REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

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

Docket No. 52-046

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Question No. 19-28

10 CFR 52.47(a)(27) requires that a standard design certification applicant provide a description of the design specific PRA and the results. The low-power shutdown (LPSD) large release frequency (LRF) contribution from midloop operation is reduced because credit is taken for initiation of safety injection (SI) to arrest core damage in the vessel as a severe accident mitigation guidelines (SAMG) action. However, a key contributor to the LPSD core damage frequency (CDF) in the mid-loop plant operational state (POS) is due to operator failure to initiate SI before core damage. The staff noted that credit for the SAMG action of initiating SI is included in the Containment Event Tree top event, MELTSTOP. The staff searched through the LPSD human reliability analysis (HRA) notebook and could not find how dependence between the Level 1 and Level 2 LPSD PRA was calculated for these two actions or what factors were considered in the dependence calculation (e.g. similar alarms and cues). The staff is requesting KHNP to provide the staff additional information on how dependence was calculated between the operator action to initiate SI to prevent core damage and the SAMG action to initiate SI to arrest core damage in the vessel and to update the DCD, as necessary. The staff needs this information to better understand the numerical results of the KHNP LPSD PRA.

Response – (Rev. 2)

New text will be added to the DCD to address the Level 2 dependence in the credit for SI initiation.

Impact on DCD

DCD Section 19.1.6.2.1.3 will be revised as shown in Attachment 1.

The following paragraph will be added to DCD Section 19.1.6.2.1.3, in the subsection on Safety Injection:

"SI Initiation is first credited early in the accident sequence for the prevention of core damage, and again later, during SAMG actions, to arrest core damage in the vessel. The SAMGs are entered when the Core Exit Thermocouples indicate 1200 degrees F, which is unique and unrelated to the initial cue for Safety Injection before core damage occurs. Therefore the dependency evaluation yielded a Low Dependence between the first opportunity for SI initiation and the subsequent SAMG cue. The subsequent dependency calculation increased the SAMG SI initiation HEP accordingly."

Summary tables for the dependency analysis performed for the APR1400 HFEs for LPSD Level 2 PRA are provided in Attachment 2. Also this information will be added as Appendix C of LPSD Level 2 Internal Events Quantification Notebook (APR1400-K-P-NR-013763-P).

DCD Section 19.1.6.2.2.7 will be revised as shown in Attachment 3.

The sensitivity demonstrates that the impact on total LPSD LRF is small and would not alter the conclusions of the DCD.

Impact on PRA

The DCD will be revised as shown in Attachment 1 and 3.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on Technical/Topical/Environmental Report.

some point after core damage but before vessel failure in which recovery of SI prevents vessel failure; there is uncertainty as to the exact criteria to define this point, so conservatism is applied in this instance.

For the LPSD analysis, successful initiation of SI to prevent vessel failure is assumed until the time of core damage. This allows some conservatism to account for uncertainties in the thermal-hydraulic analysis, which provides sufficient realism to credit the SAMG action. The time to reach 1,200 °F and the time to core damage were developed using the MAAP code for a mid-loop scenario with loss of SDC and no SI.

External Reactor Vessel Cooling (ERVC)

insert A in next page

When the core exit thermocouple temperature of 1,200 °F is reached, another SAMG action is initiation of the cavity flooding system (CFS). This is credited if there is a mechanical failure of SI, but if there is an operator failure to initiate SI by the SAMG action, then complete dependence is assumed, and no credit is given to cavity flooding by SAMG action. In addition, the ERVC system provides a means to flood the containment cavity in an attempt to prevent vessel failure by cooling the molten core from outside the vessel. Consistent with the at-power Level 2 PRA, ERVC is not credited in the baseline LPSD analysis.

d. DCF – No Dynamic Containment Failure

Given that the RV has failed (failure of the MELTSTOP top event), the LPSD CET then questions whether the containment fails dynamically at vessel breach. This event is similar to the at-power Level 2 CET event DCF, except that in the LPSD model for POS 4B-12A, the RCS pressure will always be “low” at vessel breach (due to the open pressurizer manway). The evaluation of “low” pressure vessel failure from the at-power Level 2 analysis presents a $1x10^{-3}$ probability of dynamic containment failure due to Alpha-mode containment failure. The same value is conservatively used for the LPSD Level 2.

e. ECF – No Early Containment Failure

A

SI Initiation is first credited early in the accident sequence for the prevention of core damage, and again later, during SAMG actions, to arrest core damage in the vessel. The SAMGs are entered when the Core Exit Thermocouples indicate 1200 degrees F, which is unique and unrelated to the initial cue for Safety Injection before core damage occurs. Therefore the dependency evaluation yielded a Low Dependence between the first opportunity for SI initiation and the subsequent SAMG cue. The subsequent dependency calculation increased the SAMG SI initiation HEP accordingly.

