Fuel Loading Error Event Radiological Analyses for Offsite and Control Room Dose

B.1 INTRODUCTION

Radiological evaluations were performed to address the potential offsite dose consequences associated with a fuel loading error event. No specific NRC guidance is provided in Standard Review Plan 15.4.7, "Inadvertent Loading And Operation Of A Fuel Assembly In An Improper Position," (Reference 1) as to acceptable methods for radiological analysis. Therefore, recourse was made to SRP 15.4.9 "Radiological Consequences of Control Rod Drop Accident (BWR)" (Reference 2) for guidance. The reference source term selected for these evaluations was based on NRC conservative assumptions for analysis of a design basis Control Rod Drop Accident.

Two alternate scenarios for the fuel loading error (FLE) event were considered. The first followed the standard approach to analysis of the FLE as outlined in U.S. NRC SRP 15.4.9. In this case, it was assumed that the fission product activity is airborne in the turbine and condenser following Main Steam Isolation Valve (MSIV) closure and leaks directly from the condenser to the atmosphere. In the second scenario, it was assumed that no automatic MSIV closure occurred in that the activity was transported to an augmented[1] offgas system. The release of this activity to the environment would be from the normal offgas release point after holdup in the treatment system. Calculations of post–accident doses for the Exclusion Area Boundary (EAB) were performed for each scenario to compare radiological consequences with the applicable exposure limits.

EAB doses were also calculated for both scenarios utilizing the alternate source term (AST) methodology of Regulatory Guide 1.183 (Reference 11). As stated above, recourse was made to SRP 15.4.9 "Radiological Consequences of Control Rod Drop Accident (BWR)" (Reference 2) for radiological analysis guidance. Along those lines, Appendix C of Regulatory Guide 1.183 ("Assumptions for Evaluating the Radiological Consequences of a BWR Rod Drop Accident") was utilized for AST radiological analysis guidance.

In addition to the offsite dose evaluations, doses to the Control Room operators were calculated. The assumptions, inputs, and results are discussed in section B.6 of this attachment.

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[1] An augmented offgas system employs charcoal beds to hold up and delay the release of the non-condensable gas flow.

B.2 CONCLUSION

An analysis for a fuel loading error has been made assuming that all the rods in the fuel loading error plus all of the rods in the adjacent four bundles experience mechanical degradation resulting in fission gas release. To bound any potential variations in core and fuel two safety factors were applied: first a safety factor of 1.4 (see Table B-1) to account for variations in fission product inventory over the operational cycle; and second a safety factor of 2.5 was applied to account for variations in cycle dependent bundle power as a ratio to end of cycle average bundle power.

Two scenarios were evaluated (1) an analysis based upon similar accidents in which the plant is isolated and (2) a second scenario without isolation where the release is treated by an augmented offgas system. The results of the first scenario using conservative siting parameters are 30 Rem to the thyroid and 0.58 Rem whole–body with a 2-hour Chi/Q value at the EAB of $1.67\text{x}10^{-3}$ s/m^3. The second scenario produced a family of curves to be applied on a case–by–case basis for plant specific offgas design.

With the application of the AST methodology, the results of the first scenario are 2.5 Rem Total Effective Dose Equivalent (TEDE) with a 2-hour Chi/Q value at the EAB of 5.04 x 10^{-3} s/m^3. The second scenario requires a family of curves to be applied on a case-by-case basis using plant specific offgas design parameters.

Regarding the Control Room operator dose, the AST 5.0 Rem TEDE regulatory accident dose limit is reached with an atmospheric dispersion factor of 1.25 x 10^{-2} s/m^3. Only the first scenario was considered for Control Room operator accident dose, as the second scenario would yield a negligible dose, as iodine is the major contributor to the Control Room dose, and iodine is not considered in the second scenario as discussed in section B.4.2.1. The control room non-AST accident dose limit is reached with an atmospheric dispersion factor of 1.81 x 10^{-3} s/m^3.

B.3 SOURCE TERM ASSUMPTIONS

Evaluation of both scenarios was based on the noble gas and iodine activity releases from the fuel resulting from the following assumptions.

B.3.1 Fuel Damage

To obtain a bounding analysis, the FLE was assumed to result in failure of the equivalent of five bundles (primary and four adjacent). No fuel melt was assumed to occur as a result of this event.

B.3.2 Fission Product Release from Fuel

Fission product released from the fuel is consistent with the provisions of SRP 15.4.9. The fission product inventory was based on previous long–term operation at full power with no allowance for decay prior to initiation of the event. To insure that the inventory is bounding upon such an event, a safety factor of 1.4 was generated which encompasses the variation in fission product inventory over the cycle of the operating fuel. For fuel that does not reach the melting temperature (all the involved fuel in this analysis), 10% of the noble gas inventory and 10% of the iodine inventory was assumed to be released to the coolant.

With respect to AST methodology, fission product released from the fuel is consistent with the provisions of Regulatory Guide1.183. For fuel that does not reach the melting temperature (all the involved fuel in this analysis), 10% of the noble gas inventory, 10% of the iodine inventory, and 20% of the alkali metals was assumed to be released to the coolant. Table 3 of Regulatory Guide 1.183 assumes 12% of the alkali metals, but 20% was conservatively used for the analysis.

B.3.2.1 Bounding Assumption for Analysis

The calculations were performed with fission product inventories based on a power level of 5.75 MWt per bundle. A safety factor of 2.5 (Reference 10) was used to insure that the peak bundle power to bundle average cycle power was bounded. Therefore, the bundle end of cycle inventory was multiplied by 1.4 x 2.5 = 3.5 to bound variations in bundle inventory.

B.4 SCENARIO EVALUATIONS

B.4.1 Analysis for FLE with MSIV Closure (Scenario 1)

This analysis followed the SRP 15.4.9 conservative assumptions and utilized the source term previously described. This scenario assumes that the fission product activity is airborne in the main condenser.

The analysis utilizing AST methodology followed the Regulatory Guide 1.183 assumptions and used the source term previously described.

B.4.1.1 Assumptions

The conservative analysis assumptions stated in SRP 15.4.9 provide that 100% of the noble gases and 10% of the iodines released to the coolant should be assumed to enter the steam and be transported to the condenser before MSIV closure. The 10% iodine fraction is a very conservative basis for partitioning of iodine between water and steam in the vessel because carryover values are typically less than 2% (Reference 3). Since the 10% iodine fraction and all of the noble gases are assumed to reach the condenser, no practical credit is taken for reduction of the available source term as a result of MSIV closure. A more realistic analysis of the transport can be reviewed on a case–by–case basis. The conservative transport assumptions have been used in the present analysis.

