NUREG-0800

U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

9.3.4 CHEMICAL AND VOLUME CONTROL SYSTEM (PWR) (INCLUDING BORON RECOVERY SYSTEM)

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of PWR reactor coolant systems

Secondary - Organization responsible for reactor coolant chemistry

I. AREAS OF REVIEW

Pressurized water reactor (PWR) plants include a chemical and volume control system (CVCS) and boron recovery system (BRS). These systems maintain the required water inventory and quality in the reactor coolant system (RCS), provide seal-water flow to the reactor coolant pumps and pressurizer auxiliary spray, control the boron neutron absorber concentration in the reactor coolant, and control the primary water chemistry and reduce coolant radioactivity level. Further, the system provides recycled coolant for demineralized water makeup for normal operation and the design may also provide high pressure injection flow to the emergency core cooling system (ECCS) in the event of postulated accidents. The review is performed to assure conformance with the requirements of General Design Criteria (GDC) 1, 2, 5, 14, 29, 33, 35, 60, and 61. In addition, the CVCS may provide reactor coolant inventory control and/or reactor coolant pump seal injection necessary for withstanding or coping with a station blackout. The CVCS capability to perform these functions is reviewed as necessary to assure conformance with 10 CFR 50.63(a)(2).

The staff reviews the system from the letdown line of the primary system to the charging lines that provide makeup to the primary system and the reactor coolant pump seal-water system. The system is reviewed to the interfaces with the demineralized water makeup system and radioactive waste system.

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The specific areas of review are as follows:

1. The safety-related functional performance characteristics of CVCS components and the effects of adverse environmental occurrences, abnormal operational requirements, or accident conditions such as those due to a loss-of-coolant accident (LOCA).

2. The determination that a malfunction, a single failure of an active component, or the loss of a cooling source will not reduce the safety-related functional performance capabilities of the system.

3. That quality group and seismic design requirements are met and the effects of failure of equipment or components not designed to withstand seismic events on safety-related functions of the system are evaluated.

4. The system features provided to prevent precipitation of boric acid in components and lines containing boric acid solutions, and the adequacy of the system design to allow personnel access considering the effects of toxic, irritating, or explosive chemicals that may be used.

5. Provisions for operational testing and the instrumentation and control features that determine and verify that the system is operating in the correct mode.

6. The system provisions to prevent the formation of such vacuum conditions that could cause wall inward buckling and failure in tanks that can contain primary system water.

7. <u>Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC)</u>. For design certification (DC) and combined license (COL) reviews, the staff reviews the applicant's proposed ITAAC associated with the structures, systems, and components (SSCs) related to this SRP section in accordance with SRP Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria." The staff recognizes that the review of ITAAC cannot be completed until after the rest of this portion of the application has been reviewed against acceptance criteria contained in this SRP section. Furthermore, the staff reviews the ITAAC to ensure that all SSCs in this area of review are identified and addressed as appropriate in accordance with SRP Section 14.3.

8. <u>COL Action Items and Certification Requirements and Restrictions</u>. For a DC application, the review will also address COL action items and requirements and restrictions (e.g., interface requirements and site parameters).

   For a COL application referencing a DC, a COL applicant must address COL action items (referred to as COL license information in certain DCs) included in the referenced DC. Additionally, a COL applicant must address requirements and restrictions (e.g., interface requirements and site parameters) included in the referenced DC.

<u>Review Interfaces:</u>

Other SRP sections interface with this section as follows:

1. Evaluation of the capability of the CVCS to withstand external and internal flood conditions is performed under SRP Sections 3.4.1 and 9.3.3.

2. Evaluation of the capability of structures and barriers designed to protect the CVCS from internally generated missiles both inside and outside primary containment is performed under SRP Sections 3.5.1.1 and 3.5.1.2.

3. Evaluation of the capability of safety-related systems to withstand the effects of missiles generated by natural phenomena or externally generated missiles is performed under SRP Sections 3.5.1.4 and 3.5.2.

4. Evaluation of the effect of high- and moderate-energy CVCS system piping failures outside containment to assure that other safety-related systems will not be made inoperable is performed under SRP Section 3.6.1.

5. Review of the environmental qualification of mechanical and electrical safety-related equipment is performed under SRP Section 3.11.

6. Evaluation of the effect of cooling water system failures on reactor coolant pump seal integrity is performed under SRP Section 9.2.2.

7. Review of the CVCS with respect to fire protection is performed under SRP Section 9.5.1.

8. Reviews of liquid, solid, and gaseous waste treatment aspects of the CVCS are performed under SRP Sections 11.2, 11.3, and 11.4, respectively.

9. Reviews of the CVCS to verify that low-pressure portions of the CVCS that interface with the RCS are designed, to the extent practical, to withstand full RCS pressure. If designing the CVCS with an ultimate rupture strength capable of withstanding full RCS pressure is not possible, the reviewer verifies that appropriate compensating measures have been taken in accordance with the review provided in SRP Section 3.12.

