NUREG-75/087

U.S. NUCLEAR REGULATORY COMMISSION

# STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

SECTION 5.4.6 REACTOR CORE ISOLATION COOLING SYSTEM (BWR)

REVIEW RESPONSIBILITIES

Primary - Reactor Systems Branch (RSB)

Secondary - Containment Systems Branch (CSB)
Core Performance Branch (CPB)
Electrical, Instrumentation and Control Systems Branch (EICSB)
Mechanical Engineering Branch (MEB)
Materials Engineering Branch (MTEB)

## I. AREAS OF REVIEW

The reactor core isolation cooling (RCIC) system in a boiling water reactor (BWR) is a safety system which serves as a standby source of cooling water to provide a limited decay heat removal capability whenever the main feedwater system is isolated from the reactor vessel. Abnormal events which could cause such a situation to arise include an inadvertent isolation of all main steam lines, loss of condenser vacuum, pressure regulator failure, loss of feedwater, the loss of offsite power, and total loss of all a-c power (both offsite and diesel generators). Each of these transients is analyzed in Chapter 15 of the applicant's safety analysis report (SAR). For each of these events, the high pressure part of the emergency core cooling system (ECCS) provides a backup function to the RCIC system.

The RCIC system consists of a steam-driven turbine-pump unit and associated valves and piping capable of delivering makeup water to the reactor vessel. Fluid removed from the reactor vessel following a shutdown from power operation is normally made up by the feedwater system, supplemented by in-leakage from the control rod drive system. If the feedwater system is inoperable, the RCIC turbine-pump unit starts automatically or is started by the operator from the control room. The water supply for the RCIC system comes from the condensate storage tank, with a secondary supply from the suppression pool.

The review of the RCIC system includes the system design bases, design criteria, description, and the points noted below.

1. The piping and instrumentation diagram is reviewed to determine that the system is capable of performing its intended function and of being preoperationally and operationally tested.

2. The degree of separation from the high pressure core spray (HPCS) system, or high pressure core injection (HPCI) system for 1967 product line or earlier BWR's, and protection against common mode failures of both redundant systems (e.g., from flooding, fire, pipe whip, or high temperature, pressure, and humidity) are reviewed.

3. The process flow diagram is reviewed to confirm that the RCIC system design parameters are consistent with expected pressures, temperatures, and flow rates.

4. The complete sequence of operation is reviewed to determine that the system can function as intended and that the system is capable of manual operation.

5. The proposed preoperational and initial startup test programs are reviewed to determine their adequacy.

6. The proposed technical specifications are evaluated to assure that they are adequate in regard to limiting conditions of operation and periodic surveillance testing.

7. The RCIC system is reviewed to assure that it has the proper seismic and quality group classifications. This aspect of the review is performed as part of the effort described in Standard Review Plans (SRP) 3.2.1 and 3.2.2. The RCIC system is to be enclosed in a structure having the proper seismic classification. The review of the building seismic category is also accomplished as a portion of the effort described in SRP 3.2.2.

   The RCIC is to be located in a structure that provides adequate protection against wind, tornadoes, floods, and missiles (as appropriate). The review of the building adequacy is performed as described in other sections of the standard review plans.

8. The CSB reviews the RCIC system, as described in SRP 6.2.4, to confirm that the design is compatible with the containment system and can be isolated.

9. The EICSB, as described in SRP 7.4, evaluates the adequacy of controls and instrumentation of the RCIC system with regard to the required features of automatic actuation, remote sensing and indication, remote control, emergency onsite power, sufficient battery capacity, and use of d-c power only.

10. The MEB, as described in SRP 3.9.3, ensures that the design and installation of the RCIC system meet applicable codes and are adequate for its proper functioning.

11. The CPB, on request, reviews the core decay energy output on which the design is based to see that it is applicable and suitably conservative.

12. The MTEB reviews the materials and the inservice inspection program for the RCIC system.

II. ACCEPTANCE CRITERIA

The general objective of the review is to determine that the RCIC system, in conjunction with the HPCS (or HPCI) system meets the requirements of General Design Criteria 34, (Ref. 3) by providing the capability for decay heat removal to allow complete shutdown of the reactor under conditions requiring its use. It must maintain the reactor water inventory until the reactor is depressurized sufficiently to permit operation of the low pressure cooling systems. The RCIC system, in conjunction with the HPCS (or HPCI) system, must be capable of removing fission product decay heat and other residual heat from the reactor core following shutdown so as to preclude fuel damage or reactor coolant pressure boundary over-pressurization. For the purposes of this plan, the minimum critical heat flux ratio (MCHFR) should be greater than 1.0, based on Reference 7, or the minimum critical power ratio (MCPR) should be greater than X*, based on Reference 8, to preclude fuel damage. The maximum reactor pressure should be less than 110% of design pressure (Ref. 9).

