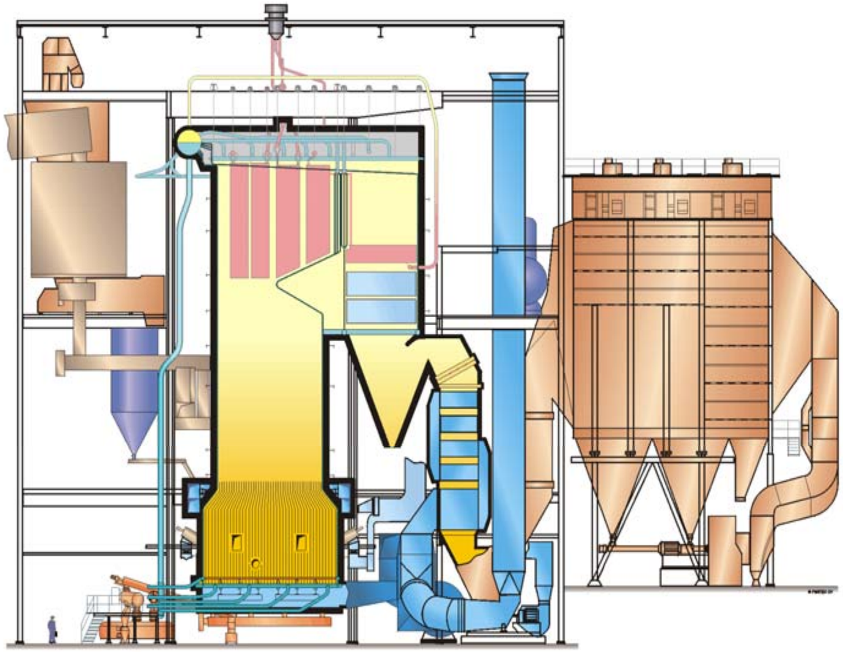
REINHOLD ENVIRONMENTAL Ltd.

2011 NOx-Combustion Round Table & Expo Presentation

February 7-8, 2011, in Birmingham, AL / Hosted by Southern Company



Bubbling Fluid Bed Boiler Conversions

BFB Conversion Benefits

- **Fuel Switch to Low Cost Opportunity Fuels**
- **Reduce Boiler Emissions**
- **Restore Unit Steam Capacity**

FW's BFB Conversion Experience

Original Unit Design

- Grate Fired
- Chemical Recovery
- Pulverized Coal
- Pulverized Peat
- Oil
- MgO
- La Mont
- Pyrite Roasting

New Fuels

- Anthracite
- Coal
- Peat
- Graphite
- Bark

- Wood Residue
- Wood Chips
- Waste Fiber
- Primary Sludge
- Bio Sludge
- De-inking Sludge

Converted 30 Units With Over 2000 MWth Capacity

Bubbling Fluid Bed Retrofits In Europe and Russia

Paper Mill
Rauma, Finland
BFB, 50 MW
Delivery year: 1985
Fuels: Wood waste, peat, oil
Retrofit to a recovery boiler

Outokumpu Oy
Kokkola, Finland
BFB, 17.5 MW
Delivery year: 1977
Fuels: Coal, peat, wood waste
Retrofit to a pyrite roasting plant

Outokumpu Oy
Kokkola, Finland
BFB, 24 MW
Delivery year: 1977
Fuels: Coal, peat, wood waste
Retrofit to a pyrite roasting plant

Mäntän Energia Oy
Mänttä, Finland
BFB, 94.3 MW
Delivery year: 1993
Fuels: Peat, oil, biofuel, sludge
Retrofit to a MgO-boiler

Metsä-Sellu Oy
Äänekoski, Finland
CFB, 76 MW
Delivery year: 1985
Fuels: Coal, wood, peat, oil
Retrofit to a recovery boiler

Imatran Voima Oy
Uimaharju, Finland
BFB, 91.4 MW
Delivery year: 1993
Fuels: Bark, sludge
Retrofit to a recovery boiler

Paper Mill
Rauma, Finland
BFB, 60 MW
Delivery year: 1990
Fuels: Waste fiber, bark, coal
Retrofit to a recovery boiler