Regarding AST methodology, Appendix C of Regulatory Guide 1.183 also states that 100% of the noble gases and 10% of the iodines released to the coolant should be assumed to enter the steam and be transported to the condenser before MSIV closure. In addition, 1% of the remaining radionuclides are assumed to reach the condenser, which differs from SRP 15.4.9.

All of the noble gases reaching the condenser are assumed to remain airborne and available for leakage. Washout/plateout of 90% of the iodines reaching the condenser is assumed, with 10% remaining airborne and available for leakage. In addition to the 90% iodine plateout above, AST methodology states that washout/plateout of 99% of the remaining radionuclides reaching the condenser is assumed. All airborne activity in the condenser is assumed to leak from the condenser to the atmosphere at a rate of 1% per day. It is also assumed that the main condenser's mechanical vacuum pump is isolated.

No credit is taken for holdup and decay in the turbine building after release from the condenser. The release from the turbine building is assumed to occur at ground level, which is considered the worst case for this event.

Thyroid dose conversion factors were taken from Regulatory Guide 1.109 (Reference 4) or Federal Guidance Report 11 (Reference 5) where Regulatory Guide 1.109 did not provide a value. Assumed breathing rates are from Regulatory Guide 1.3 (Reference 6). Whole–body gamma doses were based on a semi–infinite cloud calculation in accordance with Regulatory Guide 1.3 or Federal Guidance Report 12, Table 3.1 (Reference 7).

Regulatory Guide 1.183 provides dose conversion factors and assumed breathing rates for AST methodology.

B.4.1.2 Methods of Analysis

The calculations were performed using methods derived from the CONAC04 computer program (Reference 8). The models and data used in CONAC04 are based on the Regulatory Guides or Standard Review Plans which define the NRC accepted methods and assumptions for evaluation of the accidents.

Calculations with AST methodology were performed through the use of the RADTRAD computer code (Reference 12).

B.4.1.3 Results of Analysis

Activity inventories of nuclides that are airborne in the condenser are shown in Table B-2 for various times after initiation of the accident. The leakage rate from the condenser was 1% per day for all time periods. The corresponding time–integrated releases from the condenser to the environment are found in Table B-3.

The Chi/Q dispersion limit is back calculated from the 30 Rem thyroid dose based on the 2–hour Chi/Q at the EAB for a ground level release (though the total release integrated to 24 hours is used in the dose calculation). The resultant Chi/Q dispersion value was found to be 1.67×10^{-3} s/m^3, which bounds BWRs surveyed in Reference 9. 2–hour Chi/Q dispersion values at the EAB less than 1.67×10^{-3} s/m^3 will result in a thyroid dose below the 30 Rem limit. Note that the curve given in Figure B-1 is conservative in that the dispersion coefficient is constant over the 24 hour period of release and does not provide for reductions in dose for longer term dispersion factors. Doses for any other Chi/Q value may be scaled directly from these results and will be lower for any site when time variations in meteorology are accounted for. The relationships between calculated thyroid and whole–body doses and Chi/Q are shown in Figure B-1.

The offsite dose criterion established by SRP 15.4.7 for this accident is that doses should be a small fraction (10%) of the 10 CFR Part 100 guidelines; i.e., that the thyroid dose should be less than 30 Rem and the whole–body dose should be less than 2.5 Rem. Consequently, any dispersion coefficient less than the limiting 2–hour Chi/Q dispersion values at the EAB of 1.67×10^{-3} s/m^3 will result in doses less than the regulatory limit.

The offsite dose criterion for the FLE is 2.5 Rem TEDE. Utilizing AST methodology, a Chi/Q value of 5.04×10^{-3} s/m^3 yields an offsite dose of 2.5 Rem TEDE. A 2–hour Chi/Q dispersion value at the EAB less than the value of 5.04×10^{-3} s/m^3 will result in a dose less than the regulatory limit. Offsite AST TEDE doses as a function of the Chi/Q value are presented in Figure B-4.

B.4.2 Analysis for FLE without MSIV Closure (Scenario 2)

The method of analysis and assumptions, other than the release path assumptions discussed above, were consistent with the standard FLE analysis described in the previous section. In Scenario 2 it was assumed that the MSIVs did not close immediately after initiation of the accident and that steam flow continued for some period of time. If sufficient reactor power is available for steam jet air ejector (SJAE) operation, some or all of the available activity is transported to the augmented offgas system. It was assumed that the activity processed by the treatment system would be released from the normal offgas release point after some holdup time in the system.

B.4.2.1 Assumptions

The available noble gas source term for the analysis is the same as that assumed in the analysis for the FLE with MSIV closure; i.e., 10% of the activity released from the fuel and 100% transported to the offgas system. For the purpose of this scenario, the entire FLE noble gas source term was assumed to be released via the augmented offgas treatment system path to permit direct comparisons with doses calculated for the normal design basis FLE condenser leakage path.

It was assumed that the iodine activity transported to the augmented offgas system was retained indefinitely and did not contribute to offsite doses. It might be argued that some iodine activity transport to the condenser, in addition to the conservatively assumed initial 10% fraction of the total fuel release, could occur because of continued iodine carryover with steam through the open MSIVs. No offsite dose impact is expected, however, if the activity is being removed to the augmented offgas system by the air ejector.

If the event occurs at low power without the SJAE operating, the additional iodine activity due to carryover would not be expected to be significant. For Scenario 2 at low power levels without the SJAE operating, the offsite dose impact for noble gases is equivalent to Scenario 1, since 100% of the noble gas is assumed to be transported to the condenser. For example, if a carryover factor of 0.02 (ratio of microcuries of iodine per gram of steam to microcuries of iodine per gram of water) is assumed, the calculated iodine removal rate from the vessel at 5% of rated steam flow is in the approximate range of only 0.03 to 0.05% per minute. Moreover, the NRC assumption that 10% of the released iodines are instantaneously transported to the condenser is sufficiently conservative to bound the integrated carryover during the shutdown transient. For extended release periods (in excess of 3 hours), appropriate guidance should be provided for the operator to limit offsite releases.

The assumptions utilizing AST methodology do not differ from the assumption listed above.

