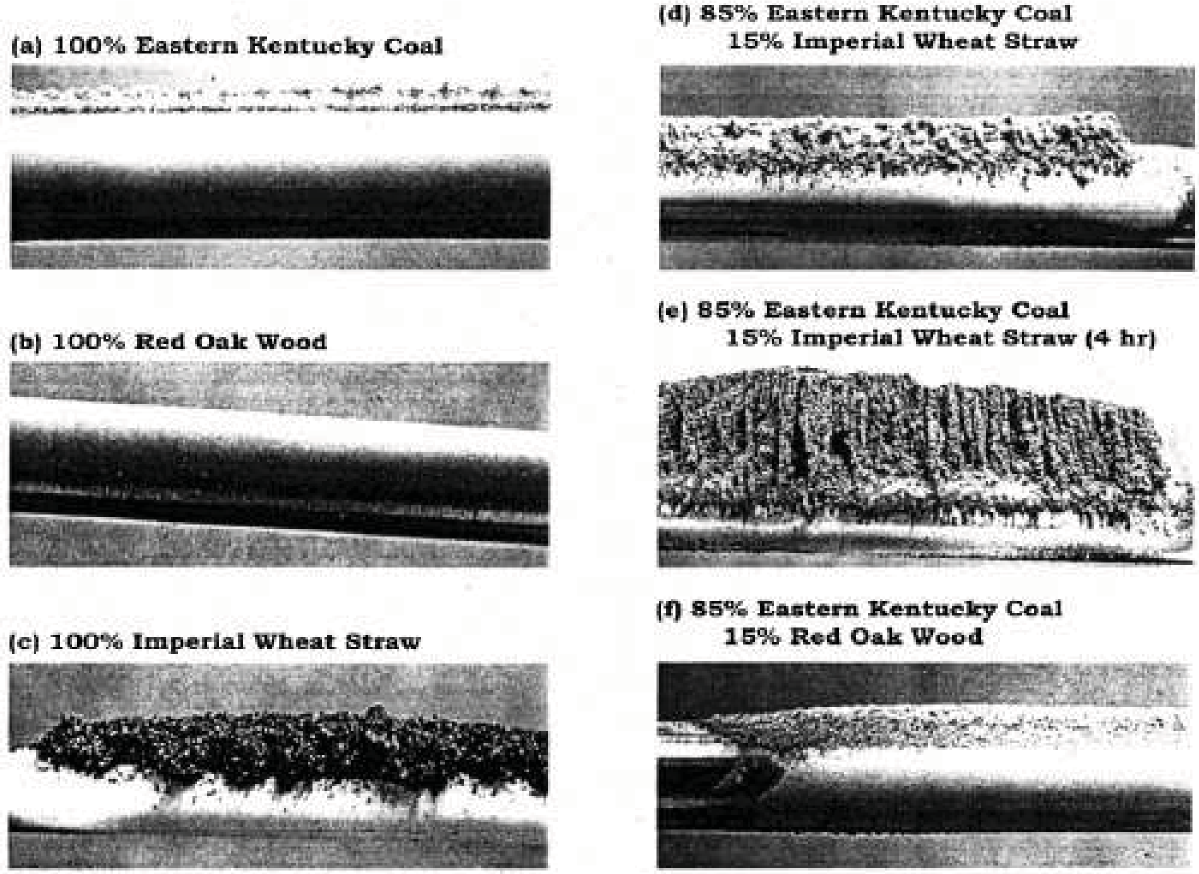


Figure 2. Pictures of deposits formed while firing unblended fuel (a, b, c) and cofire blends (d, e, f). Each of the pictures has a slightly different scale; the diameter of the probe in each picture is 1.6 cm.

All other pictures show 1 hour of accumulation

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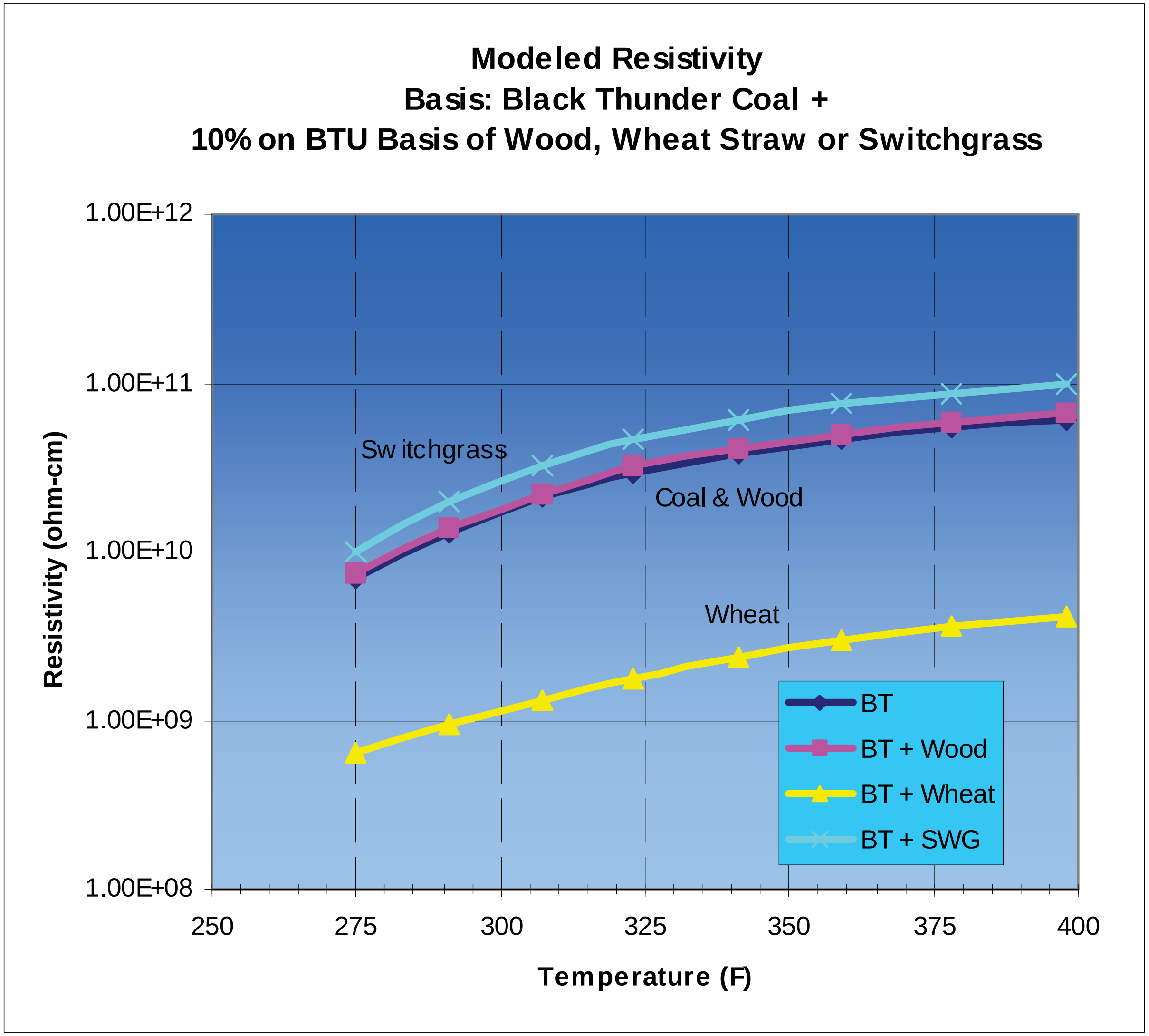
Fuel Data used in Analysis

