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# REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

## REGULATORY GUIDE 1.56

# MAINTENANCE OF WATER PURITY IN BOILING WATER REACTORS

## A. INTRODUCTION

General Design Criteria 14 and 31 of Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants" require assurance that the reactor coolant pressure boundary will have minimal probability of gross rupture or rapidly propagating fracture. General Design Criterion 15 requires that the reactor coolant system and associated auxiliary, control, and protection systems be designed with sufficient margin to ensure that the design conditions of the reactor coolant pressure boundary are not exceeded during any condition of normal operation, including anticipated operational occurrences. General corrosion and stress-corrosion cracking induced by impurities in the reactor coolant are mechanisms whereby failures of the reactor coolant pressure boundary may be postulated. This guide describes an acceptable method for implementing these criteria with regard to minimizing the probability of corrosion-induced failure of the reactor coolant pressure boundary in boiling water reactors by maintaining acceptable purity levels in the reactor coolant.

In addition, General Design Criterion 13 requires in part, that instrumentation be provided to monitor variables and systems that can affect the reactor coolant pressure boundary over their anticipated ranges for normal operation, for anticipated operational occurrences, and for accident conditions as appropriate to assure adequate safety. This guide further describes acceptable instrumentation for determining the condition of the reactor coolant and coolant purification systems in boiling water reactors. The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.

## B. DISCUSSION

In boiling water reactors (BWRs) the various heat exchangers are barriers between high-purity reactor water and cooling water that may be contaminated with dissolved and/or suspended solids. The probability of heat exchanger leakage, allowing some of these contaminants to enter the reactor water, is significant. Of particular concern is the main condenser which represents the major source of such inleakage. The rate of condenser leakage may be estimated from measurements of the electrical conductivity of the water in the condenser hot well or in the line between the hot well and the demineralizer. A meter with sufficient range to measure all water conductivity levels at least up to the limiting condition of the technical specifications requiring immediate shutdown of the reactor should be provided.

The condensate demineralizer system is provided between the condenser and the reactor vessel to reduce impurities from condenser leakage and other sources to an acceptable level. A typical condensate demineralizer consists of several parallel ion exchange units, the resins in which serve both to remove ionic impurities and to filter out suspended solids.

The capacity of demineralizer resin is the equilibrium amount of ions that can be adsorbed by that resin. At the high flow rates common to BWR full-flow demineralizers, only a portion of this capacity is consumed before decontamination factors become unacceptably low. Also, sufficient demineralizer capacity should be available to permit orderly shutdown of the reactor in case of a serious condenser leak. In general, no more than one-half the total capacity of the demineralizer should be considered to be available in high-flow-rate systems.

There are no commercial instruments that will directly measure the capacity of a demineralizer unit. It may be determined indirectly, however, from the initial capacity of the unit and the calculated flow of ions through the unit. Subtraction of the total ion flow from the initial capacity gives the remaining capacity.

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Operation of a demineralizer unit after its ion-exchange capacity has been depleted results in the direct passthrough of ions into the reactor vessel. Depending on the nature of these ions, stress-corrosion cracking and/or other forms of corrosion might be accelerated, crud buildup on fuel and other components might be promoted, and plant radiation levels might be increased.

Demineralizer performance should be monitored by measurement of the conductivity of the demineralizer effluent water. The monitoring instrument, which should be set to trigger alarms in the control room, should be capable of quickly detecting demineralizer breakthrough (defined as an effluent conductivity exceeding 1 micromho/cm) and should have sufficient range to measure all conductivity levels up to and including the limiting condition of the technical specifications requiring immediate shutdown of the reactor.

Even with highly efficient condensate demineralizers, some contaminants, at very low concentrations, pass into the reactor vessel. Chloride ions, which may promote stress-corrosion cracking of austenitic stainless steel components and structures, are of particular concern. Because these contaminants are virtually insoluble in the steam phase, they would remain in the reactor vessel and would build up to unacceptable levels within a relatively short time unless they were removed by a reactor water cleanup system. For this reason, conductivity of water from the reactor vessel should be continuously monitored and the chloride content determined periodically. The reactor should not be operated for extended periods of time with the reactor water cleanup system out of service. Limits of chloride concentration in the reactor vessel water of BWRs that have been found acceptable to the Regulatory staff are presented in the appendix to this guide. Also presented in the appendix are representative limits of electrical conductivity of the water at serveral locations in the BWR.

