ASH VOLUME REDUCTION AND BOILER EFFICIENCY IMPROVEMENT BY ASH REBURNING

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ABSTRACT

The ash reborn system, described in this paper, was developed in response to a growing wood burning industry need for reduction of ash volume and more efficient carbon burnout on existing wood fired boilers. Experience in wood and fuel burning coupled with Customer feedback indicated that on older boiler designs improvements in traditional ash reinjection andlor overfire air systems would not yield the significant improvements that are now desired Consequently a system was developed that utilizes an external ash reborn cell run in parallel with the existing stoker. The heat generated from the rebum cell is in-turn recovered in the existing boiler.

The system that will be discussed comprises of an ash reborn cell which is fed with ash from the existing ash handling system (modified to reroute ash to the chamber), inlet air ducting outlet gas breeching and controls to make up a complete package. Combustion air is taken from a separate combustion air fan located below the combustion chamber.

The complete ash reburn system (patent pending) was designed and supplied by both Riley Stoker Corporation, Worcester, Massachusetts and Konus Energy Systems, Atlanta, Georgia.

INTRODUCTION

Environmental pressures on the lumber and pulp and paper industry to conserve trees have led to increased costs for once abundant waste wood fuel. Simultaneous environmental pressures on the limiting of landfill space have driven costs of landfilling boiler ash to new highs. These two factors have generated the need to both reduce the ash volume and increase boiler efficiency by reducing the ash carbon content from wood fired boilers.

This paper discusses a new combustion system that reburns the ash to reduce both it's carbon content and volume. This ash reburn system is located parallel to the main stoker combustion system and the heat generated is recovered in the main boiler. The ash reburn system is comprised of a ash feed system, an ash reburn cell, outlet duct and main boiler connection, de-ashing system, start-up burner and separate control system. The system configuration and actual performance will be discussed in this paper. The first ash reburn system of this type has been installed at the Fairhaven Power plant in Eureka, California and has been on line since February 1992 burning a maximum of twenty four (24) tons of wood ash per day. The Fairhaven Power boiler produces a steam flow of 180,000 lbs/hr at 825 °F/625 psig. The boiler has an existing ash reinjection system from the dust collector (after sand separation). The ash that is reburned is routed from the airheater hoppers and dust collector hoppers bypassing the existing reinjection system. The ash reburn system is designed for a maximum ash flow of 2400 lbs/hr.

DESCRIPTION OF ASH REBURN SYSTEM

One of the most important design criteria for the ash reburn system was that it not interfere with the main boiler capability of being on line continuously at the highest loads possible. This has been accomplished such that the ash reburn system is an independent system which can be shut-down and easily isolated while the main boiler remains on line.

The Ash Reburn System described in this paper and as shown in **Figures 1 and 2** comprises the following:

Ash Feed System

A series of conveyors transport the ash from the airheater and dust collector hoppers to the ash reburn system. The conveyors feed ash to a rotary air lock valve which in-turn discharge to the reburn cell through a water cooled chute. The fuel is then distributed across the cell by a pneumatic distribution system.

Reburn Cell

The ash reburn cell consists of a refractory walled circular chamber with a bubbling bed combustion system. Combustion air is supplied through nozzles located in the sand bed and from overfire air ports located in the upper section of the reburn cell. A separate fan supplies ambient air to the bubbling bed combustion system.

Outlet Duct & Main Boiler Connection

The flue gas from the cell is discharged through a refractory duct to the side of the main boiler. The outlet connection into the main furnace is rectangular in shape measuring 2'-10" high by 8'-6" wide and is located 17' above the main wood fired stoker. The furnace entrance connection was constructed by bending the water wall tubes and forming a water cooled screen at the inlet connection. For isolation of the reburn cell, a slide gate damper is installed in the refractory duct adjacent to furnace.

De-ashing System

The objective of the cell de-ashing system is to automatically remove sand from the bed while on-line to maintain the proper sand level in the combustor. The de-ashing system consists of a drain pipe, shut-off valve and water cooled screw conveyor. The sand bed height is determined from the direct differential pressure measurement across the sand bed.

Start-up Burner

A natural gas fired burner is installed to initially warm the cell, start ignition of the ash, and, if required, to maintain the cell in a hot stand by condition.

Controls

The reburn cell control system is very simple and utilizes air flow to control the combustion temperature within maximum and minimum set-points. Instrumentation consists of cell thermocouples and an accurate air flow measuring annubar. The customers existing Bailey Net 90 main boiler control system easily handles the additional reburn cell data for effective automatic control.

