1.6 Wood Residue Combustion In Boilers

1.6.1 General[1-6]

The burning of wood residue in boilers is mostly confined to those industries where it is available as a byproduct. It is burned both to obtain heat energy and to alleviate possible solid residue disposal problems. In boilers, wood residue is normally burned in the form of hogged wood, bark, sawdust, shavings, chips, mill rejects, sanderdust, or wood trim. Heating values for this residue range from about 4,500 British thermal units/pound (Btu/lb) of fuel on a wet, as-fired basis, to about 8,000 Btu/lb for dry wood. The moisture content of as-fired wood is typically near 50 weight percent for the pulp, paper and lumber industries and is typically 10 to 15 percent for the furniture industry. However, moisture contents may vary from 5 to 75 weight percent depending on the residue type and storage operations. Generally, bark is the major type of residue burned in pulp mills; either a mixture of wood and bark residue or wood residue alone is burned most frequently in the lumber, furniture, and plywood industries.

1.6.2 Firing Practices[5, 7, 8]

Various boiler firing configurations are used for burning wood residue. One common type of boiler used in smaller operations is the Dutch oven. This unit is widely used because it can burn fuels with very high moisture content. Fuel is fed into the oven through an opening in the top of a refractory-lined furnace. The fuel accumulates in a cone-shaped pile on a flat or sloping grate. Combustion is accomplished in two stages: (1) drying and gasification, and (2) combustion of gaseous products. The first stage takes place in the primary furnace, which is separated from the secondary furnace chamber by a bridge wall. Combustion is completed in the secondary chamber before gases enter the boiler section. The large mass of refractory helps to stabilize combustion rates but also causes a slow response to fluctuating steam demand.

In another boiler type, the fuel cell oven, fuel is dropped onto suspended fixed grates and is fired in a pile. Unlike the Dutch oven, the refractory-lined fuel cell also uses combustion air preheating and positioning of secondary and tertiary air injection ports to improve boiler efficiency. Because of their overall design and operating similarities, however, fuel cell and Dutch oven boilers have many comparable emission characteristics.

The firing method most commonly employed for wood-fired boilers with a steam generation rate larger than 100,000 lb/hr is the spreader stoker. In this boiler type, wood enters the furnace through a fuel chute and is spread either pneumatically or mechanically across the furnace, where small pieces of the fuel burn while in suspension. Simultaneously, larger pieces of fuel are spread in a thin, even bed on a stationary or moving grate. The burning is accomplished in three stages in a single chamber: (1) moisture evaporation; (2) distillation and burning of volatile matter; and (3) burning of fixed carbon. This type of boiler has a fast response to load changes, has improved combustion control, and can be operated with multiple fuels. Natural gas, oil, and/or coal, are often fired in spreader stoker boilers as auxiliary fuels. The fossil fuels are fired to maintain constant steam production when the wood residue moisture content or mass rate fluctuates and/or to provide more steam than can be generated from the residue supply alone. Although spreader stokers are the most common stokers among larger wood-fired boilers, overfeed and underfeed stokers are also utilized for smaller units.

Another boiler type sometimes used for wood combustion is the suspension-fired boiler. This boiler differs from a spreader stoker in that small-sized fuel (normally less than 2 mm and normally low moisture) is blown into the boiler and combusted by supporting it in air rather than on fixed grates. Rapid changes in combustion rate and, therefore, steam generation rate are possible because the finely divided fuel particles burn very quickly.

A later innovation in wood firing is the fluidized bed combustion (FBC) boiler. A fluidized bed consists of inert particles through which air is blown so that the bed behaves as a fluid. Wood residue enters in the space above the bed and burns both in suspension and in the bed. Because of the large thermal mass represented by the hot inert bed particles, fluidized beds can handle fuels with moisture contents up to near 70 percent (total basis). Fluidized beds can also handle dirty fuels (up to 30 percent inert material). Wood fuel is pyrolyzed faster in a fluidized bed than on a grate due to its immediate contact with hot bed material. As a result, combustion is rapid and results in nearly complete combustion of the organic matter, thereby minimizing the emissions of unburned organic compounds.

1.6.3 Emissions And Controls[7-12]

The major emission of concern from wood boilers is particulate matter (PM). These emissions depend primarily on the composition of the residue fuel burned, and the particle control device. Oxides of nitrogen (NO_x) may also be emitted in significant quantities when certain types of wood residue are combusted or when operating conditions are poor.

1.6.3.1 Criteria Pollutants

The composition of wood residue and the characteristics of the resulting emissions depend largely on the industry from which the wood residue originates. Pulping operations, for example, produce great quantities of bark that may contain more than 70 weight percent moisture, sand, and other non-combustibles. As a result, bark boilers in pulp mills may emit considerable amounts of particulate matter to the atmosphere unless they are controlled. On the other hand, some operations, such as furniture manufacturing, generate a clean, dry wood residue (2 to 20 weight percent moisture) which produces relatively low particulate emission levels when properly burned. Still other operations, such as sawmills, burn a varying mixture of bark and wood residue that results in PM emissions somewhere between these two extremes. Additionally, NO_x emissions from wet bark and wood boilers are typically lower (approximately one-half) in comparison to NO_x emissions from dry wood-fired boilers.

Furnace operating conditions are particularly important when firing wood residue. For example, because of the high moisture content that may be present in wood residue, a larger than usual area of refractory surface is often necessary to dry the fuel before combustion. In addition, sufficient secondary air must be supplied over the fuel bed to burn the volatiles that account for most of the combustible material in the residue. When proper drying conditions do not exist, or when secondary combustion is incomplete, the combustion temperature is lowered, and increased PM, CO, and organic compound emissions may result from any boiler type. Significant variations in fuel moisture content can cause short-term emissions to fluctuate.

1.6.3.2 Greenhouse Gases[13-18]

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions are all produced during wood residue combustion. Nearly all of the fuel carbon (99 percent) in wood residue is converted to CO_2 during the combustion process. This conversion is relatively independent of firing configuration. Although the formation of CO acts to reduce CO_2 emissions, the amount of CO produced is insignificant compared to the amount of CO_2 produced. The majority of the fuel carbon not converted to CO_2, due to incomplete combustion, is entrained in the bottom ash. CO_2 emitted from this source is generally not counted as greenhouse gas emissions because it is considered part of the short-term CO_2 cycle of the biosphere.

Formation of N_2O during the combustion process is governed by a complex series of reactions and its formation is dependent upon many factors. Formation of N_2O is minimized when combustion temperatures are kept high (above 1475ºF) and excess air is kept to a minimum (less than 1 percent).

Methane emissions are highest during periods of low-temperature combustion or incomplete combustion, such as the start-up or shut-down cycle for boilers. Typically, conditions that favor formation of N_2O also favor emissions of CH_4.

1.6.4 Controls

Currently, the four most common control devices used to reduce PM emissions from wood-fired boilers are mechanical collectors, wet scrubbers, electrostatic precipitators (ESPs), and fabric filters. The use of multitube cyclone (or multiclone) mechanical collectors provides particulate control for many wood-fired boilers. Often, two multiclones are used in series, allowing the first collector to remove the bulk of the dust and the second to remove smaller particles. The efficiency of this arrangement varies from 25 to 65 percent. The most widely used wet scrubbers for wood-fired boilers are venturi scrubbers. With gas-side pressure drops exceeding 15 inches of water, particulate collection efficiencies of 85 percent or greater have been reported for venturi scrubbers operating on wood-fired boilers.

ESPs are employed when collection efficiencies above 90 percent are required. When applied to wood-fired boilers, ESPs are often used downstream of mechanical collector precleaners which remove larger-sized particles. Collection efficiencies of 90 to 99 percent for PM have been observed for ESPs operating on wood-fired boilers.

