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MFN 12-111 R2

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

Subject: Completed Evaluation of Part 21 Potentially Reportable Condition Notification: Error in Main Steam Line High Flow Calculational Methodology

This letter provides information concerning the evaluation now completed by GE Hitachi Nuclear Energy (GEH) regarding a potential non-conservatism in the calculation of Main Steam Line (MSL) choked flow rates. As stated herein, GEH has concluded that this **is not a Reportable Condition** for all U.S. BWR/2-6 plants in accordance with the requirements of 10 CFR 21.21(d).

This letter closes the supplemental 60-Day Interim Report Notification (MFN 12-111 R1), provided on December 12, 2102, per §21.21(a)(2).

If you have any questions, please call me at (910) 819-4491.

Sincerely,

Dale E. Porter
Safety Evaluation Program Manager
GE-Hitachi Nuclear Energy Americas LLC
Attachments:

1. Description of Evaluation
2. US Plants Potentially Affected

References:

1. MFN 12-111 R1, Part 21 60-Day Interim Report Notification: Error in Main Steam Line High Flow Calculational Methodology, Dated December 12, 2012.

2. MFN 12-111 R0, Part 21 60-Day Interim Report Notification: Error in Main Steam Line High Flow Calculational Methodology, Dated September 27, 2012.

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Summary

GEH recently discovered that some calculations of the choked flow rate in the Main Steam Lines (MSLs) of GEH BWRs were non-conservative, with potential effects on margins between choked flow conditions and existing MSL high-flow Nominal Trip Setpoints (NTSPs), Allowable Values (AVs), and Analytical Limits (ALs).

GEH has now completed the evaluation of this condition and has determined this condition **is Not Reportable** under 10 CFR Part 21 for all U.S. BWR/2-6 plants. The effect of the discovered non-conservatisms in choked flow rate values was offset by unintended conservatisms in the GEH recommended formulation for calculating pressure drop across the MSL flow restrictor. As a result, GEH has determined that the flow-instrument pressure values associated with MSL high-flow Analytical Limits established using GEH methodology remain at conservative values (which would ensure that the associated Nominal Trip Setpoints and Allowable Values expressed in psid also remain at conservative values), and the MSL high-flow trip will function as designed. This update to the 60-day Interim Notification issued on December 12, 2012 (MFN 12-111 R1) will be sent to all US BWR/2-6 plants licensed using the GEH design basis and safety analysis.

Introduction

GEH recently discovered that some calculations of choked flow rates in the Main Steam Lines (MSLs) of GEH BWRs were non-conservative, with potential effects on margins between choked flow conditions and existing MSL high-flow Analytical Limits (ALs), Allowable Values (AVs), Nominal Trip Setpoints (NTSPs), and other setpoints values based on the AL. The choked flow rate (or critical flow) in this application is the maximum MSL flow rate experienced during a postulated double-ended guillotine steam line break downstream of the MSL flow restrictor and outside of containment. This maximum flow rate is determined in part by the geometry of the in-line MSL flow restrictor (which also serves as a venturi flow meter), the stagnation pressure of the flow at the inlet to the flow restrictor, and the steam quality (or moisture content) of the flow through the restrictor. Establishing this choked flow rate is important for proper setpoints calculations because the MSL high-flow trip ensures that MSL isolation is initiated (i.e., Group 1 isolation) when high flow is detected. For the purpose of evaluating this condition, conservative establishment of the MSL high-flow AL is considered sufficient for ensuring MSL high-flow trip function, given that GEH setpoint methodology and other setpoint methodologies that follow U.S. NRC Regulatory Guide 1.105 and ANSI/ISA-67.04 ensure suitable values are derived for the NTSP, AV, and other setpoints values based on the AL.

The concern raised with this discovery has been that the actual choked flow rate would be lower than the values previously calculated. Underlying this concern is the intended design function of the MSL high-flow trip to activate MSL isolation (Group 1 isolation) during a postulated Main Steam Line Break (MSLB) outside of containment.

The licensing basis for the function of the MSL high-flow trip (more formally termed the "Main Steam Line Flow - High instrument trip") is as follows:

- The GEH BWR design basis incorporates flow restrictors into the MSL, and MSL isolation is activated by flow-restrictor pressure-drop instrument signals to mitigate release from a MSLB, which satisfies General Design Criteria (GDCs; or the plant's equivalent in their licensing basis), 10 CFR 50.46, and 10 CFR 100 (and other regulations on dose consequences).
- The safety analysis report (SAR) credits these design features, to limit coolant flow rate during the release and to terminate the release, which ensures that GDCs or their equivalents, 10 CFR 50.46 and regulatory dose limits (such as 10 CFR 100) are met.
- The licensing basis for the function of the MSL high-flow instrument trip is, therefore, the SAR and the plant Technical Specifications that establish a Limiting Condition for Operation for the instrument signal.
- There is no other stated licensing requirement; although other documents (such as the GEH Constant Pressure Power Uprate Licensing Topical Report and the Standard Technical Specifications bases documents, NUREG-1433, rev. 4 and NUREG-1434, rev. 4) note that the purpose of the trip is to mitigate release as credited in the SAR.

