## KHNPDCDRAIsPEm Resource

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| **Sent:** | Wednesday, February 03, 2016 7:58 AM |
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| **Cc:** | Gilmer, James; Karas, Rebecca; Steckel, James; Lee, Samuel |
| **Subject:** | APR1400 Design Certification Application RAI 399-8510 (15.06.05 - Loss of Coolant Accidents Resulting From Spectrum of Postulated Piping Breaks Within the Reactor Coolant Pressure Boundary) |
| **Attachments:** | APR1400 DC RAI 399 SRSB 8510.pdf |

KHNP,

The attachment contains the subject request for additional information (RAI). This RAI was sent to you in draft form. Your licensing review schedule assumes technically correct and complete responses within 30 days of receipt of RAIs. However, KHNP requests, and we grant, 90 days to respond to RAI question 15.06.05-9. We may adjust the schedule accordingly.

Please submit your RAI response to the NRC Document Control Desk.

Thank you,

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United States Nuclear Regulatory Commission
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# REQUEST FOR ADDITIONAL INFORMATION 399-8510

Issue Date: 02/03/2016
Application Title: APR1400 Design Certification Review – 52-046
Operating Company: Korea Hydro & Nuclear Power Co. Ltd.
Docket No. 52-046
Review Section: 15.06.05 - Loss of Coolant Accidents Resulting From Spectrum of Postulated Piping Breaks Within the Reactor Coolant Pressure Boundary
Application Section: 15.6.5

QUESTIONS

15.06.05-6

**Provide additional information regarding the choice of assumptions with respect to LOOP in context of a LBLOCA**

Regulatory Basis: NUREG-0800, Section 15.6.5, requires that the evaluation of a LBLOCA address whether the *appropriate break locations, break sizes, and initial conditions were selected in a manner that conservatively predicts the consequences of the LOCA for evaluating ECCS performance; and whether an adequate analysis of possible failure modes of ECCS equipment and the effects of the failure modes on the ECCS performance have been provided. For postulated break sizes and locations, the reactor systems review includes the postulated initial reactor core and reactor system conditions, the postulated sequence of events including time delays prior to and after emergency power actuation, the calculation of the power, pressure, flow and temperature transients, the functional and operational characteristics of the reactor protective and ECCS systems in terms of how they affect the sequence of events, and operator actions required to mitigate the consequences of the accident*.

Technical Basis: The applicant states that LOOP is assumed at the beginning of the LBLOCA transient evaluation and that the reactor coolant pumps (RCPs) are assumed to coast down. Additionally, the applicant takes no credit for control element assembly (CEA) insertion at the same time the power is lost to the RCPs.

Question:

1. Has loss of RCP flow been demonstrated to be more limiting than the same event with the RCPs operating?
2. With the assumption of LOOP, why is no credit taken for CEA insertion at the same time the power is lost to the RCPs? (CEA insertion and turbine trip are delayed until the low-pressure trip).
3. Has the stuck/windmilling flow resistance (both flow directions) for the RCPs been measured as part of a test program and are these data used to develop the homologous curves used in RELAP5/MOD/3.3K?

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 4.2

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: The applicant is requested to provide:

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.

15.06.05-8

**LBLOCA evaluation with a stuck check valve in the SIT**

Regulatory Basis:

General Design Criterion (GDC) 35, as it relates to demonstrating that the ECCS would provide abundant emergency core cooling to satisfy the ECCS safety function of transferring heat from the reactor core following any loss of reactor coolant at a rate that (1) fuel and clad damage that could interfere with continued effective core cooling would be prevented, and (2) clad metal-water reaction would be limited to negligible amounts. The analysis should consider the possibility of a single failure.

Technical Basis: It is not clear that the applicant has considered the potential for a check valve in the SIT to stick. The single failure could occur prior to, or at any time during, the design basis event for which the safety system is required to function.

Question: Provide a LBLOCA evaluation with a stuck check valve in the SIT (potential single failure). If no evaluation exists, provide a justification for not considering this potential failure.

15.06.05-9

Regulatory Basis

Title 10 of the Code of Federal Regulations, Part 50.46 requires an analysis of ECCS performance following loss of coolant accidents. The calculational framework used for the evaluation of the ECCS system in terms of core short term behavior and long term cooling performance are referred to as an evaluation model. It includes one or more computer programs, the mathematical models used, the assumptions and correlations included in the program, the procedure for selecting and treating the program input and output information, the specification of those portions of the analysis not included in computer programs, the values of parameters, and all other information necessary to specify the calculational procedure.

The evaluation model used by the applicant must comply with the acceptance criteria for ECCS given in 10 CFR 50.46. The following questions pertain to the RELAP5/MOD3.3 and CONTEMP4/MOD5 programs which comprise the APR1400 Evaluation Model:

1. The version of RELAP5/MOD3.3 used in these analyses has known errors in the Groeneveld (1986) tables implementation. These errors were corrected in RELAP5/MOD3.3 Patch04 in October, 2010. Additionally, the Groeneveld (2006) tables were updated in a later RELAP5/MOD3.3 version (incremental version3.3kg).