A variation of the ESP is the electrostatic gravel bed filter. In this device, PM in flue gases is removed by impaction with gravel media inside a packed bed; collection is augmented by an electrically charged grid within the bed. Particulate collection efficiencies are typically over 80 percent.

Fabric filters (i.e., baghouses) have had limited applications to wood-fired boilers. The principal drawback to fabric filtration, as perceived by potential users, is a fire danger arising from the collection of combustible carbonaceous fly ash. Steps can be taken to reduce this hazard, including the installation of a mechanical collector upstream of the fabric filter to remove large burning particles of fly ash (i. e., "sparklers"). Despite complications, fabric filters are generally preferred for boilers firing salt-laden wood. This fuel produces fine particulates with a high salt content having a quenching effect, thereby reducing fire hazards. Particle collection efficiencies are typically 80% or higher.

For stoker and FBC boilers, overfire air ports may be used to lower NO_x emissions by staging the combustion process. In those areas of the U.-S. where NO_x emissions must be reduced to their lowest levels, the application of selective noncatalytic reduction (SNCR) to residue wood-fired boilers has been accomplished; the application of selective catalytic reduction (SCR) is being contemplated. Both systems are postcombustion NO_x reduction techniques in which ammonia (or urea) is injected into the flue gas to selectively reduce NO_x to nitrogen and water. In one application of SNCR to an industrial wood-fired boiler, NO_x reduction efficiencies varied between 35 and 75 percent as the ammonia-to-NO_x ratio increased from 0.4 to 3.2.

Emission factors and emission factor ratings for wood residue boilers are summarized in Tables 1.6-1, 1.6-2, 1.6-3, 1.6-4. The factors are presented on an energy basis (pound of pollutant per million Btu of heat input). Factors for wet wood represent facilities that burn wood residue with a moisture content of 20 percent or greater. Factors for dry wood represent wood residue with less than 20 percent moisture content. Cumulative particle size distribution data and associated emission factors are presented in Table 1.6-5. Uncontrolled and controlled size-specific emission factors are plotted in Figure 1.6-1.

1.6.5 Updates Since the Fifth Edition

The Fifth Edition was released in January 1995. Revisions to this section since that date are summarized below. For further detail, consult the background report for this section. This and other documents can be found on the CHIEF Web Site at http://www.epa.gov/ttn/chief/, or by calling the Info CHIEF Help Desk at (919)541-1000.

Supplement A, February 1996

- Significant figures were added to some PM and PM-10 emission factors.
- In the table with NO_x and CO emission factors, text was added in the footnotes to clarify meaning.

Supplement B, October 1996

- SO_x, CH_4, N_2O, CO_2, speciated organics, and trace elements emission factors were corrected.
- Several HAP emission factors were updated.

Supplement D, February 1998

- Table 1.6-1, the PM-10 and one PM emission factors were revised to present two significant figures and the PM-10 emission factor for wood-fired boilers with mechanical collectors without flyash reinjection was revised to 2.6 lb/ton to reflect that these values are based on wood with 50% moisture. A typographical error in the wet scrubber emission factor for PM-10 was corrected.
- Table 1.6-2, the SO_x emission factors for all boiler categories were revised to 0.075 lb/ton to reflect that these factors are based on wood with 50% moisture.
- Tables 1.6-4 and 1.6-5 were re-titled to reflect that the speciated organic and trace element analysis presented in these tables are compiled from wood-fired boilers equipped with a variety of PM control technologies.

Supplement D, August 1998

- Table 1.6-4, the emission factor for trichlorotrifluoroethane was removed. The phenol emission factor was corrected to 1.47E-04; the phenanthrene factor was corrected to 5.02E-05; the chrysene factor was corrected to 4.52E-07; and, the polychlorinated dibenzo-p-furans factor was corrected to 2.9E-08.

Supplement E, February 1999

- X In the footnotes of tables 1.6-1, 2, 3, 4, 5, 6, 7, some text was removed that described how to adjust the factors when burning wood with moisture and thermal content significantly different from 50% or 4500 Btu/lb, respectively. The EPA is revising Section 1.6 and, in the interim, consistent with EPA=s recommendations regarding proper use of AP-42, the EPA encourages users of the wood combustion emission factors to account for the specific assumptions included in the factors and to convert the factors to a thermal content basis (i.e., lb/MMBtu) to estimate emissions when burning wood that differs significantly from 4500 Btu/lb or 50% moisture.

July 2001

- X All emission factors were revised and new factors were added. In some cases separate factors were developed for wet wood (greater than or equal to 20 percent moisture content) and dry wood (less than 20 percent moisture).
- X Separate PM and NOx emission factors are provided for dry wood combustion.
- X All emission factors have been converted to units of lb/MMBtu.
- X PM emission factors are specified by fuel type and control device type but not by boiler type.
- X NOx, SOx and CO emission factors are specified by fuel type and not by boiler type.
- X Additional toxic emission factors have been added.
- X The general quality rating for PM factors are higher than before.
- X TOC and CO2 emission factors are specified by all wood types and not by boiler type.
- X New Source Classification Codes (SCC) were assigned for dry wood.

March 2002

- X The VOC and TOC emission factors in Table 1.6-3 were calculated incorrectly. This has been corrected. The correct factors are 0.013 and 0.039, respectively.

September 2003

- X The VOC emission factor in Table 1.6-3 was calculated incorrectly. This has been corrected. The correct factor is 0.017.

November 2021

- X Added new PM-FIL factor to Table 1.6-1 for SCC 10200902. Added new CO factor to Table 1.6-2 for SCC 10200902. Added references for these factors and added links to available references.

1.6-6 EMISSION FACTORS

Table 1.6-1. EMISSION FACTORS FOR PM FROM WOOD RESIDUE COMBUSTION[a]

~~Fuel~~		~~Filterable PM~~		~~Filterable PM-10[b]~~		~~Filterable PM-2.5[b]~~			
Fuel	PM Control Device	Filterable PM Emission Factor (lb/MMbtu)	~~EMISSION FACTOR RATING~~Filterable PM Emission Factor Rating	Filterable PM-10[b] Emission Factor (lb/MMbtu)	~~EMISSION FACTOR RATING~~Filterable PM-10[b] Emission Factor Rating	Filterable PM-2.5[b] Emission Factor (lb/MMbtu)	~~EMISSION FACTOR RATING~~Filterable PM-2.5[b] Emission Factor Rating	Condensable PM Emission Factor (lb/MMbtu)	Condensable PM Emission Factor Rating
Bark/Bark and Wet Wood (10100901, 10100902, 10200901, 10200902, 10300901, 10300902)	No Control[c]	0.56[d]	C	0.50[e]	D	0.43[e]	D	No Data	N/A
Dry Wood (10100908, 10200908, 10300908)	No Control[c]	0.40[f]	A–	0.36[e]	D–	0.31[e]	D	No Data	N/A
Wet Wood (10100903, 10200903, 10300903)	No Control[c]	0.33[g]	A	0.29[e]	D	0.25[e]	D	No Data	N/A
~~(10100908, 10200908, 10300908)~~ ~~Wet Wood (10100903, 10200903, 10300903)~~	~~No Control[c]~~	~~0.33[g]~~	~~A~~	~~0.29[e]~~	D	~~0.25[e]~~	D	No Data	N/A
Bark (10100901, 10200901, 10300901) ~~Bark and Wet Wood~~	Mechanical Collector[*] ~~Mechanical Collector[*]~~	0.54[h] ~~0.35[i]~~	D ~~C~~	0.49[e] ~~0.32[e]~~	~~D~~ ~~D~~	0.29[e] ~~0.19[e]~~	~~D~~ ~~D~~		
Bark and Wet Wood (10100902, 10200902, 10300902) ~~Dry Wood~~	Mechanical Collector[*]	0.~~30[i]~~35[i]	~~A~~C	0.~~27[e]~~32[e]	D–	0.~~16[e]~~19[e]	D	No Data	N/A
Dry Wood (10100908, 10200908, 10300908)	Mechanical Collector[*]	0.30[j]	A	0.27[e]	D	0.16[e]	D	No Data	N/A
~~(10100908, 10200908, 10300908)~~ Wet Wood (10100903, 10200903, 10300903)	Mechanical Collector[*]	0.22[k]	A–	0.20[e]	D–	0.12[e]	D	No Data	N/A
Bark and Wet Wood (10200902)	Electrostatic Precipitator	0.013[r]	Highly[s]	No Data	N/A	No Data	N/A	No Data	N/A
All Fuels[m] ~~All Fuels[m]~~	Electrolyzed Gravel Bed	0.1[m] ~~0.066[n]~~	D ~~A~~	0.074[e] ~~0.065[e]~~	D ~~D~~	0.065[e] ~~0.065[e]~~	D ~~D~~	No Data	N/A

