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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 44 Related to ESBWR Design Certification Application – Reactivity Control System – RAI Numbers 4.6-24 through 4.6-26, 4.6-29 through 4.6-33, 4.6-35 through 4.6-37**

Enclosure 1 contains GE's response to the subject NRC RAIs transmitted via the Reference 1 letter.

If you have any questions about the information provided here, please let me know.

Sincerely,

Kathy Sedney for

David H. Hinds
Manager, ESBWR

D068

Reference:

1. MFN 06-255, Letter from U.S. Nuclear Regulatory Commission to David Hinds, *Request for Additional Information Letter No. 44 Related to ESBWR Design Certification Application,* July 25, 2006

Enclosure:

1. MFN 06-261 – Response to Portion of NRC Request for Additional Information Letter No. 44 Related to ESBWR Design Certification Application – Reactivity Control System – RAI Numbers 4.6-24 through 4.6-26, 4.6-29 through 4.6-33, 4.6-35 through 4.6-37

cc:		
	WD Beckner	USNRC (w/o enclosures)
	AE Cubbage	USNRC (with enclosures)
	LA Dudes	USNRC (w/o enclosures)
	GB Stramback	GE/San Jose (with enclosures)
	eDRF	0000-0056-2313

Enclosure 1

MFN 06-261

Response to Portion of NRC Request for

Additional Information Letter No. 44

Related to ESBWR Design Certification Application

Reactivity Control System

RAI Numbers 4.6-24 through 4.6-26, 4.6-29 through 4.6-33,

4.6-35 through 4.6-37

NRC RAI 4.6-24

DCD Tier 1, Section 2.2.2 and ITAAC #4 of Table 2.2.2-1 provide time requirements for the "average" scram insertion for all FMCRDs. The hydraulic-powered rapid control rod insertion time requirements for each FMCRD needs to be specified as maximum allowable insertion time to a given insertion point (e.g. notch) similar to Standard Technical Specifications.

GE Response

GE will change the text in Tier 1 and Tier 2 as follows.

DCD Tier 1 Subsection 2.2.2 (Page 2.2-9):

"The ~~average~~ maximum allowable scram insertion times ~~of all~~ for each FMCRD~~s~~ are:

DCD Tier 1 Table 2.2.2-1, Item 4, Design Commitment and Acceptance Criteria columns (Page 2.2-12):

"The ~~average~~ maximum allowable scram insertion times ~~of all~~ for each FMCRD~~s~~ are . . ."

DCD Tier 2 Subsection 4.6.1.2.4 (Page 4.6-15):

"Table 4.6-2 shows the scram performance provided by the CRD system at full power operation, in terms of the ~~average~~ maximum elapsed time for each control rod to attain the listed scram position (percent insertion) after loss of signal to the scram solenoid pilot valves (time zero)."

Tier 1 DCD Subsection 2.2.2 and Tier 2 DCD Section 4.6 will be revised in the next update as noted above.

NRC RAI 4.6-25

DCD Tier 1, Section 2.2.2 states that each hydraulic control unit (HCU) "also provides the flow path for purge water to the associated drives during normal operation." Discuss this mode and any other CRD system line-up and their potential impact on scram insertion. Also, is it possible to unseat the hollow piston from the ball nut as a result of excess purge flow?

GE Response

During normal plant operation, the air-operated flow control valves located in the purge water header maintain the FMCRD purge water flow to the HCUs at a constant value. To accomplish this, the control valves provide pressure breakdown of the high CRD pump discharge pressure so that the pressure of the purge flow entering the individual HCUs is only slightly above that of the reactor. At the same time the scram accumulators are maintained fully charged and pressurized through the charging water header by the full discharge pressure of the CRD pumps. When the scram valve is opened the full accumulator pressure is applied to the downstream piping. The high differential pressure between the accumulator and the purge water header causes the purge water check valve to close. This allows all scram flow to be directed to the FMCRDs.

As long as the scram accumulator remains charged, there is no operating mode of the CRD system that can impact the scram insertion mode. As described in DCD Tier 2 Subsection 4.6.1.2.4, the accumulator charging water header incorporates the following features to maintain the capability of the scram function.

