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Multivariable Method To Estimate The Mercury Emissions Of The Best-Performing Coal-Fired Utility Units Under The Most Adverse Circumstances Which Can Reasonably Be Expected To Recur

ENSR Corporation
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EXECUTIVE SUMMARY

The U. S. Environmental Protection Agency ("EPA") is currently considering how to use the information contained in two mercury (Hg) information collection request ("ICR") databases (EPA ICR III ("ICR III") and EPA ICR II ("ICR II"))[1] to determine MACT floors for the regulation of mercury emissions from coal-fired utility units. In order to account for the inherent variability of unit emissions, it is ENSR's understanding that MACT floors should be set at levels that are achievable under the most adverse circumstances which can reasonably be expected to recur. Based on this understanding, ENSR has examined the data included in the ICR II and ICR III databases and developed a methodology for utilizing the maximum amount of information contained in the ICR II and ICR III databases to account for the variability of unit emissions and determine appropriate mercury MACT floor emission levels for bituminous, subbituminous and lignite coal-fired utility units.

The variability of mercury emissions from coal-fired units is significantly influenced by the variability over time in the composition of coal burned as fuel (*i.e*., differences in

[1] The ICR II dataset consists of periodic coal composition data for 455 power plants collected over the course of a year. The ICR III data set consists of stack testing results from 80 units with 3 tests per unit (240 tests) and other applicable coal mercury and chlorine data. Testing on a small number of these units produced only 2 useable stack tests, so the total number of stack tests is slightly lower.

mercury content, chlorine content and heat content of coal). In particular, the chlorine content of coal can be used as a key indicator of the type of mercury compound in flue gas. The effectiveness of control devices at removing mercury depends to a large extent on the levels of chlorine in the coal and the resultant type of mercury compound in the flue gas. Thus, which mercury compounds are present in the flue gas impacts the amount of mercury that will be captured by control devices and how much mercury will be released in stack emissions. Importantly, chlorine content has a significant impact on which mercury compounds are contained in the flue gas. When combined with other relevant data, such as coal mercury content, the chlorine content of coal can be used to predict mercury emissions. Accordingly, this study attempts to use the available data from the ICR II and ICR III databases, including coal chlorine composition where appropriate, to developed statistically robust estimates of the variability of mercury emissions as a result of variability over time in the composition of coal burned as fuel.

As discussed in Section 3, the data results from this multi-variable study lend support to the significance of coal chlorine content to mercury controllability. This is of particular significance in the control of mercury emissions from the western bituminous coal which as a result appear to behave similar to western subbituminous coal.

More specifically, ENSR utilizes both the ICR II and ICR III databases to evaluate the impact of fuel variability on mercury emissions of the top-performing units that comprise the MACT floor for each coal rank subcategory: bituminous, subbituminous and lignite. With only 3 stack tests (taken under essentially identical conditions) for each of 80 units, the ICR III stack test data provides only a limited number of short-term observations along the true range of mercury emissions from the tested generating units. While the ICR III database of stack tests is limited, the ICR II database contains extensive data on variation in coal composition recorded over the course of a year. The ICR II database, however, does not contain associated mercury stack emission data. Thus, the challenge in utilizing this extensive database of fuel variability is to link fuel composition to mercury emissions.

Previous approaches to incorporating emissions variability in the MACT floor have either not fully utilized the ICR III and ICR II databases (*i.e.,* Cole 2002 Study) to account for actual physical and chemical processes that cause variability or used correlation equations (*i.e*., UARG 2002 Study) that, while useful, do not provide a statistically sufficient level of confidence[2] that the predicted emission levels reflect actual unit performance. The technique utilized in this analysis has sought to overcome the limitations of both approaches.

Fundamental to this analysis is that it utilizes the ICR III stack test database to determine relationships between coal composition and mercury emissions so that the extensive ICR II fuel composition data can be utilized to assess the variation in mercury emissions over the full range of coal compositions. Where the ICR III data can be used to derive correlation equations between chlorine content and mercury removal that are statistically robust, an approach incorporating the chlorine, mercury and heat content of the coal is applied. In those instances where the data does not support such a correlation of mercury removal with chlorine content, a less sophisticated, but straightforward, secondary approach is used that applies the ICR III tested mercury removal fractions to the full range of ICR II coal mercury and heat content. It is necessary to use this secondary approach in order to apply the maximum amount of information in the

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[2] As used in this report, the terms "statistically sufficient level of confidence" or "statistically robust" typically mean a correlation coefficient ("r" squared) in a range of approximately 0.6 to 0.8, or higher.

ICR II database, that can be used in a statistically robust manner, to the determination of variability.

Specifically, ENSR first selected the best performing units for each coal rank subcategory (*i.e*., bituminous, subbituminous and lignite) as those having the lowest mercury emissions observed in the ICR III stack testing results. The different control configurations used by the best performing units were then identified and an analysis performed on each such control configuration to determine the relationship between mercury removal fraction and coal chlorine concentration. This relationship was represented as a correlation equation.

For each of the best performing units, a range of controlled mercury emission levels were then calculated using the test data for coal deliveries throughout a one-year period from the ICR II database. For each set of coal composition data from the ICR II database, the controlled mercury emissions were calculated by multiplying uncontrolled mercury emissions by (1 – mercury removal fraction).

For the above computation, test coal composition data from the ICR II database (heat and mercury content) was used to calculate the uncontrolled mercury emission level. The mercury removal fraction was derived in one of the following two ways: When the correlation equation for a particular unit's control configuration had adequate explanatory power (*i.e*., was a good fit to the data) the correlation equation was used to calculate the mercury removal fraction. If the applicable correlation equation had insufficient explanatory power, then the mercury removal fraction was based on the coal stack removal fraction observed in the ICR III stack tests of that unit.

For each of the best-performing sources, this process was repeated for each set of measured coal composition values, yielding a range of mercury emission levels for that unit. The estimated mercury emission levels for each best performing unit were then sorted from smallest to largest to obtain a cumulative frequency distribution. The 95th percentile value of this distribution (*i.e*., an emission rate that is expected to be exceeded only 5% of the time) was then determined to represent the operation of the unit under the most adverse circumstances reasonably expected to recur.

Finally, because the ICR III stack test units represent only a small portion of the true population of coal-fired utility units, ENSR considered it appropriate to account also for inter-unit variability between the top performers by calculating a 95% upper confidence level (UCL_{95}) for the average 95th percentile emission levels of the top performers from each coal rank subcategory.[3] This 95% upper confidence level, incorporating within-unit variability and between-unit variability, is reported as the MACT floor.

The MACT floor emission levels for each coal rank obtained using the above approach are shown in Table 1.

Table 1. Determined MACT Floor By Coal Rank

Coal Rank	**MACT Floor (lb Hg/TBtu)**
Bituminous	2.26
Subbituminous	5.75
Lignite	10.15

In addition, because of certain anomalies in the ICR III data and certain technical statistical reasons, as discussed in more detailed in the body of this report, alternative MACT

[3] This adjustment reflects the fact that the 5 sources do not represent the full population of the best performing 12% of coal-fired utility boiler units.

floors have been calculated for subbituminous and lignite MACT floors as set forth in Table 2.

Table 2. Alternative MACT Floor for Subbituminous and Lignite Coal

Coal Rank	MACT Floor (lb Hg/TBtu)
Bituminous	2.26
Subbituminous	4.15
Lignite	8.20

Although fuel variability accounts for most of the variability in the stack testing of each unit that comprises the ICR III database, other variability drivers, such as measurement error and intermittent maintenance events, also play a role in contributing to short-term increases in mercury emissions. Insofar as the methodology discussed herein does not incorporate these effects, the results likely underestimate the most adverse circumstances which can reasonably be expected to recur.

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INTRODUCTION

The Clean Air Act defines the MACT floor for existing sources as "the average emission limitation achieved by the best performing twelve percent of existing sources."[4] ENSR understands that, in order to account for the inherent variability of utility unit emissions, this standard has been interpreted by both the EPA and the courts as requiring that a MACT floor be "achievable under the most adverse circumstances which can reasonably be expected to recur."[5]

The variability of mercury emissions from coal-fired units is significantly influenced by the variability over time in the composition of coal burned as fuel (*i.e.*, differences in mercury content, chlorine content and heat content of coal). In particular, the chlorine content of coal can be used as a key indicator of the type of mercury compound in flue gas. The effectiveness of control devices at removing mercury depends to a large extent on the levels of chlorine in the coal and the resultant type of mercury compound in the flue gas. Thus, which mercury compounds are present in the flue gas impacts the amount of mercury that will be captured by control devices and how much mercury will be released in stack emissions. Importantly, chlorine content has a significant impact on which mercury compounds are contained in the flue gas. When combined with other relevant data, such as coal mercury content, the chlorine content of coal can be used to predict mercury emissions. Accordingly, in an effort to predict mercury emission levels of the best performing bituminous, subbituminous and lignite coal-fired units under the most adverse circumstances reasonably expected to recur, ENSR attempts to use available data from the ICR II and ICR III databases, including coal chlorine composition where appropriate, to developed statistically robust estimates of the variability of mercury emissions as a result of variability over time in the composition of coal burned as fuel.

The ICR II database contains the results of regular fuel composition sampling at approximately 455 power plant facilities over the course of a year. The ICR III database contains a collection of stack test reports on 80 units selected from the ICR II database. With only three stack tests per unit conducted under essentially identical conditions, the ICR III data alone are an insufficient basis for a robust estimate of emission variability

4 Clean Air Act §112 (d)(3)(A), 42 U.S.C. § 7412 (d)(3)(A).

5 64 Fed. Reg. 31898, 31915 (June 14, 1999) (National Emission Standards for Hazardous Air Pollutants for Source Categories; Portland Cement Manufacturing Industry) (final rule).

because the stack test results provide only a limited number of short-term observations over the true range of mercury emissions from the tested generating units. This is because the stack testing represents short-term measures of emissions performance that cannot eliminate the possibility that emissions may be higher (or lower) during the intervening periods when the unit's emissions are *not* being tested. Further, the stack testing was conducted under near-optimum conditions of full load, steady state operation and without intermittent maintenance events that tend to increase mercury emissions.

While the ICR III database of stack tests is limited, the ICR II database allows for at least some of these limitations to be overcome, as it contains extensive data on variation in coal composition recorded over the course of a year. However, the ICR II database does not contain mercury stack emission data. Thus, the challenge in utilizing the extensive ICR II database is to link fuel composition to mercury emissions.

