



# DRAFT REGULATORY GUIDE

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## DRAFT REGULATORY GUIDE DG-1253

(Proposed Revision 2 of Regulatory Guide 1.79, dated September 1975)

# PREOPERATIONAL TESTING OF EMERGENCY CORE COOLING SYSTEMS FOR PRESSURIZED-WATER REACTORS

## A. INTRODUCTION

This guide describes methods that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers acceptable to implement Title 10, of the *Code of Federal Regulations*, Part 50, “Domestic Licensing of Production and Utilization Facilities” (10 CFR Part 50) (Ref. 1), Appendix A, “General Design Criteria for Nuclear Power Plants,” with regard to preoperational testing features of emergency core cooling systems (ECCSs) for pressurized-water reactors (PWRs). This regulatory guide (RG) also describes methods that the NRC staff finds acceptable for preoperational testing of ECCS structures, systems, and components (SSCs), in accordance with the regulations in 10 CFR Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants” (Ref. 2), Subpart B, “Standard Design Certifications,” and Subpart C, “Combined Licenses.”

Nuclear power plant SSCs must be tested to quality standards commensurate with their importance to safety. Criterion XI, “Test Control,” of Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants,” to 10 CFR Part 50 requires licensees to establish a testing program to identify and perform all tests needed to demonstrate that SSCs will perform satisfactorily in service.

This testing program is to be conducted in accordance with written test procedures that incorporate the requirements and acceptance criteria in applicable design documents. The ECCS functions to be tested are those necessary to ensure that specified design functions of the ECCS are met during any condition of normal operation, including abnormal operating occurrences, or because of postulated accident conditions.

RG 1.68, “Initial Test Programs for Water-Cooled Nuclear Power Plants,” Revision 3, issued March 2007 (Ref. 3), describes a method acceptable to the NRC staff for complying with the Commission’s regulations with regard to preoperational testing of nuclear power plant SSCs that perform

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This regulatory guide is being issued in draft form to involve the public in the early stages of the development of a regulatory position in this area. It has not received final staff review or approval and does not represent an official NRC final staff position. Public comments are being solicited on this draft guide (including any implementation schedule) and its associated regulatory analysis or value/impact statement. Comments should be accompanied by appropriate supporting data. Written comments may be submitted to the Rules, Announcements, and Directives Branch, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001; submitted through the NRC’s interactive rulemaking Web page at <http://www.nrc.gov>; or faxed to (301) 492-3446. Copies of comments received may be examined at the NRC’s Public Document Room, 11555 Rockville Pike, Rockville, MD. Comments will be most helpful if received by August 5, 2011.

Electronic copies of this draft regulatory guide are available through the NRC’s interactive rulemaking Web page (see above); the NRC’s public Web site under Draft Regulatory Guides in the Regulatory Guides document collection of the NRC’s Electronic Reading Room at <http://www.nrc.gov/reading-rm/doc-collections/>; and the NRC’s Agencywide Documents Access and Management System (ADAMS) at <http://www.nrc.gov/reading-rm/adams.html>, under Accession No. ML110110480. The regulatory analysis may be found in ADAMS under Accession No. ML110110489.

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functions important to safety. This guide describes preoperational testing acceptable to the staff specifically for ECCSs in PWRs. This guide is applicable to all PWRs licensed under 10 CFR Part 50 and 10 CFR Part 52. Where a SSC is not part of the specific nuclear plant design, the associated testing would not apply.

The NRC issues regulatory guides to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to applicants and licensees. Regulatory guides are not substitutes for regulations and compliance with them is not required.

This regulatory guide contains information collection requirements covered by 10 CFR Part 50 and 10 CFR Part 52 that the Office of Management and Budget (OMB) approved under OMB control numbers 3150-0011 and 3150-0151, respectively. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number. The NRC has determined that this Regulatory Guide is not a major rule as designated by the Congressional Review Act and has verified this determination with OMB.

The staff will consult the Advisory Committee on Reactor Safeguards concerning this guide before final issuance.

## **B. DISCUSSION**

The NRC staff concluded that additional guidance should be provided regarding the scope of ECCS preoperational tests identified in RG 1.79, "Preoperational Testing of Emergency Core Cooling Systems for Pressurized-Water Reactors," issued September 1975 (Ref. 4), as a result of the NRC's design certification of the AP1000 and the ongoing NRC review of the design certification applications for the U.S. Evolutionary Power Reactor (U.S. EPR) and the U.S. Advanced PWR (US-APWR). The NRC staff also concluded that this RG should include additional guidance for ECCS preoperational tests based on recent operating experience from PWRs.

## **C. REGULATORY POSITION**

A comprehensive preoperational test program of the ECCS should ensure that it will accomplish its intended functions when required. The program should cover all test-related activities, including the following:

1. the development of test descriptions, test objectives, and specific acceptance criteria,
2. the preparation of test procedures,
3. the conduct of the tests and acquisition of system and component performance data, and
4. the resolution of deficiencies and deviations from expected performance.

The test program should include prerequisites for completion of construction tests and preoperational tests in coordination with the startup test group approval of test procedures, test configuration and test initiation.

As a prerequisite to ECCS tests, verify that noncondensable gases in the ECCS systems are kept to an acceptable level. This verification should be accomplished by either performing nondestructive examination techniques, opening vent valves to remove noncondensable gases or by methods justified through an engineering evaluation. The engineering evaluation should consider void volume, void

transport to pumps and pump void acceptance criteria and include performance of void transport analysis. The evaluation should document the rationale and determination that gas intrusion into the ECCS system would not adversely affect the ability of the system to perform its function. If noncondensable gases are vented through high-point vent valves, verify closure of the valves before starting the ECCS pumps.

The test program should also include prerequisite tests for motor and steam operated pump capabilities and motor and air operated valve actuation times. This testing should be performed under the most limiting design basis conditions and may be verified by either testing or analyses.

