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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 100 Related to ESBWR Design Certification Application – Safety Analyses – RAI Number 15.3-30**

Enclosure 1 contains GE-Hitachi Nuclear Energy Americas (GEH) response to the subject NRC RAI transmitted via Reference 1. Enclosure 2 contains the DCD Markups associated with this response.

If you have any questions or require additional information regarding the information provided here, please contact me.

Sincerely,

Kathy Sedney for

James C. Kinsey
Vice President, ESBWR Licensing

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MRO

Reference:

1. MFN 07-327 – Letter from US Nuclear Regulatory Commission (NRC) to Robert E. Brown, *Request for Additional Information Letter No. 100 Related to ESBWR Design Certification Application,* dated May 30, 2007

Enclosures:

1. Response to NRC Request for Additional Information Letter No. 100 Related to ESBWR Design Certification Application – Safety Analyses, RAI Number 15.3-30
2. DCD Markup

cc:	AE Cubbage	USNRC (with enclosures)
	GB Stramback	GEH /San Jose (with enclosures)
	RE Brown	GEH /Wilmington (with enclosures)
	eDRF	0073-4640

Enclosure 1

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Response to NRC Request for Additional Information Letter No. 100 Related to ESBWR Design Certification Application

Safety Analyses

RAI 15.3-30

NRC RAI 15.3-30:

For the Control Rod Withdrawal Error During Start-up event, the description of the method in the DCD 15.3.8.3.1 does not state whether the adiabatic heating assumption is conservative as far as reactivity is concerned. If the heat is restricted in the fuel, it will exaggerate the Doppler feedback and eliminate the density feedback. In reality, both feedbacks will be present. Explain why the adiabatic assumption produces conservative results?

GEH Response:

The adiabatic fuel model assumption (which assumes no effective heat transfer to the coolant) has been demonstrated to be conservative in past reactivity analyses of this type. Due to the mild nature of the RWE event, there is no fuel temperature increase at this time, and the Doppler effect is insignificant at the time of the scram. Several assumptions make this analysis conservative: use of the high rod worth, maximizing initial fuel temperature, and zero void feedback. Also, no credit is taken for the scram in this analysis. The enthalpies are conservatively reported at 2.3 seconds (the scram time) after a scram based on a 10 second period would have occurred. The hot startup condition maximizes the initial enthalpy of the fuel and since the RWE event is very mild, increasing enthalpy by less than 1 $^{J}/_{g}$, the high initial temperature is appropriate. However, the important conclusion is that the final peak pin enthalpy from a start-up (SU) rod withdrawal has shown an approximate 145 $^{J}/_{g}$, which is much lower than the RWE criteria of 712 $^{J}/_{g}$.

DCD Impact:

The adiabatic fuel model assumption is discussed in Subsections 15.3.8.3.2 and 15.3.8.3.3 of DCD Tier 2, Revision 4 (as provided on September 28, 2007) as shown on the attached markup.

Enclosure 2

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DCD Markup

selection status is in the SINGLE rod selection mode. When the RC&IS SINGLE/GANG rod selection status is in the GANG rod selection mode, only one control rod pair with the same HCU may be withdrawn. The RC&IS Single/Dual Rod Sequence Restriction Override by-pass feature controls the movement of the control rods. Any attempt to withdraw an additional rod results in a rod block initiated by the RC&IS RAPI/RWM rod block logic. Because the core is designed to meet shutdown requirements with one control rod pair (with the same HCU) or one rod of maximum worth withdrawn, the core remains subcritical even with one rod or a rod pair associated with the same HCU withdrawn.

Control Rod Removal Without Fuel Removal

The design of the control rod, incorporating the bayonet coupling system does not physically permit the upward removal of the control rod without decoupling by rotation and the simultaneous or prior removal of the four adjacent fuel bundles.

Identification of Operator Actions

No operator actions are required to preclude this event, because the protection system design, as previously presented, prevents its occurrence.

