Potential Impacts of Biomass and Alternate Fuels on Boiler Equipment

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CIBO Industrial Emissions Control Technology VII Conference, Portland, ME

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Agenda

- Fuel Considerations
- Supply Considerations
- Delivered Cost Considerations

Biomass Considerations

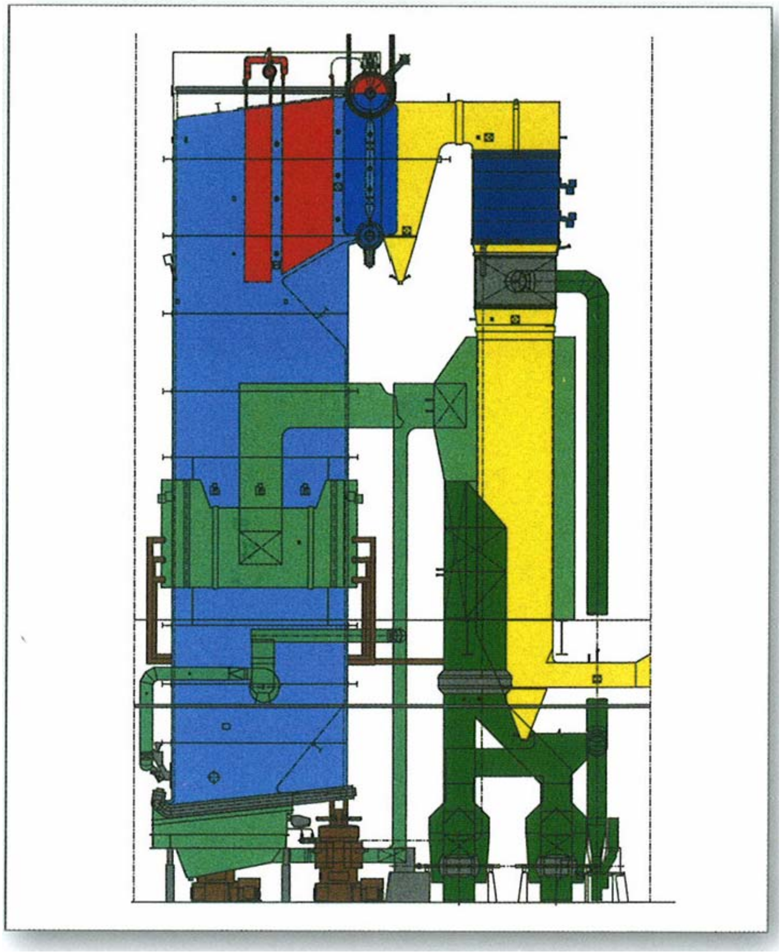
- It's all about the fuel !!
  - Biomass fuel is variable
  - The same type of fuel varies from different sources
    - ie wood that floats in salt water
    - rice hulls that grow in brackish water
    - demolition waste
- Unit size and choice are fuel dependent
  - Biomass is generally not economical to ship
  - Although biomass is widely available, it is often difficult to contract for substantial quantities for any length of time in order to secure financing.
  - Handling of biomass is also an issue
    - bundling
    - sizing, shredding, grinding, etc.
- There are solutions for each of these issues, but the boiler designer will need to know them in order to take them into account.

Biomass Considerations

- Existing units
  - design fuel
    - switch
    - co fire
  - type of unit
  - unit condition

