Worldwide Pollution Control Association

WPCA

WPCA/FirstEnergy Biomass Seminar

Akron, Ohio
December 3, 2009

WPCA

Visit our website at www.wpca.info

Biomass Combustion Technology & Efficiency Improvements WCPA-FE Seminar

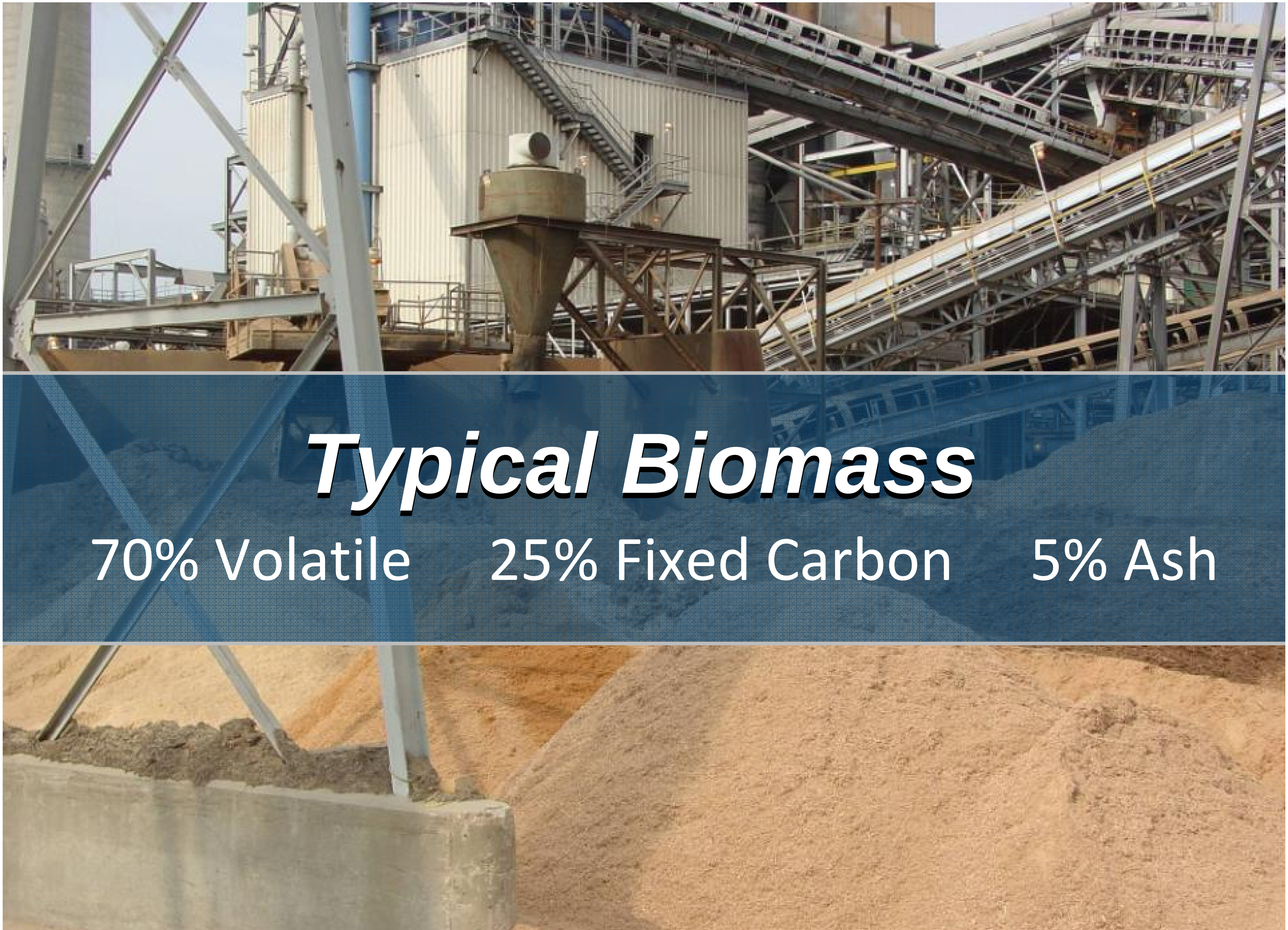
December 3, 2009

WR Stirgwolt
BWSC Biomass Engineering



The Biomass Challenge – Fuel Variability





Typical Biomass

70% Volatile 25% Fixed Carbon 5% Ash

Constituent Comparison

Coal Proximate Analysis

	Bituminous	Subbituminous
Volatile matter	40.2%	40.8%
Fixed carbon	50.7%	54.0%
Ash	9.1%	5.2%
Total	100.0%	100.0%

Biomass Proximate Analysis

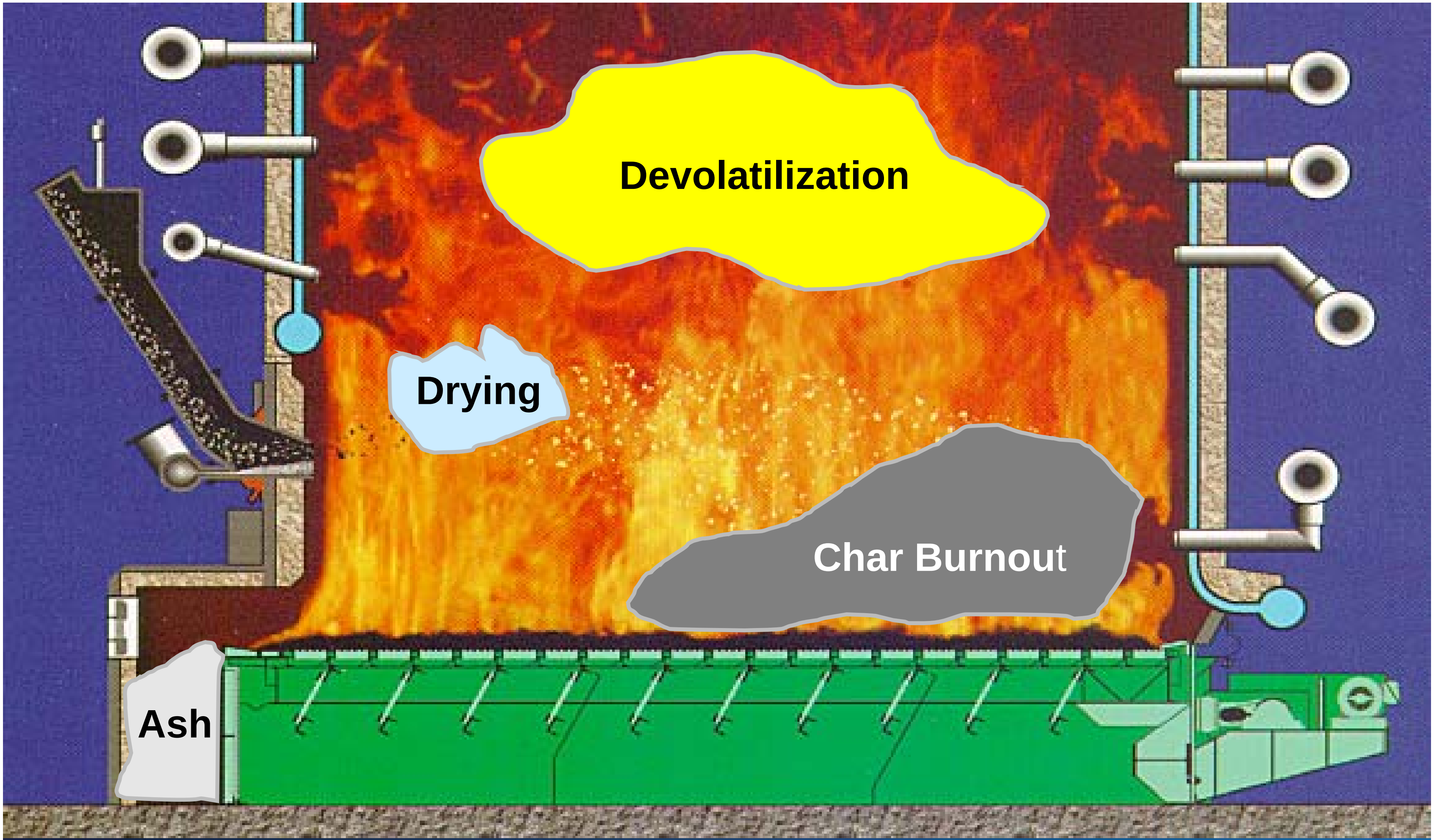
	Pine Bark
Volatile matter	72.9%
Fixed carbon	24.2%
Ash	2.9%
Total	100.0%

Biomass Combustion

Combustion is predominately gas (volatiles) phase

- **Gas** is ready to burn
- **Liquids** volatilize to **Gas**
- **Solids** melt to **Liquid** then volatilize to **Gas**
- **Solids** also volatilize directly (sublime) to **Gas**
- Remaining fixed carbon slowly oxidizes (char burnout)

The Combustion Process



Combustion Characteristics

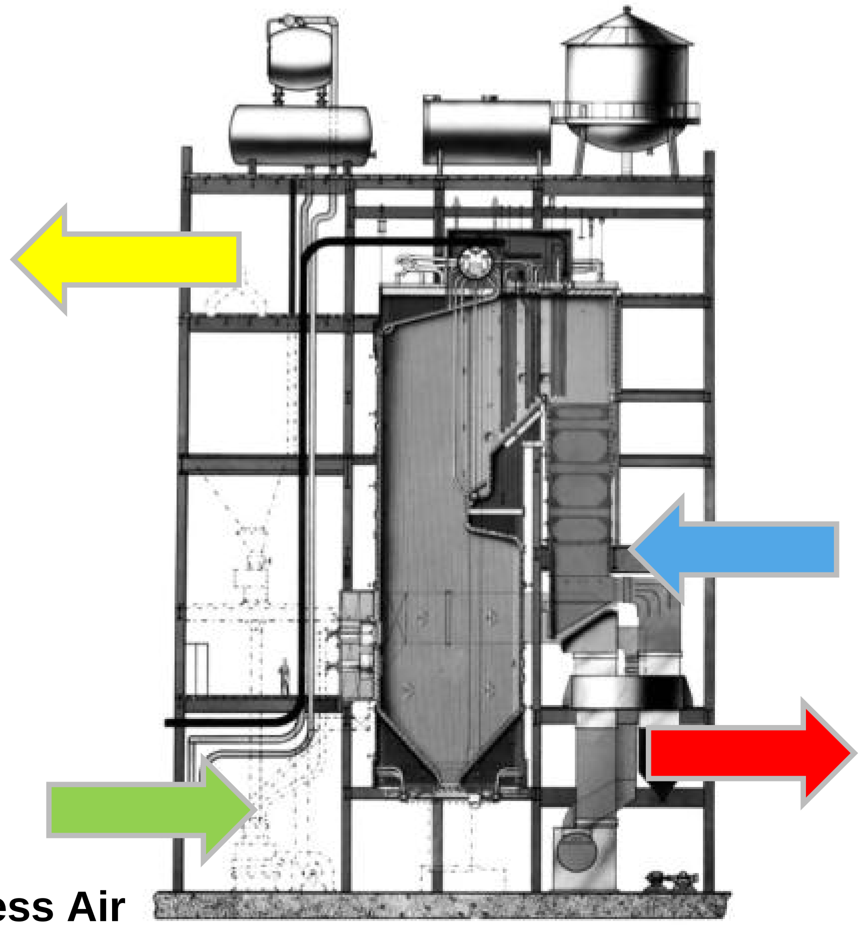
- **Biomass can have high moisture content:** *Delays ignition, lowers flame temp, lowers boiler efficiency*
- **Biomass has lower heating value:** *More mass (material handling) to supply heat input*
- **Biomass is highly reactive relative to coal:** *Twice the volatile matter, 1/3 to 1/4 of the fixed carbon*

Fuel	Moisture range (%)	HHV high (BTU/lb)	HHV low (BTU/lb)	typical Volatile Matter (%daf)	typical Fixed Carbon (%daf)	FC/VM
Coal-Bituminous	5 - 15	13,500	10,000	40	60	1.50
Coal-Subbit (PRB)	23 - 32	9,600	7,900	48	52	1.08
Wood	6 - 55	7,800	3,500	85	15	0.18
Grass	8 - 65	7,200	2,700	85	15	0.18

Heat & Material Balance Example

Boundary Conditions:

Steam
500,000 lb/hr
950 F & 1500 psi



Feedwater
500,000 lb/hr
400 F & 1600 psi

Air
80 F

Flue Gas
350 F

25% Excess Air

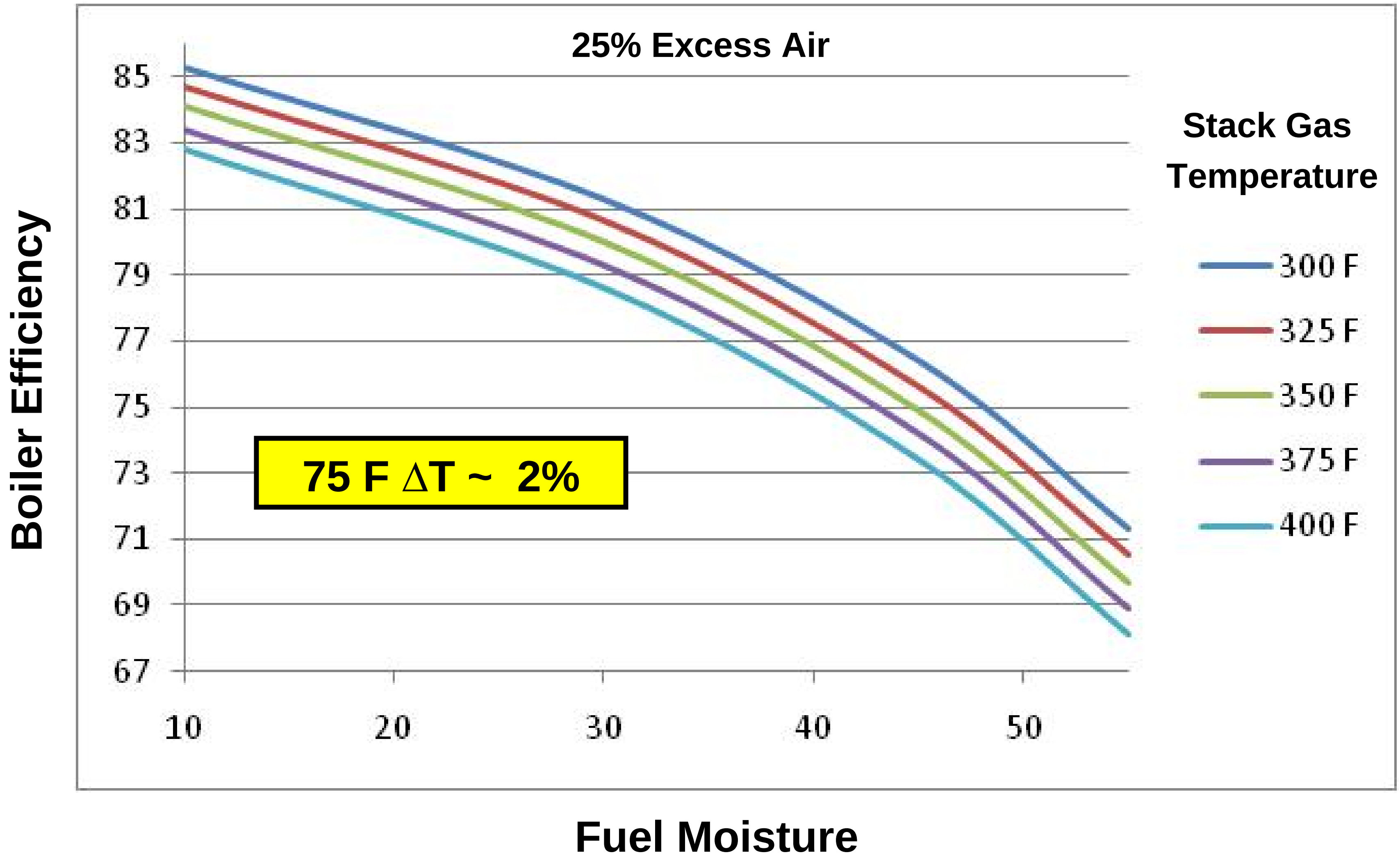
Heat & Material Balance Example

Fuel		Coal Bituminous	Coal Subbit.	Wood Pine	Wood Pine
H_2O	%	5.2	23.4	10.0	55.0
Efficiency	%	87.2	84.7	84.1	69.7
Input from fuel	mmb/hr	620.9	103%	104%	125%
Gas Weight	mlb/hr	637.6	105%	103%	139%
Air Weight	mlb/hr	583.1	102%	98%	118%
Fuel Rate	mlb/hr	49.5	135%	160%	386%

Boiler Efficiency

Fuel	Coal Bituminous	Coal Subbit.	Wood Pine	Wood Pine
H_2O	5.2	23.4	10.0	55.0
Water from fuel	4.5	7.1	7.6	22.3
Dry gas	6.3	6.3	6.1	6.1
Moisture in Air	0.2	0.2	0.1	0.1
Unburned Combustible	0.5	0.5	0.5	0.5
Radiation Loss	0.3	0.3	0.3	0.3
Unaccounted for Mfrs. Margin	1.0	1.0	1.0	1.0
Efficiency	87.2	84.7	84.1	69.7

Dry Gas Loss


25% Excess Air
Boiler Efficiency
85
83
81
79
77
75
73
71
69
67
10
20
30
40
50
75 F ΔT ~ 2%
Stack Gas Temperature
300 F
325 F
350 F
375 F
400 F
Fuel Moisture

Boiler Design

100% Biomass vs. 100% Coal

Flue gas mass flow x 1.5 on biomass

- Furnace residence time
- Convection pass velocities
- Particulate carryover

Flue gas properties

- Higher FEGT
- Slagging, fouling & cleanability
- Heat transfer surface configuration

Fuel moisture

- Increased hot combustion air

Fuel Related Considerations

Fuel sizing: *Requirements driven by combustion process.*

- Longer furnace residence times enable larger sized biomass (Stokers, fluid bed)
- Short residence times (Suspension/co-firing w/ PC) necessitate small particle size for efficient combustion

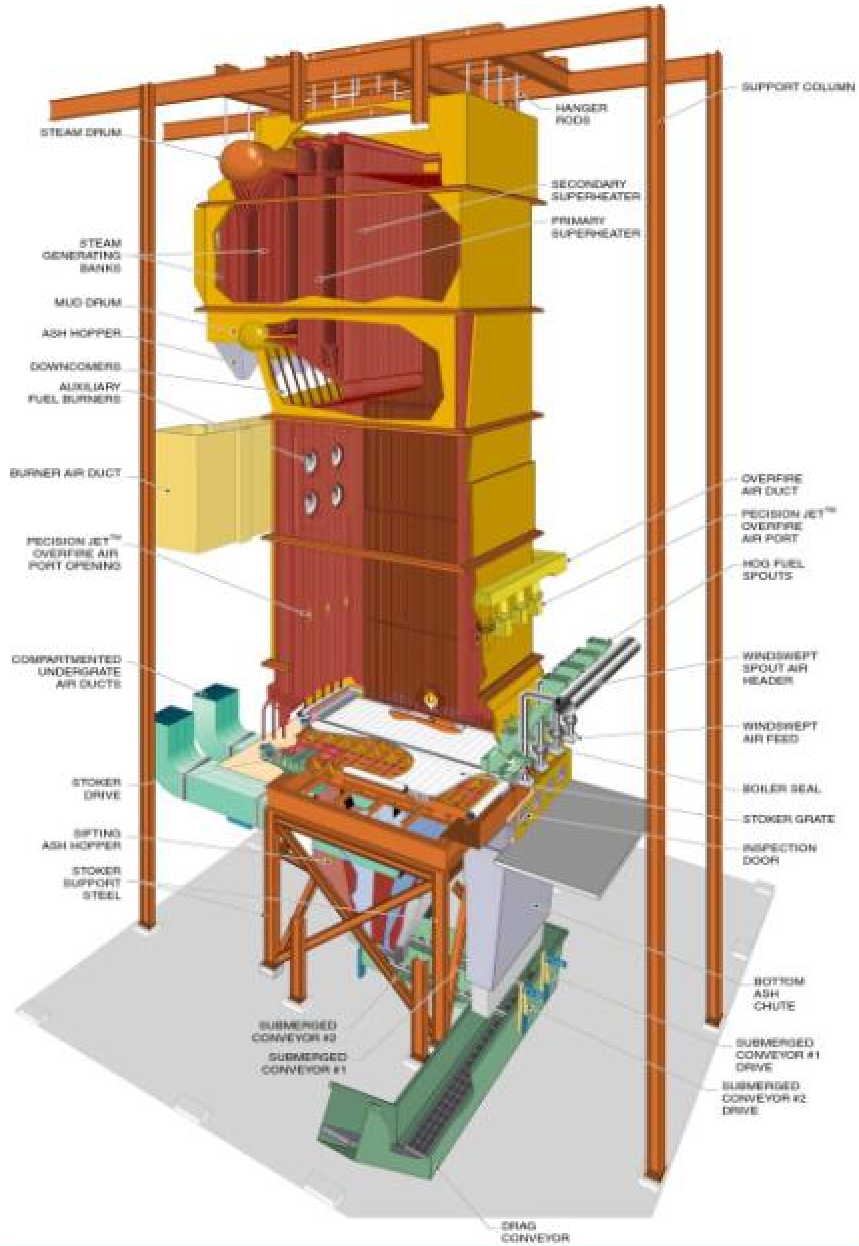
Fuel preparation: *Off-site by others or on-site preparation.*

- Preparation requirements and systems differ fundamentally for biomass species, moisture content and desired “fineness”.

Fuel handling: *Fuel yard to combustion equipment.*

- Storage, transport, metering and safety equipment.

Stoker-Fired Boilers

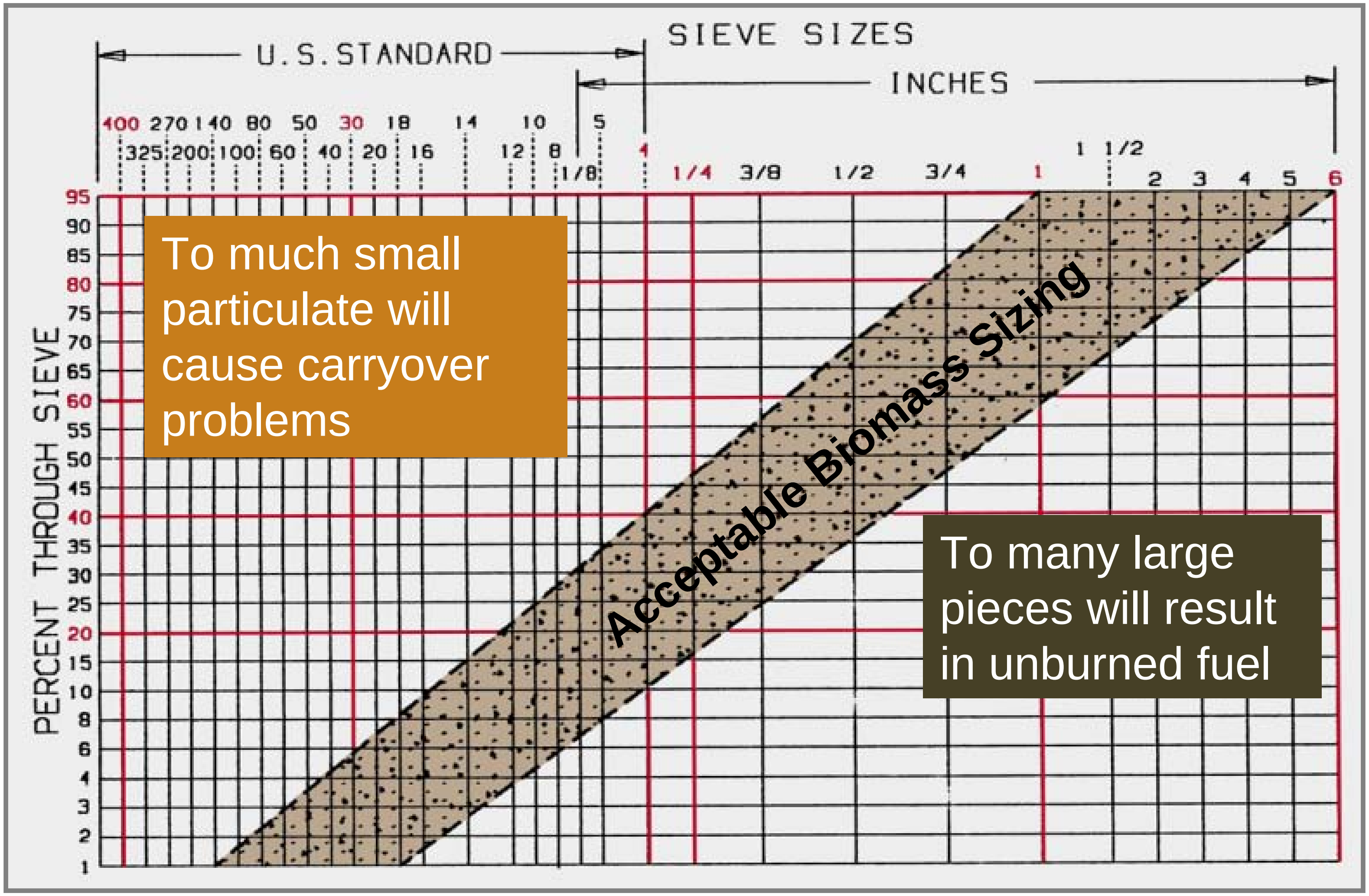


Suitable Grate Fuels

Fuel Flexibility (<55% Moisture)

