From:	DUNCAN Leslie E (AREVA NP INC) [Leslie.Duncan@areva.com]
Sent:	Friday, December 05, 2008 5:07 PM
To:	Getachew Tesfaye
Cc:	John Rycyna; Pederson Ronda M (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); DELANO Karen V (AREVA NP INC)
Subject:	Response to U.S. EPR Design Certification Application RAI No. 125, FSAR Ch. 9
Attachments:	RAI 125 Response US EPR DC.pdf

Getachew,

Attached please find AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 125 Response US EPR DC.pdf" provides technically correct and complete responses to 16 of the 18 questions.

Appended to this file are affected pages of the U.S. EPR Final Safety Analysis Report in redline-strikeout format which support the response to RAI 125 Questions 09.03.04-1, 09.03.04-2, 09.03.04-3, 09.03.04-4, 09.03.04-7, 09.03.04-12, 09.03.04-13, 09.03.04-14 and 09.03.04-18.

The following table indicates the respective pages in the response document, "RAI 125 Response US EPR DC.pdf," that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 125 — 09.03.04-1	2	2
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A complete answer is not provided for 2 of the 18 questions. The schedule for a technically correct and complete response to these questions is provided below.

Question #	Response Date
RAI 125 — 09.03.04-6	February 25, 2009
RAI 125 — 09.03.04-8	January 21, 2009

Sincerely,

(Les Duncan on behalf of)
Ronda Pederson

ronda.pederson@areva.com
Licensing Manager, U.S. EPR Design Certification
New Plants Deployment
AREVA NP, Inc.
An AREVA and Siemens company
3315 Old Forest Road
Lynchburg, VA 24506-0935
Phone: 434-832-3694
Cell: 434-841-8788

From: Getachew Tesfaye [mailto:Getachew.Tesfaye@nrc.gov]
Sent: Wednesday, November 05, 2008 3:45 PM
To: ZZ-DL-A-USEPR-DL
Cc: John Budzynski; Shanlai Lu; Joseph Donoghue; Jeffrey Poehler; David Terao; Peter Hearn; Joseph Colaccino; John Rycyna
Subject: U.S. EPR Design Certification Application RAI No. 125 (1302, 1440),FSAR Ch. 9

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on October 24, 2008, and on November 4, 2008, you informed us that the RAI is clear and no further clarification is needed. As a result, no change is made to the draft RAI. The schedule we have established for review of your application assumes technically correct and complete responses within 30 days of receipt of RAIs. For any RAIs that cannot be answered within 30 days, it is expected that a date for receipt of this information will be provided to the staff within the 30 day period so that the staff can assess how this information will impact the published schedule.

Thanks,
Getachew Tesfaye
Sr. Project Manager
NRO/DNRL/NARP
(301) 415-3361

Hearing Identifier: AREVA_EPR_DC_RAIs
Email Number: 8

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From: DUNCAN Leslie E (AREVA NP INC)

Created By: Leslie.Duncan@areva.com

Recipients:
"John Rycyna" <John.Rycyna@nrc.gov>
Tracking Status: None
"Pederson Ronda M (AREVA NP INC)" <Ronda.Pederson@areva.com>
Tracking Status: None
"BENNETT Kathy A (OFR) (AREVA NP INC)" <Kathy.Bennett@areva.com>
Tracking Status: None
"DELANO Karen V (AREVA NP INC)" <Karen.Delano@areva.com>
Tracking Status: None
"Getachew Tesfaye" <Getachew.Tesfaye@nrc.gov>
Tracking Status: None

Post Office: AUSLYNCMX01.adom.ad.corp

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Response to

Request for Additional Information No. 125 (1302, 1440), Revision 0

11/05/2008

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 09.03.04 - Chemical and Volume Control System (PWR) (Including Boron Recovery System)
Application Section: FSAR Section 9.3.4

QUESTIONS for Reactor System, Nuclear Performance and Code Review (SRSB)
QUESTIONS for Component Integrity, Performance, and Testing Branch 1 (AP1000/EPR Projects) (CIB1)

Question 09.03.04-1:

CVCS-1

Two different terms are used to characterize the same system discussed in various sections of EPR FSAR. EPR FSAR Section 9.3.4, Chemical and Volume Control System (CVCS), page 9.3-47 discusses the Reactor Makeup and Inventory Control System. It states that "A flow diagram of the reactor boron and water makeup system (RBWMS) is shown in Figure 9.3.4-4 – RBWMS Flow Diagram." Figure 9.3.4-4 is shown on pages 9.3-82 and 9.3-83. The title of this figure is "Reactor Makeup and Inventory Control System." This title is consistent with the title given in Table 1.7.2 of the FSAR. As stated in Section 1.7.2, the U.S. EPR subscribes to the Kraftwerks Kennzeichen System (KKS) for coding and nomenclature of structures, systems and components which are also used in P&IDs. Therefore, these names appear to be used to refer to the same system. In addition, Table 1.3-1, "Abbreviations and Acronyms List" list Reactor Boron and Water Makeup System as RBWMS; whereas, Reactor Makeup and Inventory Control System is not listed. Also note, for example, Tier 2 Section 14.2, test #007 refers to the reactor boron and makeup water system, as does FSAR Tier 2 Section 6.8, extra borating system. To prevent possible confusion in the FSAR, eliminate one of the two names referring to the same system.

Response to Question 09.03.04-1:

The correct term for the system is the reactor boron and water makeup system. U.S. EPR FSAR, Tier 2, Section 9.3.4.2.1 and Figure 9.3.4-4—Reactor Makeup and Inventory Control System will be revised to indicate the above system name to agree with the Kraftwerks Kennzeichen System (KKS) coding for the KBC System. The title of the KBC system listed in U.S. EPR FSAR, Tier 2, Table 1.7-2—U.S. EPR System Designators and System Diagrams will also be changed to the terminology above.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 9.3.4.2.1, Figure 9.3.4-4 and Table 1.7-2 will be revised as described in the response and indicated on the enclosed markup.

Question 09.03.04-2:

CVCS-2

Section 9.3.4, CVCS, does not reference the use of enriched boron. Section 9.3.4.2.1 states "The boric acid solution in the boric acid column is measured and controlled to maintain its boric acid concentration at an approximately constant four percent by weight which corresponds to 7100 ppm ± 100. The boric acid solution is cooled and transferred to the RBWMS storage tanks for reuse in the CVCS makeup. Table 6.8-1 – Extra Borating System (EBS) Design and Operating Parameters states "Boron Concentration in tank 7000 to 7300 ppm". Based on above, CVCS and EBS have the same boron concentration range. The EBS uses enriched Boron. Table 6.8-1 states "Minimum boron enrichment 37% B-10." Describe the reasons for the use of enriched boron in CVCS, including any advantages and disadvantages. Section 9.3.4, does not discuss EBS, and design basis events for which each of these two systems are used. Also interfaces between CVCS and EBS are not being discussed. Describe these interfaces.

Response to Question 09.03.04-2:

A four weight percent boric acid (H_3BO_3) solution corresponds to approximately 7000 ppm boron. The statement "7100 ppm ± 100" is a typographical error and will be corrected to "7000 ± 100 ppm boron".

The boric acid solution makes the coolant slightly acidic at operating conditions. Lithium is added to the coolant (as lithium hydroxide, LiOH) to neutralize the boric acid and produce a slightly basic pH at operating conditions. Operating with a slightly basic coolant reduces the generation and mobility of corrosion products in the reactor coolant system (RCS). Minimizing corrosion products is important since their activation increases the source term. Corrosion product reduction also minimizes the potential for axial offset anomaly and for crud-induced fuel corrosion.

Combinations of power up-rates, longer fuel cycles, higher uranium enrichment, increased heat flux, increased discharge burn-up, and low neutron leakage cores result in higher coolant boron concentrations at the beginning of cycle (BOC) in pressurized water reactors (PWR). To avoid operating with an acidic pH, more lithium is required in the coolant. Lithium hydroxide accelerates Zircaloy cladding corrosion. The corrosion depends on the amount of lithium picked up by the cladding oxide, which in turn depends on the coolant lithium concentration, the heat flux, the zirconium oxide layer thickness, and the cladding composition. A maximum lithium concentration is established to limit the lithium concentration in the cladding oxide. This limit may delay achieving a constant and slightly basic pH in the coolant at BOC.

Naturally occurring mineral sources of boron contain two isotopes, B-10 at 19.9 atom percent and B-11 at 80.1 atom percent. Enriched boric acid (EBA) contains a higher atom percent of B-10 than natural boric acid (NBA). Enriching the B-10 isotope decreases the atom percent of B-11. The net effect is a decrease in the overall boric acid concentration since the effective number of B-10 atoms per gram is the same for a given level of soluble reactivity control.

