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.:	**433-8363**
SRP Section:	**19 – Probabilistic Risk Assessment and Severe Accident Evaluation Section: 19**
Application Section:	**19**
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Question No. 19-71

10 CFR 50.44(c)(5) and SECY-93-087 require a deterministic analysis that demonstrates containment structural integrity under internal pressure loads. Regulatory Guide 1.216, Regulatory Position 3 discusses the methods acceptable to the staff to address the Commission's performance goal related to the prevention and mitigation of severe accidents. Specifically, RG 1.216 states that "an acceptable way to identify the more likely severe accident challenges is to consider the sequences or plant damage states that, when ordered by percentage contribution, represent 90 percent or more of the core damage frequency".

APR1400 design control document (DCD) Tier 2, Section 19.2.4, "Containment Performance Capability," does not clearly explain how the more likely severe accidents were identified. The staff reviewed the information contained in the DCD, and in supporting calculations 1-316-C304-006 and 1-316-C304-007. The staff identified information that needs to be explained in the DCD to complete its evaluation. In accordance with RG 1.216, Regulatory Position 3, the applicant is requested to address the following in the DCD:

1. Provide the technical basis for identifying the more likely severe accident challenges. In Section 19.2.4, the methodology for selecting the more likely severe accident challenges is not clearly explained. In calculation #1-316-C304-006, Table 4-1, the maximum pressures and temperatures corresponding to severe accident scenarios station blackout (SBO), large-break loss-of-coolant accident (LBLOCA), and total loss of feed water (TLOFW) are provided. The basis for selecting these severe accidents is not clear to the staff.

2. In Section 19.2.3.3.7.2.2, the applicant states that the bounding containment pressure expected during a severe accident is 95.3 psig (110 psia). This section does not explain which severe accident corresponds to this accident pressure, which is greater than those accident pressures provided in calculation #1-316-C304-006 stated to produce the most significant pressure loading histories. Additionally, in calculation #1-316-C304-

006 the highest pressure generated is a result of the LLOCA scenario. The staff requests that the bounding severe accident and pressure are included in DCD Section 19.2.4. This is consistent with RG 1.216 Regulatory Position 3, Section 3.1b, “From the set of pressure and temperature transient loadings… identify which pair of pressure and corresponding temperature loadings envelope the entire set of pressure and temperature loadings.”

The staff also requests the applicant explain why SBO was selected as the representative severe accident, since it is not bounding, and describe how the analysis would have been different had a different severe accident been selected as the representative severe accident.

3. In calculation #1-316-C304-006, the results of the analysis are presented for SBO loading. Clarify what pressure load corresponds to the results provided in Table 5-2. Confirm that the results presented in calculation #1-316-C304-007 Section 5 correspond to the same pressure load.

4. In calculation #1-316-C304-006, the applicant describes a process using a pressure amplification factor between Tables 4-1 and 4-2. It is not clear what is meant by pressure amplification factor. Please explain what is meant by pressure amplification factor and explain how it is related to the ratio between the pressure obtained for each severe accident scenario and the maximum pressure and temperature for performance assessment. Please also explain how the maximum pressure provided in Table 4-2 was determined.

Response – (Rev.2)

1. Regarding RG 1.216 Regulatory Position 3.1 a, selection of accident sequences based on Level 1 probabilistic risk assessment (PRA) study is made in the following way. The more likely severe accident sequences to be analyzed for the containment performance are selected using a combination of deterministic and probabilistic approaches.

   The top ten dominant sequences contributing to the core damage frequency (CDF) are selected from the Level 1 PRA results at the time of performing the analysis. Accident initiators for these sequences include: station blackout (SBO), large break LOCA (LLOCA), small break LOCA (SLOCA), loss of feedwater (LOFW), and steam generator tube rupture (SGTR). These ten sequences account for 87.6% of the cumulative CDF. The applicant believes this to be an acceptable approach to identifying the more likely severe accident challenges since the probabilistic sequences and the dominant sequences from the deterministic approach are included. Details regarding the identification of the more likely severe accident challenges are given in Section 3.1.2 of “Containment Performance Analysis”, 1-035-N389-501, Rev. 04, which has been provided in the ERR. Response to Action Item 19-171 Section 19.2 Issue #SA-10 (AI-19-171) also includes the description on the accident selection and provides the DCD subsection 19.2.4.1 markup accordingly.

