U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

SECTION 6.2.1.2 SUBCOMPARTMENT ANALYSIS

REVIEW RESPONSIBILITIES

Primary - Containment Systems Branch (CSB)

Secondary - Mechanical Engineering Branch (MEB)
Core Performance Branch (CPB)
Auxiliary and Power Conversion Systems Branch (APCSB)
Structural Engineering Branch (SEB)

I. AREAS OF REVIEW

The CSB reviews the information presented by the applicant in the safety analysis report concerning the determination of the design differential pressure values for containment subcompartments. A subcompartment is defined as any fully or partially enclosed volume within the primary containment that houses high energy piping and would limit the flow of fluid to the main containment volume in the event of a postulated pipe rupture within this volume. A short-term pressure pulse would exist inside a containment subcompartment following a pipe rupture within this volume. This pressure transient produces a pressure differential across the walls of the subcompartment which reaches a maximum value generally within the first second after blowdown begins. The magnitude of the peak value is a function of several parameters, which include blowdown mass and energy release rates, subcompartment volume, vent area, and vent flow behavior. A transient differential pressure response analysis should be provided for each subcompartment or group of subcompartments that meets the above definition.

The CSB review includes the manner in which the mass and energy release rate into the break compartment were determined, nodalization of subcompartments, subcompartment vent flow behavior, and subcompartment design pressure margins. This includes a coordinated review effort with the CPB. The CPB is responsible for the adequacy of the blowdown model.

The CSB review of the mass and energy release rates includes the basis for the selection of the pipe break size and location within each subcompartment containing a high energy line and the analytical procedure for predicting the short-term mass and energy release rates.

The CSB review of the subcompartment model includes the basis for the nodalization within each subcompartment, the initial thermodynamic conditions within each subcompartment, the nature of each vent flow path considered, and the extent of entrainment assumed in the vent flow mixture. The review may also include an analysis of the dynamic characteristics of components, such as doors, blowout panels, or sand plugs, that must open or be removed to provide a vent flow path, and the methods and results of components tests performed to demonstrate the validity of these analyses. The analytical procedure to determine the loss coefficients for each vent flow path and to predict the vent mass flow rates, including flow correlations used to compute sonic and subsonic flow conditions within a vent, is reviewed. The design pressure chosen for each subcompartment is also reviewed. On request from the APCSB, the CSB evaluates or performs pressure response analyses for subcompartments outside containment.

MEB is responsible for reviewing the acceptability of postulated break locations, and the design criteria and methods employed to limit pipe motion for postulated breaks within subcompartments (See Standard Review Plan 3.6.2).

MEB and SEB are responsible for reviewing the capability of components and their supports to withstand the loads associated with high energy pipe breaks postulated to occur within the subcompartments.

II. ACCEPTANCE CRITERIA

1. The subcompartment analysis should incorporate the following assumptions:

   a. Break locations and types should be chosen according to Regulatory Guide 1.46 for subcompartments inside containment and to Branch Technical Position MEB 3-1 (attached to Standard Review Plan 3.6.2) for subcompartments outside containment. An acceptable alternate procedure is to postulate a circumferential double-ended rupture of each high pressure system pipe in the subcompartment.

   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. The initial plant operating conditions, such as pressure, temperature, water inventory, and power level, should be selected to yield the maximum blowdown conditions. The selected operating conditions will be acceptable if it can be shown that a change of each parameter would result in a less severe blowdown profile.

2. 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-VI (Ref. 24), CRAFT (Ref. 23), CE FLASH-4 (Ref. 25), and RELAP-3 (Ref. 21), 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. When RELAP-4 is accepted by the staff as an operational ECCS blowdown code, it will be acceptable for subcompartment analyses.

3. The initial atmospheric conditions within a subcompartment should be selected to maximize the resultant differential pressure. An acceptable model would be to assume air at the maximum allowable temperature, minimum absolute pressure, and zero percent relative humidity. If the assumed initial atmospheric conditions differ from these, the selected values should be justified.

   Another model that is also acceptable, for a restricted class of subcompartments, involves simplifying the air model outlined above. For this model, the initial atmosphere within the subcompartment is modeled as a homogeneous water-steam mixture with an average density equivalent to the dry air model. This approach should be limited to subcompartments that have choked flow within the vents. However, the adequacy of this simplified model for subcompartments having primarily subsonic flow through the vents has not been established.

