COMPARING WASTE WOOD BOILERS

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To understand wood waste boilers and compare them with natural gas and oil fired boilers, we need to understand a little about the nature of the fuels they use. With both natural gas and diesel fuel, these fuels are very consistent. Their heating values are constant. These fuels do not vary measurably and they will burn the same, day in and day out.

Wood waste however varies substantially in its properties. It varies with wood species, it varies with moisture content, it varies from fiber to bark, it varies with dirt and rock content, and it energy content also varies with age. We will look briefly at the fuel type, moisture content, and the effect on the boilers efficiency.

On a gas or oil fired boiler, if you increase the fuel and air by 20% within seconds, the steaming rate will climb, and your steam rate will be up 20%. It is just like a powerful car when you press down on the gas pedal, you go faster. This same response happens when increasing the fuel and air supply to a sander dust burner (suspension fired boiler). This fuel is bone dry and will respond almost instantaneously, just like gas pedal in your car. This is how it should work! It makes sense! Well, it makes sense until you start burning wet wood in the boiler!!!

Let's say in our hog fuel boiler the steam load increases 20%, we add 20% more fuel with a typical moisture content of 45%, and we add 20% more air... BINGO... our steaming rate goes down 1-2%...(hey that's not what's suppose to happen)... and we wait... and wait... and after a minute or two the steam rate starts to climb and finally the boiler gets up to the steaming rate you needed a few minutes ago. This is like a car at a stoplight..... The light turns green.... you hit the gas; the car backs up for a minute before starting to accelerate forward. Well, this is exactly what can happen to boilers burning wet fuel.

With older hog fuel boilers it was a necessity to have a trained boiler operator actually controlling the fuel rate, the combustion air, and some times even the boiler feed water. This was the way they to adjusted for the variable loads and variable fuels. Today, with current technology, modern instrumentation, hog fuel boilers can adjust for these variations automatically and run with out operator participation. To understand the wood waste boiler we must understand a little about the combustion process and the fuels involved.

Wood fiber and bark are composed of cellulose, which is a carbohydrate containing mainly carbon, hydrogen, and oxygen. Combustion of wet wood has a few distinct phases:

1. Dehydration or drying of the wood.
2. Evaporation of the volatiles happens as the wood heats from 200 – 1100° F where the volatile components are heated until they come off as gases.

3. Pyrolysis is a chemical decomposition into volatile gases and other compounds, which then contribute to...

4. Oxidation and reduction reactions creating heat and light just like in your fireplace.

Now if you point to the fireplace and tell your dinner guest that dehydration, evaporation, pyrolysis, and oxidation was going on simultaneously in your fireplace, they would think you were a geek. We do not need to know how the complex chemical reactions proceed; however, we do need to know the effects of moisture on the dehydration and evaporation in the boiler.

Wet fuel coming into a boiler needs to dry, get rid of the water, before it can start the evaporation of the volatile compounds. To dehydrate, the wet fuel will need to adsorb a large amount of heat from the boiler, at this instant we are sucking heat out of the burning fuel pile not adding heat. Once this heat is absorbed and the moisture is liberated, the volatile organic compounds will evaporate and these gases will rapidly burn creating energy to dry wood, evaporating more volatiles and furthering the pyrolysis, and creating steam. The important factor is you have to dry most of the moisture out of the wood to get it to liberate the volatile compounds that burn and create thermal energy.

After we burn the wood we have formed a large quantity of gases they include carbon dioxide, water vapor, also present in the exhaust stream is the excess air that was not used for combustion this includes mainly nitrogen and oxygen. Typical exhaust temperatures are around 350˚F. to 450˚F. As we burn the wood, the carbon in the wood combines with oxygen to form carbon dioxide (CO_2) and the hydrogen in the wood and oxygen from the air combines to form water (H_2O) vapor. After we extract the heat with the boiler we a left with the exhaust gases at around 400˚F. There is a substantial amount of energy in the exhaust gases, usually 18% to 34% of the total heat of the wood. The largest amount of this heat in the exhaust is water vapor. Water vapor is formed by combustion of the hydrogen in the wood, and water on the fuel is dehydrated (evaporated) into the exhaust gases. Of the two sources of heat loss we have to accept the water vapor formed in combustion, but the water formed by the drying of the wood is something we can control to some degree. If we look at Table 1 we can see the effect of moisture on fuel heating value in column 2, and in column 3 you can see the effect on the boiler efficiency.

The more moisture in your fuel the lower the heating value of the fuel and the lower the efficiency of your boiler. The stack losses are the primary factor controlling the efficiency of any boiler, and water vapor is the largest component of these losses.