15.3.7.3 Core and System Performance

Because the possibility of inadvertent criticality during refueling is precluded, the core and system performances are not analyzed. The withdrawal of the highest worth control rod (or highest worth pair of control rods associated with the same HCU) during refueling does not result in criticality. This is verified experimentally by performing shutdown margin checks (see Section 4.3 for a description of the methods and results of the shutdown margin analysis). Additional reactivity insertion is precluded by refueling interlocks. Because no fuel damage can occur, no radioactive material is released from the fuel. Therefore, this event is not reanalyzed for specific core configurations.

15.3.7.4 Barrier Performance

An evaluation of the barrier performance is not made for this event because there is no postulated set of circumstances for which this event could occur.

15.3.7.5 Radiological Consequences

An evaluation of the radiological consequences is not made for this event, because no radioactive material is released from the fuel.

15.3.8 Control Rod Withdrawal Error During Startup

15.3.8.1 Identification of Causes

It is postulated that during a reactor startup, a gang of control rods or a single control rod is inadvertently withdrawn continuously due to a procedural error by the operator or a malfunction of the automated rod movement control system

The Rod Control and Information System (RC&IS) has a dual channel rod worth minimizer function that prevents withdrawal of any out-of-sequence rods from 100% control rod density to 50% control rod density (i.e., for Group 1 to Group 4 rods). It also has ganged withdrawal sequence restrictions at less than 50% control rod density such that, if the specified withdraw sequence constraints are violated, the rod worth minimizer function of the RC&IS initiates a rod block. These rod worth minimizer rod pattern constraints are in effect from 50% control rod density to the low power setpoint.

The startup range neutron monitor (SRNM) has a period-based trip function that stops continuous rod withdrawal by initiating a rod block if the flux excursion, caused by rod withdrawal, generates a period shorter than 20 seconds. The period-based trip function also initiates a scram if the flux excursion generates a period shorter than 10 seconds. Any single SRNM rod block trip initiates a rod block. Any two divisional scram trips out of four divisions initiates a scram. The SRNM also has upscale rod block and upscale scram functions as a double protection for flux excursion. A detailed description of the period-based trip function is presented in Chapter 7.

For this transient to happen, a large reactivity addition must be introduced. The reactor must be critical, with control rod density greater than 50%. Additionally, rod block logic of both rod worth minimizer channels must fail such that an out-of-sequence (i.e., in violation of Ganged Withdrawal Sequence Restriction (GWSR) rules) gang of rods (or a single rod) can be continuously withdrawn. The causes of the event are summarized in Figure 15.3-7b. The probability for this event to occur is considered low enough to warrant being categorized as an infrequent event. The frequency of this event is evaluated in Subsection 15A.3.12.

15.3.8.2 Sequence of Events and Systems Operation

15.3.8.2.1 Sequence of Events

The sequence of events of a typical continuous control rod withdrawal error during reactor startup is shown in Table 15.3-8.

15.3.8.2.2 Identification of Operator Actions

No operator actions are required to terminate this event, because the SRNM period-based trip functions initiate and terminate this event.

15.3.8.3 Core and System Performance

15.3.8.3.1 Analysis Method and Analysis Assumptions

The analysis uses the reactivity insertion model described in References 15.3-8, 15.3-9, and 15.3-10 then implemented in the PANACEA code. The analysis uses a three-dimensional adiabatic model and assumes that no heat is transferred to the coolant. An initial ESBWR core, Reference 15.3-5, with ganged control rods is considered with the error rods being continuously withdrawn from full-in to full-out, i.e. a continuous reactivity insertion. The code calculates the average power and period change as a function of time. Other assumptions used in the analysis are:

(1) The standard BWR data of the adiabatic model is used

(2) Six delayed neutron groups are assumed

15.3.8.3.2 Analysis Conditions and Results

(1) Analysis Conditions

a. The reactor is assumed to be in the critical condition before the control rod withdrawal, with an initial power of 0.001% rated, and a temperature of 271°C at the fuel cladding surface.

b. The worth of the withdrawn rods (gang) is 3% Δ k from full-in to full-out. Gang rod withdrawal is used during a normal startup to provide a larger reactivity change than a single rod withdrawal case.

c. The control rod withdrawal speed is 28.0 mm/s (1.1 in/s), the nominal ESBWR FMCRD withdrawal speed.

d. With the gang rod withdrawal, the reactor period monitored by any SRNM is relatively the same. Any single channel bypass of the SRNM does not affect the result.