4. Subcompartment nodalization schemes should be chosen such that there is no substantial pressure gradient within a node, i.e., the nodalization scheme should be verified by a sensitivity study that includes increasing the number of nodes until the peak calculated pressures converge to small resultant changes.

5. If vent flow paths are used which are not immediately available at the time of pipe rupture, the following criteria apply:

   a. The vent area and resistance as a function of time after the break should be based on a dynamic analysis of the subcompartment pressure response to pipe ruptures.
   b. The validity of the analysis should be supported by experimental data or a testing program should be proposed at the construction permit stage that will support this analysis.
   c. The effects of missiles that may be generated during the transient should be considered in the safety analysis.

6. The vent flow behavior through all flow paths within the nodalized compartment model should be based on a homogeneous mixture in thermal equilibrium, with the assumption of 100% water entrainment. In addition, the selected vent critical flow correlation should be conservative with respect to available experimental data. Currently acceptable vent critical flow correlations are the "frictionless Moody" with a multiplier of 0.6 for water-steam mixtures, and the thermal homogeneous equilibrium model for air-steam-water mixtures.

7. At the construction permit stage, a factor of 1.4 should be applied to the peak differential pressure calculated in a manner found acceptable to the CSB for the subcompartment. The calculated pressure multiplied by 1.4 should be considered the design pressure. At the operating license stage, the peak calculated differential pressure should not exceed the design pressure. It is expected that the peak calculated differential pressure will not be substantially different from that of the construction permit stage. However, improvements in the analytical models or changes in the as-built subcompartment may affect the available margin.

III. REVIEW PROCEDURES

The procedures described below are followed for the subcompartment analysis review. 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 adopting the results of previous reviews of plants with essentially the same subcompartment and high pressure piping design.

The CSB reviews the initial conditions selected for determining the mass and energy release rate to the subcompartments. These values are compared to the spectrum of allowable operating conditions for the plant. The CBS will ascertain the adequacy of the assumed conditions based on this review.

The CSB confirms with the MEB the validity of the applicant's analysis of subcompartments containing high energy lines and postulated pipe break locations, 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 may perform confirmatory analyses of the blowdown mass and energy profiles within a subcompartment. The analysis is done using the RELAP3 computer program (See Reference 21 for a description of this code). 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 this analysis. The use of RELAP3 will continue until the RELAP4 computer code has been approved by the staff as an acceptable blowdown code. At that time, the CSB will replace RELAP3 with RELAP4 for all subsequent analyses.

The CSB determines the adequacy of the information in the safety analysis report regarding subcompartment volumes, vent areas, and vent resistances. If a subcompartment must rely on doors, blowout panels, or equivalent devices to increase vent areas, the CSB reviews the analyses and testing programs that substantiate their use.

The CSB reviews the nodalization of each subcompartment to determine the adequacy of the calculational model. As necessary, CSB performs iterative nodalization studies for subcompartments to confirm that sufficient nodes have been included in the model.

The CSB compares the initial subcompartment air pressure, temperature, and humidity conditions to the criteria of II, above, to assure that conservative conditions were selected.

The CSB reviews the bases, correlations, and computer codes used to predict subsonic and sonic vent flow behavior and the capability of the code to model compressible and uncompressible flow. The bases should include comparisons of the correlations to both experimental data and recognized alternate correlations that have been accepted by the staff.

Using the nodalization of each subcompartment as specified in the safety analysis report, the CSB performs analyses using one of several available computer programs to determine the adequacy of the calculated peak differential pressure. The computer program used will depend upon the subcompartment under review as well as the flow regime. At the present time, the two programs used by the CSB are RELAP3 (Ref. 21) and CONTEMPT-LT (Refs. 7, 8, and 9). A multi-volume computer code is currently under development.

At the construction permit stage, the CSB will ascertain that the subcompartment design pressures include appropriate margins above the calculated values, as given in II, above.

IV. EVALUATION FINDINGS

The conclusions reached on completion of the review of this section are presented in Standard Review Plan 6.2.1.

V. REFERENCES

The references for this plan are those listed in Standard Review Plan 6.2.1, together with the following:

1a. Regulatory Guide 1.46, "Protection Against Pipe Whip Inside Containment."

2a. Standard Review Plan 3.6.2, "Determination of Break Locations and Dynamic Effects Associated with the Postulated Rupture of Piping," and attached Branch Technical Position MEB 3-1, "Postulated Break and Leakage Locations in Fluid System Piping Outside Containment."

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SRP 6.2.1.5