RESPONSE TO AUDIT ISSUES

APR1400 Topical Reports

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. PROJ0782

Review Section	**TR Realistic Evaluation Methodology for LBLOCA of the APR1400**
Application Section	**Topical Report: APR1400-F-A-TR-12004 Realistic Evaluation Methodology for Large-Break LOCA of the APR1400**
Issue Date	**08/13/2015**

Audit Issues No. 15

It appears that what is being termed the APR1400 PIRT in Table 3-2 and Table 5 of Appendix A of the topical report is actually a subset of the Korea Next Generation Reactor (KNGR) PIRT, shown in Table 3 in Appendix A, that includes only those phenomena from the KNGR PIRT (with modifications for APR1400) that are ranked 4 or higher during at least one of the accident periods. A complete PIRT, as described in NUREG/CR-5249 includes all the phenomena and their corresponding ranking. Both the KNGR and the APR1400 PIRTs lack a state-of-knowledge ranking for each phenomenon. In addition, according to RG 1.203, the PIRT generated to guide the evaluation model (EM) development process must be adequately documented. A complete documentation of the PIRT for APR 1400 that includes the rationale for the assigned ranks and state-of-knowledge is needed.

Response

The APR1400 PIRT has been developed based on KNGR PIRT [1]. The presentation material attached [2] describes the changes from KNGR PIRT and the rationales for the changes. The APR1400 PIRT in the topical report will be revised to the document attached [3] where the rationales for the assigned ranks and state-of-knowledge column are added. The changes from KNGR PIRT are written in red and their rationales are reinforced.

Reference

[1] "Phenomena Identification and Ranking Tabulation Korean Next Generation Reactor Large Break Loss of Coolant Accident," KINS/INEEL, 2001

[2] Presentation Material, "PIRT to Uncertainty Parameter," presented at the face to face meeting with NRC, 2016. 1. 12 ~ 2016. 1. 15. (Modifications are made in accordance to the reference [2]), Revision 1.

[3] Presentation Material, "APR1400 PIRT revision," attached document of the response to the audit issue no. 15, July, 2016

Impact on DCD

There is no impact to 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 Report

Topical report will be revised according to the PIRT revision as described in the attachment for the response of Audit Issue No. 14.

There is no impact on any Technical or Environmental Report.

PIRT to Uncertainty Parameter

➢ Contents

PIRT to Uncertainty Parameter

- KNGR LBLOCA PIRT (WFO861702, 2001)
  - Former APR1400, KNGR (Korea Next Generation Reactor)
    - Developed by KINS/INEEL
    - Internationally recognized panel members: Dr. Brent E. Boyack (LANL), Dr. Bub-Dong Chung (KAERI), Dr. Lawrence E. Hochreiter (PSU), Dr. Jose N. Reyes (OSU), Mr. Gary E. Wilson (INEEL)
    - Time period definition

      1: Blowdown (break ~ lower plenum begins to refill)

      2: Refill (~ mixture level approaches the core inlet)

      3: Reflood (~ initial core quenched)

      4: long-term cooling period (~ stable core quenched)

PIRT to Uncertainty Parameter

- KNGR LBLOCA PIRT (WFO861702, 2001)
  - Constitutes of
    - PIRT KNGR LBLOCA (main body)
    - Description of process/phenomena used in the PIRT (Appendix A)
    - Importance Ranking, Knowledge-Level and Rationales LBLOCA PIRT for the KNGR (Appendix B)
    - Summary of KNGR RELAP5 LBLOCA Sensitivity Calculations (Appendix C)
    - TRAC-M Simulations of LBLOCA in the KNGR (Appendix D)
    - Curriculum Vitae for KNGR PIRT panel (Appendix E)

PIRT to Uncertainty Parameter

- KNGR LBLOCA PIRT (WFO861702, 2001)
  - KNGR LBLOCA PIRT table
- APR1400 PIRT
  - Some modifications made for APR1400 PIRT
    - Definition of time periods modified
      1. blowdown (~ SIT injection initiates)
      2. refill (~ level approaches the core inlet)
      3. early reflood (~ SITs empty)
      4. late reflood (SITs empty ~)
    - SIT flow path, IRWST water level, IRWST-SIP flow, Pressurizer stored energy, etc… are modified
    - Due to better knowledge, change in the definition of time phases, corrections…

PIRT to Uncertainty Parameter

- Adjustment of rankings modified

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PIRT to Uncertainty Parameter

➢ Adjustment of rankings modified

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PIRT to Uncertainty Parameter

- Adjustment of rankings modified

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➤ Adjustment of rankings modified