The selected sequences used for severe accident analysis based on draft PRA Level 1 study, are shown in the following Table 1. Sequences from deterministic approach are also listed in the table. The final PRA Level 1 study result is shown in the following Table 2. The used sequences are account for around 15.7 % contribution to the final Level 1 CDF result. However, as per the following two statements, it can be concluded that the present accident sequences based on the draft PRA Level 1 study can account for the more than 90 % contribution to the final Level 1 study, hence, selection of more likely severe accident in terms of RG 1.216 Regulator Position 3.1a is made.

- High degree of similarity for accident initiators for draft and final Level 1 study: Both top 10 sequences (87.6% of CDF) in draft Level 1 study and top 30 sequences (93.7 % of CDF) in final Level 1 study is mainly composed by SBO, LLOCA, SLOCA, LOFW, and SGTR.

Initiators in Top 10 sequences in draft CDF table	Initiators in Top 30 sequences in final CDF table	Re-categorized initiators in Top 30 sequences
2 LOFW (1 TLOEWS, 1 LOOP), 4 LOCA (2 SLOCA, 2 MLOCA) 3 SBO (3 SBO), 1 SGTR	1 PLOCCW, 1 PLOEWS, 2 TLOCCW, 2 TLOESW, 1 FWLB, 1 LOFW, 1 GTRN, 1 LOCV, 3 LOOP, 5 SBO, 1 GRID-SBO, 1 GRID-LOOP, 2 MLOCA, 1 SLOCA, 1 LLOCA, 2 LSSB-D 2 SGTR, 1 ATWS, 1 RVR	15 LOFW (1 PLOCCW, 1 PLOESW, 2 TLOCCW, 2 TLOESW, 1 FWLB, 1 LOFW, 1 GTRN, 1 LOCV, 3 LOOP, 1 GRID-LOOP, 1 GRID-SBO) 5 SBO (5 SBO) 5 LOCA (2 MLOCA, 1 SLOCA, 1 LLOCA, 1 LSSB-D_009) 4 SGTR (2 SGTR, 1 ATWS, 1 LSSB-D_019) 1 RVR

Here, RVR initiator (Rank 13, 2.3 %) is excluded due to its abnormal event tree, however, sequences of 91.4 % of CDF is still considered.

- Combination of probabilistic and deterministic approaches: In addition to the top 10 sequences, 9 sequences initiated by dominant events such as SBO, SLOCA, LOCA, SGTR, and LOFW are constructed and analyzed (D1 to D9 in Table 1) in the light of the deterministic approach. ECSBS is assumed in 6 sequences of them unavailable and 3 sequences available. Deterministic sequences aim to bounding the accident consequence.

- For example LOOP_005 (Rank 1 in final CDF table), LOOP_004 (Rank 9 in final CDF table), and LOOP_003 (Rank 14 in final CDF table) sequences can be bounded by the analyzed LOFW (D9 in Table 1) since accident definitions for these LOOP sequences (LOOP * Success of EDG * Failure of secondary heat removal) are bounded by LOFW (D9) since all of AAC failure and AFW failure are assumed in LOWF (D9).

- For example 5 SBO sequences, 5 SBO sequences are bounded by SBO (D7 in Table 1) since all of AAC failure is assumed in SBO (D7).

Therefore sequences given in Table 1 represent the entire spectrum of severe accident conditions important to containment pressurization. PRA accident sequences not involved in the present calculation matrix can be either represented or bounded by these analyzed sequences such that analysis of those specific sequences is not necessary.

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The pressure and temperature response of the selected more likely severe accident sequences is employed as the input loads profiles in the finite element study.

Table 1 Draft Level 1 Top Accident Sequences and Deterministic Sequences used in Severe Accident Analysis