The MSL high-flow AL corresponds to the maximum allowable flow rate protected against by the MSL high-flow setpoint function in the event of a MSLB. Thus, the AL must be established as a value at, or marginally below, the choked flow rate to ensure that flow does not choke at some rate less than needed (considering uncertainty) for actuation of the MSL high-flow trip. Margins between choked flow rate and the MSL high-flow AL (termed "MSL flow margin" here) at or near the original licensed thermal power are relatively large, greater than 30% of rated flow for many plants. Increases in the MSL flow rate at uprated power have often included raising the AL to keep the AL at the same value of rated flow, which decreases the MSL flow margin. As an example, for a constant pressure power uprate for which the choked flow rate remains the same, an AL set at 140% of uprated flow is higher than an AL set at 140% of original flow, and the margin between choked flow conditions and the AL is thereby reduced. This trend of decreasing margin motivates prior and current efforts to ensure that MSL flow margins remain sufficient to ensure reliable high-flow trip functionality.

Additional work on this issue revealed that the formulations previously used for calculating the pressure drop across the MSL flow restrictor (i.e., the flow instrument pressure drop) introduced excess conservatism. The over-conservatism offsets against the discovered non-conservatism such that current flow-instrument pressure drop values associated with MSL ALs, and therefore AVs and NTSPs, remain conservative with respect to this discovery. Furthermore, diverse methods incorporated into the reactor design-basis instrumentation (such as trip signals for low MSL pressure and for high main steam tunnel temperature and differential temperature) provide high confidence that a reactor scram and MSIV isolation will occur during design basis events.

This update summarizes the results of the GEH evaluation, to provide background supporting the determination that this condition **is not a Reportable Condition** under 10 CFR 21 for all U.S. BWR plants.

Description of Discovery

Non-conservatisms present in GEH calculations of choked flow rate are attributed to the choice of flow pressure and choice of steam properties used in the calculations. The over-conservatism in previous calculations of flow-restrictor pressure drop is similarly due to choice of steam properties used.

Choice of Flow Pressure

In many cases, GEH's previous calculations of choked flow rate did not explicitly consider MSL pressure losses between the reactor pressure vessel and the inlet to the MSL flow restrictor. These calculations often used pressure values at or near reactor dome pressure, rather than the stagnation pressure values associated with the flow restrictor inlet, which are lower than the pressure in the reactor pressure vessel and represent the pressure that drives choked flow phenomena in the restrictor. This choice of pressure resulted in a higher calculated choked flow rate than would result if calculated using the pressure at the flow restrictor inlet. This non-conservatively high value of choked flow rate often resulted in a non-conservative calculation of margin between choked flow rate and the MSL high-flow AL, particularly when the AL was established in terms of % of rated flow. At original licensed thermal power with relatively large margins (discussed in the previous section), the choice of pressure input for the calculations did not appreciably affect the results, but a trend of reduced flow margins with power uprates (with associated increases in steam flow and adjusted ALs) now motivates use of the most representative input values.

Choice of Steam Properties

GEH noted that multiple models (or equations) for calculating choked flow rate are available, and differences in results from the various methods can be significant for cases with lower MSL flow margin. Flow models differ primarily in treatment of two-phase flow phenomena, which is challenging, with the simpler models assuming ideal gas behavior. However, more significant than the impact of different flow models is the impact of fluid properties input into the model formulations. GEH found that certain input values were representative of dry steam behaving as an ideal gas rather than steam with small amounts of moisture, as is typical of the MSL. The reason that previously selected input values were not more representative of MSL flow conditions is uncertain; however, simplifications applied in previous years were appropriate for cases with relatively large margin between choked flow rate and the MSL high-flow AL. But reduction of that margin reduces the ability to accommodate flow uncertainties.

The previous input values tended to result in higher calculated choked flow rates and in lower values of calculated flow-restrictor (or flow-instrument) pressure drop than obtained with the updated method. So, although the real margin between choked flow rate and the chosen MSL high-flow AL may have been obscured, the previously calculated flow-instrument pressure drop values associated with flow rates at choked flow conditions and at the ALs were lower than intended, and the ALs have been sufficiently low to ensure intended function of the MSL high-flow trip.

Extent of Condition

This condition extends to all GEH BWR/2-6 plants licensed using GEH design basis and safety analysis; specifically, plants for which choked flow rates were calculated using the previous methods. GEH has now established updated formulations for calculating choked flow rate and flow-instrument pressure drop, including clarification of conditions and input values appropriate for MSL application.

The following may be helpful when considering this issue. When establishing the MSL high-flow AL, AV and NTSP, an engineer will typically think of margin against choked flow conditions and spurious trip margin in terms of flow rate – this is intuitive. However, the MSL high-flow instrumentation in the plant does not measure a flow rate, but rather a pressure drop across the flow restrictor. So, any margins are ultimately managed by establishing flow-instrument pressure drop values for the AL, AV, and NTSP. For this reason, and because the GEH revised calculation in minimum MSL flow margin was determined in units of pressure drop (psid), this issue has been evaluated by considering the AL at the plants in terms of flow-instrument pressure drop, rather than in terms of MSL flow rate.