10. Evaluation of the injection of borated water into the RCS to meet combined reactivity control system redundancy and capability requirements of GDC 26 and 27 is performed under SRP Section 4.3.

11. For the plant designs that rely on the CVCS to perform safety functions of emergency boration and core cooling as part of ECCS for mitigation of the design basis events, review of the CVCS flow capacity and injection pressure to verify that specified acceptable fuel design limits are not exceeded following an inadvertent opening of a pressurizer relief valve, and the acceptance criteria of 10 CFR 50.46 are complied with following a postulated LOCA in evaluating the ECCS function is performed under SRP Sections 6.3, 15.6.1, and 15.6.5.

12. Review of CVCS malfunctions that can result in a decrease in boron concentration in the reactor coolant to assure that fuel damage limits are not exceeded and that adequate time is available to terminate the dilution before the shutdown margin has been eliminated is performed under SRP Section 15.4.6.

13. Review of the process and effluent radiological monitoring aspects of the CVCS is performed under SRP Section 11.5.

14. Review of the system with respect to maintaining occupational radiation exposure as low as reasonably achievable (ALARA) and to providing radiation protection design features, respectively, is performed under SRP Sections 12.1 and 12.3.

15. Evaluation of the adequacy of the design, installation, inspection, and testing of all instrumentation, sensing, and controls required to provide the safety-related functions of the CVCS is performed under SRP Sections 7.1, 7.6, and Appendix 7A.

16. Evaluation of the adequacy of the design, installation, inspection, and testing of all electrical systems required to provide the safety-related functions of the CVCS is

performed under Sections 8.3.1 and 8.3.2. In addition, review of the plant's overall capabilities to withstand or cope with, and recover from a Station Blackout (SBO) as required by 10 CFR 50.63 is performed under SRP Section 8.4.

17. Determination of the acceptability of the design analysis, procedures, and criteria used to establish the ability of seismic Category I structures housing the system and supporting systems to withstand the effects of natural phenomena, such as the safe shutdown earthquake (SSE), the probable maximum flood (PMF), and tornado missiles is performed under SRP Sections 3.3.1, 3.3.2, 3.4.2, 3.5.3, 3.7.1, 3.7.2, 3.7.3, 3.8.4, and 3.8.5.

18. Verification that inservice nondestructive examination requirements are met for system components is performed under SRP Sections 5.2.4 and 6.6.

19. Determination of the acceptability of the seismic and quality group classifications for systems components is performed under SRP Sections 3.2.1 and 3.2.2.

20. Determination that the piping, components, and structures are designed in accordance with applicable codes and standards is performed under SRP Sections 3.9.1, 3.9.2, and 3.9.3.

21. Review of the adequacy of the inservice testing program of pumps and valves is performed under SRP Section 3.9.6.

22. Review of the seismic qualification of Category I instrumentation and electric equipment is performed by under SRP Sections 3.10.

23. Review of the design of isolation provisions of those portions of the CVCS that penetrate primary containment is performed under SRP Section 6.2.4.

24. Review of technical specifications is coordinated and performed under SRP Section 16.0.

25. Review of quality assurance is coordinated and performed under SRP Sections 17.5.

The specific acceptance criteria and review procedures are contained in the referenced SRP sections.

II. <u>ACCEPTANCE CRITERIA</u>

<u>Requirements</u>

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations:

1. General Design Criterion (GDC) 1, as it relates to system components being assigned quality group classifications and application of quality standards in accordance with the importance of the safety function to be performed.

2. GDC 2, as it relates to structures housing the facility and the system itself being capable of withstanding the effects of earthquakes.

3. GDC 5, as it relates to shared systems and components important to safety being capable of performing required safety functions.

4. GDC 14, as it relates to assuring reactor coolant pressure boundary material integrity by means of the CVCS being capable of maintaining RCS water chemistry necessary to meet PWR RCS water chemistry technical specifications.

5. GDC 29, as it relates to the reliability of the CVCS to provide negative reactivity to the reactor by supplying borated water to the RCS in the event of anticipated operational occurrences, if the plant design relies on the CVCS to perform the safety function of boration for mitigation of design basis events.

6. GDCs 33 and 35, as they relate to the CVCS capability to supply reactor coolant makeup in the event of small breaks or leaks in the reactor coolant pressure boundary (RCPB), to function as part of ECCS assuming a single active failure coincident with the loss of offsite power, and to meet ECCS technical specifications, if the plant design relies on the CVCS to perform the safety function of safety injection as part of ECCS.

7. GDCs 60 and 61, as they relate to CVCS components having provisions for venting and draining through closed systems.

8. 10 CFR 50.34(f)(2)(xxvi), with respect to the provisions for a leakage detection and control program to minimize the leakage from those portions of the CVCS outside of the containment that contain or may contain radioactive material following an accident.