The use of EBA lowers the reactor coolant boron concentrations required during all operating modes. For example, the neutron absorption of 1000 ppm boron at 37 atom percent B-10 (EBA) is equivalent to 1889 ppm boron at 19.9 atom percent B-10 (NBA). If a PWR requires high BOC boron concentration, the boron concentration can be reduced by B-10 enrichment. This means achieving a slightly basic pH in the coolant at BOC requires less lithium, and this in turn lowers Zircaloy corrosion throughout the fuel cycle.

The extra borating system (EBS) is described in U.S. EPR FSAR, Tier 2, Section 6.8. The interfaces between the EBS and the chemical volume control system (CVCS) are addressed in U.S. EPR FSAR, Tier 2, Section 6.8.2, which describes how the EBS pumps taking suction from the CVCS volume control tank and discharge to the CVCS seal injection header for hydrostatic testing of the RCS.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 9.3.4.2.1 will be revised as described in the response and indicated on the enclosed markup.

Question 09.03.04-3:

CVCS-3

In Section 9.3.4.1, Design Basis, one of the stated safety-related functions of the CVCS is:

Mitigate boron dilution event by automatically isolating the charging pump suction from the volume control tank (VCT) and normal letdown path, and automatically aligning the charging pump suction to the in-containment refueling water storage tank (IRWST).

However, in Section 9.3.4.3, Safety Evaluation, it is stated:

GDC 29 requires that safety-related portions of the CVCS reliably provide negative reactivity to the reactor by supplying borated water to the RCS in the event of AOOs if the plant design relies on the CVCS to perform the safety function of boration for mitigation of DBEs.

1. The CVCS is not designed to perform the safety function of RCS boration for the mitigation of DBEs.
2. The CVCS is designed to supply borated water to the RCS during normal power operating conditions….

In addition, the above description of GDC 29, as it relates to the CVCS, contains a conditional statement which is less conservative and not included in the description of GDC 29 provided in Appendix A of 10 CFR Part 50 but is included in SRP 9.3.4. Therefore, provide an explanation for the inconsistency between the 1. above and the statement made in 9.3.4.1 above.
Also, confirm the safety-related portions of the CVCS reliably provide negative reactivity to the reactor by supplying borated water to the RCS in the event of AOOs.

Response to Question 09.03.04-3:

The safety function for mitigating a boron dilution event is complete when the three safety-related motor operated valves that isolate the charging pump suction from the volume control tank (VCT) and the normal letdown path are closed. The automatic aligning of the charging pump suction to the in-containment refueling water tank (IRWST) is not a safety function and no credit is taken for it in U.S. EPR FSAR, Tier 2, Section 15.4.6 events. Therefore, U.S. EPR FSAR, Tier 2, Section 9.3.4.1 will be revised to state only the automatic isolation safety function.

The plant design does not rely on the chemical volume control system (CVCS) to perform the boration safety function for mitigating design basis events. The extra borating system (EBS) or the safety injection system (SIS) supplies borated water for negative reactivity addition to the reactor coolant system in the event of abnormal operational occurrences. The EBS and SIS are safety-related systems that are redundant and single failure proof. The CVCS connection to the IRWST is not redundant or single failure proof.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 9.3.4.1 will be revised as described in the response and indicated on the enclosed markup.

Question 09.03.04-4:

CVCS-4

In Section 9.3.4.3 and in regards to GDC 29, the applicant states that “The CVCS is not designed to perform the safety function of RCS boration for the mitigation of DBEs”.

However, in section 9.3.4.2.3.4, Abnormal Operation, the applicant states:

“If the boron concentration decreases below a setpoint to indicate **a possible dilution event**, a signal is sent to isolate the charging pump suction. Three MOVs automatically isolate the normal letdown line and the line from the VCT and a valve from the IRWST automatically aligns to the charging pump suction **providing borated water to the RCS**. Simultaneously, the charging line isolation valves are closed and the three way valve to the coolant storage and supply tanks fully opens. The charging flow to the RCP seal water system remains in service during this evolution.”

The abnormal scenario is a design basis event (DBE). Therefore, it appears that there is an inconsistency between the two sections. Amend the FSAR to correct this inconsistency.

Response to Question 09.03.04-4:

U.S. EPR FSAR, Tier 2, Section 9.3.4.2.3.4 will be revised to indicate that the dilution event is terminated by closing the three safety-related valves that isolate the charging pump suction. The revisions will state that the alignment of the charging pump suction to the in-containment refueling water storage tank, the closure of the charging line isolation valves, and the opening of the 3-way valve to the coolant storage and supply tanks will be performed, but as non-safety-related actions that are not credited in the safety analysis.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 9.3.4.2.3.4 will be revised as described in the response and indicated on the enclosed markup.

Question 09.03.04-5:

CVCS-5

Two scenaria were identified in Chapter 15 analyses which referred to switchover from VCT to IRWST. The first is mentioned in 15.4.6.1.1 in regards to malfunction of RBWMS or operator error that causes boron dilution. The FSAR states that:

Three motor-operated valves (MOVs) automatically isolate the normal letdown line and the line from the volume control tank (VCT), and a valve from the in-containment refueling water storage tank (IRWST) automatically aligns to the charging pump suction providing borated water to the RCS. Simultaneously, the charging line isolation valves close and the three-way valve to the coolant storage and supply tanks fully opens. The charging flow to the RCP seal water system remains in service during this evolution. This action effectively isolates potential sources of dilution flow to the RCS. No credit is taken in transient analysis for the automatic lineup of boration flow to the RCS since this operation is performed with non-safety-grade equipment.

Explain the purpose of switchover from VCT to IRWST, even though no credit is taken in transient analysis.

The second scenario leading to switchover of the charging pumps from VCT to IRWST is mentioned in 15.6.3, steam generator tube failure. In case of operating charging pumps (bottom of page 15.6-6), automatic switchover from VCT to IRWST seems to be taken credit for on top of page 15.6-7. Clarify and explain the difference from the above position, when credit is not taken.

Finally, boron dilution occurs also during SBLOCA, Section 15.6.5.4, page 15.6-33. IRWST is mentioned in regards to SBLOCA, p. 15.6-25, but is not mentioned in the context of CVCS. Confirm boron dilution is addressed by using Extra Borating System. Amend the FSAR to explain this scenerio.

Response to Question 09.03.04-5:

U.S. EPR FSAR, Tier 2, Section 15.4.6.1.1 identifies an inadvertent boron dilution event caused by either an operator error or a malfunction in the reactor boron and water makeup system (RBWMS). The event is terminated by closing the three safety-grade motor operated valves that automatically isolate the normal letdown line and the line from the volume control tank (VCT). No credit is taken for the automatic switchover to the in-containment refueling water storage tank (IRWST). The purpose of the switchover to the IRWST is to allow the charging pump to continue to operate providing flow to the reactor coolant pump seals.

The second scenario is a steam generator tube failure described in U.S. EPR FSAR, Tier 2, Section 15.6.3. In this case the charging pumps are automatically switched to the IRWST on a low level in the VCT. This allows the charging pumps to offset the coolant loss through a single steam generator tube failure. The reason credit is taken for the switchover to the IRWST is that the transient is extended because the operator trips the reactor instead of an automatic reactor trip occurring. This results in a longer time for event identification and thus an additional loss of reactor coolant into the faulted steam generator.

There are several issues identified in U.S. EPR FSAR, Tier 2, Section 15.6.5.4 that affect the long-term cooling following a small break loss of coolant accident (SBLOCA). One is the boron dilution event raised in GSI-185 and stated in U.S. FSAR, Tier 2, Section 15.6.5.4. This condition is analyzed in U.S. EPR FSAR, Tier 2, Section 15.6.5.4.2 and the conclusions are described in U.S. EPR FSAR, Tier 2, Section 15.6.5.4.4.