Let us now look at Table 2, this table lists ten different wood groups, and their density, heating valve, and ash content. By the way, ash is the inert material that is not combustible in our boiler, it is often composed of minerals such as Calcium, Magnesium, Sodium, Potassium, Alumina, Silica and other minor elements. It ranges from .1% to 2.5% of the weight of wood burned...... 100# of wood would yield .1# to 2.5# of ash when burned completely. If you look at the heating value of dry wood, the heating values range from 7800 BTU per pound up to 11,000 BTU per pound. Our common northwest wood ranges from 7800-9800 BTU per Pound. To give you a point of reference one pound of oil is equal to 19,700 BTU, one pound of dry wood is equal to about 9,000 BTUs. The energy of 2.2# of dry wood is equal to the energy of one pound of diesel oil.

TABLE 1. BTU for Douglas-fir fiber.

WOOD BOILER AT 7.5% O_2 (50% EXCESS AIR) / 400°F STACK TEMP

	BTU/#	BOILER EFFICIENCY	EQUIVALENT STEAM OUTPUT 0% - 100	EQUIVALENT STEAM OUTPUT 45% - 100
0%	9368	80.2	100	
5%	8900	79.6	106	
10%	8375	79.0	114	
20%	7325	77.8	132	
30%	6274	76.7	156	73
40%	5252	75.5	189	89
45%	4700	74.9	213	100
50%	4174	74.3	242	113
55%	3649	73.7	279	131
60%	3107	73.2	330	155
65%	2600	72.6	397	186

EVERY 10% INCREASE IN FUEL MOISTURE, BOILER EFFICIENCY GOES DOWN 1.5%
A 10% INCREASE IN FUEL @ 45% MOISTURE REQUIRES 30% MORE FUEL.
EVERY 10% INCREASE IN FUEL MOISTURE REDUCES BTU'S BY 1000 BTU/#.

TABLE 2. Heating and ash content.

	Coastal Doug Fir	Interior Doug Fir	Coastal Fir Bark	Western Hemlock	Western Hemlock Bark	Ponderosa Pine	Yellow Pine	White Pine	Western Red Cedar	Red Alder
O.D. DENSITY	28.0	28.7	31	26.2	34	23.0	25.5	22.5	20.0	23.1
H.H.V. BTU/#	8900	8900	9800	8500	9400	9100	9610	8900	9700	8000
ASH %	.8	.8	1.2	2.2	2.2	1.3	1.31	.12	.4	.9

Now we go back to Table 1. This table lists Douglas-fir fiber at a number of different moisture contents. On the left column is moisture content, and the heating value of wood is in the second column. As you can see, the heating value of this material is 9368 BTU# at 0% moisture (as you know, that 0% moisture is hard to achieve). At 5% moisture the heating value is 8900 BTU.

Let me stop and clarify one thing. Wood moisture is expressed in two ways, the first is on a % of total weight. This is referred to as wet basis, or total weight basis. For example, if you had 2 pounds of wet wood, containing one pound wood fiber, and one pound was water, you would say this is 50% moisture on wet basis.

The other system is the dry basis that is to say the moisture is expressed as a percent of the dry weight of wood. In our example, the one pound of wood with one pound of water would be expressed as 100% moisture on a dry basis. For the purpose of this talk we will only use the wet basis, or total weight basis in our references to moisture content.

Now back to the heating value of wood. As you move down the page of Table 1, you see the heating value of wood going down as the moisture goes up. Please note that our 1# of diesel oil is now equivalent of 4.7# of wood @ 50% moisture.

Lets look at the third column titled "Boiler Efficiency". As you can see, we might expect 79.6% boiler efficiency burning 5% moisture wood, but when burning 50% moisture wood, we can only expect 74.3% efficiency. Our oil will burn at about 86% efficiency, so to produce the same amount of steam as one pound of oil, we will need 5.5# of wood @ 50% moisture. In Columns 4 & 5, we have listed equivalent weights of fuel to give us the same steam output. As you can see a 100# dry wood has the same useable energy as 279# of fiber with 55% moisture... so this moisture has a huge effect on the energy of your wood waste.

Moisture in your fuel reduces its heat value and reduces the boiler's efficiency. In Table 3, we compare firing the same fuel in a theoretical modern multi-fuel boiler. I have listed a number of conditions of the boiler and fuel, and on the far right are the theoretical efficiencies (maximum) for your comparison. As you can see, #2 oil is highest, followed by dry wood suspension fired, followed by natural gas, and dry wood fired on the grate. These efficiencies are to give you a relative feel for the maximum efficiencies of each fuel. As you can see when the moisture goes up, your efficiency goes down.