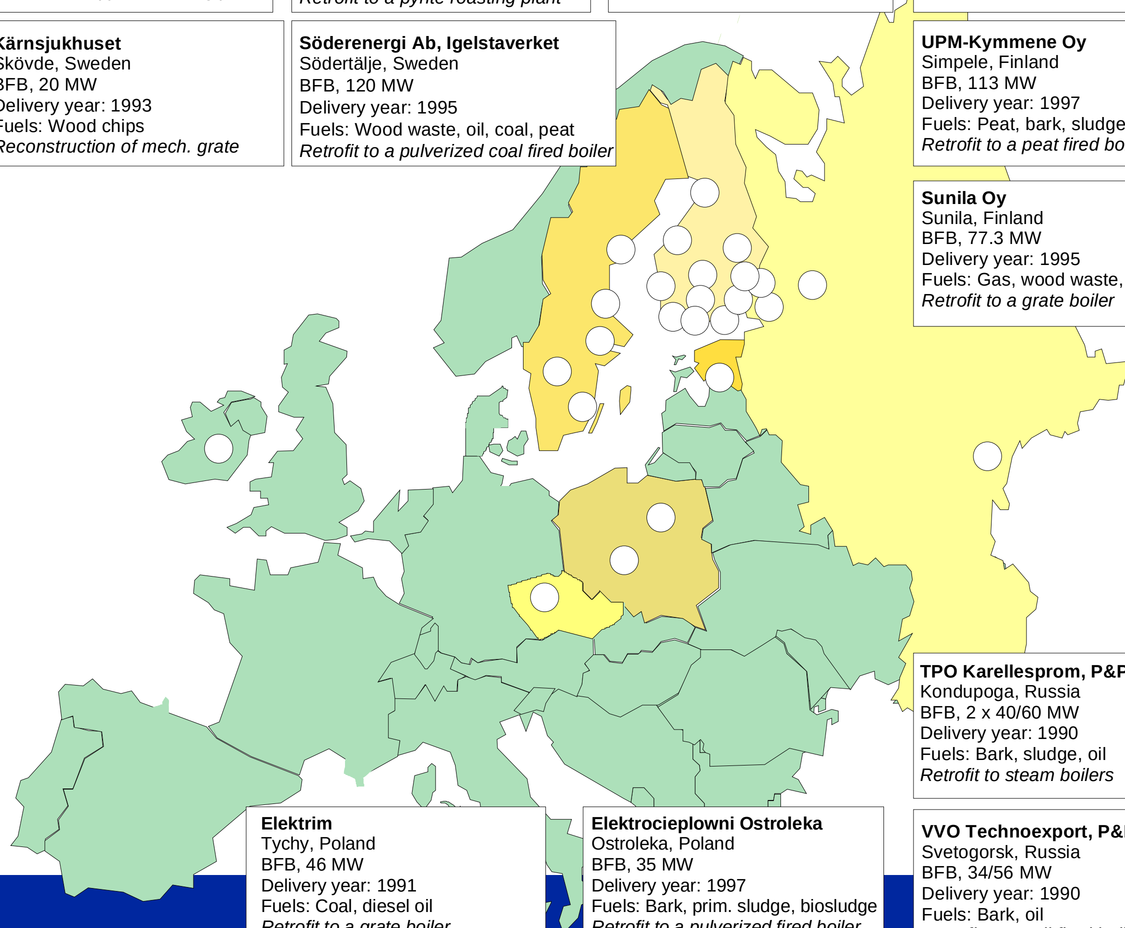
Kärnsjukhuset
Skövde, Sweden
BFB, 20 MW
Delivery year: 1993
Fuels: Wood chips
Reconstruction of mech. grate

Söderenergi Ab, Igelstaverket
Södertälje, Sweden
BFB, 120 MW
Delivery year: 1995
Fuels: Wood waste, oil, coal, peat
Retrofit to a pulverized coal fired boiler

UPM-Kymmene Oy
Simpele, Finland
BFB, 113 MW
Delivery year: 1997
Fuels: Peat, bark, sludge, oil
Retrofit to a peat fired boiler

Kaukas Oy
Lappeenranta, Finland
BFB, 109.3 MW
Delivery year: 1996
Fuels: Bark, sludge, peat, gas
Retrofit to a grate boiler

Stora Cell AB
Norrsundet, Sweden
BFB, 50 MW
Delivery year: 1997
Fuels: Bark
Retrofit to a grate boiler



Sunila Oy
Sunila, Finland
BFB, 77.3 MW
Delivery year: 1995
Fuels: Gas, wood waste, sludge
Retrofit to a grate boiler

Oy Metsä-Botnia Ab
Kaskinen, Finland
BFB, 77.5 MW
Delivery year: 1997
Fuels: Wood waste, sludge, oil
Retrofit to a grate boiler

Södra Cell AB
Mönsterås, Sweden
BFB, 73/105 MW
Delivery year: 2000
Fuels: Bark, sludge, oil
Retrofit to a grate boiler

Enso Oy
Varkaus, Finland
CFB, 20 MW
Delivery year: 1983
Fuels: Wood waste
Retrofit to a La Mont boiler

AS Anne Soojus
Luunja, Estonia
BFB, 2 x 18 MW
Delivery year: 1995
Fuels: Peat, wood chips
Retrofit to oil fired boilers

Suomen Kuitulevy
Pihlava, Finland
CFB, 15 MW
Delivery year: 1979
Fuels: Peat, wood waste
Retrofit to a grate boiler

Modo Paper AB
Husum, Sweden
BFB, 87 MW
Delivery year: 2000
Fuels: Bark, sludge, oil
Retrofit to a grate boiler

TPO Karellesprom, P&P Mill
Kondupoga, Russia
BFB, 2 x 40/60 MW
Delivery year: 1990
Fuels: Bark, sludge, oil
Retrofit to steam boilers

Oy Metsä-Botnia Ab
Kemi, Finland
BFB, 115 MW
Delivery year: 1994
Fuels: Wood waste, peat, sludge
Retrofit to a grate boiler

AssiDöman Sepap a.s.
Steti, Czech Republic
CFB, 176 MW
Delivery year: 1998
Fuels: Coal, bark, sludge
Retrofit to a coal fired boiler

Elektrim
Tychy, Poland
BFB, 46 MW
Delivery year: 1991
Fuels: Coal, diesel oil
Retrofit to a grate boiler