	Black Thunder	Red Oak	American Wheat Straw	Switchgrass
HHV (BTU/lb)	8802	8023	6420	7002
Ultimate %				
Moisture	27.5	3.41	4.91	8.08
Carbon	50.9	47.84	39.02	40.75
Hydrogen	3.6	5.39	4.57	6.07
Nitrogen	0.6	0.09	0.84	0.76
Chlorine	0.001	0.00	1.78	0.10
Sulfur	0.34	0.06	0.40	0.11
Ash	5.1	1.27	14.00	7.59
Oxygen	12.1	44.97	34.71	37.16
	100.1	**103.0**	**100.2**	**100.6**

Fuel Data used in Analysis

	Black Thunder	Red Oak	American Wheat Straw	Switchgrass
Ash Minerals %				
Silica	30.4	44.73	36.68	58.15
Alumina	15.8	9.1	1.36	2.3
Titania	1.3	0.56	0.09	0.26
Feric Oxide	5.4	7.81	0.57	11.51
Calcium Oxide	22.9	16.2	4.32	11.18
Magnesium	4.9	1.25	1.66	5.44
Potassium	0.3	9.31	20.5	9.06
Sodium	1.2	0.77	13.5	0.38
Phosphorous	1	1.15	3.07	4
Sulfur Trioxide	14.6	1.41	4.29	3.04
Chlorine	0	0.58	14.5	0

10% Biomass, 90% Coal on BTU Basis



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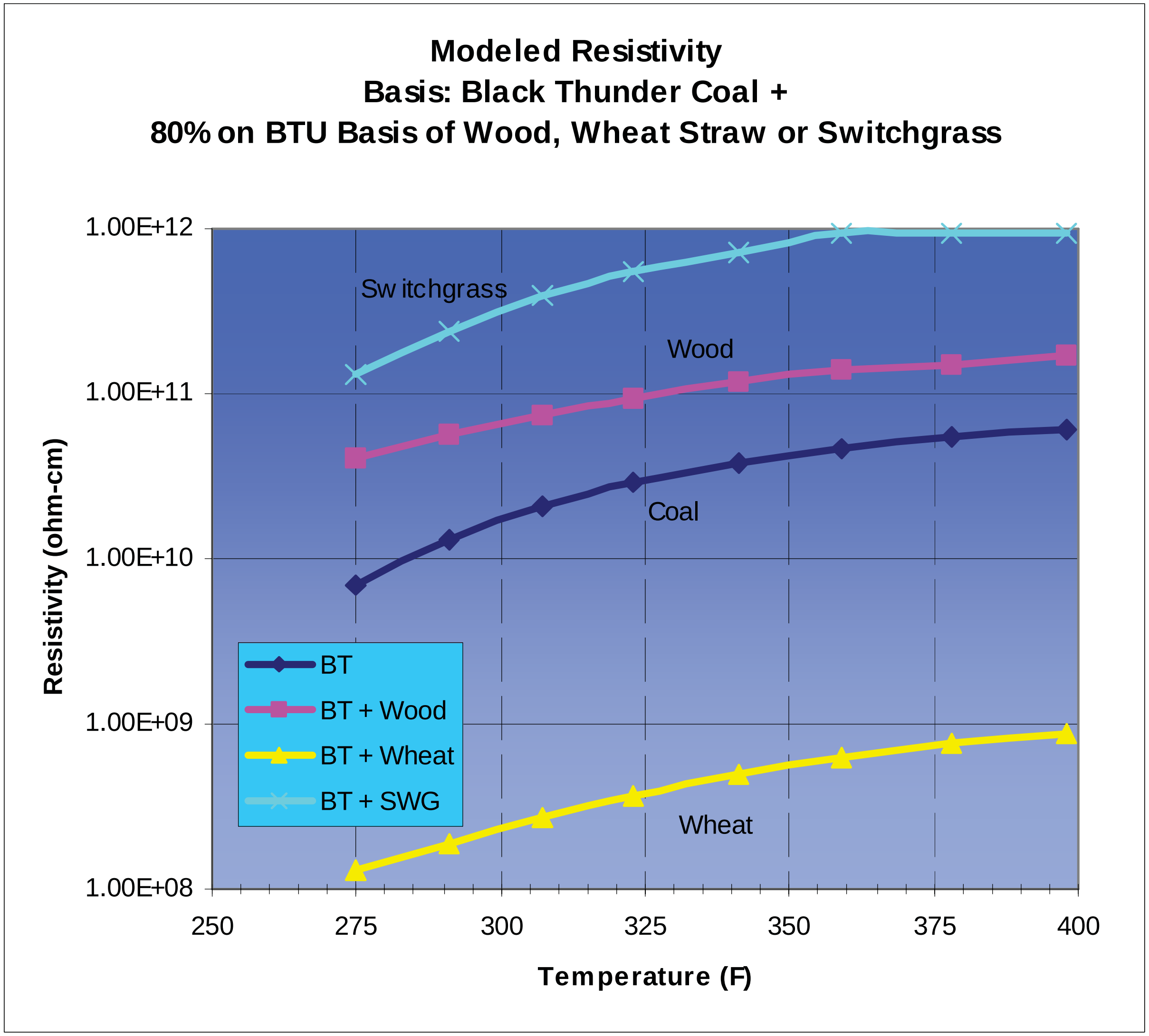
Resistivities are calculated values via the WinESP model from SRI using Ash Analysis Data

