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COMPILATION OF AIR POLLUTANT EMISSION FACTORS

Volume I: Stationary Point And Area Sources

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than from multiple cyclones.

Uncontrolled overfeed and underfeed stokers emit considerably less particulate than do pulverized coal units and spreader stokers, since combustion takes place in a relatively quiescent fuel bed. Fly ash reinjection is not practiced in these kinds of stokers.

Variables other than firing configuration and fly ash reinjection can affect PM emissions from stokers. Particulate loadings will often increase as load increases (especially as full load is approached) and with sudden load changes. Similarly, particulate can increase as the coal ash and "fines" contents increase. Fines, in this context, are coal particles smaller than about 1.6 millimeters (1/16 inch) in diameter. Conversely, particulate can be reduced significantly when overfire air pressures are increased.

FBCs may tax conventional particulate control systems. The particulate mass concentration exiting FBCs is typically 2 to 4 times higher than that from pulverized coal boilers[13]. Fluidized bed combustor particles are also, on average, smaller in size, irregularly shaped, and have higher surface area and porosity relative to pulverized coal ashes. Fluidized bed combustion ash is more difficult to collect in electrostatic precipitators (ESPs) than pulverized coal ash because FBC ash has a higher electrical resistivity. In addition, the use of multiclones for fly ash recycling, inherent with FBC processes, tends to reduce flue gas stream particulate size[13].

The primary kinds of PM control devices used for coal combustion include multiple cyclones, ESPs, fabric filters (or baghouses), and scrubbers. Some measure of control will even result from fly ash settling in boiler/air heater/economizer dust hoppers, large breeching, and chimney bases. The effects of such settling are reflected in current emission factors.

ESPs are the most common high-efficiency PM control device used on pulverized coal and cyclone units; they are also being used increasingly on stokers. Generally, ESP collection efficiencies are a function of collection plate area per unit volumetric flow rate of flue gas through the device. Particulate control efficiencies of 99.9 percent or above are obtainable with ESPs. Electrostatic precipitators located downstream of air preheaters (i.e., cold side precipitators) operate at significantly reduced efficiencies when low sulfur coal is fired. Fabric filters have recently seen increased use in both utility and industrial applications, generally achieving at least 99.8 percent efficiency. An advantage of fabric filters is that they are unaffected by the high fly ash resistivities associated with low sulfur coals. Scrubbers are also used to control particulate, although their primary use is to control sulfur oxides. One drawback of scrubbers is the high energy usage required to achieve control efficiencies comparable to those for ESPs and baghouses[2].

Mechanical collectors, generally multiple cyclones, are the primary means of PM control on many stokers. They are sometimes installed upstream of high-efficiency control devices in order to reduce the ash collection burden on these devices. Cyclones are also an integral part of most FBC designs. Depending on application and design, multiple cyclone efficiencies can vary widely. Where cyclone design flow rates are not attained (which is common with underfeed and overfeed stokers), these devices may be only marginally effective and may prove little better in reducing particulate than a large breeching. Conversely, well-designed multiple cyclones, operating at the required flow rates, can achieve collection efficiencies on spreader stokers and overfeed stokers of 90 to 95 percent. Even higher collection efficiencies are obtainable on spreader stokers with reinjected fly ash because of the larger particle sizes and increased particulate loading reaching the controls[5-6].

Sulfur Oxides[7-9] - Gaseous sulfur oxides (SO_x) from coal combustion are primarily sulfur dioxide (SO_2), with a much lower quantity of sulfur trioxide (SO_3) and gaseous sulfates. These percent sulfur in the coal by the numerical value preceding S. On average for bituminous coal, 95% of fuel sulfur is emitted as SO_2, and only about 0.7% of fuel sulfur is emitted as SO_3 and gaseous sulfate. An equally small percent of fuel sulfur is emitted as particulate sulfate (References 9, 13). Small quantities of sulfur are also retained in bottom ash. With subbituminous coal, about 10% more fuel sulfur is retained in the bottom ash and particulate because of the more alkaline nature of the coal ash. Conversion to gaseous sulfate appears about the same as for bituminous coal.

c. Expressed as NO_2. Generally, 95+ volume % of nitrogen oxides present in combustion exhaust will be in the form of NO, the rest NO_2 (Reference 11). To express factors as NO, multiply factors by 0.66. All factors represent emission at baseline operation (i.e., 60 to 110% load and no NO_x control measures).