## 1. System Testing

The preoperational testing of the ECCS should include the tests described below.

### a. High-Pressure Safety Injection (Current Fleet of PWRs and US-APWR)

The preoperational test program should test each train of the High Pressure Safety Injection (HPSI) under both cold and simulated hot operating conditions before fuel loading. The tests below should verify all critical parameter acceptance criteria that are required for HPSI to meet its design basis.

- (1) Flow Test—Cold Conditions. The reactor vessel may be open and flooded with the reactor coolant system (RCS) pressure at essentially atmospheric (zero gauge pressure) conditions. No attempt is made to control the temperature of the water in the storage tank or in the accumulators. This test demonstrates system and component capability by injecting water<sup>1</sup> from the water storage tank into the reactor vessel through various combinations of injection legs and pumps.
  - (a) This test should be initiated by the safety injection signal with affected auxiliary systems in their standard operating mode.
  - (b) Testing should demonstrate that flow rates delivered through each injection flow path using all pump combinations are within the design specifications. Proper system activation time and sequencing should also be verified. Those plants that use this scheme to handle the loss-of-coolant accident (LOCA) should demonstrate the capability of the HPSI pumps to take suction from the low-pressure safety injection (LPSI) pumps.
  - (c) Testing should verify that pump motors will not trip out under maximum possible flow conditions and that adequate design margin exists between trip points and maximum operating conditions for all pump motor trips.
  - (d) Testing should verify that the electric power supply meets design acceptance criteria under all applicable design basis loading conditions.
- (2) Flow Test—Hot Conditions. The intent of this test is to demonstrate, by injecting water into the primary system at operating pressure and temperature conditions, that emergency core cooling water can be delivered into the reactor under conditions as close as possible to postulated accident conditions. Any planned or unplanned actuation of the HPSI that

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<sup>1</sup> Because borated water is not made up until the hot functional testing program is completed, the use of unborated water is acceptable for this test.

results in the injection of cold fluid into the hot RCS should be documented in the preoperational test records discussed in Regulatory Position C.3 of this RG.

- (a) The reactor vessel should be closed and the RCS filled and maintained at the acceptable operating pressure and temperature level. The water level in the pressurizer should be as low as practical. Actuation of the safety injection signal should initiate system operation. The temperature of the RCS will be much higher than that of the injection water, and there will be a thermal shock to the piping and reactor vessel as a result of the hot injection test of the HPSI.
- (b) This test should verify the capability of all HPSI pumps to deliver water as required under postulated accident conditions, based on as-built HPSI pumps and system head-capacity curves. In addition, proper operation of the motor operated valves and check valves should be verified.

b. Medium-Pressure Safety Injection (Westinghouse Four-Loop PWRs, U.S. EPR)

The preoperational test program should test the performance of critical components of the medium-pressure safety injection (MPSI) system (for those plants so equipped) under cold and simulated hot operating conditions before fuel loading.

- (1) Flow Test—Cold Conditions. Flow testing of the MPSI system should be conducted in a manner similar to that for the HPSI system (see Regulatory Position C.1.a(1) above).
- (2) Recirculation Test—Cold Conditions. If MPSI can be used to directly take suction from the containment sump, the recirculation test discussed in Regulatory Position C.1.c(2) below should be performed.
- (3) Flow Test—Hot Conditions. Flow testing of the MPSI system should be conducted in a manner similar to that for the HPSI and LPSI system (see Regulatory Positions C.1.a(2) and C.2.c.(2)).

c. Low-Pressure Safety Injection (LPSI) (Current Fleet of PWRs, US-APWR, U.S. EPR)

- (1) Flow Test—Cold Conditions. Flow testing of the LPSI system should be conducted in a manner similar to that for the HPSI system (see Regulatory Position C.1.a(1) above).
- (2) Recirculation Test—Cold Conditions. This test should demonstrate the ability of the injection pumps to recirculate cooling water from the containment floor or sump into the RCS and should cover any aspects of the design where both ECCS trains utilize a common component such as a containment emergency sump. This test should also demonstrate the capability to realign the valves for recirculation mode.
  - (a) Testing should verify proper vortex control in the suction lines from the sump and acceptable pressure drops in filtering mechanism, suction lines, and valves. Water level should be at a minimum level that may exist when recirculation flow from a containment emergency sump is initiated under actual accident conditions when assessing vortex behavior. To avoid RCS contamination, the sump water may be discharged to external drains or other systems.

- (b) Testing should verify that the available net positive suction head (NPSH) is greater than that required for the pumps to achieve their design function. Containment pressure and pump fluid temperature do not have to be controlled, but the NPSH available should be adjusted to the maximum design pumped fluid temperature and the minimum design containment pressure before the postulated LOCA. The postulated effect of debris should be considered when evaluating test results since test conditions and actual accident conditions may differ. (See Regulatory Position C.2.c(2) below).
    - (c) Testing should demonstrate proper operation of the containment sump instrumentation by simulating the containment flood-up water levels.
- d. Core Flooding (Current Fleet of PWRs, US-APWR, U.S. EPR) (For AP1000 design, see Regulatory Position C.1.f below.)
  - (1) Flow Test—Cold Conditions. This test should demonstrate proper system actuation and flow rates. For this test, the accumulators should be discharged one at a time into the reactor vessel after being filled to their normal level and pressurized with gas. Accumulator pressure and temperature are not critical, and the test may be conducted at any pressure up to normal precharge pressure. Test results for flow rates should be adjusted for the actual test pressure and temperature versus the design temperature and pressure. These tests apply to all passive injection systems.
  - (2) Isolation Valve Test. At some facilities, the accumulator isolation valves receive a confirmatory open signal whenever the safety injection signal is activated. This ensures that inadvertent valve closures do not prevent operation of the core flooding system. At facilities that have this design feature, testing should demonstrate that the valve will open under the maximum differential pressure conditions and maximum expected accumulator precharge pressures. This test should be conducted using both normal and emergency power supplies.
  - (3) Flow Test—Hot Conditions. This test should verify that check valves subject to higher-than-ambient temperatures during power operation will function properly at the higher temperatures. Any planned or unplanned actuation of core flooding that results in the injection of cold fluid into the hot RCS should be documented in the preoperational test records discussed in Regulatory Position C.3 of this RG.
    - (a) Initially, the RCS and the accumulators should be at their normal operating temperature and pressure, with the RCS pressure higher than the accumulator pressure. Each accumulator injection train should be tested individually or simultaneously by opening the isolation valve and then slowly decreasing RCS pressure and temperature until the check valves operate as indicated by a decrease in the fluid level of each accumulator. To minimize the thermal cycling, the isolation valve should be closed as soon as check valve operation is verified.
    - (b) If the operability of these valves at high temperature is demonstrated during a different phase of the testing program, this specific test may be eliminated.

