REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**399-8510**
SRP Section:	**15.06.05 – Loss of Coolant Accidents Resulting From Spectrum of Postulated Piping Breaks Within the Reactor Coolant Pressure Boundary**
Application Section:	**15.06.05**
Date of RAI Issue:	**02/03/2016**

Question No. 15.06.05-7

Provide an evaluation of the potential for fuel failure during the initial power spike in the LBLOCA evaluation (Fig 15.6.5-5)

Regulatory Basis:

NUREG-0800, Section 15.6.5, requires that the evaluation of a LBLOCA address:

- Design basis radiological consequence analyses associated with design basis accidents per NUREG-0800, Section 15.0.3.3.
- Fuel failure modes and burst correlations are evaluated for compliance with 10 CFR 50.46 as part of its fuel design review per NUREG-0800, Section 4.2required to mitigate the consequences of the accident.

Technical Basis:

The LBLOCA reactor power response (Figure 15.6.5-5 of the APR1400 DCD) shows normalized power increasing to 1.7 times nominal in the first 0.5 sec of a 100 percent double-ended guillotine LBLOCA transient. Values approaching 1.8 times nominal are seen for 60 percent double-ended cases (Figure15.6.5-13). This behavior is not as expected for this event, since core depressurization and voiding usually result in the insertion of significant negative reactivity.
The power increase is suspected to be due to the moderator reactivity curve being used (this curve is taken from the RELAP5/MOD3.3K input file).
Such a large increase in power may cause fuel failures.
It is recognized that this conservative reactivity versus density curve was developed for the analysis of other events evaluated in Chapter 15 which are assessed using a conservative (versus best estimate plus uncertainty) basis. This conservatism results in the inclusion of

positive moderator reactivity feedback which is not allowed per the Technical Specifications. However, the use of the conservative curve in the best estimate application leads to large power excursions.

Question:

1. A verification and an explanation for the shape and magnitude (positive reactivity at some densities) of the curve. In particular, the increase in reactivity with decreasing moderator density for densities above 500 kg/m^3.

2. A justification for the use of the conservative curve in a best estimate plus uncertainty evaluation.

3. An explanation for the rapid increase in reactor power during the first 0.5 sec of the LBLOCA transient, and

4. An evaluation of fuel performance during this spike in power to determine if the fuel fails due to PCMI or fuel melt.

Response – Rev. (1)

1)

Figure 1 shows a curve of reactivity vs. moderator density used in the LOCA evaluation. The value of the density coefficient used corresponds to a 0 MTC for the small break events and $+0.5\times10^{-4}$ Δρ/°F for the large breaks (Table 4.3-3 of the APR1400 DCD).

As moderator temperature increases or pressure decreases, the moderator density decreases reducing the amount of moderator in the core. Decreasing moderation leads MTC to become more negative. But the amount of soluble boron is also reduced when the moderator density decreases. Reducing neutron absorption of boron leads to a positive effect on reactivity.

The higher boron in the MDC curve corresponding to $+0.5\times10^{-4}$ Δρ/°F MTC causes positive reactivity with decreasing moderator density compared with a MDC curve corresponding to 0 MTC.

2)

The maximum positive limit of MTC is 0.0 Δk/k/˚F at 100% RTP (LCO 3.1.3). The realistic MTC value for full power operation is negative. But the moderator density coefficient corresponding to 0.5 x 10^{-4} Δρ/°F MTC is used for the large break LOCA to conservatively account the non-uniform voiding. It is not the realistic value, but a very conservative one.

3)

The major cause of the rapid power spike is due to the positive reactivity with decreasing moderator density during the early phase of LBLOCA transient. Figure 2 shows the normalized core power during 1.0 × Double-ended Guillotine Break in Pump Discharge Leg (same case as

Figure 15.6.5-5 of the APR1400 DCD) using the density coefficient of 0 MTC. In this case, there is almost no power excursion.

4)

The melting temperature of uranium dioxide pellets is 2,804 °C (5,080 °F) for unirradiated fuel and decreases by 32 °C (58 °F) per 10,000 MWD/MTU (Section 4.4.1.2 of the APR1400 DCD). The highest fuel temperature in the large breaks analyzed is [ ]TS, which is lower than the fuel melting temperature limit.

The current LBLOCA evaluation is based on an unrealistic positive MDC. For realistic evaluation, a sensitivity study using 0 MTC demonstrates that there is no power excursion. Therefore it is not necessary to perform an evaluation of fuel performance due to PCMI.

The re-analysis of large break LOCA using realistic density coefficient and 181 SRS(Simple Random Sampling) calculations with the additional application of thermal conductivity degradation (TCD) effect was performed. DCD revision which includes the results of re-analysis is provided.