The reason the IRWST is mentioned in U.S. EPR FSAR, Tier 2, Section 15.6.5.2.2 is to provide the suction temperature for the medium head safety injection and low head safety injection pumps, which are used to mitigate a SBLOCA. The chemical volume control system does not perform any safety function in mitigating a SBLOCA.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 09.03.04-6:

Quality Group Classification

GDC 1 requires that equipment important to safety be designed to quality group standards commensurate with the level of importance. Quality group classifications for the CVCS system are identified in FSAR Tier 1 Figure 2.2.6-1 and FSAR Tier 2 Figure 9.3.4-1. Classifications are also given in FSAR Tier 1 Table 2.2.6-1. The supply piping from the RCS to the CVCS can be isolated by two (in series) motor-operated valves and both return lines to the RCS loops can be isolated by sets of two check valves (also in series). All of these valves are shown in Tier 1 Table 2.2.6-1 as ASME III, Class 1 valves. However, Table 2.2.6-1 does not show the piping between the two motor-operated valves or between the two check valves to be Class 1. Also, the pressurizer auxiliary spray line is isolated from the RCS by a check valve and a motor-operated valve (MOV). The check valve is ASME Class 1 and the MOV is Class 3. Again in this case, the classification of the piping between the check valve and the MOV is not listed on Table 2.2.6-1. In view of the above, respond to the following:

1. Justify not listing the piping between the isolation valves in Table 2.2.6-1.
2. Justify the pressurizer spray isolation valve being Class 3 rather than Class 1.
3. Justify not listing the containment isolation valves in Table 2.2.6-1as Class 2.

Response to Question 09.03.04-6:

A response to this question will be provided by February 25, 2009.

Question 09.03.04-7:

Charging Pump Suction Swap

GDC 1 requires that equipment important to safety be designed to quality group standards commensurate with the level of importance. When a potential boron dilution event is detected, the chemical and volume control system automatically shifts the charging pump suction from the volume control tank (VCT) and the normal letdown line to the in-containment refueling water storage tank (IRWST). Motor operated isolation valves from the VCT and the letdown line automatically close, and an isolation valve from the IRWST automatically opens. The VCT and letdown isolation valves are shown in FSAR Tier 2 Figure 9.3.4-1 as quality group C and seismic category I. The valve that appears to be the IRWST isolation valve is 30KBA31 AA0031, which is shown on FSAR Tier 2 Figure 9.3.4-1, sheet 4 of 9. However, this valve classified as quality group D and non-seismic.

The Staff recognizes that the design of the U.S. EPR does not credit the CVCS for boration of the RCS during anticipated operational occurrences such as a boron dilution event. At the same time, the operation of the single suction valve from the IRWST is important in that it does align a source of borated water for charging to the RCS whether or not it is credited in the analysis. GDC 29 states "reactivity control systems shall be designed to assure an extremely high probability of accomplishing their safety functions in the event of anticipated operational occurrences." Since boration is not a CVCS safety function, quality group D and non-seismic are acceptable classifications. However, in view of the benefits of aligning the IRWST to the charging pump suction in a boron dilution event, the applicant should consider making the entire swap-over using safety related valves. In the alternative, indicate if any inspection or testing requirements will be imposed on the IRWST suction valve to provide improved reliability.

In addition to the above, the statement in FSAR Tier 2 Section 9.3.4.1 (2nd bullet under safety-related functions) is not technically correct in that the alignment of the charging pump suction to the IRWST is performed by non-safety grade equipment. Hence, if the isolation valve to the IRWST remains as quality group D and non-seismic, the statement in Section 9.3.4.1 should be corrected.

Response to Question 09.03.04-7:

The Reliability Assurance Program (RAP) identifies the chemical volume control system (CVCS) as a safety significant system. The in-containment refueling water tank (IRWST) suction valve (30KBA31 AA0013) will be included in the RAP.

The safety function for mitigating a boron dilution event is complete when the three safety-related motor operated valves that isolate the charging pump suction from the volume control tank and the normal letdown path are closed. The automatic aligning of the charging pump suction to the IRWST is not a safety function and no credit is taken for it in U.S. EPR FSAR, Tier 2, Section 15.4.6 events. Therefore, U.S. EPR FSAR, Tier 2, Section 9.3.4.1 will be revised to state only the automatic isolation safety function.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 9.3.4.1 will be revised as described in the response and indicated on the enclosed markup.

Question 09.03.04-8:

Seismic Design for Non-Safety CVCS

GDC 2 requires that safety related equipment be protected from the effects of natural phenomena, such as earthquakes. FSAR Tier 2 Section 9.3.4.3 states that the safety-related portions of the CVCS meet Position C.1 of Regulatory Guide (RG) 1.29 and the non-safety portions meet Position C.2. Position C.2 of RG 1.29 requires a design that precludes equipment or piping failure during an SSE that can adversely affect safety-related equipment (i.e. Seismic II). However, FSAR Tier 2 Figure 9.3.4-1 identifies non-safety portions of the CVCS as NSC (non-seismic class), which does not imply the protection of Seismic II piping. If the non-safety portions of the CVCS are designed to Seismic II criteria, clarify the seismic classifications shown on FSAR Tier 2 Figure 9.3.4-1. If non-safety portions are not designed to Seismic II, identify any design features supplied to protect safety-related portions from being impacted by NSC piping or components during design basis events.

Response to Question 09.03.04-8:

A response to this question will be provided by January 21, 2009.

Question 09.03.04-9:

Single Active Failure Considerations

GDC 29 requires protection and reactivity control systems be designed to assure an extremely high probability of accomplishing their safety functions in the event of anticipated operational occurrences. CVCS has a safety function to isolate charging in order to preclude RCS over fill; however, the FSAR did not provide enough information to determine that this function can be achieved in spite of the failure of a single active component. Justify the non-overfill function can achieve its safety functions concurrent with the most limiting single active component failure.

Response to Question 09.03.04-9:

To prevent reactor coolant system (RCS) overfill, three safety-related isolation valves in the chemical volume control system close to terminate the overfill event. The three valves (30KBA34 AA002, 30KBA34 AA012, and 30KBA35 AA001) are shown on U.S. EPR FSAR, Tier 2, Figure 9.3.4-1—Chemical and Volume Control System, Sheet 5. The charging line containment isolation valve (30KBA34 AA002) is powered from an emergency bus that can be powered from an alternate feed. The charging line isolation valve (30KBA34 AA012) and the pressurizer auxiliary spray isolation valve (30KBA35 AA001) are powered from a different emergency bus that is also capable of being powered from a different alternate feed. The closure of valve 30KBA34 AA002 or the closure of valve 30KBA34 AA012 and valve 30KBA35 AA001 terminates the event. Therefore, the safety function of isolating charging to preclude RCS overfill is achieved in the event of a single active component failure.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 09.03.04-10:

Charging Pump Low Suction-Pressure Trip

GDC 29 requires protection and reactivity control systems be designed to assure an extremely high probability of accomplishing their safety functions in the event of anticipated operational occurrences. A low charging-pump suction-pressure signal trips the operating charging pumps. However, the FSAR did not provide further details on this trip function and did not explain the control of the trip when suction sources swap.

Describe the control of the charging pump low-pressure suction trip function during an automatic swap of suction sources from the volume control tank to the in-containment refueling water storage tank (IRWST). Specifically, provide the methodology for accommodating the differences in suction pressure sources between the VCT and the IRWST.

Response to Question 09.03.04-10:

The charging pumps do not perform the reactivity control safety function in the event of anticipated operational occurrences, as explained in the response to Question 09.03.04-3. The charging pump swap-over to the in-containment refueling water storage tank (IRWST) is a non-safety function.

The charging pump trip on low suction pressure protects the pump from operating with an isolated suction line. During the swap-over of the charging pump suction to the IRWST, the charging pump suction is maintained. The three safety-related valves that isolate the letdown line and volume control tank (VCT) receive the signal to close and at the same time the valve from the IRWST receives a signal to open. The travel time for all the valves is the same. A check valve in the line from the IRWST prevents reverse flow from the VCT into the IRWST. As the valves from the letdown line and VCT close, the suction pressure is reduced to the pressure exerted by the head of water in the IRWST as the IRWST valve opens, then the flow to the charging pump is from the IRWST.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 09.03.04-11:

Station Blackout Capabilities

10 CFR 50.63 requires certain plant design provisions necessary to cope with postulated station blackout conditions. FSAR Tier 2 Section 9.3.4.1 (Design Basis) states that safety-related portions of the CVCS provide capacity and capability to assure the core is cooled in the event of a station blackout. However, Tier 2 Section 9.3.4.3 (Safety Evaluation) states that CVCS provides no function with regard to RCS makeup or RCP seal injection during an SBO event, and therefore 10 CFR 50.63 is not applicable to CVCS. In addition to these potentially conflicting statements, the station blackout (SBO) coping descriptions of FSAR Tier 2 Section 8.4 are not clear on maintaining the reactor coolant inventory under SBO conditions. Tier 2 Section 8.4 discusses assumptions of RCP seal leakage in a SBO and also discusses the RCP standstill seal system that subsequently terminates seal leakage. However, the issue of makeup and volume control is not fully explained. In view of the above, explain the required functions of the CVCS under station blackout conditions, if any, and the design provisions provided to meet these requirements. Response to Question xx-1:

Response to Question 09.03.04-11:

The statements in U.S. EPR FSAR Tier 2, Section 9.3.4.1 (Design Basis) are restatements of the requirements identified in Section II Acceptance Criteria of the Standard Review Plan (NUREG-0800). The statements provided in U.S. EPR FSAR Tier 2, Section 9.3.4.3 (Safety Evaluation) are statements that indicate how the chemical volume control system (CVCS) meets the Standard Review Plan.

