RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**307-7835**
SRP Section:	**05.04.01 – Reactor Coolant Pumps**
Application Section:	**5.4.1**
Date of RAI Issue:	**11/16/2015**

Question No. 05.04-1

10 CFR 52.47(a)(2) and GDC 44 of Appendix A to 10 CFR Part 50 provide the regulatory basis for the following questions.

10 CFR 52.47(a)(2) requires that a standard design certification applicant provide a description and analysis of the structures, systems, and components (SSCs) of the facility, with emphasis upon performance requirements, the bases, with technical justification therefor, upon which these requirements have been established, and the evaluations required to show that safety functions will be accomplished.

GDC 44, "Cooling Water," states "a system to transfer heat from structures, systems, and components important to safety, to an ultimate heat sink shall be provided. The system safety function shall be to transfer the combined heat load of these structures, systems, and components under normal operating and accident conditions." SRP Section 9.2.2, "Reactor Auxiliary Cooling Water System," provides guidance for this area of review. SRP Section 9.2.2, Point II.4.G (for meeting, in part, requirements of GDC 44) requires "[D]emonstration by testing that RCPs withstand a complete loss of cooling water for 20 minutes and instrumentation in accordance with Institute of Electrical and Electronics Engineers Standard (IEEE Std) 603, as endorsed by RG 1.153 with control room alarms detecting loss of cooling water so a period of 20 minutes is available for the operator to have sufficient time to initiate manual protection of the plant."

1. DCD Subsection 5.4.1.2 states that "The RCP shaft seals are cooled by (1) seal injection water from the CVCS and (2) the component cooling water (CCW) through a high-pressure seal cooler. Pump seal <u>operation may continue indefinitely</u> provided either seal injection water or the CCW is available. The APR1400 design includes an additional support system (i.e., auxiliary charging pump). This system features a positive displacement pump to provide a diverse means of seal injection to the RCPs if the normal means of seal cooling are lost. Detailed descriptions are given in Subsections 9.2.2.3 and

9.3.4.2." The staff could not find a detailed description of the seal injection flow paths into and within each of the seal stages in the DCD Subsections 9.2.2.3 and 9.3.4.2. Without such details, the staff could not validate that pump seal operation may continue indefinitely as stated above. At the staff's request in the non-Chapter 15 audit plan, the applicant presented a non-proprietary document which shows the seal injection flow paths including the existence of an auxiliary impeller, integral to the pump shaft, which provides the driving force for recirculation of seal water through the external high-pressure seal cooler. The applicant is requested to add those details to DCD Subsection 5.4.1 as part of the pump design description.

2. DCD Subsection 9.2.2.5, Instrumentation Requirements, states, in part, "RCPs 1A, 1B, 2A, and 2B thermal barrier (e.g., seal cooler, high-pressure cooler) outlet temperatures." The staff noted that term "thermal barrier" is not used nor described in DCD Subsection 5.4.1. The applicant is requested to address this inconsistency between DCD Subsection 9.2.2.5 and DCD Subsection 5.4.1.

3. DCD Subsection 5.4.1.2 states that "In the event of loss of either seal injection to the seal assembly or loss of CCWS flow to the high-pressure seal cooler, the seal cooling water temperature increases. Performance tests and analyses have shown that a minimum margin of 12.2 C (22 F) exists between the seal cooling water outlet temperature and the seal cooling water temperature limit specified by the pump manufacturer. The staff could not find a summary of these performance tests and analyses within DCD Subsection 5.4.1. Without such information, the staff could not validate the stated temperature margin. The applicant is requested to provide a summary of the test results in DCD Subsection 5.4.1, and a reference to the document where these tests and analyses are described.

4. In DCD Figure 5.1.2-2, the staff noted the use of a jet pump in the seal injection line from CVCS. A description of this jet pump and its functional requirements are not provided in DCD Subsection 5.4.1. The applicant is requested to add these details for the jet pump in DCD Subsection 5.4.1.

