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FINAL REPORT

DEVELOPMENT OF ANNUALIZED SO_2 EMISSION CONVERSION FACTORS

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ABSTRACT

This report documents the results of a study to develop factors that can be used to estimate utility units's sulfur dioxide (SO_2) allowable emissions under the Clean Air Act Amendments of 1991. To accomplish the objective, a database of utility units continuous emission monitoring systems' results was constructed and factors were developed based on accepted EPA statistical methods. The database is a cross-sectional representation of utility plants with units of different sizes, with or without flue gas desulfurization systems, and different coals. Factors were developed using various averaging periods and exceedance policies being implemented by the States. Results are presented for utility units with and without flue gas desulfurization systems.

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Title IV of the Clean Air Act Amendments of 1990 establishes a system of allowances for sulfur dioxide (SO_2) emissions from utility units. The legislation provides for a two-phase program. In Phase I, an annual emission limit of 2.5 lb/MMBtu is imposed on 110 plants. In Phase II, a maximum limit of 1.2 lb/MMBtu will be applied to all utility units. The Environmental Protection Agency (EPA) Office of Atmospheric and Indoor Air Program (OAIAP) is responsible for calculating SO_2 allowances for all utility units, as defined in the Amendments, and developing a national allowance data base that contains all the units covered under Title IV.

The term "allowance" is defined in the Amendments as the tonnage of SO_2 that an affected unit may emit during a specified calendar year. Allowances are allocated by the EPA Administrator. One allowance is equal to one ton of SO_2 emissions. The SO_2 allowance for each utility unit is calculated by multiplying the annual quantity of fossil fuel consumed, in millions of Btu, by the actual or allowable emission rate, in lb SO_2/MMBtu, for a previous or anticipated time period.

Under Phase II, utility units that are burning high-sulfur fossil fuels and, as a result, emitting more than 1.2 lb SO_2/MMBtu will receive an allowance of 1.2 lb SO_2/MMBtu. For units with low to medium SO_2 emissions, actual or allowable emissions, whichever is lower (and they are usually less than 1.2), must be used.

To estimate SO_2 allowances for utility units, EPA can use available data bases such as the Department of Energy Form 767, the National Acid Precipitation Assessment Program (NAPAP) Emission Inventory version 2, the National Utility Reference File (NURF), or a corrected data base, as established by the Administrator, as a base reference. However, some of the above data bases contain shortcomings, such as incomplete lists of plants covered under Title IV, different bases (e.g., different averaging periods), different units of measure, or incorrect data.

In order for EPA to set an allowable emissions level, all current regulatory limits must be converted to the same units -- lb SO_2/MMBtu per year. The regulatory limits in effect across the nation use varying averaging periods. Converting these limits to an annual basis is not straightforward, since averaging time, compliance policy, and emissions variability all affect the emissions limit that a facility can meet.

The variability in emissions is particularly important to consider. Facilities with high variability in their emissions need to operate at a mean emission rate below the regulatory limit in order to avoid exceedances. The higher the variability, the lower the mean emissions need to be in order to avoid an exceedance.

The averaging period affects the mean only slightly, but it has considerable effect on the standard deviation (a measure of variability). As averaging periods are lengthened, the standard deviation goes down. Thus, a facility may be able to meet a given limit if a 24-hour averaging period is used, but perhaps not if a 3-hour averaging period is used.

In order to convert existing regulatory limits to an annual basis, a factor is needed that reflects the differences in variability and, thus, in attainable emission limits, between utility boilers. Since variability in emissions is largely a function of coal characteristics and control equipment it should be possible to group boilers based on these characteristics and assign a specific factor to each grouping.

1.1 OBJECTIVE

The objective of this study was to assist EPA in developing conversion and equivalency factors to be used in the national allowance data base. These factors could be used to normalize the different forms of existing SO_2 regulations data (e.g., data given in percent sulfur or in different averaging periods) into an annual average basis (in lb SO_2/MMBtu). The conversion factors can be used to estimate total tons of allowable emissions for units not included in the data bases or to correct the existing data bases. To estimate total tons of allowable SO_2 emissions for a given utility unit, conversion factors could be multiplied by the emission limits (in lb SO_2/MMBtu) and annual average heat input (in MMBtu) of that unit divided by 2000.

1.2 TECHNICAL APPROACH

Conversion factors were developed by performing the following technical tasks:

- The various averaging periods being implemented by the States were reviewed.
- Continuous Emission Monitoring (CEM) data on emission variability for 23 coal-burning plants were collected and reviewed. When inconsistent or inaccurate data were identified, they were deleted from the analysis.
- A telephone survey of utilities and suppliers was conducted, and the literature was reviewed to estimate sulfur variability in oil.
- SO_2 variability characteristics were analyzed and power plants were categorized accordingly.

- Conversion factors for each power plant were developed based on accepted EPA statistical methods.

2.0 DATA REVIEW AND ANALYSIS

Initially, the averaging periods implemented by each State were reviewed. One or more of the following averages were used by each State: 1-hr, 2-hr, 3-hr, 24-hr block, 24-hr rolling, 7-day, 30-day block, 30-day rolling, 90-day block, and 90-day rolling.

A data base of CEM data on 23 coal-burning utility units was assembled and used to analyze the variability characteristics of SO_2 emissions from coal-burning units subject to the acid rain provisions of the Amendments. The data from these units were screened for errors and deviations from normal operating variability. Two types of data were collected: (1) hourly CEM SO_2 emissions; and (2) summary statistics, including means, standard deviations, and, in some cases, autocorrelation factors found in other reports. Detailed hourly CEM data were not available for the second type of data.

Due to the lack of data for oil-burning units, utilities and suppliers were contacted to estimate sulfur variability in oil. As such, the SO_2 variability in oil-burning units was qualified based on the telephone and literature survey, and a data base was not assembled.

After all relevant data sets had been identified, the following approach was taken to develop the factors:

- Identify all relevant utility boiler data and sort into a small number of categories. Categories were based on boiler and coal characteristics that might affect the variability as well as the average SO_2 emissions;
- Calculate means and standard deviations at various averaging periods and for different compliance policies;
- Develop a set of factors (using different averaging periods and compliance policies) based on the mean emissions and the maximum expected emissions; and
- Determine the probability distribution of these factors so that a statistical method can be used to choose an "appropriate" factor for each category.

Two types of data were collected: (1) data with hourly CEM SO_2 emissions; and (2) summary statistics, including means, standard deviations, and, in some cases, autocorrelation factors. SO_2 emissions values have been found to have a relatively high amount of autocorrelation (greater than 0.5).[1] An autocorrelation factor is a measure of the degree of association between observations in a time series. The factor can range from -1.0 for inversely related observations to +1.0 for extremely linear associations. The standard formula for calculating autocorrelations factors[2] is:

$$r_k = \frac{\sum_{t=1}^{n-k} (z_t - \bar{z})(z_{t+k} - \bar{z})}{\sum_{t=1}^{n} (z_t - \bar{z})^2}$$

where

z_t = sample data point at time t;

z_{t+k} = sample data point at time t+k; and

$\bar{z}$ = sample data average.

The autocorrelation factors for this data set ranged from 0.59 to 0.98.

Detailed hourly CEM data were not available for all of the data sets. Means and standard deviations for one averaging period were available for some utility units. For these units, means and standard deviations for other averaging periods were estimated. The estimate was based on a ratio of averaging periods with a similar boiler with known mean and standard deviation for the particular averaging period.

A unit was considered similar if it was similarly equipped (with or without an FGD) and if it burned the same (or close to the same) percent sulfur coal. For example, plants A and B are considered similar. Both plant A and B have known means for the 3-hour averaging period, plant A has known mean for the 24-hour averaging period, and the mean for the 24-hour averaging period for plant B is unknown. A ratio of this information allows for the estimation of the mean for the 24-hour averaging period for plant B:

$$\frac{\bar{X}_{3\text{-}hr_A}}{\bar{X}_{3\text{-}hr_B}} = \frac{\bar{X}_{24\text{-}hr_A}}{\bar{X}_{24\text{-}hr_B}}$$

A similar ratio is established for the standard deviation. These estimates are then used to calculate the mean for the particular plant and averaging period.

