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July 8, 2005

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Subject: Duke Energy Corporation
Catawba Nuclear Station, Units 1 and 2
Docket Numbers 50-413 and 50-414

Proposed Technical Specifications and Bases Amendment
Technical Specification and Bases 3.6.10
Annulus Ventilation System (AVS)
Technical Specification and Bases 3.6.16
Reactor Building
Technical Specification Bases 3.7.10
Control Room Area Ventilation System (CRAVS)
Technical Specification Bases 3.7.12
Auxiliary Building Filtered Ventilation Exhaust System (ABFVES)
Technical Specification Bases 3.7.13
Fuel Handling Ventilation Exhaust System (FHVES)
Technical Specification and Bases 3.9.3
Containment Penetrations
Technical Specification 5.5.11
Ventilation Filter Testing Program (VFTP)
TAC Numbers MB7014 and MB7015

References:

1. Letters from Duke Energy Corporation to NRC, dated November 25, 2002, November 13, 2003, December 16, 2003, September 22, 2004, April 6, 2005, and June 14, 2005

2. Electronic communication from S.E. Peters to L.A. Keller and L.J. Rudy, dated June 21, 2005

In Reference 2, NRC provided a draft Request for Additional Information (RAI) concerning the subject Catawba license amendment request submittal. On June 23, 2005, a telephone

A001

conference call was held among Duke Energy Corporation and NRC representatives to discuss this RAI.

The purpose of this letter is to provide a response to this RAI.

Pursuant to 10 CFR 50.91, a copy of this letter is being sent to the appropriate State of South Carolina official.

Inquiries on this matter should be directed to L.J. Rudy at (803) 831-3084.

Very truly yours,

James R. Morris

Attachment

James R. Morris affirms that he is the person who subscribed his name to the foregoing statement, and that all the matters and facts set forth herein are true and correct to the best of his knowledge.

James R. Morris, Vice President, Nuclear Support

Subscribed and sworn to me: July 8, 2005
Date

Notary Public

My commission expires: March 9, 2009
Date

NOTARY
My Comm. Exp.
March 09, 2009
PUBLIC

SEAL

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ATTACHMENT

RESPONSE TO NRC REQUEST FOR ADDITIONAL INFORMATION

1) *Regarding iodine release (partitioning) from ESF systems and RWST* [Refueling Water Storage Tank] *leakage, the staff structured regulatory positions in RG 1.183, Appendix A, Section 5.5, to be deterministic and conservative in order to compensate for the lack of research into iodine release, partitioning, and speciation from systems outside containment, and the uncertainties of applying laboratory data to the post-accident environment in the plant. Regulatory Position 5.5 does state that a smaller flash fraction could be justified based on the actual sump pH history and area ventilation rates. The staff needs additional information to provide justification for Duke's proposed treatment of ESF* [Engineered Safety Features] *system and RWST leakage:*

Response: Duke Energy Corporation (Duke) submitted an analysis of the radiological consequences (henceforth denoted as dose analysis) of the design basis LOCA (Ref. 2,5). Duke later submitted dose analyses for the design basis locked rotor accident (LRA) and rod ejection accident (REA, Ref. 8). Finally, Duke has submitted dose analyses for these design basis accidents demonstrating the effect of mixed oxide (MOX) lead fuel assemblies on the radiological consequences of the design basis LOCA, LRA, and REA (Ref. 8). These analyses were completed with the method of Alternative Source Terms (AST, comp. Ref. 21-24). The dose analysis of the design basis LOCA and REA incorporated leakage from Engineered Safety Features (ESF) inside the Auxiliary Building and to the RWST. The analyses of radiation doses for these post accident leak paths featured calculations of iodine partitioning (defined to include the formation of volatile iodine forms and the partitioning of the volatile forms to the airspace above the leakage) from the leakage in the Auxiliary Building and from the contaminated inventory in the RWST. The method for these calculations was developed based on NUREG/CR-5950 (Ref. 1). The resultant iodine partition fractions were used in place of the value of 10% or 0.1 cited in the germane staff positions for post LOCA ESF leakage (Ref. 22, cf. Ref. 2). The values calculated for iodine partition fraction for ESF leakage in the Auxiliary Building and to the RWST following a design basis LOCA and REA are presented in Tables Q1-1 through Q1-5 (Ref. 2,8).

The calculations of iodine partitioning and release for post LOCA leakage from ESF systems in the Auxiliary Building or to the RWST incorporate a number of conservative features. The first conservative feature is embedded in the method of

NUREG/CR-5950 itself. Additional conservative features were included in the calculations of post ESF leakage iodine partition fraction to offset uncertainties associated with the method and its applications in these calculations. In addition, other processes by which iodine might be prevented from escaping to the environment were ignored.

The conservative features of the calculations of iodine partition fractions following a design basis LOCA and REA are listed below. For some of these features, estimates of the degrees to which the features are conservative are provided. Some of the features are further discussed in the responses to the specific questions below.

1.1) The method of NUREG/CR-5950. (Ref. 1) is based on reactions of diatomic iodine (I_2), iodide (I^-) ions, water, and hydrogen peroxide (H_2O_2). The mathematical model for formation of I_2 makes use of equilibrium and reaction rate constants that are referenced at 25 °C (77 °F). NUREG/CR-5950 states that the model based on these constants begins to fail at temperatures above 30 °C (86 °F) in that it over predicts the formation of I_2. Pursuant to the recommendation made within, the model of NUREG/CR-5950 has been used without modification of these constants. At the same time, the calculations of formation of volatile I_2 were performed with the pH of the leakage based on leakage temperature for ESF leakage in the Auxiliary Building and inventory temperature for ESF leakage to the RWST. This introduces additional conservative margin in the analysis of iodine partitioning for ESF leakage in the Auxiliary Building and to the RWST.

NUREG/CR-5950 (Ref. 1) provides information from which the degree of this conservatism can be estimated. They cite a test completed by Burns (1990) conducted of an irradiated solution of 1×10^{-4} gm-atoms/L of I^- ions. The test showed a conversion of about 45% of the iodine into I_2 at 30 °C (86 °F) but conversion of about 10% of the iodine into I_2 at 158 °F (70 °C). This implies a safety factor of about 4.5. NUREG/CR-5950 also provides data from an ORNL test of an irradiated solution of 1×10^{-4} gm-atoms/L of I^- ions at 198 °F (92 °C). The measured value of amount of I_2 formed for a solution pH of 4 was 38.9% versus a calculated value of 72.6% for a safety factor of about 1.9. For a solution pH of 5, the measured value was 3.1% versus a calculated value of 17.9% yielding a safety factor of about 5.8. By comparison, the calculated temperatures in the dose analyses for Catawba range from 145 °F to 185 °F for post accident ESF leakage in the Auxiliary Building and from 100 °F to 183 °F for ESF backleakage to the RWST. This demonstrates that use of the reaction constants provided in the model of NUREG/CR-5950 is conservative.

