ENCLOSURE 2

MFN 10-355 Supplement 1

Response to NRC Supplemental RAIs - NEDC-33173P, Revision 2 and Supplement 2, Parts 1-3

Non-Proprietary Information – Class I (Public)

INFORMATION NOTICE

This is a non-proprietary version of Enclosure 1 to MFN 10-355 Supplement 1, from which the proprietary information has been removed. Portions of the enclosure that have been removed are indicated by an open and closed bracket as shown here. [[ ]]

RAI 20 Supplement 1

The response to RAI 20 provides justification for an extended LPRM calibration interval based on extrapolation of the error to higher LPRM calibration intervals. However, previous data indicate a trend of increasing local power distribution uncertainty with increasing power-to-flow ratio. If simultaneous extrapolation in both LPRM calibration interval and power-to-flow ratio is considered, what is the magnitude of the update uncertainty for MELLLA+ operation? Using this revised update uncertainty, what is the uncertainty in LHGR?

Response:

1 Summary

The RAI 20 responses previously submitted (MFN 10-355, December 17, 2010), provided summaries of the change in thermal margins following a TIP calibration (of the LPRMs) as a function of the exposure interval between the TIP calibrations. No calibration interval dependency was seen in the change in CPR (MFLCPR) or nodal average kW/ft (MAPRAT, ECCS nodal limit comparison), with only a slight upward trend in the change in the local peak kW/ft (MFLPD).

In a similar manner, the change in thermal margins can be evaluated as a function of the core power to core flow ratio (P/F). When this is done, no dependency is seen in the change in thermal margins for MFLCPR or MAPRAT when considered as a function of P/F, while only a slight upward trend of MFLPD with P/F is seen. Thus, there is no SLMCPR impact as a result of these trends. The only impact may be a slight increase in the LPRM update uncertainty component of the LHGR total uncertainty.

The current [[ ]]% allowance for the LPRM update uncertainty results in a total LHGR uncertainty of [[ ]]% compared to the process limit of [[ ]]%. The LPRM update uncertainty component could grow to [[ ]]% before adversely impacting the [[ ]]% process limit on total LHGR uncertainty. A simultaneous extrapolation in both LPRM calibration interval and power-to-flow ratio results in a [[ ]]% nominal LPRM update uncertainty, evaluated at [[ ]]. Using the [[ ]]% nominal LPRM update uncertainty combined with the standard squared error results in a bounding LPRM update uncertainty of [[ ]]%. Using this [[ ]]% uncertainty value for the LPRM update uncertainty, a total uncertainty of [[ ]]% results, which continues to demonstrate margin to the [[ ]]% total LHGR uncertainty process limit.

1.1 Identification of P/F Operating States

The ratio of total reactor power to total core flow (P/F) has previously been identified as a key parameter for understanding potential effects in the progression to EPU and MELLLA+ operation in MFN 05-029. The ‘target upper value’ used in this discussion is [[ ]].

The following plot of actual operational data (P/F plotted vs. Cycle Exposure, where RP is reactor power and WCT is core flow) is extracted from all of the available off-line core tracking cases from the core tracking database (all BWR 2-6 plants supported by GNF / GEH), and is composed of more than [[ ]] data points. As can be seen, the majority of the plant data is below [[ ]], but clearly plants have been occasionally operating in the range of [[ ]]. However, the available database of TIP comparison cases does not extend to this full range.

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Figure 20 S1-0

1.2 TIP RMS as a Function of Reactor Power / Core Flow – Non-Adapted

RAI 25 (MFN 05-029, April 8, 2005) discussed TIP RMS values as a function of P/F for non-adapted off-line core tracking with PANAC11. In particular, Figure 25-19 (page 94 of MFN 05-029) provides TIP RMS differences vs. P/F ratio for Gamma TIP Cycles. For clarity, this figure is included in this discussion as Figure 20 S1-1.

As per the MFN 05-029 discussion (page 49), for the Gamma TIP plants, the linear trend line indicates [[ ]]. The Axial RMS [[ ]]. The Bundle RMS [[ ]] Extrapolating the trend lines for the Gamma TIP plants to [[ ]], the Nodal and Axial RMS values would be on the order of [[ ]]%, while the Bundle RMS would be less than [[ ]]%.

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Figure 20 S1-1

1.3 TIP RMS Addition of Cofrentes Data – Non-Adapted

When data from the Cofrentes Cycle 15 non-adapted off-line core tracking is added to this plot (Figure 20 S1-2), the trends of the Cofrentes data are seen to be quite consistent with the previous data. This presentation of the data has too much information, so individual components are provided in the following Figures 20 S1-3, -4, and -5.

As is seen, there is no [[ ]], while a [[ ]].

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Figure 20 S1-2

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Figure 20 S1-3

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Figure 20 S1-4

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Figure 20 S1-5

1.4 TIP RMS Impact of Adaption in On-Line Core Monitoring

In the on-line core monitoring with 3D Monicore™ using PANAC11, shape adaption is used to modify the thermal margins. In the shape adaption process, [[

]]. Figures 20 S1-6, -7, and -8 show the impact of the on-line adaptive process on the TIP RMS values for the bundle, axial, and nodal comparisons.

