U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

15.6.3 RADIOLOGICAL CONSEQUENCES OF STEAM GENERATOR TUBE FAILURE (PWR)

REVIEW RESPONSIBILITIES

Primary - Accident Evaluation Branch (AEB)

Secondary - Reactor Systems Branch (RSB)

I. AREAS OF REVIEW

This SRP section covers the review of the radiological consequences of a postulated steam generator tube failure accident at a pressurized water reactor (PWR) facility and includes the following:

(1) A review of the sequence of events and plant procedures for recovery from the accident, as described by the applicant, with and without offsite power available, to assure that the most severe case of radioactive releases has been considered.

(2) A review of the models and assumptions used by the applicant for the calculation of the thyroid and whole-body doses for the postulated accident.

(3) An independent calculation by the staff of the thyroid and whole-body doses for the accident

(4) A comparison of the doses calculated by the applicant and by the staff with the appropriate exposure guidelines, as stated in subsection II below, and

(5) An evaluation of the technical specifications on the primary and secondary coolant iodine activity concentration.

The review includes two cases for the reactor coolant iodine concentration corresponding to (1) a preaccident iodine spike and (2) a concurrent iodine spike. The potential for fuel failures resulting from the postulated accident is routinely evaluated by the RSB and such information is provided to the AEB as an additional source of iodine activity in the reactor coolant for consideration in the evaluation of the radiological consequences.

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II. ACCEPTANCE CRITERIA

The acceptance criteria are based on the relevant requirements of 10 CFR Part 100 as it relates to mitigating the radiological consequences of an accident. The plant site and the dose mitigating engineered safety features are acceptable with respect to the radiological consequences of a postulated steam generator tube failure accident at a PWR facility if the calculated whole-body and thyroid doses at the exclusion area and the low population zone outer boundaries do not exceed the following exposure guidelines:

(1) for the postulated accident with an assumed preaccident iodine spike in the reactor coolant and for the postulated accident with the highest worth control rod stuck out of the core the calculated doses should not exceed the guideline values of 10 CFR Part 100, Section 11 (Ref. 1), and

(2) for the postulated accident with the equilibrium iodine concentration for continued full power operation in combination with an assumed accident initiated iodine spike, the calculated doses should not exceed a small fraction of the above guideline values, i.e., 10 percent or 2.5 rem and 30 rem, respectively, for the whole-body and thyroid doses.

The methodology and assumptions for calculating the radiological consequences should reflect the regulatory positions of Regulatory Guide 1.4 (Ref. 2) except for the atmospheric dispersion factors which are reviewed under SRP Section 2.3.4. Plant technical specifications are required for iodine activity in the primary and secondary coolant systems. These specifications are acceptable if the calculated potential radiological consequences from the steam generator tube failure accident are within the exposure guidelines for the above two cases.

III. REVIEW PROCEDURES

The reviewer selects and emphasizes specific aspects of this SRP section as appropriate for a particular plant. The judgment which areas need to be given attention and emphasis during the review is based on a determination if the material presented is similar to that recently reviewed on other plants and whether items of special safety significance are involved.

At the construction permit (CP) stage, the review is limited to a brief survey of the pertinent portions of the SAR regarding the plant design and the applicant's accident evaluation to determine that there are no unusual features which would prevent limitation of radiological consequences to acceptable levels by appropriate limits on coolant activity concentrations. The detailed review of the radiological consequences of a steam generator tube failure is done at the operating license (OL) stage when system parameters and accident analyses are fully developed.

Standard technical specifications for each of the three PWR vendors' NSSS include limits on the primary and secondary coolant activities which are used in the staff's independent dose calculations (Ref. 3, 4, and 5). If the applicant proposes to use these standard limits and the plant is one of the standard NSSS/BOP plants for which the tube failure accident has been evaluated generically with the standard coolant activity and leakage limits, the reviewer need not reevaluate the offsite doses from this accident provided that the atmospheric dispersion factors (X/Q values) for the site under review do not

exceed the limiting X/Q values used in the generic review of the standard plant tube failure accident.