e. Emergency Letdown System (US-APWR)

The emergency letdown system (ELS) flow and isolation test verifies safe preparation for maintenance on the reactor pressure vessel and steam generators by draining down and isolating the RCS. During small-break LOCAs and safe-shutdown seismic events, when the residual heat removal (RHR) is in service and the chemical volume and control system letdown is isolated from the RCS, the ELS provides water to the refueling water storage pit (RWSP). Water from the RWSP then flows to the safety injection system (SIS) pumps.

- (1) Flow and Isolation Test—Cold Conditions. This test should verify the ELS flow and isolation functions. Flow testing should be conducted in a manner similar to that for the LPSI system (see Regulatory Position C.1.c.(1) above).
- (2) Flow and Isolation Test—Hot Conditions. This test should demonstrate the ability of the ELS gate and globe valves to control and throttle flow to the RWSP and supply depressurized water to the SIS. The test should successfully demonstrate a controlled cooldown of the RCS from hot-shutdown to cold-shutdown conditions while maintaining an adequate RCS water level in the pressurizer. When the system design includes isolation requirements for inservice conditions, this function test should include actuation methods and actuation completion time requirements.

f. Passive Core Cooling System—Safety Injection (AP1000)<sup>2</sup>

- (1) Flow Tests—Cold Conditions. This test should verify the ability of the passive core cooling system (PCCS) components (core makeup tanks (CMTs), accumulators, in-containment refueling water storage tank (IRWST), containment sump, automatic depressurization system (ADS), and their associated piping and valves) to perform their intended safety function:
  - (a) Verify design acceptance criteria are met for flow resistance of each CMT injection line, accumulator injection line, IRWST tank injection line, the ADS stage flowpaths and each of the flowpaths from the IRWST to each containment sump, as well as from each containment sump to the reactor.
  - (b) Verify design acceptance criteria are met for operation of the vacuum breakers in the ADS discharge lines.
  - (c) Verify design acceptance criteria are met for operation of at least one of each squib valve size and type including containment recirculation, IRWST injection, and a Stage 4 ADS squib valve. Verify that the squib valve receives a simulated signal at the valve electrical leads that is capable of actuating the valve. Verify, by analysis or other simulated test, that the squib valve flow resistance is consistent with the flowpath resistance. A test fixture with prototypical resistance may be used to simulate the squib valve in the flowpaths being tested.
  - (d) Verify design acceptance criteria are met for operation of the containment sump instrumentation by simulating the containment flood-up water levels.

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<sup>2</sup> This regulatory guide does not include testing guidance for first-plant-only or first-three-plant-only tests for the AP1000 design.

- (e) Verify design acceptance criteria are met for operation of the CMT level instrumentation during draindown testing of the CMTs.
- (2) Flow Tests—Hot Conditions. Any planned or unplanned actuation of the PCCS that results in the injection of cold fluid into the hot RCS should be documented in the preoperational test records discussed in Regulatory Position C.3 of this RG.
- During hot functional PCCS testing, the following should be verified:
- (a) Verify design acceptance criteria are met for operation of the ADS Stage 1, 2, and 3 components, including the spargers, by blowing down the RCS to the IRWST.
  - (b) Verify design acceptance criteria are met for operation of the CMTs during transition from the recirculation mode to the draindown mode of operation.
- g. Passive Core Cooling System—Emergency Makeup and Boration (AP1000)
- (1) Flow Test—Cold Conditions. System actuation and flow rates are verified to meet design acceptance criteria by the following test of the CMTs. Determine the resistance of the CMT cold-leg balance lines by filling the CMTs with flow from the cold legs.
  - (2) Flow Tests—Hot Conditions. The PCCS emergency makeup and boration function is verified by the following test of the CMTs. During hot functional testing of the RCS, the CMT cold-leg balance line piping water temperature at various locations should be recorded to verify that the water in this line is sufficiently heated to initiate recirculation flow through the CMTs.
- h. Passive Core Cooling System—Emergency Core Decay Heat Removal (AP1000)
- (1) Flow Test—Cold Conditions. The resistance of the CMT cold-leg balance lines is determined by filling the CMTs with flow from the cold legs. This test is normally performed by filling the cold, depressurized RCS using a constant, measured discharge flow from the normal RHR pumps. The RCS is maintained at a constant level above the top of the cold-leg balance line(s).
  - (2) Flow Test—Hot Conditions. Testing should verify the PCCS emergency core decay heat removal function by testing of the passive RHR (PRHR) heat exchanger.
    - (a) During hot functional testing of the RCS, record the piping water temperature for the heat exchanger supply and return lines and verify that natural circulation flow initiates.
    - (b) Testing should verify the heat transfer capability of the PRHR heat exchanger while the RCS is being cooled from hot-shutdown conditions with the reactor coolant pumps not running. The heat transfer rate measured in the test should be adjusted to account for differences in the hot-leg and IRWST temperatures, as well as the number of tubes plugged.