9. Paragraph (a)(2) in 10 CFR 50.63, "Loss of All Alternating Current Power," as it relates to the ability of the CVCS to provide sufficient capacity and capability to ensure that the core is cooled in the event of a station blackout.

10. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed inspections, tests, analyses, and acceptance criteria (ITAAC) that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the design certification is built and will operate in accordance with the design certification, the provisions of the Atomic Energy Act, and the NRC's regulations.

11. 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the combined license, the provisions of the Atomic Energy Act, and the NRC's regulations.

<u>SRP Acceptance Criteria</u>

Specific SRP acceptance criteria acceptable to meet the relevant requirements of the NRC's regulations identified above are as follows for the review described in this SRP section. The SRP is not a substitute for the NRC's regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide acceptable methods of compliance with the NRC regulations.

1. The CVCS safety-related functional performance should be maintained in the event of adverse environmental phenomena such as earthquakes, tornadoes, hurricanes, and floods, or in the event of certain pipe breaks or loss of offsite power. For compliance with GDC 29, 33 and 35, the CVCS should provide sufficient pumping capacity to supply borated water to the RCS, maintain RCS water inventory within the allowable

pressurizer level range for all normal modes of operation, and function as part of the ECCS, if so designed, to supply reactor coolant makeup in the event of small pipe breaks assuming a single active failure coincident with the loss of offsite power.

Also, Regulatory Guide 1.155 describes a means acceptable to the NRC staff for meeting the requirements of 10 CFR 50.63, “Loss of all alternating current power.” If the CVCS is necessary to support a plant SBO coping capability as required by 10 CFR 50.63, the positions in Regulatory Guide 1.155 regarding CVCS design provide an acceptable method for showing compliance.

2. SECY-77-439 describes the concept of single failure criteria and the application of the single failure criterion that involves a systematic search for potential single failure points and their effects on prescribed missions. Application of the single failure assumption in system design and analysis provides redundancy and defense-in-depth to ensure functional performance of the CVCS.

   Also, the requirements of GDC 5 prohibiting the sharing among nuclear units the SSCs important to safety would be met by the use of a separate CVCS for each unit.

3. 10 CFR 50.55(a) requires that components of the RCPB be designed, fabricated, erected, and tested in accordance with the requirements for Class 1 components of Section III of the ASME Boiler and Pressure Vessel Code or equivalent quality standards. Regulatory Guide 1.26 describes a quality classification system that may be used to determine quality standards acceptable to the NRC staff for satisfying GDC 1 for other safety related components containing water, steam, or radioactive materials in light-water-cooled nuclear power plants. RG 1.29 describes a method acceptable to the NRC staff for identifying and classifying those features of LWRs that should be designed to withstand the effects of the safe shutdown earthquake (SSE).

   The requirements of GDC 1 regarding the quality standard are met by acceptable application of quality group classifications and application of quality standards as described in RG 1.26. The requirement of GDC 2 regarding the protection against natural phenomena are met by meeting the guidance of RG 1.29, Position C.1, for safety-related portions of the system and Position C.2 for nonsafety-related portion.

4. The CVCS design and arrangement should be that all components and piping that can contain boric acid will either be heat traced or will be located within heated rooms to prevent precipitation of boric acid.

   As additional specific criteria used to review the CVCS and BRS design, the CVCS should include provisions for monitoring: (a) temperature upstream of the demineralizer to assure that resin temperature limits are not exceeded, and (b) filter demineralizer differential pressure to assure that pressure differential limits are not exceeded. In addition, the CVCS should have provision for automatically diverting or isolating the CVCS flow to the demineralizer in the event the demineralizer influent temperature exceeds the resin temperature limit.

5. 10 CFR 50.34(f)(2)(xxvi), as applicable, specifies the provisions regarding detection of reactor coolant leakage outside containment. These requirements will be met, in part, by providing leakage control and detection systems in the CVCS and implementation of appropriate leakage control program.

6. Implementation of Action 1 specified in Bulletin 80-05 provides an acceptable means for the system to prevent the CVCS holdup tanks, which can contain radioactive release, from the formation of such vacuum conditions that could cause wall inward buckling and failure.

The requirements of GDC 60 and 61 can be met, in part, by providing in the CVCS appropriately designed venting and draining closed systems to confine the radioactivity associated with the effluents.

7. 10 CFR 52.47(a)(1)(vi) specifies that the application of a design certification should contain proposed ITAAC necessary and sufficient to assure the plant is built and will operate in accordance with the design certification. 10 CFR 52.97(b)(1) specifies that the COL identifies the ITAAC necessary and sufficient to assure that the facility has been constructed and will be operated in conformity with the license. SRP 14.3 provides guidance for reviewing the ITAAC. The requirements of 10 CFR 52.47(a)(1)(vi) and 10 CFR 52.97(b)(1) will be met, in part, by identifying inspections, tests, analyses, and acceptance criteria of the top-level design features of the CVCS in the design certification application and the combined license, respectively.