As can be seen, the [[ ]] is not affected by this process. Any [[ ]] is eliminated, and the [[ ]] becomes essentially the same as the [[ ]]. Thus, for core monitoring with 3D Monicore™, **any potential concerns** regarding the impact of [[ ]] that might lead to increased uncertainty in the thermal margins **are eliminated by the adaption process.**

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Figure 20 S1-6

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Figure 20 S1-7

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Figure 20 S1-8

1.5 LPRM Update Uncertainty as a Function of Reactor Power / Core Flow

The original RAI 20 response (MFN 10-355, December 17, 2010) discussed the LPRM update uncertainty as a function of the exposure interval between TIP calibrations. Data from a relatively large number of TIP calibrations were retrieved to enable evaluation of the change in thermal margins as a result of the re-calibration of the LPRMs using the TIP measurements. All of this data was obtained from 3D Monicore™ on-line shape adapted core tracking. For the majority of the database that had been constructed, data on the reactor power and core flow had also been obtained, so that trending of the change in thermal margins with the P/F ratio could also be examined. One sub-set of data, however, did not contain data for the P/F ratio. Therefore only [[ ]] were used for this trending vs. P/F ratio. Again, changes in [[ ]] were considered.

Figure 20 S1-9 provides the change in [[ ]] as a result of a TIP calibration, plotted as a function of the P/F ratio. As can be seen, there is no trending of the change in [[ ]] as a function of the P/F ratio. The reason for this lack of trending is that the shape adaption process does not materially impact the [[ ]], and hence the use of TIP and LPRM shape adaption does not cause any significant change in the [[ ]] distributions.

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Figure 20 S1-9

Figures 20 S1-10 and 20 S1-11 provide the trending with the change in [[ ]] and [[ ]] following TIP calibration as a function of P/F. As can be seen, there is no trending with [[ ]], but a slight upward trend with [[ ]].

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Figure 20 S1-10

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Figure 20 S1-11

1.6 Double Extrapolation of Slight [[ ]] Trending

Because slight trending exists in [[ ]] for LPRM updates for both the exposure interval and P/F individually, it is reasonable to consider these slight tendencies in combination. The RAI 20 Supplement 1 question reads in part: "*If simultaneous extrapolation in both LPRM calibration interval and power-to-flow ratio is considered, what is the magnitude of the update uncertainty for MELLLA+ operation?*" To evaluate this question, the "Change in [[ ]]" is assumed to be a linear function of both the "Exposure Interval between TIP sets" and the ratio "RP/WCT", and a least squared fit analysis in three dimensions is used, with

$$z = a_0 + a_1 x + a_2 y, \quad (1)$$

where z represents the "Change in [[ ]]", x represents the "Exposure Interval between TIP sets" and y represents the ratio "RP/WCT", where RP is the Reactor Power in MWt and WCT is the total core flow in Mlb/hr. The symbols a_0, a_1 and a_2 are the least square fit parameters. Using this approach, the extrapolated "Change in [[ ]]" at with the "Exposure Interval between TIP sets" equal to [[ ]] and the ratio RP/WCT = [[ ]] MWt / Mlb/hr, is [[ ]]%.

Graphically, the process is shown below in Figure 20 S1-12.

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Figure 20 S1-12: Change in [[ ]] as a function of Exposure Interval and RP/WCT

The individual least square estimates of the “Change in [[ ]]” is given by $z_{i,fit}$ and the error mean square is given by

$$EMS = \frac{\sum_{i=1}^{n}(z_i - z_{i,fit})^2}{n-3}$$

The evaluated value of the EMS is [[ ]]. A total RMS estimate can be computed by taking the square root of the sum of the square of the extrapolated value and the EMS, which yields a result of [[ ]]% for the doubly extrapolated LPRM update uncertainty.

The current [[ ]]% allowance for the LPRM update uncertainty results in a total LHGR uncertainty of [[ ]]% compared to the process limit of [[ ]]%. The LPRM update uncertainty component could grow to [[ ]]% before adversely impacting the [[ ]]% process limit on total LHGR uncertainty.

A simultaneous extrapolation in both LPRM calibration interval and power-to-flow ratio results in a [[ ]]% nominal LPRM update uncertainty, evaluated at [[ ]] MWt/Mlb/hr power to flow ratio and [[ ]] TIP calibration interval. Using the [[ ]]% nominal LPRM update uncertainty combined with the standard squared error results in a bounding LPRM update uncertainty of [[ ]]%. Using this [[ ]]% uncertainty value for the LPRM update uncertainty, a total uncertainty of [[ ]]% results, which continues to demonstrate margin to the [[ ]]% total LHGR uncertainty process limit.

RAI 21

Please provide justification for the assumption made in the SLMCPR calculation that the power distribution uncertainties are normally distributed.

Response:

This question is similar to Question III – 3 in NEDC-32694P-A, page A-11 (MFN-005-98, January 9, 1998). The data for the power allocation factor comparisons from the Cofrentes Gamma Scan provides essentially the same results as the previous confirmation. In MFN-005-98, the Anderson-Darling Normality Test was satisfied with a P-Value of [[ ]] from Millstone Cycle 7 gamma scan data were removed. For the Cofrentes data, the Anderson-Darling Normality Test was satisfied with a P-Value of [[ ]]. Figure 21-1 below provides the normal probability plot for the Cofrentes power allocation factors (data for both Cycle 13 and Cycle 15 gamma scans is combined). As was noted in the MFN-005-98 response to Question III – 3, the P-value is the probability that the proposition that the distribution is not normal is false. Normally, a P-Value of 0.1 or higher is sufficient to show the distribution is normal.

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Figure 21-1