d. Nominal values achievable under normal operating conditions. Values are one or two orders of magnitude higher can occur when combustion is not complete.

e. Emission factors for CO_2 emissions from coal combustion should be calculated using CO_2/ton coal = 73.3C, where C is the weight percent carbon content of the coal.

f. Includes traveling grate, vibrating grate and chain grate stokers.

g. Sulfur dioxide emission factors for fluidized bed combustion are a function of fuel sulfur content and calcium-to-sulfur ratio. For both bubbling bed and circulating bed design, use: lb SO_2/ton coal = $39.6(S)(Ca/S)^{-1.9}$. In this equation, S is the weight percent sulfur in the fuel and Ca/S is the molar calcium-to-sulfur ratio in the bed. This equation may be used when the Ca/S is between 1.5 and 7. When no calcium-based sorbents are used and the bed material is inert with respect to sulfur capture, the emission factor for underfeed stokers should be used to estimate the FBC SO_2 emissions. In this case, the emission factor ratings are E for both bubbling and circulating units.

SCC = Source classification code.

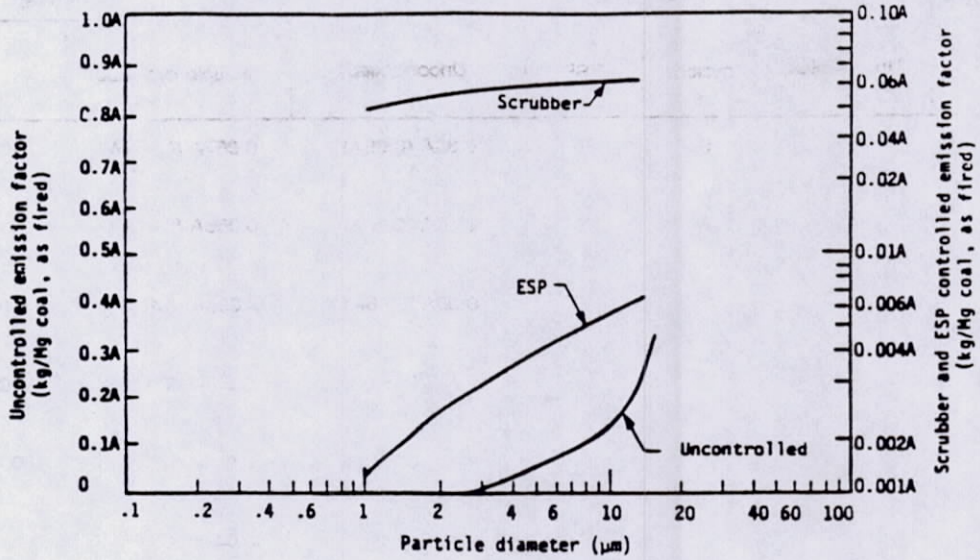

Figure 1.1-3. Cumulative size specific emission factors for cyclone furnaces burning bituminous coal.

