



## Emissions Data Comparison of Forest Wood Debris Burning Open Burn vs. Air Curtain Firebox Burning

The data shown here is based on tests carried out by the USDA-FS (San Dimas) in Baker City, Oregon for which an Air Burners, LLC firebox Model S-217 was used. The test was conducted in November, 2002. A copy of this report was received by Air Burners, LLC in February, 2003. The full report can be accessed at [www.airburners.com](http://www.airburners.com).

<b>Table 1</b> <i>Air Curtain Burner Emission Factors (Air Burners, LLC Firebox)</i>						
<b>Sample Number</b>	<b>EFCO<sub>2</sub> (lbs/ton)</b>	<b>EFCO (lbs/ton)</b>	<b>EFCH<sub>4</sub> (lbs/ton)</b>	<b>EFNMHC (lbs/ton)</b>	<b>EFPM2.5 (lbs/ton)</b>	<b>CE %</b>
1	3634	15.9	1.14	0.916	0.7	99%
2	3636	16.9	0.92	0.580		99%
3	3589	39.6	2.64	1.749	1.1	98%
4	3613	27.9	1.46	1.158	1.1	98%
5	3646	11.4	0.60	0.519		99%
6	3587	41.4	2.71	1.744	0.9	98%
7	3624	23.4	0.59	0.685	0.9	99%
8	3603	33.7	1.16	1.154	1.7	98%
Average	3616	26.3	1.40	1.063	1.1	99%

<b>Table 2</b> <i>Ponderosa Pine Understory Burn Emission Factors</i>						
	<b>EFCO<sub>2</sub> (lbs/ton)</b>	<b>EFCO (lbs/ton)</b>	<b>EFCH<sub>4</sub> (lbs/ton)</b>	<b>EFNMHC (lbs/ton)</b>	<b>EFPM2.5 (lbs/ton)</b>	<b>CE %</b>
Average	3286	179.8	6.6	5.4	36.0	90%

<b>Table 3</b> <i>Ponderosa Pine Pile Burn Emission Factors</i>						
<b>Fire Code</b>	<b>EFCO<sub>2</sub> (lbs/ton)</b>	<b>EFCO (lbs/ton)</b>	<b>EFCH<sub>4</sub> (lbs/ton)</b>	<b>EFNMHC (lbs/ton)</b>	<b>EFPM2.5 (lbs/ton)</b>	<b>CE %</b>
Average F	3444	99.2	6.22	6.84	14	94%
Average S	3092	257.8	21.5	12.96	36.9	84%
Average all	3268	178.5	13.86	9.9	25.5	89%

## Notes on the data presented:

Table 1 shows that 8 samples taken during the demonstration were analyzed.

Terminology used:

**EF** is defined as the "Emissions Factor"

**EF<sub>CO<sub>2</sub></sub>** would be the Emission factor for Carbon Dioxide

**EF<sub>CO</sub>** is for Carbon Monoxide

**EF<sub>CH<sub>4</sub></sub>** is Methane based gases such as propane, butane etc.

**EF<sub>NMHC</sub>** is for the non-methane gases, hydrocarbons such as benzene

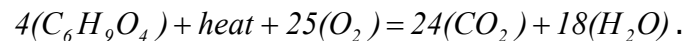
**CE** is Combustion Efficiency

**EF<sub>PM2.5</sub>** The PM is the Particulate Matter expressed pounds per ton. Environmental Protection Agency regulates Particulate Matter starting from 2.5PM on down to the smaller PM

Dr. Ron Sussott, Rocky Mountain Research Center, Missoula Fire Sciences Laboratory in Missoula, Montana, stated that the particulate matter from the air curtain was 20 to 30 times (on average) less in particulate matter per ton than that of a ponderosa pile burn.

## Notes on combustion efficiency:

Byrum's chemical model for wood is  $C_6H_9O_4$ , and for ideal combustion, the only products from the combustion process are  $CO_2$  and water:



In reality, as the availability of  $O_2$  decreases, many other products of incomplete combustion such as  $CO$ ,  $CH_4$ , and NMHC are produced.  $CO_2$  is normally produced in the breakdown and decay of woody material and is not usually considered to be a pollutant, while many of the products of incomplete combustion are.

Combustion Efficiency (CE) is defined to be the ratio of the carbon in  $CO_2$  to the carbon contained in all of the emissions:

$$CO_2 / (CO_2 + CO + CH_4 + C_2H_2 + C_2H_4 + C_2H_6 + \dots)$$

If the combustion were ideal, the only gas produced would be  $CO_2$ , and the combustion efficiency would be 100%. As the quantity of the products of incomplete combustion increases, the CE decreases. For Ponderosa Pine emissions studied Arizona in 1993 and 1994, the CE was typically about 90% (tables below) for understory burns and 89% for pile burns. This means that 10 to 11% of the carbon emissions were in the form of

products of incomplete combustion for these types of fires. The air curtain burner averaged a much higher combustion efficiency at 99%.

An Emission Factor (EF) is defined to be the quantity of a specific emission produced per some quantity of fuel consumed. EF's are usually given in units of grams/kilogram or lbs/ton. For example, for the pile burns, the EFCO was measured to be 178 lbs /ton; that is 178 pounds of CO is produced for every ton of fuel consumed.

Of particular interest are the reduced PM2.5 emission factors for the air curtain burner. Only about 1 lb. of PM2.5 per ton of (wood) fuel burned was produced by the air curtain incinerator verses a range of 14 to 37 lbs. of PM2.5 per ton (EF values for flaming and smoldering) with an average of 26 lbs. per ton for open pile burning. Thus the pile burn emissions were about 13 times higher in the flaming phase and 34 times higher in the smoldering phase, with the average being 23 times higher than the air curtain. At an average of 36 lbs. per ton, the understory burns produced about 33 times the amount of PM2.5, as did the air curtain incinerator.

Other EPA criteria pollutants, such as  $NO_x$  and ozone are produced, but these have not been measured in any significant quantities during normal biomass burning.

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