Retrofitting Coal Boilers With Fluidized Bed Technology

... or ...

"Recycling Power Plants For Fun and Profit!"

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You have an old power plant sitting out on the back forty; its not meeting current environmental standards; you want to use a biomass fuel to meet new RPS standards but, well.... let's face it, its an old fashioned hunk of iron and can only use coal. I'm sure this is a problem we've all faced. Well, this here paper is about to offer a couple of suggestions.

Why Retrofit a Boiler?

There are many reasons you or your client may wish to retrofit a boiler to either full or partial operation on biomass fuels. A utility may be looking for ways to meet a Renewable Portfolio Standard (RPS), reduce plant emissions, use a CO_2 neutral fuel, or bring an out of compliance boiler back into service. As an independent power project developer, you may be looking to generate renewable power from an existing coal boiler to take advantage of higher green energy revenue, or want to repower an inexpensive moth balled coal boiler.

As there are many reasons you may want to retrofit a boiler, there are also many options for retrofit technology available for your consideration. These options include a diversity of technologies and/or fuels.

Most people agree that of all of the options for adding renewable energy to your portfolio, biomass combustion or gasification offers the best proven options for generating ***baseload*** renewable energy. Of the possibilities for adding or increasing a biomass component to your generating mix, the retrofit of existing coal fired boilers represents the lowest cost per kilowatt of any generation option.

This paper explores the various ways Energy Products of Idaho's atmospheric fluidized bed technology is used for the partial or total conversion of an existing coal fired boiler to utilize a variety of biomass fuels.

First ..... Identifying and Selecting a Boiler for Retrofit

In most cases, newer boilers are meeting emission requirements, have a reasonable efficiency and are capable of a relatively long operating life with reasonable maintenance levels. So these are not typically considered good candidates for conversion to 100% biomass. They may be considered for partial conversion utilizing EPI's gasifier add-on which is discussed later in this paper. The primary targeted boilers are typically at least 30 years old, require upgrades to their emissions control system in the near future, are currently out of compliance with air quality regulations or are boilers which are currently out of service.

In addition to identifying a boiler, other considerations are the available space for biomass fuel storage, physical access to the boiler proposed for the retrofit and access to a steady supply of biomass fuels.

Retrofit Options

Boiler retrofits can be accomplished in a number of ways depending on the type and condition of the existing equipment. Boiler retrofit options include:

✓ Complete replacement of the existing boiler and emissions control systems with a new boiler island. This option reuses the remaining power plant systems including the turbine generator, condenser, cooling tower, water treatment, switch gear and controls.

✓ Removing the existing boiler's bottom and replacing it with either a new fluidized bed thermal oxidizer bottom or air blown gasifier bottom. This option is best suited to old stoker style boilers. The replacement of the existing boiler bottom with a new EPI fluidized bed bottom is typically used to convert the boiler to 100% biomass, but under certain conditions, coal or other non-biomass fuels can also be used.

✓ The addition of an external gasifier can be used for partial or full conversion of a boiler from coal to biomass.

Second ..... The Biomass Fuel

Once a boiler is identified for retrofit, the most important consideration in deciding the feasibility of retrofitting the boiler to utilize biomass is identifying the fuel supply. It may seem some areas of the country are devoid of biomass fuels and therefore this concept may not seem feasible, but with the right technology, many unlikely opportunities exist. The following are just some of the biomass fuels that have been used in EPI's biomass energy systems:

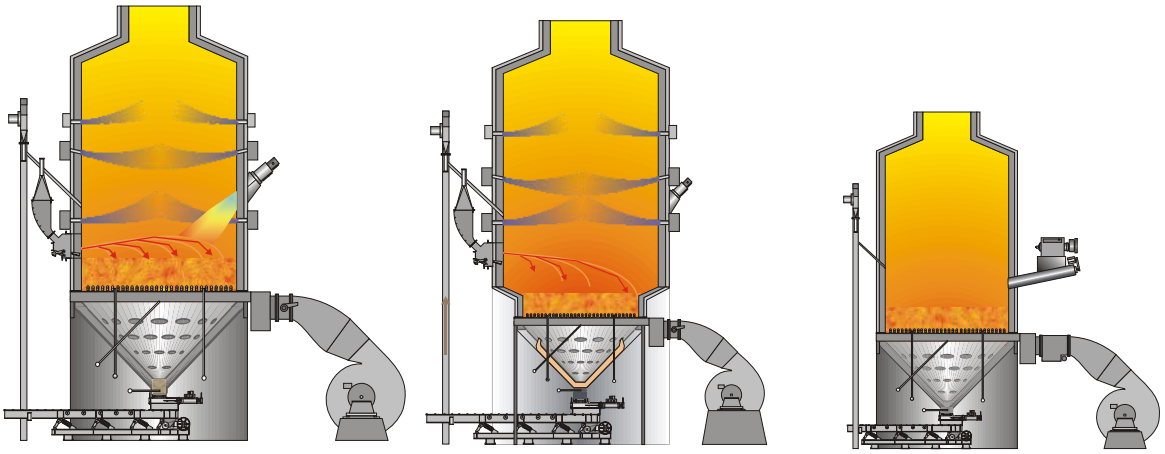
Alfalfa Straw, Almond Brush, Almond Shells, Almond Wood, Apple Wood, Apricot Wood, Bark, Barley Straw, Bean Stover, Board Plant Waste, Bran, Cherry Pits, Cattle Manure, Chicken Litter, Citrus Trees, Coffee Grounds, Construction & Demolition (C&D) Waste, Corn Cobs, Corn Stalks, Cotton Gin Wastes, Cotton Seed Hulls, Cotton Stalks, Cow Manure, Cubed Garlic, Distillers Grains (wet or dry), Energy Grass, Fig Culls, Fig Wood, Garlic & Onion Skins, Germ, Grape Canes, Grape Pomace, Grape Scaffolds, Hardwoods, Lignin, Manure & Straw, Municipal Sludge, Nectarine Wood, Oat Straw, Olive Pits, Orange Peel & Pulp, Paper Sludge, Paunch Manure, Peach Pits, Peach Wood, Pear Wood, Peat, Pecan Shells, Pistachio Shells, Pistachio Wood, Planer Shavings, Plum Wood, Prune Pits, Prune Wood, Race Track Shavings, Race Track Straw, Railroad Ties, Refuse Derived Fuels (RDF), Rice Hulls, Rice Straw, Safflower Stalks, Scum Grease, Sander Dust, Saw Dust, Sewage Sludge, Slash, Softwoods, Sunflower Hulls, Syrup, Tobacco Sludges, Tomato Pomace, Urban Wood Waste, Walnut Shells, Walnut Wood, Wheat Straw, Woodex Pellets, Zinc Borate OSB Waste.

When considering a retrofit technology, the ability to utilize multiple fuels in a single system is critical. Your technology of choice should be capable of accepting wet fuels (65-70% moisture) and dry fuels (<5% moisture), fuels in "chunks" through powders, solids to sludges and everything in between.

Third ..... Retrofit Technology Choices

The retrofit technologies discussed in this paper are all based on *fluidized bed* technology. Fluidization is a term used to describe a phenomenon occurring when an air stream passes vertically upward through a mass of solid particles. The upward velocity creates a lifting or buoyancy effect on the particles and results in the suspension of those particles within the air. As the air velocities are increased above a minimum fluidization velocity, the particles are no longer held to normal solid-to-solid contact and they begin to float and travel within the air stream. The fluidized media exhibits the physical characteristics of a fluid and resembles a pot of water in a rolling boil. The result is that the physical properties of the mixture become very homogenous; all concentrations are evenly distributed throughout the fluidized bed and temperatures are uniform throughout.

EPI offers three commercially proven types of fluidized bed energy systems. These include thermal oxidizers, advanced staged gasifiers and air or oxygen & steam blown gasifiers. Each of these variations are based on the same fluidized bed process and mechanical components, but with significant operational differences (Figure 1).