(2) Analysis Result

There were two evaluations performed using the initial ESBWR core with no credit taken for the scram reactivity in the enthalpy calculation. For each case, the peak pin enthalpy is the calculated enthalpy at the time that corresponds to full control rod insertion following the scram. The first case examines a 10 second period scram trip, which is initiated as early as 15 seconds or as late as 28 seconds after the start of the transient, depending on the exposure. The peak pin enthalpy reached for this scram is then conservatively extracted at a time corresponding to a 10 second period with an additional 2.23 second scram time. The result for the 10 second period trip showed that the peak fuel enthalpy was approximately 145 J/g, much lower than the control rod withdrawal error criteria of 712 J/g.

The second case examines a 15% rated power high neutron flux scram, which is initiated as early as 26 seconds or as late as 40 seconds after the start of the transient, depending on the exposure. The core average enthalpy reached for this scram is then conservatively extracted at a time corresponding to 15% rated power high neutron flux scram with an additional 2.23 second scram time. The result for the 15% rated power high neutron flux scram showed that the peak fuel enthalpy was approximately 391 J/g, which is also much lower than the control rod withdrawal error criteria of 712 J/g.

The results are illustrated in Figure 15.3-7a. Table 15.3-8 contains a sequence of events for a continuous rod withdrawal error during reactor startup assuming both a period and high flux scram.

15.3.8.3.3 Evaluation Based On Criteria

Due to the effective protection function of the period-based trip function, the fuel enthalpy increase is small. The fuel enthalpy increase criterion of 712 J/g (170 cal/gm) for a control rod withdrawal error event is satisfied. An additional analysis was performed with the same assumptions and conditions as stated above, but without the SRNM protection function. Under this condition, the APRM startup mode scram trip at 15% power provides the protection function. Flux and power excursion caused by continuous rod withdrawal error reaches the 15% power scram level and the reactor scrams.

15.3.8.4 Barrier Performance

An evaluation of the barrier performance is not made for this event, because there is no fuel damage in this event and only with mild change in gross core characteristics.

15.3.8.4.1 Radiological Consequences

An evaluation of the radiological consequences is not required for this event, because no radioactive material is released from the fuel.

15.3.8.4.2 COL Action Item (Deleted)

15.3.9 Control Rod Withdrawal Error During Power Operation

15.3.9.1 Identification of Causes

In ESBWR, the Automated Thermal Limit Monitor (ATLM) subsystem performs the associated rod block monitoring function. The ATLM is a dual channel subsystem of the RC&IS. Each ATLM channel has two independent thermal limit monitoring functions. One function monitors the Minimum Critical Power Ratio (MCPR) limit and protects the operating limit MCPR, another function monitors the Maximum Linear Heat Generation Rate (MLHGR) limit and protects the operating limit of the MLHGR. The rod block algorithm and setpoint of the ATLM are based on actual on-line core thermal limit information. If any operating limit protection setpoint limit is reached, such as due to control rod withdrawal, control rod withdrawal permissive is removed. Detailed description of the ATLM subsystem is presented in Chapter 7.

The causes of a potential control rod withdrawal error are either a procedural error by the operator in which a single control rod or a gang of control rods is withdrawn continuously, or a malfunction of the automated rod withdrawal sequence control logic during automated operation in which a gang of control rods is withdrawn continuously. In either case, the operating thermal limits rod block function blocks any further rod withdrawal when the operating thermal limit is reached. That is, the withdrawal of rods is stopped before the operating thermal limit is reached. Because there is no operating limit violation due to the preventive function of the ATLM, there is no rod withdrawal error transient event.

The frequency of this event is evaluated in Subsection 15A.3.13.

15.3.9.2 Sequence of Events and System Operation

A single control rod or a gang of control rods is withdrawn continuously due to an operator error or a malfunction of the automated rod withdrawal sequence control logic,. The ATLM operating thermal limit protection function of either the MCPR or MLHGR protection algorithms stops further control rod withdrawal when either operating limit is reached. As there are no operating limit violations, there is no basis for occurrence of the continuous control rod withdrawal error event in the power range.

No operator action is required to preclude this event, because the plant design as described above prevents its occurrence.