ENCLOSURE 2

MFN 10-245 R5

Description of the Evaluation and Surveillance Recommendations for BWR/2-5 Plants

Non-Proprietary Information - Class I (Public)

IMPORTANT NOTICE

This is a non-proprietary version of Enclosure 1 to MFN 10-245 R5, from which the proprietary information has been removed. Portions of the enclosure that have been removed are indicated by open and closed double square brackets as shown here [[ ]].

Description of Evaluation and Surveillance Recommendations for BWR/2-5 Plants

Background

In 2010, GE Hitachi Nuclear Energy (GEH) identified that the engineering evaluations supporting the guidance provided in MFN 08-420, did not address the potential impact of a seismic event on the ability of control rods to fully insert during a scram under conditions with substantial channel – control blade interference. GEH issued three 60-Day Interim Reports in accordance with the requirements set forth in 10CFR 21.21(a)(2) to allow additional time for the evaluation to be completed.

In September 2010, GEH issued MFN 10-245 (and MFN 10-245 R1) to communicate the following results from the evaluation completed as of that date:

1. The required scram performance for the BWR/6 plants is not adversely impacted by the seismic events (Operating Basis Earthquake, OBE, or Safe Shutdown Earthquake, SSE). The guidance specified in MFN 08-420 continues to ensure that the BWR/6 control rods will fully insert during a seismic event (OBE or SSE) at all normal and abnormal operating conditions.
2. For BWR/2-5 plants, at reactor system pressures of 1000 psig and above, the required scram capability is not adversely impacted by the inclusion of seismic events (OBE or SSE). The guidance specified in MFN 08-420 continues to ensure that the BWR/2-5 control rods will fully insert during a seismic event (OBE or SSE).
3. For BWR/2-5 plants, the potential existed that, during a seismic event (OBE or SSE), control rods with scram friction near the limits specified in MFN 08-420 may not fully insert at the Main Steam Isolation Valve (MSIV) isolation set point pressure condition, or at lower reactor system pressures (with maximum adverse effects occurring at roughly 550 to 600 psig reactor system pressure).

On December 15, 2010, GEH issued MFN 10-245 R2 to communicate the status of the on-going evaluation. Additional time was needed to modify and verify the model used for establishing the maximum allowable control rod friction limits in MFN 08-420 in order to incorporate the effects of these seismic loads. The scope of the modification, upon verification, also included other changes needed to account for the depletion of the Hydraulic Control Unit (HCU) scram accumulator and pressurization of the Scram Discharge Volume (SDV).

On August 11, 2011, GEH issued MFN 10-245 R3 to communicate that further time was needed to complete and verify the predictions of scram performance using the modified model that accounted for the seismic condition. Interim guidance was also issued at that time and in the weeks that followed, in support of reactor engineers and operators assessing the implications for reactor plants.

The evaluation has been completed and the implications for reactor operations have been assessed, as initially reported in MFN 10-245 R4. This current communication is a reissue of the MFN 10-245 R4 document for the purpose of clarifying or updating the information and recommendations provided, based in part on feedback from BWR owners.

For the purposes of this communication, the scram capability of the control rod drive (CRD) mechanism in BWR/2-5 plants is discussed in context of operation above and below the MSIV isolation set point pressure.[1] For this evaluation it is understood that a plant's normal operating condition is at reactor system pressure considerably above the MSIV isolation set point pressure (e.g., typically 900 psig and above), and operation below the MSIV isolation set point pressure typically occurs during plant startup and shutdown.

In addition to the evaluation of condition and the assessment of implications, GEH and Global Nuclear Fuel (GNF) have also prepared a probabilistic risk assessment (PRA) of the condition, to help plant staffs appropriately assess conditions at their respective plants. The PRA treatment of this condition is described near the end of this document.

Evaluation Method

For the purposes of this communication, the scram capability of the control rod drive mechanism in BWR/2-5 plants is discussed in the context of Reactor operation above and below the MSIV isolation set point pressure. A typical plant spends the most time operating at full reactor system pressure. The plants do occasionally perform reactor down-powers for various reasons that result in slightly reduced reactor system pressures but remain above the MSIV isolation set point pressure. There is also the potential for reductions in reactor system pressure by Anticipated Operational Occurrences (AOOs) and transients that can take reactor system pressure down to as low as the MSIV isolation set point pressure. Operation below the MSIV isolation set point pressure is typically limited to reactor startup and shutdown

[1] It is left to the users of this guidance to determine whether the MSIV nominal isolation set point or the lower MSIV analytical limit isolation set point as found in Technical Specifications is appropriate.

conditions[2]. One important reason for this distinction is to associate different values of control rod friction limits with the reactor system pressure condition to which they apply and indicate the recommended control rod monitoring frequency for these different reactor system pressure conditions. Monitoring for control rod friction applicable above the MSIV isolation set point pressure must occur periodically to maintain control rod operability (similar to the recommended monitoring in MFN 08-420). Monitoring for control rod friction applicable below the MSIV isolation set point pressure is necessary only prior to initiating a startup sequence or prior to reaching the MSIV isolation set point in a controlled shutdown sequence.