DCD revision also contains the increased data number of the containment time table applied to transfer mass and energy data (M/E data) from RELAP5 to CONTEMPT4 which reads the transferred data at given time points. During the large break LOCA the containment pressure rapidly increases after RCS piping break because of high M/E release from the break and gradually decreases over time with the operations of containment spray and cooling fan.

After performing the analyses before the revision, time reading points tended to over-estimate the M/E data in the minimum containment pressure analysis. When coupling the RELAP and CONTEMPT codes it was found that denser data reading time points resulted in better convergence of the M/E data and more conservative results in the estimation of containment pressure. Sensitivity studies showed that using denser data points made visible changes to the results, e.g. going from 29 time steps to 100 time steps. However, when evaluating the combined effects with or without TCD and MDC, with keeping time steps constant (29), the results indicated that there were negligible differences between the Rev. 1 and Rev. 2 results of the minimum containment pressure analysis.

Figure 3 shows the comparison of containment pressure curves for the different time table numbers in the minimum containment pressure analysis. Specifically, the red solid line (Rev.1_29 time table) represents the result from the case of 29 time table number with previous MDC curve with no TCD input application. The blue dash-dot line (Rev.2_100 time table) represents the final containment pressure analysis results with using a 100 time table number including TCD input and revised MDC curve. The black dotted line (Rev.2_29 time table) represents the same case as the final analysis results (blue line) however it represents results at a reduced time table number of 29.

The input differences of the containment pressure comparison analysis shown in Figure 3 are summarized in Table 1. The input of ‘Rev.2_100 Time Table’ is applied to current revised LBLOCA analysis of DCD sections 6.2.1.5 and 15.6.5.

Table 1. Major Input Differences for Containment Pressure Comparison

Legends in Figure 3	TCD Inputs	MDC Revision	Containment Time Table
Rev. 1_29 Time Table	None	None	29
Rev. 2_29 Time Table	✓	✓	29
Rev. 2_100 Time Table	✓	✓	100