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PIRT to Uncertainty Parameter

- APR1400 LBLOCA PIRT (as described in Appendix A of the ToR)

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Continued to next page

PIRT to Uncertainty Parameter

- APR1400 LBLOCA PIRT (Appendix A of Topical Report)

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APR1400 LBLOCA PIRT (1/3)

Non-Proprietary

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APR1400 LBLOCA PIRT (2/3)

Non-Proprietary

APR1400 LBLOCA PIRT (3/3)

Non-Proprietary

PIRT to Uncertainty Quantification

- General guideline
  - In CAREM, all phenomena of importance (≥ 4) should be considered by each uncertainty parameters (UCP) and their uncertainty ranges, in principle. (e.g. 1 to 1 match)
  - However, there are some exceptions such as…

    (1) Phenomena already considered by other UCP

    ex) Flashing in the core ⇨ depressurization of RCS ⇨ treated as the uncertainty of critical flow, break size, etc.

    (2) Phenomena treated conservatively

    ex) Radiation to surroundings ⇨ conservative when not considered

    (3) Phenomena treated as bias

    ex) ECC bypass during refill

PIRT to Code Parameters (1/7)

- APR1400 LBLOCA PIRT (ToR)

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- Descriptions: Sections in ToR.
- (R) considered in other parameter, (C) conservatively treated, (B) bias
- (Y) handled by uncertainty parameter

PIRT to Code Parameters (2/7)

- APR1400 LBLOCA PIRT (ToR)

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PIRT to Code Parameters (3/7)

- APR1400 LBLOCA PIRT (ToR)

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PIRT to Code Parameters (4/7)

- APR1400 LBLOCA PIRT (ToR)

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PIRT to Code Parameters (5/7)

- APR1400 LBLOCA PIRT (ToR)

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PIRT to Code Parameters (6/7)

- APR1400 LBLOCA PIRT (ToR)

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Non-Proprietary

PIRT to Code Parameters (7/7)

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Final Uncertainty Parameter Selection

- ➢ Total 82 phenomena → 27 uncertainty parameter
- ➢ In addition to the parameters selected from PIRT,

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- Distribution of the uncertainty parameter is assumed as either normal or uniform. (Uniform is used when the knowledge level is low for conservatism.)

Final Uncertainty Parameter Selection

➢ As a results,

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- Bias evaluation performed for the high (reflood) PCT cases and added
- Uncertainty from all PIRT phenomena/process are considered in the final calculation of the safety parameters, i.e., PCT, PLO, …

Distributions and Ranges of the Uncertainty Parameters (1/2)

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Distributions and Ranges of the Uncertainty Parameters (2/2)

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Thank you for your attention

APR1400 LBLOCA PIRT
Revision 1

2016. 7.

KEPCO KHNP

Acronyms

APR1400	Advanced Power Reactor 1400
CCF	Counter Current Flow
CHF	Critical Heat Flux
CL	Cold Leg
DC	Downcomer
DVI	Direct Vessel Injection
ECC	Emergency Core Coolant
FD	Fluidic Device
HL	Hot Leg
IR	Importance Ranking
KL	Knowledge Level
LP	Lower Plenum
PCT	Peak Cladding Temperature
PZR	Pressurizer
NC	Non-condensible
RCS	Reactor Coolant System
SG	Steam Generator
SIP	Safety Injection Pump
SIT	Safety Injection Tank
SIT-FD	Safety Injection Tank with Fluidic Device
UP	Upper Plenum

Definition of IR and KL

- Same definition with KNGR PIRT [1] is used

Importance Ranking

Importance Ranking (IR)	Meaning
5	Highest of the high in importance
4	High importance
3	Moderate importance
2	Low importance
1	Lowest of the low in importance

Knowledge Level

Knowledge-Level (KL)	Meaning
5	Fully Known. Small uncertainty.
4	Known. Moderate uncertainty.
3	Partially Known. Large uncertainty.
2	Very Limited Knowledge. Uncertainty cannot be characterized.
1	Totally Unknown.

added

General guide lines of KNGR PIRT[1]

- IR and KL was determined from votes by PIRT panel, and there are general guide lines for the ranks.
- The general guide lines for the IR and KL are described in slide 4 and 5.

