A DB RILEY TECHNICAL PUBLICATION

MODERN WOOD FIRED BOILER DESIGNS— HISTORY AND TECHNOLOGY CHANGES- PLANT RETROFITS-INDUSTRY DIRECTION

by

Kevin Toupin
Group Manager
Boiler Design & Results Department
DB Riley, Inc.

Presented at the
ABMA - 1994 Clean Power for the 90s
World Class Technology Conference
Arlington, Virginia
May 11-13, 1994

RST-123

DEUTSCHE BABCOCK
DB RILEY, INC.

Post Office Box 15040
Worcester, MA 01615-0040

MODERN WOOD FIRED BOILER DESIGNS—HISTORY AND TECHNOLOGY CHANGES—PLANT RETROFITS—INDUSTRY DIRECTION

by

Kevin *Toupin*
Group Manager
Boiler Design & Results Department
DB Riley, Inc.

ABSTRACT

Boiler and combustion system designs for firing waste wood have evolved as a direct function of the perception of wood as fuel.

The objective of wood firing technology has evolved from incineration of nuisance wood waste to efficient combustion. of a valuable and desirable fuel. With this evolution, the combustion and boiler systems have been upgraded to improve reliabilit' boiler efficiency', and combustion efficiency. In addition, steam temperatures and pressures have gradually increased to meet higher turbine cycle requirements resulting in new superheater designs. Recently environmental emission regulations have added further changes to the unit designs. The industry is also adding a new direction with the firing of wood derived fuels such as demolition wood and various contaminated waste woods.

This paper discusses the history and evolution of wood firing including a review of the boiler and combustion system design changes/improvements and modifications required to meet environmental emission limits. The recent industry direction of firing wood derived fuels is also discussed.

HISTORY AND TECHNOLOGY CHANGES

The history of burning wood waste can be separated into four stages of technology development. The objective and development of each stage is based on the perception of wood as a fuel.

STAGE 1— Incineration
STAGE 2— "Free" Steam
STAGE 3—Wood Waste as a Fuel
STAGE 4—Emissions Reductions and Further Heat Rate Improvements

STAGE 1– Incineration

In the era when waste wood was considered a waste product and a nuisance to be disposed of, combustion designs were based on incineration at minimum capital cost. Combustion was commonly done by pile burning in an exterior metal enclosure called a "Tepee" Incinerator. No heat recovery equipment was desired, and no emission control equipment was required during this period. Figure 1 shows a typical side view arrangement of this system.