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~~All Fuels[m]~~ ~~All Fuels[m]~~ ~~All Fuels[m]~~	~~Wet Scrubber~~ ~~Fabric Filter~~ ~~Electrostatic Precipitator~~ ~~All Controls/No Controls~~	~~0.1[e]~~ ~~0.054[e]~~ ~~Condensible PM~~ ~~0.017[q]~~	~~C~~ ~~B~~ ~~A~~	~~0.074[e]~~ ~~0.04[e]~~	~~D~~ ~~D~~	~~0.065[e]~~ ~~0.035[e]~~			
All Fuels[m]	Wet Scrubber	0.066[n]	A	0.065[e]	D	0.065[e]	D	No Data	N/A
All Fuels[m]	Fabric Filter	0.1[o]	C	0.074[e]	D	0.065[e]	D	No Data	N/A
All Fuels[m]	Electrostatic Precipitator	0.054[p]	B	0.04[e]	D	0.035[e]	D	No Data	N/A
All Fuels[m]	All Controls/No Controls	No Data	N/A	No Data	N/A	No Data	N/A	0.017[q]	A

Table 1.6-1. (cont.)

[a] Units of lb of pollutant/million Btu (MMBtu) of heat input. To convert from lb/MMBtu to lb/ton, multiply by (HHV * 2000), where HHV is the higher heating value of the fuel, MMBtu/lb. CPM = CondensibleCondensable Particulate Matter. These factors apply to Source Classification Codes (SCC) 1-0X-009-YY, where X = 1 for utilities, 2 for industrial, and 3 for commercial/institutional, and where Y = 01 for bark-fired boiler, 02 for bark and wet wood-fired boiler, 03 for wet wood-fired boiler, and 08 for dry wood-fired boiler.
[b] PM-10 = particulate matter less than or equal to 10 microns in aerodynamic diameter. PM-2.5 = particulate matter less than or equal to 2.5 microns in aerodynamic diameter. Filterable PM = PM captured and measured on the filter in an EPA Method 5 (or equivalent) sampling train. CondensibleCondensable PM = PM captured and measured in an EPA Method 202 (or equivalent) sampling train.
[c] Factor represents boilers with no controls, Breslove separators, Breslove separators with reinjection, and mechanical collectors with reinjection.
[*] Mechanical collectors include cyclones and multiclones. (Asterisk added 4/2012 to denote separate notation in the table.)
[d] References 19-21, 88.
[e] Cumulative mass % provided in Table 1.6-6 for Bark and Wet Wood-fired boilers multiplied by the Filterable PM factor.
[f] References 22-32, 88.
[g] References 26, 33-36, 88.
[h] References 37, 38, 88.
[i] References 26, 39-41, 88.
[j] References 26, 27, 34, 42-54, 88.
[k] Reference 55-57, 88.
[l] All fuels = Bark, Bark and Wet Wood, Dry Wood, and Wet Wood.
[m] References 27, 58, 88.
[n] References 26, 59-66, 88.
[o] References 26, 67-70, 88.
[p] References 26, 71-74, 88.
[q] References 19-21, 25, 28, 29, 31, 32, 36-41, 46, 51, 53-60, 62 - 65, 67-69, 72-75, 88.
[r] Reference 91.
[s] Value represents new quality ratings given to factors based on Emissions Factors Procedures Document. Factors are given quality ratings based on representativeness of factor (i.e. Highly = factor is highly representative of the population).

Table 1.6-2. EMISSION FACTORS FOR NO_x, SO_2, AND CO FROM WOOD RESIDUE COMBUSTION[a]

~~Source Category[c]~~	~~NO_x [b]~~	~~SO_2 [b]~~	~~CO[b]~~

Source Category[c]	NO_x [b] Emission Factor (lb/MMbtu)	NO_x [b] EMISSION FACTOR RATING	SO_2[b] Emission Factor (lb/~~MMBtu~~MMbtu)	SO_2[b] EMISSION FACTOR RATING	CO[b] Emission Factor (lb/MMbtu)	CO[b] EMISSION FACTOR RATING
Bark/bark and wet wood/wet wood-fired ~~boiler~~boilers (10100901, 10100902, 10200901, 10300901, 10300902)	0.22[d]	A⁻	0.025[e]	A⁻	0.60[f,g,i,j]	A
Dry wood-fired boilers (10100908, 10300908, 10300908)	0.49[h]	C	0.025[e]	A	0.60[f,g,i,j]	A
Industrial wood/bark-fired boiler (10200902)	0.22[d]	A	0.025[e]	A	0.75[k]	Highly[m]
Fluidized Bed Combustors (10100912, 10200912, 10300912)	No Data	N/A	No Data	No Data	0.17[l]	D

[a]Units of lb of pollutant/million Btu (MMBtu) of heat input. To convert from lb/MMBtu to lb/ton, multiply by (HHV * 2000), where HHV is the higher heating value of the fuel, MMBtu/lb. To convert lb/MMBtu to kg/J, multiply by 4.3E-10. NO_x = Nitrogen oxides, SO_2 = Sulfur dioxide, CO = Carbon monoxide.
[b]Factors represent boilers with no controls or with particulate matter controls.
[c]These factors apply to Source Classification Codes (SCC) 1-0X-009-YY, where X = 1 for utilities, 2 for industrial, and 3 for commercial/institutional, and where Y = 01 for bark-fired boiler, 02 for bark and wet wood-fired boiler, 03 for wet wood-fired boiler, ~~and~~ 08 for dry wood-fired boiler, and 12 for fluidized bed combustors.
[d]References 19, 33, 34, 39, 40, 41, 55, 62-64, 67, 70, 72, 78, 79, 88-89.
[e]References 26, 45, 50, 72, 88-89.
[f]References 26, 59, 88-89.
[g]References 19, 26, 39-41, 60-64, 67, 68, 70, 75, 79, 88-89.
[h]References 30, 34, 45, 50, 80, 81, 88-89.
[i]References 26, 30, 45-51, 80-82, 88-89.
[j]Emission factor is for stokers and dutch ovens/fuel cells. References 26, 34, 36, 55, 60, 65, 71, 72, 75. ~~**CO Factor for fluidized bed combustors is 0.17 lb/MMbtu.** References 26, 72, 88-89.~~
[k]Reference 90.
[l]References 26, 72, 88-89.
[m] Value represents new quality ratings given to factors based on Emissions Factors Procedures Document. Factors are given quality ratings based on representativeness of factor (i.e. Highly = factor is highly representative of the population).