Technical Rationale:

The technical rationale for application of these acceptance criteria to the areas of review addressed by this SRP section is discussed in the following paragraphs:

1. GDC 1 requires that structures, systems, and components (SSCs) important to safety be designed, fabricated, erected and tested to quality standards commensurate with the importance of the safety functions to be performed. The CVCS may be important to safety in that: 1) the CVCS may be capable of emergency boration with boron concentration that exceeds the requirements for safe shutdown during a safety injection to a RCS; 2) the CVCS may provide a means of makeup for the RCS coolant inventory in the event of small leaks; 3) portions of the CVCS may provide seal water to the reactor coolant pump (RCP) components important to safety; 4) the CVCS may be capable of borating the RCS to a safe cold shutdown condition; 5) the CVCS is relied upon to control RCS water chemistry to maintain the integrity of the RCS pressure boundary; 6) through connections to the RCS a CVCS failure could adversely affect the integrity of the RCS or containment systems; and 7) portions of the CVCS may contain radioactive material. Meeting the requirements of GDC 1 (and the guidance of RG 1.26) ensures that the CVCS will be designed, fabricated, erected and tested to generally accepted and recognized codes and standards that are sufficient to assure a quality system in keeping with the importance of the designated safety functions.

2. GDC 2 requires that SSCs important to safety be designed to withstand the effects of natural phenomena without the loss of capability to perform their safety functions. Certain portions of the CVCS may have functions important to plant safety that should be designed to withstand the safe shutdown earthquake (SSE). RG 1.29 provides guidance for determining which systems should be designated Seismic Category I; position C.1 provides guidance for safety related portions and position C.2 provides guidance for nonsafety related portions. For example, the CVCS connects to the RCS, and components that form interfaces between Seismic Category I and non-Seismic Category I features should be designed to Seismic Category I requirements. Meeting the requirements of GDC 2 (and the guidance of RG 1.29) will enhance plant safety by ensuring the integrity of Seismic Category I portions of the system during a design basis seismic event.

3. GDC 5 prohibits the sharing of SSCs among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining units. The CVCS may be designed to provide essential safety-related functions necessary for continued safe operation of the unit(s), such as the ability to provide seal injection to the RCPs or the capability to maintain RCS chemistry to prevent gross failure of the reactor coolant pressure boundary (RCPB). The CVCS must be

designed such that the ability to perform these and other designated safety-related functions are not compromised for each unit regardless of equipment failures or other events that may occur in another unit. Meeting the requirements of GDC 5 provides assurance that unacceptable effects of equipment failures or other events occurring in one unit of a multi-unit site will not propagate to the unaffected unit(s).

4. GDC 14 requires assurance that the RCPB will have an extremely low probability of abnormal leakage, of rapidly propagating failure and of gross rupture. Failure of the RCPB may be postulated where the mechanisms of general corrosion and/or stress corrosion cracking induced by impurities in the reactor coolant are present. The CVCS maintains acceptable purity levels in the reactor coolant through the removal of insoluble corrosion products and dissolved ionic material by filtration and ion exchange. In addition, the CVCS maintains proper RCS chemistry by controlling total dissolved solids, pH, oxygen concentration, and halide concentrations within the acceptable ranges. Meeting the requirements of GDC 14 enhances plant safety by providing assurance that the probability of corrosion-induced failure of the RCPB will be minimized, thereby maintaining the integrity of the RCPB.

5. GDC 29 requires that the reactivity control systems be designed to assure an extremely high probability of accomplishing their safety functions in the event of anticipated operational occurrences (AOO). Portions of the CVCS may be relied upon to provide negative reactivity addition by injection of boric acid to the RCS, and assures that specified acceptable fuel design limits (SAFDLs) will not be exceeded. Meeting the requirements of GDC 29 enhances plant safety by assuring that the reactivity control aspects of the CVCS will have a high probability of injecting sufficient negative reactivity to prevent exceeding SAFDLs during AOOs, thereby preventing damage to the fuel matrix and cladding.

6. GDC 33 requires that a system be provided to supply reactor coolant makeup for protection against small breaks in the RCPB. The CVCS may be relied upon to provide charging and makeup in the event of small leakage from the RCPB and rupture of small piping or components that are part of the pressure boundary. Meeting the requirements of GDC 33 enhances plant safety by ensuring that the CVCS can provide sufficient makeup capacity to maintain the required RCS water inventory and prevent the violation of SAFDLs given a small break in the reactor coolant pressure.

7. GDC 35 requires that the ECCS safety function can be performed assuming a single component failure coincident with a loss of power. The CVCS may be relied upon to provide ECCS high head injection capability necessary to ensure that emergency core cooling is provided during an accident. One of the functions of the CVCS is to transfer sufficient heat from the core to prevent fuel and clad damage that could interfere with core cooling and to limit the cladding metal-water reaction to negligible amounts. Meeting the requirements of GDC 35 for the applicable portions of the CVCS enhances plant safety by ensuring that sufficient emergency core cooling is provided during design basis accidents, thereby preventing damage to the fuel and cladding that could interfere with core cooling.