Previous approaches to incorporating emissions variability in the MACT floor have been subject to certain deficiencies. One study (Cole 2002 Study) sought to ascertain the variability of mercury emissions by applying statistical techniques to the ICR III stack test data alone.[6] However, the primary driver of emissions variability is the variability of coal mercury and chlorine content. As noted, the ICR III stack test database fails to provide sufficient data, on its own, to develop robust estimates of the effect of fuel variability on mercury emissions. The ICR III stack test data provides only a limited number of short-term observations, failing to account for variability of emissions over the full range of operating conditions over an extended period of time. As a result, approaches that simply develop confidence intervals around the ICR stack test results are not grounded in the physical and chemical processes that drive emission variability.

On the other hand, another study (UARG 2002 Study) attempted to use the information contained in the ICR II and ICR III databases to account explicitly for the effects of fuel variability on mercury emissions. That study, however, used certain statistical correlations between coal composition and emissions (expressed as control device effectiveness) with limited predictive power. Similar to the current approach, correlation

[6] Research Triangle Institute ("RTI") has conducted a statistical analysis of the ICR III stack test data in an effort to quantify the uncertainty component that should be added to the mean values of the best 12 percent of the units chosen for MACT floor ("Cole 2002 Study"). ENSR has reviewed the results and methodology of the Cole 2002 Study and believes that it does not account for significant elements of variability, so that the MACT floors it recommends do not represent the performance of the best-performing sources under the worst reasonably foreseeable circumstances.

equations were developed to predict the mercury control efficiency of control devices as a function of coal chlorine content. However, an analysis of how well these correlation equations capture the relationships in the underlying data (expressed as a "correlation coefficient") indicate that, for certain control configurations, the derived correlation equations do not perform well. As a result, for some control configurations, the method does not provide a sufficiently high correlation coefficient ("r" squared) to justify confidence that its predictions accurately reflect the underlying effects of fuel variability on mercury emissions. Thus, use of such correlation equations in the UARG 2002 Study, while useful, may not accurately predict the impact of fuel variability on mercury emissions. The methodology presented in this report refines this approach to produce results that more accurately reflect actual unit performance.

ENSR's approach utilizes the ICR III stack test database to determine relationships between coal composition and mercury emissions so that the extensive ICR II fuel composition data can be used to assess the variation in mercury emissions over the full range of coal compositions. For those control configurations for which the ICR III data yields correlation equations between mercury removal fraction and chlorine concentration that are statistically robust, an approach incorporating the chlorine, mercury and heat content of the coal is applied. In those instances where the data does not support such a correlation between mercury removal fraction and chlorine content, a less sophisticated approach is used that applies the actual ICR III tested mercury removal fractions to the full range of ICR II tested coals. In this manner, the maximum amount of information in the ICR II database that can be used in a statistically robust manner is brought to bear on the determination of variability.

More specifically, ENSR first selected the best performing units for each coal rank subcategory (*i.e.*, bituminous, subbituminous and lignite) as those having the lowest mercury emissions observed in the ICR III stack testing results. The different control configurations used by the best performing units were then identified and an analysis performed on each such control configuration to determine the relationship between mercury removal fraction and coal chlorine concentration. This relationship was represented as a correlation equation.

For each of the best performing units, a range of controlled mercury emission levels were then calculated using the test data for coal deliveries throughout a one-year period from the ICR II database. For each set of coal composition data from the ICR II database, the controlled mercury emissions were calculated by multiplying uncontrolled mercury emissions by (1 – mercury removal fraction).

For the above computation, test coal composition data from the ICR II database (heat and mercury content) was used to calculate the uncontrolled mercury emission level. The mercury removal fraction was derived in one of the following two ways: When the correlation equation for a particular unit's control configuration had adequate explanatory power (*i.e*., was a good fit to the data) the correlation equation was used to calculate the mercury removal fraction. If the applicable correlation equation had insufficient explanatory power, then the mercury removal fraction was based on the coal stack removal fraction observed in the ICR III stack tests of that unit.

For each of the best-performing units, this process was repeated for each set of measured coal composition values, yielding a range of mercury emission levels for each unit. To determine emission levels under the most adverse circumstances reasonably expected to recur, the estimated mercury emission levels for each of the best performing units were sorted from smallest to largest to obtain a cumulative frequency distribution. The 95th percentile value of this distribution (i.e., an emission rate that is expected to be exceeded only 5% of the time) was determined to represent the operation of the unit under the most adverse circumstances reasonably expected to recur.

Finally, because the ICR III stack test units represent only a small portion of the full population of coal-fired utility units, simply averaging the results of emission levels estimated for the top 5 ICR III units in each subcategory would not account for the variability among all of the units in the top 12% of the full population of utility units. Thus, instead of simply averaging these results, ENSR calculated a 95% confidence level for this average. This 95% confidence level is reported as the MACT floor.

Mercury Chemistry in coal-fired boiler units

The variability of mercury emissions from coal-fired units is significantly influenced by the variability over time in the composition of coal burned as fuel (*i.e.*, differences in mercury content, chlorine content and heat content of coal). In particular, the chlorine content of coal can be used as a key indicator of the type of mercury compound in flue gas. The effectiveness of control devices at removing mercury depends to a large extent on the type of mercury compound in the flue gas. Thus, which mercury compounds are present in the flue gas impacts the amount of mercury that will be captured by control devices and how much mercury will be released in stack emissions. Importantly, chlorine content has a significant impact on which mercury compounds are contained in the flue gas. When combined with other relevant data, such as coal mercury content, the chlorine content of coal can be used to predict mercury emissions.

The data results from this multi-variable study (see Table 4 of this report) lend support to the significance of coal chlorine content to mercury controllability. The average emission factor for the best performing bituminous coal units is nearly one-eighth the average emission factor for the subbituminous coal units. This occurs in spite of the fact that the average concentration of mercury in the test coals is almost 2 times higher for the bituminous coals than for the subbituminous coals. This means that the mercury removal rates for these bituminous units are much higher than the mercury removal rates for the sub bituminous units. Coincidentally, the high average chlorine concentration in bituminous coal versus subbituminous (950 ppm vs. 120 ppm for the subbituminous coals) provides a possible explanation for this discrepancy. Each of the 5 bituminous coal units has a fabric filter to control particulate emissions, and 3 of the best performing bituminous coal units had a fabric filter in conjunction with a spray dryer absorber together with the highest chlorine concentrations in the test coals. With this configuration, the high chlorine concentration in the coal likely enhances the formation of mercuric chloride (ionic or oxidized mercury) that is captured by the fabric filter. In short, the 8 times higher average chlorine content in the best performing bituminous units appears to significantly facilitate mercury removal by those existing units. This is critical information portending the determination of mercury MACT floors for bituminous versus sub bituminous and lignite units.

In sum, coal chlorine content is one of the primary determinants of which mercury-containing compounds will be present – and in what amounts – in the flue gas of an individual utility unit. The differing physical and chemical properties of mercury-containing compounds in the flue gas result in significant differences in the feasibility and effectiveness of controls for removing the compounds from flue gas. Accordingly, when combined with other relevant data, such as coal mercury content, the chlorine content of coal can be used as a key indicator of mercury emissions.

STATISTICAL APPROACH

The following discussion presents ENSR's methodology for developing MACT floors for bituminous, subbituminous and lignite coals, taking into account the variability of mercury, chlorine and heat content of coal. Two data sets have been used in this analysis. The ICR III data set contains test results for mercury emissions at 80 units covering a range of coals and pollution control equipment. The ICR II data set is a collection of coal property values sampled over a one-year period for all coal-fired power plants > 25 MW, including the 80 units tested for mercury emissions.

The methodology consists of the following elements, each of which is discussed in more detail below:

1. The 80 units subject to stack testing were sorted by coal rank and certain units, such as fluidized bed combustors (FBCs), were eliminated from consideration based on characteristics that were not representative of the larger population of tested units.

2. For each coal rank, the best-performing 12% of units were identified.

3. The configuration of particulate/SO_2 controls at each of the best performing units was identified. For each identified control configuration, a study was performed to determine the relationship between mercury removal fraction and coal chlorine concentration. This analysis used test data from the ICR III database for all units employing one of the identified control configurations (not only the best-performing units). The relationship between mercury removal fraction and coal chlorine concentration was represented as a correlation equation.

4. For each of the best performing units, a range of controlled mercury emission levels were then calculated using the test data for their coal deliveries throughout a one-year period from the ICR II database. The uncontrolled mercury emission level and mercury removal fraction for each set of coal composition data in the ICR II database were derived to help calculate corresponding mercury emission levels. Test coal composition data from the ICR II database (heat and mercury content) was used to calculate the uncontrolled mercury emission level. The mercury removal fraction was calculated in one of the following two ways:

a. If the correlation equation determined in Step 3 for the particular unit's control configuration had adequate explanatory power (*i.e.,* was a good fit to the data), and the chlorine concentrations in the test coal data used to derive the equation were not uniformly low, then the equation derived in Step 3 was used to calculate the mercury removal fraction for the delivered coal. This approach accounted for variations in the mercury, chlorine and heat content of fuel.

b. If the applicable correlation equation had insufficient explanatory power, then mercury removal fraction was based on the average mercury removal fraction observed in the ICR III stack tests of that unit. Under this approach, the measured impact of fuel variability was limited to the effect of variations in mercury and heat content, while variations in chlorine concentration were not accounted for.

The uncontrolled mercury emission level was then multiplied by (1 – mercury removal fraction) to obtain the controlled mercury emission level. For each of the best-performing sources, this process was repeated for each set of measured coal composition values, yielding a range of mercury emission levels for that unit. All of the mercury emissions data for a given unit was calculated using one or the other of approach (a) or (b); approaches were not mixed for a given unit, but may have varied *among* units.

5. For each of the best performing units, the calculated mercury emission levels were then sorted from smallest to largest to obtain a cumulative frequency distribution. The 95th percentile value of this distribution (*i.e.,* an emission rate that is expected to be exceeded only 5% of the time) was then determined to represent the operation of the unit under the most adverse circumstances reasonably expected to recur. This value represents a measure of the within-unit variability of mercury emissions for a given unit. Finally, because the ICR III stack test units represent only a small portion of the full population of coal-fired utility units, simply averaging the results of emission levels estimated for the top 5 ICR III units in each subcategory would not account for the variability among all of the units in the top 12% of the full population of utility units. Thus, instead of simply averaging these results, ENSR calculated a 95% confidence level for this average. This 95% confidence level is reported as the MACT floor.