PERFORMANCE REVIEW

The Ash Reburn System retrofited to the Fairhaven Power Plant had the following results:

1. Reduction of the Ash Volume to the Landfill by 60 - 70%.

2. Increase in overall Boiler Efficiency by 2.3%, resulting in a fuel savings of 2000 lbs/hr.

3. Low measured Emissions from the Ash Reburn Cell.

- Carbon Monoxide (CO) 200 - 400 ppm @ 3.0% oxygen.
- Nitric Oxides (NOx) 180 - 190 ppm @ 3.0% oxygen.

Ash volume reduction to the landfill was recorded by Fairhaven Power. The analysis was performed over a two month period with the ash reburn system in operation and is based upon a comparison to Fairhavens historical records of before the ash reburn system was installed.

Boiler efficiency testing was performed both with the ash reburn system in operation and not in operation. The boiler efficiency comparison is shown in **Figure 3**. The items which affect boiler efficiency are:

- The reduction in unburned combustibles in the ash from 60% to 35% resulting in a boiler efficiency gain of 3.2% with the ash reburn system in operation. Refer to **Figure 4** which plots the ash unburned combustibles content verses heat loss (boiler efficiency loss) based on a average fuel analysis with 1% ash and a HHV of 4450 btu/lb.
- The increased excess oxygen of 3.6 to 5.1 and the increased stack temperature of 5 °F resulted in a additional boiler efficiency heat loss of 0.89% with the ash reburn system in operation.

Combining the boiler efficiency heat gains and losses results in a net gain of 2.3% in boiler efficiency. Refer to **Figure 5** for the complete summary of the boiler performance with the cell in operation and not in operation.

Carbon monoxide (CO) and nitric oxide (NOx) emissions were measured at the reburn cell outlet. Based on this testing it was discovered that the reburn cell operating temperature dramatically affects CO emissions and slightly affects NOx emissions produced from the cell. CO emissions were reduced from 850 ppm to 200 ppm by increasing the cell operating temperature from 1500 °F to 1600 °F. With the reburn system operating above 1600 °F, CO emissions are less than 200 ppm. The NOx emissions range from 180 - 195 ppm when operating the reburn cell within 1550 °F - 1750 °F. Refer to **Figure 6**, which plot the CO and NOx emissions verses the reburn cell operating temperature.

INITIAL START-UP AND OPERATION

As with all "first of a kind" systems there is a learning curve required during the initial commissioning or start-up. Based on the initial start-up and operation the following operational procedures and subsystems were added or modified.

1. Operating temperatures were established to reduce cell and outlet duct slagging.
2. A pneumatic fuel distribution system was added to improve the bed temperature distribution and bed fuel mixing.
3. Additional thermocouples were added to monitor the sand bed temperatures to ensure proper fuel distribution in the bed.
4. The OFA system was modified to improve the combustion occurring in suspension.
5. The bubbling bed air nozzles were modified to improve the air distribution to and in the sand bed.
6. The bed sand level was adjusted and optimized to produce the best mixing and bed pressure drop.
7. A system to measure the sand bed height was developed and guidelines were established for de-ashing.
8. A natural gas fired burner was added to simplify the start-up and to maintain the cell in a hot standby mode.

Reviewing the above list of initial start-up work it can be seen that the majority of additional work was performed on the fuel and air distribution systems. It was found that to control slagging and emissions, it is essential that the combustion process be completely controlled with no fuel rich or lean zones and/or high temperature and low temperature zones. There was a start-up and shake-down period of approximately 2 months after which the reburn system ran continuously following the main boiler load requirements.

BUBBLING BED COMBUSTION SYSTEM

The bubbling bed combustion system has a flat bottom containing air nozzles with a 9" x 9" spacing. Located under the flat bottom is a windbox which supplies and distributes combustion air to the air nozzles. The main design objective of the windbox and air nozzles is to uniformly distribute combustion air to the bubbling bed.

The bubbling bed inert material is sand. The sand depth is approximately 14" in a nonfluidized condition. When fluidized the bed expands to 18" - 30" depending upon air and ash flow. Refer to the schematic of the ash reburn cell in **Figure 7**.

A bubbling bed combustion system was utilized for this application due to its low air velocities, excellent air and fuel mixing and its ability of capturing and combusting the ash. Wood ash is a difficult fuel to burn and control. The ash is a light, dry fuel which ranges in size from fine to course with a high percentage of carbon with no volitiles. Refer to **Figure 8** for the typical chemical analysis of wood ash burned at Fairhaven Power. Due to its low density and dry characteristics the ash is easily entrained in the flue gas and carried out of the combustion process. The selection of a simple bubbling bed combustor for this application was in our opinion the best system for maximizing burnout of this difficult fuel.