Emissions data were collected from a total of 23 units burning coal. Table 1 summarizes the coal-burning utility units by identification number, type of coal being used, scrubber availability, and unit size. Appendix A presents means, standard deviations, and autocorrelations factors for all the units

TABLE 1. LIST OF UTILITY UNITS

ID Number	Coal Supply	(% Sulfur)	Scrubber	Size (MW)
1	Low Sulfur	(0.32)	No FGD	512
2	Low Sulfur[a]	(0.68)	No FGD	750
3	High Sulfur	(3.82)	FGD	195
5	Low Sulfur	(0.34)	No FGD	640
6	Low Sulfur[a]	(NA)	No FGD	795
7	Low Sulfur	(NA)	No FGD	725
8	Low Sulfur	(NA)	No FGD	580
9	Low Sulfur	(NA)	FGD	445
10	Low Sulfur	(NA)	FGD	550
11	Low Sulfur	(0.33)	FGD	720
12	Low Sulfur	(0.33)	FGD	720
13	Low Sulfur	(0.33)	FGD	720
14	High Sulfur	(2.33)	FGD	235
15	High Sulfur	(3.6)	FGD	195
16	High Sulfur	(3.75)	FGD	835
17	High Sulfur	(3.41)	FGD	272
18	High Sulfur	(3.85)	FGD	265
19	High Sulfur	(3.85)	FGD	265
20	Low Sulfur	(0.3)	FGD	NA
21	High Sulfur	(2.8)	FGD	684
22	High Sulfur	(2.8)	FGD	684
23	Medium Sulfur	(1.7)	FGD	65
24	High Sulfur	(2.5)	FGD	NA

[a]Washed coal.
NA = not available.

considered in this analysis. The data base is a cross-sectional representation of utility plants with units of different sizes, with or without flue gas desulfurization (FGD) systems burning low- or high-sulfur coals, using washed or unwashed coals, having different averaging periods, and having different exceedance policies.

These units were subdivided into three groups: six (6) non-FGD units burning low sulfur coal, eleven (11) FGD units burning high sulfur coal, and six (6) FGD units burning low sulfur coal. These groups were used in the statistical analysis described below.

3.0 FACTOR DEVELOPMENT

A utility plant has a specific SO_2 emissions limit. Due to the random fluctuation in emission levels both above and below the long-term average, the mean emission rate must be maintained at an emission level below the emission standard in order to assure compliance. Ideally, a unit would never exceed the emissions limit. In fact, "compliance policies" are established to ensure a limited number of exceedances. Typically one exceedance per year, one exceedance per ten (10) years, etc., have been used to set emission limit standards.

Through analysis of the variability in emissions, Giguere[1] developed a procedure that allows the projection of long-term mean SO_2 emission levels required to meet a desired lb SO_2/MMBtu emission limit. The method requires knowledge of the following variables:

- Standard deviation and relative standard deviation;
- Autocorrelation;
- Emissions distribution (normal vs. lognormal);
- Length of averaging period and averaging method; and
- Compliance policy (exceedance rate).

The relative standard deviation (RSD) is defined as the ratio of the standard deviation to the average or mean and is typically used to describe emissions variability. Autocorrelation (defined above) is not as important as RSD in determining SO_2 variability and predicting long-term mean emission levels. Longer averaging periods dampen the effects of variability, allowing plants to operate with SO_2 emission rates closer to the actual emissions limit.

The probability of violating the limit can be calculated for a specific averaging period and exceedance policy. For example, consider a 30-day rolling averaging period in combination with a one exceedance per ten (10) year policy. There are 3,650 days over a 10-year period, so that one exceedance divided by the total number of potential exceedances yields 0.00027. Therefore, the probability of violating the limit each day is a constant of 0.00027. The daily exceedance probability of 0.00027 translates to a standard normal distribution Z value of 3.46.

The implication of the above is that, in order to comply with the emission limit, the unit should be run at a target level that is less than the given limit by an amount equal to Z times the standard deviation of the 30-day rolling averages. Thus, the maximum expected emissions is the target level plus Z times the standard deviation.

Given the mean and maximum expected emissions for a specific averaging period and exceedance policy, a factor can be created that could be used to adjust the emission limits for the averaging periods:

$$\text{Factor} = \frac{Mean}{Max}$$

The factor is simply a ratio of mean emissions to expected maximum emissions. For a facility with low variability (and therefore operating very near the limit), this factor will be close to 1. Also for any facility, the factor should approach 1 as the averaging period lengthens. The compliance policy assumed to be used by a facility will also affect the factor.

The Giguere method adjusts the standard deviation to account for the autocorrelation of the data. However, autocorrelations were not available for most of the facility data. Therefore, for each different unit and averaging period, the expected maximum emissions under a particular exceedance policy were calculated using the following formula:

$$\text{Max} = \bar{x} + Z \cdot s$$

where

Max	=	expected maximum emissions;
$\bar{x}$	=	average emissions for averaging period;
Z	=	z-score for compliance policy and averaging period; and
s	=	(sample) standard deviation for averaging period.

To test the validity of this approach, the data sets for which an autocorrelation value was available were used to conduct a comparison of the Giguere method and the simplified method shown in the above equation. Factors were computed using both methods to estimate the expected maximum, and the differences between the resulting factors of the two methods were computed. In looking at the results from the two methods, there does not appear to be a significant difference between them. Therefore, the simplified method requiring only the mean and standard deviation was used for determining factors for the 23 units since it gives results that are comparable to the Giguere method. The resulting equation used for factor development was:

$$\text{Factor} = \frac{\bar{X}}{(\bar{X} + Z \cdot s)}$$

In order to use this methodology to develop conversion factors for SO_2 emission limits, it is necessary to determine the mean and expected maximum for each facility using different averaging periods and compliance policies. In the analysis below, the effects of three different compliance policies were included:

- One exceedance allowed in a 10-year period;
- One exceedance allowed in one year; and
- A 1 percent exceedances (that is, 1 percent of the emission averages in a year may be in excess of the limit).

For example, a facility under a 3-hour block average regulation will have 8,760 hrs/yr/3 hrs = 2920 chances to exceed. A 1 percent exceedance policy would allow the possibility of 29 exceedances in a year. Appendix B gives a comparison of the effects of various compliance policies.

The set of factors in each category can be used to statistically characterize the category. The probability distribution of factors for a given category could be used to choose the factor that applies to a specific percentage of the population of boilers within a category. For example, one half the boilers would have a factor less than or equal to the 50th percentile factor. Choosing a factor at the 95th percentile would mean that 95 percent of the boilers could meet (or do better than) the emission limit calculated by using that factor.

The derived factors are not normally distributed. The familiar methods of calculating means of normal distributions, sample standard deviations of normal distributions, and percentiles of normal distributions are not applicable. Because the factors are continuous and bounded above and below, they can be represented by a beta distribution. A beta distribution is defined by the data points, the end points, and by two shape parameters, $v > 0$ and $w > 0$. It is necessary to calculate the end points for each group exceedance policy and averaging period. Lower end points are chosen to be below the minimum RSD for the particular averaging period under a given exceedance policy and group. The upper end points are selected to be above the maximum RSD for the particular averaging period under a given exceedance policy and group. The factors are then normalized as follows:

$$X_1 = \frac{x - a}{b - a}$$

where

a = lower bound

b = upper bound, and

x_1 = normalized factor.

Next, it is necessary to calculate the shape parameters for each category averaging time and exceedance policy based on the sample data. The shape parameters are estimated as follows[3]:

$$v = \bar{x}\left[\frac{\bar{x}(1-\bar{x})}{s^2} - 1\right]$$

$$w = (1-\bar{x})\left[\frac{\bar{x}(1-\bar{x})}{s^2} - 1\right]$$

where

$\bar{x}$ = arithmetic mean and

s^2 = sample variance.

For each category averaging period and exceedance policy, a beta distribution has been defined by the shape parameters v and w as described above. The mean and standard deviation for a given beta distribution are then calculated as follows[3]:

$$\text{Mean} = \frac{v}{(v + w)}$$

$$\text{Variance} = \frac{v\,w}{(v + w)^2(v + w + 1)}$$

$$\text{Standard Deviation} = \sqrt{\text{variance}}$$

Following the calculation of the summary statistics for each category and exceedance policy and averaging period, the probability values from each beta distribution were calculated. The probability density function of a beta distribution is given by[3]:

$$x^{v-1}(1-x)^{w-1}\frac{\Gamma(v+w)}{\Gamma(v)\Gamma(w)}$$

where

$$\Gamma(a)=\int_0^\infty \exp(-u)u^{a-1}\,du$$

and

x	=	value at which the distribution is to be evaluated and
v,w	=	shape parameters.

Calculations were performed to determine the value where 5 percent, 25 percent, 50 percent, 75 percent, 95 percent, or 99 percent of the sample factors were below it.