The CVCS provides no station blackout mitigation function.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 09.03.04-12:

Clarification RAI

FSAR Tier 2 Section 9.3.4, page 9.3.4-47, under the heading reactor makeup and inventory control, states that the reactor boron and makeup water system is shown in Figure 9.3.4-4. However, the system name on Figure 9.3.4-4 is shown as the reactor makeup and inventory control system. These names appear to be used to refer to the same system. For example, Tier 2 Section 14.2, test #007 refers to the reactor boron and makeup water system, as does FSAR Tier 2 Section 6.8, extra borating system. To prevent possible confusion, a consistent name should be used throughout the FSAR.

Response to Question 09.03.04-12:

The correct term for the system is the reactor boron and water makeup system. U.S. EPR FSAR, Tier 2, Section 9.3.4.2.1 and Figure 9.3.4-4—Reactor Makeup and Inventory Control System will be revised to indicate the above system name to agree with the Kraftwerks Kennzeichen System (KKS) coding for the KBC System. The title of the KBC system listed in U.S. EPR FSAR, Tier 2, Table 1.7-2—U.S. EPR System Designators and System Diagrams will also be changed to the terminology above.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 9.3.4.2.1, Figure 9.3.4-4 and Table 1.7-2 will be revised as described in the response and indicated on the enclosed markup.

Question 09.03.04-13:

GDC 61 requires that the flow rate of the cooling and purification system be appropriately sized to maintain temperatures and radiation levels at acceptable values. The current design may challenge that requirement. Demineralizer beds normally have both inlet and outlet filters with the inlet filter having the large micron size and the outlet filter having the smaller outlet size.

1. Justify the small inlet micron size small, and provide the effects of this micron size on the frequency of require changes of the filter and the increase in the amount of solid radwaste.
2. Provide the reason for having a “resin trap” on the mixed bed effluent versus a filter of 0.1 microns.
3. Provide the mesh size of the ‘resin trap’.

Response to Question 09.03.04-13:

1. The micron size of the filtration media should be ten microns for the inlet filters (coolant filters) and one micron for the outlet filters (resin traps). U.S. EPR FSAR Tier 2, Table 9.3.4-1—Major CVCS Component Design Data will be revised accordingly.

2. Historically, the term “resin trap” has been used to refer to a coarse mesh strainer (for low pressure drop) used to prevent complete loss of the ion exchange resin in the event the demineralizer vessel under-drains system failed. The housings for the U.S. EPR coolant filters and resin traps are identical and will use similar disposable filter cartridges that differ only in micron size. As stated in U.S. EPR FSAR Tier 2, Section 9.3.4.2.1 the outlet filters “operate in parallel and act as resin traps to prevent resin carry over into the CVCS and connecting systems.”

3. See the response to Part 1 of this question.

FSAR Impact:

U.S. EPR FSAR Tier 2, Table 9.3.4-1 will be revised as described in the response and indicated on the enclosed markup.

Question 09.03.04-14:

The ALARA principle of plant operation (10 CFR 20.1101) can only be achieved if the demineralizer resins for the RCS function properly. Anion resins (principally removing radioiodines) are much more sensitive to temperature than cation resins. The normal upper temperature limit, in the absence of radiation fields is 120 0F. The current description of the CVCS temperature bypass for the CVCS demineralizers would allow temperatures to reach as high as 150°F prior to bypassing the demineralizers.

1. Provide a technical reference that shows the stability of the anion resin material above 120°F in the presence of a radiation field of several thousand rad.
2. Provide the location upstream of the resin beds for performimng the temperature monitoring.
3. Provide the time frame between sensing of the setpoint temperature and the full bypass occurring.

Response to Question 09.03.04-14:

1. Nuclear grade cation and anion ion exchange resin have ion exchange sites (functional groups) attached to a cross-linked polystyrene backbone. The temperature limit for the backbone is about 300°F. However, a practical temperature limit is imposed by the decomposition of the functional groups as temperature increases. As a result, decomposition of the ion exchange sites produces a loss in capacity, as well as a loss of species held by the ion exchange sites.

   According to major U.S. suppliers of nuclear grade ion exchange resins used in chemical volume control system (CVCS) applications (Rohm & Haas and Dow Chemical), nuclear grade anion resin can be used up to 140°F in the hydroxide (OH-) form and up to 176°F in the chloride (Cl-) form; whereas, nuclear grade cation resin can be used up to 248°F.

   The statements of “150°F” associated with protection of the coolant purification ion exchange resin in U.S. EPR FSAR, Tier 2, Section 9.3.4.2.1 will be changed to “140°F”.

2. The location of the letdown temperature monitoring for bypassing the resin beds is shown on U.S. EPR FSAR, Tier 2, Figure 9.3.4-1—Chemical and Volume Control System, Sheet 2. The temperature sensors are located on both the high-pressure letdown line and the low-pressure letdown line.

3. Details regarding the time interval between sensing of the setpoint temperature and full bypass occurring are defined later in the design process and will meet the applicable requirements of 10 CFR 20.1101.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 9.3.4.2.1 will be revised as described in the response and indicated on the enclosed markup.

Question 09.03.04-15:

The ALARA principle of plant operation (10 CFR 20.1101) can only be achieved if the demineralizer resins for the RCS are operating to maintain a constant equilibrium concentration of radionulcides. Removing a demineralizer from service for short periods (hours to one shift) is not a significant impact to the RCS radionuclide concentrations. However, longer periods of time without clean-up can lead to higher dose rates in low flow areas in the Nuclear Auxiliary Building, and pH excursions that can solubilize soluble and insoluble CRUD.

1. Provide the time to lithiate the hydrogen form mixed bed while at power.
2. Provide the time to sluice the depleted resin and sluice in new, fresh resin.
3. Provide documented evidence of the times of these actions so that it can be assured that lithium will be controlling RCS pH in the correct band.

Response to Question 09.03.04-15:

1. U.S. PWR plants have moved away from in-place conversion of a mixed bed demineralizer to the lithium-form by purchasing mixed bed resin containing lithium-form cation resin. This was motivated by the need to attain a minimum at-temperature pH of 6.9 as soon as possible during plant startup after the refueling outage. The leading lithium-form mixed bed resins used are Rohm & Haas IRN-217 and Dow Chemical HGR NG (Li).

2. U.S. PWR plants typically place new mixed purification resin in service at the beginning of a fuel cycle. The bed remains in-service for the duration of the fuel cycle and is then replaced during the subsequent refueling outage. The in-place conversion of new mixed purification resin to the borate-form typically occurs during the refueling outage or during plant deboration in preparation for plant startup.

   The in-place boration of a demineralizer or the rinsing of a previously borated demineralizer generally occurs in a series of steps. The demineralizer undergoing adjustment is temporarily placed in-service and the effluent diverted to coolant storage. The process continues until the demineralizer effluent matches coolant conditions. The volume of coolant put through the demineralizer in any given step is generally limited by the plant's ability to manage reactor coolant system (RCS) inventory or RCS lithium.

3. The U.S. EPR Primary Water Chemistry Program is based on NEI 97-06, "Steam Generator Program Guidelines," and is consistent with the guidance provided by NEI 03-08, "Guideline for the Management of Materials Issues" and the "Materials Initiative Guidance" Addenda. The NEI initiative requires that U.S. utilities meet the intent of the latest revision of the EPRI PWR Primary Water Chemistry Guidelines as the basis for an optimized chemistry program, including controlling RCS pH in the correct band.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 09.03.04-16:

Technical Specification 3.4.15 limits the specific reactor coolant activity for Dose Equivalent ^{131}I and Dose Equivalent ^{133}Xe. These are fuel integrity monitoring parameters. If RCS oxygen is not adequately controlled by having significant enough hydrogen concentrations, the fuel integrity cannot be assured. Control of hydrogen in PWRs is usually performed by 100% of letdown flow through the VCT. The VCT is maintained under hydrogen pressure (only) between 20 and 35 psig. The design identified in the FSAR has a significantly different approach to hydrogen control, that it is not well described.