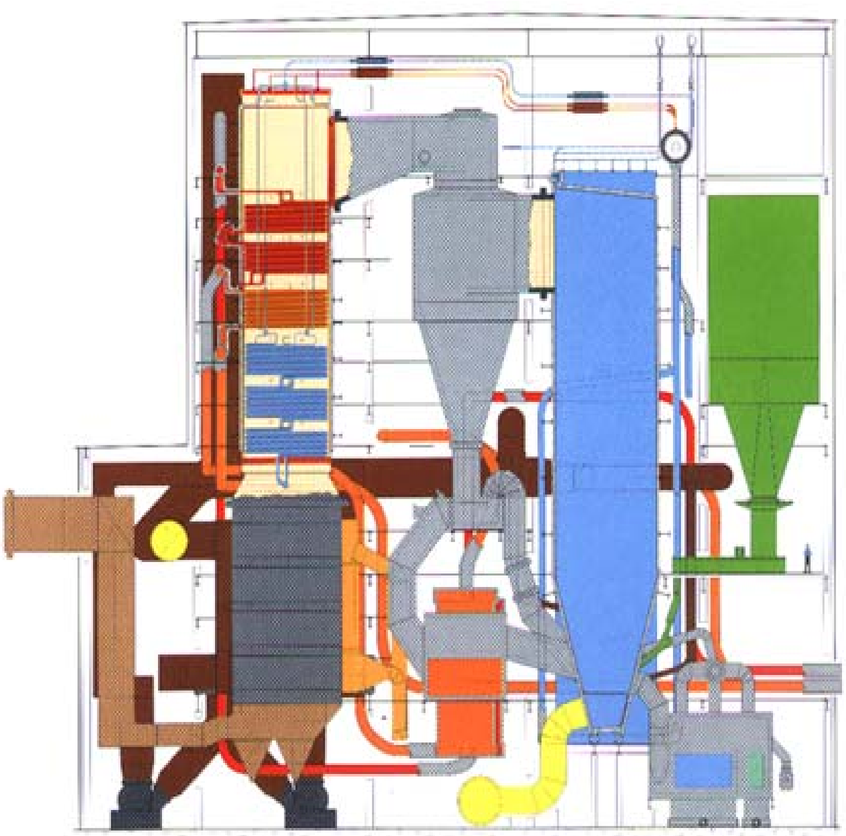
- New units
  - fuel properties for proposed fuels
  - type of unit

Stoker/PF Boilers



- Fuels:
  - Solid Fuel -- coal, coke, sludges, wood, waste fuels
- Firing Systems
  - Tangential Firing
  - Front Firing
  - Stoker Firing
- Natural or Controlled Circulation
- Types
  - VU-40 (solid fuel)
  - VU-60 (liquid and gaseous fuels)
  - Radiant (solid, liquid, and gaseous)

Fluidized Bed Boilers



- Well-Suited to a Wide Range of Fuels
  - Anthracite
  - Brown Coal
  - Petroleum coke
  - Culm and gob
  - Wood and wood waste
  - Agricultural waste
  - Sludges
- Inherently Low Environmental Emissions
- Moderate Fuel Preparation
- Innovative Technology

FBC Offers a Wide Fuel Range Capability

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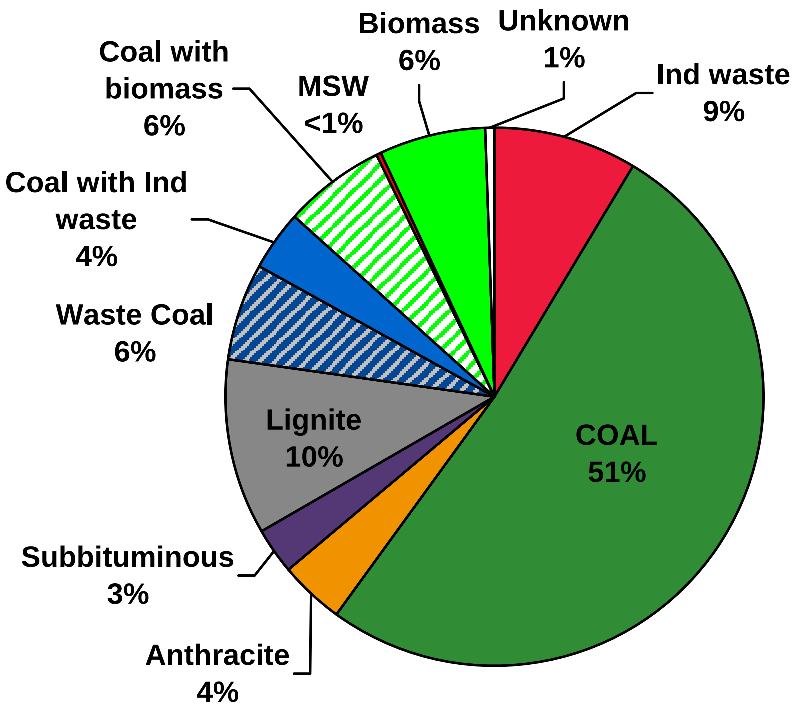
World Wide Fluidized Bed Experience