The review of the steam generator tube failure accident at the OL stage includes the following:

1. Review of the applicant's description of the tube failure accident, with and without offsite power. This includes a review of the sequence of events, the bases for the occurrence, and assurance of an adequate degree of conservatism.

2. Review of the signals available to the reactor operator that indicate the occurrence of the accident and the state of the system throughout the recovery period. Automatic and required manual operations by the operator as a function of time are reviewed. The AEB reviewer verifies with the RSB the acceptability of the applicant's description of events, including operator actions, to assure that the most severe case has been considered with respect to the release of fission products and calculated doses.

3. The post-accident thermohydraulic characteristics and radiological consequences of this accident are plant-specific. The reviewer, determines post-accident thermohydraulic profiles and compares these with those presented by the applicant. The purpose of such comparison is not to attain an exact match but to confirm the validity of the applicant's calculated results.

4. The appropriate atmospheric dispersion factors (X/Q values) for the staff's independent dose analysis will be determined by the assigned meteorologist in accordance with SRP Section 2.3.4.

5. Determination of the initial primary and secondary coolant activity concentrations. The reviewer assumes the primary and secondary coolant activity concentrations allowed by the technical specifications (SAR Chapter 16 or the standard technical specifications given in References 3, 4, and 5) as equilibrium conditions prior to the accident.

6. Determination of iodine spiking effects. For the dose calculations the following two cases of iodine spiking are analyzed:

   (a) A reactor transient has occurred prior to the postulated steam generator tube failure accident and has raised the primary coolant iodine concentration to the maximum value permitted by the standard technical specifications (i.e., a preaccident iodine spike case). The primary coolant iodine concentration for this case is obtained from Figure 3.4-1 of the NSSS vendor standard technical specification (Ref. 3, 4, or 5) or from the plant-specific technical specifications proposed in Chapter 16 of the applicant's SAR.

   (b) The reactor trip or the primary system depressurization associated with the postulated accident creates an iodine spike in the primary system (Ref. 6 and 7). The increasing primary coolant iodine concentration is estimated using a spiking model which assumes that the iodine release rate from the fuel rods to the primary coolant (expressed in curies per unit time) increases to a value 500 times greater than the release rate corresponding to the iodine concentration at the equilibrium value stated in the NSSS vendor standard

technical specifications or from the plant-specific technical specifications (i.e., concurrent iodine spike case).

7. Evaluation of the effects of fuel failure. As a result of the steam generator tube rupture accident, fuel failures can occur, releasing fission products into the reactor coolant and thus making additional activity available for release to the atmosphere. The RSB reviews the effects of the accident on the core thermal margins and the associated amount of fuel failures, assuming that the highest worth control rod is stuck at its fully withdrawn position. The RSB, as a secondary review branch, informs the AEB of the fuel failure estimate. If the accident is predicted to cause such fuel failure, the dose analysis will be performed with the corresponding iodine activity but without a concurrent iodine spike.

8. Determination of the primary to secondary system leakage in the unaffected steam generators. The operating primary-to-secondary leakage is assumed to exist in the unaffected steam generators. at the maximum rate allowed by the standard technical specifications (Ref. 3, 4, and 5). This value is 1 gpm. However, a lower value may be needed to limit the consequences of other events such as a control rod ejection accident.

9. Determination of the coolant flow through the failed tube. In conjunction with review step (3) above the flow rates through the two ends of the failed tube are calculated using a suitable flow model, taking credit for critical flow where appropriate.

10. Determination of the iodine transport to the atmosphere. The iodine transport model to be used is described in Reference 8. A fraction of the iodine in the primary coolant escaping to the secondary system is assumed to become airborne immediately due to flashing and atomization. Credit may be given for "scrubbing" of iodine contained in the steam phase and in the atomized primary coolant droplets suspended in the steam phase for release points which are below the steam generator water level. That fraction of the primary coolant iodine which is not assumed to become airborne immediately enters the secondary system water and is assumed to become airborne at a rate determined by the steaming rate and iodine partition coefficient. An iodine partition coefficient of 100 between steam generator water and steam phases may be conservatively assumed unless the applicant presents reasonable evidence that the use of some other value is justified.