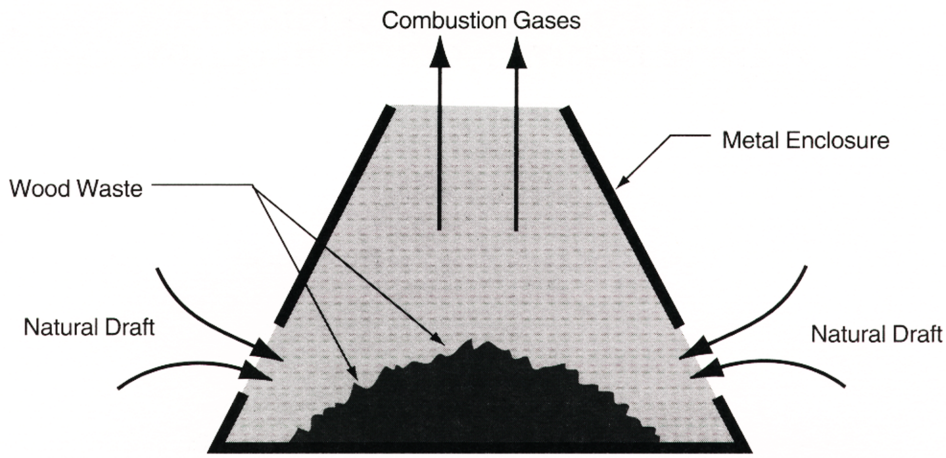

Figure 1 "Teepee" Incinerator

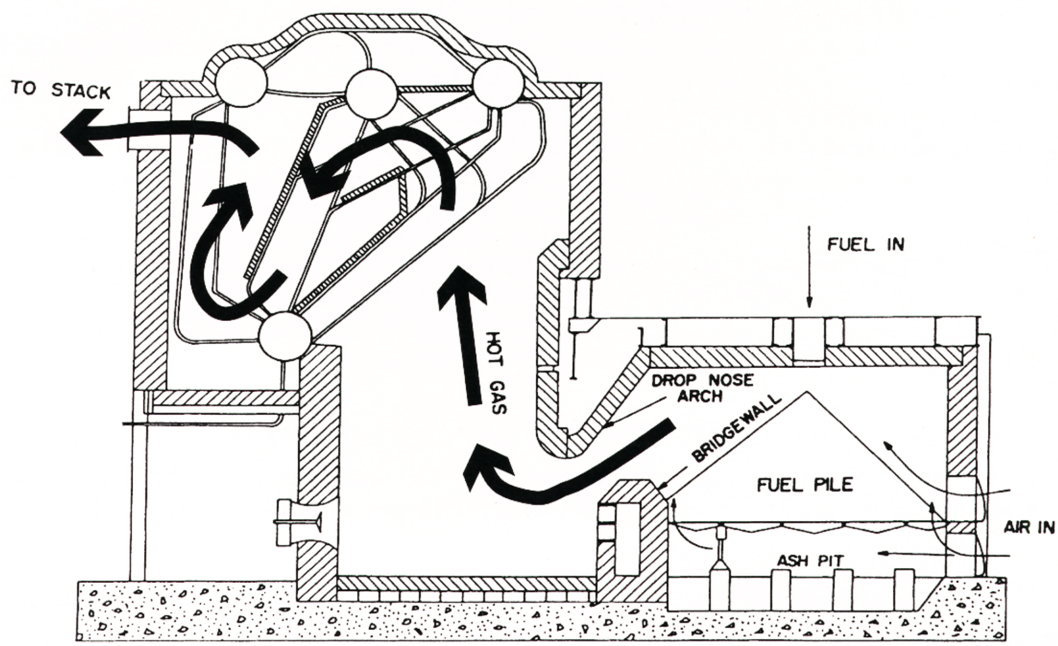

Figure 2 "Dutch Oven"–Free Steam

STAGE 2– Free Steam

In this era waste wood was still considered a waste fuel to be disposed of. The realization of a side benefit, the generation of "free" steam for process and/or heating, resulted in the addition of heat recovery equipment. The combustion process was also improved with the development of the "Dutch-oven," as shown in Figure 2. This method demonstrated initial combustion system improvements consisting of the following:

- a refractory combustion chamber.
- initial stages of overfire air to aid combustion occurring above the fuel pile.

These systems were reliable but produced low combustion efficiency, high carbon monoxide (CO), high ash loss on ignition (the weight percent of unburned combustibles in the ash sample), and low boiler efficiency (high stack temperature and high excess air requirements).

The ash removal systems were manual. These units normally generated steam flows of 10,000 to 40,000 lbs/hr of low pressure steam at saturated or slightly superheated temperatures.

STAGE 3–Wood Waste as a Fuel

As the perception of wood wastes changed from a nuisance waste product to an actual fuel, the combustion process and boiler designs began to change. The objective now was to improve the efficiency of the combustion and heat recovery processes. Improvements in these areas included:

- Suspension burning, with the development of spreader stokers withpneumatic fuel distributors and further development of overfire air systems.
- Stokers with automatic ash discharge, including dumping grates, steam cleaned stationary water cooled grates, water cooled vibrating grates, and traveling grates.
- Cinder reinjection systems to reduce unburned combustibles in the. ash.
- Addition of economizers to increase boiler efficiency.
- Addition of air heaters to improve the combustion process by aiding the evaporation of moisture in the wood waste and to increase the boiler efficiency by reducing the flue gas stack temperature.
- Further development of overfire air systems with multiple levels and configurations, with the objective of improving the combustion occurring in suspension.
- The use of water-cooled furnaces to reduce refractory maintenance and slagging on the walls.
- Methods to reduce tube erosion, including the addition of tube shields and the reduction of passes in the generating banks.
- Addition of superheaters for improved heat rate.
- Increasing steaming pressures to improve the heat rate.