- **Bark and chip rejects**
- **Clarifier and deinking sludges (in combination)**
- **Sawdust**
- **Construction/demolition debris**
- **Low moisture agriculture waste**
  - **Straw**
  - **Sugar cane waste**
- **Coal (in combination)**
- **TDF (in combination)**

Stoker Fuel Sizing



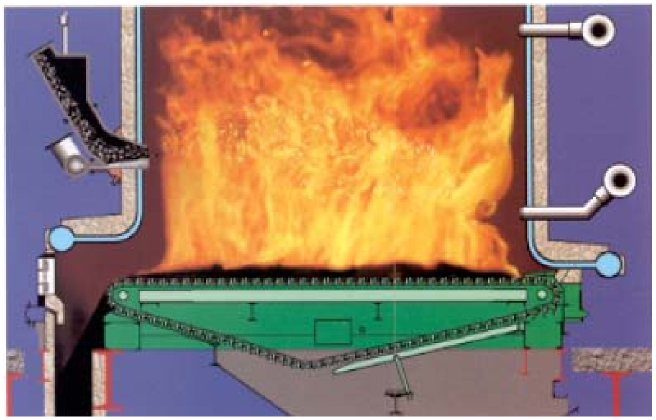
Typical Stokers

RotoGrate™ – Not typically used (municipal waste)

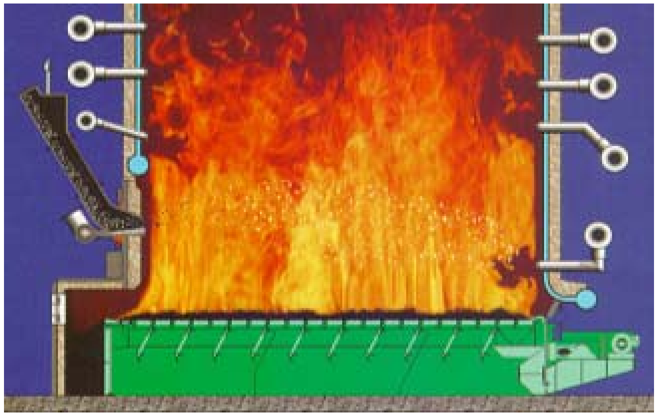
Vibrating

Hydrograte™- Water Cooled

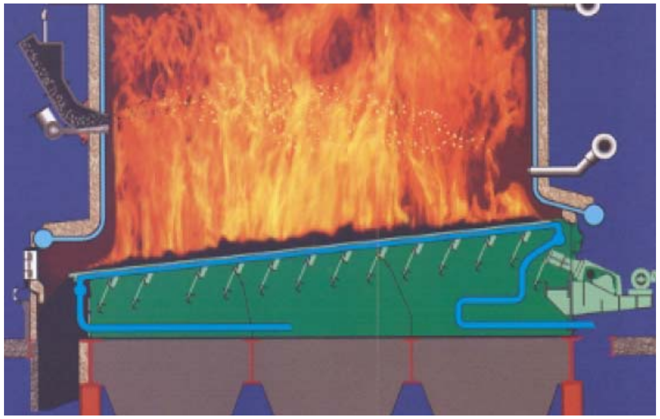
VCG™ - Air Cooled



Rotograte™



VCG™

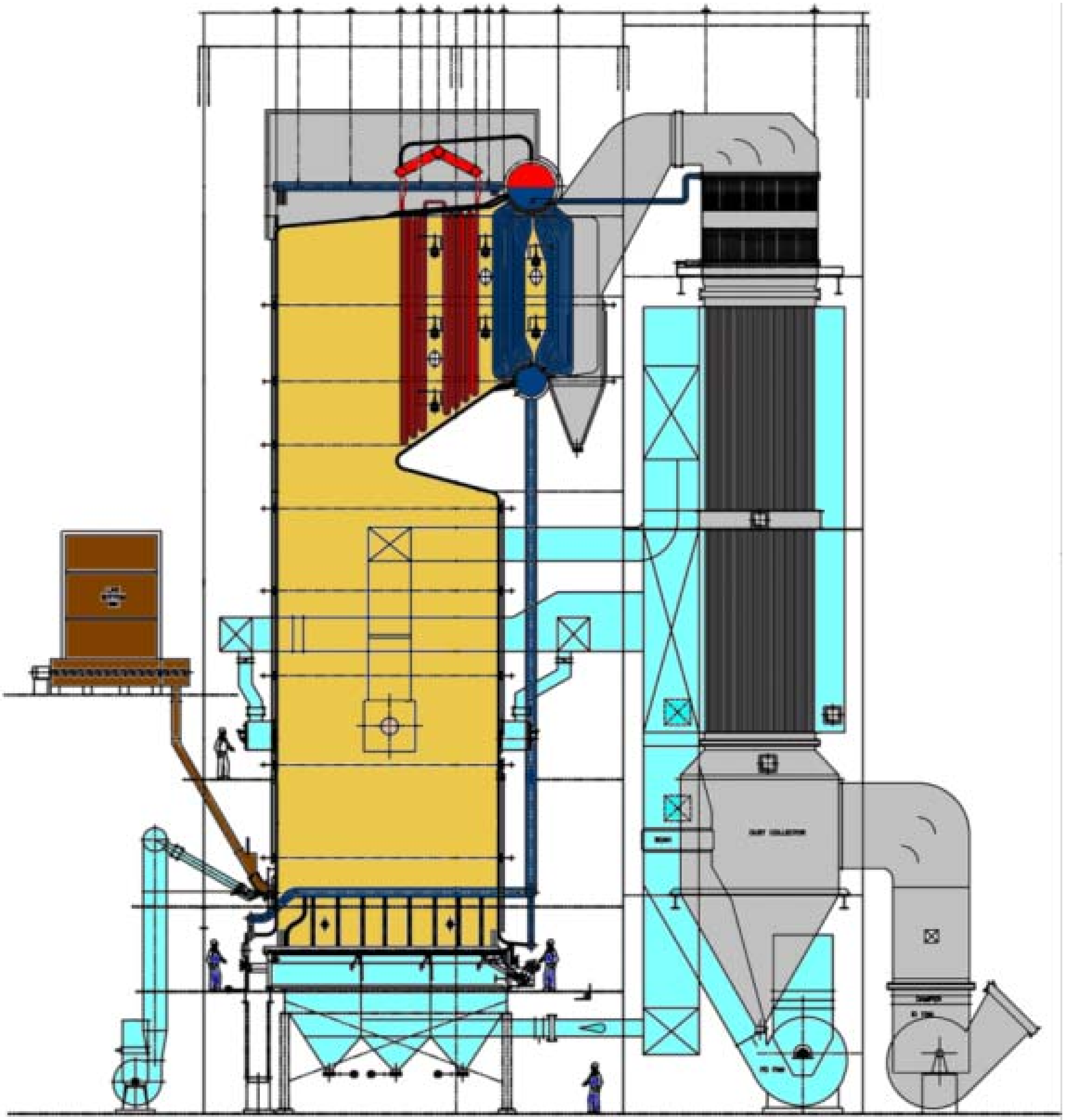


Hydrograte™

Courtesy Detroit Stoker Co.

Keys to Effective Grate Bark Burning

1. **Even Bark Distribution**
2. **High Undergrate Air Temperature**
3. **Compartmentalized and Automated Undergrate Air**
4. **Effective Interlaced Overfire Air**



Top Supported

up to

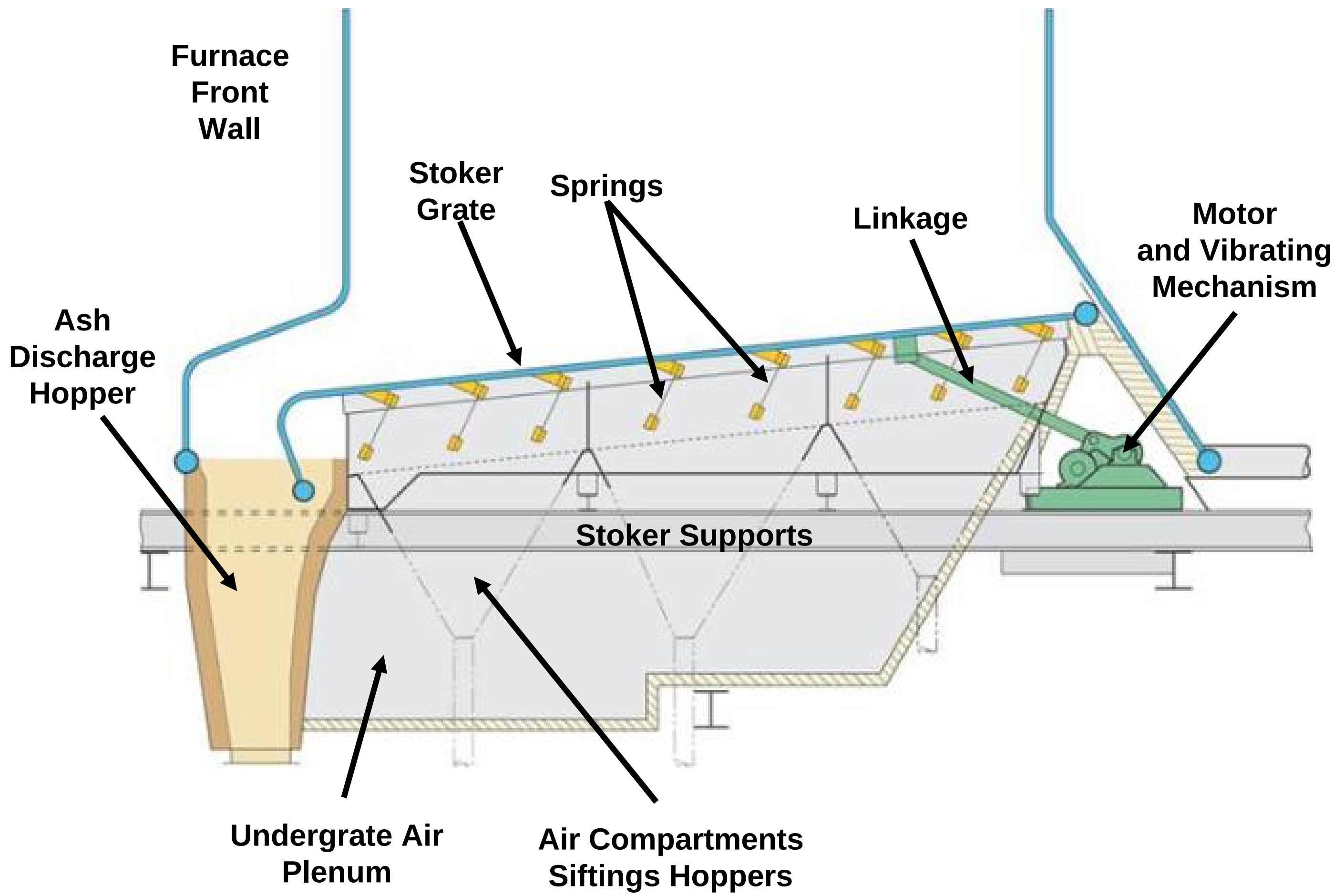
650,000#/hr

Air Swept Spouts

- Varying (cycling) air pressure from rotary dampers
- Adjustable peak pressure from remote damper
- Adjustable angle plate