B.4.2.2 Results of Analysis

Dose calculations were performed for an assumed release of 10% of the kryptons and for an assumed release of 10% of the xenons. Results of each of these calculations were plotted against an assumed delay time before release and shown in Figures B-2 and B-3. In Scenario 2 it was assumed that all of the remaining activity of each gas was released at approximately the same time. The doses shown in Figures B-2 and B-3 are integrated doses subsequent to release from the augmented offgas system. Offsite doses for Chi/Q values not shown may be obtained by scaling directly from any of the curves, since the calculated dose is proportional to the Chi/Q value.

Results of the dose calculations utilizing AST methodology were plotted against an assumed delay time before release and shown in Figures B-5 and B-6. It should be noted that the dose limit for the AST methodology is 2.5 Rem TEDE.

One method for establishing a conservative lower limit on the holdup time provided by the charcoal system would be to assume that the offgas system continues to operate after the FLE, and that the condenser air inleakage rate which applies at rated conditions continues undiminished. The noble gas holdup times appropriate for normal operation would be applicable under these assumptions. This approach, however, ignores the potential for any operator control and the fact that the plant would be shutdown by other systems. In reality, interruption of system operation will increase the holdup time in the charcoal.

With the augmented offgas treatment systems that are presently in use, substantial decay times are assured for noble gases, and any iodine releases are negligible because of retention in the charcoal beds. The delay time in the charcoal beds is proportional to the mass of charcoal and to the dynamic adsorption coefficient for the gas (which is a function of operational temperature and humidity conditions in the charcoal) and inversely proportional to the condenser air inleakage flow rate. As a specific example, low temperature offgas systems supplied by GE provide minimum decay times of 46 hours for kryptons and 42 days for xenons, with the relatively high design basis air inleakage rate of 30 cubic feet per minute. For these decay times, the doses corresponding to 100% release from Figures B-2 and B-3 for the enveloping 2–hour Chi/Q at the EAB value of 3×10^{-4} are approximately 1.6×10^{-3} and 7.9×10^{-3} for kryptons and xenons, respectively. Summing these doses results in an approximate total of 9.5×10^{-3} Rem, which is much less than the 2.5 Rem whole body dose limit.

Delay times in ambient temperature charcoal offgas systems depend on plant–specific design conditions, but, in general, are shorter than delay times in low temperature systems. If, for example, it is assumed that such a system provides a decay time of 12 hours for kryptons and a typical factor of about 18 is used for the ratio between xenon holdup and krypton holdup (Reference 3), the corresponding xenon decay time would be about 216 hours or 9 days. Reading the curves in Figures B-2 and B-3 for Chi/Q = 3×10^{-4} results in doses of 1.61 Rem for kryptons and 0.57 Rem for xenons or a sum of 2.18 Rem which is close to the 2.5 Rem whole body dose limit.

B.5 DELAYED AUGMENTED OFFGAS SYSTEM OPERATION

As needed for offgas system operational occurrences or maintenance, BWR plant operating procedures typically allow bypass of the offgas charcoal adsorbers. This operating mode is acceptable, provided the offgas radiation monitors (pre-treatment and/or post-treatment) are being utilized to automatically isolate the adsorber bypass line and/or offgas process line before the release rate limit is exceeded.

It is assumed that if the plant is at power and is bypassing the charcoal adsorbers, then the radioactive offgas release rate is acceptable. If, however, a subsequent condition develops such that excessive radioactivity is released from the reactor core, then the radiation detectors monitoring the offgas process line must have sufficient sensitivity and setpoint margin to isolate either the adsorber bypass or process line before release rate limits are exceeded. The actual speed of response of these detectors is a function of the manufacturer and the method by which a continuous sample is obtained. Nevertheless, the selection of alarm setpoints and trip actions (including applicable timer delays) for offgas radiation monitors, according to NRC guidance, is based on a correlation of acceptable offsite doses with system sensitivity to assure compliance with a plant' s Offsite Dose Calculation Manual.

B.6 CONTROL ROOM OPERATOR DOSES

Non-AST Methodology

The calculations were performed using methods derived from the CRDOS computer program (Reference 13). The models and data used in CRDOS are based on the Regulatory Guides or Standard Review Plans which define the NRC accepted methods and assumptions for evaluation of the accidents. The scenario with MSIV closure (Scenario 1) was used for dose determination, as Scenario 2 assumed that the iodine activity transported to the augmented offgas system was retained indefinitely and did not contribute to offsite (or Control Room) doses. The source term used for the analysis was the same source as was used for non-AST methodology Scenario 1.

The atmospheric dispersion factor must be considered in determining the dose to control room operators; however, other variables have an impact on the dose. Two variables are considered:

- Control room volume
- Flow rate of air through the control room

The condenser free air volume does not need to be considered as a variable, as the leakage rate from the condenser is 1% per day for the first 24 hours. The release from the condenser is in units of activity (Curies), thus, condenser volume is irrelevant. The control room filtered in-leakage and recirculation rate are conservatively assumed to be zero. A parametric study was performed to determine the impact, if any, of the dependence of the two variables on one another and on the control room dose.

The following ranges of values were selected for the two variables:

Control room volume: $1.0 \times 10^3 - 1.0 \times 10^6$ ft^3

Flow rate through the control room: $1.0 \times 10^2 - 1.0 \times 10^5$ cfm

The following assumptions were applied to the analysis:

- The inlet flow rate into the control room from the environment was identical to the exit flow rate from the control room to the environment
- The flow rate into and out of the control room (in cfm) was not larger than the control room volume (in ft^3), i.e., X<Y, where X = flow rate in cfm and Y = control room volume in ft^3
- No emergency charcoal filtration was credited

Of the control room doses (whole body gamma dose, thyroid dose, and beta skin dose) discussed in Standard Review Plan 6.4 (Reference 14), the thyroid dose was found to be the limiting dose for a control room operator due to a FLE. The highest thyroid dose occurs when the flow rate is highest relative to the control room volume. The 30 Rem thyroid regulatory accident dose limit is reached with an atmospheric dispersion factor of 1.81×10^{-3} s/m^3. Chi/Q dispersion values less than 1.81×10^{-3} s/m^3 will result in a thyroid dose below the 30 Rem limit. Control Room doses as a function of the atmospheric dispersion factor are presented in Figure B-7.

AST Methodology

RADTRAD was used to model the control room and calculate AST operator doses for the duration of the accident. The analysis runs performed used the same assumptions, variables, and ranges of variables as were used in the non-AST control room dose analysis described above. The source term was the same source as was used for AST methodology Scenario 1.