During this era boilers were short, which reduced furnace retention time (approximately 1.25 seconds) and allowed little space for the overtire air system. Figure 3 shows a side view arrangement of this boiler system. As the designs progressed and the height of the furnaces increased, it brought about an increased furnace retention time (approximately 2.25 seconds) and reduced both CO emissions and unburned combustibles in the ash. Figure 4 shows a side view arrangement of this boiler system.

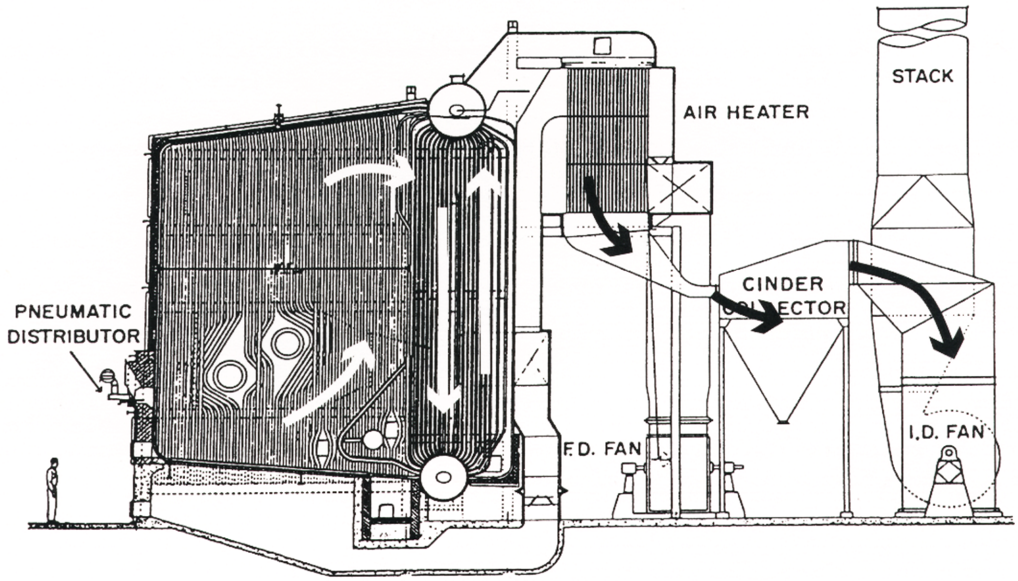

Figure 3 Wood Waste as Fuel —Initial Boiler Design (Short Furnace)