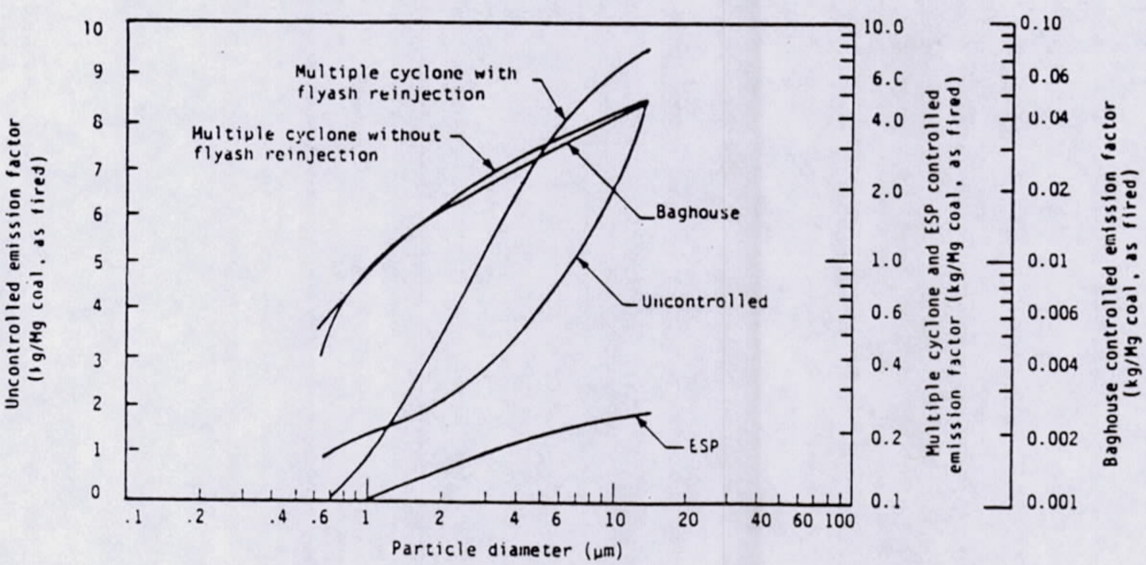

Figure 1.1-4. Cumulative size specific emission factors for spreader stokers burning bituminous coal.

TABLE 1.3-1 (METRIC UNITS). CRITERIA POLLUTANT EMISSION FACTORS FOR UNCONTROLLED FUEL OIL COMBUSTION

Firing Configuration (SCC)[a]	SO_2 [b]		SO_3 [c]		NO_x [d]		CO[e,f]		Filterable PM[g]	
	Emission Factor kg/10³ ℓ	Rating	Emission Factor kg/10³ ℓ	Rating	Emission Factor kg/10³ ℓ	Rating	Emission Factor kg/10³ ℓ	Rating	Emission Factor kg/10³ ℓ	Rating
Utility boilers										
No. 6 oil fired, normal firing (10100401)	19S	A	0.69S	C	8	A	0.6	A	h	A
No. 6 oil fired, tangential firing (10100404)	19S	A	0.69S	C	5	A	0.6	A	h	A
No. 5 oil fired, normal firing (10100405)	19S	A	0.69S	C	8	A	0.6	A	h	B
No. 5 oil fired, tangential firing (10100406)	19S	A	0.69S	C	5	A	0.6	A	h	B
No. 4 oil fired, normal firing (10100504)	18S	A	0.69S	C	8	A	0.6	A	h	B
No. 4 oil fired, tangential firing (10100505)	18S	A	0.69S	C	5	A	0.6	A	h	B
Industrial boilers										
No. 6 oil fired (102004-01/02/03)	19S	A	0.24S	A	0.6	A	0.6	A	h	A
No. 5 oil fired (10200404)	19S	A	0.24S	A	0.6	A	0.6	A	h	B

TABLE 1.3-3 (METRIC UNITS). EMISSION FACTORS FOR TOTAL ORGANIC COMPOUNDS (TOC), METHANE, AND NONMETHANE TOC (NMTOC) FROM UNCONTROLLED FUEL OIL COMBUSTION

Firing Configuration (SCC)[a]	TOC[b]		Methane[b]		NMTOC[b]	
	Emission Factor kg/10³ ℓ	Rating	Emission Factor kg/10³ ℓ	Rating	Emission Factor kg/10³ ℓ	Rating
Utility boilers						
No. 6 oil fired, normal firing (10100401)	0.125	A	0.034	A	0.091	A
No. 6 oil fired, tangential firing (10100404)	0.125	A	0.034	A	0.091	A
No. 5 oil fired, normal firing (10100405)	0.125	A	0.034	A	0.091	A
No. 5 oil fired, tangential firing (10100406)	0.125	A	0.034	A	0.091	A
No. 4 oil fired, normal firing (10100504)	0.125	A	0.034	A	0.091	A
No. 4 oil fired, tangential firing (10100505)	0.125	A	0.034	A	0.091	A
Industrial boilers						
No. 6 oil fired (102004-01/02/03)	0.154	A	0.12	A	0.034	A
No. 5 oil fired (10200404)	0.154	A	0.12	A	0.034	A
Distillate oil fired (102005-01/02/03)	0.030	A	0.006	A	0.024	A
No. 4 oil fired (10200504)	0.030	A	0.006	A	0.024	A
Commercial/institutional/residential combustors						
No. 6 oil fired (103004-01/02/03)	0.193	A	0.057	A	0.136	A
No. 5 oil fired (10300404)	0.193	A	0.057	A	0.136	A