Using an atmospheric dispersion factor of 2.5×10^{-3} s/m^3 for all the runs, the largest control room dose calculated was 1.0 Rem, which results from the largest volume (1.0E+06 ft^3) and highest flow rate (1.0E+05 cfm). Although the range of control room doses is very small for the majority of the volume/flow rate combinations (most of the doses are between 0.95 and 1.0 rem), the reason that the highest dose occurs at the highest volume and flow rate is that the high flow rate increases (slightly) the inhalation dose, and the larger control room volume increases (slightly) gamma immersion dose. Large control room volumes with low flow rates result in smaller doses, on the order of 0.3 to 0.7 Rem.

Since the Chi/Q value is directly proportional to dose, the 5.0 Rem TEDE regulatory accident dose limit is reached with an atmospheric dispersion factor of 1.25×10^{-2} s/m^3. AST Control Room doses as a function of the atmospheric dispersion factor are presented in Figure B-8.

B.7 REFERENCES

1. U.S. NRC Standard Review Plan, Section 15.4.7, NUREG–0800, July 1981.
2. U.S. NRC Standard Review Plan, Section 15.4.9, NUREG–0800, July 1981.
3. NUREG–0016, Rev. 1, “Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling Water Reactors,” January 1971.
4. Regulatory Guide 1.109, “Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I,” March 1976.
5. Eckerman, Keith F., Wolbarst, Anthony B., and Richardson, Allan C.B., “Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion,” U.S. EPA Federal Guidance Report No. 11, dated 1988.
6. Regulatory Guide 1.3, “Assumptions used for Evaluating the Potential Radiological Consequences of a Loss–of–Coolant Accident for Boiling Water Reactors,” June 1974.
7. Eckerman, Keith F and Ryman, Jeffrey C., “External Exposure to Radionuclides in Air, Water, and Soil,” U.S. EPA Federal Guidance Report No. 12, dated 1993.
8. NEDO–32708, "Radiological Accident Evaluation — The “CONAC04A Code,” August 1997.
9. NEDO–31400A, “Safety Evaluation for Eliminating The Boiling Water Reactor Main Steam Line Isolation Valve Closure Function and SCRAM Function of the Main Steam Line Radiation Monitor,” Class I, October 1992.
10. Letter, February 4, 2004, “Peaking Factor of 2.5, Justification and Approval,” GE eDRF 0000–0006–0282.
11. Regulatory Guide 1.183, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Plants,” July 2000.
12. NUREG/CR-6604 (including Supplements 1 and 2), “RADTRAD: A Simplified Model for Radionuclide Transport and Removal and Dose Estimation.”
13. NEDO-32709, “Control Room Accident Exposure Evaluation – The CRDOS Code,” August 1997.
14. U.S. NRC Standard Review Plan, Section 6.4, NUREG–0800, July 1981.

Table B-1 Analysis Parameters

Analysis Parameter	Scenario 1 – Isolation	Scenario 2 – No Isolation
Inventory Parameters		
Bundle Power	5.75 MWt	5.75 MWt
Radial Peaking Factor	2.5	2.5
Safety Factor	1.4	1.4
Release Parameters		
Bundles Breached	5	5
Gap Fractions		
Noble Gas	10%	10%
Iodine	10%	10%
Fraction of Gap Released to coolant		
Noble Gas	100%	100%
Iodine	100%	100%
Fraction of fuel exceeding 2842°C	0%	0%
Transport to Turbine Condensers		
Noble Gas	100%	100%
Iodines	10%	10%
Particulate Radionuclides (AST methodology only)	1%	1%
Condenser Removal and Transport		
Removal Fractions		
Noble Gas	0%	
Iodines	90%	
Particulate Radionuclides (AST methodology only)	99%	
Leakage Rate	1% per day	
Period of Leakage	24 hours	
Offgas Removal and Transport		Iodines Removed. Noble Gas decay parameterized with Xe K_d = 18x Kr K_d
Meteorology and Dose Conversion Coefficients		
Dispersion Coefficient	1.67×10^{-3} s/m^3	Figures B-2 & B-3
Dispersion Coefficient (AST)	1.27×10^{-2} s/m^3	Figures B-5 & B-6
Dose Conversion Factors	R.G. 1.109 R.G. 1.183 (AST)	R.G. 1.109
Breathing Rate	3.7×10^{-4} m^3/s R.G. 1.183 (AST)	n/a

Table B-2 Scenario 1 Inventory In Condenser in Curies

	Time into event in Hours						
	0	0.5	1	2	8	16	24
I-128	3.3E+01	1.4E+01	6.2E+00	1.2E+00	5.4E-05	8.9E-11	1.5E-16
I-129	1.0E-04	1.0E-04	1.0E-04	1.0E-04	1.0E-04	1.0E-04	9.9E-05
I-130	8.6E+01	8.4E+01	8.1E+01	7.7E+01	5.5E+01	3.5E+01	2.2E+01
I-131	2.6E+03	2.6E+03	2.6E+03	2.6E+03	2.6E+03	2.5E+03	2.4E+03
I-132	3.8E+03	3.3E+03	2.8E+03	2.1E+03	3.4E+02	3.0E+01	2.6E+00
I-133	5.4E+03	5.3E+03	5.2E+03	5.1E+03	4.1E+03	3.2E+03	2.4E+03
I-134	6.0E+03	4.0E+03	2.7E+03	1.2E+03	1.1E+01	1.9E-02	3.4E-05
I-135	5.1E+03	4.8E+03	4.6E+03	4.1E+03	2.2E+03	9.3E+02	4.0E+02
Kr-83m	3.4E+04	2.8E+04	2.3E+04	1.6E+04	1.7E+03	8.6E+01	4.4E+00
Kr-85	3.3E+03	3.3E+03	3.3E+03	3.3E+03	3.3E+03	3.3E+03	3.3E+03
Kr-85m	7.2E+04	6.6E+04	6.1E+04	5.3E+04	2.1E+04	6.0E+03	1.7E+03
Kr-87	1.4E+05	1.1E+05	8.0E+04	4.6E+04	1.7E+03	2.2E+01	2.7E-01
Kr-88	1.9E+05	1.7E+05	1.5E+05	1.2E+05	2.7E+04	3.7E+03	5.1E+02
Kr-89	2.4E+05	3.3E+02	4.6E-01	8.8E-07	4.5E-41	8.4E-87	1.6E-132
Kr-90	2.4E+05	0.0	0.0	0.0	0.0	0.0	0.0
Kr-91	1.8E+05	0.0	0.0	0.0	0.0	0.0	0.0
Kr-92	8.5E+04	0.0	0.0	0.0	0.0	0.0	0.0
Xe-131m	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.9E+03	2.8E+03	2.7E+03
Xe-133	5.4E+05	5.4E+05	5.4E+05	5.4E+05	5.2E+05	4.9E+05	4.7E+05
Xe-133m	1.7E+04	1.7E+04	1.7E+04	1.6E+04	1.5E+04	1.4E+04	1.2E+04
Xe-135	1.8E+05	1.8E+05	1.7E+05	1.6E+05	1.0E+05	5.4E+04	3.0E+04
Xe-135m	1.1E+05	2.7E+04	7.0E+03	4.6E+02	3.8E-05	1.4E-14	4.9E-24
Xe-137	4.7E+05	2.1E+03	9.4E+00	1.9E-04	1.1E-32	2.6E-70	6.1E-108
Xe-138	4.5E+05	1.0E+05	2.4E+04	1.3E+03	3.0E-05	2.0E-15	1.3E-25
Xe-139	3.5E+05	0.0	0.0	0.0	0.0	0.0	0.0