8. GDC 60 requires that the release of radioactive material to the environment be controlled. The CVCS during normal reactor operation can contain radioactive material in gaseous and liquid forms. The CVCS is designed with storage tanks to handle venting and draining from various CVCS systems. The CVCS vent and drain systems are designed to appropriately confine the radioactivity associated with the effluents. Meeting the requirements of GDC 60 enhances plant safety by preventing the uncontrolled release of radioactive material to the environment.

9. GDC 61 requires that systems that may contain radioactivity be designed to assure adequate safety under normal and postulated accident conditions. The CVCS is connected to the RCS and during normal and postulated accident conditions may contain radioactivity throughout the system. Meeting the requirements of GDC 61 ensures that applicable portions of the CVCS are designed to provide confinement of radioactive material and to reduce the potential exposure to radioactive materials to the lowest practical levels.

10. 10 CFR 50.63 establishes requirements on the plant regarding the capability to ensure that the core is cooled in the event of a station blackout (SBO) for a specific duration. The CVCS is capable of providing core cooling to the reactor core through coolant charging and letdown functions. In addition, the CVCS provides coolant makeup and RCP seal injection. Regulatory Guide 1.155 identifies guidance and acceptable methods for complying with the requirements of 10 CFR 50.63. Compliance with this Regulatory Guide and 10 CFR 50.63 provides assurance that the CVCS is capable of performing their intended functions to support core cooling in the event of an SBO.

III. <u>REVIEW PROCEDURES</u>

The reviewer will select material from the procedures described below, as may be appropriate for a particular case.

These review procedures are based on the identified SRP acceptance criteria. For deviations from these acceptance criteria, the staff should review the applicant’s evaluation of how the proposed alternatives provide an acceptable method of complying with the relevant NRC requirements identified in Subsection II.

The design of the CVCS will vary with each PWR plant supplier. For example, some PWR designs use the CVCS charging pumps as high pressure safety injection pumps as part of the ECCS, while in other PWR designs, the CVCS is not a part of the ECCS and not relied upon to perform safety function for mitigation of the design basis events. Also, most PWR designs use CVCS to provide seal injection for the reactor coolant pump seal, while other designs, such as Westinghouse’s AP1000, have sealless, canned-motor, reactor coolant pumps that do not require seal injection from the CVCS. For the purpose of this SRP section, a typical system is assumed for use as a guide. It is assumed that the typical system consists of a regenerative heat exchanger to cool the letdown flow from the RCS before processing through the demineralizers (or ion exchangers) and to reheat it prior to reinjection into the RCS, demineralizers, and filters for removal of suspended and dissolved impurities, high pressure charging pumps to inject makeup flow into the RCS, a volume control tank for system surge capacity and makeup volume, a boron makeup and storage system to provide neutron absorber to the RCS as needed, evaporators and tanks for boron recovery and demineralized water makeup, and a boron thermal regeneration subsystem to minimize the quantity of waste water and allow reactivity control by varying the temperature of demineralizers so as to remove or add boron to the CVCS. For cases where there are variations from this system, the reviewer would adjust the review procedures given below. However, the system design should meet the acceptance criteria given in subsection II.

1. The staff reviews the safety analysis report (SAR) to determine that the system description and piping and instrumentation diagrams (P&IDs) show the CVCS equipment that is used for normal operation, and the minimum system heat transfer and flow requirements for normal plant operation. The system performance requirements will also be reviewed to determine that it limits expected component operational degradation (e.g., pump leakage, heat exchanger scaling, resin deterioration) and describes the procedures that will be followed to detect and correct these conditions when they become excessive. The reviewer, using the results of failure modes and effects analyses, comparisons with previously approved systems, or independent

calculations, as appropriate, determines whether the system can sustain the loss of any active component and meet the minimum system requirements for plant shutdown or accident mitigation. The system P&IDs, layout drawings, and component descriptions and characteristics are then reviewed for the following points:

A. Essential portions of the CVCS are correctly identified and are verified to be isolable from the nonessential portions of the system and from interfacing systems such as demineralized water makeup and radioactive waste systems. The P&IDs will be reviewed to verify that they clearly indicate physical divisions between such portions and indicate design classification changes. Systems drawings are also reviewed to see whether they show the means for accomplishing isolation and the system description is reviewed to identify minimum performance requirements for the isolation valves.

B. The review is performed to assure that essential portions of the CVCS, including the isolation valves separating essential portions from nonessential portions are classified Quality Group A, B, or C and seismic Category I in accordance with the guidelines of Regulatory Guides 1.26 and 1.29; also, system descriptions in the SAR are reviewed to verify that the above seismic and safety classifications have been included, and that the P&IDs indicate any points of change in piping quality group classification.