4.0 RESULTS

Table 2 presents the estimated means, minimum and maximum values, and standard deviations for all 23 coal-burning units for different averaging periods and exceedance policies. Originally the units were divided into three categories: (1) non FGD units burning low sulfur coals (6 units), (2) FGD units burning low sulfur coals (7 units), and (3) FGD units burning medium to high sulfur coals (10 units). Figures 1 through 3 show the factors for different averaging periods. Coals containing less than one percent of sulfur by weight were categorized as low sulfur coals. Above one percent sulfur, coals were considered as medium- to high- sulfur coals. Units with FGD systems burning low- and high-sulfur coals were examined separately and a summary of conversion factors is presented in Appendix C. Units with FGD systems demonstrated similar conversion factors regardless of coal sulfur content. Therefore, two

TABLE 2. ESTIMATED MEAN WITH MINIMUM AND MAXIMUM VALUES

Averaging Period	FGD Equipped					Non-FGD Equipped				
	Count	Minimum	Maximum	Mean	Standard Deviation	Count	Minimum	Maximum	Mean	Standard Deviation
<u>One Exceedance/10Years</u>										
1-hr Block	17	0.18	0.70	0.42	0.16	5	0.45	0.71	0.55	0.19
2-hr Block	17	0.19	0.71	0.44	0.16	5	0.56	0.74	0.61	0.18
3-hr Block	17	0.20	0.73	0.45	0.16	5	0.57	0.74	0.60	0.17
24-hr Rolling	17	0.25	0.79	0.51	0.17	5	0.59	0.78	0.63	0.18
7-day Rolling	12	0.36	0.82	0.68	0.15	5	0.74	0.90	0.75	0.17
30-day Rolling	9	0.61	0.99	0.86	0.13	5	0.69	0.92	0.83	0.09
<u>One Exceedance/Year</u>										
1-hr Block	17	0.20	0.72	0.45	0.16	5	0.48	0.74	0.57	0.19
2-hr Block	17	0.22	0.74	0.47	0.16	5	0.60	0.77	0.63	0.18
3-hr Block	17	0.23	0.76	0.49	0.16	5	0.61	0.77	0.63	0.18
24-hr Rolling	17	0.28	0.81	0.54	0.17	5	0.62	0.80	0.65	0.18
7-day Rolling	12	0.41	0.85	0.70	0.15	5	0.78	0.92	0.77	0.16
30-day Rolling	9	0.66	0.99	0.86	0.13	5	0.73	0.94	0.85	0.08

(Continued)

TABLE 2. ESTIMATED MEAN WITH MINIMUM AND MAXIMUM VALUES
(Continued)

Averaging Period	All				
	Count	Minimum	Maximum	Mean	Standard Deviation
One Exceedance/10Years					
1-hr Block	22	0.14	0.71	0.45	0.17
2-hr Block	22	0.19	0.74	0.47	0.18
3-hr Block	22	0.20	0.74	0.48	0.17
24-hr Rolling	22	0.22	0.79	0.53	0.18
7-day Rolling	17	0.36	0.90	0.69	0.16
30-day Rolling	14	0.61	0.99	0.83	0.13
One Exccedance/Year					
1-hr Block	27	0.15	0.74	0.48	0.18
2-hr Block	27	0.22	0.77	0.51	0.18
3-hr Block	27	0.23	0.77	0.52	0.18
2-hr Rolling	27	0.25	0.81	0.56	0.17
7-day Rolling	17	0.41	0.92	0.72	0.16
30-day Rolling	14	0.66	0.99	0.86	0.11