80% Biomass, 20% Coal on BTU Basis



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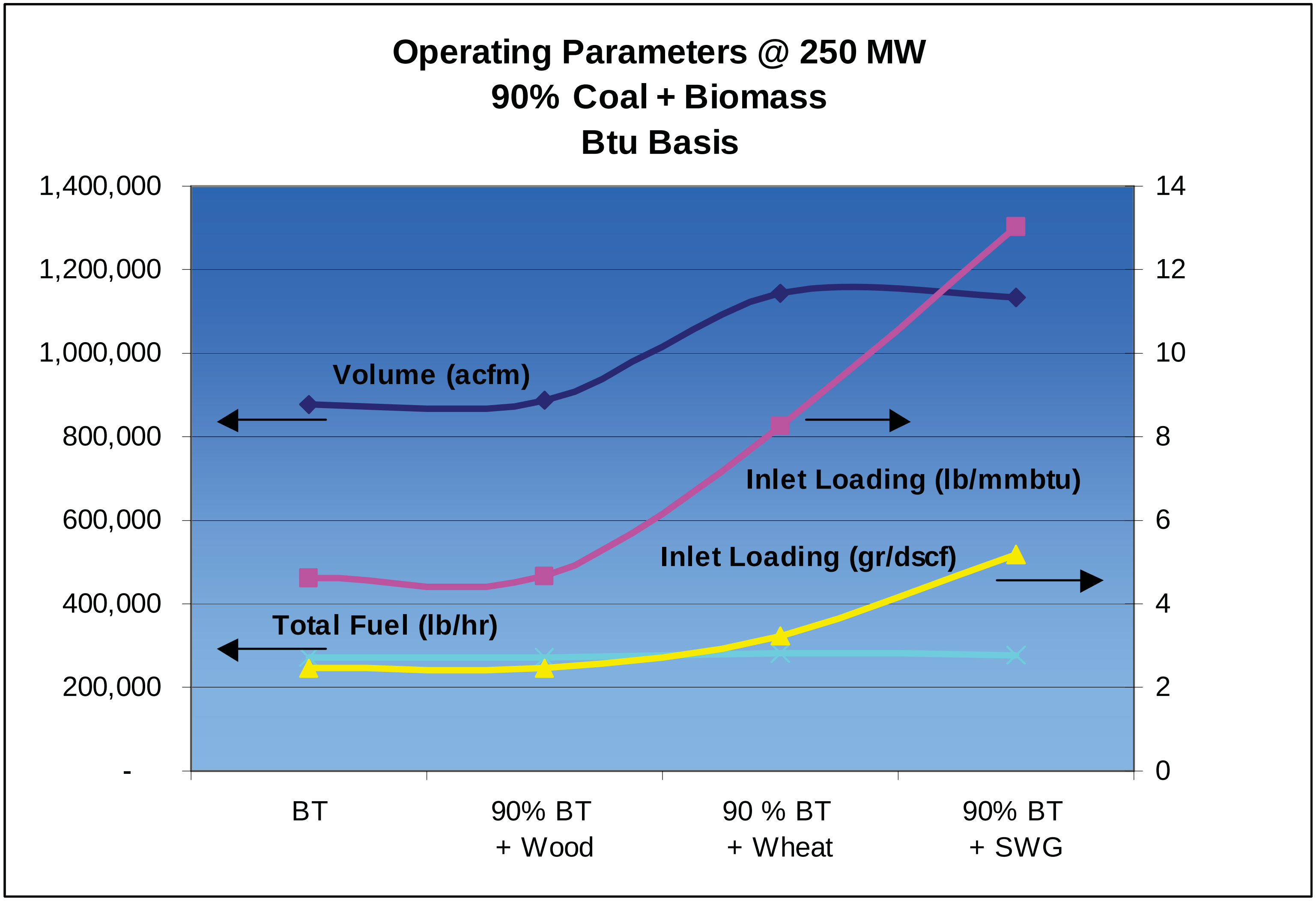
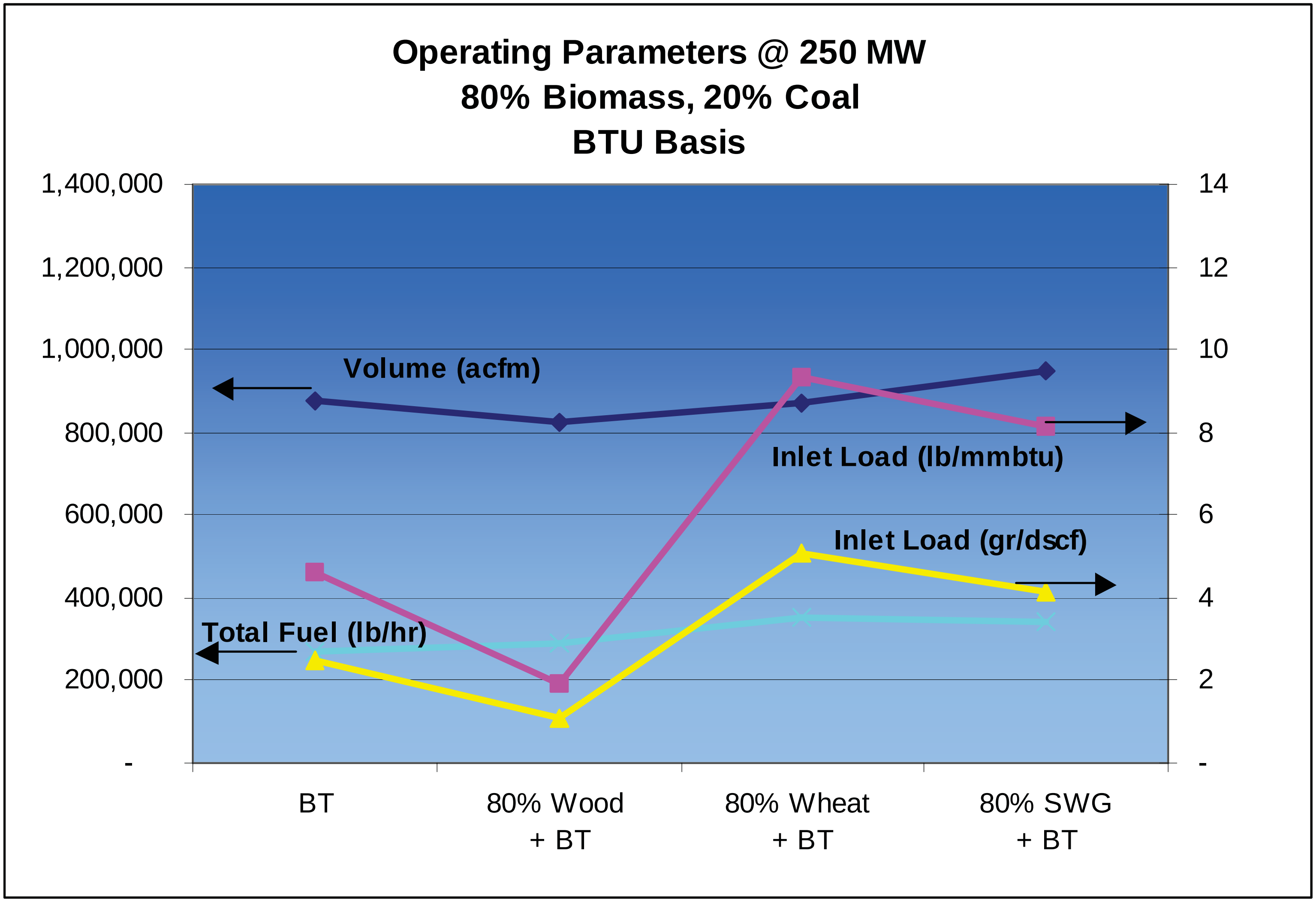