CONTROL PHILOSOPHY

The control philosophy used has one major principle, to maintain combustion temperatures in the cell with-in the following guidelines:

- Operating Temperature Range 1550 - 1750 °F
- High Temperature Trip 1900 °F
- Low Temperature Trip 1300 °F

Combustion temperature is controlled by air flow. The cell has no heat recovery surfaces, control of combustion temperature is achieved through dilution with air flow. The cell normally operates in the range of 130 - 160% excess air. In addition to cell temperature, the control system maintains air flow through the bed greater than the minimum required to initiate bed bubbling.

- Increasing air flow decreases the cell combustion temperature.
- Decreasing air flow increases the cell combustion temperature.
- Minimum air flow to the bed is approximately 50% of full reburn cell capability.

It is important to note that the ash reburn system is a "slave" to the main boiler. The ash system receives ash directly from the main boiler with no control of the ash flow (no storage system). The control system must automatically adjust to varying ash flow conditions based on the main boiler firing conditions. This is achieved simply by monitoring the cell combustion temperature and modulating air flow.

- As ash flow increases the cell temperature increases .
- As ash flow decreases the cell temperature decreases.

Air plenum pressure, fan damper position and additional cell temperatures are also monitored in the control room and are used as indicators of air flow and cell operation. These items are strictly used for monitoring and diagnostic indicators for the operators and are not used directly by the control system. Other items monitored locally on the system during a operator shift walk-down (8 - 12 hour shifts) are:

1. Temperatures within the sand bubbling bed. This data is used to evaluate the ash distribution and mixing in the bed. Based on this information the operator may adjust the ash pneumatic distribution system.
2. Bed to freeboard differential pressure. This information is used to determine the sand bed height and if bed de-ashing is required to lower the height or if sand addition is required to raise the height.
3. Water temperature in and out of the water cooled fuel chute. This information is to evaluate the operation of the cooling water supply system.
4. Visual observations of the bubbling bed.

SUMMARY

The concept of reburning wood ash to conserve fuel and minimize ash disposal is relatively new to the industry. Its economic analysis and application is being reviewed on several prospects for existing wood fired boilers with high unburned carbon in their ash. Based on the application at Fairhaven Power, ash reburning has been demonstrated that the process meets the objectives of both reducing the ash to disposal and increasing boiler efficiency. The system has also been shown capable of operating automatically regardless of the main boiler firing conditions with almost no manual operations.

ACKNOWLEDGMENTS

Behind any successful project there must be commitment and cooperation among the customer, the designer and the field engineers. I would like to thank Mr. Dennis Johnston, Fairhaven Power Plant Manager, Mr. Richard Overman, Riley Field Engineering and Mr. Daniel Wolff, Konus Engineering for their confidence, commitment and cooperation.