To ensure that plant operations meet the NRC General Design Criteria (GDC) requirements, GEH assessed the requirements for control rod performance during a scram, concurrent with an OBE or SSE. That assessment determined that the control rods must fully insert during a scram, concurrent with an OBE or SSE for the reactor to be considered shutdown under all conditions, and to assure that the assumptions of scram reactivity in the design basis and transient analyses are not violated. Although partial insertion of some control rods does not necessarily preclude reactor shutdown, this evaluation seeks conditions providing high confidence that all rods will fully insert. Partial insertion of some rods is considered in the probabilistic analysis summarized at the end of this document, which is provided for informational purposes.

Because the SSE loads are larger than the OBE loads, the SSE is bounding and the subsequent scram performance predictions in this evaluation characterize only the SSE attributes. For operations in plants with a Mark II containment, the load combination analyzed includes interference from an SSE plus design basis Loss of Coolant Accident (LOCA) and Safety Relief Valve (SRV) events to ensure control rod insertion is achieved to satisfy the acceptance criteria specified in NUREG-0800, Section 4.2. Because the licensing requirements for the Mark I containment do not require consideration of combined SSE plus LOCA dynamic loads, and the SSE loads bound the LOCA loads, the dynamic loads considered herein for Mark I containment result from the SSE only.

To predict scram performance during an SSE event, GEH modified the model previously used in the development of the maximum allowable friction limits in MFN 08-420. This modification was required [[ ]], not previously included in the model. In addition, due to the longer scram times expected during a seismic event at low reactor

[2] It is recognized that the transition from Mode 2 to Mode 1 during startup or the transition from Mode 1 to Mode 2 during shutdown does not necessarily occur at the MSIV isolation set point pressure. However, the MSIV isolation set point pressure is useful for distinguishing differences in control rod monitoring guidance for normal operating conditions compared to startups and shutdowns.

system pressure, the model was modified to account for the depletion of the HCU accumulator, which assists in rod insertion, and the pressurization of the SDV that opposes control rod insertion. Other assumptions incorporated into the model or used as inputs were selected to conservatively bound conditions in the BWR/2-5 fleet and include the following:

- [[

]] The response spectrum for that plant was selected because it was considered to conservatively bound those for other plants after being scaled to represent the respective seismic load magnitudes. [[

]]

<u>GNF-Specific Determination of Dynamic Loads and Deflections</u>: [[

]]

Application to non-GNF Fuel: Application of this guidance to non-GNF fuel is best accomplished through consideration of dynamic horizontal deflections at the axial mid-length of the non-GNF fuel bundle, as induced by a particular dynamic loading and as determined by applicable plant dynamic load analysis. The GEH scram performance model uses [[

]] Therefore, the deflection-associated friction limits can be applied to other fuel bundle designs, if the dynamic deflection is known. GEH/GNF believes the characteristics of all BWR fuel bundles will be sufficiently similar to allow generic application of the model for time-dependent dynamic loading, but does not have sufficient information for non-GNF fuel designs to confirm that assertion. However, given this assumption, the calculated friction limits for a given lateral bundle deflection (see Tables 2 – 5) can be applied to non-GNF fuel by confirming that the bundle deflections for the fuel design under a plant's specific dynamic loading are bounded by the indicated deflections (e.g., for a plant with dynamic fuel bundle deflections of 18 mm, the closest bounding friction limits would be those in the tables for 20-mm deflections).

When the dynamic deflection of the non-GNF fuel bundle is not known, BWR plant staff can compare fuel bundle characteristics for GNF fuel with those for non-GNF fuel to determine whether the seismic response of the two fuel bundle designs are sufficiently equivalent to allow GNF-fuel dynamic deflections to be applied to the non-GNF fuel. Specifically, non-GNF fuel bundles with [[

]] will have a dynamic response, and subsequent peak deflection that is nearly identical to that of the GNF bundles. [[

]] Addressing non-GNF fuel bundles that do not meet [[ ]] will likely require additional analysis; please contact a GEH or GNF account representative to request assistance.

Tables 1a and 1b provide data regarding GNF fuel response to events in specific plants (i.e., those plants for which GEH has available and appropriate seismic analyses; see Table 1a) and the GNF fuel bundle characteristics (Table 1b) that most affect the values of dynamic deflections. The [[ ]] Given a determination of equivalency, the plant-specific dynamic deflections listed in Table 1a, can be applied to the non-GNF fuel, and friction limits found in Tables 2 – 5 (described under "Evaluation Results") applied accordingly.