Throw distance limits grate size to 26ft deep

Water-cooled Vibrating Stoker



Heated Combustion Air

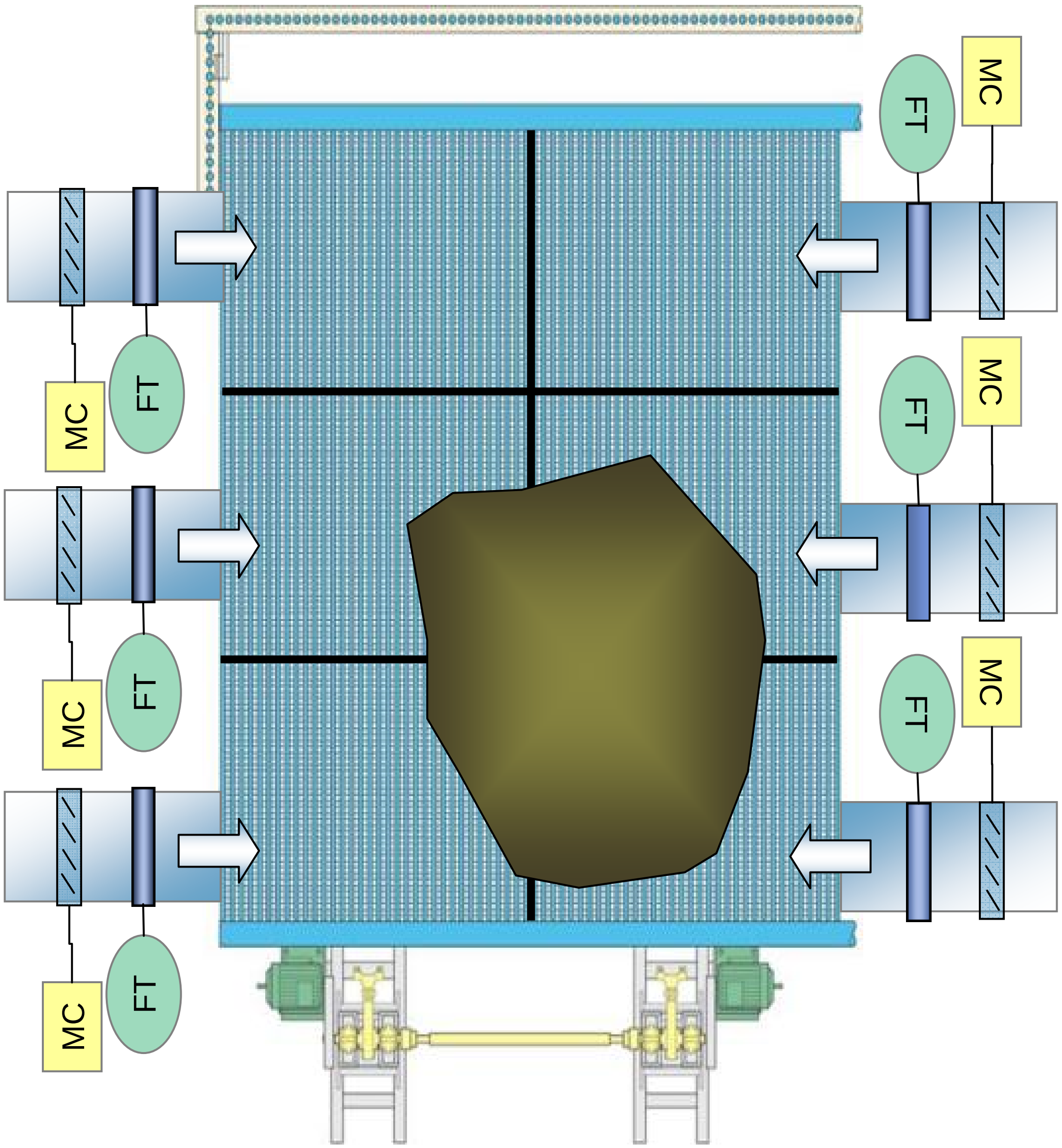
Needed to evaporate high fuel moisture

Excessive temperature drives up NO_X, particulate

Insufficient temperature drives up CO, and causes unstable combustion

General Guide: Fuel Moisture vs Air Temp

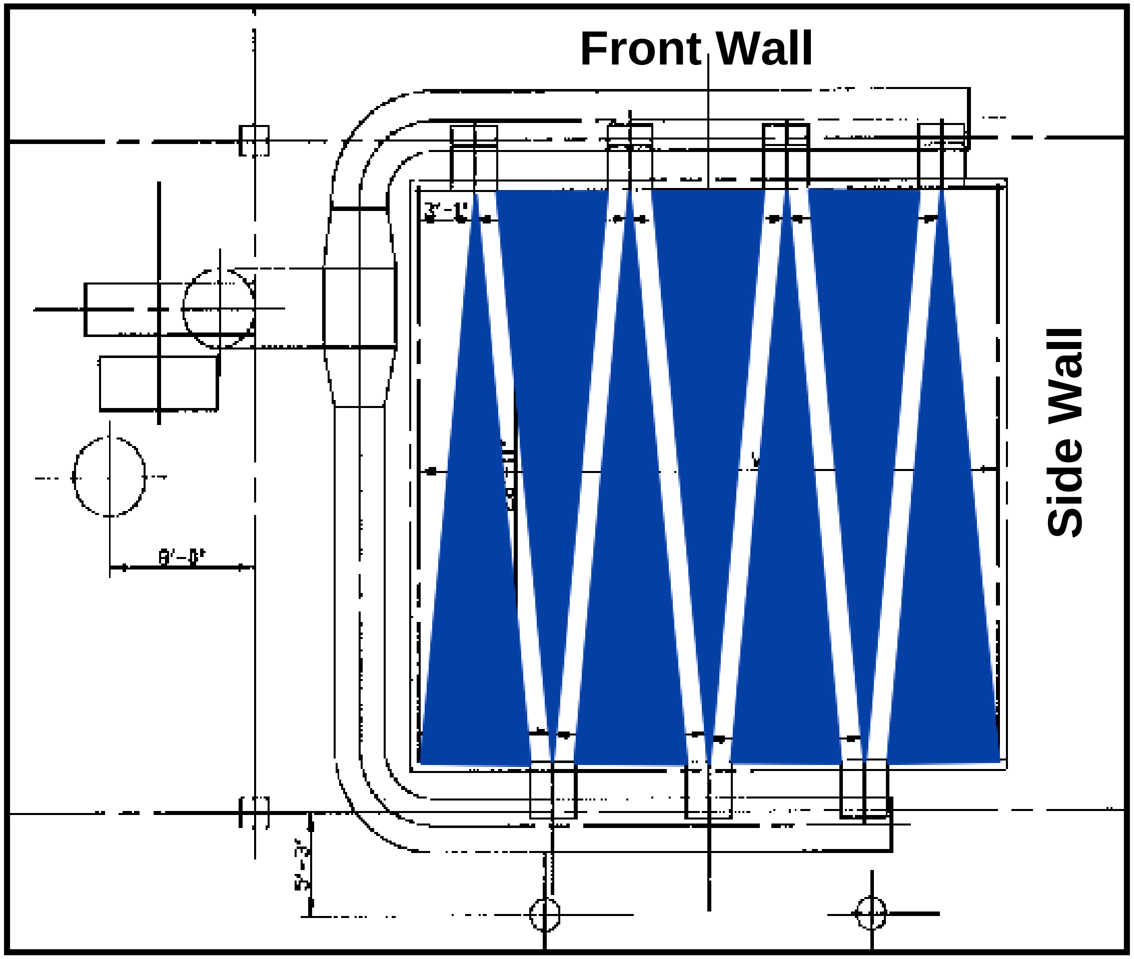
30% and below	Ambient to 200F
Above 30%	10 F for each % H_2O



- 6 Compartments
- 6 Flow measurements
- 6 dampers
- 6 Independent control loops

Air system will automatically adjust by opening dampers to areas where there is more fuel

Overfire Air System

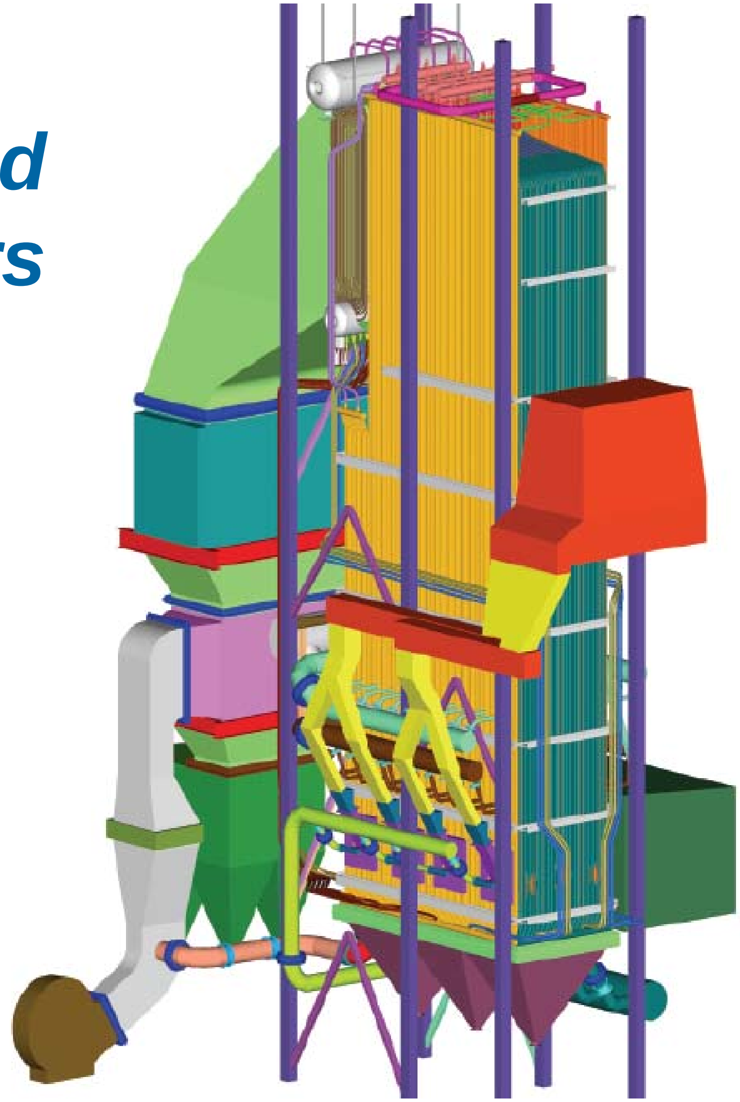


- Large Dia. Ports
- Interlaced Aggt.
- Multi-level
- Individual Dampers
- Flow Monitors

Stoker Technology Drivers

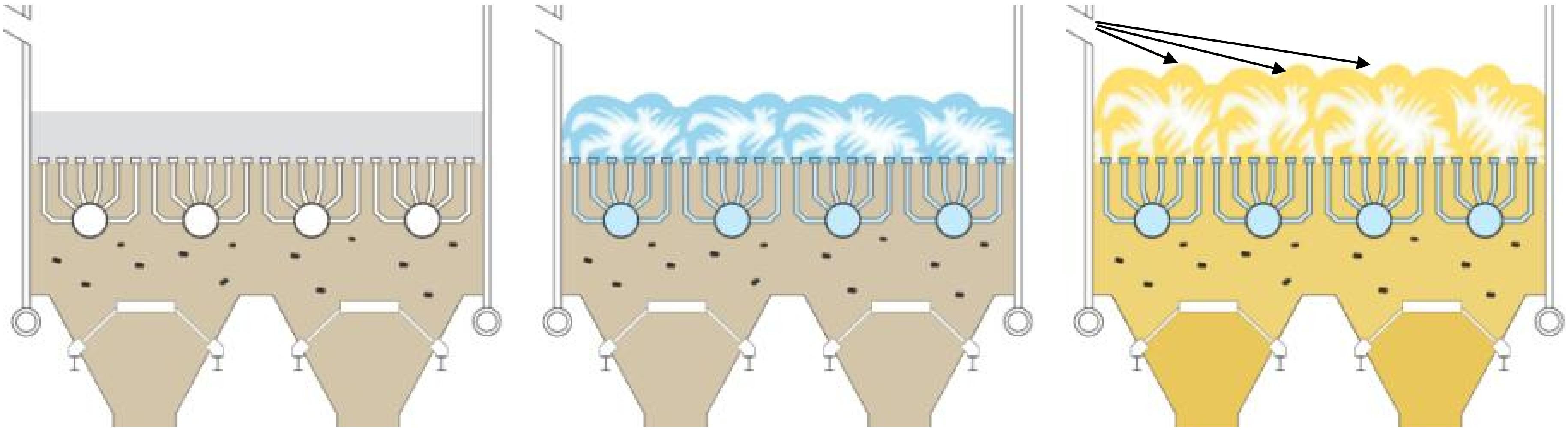
- Accepts opportunity fuels that can be problematic for fluidized bed technologies
  - Construction & demolition debris
  - Agriculture waste
- Lower auxiliary power requirements
- Low maintenance costs
- Good availability and reliability