Thermal Oxidizer **Advanced Staged Gasifier**
Gasifier

Figure 1

Technology Similarities

❖ **Basic Fluidization Technology** ❖ **Bed Cleaning & Reinjection**
❖ **Construction** ❖ **Fuel Metering** ❖ **Control System**

Technology Differences

Thermal Oxidation

✔ Complete thermal oxidization
✔ Low bed energy density
✔ Limestone Injection & SNCR
✔ Overfire air
✔ Extremely wide fuel variations

Gasification

✔ Incomplete oxidization
✔ High bed energy density
✔ No limestone or SNCR used
✔ No overfire air
✔ Limitations on fuel

All three types of fluidized bed energy systems share EPI's proprietary fluidized bed mechanical design components, bed cleaning and reinjection system, modular construction, fuel metering systems, and system instrumentation and control design. These integral design components form the basis of all EPI systems and success with the widest range of fuels of any manufacturer of fluidized bed systems today.

Thermal Oxidization

The first application for a fluidized bed energy system is thermal oxidization.

The scrubbing action of the bed material on the fuel particles enhances the thermal oxidization process by stripping away the carbon dioxide and char layers that normally form around the fuel particle. This allows oxygen to reach the combustible material much more readily and increases the rate and efficiency of the thermal oxidization process.

The turbulence in the thermal oxidizer vapor space combined with the tumultuous scouring effect and thermal inertia of the bed material provide for complete, controlled and uniform thermal oxidization. These factors are key to maximizing the thermal efficiency, minimizing char and controlling emissions. The high efficiency of a fluidized bed thermal oxidizer makes it particularly well suited to problem fuels with low BTU value and high moisture characteristics.

Emissions from a fluidized bed thermal oxidizer are inherently lower than conventional technologies for the following reasons:

- ✓ Low combustion temperatures and low excess air within the bed reduces the formation of certain emissions such as NOx.
- ✓ High combustion efficiency results in flue gases that contain low amounts of CO.
- ✓ Emissions such as SOx and NOx may be abated within the fluidized bed system by injecting limestone into the bed and ammonia into the vapor space.

These features of fluidized bed thermal oxidization, combined with EPI's vast experience with a variety of fuels have allowed EPI units to comply with some of the most stringent air quality regulations in the country.

Thermal oxidizers are the technology of choice for repowering an existing facility:

- ✓ Where the existing boiler is in good repair but cannot be converted to utilize biomass fuels, such as a boiler designed to operate on natural gas or fuel oil, or where physical limitations prevent simply removing the existing boiler bottom and replacing it with a fluidized bed bottom. An example of this is the EPI retrofit of the Tacoma Power & Light's Steam Plant #6 which won the Power Plant of the Year Award.
- ✓ When the existing steam turbine and generating equipment are in good condition but the boiler and/or pollution control devices are not repairable or need to be completely replaced to meet new emissions standards.

A retrofit of this type includes a new fluidized bed thermal oxidizer or staged gasifier and, if required, new pollution systems and ash collection and storage systems. The balance of the

existing plant infrastructure is reused.

A typical fluidized bed thermal oxidizer system is shown in Figure 2.