C. The failure of portions of the system or of other systems not designed to seismic Category I standards and located close to essential portions of the system, or of nonseismic Category I structures that house, support, or are close to essential portions of the CVCS, will not preclude operation of the essential portions of the CVCS (Position C.2 of Regulatory Guide 1.29). Reference to SAR sections describing site features and the general arrangement and layout drawings should be provided, as well as the SAR tabulation of seismic design classifications for structures and systems. Statements in the SAR that verify that the above conditions are met are acceptable (CP).

D. The reviewer verifies the adequacy of the system for reactivity control in the following areas:

    i. Boration of the reactor coolant system is accomplished with boric acid source, such as boric acid storage tank (BAST) or refueling water storage tank (RWST) where applicable, through redundant flow paths, and CVCS meets PWR boration technical specifications. This is verified from the review of P&IDs and system description.

    ii. The amount of boric acid stored in the CVCS, such as BAST or RWST where applicable, exceeds the amount required to borate the reactor coolant system to cold shutdown concentration, assuming that the control rod assembly with the highest reactivity worth is held in the fully withdrawn position, and to compensate for subsequent xenon decay during any part of core life.

E. The adequacy of the CVCS for control of water chemistry is verified by examination of the information provided in the SAR (i.e., the allowable ranges for primary coolant activity, total dissolved solids, pH, and maximum allowable oxygen and halide concentrations and verification that the CVCS can meet industry guidelines and reactor plant supplier recommendations for PWR reactor coolant system water chemistry). The reviewer verifies that the primary water chemistry program provides for compatibility with materials to be exposed to reactor coolant under the expected service conditions. The reviewer evaluates the proposed chemistry program with respect to that described in the latest version in the Electric Power Research Institute (EPRI) report series, “PWR Primary Water Guidelines,” (Ref. 22).

F. The adequacy of resin over-temperature protection is verified by reviewing the system description and drawings to determine that temperature sensors are provided that will actuate the demineralizer bypass or isolation valves. Also, verify that instrumentation is available to monitor filter and demineralizer differential pressures.

G. The boron thermal regeneration subsystem is reviewed to determine the maximum change in primary coolant boron concentration due to equipment or control errors as determined from failure modes and effects analyses.

H. The operating procedures and controls for boron addition and primary coolant dilution are reviewed for adequacy.

I. The system P&IDs are examined to determine whether all components and piping that can contain boric acid will either be heat traced or will be located within heated rooms to prevent precipitation of boric acid.

J. The application is reviewed with respect to establishing a leakage control program, for those portions of the CVCS located outside containment that may contain radioactive material following an accident, consistent with item III.D.1.1 of NUREG-0737.

K. The CVCS low pressure or holdup tanks that can contain primary system water are reviewed to assure adequate measures have been taken to protect against vacuum conditions that could result in tank damage (see Reference 18). With respect to the prevention of vacuum conditions in system tanks, the reviewer should consider the following: (a) tanks with a cover gas are able to admit the cover gas fast enough to keep up with the maximum rate of liquid removal; (b) vacuum relief valves are included in a surveillance program; and (c) tanks subject to freezing conditions have adequate freeze protection for the tank and the vacuum relief system.

L. The reviewer verifies that the applicant has considered the following guidance regarding the design of the CVCS miniflow systems necessary to ensure safety related CVCS pump protection (References 19, 20 and 21):

   i. Ensure that the minimum cooling flow provided for the CVCS pumps is adequate under minimum flow operating conditions, including verification that the system configuration precludes pump-to-pump interaction during miniflow operation that could result in dead-heading one or more of the pumps. The miniflow should be sufficient to prevent damage to the pump(s) under minimum flow operating conditions conditions.

   ii. In cases where only the miniflow return line is available for pump testing, flow instrumentation must be installed on the miniflow return line. This instrumentation should provide flow rate measurements during pump testing so this data can be evaluated with the measured pump differential pressure to monitor for pump hydraulic degradation.

2. The reviewer verifies that the safety function of the system will be maintained as required in the event of adverse environmental phenomena such as earthquakes, tornadoes, hurricanes, and floods, or in the event of certain pipe breaks or loss of offsite

power. The reviewer uses engineering judgment, failure modes and effects analyses, and the results of reviews performed under other SRP sections, as applicable, to determine the following:

A. The system description and drawings are reviewed in conjunction with the reactor coolant system to determine whether the CVCS has sufficient pumping capacity to maintain the RCS water inventory within the allowable pressurizer level range for all normal modes of operation, including startup from cold shutdown, full power operation, and plant cooldown. If the plant design relies on the CVCS to perform the safety function of emergency safety injection as part of ECCS, verify that CVCS can supply reactor coolant makeup in the event of small pipe breaks and can function as part of the ECCS, assuming a single active failure coincident with the loss of offsite power. It is further ascertained from a review of the P&IDs whether makeup to the RCS can be accomplished via two redundant appropriately designed flow paths.