   If the applicant has not corrected these errors in the version used to performi the analyses in DCD Section 15.6.5, provide an assessment of the effect of these errors. Note that because these results will be used in a CSAU/BEPU analysis, it is not sufficient to determine if the results are conservative. As a minimum, the effect of the errors should affect the uncertainty in the analysis results.

2. When using the coupled codes RELAP5 and CONTEMPT with a one-to-one time step correspondence, it is correct to use fluid, vapor and non-condensable flows as calculated by each code. However, if either of the codes uses more than one time step to reach the next coupling time, it is necessary to provide the integral of some properties over the coupling time interval (fluid enthalpy, vapor enthalpy, fluid mass flow, vapor mass flow and air mass flow) not just the last times step values. If this is not done, these properties are not conserved.

Explain how the passed quantities are defined to ensure conservation of mass and energy.

3. In the LBLOCA Topical Report, it is stated that the break flow is underpredicted for the LOBI experiments. There are multiple critical flow models in RELAP5/MOD3.3 for subcooled and saturated critical flow. Please specify which correlation was used in each flow regime. For example, was the Henry-Fauske (recommended) or the default Ransom-Trapp model used? What discharge factors were used in the chosen model and how were they determined?

4. It is well known that RELAP5 convects an incorrect amount of energy into the downstream volume connected to a junction. There is a junction flag (the e flag) that can be used to correct this. This is only an issue at the breaks where the pressure change across the junction is large.

Provide justification that break flow is correctly treated in this regard. Otherwise, containment pressures will be too low.

5. Due to the location of the break and the location of the pressurizer, there will be times during the transient that flow and thermal conditions from each loop will be different. Assuming that the inlet plenum nodalization in the full plant model is the same as that used in the topical report, the inlet plenum is modeled as a single volume. This implies that there is complete mixing of the flows from each loop and that the core inlet conditions are therefore uniform across the core.

Please justify that the use of a single volume, hence uniform inlet conditions, is based on some experimental data or iexplain if loop-to-loop mixing is accounted for using some other model?

6. The modeling of the reactor vessel in the downcomer region and the thermal shield on the other side of the downcomer are critical to the prediction of downcomer filling during the refill and reflood phases. Since rapid temperature transients caused by fluid heating (or cooling) the walls initially only affects the surface of the metal and does not involve all of the metal mass. It is crucial to choose a “good” mesh spacing to capture accurately these effects. There are modeling guidelines based on the component Biot Number in the RELAP5-3D manuals to provide help on the development of an accurate mesh spacing.

Please provide a discussion of the adequacy of the mesh size size selected for the analyses.

7. For the LOBI experiments discussed in the LBLOCA Methodology Topical Report, late in the transient, the RELAP5 based Engineering Model predicts 150K superheat in both hot legs and the intact loop cold leg. This seems to be unrealistically high.

Is the same level of vapor superheat seen in the full plant model? If so, are there modeling adjustments that can be made to reflect more closely the experimental data? How was this uncertainty handled in the final evaluation?

8. In the early reflood phase, there are series of cyclic events that involve steam binding caused by reverse heat transfer in the steam generation. Subsequent lower reflood rates in the core are followed by increased steam generation in the core. Through this cyclical process, the core is eventually reflooded. The cyclical behavior involves a number of complex and interrelated processes. Has the ability of RELP5/MOD3.3 to model these types of phenomena been demonstrated through comparisons to test data or other methods?

9. In the analysis of the LOFT test in the LBLOCA topical report the applicant notes: *"For all calculations, this accumulated liquid in the core is larger than the amount obtained by subtracting the expelled liquid amount out of the downcomer from the delivered liquid amount to the downcomer. This implies that a portion of the liquid in the downcomer is carried to the core by the core up-flow behavior."* RELAP5 has a tendency to accumulate "mass error" particularly in two-phase regions. When the mass error is large relative to the change in mass of interest, it often masks the actual behavior of the system. The mass error can usually be reduced by using smaller time steps and/or renodalizing the region where the mass error is occurring.

Provide justification that the mass error for full plant evaluation as well as the LOFT test results ensure that the conclusions remain correct and that mass error is not influencing the conclusions.

10. During the early reflood phase, it is stated that the entrained liquid travels to the upper plenum where it is de-entrained and accumulates in the upper plenum where it subsequently flows down through the lower power (cooler) assemblies. This sets up a three-dimensional flow pattern (essentially a Natural Circulation flow path up the hot assemblies and down the cooler assemblies).

Since RELAP5/MOD3.3 is a set of one-dimensional models, how is the model constructed to capture these three-dimensional phenomena and how is the model qualified/validated?

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