- (c) Testing should verify proper operation of the PRHR heat exchanger and its heat transfer capability with every reactor coolant pump running. The heat transfer rate measured in the test should be adjusted to account for differences in the hot leg and IRWST temperatures, as well as the number of tubes plugged.

## 2. Component Testing

The components of the systems involved in the system tests described in Regulatory Position C.1 should be tested, either in conjunction with the system tests or by independent component tests. Components that are common to the ECCS and other systems should be tested to the more stringent criteria. Performance data should be recorded and the following items verified:

### a. Instrumentation

- (1) Verify design acceptance criteria are met for operation of initiating instrumentation in various combinations of logic and instrument channel trip.
- (2) Verify design acceptance criteria are met for functioning of instrumentation and alarms used to monitor system availability. Instruments and alarms should be calibrated and tested before plant startup.

### b. Valves

- (1) Verify design acceptance criteria are met for operation of system valves including response times with the energy source (e.g., air/nitrogen supply or electric power source) at its limiting design condition. This should include visual verification of valve position, as well as proper control room indication.
- (2) Valve operation under maximum expected differential pressure conditions (consistent with system test limitations).
- (3) Operability at maximum expected pressure and temperature (consistent with system test limitations).

### c. Pumps and Motors

- (1) Proper operation of injection pumps and motors in all design operating modes.
- (2) Verify design acceptance criteria are met for NPSH performance under maximum system flow and temperature conditions. The test should also verify, by inspection, that no foreign material has entered into the pump to ensure that performance degradation does not occur and verify that the pump suction strainer is not clogged with debris so that pump failures or other system degradation does not occur.
- (3) Verify design acceptance criteria are met for individual pump capacity and discharge head.
- (4) Verify design acceptance criteria are met for pump response time (time to reach rated flow conditions) under minimum design voltage and frequency.



- (5) Verify design acceptance criteria are met for pump motor start sequence, overspeed protection, and adequate margins between motor running currents and protective breaker ratings. National Fire Protection Association (NFPA) Standard 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants," 2001 Edition (Ref. 5), provides additional guidance for the coordination of protective breakers.
- (6) Verify design acceptance criteria are met for vibration levels. Direct contact accelerometers or noncontacting vibration measurement methods are acceptable.

d. Controls

- (1) Verify design acceptance criteria are met for operation of controls, including controls that transfer pump suction. The tests should also verify separately and independently each channel or bus to identify any failures or losses of redundancy. Testing should include all backup and redundant controls.
- (2) Verify design acceptance criteria are met for operation of interlocks and equipment protective devices in pump and valve controls.

e. Power Supplies

- (1) Verify design acceptance criteria are met for operation of normal and all alternative electric power supplies used for system valves, pumps, and motors.
- (2) Verify design acceptance criteria are met for operation of automatic and manual power transfer switches.

f. System Piping and Supports

Verify design acceptance criteria are met for system piping movements under system startup conditions and during steady-state operation. The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Sections NB/NC/ND-3620, "Design Considerations," and NB/NC/ND-3622.3, "Vibration" (Ref. 6), provides a robust methodology for testing, monitoring, evaluating, and controlling piping system vibration.

### 3. Documentation

The preoperational testing program should be documented in a summary report and retained as part of the plant historical record. This summary report should include the following:

- a. a listing and description of the objectives of each test;
- b. a description of how each test was conducted;
- c. the parameters monitored;
- d. complete comparisons and evaluations against design predictions or system performance requirements for the HPSI flow tests, the MPSI flow tests, the LPSI flow and recirculation tests, the core flooding tests, the ELS flow and isolation tests, and the passive AP1000 ECCS tests;
- e. any discrepancies or deficiencies noted;

- f. system modifications and corrective actions required;
- g. appropriate justification for acceptance of systems or components not in conformance with design predictions or performance requirements;
- h. any unexpected or unusual conditions during test observations; and
- i. conclusions.

Retention of the test procedures, data, and summaries by the licensee should be consistent with paragraph 9 of Appendix C to RG 1.68 (Ref. 3) and in accordance with General Design Criterion 1, “Quality Standards and Records,” of Appendix A and Criteria XI, “Test Control,” and XVII, “Quality Assurance Records,” of Appendix B to 10 CFR Part 50.

## **D. IMPLEMENTATION**

The purpose of this section is to provide information on how applicants and licensees<sup>3</sup> may use this regulatory guide, as well as the NRC’s plans for using it. In addition, it describes the NRC staff’s compliance with, 10 CFR 50.109, “Backfitting,” and any applicable finality provisions in 10 CFR Part 52.

The NRC has issued this draft guide to encourage public participation in its development. The NRC will consider all public comments received in development of the final guidance document. In some cases, applicants or licensees may propose an alternative or use a previously established acceptable alternative method for complying with specified portions of the NRC’s regulations. Otherwise, the methods described in this guide will be used in evaluating compliance with the applicable regulations for license applications, license amendment applications, and amendment requests.

### **Use by Applicants and Licensees**

Applicants and licensees may voluntarily use the information in this regulatory guide (1) to develop applications for initial licenses, amendments to licenses, or other requests for NRC regulatory approval (e.g., exemptions), (2) for actions that do not require prior NRC review and approval (e.g., changes to a facility design under 10 CFR 50.59, “Changes, Tests and Experiments”), or (3) to resolve regulatory or inspection issues (e.g., by committing to comply with the provisions in the regulatory guide).

Current licensees may continue to use the guidance, such as a previous version of this regulatory guide that the staff found acceptable for complying with specific portions of the regulations as part of the license approval process.

A licensee who believes that the NRC staff is inappropriately imposing this regulatory guide in response to a request for a license amendment or a change to a previously issued NRC regulatory approval may file a backfitting appeal with the NRC in accordance with applicable procedures.