Assumptions: 30% Excess Air, 5% Inleakage,
325 °F Exit Temperature,
5% Oxygen in Exhaust

80% Biomass, 20% Coal on BTU Basis



Assumptions: 30% Excess Air, 5% Inleakage,
325 °F Exit Temperature,
5% Oxygen in Exhaust

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PM Collection – External Factors

- From an Air Pollution Control Perspective
- There are certainly affects to be dealt with
- Key is to Define **THE** Fuel Mix, then you can deal with it.

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You have a PM control event (problem)

Define the nature of the event to focus your efforts:

Try to determine if it's the Control Device or the Process.

> Characterize PM event
  - **Random in nature or Cyclical**
  - **Rapid spikes or Gradual increase**

> ESP - Review Electrical Conditions
  - **Specific Sections or is Whole Unit involved**

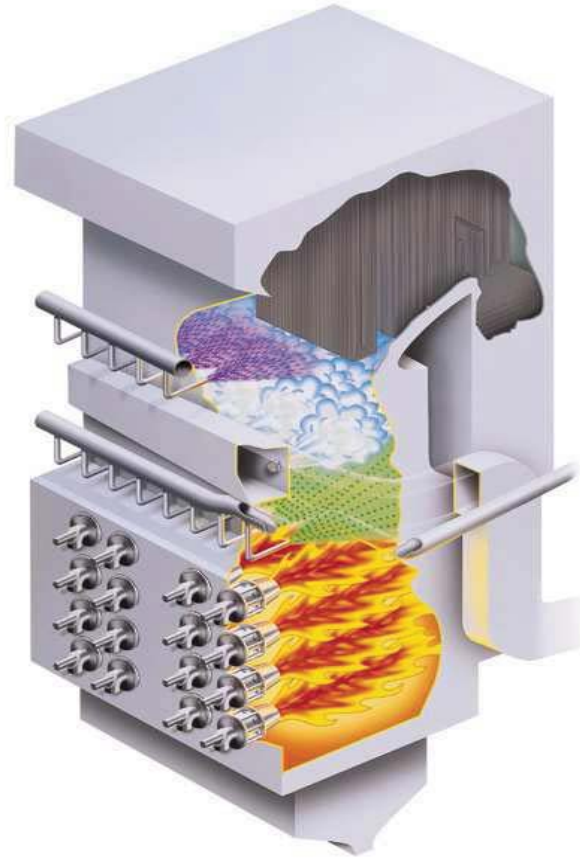
> Fabric filter - review broken bag detector data
  - **Specific Compartments or is Whole Unit involved**

Assuming it isn't the PM control devices fault, where do you start?

Two Key Questions: What's changed and why?

Major factors affecting PM removal

- Flue Gas Composition
- Inlet Dust Load
- Flue Gas Flow Rate
- Flue Gas Temperature
- Particle Size Distribution
- Carbon Content of Ash