Pressure instrumentation is provided in the charging water header to monitor header performance. The pressure signal from this instrumentation is provided to both the RC&IS and RPS. If charging water header pressure degrades, the RC&IS initiates a rod block and alarm at a predetermined low-pressure setpoint. If pressure degrades even further, the RPS initiates a scram at a predetermined low-low pressure setpoint. This ensures the capability to scram and reactor shutdown before the HCU accumulator pressure can degrade to the level where scram performance is adversely affected following the loss of charging header pressure.

The charging water header contains a check valve and a bladder type accumulator. The accumulator is located downstream of the check valve in the vicinity of the low header pressure instrumentation. It is sized to maintain the header pressure downstream of the check valve above the scram setpoint until the standby CRD pump starts automatically, following a trip or failure of the operating CRD pump. Pressure instrumentation installed on the pump discharge header downstream of the CRD pump drive water filters monitors system pressure and generates the actuation signals for startup of the standby pump if the pressure drops below a predetermined value that indicates a failure of the operating pump.

With regard to the possibility of unseating the hollow piston from the ball nut as a result of excess purge flow, this is not considered a concern. Normal purge flow to an individual drive is 1.3 liter/minute. The flow needed to generate enough pressure drop across the hollow piston to overcome the weight of the hollow piston and control rod to cause the separation to occur is approximately 40 liter/minute or more. Because the HCUs are all headered together downstream of the purge water flow control valves and the purge flow is distributed uniformly to all the FMCRDs it is impossible to deliver this magnitude of flow to an individual FMCRD. The CRD pump does not have sufficient capacity for this to occur. Even during the post-scram condition with the CRD pump at its runout condition the flow to the FMCRDs is only 1.7 liter/minute per drive.

No DCD changes will be made in response to this RAI.

NRC RAI 4.6-26

With regard to blowout support, DCD Tier 2, Section 4.6.1.2.2 states, "...after the interconnected assembly of the housing, CRD and [control rod guide tube] CRGT moves down a short distance, the flange at the top of the CRGT contacts the core plate, stopping further movement of the assembly." Whereas, DCD Tier 2, Section 4.1.2.1.2 states, "Each guide tube, with its orificed fuel support, bears the weight of four assemblies and is supported on a CRD penetration nozzle in the bottom head of the reactor vessel."

(a) Describe in further detail the support of the fuel assemblies and the core support plate. Include in your response, address thermal expansion and contraction of the reactor vessel and internals.

(b) Describe the design margin between the CRGT flange elevation and core support plate elevation. In your response, address (1) thermal expansion and contraction of the reactor vessel and (2) differential growth between the reactor vessel and CRGT.

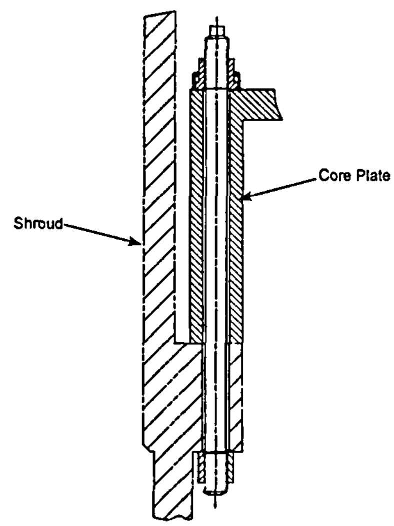
GE Response

There is no contradiction between DCD Tier 2 Subsections 4.6.1.2.2 and 4.1.2.1.2. Subsection 4.1.2.1.2 describes the reactor configuration in its normal state. In this condition the weld between the CRD housing and the CRD penetration nozzle in the reactor bottom head carries the full weight of the four fuel assemblies, the orificed fuel support, the control rod guide tube and the FMCRD. There is a small gap between the flange at the top of the control rod guide tube and the top of the core plate in this normal state. Subsection 4.6.1.2.2 describes the rod ejection condition in which the weld between the CRD housing and CRD penetration nozzle fails completely. In this case the control rod guide tube drops down a distance equal to the normal gap until its flange at the top engages with the core plate. The core plate then supports the full weight of the four fuel assemblies, the orificed fuel support, the control rod guide tube and the FMCRD and thereby prevents a rod ejection. The core plate is supported by a flange on the inside diameter of the shroud. Shroud support brackets attached to the vessel bottom head in turn support the shroud.