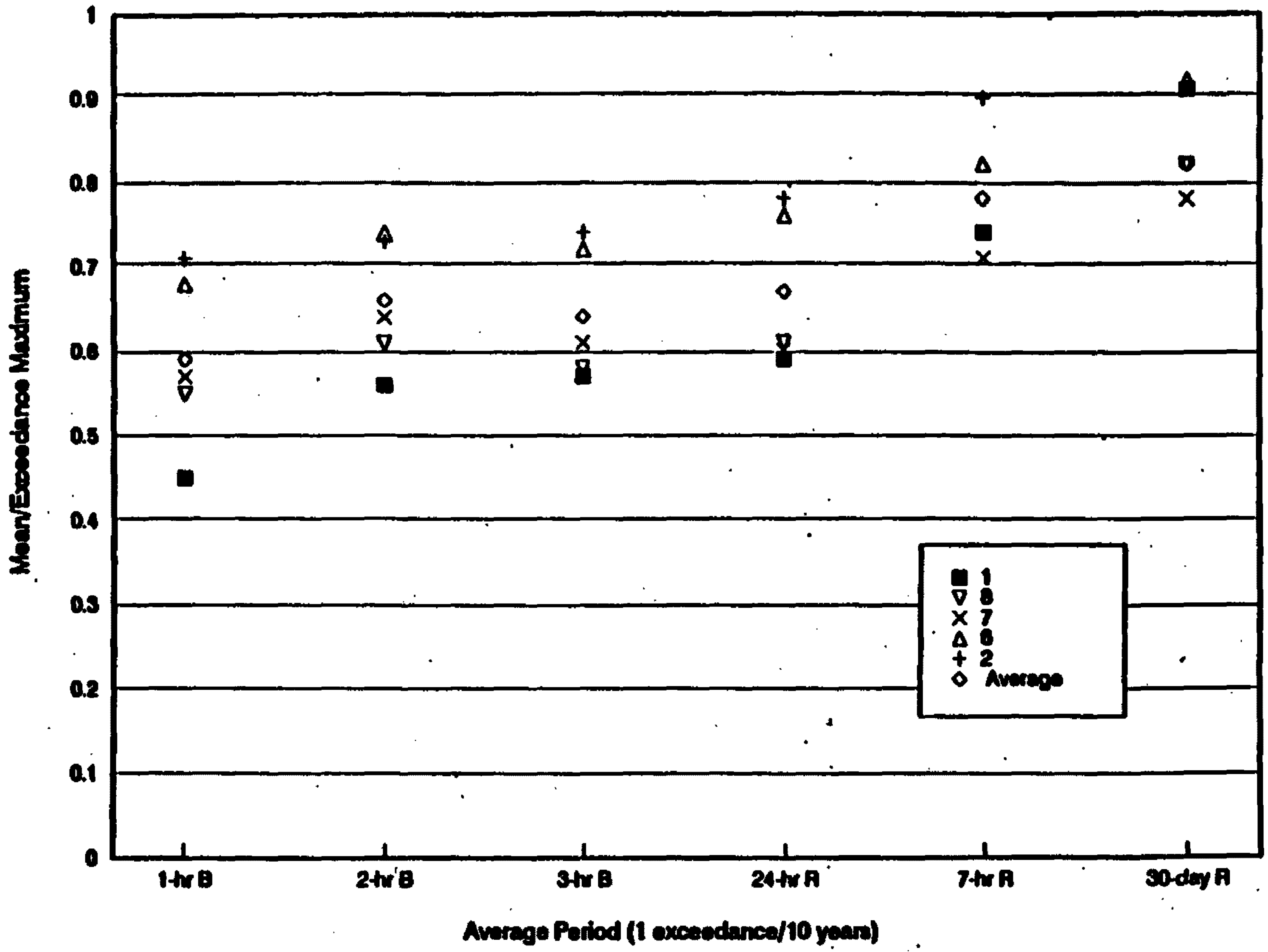

Figure 1. Non-FGD - Low Sulfur Coal

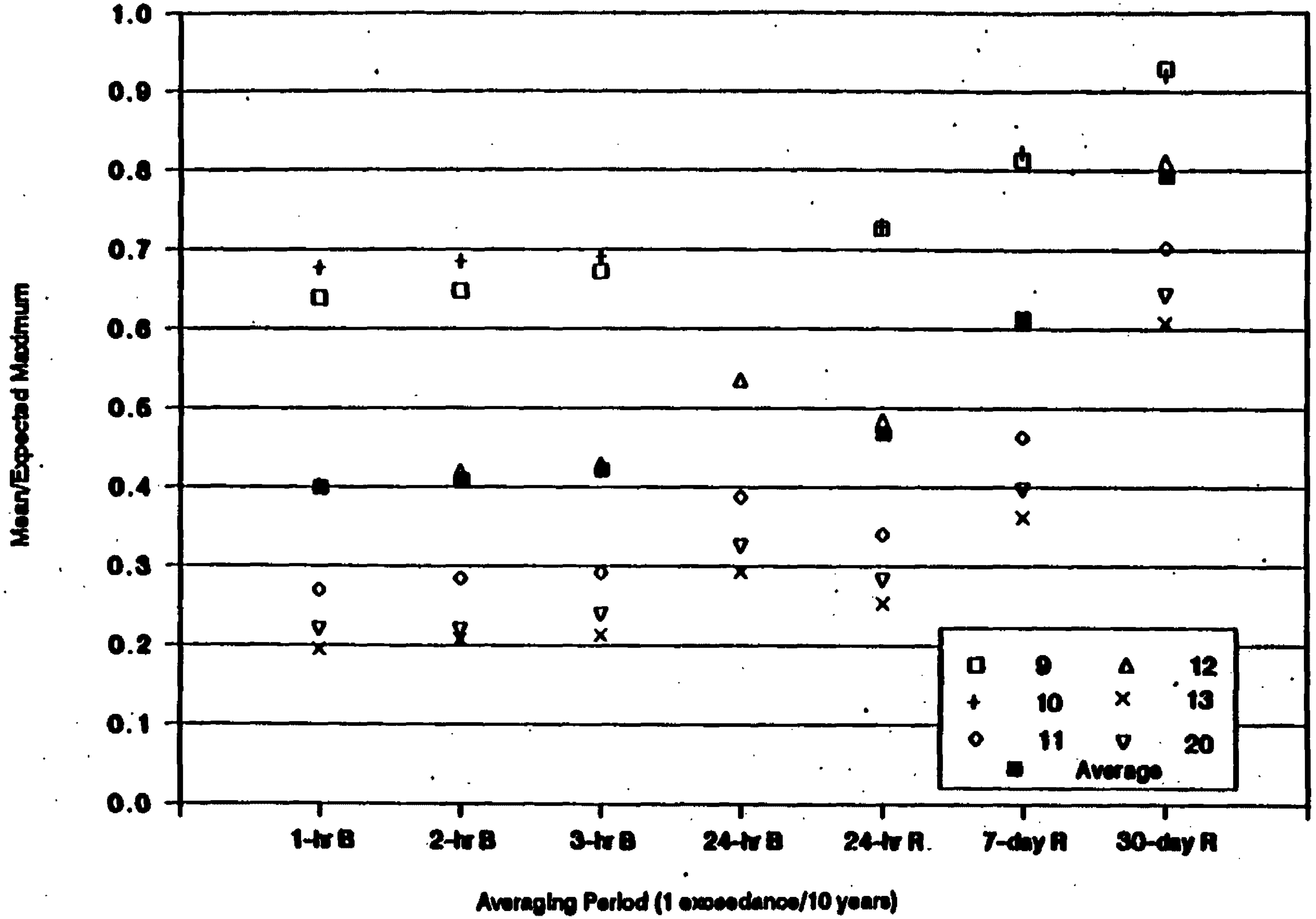

Figure 2. FGD Low-Sulfur Coal

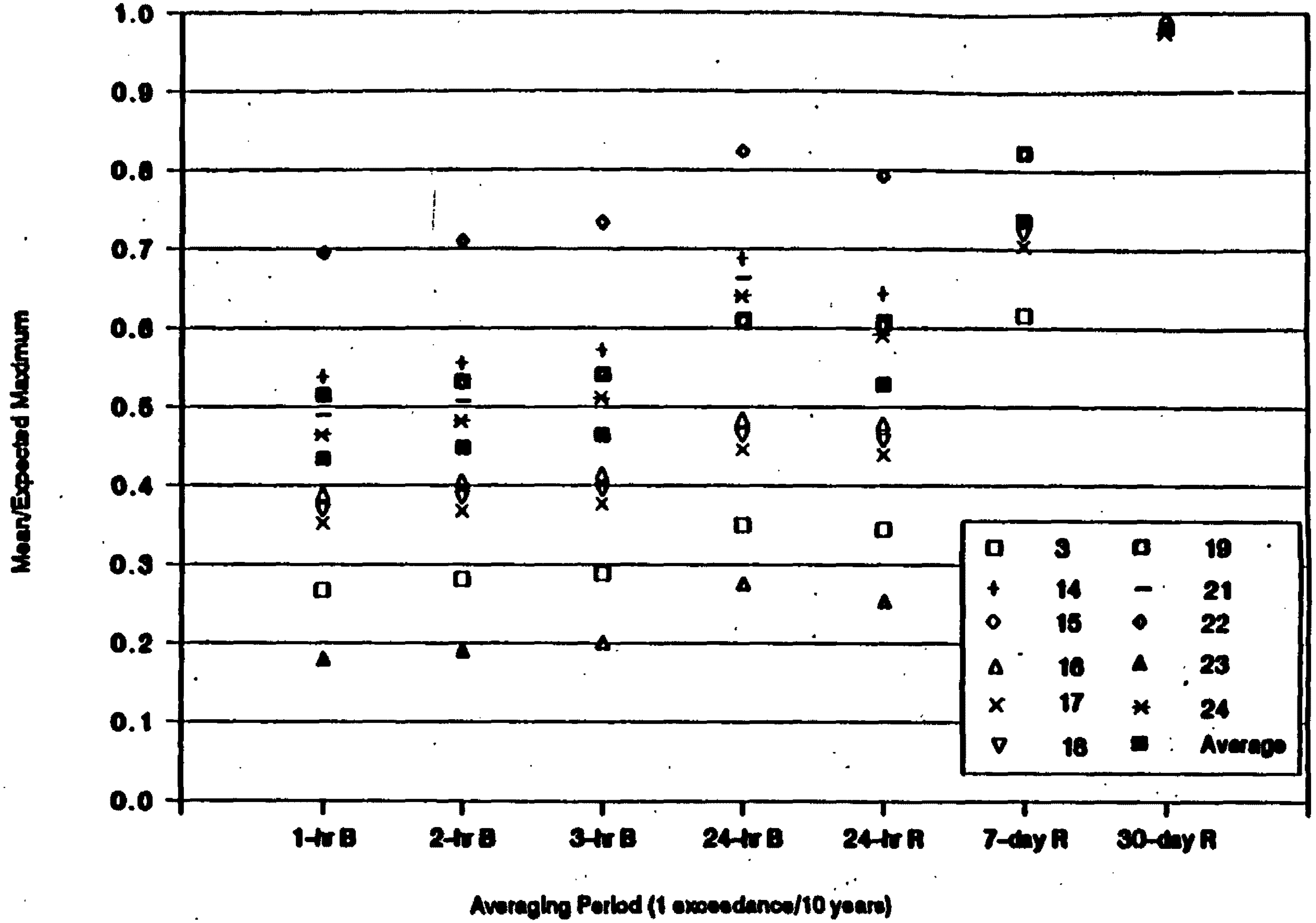

Figure 3. FGD High-Sulfur Coal

categories were used for the final analysis: units without FGD (6 units), and units with FGD (17 units). In addition, all cases (23 units) were combined to give average values to all units.

Appendix D presents factors for all cases considered in this study for different averaging periods, different cumulative probabilities ranging from 5 percent to 99 percent, and two exceedance cases. For this study, two exceedance cases as being used by States were considered: (1) one exceedance per 10 years, (2) one exceedance per year. As Appendix D shows, both cases have similar results. For all units combined with a 1-hour block average, a conversion factor of 0.74 would cover about 75 percent of the population. In another word, 75 percent of the units considered in this analysis have conversion factors equal to or less than 0.74. Table 3 summarizes means and conversion factors with cumulative probability for covering 95 and 99 percent of the population for units without FGD, with FGD, and all units combined.

Conversion factors were not developed for the following averaging periods: 24-hr block, 30-day block, 90-day block, and 90-day rolling. The conversion factors for the above averaging periods, however, can be estimated using the trend in the factors from one averaging period to the next. For example, 30-day rolling average for 95 percent confidence limit and one exceedance per year for FGD units is 0.99. Therefore, 90-day averages should be between 0.99 and 1.0.

As specified in a 1980 EPA report,[4] the sample statistics from the analyses of coals failed to identify any consistent, predictable relationships that would explain coal sulfur variabilities.

Emission data were typically reported as lb SO_2/MMBtu, lb S/MMBtu, or percent sulfur in the fuel. In order to put all data on the same basis, data reported in lb S/MMBtu or percent sulfur were converted to lb SO_2/MMBtu using the following equations:

COAL

lb SO_2/MMBtu = 2 * lb S/MMBtu,

lb SO_2/MMBtu = 18143 * $(HHV)^{-0.99}$ * S%

OIL

lb SO_2/MMBtu = 1.1 * S% * DEN

where

HHV = higher heating value, Btu/lb

S% = sulfur percent

DEN = oil density, lb/gallon

Oil heating value was assumed to be 6.2 MMBtu/bbl.