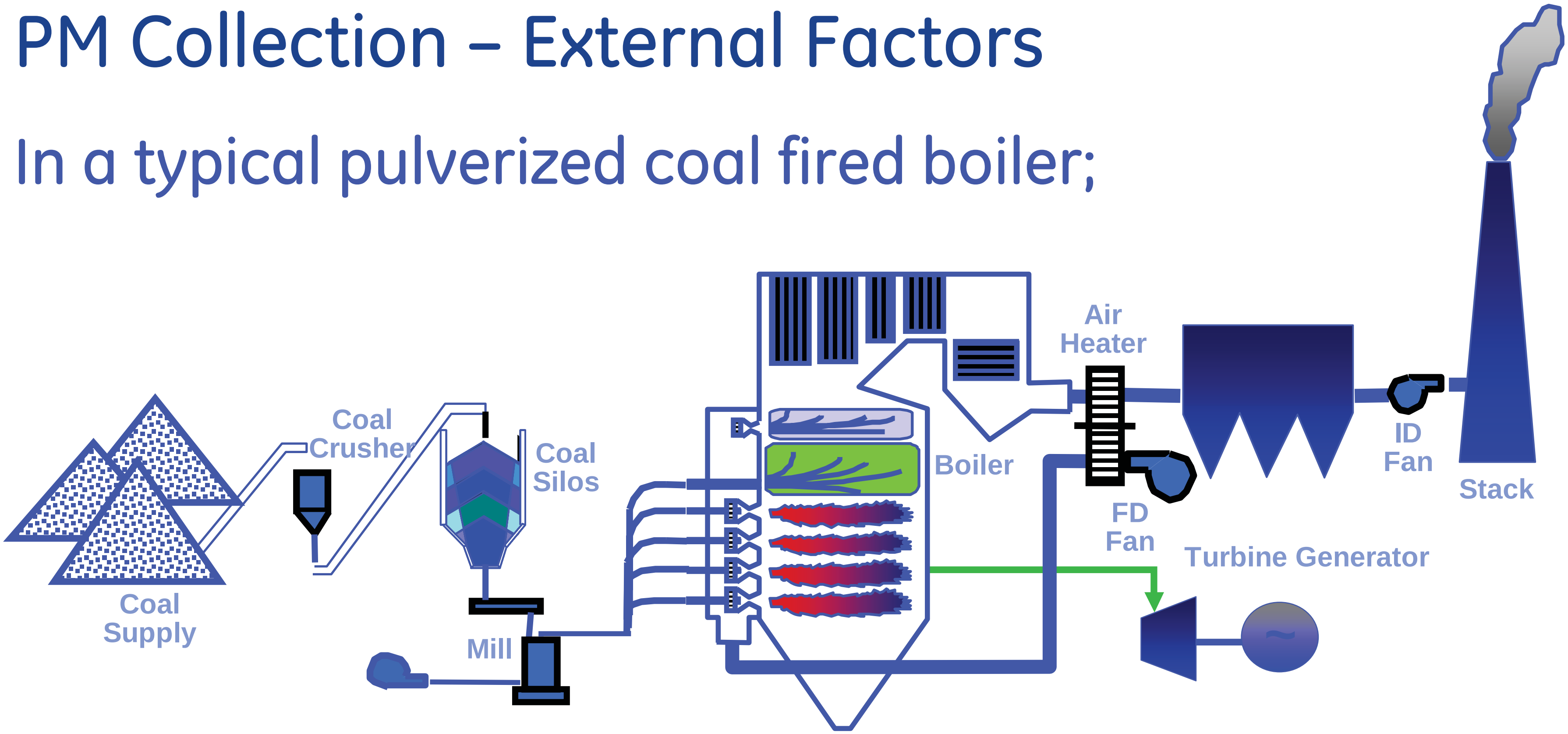


PM Collection – External Factors

- Fly Ash is a constituent of the fuel burned.
- So, dust loading is proportional to firing rate and ash content.
- Why might inlet dust burden change?
  - Change in boiler load
  - Change in fuel ash content
  - Increased unburned carbon in ash
  - Injection of sorbent ahead of PM device
  - Short term activities such as soot blowing

PM Collection – External Factors

In a typical pulverized coal fired boiler;



About 15% to 20% of Ash Falls out as Bottom Ash

About 80% to 85% Passes Through Boiler as Fly Ash

For a 250 MW Plant – 5 to 7 Tons/hr ash

What happens when dust load increases?

Electrostatic Precipitator

- Increased emissions
- Increased spark rate
- Constant pressure drop
- Need for increased rapping
- Potential for increased erosion
- More ash to remove

Fabric Filter

- Constant emissions
- Increased pressure drop
- Need to reduce pulse cleaning interval
- Increased bag wear
- Increased compressed air consumption
- More ash to remove

What can I do when dust loading increases?

Electrostatic Precipitator

- Increase hopper evacuation rate.
- Reduce inlet field collecting rapping interval, increase force.
- Monitor second field to quantify impact of first field changes.
- If using flue gas conditioning, increase SO_3 injection rate.

Fabric Filter

- Increase hopper evacuation rate.
- If using POD, monitor upper pressure set point limit versus pulsing interval.
- If using timer pulsing, decrease interval between pulses.
- Monitor sample bags for signs of wear.