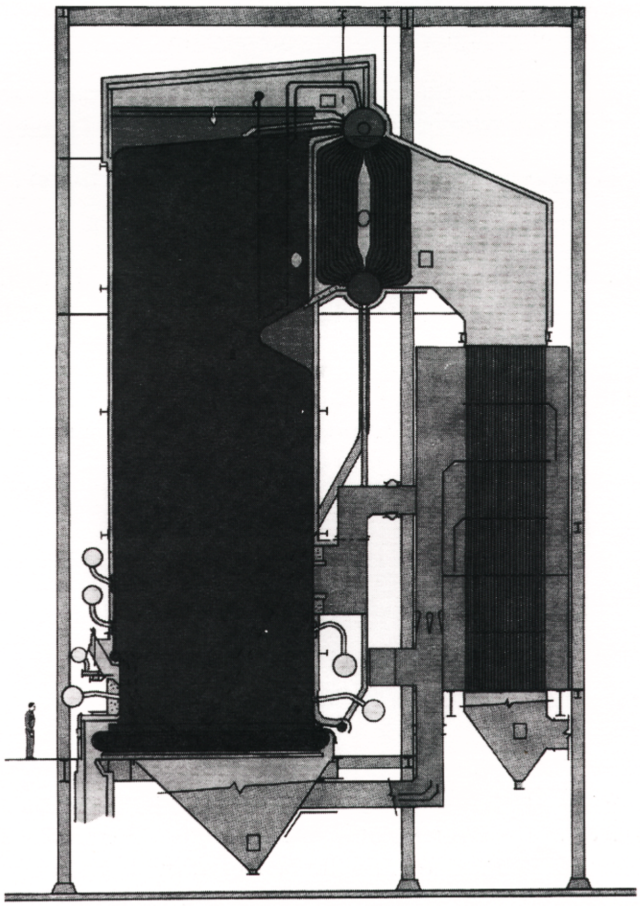

Figure 4 Wood Waste as Fuel—
Increased Furnace Retention Time (Tall Furnace)

These units generated steam flows from 30,000 to 400,000 lbs/hr generally at pressures of 600 to 900 psi and steam temperatures of 750 to 825°F.

STAGE 4 - Emissions Reductions and Further Heat Rate Improvements

With the increased value of wood waste as a fuel, new boiler designs were developed based on improved efficiency with regard to NOx and CO emissions requirements. Design changes include the following:

- More advanced overfire air systems.
- Improved fuel distribution across the grate.
- Improved combustion air distribution with the development of the compartmentalized windbox and stoker modifications.
- Reduced excess air requirements from 40% to 30%
- Reduced grate heat release rates from a maximum design of 1,000,000 to 850,000 Btu/hr-ft^2.
- Increased furnace retention time to approximately 3.0 seconds.
- Increased steaming conditions to 1500 psi and 955°F
- Improved combustion efficiency with new furnace configurations.
- Added Selective Noncatalytic Reduction (SNCR) systems to reduce NOx up to a maximum of 50%.

Figure 5 shows a side view arrangement of this boiler system. These units generate steam flows from 100,000 to 500,000 lbs/hr at pressures up to 1500 psi and superheat temperatures up to 955°F.

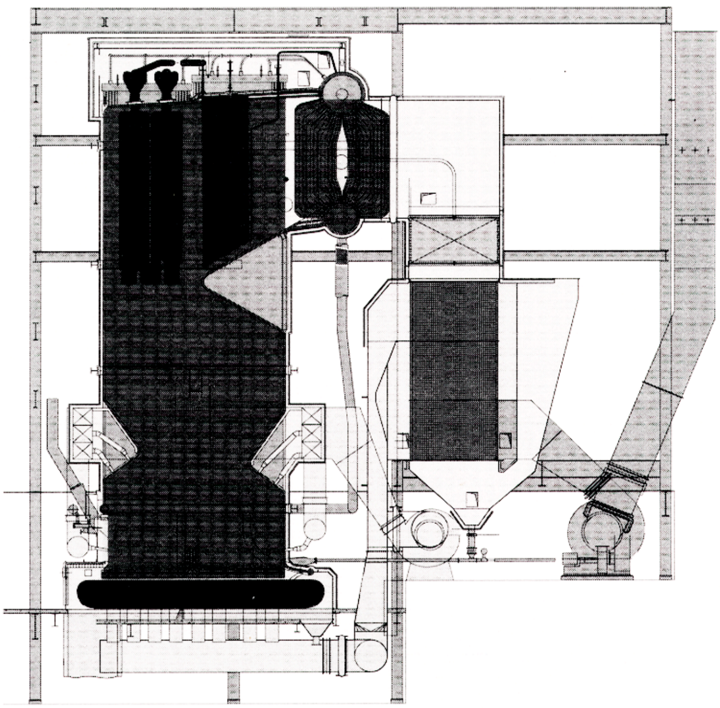

Figure 5 Emissions Reductions and Further Heat Rate Requirements–Stage 4

This table lists and compares the general performance summary for historical stages 2, 3, and 4