The figures I have shown on efficiency are perhaps 1 or 2% higher than you might actually achieve in the field. Let's look at B-1 and B-2 at the bottom of the table. This is my reality check; these are old boilers in poor to fair condition. These boilers were designed when we had a great surplus of wood on the west coast at a low price, and one of the main functions of a boiler was to reduce the size of hog fuel piles. With nearly free fuel, burning efficiency was not important in the late 60's. Now at most locations, the sale of hog fuel is one of the many revenue sources for sawmills.

As you can see, B-1 is 54.9% efficient and B-2 is 66.9% efficient. B-2 appears to be 12% more efficient than B-1, but when you compare the fuel consumed, B-1 consumes 21.8% more fuel than B-2 for the same output! We are comparing the ratio of ((66.9/54.7) –1). This is a huge difference in fuel cost to the company. This plant should shift as much load to boiler B-2 as possible.

TABLE 3. Boiler relative efficiencies.

STACK TEMPERATURE 400°
TYPICAL OXYGEN LEVELS

FUEL	MOISTURE	OXYGEN	EXCESS AIR	STACK TEMP	STACK LOSSES	RAD	CARBON LOSSES	THEORETICAL EFFICIENCY (MAX)
#2 OIL	---	4.0%	21.8%	400°	13.4	1.0	---	85.6
NATURAL GAS	---	3.5%	17.5%	400°	16.0	1.0	---	83.0
WOOD FIBER (SUSPENSION FIRED)	10%	4.0%	23%	400°	15.2	1.0	.1	83.7
WOOD FIBER – GRATE	10%	7.5%	54%	400°	16.9	1.5	.5	81.1
WOOD FIBER – GRATE	40%	7.5%	54%	400°	20.5	1.5	.7	77.3
BARK – GRATE	45%	7.5%	54%	400°	21.1	1.5	1.0	76.4
BARK - GRATE	60%	7.5%	54%	400°	22.9	1.5	1.2	74.4
REALITY CHECK	**BOILERS 03/27/2002**							
B-1 (1965)	48%	12.5%	142%	658°	38.1	4.0	3.0	54.9
B-2 (1970)	48%	9.6%	82%	612°	30.1	1.5	1.5	66.9

B-1 & B-2 COMPARISON. B-1 IS 12% LOWER IN EFFICIENCY ((66.9/54.9)- 1) = 21.8

B-1 BURNS 21.8% MORE FUEL THAN B-2 TO PRODUCE THE SAME VOLUME OF STEAM.

TABLE 4. Cost and BTU requirements.

FUEL	MOISTURE	BTU	EFFICIENCY	FUEL COST	FUEL COST 1,000,000 BTU STEAM
NATURAL GAS	--	100,000	83%	$.50/THERM	$6.02
NATURAL GAS	--	100,000	83%	$.60/THERM	$7.23
NATURAL GAS	--	100,000	83%	$.70/THERM	$8.43
NATURAL GAS	--	100,000	83%	$.80/THERM	$9.63
#2 OIL	--	142,000	86%	$.80/GAL	$6.55
#2 OIL	--	142,000	86%	$.90/ GAL	$7.37
#2 OIL	--	142,000	86%	$1.00/ GAL	$8.18
HOG BARK	45%	4,700	76%	$8/T $16.72/U	$1.12
	45%	4,700	76%	$12/T $25.08/U	$1.67
	45%	4,700	76%	$16/T $33.44/U	$2.24
	45%	4,700	76%	$20/T $41.8/U	$2.80
DRY FIBER	10%	8,375		$20/T $29.20/U	$1.47
	10%	8,375		$25/T $30.25/U	$1.86
	10%	8,375		$36/T $36.30/U	$2.21
	10%	8,375		$35/T $42.30/U	$2.58

Now, lets get back the relative cost of natural gas versus #2 oil and wood waste. To evaluate the true value of what energy costs, you must factor the cost of fuel by the efficiency in which it can generate useful energy. Notice I said useful!!!! Energy going up the stack is not very useful. Energy in the form of hot water steam or thermal oil can be very useful, especially in the winter when you have lots of wood to dry.

Looking at Table 4 we see natural gas at $.50 per therm(a therm is 100,000 BTU's of energy). Looking to the right hand column you can see that natural gas cost $6.02 per million BTU of steam. This could be hot water or thermal oil and the cost would be the same. At $.80 a gallon for oil a million BTU's of steam would have a fuel cost of $6.55. Hog Bark at $12.00 per ton ($25.08/unit) would cost $1.67 for a million BTU of steam. The fuel cost for natural gas is three and a half times the cost of hog bark, and oil costs almost four times as much as hog bark. As you can see there are some strong economic reasons to burn wood.

