Request for Additional Information
Framatome ANP
ANF-1358(P), Revision 3
"The Loss of Feedwater Heating Transient in Boiling Water Reactors"

Question 1:

Recently, Global Nuclear Fuel (GNF) and General Electric Nuclear Energy (GENE) notified the NRC by issuing a Part 21 report (ADAMS Accession no. ML042720293) that using limiting control rod blade patterns developed for less than rated flow at rated power conditions could sometimes yield more limiting bundle-by-bundle minimum critical power ratio (MCPR) distributions and/or more limiting bundle axial power shapes than the limiting control rod patterns developed for a rated flow/rated power safety limit MCPR (SLMCPR) calculation. GNF and GENE took corrective actions that require the SLMCPR to be calculated at the rated power/rated flow and at the minimum core flow/rated power conditions, using appropriate limiting control rod patterns. Figure 4.1 of the submittal shows the state points selected by the applicant (Framatome ANP) for the analysis, as plotted on a generic BWR power/flow map. It is apparent from the figure that the number of state points selected at the high-power/high-flow region of the map are significantly large; whereas, fewer state points were selected at the high-power/low-flow region. Clarify if the data used to develop the correlation also includes the state points that represent the minimum core flow at rated power conditions, using appropriate limiting control rod patterns.

Response 1:

The data used in developing the correlation does include the state points that represent the minimum core flow at rated power conditions. These data included the actual state points of the high power/high flow and the high-power/low-flow which includes actual control rod patterns for a variety of BWR plants and different BWR classes. In particular, a LFWH event was simulated whenever a significant change in the control rod pattern was made. The incremental exposure between events is approximately 500 MWd/MTU or less.

The LFWH analysis is an evaluation of how [ ]. Figure 6.6 and Figure 6.7 show that the bounding correlation has no dependency on the core thermal power and core flow.

Question 2a:

In the last approved version of the methodology, as described in ANF-1358(P)(A), Revision 1, April 1992, the methodology was not used to calculate the limiting linear heat generation rate (LHGR); whereas, the proposed version of the methodology (Revision 3) will be used to calculate the limiting LHGR (in addition to the limiting MCPR). Please explain the rationale behind the decision now to perform LHGR calculation using the methodology.

Response 2a:

In hindsight the originally approved licensing topical report (Revision 1) should have included a discussion on LHGR. Since it did not, FANP has for each reload fuel licensing analysis evaluated the impact of the LFWH event on LHGR on a cycle-by-cycle specific basis. In addition, [

], It was necessary for completeness to add the LHGR analysis as well.

Question 2b:

Loss of feedwater heating (LFWH) can be the limiting event when establishing the reload MCPR operating limit. Is the same event also generating the limiting LHGR? Describe in detail how the limiting LHGR is currently calculated, and whether the proposed approach will predict a more conservative LHGR and MCPR, compared to the currently calculated values.

Response 2b:

The LFWH event is seldom a limiting event that sets the reload MCPR operating limit. Relative to LHGR, a LFWH event does not necessarily give the limiting, i.e., worst, LHGR increase.

A Fuel Design Limit Ratio (FDLRX) is defined as the calculated LHGR over the steady-state LHGR limit.

$$FDLRX = LHGR / LHGR_{\text{Steady-State Limit}}$$

Under normal operation, FDLRX is maintained below 1.0 to ensure that the steady-state LHGR limit will not be exceeded. [

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The steady-state and the AOO LHGR limits are exposure dependent. They are established for each fuel design and are based on nuclear design analyses and the fuel mechanical design criteria. Conservative power histories based on proposed LHGR limits are used in the mechanical analyses to show compliance to the fuel rod mechanical design criteria. The AOO LHGR design limit protects the fuel from cladding strain and fuel overheating.

The mechanical analyses were performed using the NRC approved methodology as described in the Topical Report EMF-85-74(P) Revision 0 Supplement 1(P)(A) and Supplement 2(P)(A), RODEX2A (BWR) Fuel Rod Thermal-Mechanical Evaluation Models, February 1998. The mechanical design criteria are contained in the NRC-approved topical, ANF-89-98(P)(A) Revision 1, Generic Mechanical Design Criteria for BWR Fuel Designs, May 1995.

An example of the [ ] ratio between the normal operation LHGR limit and the AOO limit can be found in the approved Topical Report, ANF-89-014(P)(A) and Supplements 1 and 2, Generic Mechanical Design for Advanced Nuclear Fuels 9x9-IX and 9x9-9X BWR Reload Fuel, October 1992. Although this topical report predates the approved generic design criteria topical and the current methodology topical, the same methods were used in establishing the LHGR limits as currently approved.

The bounding correlation for determining delta-CPR reported in Revision 3 (this report) gives slightly more conservative values (about 0.03 higher than the original bounding correlation for a core with 2894 rated MWth, 12.47 Mlbm/hr rated feedwater flow, and a delta feedwater temperature of 100 °F) than in the originally approved licensing topical report (Revision 1) because it includes the original data as well as additional data that covers more diverse core conditions. Additional conservatism was incorporated in defining the bounding fit coefficients. The method in the topical report for determining compliance to LHGR criteria for the LFWH event is the same as was done in the past on either a plant or cycle-specific basis. Hence, it is no more or less conservative compared to the currently calculated values.

Question 2c:

FDLRX is defined as the nodal value of LHGR divided by the LHGR fuel design limit. [

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How do you justify operating with such values of LHGRs? If it is at all justifiable to operate [
] then your response should also include the maximum value of FDLRX that is acceptable before fuel damage can occur.

Response 2c:

Under steady state operation, FDLRX must always be less than 1.0. As discussed on the previous response, LHGR limits are set to ensure the AOO LHGR limit is not violated during or after an LFWH event.

Under normal and Anticipated Operational Occurrence (AOO), the General Design Criteria requires that fuel and cladding be protected from excessive strain and overheating. To protect against such failures, FANP imposes requirements that the fuel centerline temperature cannot exceed the melting point and the cladding strain during a transient cannot exceed 1%. [

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The submitted Licensing Topical Report (Revision 3) has shown that the LFWH event does not results in [ ].

Applicability of the Topical Report to SVEA fuel

The NRC asked a question, during the meeting between Framatome ANP and the NRC to initiate the review of the topical report, about the applicability of the report to other fuel types (Specifically SVEA fuel).

The bounding correlation database presented in the topical report did not contain SVEA fuel. This is because the database consists of measured reactor state points and no measured data for cores containing SVEA fuel was available. However, the bounding correlation has been applied to calculated results for future cycles of a mixed core containing SVEA fuel and Framatome ANP fuel. The bounding correlation was demonstrated to be applicable to the SVEA fuel as well as the Framatome ANP fuel for these future cycles. The increase in LHGR for the LFWH event was found to be less than the AOO LHGR limit for both Framatome ANP and SVEA fuel.

Following the submittal of the topical report, a complete cycle of measured reactor state points containing mixed ATRIUM 10 and SVEA fuels become available in November 2004. The bounding correlation was then applied to the measured data. The results demonstrate that the bounding correlation is applicable to the SVEA fuel, i.e., the correlation results bound the calculated results. The application results are shown in Table 1.

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Table 1 LFWH Transient Analysis for AVEA Fuel

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