### **Use by NRC Staff**

The NRC staff does not intend or approve any imposition or backfitting of the guidance in this regulatory guide. It does not expect any existing licensee to use or commit to using the guidance in this regulatory guide in the absence of a licensee-initiated change to its licensing basis. The NRC staff does

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<sup>3</sup> In this section, “licensees” include applicants for standard design certifications under 10 CFR Part 52.

not plan to ask licensees to voluntarily adopt this regulatory guide to resolve a generic regulatory issue, nor does it expect to initiate, without further backfit consideration, regulatory action that would require the use of this regulatory guide (e.g., issuance of an order, generic communication, or rule requiring the use of the regulatory guide, or requests for information under 10 CFR 50.54(f) as to whether a licensee intends to commit to use of this regulatory guide).

During inspections of specific facilities, the staff may suggest or recommend that licensees consider various actions consistent with staff positions in this regulatory guide. Such suggestions and recommendations would not ordinarily be considered backfitting, even if prior versions of this regulatory guide are part of the licensing basis of the facility with respect to the subject matter of the inspection. However, the staff may not represent to the licensee that (1) the licensee's failure to comply with the positions in this regulatory guide constitutes a violation, (2) the licensee may avoid the violation by agreeing to comply with this regulatory guide, or (3) the only acceptable way for the licensee to address the NRC-identified noncompliance or violation is to commit to this regulatory guide (i.e., including it in the facility's licensing basis).

If an existing licensee seeks a license amendment or change to an existing regulatory approval, and the staff's consideration of the request involves a regulatory issue that is directly relevant to this regulatory guide, and if the specific subject matter of the new or revised guidance is an essential consideration in the NRC staff's determination of the acceptability of the licensee's request, the licensee may use this regulatory guide as a prerequisite for NRC approval. This is not considered backfitting as defined in 10 CFR 50.109(a)(1) or a violation of any of the issue finality provisions in 10 CFR Part 52.

## **Conclusion**

While current licensees may voluntarily use this regulatory guide, the NRC is not imposing it. In addition, its publication is in conformance with all applicable internal NRC policies and procedures governing backfitting. Accordingly, the issuance of this regulatory guide is not considered backfitting, as defined in 10 CFR 50.109(a)(1), nor is it deemed to be in conflict with any of the issue finality provisions in 10 CFR Part 52.

## **GLOSSARY OF ACRONYMS**

ADAMS - Agency Document Access and Management System

ADS – Automatic Depressurization System

AP1000 – Advanced Passive 1000

ASME - American Society of Mechanical Engineers

CFR – Code of Federal Regulations

CMT – Core makeup tank

ECCS – Emergency Core Cooling System

HPSI- High Pressure Safety Injection

IRWST – In- Containment Refueling Water Storage Tank

LOCA- Loss of Coolant Accident

LPSI- Low Pressure Safety Injection

MPSI – Mid Pressure Safety Injection

NFPA – National Fire Protection Association

OMB – Office of Management and Budget

PCCS – Passive Core Cooling System

PRHR – Passive Residual Heat Removal

PWR\_ Pressured Water Reactor

RG – Regulatory Guide

RCS – Reactor Coolant System

RHR – Residual Heat Removal

SSCs – Structures, Systems and Components

US EPR - United States Evolutionary Power Reactor

US APWR – United States Advanced PWR

US NRC – United States Nuclear Regulatory Commission

## REFERENCES<sup>4</sup>

1. 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” U.S. Nuclear Regulatory Commission, Washington, DC.
2. 10 CFR Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants,” U.S. Nuclear Regulatory Commission, Washington, DC.
3. Regulatory Guide 1.68, “Initial Test Programs for Water-Cooled Nuclear Power Plants,” Revision 3, March 2007.
4. Regulatory Guide 1.79, “Preoperational Testing of Emergency Core Cooling Systems for Pressurized Water Reactors,” September 1975.
5. National Fire Protection Association (NFPA) Standard 805, “Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants,” 2001 Edition.<sup>5</sup>
6. Boiler and Pressure Vessel (B&PV) Code, American Society of Mechanical Engineers, ASME Standard, ASME Section III, Section NB/NC/ND-3620, “Design Considerations,” NB/NC/ND-3622.3, “Vibration,” New York, NY.<sup>6</sup>
7. NUREG/CR-5640/SAIC-89/1541, “Overview and Comparison of U.S. Commercial Nuclear Power Plants,” September 1990.

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<sup>4</sup> Publicly available NRC published documents are available electronically through the Electronic Reading Room on the NRC’s public Web site at: <http://www.nrc.gov/reading-rm/doc-collections/>. The documents can also be viewed on-line or printed for a fee in the NRC’s Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone (301) 415-4737 or (800) 397-4209; fax (301) 415-3548; and e-mail [pdr.resource@nrc.gov](mailto:pdr.resource@nrc.gov).

<sup>5</sup> The listed National Fire Protection Association (NFPA) code names and titles are based on the current editions of the codes. The “code of record” for an existing plant will typically be an earlier edition and/or may be an edition with a different title and/or number that addresses the same subject. The code of record for fire protection system modifications and for new reactors should be in accordance with the “Code of Record” subsection in Section B of this regulatory guide. Copies may be purchased from the NFPA, 1 Batterymarch Park, Quincy, MA; telephone (800) 344-3555 and fax (800) 593-NFPA (6372). Purchase information is available through the NFPA Web based store at <http://www.nfpa.org/Catalog/>.

<sup>6</sup> Copies of American Society of Mechanical Engineers (ASME) standards may be purchased from ASME, Three Park Avenue, New York, NY 10016-5990; telephone (800) 843-2763. Purchase information is available through the ASME Web-based store at <http://www.asme.org/Codes/Publications/>.