(a) In addition to the description of the support of the fuel assemblies given in DCD Tier 2, Sections 4.1.2.1.2 and 4.6.1.2.2, further descriptions of the fuel supports and the core plate are given in Section 3.9.5.1. Schematic illustrations of the fuel support pieces are shown in Figure 3.9-4. The core plate that provides lateral support of the fuel is bolted to a ledge at the inside lower portion of the shroud as shown in the figure below.

The width of the gap between the flange at the top of the CRGT and the core plate as shown in DCD Tier 2, Figure 4.6-7 is determined to ensure that there will be no interference between the two components during any loading condition of the reactor. In calculating the required gap, the differential thermal expansion between the low alloy reactor vessel and the austenitic stainless steel shroud, core plate and CRGT are considered. Also, included in the calculation are the dilation of the vessel due to internal

pressure and the upward movement of the core plate due to the differential pressure across the core plate.



Typical Core Plate to Shroud Connection

(b) The size of the gap between the CRGT flange and core plate will be determined upon completion of the detailed design of the reactor vessel and the core support structure. A margin comparable to that of earlier BWRs will added to the calculated value to ensure that there will be no interference during any loading condition of the reactor.

No DCD changes will be made in response to this RAI.

NRC RAI 4.6-29

DCD Tier 2, Section 4.6.1.2.1 describes the spring-loaded latches on the hollow piston that engage slots in the guide tube and support the control rod and hollow piston in the inserted position following a scram.

(a) Failure of these latches to secure the control rod in the full in position would result in significant power peaking and loss of shutdown margin (until the motor driven ballnut travels a distance and reinserts the control rod). Due to the importance of these spring-loaded latches, an new ITAAC should be added (or an existing one modified) to specifically test this device.

(b) Describe the slot locations on the guide tube.

GE Response

(a) The latches are exercised on every scram. They engage with slots in the guide tube to retain the hollow piston in the top latched position until the ball nut is driven up to reengage the hollow piston and release the latch. The continuous full-in position indicator light provides the confirmation following scram that the latches perform their holding function. This function will be tested as part of the scram testing defined by the ITAAC Item No. 4 in Tier 1 DCD Table 2.2.2-1. GE believes this is sufficient confirmation of the latches operability and that no additional ITAAC test specific to the latches is necessary.

(b) There are two rows of slots (latching positions) in the guide tube wall located diametrically opposite from each other. In each row the slots are at 420 mm intervals; however, the two rows are offset from each other such that slots are staggered at 210 mm intervals. In other words, there is a slot located at every 210 mm interval alternating from one side of the guide tube to the other. At the full-in position there are slots on both sides of the guide tube for the post-scram holding function.

No DCD changes will be made in response to this RAI.

NRC RAI 4.6-30

DCD Tier 2, Section 4.6.1.2.2 states, "Each FMCRD provides two position detectors, one for each control system channel, in the form of signal detectors directly coupled to the motor shaft through gearing." This section goes on to state, "This configuration provides continuous detection of rod position during normal operation." Please provide detail on the accuracy of this position indication and all others and address the concern that the above position detection is on the motor and not on the hollow piston.

GE Response

The signal detectors and RC&IS control logic provide a total closed loop positioning accuracy of ± 15 mm. This means that the actual position of the control rod is always within 15 mm of the target position.

The ESBWR FMCRD and its control uses a simple on/off control via contactor for motor start and stop operation. Upon the loss of motor power, a built-in AC brake engages and stops the motor rotation. The drive position information is used to determine the timing of the loss of motor power such that motor power is cut off when the drive position reaches a certain distance short of the target position. The positioning accuracy of ± 15 mm comprises the variation in braking distance and the accuracy of position detection.

The use of signal detectors geared to the motor shaft is the same as the ABWR FMCRD. The ABWR FMCRD design, in turn, was based on European FMCRD designs that also use the same approach for position detection. Thus, there are many years of operating experience demonstrating the reliability of this design. Essentially, the signal detectors sense the number of rotations of the FMCRD ball screw and translate that information into an analog signals corresponding to control rod position. This provides the required accuracy required for fine positioning of the control rod in the 36.5 mm step increments.

No DCD changes will be made in response to this RAI.