## C. REGULATORY POSITION

Condensate demineralizers in boiling water reactors should be designed and operated so as to permit an orderly shutdown of the reactor in case of serious leakage in the condenser or in other heat exchangers without contaminating the reactor coolant pressure boundary or core structural components with potentially deleterious constituents of the condenser cooling water. Sufficient instrumentation should be provided so that (1) the electrical conductivity of the condensate is known, (2) the available capacity of the condensate demineralizers can be determined at all times, and (3) the purity of the demineralizer effluent is known. Additional protection to the pressure vessel and core structural components should be provided in the form of a functioning reactor water cleanup system and instrumentation to measure reactor water conductivity. An acceptable approach is as follows:

1. The licensee should establish appropriate limits on condensate composition and electrical conductivity. Separate limits may be required for such conditions as startup, low-power operation, and full-power operation. Chemical analyses for dissolved and suspended impurities should be performed as called for in the plant technical specifications. A conductivity meter should be provided at each condenser hot well or in the line between the hot well and the condensate demineralizer with sufficient range to measure at least all levels of conductivity up to and including the limiting conditions of the technical specifications requiring immediate shutdown of the reactor. The recording conductivity meter called for in regulatory position C.4.a. below may be utilized for this purpose.

2. The licensee should establish the minimum residual demineralizer capacity which must be available in each of several parallel condensate demineralizer units in service. This minimum capacity will depend on several parameters including composition of condenser cooling water, flow rate in each unit, type of resins, cation/anion resin ratio, postulated condenser leak, and time for orderly reactor shutdown.

3. The initial total capacity of the new anion and cation demineralizer resins should be measured. Anion exchange capacity may be determined by a procedure recommended by the resin manufacturer. The total exchange capacity of the cation resin may be measured by a procedure recommended by the resin manufacturer or by paragraphs 41 through 49 of ASTM D2187-71 "Standard Methods of Test of Physical and Chemical Properties of Ion-Exchange Resins." For resins that are to be regenerated, these determinations should be repeated at least semiannually and the resins should be discarded and replaced when their capacity following regeneration falls below sixty percent of the initial value. More frequent determinations should be made at plants using seawater or other water containing large amounts of dissolved or suspended matter as coolant in their heat exchangers. For resins that are not regenerated, but are instead replaced periodically with material of the same type, measurements of initial capacity should be made on a sample of new material at least once a year when the time between replacements is less than one year or at each replacement when the time between replacements exceeds one year. When the type of anion or cation resin is changed, a measurement of total capacity of the replacement resin should be made prior to use in the demineralizer.

4. The licensee should verify that the minimum residual demineralizer capacity in the most depleted demineralizer unit established in accordance with the requirements of regulatory position C.2 above is maintained. The following is an example of an

acceptable method for determining the condition of the demineralizer units so that the ion exchange resin can be replaced or regenerated before an unacceptable level of depletion is reached.

a. A recording conductivity meter should be installed in the line between the condenser hot well and the demineralizer. The range of this instrument should be sufficiently broad to include all potential water conductivity levels up to the limiting condition of the technical specifications requiring immediate shutdown of the reactor. The conductivity meter should be calibrated against the principal ion or ions likely to cause demineralizer breakthrough. In those demineralizer systems in which the cation capacity exceeds the anion capacity, calibration should be based on anion measurements (i.e., chloride and sulfate ions in the case of seawater-cooled condensers and total anions, except hydroxyl, in the case of freshwater-cooled condensers). In those demineralizer systems where anion capacity exceeds cation capacity calibration should be based on cation measurements (i.e., sodium and magnesium ions in the case of seawater-cooled condensers and total cations, except hydrogen, in the case of freshwater-cooled condensers).

b. A recording flowmeter should be utilized to measure the rate of flow through each demineralizer.

c. The quantity of the principal ion(s) likely to cause demineralizer breakthrough flowing through the demineralizer should be calculated by:

(1) Converting the conductivity readings of the water entering the demineralizer to weight fraction (e.g., ppm or ppb) of the principal ion(s) and

(2) Integrating over time the product of concentration of this ion(s) and demineralizer flow.