Table 1.4-1. EMISSION FACTORS FOR PARTICULATE MATTER (PM) FROM NATURAL GAS COMBUSTION[a]

Combustor Type (Size, 10^6 Btu/hr heat input) [SCC][b]	Filterable PM[c]			Condensible PM[d]		
	kg/10^6 m^3	lb/10^6 ft^3	Rating	kg/10^6 m^3	lb/10^6 ft^3	Rating
Utility/large industrial boilers (>100) [10106001, 10100604]	16-80	1-5	B	ND[e]	ND	
Small industrial boilers (10 - 100) [10200602]	99	6.2	B	120	7.5	D
Commercial boilers (0.3 -<10) [10300603]	72	4.5	C	120	7.5	C
Residential furnaces (<0.3) [no SCC]	2.8	0.18	C	180	11	D

[a]References 9-14. All factors represent uncontrolled emissions. Units are kg of pollutant/10^6 cubic meters and lbs. of pollutant/10^6 cubic feet. Based on an average natural gas higher heating value of 8270 kcal/m^3 (1000 Btu/scf). The emission factors in this table may be converted to other natural gas heating values by multiplying the given emission factor by the ratio of the specified heating value to this average heating value.
[b]SCC = Source Classification Code.
[c]Filterable PM is that particulate matter collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train.
[d]Condensible PM is that particulate matter collected in the impinger portion of an EPA Method 5 (or equivalent) sampling train. Total PM is the sum of the filterable PM and condensible PM. All PM emissions can be assumed to be less than 10 microns in aerodynamic equivalent diameter (PM-10).
[e]ND = No data.

Table 1.4-2. EMISSION FACTORS FOR SULFUR DIOXIDE (SO_2), NITROGEN OXIDES (NO_x), AND CARBON MONOXIDE (CO) FROM NATURAL GAS COMBUSTION[a]

Combustor Type (Size, 10^6 Btu/hr heat input) [SCC][b]	SO_2[c]			NO_x[d]			CO[e]		
	$kg/10^6 m^3$	$lb/10^6 ft^3$	Rating	$kg/10^6 m^3$	$lb/10^6 ft^3$	Rating	$kg/10^6 m^3$	$lb/10^6 ft^3$	Rating
Utility/Large Industrial Boilers (>100) [10100601, 10100604]									
Uncontrolled	9.6	0.6	A	8800	550[f]	A	640	40	A
Controlled - Low NO_x burners	9.6	0.6	A	1300	81[f]	D	ND[g]	ND	
Controlled - Flue gas recirculation	9.6	0.6	A	850	53[f]	D	ND	ND	
Small Industrial Boilers (10-100) [10200602]									
Uncontrolled	9.6	0.6	A	2240	140	A	560	35	A
Controlled - Low NO_x burners	9.6	0.6	A	1300	81[f]	D	980	61	D
Controlled - Flue gas recirculation	9.6	0.6	A	480	30	C	590	37	C
Commercial Boilers (0.3-<10) [10300603]									
Uncontrolled	9.6	0.6	A	1600	100	B	330	21	C
Controlled - Low NO_x burners	9.6	0.6	A	270	17	C	425	27	C
Controlled - Flue gas recirculation	9.6	0.6	A	580	36	D	ND	ND	
Residential Furnaces (<0.3) [no SCC]									
Uncontrolled	9.6	0.6	A	1500	94	B	640	40	B

[a]Units are kg of pollutant/10^6 cubic meters and lbs. of pollutant/10^6 cubic feet. Based on an average natural gas higher heating value of 8270 $kcal/m^3$ (1000 Btu/scf). The emission factors in this table may be converted to other natural gas heating values by multiplying the given emission factor by the ratio of the specified heating value to this average heating value.
[b]SCC = Source Classification Code.
[d]Reference 7. Based on average sulfur content of natural gas, 4600 $g/10^6 Nm^3$ (2000 $gr/10^6$ scf).
[e]References 10, 15-19. Expressed as NO_2. For tangentially fired units, use 4400 $kg/10^6 m^3$ (275 $lb/10^6 ft^3$). At reduced loads, multiply factor by load reduction coefficient in Figure 1.4-1. Note that NO_x emissions from controlled boilers will be reduced at low load conditions.
[f]References 9-10, 16-18, 20-21.
[g]Emission factors apply to packaged boilers only.
[h]ND = No data.