NRC RAI 4.6-31

DCD Tier 2, Section 4.6.1.2.2 describes the FMCRD components. Included in this section is a discussion of the spring-loaded control rod separation mechanism. Over time, irradiation-induced spring relaxation may impact the ability of this mechanism to perform its safety-related function. Please discuss the potential impact of neutron fluence on this component as well as other spring-loaded mechanisms.

GE Response

Irradiation-induced spring relaxation is not considered a concern until neutron fluence is greater than 10^{19} n/cm^2 (E> 1 Mev).

The FMCRD control rod separation spring is housed in the spool piece assembly that attaches to the upper drive assembly at the CRD housing flange located below the reactor bottom head in the undervessel region. This location is more than 7 meters below the bottom of the active fuel. The neutron fluence in the region of the CRD housings is negligible because of the shielding provided by the several meters of water in the reactor vessel between the core plate and the vessel bottom head.

Additionally, neutron induced relaxation is actually neutron enhanced thermal relaxation. Since the spring is located in a part of the FMCRD below the bottom head, it operates at ambient dry well temperature so no thermal relaxation will occur either.

For these reasons, irradiation-induced spring relaxation caused by neutron fluence is not considered to be a concern for the FMCRD control rod separation spring.

No DCD changes will be made in response to this RAI.

NRC RAI 4.6-32

DCD Tier 2, Section 4.6.1.2.2 describes the FMCRD components. Included in this section is a discussion of the FMCDR electro-mechanical brake which states that a "braking torque of 49 N-m (minimum) and the magnetic coupling torque between the motor and the drive shaft are sufficient to prevent control rod ejection in the event of failure in the pressure retaining parts of the drive mechanism." Please provide details of this calculation including the assumed system pressure.

GE Response

The FMCRD brake torque of 49 N-m was established for the ABWR and confirmed to be acceptable for ESBWR. The required brake torque is determined by the backdrive torque on the FMCRD ball screw due to the load on the ball nut resulting from a break of the connected scram line. This assumes that the ball check valve in the FMCRD housing fails to close and seal the pressure in the drive.

The governing equation for backdrive torque on a ball screw is:

$$T_b = \frac{L \times P \times e_b}{2\pi}$$

Where L = ball screw lead

P = load on the ballnut
$= W_{CR} + W_{HP} + P_{HP}$

W_{CR} = control rod weight

W_{HP} = hollow piston weight

P_{HP} = reactor pressure load on the hollow piston
$= A_{HP} \times P_R$

A_{HP} = hollow piston cross-sectional area
$= \pi(D_{HP})^2/4$

D_{HP} = hollow piston diameter

P_R = reactor pressure at bottom head

e_b = backdrive efficiency of ball screw

Input Data:

L = 0.012 m

W_{CR} = 104 kg (max) See Note
W_{HP} = 36.5 kg See Note
D_{HP} = 5.4 cm
P_R = 76.3 kg/cm^2 (1085 psig)
e_b = 1.0

Note: The heavier ABWR control rod and hollow piston weights are used for conservatism.

Using the input data the torque is calculated as follows:

$$T_b = \frac{0.012 \times \left[104 + 36.5 + \frac{\pi(5.4)^2}{4} \times 76.3\right] \times 1.0}{2\pi}$$

$$= 3.61 \text{ kg-m } (35.4 \text{ N-m})$$

This provides a margin of 13.6 N-m (28%) to the required minimum value of 49 N-m.

No DCD changes will be made in response to this RAI.

NRC RAI 4.6-33

DCD Tier 2, Section 4.6.3.5 states, "A test of the scram times at each refueling outage is sufficient to identify any significant lengthening of the scram times." Current Technical Specification surveillance (STS SR 3.1.4.2) require routine (e.g. 120 days) sampling of scram times for a representable set of control rods. Based on recent experience with channel bow, the staff believes that routine scram tests are necessary to detect the onset of control blade interference due to channel bow and to ensure control rod operability and scram time requirements. Please provide further justification for removing this routine surveillance or justify a sampling frequency.

GE Response

There is no intention of removing the routine scram testing of a representative sample set of control rods. Tier 2 DCD Subsection 4.6.3.5 will be revised to conform with the Technical Specification surveillance (STS SR 3.1.4.2) as follows:

"At the time of each major refueling outage, each operable control rod is subjected to scram time tests from the fully withdrawn position. Experience indicates that the scram times of the control rods do not significantly change over the time interval between refueling outages. A test of the scram times at each refueling outage is sufficient to identify any significant lengthening of the scram times. However, an additional test of a representative sample of the control rods, as defined in the plant Technical Specifications, is performed every 120 days of cumulative operation in Mode 1."