This quantity should be determined at suitable intervals not to exceed weekly. More frequent determinations should be conducted in plants using sea water or other highly contaminated water as coolant and at all plants during startup and under abnormal conditions.

d. Each demineralizer unit should be replaced or regenerated when the remaining capacity, calculated by subtracting the total utilization determined from conductivity and flow measurements in accordance with regulatory position C.4.c from the initial capacity determined in accordance with regulatory position C.3, approaches the minimum residual demineralizer capacity determined in accordance with regulatory position C.2. The accuracy of the above calculation should be checked by measurements made on resin samples taken when demineralizer units are removed from service for regeneration or resin cleaning. Measurements on samples from each unit should be made at each of the first two such removals from service and at every fifth such removal from service thereafter. If appropriate, the actual measurements may be used to adjust the calculated value of residual demineralizer capacity. Such adjustment and its justification should be reported to the Commission in the semiannual operating report.

5. A conductivity meter located in the line between the condensate demineralizer outlet and the reactor vessel inlet should be set to trigger alarms in the control room when, as a minimum, each of the following conductivity levels, values of which should be predetermined by the licensee, is reached:

a. The level that indicates breakthrough in one or more demineralizer units,

b. The level that requires orderly shutdown of the reactor, and

c. The level that requires immediate shutdown of the reactor.

6. The chloride content in the reactor vessel should be maintained as low as practical. The licensee should establish limits for conductivity and chlorides in the reactor vessel and should specify procedures to be used for their determination. If either of the limiting values is exceeded at a time when the reactor water cleanup system is fully functioning, appropriate corrective action as required in the plant technical specifications should be taken. If either of these values is exceeded at a time when the reactor water cleanup system is not fully functioning, the plant should be shut down.

## APPENDIX

The data presented in this appendix illustrate the levels of chloride in the reactor vessel water of boiling water reactors (BWRs) that have been found acceptable to the Regulatory staff. Also presented in this appendix are representative limiting values of electrical conductivity of the water at several locations in the reactor that have been found to correlate on a conservative basis with the acceptable levels of chloride.

Because of the disparity in conductivity/chloride ratios, separate limiting values of electrical conductivity are presented for seawater-cooled and freshwater-cooled plants. Since there is considerable local variation in water composition, each applicant should evaluate the conditions prevailing at its plant site in determining the appropriate conductivity limits.

Representative limits of electrical conductivity of the condensate are 1 μmho/cm for seawater-cooled BWRs and 2 μmho/cm for freshwater-cooled BWRs. Table 1 presents representative limits of electrical conductivity at the demineralizer outlet that can be considered to (1) indicate imminent breakthrough in one or more demineralizer units, (2) require orderly shutdown of the reactor, and (3) require immediate shutdown of the reactor.

Representative limits for conductivity and chlorides in the reactor vessel water of BWRs are presented in Table 2.

### TABLE 1

### REPRESENTATIVE CONDUCTIVITY LIMITS AT THE DEMINERALIZER OUTLET (μmho/cm)

| Level | Startup | Low Steaming Rates, $<10^5$ lb/hr | High Steaming Rates, $>10^5$ lb/hr |
|---|---|---|---|
| (1) | 0.2 | 0.1 | 0.1 |
| (2) | 1.0 | 0.5 | 0.5 |
| (3) | 2.0 | 1.0 | 1.0 |

### TABLE 2

### REPRESENTATIVE LIMITS FOR CONDUCTIVITY AND CHLORIDES IN THE REACTOR VESSEL WATER

| | Conductivity (μmho/cm) | Chloride (ppm) |
|---|---|---|
| Seawater-Cooled BWRs: | | |
| Startup | 10 | 0.1 |
| Steaming rates $<10^5$ lb/hr | 2 | 0.1 |
| Steaming rates $>10^5$ lb/hr | 2 | 0.5 |
| Freshwater-Cooled BWRs: | | |
| Startup | 10 | 0.1 |
| Steaming rates $<10^5$ lb/hr | 5 | 0.1 |
| Steaming rates $>10^5$ lb/hr | 5 | 0.5 |