5. DCD Subsection 5.4.1.2 states "If there is a simultaneous loss of CCW to all RCP and motor bearing assemblies but seal injection water is available to the seals, the RCP can operate for at least 30 minutes without bearing seizure, which could affect normal RCP coastdown." DCD Subsection 9.2.2 identifies RCP pump/motor oil coolers and the charging pump mini-flow heat exchanger as nonessential components supported by the Division I CCW pump. Based on the above descriptions, a failure of the Division I CCW pump will affect both the charging pump and the RCP pump/motor bearings. Therefore, the staff questions the availability of seal injection water during the stated 30-minute period. The applicant is requested to provide more detail on the following: a) Since the CCWS provides cooling water to both the CVCS (charging pump mini flow heat exchangers) and oil coolers for the RCP pump/motor bearings, explain what is meant by loss of CCW, and b) If "loss of CCW" includes cooling flow to CVCS, explain how seal injection flow to the RCPs will not be affected for "up to 30 minutes" to prevent seal damage.

6. In DCD Subsection 5.4.1.2, the bases for the design of an anti-reverse rotation device are provided, but the staff could not find the description of this device within DCD Section 5.4.1. At the staff's request in the non-Chapter 15 audit plan, the applicant presented a non-proprietary document which shows details of the anti-reverse rotation device. The applicant is requested to add those details to DCD Subsection 5.4.1 as part of the pump design description.

7. In DCD Subsection 5.4.1.2, the applicant states "As the seal is intended to withstand adverse SBO conditions, it is verified by a robust test program. The applicant is requested to provide a summary of the test results in DCD Section 5.4.1, and a reference to the document that describes this program.

8. In DCD Subsection 5.4.1.2, the applicant provides very limited information on the pump and motor bearing types used to support safe and reliable pump operation. At the staff's request in the non-Chapter 15 audit plan, the applicant presented a non-proprietary document which shows needed details for these pump and motor bearings. The applicant is requested to add those details to DCD Subsection 5.4.1 as part of the pump design description.

Response

1. Additional information from those provided for the non-Chapter 15 audit will be included in DCD Subsection 5.4.1.

2. DCD Subsection 9.2.2.5 will be corrected by removing "thermal barrier" to be consistent with 5.4.1.

3. A summary report of the test results for the 22 ℉ temperature margin has been uploaded to ERR, titled "Justification that the APR1400 RCP seals will not exceed the exit temperature specification limit" which is proprietary and not intended to be included in DCD. This report provides 1) documentation of the basis for the 22°F margin and 2) a justification that this margin is applicable to the APR1400 RCP seals. APR1400 RCP specification identifies the same 180°F limit for the RCP outlet temperature as the System 80 RCP specification and similar loss of component cooling water and/or loss of seal injection tests have been performed on both pumps to sufficiently justify the 22°F margin for the APR1400 RCPs.

4. Additional information from those provided for the non-Chapter 15 audit will be included in DCD Subsection 5.4.1.

5. The seal injection flow is provided by one of two charging pumps or an auxiliary charging pump of CVCS as described in DCD Subsections 5.4.1.2, 9.2.2.3, and 9.3.4.2. The auxiliary charging pump provides diverse means of seal injection when the normal means by the charging pump are unavailable. The operation of the auxiliary charging pump is not affected by loss of CCW whereas the charging pump is affected by improper function of the charging pump mini flow heat exchangers due to loss of CCW. If loss of CCW

prevents the charging pump from proper operating, the seal injection flow to the RCP can be supplied by the auxiliary charging pump to prevent seal damage.

6. The only functional requirement of the anti-reverse rotation device for APR1400 RCP Motor is to prevent rotation in the reverse direction without damage when reverse torques are induced as described in Subsection 5.4.1.2 of DCD. Safety and function of APR1400 are not affected by the type of an anti-reverse rotation device. The document that was reviewed by staff in the non-Chapter 15 audit is actually proprietary as opposed to non-proprietary. Thus the details on the design of the device are vendor specific data; therefore, APR1400 DCD will not incorporate the details on the device.