Table B-3 Scenario 1 Integrated Release to Environment in Hours

	Time into event in Hours					
	0.5	1	2	8	16	24
I-128	4.61E-03	6.61E-03	7.87E-03	8.16E-03	8.16E-03	8.16E-03
I-129	2.09E-08	4.18E-08	8.36E-08	3.34E-07	6.67E-07	9.98E-07
I-130	1.77E-02	3.49E-02	6.79E-02	2.31E-01	3.78E-01	4.72E-01
I-131	5.50E-01	1.10E+00	2.19E+00	8.66E+00	1.71E+01	2.52E+01
I-132	7.37E-01	1.37E+00	2.38E+00	4.77E+00	5.19E+00	5.22E+00
I-133	1.12E+00	2.22E+00	4.37E+00	1.58E+01	2.79E+01	3.71E+01
I-134	1.03E+00	1.72E+00	2.49E+00	3.13E+00	3.14E+00	3.14E+00
I-135	1.03E+00	2.00E+00	3.81E+00	1.14E+01	1.63E+01	1.84E+01
Kr-83m	6.40E+00	1.17E+01	1.98E+01	3.57E+01	3.75E+01	3.76E+01
Kr-85	6.97E-01	1.39E+00	2.79E+00	1.11E+01	2.22E+01	3.33E+01
Kr-85m	1.44E+01	2.77E+01	5.15E+01	1.37E+02	1.77E+02	1.88E+02
Kr-87	2.52E+01	4.44E+01	7.01E+01	1.04E+02	1.05E+02	1.05E+02
Kr-88	3.82E+01	7.19E+01	1.28E+02	2.83E+02	3.21E+02	3.27E+02
Kr-89	7.55E+00	7.56E+00	7.56E+00	7.56E+00	7.56E+00	7.56E+00
Kr-90	1.27E+00	1.27E+00	1.27E+00	1.27E+00	1.27E+00	1.27E+00
Kr-91	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01
Kr-92	2.60E-02	2.60E-02	2.60E-02	2.60E-02	2.60E-02	2.60E-02
Xe-131m	6.11E-01	1.22E+00	2.44E+00	9.68E+00	1.91E+01	2.84E+01
Xe-133	1.13E+02	2.25E+02	4.50E+02	1.77E+03	3.45E+03	5.06E+03
Xe-133m	3.50E+00	6.98E+00	1.39E+01	5.33E+01	1.01E+02	1.44E+02
Xe-135	3.75E+01	7.37E+01	1.42E+02	4.58E+02	7.08E+02	8.44E+02
Xe-135m	1.20E+01	1.51E+01	1.61E+01	1.62E+01	1.62E+01	1.62E+01
Xe-137	1.81E+01	1.82E+01	1.82E+01	1.82E+01	1.82E+01	1.82E+01
Xe-138	4.92E+01	6.06E+01	6.38E+01	6.40E+01	6.40E+01	6.40E+01
Xe-139	2.38E+00	2.38E+00	2.38E+00	2.38E+00	2.38E+00	2.38E+00