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Table 1.6-3. EMISSION FACTORS FOR SPECIATED ORGANIC COMPOUNDS, TOC, VOC, NITROUS OXIDE, AND CARBON DIOXIDE FROM WOOD RESIDUE COMBUSTION[a]

Organic Compound	Average Emission Factor[b] (lb/MMBtu)	EMISSION FACTOR RATING
Acenaphthene	9.1 E-07[c]	B
Acenaphthylene	5.0 E-06[d]	A
Acetaldehyde	8.3 E-04[e]	A
Acetone	1.9 E-04[f]	D
Acetophenone	3.2 E-09[g]	D
Acrolein	4.0 E-03[h]	C
Anthracene	3.0 E-06[i]	A
Benzaldehyde	<8.5 E-07[j]	D
Benzene	4.2 E-03[k]	A
Benzo(a)anthracene	6.5 E-08[l]	B
Benzo(a)pyrene	2.6 E-06[m]	A
Benzo(b)fluoranthene	1.0 E-07[l]	B
Benzo(e)pyrene	2.6 E-09[f]	D
Benzo(g,h,i)perylene	9.3 E-08[n]	B
Benzo(j,k)fluoranthene	1.6 E-07[o]	D
Benzo(k)fluoranthene	3.6 E-08[p]	B
Benzoic acid	4.7 E-08[q]	D
bis(2-Ethylhexyl)phthalate	4.7 E-08[g]	D
Bromomethane	1.5 E-05[f]	D
2-Butanone (MEK)	5.4 E-06[f]	D
Carbazole	1.8 E-06[f]	D
Carbon tetrachloride	4.5 E-05[r]	D
Chlorine	7.9 E-04[s]	D
Chlorobenzene	3.3 E-05[f]	D
Chloroform	2.8 E-05[f]	D
Chloromethane	2.3 E-05[f]	D
2-Chloronaphthalene	2.4 E-09[f]	D
2-Chlorophenol	2.4 E-08[u]	C
Chrysene	3.8 E-08[c]	B
Crotonaldehyde	9.9 E-06[j]	D
Decachlorobiphenyl	2.7 E-10[r]	D
Dibenzo(a,h)anthracene	9.1 E-09[l]	B
1,2-Dibromoethene	5.5 E-05[f]	D
Dichlorobiphenyl	7.4 E-10[r]	C
1,2-Dichloroethane	2.9 E-05[r]	D
Dichloromethane	2.9 E-04[v]	D
1,2-Dichloropropane	3.3 E-05[f]	D
2,4-Dinitrophenol	1.8 E-07[w]	C
Ethylbenzene	3.1 E-05[f]	D
Fluoranthene	1.6 E-06[x]	B
Fluorene	3.4 E-06[i]	A
Formaldehyde	4.4 E-03[y]	A
Heptachlorobiphenyl	6.6E-11[r]	D

Organic Compound	Average Emission Factor[b] (lb/MMBtu)	EMISSION FACTOR RATING
Hexachlorobiphenyl	5.5 E-10[r]	D
Hexanal	7.0 E-06[z]	D
Heptachlorodibenzo-p-dioxins	2.0 E-09[aa]	C
Heptachlorodibenzo-p-furans	2.4 E-10[aa]	C
Hexachlorodibenzo-p-dioxins	1.6 E-06[aa]	C
Hexachlorodibenzo-p-furans	2.8 E-10[aa]	C
Hydrogen chloride	1.9 E-02[j]	C
Indeno(1,2,3,c,d)pyrene	8.7 E-08[l]	B
Isobutyraldehyde	1.2 E-05[z]	D
Methane	2.1 E-02[f]	C
2-Methylnaphthalene	1.6 E-07[z]	D
Monochlorobiphenyl	2.2 E-10[r]	D
Naphthalene	9.7 E-05[ab]	A
2-Nitrophenol	2.4 E-07[w]	C
4-Nitrophenol	1.1 E-07[w]	C
Octachlorodibenzo-p-dioxins	6.6 E-08[aa]	B
Octachlorodibenzo-p-furans	8.8 E-11[aa]	C
Pentachlorodibenzo-p-dioxins	1.5 E-09[aa]	B
Pentachlorodibenzo-p-furans	4.2 E-10[aa]	C
Pentachlorobiphenyl	1.2 E-09[r]	D
Pentachlorophenol	5.1 E-08[ac]	C
Perylene	5.2 E-10[f]	D
Phenanthrene	7.0 E-06[ad]	B
Phenol	5.1 E-05[ae]	C
Propanal	3.2 E-06[z]	D
Propionaldehyde	6.1 E-05[f]	D
Pyrene	3.7 E-06[af]	A
Styrene	1.9 E-03[f]	D
2,3,7,8-Tetrachlorodibenzo-p-dioxins	8.6 E-12[aa]	C
Tetrachlorodibenzo-p-dioxins	4.7 E-10[ag]	C
2,3,7,8-Tetrachlorodibenzo-p-furans	9.0 E-11[aa]	C
Tetrachlorodibenzo-p-furans	7.5 E-10[aa]	C
Tetrachlorobiphenyl	2.5 E-09[r]	D
Tetrachloroethene	3.8 E-05[t]	D
o-Tolualdehyde	7.2 E-06[j]	D
p-Tolualdehyde	1.1 E-05[z]	D
Toluene	9.2 E-04[v]	C
Trichlorobiphenyl	2.6 E-09[r]	C
1,1,1-Trichloroethane	3.1 E-05[t]	D
Trichloroethene	3.0 E-05[t]	D
Trichlorofluoromethane	4.1 E-05	D
2,4,6-Trichlorophenol	<2.2 E-08[ak]	C
Vinyl Chloride	1.8 E-05[r]	D
o-Xylene	2.5 E-05[v]	D

Organic Compound	Average Emission Factor[b] (lb/MMBtu)	EMISSION FACTOR RATING
Total organic compounds (TOC)	0.039[ai]	D
Volatile organic compounds (VOC)	0.017[aj]	D
Nitrous Oxide (N_2O)	0.013[ak]	D
Carbon Dioxide (CO_2)	195[al]	A

[a] Units of lb of pollutant/million Btu (MMBtu) of heat input. To convert from lb/MMBtu to lb/ton, multiply by (HHV * 2000), where HHV is the higher heating value of the fuel, MMBtu/lb. To convert lb/MMBtu to kg/J, multiply by 4.3E-10. These factors apply to Source Classification Codes (SCC) 1-0X-009-YY, where X = 1 for utilities, 2 for industrial, and 3 for commercial/institutional, and where Y = 01 for bark-fired boiler, 02 for bark and wet wood-fired boiler, 03 for wet wood-fired boiler, and 08 for dry wood-fired boiler.
[b] Factors are for boilers with no controls or with particulate matter controls.
[c] References 26, 34, 36, 59, 60, 65, 71-73, 75.
[d] References 26, 33, 34, 36, 59, 60, 65, 71-73, 75.
[e] References, 26, 35, 36, 46, 50, 59, 60, 65, 71-75.
[f] Reference 26.
[g] Reference 33.
[h] Reference 26, 50, 83.
[i] References 26, 34, 36, 59, 60, 65, 71-73, 75.
[j] References 26, 50.
[k] References 26, 35, 36, 46, 59, 60, 65, 70, 71-75.
[l] References 26, 36, 59, 60, 65, 70-75.
[m] References 26, 33, 36, 59, 60, 65, 70-73, 75.
[n] References 26, 33, 36, 59, 60, 65, 71-73, 75.
[o] Reference 34.
[p] References 26, 36, 60, 65, 71-75.
[q] References 26, 33.
[r] References 26.
[s] Reference 83.
[t] References 26, 72.
[u] References 35, 60, 65, 71, 72.
[v] References 26, 72.
[w] References 35, 60, 65, 71, 72.
[x] References 26, 33, 34, 59, 60, 65, 71-75.
[y] References 26, 28, 35, 36, 46 - 51, 59, 60, 65, 70, 71-75, 79, 81, 82.
[z] Reference 50.
[aa] Reference 26, 45.
[ab] References 26, 33, 34, 36, 59, 60, 65, 71-75, 83.
[ac] References 26, 35, 60, 65, 71, 72.
[ad] References 26, 33, 34, 36, 59, 60, 65, 71 - 73.
[ae] References 26, 33, 34, 35, 60, 65, 70, 71, 72.
[af] References 26, 33, 34, 36, 59, 60, 65, 71 - 73, 83.
[ag] References 26, 45.
[ah] References 26, 35, 60, 65, 71.
[ai] TOC = total organic compounds. Factor is the sum of– all factors in table except nitrous oxide and carbon dioxide.
[aj] VOC volatile organic compounds. Factor is the sum of all factors in table except hydrogen chloride, chlorine, formaldehyde, tetrachloroethene, 1,1,1,-trichloroethane, dichloromethane, acetone, nitrous oxide, methane, and carbon dioxide.
[ak] Reference 83.
[al] References 19 - 26, 33 - 49, 51- 57, 77, 79 - 82, 84 - 86.