1. Provide the equations that identify the flow and concentration of hydrogen into the RCS liquid from the letdown system gassifier and VCT.
2. Justify only 10% of the letdown flow being directed through the VCT.
3. In order to assess the concentration of hydrogen in the RCS, the mole fraction of hydrogen in the VCT gas phase must be known. A sample line from the VCT gas space does not appear in the plant design for the NSS. Provide the methodology for determining the %H_2 in the VCT gas phase so that the RCS hydrogen in cc/Kg ca be properly calculated.

Response to Question 09.03.04-16:

1. The equations that identify the flow and concentration of hydrogen into the RCS liquid from the operation of the gas separator, water-jet pump and VCT will be identified later in the design process.

2. The basis for directing only ten percent of the letdown flow through the VCT is to maintain the boron concentration in the tank in chemical equilibrium with the RCS. This is stated in U.S. EPR FSAR Tier 2, Section 9.3.4.2.1.

3. U.S. EPR FSAR Tier 2, Section 9.3.4.2.1 states “The concentration of hydrogen in the reactor coolant depends on the hydrogen partial pressure in the gassing unit. The pressure in the VCT maintains the pressure in the gassing unit.” U.S. EPR FSAR Tier 2, Section 9.3.4.2.2 states “The gaseous waste processing system maintains the VCT at a constant pressure by providing a continuous feed and bleed of (nitrogen) gas to the tank.” Hydrogen is added to the coolant via the gas separator and controlled via the water-jet pump. As a result, the RCS dissolved hydrogen concentration is a function of the hydrogen partial pressure in the water-jet pump and the pressure applied to the water-jet pump by the VCT nitrogen gas over-pressure. For the U.S. EPR, the purpose of a continuously vented VCT is to prevent the accumulation of an explosive concentration of hydrogen in the VCT gas space. However, a continuously vented VCT prevents non-condensable gases coming to equilibrium in the VCT gas space. As a result, the RCS hydrogen concentration for the U.S. EPR cannot be predicted from the VCT gas space mole fraction of hydrogen.

   The U.S. EPR will follow the current U.S. PWR industry practice of determining the RCS hydrogen concentration (cc/kg (STP) H2O) using a liquid coolant sample.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 09.03.04-17:

Technical Specification 3.4.5 identifies the operational requirements for assuring that the boron concentration is “not diluted.” GDC 29 also identifies a function of Chemical and Volume Control System (CVCS) as supplying boric acid solution reliably for negative reactivity in the Reactor Collant System (RCS). This requirement concerns both the total boron and the specific atom % of ^{10}B. The coolant treatment system (CTS) as described in FSAR Tier 2 Section 9.3.4.2 (and accompanying figures 9.3.4-6) uses evaporative techniques to separate pure water from concentrated boric acid solution. The evaporator feed is purified through a demineralizer and then sent to an evaporator where the water is distilled through a series of trays to ‘purify’ the distillate removing additional boric acid. Concentration of contaminants in the boric acid phase, such as chlorides, silica, sulfate and sodium, and difficulty in maintaining flow continuity at higher boron concentrations and temperatures due to boric acid insolubility at high concentrations, have caused all plants to abandon operations of these systems for recycle purposes. Am/Be neutron sources and their associated BF_3 detectors have been difficult to maintain in the past and most plants have removed these systems from their letdown lines.

1. Provide additional details regarding the ‘trays’ in the boron evaporator and their physical functionality (e.g., percent boron removed for each tray).
2. Provide the mechanism for removing anionic contaminants from the boric acid concentrate so that it may be reused and still meet the EPRI PWR Primary Water Chemistry Guideline requirements for boric acid solution.
3. Describe the control logic for the four Am/Be neutron sources and their associated detectors for providing auto blended makeup to the RCS: one of four, two of four.
4. Provide the maintenance activities in both calibration and cleanliness of the portion of the letdown line adjacent to the detectors, that will be made to assure their accuracy.
5. Confirm that BF_3 detectors are used for the measurement of neutron flux reduction from the Am/Be sources, and if so describe their placement and maintenance.
6. Provide the methodology for the determination of the ^{10}B concentration (atom %) in the recycled boric acid and provide the frequency of that determination.

Response to Question 09.03.04-17:

1. The detailed design, construction, and functionality of the boron evaporator internal components are unique (and usually proprietary) to the equipment manufacturer. As for the equipment requirements imposed on the manufacturer, the demineralized water vapor is specified to have a residual boron concentration of <2 ppm. The U.S. EPR plant design achieves this concentration utilizing eight trays. For the U.S. EPR, equipment component configurations may vary depending on the selected manufacturer's detailed component design.

2. The boron recycle purification portion of the coolant purification system (CPS) contains a mixed bed ion exchanger (30KBE20 AT001) for removing cation and anion impurities in stored coolant. Stored coolant is processed through this mixed bed demineralizer prior to entering the coolant treatment system (CTS), where the coolant is converted into a purified distillate and a concentrated boric acid solution for future reuse in the reactor coolant system.

3. U.S. EPR FSAR, Tier 2, Section 9.3.4.2.3.4 specifies that the boron concentration detectors are located on the charging line, upstream of the branch line to the seal water to measure the concentration of the total charging flow. Additionally, this section describes how the detectors measure B-10 concentration. U.S. EPR FSAR, Tier 2, Section 7.3.1.2.11 states that an online calculation of the boron concentration in the reactor coolant system (RCS) is performed during power operation based on the boron concentration measurement in the chemical volume control system (CVCS) charging line and the measured CVCS charging flow. The section also addresses the mitigation of risk of RCS boron concentration dilution. U.S. EPR FSAR, Tier 2, Figure 7.3-22—CVCS Isolation for Anti-Dilution provides the control logic for this function.

4. Details concerning maintenance activities in both calibration and cleanliness of the portion of the letdown line adjacent to the detectors will be identified later in the design process. One objective will be to confirm the accuracy of the detectors.

5. Details regarding the use of BF_3 detectors for the measurement of neutron flux reduction from the Am/Be sources will be identified later in the design process and will include specific detector placement and required maintenance of the detectors.

6. The relative abundance of the B-10 and B-11 isotopes can be determined using mass spectrometry. Acceptable methods include glow discharge mass spectrometry (GDMS), thermal ionization mass spectrometry (TIMS), secondary ion mass spectrometry (SIMS), and inductively coupled plasma mass spectrometry (ICP-MS). The minimum frequency for the isotope abundance determination is once per year.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 09.03.04-18:

PWR water chemistry must be maintained to the highest quality to support integrity of the nuclear fuel and thus minimize RCS specific activity as identified in Technical Specification 3.4.15. Additionally, per SRP Section 9.3.4 the latest edition of the EPRI PWR Primary Water Chemistry Guidelines is an acceptable standard for determining whether a primary water chemistry control program is adequate to comply with GDC 14 with respect to minimizing corrosion-induced degradation of the reactor coolant pressure boundary. FSAR Tier 2 Section 9.3.4.6 reference 1 identifies the EPRI PWR Water Chemistry Guidelines Revision 3 (1995). The guidelines have been updated since that time and have significant changes.

1. Confirm that the reference be updated to the latest edition, Revision 6 (2007), of the EPRI Guidelines.
2. If not, provide a detailed explanation of meeting and presenting the changes to the guidelines.
3. The EPRI Primary Water Chemistry Guidelines provide specific Action Level 1, 2 and 3 limits for many primary water chemistry control parameters. Specific actions including reduced power and/or shutdown are required if these limits are exceeded. Describe the implementation of these action levels.
4. Justify providing a lower range for hydrogen (17-28 cc/Kg) than is in the EPRI PWR Primary Water Chemistry Guidelines.
5. Since the EPRI PWR Primary Water Chemistry Guidelines are periodically updated to reflect evolving industry practices, the staff requests that the applicant consider whether a COL information item should be identified in the FSAR requiring that the COL applicant describe the method for maintaining the primary water chemistry program current with industry best practices, for example, via a commitment to follow the latest EPRI PWR Primary Water Chemistry Guidelines.

Response to Question 09.03.04-18:

1. The U.S. EPR Primary Water Chemistry Program is based on NEI 97-06, “Steam Generator Program Guidelines,” and is consistent with the guidance provided by NEI 03-08, “Guideline for the Management of Materials Issues” and the “Materials Initiative Guidance” Addenda. The NEI initiative requires that U.S. utilities meet the intent of the latest revision of the EPRI PWR Primary Water Chemistry Guidelines as the basis for an optimized chemistry program.