Bubbling Fluidized Bed (BFB) Biomass Boilers

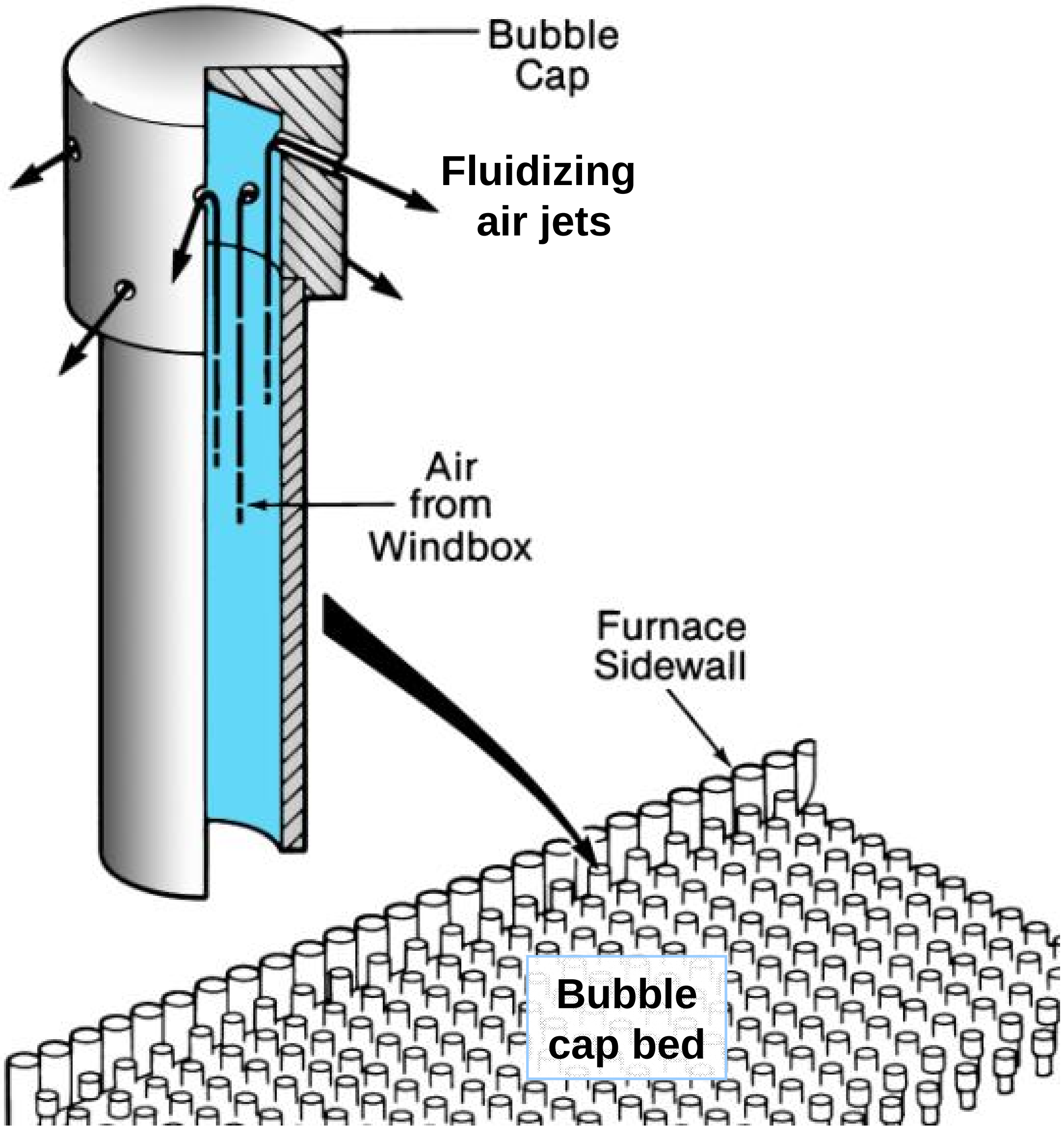


Fluidized Bed Boiler – Basic Operation

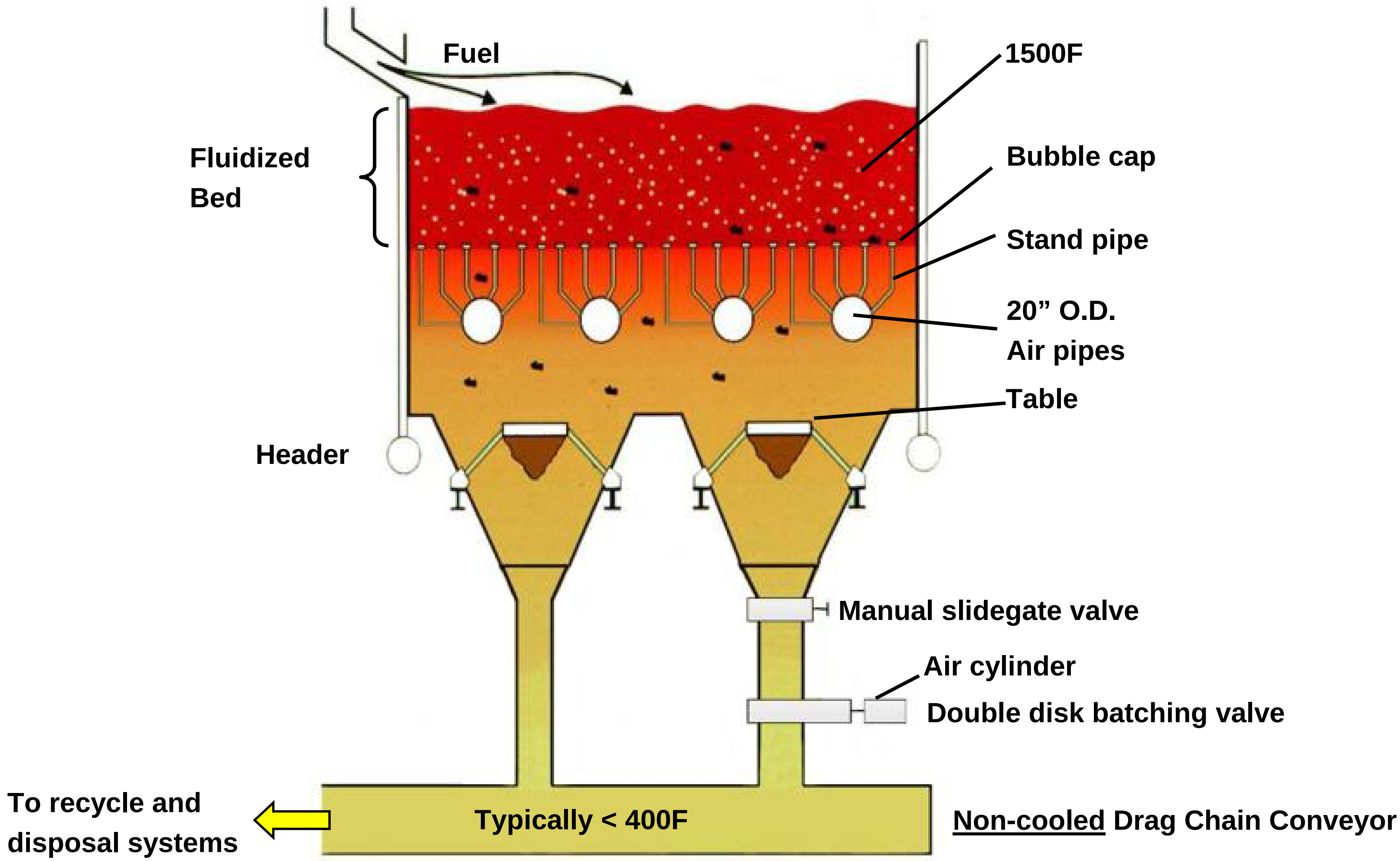
Not Operating Bed Height ≈ 20”	Fluidized Bed With Air Bed Height ≈ 32”	Heat Bed and add Fuel – Normal Operation