Fuel Quality	High	Low
HHV Btu/lb	14,500	2,500
Moisture	62%	3%
Ash	76%	4%
Carbon	88%	9%
Sulfur	7%	0.3%
Volatiles	58%	4%

Global experience, all suppliers, all FBC (bubbling, hybrid, circulating)

Fuel Considerations

- Alkalies (Na and K) (Found in all fuels)
- Chlorides (Found in all fuels)
- Sulfur (More likely in waste fuels such as culm, petcoke, etc.)
- Lead and Zinc (More likely in MSW, RDF, TDF, Construction debris)
- Ash Content (Generally low in biomass)
  - not just the non combustible associated with the fuel, but also the “tramp” that is picked up along with the fuel pile.
    - rocks that come with frozen bark
    - spikes, nails,and metal that comes with waste wood
- Moisture Content (Found in all fuels)

Implications

- Alkalies
  - high concentrations of alkalies imply low melting temperature ash components.
  - low melting ash implies sticky deposits.
  - these deposits can form on either water walls or convective tubing.
  - these deposits are difficult to clean.
  - potassium deposits can be corrosive (potassium is more aggressive than sodium).
- Solutions
  - Limit the amount of alkalies (ie amount of co-firing).
  - Blend in other fuels with low alkali content.
  - Control temperatures to avoid sticky deposits.

Implications

- Alkalies
  - sticky ash material can cause agglomeration of the bed in fluid bed combustion boilers.
  - bed agglomeration is a serious problem.
  - deposits can form on water walls, refractories, cyclones, or convective tubing that are difficult to clean.
- Solutions
  - bauxite can be added at the risk of liberating chlorides and sulfates.
  - sand can be added coupled with additional bleed of bed material.
  - bed temperature can be reduced somewhat.
  - limit the amount of alkali

Implications

- **Chloride**s
  - **High levels of chlorides imply corrosion on higher temperature tubing (typically SH tubes). Corrosion can come from all phases.**
  - **Relatively high moisture content assures that most of the chloride that is present in the gas phase is HCl.**
    - **At low concentrations and moderate temperatures, reaction rates with HCl are slow.**
    - **At higher concentrations and the presence of deposits, HCl reacts with iron to form iron chloride. Iron chloride is vaporous and tends to diffuse into the deposit, where the temperature is higher. The iron chloride becomes unstable and breaks down into iron oxide and HCl, which in turn diffuses back into the iron in a process known as thermophoresis.**
  - **Chlorides can also be responsible for low temperature corrosion with high moisture content fuels.**
- **Solutions**
  - **Using a separate fluid bed heat exchanger for SH duty in a CFB can locate the higher temperature tubes away from the chloride gases.**
  - **Limiting or controlling temperatures.**
  - **Limit chloride levels.**

