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U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

SECTION 15.3.3
15.3.4

REACTOR COOLANT PUMP ROTOR SEIZURE AND REACTOR COOLANT PUMP SHAFT BREAK

REVIEW RESPONSIBILITIES

Primary - Reactor Systems Branch (RSB)

Secondary - Accident Analysis Branch (AAB)
Core Performance Branch (CPB)
Electrical, Instrumentation and Control Systems Branch (EICSB)

I. AREAS OF REVIEW

The events postulated are an instantaneous seizure of the rotor or break of the shaft of a reactor coolant pump in a pressurized water reactor (PWR) or recirculation pump in a boiling water reactor (BWR). Flow through the affected loop is rapidly reduced, leading to a reactor and turbine trip. The sudden decrease in core coolant flow while the reactor is at power results in a degradation of core heat transfer which could result in fuel damage. The initial rate of reduction o, coolant flow is greater for the rotor seizure event. However, the shaft break event permits a greater reverse flow through the affected loop later during the transient and, therefore, results in a lower core flow rate at that time.

This review plan is intended to cover both of these infrequent transients. Each of these transients should be discussed in individual sections of the safety analysis report (SAR), as required by the Standard Format (Ref. 1).

The review is concerned with the postulated initial core and reactor conditions that are pertinent to the rotor seizure or broken shaft events, the methods of thermal and hydraulic analysis, the postulated sequence of events including time delays prior to and after protective system actuation, the assumed reactions of reactor system components, the functional and operational characteristics of the reactor protection system in terms of how it affects the sequence of events, and all operator actions required to secure and maintain the reactor in a safe condition.

The results of the applicant's analyses are reviewed to ensure that values of pertinent system parameters are within expected ranges for the type and class of reactor under review. The parameters include: peak clad temperature, peak fuel temperature, core flow and flow distribution, channel heat flux (average and hot), minimum critical heat flux ratio or critical power ratio, departure from nucleate boiling ratio, vessel water level, thermal power, vessel pressure, steam line pressure (BWR), steam line flow (BWR), and feedwater flow (BWR).

The sequence of events described in the SAR is reviewed by both RSB and EICSB. The RSB reviewer concentrates on the need for the reactor protection system, the engineered safety systems, and operator action to secure and maintain the reactor in a safe condition. The EICSB reviewer, as described in Standard Review Plans (SRP) 7.2 and 7.3, concentrates on the instrumentation and controls aspects of the sequence described in the SAR and evaluates whether the reactor and plant protection and safeguards controls and instrumentation systems will function as assumed in the safety analysis with regard to automatic actuation, remote sensing, indication, control, and interlocks with auxiliary or shared systems. EICSB also evaluates potential bypass modes and the possibility of manual control by the operator.

The analytical methods are reviewed by RSB to ascertain whether the mathematical modeling and computer codes have been previously reviewed and accepted by the staff. If a referenced analytical method has not been previously reviewed, the reviewer requests initiation of a generic evaluation of the new analytical model by CPB. CPB, as described in SRP 4.4, performs generic reviews of the thermal-hydraulic computer models used for this transient. CPB also performs, upon request, additional analyses related to these accidents for selected reactor types.

The values of all parameters used in a new analytical model, including the initial conditions of the core and system, are reviewed. It is the responsibility of the RSB engineer to contact his counterpart in CPB to ensure that the relevant physics data have been used in any staff calculations.

AAB is notified regarding the extent of fuel failures that are predicted by the analysis. AAB then evaluates the radiological consequences.

II. ACCEPTANCE CRITERIA

1. The basic objectives of the review of the transients resulting from a rotor seizure or shaft break in a reactor coolant pump are:

   a. To identify which of these infrequent transients is the more limiting.

   b. To verify that, for the more limiting transient, the plant responds in such a way that the criteria regarding fuel damage, radiological consequences, and system pressure (discussed in the following paragraphs) are met.

2. The specific criteria for the rotor seizure and shaft break transients are:

   a. For infrequent incidents*, such as the rotor seizure or shaft break in a reactor coolant pump, the plant should be designed to limit the release of radioactive

*The term "infrequent incidents" is used in this review plan in the same sense as in the descriptions of design and plant process conditions in References 7 and 8.

material to assure that doses to persons offsite are kept to values which are a small fraction of 10 CFR Part 100 guidelines.

b. The reactor coolant pump rotor seizure or shaft break event should be accommodated with the failure of only a small fraction of the fuel rods in the reactor, and the core geometry should remain intact so there is no loss of core cooling capability. Safety functions should be accomplished assuming the worst single failure of a safety system active component.

c. A rotor seizure or shaft break in a reactor coolant pump should not, by itself, generate a more serious condition or result in a loss of function of the reactor coolant system or containment barriers.

3. The applicant's analyses should be performed using an acceptable analytical model. The equations, sensitivity studies, and models described in References 2 through 6 are acceptable. If other analytical methods are proposed by the applicant, these methods are evaluated by the staff for acceptability. For new generic methods, the reviewer requests an evaluation by CPB.

The values of the parameters used in the analytical model should be suitably conservative. The following values are considered acceptable:

a. Initial power level is taken as the rated output (licensed core thermal power) for the number of loops assumed operating, plus an allowance of 2% to account for power measurement uncertainty. An analysis to determine the effects of rotor seizure or pump shaft break should be made for each allowed mode of operation (e.g., one-, two-, three-, and four-loop operation) or the effects referenced to a limiting case.

b. Core coolant inlet subcooling is at the minimum of the operating range in the technical specifications so as to maximize the calculated coolant enthalpy in the core.

c. Conservative scram characteristics are assumed, i.e., maximum time delay with the most reactive rod held out of core.

d. The core burnup is selected to yield the most limiting combination of moderator temperature coefficient, void coefficient, Doppler coefficient, axial power profile, and radial power distribution.