Project Economics

Fairhaven Power

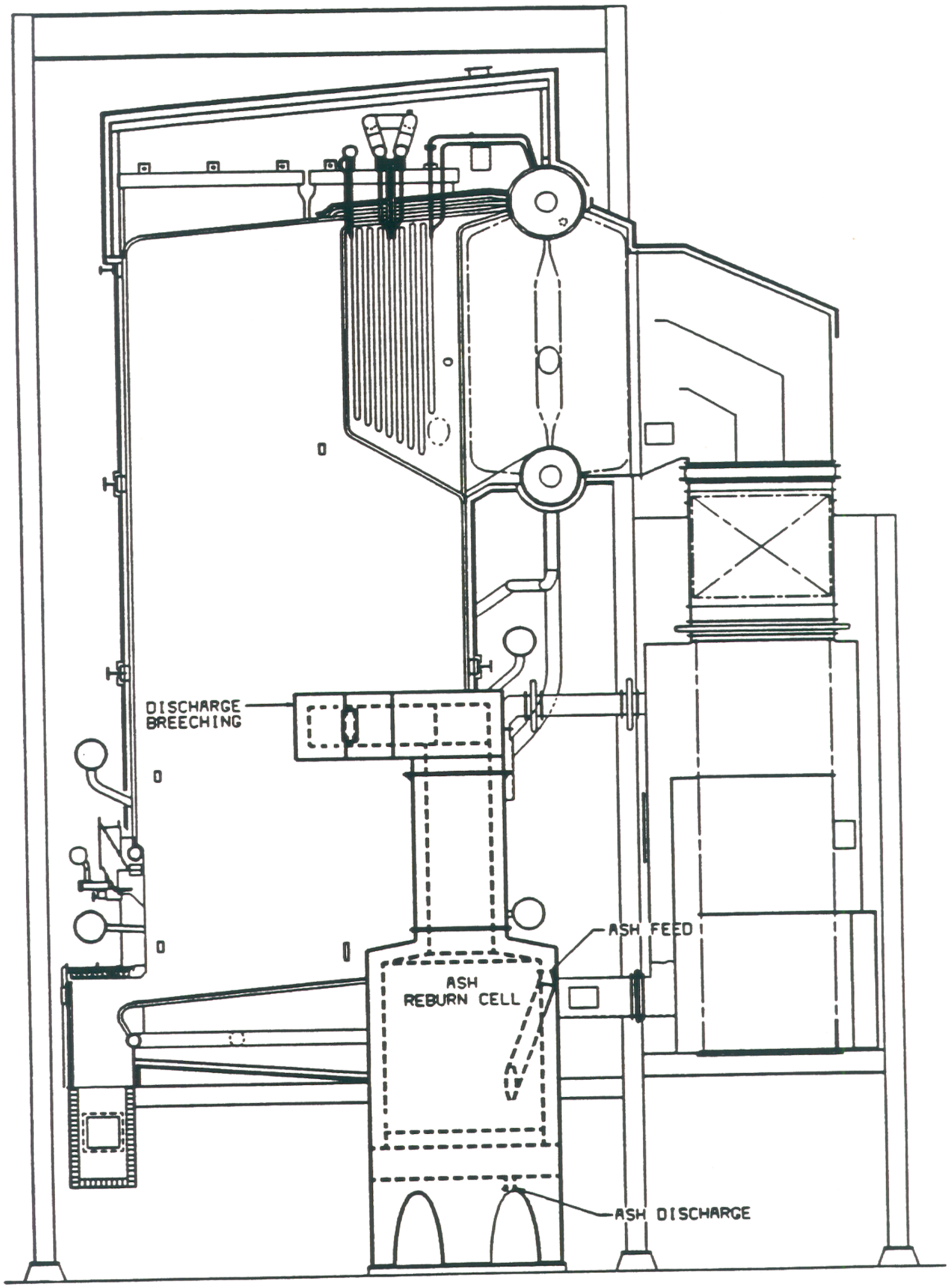
Projected Payback 16 Months

Costs	
- Initial Complete System Costs	$820,000
Annual Costs	
- Maintenance	$10,000/yr
- Power Costs (Blower @ 40 Hp)	$20,000/yr