B. Essential components and subsystems (i.e., those necessary for safe shutdown) can function as required in the event of loss of offsite power. The system design will be acceptable if the CVCS meets minimum system requirements as stated in the SAR assuming a failure of a single active component, within the system or in the auxiliary electric power source, which supplies the system. The SAR is reviewed to verify that for each CVCS component or subsystem affected by the loss of offsite power, boric acid addition and coolant charging capabilities meet or exceed minimum requirements. Statements in the SAR and the results of failure modes and effect analyses are considered in assuring that the system meets these requirements. This will be acceptable verification of system functional reliability.

3. The descriptive information, P&IDs, layout drawings, and failure modes and effects analyses in the SAR are reviewed to assure that essential portions of the system will function following design basis accidents assuming a single active component failure. The reviewer evaluates the analyses presented in the SAR to assure function of required components, traces the availability of these components on system drawings, and checks that the SAR contains verification that minimum system flow and heat transfer requirements are met for each accident situation for the required time spans. For each case, the design will be acceptable if minimum system requirements are met.

4. The boron recovery system (BRS) is not required for safe shutdown, or for the prevention or mitigation of postulated accidents. The BRS will be reviewed for the following: if the system tankage is of nonseismic Category I design, the results of analyses which postulate the rupture of tanks are reviewed to verify that the accident releases are in accordance with safe limits.

5. The reviewer confirms that the CVCS system's capability is sufficient with respect to the plant's ability to withstand or cope with, as applicable, and recover from, a SBO by determining compliance with Regulatory Guide 1.155 positions C.3.2, C.3.3.4, and C.3.5. This review is coordinated with the review of the SBO event under SRP Section 8.4 (proposed).

   For plants/applicants that do not submit adequate test data to demonstrate the integrity of the reactor coolant pump seals during a SBO for an extended period, the reviewer verifies that there are adequate means to provide RCP seal cooling during a SBO. A diverse seal injection system, that is independent of the CVCS and associated support systems to the extent practicable, is an acceptable approach. If a diverse seal injection system is proposed by the applicant, the reviewer verifies that the system can be powered from the alternate AC power source for station blackout.

For those plant designs that use sealless reactor coolant pumps such as canned-motor pumps in the AP1000 design that have no pump seals, nor the need for seal injection or cooling from the CVCS, this review step is not needed.

6. For those PWR designs, such as Westinghouse's AP1000, where the CVCS makeup isolation valves are designed to perform the safety functions of containment isolation and makeup isolation for termination of the RCS makeup to prevent overfilling of the pressurizer during non-LOCA transients or to prevent steam generator overfilling during a steam generator tube rupture, the reviewer should ensure that proper limiting conditions for operation and surveillance requirements for the CVCS makeup isolation valves be incorporated in the plant technical specifications.

7. For review of a DC application, the reviewer should follow the above procedures to verify that the design, including requirements and restrictions (e.g., interface requirements and site parameters), set forth in the final safety analysis report (FSAR) meets the acceptance criteria. DCs have referred to the FSAR as the design control document (DCD). The reviewer should also consider the appropriateness of identified COL action items. The reviewer may identify additional COL action items; however, to ensure these COL action items are addressed during a COL application, they should be added to the DC FSAR.

   For review of a COL application, the scope of the review is dependent on whether the COL applicant references a DC, an early site permit (ESP) or other NRC approvals (e.g., manufacturing license, site suitability report or topical report).

8. For review of both DC and COL applications, SRP Section 14.3 should be followed for the review of ITAAC. The review of ITAAC cannot be completed until after the completion of this section.

IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the review and calculations (if applicable) support conclusions of the following type to be included in the staff's safety evaluation report. The reviewer also states the bases for those conclusions.

> The chemical and volume control system (including boron recovery system) includes components and piping associated with the system from the letdown line of the primary system to the charging lines that provide makeup to the primary system and the reactor coolant pump seal water system. Based on the review of the applicant's proposed design criteria, design bases, and safety classification for the chemical and volume control system, and the requirements for system performance of necessary functions during normal, abnormal, and accident conditions, the staff concludes that the design of the chemical and volume control system and supporting system is acceptable and meets the requirements of General Design Criteria 1, 2, 5, 14, 29, 33, 35, 60, and 61, 10 CFR 50.34(f)(2)(xxvi) and 10 CFR 50.63(a)(2).
>
> This conclusion is based on the following: the applicant's design of the chemical and volume control system meets (1) the requirements of General Design Criterion 1 and the guidelines of Regulatory Guide 1.26 by assigning quality group classifications to system components in accordance with the importance of the safety function to be performed; (2) the requirements of General Design Criterion 2 and the guidelines of Regulatory Guide 1.29 by designing safety-related portions of the system to seismic Category I requirements; (3) the requirements of General Design Criterion 5 by designing the CVCS so that components important to safety are not shared between nuclear power units