Table 1.4-3. EMISSION FACTORS FOR CARBON DIOXIDE (CO_2), AND TOTAL ORGANIC COMPOUNDS (TOC) FROM NATURAL GAS COMBUSTION[a]

Combustor Type (Size, 10^6 Btu/hr heat input) [SCC][b]	CO_2[c]			TOC[d]		
	kg/$10^6 m^3$	lb/$10^6 ft^3$	Rating	kg/$10^6 m^3$	lb/$10^6 ft^3$	Rating
Utility/large industrial boilers (>100) [10100601, 10100604]	ND[e]	ND		28[f]	1.7[f]	C
Small industrial boilers (10-100) [10200602]	1.9E06	1.2E05	D	92[g]	5.8[g]	C
Commercial boilers (0.3-<10) [10300603]	1.9E06	1.2E05	C	92[h]	5.8[h]	C
Residential furnaces [no SCC]	2.0E06	1.3E05	D	180[h]	11[h]	D

[a]All factors represent uncontrolled emissions. Units are kg of pollutant/10^6 cubic meters and lbs. of pollutant/10^6 cubic feet. Based on an average natural gas higher heating value of 8270 kcal/m^3 (1000 Btu/scf). The emission factors in this table may be converted to other natural gas heating values bay multiplying the given factor by the ratio of the specified heating value to this average heating value.
[b]SCC = Source Classification Code.
[c]References 10, 22-23.
[d]References 9-10, 18.
[e]ND = No data.
[f]Reference 8: methane comprises 17 percent of organic compounds.
[g]Reference 8: methane comprises 52 percent of organic compounds.
[h]Reference 8: methane comprises 34 percent of organic compounds.

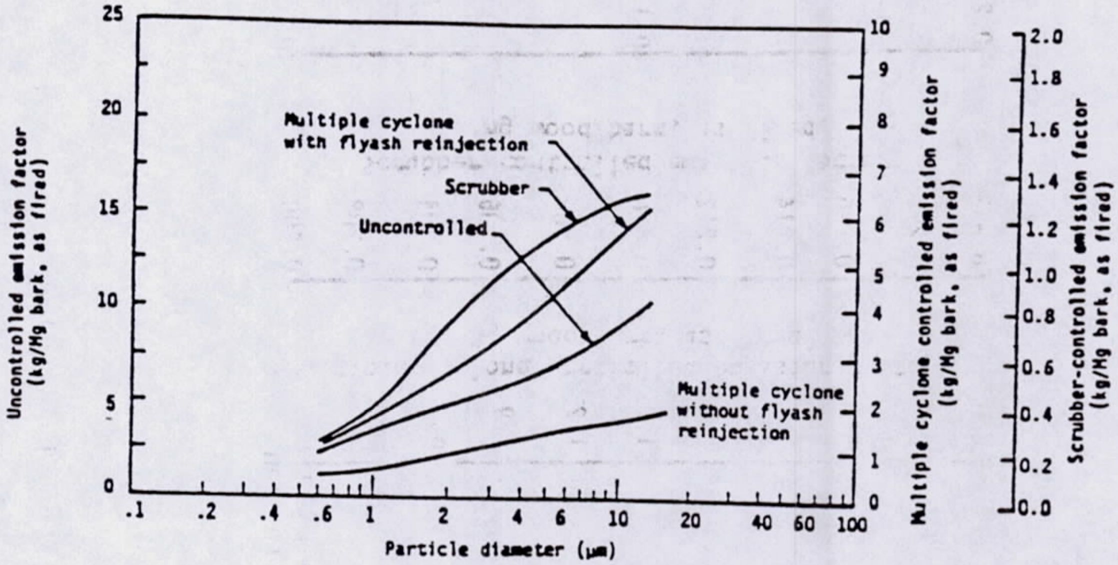

Figure 1.6-1. Cumulative size specific emission factors for bark fired boilers.