## BIBLIOGRAPHY

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GL 98-04, "Potential for Degradation of the Emergency Core Cooling System and the Containment Spray System after a Loss-of-Coolant Accident Because of Construction and Protective Coating Deficiencies and Foreign Material in Containment," July 14, 1998. (ADAMS Accession No. ML031110081)

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## APPENDIX A

### EMERGENCY CORE COOLING SYSTEMS DESIGN DESCRIPTIONS

#### A.1 Emergency Core Cooling Systems for Current Pressurized-Water Reactors

For additional design details, see NUREG/CR-5640/SAIC-89/1541, "Overview and Comparison of U.S. Commercial Nuclear Power Plants," issued September 1990. Specifically, for pressurized-water reactors (PWRs), see Section 3.9, "Emergency Core Cooling Systems," and Section 4.4, "4-Loop Westinghouse PWRs," of that report. The emergency core cooling system (ECCS) for the current fleet of PWRs uses a high-pressure safety injection (HPSI) system except for two four-loop Westinghouse PWRs that use a medium-pressure safety injection (MPSI) system. The ECCS for the current fleet of PWRs also uses core flooding and a low-pressure safety injection (LPSI) system.

#### A.2 U.S. Advanced Pressurized-Water Reactor Safety Injection System

The U.S. Advanced Pressurized-Water Reactor (US-APWR) ECCS consists of the safety injection system (SIS) (Figure A.2-1), which includes the high-pressure injection system, the accumulator system, and the emergency letdown system.

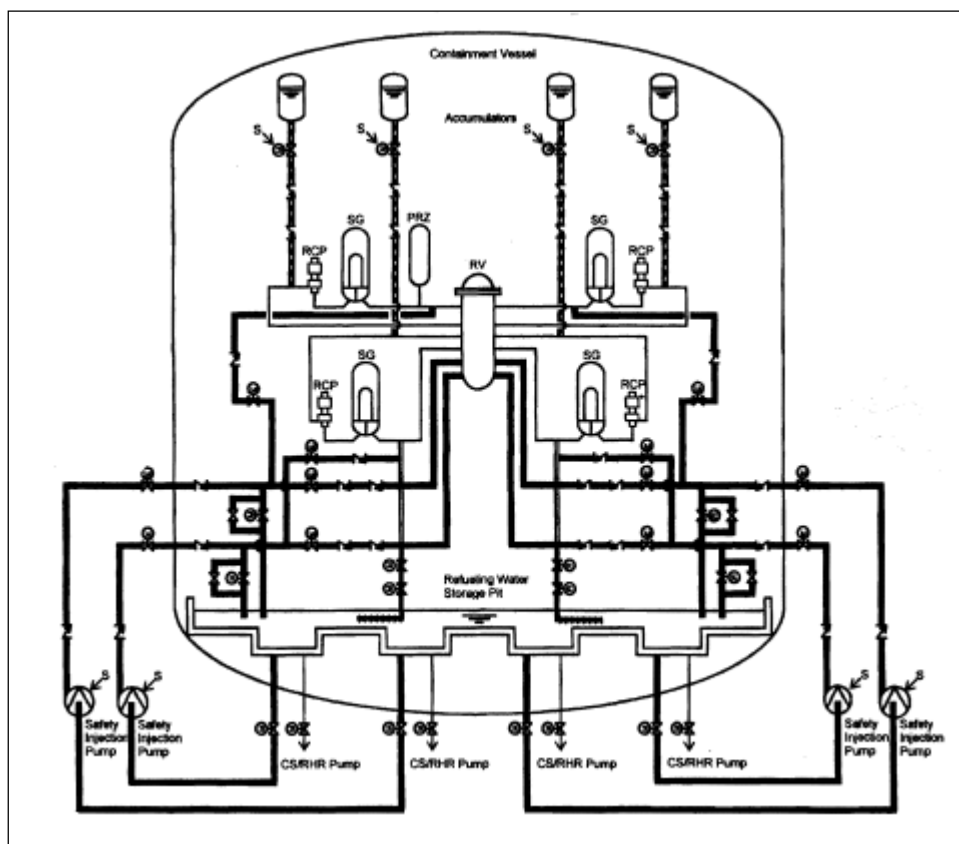


Figure A.2-1. US-APWR Safety Injection System

The ECCS is designed to perform the following major safety-related functions:

- a. safety injection,
- b. safe shutdown, and
- c. containment pH control.

These functions are provided by safety-related equipment with redundancy to deal with single failure, environmental qualification, and protection from external hazards.

The ECCS automatically initiates with redundancy sufficient to ensure that these functions are accomplished, even in the unlikely event of the most limiting single failure occurring coincident with, or during, the event.

The SIS, in conjunction with the rapid insertion of the control rod cluster assemblies (reactor scram), provides protection during the following events:

- a. loss-of-coolant accident (LOCA),
- b. ejection of a control rod cluster assembly,
- c. secondary steam system piping failure,
- d. inadvertent opening of main steam relief or safety valve, and
- e. steam generator tube rupture.

### A.3 U.S. Evolutionary Power Reactor Safety Injection System

The ECCS for the U.S. Evolutionary Power Reactor (U.S. EPR) is the SIS (Figure A.3-1).

