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.:	**411-8505**
SRP Section:	**15.00.02 – Review of Transient and Accident Analysis Methods**
Application Section:	**15.00.02**
Date of RAI Issue:	**02/22/2016**

Question No. 15.00.02-6

Provide evidence that the STRIKIN-II computer code has previously been approved for conservatively calculating fuel and clad temperatures during steam line break (SLB) events

Regulatory Basis

10 CFR 52.47(a)(4) requires that applications for standard design certifications include an analysis and evaluation of the design and performance of structures, systems, and components (SSCs) with the objective of assessing the adequacy of SSCs provided for the prevention of accidents and the mitigation of the consequences of accidents. Additionally, NUREG-0800, Standard Review Plan (SRP) Section 15.0.2, “Review of Transient and Accident Analysis Methods,” specifies that an evaluation model must be able to predict important physical phenomena reasonable well from both qualitative and quantitative points of view or should treat the phenomena conservatively.

Technical Basis

STRIKIN-II was originally developed and designed for the analysis of LOCAs. However, a non- LOCA version of STRIKIN-II was derived from the LOCA analysis version and has been maintained independently with various modifications since 1975. In the APR1400 Chapter 15 safety analysis, STRIKIN-II is used to simulate the heat conduction within reactor fuel rods and its associated surface heat transfer during CEA ejection and SLB events to calculate the cladding and fuel temperatures for an average or hot fuel rod. The staff has previously reviewed and accepted STRIKIN-II in the SER to CENPD-190 for use in calculating fuel and clad temperatures for CEA ejection accidents. STRIKIN-II was also approved as an acceptable method for CE System 80+ non-LOCA fuel thermal analysis in the NUREG-1462 FSER.

Question

The use of STRIKIN-II to calculate fuel and clad temperatures for SLB has not previously been approved. The applicant is requested to provide evidence of prior approval of STRIKIN-II for SLB analysis or provide justification for the acceptability of STRIKIN-II for conservatively calculating cladding and fuel temperatures for SLB events.

Response

In the APR1400 Chapter 15 safety analysis, the use of STRIKIN-II code has not been approved to calculate fuel and cladding temperatures for SLB, therefore, it would not be used for the SLB event. If there is a return-to-power (RTP) during SLB event, the use of HRISE would be needed to check the fuel integrity. However, a post-trip RTP does not occur in all cases as shown in DCD Table 15.1.5-11 so that the fuel integrity is not challenged by this event. It means that the core remains in place and is unaffected with no loss of core cooling capability, therefore, the calculation of the cladding and fuel temperatures for SLB events is not needed.

Impact on DCD

There is no impact on the DCD.

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.

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Date of RAI Issue: **02/22/2016**

Question No. 15.00.02-7

Provide additional information on the moderator reactivity feedback model used in the analysis of SLB events

Regulatory Basis

10 CFR 52.47(a)(4) requires that applications for standard design certifications include an analysis and evaluation of the design and performance of structures, systems, and components (SSCs) with the objective of assessing the adequacy of SSCs provided for the prevention of accidents and the mitigation of the consequences of accidents. Additionally, NUREG-0800, Standard Review Plan (SRP) Section 15.0.2, “Review of Transient and Accident Analysis Methods,” requires a verification that parameters used in the analyses are suitably conservative. For instance, Section III.2.B of the SRP for Section 15.0.2 requires confirmation that the equations in the evaluation model are correct. Section I.6.C.i of the SRP for 15.0 requires a verification of the evaluation model used to perform transient and accident analyses. Section I.6.C.ii of the SRP for 15.0 requires a verification that parameters used in the analyses are suitably conservative.

Technical Basis

Sections 2.3 and 3.1.2.1 of technical report APR1400-Z-A-NR-14006-P state that for Steam Line Breaks (SLB), the calculation of moderator reactivity feedback is based on a density computed using the “cold edge enthalpy” of the affected side where the “cold edge enthalpy” is defined as the enthalpy of the fluid from the cold legs of the loop with the ruptured SG without the effect of mixing with fluid from the intact loop. However, the CESEC-III code descriptions, CENPD-107 and Enclosure 1-P to LD-82-001, do not discuss or mathematically define “cold edge enthalpy”. CENPD-107 instead states that moderator reactivity feedback accounts for unequal inlet temperatures by calculating the lowest possible average core temperature defined as the average core temperature minus one-half the difference in cold leg inlet temperatures. The amount of conservatism in the evaluation models for SLB with respect to moderator reactivity feedback needs to be verified.

Question

The applicant is requested to provide additional information regarding the actual moderator reactivity feedback model used for SLB analysis, the documentation and Validation & Verification of this model, and an explanation of how the conservatism of the model has been quantified.

Response

Cold edge enthalpy is defined as the enthalpy of the fluid from the cold legs of the loop with the ruptured steam generator, with the addition of core heat up to the core axial mid-plane, and without the effect of mixing fluid with the other loop.

Based on the above, CENPD-107 states that moderator reactivity feedback accounts for unequal inlet temperatures by calculating the lowest possible average core temperature defined as the average core temperature minus one-half the difference in cold leg inlet temperatures. It means that cold edge enthalpy is modeled in the CESEC-III and used in the calculation of moderator reactivity feedback for the SLB analysis. This enthalpy is conservative with respect to the actual system as it removes the impact of mixing, therefore, cold enthalpy from the ruptured steam generator does not have the heatup from mixing with the hotter intact steam generator. Using the conservative cold edge enthalpy as the core enthalpy for the SLB yields a greater moderator feedback.