This wording is the same as that of a typical operating BWR SAR.

Tier 2 DCD Section 4.6 will be revised in the next update as noted above.

<u>NRC RAI 4.6-35</u>

DCD Tier 2, Section 4.6.3.5 describes the surveillance test for the high pressure makeup mode. No frequency for this surveillance is stated. Please provide the frequency.

<u>GE Response</u>

The frequency for periodic testing of the high pressure makeup mode is once each refueling outage to verify the automatic response of the system to a simulated initiation signal. Additionally, every three months each CRD pump is tested to verify that it can develop the required flow rate against a system head corresponding to the required reactor pressure. This test uses the system test return line to the CST. These test frequencies are consistent with normal industry practice for periodic testing for motor-driven high pressure ECCS pumps. While the high pressure makeup mode of the CRD system for ESBWR is not a safety related function, using the test frequencies for a comparable high pressure ECCS provides an acceptable basis for demonstrating system readiness and operability.

The text in Tier 2 DCD Subsection 4.6.3.5 (Page 4.6-25) will be changed as follows:

"The high-pressure makeup mode of operation is tested <u>every refueling outage</u> to verify the automatic response of the system to a simulated or actual initiation signal. <u>Every three months each</u> ~~The~~ CRD pump~~s are~~ <u>is</u> tested to verify <u>that it</u>~~they~~ can develop the required flow rate for high-pressure makeup against a system head corresponding to the required reactor pressure. This test uses the system test return line to the CST."

Tier 2 DCD Section 4.6 will be revised in the next update as noted above.

NRC RAI 4.6-36

Standard Technical Specification require certain surveillance tests following maintenance and prior to declaring a system operable. No such requirements are included in DCD Tier 2, Section 4.6.3.5. Please discuss this omission.

GE Response

Tier 2 DCD Subsection 4.6.3.5 will be revised to add the following text to address post-maintenance surveillance testing:

"Each affected control rod is subjected to scram time tests from the fully withdrawn position following work on the control rod or CRD system that could affect scram time, and after fuel movement has occurred within the affected cell."

Tier 2 DCD Section 4.6 will be revised in the next update as noted above.

NRC RAI 4.6-37

The ESBWR CRD system design represents a departure from the current operating BWR fleet. Discuss any reactor operating experience with CRD system designs similar to the ESBWR. Discuss any manufacturing and qualifying experience with CRD systems similar to the ESBWR (e.g. ABWR).

GE Response

There are four ABWRs operating in Japan with approximately 20 reactor-years of combined operating experience as of July 2006. These plants and their commercial operation dates are:

Kashiwazaki Kariwa Unit No. 6 (K-6)	November 1996
Kashiwazaki Kariwa Unit No. 7 (K-7)	July 1997
Hamaoka Unit No. 5 (H-5)	January 2005
Shika Unit No. 2 (NN-2)	March 2006

With regard to the FMCRD and HCU, no incident concerned with safety that requires reporting to the regulatory agency has been reported since the first ABWR started commercial operation. In addition no anomaly indicating a fundamental or serious design issue has been experienced in plant operation. This indicates that issues associated with application of first-of-a-kind features in ABWR were resolved through various tests and inspections before the start of commercial operation. In general, the FMCRD and HCU designs similar to that of ESBWR have exhibited acceptable and sound operating experience in ABWR application.

Prior to their operational in-plant service, these ABWR FMCRD and HCU designs were qualified by the following testing:

- Environmental and seismic qualification tests
- Design acceptance tests on a prototype unit to confirm design acceptability
- Production testing including factory quality control tests, functional tests and acceptance tests of the kind described in Tier 2 DCD Subsections 4.6.3.1, 4.6.3.2 and 4.6.3.4.

With respect to manufacturing experience, based on the most recent experience with the Lungmen Project in Taiwan, the FMCRDs and HCUs, met all specification requirements. No design deviations were encountered except for some minor materials issues relating to differences between JIS material specifications and ASME/ASTM specifications. None of these issues involved ASME Code Section III pressure boundary parts and were dispositioned satisfactorily.

No DCD changes will be made in response to this RAI.