Rank	Sequence number	Cumulative contribution (%)	Sequence Description	Remarks
1	TLOESW_003	30.3	See Rank 17 in Table 2	
2	MLOCA_003	50.8	See Rank 22 in Table 2	
3	LOOP_004	60.7	See Rank 9 in Table 2	
4	SBO_002	68.0	SBO * Success of AAC * Success of secondary heat removal * RCP seal LOCA occurs	Rank 45 in Final Level 1 study
5	SBO_005	74.8	See Rank 30 in Table 2	
6	SLOCA_008	79.3	SLOCA * Success of reactor trip * Failure of SI * Success of aggressive secondary cooling * Failure of SC	
7	PR-A-SL_007	81.9	SLOCA by POSRV stuck open * Failure of SI	
8	MLOCA_002	85.0	See Rank 4 in Table 2	
9	SBO_006	85.9	SBO * Success of AAC * Failure of secondary heat removal * Failure of bleed for F&B operation	Rank 51 in Final Level 1 study
10	SGTR_010	87.6	SGTR * Success of reactor trip * Failure of SI * Success of aggressive secondary cooling * Failure of SC	
D1	SBO-C01-NoECSBS-MCCI	NA	SBO * Failure of AAC * Failure of secondary cooling * Failure of ECSBS	- 4 SI tanks available - AFW, SI pump, Charging pump, CS pump unavailable
D2	SBO-C03-NoECSBS-MCCI	NA	SBO * Failure of AAC * Success of secondary cooling * Failure of ECSBS	- 4 SI tanks available - TDAFW available - MDAFW, SI pump, Charging pump, CS pump unavailable

Rank	Sequence number	Cumulative contribution (%)	Sequence Description	Remarks
D3	LLOCA-C04-NoECSBS-MCCI	NA	LLOCA * Failure of SI * Success of secondary cooling * Failure of ECSBS	- 4 SI tanks and MDAFW available - SI pump, Charging pump, CS pump unavailable
D4	SLOCA-C06-NoECSBS-MCCI	NA	SLOCA * Failure of SI * Success of secondary cooling * Failure of ECSBS	- 4 SI tanks, Charging pump, MDAFW available - SI pump, CS pump unavailable
D5	LOFW-C08-NoECSBS-MCCI	NA	TLOFW * Failure of SI * Failure of secondary cooling * Failure of ECSBS	- 4 SI tanks and Charging pump available -AFW, SI pump, CS pump unavailable
D6	SGTR-C10-NoECSBS-MCCI	NA	SGTR * Failure of SI * Failure of secondary cooling * Failure of ECSBS	- 4 SI tanks available - AFW, SI pump, Charging pump, CS pump unavailable
D7	SBO-C01-ECSBC-M-MCCI	NA	SBO * Failure of AAC * Failure of SI * Failure of secondary cooling * Success of ECSBS	- 4 SI tanks available - SI pump, Charging pump, CS pump, AFW unavailable
D8	LLOCA-C04-ECSBS-M-MCCI	NA	LLOCA * Failure of SI * Success of secondary cooling * Success of ECSBS	- 4 SI tanks and MDAFW available - SI pump, Charging pump, CS pump unavailable
D9	LOFW-C08-ECSBS-M-MCCI	NA	LOFW * Failure of SI * Failure of secondary heat removal * Success of ECSBS	- One charging pump and 4 SI tanks available - AFW, SI pump, CS pump unavailable

Table 2 Level 1 Internal Events Top Accident Sequences (from DCD Rev. 0 Table 19.1-18)

Rank	Sequence number	Cumulative contribution (%)	Sequence Description	Remarks
1	LOOP_005	13.4	LOOP * Success of reactor trip * No POSRV challenge * Success of one or more EDGs * Failure of secondary heat removal * Failure of bleed for F&B operation	Bounded by D9 (LOFW)
2	SBO_009	22.2	SBO * Failure of AAC * Success of secondary heat removal with AF TDPs * No RCP seal LOCA * Failure of offsite power recovery within 16 hours	Bounded by D7 (SBO)
3	PLOCCW_007	30.9	PLOCCW * Success of reactor trip * Failure of secondary heat removal * Success of bleed for F&B operation * Failure of SI feed for F&B operation	Bounded by D9 (LOFW)
4	MLOCA_002	39.4	MLOCA * Success of reactor trip * Success of SI injection * Failure of CS operation	Considered in Rank 8 in Table 1
5	PLOESW_007	44.4	PLOESW * Success of reactor trip * Failure of secondary heat removal * Success of bleed for F&B operation * Failure of SI feed for F&B operation	Bounded by D9 (LOFW)
6	SBO_004	49.3	SBO * Success of AAC * Failure of secondary heat removal * Success of F&B operation * Failure of long term cooling with SC/CS	Bounded by D7 (SBO)
7	TLOCCW_002	53.8	TLOCCW * Success of reactor trip * No consequential LOOP * Success of secondary heat removal * RCP seal LOCA occurs	Bounded by D9 (LOFW)
8	TLOESW_002	58.3	TLOESW * Success of reactor trip * No consequential LOOP * Success of secondary heat removal * RCP seal LOCA occurs	Bounded by D9 (LOFW)
9	LOOP_004	62.2	LOOP * Success of reactor trip * No POSRV challenge * Success of one or more EDGs * Failure of secondary heat removal * Success of bleed for F&B operation *	Considered in Rank 3 in Table 1