Changes for APR1400 PIRT

- After SIT-FD design is completed, it is revealed that the time period definition based on the SIT injection is more useful than that of KNGR PIRT.
- The general IR and KL changes as well as the change in the definition of time period are described in slide 6 through 8.

added

IR General Descriptors, pp. 17 of Reference [1], also pp. A-13 of Appendix A of ToR

Rank	General Descriptors
5	a. Highest of the high b. Experimental simulations and analytical modeling, with high degree of accuracy, is critical
4	a. High influence on FOM b. Needs to be experimentally present[1] and/or analytically modeled[2] with high degree of accuracy c. Approximately one –half the importance of rank 5
3	a. Moderate influence on FOM b. Needs to be experimentally present and/or analytically modeled with moderate degree of accuracy c. Approximately one –half the importance of rank 4
2	a. Low influence on (or importance to) FOM b. Needs to be experimentally present and/or analytically modeled, but high uncertainty or inaccuracy is acceptable c. Approximately one –half the importance of rank 3
1	a. Lowest of the low in importance b. Very low influence on (or importance to) FOM c. Approximately one –half the importance of rank 2
IS	A system, component or process/phenomena may be active; however, its influence on the FOM is insignificant and may be ignored
NA	A system, component or process/phenomena is not active or present

[1]: As used here, “experimentally present” relates to test facilities used to simulate the reactor

[2]: Likewise, “analytically modelled” relates to models and computer codes used to simulate the reactor

added

KL Relationships (General rationale of KL in KNGR PIRT), pp. 19 or pp. B2 of Reference [1]

Knowledge-Level (KL)	Meaning
5	Stored energy release for well-defined geometries is ranked at level 5. Stored energy release in pellets with cracks is an exception.
5	Flashing phenomenon is well known.
5	Reactivity parameters are well known.
5	Oxidation kinetics is well known. There is more uncertainty when double-sided oxidation is being considered.
5	Single-Phase pressure-drop in simple geometries.
4	One-Phase pressure-drop in complex geometries.
4	Two-Phase pressure-drop in simple geometries.
3	Two-Phase pressure-drop in complex geometries.
3	Multi-dimensional flow knowledge is ranked 3 because of the effects of complex geometry and the complications caused by multiple fluid streams, condensation, entrainment and de-entrainment.
3-4	Level in components is ranked between 3 and 4 depending on flow paths.
Note	Transient dynamic phenomena have a lower knowledge level than quasi-steady behavior for same phenomena. (e.g., blowdown phase versus long term cooling phase).

added

Change in the definition of time period

Definition of time period (KNGR)

Time period	Definition
Blowdown (1)	Break initiation ~ Initiation of lower plenum refill
Refill (2)	Initiation of lower plenum refill ~ Initiation of core recovery (liquid level at bottom of fuel rod heated length)
Reflood (3)	End of refill ~ Initial core quench
Long-term cooling (4)	Initial core quench ~ Stable core quench

Downcomer boiling was considered as being important and this is the reason for division of reflood period to reflood and long-term cooling periods.

Definition of time period (APR1400)

Time period	Definition
Blowdown (1)	Break initiation ~ Initiation of SIT injection
Refill (2)	Initiation of SIT injection ~ Initiation of core recovery (mixture level at the bottom of fuel rods)
Early Reflood (3)	End of refill ~ End of SIT injection
Late Reflood (4)	End of SIT injection ~ Stable core quench

Time period change have been made due to practical application, better knowledge on phenomena:
- Initiation of lower plenum refill is not easy to determine and changed to SIT injection initiation.
- Division of Initial core quench and long-term cooling is not meaningful any more. It is required to confirm the core quench behavior when the SI is not sufficient(late reflood).

added

IR adjustment due to time period change

- Blowdown
  - "SIT injection" is NOT included during blowdown period in APR1400 PIRT
    - ECC injection during blowdown does not occur
    - The rank of phenomena related with SIT or ECC interaction become "NA"
- Refill
  - "Early SIT injection" is included during refill period in APR1400 PIRT
    - The blowdown period importance rank of KNGR PIRT is used as the rank for the refill period of APR1400 PIRT
- Early reflood, late reflood
  - Massive NC gas release does NOT occur during early reflood period in APR1400 PIRT
    - The earliest massive NC gas release occurs during late reflood period
    - However, NC gas release due to vortex motion of SIT-FD can occur during early reflood period
  - Full Scale SIT-FD experiment was performed
    - Sufficient amount of ECC is guaranteed during early reflood, IR during early period can be lowered.

added

KL change due to design completion

- SIT-FD
  - Full-scale VAPER test has been performed
    - Knowledge levels of phenomena related with SIT-FD, such as level, flow deliveries and noncondensable gas are increased to 5.

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- References

[1] "Phenomena Identification and Ranking Tabulation Korean Next Generation Reactor Large Break Loss of Coolant Accident", WFO861702, KINS/INEEL, January 2001.