Evaluation Results

The results of the evaluation are compiled in Tables 2 – 5, which provide limiting values of friction above which control rods may not insert during an SSE,[3] for ranges of reactor system pressure and CRD scram accumulator pressure. Table 2 contains the control rod friction limits with 20-mm dynamic deflection impact considered at all reactor system pressures, and Table 3 contains those limits applicable to 30-mm dynamic deflection. Tables 4 and 5 contain, for 20-mm and 30-mm deflection, respectively, the control rod friction limits with the dynamic impact incorporated only for reactor system pressure ranging from full pressure down to and including 900 psig. For pressures below 900 psig down to MSIV isolation set point pressure, Tables 4 & 5 list the lesser of either the 900 psig value or the corresponding value from MFN 08-420.[4] Therefore, Tables 4 and 5 provide GEH/GNF-recommended limits if considering the impact of SSEs during normal and anticipated down-power operation for reactor pressures above 900 psig and for pressures below 900 psig down to the MSIV isolation set point pressure if SSEs are not considered to occur in conjunction with a de-pressurization transient that would bring reactor pressure to this low range. Tables 2 and 3 friction limits apply when considering impact of SSEs below 900 psig to the MSIV isolation set point pressure (e.g., if considering an SSE in conjunction with a transient that takes the plant to MSIV isolation set point pressure). Tables 2 and 3 also provide the control rod friction limits applied to low-reactor system pressure operation, such as during plant startup and shutdown. [[ ]]

[3] Or SSE with concurrent LOCA and SRV for plants with Mark II containment.

[4] An AOO may cause the reactor system pressure to decrease below 900 psig. However because licensing requirements do not consider the simultaneous occurrence of an AOO and SSE, it is acceptable to define the limiting friction levels for an SSE (or, SSE + LOCA + SRV, for Mark II containment plants) at 900 psig.

Control rod drive performance and sources of control rod friction: Friction observed in testing and the friction that opposes scram insertion is the sum effect of friction applied from several sources. These sources include CRD driveline friction and channel-control blade interference that might be caused by control blade deformation (which would be unusual) in addition to channel-control blade interference caused by channel deformation. Of these phenomena, only channel deformation is observed on a systematic basis, rather than rarer and isolated instances, so effects of that phenomenon in association with SSE-induced friction are appropriately addressed here. But users of this guidance should bear in mind that any other friction effects would be superimposed on top of those arising from channel deformation. GEH/GNF believes that the monitoring recommended in this document reduces overall risk, because other friction effects, if present in appreciable amounts are more likely to be revealed in the course of monitoring and managing channel-deformation-induced friction.

Other CRD performance characteristics might complicate interpretation of friction test results. [[

]] Those systematic or anomalous characteristics are difficult to address in a generic manner. Therefore, if users of this document encounter a situation that cannot be addressed within their available experience, then consultation with a CRD expert is recommended, such as those available by contacting a GEH or GNF account representative.

Distinction of 900 psig as used in this recommendation: Reactor system pressure of 900 psig is used as a discriminator here because discussions with BWR plant staff indicate that most, if not all, normal steady-state operations are conducted at reactor system pressure of 900 psig and above- it is only during event response or intentional startup and shutdown that a plant operates below 900 psig. For that reason, addressing SSE impacts on scram during normal steady-state operation would consider reactor system pressure of 900 psig and above, while addressing SSE impacts on operation during AOOs or other events would consider reactor system pressure from rated pressure down to the MSIV isolation set point pressure. Other than this discrimination, there is no distinction to 900 psig reactor system pressure; SSE-induced friction will act to impede scram at any and all reactor pressures, and the amount of friction allowed in addition to that SSE-induced friction is as indicated in Tables 2 – 5. Although friction limits are provided for reactor system pressures above 900 psig, GEH/GNF recommend monitoring the 900 psig friction limit, or the MSIV-isolation-set-point-pressure friction limit if AOOs and other events are to be considered as well, to ensure operability of control rods (relative to the present issue) through the reactor system pressure range being addressed.

Distinction of Control Rod Weight as used in this recommendation: Close inspection of Tables 2 – 5 will reveal that [[

]] The total wet weight of these components is termed the "control rod weight" for the present purpose, and a list of these weights for most GEH C-lattice and D-lattice control blade designs is provided in Table 6. [[

]] Guidance for identifying those two populations is provided in the Recommendations section.

Relevance to MFN 08-420 (SC 08-05, Rev.1)

Guidance for monitoring control-rod friction caused by channel-control blade interference was previously provided and later updated in MFN 08-420 (or SC 08-05, Rev. 1). Because the guidance in this communication addresses a more severe set of conditions (i.e., the friction effects of an SSE that impedes scram motion in addition to friction caused by channel-control blade interference), the friction limits herein conservatively cover the non-SSE conditions addressed by the MFN 08-420 guidance for BWR/2-5 plants. Specifically, monitoring for and taking action on friction addressed in this document will obviate the need to monitor for BWR/2-5 friction limits, for a given reactor system pressure, in MFN 08-420. Furthermore, because this document addresses more severe scram impacts (i.e., combined static and dynamic friction effects that dramatically slow or stop scram motion) as compared to MFN 08-420 (which addresses friction effects that could slow scram motion to less than [[ ]]), the scram-time testing described in MFN 08-420 is not necessary for plants that monitor to the recommendations in this document. Other specific provisions or recommendations from MFN 08-420 are not incorporated into this current revised document. It is acknowledged that plant staff might find good justification for setting aside other recommendations of MFN 08-420.