7. The planning and execution of the seal tests is now in progress so that any documented information for the tests is currently not available. Test results are considered proprietary for the seal supplier and inappropriate to be included or referred in DCD. However, after the tests have been completed, available information will be uploaded to ERR for NRC review. Incorporating a general summary of tests into DCD will be considered in the future.

8. Additional information from those provided for the non-Chapter 15 audit will be included in DCD Subsection 5.4.1.

Impact on DCD

DCD Subsections 5.4.1 and 9.2.2.5 will be revised as indicated on the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environment Report.

e. A surface examination of all exposed surfaces and a 100 percent volumetric examination by ultrasonic methods are conducted at approximately 10-year

The pump shaft assembly is supported by a lower water lubricated journal bearing and an oil lubricated combination journal and thrust bearing. The lower bearing is a conventional hydrodynamic sleeve bearing. The combination journal and thrust bearing consists of two journal bearings and a double-acting tilting pad type thrust bearing. The thrust bearing carries upward thrust during normal operation and downward thrust during operation under low system pressure. Two journal bearings are used to increase shaft stiffness and ensure positive guidance of the shaft assembly during normal operation of the pump.

5.4.1.2 <u>Description</u>

Table 5.4.1-1 lists the principal parameters of the reactor coolant pumps, and Figure 5.4.1-1 depicts the arrangement of the pump and motor. Reactor coolant pump supports are described in

Figure 5.1.2-

As indicated in Figure 5.4.1-2, seal injection water enters into the high pressure piping at a point below the water lubricated bearing and is directed through the cyclone filter/jet pump assembly to the high pressure cooler before being injected into seal system. The effluent from the high pressure cooler enters the high pressure side of the first seal and is divided into two flow paths. A majority of the flow is pumped through the journal bearing by the auxiliary impeller. This cools the journal bearing and minimizes the ingress of contaminants into the seal system. The second flow path is into the first seal and through a throttle coil to the high pressure side of the second seal. Flow from the second seal continues through another throttle coil to the third seal and then to the volume control tank within the chemical and volume control system. The controlled leakage around the seals is required for seal pressure distribution. Should injection water fail, controlled bypass leakage comes from the pump casing and passes through the high pressure cooler by natural circulation. As described above, a portion of this water is circulated by the auxiliary impeller through the journal bearing, high pressure cooler and back to the seal area.

The four re

discharge, m

its shaft. P

the pump ar

motor shafts

The pump ro

is a one-piec

one-piece ca

The pressure boundary materials used for the reactor coolant pump assembly are listed in Table 5.2-2, are compatible with the reactor coolant addressed in Subsection 5.2.3.2.1.

The shaft seal assembly consists of two face types, mechanical seals in series, with a controlled leakage bypass to provide the same pressure differential across each seal. The seal assembly is designed for the pressure differential of 175.8 kg/cm^2 (2,500 psi) and to reduce the leakage pressure from the RCS pressure to the volume control tank pressure. A third, face-type, low-pressure vapor seal at the top is designed to withstand system operating pressure when the pumps are not operating. ~~The leakage past the second~~

~~pressure seal and the controlled leakage are piped to the volume control tank in the chemical and volume control system.~~ Leakage past the low-pressure vapor seal is collected and piped to the reactor drain tank.

The temperature of the water in the seal assembly is maintained within acceptable limits by a water-cooled heat exchanger (HX). Water is also injected into the seal area from an external seal injection system. The performance of the shaft seal system is monitored by pressure and temperature sensing devices in the seal system. The seal assembly can be replaced without draining the pump casing or removing the shaft.

The RCP shaft seals are cooled by (1) seal injection water from the CVCS and (2) the component cooling water (CCW) through a high-pressure seal cooler. Pump seal operation may continue indefinitely provided either seal injection water or the CCW is available. The APR1400 design includes an additional support system (i.e., auxiliary charging pump). This system features a positive displacement pump to provide a diverse means of seal injection to the RCPs if the normal means of seal cooling are lost. Detailed descriptions are given in Subsections 9.2.2.3 and 9.3.4.2.