Total Annual Costs	$30,000/yr

Savings	
- Plant Waste Disposal	
Before Ash Reburning	$900,000
After Ash Reburning	$300,000
Savings	$600,000/yr
- Fuel Savings	
$204/Day	$70,000/yr
Total Savings	$670,000/yr

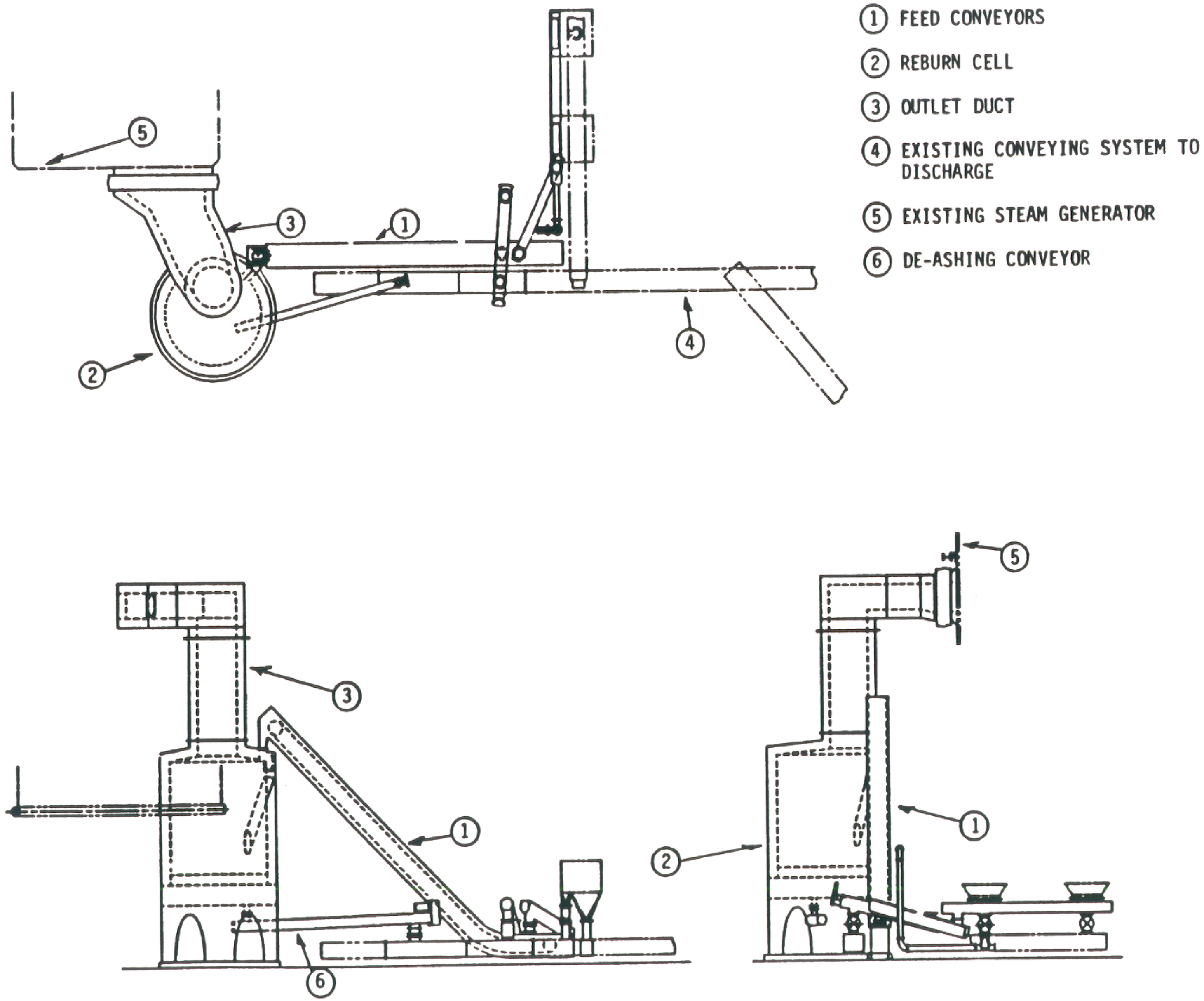
Notes:

- Based on 94% Availability
- 8¢/KW



SIDE VIEW OF BOILER AND ASH REBURN CELL

FIGURE 1



ASH REBURN SYSTEM ARRAGEMENT

FIGURE 2

BOILER EFFICIENCY COMPARISON

(BY HEAT LOSS METHOD)

		With Ash Reburn	Without Ash Reburn
1. Dry Flue Gas Loss	%	7.12	6.19
2. Fuel Hydrogen Loss	%	13.43	13.40
3. Fuel Moisture Loss	%	7.11	7.09
4. Radiation Loss	%	0.40	0.40
5. Unburned Combustibles	%	1.77	4.99
6. Air Moisture Loss	%	0.17	0.14
7. Unmeasured Losses	%	0.50	0.50
8. Total Losses	%	30.50	32.71
9. Boiler Efficiency	%	69.50	67.29
Reference Temperature	°F	59	59

Figure 3

TOTAL BOILER ASH UNBURNED COMBUSTIBLES VERSUS BOILER EFFICIENCY HEAT LOSS

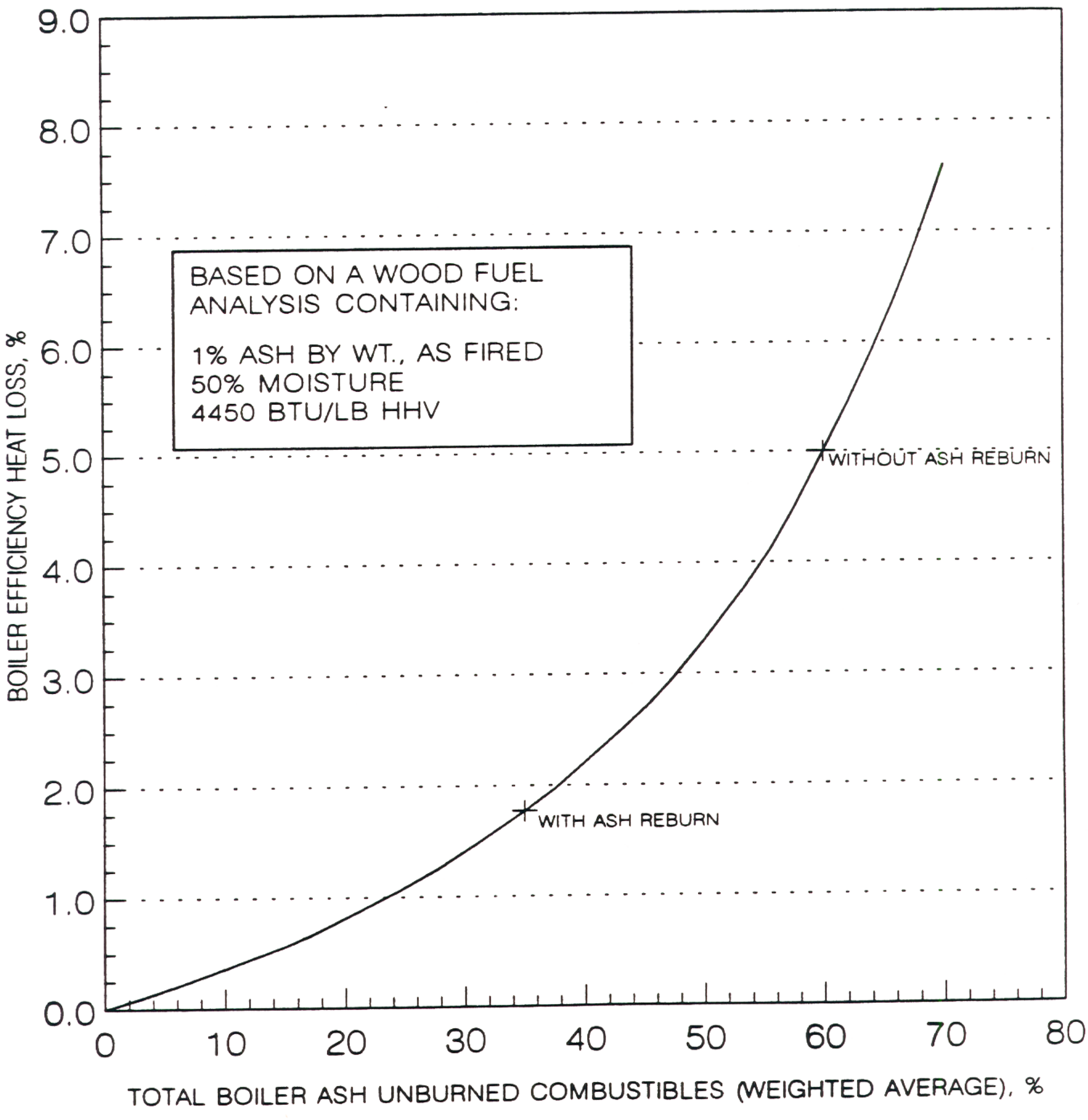


FIGURE 4

FAIRHAVEN POWER COMPANY
EUREKA, CALIFORNIA
RSC CONTRACT NO. 91544

RILEY STOKER CORPORATION
BOILER DESIGN
WORCESTER, MA

BOILER PERFORMANCE COMPARISION

TEST		WITH ASH	WITHOUT	PERFORMANCE
DESCRIPTION		REBURN	ASH REBURN	CHANGE
DATE		6/10/92	6/11/92	BETWEEN CELL
START TIME	HOURS	1730	1400	IN SERVICE AND
END TIME	HOURS	2000	NA	CELL OUT OF
FUEL FIRED		WOOD	WOOD	SERVICE
BOILER LOAD	% OF MCR	101	101	
STEAM AND WATER FLOWS				
MAIN STEAM	LB/HR	181,000	181,000	--
STEAM AND WATER TEMPERATURES				
FINAL SUPERHEATER OUTLET	°F	836	836	--
DRUM SATURATION	°F	502	503	--
ECONOMIZER INLET	°F	320	320	--
STEAM AND WATER PRESSURES				
SUPERHEATER OUTLET	PSIG	620	625	--
DRUM	PSIG	681	687	--
AIR AND GAS TEMPERATURES				
AIR HEATER AIR INLET	°F	58	60	--
AIR HEATER GAS INLET	°F	542	539	--
AIR HEATER GAS OUTLET	°F	357	353	--
AH GAS OUTLET, CORR. TO 59 °F	°F	357	353	4
GAS ANALYSIS, DRY BASIS				
OXYGEN	%	5.1	3.6	1.5
ASH ANALYSIS				
UNBURNED COMBUSTIBLES IN FLYASH, TOTAL WEIGHTED AVERAGE	%	35.20	60.50	(25.30)
WOOD ULTIMATE ANALYSIS				
CARBON	%	26.70	26.70	--
HYDROGEN	%	2.96	2.96	--
NITROGEN	%	0.04	0.04	--
OXYGEN	%	19.30	19.30	--
ASH	%	1.00	1.00	--
SULFUR	%	0.00	0.00	--
MOISTURE	%	50.00	50.00	--
HIGHER HEATING VALUE	BTU/LB	4450	4450	--
BOILER EFFICIENCY, BY HEAT LOSS				
REFERENCE TEMPERATURE	°F	59	59	--
LOSSES:				
DRY FLUE GAS	%	7.12	6.19	0.93
COMBUSTION OF HYDROGEN	%	13.43	13.40	0.03
MOISTURE IN FUEL	%	7.11	7.09	0.02
RADIATION	%	0.40	0.40	0.00
UNBURNED COMBUSTIBLES	%	1.77	4.99	(3.22)
AIR MOISTURE	%	0.17	0.14	0.03
UNMEASURED	%	0.50	0.50	0.00
TOTAL LOSSES	%	30.50	32.71	(2.21)
EFFICIENCY	%	69.50	67.29	2.21
CALCULATED WOOD FUEL FLOW	LB/HR	62,969	65,037	(2,068)