Recommendations

The guidance presented here is conservative, intended for generic application to all BWR/2-5 plants. The generic nature of the guidance necessitates conservatism to address behavior and potential issues for all plants, with differentiation only as the calculated values of control rod friction for different conditions allow. However, experience and observations at international GE-design BWR plants indicate that channel distortion and its effects do not manifest to the same degree in all plants; this is true under conditions or parameters that appear to be similar. Therefore, utility or plant operating experience can be considered to develop more appropriate plant-specific approaches as an alternative to these recommendations.

Because this guidance is generic, and because the postulated conditions addressed herein are not specific to a fuel design or a particular vendor's product line, guidance is presented in a manner to enable application to any fuel design. However, GNF has additional guidance that can be applied to GNF fuel bundles and/or GNF-designed cores, which is also provided and so-labeled. In particular, GNF's Cell Friction Methodology (CFM values) can be used to help define the population of control cells that might develop friction due to channel-control blade interference and the population of control cells with potential to develop no-settle-levels of friction. Other means to define these populations might be applied, making use of information available from fuel vendors or plant-specific observations.

As described above, the guidance defines two test populations of control cells, [[ ]] (the Settle Test Population) [[ ]] (the Full-Stroke Insertion Test Population), which are named for the tests recommended to address them and are described in the following sections. [[ ]] so the monitoring population must be expanded beyond the recommendations in MFN 08-420 to include control cells with potential to develop [[ ]] control rod friction. Although it was previously deemed acceptable to risk an undetected no-settle condition in unmonitored cells because the probability that the control rod friction exceeded the friction limits was low enough to ignore, the objective of monitoring for the presently postulated conditions must now be to identify all no-settle conditions for the Settle Test Population and control rod friction approaching friction limits for the Full-Stroke Insertion Test Population.

Because some plant conditions might otherwise lead to large numbers of control rods to be tested in accordance with this guidance, and because testing of large numbers of control rods might introduce risk (e.g., due to degradation of equipment, or additional opportunity for operator error) that is commensurate with or greater than the risk associated with the postulated condition (see the probabilistic analysis summary near the end of this document), GEH/GNF encourages implementation of a statistically-based sampling plan for either or both test populations. Development of such a sampling plan should consider accepted principles or standards for statistically based sampling, but sampling should emphasize testing of the more friction-susceptible cells. This approach might be particularly helpful for plants for which cell friction predictions based on fleet-wide characteristics are overly conservative.

Application to Ranges of Reactor Operating Pressure

Control rod friction limits for operation above MSIV isolation set point pressures are [[ ]] addressed by the Settle Test Population. However, some control rod friction limits for MSIV isolation set point pressures, as found in Tables 2 and 3, [[ ]] could be necessary to address those conditions (specifically, if SSE-impacted limits are to be applied for main steam isolation transients). Otherwise, [[ ]] will be performed to address these operating conditions [[ ]] After a control cell is placed into a population, frequency of testing for that cell is determined [[ ]], as indicated in the testing recommendations below.

Control rod friction limits applicable to [[ ]], typical of reactor startup and shutdown, [[ ]]. Therefore, testing from either the Settle Test Population or the Full-Stroke Insertion Population may be necessary to ensure control rod function for these operating pressures. [[ ]] Testing for this operating range need be performed only prior to entering that pressure range – e.g., prior to a planned startup or shutdown. However, GEH/GNF recommends that operability for this pressure range be determined from testing [[ ]].[5]

[5] Or alternatively, as stated in the section titled "Testing Recommendations for the Full-Stroke Insertion Test Population," [[ ]].

The following procedural steps are provided for information only to assist the development of a monitoring plan. Plant operating staff will determine the most appropriate procedures.
[[

[6] The GEH/GNF interpretation is that evaluation of an SSE concurrent with a steam isolation (or MSIV) transient is not a licensing requirement in the U.S

]]

The following sections provide instruction on testing technique and on the specifics for the GNF recommendations regarding settle testing or full-stroke insertion testing.

Settle Test Technique

[[

]]

Full-Stroke Insertion Test Technique

The Full Stroke Insertion Test for the present purpose may be a modified version of that previously recommended in MFN 08-420. For the testing recommended below, an acceptable test is as follows: [[

]]

[7] [[

]]

When the Full-Stroke Insertion Test is performed as described above, [[

]]

Two precautions should be taken into consideration when performing the modified Full-Stroke Insertion Test:

1) Some plants may experience sluggish rod movement at the start of rod motion from notch positions 48 to 46. This is indicated by a significantly shorter notch-to-notch time between notch positions 46 to 44, as compared to 48 to 46. In this event it is recommended that [[
]] Plants should also be aware that sluggish rod movement may be an indication of other problems with the CRDM or HCU, and should take action to troubleshoot and eliminate this issue.
2) If the insertion test is performed as described here, it is likely that the insert stall flow will not change during the test and [[

]]

If the CRD stalls (no motion) during the performance of the full-stroke insertion test at 260 psid drive water differential pressure, refer to Appendix A (pages 42 and 43) for further guidance.