Rank	Sequence number	Cumulative contribution (%)	Sequence Description	Remarks
			Failure of SI feed for F&B operation	
10	SLOCA_007	65.7	SLOCA * Success of reactor trip * Failure of SI injection * Success of aggressive secondary cooling operation * Failure of shutdown cooling injection	Bounded by D8 (LLOCA)
11	ATWS_007	68.9	ATWS * Adverse MTC (Moderator Temperature Coefficient)	Bounded by D6 (SGTR)
12	GRID-SBO_003	71.7	GRID-SBO * Success of AAC * Failure of secondary heat removal	Bounded by D9 (LOFW)
13	RVR_001	74.0	Reactor vessel rupture	Excluded
14	LOOP_003	76.3	LOOP * Success of reactor trip * No POSRV challenge * Success of one or more EDGs * Failure of secondary heat removal * Success of F&B operation * Failure of long term cooling with SC/CS	Bounded by D9 (LOFW)
15	LSSB-D_019	78.3	LSSB * Success of reactor trip * No POSRV challenge * Pressure-induced SGTR occurs * Success of SI injection * Failure of steam line isolation	Bounded by D6 (SGTR)
16	TLOCCW_003	79.9	TLOCCW * Success of reactor trip * No consequential LOOP * Failure of secondary heat removal	Bounded by D9 (LOFW)
17	TLOESW_003	81.4	TLOESW * Success of reactor trip * No consequential LOOP * Failure of secondary heat removal	Considered in Rank 1 in Table 1
18	SGTR_006	82.9	SGTR * Success of reactor trip * Success of SI injection * Success of secondary heat removal * Failure of initial RCS cooldown and late cooldown * Failure of IRWST refill	Bounded by D6 (SGTR)
19	SGTR_009	84.2	SGTR * Success of reactor trip * Success of SI injection * Failure of secondary heat removal * Failure of bleed	Bounded by D6 (SGTR)

Rank	Sequence number	Cumulative contribution (%)	Sequence Description	Remarks
			for F&B operation	
20	GTRN_005	85.5	GTRN * Success of reactor trip * No POSRV challenge * No consequential LOOP * Failure of secondary heat removal * Failure of bleed for F&B operation	Bounded by D9 (LOFW)
21	FWLB_005	86.7	FWLB * Success of reactor trip * No Pressure-induced SGTR * Success of steam line isolation * Failure of secondary heat removal * Failure of bleed for F&B operation	Bounded by D9 (LOFW)
22	MLOCA_003	87.7	MLOCA * Success of reactor trip * Failure of SI injection	Considered in Rank 2 in Table 1
23	LSSB-D_009	88.7	LSSB * Success of reactor trip * No POSRV challenge * No Pressure-induced SGTR * Failure of steam line isolation * Failure of bleed for F&B operation	Bounded by D4 (SLOCA)
24	SBO_011	89.5	SBO * Failure of AAC * Failure of secondary heat removal with AF TDPs	Bounded by D7 (SBO)
25	GRID-LOOP_005	90.2	GRID-LOOP * Success of one or more EDGs * Failure of secondary heat removal * Failure of bleed for F&B operation	Bounded by D9 (LOFW)
26	LOFW_005	91.0	LOFW * Success of reactor trip * No POSRV challenge * No consequential LOOP * Failure of secondary heat removal * Failure of bleed for F&B operation	Bounded by D9 (LOFW)
27	LLOCA_003	91.7	LLOCA * Success of SIT injection * Success of SI injection * Failure of SI hot leg injection	Bounded by D8 (LLOCA)
28	LOCV_005	92.4	LOCV * Success of reactor trip * No POSRV challenge * No consequential LOOP * Failure of secondary heat removal * Failure of bleed for F&B operation	Bounded by D9 (LOFW)

Rank	Sequence number	Cumulative contribution (%)	Sequence Description	Remarks
29	SBO_010	93.1	SBO * Failure of AAC * Success of secondary heat removal with AF TDPs * RCP seal LOCA occurs	Bounded by D7 (SBO)
30	SBO_005	93.7	SBO * Success of AAC * Failure of secondary heat removal * Success of bleed for F&B operation * Failure of SI feed for F&B operation	Considered in Rank 5 in Table 1