Sorting Of ICR Stack Test Database By Coal Rank

The first step in the analysis was to sort the units in the ICR III stack test by coal rank: bituminous, subbituminous and lignite. Six of the units that utilized FBCs were eliminated from the analysis at the outset, because they process coal in a fundamentally different way from other units. Also excluded were units burning the following coals during the test: 2 units burning waste bituminous coal; 4 units burning a combination of bituminous coal and petroleum coke; 1 unit burning a combination of subbituminous coal and petroleum coke; and 5 units burning a combination of bituminous and subbituminous coal. These units were excluded because the mixture of coals burned during the test does not allow extrapolation of the stack test results to predict mercury emissions from unmixed fuel. This left 29 bituminous units, 26 subbituminous units and 10 lignite units among the ICR III stack test database.

Identification Of Best Performing 12% Of Utility Units

The remaining units in each of the 3 coal ranks were then sorted in ascending order of stack tested mercury emission factor, measured in units of pounds of mercury per trillion Btu of heat input (lb Hg/TBtu) (as adjusted by a method that normalizes mercury emissions to coal heat content (F-factor Adjustment)).[7] The results of this sort are presented in Table 3. Because each subcategory consists of fewer than 30 units, in accordance with the Clean Air Act, the best performing 12% was taken to be the 5 units with the lowest emissions in each coal rank.[8] Accordingly, the top 5 best performing units of each coal rank were selected for further analysis. Selected parameters for these units are given in Table 4.

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[7] Coals vary somewhat in the amount of energy, or heat content, they contain. The purpose of the F-factor Adjustment is to ensure that mercury emission comparisons are related to the amount of energy contained in coal – *i.e.*, lb/TBtu – not the weight of the coal.

[8] *See* Clean Air Act §112(d)(3)(B), 42 U.S.C. §7412(d)(3)(B).

Table 3. Tested Coal Fired Units Sorted by Coal Type and Mercury Emission Factor

Bituminous			Subbituminous			Lignite		
Plant	Unit	lb Hg/TBtu F-Factor Out Control	Plant	Unit	lb Hg/TBtu F-Factor Out Control	Plant	Unit	lb Hg/TBtu F-Factor Out Control
Mecklenburg Cogen Facility	GEN 1	0.106	Clay Boswell	2	0.663	Antelope Valley Station	B1	4.004
Dwayne Collier Battle Cogen Facility	2B	0.107	Craig	C3	0.725	Leland Olds Station	2	4.023
Valmont	5	0.127	Cholla	3	1.207	Stanton Station	10	6.252
SEI - Birchwood Power Facility	1	0.238	Craig	C1	1.446	Stanton Station	1	6.902
Intermountain	2SGA	0.247	Coronado	U1B	2.447	Coyote	1	7.952
Logan Generating Plant	GEN 1	0.280	Comanche	2	2.593	Lewis & Clark	B1	10.832
Salem Harbor	3	0.335	Laramie River	1	3.018	Limestone	LIM1	13.661
Clover Power Station	2	0.353	Cholla	2	3.186	Monticello	3	18.323
W. H. Sammis	1	0.829	Laramie River	3	3.341	Big Brown	1	30.089
Charles R. Lowman	2	0.971	Clay Boswell	3	4.045	Monticello	1	55.869
Widows Creek Fossil Plant	6	1.399	San Juan	2	4.285			
Big Bend	BB03	1.565	Clay Boswell	4	4.455			
AES Cayuga (NY)	2	2.065	Jim Bridger	BW 74	4.704			
R. D. Morrow Sr. Generating Plant	2	2.127	Presque Isle	9	5.074			
Bailly	7	2.231	Lawrence	4	5.118			
Navajo	3	2.736	La Cygne	1	5.514			
Jack Watson	4	2.933	Colstrip	3	5.726			
Brayton Point	1	3.200	Montrose	1	5.857			
Bay Front Plant Generating	5	3.579	Newton	2	6.988			
Brayton Point	3	3.698	Wyodak	BW 91	7.070			
Cliffside	1	4.322	Sherburne County	#3	7.540			
Wabash River Generating Station	1 + 1A	5.334	George Neal South	4	7.727			
Polk Power	1	5.471	Rawhide	101	7.763			
Gaston	1	6.074	Sam Seymour	3	8.635			
Port Washington	4	6.692	Columbia	1	10.310			
Dunkirk	2	6.803	Platte	1	10.612			
Bruce Mansfield	1	7.099						
Gibson Generating Station (1099)	3	9.745						
Gibson Generating Station (0300)	3	29.061						

Table 4. Parameters for Best Performing Coal-Fired Units

Coal Type	Unit	Emission Control	Hg Concentration in Test Coal (ppm)	Average Hg Concentration in Sampled Coals (ppm)	Chlorine Concentration in Test Coal (ppm)	Hg Fraction Removal	lb Hg/TBtu F-Factor Out Control
Bituminous	Mecklenburg Cogeneration Facility GEN 1	FF/SDA	0.097	0.095	1893	0.988	0.106
	Dwayne Collier Battle Cogeneration Facility 2B	FF/SDA	0.030	0.077	1700	0.937	0.107
	Valmont 5	FF	0.008	0.039	39	0.865	0.127
	SEI - Birchwood Power Facility 1	FF/SDA	0.110	0.147	917	0.974	0.238
	Intermountain 2SGA	FF/WS	0.023	0.039	200	0.838	0.247
	Averages		***0.054***	***0.079***	**950**	-	**0.165**
Subbituminous	Clay Boswell 2	FF	0.057	0.070	50	0.826	0.663
	Craig C3	FF/SDA	0.010	0.025	117	0.336	0.725
	Cholla 3	HS	0.037	0.058	50	0.642	1.207
	Craig C1	HS/WS	0.023	0.025	267	0.237	1.446
	Coronado U1B	HS/WS	0.035	0.057	117	0.306	2.447
	Average		***0.032***	***0.047***	***120***	-	**1.297**
Lignite	Antelope Valley Station B1	FF/SDA	0.062	0.069	107	0.333	4.004
	Leland Olds Station 2	CS	0.041	0.073	91	0.049	4.023
	Stanton Station 10	FF/SDA	0.084	0.088	28	0.015	6.252
	Stanton Station 1	CS	0.082	0.088	50	0.441	6.902
	Coyote 1	FF/SDA	0.111	0.135	100	0.382	7.952
	Average		***0.076***	***0.091***	**75**	-	**5.827**

Notes:
FF - fabric filter
SDA - spray dryer absorber
WS - wet scrubber
HS - hot-side electrostatic precipitator
CS - cold-side electrostatic precipitator

Development Of Mercury Removal Correlation Equations For Each Particulate/SO_2 Control Combination

The limited number of stack tests in the ICR III database are insufficient to estimate the effect of fuel variability over time on the emissions of the best performing facilities. The ICR II database contains extensive data on variation in coal composition recorded over the course of a year. However, the ICR II database does not contain mercury emission data. Thus, the challenge in utilizing this extensive database of fuel variability was to link fuel composition to mercury emissions, the parameter of interest. To help make this link, correlation equations were developed to represent the relationship between mercury removal fraction and chlorine concentration for each of the control configurations used by the best performing units. The steps used to develop these correlation equations are set forth below.

First, the control configuration of each of the best performing 15 units identified in Table 3 was identified.[9] Next, the mercury removal fraction[10] and test coal chlorine concentrations were obtained from the ICR III database for each of the 65 non-excluded units in the ICR III database that have one of the identified control configurations.

Finally, a correlation equation was derived for each identified control configuration by fitting the following mathematical expression to the mercury removal fractions and corresponding chlorine concentrations obtained from the ICR III stack test database:

9 The identified control configurations are as follows (i) fabric filter / wet scrubber; (ii) fabric filter / spray dryer; (iii) fabric filter / no SO_2 control; (iv) hot-side ESP / wet scrubber; (v) hot-side ESP / no SO_2 control; cold-side ESP / no SO_2 control. No correlation equation was developed for the fabric filter / wet scrubber control configuration because there were an insufficient number of units to calculate an adequate correlation, leaving 5 control configurations for further analysis.

10 In this analysis, the mercury removal fraction was taken to be the following: In cases where a wet scrubber was used in conjunction with an electrostatic precipitator (ESP) (cold-side or hot side), the "coal-stack" removal fraction was used in the analysis to represent the mercury remove fraction because the ICR III stack test results for these configurations reported only the removal across the wet scrubber. For all other configurations, the control equipment removal fraction was used.

$$F_r = 1 - \beta \exp(-\alpha C_{CL}) \quad (1)$$

where

F_r = fraction of mercury removed during the test

C_{CL} = chlorine concentration in the test coal (ppm)

In the selection of the format of this correlation equation, care was taken that the mathematical expression accurately reflected the physical and chemical process by which chlorine contributes to the controllability of stack mercury emissions. Equation (1) is based on the assumption that the rate of conversion of mercury to mercury chloride is proportional to the chlorine concentration in the coal. With this expression, the maximum removal fraction is limited to 1, because the exponent term is always non-negative, regardless of the chlorine concentration. This corresponds to the real-world limitation that no more than 100% of the mercury in flue gas can be removed (*i.e.* there cannot be negative mercury emissions). And, as the coal chlorine concentration drops to zero, the mercury removal fraction approaches 1-â (this value does not of necessity approach zero because some mercury removal may be achieved without reaction with chlorine).[11]

For the purposes of performing the actual fit to the data, Equation (1) was converted to the following linear ("y = ax+ b") form:

$$-\ln(1 - F_r) = \alpha C_{CL} - \ln(\beta) \quad (2)$$

where

$x = C_{CL}$

$y = -\ln(1-F_r)$

a(slope) = á

b(intercept) = -ln(â)

[11] The correlation equation for hot-side ESP with no SO_2 control yielded a â > 1, implying a negative removal. Due to the physical impossibility of this outcome, this correlation equation was not used to predict mercury emissions.

The slope (a) and intercept (b) were determined by a least-squares fit. The Equation (1) parameters á and â were then determined from the slope and intercept as follows:

$$\boldsymbol{a} = a \qquad 3(a)$$

$$\boldsymbol{b} = \exp(-b) \qquad 3(b)$$

The purpose of deriving a correlation equation for each control configuration used by the top performing units was to provide a numerical means of predicting the fraction of mercury removed for the best performing sources over the entire range of fuel variability experienced over the course of a year. Correlation equations were derived for each control configuration, but were only used to predict mercury removal if they were found to have acceptable explanatory power.