1.2) Additional processes which may prevent the escape of iodine airborne in the Auxiliary Building were not credited. In particular, no credit was taken for plate-out of iodine in the Auxiliary Building. In addition, dilution of airborne iodine within the Auxiliary Building was not simulated in the analysis. The germane regulatory position states the following:

"Reduction in release activity by dilution or holdup within buildings, or by ESF ventilation systems, may be credited where applicable." (Credit is taken for the Class 1E Auxiliary Building Filtered Ventilation Exhaust System - ABFVES - to filter iodine from rooms to which it is aligned.)

Studies of post accident iodine transport in the Auxiliary Building have been performed (Ref. 25,31,32). From these studies, it is estimated that the fraction of fission products retained in the Auxiliary Building internal structures ranges from 25% to 75% of fission products released from a leak within it (that is, a reduction by a factor ranging from 1.3 to 4). Additional margin for simulation of dilution of iodine within the Auxiliary Building is available. In addition, iodine airborne from a leak in a room to which the ABFVES is aligned must diffuse in at least part of that room before induction into the ABFVES. Iodine airborne from a leak in a room to which the ABFVES is not initially aligned must traverse additional rooms before escaping to the environment. Therefore, iodine airborne from ESF leakage in the Auxiliary Building to the environment is likely to undergo a significant degree of dilution before release to the environment.

1.3) A lower bound of 1% has been set for iodine partition fraction for ESF leakage in the Auxiliary Building following a design basis LOCA. This creates a margin ranging from 1.3 to 6.7 in these cases.

1.4) The model for convective transfer of iodine across a surface of a pool (of ESF leakage in the Auxiliary Building) includes coefficients for film transfer for the gas and liquid phase. The liquid film mass transfer coefficient of iodine is set to zero (0) as recommended by Yuill (Ref. 26). Since the inverse of the overall transfer coefficient is the sum of the inverses of the gas and liquid film transfer coefficients, this assumption is conservative.

1.5) No iodine is assumed to be in the airspace above ESF leakage in the Auxiliary Building for the calculation of iodine partition fraction. That is, the iodine concentration in the airspace above a pool of ESF leakage in the Auxiliary Building is set to zero (0). This maximizes the flux of iodine partitioning from the pool. (Ref. 1, 26).

1.6) No forced convection was assumed in setting the temperature for ESF leakage in the Auxiliary Building. However, the highest values were taken for the ventilation airflow assumed in the calculation of iodine partition fraction for ESF leakage in the Auxiliary Building.

1.7) The iodine concentration in the airspace of the RWST was calculated for each time interval to be instantly at equilibrium with the iodine in the water in the RWST. Since iodine concentration in the airspace of the RWST is calculated to increase monotonically, this assumption is conservative.

1.8) The maximum iodine inventory in the sump was used for all time intervals in calculating iodine partitioning from ESF leakage in the Auxiliary Building and to the RWST. This is particularly significant for the contribution for the ESF leakage to the thyroid committed dose equivalent (CDE) at the Exclusion Area Boundary (EAB). Also, the most conservative values were taken for the other solutes assumed to be in the ESF leakage. For example, the sodium content in the leakage over a time interval was set to its lowest value while upper bounds for a time interval were taken for the content of boron, nitrates, chloride, etc.

1.9) Only sodium, boron, lithium (initially in the reactor coolant), nitrates, and chlorides (the latter two formed over the course of the design basis accident as calculated) are assumed to be in the containment sump and therefore in the ESF leakage to the Auxiliary Building and to the RWST. Other impurities such as fission products other than iodine are not modeled. From the evaluation reported below, it is seen that this assumption is generally conservative. (Response to Question d.)

1.10) The effect of hydrostatic pressure of the inventory in the RWST on ESF back leakage is ignored. The value assumed for ESF leak rate to the RWST is held constant regardless of level in the tank. Accounting for hydrostatic pressure in the RWST would yield lower values of ESF leak rate over time.

1.11) ESF leakage both in the Auxiliary Building and to the RWST was assumed for the dose analysis of the design basis REA, as was assumed for the dose analysis of the design basis LOCA. This assumption is conservative with respect to the germane regulatory positions. (Ref. 24, 27-29)

The analysis of iodine partitioning for ESF leakage in the Auxiliary Building and to the RWST following a LOCA was completed based in part on a calculation of containment sump pH for the design basis LOCA. No calculation of containment sump pH following a design basis REA has been prepared. In the absence of this calculation, additional conservative assumptions were made. These assumptions are noted and discussed below.

Some features of the calculations of iodine partition fractions for post accident ESF leakage may not necessarily be conservative. These features are listed as follows:

1.12) For ESF leakage in the Auxiliary Building, neither spraying of the leak nor streaming of the leak to a floor drain is modeled. This feature of the analysis is discussed below. (Response to Question b.)

1.13) It is assumed that iodine and other solutes entrained with ESF leakage to the RWST mix instantaneously and homogeneously with the inventory in the RWST. Since the injection lines of the Emergency Core Cooling System (ECCS) and the Containment Spray System (CSS) connect to the RWST near its base, this assumption is conservative with respect to the injection lines. The recirculation lines of the Safety Injection System (SIS) and the CSS connect to the RWST near its top. Additional detail pertaining to this assumption and its comparison to the ECCS and CSS injection lines and the SIS and CSS recirculation lines is discussed in additional detail in the response to Question e.

The above features demonstrate in general that when an uncertainty in the method of calculation or an input was noted, that the conservative decision was made to use the limiting values for a parameter of calculation or input. It also shows that other processes that should retain or otherwise prevent iodine airborne from ESF leakage were not included to lower the effective iodine partition fraction. The features listed above demonstrate that when the model for iodine partitioning was simplified, the simplifying assumption was made so as to be conservative. Finally, the features listed above demonstrate that in incorporating ESF leakage for the design basis REA, Duke has incorporated release paths that are not cited in any regulatory position and has done so in a conservative manner.