Settle Test Population

This test population is determined to be those cells with potential for [[ ]], as determined by predictions or experience, and as correlated with bundle and control cell characteristics. [[

]] So, GEH/GNF recommends that this population be determined as those cells with potential for slow-to-settle or no-settle behavior, beginning at the point of time in the operating cycle when such control rod friction might be expected. Note that although a settle test is recommended for identifying elevated control rod friction in the population, [[ ]], as necessary to determine the operability of a control rod with friction identified in a settle test. [[

]]

GEH/GNF-specific guidance (i.e., guidance specific to GNF fuel and core designs) for determining this population is given below, but the indicated principles can be applied to non-GNF fuel by determining thresholds or exposures above which slow-to-settle and no-settle behavior is observed.

GEH/GNF-specific guidance for selecting the Settle Test population:

[[

]]

Full-Stroke Insertion Test Population

As mentioned above, some control rod friction limits [[

]] (Anecdotally, some reactor engineers report plant staff familiar with plant characteristics are often able to discern unusual control rod behavior leading up to slow-to-settle behavior; perhaps this discernment can be helpful in preparation of plant-specific monitoring plans.) As indicated in Tables 2 – 5, [[

]], so this test population is only required to be addressed prior to startup and before reaching the MSIV isolation set point pressure during shutdown.

The Full-Stroke insertion Test Population is conservatively defined as those cells with potential for any amount of developed friction. The control rod friction being addressed in this plan is that arising from channel-control blade interference, and the onset of channel-control blade interference (or contact) is the point in time at which control rod friction begins accumulating from zero, increasing with increasing channel deformation due to increased exposure. Typically, at the beginning of an operating cycle, control cells have little or no channel-control blade interference and therefore little or no control rod friction. This is particularly true for most cores designed currently with intention to minimize channel-control blade interference. For that reason, there would likely be no control cells in the Full-Stroke Insertion Test population at the beginning of a cycle, but the population could grow as the cycle progresses. A threshold for defining this test population can be any figure of merit that indicates the onset of channel-control blade interference, such as bundle exposure or resident time as correlated with channel dimension measurements. GEH/GNF-specific guidance for determining this population is given below, but the indicated principles can be applied to non-GNF fuel by determining thresholds or exposures below which channel dimensions remain below the point of channel-control blade contact.

GEH/GNF-specific guidance for selecting the Full-Stroke Insertion Test Population:
[[

[8] [[

]]

]]

<u>Testing Recommendations for the Settle Test Population</u>

To ensure control rods in the Settle Test Population fully insert under all postulated conditions, control rod friction from interference (as implied in a settle test or as measured in a full-stroke insertion test) should remain below the applicable values indicated in Tables 2 and 3 for the reactor system pressure of interest, if the impact of an SSE is to be considered in conjunction with transients that place the plant at MSIV isolation set point pressure. If the impact of an SSE need not be considered for main steam isolation transients, then the values in Tables 4 and 5 are recommended.

Because slow-to-settle (>7 seconds) and no-settle (>30 seconds) conditions indicate [[

]], settle testing may continue to be

used to identify the presence of channel-control blade interference during operation above the MSIV isolation set point pressure. However, [[

]]

The first time a control rod settles in > 7 second, if question remains as to whether the apparent settling behavior results from channel-control blade interference, [[

]]

The monitoring guidance recommended herein conservatively covers all GE BWR/2-5 plants, and is given below for control cells placed into the Settle Test Population.

Population(s): The Settle Test Population – control cells with control rod friction limits equal to or greater than [[

]] In lieu of testing all rods in this population, a sampling plan can be implemented, consistent with accepted sampling principles. [[

]]

First Test: Prior to reaching the time in the cycle at which a slow-to-settle or no-settle might occur.

Test Result: Notch-to-notch settle time(s) in seconds[9]

Anticipated Results & Actions:

1) [[ ]][10]

[9] [[

]]

[10] [[

]]

2) [[

]] comparison against the appropriate limit selected from Tables 2 – 5. If below the limit then place into increasing friction sub-population and determine time of next test per the recommendations for that population.

3) [[

]] Then place into increasing-friction sub-population. In addition, if control rods operationally symmetric to these cells are not already in the settle test population, include them for settle testing.