To determine whether the explanatory power of each correlation equation warranted its use on a larger range of ICR II coal composition data, ENSR validated each correlation equation against ICR III stack test data. For each of the test chlorine concentrations in the ICR III stack test database, the mercury removal fraction was calculated by use of Equation (1) with parameters selected to give the best fit to the data. A correlation coefficient was then calculated to evaluate the accuracy of the fit. The correlation equation for each control configuration, along with a graphical representation of the quality of fit, is provided below in Figures 1 through 5.

Calculation Of Mercury Emissions From The Best Performing Units Over The Range Of Coal Composition Observed During The ICR II Sampling Period

For each of the best performing units, unit-specific coal composition data for a one-year period were extracted from the ICR II database to find the coal heat content, mercury content and chlorine content. For each set of coal composition data from the ICR II database, the controlled mercury emissions were calculated by multiplying uncontrolled mercury emissions by (1 – mercury removal fraction), as set forth below:

$$E = \frac{10^6 C_{HG}(1 - F_r(C_{CL}))}{H} \quad (4)$$

where

E = controlled mercury emission level (lb Hg/TBtu)

C_{HG} = mercury concentration in the coal sample (ppm)

C_{CL} = chlorine concentration in the coal sample (ppm)

H = heat content of the coal sample (Btu/lb)

F_r = fraction mercury removal (based upon the removal-chlorine correlation (if used) or ICR III stack test mercury removal fraction)

For each of the best-performing sources, this process was repeated for each set of measured coal composition values, yielding a range of mercury emission levels for that unit over time.

In the above formula, the test coal composition data from the ICR II database (heat and mercury content) was used to calculate the uncontrolled mercury emission level. The mercury removal fraction was calculated in one of the following two ways: Where the correlation equation was found to have sufficient explanatory power, it was used to estimate the mercury removal fraction based on coal chlorine composition data from the ICR II data base. This approach accounted for variations in the mercury, chlorine and heat content of fuel. Where the correlation equation was a poor fit, the mercury removal fraction was based on the average mercury removal fraction observed in the ICR III stack tests of that unit. This latter approach yielded a constant removal fraction based upon the source test, and had the effect of reducing the variability of predicted mercury emissions. Under this approach, the measured impact of fuel variability was limited to the effect of variations in mercury and heat content, while variations in chlorine concentration were not explicitly considered.

Application of this methodology resulted in the following approaches to estimating mercury removal fraction for each control configuration:

- ***Fabric filter / wet scrubber.*** A fit was not performed for the fabric filter/wet scrubber combination because there were only 2 units that had this control configuration, providing an insufficient data set to calculate a sufficient statistical correlation. Instead, estimated mercury emission levels using ICR II coal composition data were based on the mercury removal fraction observed in the ICR III stack tests.

- ***Fabric filter / spray dryer.*** The fabric filter/spray dryer absorber combination yielded the best fit (R^2=0.935). *See* Figure 1. This fit was used for 6 of the 7 units having a fabric filter/spray dryer absorber. *See* Table 5 for the data used in determining this fit. The fit was not used for the Craig Unit C3 due to the low chlorine concentrations and low chlorine concentration variability (virtually all samples showed 50 ppm chlorine). ENSR understands that there is a significant amount of uncertainty when measurements are made at such low chlorine concentrations. Of perhaps greater significance, the lack of variability in the chlorine content of coal burned by Craig Unit C3 implies that there was little, if any, chlorine-driven variation in the mercury control efficiency achieved by this unit. There nonetheless was fuel-driven variability in emissions, due to variability in the coal mercury content. ENSR used the average control efficiency measured as part of the ICR III stack tests to account for such variability.

Figure 1

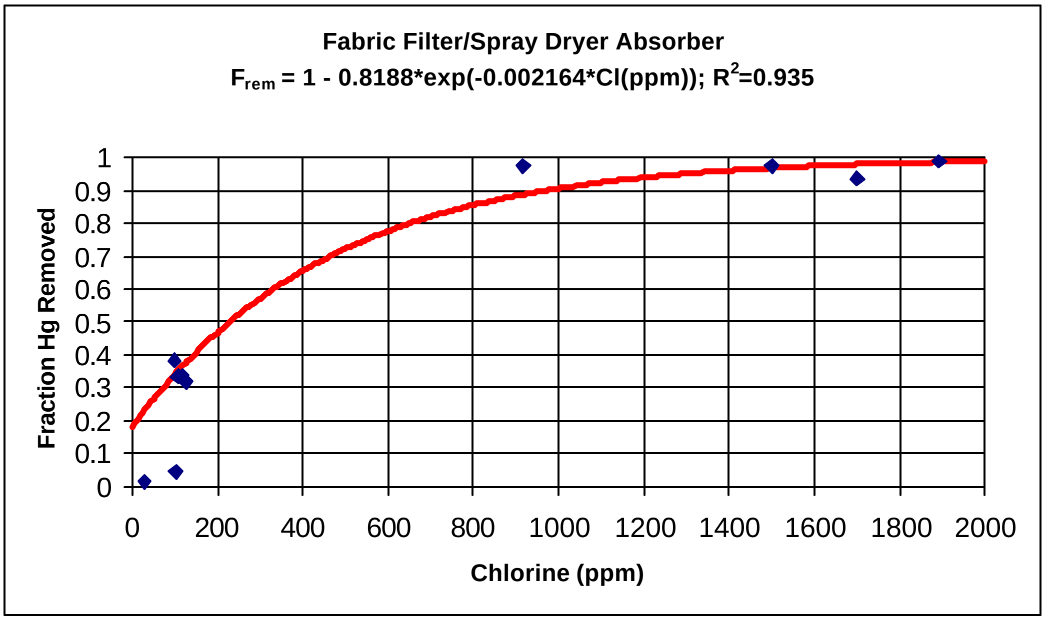


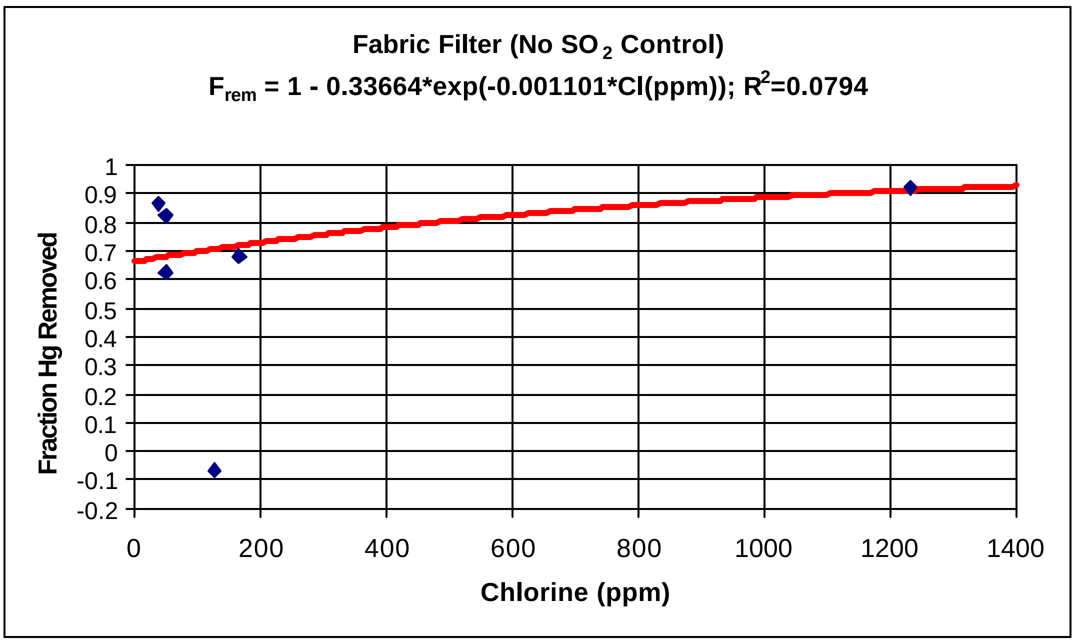
Table 5. Units Used for Removal-Chlorine Correlation for Fabric Filter/Spray Dryer Absorbers

Plant	Unit	Chlorine in Test Coal (ppm)	Fraction Hg Removed
Antelope Valley Station	B1	107	0.333
Coyote	1	100	0.382
Craig	C3	117	0.336

Dwayne Collier Battle Cogeneration Facility	2B	1700	0.937
Logan Generating Plant	GEN 1	1500	0.975
Mecklenburg Cogeneration Facility	GEN 1	1893	0.988
Rawhide	101	127	0.318
SEI - Birchwood Power Facility	1	917	0.974
Sherburne County Generating Plant	#3	102	0.045
Stanton Station	10	28	0.015

- ***Fabric filter / no SO_2 control.*** The fit for the fabric filter with no SO_2 control was poor (R^2=0.079) because there was only one coal sample with a high chlorine concentration. *See* Figure 2. The remaining chlorine concentrations fell in the low range, where measurement error can be significant. Therefore, this predicted correlation was not used in the variability analysis and predicted mercury emissions were based on the average stack test removal efficiency for this control configuration.

Figure 2



- ***Hot-side ESP / wet scrubber.*** Although the hot-side electrostatic precipitator/wet scrubber fit (Figure 3) was less than ideal (R^2=0.253), the fit was used for Coronado Unit 1B because it gave a removal fraction close to the test value. In other words, the correlation equation predicted almost exactly the removals observed in the ICR III stack tests. Also, the year-long coal sampling at this plant found considerable variation in chlorine coal concentrations, so that a method of accounting for this variation was necessary (conversely, applying the constant mercury removal rate observed in the ICR III stack test was not warranted and not conservative). *See* Table 6 for the data used in the development of this correlation.