Historically, credit has been taken for RCIC system capability to mitigate the consequences of certain abnormal events; however, since the cooling function is redundant to the HPCI or HPCS system, the RCIC system does not have to meet the single failure criterion. However, the system is to perform its function without the availability of any a-c power. As a system which must respond to certain abnormal events, the RCIC system must be designed to seismic Category I standards, as defined in Regulatory Guide 1.29 (Ref. 10).

The RCIC and HPCS (or HPCI) systems must be protected against natural phenomena, external or internal missiles, pipe whip, and jet impingement forces so that such events cannot fail both systems simultaneously. Jointly, the two systems must meet General Design Criterion 2 (Ref. 1); General Design Criterion 4 (Ref.2); Regulatory Guide 1.46 (Ref. 11); and the staff positions on protection for pipe failures outside containment (Ref. 13).

The RCIC system must meet the requirements of General Design Criteria 55, 56, and 57 (Refs. 4, 5, and 6) with regard to isolation provisions for lines passing through the primary containment.

If the RCIC system is used to control or mitigate the consequences of an accident, either by itself or as a backup to another system, it must meet the requirements of an engineered safety feature.

The preoperational and initial startup test programs for the RCIC system should meet the intent of Regulatory Guide 1.68 (Ref. 12).

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*The value of MCPR will vary for different product lines. The value of MCPR used for a particular case review is to be consistent with the value specified in the plant technical specifications as the fuel integrity safety limit.

III. <u>REVIEW PROCEDURES</u>

The procedures below are used during the construction permit (CP) review to assure that the design criteria and bases and the preliminary design as set forth in the preliminary safety analysis report meet the acceptance criteria given in Section II of this plan.

For the operating license (OL) review, the procedures are utilized to verify that the initial design criteria and bases have been appropriately implemented in the final design as set forth in the final safety analysis report. The OL review also includes the proposed technical specifications, to assure that they are adequate in regard to limiting conditions of operation and periodic surveillance testing.

The following steps are taken by the reviewer to determine that the acceptance criteria of Section II have been met. The steps are adapted to CP or OL reviews as appropriate.

1. Using the RCIC operating requirements specified in SAR Section 5.4.6 and Chapter 15, the reviewer confirms that the RCIC can function when required so as to prevent the MCHFR from decreasing below 1.0 or the critical power ratio from decreasing below X* (based on Reference 7 or Reference 8) and prevent the reactor pressure from exceeding 110% of design pressure. This determination is based on engineering judgment and independent calculations (where deemed necessary), using information as specified in steps 2 and 3 below. The reviewer consults with the CPB to assure that the decay heat loads used in the RCIC analyses are applicable and suitably conservative. The reviewer also determines that the RCIC system maintains sufficient coolant inventory in the reactor vessel to keep the core covered and assure clad integrity.

2. Using the description given in Section 5.4.6 of the SAR, including component lists and performance specifications, the reviewer determines that the RCIC system piping and instrumentation are such as to allow the system to operate as intended. This is accomplished by reviewing the piping and instrumentation diagrams to confirm that piping arrangements permit the required flow paths to be achieved and that sufficient process sensors are available to measure and transmit required information.

3. Using the comparison tables of SAR Section 1.3, the RCIC system is compared to designs and capacities of such systems in similar plants to see that there are no unexplained departures from previously reviewed plants. Where possible, comparisons should be made with actual performance data from similar systems in operating plants.

4. The reviewer checks the piping and instrumentation diagrams and equipment layout drawings for the RCIC and HPCS (or HPCI) systems to see that the systems are physically separated and can function independently and that they jointly conform to the requirements of General Design Criteria 2 and 4 and the recommendations of Regulatory Guide 1.46 and staff positions on piping failures outside containment (Refs. 1, 2, 11, and 13).

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*IBID. Page 5.4.6-3

5. Based on the description in SAR Section 5.4.6, the reviewer judges whether adequate control and monitoring information is available to allow the operator to actuate the system manually or to realign the RCIC system manually within the time allowed (i.e., change the RCIC system suction from the condensate storage tank to the suppression pool or residual heat removal system).

6. The reviewer contacts EICSB to confirm that automatic actuation and remote-manual valve controls are capable of performing the functions required, and that sensor and monitoring provisions are adequate. As part of their review, the EICSB is to ascertain that the RCIC system operation is not dependent on a-c power sources, and that there is sufficient battery capacity to permit operation of the RCIC for a period of two hours without the availability of a-c power. The instrumentation and controls of the RCIC system, in conjunction with the HPCS (or HPCI) system, are to have sufficient redundancy to satisfy the single failure criterion.