With these features in mind, responses are provided to the seven specific questions as presented below.

a. *What consideration was given to the mass transfer at the surface of the ESF leakage water pool, the possibility of evaporation to dryness, available experiments to justify the chemical forms, and the potential for changing pH in all areas subject to ESF leakage?*

Response: Conservative assumptions were made to calculate mass transfer of iodine at the surface of a pool of ESF leakage. For ESF leakage in the Auxiliary Building, the following conservative assumptions with respect to mass transfer of iodine from a pool of ESF leakage in the Auxiliary Building were made as follows:

a.1) No iodine is assumed to be in the airspace above ESF leakage in the Auxiliary Building. (Item 1.5)

a.2) Liquid film mass transfer is ignored for ESF leakage in the Auxiliary Building. (Item 1.4)

a.3) Forced convective transfer is calculated based on the maximum airflow rate from the ABFVES. It is ignored in the calculation of the temperatures of the pools of ESF leakage. (Item 1.6)

For ESF leakage to the RWST, the values of iodine in the airspace necessary to maintain equilibrium with the iodine in the water in the RWST were calculated. Since iodine concentration in the RWST is seen to increase monotonically with time, this feature of the calculation is conservative (Item 1.7 above).

The environment in the RWST is stagnant with no connection to the environment except for two small vents at its top. Contaminated inventory is assumed and calculated for the duration of the design basis LOCA and REA. Evaporation to dryness is not expected to occur in the RWST. In the model for simulation of ESF leakage in the Auxiliary Building, water from ESF leakage is assumed to accumulate in the largest rooms (one room aligned to the ABFVES, one room initially not aligned to the ABFVES). Continuous leakage is assumed for the duration of the accident. This tends to decrease the effect of evaporation to dryness.

Evidence has been gathered to demonstrate that not all iodine is released to the airspace and environment with evaporation to dryness. In one effort, a series of six tests were conducted to measure the desorption (release with evaporation) of iodine from a boric acid solution (Ref. 30). The fractions of iodine released from these solutions were seen to range from a high of 18.7% to a low of 3.8%. The release fractions will take lower values for a plant such as Catawba in which the leakage contains sodium and is basic. (It is alkaline even at elevated temperatures as the neutral pH decreases to remain below the actual pH). The lower bound for the pH of ESF flow is 6.2 while the calculated equilibrium pH is 6.6. As the ESF flow cools in the long-term, its pH increases toward its reference value of 7.8. It follows that a great majority of the iodine in the solution will take the form of I^- ions, as predicted in the calculations of the formation of volatile iodine forms. It is judged that all of the factors listed above - continuous leakage, test data, and pH - will tend to limit the effect of "evaporation to dryness.")

The inventory in the RWST at the initiation of recirculation is assumed to contain boric acid at the limiting concentrations (3075 ppm). Given this conservative assumption, the insignificant amount of impurities that initially may be in the RWST will have no discernible effect on the pH (up or down) either initially or for the duration of the design basis accident.

No significant amounts of impurities are present in the areas of postulated ESF leakage. Therefore, it is judged that the pH of the pools of ESF leakage will not discernibly change from the calculated values. Refer to the responses to Questions f. and g. for justification of the chemical forms of iodine assumed in the analysis.

b. *How would the iodine partitioning and release be expected to change as the ECCS* [Emergency Core Cooling System] *leakage is sprayed out of a leak, or streams across a floor into a building sump?*

Response: As noted above, the model for iodine partitioning from ESF leakage in the Auxiliary Building is based on the assumed collection of water from the leak in the largest rooms to form a pool. No losses of inventory from that pool are assumed. In particular, neither spraying of ESF leakage nor streaming of ESF leakage to a leak is simulated.

Not accounting for spraying of an ESF system leak in the Auxiliary Building may not be conservative. This is so since mass transfer from the spray droplets may be higher than mass transfer across the surface area of the largest rooms in which the leak is taken to occur.

The credible sources of ESF leakage in the Auxiliary Building include the stems of ESF valves and the ESF pumps including the following:

1) Low Pressure Injection (LPI pumps)
2) SIS pumps (intermediate pressure injection),
3) High Pressure Injection Pumps, and
4) CSS pumps.

The design of the ESF valve stems (packing and stem housing, leakoff connections, vent and drain pipe caps, etc.) make it very unlikely that a leak from the stem of an ESF valve will spray. The RHRS and CSS pumps are vertical pumps. Leakage from any of these pumps would exit to the narrow space between the pump and motor. This significantly limits the extent of spray from any of these pumps. The SIS and HPI pumps are equipped with collection troughs and splash guards which again significantly limit the extent of spray. (The exceptions consist of SIS pumps 1A and 1B which are provided with collection troughs but not with splash guards.) Finally, neither plate-out nor dilution of iodine from an ESF leak in the Auxiliary Building is simulated (Item 1.2). In the unlikely case that a leak should spray over an extended volume, these processes tend to offset its effects. Therefore, spraying of a leak from ESF components is unlikely or will have no significant consequences.

Streaming of ESF leakage to drains and to building sumps and liquid radwaste holdup tanks is ignored in the analysis. The stream would cover a very small surface area compared to the floor area assumed in the calculations (on the order of 2,000 sq.ft.). Furthermore, the stream would be exposed to the ventilation airflow only for a limited period of time. Therefore, partitioning of iodine from leakage streaming to a drain is seen to be very limited compared to the values calculated in the analysis for partition fractions.

Any leakage flowing into the floor drains in the Auxiliary Building will collect in (and may be pumped into) a number of tanks. At this time, nothing definitive can be stated concerning the chemistry and in particular the pH of the inventory in these tanks and sumps. This should not be a concern since a number of features offset this uncertainty. First, these sumps and tanks are essentially closed volumes and stagnant. No mechanism exists for any transfer of iodine to the airspace or gas phase of these volumes (except what natural convection currents may be found within them). No mechanism is in place to transport any iodine from these volumes to the environment except the displacement of contaminated air (or gas) from these volumes to the environment. For these reasons, no significant release of iodine from these volumes is anticipated.

