DEVELOPMENT OF FINE PARTICULATE EMISSION FACTORS AND SPECIATION PROFILES FOR OIL- AND GAS-FIRED COMBUSTION SYSTEMS

FINAL REPORT

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DEVELOPMENT OF FINE PARTICULATE EMISSION FACTORS AND SPECIATION PROFILES FOR OIL- AND GAS-FIRED COMBUSTION SYSTEMS

FINAL REPORT

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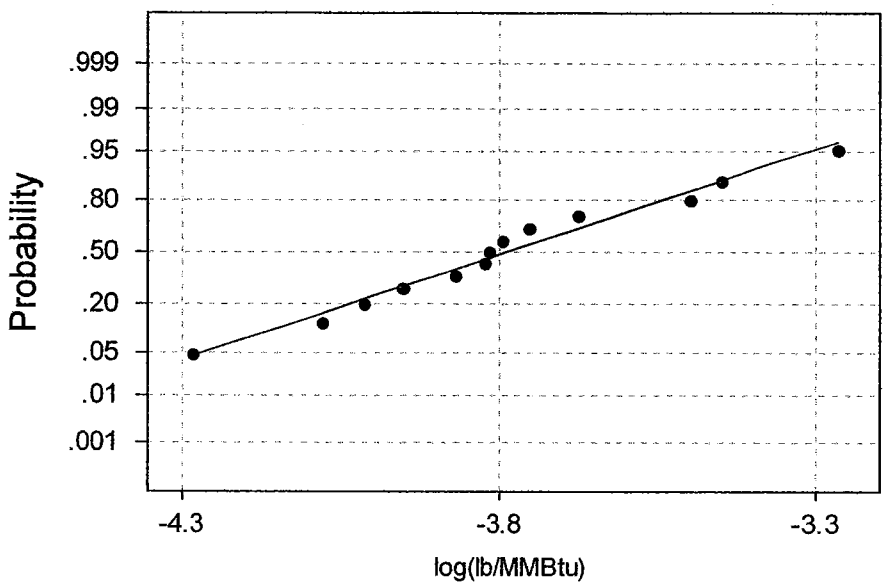
Table 3-3. PM2.5 Mass Emission Factors for No. 6 Oil-Fired Institutional Boiler.

Source	Description	Units	Value
Site Delta (Wien et al., 2004c)	Dual Fuel-fired Institutional Boiler (No. 6 Oil)	lb/MMBtu	1.0E-02
Site Delta (Wien et al., 2004c)	Dual Fuel-fired Institutional Boiler (No. 6 Oil)	lb/MMBtu	1.8E-02
Site Delta (Wien et al., 2004c)	Dual Fuel-fired Institutional Boiler (No. 6 Oil)	lb/MMBtu	1.8E-02
Site Delta (Wien et al., 2004c)	Dual Fuel-fired Institutional Boiler (No. 6 Oil)	lb/MMBtu	1.9E-02
Average (log mean)		**lb/MMBtu**	**1.6E-02**
Uncertainty (at 95% Confidence Level), %		%	40
95% Confidence Upper Bound, lb/MMBtu		lb/MMBtu	2.1E-02
5th Percentile		lb/MMBtu	1.1E-02
95th Percentile		lb/MMBtu	1.9E-02