4) If the measured friction is greater than the appropriate limit selected from Tables 2 - 5, insert the control rod, declare it inoperable and place it out of service in accordance with Technical Specifications. The rod can be inserted and retested again near end of cycle to determine whether creep phenomena have mitigated the channel-control blade interference and the associated control rod friction. A few months of complete insertion have been shown to beneficially reduce interference.[12]

Control cells that exhibit signs of channel-control blade interference as indicated in settle tests are considered to be in the increasing-friction sub-population. The recommended guidance for this Increasing-Friction population is given below.

Population(s): Increasing-friction sub-population of the Settle Test Population – [[

]]

First test: [[

]]

[11] [[

]]

[12] Paul Cantonwine, et al., "Channel –Control Blade Interference Management at La Salle 1 and 2 during 2007 and 2008," *Proceedings of Top Fuel 2009*, Paris, France, September 6-10, 2009, Paper 2154

<u>Test Result:</u> From the [[ ]], control rod friction is determined using the control rod drive model incorporated into the Level-2 code FORCE01P[13], or from an equivalent approach.

<u>Subsequent tests</u>: Test frequency, indicated by maximum number of days, is specific to each rod and is determined by: [14]

[[

]] appropriate value from Tables 2 – 5

<u>Anticipated Results & Actions:</u>

i. Test Friction < Friction $\text{Limit}_{\text{above-MSIV}}$;

Rod remains in Increasing-Friction Population; determine maximum time to next test.

ii. Test Friction ≥ Friction $\text{Limit}_{\text{above-MSIV}}$;

Declare inoperable and place out of service in accordance with Technical Specifications.

<u>Testing Recommendations for the Full-Stroke Insertion Test Population</u>

To ensure control rods in the Full-Stroke Insertion Test Population fully insert under all postulated SSE conditions (including during startup and shutdown), friction from interference as measured in a full-stroke insertion test should remain below the lowest applicable values indicated in Tables 2 and 3 (i.e., below friction values applicable for reactor system pressures encountered during startup and shutdown). As described above in the section "Full-Stroke Insertion Test Population", this population is to include all control cells with potential friction, [[

]]

[13] FORCE01P (GNF User Manual ECP ID: 0000-0081-4479)

[14] [[

]]

The monitoring guidance recommended herein conservatively covers all GE BWR/2-5 plants, and is given below for control cells placed into the Full-Stroke Insertion Test Population. The previous section entitled "Full-Stroke Insertion Test Technique" should be reviewed for clarification on the testing recommended here.

<u>Population(s):</u> Full-Stroke Insertion Test Population – control cells with control rod friction limits [[ ]] and for which channel-control blade interference is possible, as determined by fuel vendor data, models, or plant experience. In lieu of testing all rods in this population, a sampling plan can be implemented, consistent with accepted sampling principles. [[

]]

<u>First Test:</u> Prior to initiating startup or shutdown operations, test all cells in the monitoring population (or the population sample).

<u>Test Result:</u> From the [[ ]], control rod friction is determined using the control rod drive model incorporated into the Level-2 code FORCE01P[15], or from an equivalent approach.

<u>Subsequent tests</u>: Test results are valid for [[
]]

<u>Anticipated Results & Actions:</u>

i.

Test Friction ≥ Friction $\text{Limit}_{\text{sub-MSIV}}$

All control rods with Test Friction greater than the applicable limit from Table 2 or 3 must be inserted prior to reactor operation at the associated reactor system pressure, or within the time required for inoperable rods according to the Technical Specifications. These control rods may be withdrawn once reactor system pressure reaches or exceeds the pressure value in Tables 2 or 3 associated with the Test Friction. If the Test Friction is greater than the applicable limit for operation above MSIV isolation set point pressure, insert the control rod, declare it inoperable and place it out of service in

[15] FORCE01P (GNF User Manual ECP ID: 0000-0081-4479)

accordance with Technical Specifications. In addition, if control rods operationally symmetric to these cells are not already in the Full-Stroke Insertion Test Population, include them for full-stroke insertion testing.

ii.

Test Friction < Friction Limit$_{sub\text{-}MSIV}$;

Rod remains in the Full-Stroke Insertion Test Population

Additional Considerations:

1) When full-stroke insertion testing is performed more than [[ ]] prior to the shutdown or startup, the Test Friction in lbf [[ ]]
2) If testing is not desired prior to the planned shutdown, cells in the Full-Stroke Insertion Test Population but not in the Settle Test Population [[ ]] should be assumed to have [[ ]]. For cells with normal as-measured settle times, the assumed friction is dependent on the time elapsed since the most recent Settle Test was performed, as indicated below.

The friction to be assumed when determining the reactor system pressure at which a control rod with no indication of settling friction should be inserted

Days (EFPD) from Most Recent Settle Test	Assumed Cell Friction (lbf) (applies only to rods with no indications of settling friction)
30	[[
60	
120	]]

3) Control rods characterized with friction as assumed from settle tests (rather than determined from full-stroke insertion tests) should be inserted prior to reactor system pressure reaching the value in Tables 2 or 3 associated with the value of assumed friction. Alternatively, plants may consider the untested rods inoperable and insert within the time required according to the Technical Specifications.
4) These assumed friction values are also applicable for subsequent restart. Full-stroke insertion testing is necessary to determine operability of control rods at reactor system pressures lower than those associated with the assumed friction values.