Typical Bubble Cap

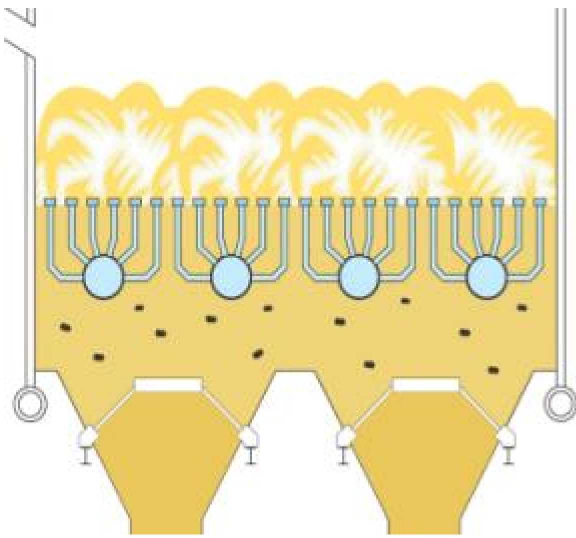


BFB Arrangement



Typical Bubble Cap/Air Pipe Assemblies and Pre-assembled Lower Hoppers

Bubbling Bed Video

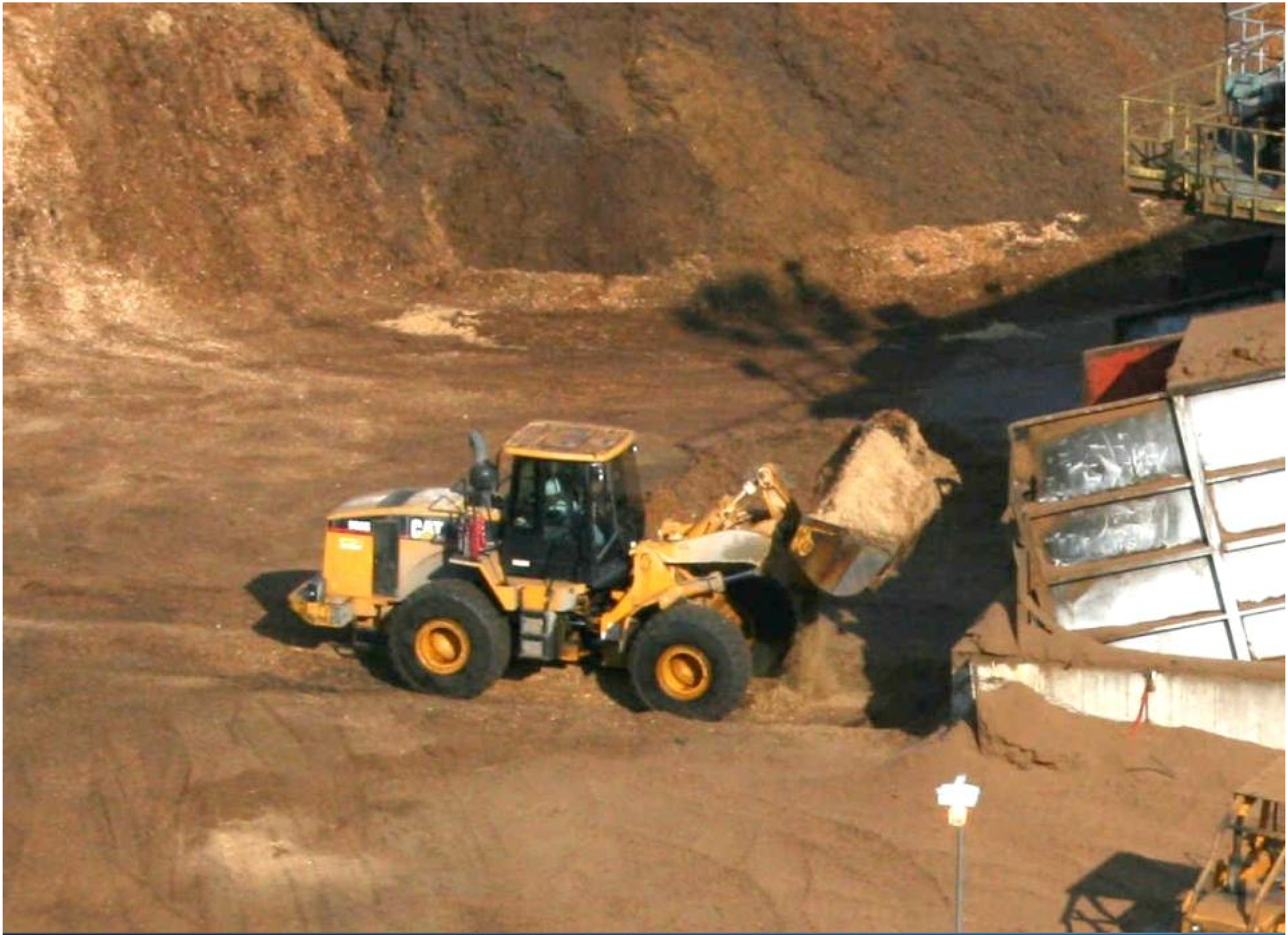


Fuel Flexibility

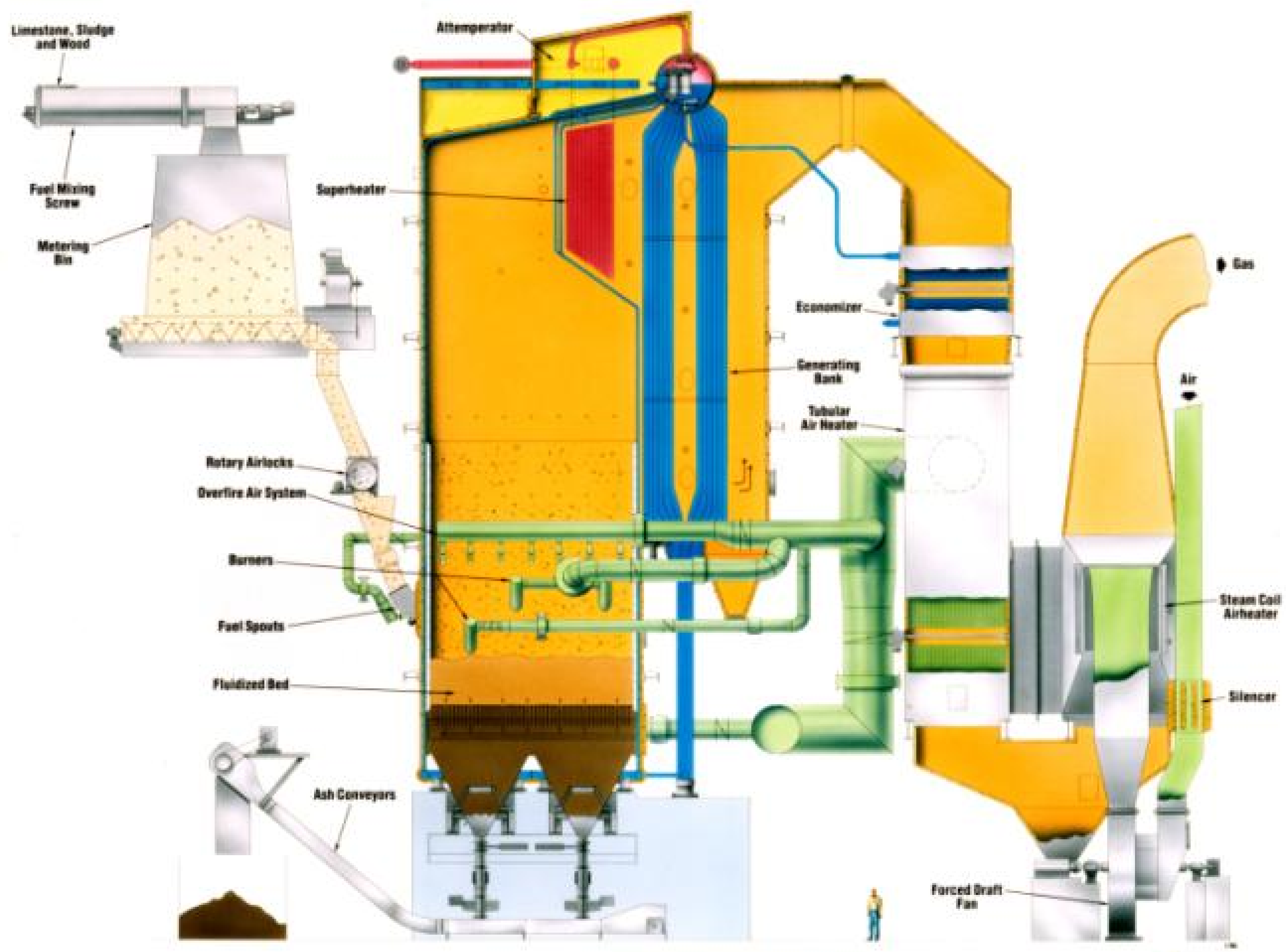
Viable fuels for a BFB:

- Wood waste
- Bark
- Paper mill sludge
- Recycled paper facility sludge
- Sewage sludge
- Tire-derived fuels (in combination)
- Oil
- Natural gas
- Coal (in combination)
- Peat
- Biomass
- Sugar cane waste
- Agricultural waste

BFB Fuel Sizing

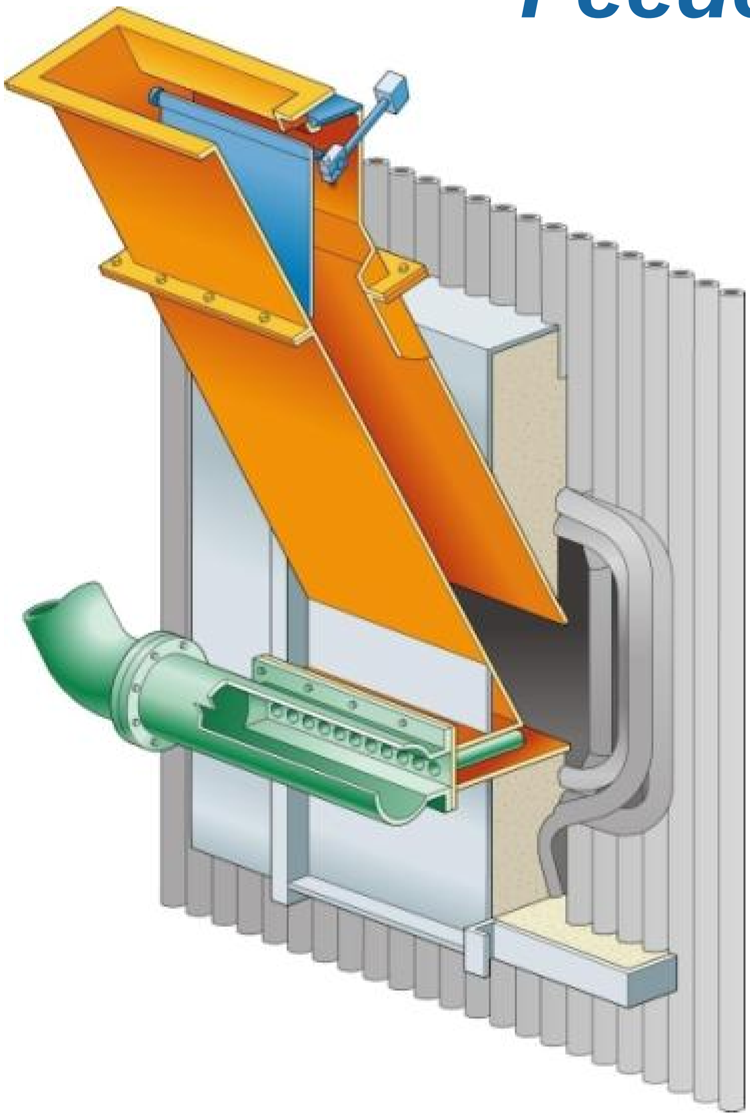

CAT

BFB Boiler



Sludge Fired Bubbling Fluidized Bed Boiler
James River Corporation
Wauna Mill CoGen Project
Babcock & Wilcox

Feeder/Spreader



Typical Fluid Bed Operating Temperature

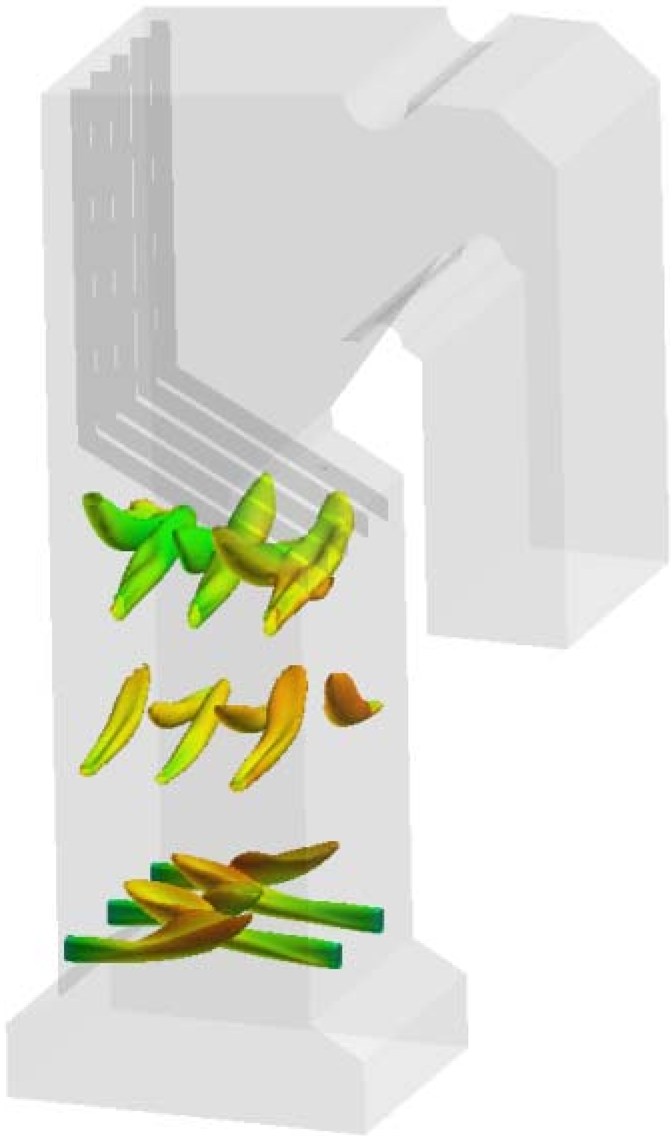
1300F to 1600F

On a BFB you measure & control combustion temperature.

Above 1600F, agglomeration is a concern

Below 1300F, combustion is poor

Agglomeration of the Bed Material



BFB Overfire Air System

- Fully Interlaced overfire Air
- Velocity Dampers
- Multi-level for NOx control

Bed Drain System and Bed Material Management

- **Proper size distribution is needed for good bed fluidization.**

- Oversized material will be removed while the boiler is operating through the hoppers.

Bed Material

Sand

- Potential for thermal breakdown
- Low cost
- Makeup comes in with the fuels

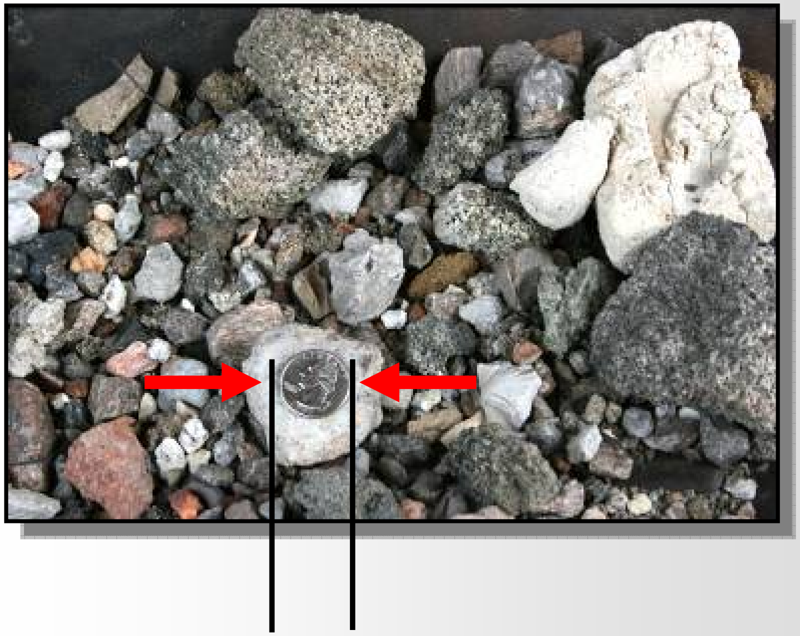
Manufactured Refractory

- Thermally stable
- High cost

Allow for On-line Removal of Tramp Material

Man-made

Naturally occurring



BFB Technology Drivers

- BFB readily accepts fuel variability
- High availabity
- Easy to retrofit
- BFB easier to operate and maintain than CFB
- Comparable to stoker capital and O&M costs
- Better uncontrolled emissions as compared to a stoker

Typical Emissions & Control Options

with Wood - Biomass Fuels*

	Grate	BFB
NO_X Uncontrolled * (#/MMBtu)	0.18 – 0.28	0.15 – 0.24
NO_X With SNCR ** (#/MMBtu)	0.12 – 0.18	0.10 – 0.15
NO_X With SCR *** (#/MMBtu)	0.05 – 0.08	0.05 – 0.08

* Emissions are dependent on specific fuel properties.

