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.:	**237-8312**
SRP Section:	**03.06.03 – Leak-Before-Break Evaluation Procedures**
Application Section:	**3.6.3**
Date of RAI Issue:	**10/08/2015**

Question No. 03.06.03-1

10 CFR 50, Appendix A, General Design Criterion (GDC) 4 allows the use of analyses reviewed and approved by the Commission to eliminate from the design basis the dynamic effects of the pipe ruptures postulated in Standard Review Plan (SRP) Section 3.6.2, “Leak-Before-Break Evaluation Procedures.” The staff reviewed the submitted documents and determined that the information requested below is needed in order for the staff to perform a confirmatory analysis of the Leak-Before-Break Piping Evaluation Diagram.

The following question pertains to Subsection 3.6.3.5.5.2 "Constructing a Leak-Before-Break Piping Evaluation Diagram":

1. The NRC staff finds that it is appropriate to include the initiation fracture toughness, Jic, in the calculation of crack opening displacement. Please re-evaluate J-R data to derive a description which includes Jic.

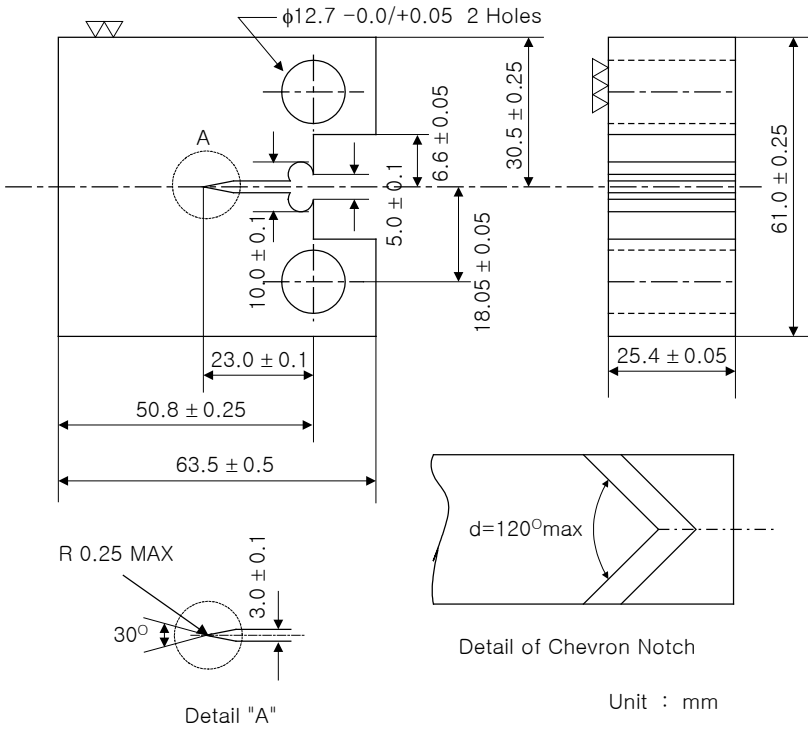
2. In order to enable the NRC staff to evaluate the J-R data, the specimen size (including specimen geometry and notch depth) must be given. Please provide this data along with tabular J-delta (a) data.

Response

1. The LBB evaluation for the APR1400 is performed using PICEP code for calculating the leakage crack length pertaining to 5 gpm, includes a margin of 10 times on the leakage detection capability of 0.5 gpm. The PICEP code uses the tensile properties of material to calculate the crack length, but it does not require the initiation fracture toughness, Jic, of materials. For this reason, the Jic data of the test materials for the APR1400 LBB evaluation was not produced.

2. The specific specimen geometry of the J-R test is provided as follows:

    1) Specimen configuration: ASTM standard specimen for fracture toughness test of 1T-CT. Refer to the figure below for the detailed dimensions of the specimen
    2) Specimen orientation: L-C orientation
    3) Initial crack length: approximately 50% of the width of the specimen
    4) Fatigue pre-crack is applied
    5) Side-groove of 10% of the specimen width on both sides of the specimen
    6) Test method: ASTM E1820



The tabular J-delta (a) data is provided as follows:

The J-delta (a) data for the surge line of the APR1400 below is the test data from Shin-kori 3 & 4 NPPs, which are the first plants of the APR1400 type in Korea. The tabular and graphical J-delta (a) information are provided below. The graph contains test results of the surge line materials including welds. Each curve of the graph is the low bound curve for the test results for each of the parts. The lower bound curve (marked as 'PED') in the graph was used in producing the piping evaluation diagram (PED) for the surge line of the APR1400.