Table 1.6-4. EMISSION FACTORS FOR TRACE ELEMENTS FROM WOOD RESIDUE COMBUSTION[a]

Trace Element	Average Emission Factor (lb/MMBtu)[b]	EMISSION FACTOR RATING
Antimony	7.9 E-06[c]	C
Arsenic	2.2 E-05[d]	A
Barium	1.7 E-04[c]	C
Beryllium	1.1 E-06[e]	B
Cadmium	4.1 E-06[f]	A
Chromium, total	2.1 E-05[g]	A
Chromium, hexavalent	3.5 E-06[h]	C
Cobalt	6.5 E-06[i]	C
Copper	4.9 E-05[g]	A
Iron	9.9 E-04[k]	C
Lead	4.8 E-05[l]	A
Manganese	1.6 E-03[d]	A
Mercury	3.5 E-06[m]	A
Molybdenum	2.1 E-06[c]	D
Nickel	3.3 E-05[n]	A
Phosphorus	2.7 E-05[c]	D
Potassium	3.9 E-02[c]	D
Selenium	2.8 E-06[o]	A
Silver	1.7 E-03[p]	D
Sodium	3.6 E-04[c]	D
Strontium	1.0 E-05[c]	D
Tin	2.3 E-05[c]	D
Titanium	2.0 E-05[c]	D
Vanadium	9.8 E-07[c]	D
Yttrium	3.0 E-07[c]	D
Zinc	4.2 E-04[o]	A

[a] Units of lb of pollutant/million Btu (MMBtu) of heat input. To convert from lb/MMBtu to lb/ton, multiply by (HHV * 2000), where HHV is the higher heating value of the fuel, MMBtu/lb. To convert lb/MMBtu to kg/J, multiply by 4.3E-10. These factors apply to Source Classification Codes (SCC) 1-0X-009-YY, where X = 1 for utilities, 2 for industrial, and 3 for commercial/institutional, and where Y = 01 for bark-fired boiler, 02 for bark and wet wood-fired boiler, 03 for wet wood-fired boiler, and 08 for dry wood-fired boiler.
[b] Factors are for boilers with no controls or with particulate matter controls.
[c] Reference 26.
[d] References 26, 33, 36, 46, 59, 60, 65, 71-73, 75, 81.
[e] References 26, 35, 36, 46, 59, 60, 65, 71-73, 75.
[f] References 26, 35, 36, 42, 46, 59, 60, 65, 71-73, 75, 81.
[g] References 26, 34, 35, 36, 42, 59, 60, 65, 71-73, 75, 81.
[h] References 26, 36, 46, 59, 60, 71, 72, 73, 75.
[i] References 26, 34, 83.
[j] References 26, 33-36, 46, 59, 60, 65, 71-73, 75, 81.
[k] References 26, 71, 72, 81.
[l] References 26, 33-36, 46, 59, 60, 65, 71-73, 75.
[m] References 26, 35, 36, 46, 59, 60, 65, 71-73, 75, 81.
[n] References 26, 33 - 36, 46, 59, 60, 65, 71-73, 75, 81.
[o] References 26, 33, 35, 46, 59, 60, 65, 71-73, 75, 81.
[p] Reference 34.

Table 1.6-5. CUMULATIVE PARTICLE SIZE DISTRIBUTION AND SIZE-SPECIFIC EMISSION FACTORS FOR WOOD/BARK-FIRED BOILERS[a]

EMISSION FACTOR RATING: E

~~Particle Size[b] (Φm)~~	~~Cumulative Mass % # Stated Size~~	~~Controlled~~			
Particle Size[b] (µm)	Uncontrolled[c] (Cumulative Mass %)	Multiple _Cyclone[d] (Cumulative Mass %)	Multiple _Cyclone[e] (Cumulative Mass %)	Scrubber[f] (Cumulative Mass %)	Dry Electrostatic Granular Filter (DEGF) (Cumulative Mass %)
15	94	96	35	98	77
10	90	91	32	98	74
6	86	80	27	98	69
2.5	76	54	16	98	65
1.25	69	30	8	96	61
1.00	67	24	6	95	58
0.625	~~ND~~No Data	16	3	~~ND~~No Data	51
Total	100	100	100	100	100

[a]Reference 89.

[b]Expressed as aerodynamic equivalent diameter.

[c]From data on underfeed stokers. May also be used as size distribution for wood-fired boilers.

[d]From data on spreader stokers with flyash reinjection.

[e]From data on spreader stokers without flyash reinjection.

[f]From data on Dutch ovens. Assumed control efficiency is 94%.

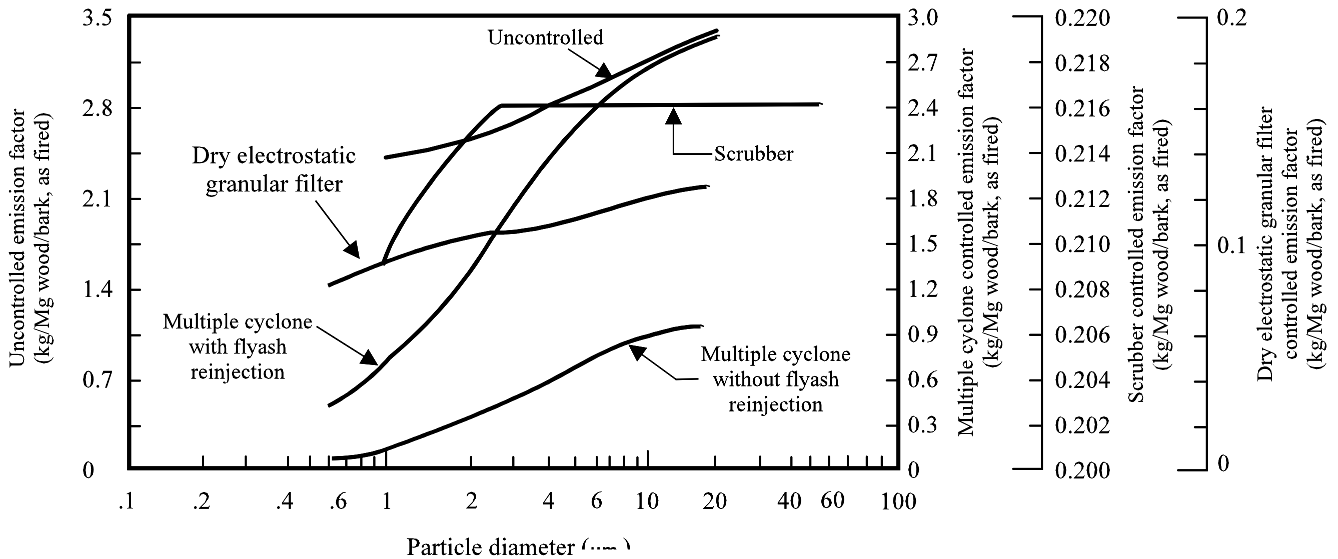

Figure 1.6-1. Cumulative size-specific particulate matter emission factors for wood/bark-fired boilers.