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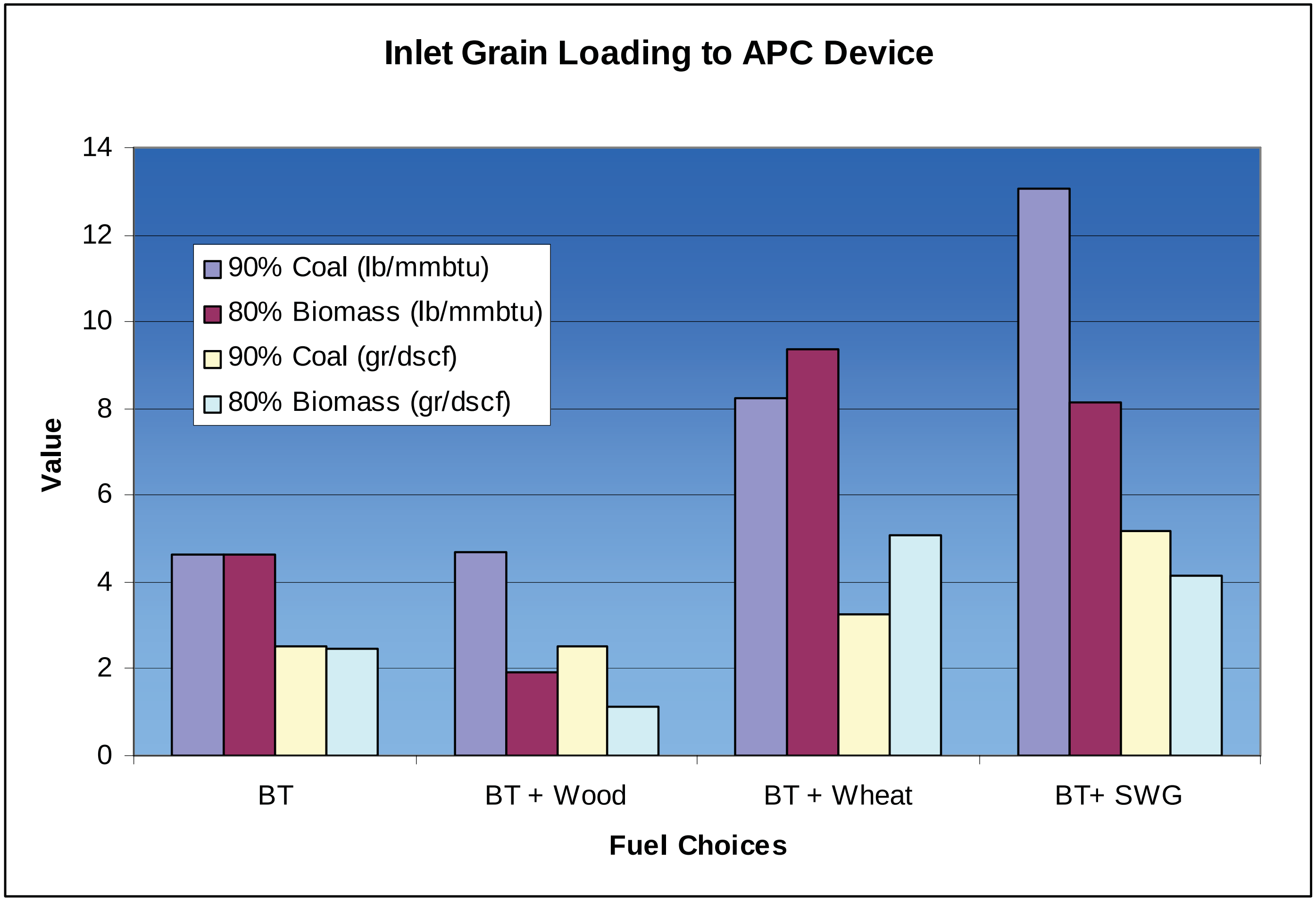
Inlet Grain Loading



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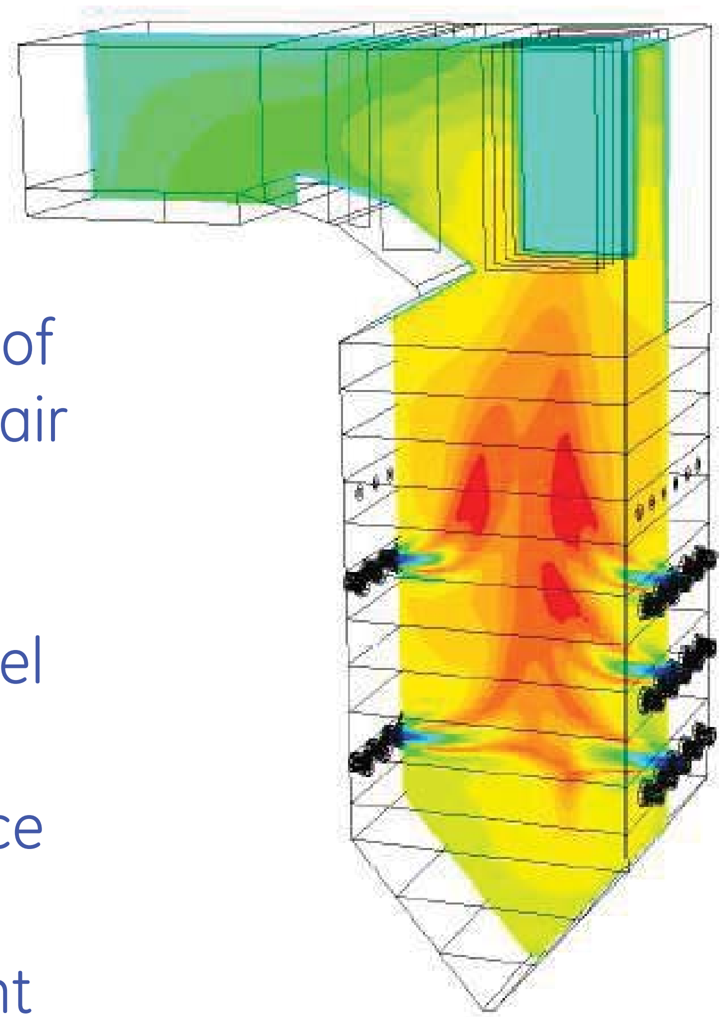
PM Collection – External Factors

Flue gas Flow Rate



>Flue gas is a combination of combustion products and air in-leakage.

>Combustion products are a function of the fuel constituents and the excess air utilized during burning.

>Perfect combustion would require a stoichiometry of “1”, as defined by fuel composition (Ultimate Analysis)

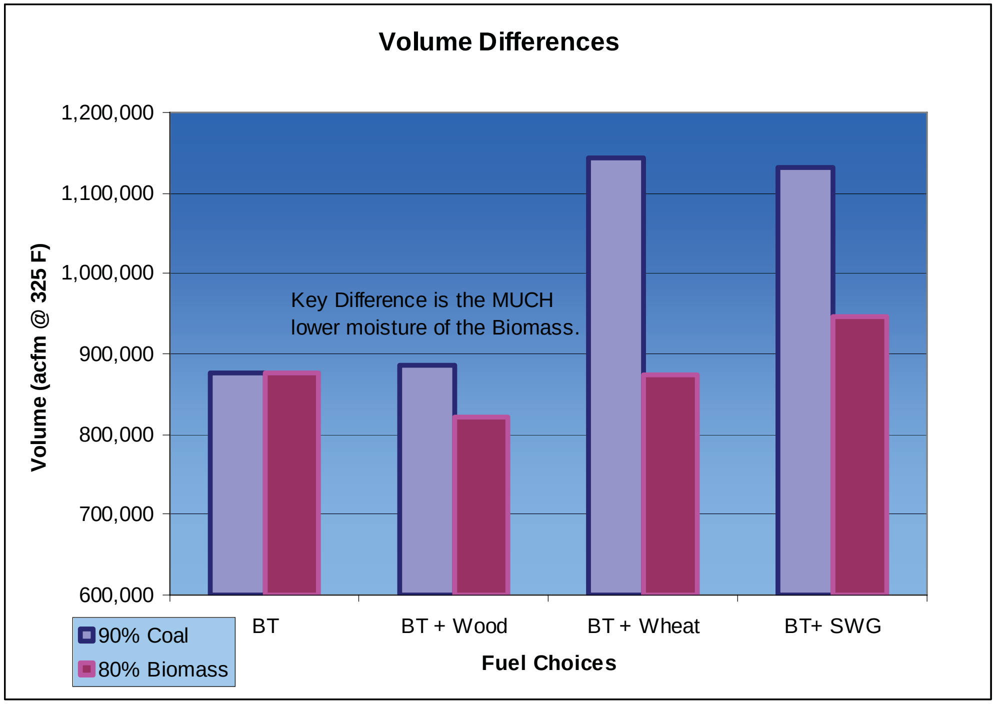
>Real world, excess is air required since fuel/air mixing less than perfect