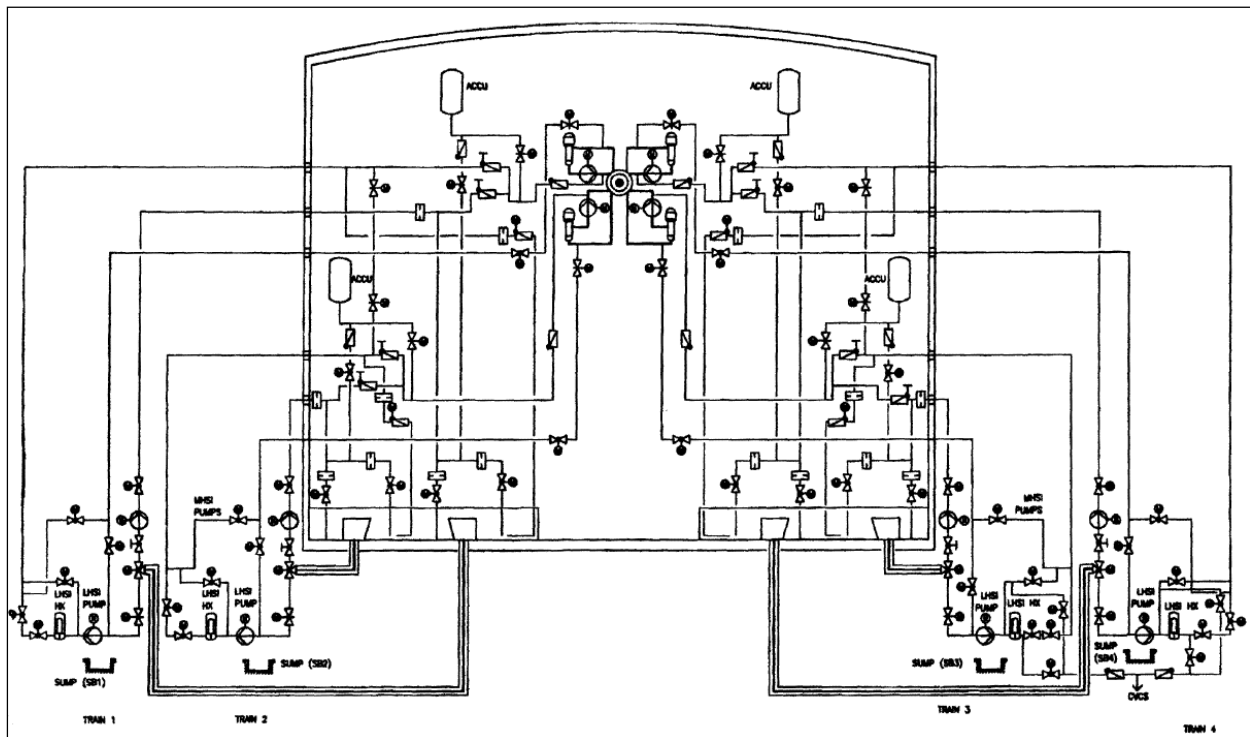


Figure A.3-1. U.S. EPR Safety Injection System

The SIS consists of four independent trains, designated trains 1, 2, 3, and 4, one supplying each reactor coolant loop. The four trains are separated into four safety divisions and are functionally identical. Each SIS train has separate MPSI and LPSI pump trains and an accumulator injection train. The MPSI and LPSI pump trains share an isolable suction line from the in-containment refueling water storage tank (IRWST). This three-way valve aligns the IRWST to both the MPSI and LPSI pump suction lines when in the open position. The LPSI pump train includes a heat exchanger and a suction line from the reactor coolant system (RCS) hot leg for residual heat removal, which can be realigned for LPSI hot-leg injection. The discharge lines for all three MPSI, LPSI, and accumulator injection trains branch together to share an injection nozzle on their associated RCS cold leg.

Cross-connects between trains 1 and 2 and between trains 3 and 4, which are normally isolated by two motor-operated valves in series to maintain train separation, allows removal of individual trains from service for maintenance. Each cross-connect provides an alternate injection path for the train that remains in service. This configuration mitigates the effect of degraded safety injection caused by steam entrainment during a LOCA, when the only available LPSI connection (considering one is unavailable because of a single failure, another is out for maintenance, and another train feeds the broken loop) is adjacent to the broken leg. During such maintenance activities, the motor-operated valves for both cross-connects are secured open (breakers racked out) for protection against active single failures.

The component cooling water system is the cooling medium for the LPSI heat exchangers (all four trains), the MPSI pump motor coolers (all four trains), and the LPSI pump motor and seal coolers for trains 2 and 3. The safety chilled water system is the cooling medium for the LPSI pump motor and seal coolers for trains 1 and 4. The essential service water system serves as the final cooling medium, rejecting the heat transferred from the component cooling water system to the ultimate heat sink.

Electrical divisions 1 through 4 power the four SIS trains, respectively. Each electrical division is a separate and independent power supply housed and protected in its own shield building. Its assigned emergency diesel generator in the event of a loss of offsite power supplies each electrical division.

## **A.4 AP1000 Passive Core Cooling System**

The ECCS for the AP1000 is the passive core cooling system (PCCS). The primary function of the PCCS is to provide emergency core cooling after postulated design-basis events. To accomplish this primary function, the PCCS is designed to perform the functions described in the following sections.

### **A.4.1 Safety Injection System**

Figure A.4-1 shows the SIS, which provides safety injection to the RCS to provide adequate core cooling for the complete range of LOCAs, up to and including the double-ended rupture of the largest primary loop RCS piping.