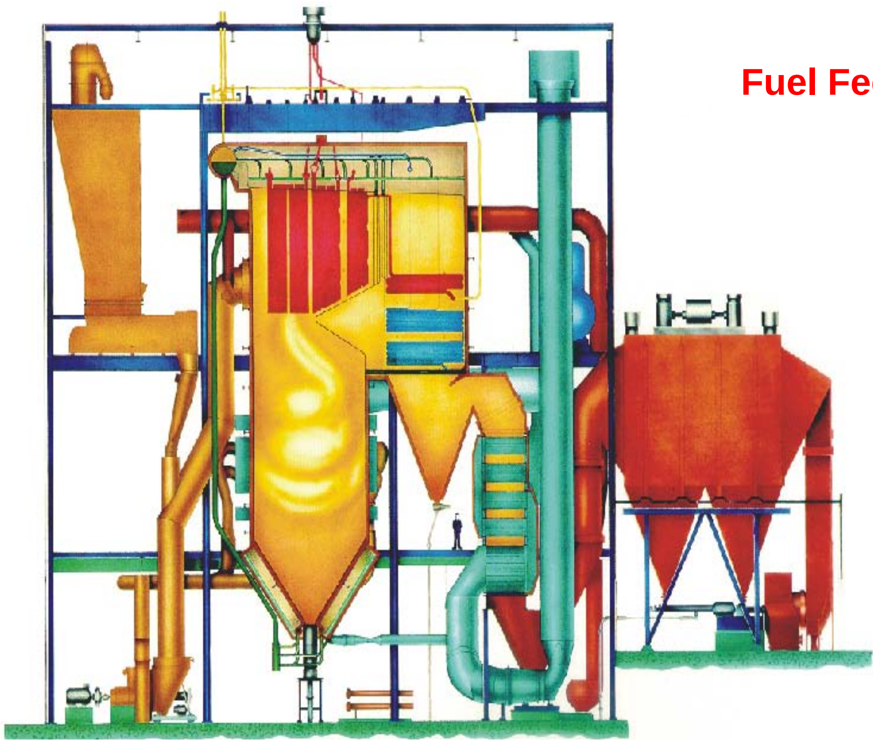
Elektrocieplowni Ostroleka
Ostroleka, Poland
BFB, 35 MW
Delivery year: 1997
Fuels: Bark, prim. sludge, biosludge
Retrofit to a pulverized fired boiler

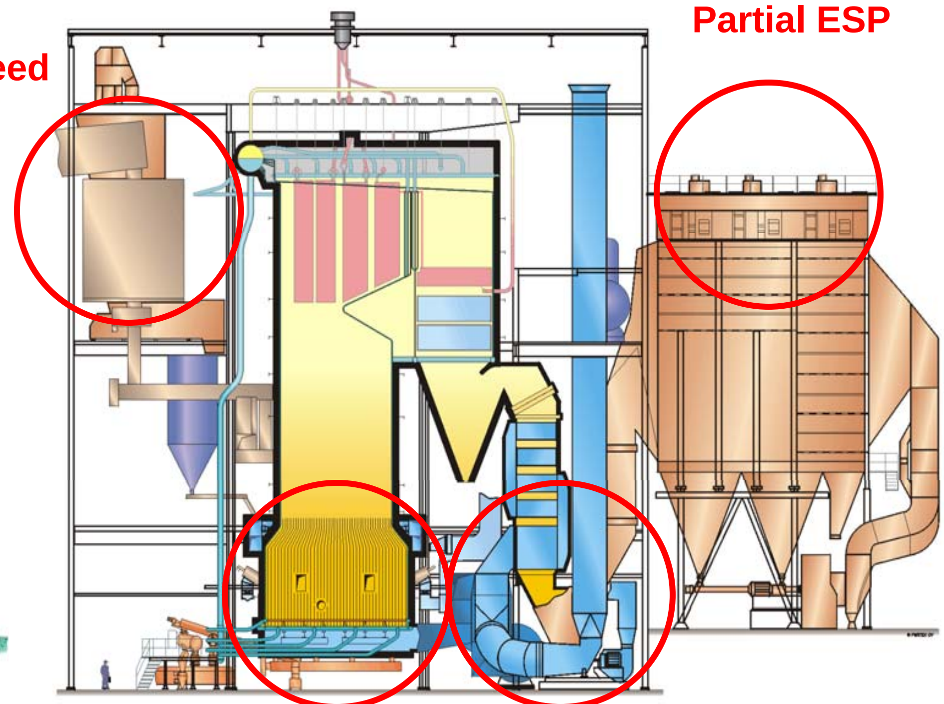
VVO Technoexport, P&P Mill
Svetogorsk, Russia
BFB, 34/56 MW
Delivery year: 1990
Fuels: Bark, oil
Retrofit to an oil fired boiler

Electrode Works
Novosibirsk, Russia
BFB, 2 x 116 MW
Delivery year: 1990
Fuels: Graphite, coal, anthracite
Retrofit to pulverized coal boilers

Before and After BFB Conversion

Before: Pulverized Peat Boiler | **After: Peat, Bark, Sludge BFB**





Metsa Serla Project in Simpele, Finland

Typical Goals of a BFB Retrofit / Conversion

- **Increase of biofuel combustion - reduction of fossile fuels- CO_2 benefit**
- **Use of high moisture fuels like bark and sludges - existing combustion technology is not suitable (pulverized coal burners, oil/natural gas burners, grates, etc.)**
- **Need to increase boiler steam production capacity**
- **Reduction of emissions (NOx, SOx, CO)**
- **Reduction of UBC**
- **Reuse of existing unused process boiler**

Potential BFB Conversion Scope Items

- Fuel Prep, Storage and Feed System
- SH, Econ Material Upgrade
- SH, Evap and Economizer Surface Rebalance
- Air Heater Sizing and Location
- PA System and SA System Upgrade
- ESP Upgrade
- Primary Air Boost
- Ash Systems Upgrade (Bed and Fly)
- Steel Support Structure Modification
- Soot Blowing Upgrade
- Electrical
- I & C