FIGURE 5

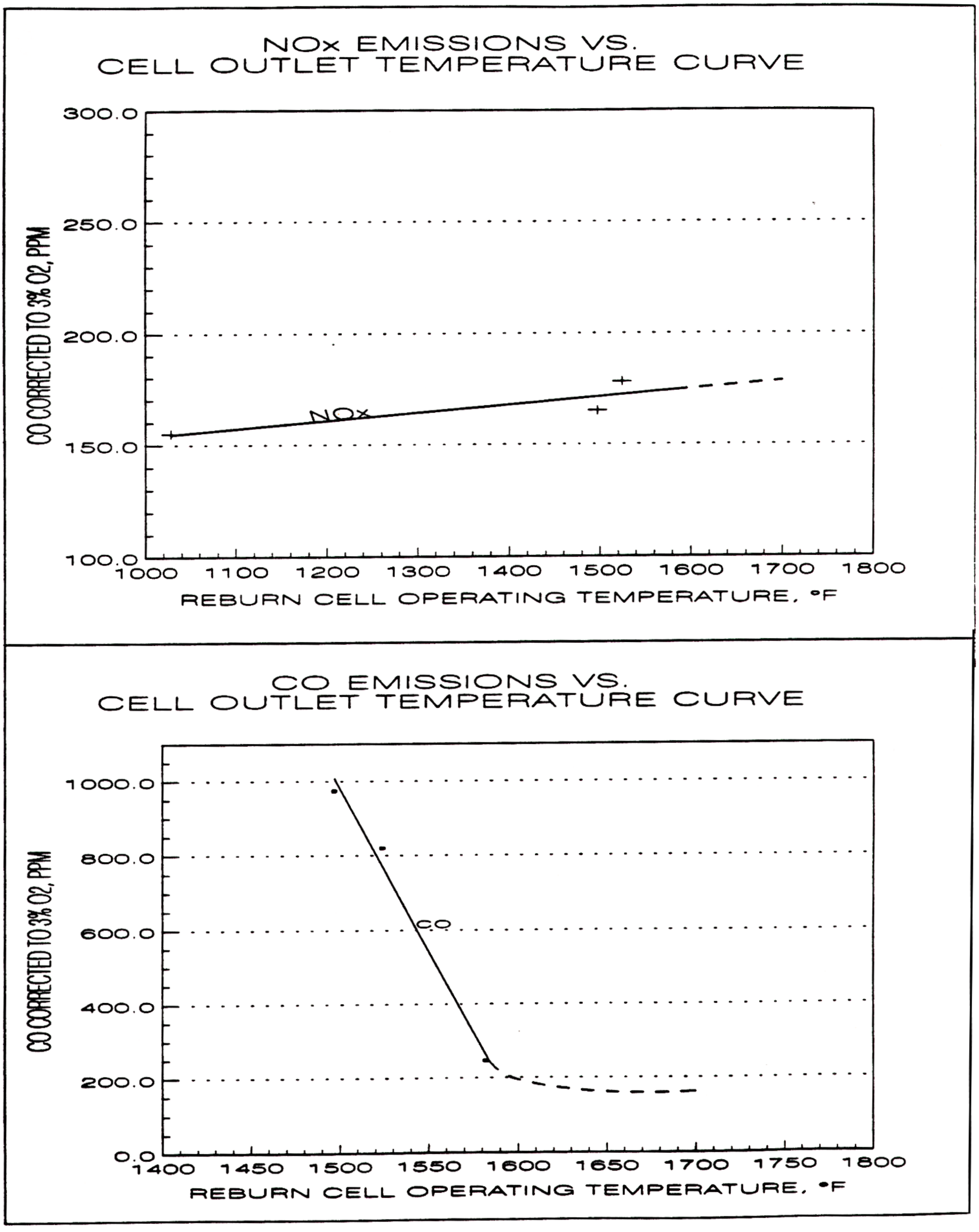
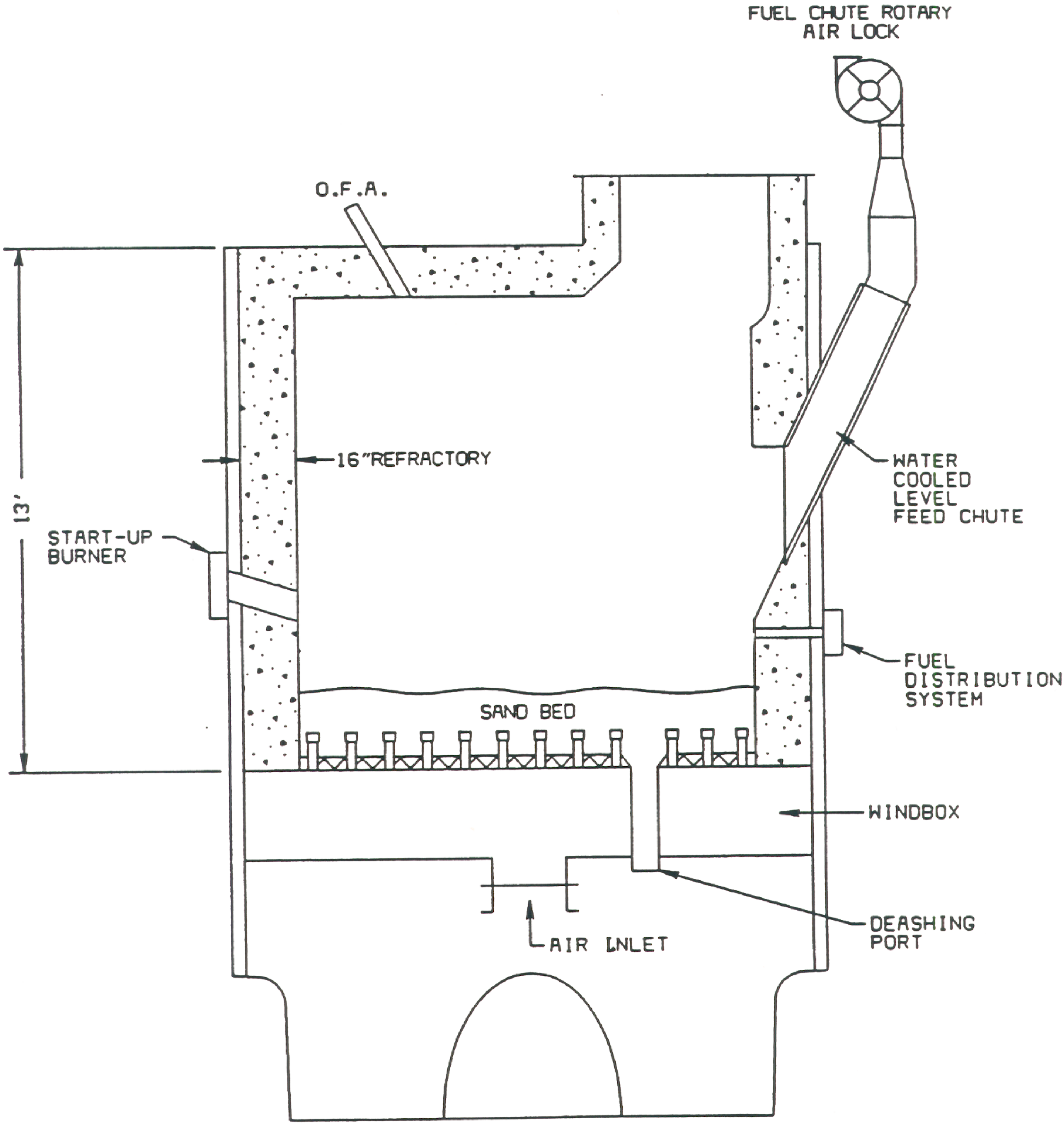