From those formulations GEH has re-evaluated choked flow rates and flow-instrument pressure drop values at choked flow and for MSL high-flow ALs. As explained in the next section, the evaluations show that for all such plants the MSL high-flow trip will actuate during a postulated double ended guillotine MSLB outside containment under rated conditions. However, due to the update to the calculation method, previous values of flow-instrument pressure drop expressed in psid now correspond to a lower flow rate, and previous values of flow rate now correspond to a higher flow-instrument pressure drop in psid. Although this determination is based on current ALs expressed in terms of flow-instrument pressure drop (i.e., in psid), the conclusion is true for the ALs, AVs, and NTSPs as they are implemented at the plant (regardless of the values of MSL flow rate previously associated with those psid values). For plants having larger MSL flow margin, the current expressions of AL and AV in flow rate may also be conservative with respect to choked flow conditions due to even the revised value of flow-instrument pressure drop (in psid) having sufficient margin to choked flow. Whether the AV appearing in the plant’s Technical Specifications should be revised depends on 1) whether the Technical Specifications AV (as expressed in either psid or % of rated flow) has sufficient margin to choked flow conditions, and 2) whether the Technical Specifications AV is high enough to provide sufficient spurious trip margin.

GEH will issue revision 2 of Services Information Letter No. 438 (last released as revision 1 in May 1994) to update the method for calculating flow-instrument pressure drop for a given flow rate. To request technical assistance from GEH, plant staff should contact their GEH customer representatives.

Evaluation of Reportability Under 10 CFR 21

This condition was evaluated under 10 CFR 21 by comparing flow-instrument pressure drop values at choked flow conditions, as determined using the updated GEH method, to those of the current ALs for a selected set of plants. The plants were selected for evaluation because they were identified as having lower MSL flow margin after power uprate. Other plants were also included in the evaluation, some uprated and some at original licensed thermal power, to confirm that the trending of lower-margin plants sufficiently identified the plants with lowest margin and to confirm no other configuration of plant parameters would lead to low MSL margin. For all plants evaluated, current values of the MSL high-flow AL, and therefore MSL high-flow NTSP and AV by inference, were found to have sufficient margin to choked flow conditions to ensure the MSL high-flow isolation will function at rated conditions as designed. The selection of plants adequately covers the spectrum of rated conditions and plant design to extend the conclusion to all GEH BWRs, licensed using GEH design basis and safety analysis.

For these reasons, GEH determined the discovered condition cannot produce a Substantial Safety Hazard and cannot contribute to exceeding a Technical Specification Safety Limit, and therefore is Not Reportable under 10CFR 21 for all U.S. BWR/2-6 plants.

ABWR and ESBWR Design Certification Documentation Applicability

The issue described herein has been reviewed for applicability to documentation associated with 10 CFR 52, and determined to have no effect on the technical information contained in either the ABWR certified design or the ESBWR design in certification. This is true because the Technical Specifications submitted with the Design Certification Documentation do not include specific or suggested values of MSL high-flow Analytical Limits or Allowable Values, and because details of specific components, such as dimensions of the MSL flow restrictor are not available at the time of design certification to allow calculations of choked flow rate.

Corrective/Preventive Actions

GEH intends to issue a revision to Services information Letter 438, “Main Steam Line High Flow Trip Setting,” (currently issued as revision 1 on May 5, 1994). This next revision will update the recommended formulation and input values used to calculate MSL flow-instrument pressure drop values associated with MSL flow rates.

Attachment 2
US Plants Potentially Affected

US BWR Plants and Associated Facilities

	Utility	Plant
X	Constellation Energy	Nine Mile Point 1-2
X	Detroit Edison Co.	Fermi 2
X	Energy Northwest	Columbia
X	Entergy	Grand Gulf
X	Entergy	River Bend
X	Entergy	FitzPatrick
X	Entergy	Pilgrim
X	Entergy	Vermont Yankee
X	Exelon	Clinton
X	Exelon	Dresden 2-3
X	Exelon	LaSalle 1-2
X	Exelon	Limerick 1-2
X	Exelon	Oyster Creek
X	Exelon	Peach Bottom 2-3
X	Exelon	Quad Cities 1-2
X	FirstEnergy Nuclear Operating Co.	Perry 1
X	NextEra Energy Resources	Duane Arnold
X	Nebraska Public Power District	Cooper
X	PPL Susquehanna LLC	Susquehanna 1-2
X	Progress Energy	Brunswick 1-2
X	PSEG Services Corp.	Hope Creek
X	Southern Nuclear Operating Co.	Hatch 1 - 2
X	Tennessee Valley Authority	Browns Ferry 1-3
X	Xcel Energy	Monticello
X	North East Utilities	Millstone