Based on the forgoing, it is concluded that the calculation of iodine partition fractions for ESF leakage in the Auxiliary Building need not account for spraying of a leak or streaming of a leak to a drain.

c. *For iodine partitioning values less than 10 percent, justification should include an analysis of the impact of any gases generated by flashing along the piping route or within the RWST. This evaluation should consider any flashing along the pipe length, the temperatures of the back-leaked fluid within the pipe and in the RWST. Provide the calculation including the results, methodology used, and justified assumptions.*

Response: The upper bound temperature of the water in the containment sump at the initiation of cold leg recirculation is 189 °F. Within 13 minutes, the sump water temperature falls below 185 °F, remaining below this value for the duration of the transient. The RWST is vented to atmosphere; the pressure at the water surface in the RWST is at ambient. The local boiling point is 211 °F. At no point does the ECCS piping reach the elevation of the base of the

RWST (grade elevation). Finally, the upper bound to the initial temperature of the water in the RWST is 100 °F (Surveillance Requirement SR 3.5.4.1 of the plant Technical Specifications - Ref. 9). The subcooled margin anywhere in the RWST or along the ESF backleakage route is at least 26 °F over the great majority of the 30 day time span of assumed ESF back leakage and releases from the RWST (22 °F over the first 13 minutes). Therefore, no flashing of ESF leakage can occur either along the pipe route to the RWST or within the RWST.

d. Duke bases the percent release of iodine from the ESF systems and RWST on NUREG/CR-5950, "Iodine Evolution and pH Control." NUREG/CR-5950 provides several fits to experimental data from controlled experiments. The release rates in NUREG/CR-5950 are for very specific laboratory conditions that do not appear to match those for the LOCA accident condition. For example, NUREG/CR-5950 does not appear to address the impact of impurities present due to core damage and other chemicals present. The data fit also contains very large errors when compared to experimental data. None of this uncertainty appears to be addressed by Duke. Please explain how this uncertainty is addressed in your calculation of the iodine release. Also provide additional information and justification (benchmarked by any experiments as known) for the methodology used to show why the values used from NUREG/CR-5950 are applicable and conservative for postulated LOCA leakage at Catawba. Include the impact of

i) impurities in the RCS and RWST fluids on the pH and iodine partitioning.

ii) Any other applicable operational issues (i.e., differences between the very specific laboratory conditions and actual plant conditions), and

iii) The uncertainty within the curve fits of data.

Response: As noted in this question, the methods developed within Duke for the calculation of release of iodine from ESF systems in the Auxiliary Building and from the RWST with ESF intersystems leakage to it are based on the work reported in NUREG/CR-5950 (Ref. 1).

NUREG/CR-5950 includes a discussion of the effect of certain impurities that may be present in the containment sump. Some of the impurities may be formed in the course of the accident by radiolysis of materials in containment or of water and air in containment. These impurities include chlorides and nitrates, respectively. The correlations presented in NUREG/CR-5950 for predicting the formation of these impurities are employed in the model developed within Duke.

Another source of impurities evaluated in NUREG/CR-5950 include fission products (Ref. 1 Section 2.3). These impurities are not taken into account in the model developed within Duke. It is noted that cesium, cesium hydroxide and cesium carbonate may be present in the containment sump. These substances will produce an increase in the pH of the solution in the containment sump (albeit to a lesser extent from cesium carbonate). Additional fission products that may produce this effect include rubidium (another alkali metal), barium and strontium (earth alkali metals). The presence of cesium and rubidium compounds are not taken into account for the analysis of ESF leakage following a design basis REA. This in particular is noted as the source term for this design basis accident includes only noble gases, iodine, bromine, cesium, and rubidium (Ref. 21). NUREG/CR-5950 also includes a synopsis of tests from Oak Ridge National Laboratory on products formed by core-concrete interactions Section 2.3.2 and Table 2.4). From the test data presented, it is seen that these products also may tend to raise the pH of the solution in the containment sump. From the forgoing it is concluded the model developed within Duke to calculate iodine partition fractions for ESF leakage is conservative with respect to the impurities included and omitted.

As noted elsewhere, there are no significant amounts of impurities in the areas of ESF leakage (cf. the responses to Questions a, f, and g). The remaining difference between controlled laboratory conditions and assumed plant post accident conditions is temperature. As noted, post LOCA sump pH and iodine partition fractions are calculated based on elevated temperatures of the containment sump inventory and the ESF leakage. However, the equilibrium and reaction rate constants used in the model are referenced at 25 °C (77 °F). This feature has been noted as conservative (Item 1.1 above) and is used to respond to the concern associated within the curve fit of data as outlined below.

d.1) The equilibrium and reaction rates constants used in NUREG/CR-5950 are referenced to 25 °C (77 °F). Use of these constants for post accident temperatures is conservative.

d.2) Some of the tests cited in NUREG/CR-5950 were performed at elevated temperatures (Item 1.1 above). These tests show the conservatism in the model and in particular the equilibrium reaction and reaction rate constants. From these tests, the degree of conservatism in these reaction rate constants can be set to a factor of 1.9-5.8.

d.3) NUREG/CR-5950 presents a table of iodine release fractions measured from various experiments, with comparisons to values calculated from their model (Ref. 1 Appendix C Table C.1). An inspection of the data presented indicates that for most of the test results the differences between the measured and calculated values lie within the factor of conservatism that are associated with the equilibrium reaction and reaction rate constants. (The authors of NUREG/CR-5950 discarded two tests associated with solution pH of 4.4 and 4.5 and initial I^- ion concentration of 1×10^{-5} gm-atoms/L.)

It is concluded that the model for iodine partitioning from ESF leakage based on the method presented in NUREG/CR-5950 is conservative with respect to the differences between laboratory conditions and projected post accident conditions.

e. Address how mixing and stratification of the combined fluids is modeled in the RWST and address how the release point of the back-leaked fluid into the RWST impacts the amount of iodine released. Provide the calculation including the results, methodology used and justified assumptions.

Response: ESF back leakage to the RWST is assumed to mix homogeneously with the solution in the RWST. An evaluation of this assumption with respect to stratification of the leakage as it enters the RWST is reported below.

Any ESF backleakage would enter the RWST through the RWST outlet to the ECCS and Containment Spray System (CSS). This outlet connects to the RWST near its base. With stratification, the concentration of iodine would decrease with height above the ECCS and CSS outlet line. In particular, stratification of the ESF leakage would result in low concentrations of iodine near the water surface in the RWST compared to the RWST iodine concentrations associated with the assumption of homogeneous mixing. This, in turn would yield lower values of rates of iodine release from the RWST. For these reasons, the assumption of homogeneous mixing of the ESF backleakage with the solution in the RWST is conservative.