Table 1.6-1. EMISSION FACTORS FOR PARTICULATE MATTER (PM), PARTICULATE MATTER LESS THAN 10 MICRONS (PM-10), AND LEAD FROM WOOD WASTE COMBUSTION[a]

Source Category (SCC)[b]	PM[c]			PM-10[d]			Lead[e]		
	kg/Mg	lb/ton	Rating	kg/Mg	lb/ton	Rating	kg/Mg	lb/ton	Rating
Bark-fired boilers (10100901, 10200901, 10200904, 10300901)									
Uncontrolled	23.5	47	B	8.4	17	D	1.4E-03	2.9E-03	D
Mechanical collector									
with flyash reinjection	7	14	B	5.5	11	D	ND[f]	ND	
without flyash reinjection	4.5	9.0	B	1.6	3.2	D			
Wet scrubber	1.5	2.9	D	1.3	2.5	D	ND	ND	
Wood/bark-fired boilers (10100902, 10200902, 10200905, 10300902)									
Uncontrolled	3.6	7.2	C	3.2	6.5	E	ND	ND	
Mechanical collector									
with flyash reinjection	3.0	6.0	C	2.7	5.5	E	1.6E-04[g]	3.2E-04[g]	D
without flyash reinjection	2.7	5.3	C	0.08	1.7	E	1.6E-04[g]	3.2E-04[g]	
Wet scrubber	0.24	0.48	D	0.23	0.47	E	1.8E-04	3.5E-04	D
Electrostatic precipitator	0.02	0.04	D	ND	ND		8.0E-05	1.6E-05	D
Wood-fired boilers (10100903, 10200903, 10200906, 10300903)									
Uncontrolled	4.4	8.8	C	ND	ND		ND	ND	
Mechanical collector without flyash reinjection	2.1	4.2	C	1.3[h]	2.6[h]	D	1.5E-04	3.1E-04	D
Electrostatic precipitator	0.08	0.17	D	ND	ND		5.5E-03	1.1E-03	D

[a]Units are kg of pollutant/Mg of wood waste burned and lbs. of pollutant/ton of wood waste burned. Emission factors are based on wet, as-fired wood waste with average properties of 50 weight percent moisture and 2,500 kcal/kg (4,\500 Btu/lb) higher heating value.
[b]SCC = Source Classification Code.
[c]References 11-15.
[d]References 13, 16.
[e]References 11, 13-15, 17.
[f]ND = No data.
[g]Due to lead's relative volatility, it is assumed that flyash reinjection does not have a significant effect on lead emissions following mechanical collectors.
[h]Based on one test in which 61 percent of emitted PM was less than 10 micrometer in size.

Table 1.6-2. EMISSION FACTORS FOR NITROGEN OXIDES (NO_x), SULFUR OXIDES (SO_x), AND CARBON MONOXIDE (CO) FROM WOOD WASTE COMBUSTION[a]

Source Category (SCC)[b]	NO_x[c]			SO_x[d]			CO[e]		
	kg/Mg	lb/ton	Rating	kg/Mg	lb/ton	Rating	kg/Mg	lb/ton	Rating
Fuel cell/Dutch oven boiler (no SCC)	0.19 (0.0017-0.75)	0.38 (0.0033-1.5)	C	0.37 (0.005-0.1)	0.075 (0.01-0.2)	B	3.3 (0.33-11)	6.6 (0.65-21)	C
Stoker boilers (no SCC)	0.75 (0.33-1.8)	1.5 (0.66-3.6)	C	0.37 (0.005-0.1)	0.075 (0.01-0.2)	B	6.8 (0.95-40)	13.6 (1.9-80)	C
FBC boilers[f] (no SCC)	1.0	2.0	D	0.37 (0.005-0.1)	0.075 (0.01-0.2)	B	0.7 (0.24-1.2)	1.4 (0.47-2.4)	D

[a]Units are kg of pollutant/Mg of wood waste burned and lbs. of pollutant/ton of wood waste burned. Emission factors are based on wet, as-fired wood waste with average properties of 50 weight percent moisture and 2,500 kcal/kg (4,500 Btu/lb) higher heating value.
[b]SCC = Source Classification Code.
[c]References 12-14, 18-20. NO_x formation is primarily a function of wood nitrogen content. Higher values in the range (parentheses) should be used for wood nitrogen contents above a typical value of 0.08 weight percent, as fired.
[d]Reference 23. Lower limit of the range (in parentheses) should be used for wood and higher values for bark.
[e]References 11-15, 18, 24-26. Higher values in the range (in parentheses) should be used if combustion conditions are less than adequate, such as unusually wet wood or high air-to-fuel ratios.
[f]FBC = Fluidized bed combustion.