   The water chemistry requirements of the chemical volume control system (CVCS) are based on the latest revision of the EPRI Pressurized Water Reactor Primary Water Chemistry Guidelines. U.S. EPR FSAR, Tier 2, Section 9.3.4.3 states “Water chemistry requirements of the CVCS meet those specified for the RCS, which are based on the latest revision of the EPRI Primary Water Chemistry Guidelines (Reference 1).”

   U.S. EPR FSAR Tier 2, Section 9.3.4.6, Reference 1 will be changed to “EPRI Report 1014986, PWR Primary Water Chemistry Guidelines, Revision 6, Electric Power Research Institute, December 2007.”

2. Refer to the response to Question 09.03.04-18, Part 1.

3. Similar to the U.S. EPR Secondary Water Chemistry Control Program, the U.S. EPR Primary Water Chemistry Program will be implemented by specific plant operating procedures prepared by the COL applicant, which will record and manage plant data and require appropriate corrective actions in response to abnormal chemistry conditions.

4. The EPRI Pressurized Water Reactor Primary Water Chemistry Guidelines recommend a hydrogen range of 25 – 50 cc/kg (STP) H_2O during normal operation. This value was established in the initial issue of the guidelines to provide a margin against oxidizing conditions. This recommendation is applicable to the present generation of U.S. pressurized water reactors (PWR) and has been shown to be conservative in protecting against oxidizing radiolysis products. Studies carried out in the 1990s indicated that hydrogen in the range of 0.1 – 5 cc/kg (STP) H_2O was sufficient to suppress radiolysis products.

   More recently, extensive studies have been carried out under the EPRI PWR Materials Reliability Program in response to stress corrosion cracking (SCC) of reactor vessel head penetrations and weld metals. These studies have led to an industry initiative to increase the hydrogen concentration during operation from the normal 25 – 40 cc/kg (STP) H_2O range towards the recommended upper limit of 50 cc/kg (STP) H_2O, or even higher. Laboratory tests suggest that the growth rates of existing cracks decrease for the sensitized stainless steels and for Alloy 600, Alloy X-750, and 182/82 weld metals when the dissolved hydrogen concentration is increased. Increasing the dissolved hydrogen concentration elevates the electrochemical potential above the value associated with the nickel/nickel oxide (Ni/NiO) phase transition. The same test program demonstrated that a similar effect occurs when the dissolved hydrogen concentration is decreased so the potential is below the Ni/NiO phase transition.

   Benefits achieved in mitigating crack growth rates by increasing hydrogen concentration may well be offset by potentially adverse side effects, including:

   - Increased hydrogen uptake by the fuel cladding, leading to embrittlement and possibly accelerated corrosion.
   - Increased crud (Fe and Ni) buildup on fuel rods and an increased risk for crud-induced power shifts.
   - Increased release of nickel from steam generator tubing and a corresponding increase in dose rates.
   - Operational difficulties due to the higher hydrogen levels (e.g., charging pump cavitation).

   In addition, an evaluation of available data for thermally treated Alloy 690 has indicated a significant improvement factor in resistance to SCC compared to mill annealed Alloy 600. Based on these test results and on favorable field experience, Alloy 690 and its weld metals (Alloys 52/152) are unlikely to develop SCC during extended PWR plant lifetimes. As an added benefit, test data for nickel-based alloys indicates that the time required to initiate SCC is increased by lower hydrogen concentrations.

   Based on this information, the optimum hydrogen concentration and hydrogen management philosophy selected for the U.S. EPR is defined in the U.S. EPR FSAR.

5. As noted in the response to Question 09.03.04-18-(Part 1), U.S. EPR FSAR, Tier 2, Section 9.3.4.3 states “Water chemistry requirements of the CVCS meet those specified for the RCS, which are based on the latest revision of the EPRI Primary Water Chemistry Guidelines (Reference 1).”

   The identification of a new COL information item requiring that a COL applicant describe the method for maintaining the primary water chemistry program current with industry best practices, for example, via a commitment to follow the latest EPRI PWR Primary Water Chemistry Guidelines, is not necessary. A COL applicant that references the U.S. EPR standard design certification is required to satisfy requirements in the U.S. EPR FSAR or take a departure and provide justification for the departure.

   Also, the standard design certification process identifies and obtains approval on specific commitments as part of the regulatory process. The inclusion of a non-specific and changing requirement is not consistent with this process.

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 9.3.4.6 will be revised as described in the response and indicated on the enclosed markup.

U.S. EPR Final Safety Analysis Report Markups

Table 1.7-2—U.S. EPR System Designators and System Diagrams
Sheet 1 of 5

KKS Designator	System	FSAR Section	FSAR Figure
JA, JDA, JE	RCS Schematic Flow Diagram	5.1	5.1-1
JA, JDA, JE	RCS Piping and Instrumentation Diagram	5.1	5.1-4
KLB	Annulus Normal Operation Train	6.2	6.2.3-1
KLB	AVS Accident Trains	6.2	6.2.3-2
JNA, JND, JNG	Safety Injection System Overview	6.3	6.3-1
JNA, JND, JNG	Safety Injection/Residual Heat Removal System Train (Typical)	6.3	6.3-2
JNK	IRWST Layout	6.3	6.3-3
JDH	Extra Borating System	6.8	6.8-1
FAK	Fuel Pool Cooling System	9.1	9.1.3-1
FAL	Fuel Pool Purification System	9.1	9.1.3-2
PEB	Essential Service Water System Piping & Instrumentation Diagram	9.2	9.2.1-1
KA	Component Cooling Water System Trains 1 through 4	9.2	9.2.2-1
KA	Component Cooling Water System Common Loop 1	9.2	9.2.2-2
KA	Component Cooling Water System Common Loop 2	9.2	9.2.2-3
KA	Component Cooling Water System Dedicated CCWS Trains	9.2	9.2.2-4
PE	Ultimate Heat Sink Piping and Instrumentation Diagram	9.2	9.2.5-1
GHW	Seal Water Supply System	9.2	9.2.7-1
QK	Safety Chilled Water System Diagram	9.2	9.2.8-1
KU	Nuclear Sampling System	9.3	9.3.2-1
KUL	Severe Accident Sampling System	9.3	9.3.2-2
KT	Nuclear Island Drain and Vent System	9.3	9.3.3-1
09.03.04-1, 09.03.04-12	Chemical and Volume Control System	9.3	9.3.4-1
KBE	Coolant Purification System	9.3	9.3.4-2
KBG	Coolant Degasification System	9.3	9.3.4-3
KBC	Reactor ~~Makeup and Inventory Control~~ Boron and Water Makeup System	9.3	9.3.4-4

9.3.4 Chemical and Volume Control System (Including Boron Recovery System)

The chemical and volume control system (CVCS) interfaces between the high pressure (HP) reactor coolant system (RCS) and low pressure (LP) systems in the Nuclear Auxiliary Building (NAB) and Fuel Building (FB). The CVCS is divided into the following three major sections:

- Letdown.
- Charging.
- Reactor coolant pump (RCP) seal water.

9.3.4.1 Design Bases

The CVCS performs the following safety-related functions:

- Maintain integrity of reactor coolant pressure boundary (RCPB) in the event of a CVCS letdown line break downstream of the RCS through closure of redundant motor-operated isolation valves. Redundant check valves in the charging line and pressurizer auxiliary spray line provide RCPB integrity.

09.03.04-3,
09.03.04-7

- Mitigate boron dilution event by automatically isolating the charging pump suction from the volume control tank (VCT) and normal letdown path.~~, and automatically aligning the charging pump suction to the in-containment refueling water storage tank (IRWST).~~
- Provide automatic isolation of charging and auxiliary spray line to prevent pressurizer over-fill in the event of a CVCS malfunction.
- Provide containment isolation by automatic closure of charging and letdown lines and RCP seal water injection and return lines.

The CVCS has the following design basis requirements and criteria:

- Safety-related portions of the CVCS are designed, fabricated, erected and tested to quality standards commensurate with the importance of the safety functions to be performed (GDC 1).
- Safety-related portions of the CVCS are designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami and seiches without loss of capability to perform their safety functions (GDC 2).
- Safety-related portions of the CVCS are not shared among nuclear power units (GDC 5).
- Safety-related portions of the CVCS are designed to maintain RCPB material integrity by means of the CVCS being capable of maintaining RCS water chemistry necessary to meet pressurized water reactor (PWR) RCS water chemistry ~~technical~~ specifications (GDC 14).

physically separated or provided with protection from internal hazards. To prevent precipitation of boric acid, CVCS components and piping containing boric acid are located within heated rooms.