Table 1 **Historical General Performance Summary (45–50% Moisture Wood)**

Furnace	**Dutch-Oven**	**Tube and Tile Short Furnace**	**Welded Wall Tall Furnace**	**Current Design Arched**
Steam Flow, lbs/hr x 10^3	10 - 40	50 - 200	100 - 500	100 - 500
Steam Pressure, psi	200 - 300	250 - 600	450 - 825	1250 - 1500
Steam Temperature, °F	Sat.	Sat. - 725	725 - 900	955
Emissions				
CO lbs/10^6 Btu (ppm)	* 0.8 - 3.2 (1000 - 4000)	0.4 - 1.6 (500 - 2000)	0.35 - 0.60 (430 - 735)	0.1 - 0.35 (100 -430)
NO_X lbs/10^6 Btu (ppm)	- -	- -	0.15 - 0.20 (112 - 149)	0.15 - 0.25 (112 - 188)
w/SNCR lbs/10^6 Btu w/SNCR ppm	- -	- -	- -	01. - 0.17 (75 - 130)
Unburned Combustibles Boiler Eff. Loss, %	* 5	4.0 - 6.0	2.0 - 4.0	1.0 - 1.5
Furnace Retention, sec.	-	1.5	2.2	3.0
Grate Heat Release Btu/hr-ft^2	-	1,000,000	1,000,000	850,000

* Based on pile burning experience, no actual data on the subject design.

The following section reviews, in more detail, the major design upgrades for the following equipment:

- Stoker Designs
- Furnace Designs
- Fuel Distributor Designs
- Overfire Designs
- Cinder Reinjection Designs
- Superheater Designs

Stoker Designs

Objective: To supply a surface to combust the larger fuel particles and to remove the ash and inorganic materials after combustion. Currently the most common stokers are the traveling grate spreader stokers, stationary water cooled grates with steam cleaning, and water cooled vibrating grates.

Enhancements:
- Improved combustion air distribution by compartmentalizing the grate air plenum. This allows for control of the air flow to the grate sections for balancing or biasing the air flow to the grate.
- Improved designs for increased grate clip pressure drop (increased back pressure) which improves the air distribution through the grate and reduces the influence of the fuellash bed thickness on air distribution.
- Improved grate clip metallurgy allowing for combustion air temperatures up to 600 °F. Higher combustion air temperatures improve the drying of high moisture woods.
- Improved stoker seal designs to reduce leakage around the periphery of the stoker.

Furnace Designs

Objective: To combust the fuel and recover radiant heat generated by the combustion process. Refer to Figure 6 for an outline of the separate furnace zones and design objectives.

Enhancements: New furnace configurations have been developed to improve combustion efficiency (reduce CO and LOI) while firing a range of wood waste fuels. The objectives of the new furnace configurations are to:

- Establish a defined combustion zone.
- Reduce stratification along the side walls.
- Increase mixing and turbulence in the combustion zone.
- Increase residence time in the combustion zone and main furnace.
- Minimize char (unburned combustibles) entrainment and char carryover.

New furnace designs include flat wall, single arch, and double arch designs each with multi-level OFA systems.

Fuel Distribution Designs

Objective: To spread the fuel uniformly over the grate surface.

- Pneumatic fuel distributors utilizing high pressure, pulsating air.
- No moving mechanical parts exposed to furnace radiation.
- Improved suspension burning of the small fuel particles.

Enhancements: Improved means of adjusting depth and side-to-side distribution by the use of air pressure, air vanes and trajectory plate angles.

Zone 4 Minimize gas velocity stratification through tube banks
- Reduce tube erosion
- Reduce temperature unbalances

Zone 3 Uniform flue gas distribution
- Minimize gas velocity stratification
- Complete CO burnout
- Minimize char particle entrainment to reduce carryover

Zone 2 Maximum turbulence, mixing, and penetration of OFA for complete suspension burning
- Reduce stratification and the water walls
- Increase the retention time in the combustion zone