The mathematical validation and verification for the cold edge enthalpy within the CESEC-III and an explanation of how the conservatism of the model has been quantified would be provided in the calculation note (63172-FSE-030) and can be provided upon request.

Impact on DCD

There is no impact on the DCD.

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.

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Question No. 15.00.02-8

Provide additional information on the use of Reynold's number independent friction and form losses and the reliance on pressure drop proportional to velocity squared

Regulatory Basis

10 CFR 52.47(a)(4) requires that applications for standard design certifications include an analysis and evaluation of the design and performance of structures, systems, and components (SSCs) with the objective of assessing the adequacy of SSCs provided for the prevention of accidents and the mitigation of the consequences of accidents. Additionally, NUREG-0800, Standard Review Plan (SRP) Section 15.0.2, "Review of Transient and Accident Analysis Methods," requires a verification that parameters used in the analyses are suitably conservative. For instance, Section III.2.B of the SRP for 15.0.2 requires confirmation that the equations in the evaluation model are correct. Section I.6.C.i of the SRP for Section 15.0 requires a verification of the evaluation model used to perform transient and accident analyses. Section I.6.C.ii of the SRP for Section 15.0 requires a verification that parameters used in the analyses are suitably conservative.

Technical Basis

Section 2.5.2 of technical report APR1400-Z-A-NR-14006-P states that the COAST computer code assumes that pressure losses due to friction and geometric losses are assumed proportional to the flow velocity squared. Neither Section 2.5.2 nor the COAST code description, CENPD-98-A, discuss the possibility that friction and geometric losses can be Reynold's number dependent and not follow the "squared" relationship between pressure losses and velocity. Proper calculation of pressure losses as a function of flow is especially important during loss-of-flow events and the use of the "squared" relationship with fixed geometric losses could result in a non-conservative flow versus time calculation. The effect of Reynold's number dependent friction and geometric losses on the "squared" relationship should be evaluated based on comparison of COAST calculations to experimental data.

Question

The applicant is requested to provide additional information as to how Reynold's number dependent friction and form losses are accounted for in COAST for loss-of-flow events or how the assumption that friction and geometric losses are proportional to the flow velocity squared has been determined to be suitably conservative.

Response

Input to the COAST code includes the pressure loss coefficients for both forward and reverse flow and the fluid densities and momentum averaged fluid weights for each of the flow segments. In addition, the flow resistance factor input to the code is a summation of the individual resistances weighted to the reference section. The equation for conservation of momentum is written for each of the flow segments for one-dimensional flow of an incompressible fluid. The path through any flow segment is based on a single flow area, a single fluid density and hence a single fluid velocity.

The Reynolds number is defined as the ratio of inertial forces to viscous forces and consequently quantifies the relative importance of these two types of forces for given flow conditions. Reynolds numbers frequently arise when performing scaling of fluid dynamics problems, and as such can be used to determine dynamic similitude between two different cases of fluid flow. They are also used to characterize different flow regimes within a similar fluid, such as laminar or turbulent flow.

The friction coefficient varies with the Reynolds number on a specific geometric characteristic in the pipe. However, the COAST adopts the equation for conservation of momentum for one-dimensional flow of an incompressible fluid, and the COAST code description, CENPD-98-A, says that experiments indicate the dynamic effects on the hydraulic characteristics are negligible. Therefore, the COAST code uses the friction and geometric losses based on RCS geometric segment pressure loss data proportional to the flow velocity squared, and it is not practical to adopt Reynolds number dependent friction.

The relevant coastdown is analyzed based on 95% of the design flow rate and 85% of the pump inertia. Therefore, the calculated friction and form loss coefficient in the COAST code is suitably conservative

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Impact on DCD

There is no impact on the DCD.

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.

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Date of RAI Issue:	**02/22/2016**

Question No. 15.00.02-10

10 CFR 52.47(a)(4) requires that applications for standard design certifications include an analysis and evaluation of the design and performance of structures, systems, and components (SSCs) with the objective of assessing the adequacy of SSCs provided for the prevention of accidents and the mitigation of the consequences of accidents. Additionally, Section 15.0 of the Standard Review Plan (NUREG-0800) requires a verification that parameters used in the analyses are suitably conservative.

NRC staff is questioning if the friction and form losses calculated in the COAST code are suitably conservative. Please explain how the friction and form loss coefficients are calculated and explain why this method is suitably conservative.

Response

The friction and form loss coefficients of the COAST code are used as an input to the COAST code based on the RCS geometric segment pressure loss data at normal operating conditions. The friction and form loss coefficients in the COAST code are calculated based on the pressure loss, fluid density, and are inversely proportional to the velocity square. The relevant coastdown is analyzed based on 95% of the design flow rate and 85% of the pump inertia. Therefore, the calculated friction and form loss coefficient in the COAST code is suitably conservative

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Impact on DCD

There is no impact on the DCD.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

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Impact on Technical/Topical/Environmental Reports

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