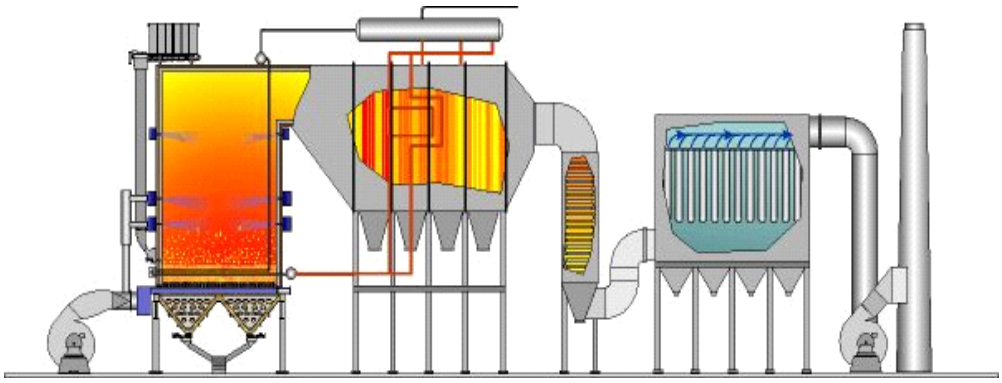


Figure 2

Biomass Gasification

Biomass gasification is a process of converting the feedstock, typically wood, paper, agricultural residue, or other waste products, into a synthesis gas to be utilized as a fossil fuel replacement.

EPI's fluidized bed gasifiers operate substoichiometricly, that is, only about 30% of the air required for complete combustion is introduced into the fluid bed cell. By operating sub-stoichiometricly only a small portion of the fuel's carbon content is converted to energy. The heat developed from the partial conversion of the fuel's carbon is used to vaporize the volatile fraction of the fuel to create CO, methane, hydrogen and other gases formed through incomplete combustion. The resultant gas from this process is called low Btu gas (LBG).

The Btu value of the LBG is typically in the range of 80 to 200 Btu per cubic foot. By comparison, natural gas, at similar pressures, contains about 1000 Btu per cubic foot.

The LBG created in the gasification process can be used in conjunction with burners specially designed for hot gases of this type, directly injected into an operating boiler or furnace through lances, or by removing the bottom of an existing boiler and replacing it with a close coupled gasifier bed.

There are two basic fluidized bed gasifier configurations used to introduce LBG into a coal boiler. In the first configuration a gasifier is located remotely from the coal boiler and the LBG is delivered to the boiler via refractory lined ducts.

In the second configuration the existing boiler's bottom is removed and replaced with a new fluidized bed gasifier bottom.

There are a number of factors that determine which technology application is best suited for a particular boiler.

Advanced Staged Gasification

Certain boilers can be retrofitted by removing the bottom from the existing boiler and replacing it with an EPI biomass gasifier bottom. In EPI's staged gasification process, the gasification of the biomass occurs in the new fluidized bed bottom. As the biomass is exposed to the fluidized bed's hot, turbulent environment, the volatile gases and moisture within the biomass are driven off and into the gas stream. The remaining carbon, or char, is converted by the fluidizing gases into additional synthesis gas plus heat that is utilized as the driving force to maintain the reaction. The exhaust from the gasification process is rich in hydrogen and hydrocarbons, such as carbon monoxide and methane, and becomes the heat source for the existing boiler.

This advanced, staged gasification system combines the advantages of gasification and the high conversion efficiencies of fluidized bed into a compact retrofit system. After the low Btu gases have been generated in the fluidized bed zone, they enter the combustion zone of the existing boiler where additional air for complete thermal conversion of the constituents is provided. The air is introduced in multiple levels or stages. The staging of the overfire air provides excellent mixing and enhanced turbulence in the gas stream at each stage of additional air injection. In addition, flexibility in the system is significantly enhanced by allowing the existing boiler to utilize bio-fuels with moisture contents of 50% or more.

A simplified diagram of the fluidized bed gasifier bottom is shown in Figure 3 below.