** SNCR with an assumed NH_3 slip $\leq$ 20 ppm.

*** SCR catalyst size is based on req'd. NO_X removal, req'd. NH_3 slip & catalyst operating life req'd.

Typical Emissions & Control Options

with Wood - Biomass Fuels*

	Grate	BFB
CO Uncontrolled (#/MMBtu)	0.10 – 0.35	0.05 – 0.15
VOC's Uncontrolled (#/MMBtu)	Typically 1/10 to 1/100 of CO value	Typically 1/10 to 1/100 of CO value
SO_2 Uncontrolled	10% to >50% of Fuel Sulfur converts to SO_2	10% to >50% of Fuel Sulfur converts to SO_2
HCL Uncontrolled	50% to 100% of Fuel Chlorine converts to HCL	50% to 100% of Fuel Chlorine converts to HCL

* **Emissions are dependent on specific fuel properties.**

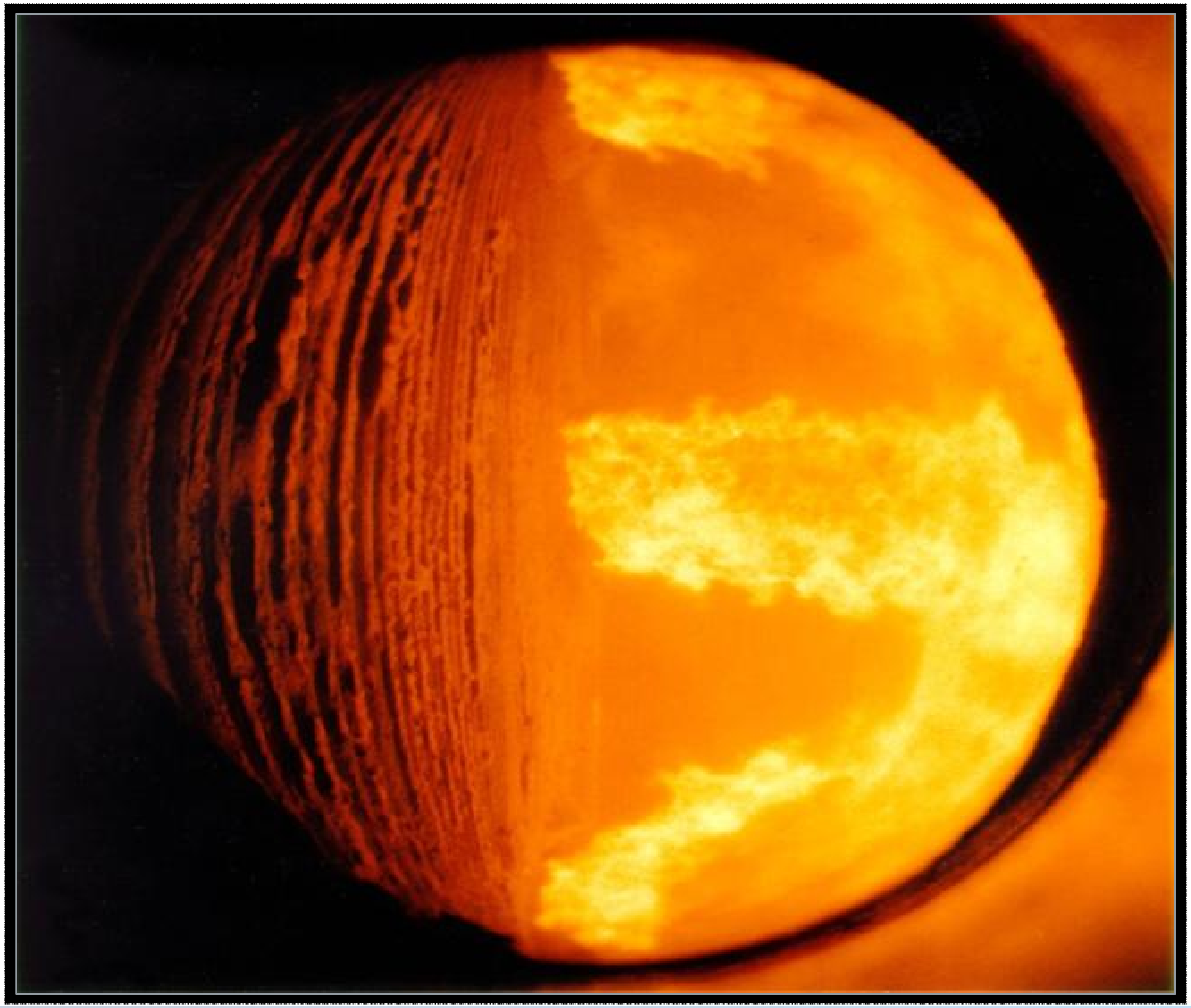
Typical Emissions & Control Options

with Wood - Biomass Fuels*

	Grate	BFB
HCL & SO_2 Control Options	• *Dry Sorbent Injection* • *Dry & Wet Scrubbers*	•*Furnace Limestone Inj.* • *Dry Sorbent Injection* • *Dry & Wet Scrubbers*
Particulate Control Options	*MDC + ESP*	*Baghouse or ESP*

* **Emissions are dependent on specific fuel properties.**

Suspension Firing



Methods & Definitions:

<u>Direct Furnace Injection</u>: *Inject biomass thru nozzles into furnace without sec. air (air scavenged from burners)*

<u>Suspension Firing</u>: *Fine particles burned in suspension in the furnace*

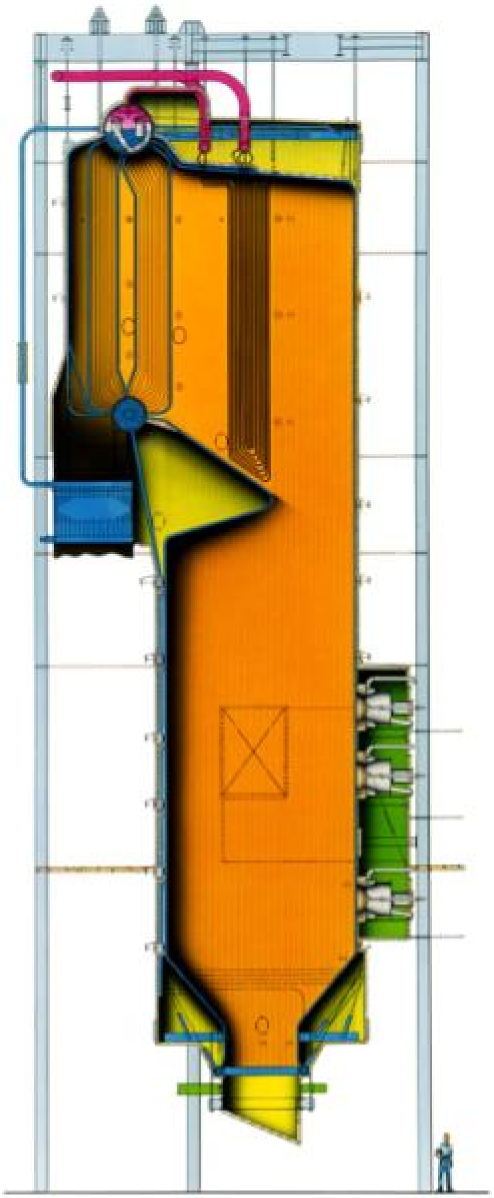
<u>Co-firing</u>: *Suspension firing with dual fuel burner, same flame front*

<u>Co-combustion</u>: *Suspension firing through separate burners dedicated to biomass*

<u>Co-milling</u>: *Feeding coal and biomass to pulverizer(s) for simultaneous size reduction and convey mix to burners*

Direct Furnace Injection

- Biomass is injected in the combustion zone between burner elevations
- Fuel sizing < 3/4”
- Up to 50% heat input
- Dump grate in hopper for large unburned material
- Applied to Utility and Industrial Units



Suspension Firing Considerations

Biomass co-firing with coal

- Rate of biomass co-firing (%)
- Type of biomass, variations, availability
- Biomass fuel preparation requirements
- Combustion equipment
- Boiler operation and efficiency
- Emissions (NO_X, CO, particulate)

Suspension Firing of Biomass

Differentiating Systems for two categories:

- Grasses: Grasses, straw, other thin vegetable matter
- Wood: Wood, bark, other more dense types

Only the small pieces fully burn in suspension

- Recommended particle size for wood ~1/16”
- Recommended size for grasses < 2” x 0

Larger pieces require more residence time to burn … some alternatives:

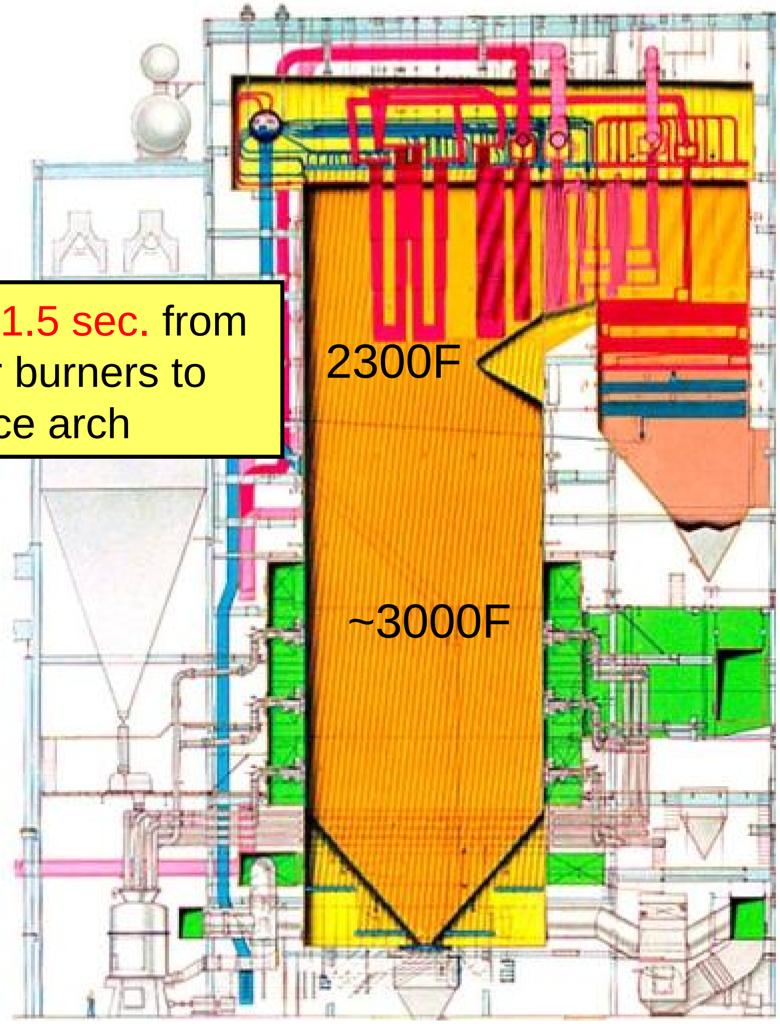
- Live with high unburned combustibles
- add dump grate stoker in furnace hopper

Fuel Preparation for Suspension Firing

Fuel preparation requirements driven by combustion process primarily *residence time*.