ESF leakage also could enter the RWST through the combined SIS miniflow line and CSS test lines. This line connects to the RWST close to the top of the tank. To not account for stratification of the leakage from this line may not be conservative. However, offsetting features of the plant configuration and the dose analyses are in place as follows: At least one valve in the SIS miniflow line will be closed during recirculation following a LOCA. Two valves in series in the CSS test lines are closed when the CSS is in standby, making back leakage through these lines very unlikely.

The iodine partition fraction for the containment sump for the design basis LOCA at Catawba has been calculated to be less than 9×10^{-6}. This low iodine partition fraction may be attributed to the high calculated values of containment sump pH. The calculated values of iodine partition fraction for post LOCA ESF back leakage to the RWST approach this value beginning four days after the initiating event. It follows that even accounting for the possible effects of stratification of ESF leakage entering the RWST through the SIS miniflow line following a design basis LOCA will not be significant.

Iodine partition fractions also have been calculated for ESF back leakage to the RWST following the design basis REA (cf. Item 1.11). In the calculations, limiting assumptions pertaining to boron concentration and sodium concentration (no sodium in the leakage) have been made (Ref. 8). These assumptions were made in the absence of a containment analysis showing ice melt and an absence of an analysis of post REA containment sump pH. Some ice will melt following the REA, releasing some of the entrapped sodium tetraborate to the containment sump, both increasing the concentration of sodium and decreasing the concentration of boron in the sump. This, in turn, will yield increased pH of the leakage relative to the values associated with the dose analyses of the design basis REA.

It is evident from the forgoing evaluation that the model for iodine partitioning for ESF back leakage to the RWST is adequately conservative with respect to the effect of stratification of the leakage.

f. Are there any organic compounds in the RWST or the area around the RWST? If so, address how these *organic compounds impact the percentage of organic iodine released.*

Response: The RWST does not contain organic compounds in significant amounts. In particular, the RWST is fabricated with all exposed internal surfaces constructed of uncoated stainless steel components. Therefore, the portion of iodine released as organic iodine compounds would not increase due to the environment in the RWST. The composition of iodine released is set to 97% diatomic iodine and 3% organic iodine in the analysis of radiological consequences of the design basis LOCA (Ref. 8). This is in accordance with the regulatory position for analysis of post accident ESF leakage with the method of Alternate Source Terms (AST, cf. Ref. 22 ¶ 5.6).

g. *Are there any organic compounds in the area around the ESF system leakage? If so, address how these organic compounds impact the percentage of organic iodine released.*

Response: A procedure internal to Duke provides controls for storage of combustible and flammable materials (including organic material) at Duke nuclear stations. The storage of flammable and combustible material (including organic material) near safety related systems, structures, and components (SSCs) is generally prohibited. Safety related SSCs include all ESF components in the Auxiliary Building. No organic compounds in significant amounts are located in the area around postulated ESF leakage. Therefore, the portion of iodine released as organic iodine compounds would not increase due to the environment in the area around ESF leakage. The composition of iodine released is set to 97% diatomic iodine and 3% organic iodine in the analysis of radiological consequences of the design basis LOCA (Ref. 8). This is in accordance with the regulatory position for analysis of post accident ESF leakage with the method of Alternate Source Terms (AST, cf. Ref. 22 ¶ 5.6).

Table Q1-1

Iodine Partition Fractions for
ESF System Leakage in the
Auxiliary Building (All LEU Fuel)

End of Time	Iodine Partition Fraction				
Interval (hr)	**Note 1**	**Note 2**	**Note 3**	**Note 4**	**Note 5**
Note 6	0.100	0.100	0.010	0.013	0.100
72	0.022	0.028	0.010	0.010	0.024
720	0.010	0.010	0.010	0.010	0.010

Table Q1-2
Iodine Partition Fractions for
ESF System Leakage in the
Auxiliary Building (With 4 MOX LFAs)

End of Time	Iodine Partition Factors				
Interval (hr)	**Note 1**	**Note 2**	**Note 3**	**Note 4**	**Note 5**
Note 6	0.100	0.100	0.010	0.014	0.100
72	0.022	0.028	0.010	0.010	0.024
720	0.010	0.010	0.010	0.010	0.010

Notes on Tables Q1-1 and Q1-2

1) This scenario involves ESF System leakage in a room to which Auxiliary Building Filtered Ventilation Exhaust System (ABFVES) is aligned. In the limiting cases, filtered ESF leakage also is upstream of the Residual Heat Removal - RHR - and Containment Spray - CSS - Heat Exchangers. This scenario also includes a design basis LOCA with Minimum Safeguards. One ABFVES train is affected by the failure and is not available.

2) This scenario also involves ESF System leakage in a room to which the ABFVES is aligned and also upstream of the RHR and CSS Heat Exchangers. This scenario includes a design basis LOCA with either a failure of a pressure transmitter of the Annulus Ventilation System (AVS), failure of a RHR or CSS Heat Exchanger to remove heat, or closed Control Room Area Ventilation System (CRAVS) Outside Air Intake. For these scenarios, all ABFVES trains are in operation.

3) This scenario includes ESF System leakage in the Mechanical Penetration Room (MPR) at EL 577 (downstream of the RHR and CSS Heat Exchangers). The ABFVES is not aligned to this room following the LOCA and Safety Injection Signal. Credit is taken for the operators aligning the ABFVES to this room three (3) days after the LOCA. Therefore, ESF System leakage in this room is not filtered for the first 3 days following the initiating event. This scenario includes a design basis LOCA with Minimum Safeguards. One ABFVES train is not available.

4) This scenario includes ESF System leakage in the MPR at EL 577. The ABFVES is not aligned to this room for the first 3 days. The scenario also includes a design basis LOCA with AVS pressure

transmitter failure or closed CRAVS Outside Air Intake. All ABFVES trains are in operation.

5) The ESF System leakage occurs in the MPR at EL 577 and is not filtered before release to the environment for the first 3 days. The scenario includes a design basis LOCA with failure of a RHR or CSS Heat Exchanger. All ABFVES trains are in operation.

6) This time period ends at 2.5 hr after the initiating event for Cases 1 and 2 and 2.9 hr after the initiating event for Cases 3, 4,and 5.