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References for Section 1.6

1. *Emission Factor Documentation For AP-42 Section 1.6 C Wood Waste Combustion In Boilers*, Technical Support Division, Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, April 1993.

2. *Steam*, 38th Edition, Babcock and Wilcox, New York, NY, 1972.

3. *Atmospheric Emissions From The Pulp And Paper Manufacturing Industry*, EPA-450/1-73-002, U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1973.

4. *C-E Bark Burning Boilers*, C-E Industrial Boiler Operations, Combustion Engineering, Inc., Windsor, CT, 1973.

5. *Nonfossil Fuel Fired Industrial Boilers C Background Information*, EPA-450/3-82-007, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 1982.

1. *Emission Factor Documentation For AP-42 Section 1.6 Wood Waste Combustion In Boilers*. Technical Support Division. Office of Air Quality Planning and Standards. U. S. Environmental Protection Agency. Research Triangle Park, NC. April 1993.

2. *Steam*, 38th Edition. Babcock and Wilcox. New York, NY. 1972.

3. *Atmospheric Emissions From The Pulp And Paper Manufacturing Industry*. EPA-450/1-73-002. U. S. Environmental Protection Agency. Research Triangle Park, NC. September 1973.

4. *C-E Bark Burning Boilers*. C-E Industrial Boiler Operations. Combustion Engineering, Inc. Windsor, CT. 1973.

5. *Nonfossil Fuel Fired Industrial Boilers Background Information*. EPA-450/3-82-007. U. S. Environmental Protection Agency. Research Triangle Park, NC. March 1982.

6. Industrial Combustion Coordinated Rulemaking Database,. Version 5.1. Process data. U.S. Environmental Protection Agency,. 1998.

7. *Control Of Particulate Emissions From Wood-Fired Boilers*, EPA 340/1-77-026, U. S. Environmental Protection Agency, Washington, DC, 1977.

8. *Background Information Document For Industrial Boilers*, EPA 450/3-82-006a, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 1982.

9. E. F. Aul, Jr. and K. W. Barnett, "Emission Control Technologies For Wood-Fired Boilers", Presented at the Wood Energy Conference, Raleigh, NC, October 1984.

10. G. Moilanen, et al., "Noncatalytic Ammonia Injection For NO_x Reduction on a Residue Wood-Fired Boiler", Presented at the 80th Annual Meeting of the Air Pollution Control Association, New York, NY, June 1987.

11. "Information On The Sulfur Content Of Bark And Its Contribution To SO_2 Emissions When Burned As A Fuel", H. Oglesby and R. Blosser, *Journal Of The Air Pollution Control Agency, 30*(7):769-772, July 1980.

7. *Control Of Particulate Emissions From Wood-Fired Boilers*. EPA 340/1-77-026. U. S. Environmental Protection Agency. Washington, DC. 1977.

8. *Background Information Document For Industrial Boilers*. EPA 450/3-82-006a. U. S. Environmental Protection Agency. Research Triangle Park, NC. March 1982.

9. E. F. Aul, Jr. and K. W. Barnett. "Emission Control Technologies For Wood-Fired Boilers." Presented at the Wood Energy Conference. Raleigh, NC. October 1984.

10. G. Moilanen, et al. "Noncatalytic Ammonia Injection For NO_x Reduction on a Residue Wood Fired Boiler." Presented at the 80th Annual Meeting of the Air Pollution Control Association. New York, NY. June 1987.

11. "Information On The Sulfur Content Of Bark And Its Contribution To SO_2 Emissions When Burned As A Fuel." H. Oglesby and R. Blosser. *Journal Of The Air Pollution Control Agency*, *30*(7):769-772. July 1980.

12. Written communication from G. Murray,. California Forestry Association,. Sacramento, CA to E. Aul, Edward Aul & Associates, Inc., Chapel Hill, NC,. Transmittal of Wood Fired Boiler Emission Test,. April, 24, 1992.

13. L. P. Nelson, L. M. Russell, and J. J. Watson, A. A Global Combustion Sources of Nitrous Oxide Emissions@,. Research Project 2333-4 Interim Report,. Radian Corporation,. Sacramento, CA,. 1991.

~~14. Rebecca L. Peer, Eric P. Epner, and Richard S. Billings, *Characterization Of Nitrous Oxide Emission Sources*, EPA Contract No. 68-D1-0031, Research Triangle Park, NC, 1995.~~

~~15. Steven D. Piccot, Jennifer A. Buzun, and H. Christopher Frey, *Emissions And Cost Estimates For Globally Significant Anthropogenic Combustion Sources Of NO_x, N_2O, CH_4, CO, And CO_2*, EPA Contract No. 68-02-4288, Research Triangle Park, NC, 1990.~~

14. Rebecca L. Peer, Eric P. Epner, and Richard S. Billings. *Characterization Of Nitrous Oxide Emission Sources*. EPA Contract No. 68-D1-0031. Research Triangle Park, NC. 1995.

15. Steven D. Piccot, Jennifer A. Buzun, and H. Christopher Frey. *Emissions And Cost Estimates For Globally Significant Anthropogenic Combustion Sources Of NO_x, N_2O, CH_4, CO, And CO_2*. EPA Contract No. 68-02-4288. Research Triangle Park, NC. 1990.

~~16. G. Marland, and R. M. Rotty, *Carbon Dioxide Emissions From Fossil Fuels: A Procedure For Estimation And Results For 1951-1981*, DOE/NBB-0036 TR-003, Carbon Dioxide Research Division, Office of Energy Research, U.S. Department of Energy, Oak Ridge, TN, 1983.~~

16. G. Marland, and R. M. Rotty. *Carbon Dioxide Emissions From Fossil Fuels: A Procedure For Estimation And Results For 1951-1981*. DOE/NBB-0036 TR-003. Carbon Dioxide Research Division, Office of Energy Research, U.S. Department of Energy. Oak Ridge, TN. 1983.

~~17. *Sector-Specific Issues And Reporting Methodologies Supporting The General Guidelines For The Voluntary Reporting Of Greenhouse Gases Under Section 1605(b) Of The Energy Policy Act Of 1992*, Volume 2 of 3, U.S. Department of Energy, DOE/PO-0028, 1994.~~

~~18. R. A. Kester, *Nitrogen Oxide Emissions From A Pilot Plant Spreader Stoker Bark Fired Boiler*, Department of Civil Engineering, University of Washington, Seattle, WA, December 1979.~~

17. *Sector-Specific Issues And Reporting Methodologies Supporting The General Guidelines For The Voluntary Reporting Of Greenhouse Gases Under Section 1605(b) Of The Energy Policy Act Of 1992*. Volume 2 of 3. U.S. Department of Energy. DOE/PO-0028. 1994.

18. R. A. Kester. *Nitrogen Oxide Emissions From A Pilot Plant Spreader Stoker Bark Fired Boiler*. Department of Civil Engineering, University of Washington. Seattle, WA. December 1979.