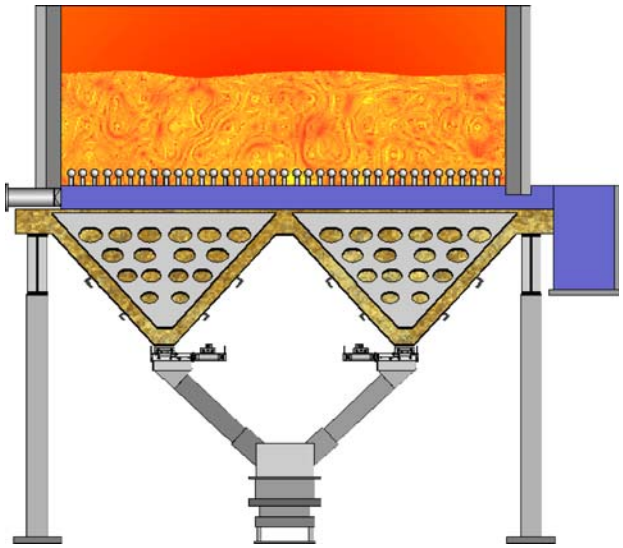


Figure 3

With a gasifier bottom retrofit, the entire boiler train, including the existing emissions control systems, are reused.

Replacing Coal With An External Fluidized Bed Gasifier (Figure 4)

In the utility industry, the pulverized coal (PC) fired power boilers present a very significant opportunity for co-firing with gasification of biomass fuels.

A fluidized bed gasification retrofit of a boiler has the specific advantage of maintaining total independence from the coal handling and processing equipment beginning at the storage system and continuing all the way to the boiler furnace or the burners. Not only does this maintain complete capacity for 100 percent coal firing as a future option, it also provides additional reliability and redundancy to the overall firing system by providing a totally independent system of fuel delivery into the furnace. In addition, the fluidized bed gasifier can use a variety of fuels ranging in size up to four inches, moisture contents as high as fifty percent and high in ash content. Having the gasification step prior to delivering the fuel into the boiler, most of the fuel variations are eliminated, and the boiler sees a constant and fairly uniform energy supply as LBG.

A hot gas ash removal system can be provided between the gasifier and the boiler. This device, typically a refractory lined cyclone, removes a majority of any ash introduced with the biomass and presents a much cleaner biomass energy to the boiler. Concerns over boiler slagging and ash contamination from the biomass fuel are minimized by significantly reducing the quantities of biomass ash allowed into the boiler.

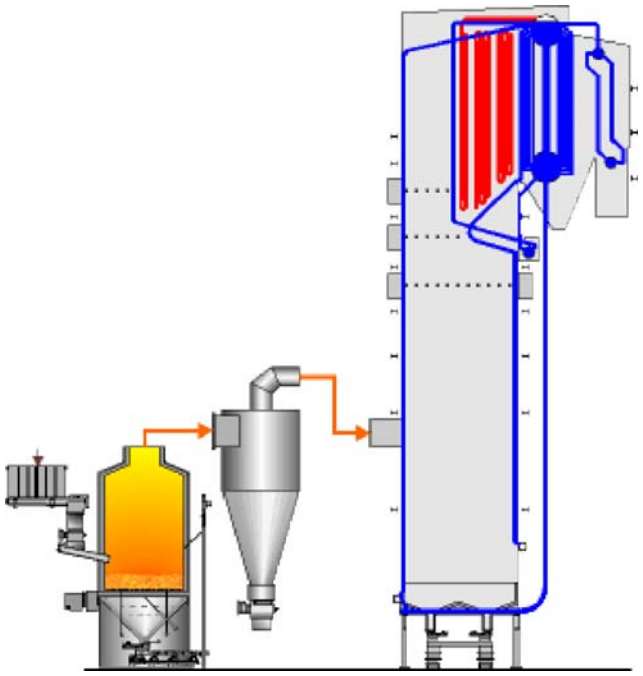


Figure 4
External Gasifier Add-On for a Coal Boiler

Summary

With the rare exception, almost all coal fired boilers can be retrofitted with one of the technologies described in this paper. The keys to a successful project start with identifying a boiler which receives the most benefit from a retrofit, identification of the biomass fuel supply and the selection of the best technology for the specific application.

In most instances any conversion or retrofit from coal to biomass requires the addition of a new fuel yard. The new fuel yard is totally separate and independent of the existing coal receiving, storage and handling systems.

The ability to reuse a major portion of an outdated coal plant for the generation of green energy represents the lowest cost option most utilities and IPP companies can find.

Reuse and renew for the lowest cost green power!