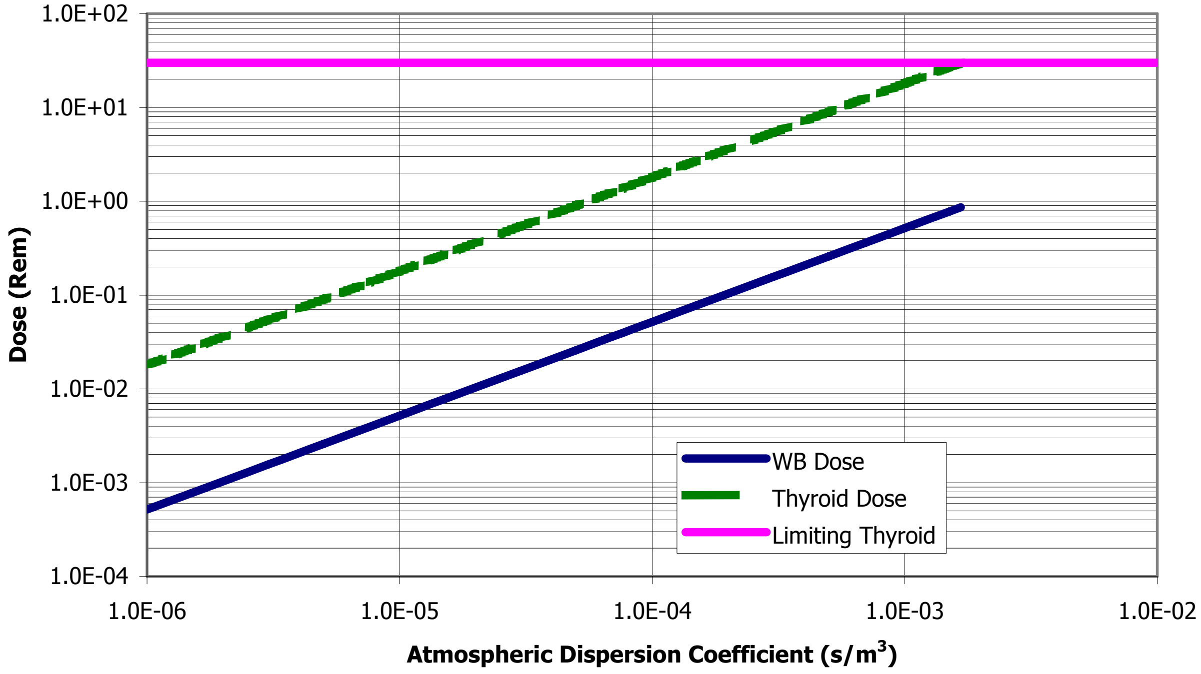

Figure B-1 Scenario 1 Dose with Respect to Dispersion Coefficient

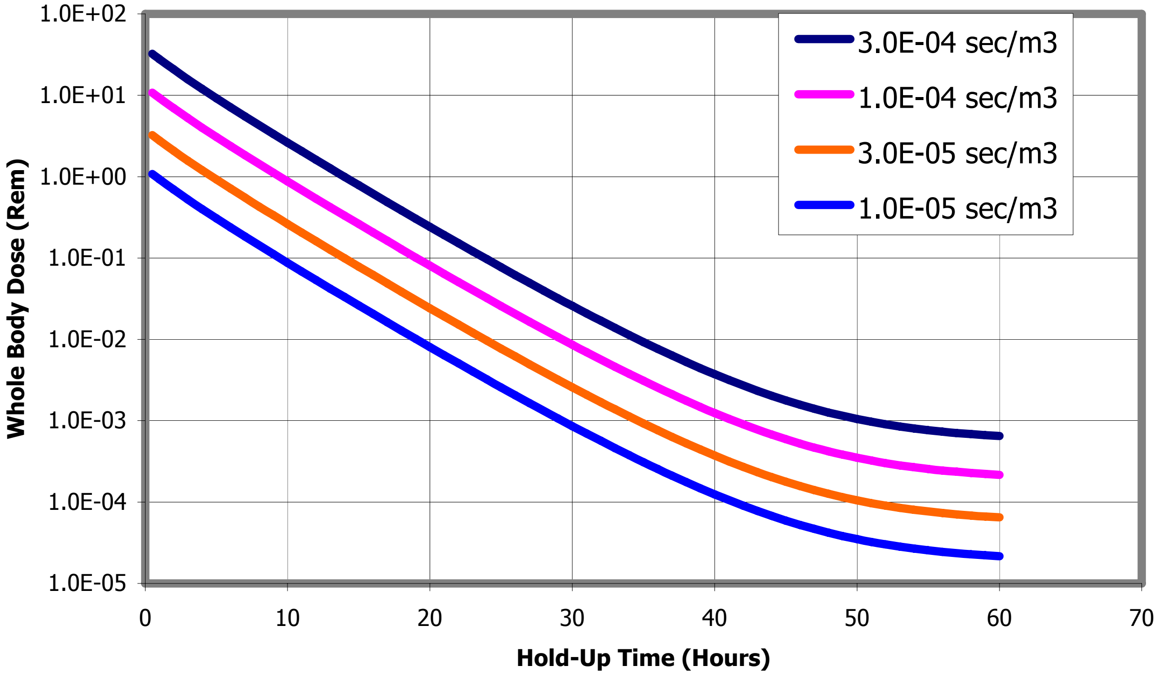

Figure B-2 Scenario 2 Krypton Whole Body Dose with Respect to Charcoal Hold Up

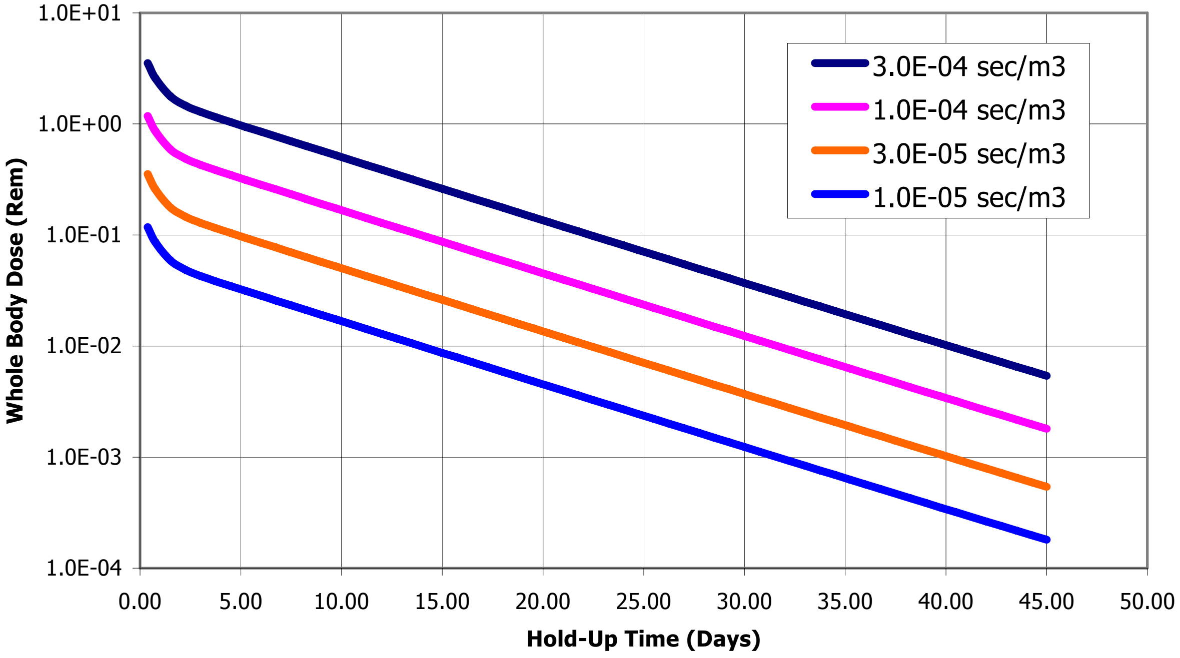

Figure B-3 Scenario 2 Xenon Whole Body Dose with Respect to Charcoal Hold Up