Coolant Purification System

09.03.04-14

The CPS provides continuous full CVCS letdown flow purification. The CPS comprises three inlet filters, two mixed-bed ion exchangers and two outlet filters. If the letdown temperature is less than ~~150~~140°F, a three-way valve in the CVCS letdown line directs reactor coolant to the system inlet. If the letdown temperature is greater than ~~150~~140°F, the three-way valve automatically closes and bypasses the purification system. A flow diagram of the CPS is shown in ~~Figure 9.3.4-2—CPS Flow Diagram~~Figure 9.3.4-2—Coolant Purification System.

During normal operation, the reactor coolant passes from the CVCS letdown line three-way valve through two inlet filters in parallel, one mixed bed ion exchanger and two outlet filters, before returning to the CVCS letdown line downstream of the three-way valve. The inlet filters are cartridges that filter undissolved corrosion products to prevent them from entering the resin beds. The outlet filters operate in parallel and act as resin traps to prevent resin carry over into the CVCS and connecting systems. The CPS allows purification of the maximum CVCS letdown flow during plant operation.

The CPS is manually operated. The main control room (MCR) provides indications of the differential pressures across the mixed bed ion exchangers and cartridge filters. If a high differential pressure is sensed, the three-way inlet valve is closed and bypasses the system.

Both ion exchangers are initially charged with the same quantity of resin in the form of H^+ and OH^-. One ion exchanger is saturated with lithium and boron. After an equilibrium concentration is reached, this ion exchanger serves as the main purification ion exchanger. The other ion exchanger removes cesium and excess lithium produced in the RCS.

The main purification ion exchanger and the lithium and cesium removal ion exchanger operate alternately. When the upper specified lithium limit is reached, the purification flow is switched to the lithium and cesium removal ion exchanger until the lithium concentration is lowered to an acceptable level. Since the boron concentration of the CVCS letdown could be different than that of the reactor coolant following the switchover to the lithium and cesium removal ion exchanger, the downstream flow is routed to the coolant storage tanks.

When the main purification ion exchanger is exhausted or if the differential pressure across the ion exchanger bed reaches an established value, the ion exchanger is

Reactor Makeup and Inventory Control

During normal operation, the RCS inventory is maintained at a constant value by varying the letdown flow with a constant charging flow.

During a power increase, the reactor coolant expands as its temperature rises. Depending on the power level, the pressurizer absorbs these expansions as the level setpoint varies in a range designed for this purpose. If the pressurizer level increases above its setpoint, then the HP reducing valve opens to increase the letdown flow and reduce the pressurizer level to its setpoint. This excess water is drained to the VCT.

If the level in the VCT increases above its upper setpoint, a three-way valve partially diverts some of the letdown flow to the CSSS. If the level continues to increase above the upper setpoint, the total letdown flow is diverted to the CSSS tanks.

If the charging flow is greater than the letdown flow, the level in the VCT may reach the low-level setpoint. In this event, the VCT level decreases below the low-level setpoint and the VCT level is automatically adjusted. A signal initiates an automatic makeup from the reactor boron and water makeup system. This makeup automatically injects boric acid and demineralized water at rates such that the boron concentration of the makeup water corresponds to the RCS boron concentration. In the event the VCT level reaches its low-low level, the charging pump suction automatically switches to the IRWST.

09.03.04-1,
09.03.04-12

Two boric acid storage tanks are provided and separated by MOVs. Each tank is initially filled with four percent boric acid (approximately 7000 ppm boron) and has an available volume of approximately 3250 ft^3. Each tank has its own boric acid makeup pump for providing the required amount of boric acid to the charging pump suction. A flow diagram of the reactor boron and water makeup system (RBWMS) is shown in ~~Figure 9.3.4-4—RBWMS Flow Diagram~~Figure 9.3.4-4—Reactor Boron and Water Makeup System.

The demineralized water pumps that take suction from the storage tanks in the CSSS provide the demineralized water. There are six coolant storage tanks (11 through 16). Each has an available volume of approximately 4061 ft^3. A flow diagram of the CSSS is shown in ~~Figure 9.3.4-5—CSSS Flow Diagram~~Figure 9.3.4-5—Coolant Supply and Storage System.

Initially, tanks 11 through 14 are full of demineralized water and tanks 15 and 16 are empty. As reactor coolant makeup is required, the aligned boric acid storage tank provides boric acid and the CSSS tanks provide demineralized water in sequence starting with tank 14 and ending with tank 11.

As adjustments to the RCS boron concentration are required because of plant conditions (i.e., plant heatup, startup, shutdown, load follow, and to compensate for fuel burnup), demineralized water is added or a blended makeup is performed. This added water to the RCS results in the increase of the VCT level above its setpoint, which requires the discharge of reactor coolant to the CSSS. As reactor coolant discharges, water transfers sequentially into tank 16 of the CSSS first and then into tank 15. When tank 16 is approximately 55 percent full, a signal is initiated to generate processing water from the tank in the coolant treatment system (CTS). The CTS produces demineralized water and recovers the boron for reuse.

Coolant Treatment and Boron Recovery

The CVCS discharges water to the CSSS, which contains boron ranging from refueling concentration to approximately zero ppm. The CTS processes this water. A flow diagram of the CTS is shown in ~~Figure 9.3.4-6—CTS Flow Diagram~~Figure 9.3.4-6—Coolant Treatment System.

In general, evaporation separates the coolant into a concentrated boric acid solution at four percent H_3BO_3 and demineralized water. Due to the low vapor pressure of boric acid at the boiling temperature of water, the vapor generated by the evaporator has a low boric acid concentration. The vapor passes through a series of trays in the boric acid column, which further removes boric acid from the vapor.

An evaporator feed pump pumps borated water from the CSSS tank through a mixed bed ion exchanger in the purification system. Following purification, the water is preheated and fed into the boric acid column. The water in the column sump circulates through the tube side of the evaporator by natural circulation and is evaporated. Most of the heat required for evaporation leaves the column with the vapor. This vapor heat is utilized by compressing the vapor, which increases its temperature. Then the vapor is discharged to the shell side of the evaporator. This process condenses the vapor so it can be collected in a condensate tank. The condensate pumps transfer the condensate to the CSSS for reuse in the CVCS makeup.

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The boric acid solution in the boric acid column is measured and controlled to maintain its boric acid concentration at an approximately constant four percent by weight which corresponds to ~~7100~~7000 ± 100 ppm boron ~~± 100~~. The boric acid solution is cooled and transferred to the RBWMS storage tanks for reuse in the CVCS makeup.

If the condensate produced by the evaporator requires degasification, it can be discharged to the degasification unit prior to its discharge to the CSSS tanks.

9.3.4.2.2 Component Description

A summary of design data for the major components of the CVCS is provided in Table 9.3.4-1—Major CVCS Component Design Data.

were in operation. Therefore, the initial cooldown is performed with two CVCS charging pumps in operation.

When the RCS temperature is about 250°F, the RHRS is connected to the RCS. The low head safety injection (LHSI) and RHR heat exchangers continue the cooldown. When the temperature downstream of the LHSI and RHR heat exchangers is approximately 130°F and primary pressure is approximately 350 psig, the HP reducing stations are isolated and the LP reducing station is opened.

After depressurization of the RCS, CVCS charging pumps are secured and bypassed, and the LHSI and RHR pumps inject water into the RCP seals or the RCP seal injection flow may be isolated.

To permit purification of the reactor coolant, the pressurizer level control system is switched from the HP reducing station to the LP reducing station at an RCS temperature of approximately 130°F, and the HP reducing station is closed. Reactor coolant, downstream of the LHSI and RHR heat exchangers, flows to the LP reducing station into the CVCS letdown line then through the CPS. The discharge from the CPS is returned to the letdown line and bypasses the VCT and charging pumps and is returned to the RCS via the charging lines.

9.3.4.2.3.4 Abnormal Operation

During abnormal operation, the CVCS continues to operate as designed. If a malfunction results in the letdown temperature exceeding that required for purification or degasification, those systems are automatically bypassed and the CVCS continues normal operation. In the event of a faulty closure of a charging line valve, a minimum flow valve opens and recirculates charging flow to the VCT to protect the charging pumps. Other abnormal operating conditions can result in a dilution incident or a loss or gain in reactor coolant inventory.