Key Steps To BFB Conversion

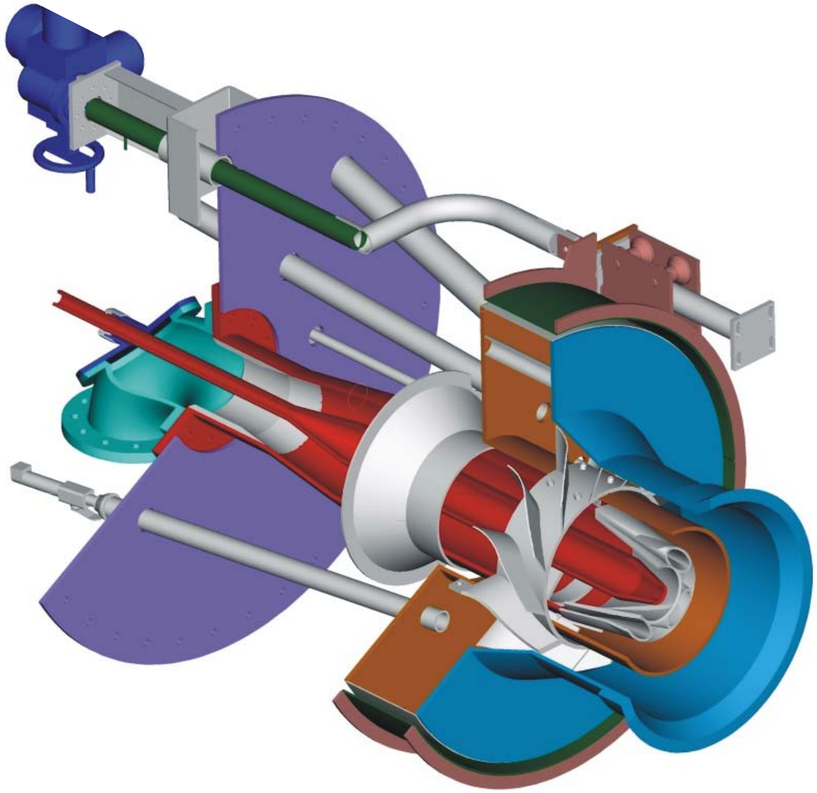
- **Establish Goals:**
  - Fuel, Emissions, Performance
- **Boiler Assessment:**
  - Space, Boiler Capacity
- **Design Study to Establish Project Scope**
- **Perform Conversion**
- **Commissioning and Performance Testing**

No Two Projects Are Alike

Expected Emissions Controls (BFB)

Emission	Avg. Uncontrolled Emission at Boiler Exit (lb/MMBtu)	Adage Emission Limit at Stack (lb/MMBtu)	Emissions Removal Required	(PRELIMINARY) Expected Control Technology
CO	0.110	0.08	26%	Tail-End CO Catalyst(1)
NOx	0.20	0.08	59%	Tail-End SCR Catalyst(2)
NH3	n/a	10 (ppmvd @7%O2)	n/a	Tail-End SCR Catalyst
SO2	0.11	0.08	24%	Dry Injection(3)
HCl (60 tpy MACT limit)	0.027	0.02	23%	Dry Injection(3)
HCl (10 tpy MACT limit)	0.027	0.0034	87%	Dry FGD(4)
PM-10	5.88	0.012	99.8%	ESP or Baghouse(5)

1. Preliminary information indicates it may be better to install CO catalyst downstream of Dust Collector - FW is evaluating both options.
2. Tail-End SCR is expected to be more economical than Hot-Side SCR, since gas must be reheated anyway to accommodate CO Catalyst. Also, it may not be feasible to install Hot-Side SCR due to possible catalyst poisoning - FW is evaluating cost and feasibility of both options.
3. Involves only injection of dry sorbent (Lime), with no water injected or Scrubber vessel required.
4. If 60 tpy MACT limit is required this will likely require a Dry-FGD - i.e., Scrubber vessel similar to Allied-type, with water and Lime injection.
5. ESP may be cheaper.



Biomass Suspension Co-Firing

Foster Wheeler Past Experience

Plant	Owner	Firing Method	FWNAC Role
Allen Fossil Plant	TVA	Cyclone	Led test program
Kingston Fossil Plant	TVA	T-fired PC	Supported tests
Colbert Fossil Plant	TVA	Wall-fired PC	Led test program
Michigan City Generating Station	NiSources (NIPSCO)	Cyclone	Led test program
Bailly Generating Station	NiSources (NIPSCO)	Cyclone	Led demonstration program
Seward Generating Station	GPU Genco	Wall-fired PC	Led demonstration program
Shawville Generating Station	GPU Genco	Wall-fired PC T-fired PC	Led test program
Albright Generating Station	Allegheny Energy Supply Co., LLC	T-fired PC	Led demonstration program
Willow Island Generating Station	Allegheny Energy Supply Co., LLC	Cyclone	Led demonstration program
Blount St. Station	Madison Gas & Electric	Wall-fired PC	Supported test program
Plant Gadsden	Southern Co.	T-fired PC	Supported test program
Ottumwa Generation Station	Alliant Energy	T-fired PC	Supported test program with preliminary engineering

Co-firing Biofuels in Coal Boilers

- **Increased volatility of biofuels is among the most critical consideration**
- **Biofuel particles volatize earlier and independently of the fossil fuel particles**
- **Causes some key changes in fuel particle-particle interactions; reducing the ignition temperature of the fuel mass**
- **Most co-firing applications on PC combustion systems use separate injection of fuel and biomass**
  - Blending of biomass and/or other fuels in the coal yard can be utilized at minimal biomass percentages
  - At >10% biomass (mass basis), separate is most applicable and at times, necessary

Biomass Co-firing – Materials Handling

Key to co-firing success

- Difficulties in grinding biomass
- Resultant particle sizes and shapes
- Particle size reduction can only occur by chopping or shredding producing high aspect ratios (length to width ratios)
- Particles are compressible providing a cushion for the coal particles reducing pulverizing phenomenon