TS

The J-delta (a) used for the evaluation of the main loop piping of the APR1400 is provided below. The tabular J-delta (a) data below is not the test data, but is fitted data which is used in producing the PED. Because there is sufficient margin in the LBB evaluation for the main loop piping, the J-R curve that is lower than the actual test data from the previous Korean plants was used. The graph below contains the test results of various Korean plants for the main loop piping materials, including welds. Each curve of the graph is the fitted lower bounding curve of the test results of the main loop piping for each Korean plant. The curve marked “APR1400 (DC)” in the graph below envelops all curves previously used for the Korean plants and was used in producing the PED for the APR1400.

TS

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 Environmental Reports.

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Question No. 03.06.03-2

10 CFR 50, Appendix A, General Design Criterion (GDC) 4 allows the use of analyses reviewed and approved by the Commission to eliminate from the design basis the dynamic effects of the pipe ruptures postulated in Standard Review Plan (SRP) Section 3.6.2, “Leak-Before-Break Evaluation Procedures.” The staff reviewed the submitted documents and determined that the information requested below is needed in order for the staff to perform a confirmatory analysis of the Leak-Before-Break Piping Evaluation Diagram.

The following question pertains to Subsection 3.6.3.5.5.2 "Constructing a Leak-Before-Break Piping Evaluation Diagram":

1. Were the tabulated material properties used in the evaluation for room temperature or operating temperature?

Response

1. The tabulated material properties used in the evaluation for LBB are for operating temperatures. Specifically, the material properties near the upper range of the normal operating temperature (600 ℉) and at the plant hot standby temperature of 350 ℉ are used in the LBB evaluation for the APR1400 RCS piping and surge line

Impact on DCD

There is no impact on 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 Environmental Reports.

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Question No. 03.06.03-3

10 CFR 50, Appendix A, General Design Criterion (GDC) 4 allows the use of analyses reviewed and approved by the Commission to eliminate from the design basis the dynamic effects of the pipe ruptures postulated in Standard Review Plan (SRP) Section 3.6.2, “Leak-Before-Break Evaluation Procedures.” The staff reviewed the submitted documents and determined that the information requested below is needed in order for the staff to perform a confirmatory analysis of the Leak-Before-Break Piping Evaluation Diagram.

The following question pertains to Subsection 3.6.3.5.5.2 "Constructing a Leak-Before-Break Piping Evaluation Diagram":

1. Please provide in detail, how the Ramsberg-Osgood parameters were calculated.

Response

1. The tensile properties in the form of Ramberg-Osgood parameters were used in calculating leakage crack length at the leak rate of 5 gpm. The Ramberg-Osgood equation is provided below:

$$\frac{\varepsilon}{\varepsilon_0} = \left(\frac{\sigma}{\sigma_0}\right) + \alpha\left(\frac{\sigma}{\sigma_0}\right)^n$$

ε: strain
ε_0: strain at yield stress
σ: stress
σ_0: yield stress
α: Ramberg-Osgood material constant
n: strain hardening coefficient

TS

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 Environmental Reports.

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Question No. 03.06.03-4

10 CFR 50, Appendix A, General Design Criterion (GDC) 4 allows the use of analyses reviewed and approved by the Commission to eliminate from the design basis the dynamic effects of the pipe ruptures postulated in Standard Review Plan (SRP) Section 3.6.2, “Leak-Before-Break Evaluation Procedures.” The staff reviewed the submitted documents and determined that the information requested below is needed in order for the staff to perform a confirmatory analysis of the Leak-Before-Break Piping Evaluation Diagram.

The following question applies to Subsection 3.6.3.5.5.2 "Constructing a Leak-Before-Break Piping Evaluation Diagram":

1. In the calculation of effective bending moment, it is not clear if the crack face pressure was included. Please identify if the crack face pressure was included in the calculation.

2. In order for the NRC Staff to perform an independent evaluation, please provide values for the applied bending moment, axial and all other forces applied in the Finite Element Model (FEM).

Response

1. The loadings applied to each line are described in FSAR Subsection 3.6.3.5.4.2. The internal pressure appropriate to the normal operating (NO) conditions of each piping system is applied to the inner surface of the pipe. Half of the internal pressure is applied to the crack face to take into account the pressure drop across the crack.