- *Longer furnace residence times enable larger sized biomass (cyclones, stokers, fluid bed)*
- *Short residence times (PC suspension firing) necessitate small particle size for efficient combustion*

1.0 – 1.5 sec. from upper burners to furnace arch



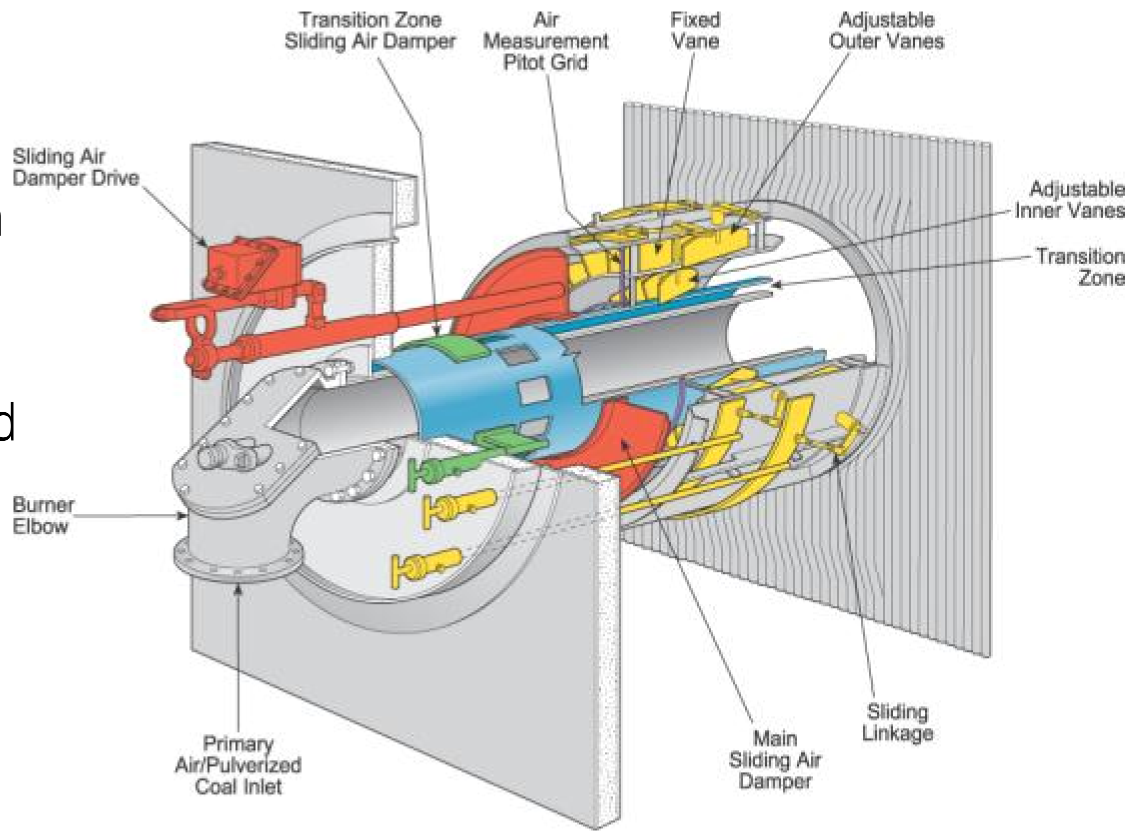
Biomass Co-Fired Burners

Biomass supplied to selected co-fired burners:

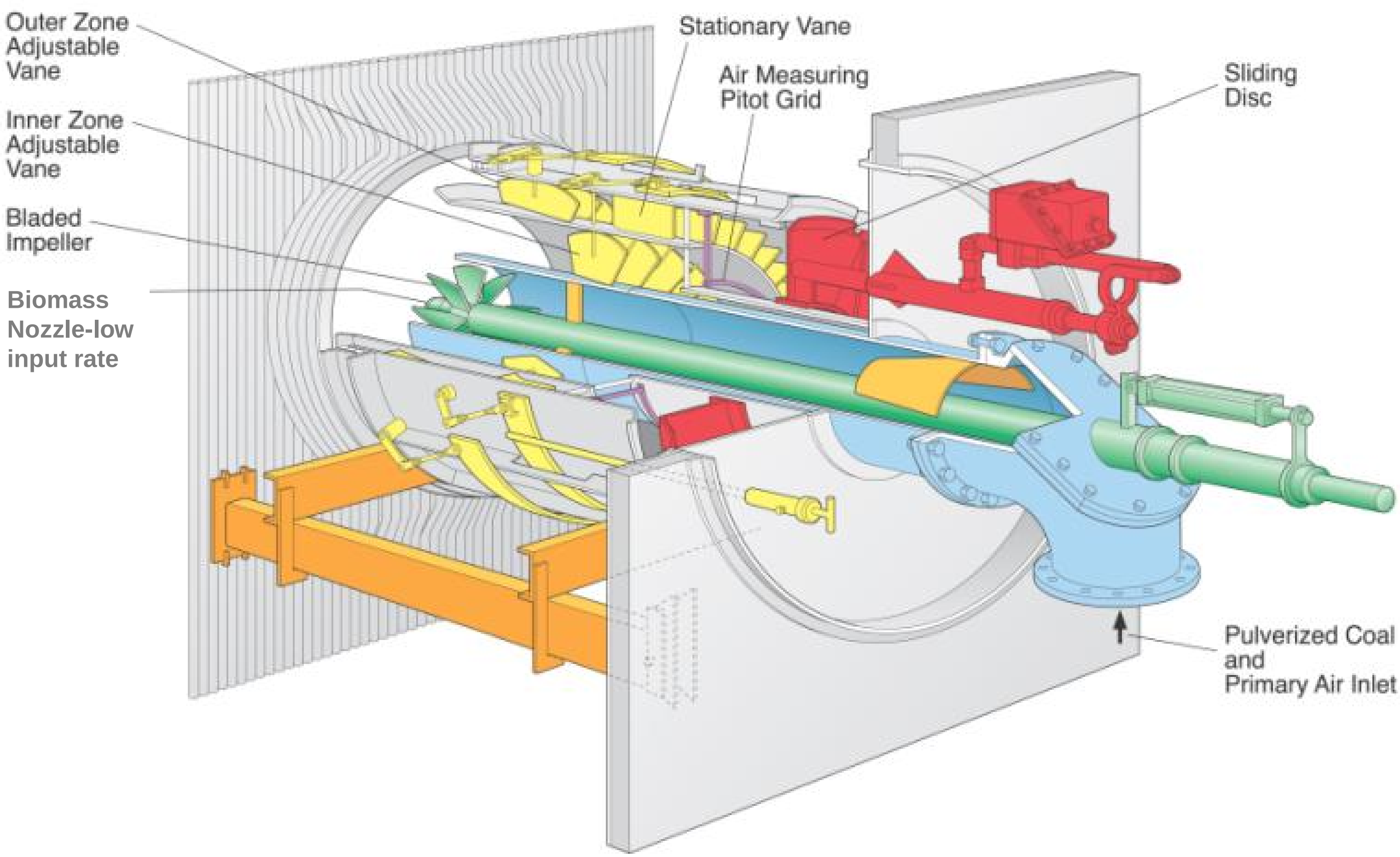
- **Do not exceed rated burner input** *(coal + biomass)*
- **If injected into coal pipe:** *Increases nozzle velocity which destabilizes flame at higher inputs. OK for low inputs; reducing PA/PC accommodates more biomass but reduces heat input (load) to boiler; flame stability can suffer with high moisture biomass.*
- **If injected through separate nozzle in burner:** *Low inputs OK with small nozzles in existing burners. High biomass inputs (40 to 50%) can be accommodated with larger nozzles but probably requires new burners.*

Direct Co-Firing with Existing Burners

- Medium capital
- Up to 10% heat input with virgin biomass can be accomplished
- Increased UBC in ash and constituents may affect traditional SCR catalyst
- May increase corrosion potential on high temperature surfaces

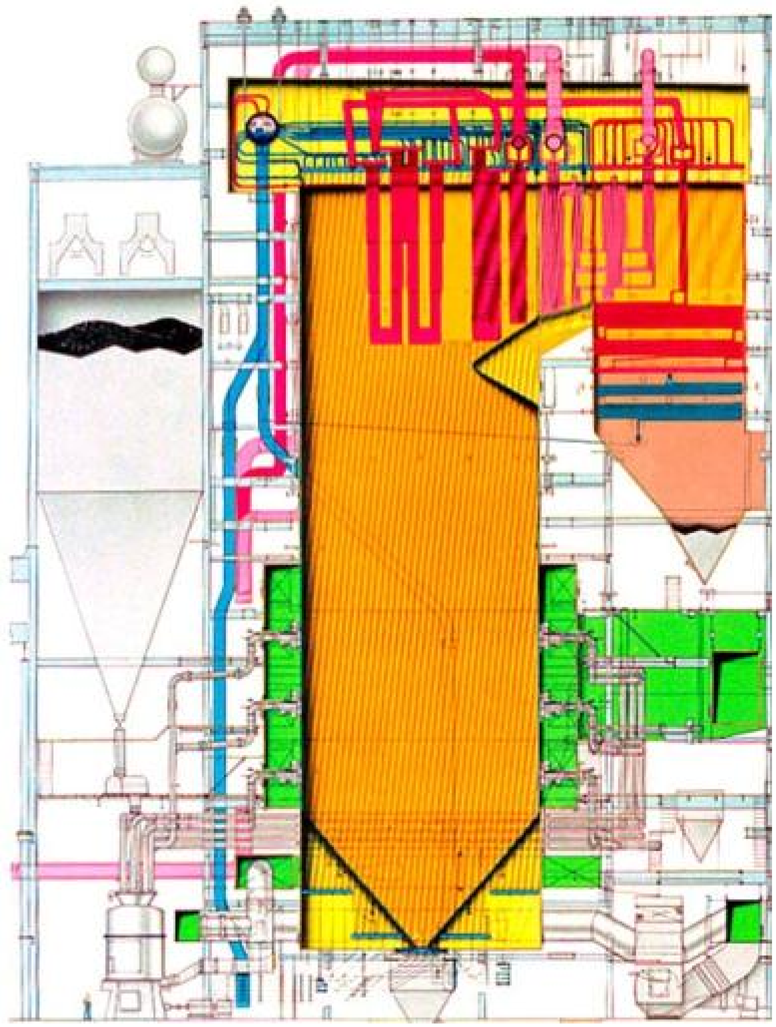


PC/Biomass Co-Fired Burner



Dedicated Biomass Burners

- Design based on fuel sizing to burner and PA/SA split
- Dual register burner derivative
- Equipped with igniters and flame detectors for start/stop & flame stabilization when necessary
- Prefer opposed wall firing



Biomass Co-Firing & Co-milling

Biomass supplied <u>through pulverizers to burners</u>:

Minimal capabitiy:

- *Coal dominates*
- *Could lower coal fineness & increase UBC*
- *< 2% on heat input basis*

High biomass rates with pelletized wood:

- *Loss of heat input and load (HHV, "grindability")*
- *PA to solids loading; density, velocity to burners*
- *Flame stability and turndown without igniters*
- *Biomass is NO_X friendly*
- *Unburned combustibles (particle size)*

Burners won't fix pulverizer inadequacies.

Emissions Co-Firing Biomass w/ PC

NO_X

- Equivalent or lower - depends on application, design
- Potential for significant NO_X reduction (higher biomass heat input, staged combustion)
- SCR performance-some pluggage; less poisons

CO

- Key issue: air/fuel balance with biomass, controls
- Challenges when intermittent and variable input

UBC

- Generally minimal change to flyash
- Increases in carbon in bottom ash depending on sizing

SO_2

- Biomass has very little sulfur (typically ~0 to 0.3%), reduction in SO_2 depending on biomass input

NO_x Emissions with Biomass

- **Intrinsic fuel properties influencing combustion behavior with suspension firing:** *Volatility, inerts, char content, char reactivity, burning profile.*
- **Application issues:** *Firing rate, furnace thermal environment, SA/PA, Burner zone stoichiometry, Excess Air.*
- **Burner and NO_x port design and placement**

Typical emissions	Suspension Firing
NO_X *Uncontrolled (#/MMBtu)*	***0.18 – 0.30***
NO_X *With SNCR ** (#/MMBtu)*	***0.12 – 0.20***

* Emissions are dependent on specific fuel properties.

** SNCR with an assumed NH_3 slip $\leq$ 20 ppm.

Typical Emissions

with Wood - Biomass Fuels*

Pollutant Species	*Suspension Firing*
CO ***Uncontrolled (#/MMBtu)***	***0.10 – 0.35***
VOCs ***Uncontrolled (#/MMBtu)***	***Typically 1/10 to 1/100 of CO value***
SO_2 ***Uncontrolled***	***50% to 100% of Fuel Sulfur converts to SO_2***
HCL ***Uncontrolled***	***50% to 100% of Fuel Chlorine converts to HCL***

Unburned carbon directly related to particle size

* Emissions are dependent on specific fuel properties


Questions