Iodine Releases from the Refueling Water Storage Tank With Post LOCA ESF System Back leakage

Table Q1-3
Design Basis LOCA with RHR or CSS Heat Exchanger Failure

Time Step Start (sec)	Time Step End (sec)	Iodine Release Fraction	Equivalent Leak (cfm)
0	791	0	0
791	810	9.197×10^{-11}	2.479×10^{-10}
810	900	2.894×10^{-9}	7.737×10^{-9}
900	1200	3.443×10^{-8}	9.205×10^{-8}
1200	1400	9.799×10^{-8}	2.620×10^{-7}
1400	1800	1.772×10^{-7}	4.738×10^{-7}
1800	3600	3.486×10^{-7}	9.320×10^{-7}
3600	4800	4.228×10^{-7}	1.130×10^{-6}
4800	6000	4.128×10^{-7}	1.104×10^{-6}
6000	7200	3.916×10^{-7}	1.047×10^{-6}
7200	28800	3.376×10^{-7}	9.206×10^{-7}
28800	36000	3.284×10^{-7}	8.780×10^{-7}
36000	86400	1.873×10^{-7}	5.008×10^{-7}
86400	345600	3.444×10^{-7}	9.208×10^{-7}
345600	2592000	6.388×10^{-6}	1.708×10^{-5}

Table Q1-4
Design Basis LOCA with No RHR or CSS Heat Exchanger Failure

Time Step Start (sec)	Time Step End (sec)	Iodine Release Fraction	Equivalent Leak (cfm)
0	791	0	0
791	810	9.145×10^{-10}	2.445×10^{-9}
810	900	2.879×10^{-9}	7.697×10^{-9}
900	1200	3.438×10^{-8}	9.192×10^{-8}
1200	1400	9.814×10^{-8}	2.624×10^{-7}
1400	1800	1.781×10^{-7}	4.762×10^{-7}
1800	3600	3.550×10^{-7}	9.491×10^{-7}
3600	4800	4.344×10^{-7}	1.161×10^{-6}
4800	6000	4.259×10^{-7}	1.139×10^{-6}
6000	7200	4.049×10^{-7}	1.083×10^{-6}
7200	28800	3.559×10^{-7}	9.515×10^{-7}
28800	36000	3.579×10^{-7}	9.569×10^{-7}
36000	86400	2.212×10^{-7}	5.914×10^{-7}
86400	345600	8.163×10^{-7}	2.303×10^{-7}
345600	2592000	5.142×10^{-6}	1.375×10^{-5}

Table Q1-5
Iodine Release Fractions And
Equivalent ESF Leak Rates to the Environment For
ESF Back leakage to the RWST Following a Design Basis REA

Time Span (Hours)	RWST Iodine Release Fractions	Equivalent Unfiltered ESF Leak Rate (cfm)
CNS Design Basis REA and All LEU Fuel in the Source Term		
0 - 2	0.000E+00	0.000E+00
2 - 8	3.135E-06	4.191E-06
8 - 10	1.266E-05	1.692E-05
10 - 24	2.332E-05	3.117E-05
24 - 96	8.910E-04	1.191E-03
96 - 720	2.415E-02	3.228E-02
CNS Design Basis REA and 4 MOX LFAs in the Source Term		
0 - 2	0.000E+00	0.000E+00
2 - 8	3.200E-06	4.278E-06
8 - 10	1.292E-05	1.727E-05
10 - 24	2.379E-05	3.180E-05
24 - 96	9.069E-04	1.212E-03
96 - 720	2.433E-02	3.252E-02

2) *It is the staff position that charcoal filter testing should be done in accordance with the guidance of RG 1.52, Rev. 2, as has been committed to by the Catawba Plant. As such, a 2 inch charcoal filter should be tested to a laboratory efficiency of 97.5%, thereby permitting licensee to claim 95% efficiency for both organic and elemental iodine in the dose analysis while providing a safety factor of 2, as outlined in GL 99-02. See Regulatory Position 6.a in RG 1.52, Rev. 2, and GL 99-02 for further discussion of the staff's position. Considering this discussion on filter testing and assumed filter efficiency in dose analyses, the explanation of how Catawba has accounted for the 1% system bypass for the in-place testing by adjusting the filter efficiency is not clear to the staff. Provide a clear explanation of how the allowable bypass is accounted for in your dose analysis.*

Response: The response will provide information on the following three topics:

2.1) Analyses of radiological consequences of the design basis LOCA, locked rotor accident (LRA), and rod ejection accident (REA) include simulation of the 2 inch carbon absorbers. An explanation of the simulation is provided. The explanation will account for the criteria for the in situ penetration and bypass test and the laboratory methyl iodide penetration test.

2.2) It will be noted that the simulation of the carbon bed absorbers is an approximation. Including an unfiltered flow path is the explicit simulation of absorber bypass airflow. An evaluation is completed to compare the simulation of bypass flow in the dose analysis submitted by Duke to this explicit method.

2.3) Duke will demonstrate that the methyl and elemental iodine safety factors used within the dose analyses are greater than two as outlined in GL 99-02 for methyl iodide.

2.1 SIMULATION OF THE 2 INCH BED CARBON ABSORBERS

Dose analyses completed with the method of Alternative Source Terms (AST) have been submitted to the NRC Staff for the design basis LOCA, LRA, and REA (Ref. 2,5,8). Credit was taken for the 2 inch carbon bed absorbers of the Annulus Ventilation System (AVS) and Auxiliary Building Filtered Ventilation Exhaust System (ABFVES) in the AST analysis of the DB LOCA and REA (Ref. 2,5,8). In particular, these analyses include the simulation of filtration of diatomic (elemental) iodine and organic iodine compounds by the carbon bed absorbers. Table Q2-1 below lists these filter efficiencies and the test criteria for methyl iodide (CH_3I) penetration and in place penetration and bypass test. (Ref. 2,9) Catawba is licensed to RG 1.52, Rev. 2, with exceptions that include Position C.6.a.

Table Q2-1
Filter Efficiencies and Corresponding
Criteria for ESF Grade 2 Inch Carbon Bed Absorbers
(AVS and ABFVES)

Parameter	**Value**	**References & Notes**
Efficiencies taken in the AST analyses		
Diatomic iodine	95%	Ref. 2,5,8,10
Organic iodine compounds	80%	Ref. 2,5,8,10
CH_3I penetration criterion	4%	Ref. 9
Penetration & Bypass criterion		
Unit 1	1%	Ref. 9
Unit 2	0.05%	Ref. 9

The values in Table Q2-1 for the efficiencies assumed in the dose analyses for these carbon bed absorbers and the methyl iodide penetration criterion of 4% have their origin in the Facility Operating License (FOL) Amendment 90/84 submitted and approved in 1991 (Ref. 10-12).