Zone 1 Uniform fuel distribution on the grate
- Fuel drying
- Fuel ignition

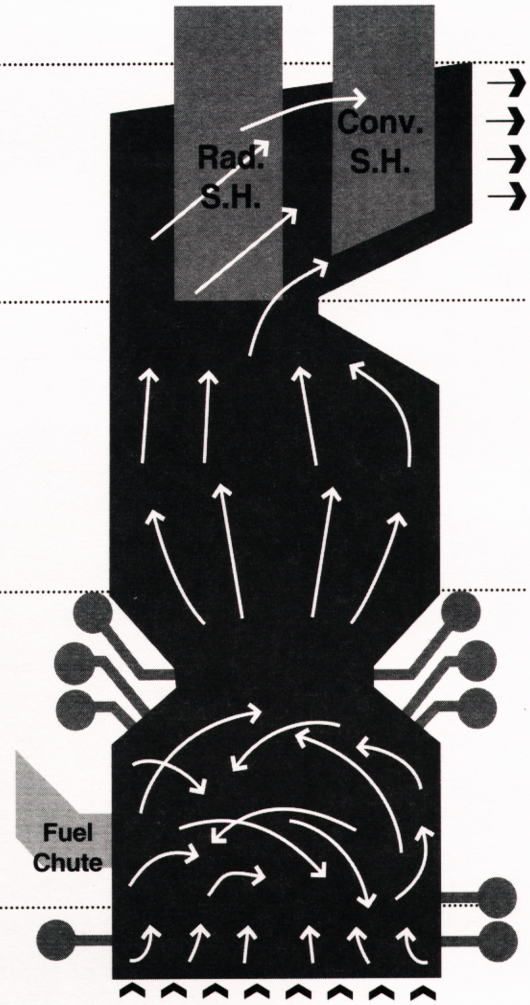

Figure 6 Furnace Design Objectives

Overfire Air Designs

Objective: To complete the combustion occurring in suspension and reduce the unburned carbon furnace carry-over.

Enhancements:
- Change designs to increase the turbulence and mixing of the OFA in the combustion process by improved nozzle penetration and optimized nozzle location.
- Reduce flue gas stratification along the water walls.

Cinder Reinjection Designs

Objective: The objective of this system is to reinject the char (unburned combustibles) from the convection pass hoppers and/or dust collector back to the combustion zone for reburning.

Enhancements: • Improved sand separator design with the development of rotary sand separators to increase reliability.
• Improved designs to maintain uniform fuel distribution across the stoker.

Superheater Designs

Objective: The objective of the superheater is to increase the steam temperature above saturation.

Enhancements: • Added radiant superheater surfaces.
• Increased transverse tube spacing for reduced fouling:
• Improved metallurgy.

EXISTING PLANT RETROFITS

The most common wood fired plant upgrades and retrofits currently are:

Combustion systems

- Overfire air system upgrades to improve the combustion process (reduce CO emissions and ash loss on ignition).
- Cinder Reinjection upgrades to reduce ash loss on ignition. Addition of " ash reburn systems" to reduce unburned carbon in the ash. Air heater material upgrades to reduce corrosion of the cold end sections
- Stoker upgrades/conversions to improve combustion and provide continuous ash discharge.
- Fuel conversions from coal firing to wood firing.

Boiler Systems

- Superheater metals upgrades for increased life.
- Tube shielding to control tube erosion.
- Superheater redesign to increase steam temperatures, reduce erosion, and reduce fouling.
- Lower furnace reconfiguration to improve combustion.
- Increase steaming capacity.

INDUSTRY DIRECTION

The recent industry direction is to burn wood waste **in** combination with other fuels or waste streams. The most common fuels burned in combination with wood have been coal and natural gas. The waste streams being burned or investigated to be burned in combination with wood are demolition wood (also referred to as urban wood waste), tire derived fuel(TDF), various paper mill sludges, pelletized paper wastes, and pelletized refuse derived fuel (RDF).

The major design considerations when firing wood in combination with other fuels and/or waste streams are:

- Slagging/fouling characteristics based on the individual fuel elements and the reaction when combined with the other fuel elements.
- Corrosive elements and the effects on boiler metals.
- Emissions.
- Fuel mixing process. Based on a history of industry problems, the importance of proper fuel mixing is often underestimated. Improper fuel mixing leads to combustion imbalances, fuel piling and consequently high CO emissions and load limitations. Proper fuel mixing is essential when burning wood in combination with other fuels and/or waste streams.
- Combined (mixed) fuel moisture content.