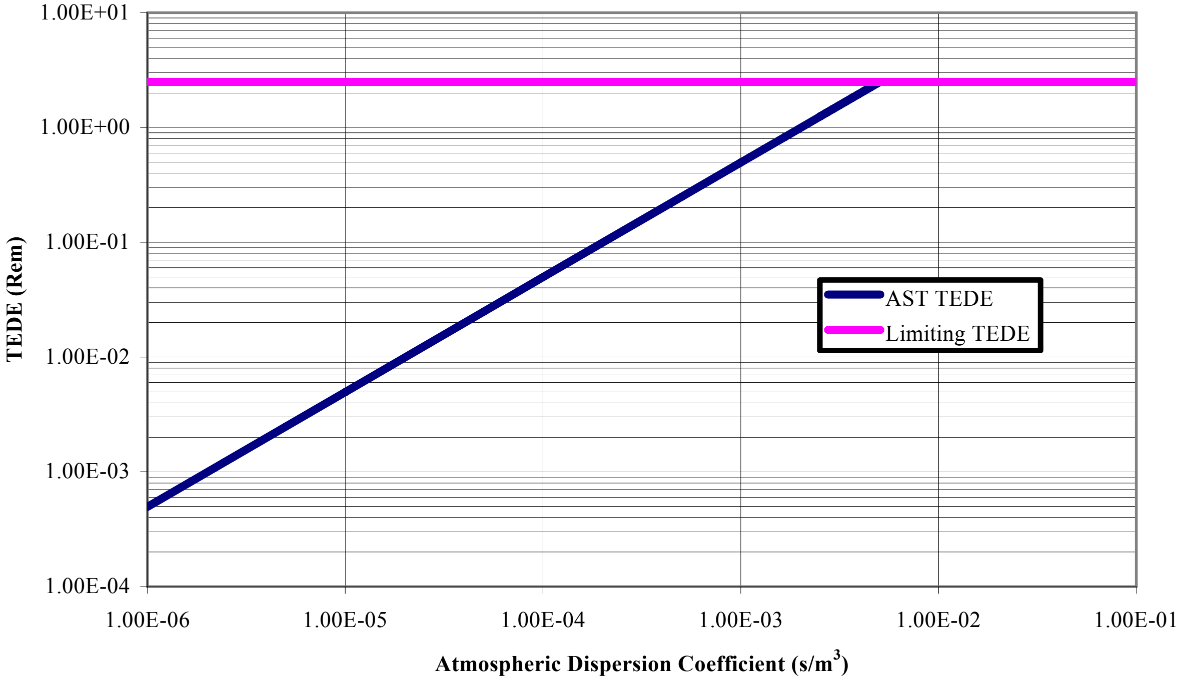

Figure B-4 Scenario 1 TEDE with Respect to Dispersion Coefficient Utilizing AST Methodology

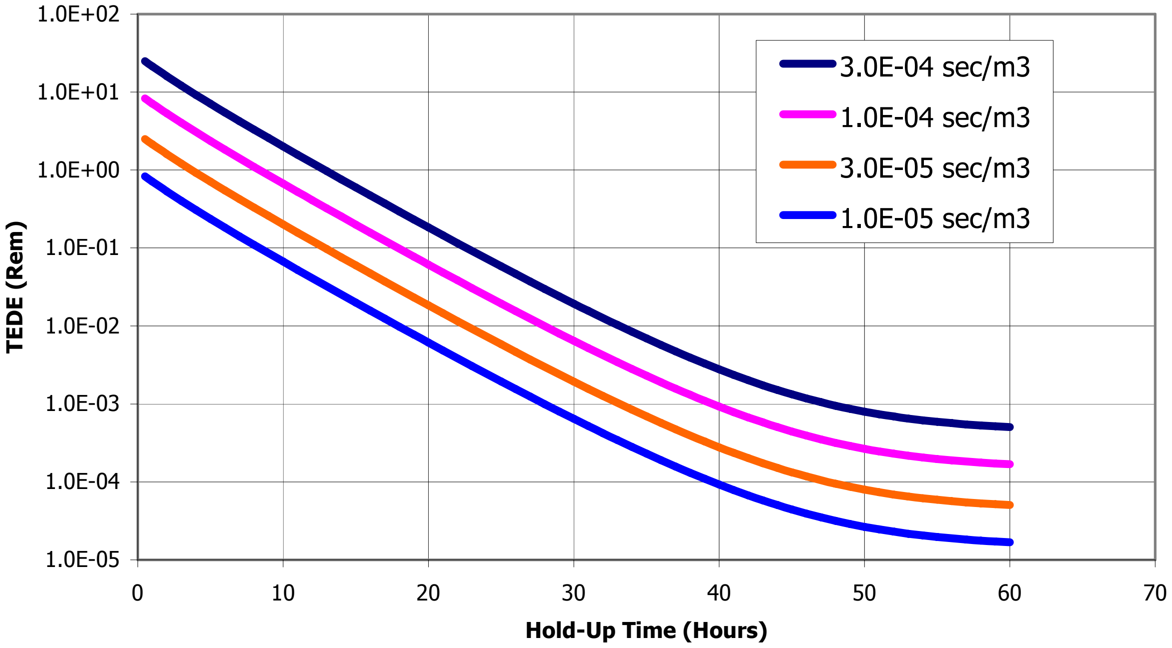

Figure B-5   Scenario 2 Krypton TEDE with Respect to Charcoal Hold Up Utilizing AST Methodology