7. The reviewer checks the piping and instrumentation diagrams to see that essential RCIC system components are designated seismic Category I.

8. The applicant's proposed preoperational and initial startup test programs are reviewed to determine that they are consistent with the intent of Regulatory Guide 1.68 (Ref. 12). At the OL stage, the reviewer assures that sufficient information is provided by the applicant to identify the test objectives, methods of testing, and test acceptance criteria (see par. C.2.b of Regulatory Guide 1.68).

   The reviewer evaluates the proposed test programs to determine if they provide reasonable assurance that the RCIC system will perform its safety function. As an alternative to this detailed evaluation, the reviewer may compare the RCIC system design to that of previously reviewed plants. If the design is essentially identical and if the proposed test programs are essentially the same, the reviewer may conclude that the proposed test programs are adequate for the RCIC system. If the RCIC system differs significantly from that of previously reviewed designs, the impact of the proposed changes on the required preoperational and initial startup testing programs are reviewed at the CP stage. This effort should particularly evaluate the need for any special design features required to perform acceptable test programs.

9. The proposed plant technical specifications are reviewed to:

   a. Confirm the suitability of the limiting conditions of operation, including the proposed time limits and reactor operating restrictions for periods when system equipment is inoperable due to repairs and maintenance.

   b. Verify that the frequency and scope of periodic surveillance testing is adequate.

10. The reviewer confirms that the RCIC is housed in a structure whose design and design criteria have been reviewed by other branches to assure that it provides adequate protection against wind, tornadoes, floods, and missiles, as appropriate.

## 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 reactor core isolation cooling (RCIC) system includes the piping, valves, pumps, turbines, instrumentation, and controls used to maintain water inventory in the reactor vessel whenever it is isolated from the main feedwater system. Certain engineered safety features (HPCS or HPCI) provide a redundant backup for this function. The scope of review of the RCIC system for the ______ plant included piping and instrumentation diagrams, equipment layout drawings, and functional specifications for essential components. The review has included the applicant's proposed design criteria and design bases for the RCIC system, his analysis of the adequacy of the criteria and bases, and the conformance of the design to these criteria and bases.

"The drawings, component descriptions, design criteria, and supporting analyses have been reviewed and have been found to conform to Commission regulations as set forth in General Design Criteria 2, 4, 34, 55, 56, and 57, and to applicable regulatory guides and staff technical positions. The RCIC system has been found to conform to Regulatory Guide 1.29. The RCIC system and HPCS (or HPCI) system jointly conform to General Design Criteria 2, 4, 34 and Regulatory Guide 1.46. The two systems have been found capable of removing core decay heat following feedwater system isolation and reactor shutdown so that the core minimum critical heat flux ratio (MCHFR) does not decrease below 1.0 (or the critical power ratio does not decrease below ______), and the pressure within the reactor coolant pressure boundary does not exceed 110% of design pressure. This capability has been found to be available even with a loss of offsite power and with a single active failure. The staff concludes that the design of the reactor core isolation cooling system conforms to the Commission's regulations and to applicable regulatory guides and staff positions, and is acceptable."

## V. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

2. 10 CFR Part 50, Appendix A, General Design Criterion 4, "Environmental and Missile Design Bases."

3. 10 CFR Part 50, Appendix A, General Design Criterion 34, "Residual Heat Removal."

4. 10 CFR Part 50, Appendix A, General Design Criterion 55, "Reactor Coolant Pressure Boundary Penetrating Containment."

5. 10 CFR Part 50, Appendix A, General Design Criterion 56, "Primary Containment Isolation."

6. 10 CFR Part 50, Appendix A, General Design Criterion 57, "Closed System Isolation Valves."

7. J. M. Healzer, et al, "Design Basis for Critical Heat Flux Conditions in Boiling Water Reactors," APED-5286, General Electric Company, September 1966.

8. "General Electric BWR Thermal Analysis Basis (GETAB): Data, Correlation and Design Application," NEDO-10958, General Electric Company, November 1973.

9. ASME Boiler and Pressure Vessel Code, Section III, Article NB-7000, "Protection Against Overpressure," American Society of Mechanical Engineers.

10. Regulatory Guide 1.29, "Seismic Design Classification," Revision 1.

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

12. Regulatory Guide 1.68, "Preoperational and Initial Startup Test Programs for Water-Cooled Power Reactors."

13. Branch Technical Positions APCSB 3-1, "Protection Against Postulated Piping Failures in Fluid Systems Outside Containment," attached to SRP 3.6.1, and MEB 3-1, "Postulated Break and Leakage Locations in Fluid System Piping Outside Containment," attached to SRP 3.6.2.

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SRP 5.4.8