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.:	**432-8377**
SRP Section:	**SRP 19**
Application Section:	**19.1**
Date of RAI Issue:	**03/08/2016**

Question No. 19-61

10 CFR 52.47(a)(27) requires that a standard design certification applicant provide a description of the design-specific PRA and its results.

Section 19.1.4.2.1.2.1 of APR1400 design control document (DCD), Rev. 0, states the following: "Containment event trees (CETs) are developed to model the containment response during severe accident progressions. These CETs depict the various phenomenological progress, containment conditions, and containment failure modes that could occur under severe accident conditions."

Section 19.1.4.2.1.2.3 of APR1400 DCD Rev. 0 states the following:

> The MAAP code was used to support many of the CET phenomenological evaluations. MAAP evaluations included evaluations of core melt, RCS failure, containment pressurization, ex-vessel core-concrete interactions, and releases from the containment. Containment failure due to overpressurization was considered using the results of the containment ultimate capacity evaluation. Many other calculations were performed to support the CET.

However, APR1400 DCD Rev. 0 does not provide information on MAAP runs performed and how results of MAAP runs were used to support the CET phenomenological evaluations. The staff needs this information to understand how containment response during severe accident progressions was addressed for the APR1400 design. Provide details of MAAP runs performed to support the APR1400 CET phenomenological evaluations. Revise the DCD as necessary.

Response – (Rev. 1)

As described in Section 19.1.4.2.1.2.3 of APR1400 DCD, a very large number of MAAP calculations were performed to support the At-power Level 2 PRA analysis, including analyses for PDS binning, CET phenomenological evaluations, and source term evaluations. However, the detailed description for each MAAP calculations is too specific to be documented in Section 19.1.4.2.1.2.3 of APR1400 design control document. Instead, the detailed information for each MAAP calculations are documented in the PDS analysis notebook (Doc No: APR1400-K-P-NR-013601-P, Rev. 0), the CET analysis notebook (Doc No: APR1400-K-P-NR-013602-P, Rev. 0), and the STC analysis notebook (Doc No: APR1400-K-P-NR-013603-P, Rev. 0).

Each MAAP calculation documented in the PRA notebooks is as follows.

(1) PDS analysis notebook (Doc No: APR1400-K-P-NR-013601-P, Rev. 0), Appendix A

- Purpose: To review the RCS pressure at the time of core damage

Case	Accident Condition
A01	LOCA (a DEGB of coldleg) without safety injection (SI)
A02	LOCA (6-inch piping break) without SI
A03	LOCA (2-inch piping break) without SI & Secondary Heat Removal (SHR)
A04	LOCA (3/8 inch piping break) without SI & SHR
A05	LOFW without SHR
A06	SBO without SHR
A07	“Case A06” + “RCP seal LOCA occurs (250 gpm/Pump)”
A08	“Case A06” + “RCP seal LOCA occurs (480 gpm/Pump)”
A09	“Case A06” + “RCP seal LOCA occurs (21 gpm/Pump)”
A10	“Case A05” + “2 POSRVs open right after CET > 1200°F”
A11	“Case A05” + “2 POSRVs open 30 minutes after CET > 1200°F”
A12	“Case A05” + “2 POSRVs open 1 hours after CET > 1200°F”
A13	“Case A06” + “2 POSRVs open right after CET > 1200°F”
A14	“Case A06” + “2 POSRVs open 30 minutes after CET > 1200°F”
A15	“Case A06” + “2 POSRVs open 1 hours after CET > 1200°F”

(2) CET analysis notebook (Doc No: APR1400-K-P-NR-013602-P, Rev. 0), Appendix A

- Purpose: To review the number of cycling of POSRV and MSSV cycles before core damage

Case	Accident Condition
T01	SLOCA without SI injection without secondary heat removal
T02	GTRN without secondary heat removal

T03	LOFW without secondary heat removal
T04	SBO without secondary heat removal

- Purpose: To review the ECSBS performance for containment depressurization

Case	Accident Condition
S01	LLOCA with SI, w/o CS
S02	LLOCA with wet cavity, w/o SI & CS
S03	LLOCA with wet cavity, w/o SI & CS, with ECSBS
S04	LLOCA with SI & wet cavity, w/o CS, with ECSBS

- Purpose: To review the containment pressurization for the sequences with a dry cavity without containment sprays

Case	Accident Condition
Q01	LLOCA with dry cavity, w/o sprays
Q02	LOFW with dry cavity, w/o sprays
Q03	SBO with dry cavity, w/o sprays

- Purpose: To review the maximum AICC pressure inside the containment

Case	Accident Condition
R01	Early CS, Wet-Cavity, Coolable debris, No early hydrogen burns
R02	Early CS, Wet-Cavity, Non-coolable debris
R03	Early CS, Dry-Cavity, PARs operate successfully
R04	Early CS, Dry-Cavity, PARs fail to operate
R05	Late CS, Wet-Cavity, Coolable debris, No early hydrogen burns
R06	Late CS, Wet-Cavity, Non-coolable debris
R07	Late CS, Dry-Cavity, PARs operate successfully
R08	Late CS, Dry-Cavity, PARs fail to operate
R09	No CS, Dry-Cavity, PARs operate successfully
R10	No CS, Dry-Cavity, PARs fail to operate