Figure 3

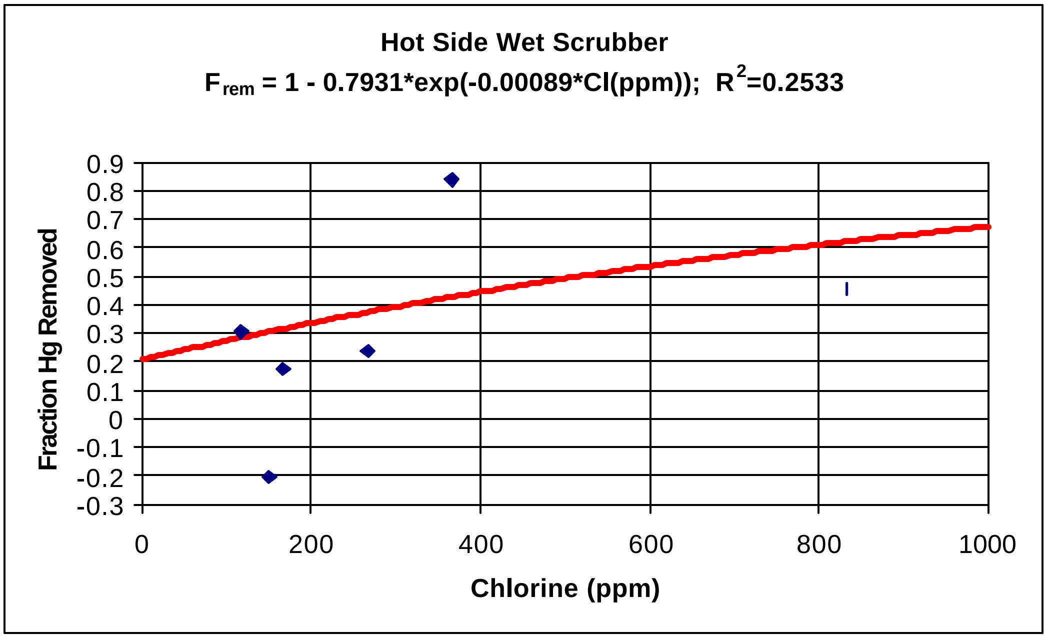
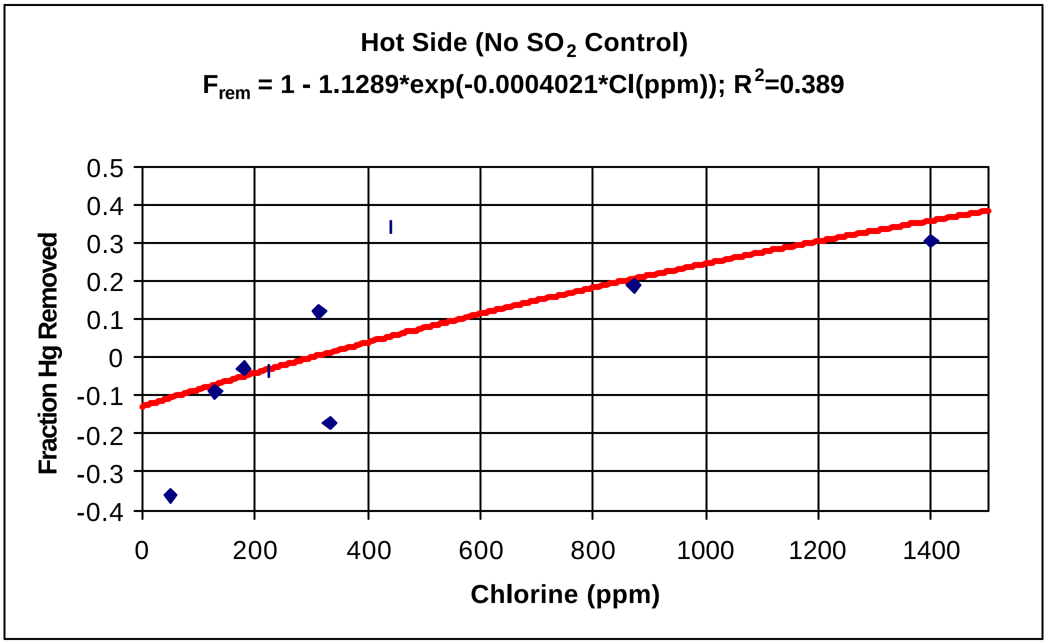


Table 6. Units Used for Removal-Chlorine Correlation for Hot-Side Precipitator/Wet Scrubber

Plant	Unit	Chlorine in Test Coal (ppm)	Fraction Hg Removed
Charles R. Lowman	2	367	0.840
Coronado	U1B	117	0.306
Craig	C1	267	0.237
Navajo	3	150	-0.205
R. D. Morrow Sr. Generating plant	2	833	0.457
San Juan	2	167	0.175

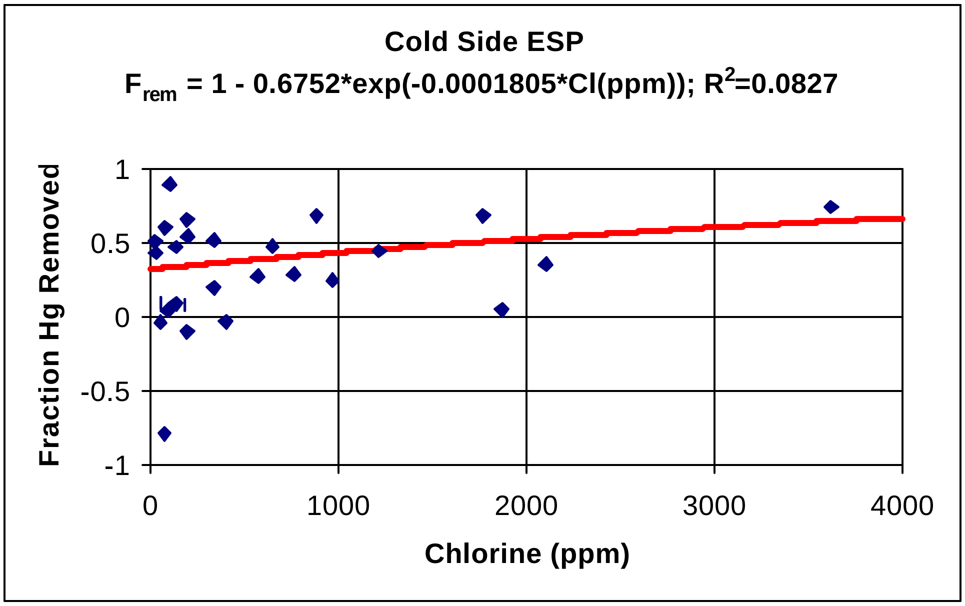
- ***Hot-side ESP / no SO_2 control.*** Although the hot-side electrostatic precipitator (no SO_2 control) fit was better (R^2=0.389), the resulting correlation equation could not be used because it gave negative removal values at chlorine concentrations below 300 ppm. In addition, the coal sampling data for this control configuration showed very little variation in chlorine concentrations. *See* Figure 4. Therefore, the predicted mercury removals were based on the relevant ICR III stack removals.

Figure 4



- ***Cold-side ESP / no SO_2 control.*** The fit for the cold-side electrostatic precipitator (no SO_2 control) could not be used because of its poor correlation (R^2=0.0827), which was due primarily to the relatively large number of low measured chlorine concentrations in the data set. *See* Figure 5. ENSR understands that chlorine measurements in this range are prone to significant measurement error. Here again the predicted mercury removals were based on the relevant ICR III stack removals.

Figure 5



Emissions Of The Best Performing Sources Under The Most Adverse Circumstances Reasonably Expected To Recur

For each of the best performing units, the calculated mercury emissions calculated in accordance with Section 3.5 above, were then sorted from smallest to largest to obtain a cumulative frequency distribution ("CDF"). The CDF for each unit is provided in Appendices 1-3. The 95th percentile value of this distribution (*i.e.,* an emission rate that is expected to be exceeded only 5% of the time) was determined to represent the operation of the unit under "worst conditions."

Because the ICR III stack test facilities represent only a small portion of the true population of coal-fired utility units, it is necessary also to account for inter-unit variability between the top performers. The ICR II database indicates that the population of coal-fired units exceeds 1000. Yet, due to the limited size of the ICR III database, the analysis of within-unit variability considered only the top 5 units in each subcategory. Therefore, the actual number of the top 12% of coal-fired units in each subcategory is significantly larger than the number of units used in this analysis, particularly with respect to units burning bituminous and subbituminous coal. Under these circumstances, a focus on within-unit variability alone is not expected to capture the full range of emissions variability among the best performing sources. ENSR accounted for this variability by calculating a 95% upper confidence level for the mean by use of the t-statistic. This adjustment reflects the fact that the 5 sources do not represent the full population of the best performing 12% of coal-fired utility units.

The 95th percent upper confidence limit for this average is calculated for each coal type as follows:

$$UCL_{95} = \overline{E_{WC}} + \frac{t_{n-1,95}\, s}{\sqrt{n}} \qquad (5)$$

$$\overline{E_{WC}} = \frac{\sum_{i=1}^{n} E_{WCi}}{n} \text{ where}$$

$$s = \sqrt{\frac{\sum_{i=1}^{n}\left(E_{WCi} - \overline{E_{WC}}\right)^2}{n-1}}$$

n = number of samples (5)

E_{WCi} = worst-case emission factor for unit i (lb Hg/TBtu)

$t_{n-1,95}$ = t-statistic for 95 percent confidence for n-1 degrees of freedom

= 2.132 for n=5

UCL_{95} values for each coal rank are set forth in Table 7. These values, expressed as an emission rate, are presented as the MACT floor.

Elements Of Variability Not Captured By This Method

Although fuel variability is a principal cause of emission variability, other factors also play a role in contributing to variability in mercury emissions. Analysis of fuel variability accounts for some, but not all of the variability in the stack testing of each unit that comprises the ICR III database. Other drivers of variability in the test results, such as measurement error, are not included in the analysis. Intermittent maintenance events, which themselves can contribute to short-term increases in mercury emissions, also are not considered.[12] In addition, the stack testing on which this assessment is based places artificial limitations on the variability of its results. Testing was performed with plants operating at full and constant load, and without on-going maintenance activities. Actual operation requires load-following in addition to intermittent maintenance activities. Insofar as the methodology discussed herein does not incorporate these effects, its results are likely to underestimate the reasonable worst-case emissions of the best performing facilities.

Alternative MACT Floors for Subbituminous and Lignite Coal

A number of factors suggest that it may be appropriate to replace Coronado with Comanche in the list of 5 top performing subbituminous coal plants. First, as evidenced in Table 2, there is a virtual tie for the 5th best performing subbituminous coal unit between Coronado Unit UB1 and Comanche Unit 2. Indeed, the emission factor for Coronado is only about 6 percent less than that for Comanche. In addition, the measured mercury removal data for Comanche show much less scatter than the corresponding data for Coronado. Finally, the percent removal across the wet scrubber at Coronado was found to be negative for all three measurements. In light of these factors, it may be appropriate to replace Coronado with Comanche in the list of 5 top performing subbituminous coal plants. The 95th percentile mercury emission factor for Comanche was calculated to be 3.53 lb/TBtu compared with the corresponding value of 6.96 lb/TBtu for Coronado. If Coronado was replaced with Comanche the UCL_{95} of the mean of the worst-case mercury emission factors drops from 5.75 to 4.15 lb/Tbtu. *See* Table 2.