Keep the biomass separate

- Coal receiving and handling is critical to the plant
- Consuming capability of coal handling with biomass risks compromising capability when it’s most needed (e.g. fuel shortage)

Example of Biomass Material Aspect Ratio

Biomass Co-firing – Materials Handling

In bunker storage

- Should be avoided if possible
  - Material may not flow well or at all
- Can be used if biomass is sawdust
  - Sawdust or 1/2” wood chips tend to work well
  - Most forms of biomass have disastrous results
- Can be used if cyclone boilers are the basis of co-firing

Biomass Co-firing – Materials Handling

- **Separate biomass from coal in PC boilers**
  - **Advantages**
    - Mill capability/performance is not compromised
    - During high electricity demand and price, ability to put fuel (Btu's) into the furnace is not limited
    - During wet coal events, separate injection of biomass into boiler adds Btu's to process – mitigating derates
    - Mitigates pluggage caused by biomass particles
  - **Disadvantages**
    - Increases temperature of gaseous combustion products exiting air heater (less air passed through air heater, less heat transferred)
    - Modest efficiency loss

- **Separate handling and injection also highly recommended for CFB boilers**
- **Co-mingling of biomass and coal in cyclones is usually necessary**

Biomass Co-firing – Materials Preparation

- **Particle sizing is important**
  - Cyclones
    - ¼” x 0” proves to be ideal
    - Sizing up to ½” x 0” or ¾” x 0” also works
    - Larger particles are typically assumed to work; particles will actually skip across the slag pool and fly through the boiler plugging up air heaters
  - PC firing
    - 1/8” x 0” is ideal
    - ¼” x 0” is acceptable
- **Recognize that biomass transport lines are subject to pluggage**
  - High aspect ratios
  - Low air/fuel ratios [1.7 – 2.0 lb air/lb fuel]
- **Must be incorporated into design**
  - Frequent clean-out provisions
  - Provisions for rapid identification where pluggage occurs

Biomass Co-firing - Transport

- **When biomass is moving, keep it moving**
  - Avoid allowing biomass material to settle
    - e.g. filling biomass bunker at night while co-firing is not used
  - Settled material can become very difficult to move, requiring excessive manpower

- **Keep transport velocities above the flame speed of biomass**
  - Flame speed of biomass is > 5000 ft/min (83 ft/sec)
  - Design of systems needs to consider this parameter
  - Transport velocities of ~ 110 – 120 ft/sec have proven to be useful

PC Firing – Injection System is a Key

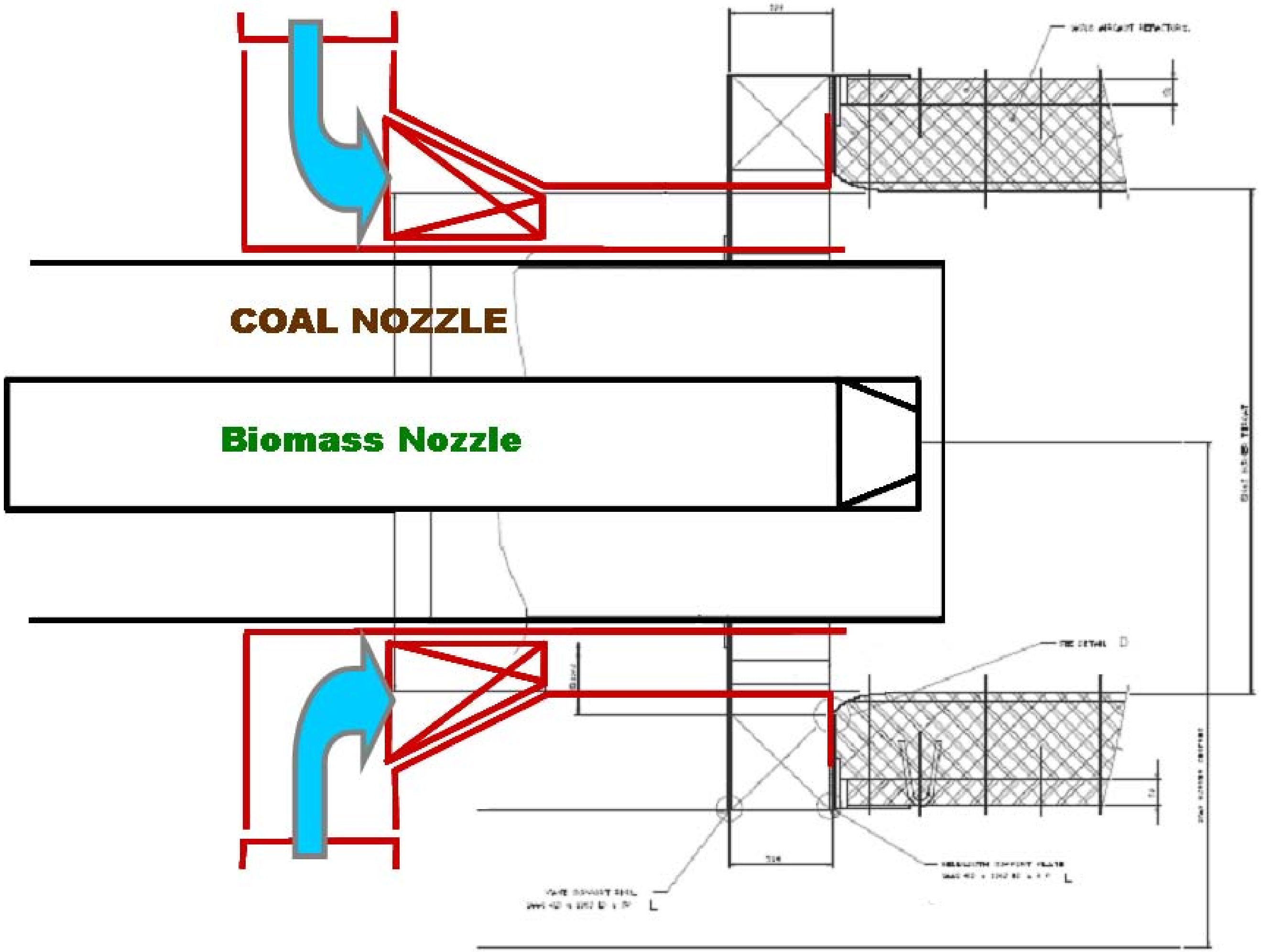
- **For tangentially-fired boilers, injectors are well developed**
  - Injector placement at center of fireball works well for flame stabilization, creating internal reducing zone
  - Transport velocities and transport air ratios are important