(3) STC analysis notebook (Doc No: APR1400-K-P-NR-013603-P, Rev. 0), Section 6

- Purpose: To evaluate the source term releases for each release category

Case	Accident Condition
STC-01	SGTR without scrubbing - Representative Sequence for STC-01 : Main Steam Line Break downstream the MSIVs, the pressure-induced SGTR, the success of SI system, the failure of SG isolation
STC-02	SGTR with scrubbing - Representative Sequence for STC-02 : SGTR initiating event, the success of the SI system, the success of the secondary heat removal, the failure of RCS cooldown, the failure to refill the IRWST, the success of rapid depressurization and the success of injecting the feedwater into ruptured SG
STC-03	ISLOCA without scrubbing - Representative Sequence for STC-03 : ISLOCA initiating event, The break point of interfacing system piping is not submerged in the water in the auxiliary building
STC-04	ISLOCA with scrubbing - Representative Sequence for STC-04 : ISLOCA initiating event, The break point of interfacing system piping is submerged in the water in the auxiliary building
STC-05	Not isolation with CS - Representative Sequence for STC-05 : LOOP initiating event, the success of EDG, the failure of secondary heat removal, the failure of F&B operation, the failure of containment isolation and the success of the containment spray.
STC-06	Not isolation without CS - Representative Sequence for STC-06 : PLOCCW initiating event, the failure of secondary heat removal, the success of bleed operation, the failure of feed operation, the failure of containment isolation and the failure of the containment spray.
STC-07	CFBRB with a leak failure size - Representative Sequence for STC-07 : MLOCA initiating event, the success of safety injection system, the failure of the containment spray and the containment fails with failure size of 0.1 ft2
STC-08	CFBRB with a rupture failure size - Representative Sequence for STC-08 : MLOCA initiating event, the success of safety injection system, the failure of the containment spray and the containment fails with failure size of 1.0 ft2

STC-09	Intact containment without RPV breach - Representative Sequence for STC-09 : LOOP initiating event, the success of EDG, the failure of secondary heat removal, the failure of bleed operation, the success of rapid depressurization, the success of in-vessel injection, the success of cavity flooding system, the success of containment spray and the core melt arrest in vessel.
STC-10	Intact containment with RPV breach - Representative Sequence for STC-10 : PLOCCW initiating event, the failure of secondary heat removal, the success of bleed operation, the failure of feed operation, the success of rapid depressurization, the success of cavity flooding system, the success of late containment spray (i.e., ECSBS) and the containment maintains its integrity
STC-11	Basemat Melt-through - Representative Sequence for STC-11 : PLOCCW initiating event, the failure of secondary heat removal, the success of bleed operation, the failure of feed operation, the success of rapid depressurization, the failure of cavity flooding system, the success of late containment spray (i.e., ECSBS) and the basemat melt-through.
STC-12	Early containment failure with a leak failure size - There is no sequence assigned in this category
STC-13	Early containment failure with a rupture failure size - Representative Sequence for STC-13 : PLOCCW initiating event, the failure of secondary heat removal, the success of bleed operation, the failure of feed operation, the failure of containment spray system, the success of rapid depressurization, the success of cavity flooding system and the containment fails approximately at the time of reactor vessel failure.
STC-14	Late containment failure with a leak failure size, with CS, with a dry cavity - Representative Sequence for STC-14 : PLOCCW initiating event, the failure of secondary heat removal, the success of bleed operation, the failure of feed operation, the success of rapid depressurization, the failure of cavity flooding system, the success of late containment spray (i.e., ECSBS) and the containment fails in late phase.
STC-15	Late containment failure with a leak failure size, with CS, with a wet cavity - There is no sequence assigned in this category