>Air in-leakage accounts for significant increase in volume

PM Collection – External Factors

Why does gas volume change?

- Fuel burn rate
- Fuel characteristics
- Integrity of the casing and duct work
- Moisture content of the gas
- Temperature of the gas



Impact of air in-leakage on Gas Volume

- In a negative pressure PM control device, ambient air will leak into the flue gas.
- Consider gas volume at two O_2 levels:
  - 4.5% O2 ~1,088,000 ACFM
  - 6.5% O2 ~1,250,000 ACFM
- What impact does that have on PM equipment?

Impact of Gas Volume on ESP

$$EFF = 1 - e^{-\frac{wA}{V}}$$

Increase gas volume,
Decrease efficiency.

$$W = \frac{Eo\ Ep\ a}{2\pi\eta}$$

EFF = Collection Efficiency
A = Collecting Area
V = Volumetric Flow Rate
w = Migration Velocity
Eo = Charging Fields ($\propto kV_{peak}$)
Ep = Collecting Field ($\propto kV_{average}$)
a = Particle Radius
η = Gas Viscosity
π = 3.1416

Impact of air in-leakage on Gas Volume

At 3.1 gr/dscf inlet dust

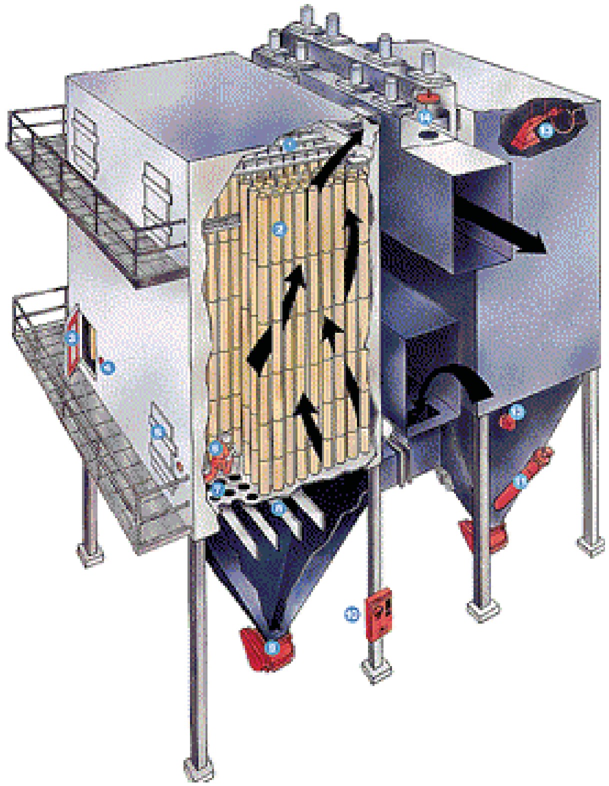
- Impact on ESP
  - > 4.5% O2 ~1,088,000 ACFM
    - 99.4% removal efficiency
    - 0.017 gr/dscf
  - > 6.5% O2 ~1,250,000 ACFM
    - 98.84% removal efficiency
    - 0.033 gr/dscf

ESP emissions almost double

Impact of Gas Volume on Fabric Filter

Two KEYS:

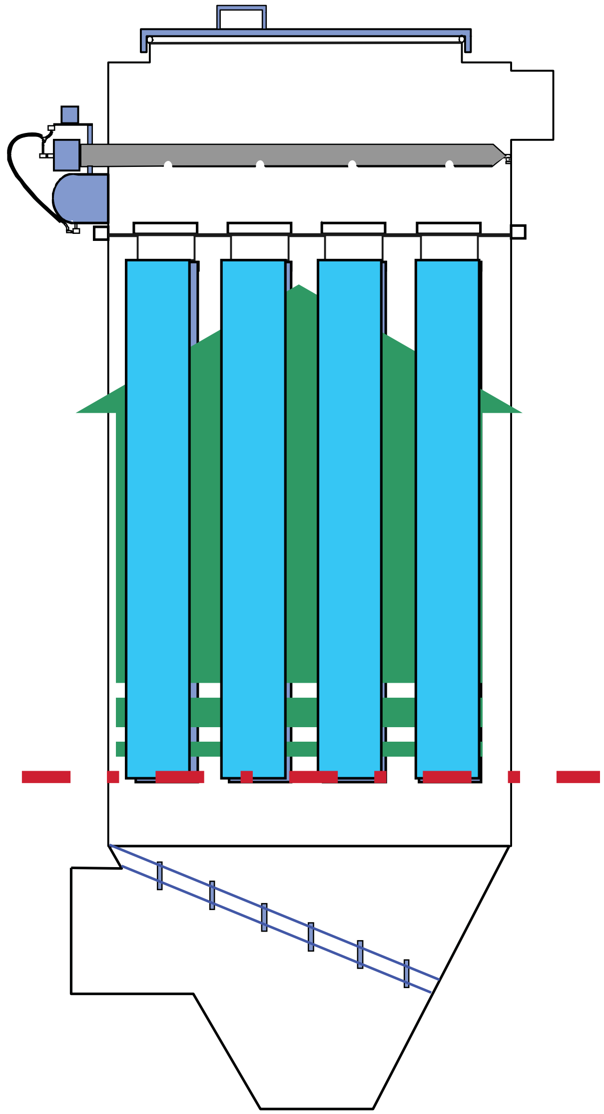
•Collection efficiency is **<u>not</u>** volume dependent.
•Increased gas volume results in higher ΔP



Air to Cloth Ratio

- Air to Cloth ratio = $\frac{\text{Volume ACFM}}{\text{Total filter area Ft2}}$
- Filter area = Filter Dia. X Length x 3.14
- No. Filters x Filter Area = Total Filter Area
- Typical pulse jet air to cloth ratios for utility boilers 2.0 through 4.0 ft/min.