5) It is recognized that if testing is performed after shutdown in the cold condition rather during operations in the hot condition, the measured friction may be greater than would have been measured in the hot condition. These measurements should be compared to the fiction limits in Tables 2 and 3 in the same way regardless of the test temperature. But this trend can be cited as an un-quantified conservatism inherent in the measurements taken at cold conditions.

ABWR and ESBWR Design Certification Documentation Applicability

The issues described above have been reviewed for applicability to documentation associated with 10 CFR 52 and it has been determined that there is no effect on the technical information contained in either the ABWR certified design or the ESBWR design in certification.

Probabilistic Analysis of the Condition

A probabilistic analysis was performed to estimate the frequency of earthquakes pertinent to this issue, defined as earthquakes higher in magnitude than the Safe Shutdown Earthquake (SSE), occurring while the plant is shutting down or starting up, and while all or some control rods are withdrawn. The analysis considered 17 US BWRs, covering a comprehensive range of SSEs and geographical locations. The frequency of exceedance for the different plant SSEs was extracted from the 2008 U.S. Geological Survey (USGS) National Seismic Hazard Maps. Based on the results of this analysis, the frequency of larger-than-SSE earthquakes occurring while the plant is shutting down or starting up, and while not all control rods are in, is expected to be less than [[ ]] per year for most U.S. BWRs. This frequency can be considered low in comparison to most initiating event frequencies used in a Probabilistic Risk Assessment (PRA).

In order to compare with the Core Damage Frequencies (CDFs) resulting from operating BWR PRAs, the probability of common cause failure of control rods to fully insert is estimated based on the postulated earthquake conditions and the channel bow concerns, which result in a failure of shutdown. The resulting consequence is a failure to achieve hot shutdown, which is comparable to the CDF contribution from the ATWS (Anticipated Transient Without Scram) sequences although additional systems/functions (e.g., the actuation of Standby Liquid Coolant, or SLC, system) can be credited. The frequency for failure to achieve hot shutdown is estimated to be [[ ]] per year.

Additionally, the failure to achieve cold shutdown is also estimated based on the minimum number of control rods that cannot be fully inserted resulting in a loss of shutdown margin. The frequency for failure to achieve cold shutdown is estimated to be [[ ]] per year.

Table 1a

Maximum Fuel Bundle Horizontal Acceleration and Associated Bundle Deflection for GNF Fuel Bundles for Various Plants*

Plant	Plant Type	Containment Type	Fuel Bundle Type	Maximum Acceleration** (g)	Deflection** (mm)	Natural Frequency Fuel First Mode (Hz)
Garona (Nuclenor)	BWR/3	Mark I	[[			
NMP 2	BWR/5	Mark II				
Hope Creek	BWR/4	Mark I				
Quad Cities 1&2	BWR/3	Mark I				
Pilgrim	BWR/3	Mark I				
Monticello	BWR/3	Mark I				
Dresden 2 & 3	BWR/3	Mark I				
Browns Ferry 1	BWR/4	Mark I				
Limerick 1 & 2	BWR/4	Mark II				
La Salle 1	BWR/5	Mark II				
La Salle 2	BWR/5	Mark II				
Fermi 2	BWR/4	Mark I				
Laguna Verde 1 & 2	BWR/5	Mark II				
Hatch 1	BWR/4	Mark I				
Hatch 2	BWR/4	Mark I				
Fitzpatrick	BWR/4	Mark I				
Duane Arnold	BWR/4	Mark I				
Brunswick 1 & 2	BWR/4	Mark I				
Peach Bottom 2 & 3	BWR/4	Mark I				
KKM	BWR/4	Mark I				
NMP 1	BWR/2	Mark I				
Cooper	BWR/4	Mark I				
Oyster Creek	BWR/2	Mark I				
Columbia	BWR/5	Mark II				]]

* The values listed are calculated for GNF fuel bundles in the indicated plants, and represent the most appropriate information available to GEH to date. See text for application guidance for non-GNF fuel.

** The values of maximum acceleration are the horizontal bundle-mid-length accelerations for Safe Shutdown Earthquake (SSE) loading only. The values of deflection are the horizontal dynamic deflections resulting from the SSE for plants with Mark I containment and from the combined loads of the SSE + loss of coolant accident (LOCA) + safety relief vale (SRV) events for plants with Mark II containment. For plants to which combined loads are applied the SSE acceleration is the primary contribution to the acceleration, so only the SSE-induced acceleration values are listed.