19. *Stack Emission Test Report on Hogged Wood Fired Boilers 1,2 and 3 at Snow Mountain Pine of Oregon, LTD, Burns, Oregon*. Horizon Engineering. May 4-5, 1993.

20. *Air Emissions Test, on the Wood-Fired Boilers No. 4 and 6 at Nicolet Hardwood Corp., Laona, Wisconsin*. Environmental Technology & Engineering. June 10-11, 1990.

21. *Boiler Emission Test at Nicolet Hardwood Corp., Laona, Wisconsin*. Badger Laboratories & Engineering. June 25, 1992.

22. *Particulate Emissions Test. Boiler Number 1. Thomasville Furniture Industries, Inc. West Jefferson, North Carolina*. PACE, Inc. April 16, 1991.

23. No title. Tests performed at Thomasville Furniture Industries Plant C, Thomasville, NC., by Entropy Environmentalists on May 25, 1978.

24. No title. Tests performed at Thomasville Furniture Industries, Winston Salem, NC., by Entropy Environmentalists on April 23/24, 1980.

25. *Report to A.A. Laun Furniture Co., Kiel, Wisconsin, for Particulate & Formaldehyde Emissions Testing, Wood-Fired Boiler*. Environmental Technology & Engineering Corp. March 30, 1995.

26. Industrial Combustion Coordinated Rulemaking (ICCR) Emissions Test database, Version 5.0. Emissions data. U.S. Environmental Protection Agency, Research Triangle Park, NC. 1998.

27. Information Submitted to EPA by Laura Herbert and Steve Maynard, North Carolina Department of Environment and Natural Resources. January 26, 1999.

28. *Boiler Emission Test at Banks Hardwood, Menomonie, Wisconsin*. _Badger Laboratories & Engineering. May 25, 1994.

29. *Brown County Cabinet Company Boiler Emission Test at Green Bay, WI*. Badger Laboratories & Engineering. November 6, 1996.

30. *Results of the November 16, 1993 State Air Emission Tests of the Cleaver Brooks Boiler at the Eggers Industries Plant Located in Two Rivers, Wisconsin*. Interpoll Laboratories, Inc. February 1, 1994.

31. *Results of the April 20, 1995 Particulate Emission Compliance Test on the Wood-Fired Boiler at the Dresser Lumber & Tie Plant, Haywood, Wisconsin*. Interpoll Laboratories. April 20, 1995.

32. *Boiler Emission Test at America Excelsior Company, Marinette, Wisconsin*. Badger Laboratories & Engineering. December 20, 1994.

33. ~~*Hazardous Air Emissions Potential From A Wood-Fired Furnace (and attachments)*. A.J. Hubbard, Wisconsin Department of Natural Resources. Madison, WI. July 1991.~~

~~34. *Environmental Assessment of a Wood-Residue -Fired Industrial Watertube Boiler*. Acurex Corporation. November 1982.~~

33. *Hazardous Air Emissions Potential From A Wood-Fired Furnace (and attachments)*. A.J. Hubbard, Wisconsin Department of Natural Resources. Madison, WI. July 1991.

34. *Environmental Assessment of a Wood-Residue -Fired Industrial Watertube Boiler*. Acurex Corporation. March 1984.

35. *Source Emission Testing of the Wood-fired Boiler at Big Valley Lumber Company, Bieber, California*. Galson Technical Services, Inc. February, 1991.

36. *Source Emission Testing of the CE Wood-Fired Boiler at Roseburg Forest Products (TAC Site #3)*. Performed for the Timber Association of California. Galston Technical Services. January, 1991.

37. *Boiler Emission Test at Nagel Lumber Company, Land O'Lakes, Wisconsin*. Badger Laboratories & Engineering. July 2, 1996.

38. *Boiler Emission Test at Nagel Lumber Company, Land O'Lakes, Wisconsin*. Badger Laboratories & Engineering. April 19, 1996.

39. *Stack Emission Test Report on Hogged Wood Fired Boiler # 5 at Snow Mountain Pine of Oregon, LTD, Burns, Oregon*. Horizon Engineering. December 1, 1992.

40. *Source Emission Evaluation on Hogged Fuel Boiler # 2 at International Paper Company, Gardiner, Oregon*. AMTEST Air Quality, Inc. November 12, 1993.

41. *Source Emission Evaluation on Boiler # 1 Outlet and Boiler # 2 Outlet at Bohemia Inc., Gardiner, Oregon*. AMTEST Air Quality, INC. May 15-16 1990.

42. *Stationary Source Sampling Report for Lexington Furniture Industries Plant Number 10, Hildebran, North Carolina. ABCO Boiler Stack*. Trigon Engineering Consultants, Inc. December, 1993.

43. *Stationary Source Sampling Report. Lexington Furniture Industries Plant Number 11, Mocksville, North Carolina*. Entropy Environmentalists. August 15 and 16, 1991.

44. *Stationary Source Sampling Report for Lexington Furniture Industries, Spruce Pine, North Carolina*. Trigon Engineering Consultants, Inc. December, 1995.

45. *Stationary Source Sampling Report. ERG Reference No. 0539. Emissions Testing For: Carbon Monoxide; Dioxins; Furans; Nitrogen Oxides; Particulate (PM-10); Sulfur Dioxide; Total Hydrocarbons*. Environmental Technical Group, Inc. May 19, 1998.

46. *Source Emission Testing of the Wood-Fired Boiler "C" Exhaust at Bohemia, Inc. Rocklin, California*. Performed for the Timber Association of California. Galston Technical Services. December, 1990.

47. *Results of the July 7, 1993 Air Emission Compliance Testing on the Wood-fired Boiler at the Ashley Furniture Facility, Arcadia, Wisconsin*. Interpoll Laboratories, Inc. August 16, 1993.

48. *Results of the April 14, 1994 Air Emission Compliance Testing on the Wood-fired Boiler at the Ashley Furniture Facility, Arcadia, Wisconsin*. Interpoll Laboratories, Inc. May 11, 1994.

49. *Results of the October 27, 1994 Air Emission Compliance Testing of the Boiler at the Endeavor Hardwoods Facility, Lyndon Station, Wisconsin*. Interpoll Laboratories, Inc. November 16, 1994.

50. *Source Test Report. Source Emission Testing of the Wood-fired Boiler at Ethan Allen, Inc.- Mayville Division. Mayville, New York*. Galson Corporation. May 13, 1994.

51. *Results of the October 27, 1994 Air Emission Compliance Test of the Boiler at the Endevor Hardwoods Facility, Lyndon Station, Wisconsin*. Interpoll Laboratories. October 27, 1994.

52. *Results of the November 10, 1994 Air Emission Compliance Testing on the Wood-Fired Boiler at the Ashley Furniture Facility, Arcadia, Wisconsin*. Interpoll Laboratories, Inc. December 2, 1994.

53. *Report to Laminated Products, Inc. Kenosha, Wisconsin for Particulate Emissions Testing Wood-Fired Boiler, May 31, 1994.* Environmental Technology & Engineering Corp. July 7, 1994.

54. *Report to Laminated Products, Inc. Kenosha, Wisconsin for Particulate Emissions Testing Wood-Fired Boiler, September 2, 1994.* Environmental Technology & Engineering Corp. September 19, 1994.

55. *Source Emission Evaluation on Wellons Boiler Exhaust Stack at WTD Industries-Trask River Lumber Company, Tillamook, Oregon*. AMTEST Air Quality, INC. August 30, 1995.

56. *Wood Fired Boiler Emission Test at Marion Plywood Corp., Marion, Wisconsin*. Badger Laboratories & Engineering. September 2 & 3, 1992.