TABLE 3. MEAN AND CUMULATIVE PROBABILITY TO COVER 95 AND 99 PERCENT OF THE UNIT POPULATION[a]

	Averaging Period					
	1 Hr	2 Hr	3 Hr	24 Hr	7 Day	30 Day
No FGD[a]						
Mean	0.54	0.61	0.60	0.62	0.75	0.85
95% Probability	0.86	0.88	0.84	0.83	0.89	0.92
99% Probability	0.92	0.93	0.90	0.90	0.94	0.96
FGD Equipped[a]						
Mean	0.45	0.47	0.49	0.54	0.70	0.86
95% Probability	0.83	0.85	0.87	0.88	0.95	0.99
99% Probability	0.92	0.93	0.94	0.94	0.98	1.00
All Cases[a]						
Mean	0.48	0.51	0.52	0.56	0.72	0.86
95% Probability	0.88	0.91	0.92	0.91	0.97	0.99
99% Probability	0.94	0.97	0.97	0.96	0.99	0.99
No FGD[b]						
Mean	0.55	0.61	0.60	0.63	0.75	0.83
95% Probability	0.82	0.80	0.79	0.79	0.85	0.90
99% Probability	0.89	0.87	0.86	0.88	0.92	0.96
FGD Equipped[b]						
Mean	0.42	0.44	0.45	0.51	0.68	0.86
95% Probability	0.80	0.81	0.83	0.85	0.93	0.99
99% Probability	0.89	0.91	0.92	0.93	0.97	1.00
All Cases[b]						
Mean	0.45	0.47	0.48	0.53	0.69	0.83
95% Probability	0.84	0.88	0.88	0.88	0.94	0.99
99% Probability	0.92	0.95	0.95	0.95	0.98	0.99

[a] Factors are for one exceedance per year.

[b] Factors are for one exceedance per 10 years.

5.0 CONCLUSIONS

For utility units, SO_2 concentration in the flue gas varies due to variability in fuel sulfur content, heating value, and control device variability. The various analyses of coal sulfur variability identified no reliable method for coal suppliers or consumers to predict variability. The conclusion was that the primary factors affecting coal sulfur distributions are possibly geologic factors, mining techniques, and coal handling procedures. For units equipped with FGD, this variability is also due to random fluctuations in operating parameters such as inlet SO_2 concentration, sorbent quality, flue gas flow rate, and liquid to gas ratio.

In order to meet an emission standard, a unit must operate in a manner that accommodates the natural variability in coal and control device such that the average emission rate does not exceed the permit limit for the specific averaging time. This ensures that any emission variations due to coal characteristics and control device are normalized over the averaging time period. As a result, the shorter the emission averaging time the lower the mean emission will be to ensure compliance.

The analysis of the limited CEM data indicated that significant reductions in the relative variability of emissions can be achieved by increasing the averaging time interval from 1 hour to 3 hours, 24 hours, and 30 days. This trend could also be seen in Figures 1 through 3 where the conversion factors were plotted versus different averaging time periods. These figures show the tendency of the conversion factors to approach 1.0 as the averaging time period increases. The conversion factors for converting data on 1-hour and 30-day averages to annual averages for 95 percent cumulative probability will be in the range of 0.83-0.88 and 0.92-0.99, respectively.

Oil purchased from refineries has a known sulfur and heating value content. Suppliers generally guarantee these two values. The price of oil with different sulfur content can be the same depending on the local oil market. If the oil sulfur content from different suppliers is below the standard, pricing is the main driver for choosing a supplier. Oil-fired source operators sample the oil from the transport container or pipelines upon delivery to ensure that it conforms with the contract specifications. In addition, the oil in the storage tanks is well mixed and has a uniform sulfur content. As such, the emissions from a utility unit burning oil from the same supplier has low variabilities. However, oil sulfur content can vary from one shipment to the next, particularly if the oil was purchased from different suppliers.

6.0 REFERENCES

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APPENDIX A

DESCRIPTIVE STATISTICS OF UTILITY BOILERS USED IN THIS ANALYSIS

DESCRIPTIVE STATISTICS OF UTILITY BOILERS USED IN THIS ANALYSIS

Table A-1 presents the descriptive statistics for the utility units used in this study. For a given averaging period, an arithmetic mean and sample standard deviation were either calculated or estimated under the assumption that SO_2 emissions are normally distributed. A description of the method of estimation is found in this report. For those units for which it was available, the autocorrelation factor for a given averaging period is also presented. A description of autocorrelation factors is found in Section 2.0 of this report.

TABLE A-1. DESCRIPTIVE STATISTICS OF THE UTILITY UNITS

ID #	Averaging Period	Mean	Standard Deviation	Auto-Correlation
1	1-hr	0.603	0.177	0.97
	2-hr	0.602	0.115	
	3-hr	0.602	0.114	
	24-hr B	0.602	0.100	
	24-hr R	0.602	0.099	
	7-day R	0.601	0.060	
	30-day R	0.606	0.016	
2	1-hr	0.875	0.084	0.71
	2-hr	0.875	0.081	
	3-hr	0.875	0.078	
	24-hr B	0.875	0.059	
	24-hr R	0.875	0.058	
	7-day R	0.871	0.029	
3	1-hr	0.612	0.396	0.92
	2-hr	0.613	0.384	
	3-hr	0.613	0.379	
	24-hr B	0.614	0.329	
	24-hr R	0.585	0.262	
	7-day R	0.546	0.099	
5	1-hr			
	2-hr			
	3-hr			
	24-hr B			
	24-hr R			
	7-day R			
	30-day R	0.569	0.074	
6	1-hr	0.8	0.09	0.73
	2-hr	0.8 [a]	0.07 [a]	
	3-hr	0.8	0.08	0.69
	24-hr R	0.8	0.06	0.72
	7-day R	0.8	0.05	0.93
	30-day R	0.8	0.02	0.81
7	1-hr	0.5	0.09	0.94
	2-hr	0.5 [a]	0.07 [a]	
	3-hr	0.5	0.08	0.90
	24-hr R	0.5	0.08	0.79
	7-day R	0.5	0.06	0.96
	30-day R	0.5	0.04	0.98
8	1-hr	0.78	0.15	0.88
	2-hr	0.78 [a]	0.12 [a]	
	3-hr	0.78	0.14	0.84
	24-hr R	0.78	0.12	0.59
	7-day R	0.77	0.08	0.94
	30-day R	0.77	0.05	0.94

TABLE A-1. CONTINUED

ID #	Averaging Period	Mean	Standard Deviation	Auto-Correlation
9	1-hr	0.9	0.12	0.74
	2-hr	0.9 [a]	0.12 [a]	
	3-hr	0.9	0.11	0.76
	24-hr R	0.9	0.08	0.67
	7-day R	0.9	0.06	0.95
	30-day R	0.9	0.02	0.95
10	1-hr	0.8	0.09	0.94
	2-hr	0.8 [a]	0.09 [a]	
	3-hr	0.8	0.09	0.88
	24-hr R	0.8	0.07	0.73
	7-day R	0.8	0.05	0.95
	30-day R	0.8	0.02	0.91
11	1-hr	0.352 [a]	0.224 [a]	
	2-hr	0.353 [a]	0.218 [a]	
	3-hr	0.352 [a]	0.214 [a]	
	24-hr B	0.352	0.161	
	24-hr R	0.352	0.161	
	7-day R	0.352 [a]	0.118 [a]	
	30-day R	0.352 [a]	0.043 [a]	
12	1-hr	0.609 [a]	0.213 [a]	
	2-hr	0.610 [a]	0.207 [a]	
	3-hr	0.609 [a]	0.204 [a]	
	24-hr B	0.609	0.153	
	24-hr R	0.609	0.153	
	7-day R	0.609 [a]	0.112 [a]	
	30-day R	0.609 [a]	0.041 [a]	
13	1-hr	0.29 [a]	0.281 [a]	
	2-hr	0.29 [a]	0.273 [a]	
	3-hr	0.29 [a]	0.269 [a]	
	24-hr B	0.29	0.202	
	24-hr R	0.29	0.202	
	7-day R	0.29 [a]	0.148 [a]	
	30-day R	0.29 [a]	0.054 [a]	
14	1-hr	1.005 [a]	0.204 [a]	
	2-hr	1.007 [a]	0.198 [a]	
	3-hr	1.001 [a]	0.188 [a]	
	24-hr B	0.947	0.124	
	24-hr R	0.947	0.124	
	7-day R			
	30-day R			