In the event of loss of either seal injection to the seal assembly or loss of CCWS flow to the high-pressure seal cooler, the seal cooling water temperature increases. Performance tests and analyses have shown that a minimum margin of 12.2 °C (22 °F) exists between the seal cooling water outlet temperature and the seal cooling water temperature limit specified by the pump manufacturer.

If there is a simultaneous loss of CCW to all RCP and motor bearing assemblies but seal injection water is available to the seals, the RCP can operate for at least 30 minutes without bearing seizure, which could affect normal RCP coastdown. This is discussed further in Subsection 5.4.1.3.

The seal assemblies are designed to limit seal leakage plus controlled bypass flow per pump to approximately the following values:

All seals functioning (normal)	12.1 L/min (3.2 gpm)
One seal functioning (abnormal)	16.7 L/min (4.4 gpm)

An acoustic leak sensor is provided on the shaft seal housing for use in detecting leakage coming through in the vapor seal of the pump. A description of the acoustic leak monitoring system (ALMS) is provided in Subsection 7.7.1.5

The need for improved station blackout (SBO) performance has led to selected improvements in the design of the seal. The seal uses an enhanced manufacturing process and improved composition of elastomer materials to provide high temperature seal performance at 300 °C (572 °F) and 163.1 kg/cm²G (2,320 psig). Key materials used in the seals are silicon carbide/graphite compound material for the glide rings (primary seals) and specially treated (high-temperature-resistant) ethylene propylene diene monomer (EPDM) elastomers (secondary seals). Both materials are capable of withstanding long-term exposure to a high temperature and pressure environment. Seal dimensions and normal operational characteristics are basically unchanged from those in pump assemblies in existing
is verified b

The motor is sized for continuous operation at the flows resulting from a four-pump or one-pump operation with a 1.0 to 0.74 specific gravity of water. The motors are designed to start and accelerate to speed under full load with a drop to 80 percent of normal rated voltage at the motor terminals.

The rotor bearing of RCP motor consists of a lower radial journal bearing and a upper combination journal and thrust bearing. Both bearings are oil lubricated and have oil-to-water coolers, which dissipate heat from the bearings when the machine is rotating.

Each RCP motor is equipped with two air-to-water heat exchangers such that the temperature of motor cooling outlet air discharged to the containment is less than the maximum containment ambient temperature. Electrical insulation of the motor is suitable for a high humidity and high radiation environment.

Each motor is provided with an anti-reverse rotation device. The device is designed to prevent impeller rotation in the reverse direction, assuming each of the following two conditions: (1) motor starting torque if the motor was incorrectly wired for reverse rotation and (2) reactor coolant flow through the pump in the reverse direction due to the largest pipe break remaining after the application of leak before break as described in Subsection 3.6.3.

The RCP assembly is equipped with an oil collection system to collect oil leakage. The oil collection system is capable of collecting lube oil from all potential pressurized and