No	HFE Name(Pa)	Description	Indep. HEP	HFE Name(Pb)	Description	Indep. HEP	HEPs dependence combinations	Dep. Level	Dep. HEP	Intervening Success	Crew	Cue Demand	Location	Sep. Timing	Stress
1	IWOPH-S-CFS	Operator Fails to Open CFS Valve	1.50E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-SAMG-DE	CD	1.00E-00	No	same	-	-	-	-
2	HR-FB-S1P04B	Operator Fails to Operate F&B at S1 POS04B	1.27E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
3	HR-FB-S1P04B-DE	HRA Dependence for RS & FB at S1 P04B	5.12E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
4	HR-FB-S1P05	Operator Fails to Operate F&B at S1 POS05	1.27E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
5	HR-FB-S1P05-DE	HRA Dependence for RS & FB at S1 P05	5.12E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
6	HR-FB-S1P06	Operator Fails to Operate F&B at S1 POS06	1.34E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
7	HR-FB-S1P06-DE	HRA Dependence for RS & FB at S1 P06	5.13E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
8	HR-FB-S1P10	Operator Fails to Operate F&B at S1 POS10	1.27E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate

No	HFE Name(Pa)	Description	Indep. HEP	HFE Name(Pb)	Description	Indep. HEP	HEPs dependence combinations	Dep. Level	Dep. HEP	Intervening Success	Crew	Cue Demand	Location	Sep. Timing	Stress
9	HR-FB-S1P10-DE	HRA Dependence for RS & FB at S1 P10	5.12E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
10	HR-FB-S1P11	Operator Fails to Operate F&B at S1 POS11	1.27E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
11	HR-FB-S1P11-DE	HRA Dependence for RS & FB at S1 P11	5.12E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
12	HR-FB-S1P12A	Operator Fails to Operate F&B at S1 POS12A	1.27E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
13	HR-FB-S1P12A-DE	HRA Dependence for RS & FB at S1 P12A	5.12E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
14	HR-FB-JLP04B-01	Operator Fails to Operate F&B at JL POS04B 01	1.27E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
15	HR-FB-JLP04B-01-DE	HRA Dependence for RS & FB at JL POS04B	5.12E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
16	HR-FB-JLP04B-02	Operator Fails to Operate F&B at JL POS04B 02	1.05E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate

No	HFE Name(Pa)	Description	Indep. HEP	HFE Name(Pb)	Description	Indep. HEP	HEPs dependence combinations	Dep. Level	Dep. HEP	Intervening Success	Crew	Cue Demand	Location	Sep. Timing	Stress
16	HR-FB-JLP04B-02-DE	HRA Dependence for MI & FB at JL POS4B	5.99E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
17	HR-FB-JLP05-01	Operator Fails to Operate F&B at JL POS05 01	1.27E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
18	HR-FB-JLP05-01-DE	HRA Dependence for RS & FB at JL POS05	5.12E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
19	HR-FB-JLP05-02	Operator Fails to Operate F&B at JL POS05 02	1.44E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
20	HR-FB-JLP05-02-DE	HRA Dependence for MI & FB at JL POS05	6.37E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
21	HR-FB-JLP06-01	Operator Fails to Operate F&B at JL POS06 01	1.30E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
22	HR-FB-JLP06-01-DE	HRA Dependence for RS & FB at JL POS06	5.12E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
23	HR-FB-JLP06-02	Operator Fails to Operate F&B at JL POS06 02	1.37E-01	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate

No	HFE Name(Pa)	Description	Indep. HEP	HFE Name(Pb)	Description	Indep. HEP	HEPs dependence combinations	Dep. Level	Dep. HEP	Intervening Success	Crew	Cue Demand	Location	Sep. Timing	Stress
24	HR-FB-JLP06-02-DE	HRA Dependence for MI & FB at JL POS06	6.30E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
25	HR-FB-JLP10-01	Operator Fails to Operate F&B at JL POS10 01	1.27E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
26	HR-FB-JLP10-01-DE	HRA Dependence for RS & FB at JL POS10	5.12E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
27	HR-FB-JLP10-02	Operator Fails to Operate F&B at JL POS10 02	1.70E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
28	HR-FB-JLP10-02-DE	HRA Dependence for MI & FB at JL POS10	5.16E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
29	HR-FB-JLP11-01	Operator Fails to Operate F&B at JL POS11 01	1.27E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
30	HR-FB-JLP11-01-DE	HRA Dependence for RS & FB at JL POS11	5.12E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
31	HR-FB-JLP11-02	Operator Fails to Operate F&B at JL POS11 02	1.27E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate

No	HFE Name(Pa)	Description	Indep. HEP	HFE Name(Pb)	Description	Indep. HEP	HEPs dependence combinations	Dep. Level	Dep. HEP	Intervening Success	Crew	Cue Demand	Location	Sep. Timing	Stress
32	HR-FB-JLP11-02-DE	HRA Dependence for MI & FB at JL POS11	5.12E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
33	HR-FB-JLP12A-01	Operator Fails to Operate F&B at JL POS12A 01	1.27E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
34	HR-FB-JLP12A-01-DE	HRA Dependence for RS & FB at JL POS12A	5.12E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
35	HR-FB-JLP12A-02	Operator Fails to Operate F&B at JL POS12A 02	1.27E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
36	HR-FB-JLP12A-02-DE	HRA Dependence for MI & FB at JL POS12A	5.12E-02	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
37	HR-FB-LXP04B	Operator Fails to Operate F&B at LX POS04B	1.95E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
38	HR-FB-LXP05	Operator Fails to Operate F&B at LX POS05	1.95E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate
39	HR-FB-LXP06	Operator Fails to Operate F&B at LX POS06	1.95E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120'	High or Moderate

No	HFE Name(Pa)	Description	Indep. HEP	HFE Name(Pb)	Description	Indep. HEP	HEPs dependence combinations	Dep. Level	Dep. HEP	Intervening Success	Crew	Cue Demand	Location	Sep. Timing	Stress
40	HR-FB-LXP10	Operator Fails to Operate F&B at LX POS10	1.95E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120)	High or Moderate
41	HR-FB-LXP11	Operator Fails to Operate F&B at LX POS11	1.95E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120)	High or Moderate
42	HR-FB-LXP12A	Operator Fails to Operate F&B at LX POS12A	1.95E-03	HR-FB-SAMG	Operator Fails to SI Initiation (SAMG)	1.40E-02	HR-FB-SAMG-DE	LD	6.33E-02	No	same	Sequential	Same	>(60~120)	High or Moderate

The ability to close the containment equipment hatch in POS 3B and 4A is significant. Without credit for hatch closure, these POS would yield an LRF of 9.6×10^{-8}/year, which would nearly double the LPSD internal events LRF. However, with credit for hatch closure, these two POS contribute 2.5×10^{-8}/year to the LRF (21 percent).

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19.1.6.3 Internal Fire PRA for Low Power and Shutdown Operations

The following subsections describe the development of the internal fires risk evaluation during low power and shutdown conditions, and the analysis results.

19.1.6.3.1 Description of Internal Fire PRA for Low Power and Shutdown Operations

The low power and shutdown (LPSD) fire PRA (FPRA) methodology for the APR1400 is based on NUREG/CR-7114 (Reference 52) and NUREG/CR-6850 (Reference 6). NUREG/CR-7114 provides a framework for quantitative analysis of fire risk during LPSD conditions. NUREG/CR-6850 provides a state-of-the-art methodology for fire PRAs. The steps in the LPSD fire PRA methodology are the same as those used in the full-power internal fire PRA (FP-FPRA) (see Subsection 19.1.5.2.1) with the exception that they are applied to the LPSD internal events model (see Subsection 19.1.6.1). The exceptions to the at-power FPRA methodology used in the development of the LPSD FPRA are described below. It should be noted that units for CDF and LRF are expressed in terms of "reactor calendar year" (shortened to "/year" when displayed in the text in this section).

19.1.6.3.1.1 Deviations from the Industry Methodology

All of the tasks described in Subsection 19.1.5.2.1 are required to perform a LPSD FPRA. These tasks involve various types of screening to eliminate assessment of non-risk-significant fire scenarios. Since the plant is in the design stage, some specific plant details are not yet known, so some of these screening tasks cannot be applied with a high degree of certainty. These tasks include the following:

a. Task 4 has not been performed. Instead, all fire compartments are included in the analysis, and those that do not result in an LPSD initiator simply have a CDF of zero (since the initiating event frequency is zero). It should be noted that all compartments are later considered for multi-compartment analysis (MCA) impacts.

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B

The LPSD CDF and LRF are highly dependent on the LPSD human error probabilities, as is expected for an LPSD PRA. In the development of the LRF model, the application of the dependent HEP event for SAMG initiation of safety injection to prevent vessel failure resulted in some cutsets that contain 3 or 4 operator actions to have a total combined human error probability below 1E-5. A sensitivity was performed examining what the impact to LRF would be if a floor HEP of was applied to each cutset in which the total probability of all operator actions was restricted to 1E-5 or higher. The result of the sensitivity was that the total LRF of POSs 4B-12A would increase from 6.64E_8/yr to 7.23E_8/yr (8.9% increase). The total LRF of all POSs would increase from 1.18E_7/yr to 1.24E_7/yr (5.1% increase). Therefore, the sensitivity demonstrates that the impact on the total LPSD LRF is small and would not alter the conclusions of the DCD.