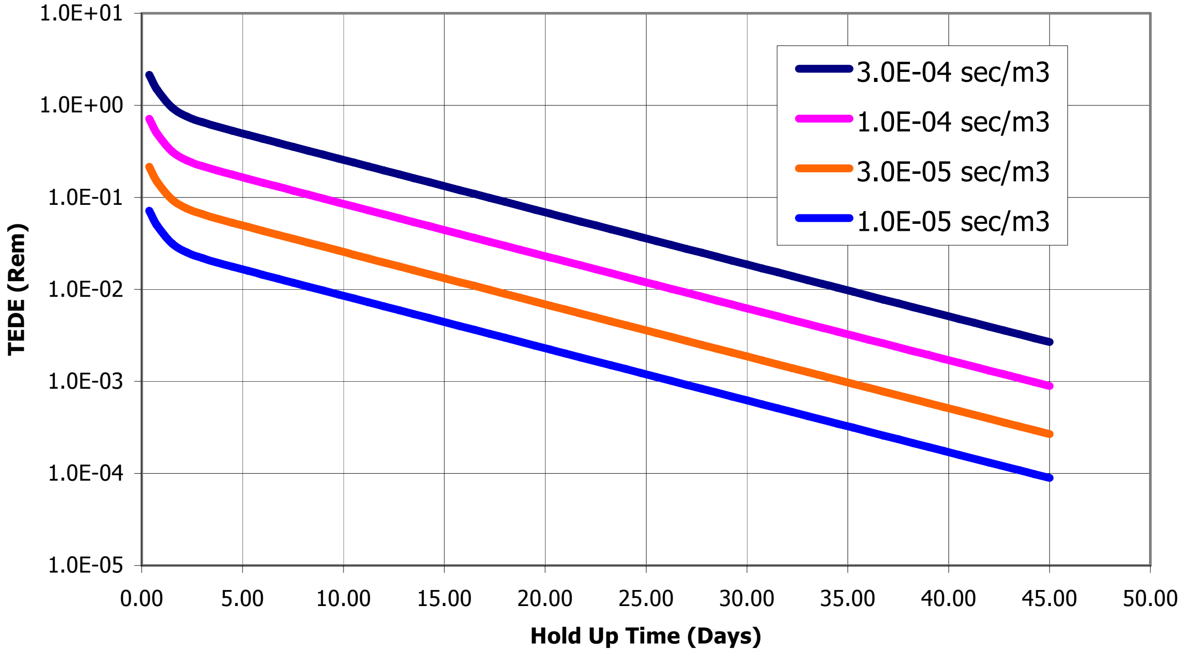

Figure B-6   Scenario 2 Xenon TEDE with Respect to Charcoal Hold Up Utilizing AST Methodology

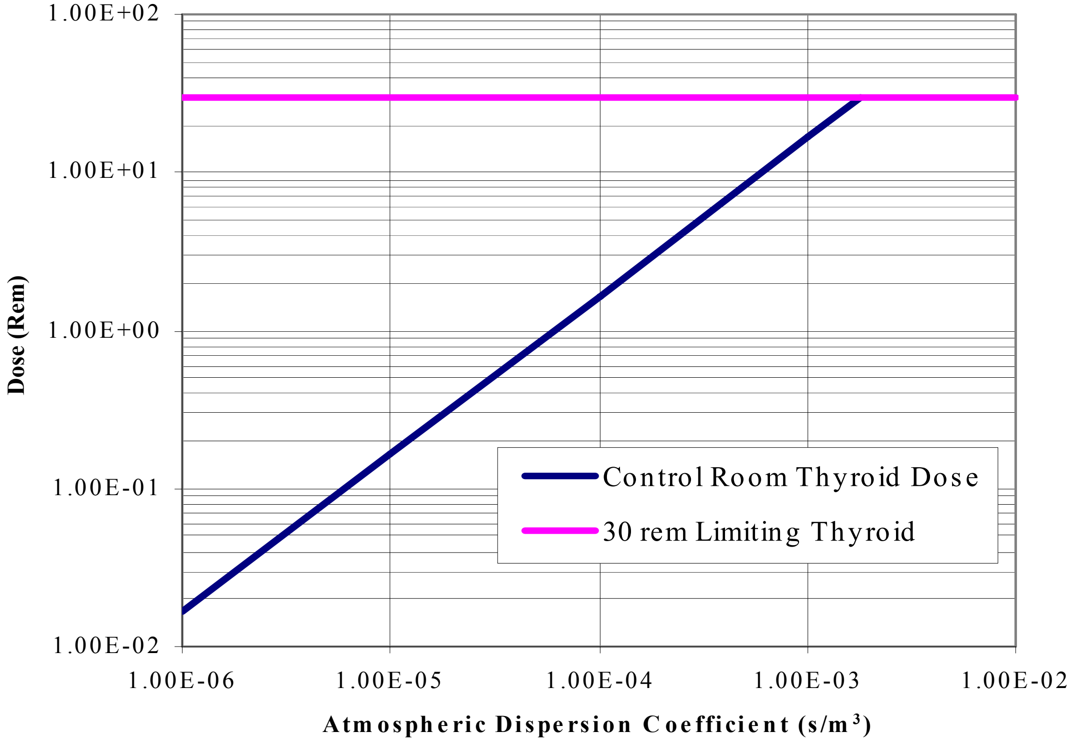

Figure B-7 Control Room Dose with Respect to Dispersion Coefficient

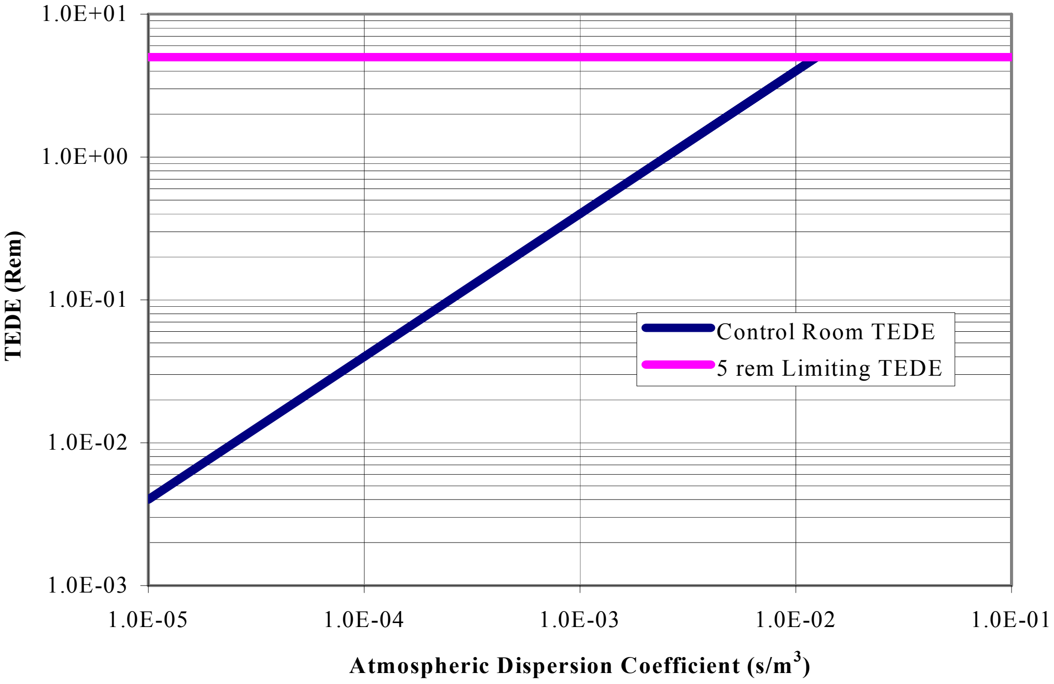

Figure B-8 Control Room TEDE with Respect to Dispersion Coefficient Utilizing AST Methodology