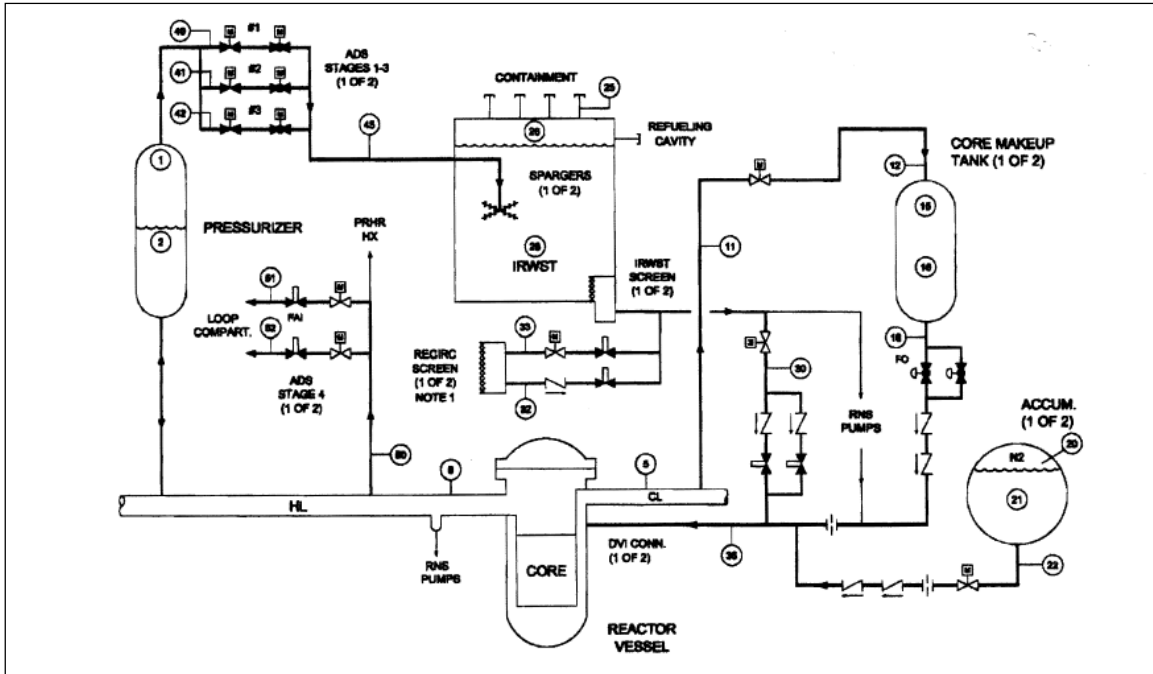


Figure A.4-1. AP1000 Passive Safety Injection System of the PCCS

#### A.4.2 Emergency Core Decay Heat Removal System

Figure A.4-2 shows the system that provides core decay heat removal during transients, accidents, or whenever normal heat removal paths are lost. This heat removal function is available for RCS conditions, including shutdowns. During refueling operations, when the IRWST is drained into the refueling cavity, other passive means of core decay heat removal are used.

#### A.4.3 Reactor Coolant System Emergency Makeup and Boration

This function provides RCS makeup and boration during transients or accidents, when the normal RCS makeup supply from the chemical and volume control system is unavailable or is insufficient.

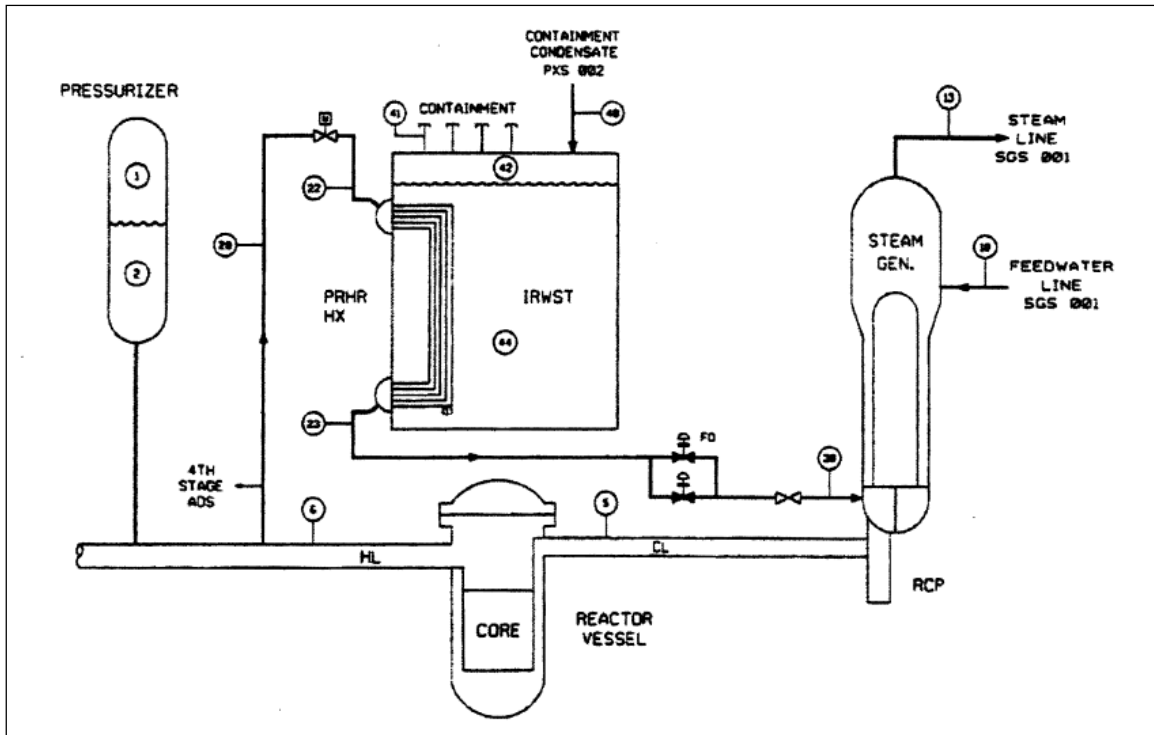


Figure A.4-2. AP1000 Passive Decay Heat Removal System of the PCCS

#### A.4.4 Containment pH Control

This function provides chemical addition during post accident conditions to establish chemistry control of the water covering the core. This ensures that highly radioactive compounds do not evolve from the fuel cladding and prevents corrosion of containment equipment during long-term post accident conditions.

The PCCS is designed to operate without the use of active equipment such as pumps and alternating current power sources. The PCCS depends on reliable passive components and processes, such as gravity injection and the expansion of compressed gases. The PCCS does require a one-time alignment of valves on actuation of the specific components.