Four online boron concentration measurement instruments are installed on the charging line, upstream of the branch line to the seal water to measure the boron concentration of the total charging flow. The online boron meters are a half shell design and are not in contact with the reactor coolant. The neutron absorption effect of Boron-10 is used to measure the concentration of boron. The number of neutrons passing through the fluid depends on its Boron-10 content. The measured count rate is used to calculate the boron concentration. To improve the accuracy of the measurement, the temperature of the reactor coolant at the measuring point is used to adjust the boron concentration.

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If the boron concentration decreases below a setpoint to indicate a possible dilution event, a signal is sent to isolate the charging pump suction. Three safety-related MOVs automatically isolate the normal letdown line and the line from the VCT.~~ and a valve from the IRWST automatically aligns to the charging pump suction providing borated~~

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~~water to the RCS.~~ The closure of these three safety-related valves terminates the dilution event. Simultaneously, a non-safety-related valve opens aligning the charging pump suction to the IRWST, the charging line isolation valves are closed and the three-way valve to the coolant storage and supply tanks fully opens. The charging flow to the RCP seal water system remains in service during this evolution. These actions are performed by non-safety-related equipment and are not credited in the safety analysis.

9.3.4.2.3.5 Accident Conditions

During accident conditions, the CVCS continues to operate normally unless an SIS actuation, containment isolation signal (CIS) (refer to Section 6.2.4) or a high pressurizer level signal is received. In the event of an SIS actuation, the RCPB valves in the letdown line isolate. In the event a CIS (Stage 1) is actuated, the CVCS letdown line isolates while the RCP seal injection and leakoff, and CVCS charging continue to operate normally. If a CIS (Stage 2) is actuated, the RCP seal injection and leakoff lines, as well as the charging line, isolate. The charging pumps continue to operate on minimum flow recirculation. The CVCS mitigates a reactor coolant inventory increase event (refer to Section 15.5.2). Upon a high pressurizer level, the charging line isolation valve, the auxiliary spray isolation valve, and the charging line CIV close.

The CVCS mitigates a boron dilution event (refer to Section 15.4.6). The sequence of events for the CVCS is described in the preceding section (Section 9.3.4.2.3.4). ~~Also, in the event of a high pressurizer level, the charging line isolation valve, the auxiliary spray isolation valve and the charging line CIV close.~~

The CVCS components and valve operators are provided with emergency power and are available following a LOOP. If the RCPs are not operating, the CVCS auxiliary spray line provides auxiliary spray.

Interfacing System Loss of Coolant Accident

Breaks of the CVCS Outside the Containment - In the event of a letdown line break in the FB during normal plant operation, the break flow has a temperature of approximately 120°F. This leakage can be identified by:

- Pressure and temperature measurements in the letdown line.
- Alarm interlocking: initiated by the VCT low water level.
- Sump high water level in the FB vent and drain system.
- Increased activity measurements in the exhaust air ducts of the FB ventilation system for noble gas, airborne, and iodine radiation monitors.

Level Measurements

VCT level high or low—As the level decreases from its normal setpoint, a low-level results in the RBWMS supply initiating automatic makeup, an MCR alarm, and the tripping of one charging pump if two are operating. A minimum level initiates an MCR alarm, the closure of the redundant charging pump suction valves from VCT and letdown line, and the opening of the isolation valve from the IRWST to the charging pump suction. A high level initiates an MCR alarm and the diversion of letdown to the CSSS.

Boron Concentration Measurement

Charging line boron concentration below setpoint—A charging flow measured boron concentration below its setpoint value initiates an MCR alarm, the closure of the redundant charging pump suction valves from the VCT and letdown line, and the opening of the isolation valve from the IRWST to the charging pump suction.

9.3.4.6 References

09.03.04-18

1. ~~EPRI TR-105714, "PWR Primary Water Chemistry Guidelines," Revision 3, Electric Power Research Institute, 1995.~~EPRI Report 1014986, "PWR Primary Water Chemistry Guidelines," Revision 6, Electric Power Research Institute, December 2007.
2. ASME Boiler and Pressure Vessel Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," The American Society of Mechanical Engineers, 2004.

Table 9.3.4-1—Major CVCS Component Design Data
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Design Parameter		Value
LP Reducing Station	Nominal diameter	4 in
	Design pressure	1160 psig
	Design temperature	664°F
	Type	Control valve
	Cv min / norm / max	Approx. 2 / 27 / 77
Coolant Filters	Number	3
	Type	Cartridge filter
	Volume gross/net	7.0 / 7.0 ft^3
	Design pressure	175 / -14.5 psig
	Design temperature	212°F
	Operating pressure	70–115 psig
	Operating temperature	122°F
	Retention rate	~~0.45~~10.0 micron
	Efficiency	98 percent
	Material	Austenitic stainless steel
Coolant Purification Mixed Bed Ion Exchanger	Number	2
	Type	Pressure tank with toro-spherical head
	Total volume	120 ft^3
	Resin volume	70 ft^3
	Design pressure	175 / -14.5 psig
	Design temperature	212°F
	Operating pressure	70 psig
	Operating temperature	122°F
	Sieve tray gap width	200 micron
	Material	Austenitic stainless steel

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Figure 9.3.4-4—Reactor Boron and Water Makeup ~~and Inventory Control~~ System
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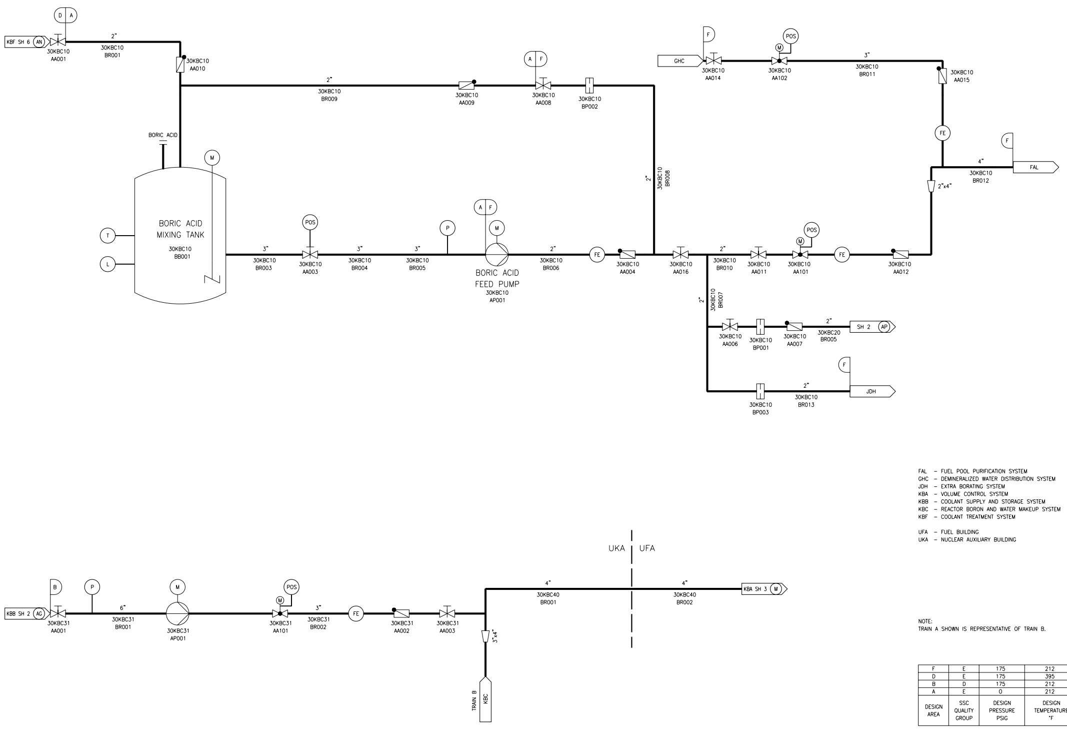

FAL – FUEL POOL PURIFICATION SYSTEM
GHC – DEMINERALIZED WATER DISTRIBUTION SYSTEM
JDH – EXTRA BORATING SYSTEM
KBA – VOLUME CONTROL SYSTEM
KBB – COOLANT SUPPLY AND STORAGE SYSTEM
KBC – REACTOR BORON AND WATER MAKEUP SYSTEM
KBF – COOLANT TREATMENT SYSTEM

UFA – FUEL BUILDING
UKA – NUCLEAR AUXILIARY BUILDING

NOTE:
TRAIN A SHOWN IS REPRESENTATIVE OF TRAIN B.

F	E	175	212	NSC
D	E	175	395	NSC
B	D	175	212	NSC
A	E	0	212	NSC
DESIGN AREA	SSC QUALITY GROUP	DESIGN PRESSURE PSIG	DESIGN TEMPERATURE °F	SSC SEISMIC CLASS

KBC01T2