Table 5 shows the annualized cost of burning natural gas, #2 oil, and hog bark. These figures have factored in the relative efficiencies of each fuel as burned in a modern boiler. These calculations are based on 100% load, and on 60% average load. The 60% load is closer to where most process boilers operate.

Over the last two years fuel prices have had some huge changes. Natural gas has gone from $.27-$.37 per therm to $.50-$.77 per therm. At one time in December of 2000 spot gas was selling for $20.00 per therm.

Oil prices at the same time were rising but did not go up much past $1.30 per gallon, this was a substantial increase over the $.70-$.80 many were paying for oil just a few months earlier. Recently oil has dipped below $.80 making it cheaper than natural gas at $.58 per therm. To minimize your plant's operating costs some one needs to follow the fuel prices and switch to the fuel that saves you the most money.

In contrast to the natural gas and oil prices taking large jumps, hog fuel prices have been relatively stable. Hog fuel prices are quite regional, due to shipping costs, in many areas the price has been quite depressed. Some of this was due to pulp mills slowdowns or shutdowns over the past two years. When a big consumer of hog fuel shuts down there will be an impact on the market price for hog fuel and prices may fall.

On the other hand if a number of sawmills start burning their wood waste instead of burning natural gas or oil, the price of hog fuel is likely to increase. This will allow the sawmill burning wood waste to reduce its cost of energy and increase the price it receives for the balance of its wood waste. In most plants you can meet all your energy needs and still have waste wood to sell to the market.

Now I get to tell you about some thing that bothers me with plants that operate wood fired boilers. And what I don't under stand is huge piles of hog fuel sitting outside waiting to go to the boiler. The problem on the west side of the Cascade Mountains is that it rains, and the hog fuel gets wet. This has two effects one it reduces the fuel value (BTU's available). Second it reduces the efficiency of boiler and causes the boiler to burn more fuel, create more air pollution, and having a higher operating cost. Lets calculate what happens to a hog pile that has an average depth of eight feet and it rains one inch over night. That fuel has picked up 3.8% more moisture than 45% moisture when arrived at the mill. The calculations indicate the wood energy drops from 4700 BTU/pound to 4300 BTU/pound. This small change in moisture requires an additional 9.8% more fuel than before it was rained on. Now what happens if it rains 3" before the fuel gets used? The most common symptom is the boiler will loose its capacity, it will use lots more fuel and it won't be able to make the steam it was designed to. Also you won't be able to dry the amount of wood the boss expects.

Well my solution is simple we put a roof over the hog pile, or we tarp the less active areas of the hog pile. We also need to slope the hog yard away from the hog pile so that the rainwater doesn't run into our hog pile from the bottom.

The other thing that we need to understand is the hog fuel losses as much a 1% of its fuel value per month starting after about 60 days. It seems that nature is working against us... but she also grows some beautiful timber.

I hope you enjoyed the information, if you have any questions I will be happy to answer them now. I also have a number of copies of this presentation with me if you would like one please let me know. Thank you for your time and the opportunity to speak to the Western Dry Kiln Association.

TABLE 5. Annual fuel usage.

Fuel	Avg. Load	Fuel Cost	200 HP 6900 #/HR	400 HP 13800 #/HR	600 HP 20700 #/HR	1200 HP 41400 #/HR	1600 HP 55200 #/HR
NATURAL GAS	100%	$.50/ THERM	$353,196	$706,393	$1,059,590	$2,119,181	$2,825,754
NATURAL GAS	60%	$.50/ THERM	$211,918	$423,836	$635,754	$1,271,508	$1,695,344
NATURAL GAS	100%	$.60/ THERM	$423,836	$847,672	$1,271,508	$2,543,016	$3,390,688
NATURAL GAS	60%	$.60/ THERM	$254,301	$508,602	$762,903	$1,525,806	$2,034,408
#2 OIL	100%	$.80/ GAL	$384,085	$768,170	$1,152,255	$2,304,510	$3,072,680
#2 OIL	60%	$.80/ GAL	$230,451	$460,902	$691,354	$1,382,708	$1,843,610
#2 OIL	100%	$.90/ GAL	$432,095	$864,191	$1,296,286	$2,592,573	$3,456,750
#2 OIL	60%	$.90/ GAL	$259,257	$518,514	$777,771	$1,555,542	$2,074,056