NUREG-0800
(Formerly NUREG-75/087)

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

6.2.1.3 MASS AND ENERGY RELEASE ANALYSIS FOR POSTULATED LOSS-OF-COOLANT ACCIDENTS

REVIEW RESPONSIBILITIES

Primary - Containment Systems Branch (CSB)

Secondary - None

I. AREAS OF REVIEW

The CSB reviews the analyses of the mass and energy release to assure that the data used to evaluate the containment and subcompartment functional design are acceptable for that purpose. The review includes the following areas:

1. The energy sources that are available for release to the containment.

2. The mass and energy release rate calculations for the initial blowdown phase of the accident.

3. For pressurized water reactor (PWR) plants, because of the additional steam generator stored energy available for release, the mass and energy release rate calculations for the core reflood and post-reflood phases of the accident.

The Mechanical Engineering Branch (MEB) is responsible for reviewing the acceptability of piping design criteria, selected break locations and break sizes based on the provisions made to limit pipe motion, for breaks postulated to occur within subcompartments (see Standard Review Plan Section 3.6.2).

II. ACCEPTANCE CRITERIA

The acceptance criteria given below applies to the mass and energy release analysis for postulated loss-of-coolant accidents. CSB accepts the mass and energy analysis if the relevant requirements of General Design Criterion 50 and 10 CFR Part 50, Appendix K, paragraph I.A are complied with. The relevant requirements are as follows:

A. General Design Criterion 50, as it relates to the containment and subcompartment being designed with sufficient margin, requires that the containment and its associated systems can accommodate, without exceeding the design leakage rate, and the containment and subcompartment design can withstand the calculated pressure and temperature conditions resulting from any loss-of-coolant accident.

B. 10 CFR Part 50, Appendix K, as it relates to sources of energy during the LOCA, provides requirements to assure that all the energy sources have been considered.

In meeting the requirements of General Design Criterion 50 the following specific criterion or criteria that pertain to the mass and energy analysis are used as included below:

1. Sources of Energy

The sources of stored and generated energy that should be considered in analyses of loss-of-coolant accidents include: reactor power; decay heat; stored energy in the core; stored energy in the reactor coolant system metal, including the reactor vessel and reactor vessel internals; metal-water reaction energy; and stored energy in the secondary system (PWR plants only), including the steam generator tubing and secondary water.

Calculations of the energy available for release from the above sources should be done in general accordance with the requirements of 10 CFR Part 50, Appendix K, paragraph I.A (Ref. 2). However, additional conservatism should be included to maximize the energy release to the containment during the blowdown and reflood phases of a LOCA.

The requirements of paragraph I.B in Appendix K to 10 CFR Part 50, concerning the prediction of fuel clad swelling and rupture should not be considered. This will maximize the energy available for release from the core.

2. Break Size and Location

a. The staff's review of the applicant's choice of break locations and types is discussed in SRP Section 3.6.2.

b. Of several breaks postulated on the basis of a., above, the break selected as the reference case for subcompartment analysis should yield the highest mass and energy release rates, consistent with the criteria for establishing the break location and area.

c. Containment design basis calculations should be performed for a spectrum of possible pipe break sizes and locations to assure that the worst case has been identified.

3. Calculations

In general, calculations of the mass and energy release rates for a loss-of-coolant accident should be performed in a manner that conservatively establishes the containment internal design pressure (i.e., maximizes the post-accident containment pressure and the containment subcompartment response). The criteria given below for each phase of the accident indicate the conservatism that should exist.

a. Subcompartment Analysis

The analytical approach used to compute the mass and energy release profile will be accepted if both the computer program and volume noding of the piping system are similar to those of an approved emergency core cooling system (ECCS) analysis. The computer programs that are currently acceptable include SATAN-V (Ref. 18), CRAFT-2 (Ref. 17), CE FLASH-4 (Ref. 19), and RELAP4 (Ref. 15), when a flow multiplier of 1.0 is used with the applicable choked flow correlation. An alternate approach, which is also acceptable, is to assume a constant blowdown profile using the initial conditions with an acceptable choked flow correlation.

b. Initial Blowdown Phase Containment Design Basis

The initial mass of water in the reactor coolant system should be based on the reactor coolant system volume calculated for the temperature and pressure conditions existing at 102% of full power (Ref. 2).

Mass release rates should be calculated using a model that has been demonstrated to be conservative by comparison to experimental data.

Calculations of heat transfer from surfaces exposed to the primary coolant should be based on nucleate boiling heat transfer. For surfaces exposed to steam, heat transfer calculations should be based on forced convection.