STC-16	Late containment failure with a leak failure size, w/o CS, with a dry cavity - Representative Sequence for STC-16 : PLOCCW initiating event, the failure of secondary heat removal, the success of bleed operation, the failure of feed operation, the success of rapid depressurization, the failure of cavity flooding system, the failure of containment spray system and the containment fails in late phase
STC-17	Late containment failure with a leak failure size, w/o CS, with a wet cavity - Representative Sequence for STC-17 : PLOCCW initiating event, the failure of secondary heat removal, the success of bleed operation, the failure of feed operation, the success of rapid depressurization, the success of cavity flooding system, the failure of containment spray system and the containment fails in late phase
STC-18	Late containment failure with a rupture failure size, with CS, with a dry cavity - Representative Sequence for STC-18 : PLOCCW initiating event, the failure of secondary heat removal, the success of bleed operation, the failure of feed operation, the success of rapid depressurization, the failure of cavity flooding system, the success of late containment spray (i.e., ECSBS) and the containment fails in late phase
STC-19	Late containment failure with a rupture failure size, with CS, with a wet cavity - Representative Sequence for STC-19 : PLOCCW initiating event, the failure of secondary heat removal, the success of bleed operation, the failure of feed operation, the success of rapid depressurization, the success of cavity flooding system, the success of late containment spray (i.e., ECSBS) and the containment fails in late phase
STC-20	Late containment failure with a rupture failure size, w/o CS, with a dry cavity - Representative Sequence for STC-20 : PLOCCW initiating event, the failure of secondary heat removal, the success of bleed operation, the failure of feed operation, the success of rapid depressurization, the failure of cavity flooding system, the failure of containment spray and the containment fails in late phase
STC-21	Late containment failure with a rupture failure size, w/o CS, with a wet cavity - Representative Sequence for STC-21 : PLOCCW initiating event, the failure of secondary heat removal, the success of bleed operation, the failure of feed operation, the success of rapid depressurization, the success of cavity flooding system, the failure of containment spray system and the containment fails in late phase

Impact on DCD

DCD Section 19.1.4.2.1.2.3 will be revised as shown in the Attachment.

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.

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The PDS and CET quantitative solution tool is the SAREX code. The bridge event tree evaluation in SAREX is similar to the functions utilized in the Level 1 portion of the PRA. The Level 2 portion of the SAREX code was used to create the PDS binning diagram, CET, the CET's supporting decomposition event trees (DETs), and the release category binning diagram. MAAP is used for phenomenological evaluation of the accident progression and for calculation of source term releases from containment.

The following subsections describe the PDS and CET analyses.

The MAAP cases are used to review the RCS pressure at the time of core damage for PDS analysis.

19.1.4.2.1.1 Plant Damage State Analysis

At several stages in the PRA, elements of the accident sequences have been grouped according to similarities in characteristics. For example, many of the initiating events defined for the core damage sequences in the Level 1 analyses actually represent groups of different specific initiators that have similar effects on the systems required to respond to them. This grouping process is used primarily to make the overall analysis process more efficient and tractable by limiting the number of discrete events and scenarios that must be considered, while retaining the degree of discrimination needed to capture differences in potential accident sequences. The PDS binning approach follows the same philosophy.

The process of the PDS analysis is as follows:

a. Define the PDS characteristics to identify the physical characteristics and the accident sequence characteristics of the core damage sequences.

b. Develop the PDS event tree logic diagram.

c. Extend the Level 1 event trees to PDS event trees by questioning the status of functions that can affect containment integrity.

d. Group the extended core damage sequences (i.e., the end point of the PDS event trees) into the plant damage states by using a systematic logic diagram.

The PDSs are defined by developing possible combinations of the PDS parameters (core-melt bins and containment safeguard states), and in some cases conservatively combining some PDSs if the frequency is negligible. A PDS logic diagram is used to systematically bin core damage sequences into PDSs. This logic diagram is constructed with PDS

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19.1.4.2.1.2.3 CET Phenomenological Evaluations

The MAAP code was used to support many of the CET phenomenological evaluations. ~~MAAP evaluations included evaluations of core melt, RCS failure, containment pressurization, ex-vessel core-concrete interactions, and releases from the containment. Containment failure due to overpressurization was considered using the results of the containment ultimate capacity evaluation.~~ ~~Many other calculations were performed to support the CET.~~ Referring to the general CET presented in Figure 19.1-42, the following top events are described:

The MAAP case are used for CET phenomenological evaluation as follows;
a. To review the number of cycling of POSRV and MSSV cycles before core damage
b. To review the containment pressurization for the sequences with a dry cavity without containment sprays
b. To review the ECSBS performance for containment depressurization
d. To review the maximum AICC pressure inside the containment

a. RCSFAIL – Mode of RCS Failure Before Vessel Breach

b. MELTSTOP – In-Vessel Core Melt Arrest

c. DCF – Dynamic Containment Failure

d. ECF – Early Containment Failure

e. CSLATE – Late Containment Heat Removal Recovery Failure

f. DBCOOL – Ex-Vessel Debris Coolability

g. LCF – Late Containment Failure

h. BMT – Basemat Melt-Through

1) RCSFAIL – Mode of RCS Failure Before Vessel Breach

The question posed in this DET is whether there is a severe accident-induced failure of the hot leg or steam generator tubes during severe accident progression. For high pressure core damage sequences, natural circulation of superheated gases can occur in the reactor coolant system after the core has uncovered. Natural circulation is a result of differences in gas density between the various regions of the reactor coolant system. Natural circulation of gases in the reactor coolant system during the severe accident is a significant phenomenon because it transports heat from the overheating core into the structure of the upper plenum, hot leg, surge line, and SG tubes. If the natural circulation flow of gases continues, it can cause failure of the hot