Gas-Fired Internal Combustion Combined Cycle and Cogeneration Plants

Results of tests from two natural gas-fired combined cycle power plants and one refinery gas-fired cogeneration plant were combined for a total set of 13 data points. All of the units are equipped with similar post-combustion air pollution controls for NO_x and carbon monoxide (CO) emissions. Two of the units employ lean premix combustion systems, while the smaller unit (Site Golf) employed water injection for NO_x control. Two of the units were tested with duct burners (supplementary firing) operating during some or all of the test runs. Two units were fired on natural gas, while the other was fired on refinery process gas. The data from Site Echo include a total of seven data points, from tests at high load and low load. All seven points were included to provide a more robust indication of dispersion, although this biases the mean and uncertainty slightly. Results from Site Echo indicated that the results are probably positively biased due to background PM2.5 in the dilution air (England, 2004). The data are not corrected since a DSB was not collected for every run at every site. The data are lognormally distributed (Figure 3-4) and no outliers were identified. Therefore, the average and uncertainty are conservative estimates of PM2.5 emissions. The average PM2.5 emission factor is 1.9×10^{-4} with an uncertainty of ±49 percent at the 95 percent confidence level (Table 3-4). The 95 percent confidence upper bound falls within the data range. It should be noted that if background PM2.5 in the dilution air is subtracted from the stack PM2.5 for Site Echo, the corrected stack PM2.5 is indistinguishable from the measured ambient PM2.5 concentration at that site.



Average: -3.79238
StDev: 0.274355
N: 13

Anderson-Darling Normality Test
A-Squared: 0.197
-Value: 0.860

Figure 3-4. Normal Probability Chart for Gas-Fired Combined Cycle and Cogeneration Power Plant PM2.5 Mass Results.

Table 3-4. PM2.5 Mass Emission Factors for Gas-Fired Combined Cycle and Cogeneration Power Plants.

Source	Description	Units	Value
Site Bravo (Wien et al., 2004a)	Natural Gas-fired Combined Cycle Power Plant with supplementary firing, oxidation catalyst and SCR (4)	lb/MMBtu	5.2E-05
Site Echo (England et al., 2004)	Natural Gas-fired Combined Cycle Power Plant with lean premix combustion system, supplementary firing, oxidation catalyst and SCR	lb/MMBtu	8.3E-05
Site Echo (England et al., 2004)	Natural Gas-fired Combined Cycle Power Plant with lean premix combustion system, supplementary firing, oxidation catalyst and SCR	lb/MMBtu	9.7E-05
Site Echo (England et al., 2004)	Natural Gas-fired Combined Cycle Power Plant with lean premix combustion system, supplementary firing, oxidation catalyst and SCR	lb/MMBtu	1.1E-04
Site Echo (England et al., 2004)	Natural Gas-fired Combined Cycle Power Plant with lean premix combustion system, supplementary firing, oxidation catalyst and SCR	lb/MMBtu	1.3E-04
Site Echo (England et al., 2004)	Natural Gas-fired Combined Cycle Power Plant with lean premix combustion system, supplementary firing, oxidation catalyst and SCR	lb/MMBtu	1.5E-04
Site Echo (England et al., 2004)	Natural Gas-fired Combined Cycle Power Plant with lean premix combustion system, supplementary firing, oxidation catalyst and SCR (5)	lb/MMBtu	1.5E-04
Site Bravo (Wien et al., 2004a)	Natural Gas-fired Combined Cycle Power Plant with lean premix combustion system, supplementary firing, oxidation catalyst and SCR (5)	lb/MMBtu	1.6E-04
Site Echo (England et al., 2004)	Natural Gas-fired Combined Cycle Power Plant with lean premix combustion system, supplementary firing, oxidation catalyst and SCR (5)	lb/MMBtu	1.8E-04
Site Golf (England and McGrath, 2004b)	Refinery Gas-fired Cogen with supplementary firing, oxidation catalyst and SCR (3)	lb/MMBtu	2.1E-04
Site Golf (England and McGrath, 2004b)	Refinery Gas-fired Cogen with supplementary firing, oxidation catalyst and SCR (3)	lb/MMBtu	3.2E-04
Site Golf (England and McGrath, 2004b)	Refinery Gas-fired Cogen with supplementary firing, oxidation catalyst and SCR (3)	lb/MMBtu	3.5E-04
Site Bravo (Wien et al., 2004a)	Natural Gas-fired Combined Cycle Power Plant with supplementary firing, oxidation catalyst and SCR (3)	lb/MMBtu	5.4E-04
Site Bravo (Wien et al., 2004a)	Natural Gas-fired Combined Cycle Power Plant with supplementary firing, oxidation catalyst and SCR (3)	lb/MMBtu	NV
Average		**lb/MMBtu**	**1.9E-04**
Uncertainty (at 95% Confidence Level), %		%	49
95% Confidence Upper Bound, lb/MMBtu (2)		lb/MMBtu	2.8E-04
5th Percentile		lb/MMBtu	7.0E-05
95th Percentile		lb/MMBtu	4.3E-04