To account for inter-unit variability the MACT floor has been chosen to be the 95 percent upper confidence limit of the mean of the worst-case emission factors. This approach was followed to account for the fact that the units tested for a particular coal were only a small fraction of the total number of possible units burning that type of coal. In the case of lignite, however, almost half (10 out of 23) of the units were tested. For this reason a straight average of the worst-case emission factors would be a more

12 For example, stack test results for Cinergy's Gibson plant – the only unit in the ICR database with two sets of stack tests – demonstrate that daily maintenance activities, such as operation of the air heater soot blowers, can cause significant increases in mercury emissions.

appropriate MACT floor than the UCL_{95}. With this modification the MACT floor for lignite would drop from 10.15 to 8.20 lb/TBtu. *See* Table 2.

DATA SETS

ENSR's analysis is based on two databases: ICR III and ICR II. The ICR II database contains the results of tests on coal delivered to 455 power plants during the year 1999. Although not every coal delivery was sampled, an effort was made to have the samples evenly distributed throughout the year. The following information was recorded for each of the samples:

- Plant name
- Delivery date
- Amount of coal delivered (tons)
- Heat content (Btu/lb)
- Sulfur content (percent)
- Ash content (percent)
- Mercury content (ppm)
- Chlorine content (ppm)

All quantities are reported on a dry basis.

The ICR III Database contains the results of source tests on 80 coal-fired units at power plants covered by the ICR II Database. For each unit, the type of unit and particulate/sulfur dioxide control are identified along with the type of coal used during the test. Each test consisted of 3 measurements of the mercury content, mercury emission factor (lb Hg/TBtu) and the fraction of mercury removed. These measurements, along with their averages, are reported in the database. The average chlorine content of the test coal is also reported. The mercury emission factor is broken down as particulate, oxidized and elemental. The fraction of mercury removed is given in two ways. The first is the removal across the control device tested based upon measurements upstream and downstream of the device. The second is the removal based upon properties of the coal used in the test and measurements downstream of the last control device.

There has been extensive discussion in the development of the NESHAP for utility units of subcategorizing units by the coal rank of their fuel. Accordingly, ENSR determined MACT floor values for subcategories burning bituminous, subbituminous and lignite coals. Such groupings are supported by a previous analysis of the basis and rationale for subcategorization in the regulation of utility mercury emissions,[13] previous studies by EPRI and the earlier study by ENSR using analysis of variance (ANOVA) techniques to identify subgroups within the ICR data set.[14]

13 M. Geers and C. O'Brien, "Basis And Rationale For Potential Subcategorization Of Coal-Fired Electric Utility Steam Generating Units" March 8, 2002.

14 West Associates, "Analysis of Variance in the EPA Mercury ICR Data Set," ENSR Corporation, October 2002, Doc. No. 06200-029-171.

RESULTS

The results of the analysis described in Section 3 are provided in Table 7 below.

[Table 7 is set forth on the following page]

Table 7. Results of the Mercury Emission Factor Variability Analysis

Coal Type	Unit	Chlorine Removal Correlation Used?	Comments	Particulate Control	Sulfur Dioxide Control	95th Percentile lb Hg/TBtu from Hg/Cl Variability
Bituminous	Mecklenburg Cogeneration Facility GEN 1	Yes	Used Removal-Chlorine Correlation for FF/SDA.	FF	SDA	1.570
	Dwayne Collier Battle Cogeneration Facility 2B	Yes	Used Removal-Chlorine Correlation for FF/SDA.	FF	SDA	0.613
	Valmont 5	No	Used Fraction Removal for Control Device for all samples because of poor Removal-Chlorine Correlation for FF.	FF	None	0.682
	SEI - Birchwood Power Facility 1	Yes	Used Removal-Chlorine Correlation for FF/SDA.	FF	SDA	2.927
	Intermountain 2SGA	No	Used Fraction Removal (Coal-Stack) for all samples due to lack of data (only 2 points) available to establish a Removal-Chlorine relationship for FF/WetScrubber.	FF	WS	0.933
	95th Percent Confidence Limit of Mean					***2.262***
Subbituminous	Clay Boswell 2	No	Used Fraction Removal for Control Device for all samples because the Removal-Chlorine Correlation was poor for FF.	FF	None	1.690
	Craig C3	No	Used Fraction Removal for Control Device for all samples because of the low chlorine concentrations and low chlorine variability for the samples.	FF	SDA	2.188
	Cholla 3	No	Used Fraction Removal for (Coal-Stack) for all samples because of low chlorine content and no variability in chlorine content of the samples.	HS	None	4.857
	Craig C1	No	Used Fraction Removal (Coal-Stack) for all samples because of the low chlorine concentrations and low chlorine variability in the samples.	HS	WS	2.515
	Coronado U1B	Yes	Used Removal-Chlorine Correlation for HS/WetScrubber.	HS	WS	6.955
	95th Percent Confidence Limit of Mean					***5.754***
Lignite	Antelope Valley Station B1	Yes	Used Removal-Chlorine Correlation for FF/SDA.	FF	SDA	6.620
	Leland Olds Station 2	No	Used Fraction Removal for Control Device for all samples due to the poor Removal-Chlorine Correlation for Cold Side Precipitators and the low chlorine concentrations in the samples.	CS	None	8.796
	Stanton Station 10	Yes	Used Removal-Chlorine Correlation for FF/SDA.	FF	SDA	7.895
	Stanton Station 1	No	Used Fraction Removal for Coal-Stack for all samples due to low chlorine concentrations in samples and the poor Removal-Chlorine Correlation for Cold Side Precipitators.	CS	None	6.300
	Coyote 1	Yes	Used Removal-Chlorine Correlation for FF/SDA.	FF	SDA	11.390
	95th Percent Confidence Limit of Mean					***10.150***

Notes:
FF - fabric filter
SDA - spray dryer absorber
WS - wet scrubber
HS - hot-side electrostatic precipitator
CS - cold-side electrostatic precipitator

Conclusions

This report presents a methodology designed to account for the effect of variation in coal mercury, chlorine and heat content on the variability of mercury emissions from coal-fired power plant units. The approach combines the ICR III stack test results with the more extensive fuel data in the ICR II database. Fundamental to this approach is that it brings to bear on the determination of variability the maximum amount of information from these two databases that can be used in a statistically robust manner.

Previous approaches for incorporating emissions variability in the MACT floor have either not fully utilized the ICR III and ICR II databases to account for actual physical and chemical processes that cause variability or used correlation equations that, while useful, do not provide robust confidence that the predicted emission levels reflect actual unit performance. This analysis is intended to bridge the gap between these previous approaches that were either not statistically robust or information-rich.

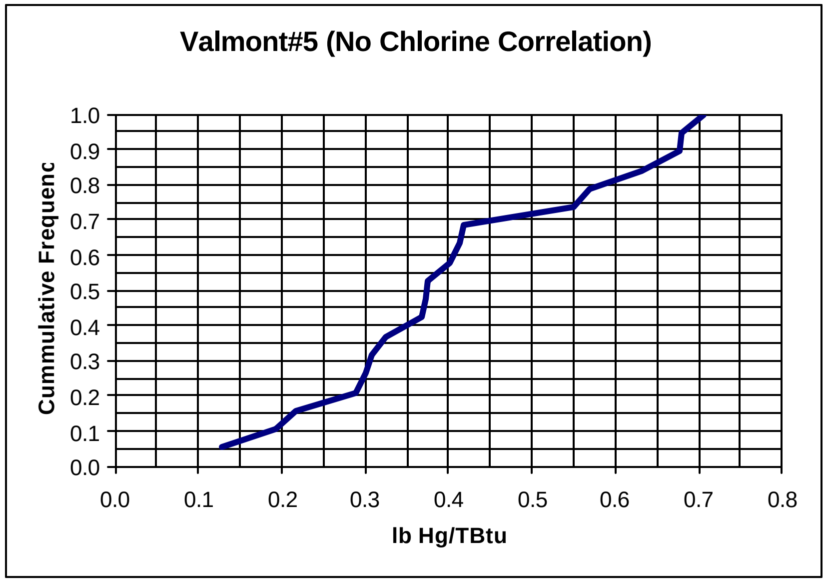
The methodology presented in this report utilizes the maximum amount of information contained in the ICR III and ICR II databases to account for the inherent variability of plant emissions over time and determine appropriate mercury MACT floor emission levels for bituminous, subbituminous and lignite coal-fired power plant units. Accordingly, the MACT floor emission levels developed in this analysis represent statistically robust estimates of the variability of mercury emissions as a result of variability over time in the composition of coal burned as fuel. Although fuel variability accounts for most of the variability in the stack testing of each unit that comprises the ICR III database, other variability drivers, such as measurement error and intermittent maintenance events, also play a role in contributing to short-term increases in mercury emissions. Insofar as the methodology discussed herein does not incorporate these effects, the results likely underestimate the most adverse circumstances which can reasonably be expected to recur.

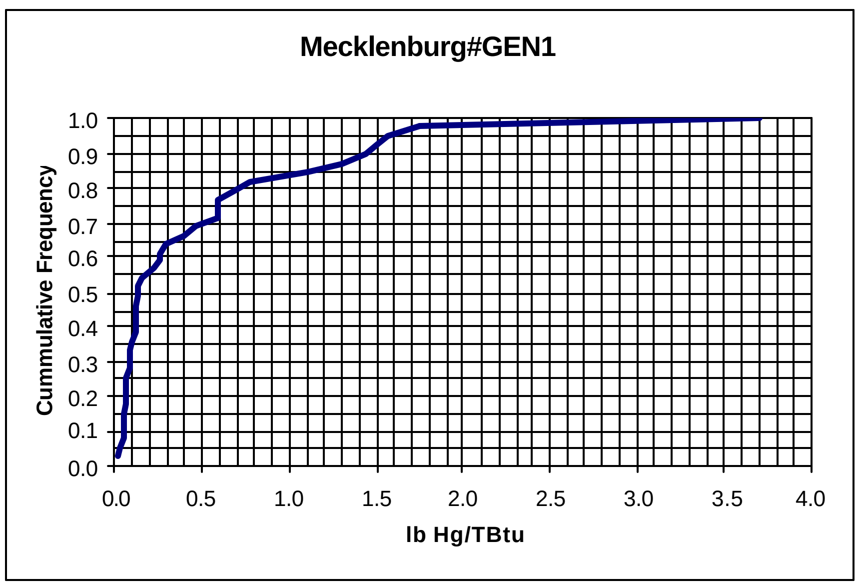
REFERENCES

Cole, Jeffrey. 2002. RTI Draft report to William Maxwell, EPA/OAQPS/ESD/CG. Statistical Analysis of Mercury Test Data Variability in Support of a Determination of the MACT Floor for the Regulation of Mercury Air Emissions from Coal-Fired Electric Utility Plants. RTI.