Circulating Fluidized Bed Boilers

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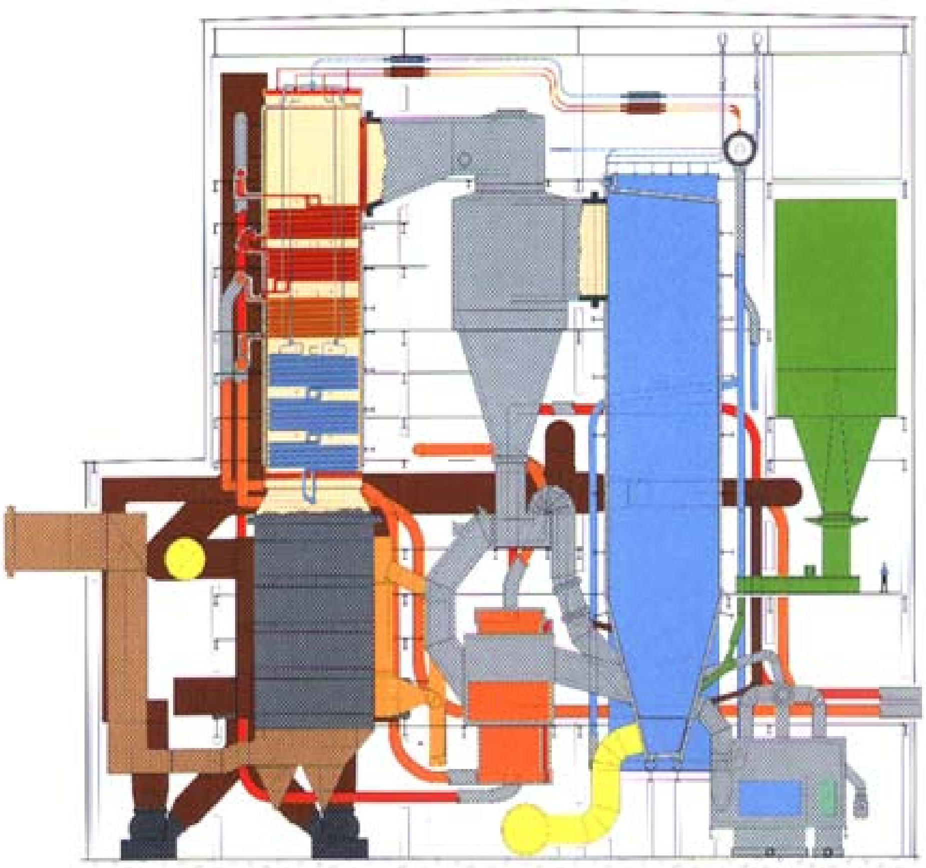

- External Fluid Bed Heat Exchanger offers the possibility of locating higher temperature surface out of the flue gas stream, reducing corrosion potential.
- Lower combustion temperature tends to avoid sticky ash temperatures.

Implications

- Sulfur (more likely in waste fuels)
  - High sulfur contents imply local sulfur corrosion as well as high dew points for acid gas corrosion in the back end.
  - When combined with reducing conditions (ie Low NOx firing, poor air mixing, etc.) can cause severe corrosion around burners, fuel introduction areas, and waterwalls.
  - At high metal temperatures (over 1200 F), pyrosulfates can form which are very corrosive
  - Can be a source of opacity problems in the form of sulfate aerosols.
  - Can combine with unburned carbon to form “acid smut”.
  - Can combine with ammonia slip to form ammonium bisulfate (plugging, corrosion, “blue haze”).
  - High sulfur fuels will require SO_2 capture.
- Solutions
  - In FBC, limestone addition mitigates the above problems and captures SO_2.
  - Limit sulfur content.
  - Limit or control temperatures appropriately.

Implications

- Lead and Zinc (mostly found in waste fuels such as MSW or RDF)
  - These components combine with other bad actors (alkalies, chlorides, and sulfates) to form very low melting compounds that are very corrosive.
  - Corrosion can occur at metal temperatures as low as 600 F.
  - Corrosion can occur on water walls as well as SH tubes.
  - Can initiate a process of deposit, corrosion, erosion, further deposit, corrosion, etc.
    - Under these conditions corrosion can be severe (failure in less than 1 month).
    - This phenomenon is more likely with waste fuels (MSW, RDF, TDF, construction debris).
- Solutions
  - Wall or tube coatings
  - Limit the content of lead and zinc
  - Idle pass for temperature control

Implications

- Ash Content
  - As the ash content of the fuel increases, the capacity required for ash handling equipment goes up in a non-linear fashion. This is because more fuel is needed to provide the same relative heat input. This additional fuel contains more ash, resulting in the need to handle that ash as well.
  - The additional ash impacts the feed system as well, as more fuel is needed to provide the same level of heat input.
  - The split between bottom ash and flyash may be impacted.
  - Particle size management is more critical for good CFB operation.
  - Ash also includes “tramp” material that happens to come along with the fuel (ie construction waste).
- Solutions
  - The more the designer knows about the ash level and content, the more likely the design of equipment can be adapted to the amount and type of ash present.