11. Calculation of the exclusion area and low population zone boundary doses. The reviewer performs an independent calculation of the doses for the steam generator tube failure accident, using the two iodine concentrations in item (6) above. A breathing rate of 3.47×10^{-4} m^3/sec is used in the calculation of thyroid doses for the first 8 hours following the steam generator tube failure and the dose conversion factors are in accordance with Regulatory Guide 1.4 (Ref. 3).

12. Review of dose calculations. The whole-body and thyroid doses calculated by the staff and by the applicant are compared with the acceptance criteria stated in subsection II. If the doses calculated by the staff are not within the exposure guidelines (i.e., they are not less than 10 percent of 10 CFR Part 100, Section 11), then the staff will pursue

alternatives with the applicant to reduce the doses to within the guideline values.

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided by the applicant and that the applicant's analysis and the staff's independent calculations support conclusions of the following type, to be included in the AEB safety evaluation report at the operating license stage:

> The steam generator tube failure accident has been evaluated with and without a concurrent loss of offsite power. The assumptions used in our analysis are listed in Table _____. The calculated doses are presented in Table ____.
>
> The staff concludes that the distances to the exclusion area and to the loe population zone outer boundaries for the (insert PLANT NAME) site, in conjunction with the operation of the dose mitigating ESF systems, are sufficient to provide reasonable assurance that the calculated radiological consequences of a postulated steam generator tube failure accident do not exceed: (a) the exposure guidelines as set forth in 10 CFR Part 100, Section 11 for the accident with an assumed preaccident iodine spike or with the highest worth control rod stuck out of the core and (b) 10 percent of these exposure guidelines, for the accident with an equilibrium iodine concentration in combination with an assumed accident generated iodine spike.
>
> The staff conclusion is based on (1) the staff review of the applicant's analysis of the radiological consequences, (2) the independent dose calculation by the staff using conservative assumptions including atmospheric dispersion factors as discussed in Chapter 2 of this report, (3) the applicant's analysis and the staff's independent dose calculations which were performed using the guidelines of Regulatory Guide 1.4, and (4) the (insert NSSS VENDOR) Standard Technical Specifications for the iodine concentration in the primary and secondary coolant system, and for the primary to secondary leakage in the steam generators. The staff will review the (PLANT NAME) specific technical specifications to assure that the dose guidelines stated above are not exceeded.

The following paragraph is inserted prior to the last paragraph if fuel damage is found to be a possible consequence of the accident:

> The steam generator tube failure accident has also been evaluated with ____% fuel damage in the core as a result of the most reactive control rod remaining fully withdrawn. The resulting doses, listed in Table 15._____, are within the guidelines of 10 CFR Part 100.

At the construction permit stage, the following paragraph is included in the staff's safety evaluation report:

> On the basis of our experience with the evaluation of steam generator tube failure accidents for pressurized water reactor plants of similar design, we have concluded that the consequences of these accidents can be controlled by limiting the permissible primary and secondary coolant system radioactivity concentrations so that potential offsite doses are small. At the operating license stage the staff will include appropriate

limits on primary and secondary coolant activity concentrations in the technical specifications.

V. IMPLEMENTATION

The following provides guidance to applicants and licensees regarding the staff's plans for using this SRP section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides.

VI. REFERENCES

1. 10 CFR Part 100, Section 11, "Determination of Exclusion Area, Low Population Zone, and Population Center Distance."

2. Regulatory Guide 1.4, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Pressurized Water Reactors."

3. Standard Technical Specifications for Combustion Engineering PWRs, NUREG-0212.

4. Standard Technical Specifications for Westinghouse PWRs, NUREG-0452.

5. Standard Technical Specifications for Babcock and Wilcox PWRs, NUREG-0103.

6. W. F. Pasedag, "Iodine Spiking in BWR and PWR Coolant Systems," CONF-770708, 3 717 (1977).

7. A. K. Postma and P. S. Tam, "Iodine Behavior in a PWR Cooling System Following a Postulated Steam Generator Tube Rupture Accident," NUREG-0409, USNRC, January 1978.

8. R. R. Bellamy, "A Regulatory Viewpoint of Iodine Spiking During Reactor Transients," Trans. Am. Nucl. Soc., 28 (1978).