57. *Wood Fired Boiler Emission Test at Marion Plywood Corp., Marion, Wisconsin*. Badger Laboratories & Engineering. August 11, 1992.

58. *Results of the January 18, 1990 Particulate Emission Compliance Test on the Konus Common Stack at the Louisiana Pacific Corporation Facility, Hayward, Wisconsin*. Pace Laboratories, Inc. January 18, 1990.

59. *Source Emission Testing of the Wood-Fired Boiler #3 Exhaust at Georgia Pacific, Fort Bragg, California*. Performed for the Timber Association of California. Galston Technical Services. February, 1991.

59. *Source Emission Testing of the Wood-Fired Boiler #3 Exhaust at Georgia Pacific, Fort Bragg, California*. Performed for the Timber Association of California. Galston Technical Services. February, 1991.

60. *Source Emission Testing of the Wood-Fired Boiler #5 Exhaust at Roseburg Forest Products, Anderson, California*. Performed for the Timber Association of California. Galston Technical Services. February, 1991.

61. *Emission Test Report on the Hogged Fuel Fired Boiler at Tillamook Lumber Company, Tillamook, Oregon*. Horizon Engineering. December 20, 1994.

62. *Emission Test Report on Wood Residue Boiler at Timber Products, Medford, Oregon*. BWR Associates, Inc. July 22, 1993.

63. *Emission Test Report on Wood Residue Boiler at Timber Products, Medford, Oregon*. BWR Associates, Inc. November 18, 1993.

64. *Emission Test Report on Wood Waste Boiler at Timber Products, Medford, Oregon*. BWR Associates, Inc. March 26, 1991.

65. *Source Emission Testing of the Wood-fired Boiler At Catalyst Hudson, Inc., Anderson, California*. Galson Technical Services, Inc. February, 1991.

65. *Source Emission Testing of the Wood-fired Boiler At Catalyst Hudson, Inc., Anderson, California*. Galson Technical Services, Inc. February, 1991.

66. *Results of the May 18, 1988 Particulate and Carbon Monoxide Emission Compliance Test on the No.1 Boiler at the Norenco Cogeneration Facility, Ladysmith, Wisconsin.* Interpoll Laboratories. May 19, 1988.

67. *Emission Test Report on Wood Waste Boilers at Stone Forest Industries, White City, Oregon*. BWR Associates, Inc. December 21, 1992.

68. *Results of the February 1, 1994 Air Emission Compliance Test on the GEKA Common Stack at the Louisiana Pacific Waferboard Plant, Tomahawk, Wisconsin*. Interpoll Laboratories, Inc. February 1, 1994.

69. *Report to Laminated Products, Inc. Kenosha, Wisconsin for Particulate Emissions Testing Wood-Fired Boiler, July 7, 1995*. Environmental Technology & Engineering Corp. July 17, 1995.

70. *Results of the August 17-19, 1993 Air Emission Compliance Test at the Louisiana Pacific Waferboard Plant, Tomahawk, Wisconsin*. Interpoll Laboratories, Inc. August 17-19, 1993.

71. *Source Emission Testing of the Wood-Fired Boiler Exhaust at Sierra Pacific, Burney, California*. Performed for the Timber Association of California. Galston Technical Services. February, 1991.

72. *Source Emission Testing of the Wood-Fired Boiler #1 Exhaust Stack at Wheelabrator Shasta Energy Company (TAC Site 9), Anderson, California*. Performed for the Timber Association of California. Galston Technical Services. January, 1991.

73. *Source Emission Testing of the Wood-Fired Boiler "C" Exhaust at Pacific Timber, Soctia, California*. Performed for the Timber Association of California. Galston Technical Services. February, 1991.

74. *Source Emission Testing of the Wood-Fired Boiler at Yanke Energy, North Fork, California*. Performed for the Timber Association of California. Galston Technical Services. January, 1991.

75. *Source Emission Testing of the Wood-Fired Boiler Exhaust at Miller Redwood Company, Crescent City, California*. Performed for the Timber Association of California. Galston Technical Services. February, 1991.

~~76. *Nitrogen Oxide Emissions from a Pilot Plant Spreader Stoker Bark Fired Boiler*. R.A. Kester, Department of Civil Engineering. University of Washington, Seattle, WA. December, 1979.~~

76. *Nitrogen Oxide Emissions from a Pilot Plant Spreader Stoker Bark Fired Boiler*. R.A. Kester, Department of Civil Engineering. University of Washington, Seattle, WA. December, 1979.

77. *Stack Emission Test Report on Hogged Wood Fired Boiler Plant at Champion International Corporation, Roseburg, Oregon*. Horizon Engineering. August 19, 1991.

78. American Furniture Manufacturers Association Test Report. *Determination of Nitrogen Oxide and Carbon Monoxide Emissions. September 22, 23, and 24, 1998*. Air Monitoring Specialists. September, 1998.

79. *Results of the April 20 & 21, 1993 Air Emission Tests on the Cleaver Brooks and Kidwell Wood-Fired Boilers at the Eggers Industries Plant in Two Rivers, Wisconsin.* Interpoll Laboratories, Inc. May 25, 1993.

80. *Report to Eggers Industries, Inc., Two Rivers, Wisconsin for Stack Emission Test, West Plant Wood-Fired Boiler*. Environmental Technology And Engineering Corporation. August 5, 1997.

81. *Test Report Prepared for American Furniture Manufacturing Association*. Air Monitoring Specialists, Inc. December, 1996.

82. *Emission Test Program on the Wood-Fired Boiler at Goodman Forest Industries, Ltd. Goodman, Wisconsin*. Air Environmental. Inc. December 14, 1995.

~~83. Emission Factor Documentation for AP-42 Section 1.6- Wood Waste Combustion in Boilers. Technical Support Division, Office of Air Quality Planning and Standards. U.S. Environmental Protection agency. Research Triangle Part, NC. April, 1993.~~

83. Emission Factor Documentation for AP-42 Section 1.6- Wood Waste Combustion in Boilers. Technical Support Division, Office of Air Quality Planning and Standards. U.S. Environmental Protection Agency. Research Triangle Part, NC. April, 1993.

84. *Report to Eggers Industries, Inc., Two Rivers, Wisconsin for Stack Emission Test, West Plant Wood-Fired Boiler*. Environmental Technology And Engineering Corporation. February 27, 1996.

85. *Lamico, Inc., Emission test at 474 Mariod Road, Oshkosh, WI~~,~~. October 5 & 6, 1989*. Badger Laboratories & Engineering Co., Inc. November 1, 1989.

86. *Cleaver-Brooks Boiler Stack Particulate Emission Testing on November 8, 1994*. Environmental Services of America, Inc. December 7, 1994.

87. *Inhalable Particulate Source Category Report for External Combustion Sources*~~,~~. EPA Contract No. 68-02-3156~~,~~. Acurex Corporation~~,~~. Mountain View, CA~~,~~. January 1985.

~~88. Oregon Department of Environmental Quality Database, Process data. State of Oregon, 2001.~~

89. *Wood Products in The Waste Stream - Characterization and Combustion Emissions*, U.S. Environmental Protection Agency, Control Technology Center, October 1996.

88. Oregon Department of Environmental Quality Database. Process data. State of Oregon. 2001.

89. *Wood Products in The Waste Stream - Characterization and Combustion Emissions*. U.S. Environmental Protection Agency. Control Technology Center. October 1996.

90. CO Stack Test Data submitted to CEDRI from 2015-2020. Each individual test report can be obtained via WebFIRE.

91. PM-FIL Stack Test Data submitted to CEDRI from 2015 – 2020. Each individual test report can be obtained via WebFIRE.