West Associates. 2002. Power Point presentation to the Clean Air Act Advisory Committee -- Permits/New Source Review/Air Toxics Subcommittee -- Utility MACT Working Group September 9, 2002.

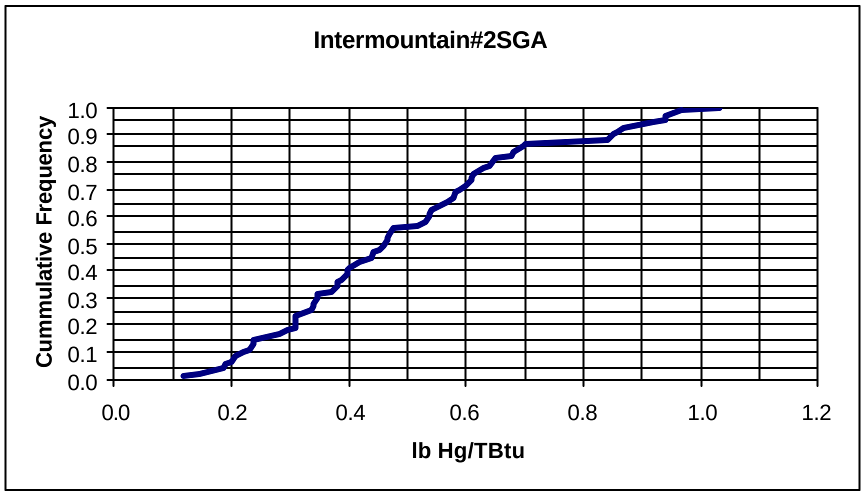
Appendix 1.
Cumulative Frequency Distributions of Mercury Emissions from Bituminous Units





DC\566987.6


SEI-Birchwood#1
Cummulative Frequency
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
lb Hg/TBtu


Intermountain#2SGA
Cummulative Frequency
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
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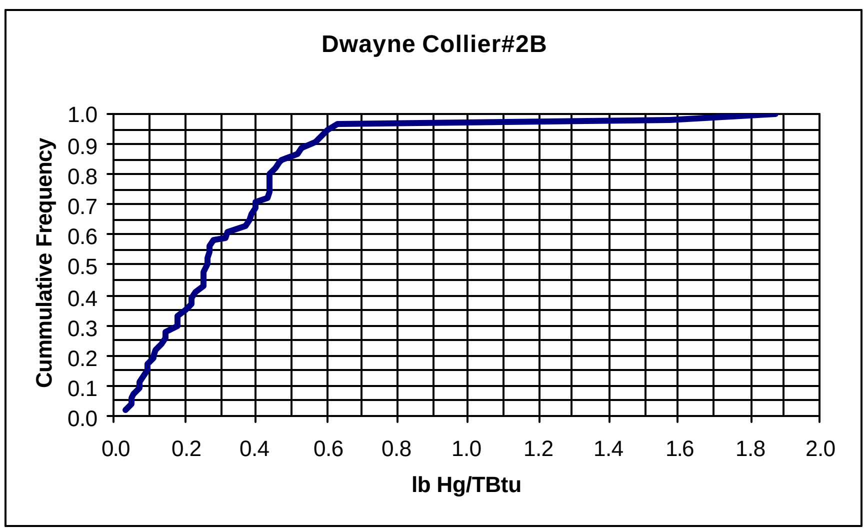
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
lb Hg/TBtu


Dwayne Collier#2B
Cummulative Frequency
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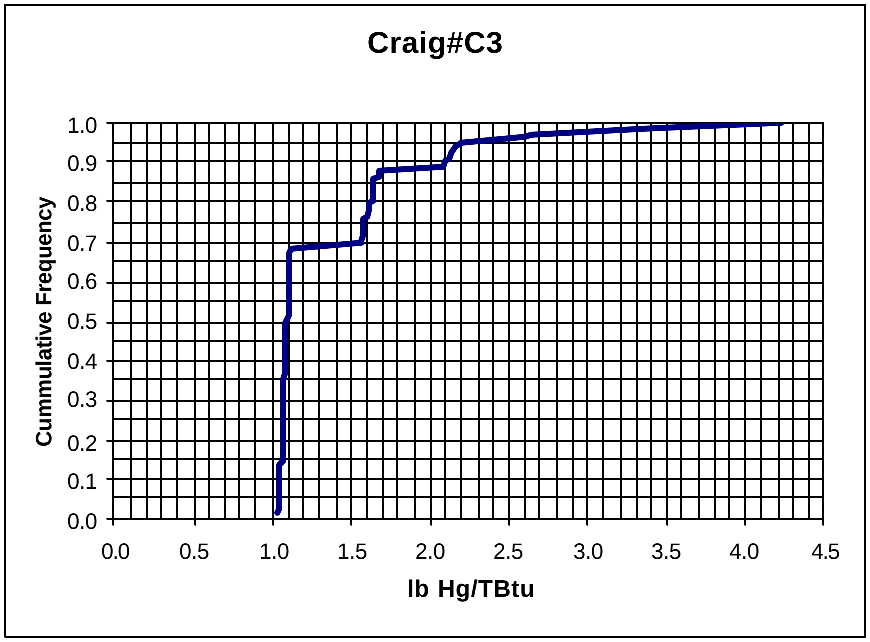
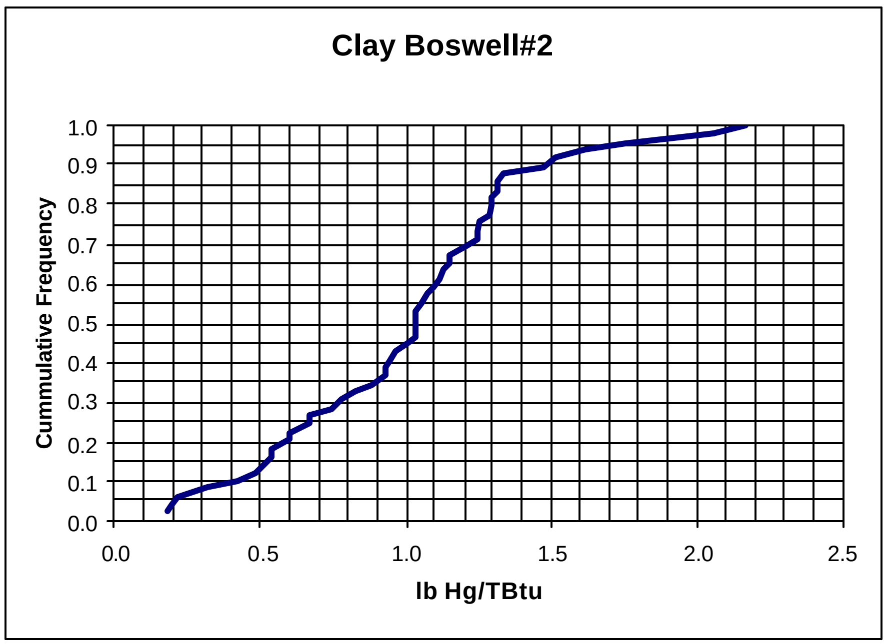
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
lb Hg/TBtu

DC\566987.6

Appendix 2.
Cumulative Frequency Distributions of Mercury Emissions from Subbituminous Units





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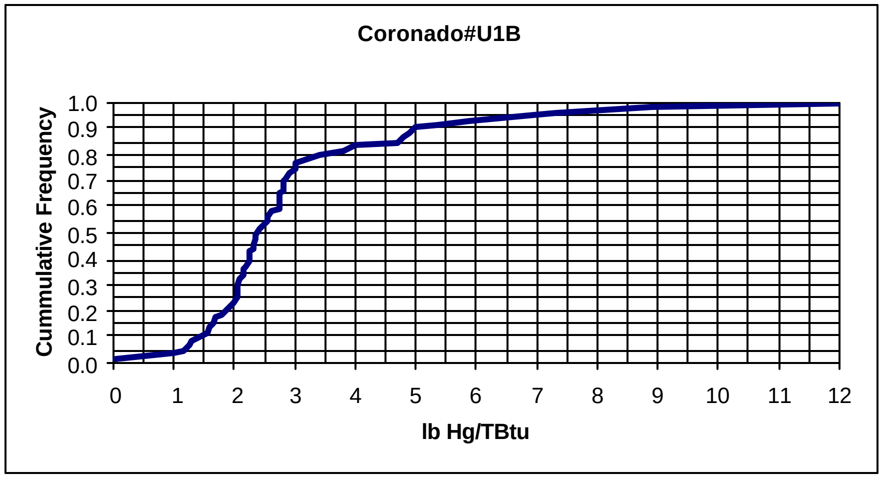
Coronado#U1B
Cummulative Frequency
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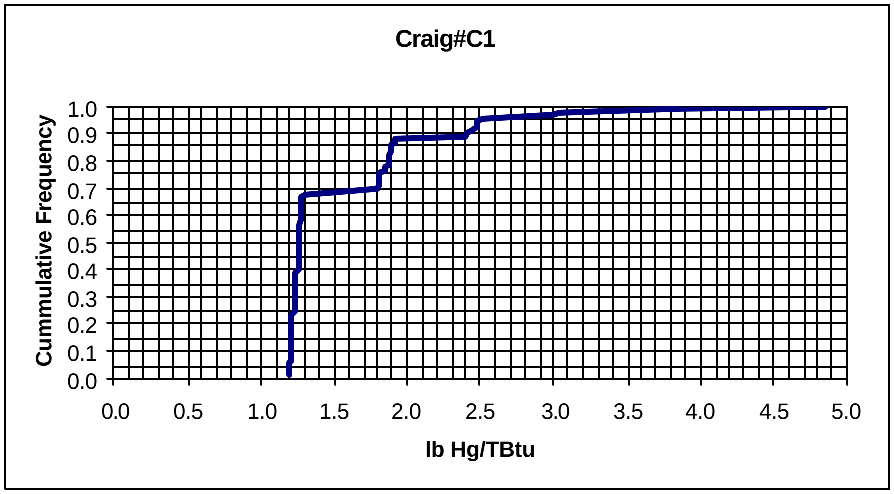
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
4
5
6
7
8
9
10
11
12
lb Hg/TBtu