TABLE A-1. CONTINUED

ID #	Averaging Period	Mean	Standard Deviation	Auto-Correlation
15	1-hr	0.998[a]	0.224[a]	
	2-hr	1.000[a]	0.217[a]	
	3-hr	1.000[a]	0.214[a]	
	24-hr B	1.001[a]	0.186[a]	
	24-hr R	0.953	0.148	
	7-day R	0.891[a]	0.056[a]	
	30-day R			
16	1-hr	0.326[a]	0.121[a]	
	2-hr	0.326[a]	0.117[a]	
	3-hr	0.326[a]	0.116[a]	
	24-hr B	0.327[a]	0.100[a]	
	24-hr R	0.311	0.080	
	7-day R	0.291[a]	0.030[a]	
	30-day R			
17	1-hr	0.303[a]	0.131[a]	
	2-hr	0.303[a]	0.128[a]	
	3-hr	0.303[a]	0.126[a]	
	24-hr B	0.304[a]	0.109[a]	
	24-hr R	0.289	0.087	
	7-day R	0.270[a]	0.033[a]	
	30-day R			
18	1-hr	0.707[a]	0.286[a]	
	2-hr	0.708[a]	0.277[a]	
	3-hr	0.708[a]	0.273[a]	
	24-hr B	0.709[a]	0.237[a]	
	24-hr R	0.675	0.189	
	7-day R	0.631[a]	0.071[a]	
	30-day R			
19	1-hr	0.838[a]	0.186[a]	
	2-hr	0.839[a]	0.180[a]	
	3-hr	0.839[a]	0.178[a]	
	24-hr B	0.841[a]	0.154[a]	
	24-hr R	0.800	0.123	
	7-day R	0.748[a]	0.046[a]	
	30-day R			
20	1-hr	0.3[a]	0.251[a]	
	2-hr	0.3[a]	0.262[a]	
	3-hr	0.3[a]	0.239[a]	
	24-hr B	0.3	0.180	
	24-hr R	0.3	0.180	
	7-day R	0.3[a]	0.132[a]	
	30-day R	0.3[a]	0.048[a]	

TABLE A-1. CONTINUED

ID #	Averaging Period	Mean	Standard Deviation	Auto-Correlation
21	1-hr	0.87 [a]	0.214 [a]	
	2-hr	0.88 [a]	0.208 [a]	
	3-hr	0.87 [a]	0.188 [a]	
	24-hr B	0.87 [a]	0.127 [a]	
	24-hr R	0.87	0.128	
	7-day R			
	30-day R	0.88 [a]	0.006 [a]	
22	1-hr	0.988 [a]	0.102 [a]	
	2-hr	0.990 [a]	0.099 [a]	
	3-hr	0.983 [a]	0.090 [a]	
	24-hr B	0.982 [a]	0.061 [a]	
	24-hr R	0.983	0.061	
	7-day R			
	30-day R	0.989 [a]	0.003 [a]	
23	1-hr	0.2607	0.2799	
	2-hr	0.2612 [a]	0.2718 [a]	
	3-hr	0.2597	0.2578	
	3-hour R	0.2584	0.2583	
	24-hr B	0.2422	0.1837	
	24-hr R	0.2456	0.1702	
24	1-hr	0.6737	0.1832	
	2-hr	0.6749 [a]	0.1779 [a]	
	3-hr	0.6699	0.1606	
	3-hr R	0.6697	0.1604	
	24-hr B	0.6697	0.1089	
	24-hr R	0.6702	0.1094	
	30-day R	0.6742	0.0050	

[a] Estimate

APPENDIX B

COMPARISON OF TWO EMISSION FACTORS CALCULATION METHODS

COMPARISON OF TWO EMISSION FACTORS CALCULATION METHODS

For five (5) utility units used in this study, an autocorrelation factor was available for five (5) different averaging periods. These units were used to compare two methods of factor calculations. The simplified factors resulting from the method requiring only the mean and standard deviation are designated Mean/Exp. Max, or A. These factors were compared to those derived using the Giguere method, designated Target Level/Limit, or B. The difference between the two factors was calculated for each unit for each of the averaging periods for three different exceedance policies. In looking at the results from the two methods, there does not appear to be a significant difference between them.

Table B-1 also shows how the factors (either A or B) increase with increasing averaging period length and the effect the exceedance policy has on the factors.

TABLE B-1. EMISSION FACTOR COMPARISON

	Averging Period	Exceedance Policy	Expected Maximum	Mean/Exp. Max (A)	Target Level	Target Level/Limit (B)	Difference (B-A)
6	1-hr	One/10 yr	1.1812	0.6773	0.8528	0.7107	0.033
	3-hr	One/10 yr	1.1185	0.7152	0.9018	0.7515	0.036
	24-hr	One/10 yr	1.0541	0.7589	0.9452	0.7877	0.029
	7-day R	One/10 yr	0.9728	0.8224	0.9635	0.8029	-0.019
	30-day R	One/10 yr	0.8691	0.9205	1.0993	0.9160	-0.004
	1-hr	One/yr	1.1317	0.7069	0.8861	0.7384	0.032
	3-hr	One/yr	1.0716	0.7465	0.9360	0.7800	0.033
	24-hr R	One/yr	1.0211	0.7834	0.9720	0.8100	0.027
	7-day R	One/yr	0.9389	0.8521	1.0023	0.8352	-0.017
	30-day R	One/yr	0.8555	0.9351	1.1177	0.9314	-0.004
	1-hr	1%	1.0094	0.7926	0.9807	0.8173	0.025
	3-hr	1%	0.9861	0.8113	1.0057	0.8381	0.027
	24-hr R	1%	0.9396	0.8514	1.0453	0.8710	0.020
	7-day R	1%	0.9163	0.8731	1.0298	0.8582	-0.015
	30-day R	1%	0.8465	0.9450	1.1303	0.9419	-0.003
7	1-hr	One/10 yr	0.8812	0.5674	0.6900	0.5750	0.008
	3-hr	One/10 yr	0.8185	0.6109	0.7480	0.6233	0.012
	24-hr R	One/10 yr	0.8388	0.5961	0.7489	0.6241	0.028
	7-day R	One/10 yr	0.7074	0.7068	0.8235	0.6863	-0.021
	30-day R	One/10 yr	0.6382	0.7834	0.9175	0.7646	-0.019
	1-hr	One/yr	0.8317	0.6012	0.7303	0.6086	0.007
	3-hr	One/yr	0.7716	0.6480	0.7919	0.6599	0.012
	24-hr R	One/yr	0.7948	0.6291	0.7873	0.6561	0.027
	7-day R	One/yr	0.6666	0.7500	0.8776	0.7313	-0.019
	30-day R	One/yr	0.6111	0.8182	0.9619	0.8016	-0.017
	1-hr	1%	0.7094	0.7048	0.8535	0.7112	0.006
	3-hr	1%	0.6861	0.7287	0.8868	0.7390	0.010
	24-hr R	1%	0.6861	0.7287	0.9014	0.7514	0.023
	7-day R	1%	0.6396	0.7818	0.9176	0.7647	-0.017
	30-day R	1%	0.5931	0.8431	0.9940	0.8283	-0.015