unless such sharing will not significantly impair the ability of the CVCS to perform its safety functions in the event of an accident in one unit and an orderly shutdown and cooldown of the remaining units; (4) the requirements of General Design Criterion 14 by maintaining reactor coolant purity and material compatibility to reduce corrosion and thus reduce the probability of abnormal leakage, rapid propagating failure, or gross rupture of the reactor coolant pressure boundary; (5) the requirements of General Design Criterion 29 as related to the reliability of the CVCS to provide negative reactivity to the reactor by supplying borated water to the reactor coolant system in the event of anticipated operational occurrences; (6) the requirements of General Design Criteria 33 and 35 by designing the CVCS with the capability to supply reactor coolant makeup in the event of small breaks or leaks in the reactor coolant pressure boundary and to function as part of ECCS assuming a single failure coincident with loss of offsite power; (7) the requirements of General Design Criteria 60 and 61 with respect to confining radioactivity by venting and collecting drainage from the CVCS components through closed systems; (8) 10 CFR 50.34(f)(2)(xxvi) for applicants subject to 10 CFR 50.34(f), with respect to leakage detection and control in the design of CVCS systems outside containment that contain (or may contain) radioactive material following an accident; and (9) the relevant requirements of 10 CFR 50.63(a)(2) and the guidance of Regulatory Guide 1.155 positions C.3.2, C.3.3.4, and C.3.5 by demonstrating the capability of the CVCS to support the plant's ability to withstand or cope with, and recover from a station blackout. Conformance with 10 CFR 50.63 requirements for station blackout is discussed in further detail in Section 8.4 of this report.

For DC and COL reviews, the findings will also summarize the staff's evaluation of requirements and restriction (e.g., interface requirements and site parameters) and COL action items relevant to this SRP section.

In addition, to the extent that the review is not discussed in other SER sections, the findings will summarize the staff's evaluation of the ITAAC, including design acceptance criteria, as applicable.

V. IMPLEMENTATION

The staff will use this SRP section in performing safety evaluations of DC applications and license applications submitted by applicants pursuant to 10 CFR Part 50 or 10 CFR Part 52. Except when the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the staff will use the method described herein to evaluate conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications submitted six months or more after the date of issuance of this SRP section, unless superseded by a later revision.

VI. REFERENCES

1. 10 CFR Part 50, §50.34(f), "Additional TMI-Related Requirements."

2. 10 CFR 50, §50.63, "Loss of All Alternating Current Power."

3. 10 CFR Part 50, Appendix A, General Design Criterion 1, "Quality Standards and Records."

4. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

5. 10 CFR Part 50, Appendix A, General Design Criterion 5, “Sharing of Structures, Systems, and Components.”

6. 10 CFR Part 50, Appendix A, General Design Criterion 14, “Reactor Coolant Pressure Boundary.”

7. 10 CFR Part 50, Appendix A, General Design Criterion 29, “Protection Against Anticipated Operational Occurrences.”

8. 10 CFR Part 50, Appendix A, General Design Criterion 33, “Reactor Coolant Makeup.”

9. 10 CFR Part 50, Appendix A, General Design Criterion 35, “Emergency Core Cooling.”

10. 10 CFR Part 50, Appendix A, General Design Criterion 60, “Control of Release of Radioactive Material to the Environment.”

11. 10 CFR Part 50, Appendix A, General Design Criterion 61, “Fuel Storage and handling and Radioactivity Control.”

12. Regulatory Guide 1.155, “Station Blackout.”

13. SECY-77-438, “Single Failure Criterion,” August 17, 1977.

14. Regulatory Guide 1.26, “Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants.”

15. Regulatory Guide 1.29, “Seismic Design Classification.”

16. NUREG-0737, “Clarification of TMI Action Plan Requirements.”

17. NUREG-0718, “Licensing Requirements for Pending Applications for Construction Permits and Manufacturing Licenses.”

18. NRC Letter to All Operating Reactor Licensees, “Vacuum Condition Resulting in Damage to Chemical Volume Control System (CVCS) Holdup Tanks (Sometimes Called ‘Clean Waste Receiver Tanks’)(Generic Letter 80-21),” March 10, 1980.

19. NRC Letter to All Holders of Light Water Reactor Operating Licenses and Construction Permits, “Guidance on Developing Acceptable Inservice Testing Programs (Generic Letter 89-04),” April 3, 1989.

20. NRC Bulletin 80-18, “Maintenance of Adequate Minimum Flow Thru Centrifugal Charging Pumps Following Secondary Side High Energy Line Rupture,” July 24, 1980.

21. NRC Bulletin 88-04, “Potential Safety-Related Pump Loss,” May 5, 1988.

22. “PWR Primary Water Chemistry Guidelines,” Electric Power Research Institute.

PAPERWORK REDUCTION ACT STATEMENT

The information collections contained in the Standard Review Plan are covered by the requirements of 10 CFR Part 50 and 10 CFR Part 52, and were approved by the Office of Management and Budget, approval number 3150-0011 and 3150-0151.

PUBLIC PROTECTION NOTIFICATION

The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid OMB control number.