Craig#C1
Cummulative Frequency
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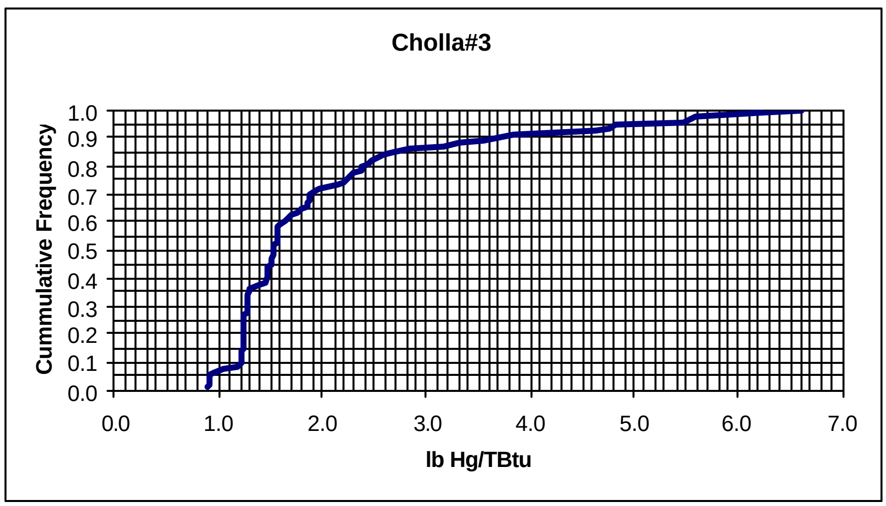
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
lb Hg/TBtu


Cholla#3
Cummulative Frequency
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0.9
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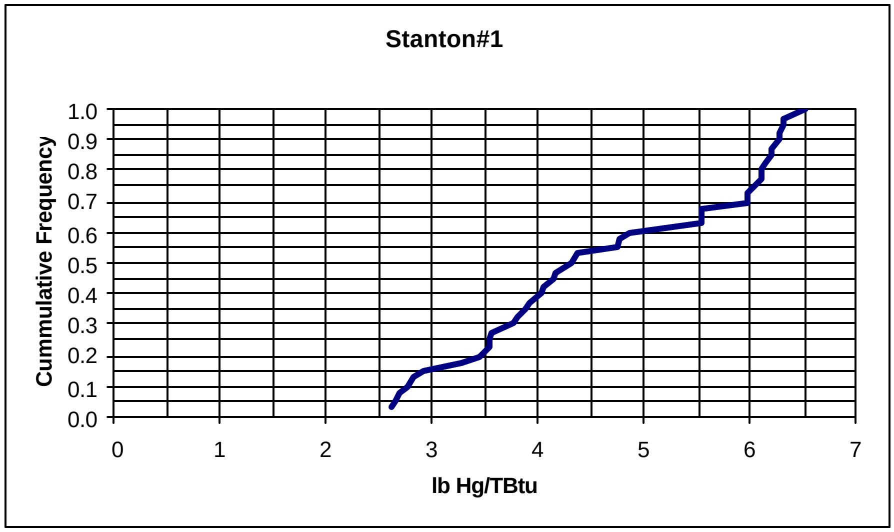
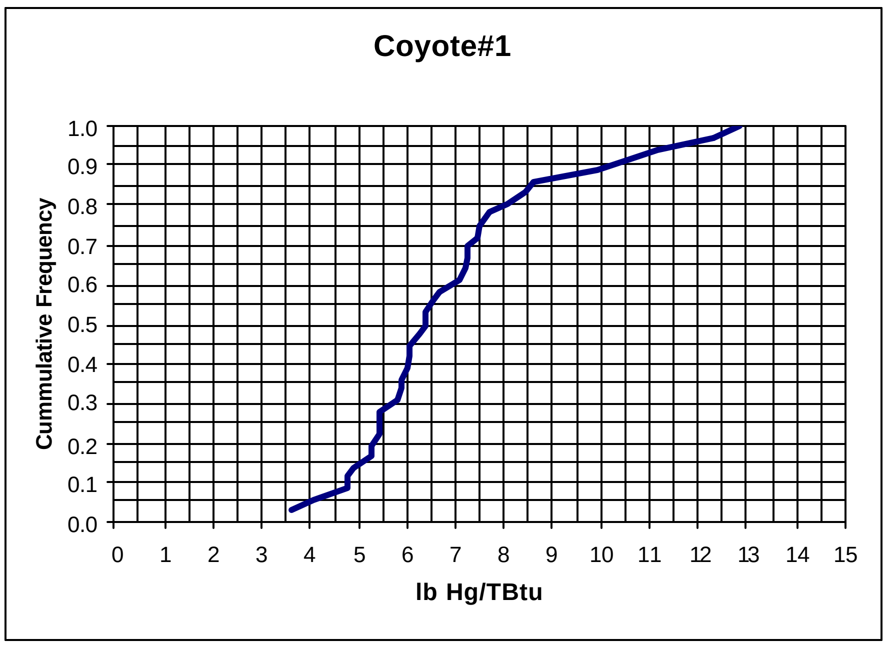
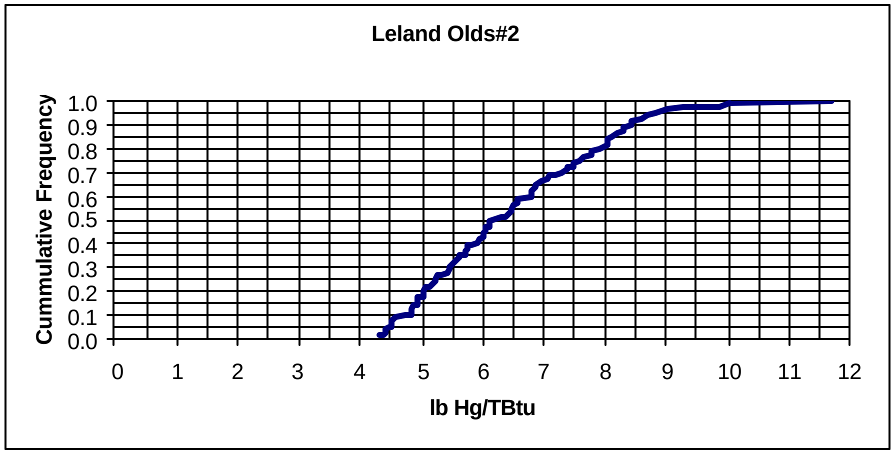
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
lb Hg/TBtu

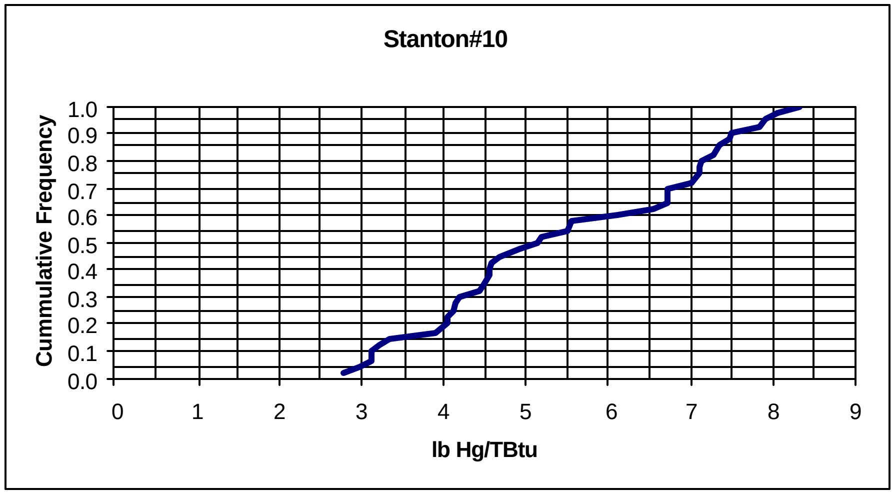
Appendix 3.
Cumulative Frequency Distributions of Mercury Emissions from Lignite Units



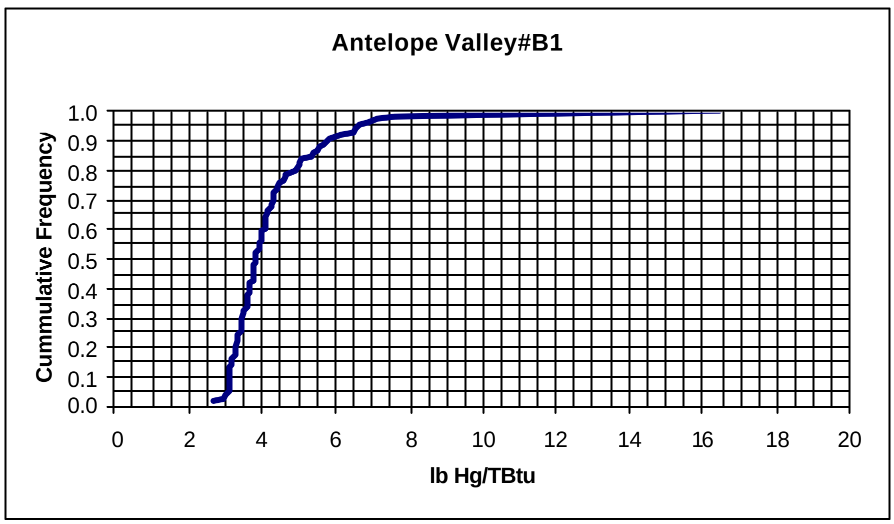




Leland Olds#2
Cummulative Frequency
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
4
5
6
7
8
9
10
11
12
lb Hg/TBtu



Stanton#10
Cummulative Frequency
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
4
5
6
7
8
9
lb Hg/TBtu



Antelope Valley#B1
Cummulative Frequency
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
2
4
6
8
10
12
14
16
18
20
lb Hg/TBtu