2. The LBB PED is prepared prior to the piping design and analysis and is used to evaluate critical points in the piping. The PED is constructed to allow the maximum design load to be plotted versus the NO load.

The LBB piping evaluation diagram requires performing two complete LBB evaluations. The evaluations are for two NO loads that span the typical loadings for the line under consideration.

The NO loads used in LBB PED are listed in the table below.

The detailed procedure to construct a LBB PED is described in FSAR Subsection 3.6.3.5.5.2.

TS

The loading applied to each line in the Finite Element Model is described in FSAR Subsection 3.6.3.5.4.2. The internal pressure appropriate to the normal operating conditions of each piping system is applied to the inner surface of the pipe. One-half the internal pressure is applied to the crack face to account for the pressure drop across the crack. An axial end load traction, (which when integrated over the pipe cross-sectional area, is equal to the continuity axial force), is applied to the far end of the pipe. Bending moments are applied as a linearly varying traction to the far end of the pipe. The pressure applied to each piping system is listed in FSAR Table 3.6-5.

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 Environmental Reports.

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Question No. 03.06.03-5

10 CFR 50, Appendix A, General Design Criterion (GDC) 4 allows the use of analyses reviewed and approved by the Commission to eliminate from the design basis the dynamic effects of the pipe ruptures postulated in Standard Review Plan (SRP) Section 3.6.2, “Leak-Before-Break Evaluation Procedures.” The staff reviewed the submitted documents and determined that the information requested below is needed in order for the staff to perform a confirmatory analysis of the Leak-Before-Break Piping Evaluation Diagram.

The staff determined that in order to evaluate the parameters influencing the leak rate calculations, the staff requests the applicant provide a plot of crack opening displacement (COD) versus crack size (c) for the target 5 gallons per minute (GPM) leak rate.

Response

The plots of crack opening displacement (COD) versus crack size (c) for the target 5 gpm leak rate are shown in the figures below.

COD - crack size for Hot leg

COD - crack size for Cold leg

COD - crack size for Intermediate Pipe

COD - crack size for Hot leg nozzle/Pipe Interface

COD - crack size for Pressurizer nozzle/Pipe Interface

COD - crack size for DVI/SC line group 1

COD - crack size for DVI/SC line group 2

COD - crack size for DVI/SC line group 3

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 Environmental Reports.

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Question No. 03.06.03-6

10 CFR 50, Appendix A, General Design Criterion (GDC) 4 allows the use of analyses reviewed and approved by the Commission to eliminate from the design basis the dynamic effects of the pipe ruptures postulated in Standard Review Plan (SRP) Section 3.6.2, “Leak-Before-Break Evaluation Procedures.” The staff reviewed the submitted documents and determined that the information requested below is needed in order for the staff to perform a confirmatory analysis of the Leak-Before-Break Piping Evaluation Diagram.

Please provide the values that are used as inputs to the PICEP Code that developed the PED curves? In addition, please provide the NRC staff with the PICEP source code

Response

The PICEP executable file and input files used for developing the PED curves will be provided separately and are considered to be proprietary information.

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 Environmental Reports.

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Question No. 03.06.03-7

10 CFR 50, Appendix A, General Design Criterion (GDC) 4 allows the use of analyses reviewed and approved by the Commission to eliminate from the design basis the dynamic effects of the pipe ruptures postulated in Standard Review Plan (SRP) Section 3.6.2, “Leak-Before-Break Evaluation Procedures.” The staff reviewed the submitted documents and determined that the information requested below is needed in order for the staff to perform a confirmatory analysis of the Leak-Before-Break Piping Evaluation Diagram.

Please discuss the parameter values that are used for the crack surface description. In addition, please include the cracking mechanism that was assumed, and where these values were obtained.

Response

The crack morphology parameters are described in FSAR Subsection 3.6.3.5.2.3.

The parameters considered in calculating the leakage crack length were determined according to NUREG 1061, Vol.3. The crack morphology required in NUREG 1061, Vol.3 considers surface roughness, while PICEP considers surface roughness, number of 45-degree turns and entrance loss coefficient. The values are listed in the table below. These values were validated and verified with testing when PICEP was developed.

Crack Morphology Parameters **TS**

Air fatigue crack morphology is considered in the calculation for determining the leak rate.

The parameter values that are used for the crack surface description will be included in the provided input files as responded to in Question No. 03.06.03-6.

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 Environmental Reports.