TS

Figure 1. Reactivity vs. Moderator Density for LOCA Evaluation

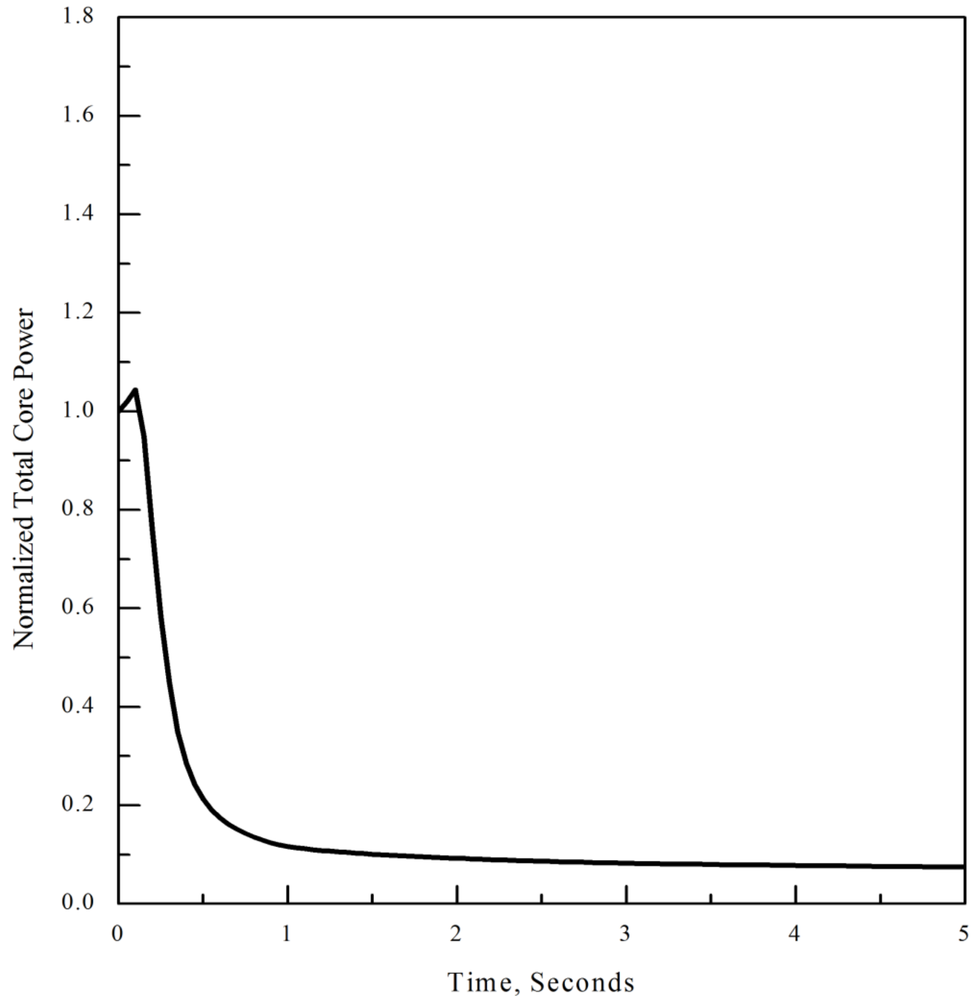

Figure 2. Normalized Core Power using Density Coefficient Corresponds to 0 MTC

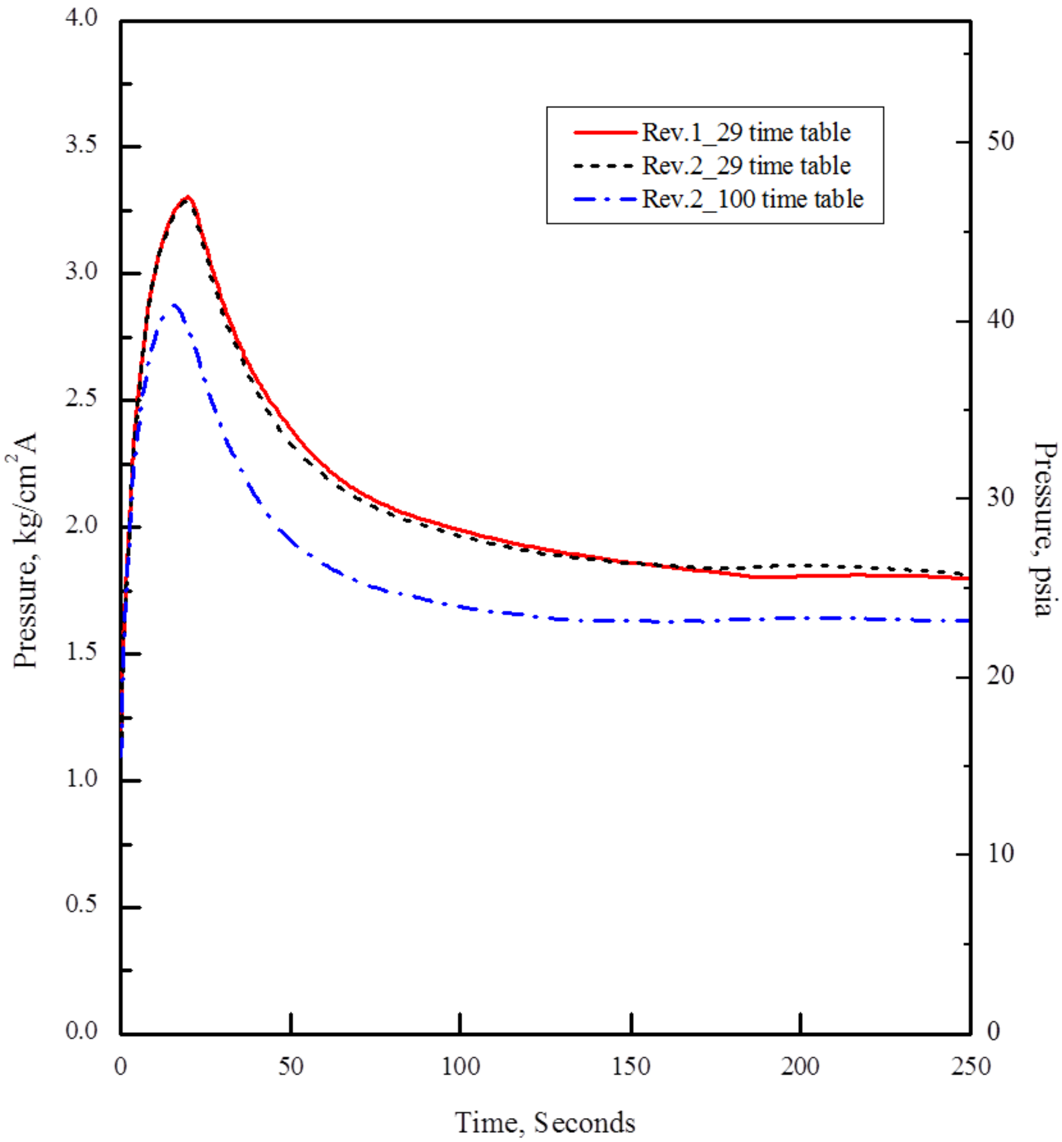

Figure 3. Comparison of Containment Pressure Curves for Different Time Table Numbers

Impact on DCD

The re-analysis of large break LOCA is performed for Question No.15.06.05-7. The DCD revisions for Section 6.2.1.5 and 15.6.5 are attached.

The original response indicates future incorporation of DCD changes. The changes that were proposed in the markup of original response to this RAI are still valid for the response of Revision 1.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environment Report.