- **For wall-fired boilers, common system utilized**
  - Injection of biomass (typically and mostly easily managed is sawdust) in the center of coal flame; modification of existing burners
  - Burner design concepts exist for multi-fuel co-firing, maximizing NO_x reduction

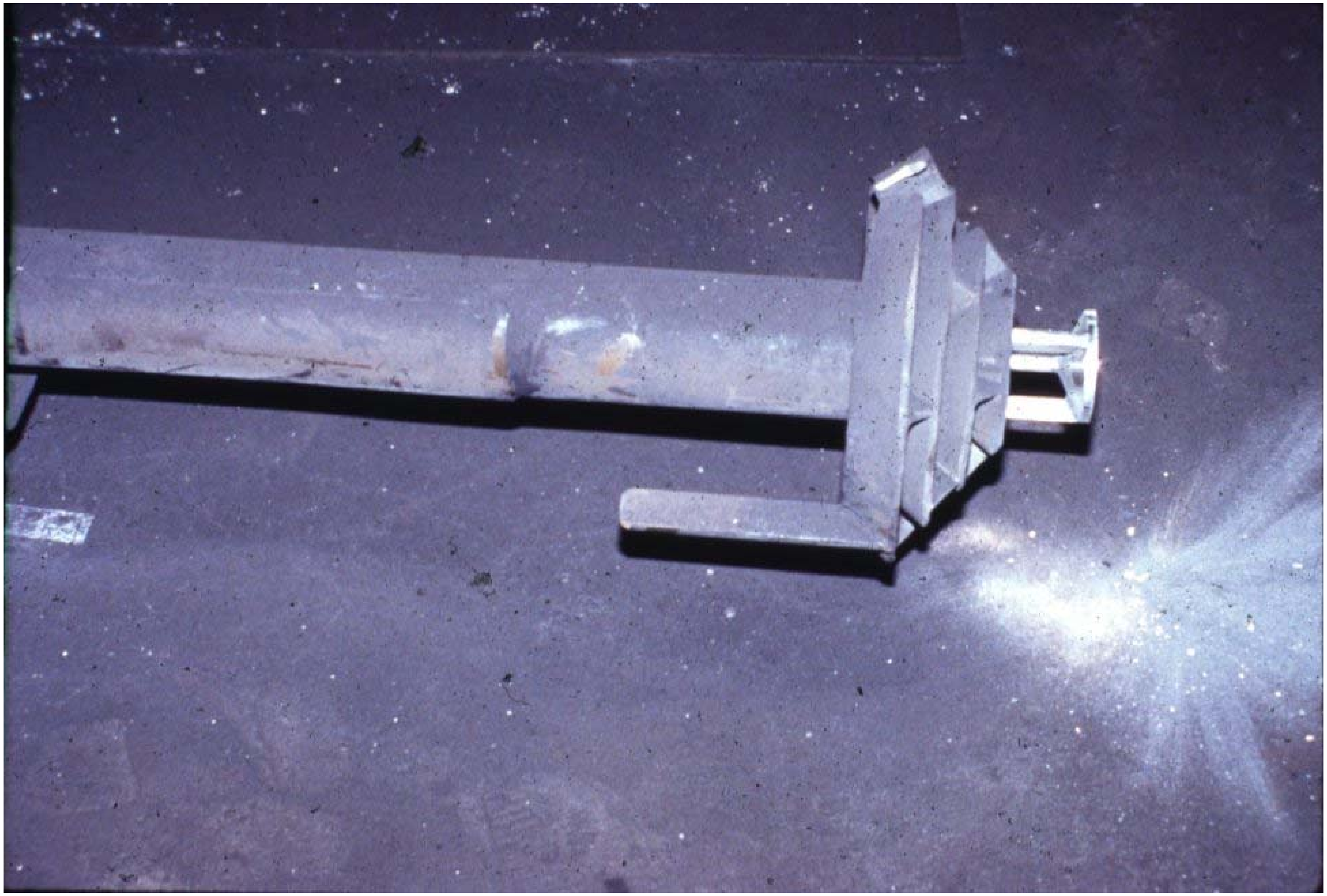
Burner Design of Wall-Fired Burners

- **Biomass can be introduced into the burners by:**
  - Injection co-axial with coal nozzles
  - Injection with biofuel nozzles replacing coal nozzles
  - Injection through separate furnace wall penetrations
- **Conversion of entire burners to biofuel burners can challenge the burner air control requirements since air requirements for both fuels are different**
- **Separate injection can be performed through lances along the burner axis**
  - High volatile biofuel at center of flame quickly consumes oxygen, promoting NO_x reduction
  - Proper dispersion of biomass into the flame is essential
- **Co-axial injection has been the most successful method**