2. The bounding pressure of 7.75 kg/cm^2 (110 psia, 95.3 psig) stated in DCD Section 19.2.3.3.7.2.2 is based on the Table 4-7 in Appendix F “Severe Accident Analysis Report for Equipment Survivability Evaluation” of Severe Accident Analysis Report Rev.0 (APR1400-E-P-NR-14003P). By following the accident selection approach addressed in the Response 1 of this RAI, the initiating event of selected accident sequences are identical to the calculation matrix used in containment performance analysis (i.e. Table A-2 in calculation note 1-035-N389-501 “Containment Performance Analysis” Rev.4).

   However, unlike the containment performance analysis during the environment prediction for the equipment survivability assessment, achieving 100% of active cladding oxidation with the water is assumed and the sensitivity cases with the uncertainties in operator actions and in phenomena such as hydrogen burns are additionally taken into account.

   In summary, as clearly shown in Table 4-7 in Appendix F of Severe Accident Analysis Report, MAAP study for the equipment survivability assessment predicts the pressure of 7.75 kg/cm^2 (110 psia, 95.3 psig) in SBO sequence envelops the transient pressure from the selected sequences.

   It is notable that the pressure of 110.9 psia for Large break LOCA sequence stated in Response 1 in this RAI corresponds to the highest pressure based on the MAAP evaluation in terms of the containment performance for the same initiating event matrix and this pressure response is applied to finite element study for the containment, as addressed in Response 1.

   Additional description on the basis of bounding pressure is given in DCD 19.2.3.3.7.2.2 like attachment.

3. The calculations #1-316-C304-006 and #1-316-C304-007 was revised and will be uploaded to the ERR system. Calculation #1-316-C304-006 shows conservative results in the global model which also includes local parts such as equipment hatch and personnel airlocks. Calculation #1-316-C304-007 also shows the results in only the local part. The loading conditions of calculation #1-316-C304-007 are identical to those of calculation #1-316-C304-006. Only the results of the analysis are checked in a different perspective (global or local). As shown, the revised calculations for the results of #1-316-C304-006 envelope the results of 1-316-C304-007.

4. In the revised calculation #1-316-C304-006, a pressure amplification factor is not used. The transient pressure response given from MAAP analysis for the selected more likely severe accident sequence is directly applied to the input load in the structural analysis.

Impact on DCD

DCD Section 19.2.3.3.7.2.2 will be revised as indicated on the attached markup.

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 Report.

used to assess survivability of individual equipment. Severe accident temperature environments can be classified as severely challenging, highly challenging, quite challenging, moderately challenging, or nominally challenging, depending on the magnitude and duration of extreme conditions. Severely challenging environments are identified by highly confined extreme conditions for a relatively long duration, such as in the reactor cavity and the IRWST. Highly challenging environments are areas close to a combustible gas source such as the steam generator compartments or the annular compartment above the IRWST. Quite challenging and moderately challenging environments are areas where combustible gas may accumulate such as the containment dome. Nominally challenging environments are compartments where the containment atmosphere can be considered well-mixed and is inerted by a high steam concentration. The equipment survivability curves constructed for each of the five types of environments are shown in Figures 19.2.3-16 through 19.2.3-20. The bounding temperature profile expected in each containment node during a severe accident is summarized in Table 19.2.3-5.

19.2.3.3.7.2.2 Bounding Pressure Environment

~~Based on the MAAP results, the bounding containment pressure expected during a severe accident is 7.75 kg/cm^2 (110 psia).~~

19.2.3.3.7.2.3 Bounding Radiation Environment

MAAP4-DOSE (Reference 29) is used to determine the bounding radiation dose during a severe accident. MAAP4-DOSE is a radiation dose calculation code that reads input from MAAP output. The maximum radiation dose that equipment in the containment is expected to receive during a severe accident is 4.4×10^5 Gy, predicted in the steam generator compartment for the LOFW sequence.

19.2.3.3.7.3 Analysis Methodology

ES is assessed by comparing reliable EQ information such as equipment suppliers' documents, research results, and experimental data with severe accident environmental conditions at the locations where the equipment is installed.

Based on the MAAP study for the selected more likely severe accident sequences, in the viewpoint of the equipment survivability assessment, the containment pressure of 7.75 kg/cm^2 (110 psia) in SBO can envelop the pressure histories from the selected sequences.