III. REVIEW PROCEDURES

The procedures below are used during both the construction permit (CP) and operating license (OL) reviews. During the CP review, the values of system parameters and setpoints used in the analysis will be preliminary in nature and subject to change. At the OL review stage, final values should be used in the analysis, and the reviewer should compare these to the limiting safety system settings included in the proposed technical specifications.

The applicants' analysis of the rotor seizure and shaft break events are reviewed by RSB regarding the occurrences leading to the initiating event. The sequence of events, from initiation until a stabilized condition is reached, is reviewed to ascertain:

1. The extent to which normally operating plant instrumentation and controls are assumed to function.

2. The extent to which plant and reactor protection systems are required to function.

3. The credit taken for the functioning of normally operating plant systems.

4. The operation of engineered safety systems that is required.

5. The extent to which operator actions are required.

If the SAR states that one of the transients is not as limiting as the other, the reviewer evaluates the justification presented by the applicant. The applicant is to present a quantitative analysis in the SAR of the transient that is determined to be more limiting. For the transient that is found more limiting, the reviewer confirms that the effects of the transient are determined for each mode of operation (e.g., one-, two-, three-, or four-loop) allowed by the technical specifications. Either a separate analysis should be presented for each mode of operation or the effects of each mode should be referenced to the limiting case.

For the more limiting transient, the RSB reviewer, with the aid of the EICSB reviewer, reviews the timing of the initiation of those protection, engineered safety, and other systems needed to limit the consequences of the transient to acceptable levels. The RSB reviewer compares the predicted variation of system parameters with various trip and system initiation setpoints. The EICSB reviewer evaluates automatic initiation, actuation delays, possible bypass modes, interlocks, and the feasibility of manual operation if the SAR states that operator action is needed or expected.

To the extent deemed necessary, the RSB reviewer evaluates the effect of single active failures of safety systems and components which may alter the course of the transient. This phase of the review uses the system review procedures described in the standard review plans for Chapters 5, 6, 7 and 8 of the SAR.

The mathematical models used by the applicant to evaluate core performance and to predict system pressure in the reactor coolant system and main steam lines are reviewed by RSB to determine if these models have been previously reviewed and found acceptable by the staff. If not, CPB is requested to initiate a generic review of the model proposed by the applicant.

The values of system parameters and initial core and system conditions used as input to the model are reviewed by RSB. Of particular importance are the reactivity coefficients and control rod worths used in the applicant's analysis, and the variation of moderator temperature, void, and Doppler coefficients of reactivity with core life. The justification provided by the applicant to show that he has selected the core burnup that yields the minimum margins is evaluated. CPB is consulted regarding the values of the reactivity parameters used in the applicant's analysis.

The results of the applicant's analysis are reviewed and compared to the acceptance criteria in Section II of this SRP regarding the maximum pressure in the reactor coolant and main steam systems. The variations with time during the transient of parameters listed in Sections 15.X.X.3(c) and 15.X.X.4(c) of the Standard Format (Ref. 1), are reviewed. The more important of these parameters (as listed in Section I, above) are compared to those predicted for other similar plants to confirm that they are within the expected range. In particular, the peak cladding temperature and percentage of fuel rods that experience a departure from nucleate boiling condition are compared.

IV. EVALUATION FINDINGS

The reviewer verifies that the SAR contains sufficient information and his review supports the following kinds of statements and conclusions, which should be included in the staff's safety evaluation report:

"The analyses and effects of an instantaneous seizure of a rotor and an instantaneous break of a shaft of a reactor coolant pump* during any allowed mode of operation have been reviewed. It was found that the more limiting of these events was the ________________. This event was evaluated by the applicant using a mathematical model that had been previously reviewed and found acceptable by the staff. The parameters used as input to this model were reviewed and found to be suitably conservative. The results of the analysis showed that ____% of the fuel rods experienced departure from nucleate boiling (DNB) and that the peak clad temperature reached was ___°F. This assures that the fuel damage will be minimal and that no loss of core cooling capability will result. The analysis showed that the maximum pressure within the reactor coolant and main steam systems did not exceed 110% of the design pressures.

"The staff concludes that the plant design is acceptable with regard to a possible seizure of a rotor or break of a shaft of a reactor coolant pump."

V. REFERENCES

1. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," Revision 2.

2. F.M. Bordelon, "Calculation of Flow Coastdown after Loss of Reactor Coolant Pump," WCAP-7973, Westinghouse Electric Corporation, August 1970.

3. C.D. Morgan, H.C. Cheatwood, and J.R. Glandermans, "RADAR - Reactor Thermal and Hydraulic Analysis During Reactor Flow Coastdown," BAW-10069, Babcock and Wilcox Company, July 1973.

*Recirculation pump shaft for a BWR.

4. R.H. Stoudt and J.E. Busby, "CADD - Computer Applications to Direct Simulation of Transient Events on Water Reactors," BAW-10080 (nonproprietary) and BAW-10076 (proprietary), Babcock and Wilcox Company, July 1973.

5. "System 80 Standard Safety Analysis Report (CESSAR)," Combustion Engineering, Inc., August 1973 (under review).

6. R. Linford, "Analytical Methods of Transient Evaluations in the General Electric Boiling Water Reactor," NEDP-10802, General Electric Company, April 1973.

7. ANSI N18.2, "Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants," American National Standards Institute (1974).

8. ANS Trial Use Standard N212, "Nuclear Safety Criteria for the Design of Stationary Boiling Water Reactor Plants," American Nuclear Society (1974).

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