The highest penetration and bypass allowance for the 2 inch carbon bed absorbers is 1% (e.g., for the AVS and ABFVES at Unit 1). The penetration and bypass criterion for Catawba Unit 2 is currently 0.05%. The license amendment requests a value of 1% to be approved for Unit 2.

The dose analyses account for the higher allowable bypass of 1% for the AVS and ABFVES carbon bed absorbers of Unit 1. The method by which the dose analyses account for a bypass of 1% is explained below.

As noted above, the total efficiency for removal of organic iodine compounds by the AVS and ABFVES carbon bed absorbers is 80%. This is equivalent to a total penetration and bypass fraction of 20% of the organic iodine in the airflow upstream of the carbon bed absorbers. The limiting bypass criterion is 1% (for the 2 inch carbon bed absorbers of Unit 1). Accounting for this places the fraction of organic iodine compounds in the airflow upstream of the carbon bed absorber assumed to penetrate the absorber at

20% - 1% = 19%.

The methyl iodide penetration criterion for the 2 inch ESF carbon bed absorbers is 4%. Using the formula presented by the NRC Staff (Ref. 13,14), the safety factor associated with penetration of organic iodine compounds is computed as

19%/4% = 4.75.

The above explanation also appears in Ref. 2, Attachment 3, Pages 14, 15, 25, and 26.

A value of 95% is taken for the total efficiency for removal of diatomic iodine by the 2 inch carbon bed absorbers of the AVS and ABFVES. This equates to a total penetration and bypass fraction of 5% for the diatomic iodine in the airflow upstream of these absorbers. Again, the limiting bypass criterion is 1%. The following comparison will demonstrate how the penetration and bypass of diatomic and organic iodine is accounted for in the dose analyses.

2.2 COMPARISON WITH SIMULATION OF BYPASS AIRFLOW PATH

As noted above, the values taken for the carbon bed filter efficiencies account for both removal and penetration. This treatment is a conservative approximation. The explicit method to account for penetration and bypass is to model an unfiltered airflow path around the carbon bed filters.

The approximate method used in the dose analyses submitted by Duke provides bounding values of penetration and bypass and therefore is conservative. This is demonstrated in the evaluation reported below.

Denote the fractions of airflow upstream of the filter that bypass the filters and flows through it as f_b and f_f. This implies $f_b + f_f = 1$. Denote the total and penetration efficiencies assumed in the dose analysis as η_d and η_p, respectively. The dose analyses assume that:

$(1 - \eta_p) + f_b = 1 - \eta_d$ or equivalently (2.1)

$\eta_d = \eta_p - f_b$.

The analyses set η_p to 96% for the removal of diatomic iodine compounds and 81% for the removal of organic iodine compounds. In all cases, f_b is set to 1%, the LAR criterion for the absorber penetration and bypass test.

With the explicit model, an activity balance around the filter for specific activity a_{us} in the flow rate Q from the upstream volume and specific activity a_{ds} downstream of the filter is developed as follows (2.2):

$$[(1 - \eta_x) f_f + f_b] Q\, a_{us} = Q\, a_{ds} = (1 - \eta_T) Q\, a_{us}.$$

In (2.2), η_x is the efficiency assumed for the removal of iodine from the flow stream through the filter in the explicit model. Also, η_T is the total filter efficiency assumed for the alternate model. The relation between η_T and η_d will determine if the model used by Duke and based on $\eta_d = \eta_p - f_b$ is conservative.

(2.2) reduces to (2.3)

$$(1 - \eta_x) f_f + f_b = 1 - \eta_T.$$

With the explicit model, the analyst will take $\eta_x = \eta_p$. This preserves the safety factor to which the analyst has committed. This yields (2.4)

$$(1 - \eta_p) f_f + f_b = 1 - \eta_T.$$

But since $0 < f_f < 1$, $(1 - \eta_p) f_f < (1 - \eta_p)$ and finally

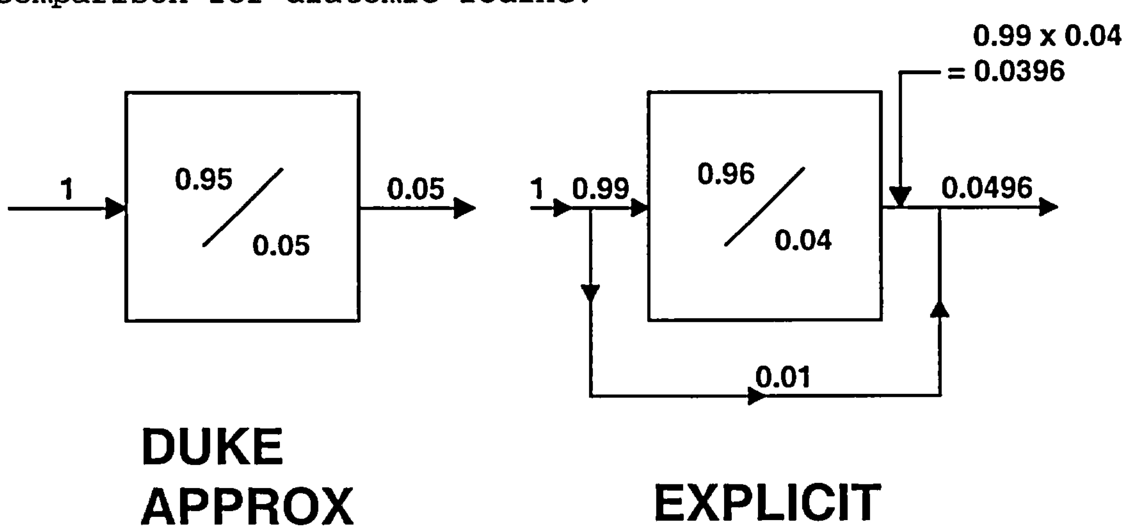
$$(1 - \eta_p) f_f + f_b = 1 - \eta_T < (1 - \eta_p) + f_b = 1 - \eta_d.$$

In particular, $1 - \eta_T < 1 - \eta_d$ from whence immediately follows $\eta_d < \eta_T$. This completes the proof that the model used by Duke for the carbon bed absorbers is conservative in comparison to the explicit simulation of unfiltered bypass flow.