Impact of Gas Volume on Fabric Filter



Can Velocity

In a pulse jet fabric filter, “can” velocity is the upward gas velocity between filter bags.

It is calculated at the horizontal cross section at the bottom of the filter bags.

Excessive can velocity prevents dust from settling into hoppers.

Increased gas volume results in increased can velocity.

Impact of air in-leakage on Gas Volume

At 3.1 gr/dscf inlet dust, the

- Impact on Fabric Filter
  - 4.5% O2 ~1,088,000 ACFM
    - 3.5 ft/min Air to cloth ratio
    - 205 ft/min
  - 6.5% O2 ~1,250,000 ACFM
    - 4.05 ft/min Air to cloth ratio
    - 235 ft/min

$$\text{Pressure Drop} \propto \left(\frac{New\ Velocity}{Old\ Velocity}\right)^2$$

Pressure Drop increases ~30% &

Fan Hp increases ~ 500 bhp

Impact of Increased Gas Volume

Electrostatic Precipitator

- Reduced collection efficiency
- Instability in high voltage system
- Increased emissions
- Increased pressure drop
- Increased abrasion

Fabric Filter

- Increased pressure drop
- Inability of dust to settle
- Reduced bag life
  - Additional cleaning cycles
  - Abrasion from swinging bags
- Relatively constant emissions

What should you do when gas volume increases?

Electrostatic Precipitator

- Look for open access points; doors, test ports, poke holes.
- Identify and repair chronic sources of in-leakage.
- Compare inlet gas temperature to normal conditions.
- Minimize outlet field rapping.
- Keep hoppers evacuated.
- Look for increased spark rate due to wire oscillation.

Fabric Filter

- Increase cleaning cycle frequency
- Increase upper pressure set point.
- Identify and repair sources of in-leakage.
- Compare inlet gas temperature to normal conditions.
- Bring all compartments on-line.
- Obtain sample bags and inspect.

Impact of Temperature on PM Collection

Electrostatic Precipitator

- Increased gas volume
- Possible dust resistivity increase
- Increased emissions
- Damage to insulators
- Damage to elastomeric seals
- Reduced sorbent effectiveness
- Possible increase in corrosion.

Fabric Filter

- Increased gas volume
- Reduced fabric life
- Loss of filter bags
- Damage to elastomeric seals
- Reduced sorbent effectiveness
- Possible increase in corrosion.

What can I do?

Electrostatic Precipitator

- Monitor secondary current and spark trends.
- If high resistivity consider:
  - > Intermittent Energization
  - > Aggressive collecting plate rapping
  - > Reduced power rapping
- Blow soot (Steam)
- Temperature too low, find and reduce in-leakage.
- Temperature too high, consider adding moisture

Fabric Filter

- Monitor temperature relative to media limits.
- If temperature too high, bleed in ambient air or introduce EGC.
- If temperature too low, reduce in-leakage or reduce water injection rate.

Impact of Reduced Particle Size

Electrostatic Precipitator

- Reduced collection efficiency
- Excessive space charge conditions; current suppression
- Increased potential for re-entrainment.
- Elevated impact on opacity

Fabric Filter

- Potential bag blinding
- Fabric “bleed Thru”
- Possible increased emissions
- Increased pressure drop due to lack of settling
- Elevated impact on opacity

Carbon in Fly Ash

Sources of Carbon in Fly Ash

- Incomplete combustion is not the only reason for carbon in ash.
- Mercury control strategies utilizing carbon based sorbents are another reason.
- Powdered activated carbon is injected into the gas stream ahead of the PM control device.
- This process increases the dust burden to the PM control device.

Carbon Content of Ash

- An ESP is not as effective at removing carbon compared to fly ash.
- Field testing indicates ESP emissions may increase when PAC is utilized.
- Performance is a function of the number of electrical fields, gas velocity, and general condition of ESP.
- Carbon has lower reflectance when compared to fly ash. (more visible emissions)
- Field testing indicates PAC can create potential for hopper fires.

Impact of Carbon in Fly Ash

Electrostatic Precipitator

- Increased spark rate
- Increased re-entrainment
- Potential for insulator tracking
- Potential for hopper fires
- Inability to sell fly ash
- Decreased effectiveness of activated carbon
- Potential increased dust resistivity.

Fabric Filter

- Hydrocarbons can blind filter bags
- Potential for hopper fires
- Inability to sell fly ash
- Decreased effectiveness of activated carbon

What can I do?

Electrostatic Precipitator

- Maintain elevated secondary current densities.
- Minimize outlet field rapping.
- Eliminate hopper in-leakage.
- Monitor operation of hopper heating equipment.
- Eliminate internal stabilizer insulators.
- Pressurize support insulators.
- Consider agglomeration.
- Evacuate hoppers frequently.
- Verify proper coal grind.
- Balance primary and over fire air.

Fabric Filter

- Pre-coat new filter bags to avoid blinding.
- Consider membrane laminated filter media.
- Establish “sacrificial” start-up compartment.
- Empty hoppers frequently.
- Minimize hopper in-leakage.
- Monitor operation of hopper heating equipment.
- Verify proper coal grind.
- Balance primary and over fire air.

Summary

> Multiple factors impact operation of the PM control device.
> Understand the result of changes in any of the critical parameters (i.e. fuel choices).
> The PM device has no direct influence over these parameters.
> Understanding "Normal" conditions helps when trouble shooting.
> Define process parameters that have most impact on equipment operation and establish trending.
> Do not focus on any single area, the problem is likely a combination of issues or a system issue.