Calculations of heat transfer from the secondary coolant to the steam generator tubes for PWRs should be based on natural convection heat transfer for tube surfaces immersed in water and condensing heat transfer for the tube surfaces exposed to steam.

c. PWR Core Reflood Phase (Cold Leg Breaks Only)

Following initial blowdown of the reactor coolant system, the water remaining in the reactor vessel should be assumed to be saturated. Justification should be provided for the refill period. An acceptable approach is to assume a water level at the bottom of the active core at the end of blowdown so there is no refill time.

Calculations of the core flooding rate should be based on the emergency core cooling system operating condition that maximizes the containment pressure either during the core reflood phase or the post-reflood phase.

Calculations of liquid entrainment; i.e., the carryout rate fraction, which is the mass ratio of liquid exiting the core to the liquid entering the core, should be based on the PWR FLECHT experiments (Ref. 20). Liquid entrainment should be assumed to continue until the water level in the core is 2 feet from the top of the core. An acceptable approach is to assume a carryout rate fraction (CRF) of 0.05 to the 18-inch core level, a linearly increasing CRF to 0.80 at the 24-inch level, and a constant CRF of 0.80 until the water level is 2 feet from the top of the core. Above this level, a CRF of 0.05 may be used.

The assumption of steam quenching should be justified by comparison with applicable experimental data. Liquid entrainment calculations should consider the effect on the carryout rate fraction of the increased core inlet water temperature caused by steam quenching assumed to occur from mixing with the ECCS water.

Steam leaving the steam generators should be assumed to be superheated to the temperature of the secondary coolant.

d. PWR Post-Reflood Phase

All remaining stored energy in the primary and secondary systems should be removed during the post-reflood phase.

Steam quenching should be justified by comparison with applicable experimental data.

The results of post-reflood analytical models should be compared to applicable experimental data.

e. PWR Decay Heat Phase

The dissipation of core decay heat should be considered during this phase of the accident. The fission product decay energy model is acceptable if it is equal to or more conservative than the decay energy model given in Branch Technical Position ASB 9-2 in SRP Section 9.2.5.

Steam from decay heat boiling in the core should be assumed to flow to the containment by the path which produces the minimum amount of mixing with ECCS injection water.

The following computer models are acceptable for calculating mass and energy releases for containment design basis calculations: the Westinghouse model (Ref. 18), the B&W model (Ref. 17), the C.E. model (Ref. 19), and the G.E. blowdown model (Ref. 23). Other methods will be acceptable if they are found by CSB to be conservative for these calculations.

III. REVIEW PROCEDURES

The procedures described below are followed for the review of the mass and energy release analysis for loss-of-coolant accidents. The reviewer selects and emphasizes material from these procedures as may be appropriate for a particular case. Portions of the review may be carried out on a generic basis or by applying the results of previous reviews of similar plants.

The CSB confirms with the MEB, the validity of the applicant's analysis of pipe break size, type and locations for subcompartments containing high energy lines by using elevation and plan drawings of the containment showing the routing of lines containing high energy fluids. The CSB determines that an appropriate reference case for subcompartment analysis has been identified. In the event a pipe break other than a double-ended pipe rupture is postulated by the applicant, the MEB will evaluate the applicant's justification for assuming a limited displacement pipe break.

The CSB compares the sources of energy considered in the loss-of-coolant analysis and the methods and assumptions used to calculate the energy available for release from the various sources with the acceptance criteria listed in section II, above. The CSB determines the acceptability of the analytical models and the assumptions used to calculate the rates of mass and energy release during the initial blowdown, core reflood; and post-reflood phases of a loss-of-coolant accident. The CSB also compares energy inventories at various times during a loss-of-coolant accident to ensure that the energy from the various sources has been accounted for and has been transferred to the containment on an appropriate time scale.

The CSB reviews comparisons made by the applicant to experimental data and makes comparisons to other available experimental data to determine the amount of conservatism in the mass and energy release models.

The CSB may perform confirmatory analyses of the mass and energy profiles. The purpose of the analysis is to confirm the predictions of the mass and energy release rates appearing in the safety analysis report, and to confirm that an appropriate break location has been considered in these analyses.

IV. EVALUATION FINDINGS

The conclusions reached on completion of the review of this SRP section are presented in SRP Section 6.2.1.

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plan 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.

VI. REFERENCES

The references for this SRP section are listed in Standard Review Plan Section 6.2.1.