Typical Wall-Fired Burner Configuration for Biomass Co-firing



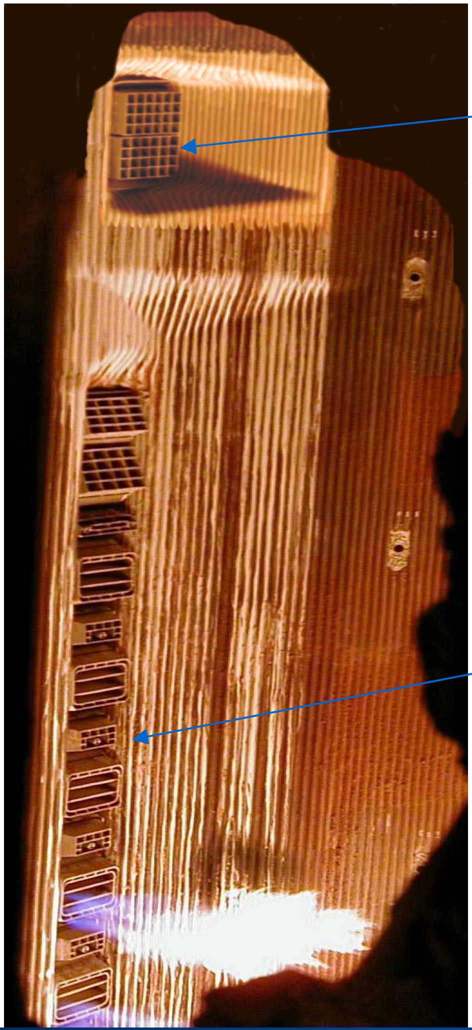
Wall-Fired Sawdust Injector



Typical TLN Configuration

4 or 8 Corner Fired Configuration

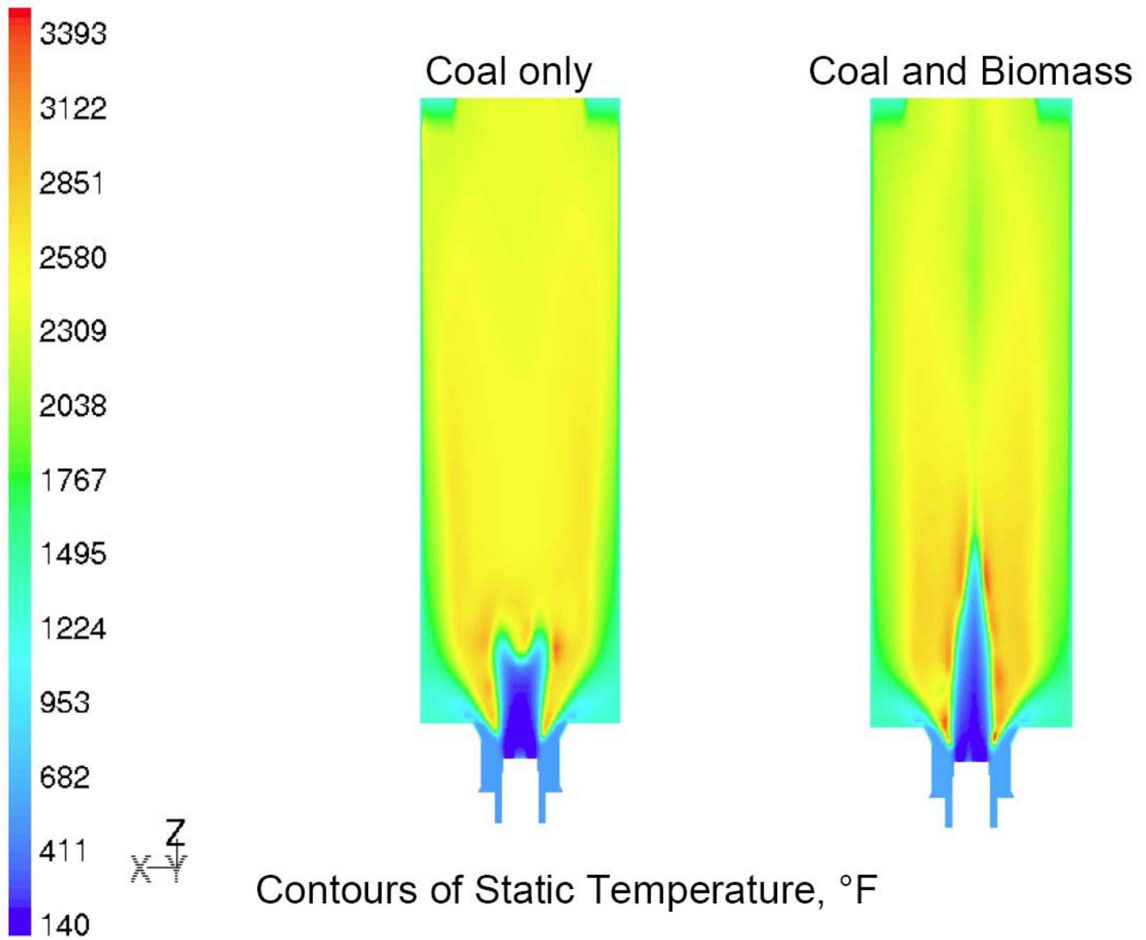
Injection can be through opposing corners



Separated Overfire Air Ports for NO_x control

Biomass Injection at center of 'fireball'

Example of Low NOx Burner Flame Temperatures Without and With Co-axial Biomass Injection