TABLE B-1. CONTINUED

ID #	Averging Period	Exceedance Policy	Expected Maximum	Mean/Exp. Max (A)	Target Level	Target Level/Limit (B)	Difference (B-A)
8	1-hr	One/10 yr	1.4153	0.5511	0.6803	0.5669	0.016
	3-hr	One/10 yr	1.3374	0.5832	0.7251	0.6042	0.021
	24-hr R	One/10 yr	1.2882	0.6055	0.7997	0.6665	0.061
	7-day R	One/10 yr	1.0465	0.7358	0.8257	0.6881	-0.048
	30-day R	One/10 yr	0.9428	0.8167	0.9351	0.7793	-0.037
	1-hr	One/yr	1.3328	0.5852	0.7208	0.6007	0.015
	3-hr	One/yr	1.2554	0.6213	0.7699	0.6416	0.020
	24-hr R	One/yr	1.2223	0.6382	0.8359	0.6966	0.058
	7-day R	One/yr	0.9922	0.7761	0.8796	0.7330	-0.043
	30-day R	One/yr	0.9089	0.8472	0.9775	0.8146	-0.033
	1-hr	1%	1.1290	0.6909	0.8453	0.7044	0.013
	3-hr	1%	1.1057	0.7054	0.8679	0.7232	0.018
	24-hr R	1%	1.0592	0.7364	0.9412	0.7844	0.048
	7-day R	1%	0.9561	0.8053	0.9195	0.7662	-0.039
	30-day R	1%	0.8863	0.8688	1.0078	0.8399	-0.029
9	1-hr	One/10 yr	1.4082	0.6391	0.8077	0.6731	0.034
	3-hr	One/10 yr	1.3380	0.6727	0.8426	0.7021	0.029
	24-hr R	One/10 yr	1.2388	0.7265	0.9173	0.7644	0.038
	7-day R	One/10 yr	1.1074	0.8127	0.9416	0.7847	-0.028
	30-day R	One/10 yr	0.9691	0.9287	1.0995	0.9162	-0.012
	1-hr	One/yr	1.3423	0.6705	0.8435	0.7029	0.032
	3-hr	One/yr	1.2735	0.7067	0.8812	0.7343	0.028
	24-hr R	One/yr	1.1948	0.7532	0.9463	0.7886	0.035
	7-day R	One/yr	1.0666	0.8438	0.9832	0.8193	-0.024
	30-day R	One/yr	0.9555	0.9419	1.1178	0.9315	-0.010
	1-hr	1%	1.1792	0.7633	0.9472	0.7894	0.026
	3-hr	1%	1.1559	0.7786	0.9616	0.8014	0.023
	24-hr R	1%	1.0861	0.8286	1.0263	0.8552	0.027
	7-day R	1%	1.0396	0.8657	1.0129	0.8441	-0.022
	30-day R	1%	0.9465	0.9508	1.1304	0.9420	-0.009

TABLE B-1. CONTINUED

#	Averging Period	Exceedance Policy	Expected Maximum	Mean/Exp. Max (A)	Target Level	Target Level/Limit (B)	Difference (B-A)
10	1-hr	One/10 yr	1.1812	0.6773	0.8208	0.6840	0.007
	3-hr	One/10 yr	1.1583	0.6906	0.8450	0.7041	0.013
	24-hr R	One/10 yr	1.0965	0.7296	0.9114	0.7595	0.030
	7-day R	One/10 yr	0.9728	0.8224	0.9628	0.8023	-0.020
	30-day R	One/10 yr	0.8691	0.9205	1.0944	0.9120	-0.008
	1-hr	One/yr	1.1317	0.7069	0.8559	0.7133	0.006
	3-hr	One/yr	1.1056	0.7236	0.8834	0.7362	0.0136
	24-hr R	One/yr	1.0580	0.7562	0.9408	0.7840	0.028
	7-day R	One/yr	0.9389	0.8521	1.0016	0.8347	-0.017
	30-day R	One/yr	0.8555	0.9351	1.1137	0.9281	-0.007
	1-hr	1%	1.0094	0.7926	0.9571	0.7976	0.005
	3-hr	1%	1.0094	0.7926	0.9635	0.8029	0.010
	24-hr R	1%	0.9628	0.8309	1.0222	0.8518	0.0021
	7-day R	1%	0.9163	0.8731	1.0293	0.8577	-0.015
	30-day R	1%	0.8465	0.9450	1.1268	0.9390	-0.006

APPENDIX C

SUMMARY OF CONVERSION FACTORS

SUMMARY OF CONVERSION FACTORS

Table C-1 presents the calculated conversion factors, using the simplified method, for each FGD-equipped utility units used in this study. Conversion factors were calculated for two different exceedance policies for a variety of averaging periods. Footnote "a" indicates that the unit burns high-sulfur coal and "b" indicates that the unit burns low-sulfur coal. Footnote "c" indicates that the factor was derived from estimated means and standard deviations, as described in Section 2.

TABLE C-1. SUMMARY OF EMISSION FACTORS - FGD-EQUIPPED SYSTEMS

Averaging Period	Plant ID #								
	3[a]	9[b]	10[b]	11[b]	12[b]	13[b]	14[a]	15[a]	16[a]
One Exceedance/10Years									
1-hr Block	0.2673	0.6391	0.6773	0.2704[c]	0.4029[c]	0.1957[c]	0.5379[c]	0.5130[c]	0.3887[c]
2-hr Block	0.2814	0.6478[c]	0.6856[c]	0.2847[c]	0.4196[c]	0.2073[c]	0.5551[c]	0.5303[c]	0.4054[c]
3-hr Block	0.2890	0.6727	0.6906	0.2922[c]	0.4291[c]	0.2132[c]	0.5725[c]	0.5399[c]	0.4147[c]
24-hr Block	0.3508	—	—	0.3875	0.5352	0.2935	0.6884	0.6094[c]	0.4850[c]
24-hr Rolling	0.3450	0.7265	0.7296	0.3405	0.4845	0.2532	0.6433	0.6032	0.4786
7-day Rolling	0.6157	0.8127	0.8224	0.4635[c]	0.6114[c]	0.3620[c]	—	0.8222[c]	0.7363[c]
30-day Rolling	—	0.9287	0.9205	0.7025[c]	0.8113[c]	0.6080[c]	—	—	—
One Exceedance/Year									
1-hr Block	0.2954	0.6705	0.7069	0.2987[c]	0.4367[c]	0.2186[c]	0.5722[c]	0.5476[c]	0.4222[c]
2-hr Block	0.3129	0.6815[c]	0.7172[c]	0.3165[c]	0.4567[c]	0.2332[c]	0.5920[c]	0.5677[c]	0.4423[c]
3-hr Block	0.3228	0.7067	0.7236	0.3261[c]	0.4684[c]	0.2412[c]	0.6109[c]	0.5791[c]	0.4538[c]
24-hr Block	0.4021	—	—	0.4405	0.5890	0.3408	0.7333	0.6600[c]	0.5396[c]
24-hr Rolling	0.3770	0.7532	0.7562	0.3723	0.5192	0.2803	0.6745	0.6360	0.5133
7-day Rolling	0.6659	0.8438	0.8521	0.5181[c]	0.6619[c]	0.4138[c]	—	0.8519[c]	0.7765[c]
30-day Rolling	—	0.9419	0.9351	0.7461[c]	0.8425[c]	0.6587[c]	—	—	—

TABLE C-1. CONTINUED

Averaging Period	Plant ID #							
	17[a]	18[a]	19[a]	20[b]	21[a]	22[a]	23[a]	24[a]
One Exceedance/10Years								
1-hr Block	0.3521[c]	0.3668[c]	0.5155[c]	0.2203[c]	0.4907[c]	0.6955[c]	0.1803	0.4648
2-hr Block	0.3681[c]	0.3851[c]	0.5328[c]	0.2198[c]	0.5080[c]	0.7100[c]	0.1908[c]	0.4820[c]
3-hr Block	0.3771[c]	0.3943[c]	0.5424[c]	0.2393[c]	0.5375[c]	0.7338[c]	0.2019	0.5116
24-hr Block	0.4459[c]	0.4639[c]	0.6118[c]	0.3253[c]	0.6638[c]	0.8240[c]	0.2761	0.6402
24-hr Rolling	0.4396	0.4575	0.6056	0.2824	0.6161	0.7919	0.2541	0.5912
7-day Rolling	0.7046[c]	0.7195[c]	0.8237[c]	0.3971[c]	—	—	—	—
30-day Rolling	—	—	—	0.6429[c]	0.9774[c]	0.9904[c]	—	0.9750
One Exceedance/Year								
1-hr Block	0.3844[c]	0.4017[c]	0.5501[c]	0.2451[c]	0.5254[c]	0.7241[c]	0.2017	0.4995
2-hr Block	0.4039[c]	0.4215[c]	0.5702[c]	0.2469[c]	0.5457[c]	0.7401[c]	0.2152[c]	0.5198[c]
3-hr Block	0.4152[c]	0.4328[c]	0.5816[c]	0.2695[c]	0.5768[c]	0.7637[c]	0.2288	0.5513
24-hr Block	0.5004[c]	0.5185[c]	0.6623[c]	0.3750[c]	0.7107[c]	0.8535[c]	0.3219	0.6889
24-hr Rolling	0.4741	0.4921	0.6383	0.3114	0.6484	0.8139	0.2814	0.6244
7-day Rolling	0.7480[c]	0.7614[c]	0.8532[c]	0.4504[c]	—	—	—	—
30-day Rolling	—	—	—	0.6914[c]	0.9818[c]	0.9922[c]	—	0.9798