NOx EMISSIONS VS.
CELL OUTLET TEMPERATURE CURVE
300.0
250.0
200.0
150.0
100.0
CO CORRECTED TO 3% O2, PPM
NOx
1000
1100
1200
1300
1400
1500
1600
1700
1800
REBURN CELL OPERATING TEMPERATURE, °F
CO EMISSIONS VS.
CELL OUTLET TEMPERATURE CURVE
1000.0
800.0
600.0
400.0
200.0
0.0
CO CORRECTED TO 3% O2, PPM
CO
1400
1450
1500
1550
1600
1650
1700
1750
1800
REBURN CELL OPERATING TEMPERATURE, °F

FIGURE 6



ASH REBURN CELL SCHEMATIC

FIGURE 7

Fairhaven Power
Typical Wood Ash Analysis

LABORATORY ANALYSIS

Analysis	#41,355	#41,356
Density (untamped)	9.6 #c/u ft	8.8 #/cu ft
Density (tampted)	13.1 #/cu ft	12.6 #/cu ft
* Loss on Ignition	60.5%	61.8%
* Ash	39.5%	38.2%
True Carbon	46.82%	47.96%

Ash Fusion	Oxid	Red	Oxid	Red
Initial Deformation	2125°F	2180°F	2180°F	2200°F
Softening Temp (H=W)	2150°F	2190°F	2200°F	2210°F
Softening Temp (H=½W)	2180°F	2200°F	2250°F	2215°F
Fluid Temp	2200°F	2210°F	2260°F	2220°F

* ASTM D-1102

BTU	6,810	6,970
Sulfur	0.10%	0.06%

Figure 8