*** Maximum acceleration and bundle deflection values for the Garona plant are being re-evaluated by Nuclenor and GEH.

Table 1b

Selected GNF Data for Assessing Seismic Response Equivalency of GNF and Non-GNF Fuel

Property/Characteristic	BWR/2,3			BWR/4,5*	
	GE11	GE14	GNF2	GE14	GNF2
Bundle Moment of Inertia (in.^{4})	[[				
Bundle Area (in.^{2})					
Bundle Weight (lb.)					
[[ ]] Channel Moment of Inertia (in.^{4})					
[[ ]] Channel Area (in.^{2})					
[[ ]] Channel Weight (lb.)					
[[ ]] Channel Moment of Inertia (in.^{4})					
[[ ]] Channel Area (in.^{2})					
[[ ]] Channel Weight (lb.)					
Elastic Modulus for Zirconium Alloy Channels	]]				
[[	]]				

* Data shown is applicable also to GE14 and GNF2 in BWR/6 and ABWR plants, but the issue being addressed herein is not applicable to those plant types.

**[[ ]], then the plant-specific dynamic deflections for GNF bundles, as listed in Table, can be assumed applicable to the non-GNF fuel bundle.

Table 2 Maximum Allowed Control Rod Friction to Protect Against Incomplete Rod Insertion for 20-mm Bundle Dynamic Deflections (at all indicated Pressures) and Various Control Rod Weights

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Table 2 (cont.) Maximum Allowed Control Rod Friction to Protect Against Incomplete Rod Insertion for 20-mm Bundle Dynamic Deflections (at all indicated Pressures) and Various Control Rod Weights

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Table 2 (cont.) Maximum Allowed Control Rod Friction to Protect Against Incomplete Rod Insertion for 20-mm Bundle Dynamic Deflections (at all indicated Pressures) and Various Control Rod Weights

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Table 3 Maximum Allowed Control Rod Friction to Protect Against Incomplete Rod Insertion for 30-mm Bundle Dynamic Deflections (at all indicated Pressures) and Various Control Rod Weights

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Table 3 (cont.) Maximum Allowed Control Rod Friction to Protect Against Incomplete Rod Insertion for 30-mm Bundle Dynamic Deflections (at all indicated Pressures) and Various Control Rod Weights

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Table 3 (cont.) Maximum Allowed Control Rod Friction to Protect Against Incomplete Rod Insertion for 30-mm Bundle Dynamic Deflections (at all indicated Pressures) and Various Control Rod Weights

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Table 3 (cont.) Maximum Allowed Control Rod Friction to Protect Against Incomplete Rod Insertion for 30-mm Bundle Dynamic Deflections (at all indicated Pressures) and Various Control Rod Weights

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Table 3 (cont.) Maximum Allowed Control Rod Friction to Protect Against Incomplete Rod Insertion for 30-mm Bundle Dynamic Deflections (at all indicated Pressures) and Various Control Rod Weights

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Table 3 (cont.) Maximum Allowed Control Rod Friction to Protect Against Incomplete Rod Insertion for 30-mm Bundle Dynamic Deflections (at all indicated Pressures) and Various Control Rod Weights

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Table 4 Recommended Control Rod Friction Limits to Protect Against Incomplete Rod Insertion for 20-mm Bundle Dynamic Deflections at > 900 psig Reactor Operating Pressure and Combined with MFN 08-420 Friction Limits for MSIV isolation set point pressure

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Table 5 Recommended Control Rod Friction Limits to Protect Against Incomplete Rod Insertion for 30-mm Bundle Dynamic Deflections at > 900 psig Reactor Operating Pressure and Combined with MFN 08-420 Friction Limits for MSIV isolation set point pressure

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Table 6

Maximum Hot Wet Weights of GEH Control Rod Types For BWR/2-5

Control Rod Type	Control Rod Hot Wet Weight, lbs	
	C-Lattice	**D-Lattice**
OEM	[[	
DuraLife 100		
DuraLife 120		
DuraLife 140		
DuraLife 140A		
DuraLife 160		
DuraLife 190		
DuraLife 215		
DuraLife 230		
Marathon C		
Marathon C+		
Marathon D		
Marathon -5S C (Ultra MD)		
Marathon -5S D (Ultra MD)		]]

Appendix A

Guidance for Addressing a Stalled CRD During a Full-Stroke Insertion Test
(referred from page 14)

In the event the control rod motion stops prior to reaching the full-in position during the Full-Stroke Insertion Test, [[ ]] per Table A-1. [[

]] The control rod should not be reinserted by scram insertion. In the event that Table A-2 pressures are required to fully insert a control rod, GEH/GNF analyses indicate that component integrity will be maintained at this level of friction loading, and fuel lift will not occur under normal operating conditions. However, it is recommended that the control rod be inspected after completion of the current operating cycle, before continued use in subsequent cycles.

Table A-1

Maximum Drive Water Header Differential Pressures** vs. CRD Insert Stall Flow

(Continuous Full-Stroke Insertion Test for 600 lb_f Friction****)

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Table A-2

Maximum Drive Water Header Differential Pressures** vs. CRD Insert Stall Flow

(Continuous Full-Stroke Insertion Test for 1000 lb_f Friction****)

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