(2) 95% confidence upper bound is calculated at the 95% confidence level using the single-tailed Student t distribution. The 95% confidence upper bound provides a plausible upper bound (i.e., it is likely actual emissions are lower) for emissions.
(3) Duct burners on.
(4) Duct burners were on for a total of approx. 30 minutes of 360 minute run.
(5) High winds interfered with dilution sampler flow. Results biased high.

Diesel Engine

Tests at Site Foxtrot included tests of a Diesel-powered backup generator with and without a catalytic DPF at two different loads (50 and 75 percent of rated load). All measurements using

two different samplers for the DPF configuration are included (the result from each sampler was averaged for each test condition). Results for 50 and 75 percent load are combined for the base configuration but not for the DPF configuration because the combined data set is neither normal nor lognormal and the difference is significant at the 95 percent confidence level (based on t-test). The highest point in the 75 percent load DPF test is an outlier; however, no valid reason was found to exclude it. The average emission factor is 0.027 lb/MMBtu without the DPF and 0.0035 to 0.0046 with the DPF (Table 3-5).

Table 3-5. PM2.5 Emission Factors for a Diesel Engine.

Source	Description	Units	Value
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine (50% load)	lb/MMBtu	2.6E-02
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine (50% load)	lb/MMBtu	2.9E-02
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine (50% load)	lb/MMBtu	2.9E-02
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine (75% load)	lb/MMBtu	3.5E-02
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine (75% load)	lb/MMBtu	2.1E-02
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine (75% load)	lb/MMBtu	2.4E-02
Average		**lb/MMBtu**	**2.7E-02**
Uncertainty (at 95% Confidence Level), %		%	35
95% Confidence Upper Bound, lb/MMBtu		lb/MMBtu	3.5E-02
5th Percentile		lb/MMBtu	2.1E-02
95th Percentile		lb/MMBtu	3.4E-02

Source	Description	Units	Value
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine with DPF (75% load)	lb/MMBtu	3.5E-03
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine with DPF (75% load)	lb/MMBtu	3.4E-03
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine with DPF (75% load)	lb/MMBtu	3.3E-03
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine with DPF (75% load)	lb/MMBtu	3.8E-03
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine with DPF (75% load)	lb/MMBtu	3.4E-03
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine with DPF (75% load)	lb/MMBtu	3.4E-03
Average		**lb/MMBtu**	**3.5E-03**
Uncertainty (at 95% Confidence Level), %		%	15
95% Confidence Upper Bound, lb/MMBtu		lb/MMBtu	4.0E-03
5th Percentile		lb/MMBtu	3.3E-03
95th Percentile		lb/MMBtu	3.7E-03

Source	Description	Units	Value
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine with DPF (50% load)	lb/MMBtu	4.7E-03
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine with DPF (50% load)	lb/MMBtu	4.6E-03
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine with DPF (50% load)	lb/MMBtu	4.7E-03
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine with DPF (50% load)	lb/MMBtu	4.0E-03
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine with DPF (50% load)	lb/MMBtu	4.8E-03
Site Foxtrot (Hernandez et al., 2004)	Diesel Engine with DPF (50% load)	lb/MMBtu	5.0E-03
Average		**lb/MMBtu**	**4.6E-03**
Uncertainty (at 95% Confidence Level), %		%	16
95% Confidence Upper Bound, lb/MMBtu		lb/MMBtu	5.4E-03
5th Percentile		lb/MMBtu	4.2E-03
95th Percentile		lb/MMBtu	5.0E-03