Coal Only Case

Two distinct area of high reaction rates:

a) The zone near the burner nozzle where volatiles are released surrounded by

b) A larger and longer zone where char oxidation occurs

Biomass Co-firing Case

1) Two strong zones of volatile release from biomass jet on burner axis

2) Flame is longer and has lower release rates of coal volatiles and char oxidation

- **Although there is appreciable quantity of unreacted biomass volatile, these volatiles will readily react in the burner interaction region and above burner zone**

- **Co-combustion demonstrations have shown modest and often favorable impact of biomass on unburned carbon**

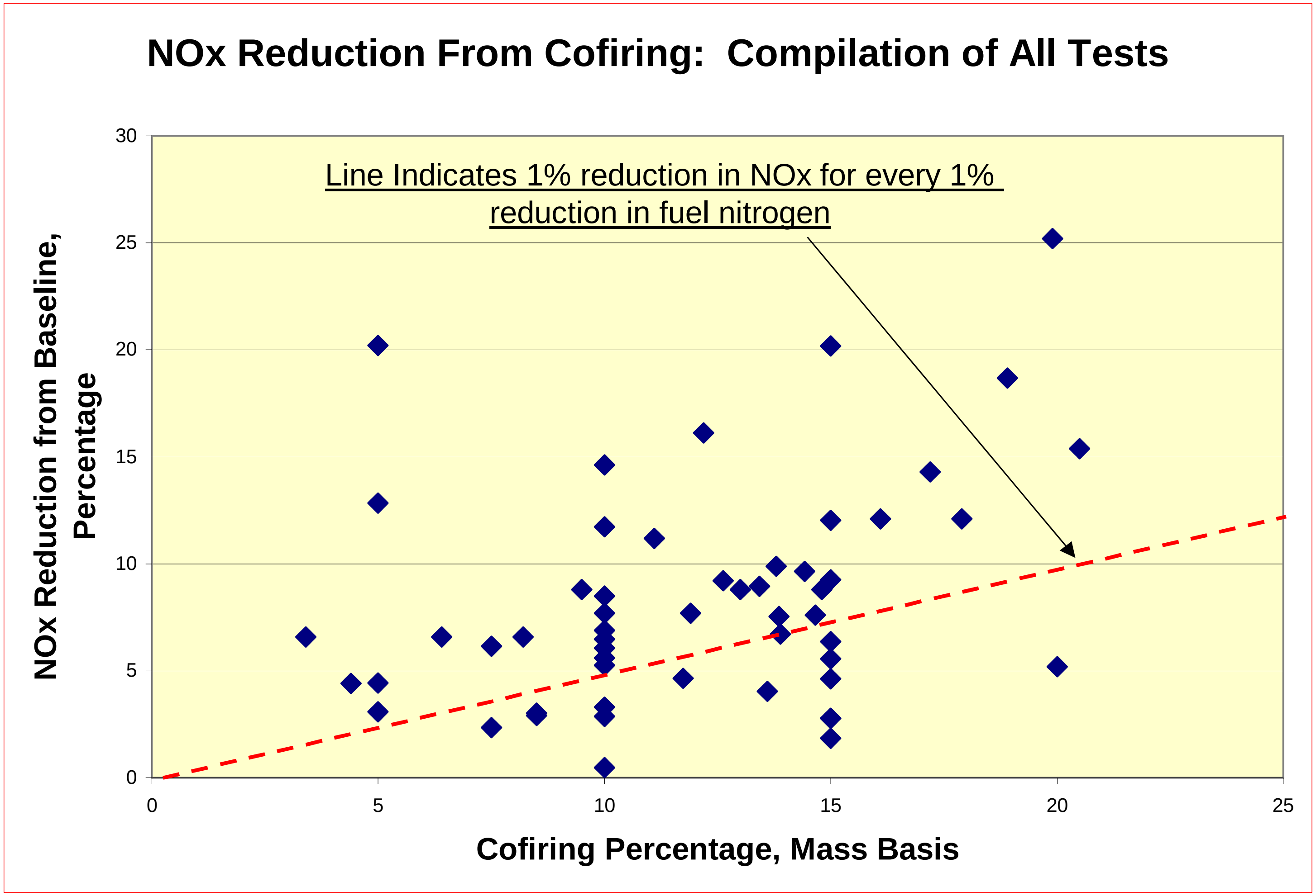
Biomass Effects for Burners

- **Biomass can enhance burner stability with the early release of volatiles – particularly when co-firing with low volatile coals**

- **Low nitrogen and high volatile matter content of biomass can significantly enhance NOx reduction**
  – Volatile matter is a key factor in creating low NOx combustion conditions in flames

- **When tri-firing with low volatile fuels such as petcoke, biomass can potentially offset negative impacts of these opportunity fuels**

Summary of NO_x Reduction from Cofiring



Biomass and Fuels Management

- **Biomass can be used to increase total fuel volatility**
  - High volatile fuel (typically >50%)
  - Low ash fuel (typically <1%)

- **Biomass can be used to modify the combustion process**
  - By increasing deep staging effects
  - By reducing FEGT without reducing steam temperatures
  - By managing unburned carbon (LOI) in flyash

Co-firing Capacity Implications

Capacity Implications:

- Cyclone boilers – capacity limitations not experienced at or below 15% co-firing – key issue is feeder speeds
- PC boilers – capacity derates can come quickly with blended fuels
  - limitations result from pulverizer performance if the plant is pulverizer limited
  - if spare pulverizer capacity exists, then fuel fineness may become an issue
- PC boilers - capacity is not limited with separate injection – provided sufficient ID fan capacity exists
- Co-firing (PC boilers) can be utilized to recover some lost capacity when there are wet coal issues