Implications

- Moisture Content (biomass, sludges, and pond fines)
  - High moisture content implies a reduced heating value of the fuel.
  - High moisture content increases the gas weight in the products of combustion (ie the flue gas).
  - These two factors combine to require a larger volume boiler with larger auxiliary equipment (fuel feeding, fans, duct work, environmental control equipment, etc.).
  - In the case of a retrofit, these factors would require a derating of the boiler.
  - The high moisture also implies a higher dew point temperature, which has implications for back end corrosion.
  - The moisture is vaporized which is pumped up the stack which results in efficiency losses.
- Solutions
  - Design for the moisture level
  - Dry the fuel

Supply issues

Transportation Issues

- Biomass fuels are typically high in moisture. This means that transportation costs are increased by the cost of transporting water. A similar situation exists for coal pond fines, MSW, sludges, and similar alternative fuels.
- Waste coal piles tend to be very high in ash content. This presents a similar problem in that transportation costs are increased by the cost of transporting ash.
- In general, it is usually not economical to transport alternate fuels large distances.
- Although regulations and tax incentives can modify the economics, the choice of fuel will likely be local.
- The designer needs to know all of the potential fuels to be used.

Supply issues

Small entities

- Many generators of alternate fuels tend to be small entities.
  - Towns for MSW
  - Tire and auto dealers for TDF
  - Construction projects for “construction debris”
  - Saw mills for saw dust.
- In some cases, the production of the biomass is seasonal.
  - Olive pits
  - Rice hulls
  - Bagasse
- In terms of putting together a project, the development time and costs are exacerbated by having to put together several small entities in order to have a reasonably reliable and sufficient supply of fuel.
- Financing usually requires some kind of fuel supply contract over the financial life of the project.

Cost Issues

Offset values for various allowance prices

- Green wood (50% moisture) has about 5.7 MMBTU/ton (USDA)
- Dried wood (10% moisture) has about 10 MMBTU/ton (USDA)
  - One ton of dried wood substitutes for about 0.4 ton of coal
  - This substitution would result in an offset of 1.2 ton of CO_2, assuming that 100% credit is given for biomass firing.

Cost Issues

Offset values for various allowance prices

Allowance Value	Equivalent for dry wood
$/ton CO2	$/ton wood
$7	$8.4
$15	$18
$30	$36
$50	$60
$100	$120

Cost Issues

Offset values for various allowance prices

- The values on the prior slide are the maximum theoretical values of the impact on the price of dried wood. This represents the value of the wood that the owner of the wood might try to collect, just as low sulfur coal costs more than high sulfur coal.
- Clearly, lesser grades of wood and biomass are less costly in terms of BTU value. These grades are likely to see an increase in price as they become recognized as viable fuels with carbon offsets.

Cost Issues

Handling Costs

- The handling processes for any of these fuels will continue to use standard, proven equipment. This includes conveyors, bins, bucket elevators, feeders, structural steel, platforms and ladders, controls, etc.
- In general, it costs between $5 – 10/ton to pick something up, move it a short distance, and put it down again, depending upon the material and how the equipment cost is financed. (amortized value of a fuel handling system)
- Thus, to move a material from a storage pile to a bin system to be ready for fuel preparation prior to feeding to a boiler carries a substantial cost. This cost is just the cost to move the material and does not include any preparation or processing costs.
- The design of the fuel handling system is a key element in the overall utilization of biomass and alternative fuels.

Final Thoughts

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- If biomass is to contribute a substantial amount to the US energy needs in an effort to offset or reduce CO_2 emissions, the amount of biomass supply will need to increase.
- Biomass and alternative fuels have been used for a long time. However, special considerations need to be taken in order to use them effectively in boiler equipment.
- Supply and cost issues tend to constrain the use of these fuels.
- While the use of biomass and other alternate fuels will likely increase, costs are also likely to increase.

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