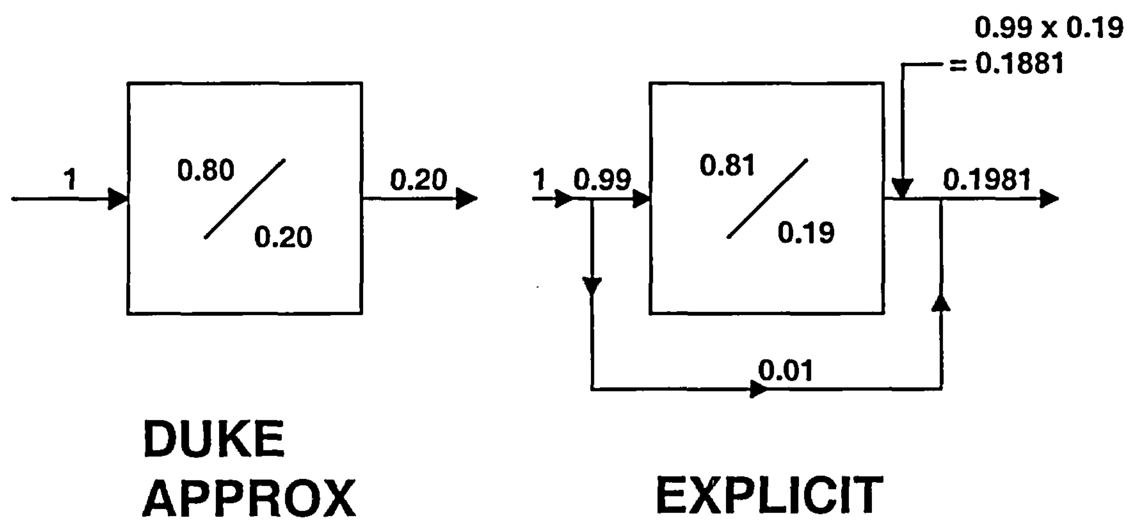
The degree of conservatism in the model employed within Duke may be calculated by taking $1 - \eta_p = 0.04$ for diatomic iodine and $f_f = 0.01$ for diatomic iodine bypass. Set f_f and f_b to 0.99 and 0.01. The resulting values for $1 - \eta_T$ and comparison to $1 - \eta_d$ are presented below:

For diatomic iodine, $1 - \eta_T = 0.0496$ vs. $1 - \eta_d = 0.05$.

The following is a pictorial demonstration of this comparison for diatomic iodine:



For organic iodine compounds, $1 - \eta_T = 0.1981$ vs. $1 - \eta_d = 0.2$. The pictorial demonstration of this comparison for organic iodine compounds follows as:



2.3 DETERMINATION OF THE SAFETY FACTOR FOR DIATOMIC IODINE RETENTION

The safety factor for the 2 inch carbon bed absorbers for the removal of organic iodine compounds when computed in conformance to the regulatory positions (Ref. 13,14) and accounting for the 1% penetration and bypass criterion (1%) is 4.75. The same approach is to be used for diatomic iodine. Duke has concluded that applying the value for methyl iodide penetration is inappropriate and results in a safety factor that is incorrect and understated.

The experience within the nuclear industry is that activated carbon bed absorbers are extremely efficient in removing diatomic iodine from the flow stream through it. In the Nuclear Air-Cleaning Handbook, the following statements appear:

"Trapping of elemental radioiodine involves physical adsorption only, and the efficiency of nearly any good grade of activated carbon, impregnated or not, will be at least 99% (DF = 100) under any combination of temperature and humidity that would be encountered in a nuclear air cleaning system. Trapping of organic radioiodine compounds, on the other hand, requires an impregnated carbon and involves physical adsorption, chemical reaction, and/or isotopic exchange. Efficiency for those compounds is dependent on temperature and relative humidity of the air or gas stream, and performance of the adsorbent must be qualified under a range of operating conditions...." (Ref. 15 Page 55)

These statements are quoted to show that the processes by which diatomic (elemental) iodine and organic iodine compounds are adsorbed by carbon bed filters are different. The diatomic iodine efficiency of carbon bed absorbers is much higher than what is taken for the adsorption of organic iodine compounds (e.g., the methyl penetration test) and the adsorption of diatomic iodine is insensitive to the range of temperatures and relative humidity associated with the design function of the filters.

Assuming that the efficiency for a 2 inch carbon bed in absorbing diatomic iodine is at least 99%, a safety factor is associated with comparing this efficiency to the methyl iodide penetration criterion of 4% as follows:

Safety factor $\geq$ 4% / (100-99)% = 4

The veracity of the statement that the efficiency of "nearly any good grade of activated carbon" for the "trapping of elemental iodine" is "at least 99%" is now evaluated. The experimental results demonstrate that this is not only true, but is conservative with significant margin. Experience within the industry indicates that the efficiency of 2 inch carbon beds for removal of diatomic iodine from the flow stream within them typically exceed 99.9% (Ref. 16-19). Note that the industry no longer performs laboratory testing for penetration of diatomic iodine by carbon bed absorbers (Ref. 19-20).

Duke has commissioned diatomic iodine penetration tests to validate this experience. All available test results will be provided to the NRC during the July 18, 2005 meeting between Duke and the NRC to discuss this license amendment request. Duke anticipates that the test results will validate earlier industry experience that the 2 inch carbon bed retention efficiency is at least 99.9%. Comparing this to a methyl iodide penetration criterion of 4% imputes a safety factor of 4/(100-99.9) = 40.

SUMMARY STATEMENT

The simulation of retention of diatomic iodine and organic iodine compounds by the 2 inch carbon bed absorbers has been explained and justified.

2.1) The dose analyses set the total efficiency for 2 inch carbon bed absorbers at 95% for elemental iodine and 80% for organic iodine compounds. These values account for both the limiting bypass flow (1%) and the limiting methyl iodide penetration (4%). The safety factor associated with organic iodine compounds, computed as prescribed by the Staff, has been found to be 4.75. The safety factor for diatomic iodine is at least four.

2.2) The treatment of bypass airflow in the dose analyses is a conservative approximation. A more accurate method for simulation of bypass airflow is to model it explicitly. The model employed in the dose analyses has been proven to be conservative with respect to the explicit model.

2.3) As noted above, the safety factor for penetration of diatomic iodine is determined to be greater than a factor of four, well in excess of the value of two endorsed by the staff.

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