[a] High sulfur coal

[b] Low sulfur coal

[c] Estimated factor

TABLE C-2. SUMMARY OF EMISSION FACTORS - NON-FGD EQUIPPED SYSTEMS

Averaging Period	Plant ID #					
	1[b]	2[b]	5[b]	6[b]	7[b]	8[b]
One Exceedance/10Years						
1-hr Block	0.4458	0.7109		0.6773	0.5674	0.5511
2-hr Block	0.5622	0.7260		0.7371[c]	0.6366[c]	0.6146[c]
3-hr Block	0.5710	0.7373		0.7152	0.6109	0.5832
24-hr Block	0.6349	0.8122		—	—	—
24-hr Rolling	0.5898	0.7794		0.7589	0.5961	0.6055
7-day Rolling	0.7430	0.8982		0.8224	0.7068	0.7358
30-day Rolling	0.9164	—	0.6899	0.9205	0.7834	0.8167
One Exceedance/Year						
1-hr Block	0.4804	0.7387	0.1543[c]	0.7069	0.6012	0.5852
2-hr Block	0.5990	0.7550	0.2276[c]	0.7653[c]	0.6708[c]	0.6497[c]
3-hr Block	0.6095	0.7669	0.2355[c]	0.7465	0.6480	0.6213
24-hr Block	0.6839	0.8433	0.2993[c]	—	—	—
24-hr Rolling	0.6230	0.8023	0.2460[c]	0.7834	0.6291	0.6382
7-day Rolling	0.7825	0.9165	0.4152[c]	0.8521	0.7500	0.7761
30-day Rolling	0.9317	—	0.7346	0.9351	0.8182	0.8472

[a] High sulfur coal

[b] Low sulfur coal

[c] Estimated factor

APPENDIX D

CONVERSION FACTORS FOR SELECTED PROBABILITIES

CONVERSION FACTORS FOR SELECTED PROBABILITIES

Because the conversion factors are continuous and bounded above and below, they can be represented by a beta distribution. The statistics presented in Table D-1 and D-2 were calculated using a beta distribution to generate cumulative probabilities for two different exceedance policies. Table D-1 summarizes the one-exceedance-per-year policy and Table D-2 the one-exceedance-per-ten-years policy.

The units were divided into two categories according to FGD equipment; statistics for the combined categories are also shown. Means and standard deviations were calculated for each averaging period under a given exceedance policy. Factors were calculated at selected cumulative probability levels of 5 percent, 25 percent, 50 percent, 75 percent, and 95 percent. For example, for non-FGD equipped units under a compliance policy of one exceedance per year and a 1-hour block averaging period, 95 percent of the conversion factors are less than (or equal to) 0.85, whereas for a 30-day rolling averaging period, 95 percent of the conversion factors are less than (or equal to) 0.95.

TABLE D-1. CONVERSION FACTORS FOR DIFFERENT PROBABILITY CASES FOR ONE EXCEEDANCE PER YEAR

Statistic	1-hr B	2-hr B	3-hr B	24-hr R	7-day R	30-day R
<u>Non-FGD</u>						
Mean	0.57	0.63	0.63	0.65	0.77	0.85
Standard Deviation	0.19	0.18	0.17	0.18	0.16	0.08
Chance of Result < x = 5%	0.35	0.38	0.37	0.24	0.39	0.37
Chance of Result < x = 25%	0.52	0.55	0.52	0.42	0.56	0.56
Chance of Result < x = 50%	0.63	0.66	0.63	0.55	0.68	0.69
Chance of Result < x = 75%	0.74	0.76	0.73	0.68	0.78	0.81
Chance of Result < x = 95%	0.86	0.88	0.84	0.83	0.89	0.92
Chance of Result < x = 99%	0.92	0.93	0.90	0.90	0.94	0.96

(Continued)

TABLE D-1. CONVERSION FACTORS FOR DIFFERENT PROBABILITY CASES FOR ONE EXCEEDANCE PER YEAR

Statistic	1-hr B	2-hr B	3-hr B	24-hr R	7-day R	30-day R
<u>FGD Equipped</u>						
Mean	0.45	0.47	0.49	0.54	0.70	0.86
Standard Deviation	0.16	0.16	0.16	0.17	0.15	0.13
Chance of Result < x = 5%	0.17	0.14	0.15	0.20	0.29	0.34
Chance of Result < x = 25%	0.35	0.33	0.35	0.39	0.53	0.65
Chance of Result < x = 50%	0.50	0.49	0.52	0.56	0.69	0.84
Chance of Result < x = 75%	0.66	0.66	0.69	0.71	0.83	0.95
Chance of Result < x = 95%	0.83	0.85	0.87	0.88	0.95	0.99
Chance of Result < x = 99%	0.92	0.93	0.94	0.94	0.98	1.00

(Continued)

TABLE D-1. CONVERSION FACTORS FOR DIFFERENT PROBABILITY CASES FOR ONE EXCEEDANCE PER YEAR

Statistic	1-hr B	2-hr B	3-hr B	24-hr R	7-day R	30-day R
<u>All</u>						
Mean	0.48	0.51	0.52	0.56	0.72	0.86
Standard Deviation	0.18	0.18	0.18	0.17	0.16	0.11
Chance of Result < x = 5%	0.20	0.17	0.18	0.23	0.25	0.29
Chance of Result < x = 25%	0.40	0.38	0.40	0.44	0.52	0.58
Chance of Result < x = 50%	0.56	0.57	0.59	0.61	0.71	0.77
Chance of Result < x = 75%	0.71	0.74	0.75	0.76	0.86	0.91
Chance of Result < x = 95%	0.88	0.91	0.92	0.91	0.97	0.99
Chance of Result < x = 99%	0.94	0.97	0.97	0.96	0.99	0.99

(Continued)

TABLE D-1. CONVERSION FACTORS FOR DIFFERENT PROBABILITY CASES FOR ONE EXCEEDANCE PER 10 YEARS

Statistic	1-hr B	2-hr B	3-hr B	24-hr R	7-day R	30-day R
<u>Non-FGD Equipped</u>						
Mean	0.55	0.61	0.60	0.63	0.75	0.83
Standard Deviation	0.20	0.18	0.18	0.20	0.18	0.09
Chance of Result < x = 5%	0.30	0.31	0.28	0.18	0.28	0.27
Chance of Result < x = 25%	0.46	0.46	0.43	0.34	0.45	0.48
Chance of Result < x = 50%	0.57	0.57	0.54	0.48	0.59	0.63
Chance of Result < x = 75%	0.68	0.68	0.65	0.62	0.71	0.76
Chance of Result < x = 95%	0.82	0.80	0.79	0.79	0.85	0.90
Chance of Result < x = 99%	0.89	0.87	0.86	0.88	0.92	0.96

(Continued)

TABLE D-1. CONVERSION FACTORS FOR DIFFERENT PROBABILITY CASES FOR ONE EXCEEDANCE PER 10 YEARS

Statistic	1-hr B	2-hr B	3-hr B	24-hr R	7-day R	30-day R
FGD Equipped						
Mean	0.42	0.44	0.45	0.51	0.68	0.86
Standard Deviation	0.16	0.16	0.16	0.17	0.15	0.13
Chance of Result < x = 5%	0.15	0.11	0.12	0.17	0.23	0.25
Chance of Result < x = 25%	0.31	0.28	0.30	0.35	0.45	0.58
Chance of Result < x = 50%	0.46	0.44	0.46	0.51	0.63	0.80
Chance of Result < x = 75%	0.61	0.61	0.63	0.67	0.78	0.94
Chance of Result < x = 95%	0.80	0.81	0.83	0.85	0.93	0.99
Chance of Result < x = 99%	0.89	0.91	0.92	0.93	0.97	1.00

(Continued)

TABLE D-1. CONVERSION FACTORS FOR DIFFERENT PROBABILITY CASES FOR ONE EXCEEDANCE PER 10 YEARS

Statistic	1-hr B	2-hr B	3-hr B	24-hr R	7-day R	30-day R
<u>All</u>						
Mean	0.45	0.47	0.48	0.53	0.69	0.83
Standard Deviation	0.17	0.18	0.17	0.18	0.16	0.13
Chance of Result < x = 5%	0.18	0.14	0.15	0.20	0.30	0.19
Chance of Result < x = 25%	0.36	0.34	0.35	0.40	0.53	0.49
Chance of Result < x = 50%	0.52	0.52	0.53	0.56	0.68	0.72
Chance of Result < x = 75%	0.67	0.69	0.70	0.72	0.82	0.89
Chance of Result < x = 95%	0.84	0.88	0.88	0.88	0.94	0.99
Chance of Result < x = 99%	0.92	0.95	0.95	0.95	0.98	0.99