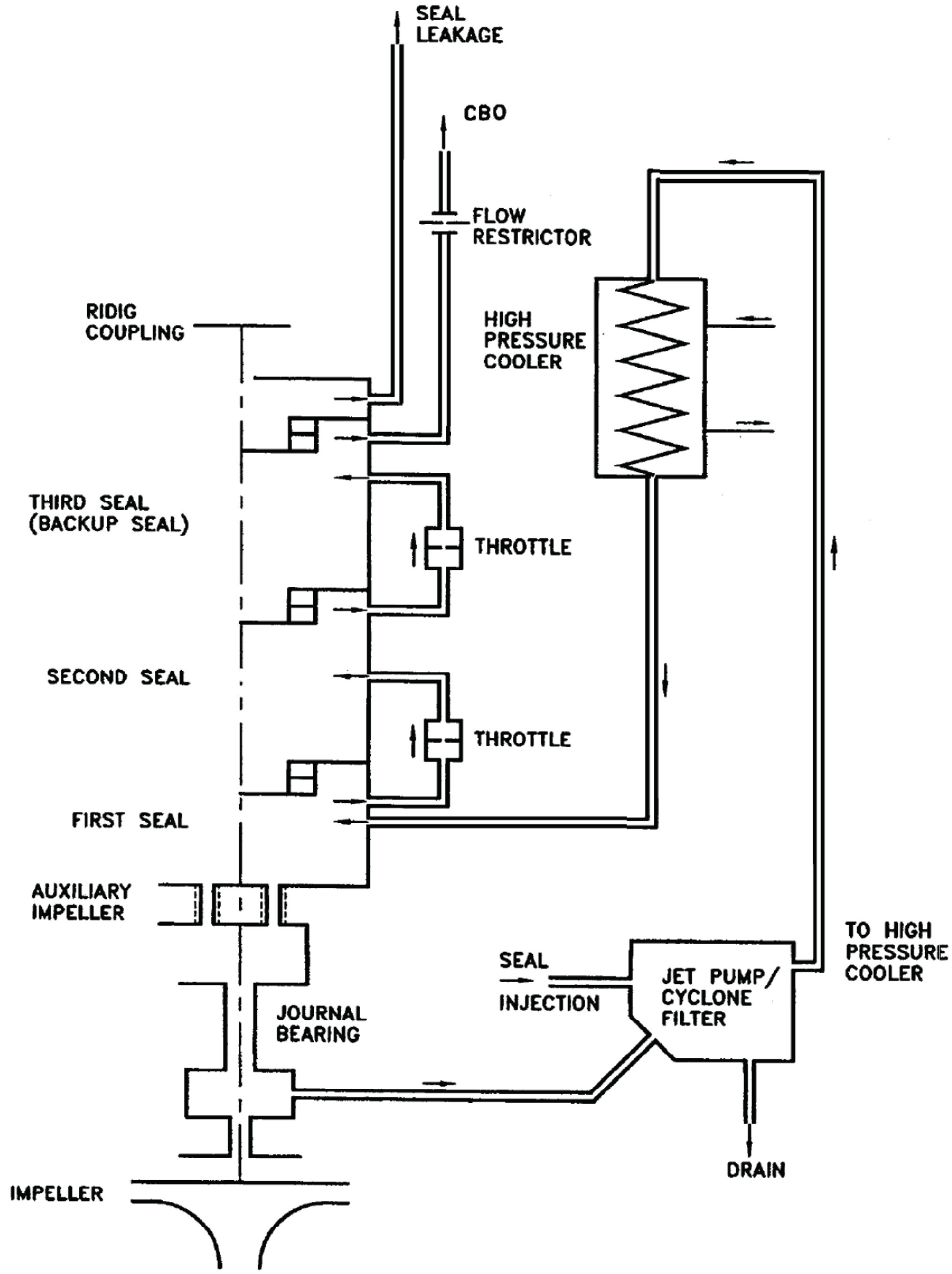

Figure 5.4.1-2 Flow Diagram for Reactor Coolant Pump Shaft Seal System

The CCWS instrumentation facilitates automatic operation, remote control, and continuous indication of system parameters locally and in the MCR. MCR process indications and alarms are provided to enable the operator to evaluate the CCWS performance and to detect malfunctions.

The major CCW parameter measurements and indication instrumentation are described below.

9.2.2.5.1 Pressure Instrumentation

a. MCR indication

CCW pump common discharge header pressure in each division is displayed.

b. Controls – CCW pump discharge pressure

When a low CCW pump discharge pressure signal is actuated, the standby pump in that division automatically starts. This signal is indicative of a failure of the operating pump, line break, or an increase of the required cooling water flow.

9.2.2.5.2 Temperature

a. Main control room indication

MCR indication is provided for the following process temperature parameters:

1) CCW heat exchanger outlet header temperature

2) SC heat exchanger 1 and 2 outlet temperatures

3) Letdown heat exchanger outlet temperature

4) RCPs 1A, 1B, 2A, and 2B motor ~~oil~~ [Delete] coolers outlet temperatures

5) RCPs 1A, 1B, 2A, and 2B ~~thermal barrier (e.g., seal cooler, high-pressure cooler)~~ [coolers] outlet temperatures