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The Risk Insights for the Spent Fuel Pool Accidents

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1. Introduction

A shutdown PSA provides insight for outage planning schedule, outage risk management practices, and design modifications. Considering the results of both LPSD PSA studies and operating experiences for low power and shutdown, the improvements can be proposed to reduce the high risk contribution. Figure 1 shows a graphical representation of the risk profile associated with the results of the typical KSNP refueling outage.

The middle part of the figure 1 which are correspond the defueled period and refueling periods seems to have a zero risk because the LPSD PSA is performed for the quantification of core damage frequency in reactor vessel. Severe accident management for the spent fuel pool is emphasized as safety enhancements of nuclear power plants after Fukushima accident in Japan. Strategies for severe accident management for the spent fuel pool should be set up and included in the development process of shutdown severe accident management guidelines (SSAMG). The scope of LPSD PSA is required to extend to the spent fuel pool accident to provide the risk insights for the SSAMG.

This paper presents the simple risk insights for the spent fuel pool accidents at Korea nuclear plants.

2. Risk Model for Spent Fuel Pool Boiling

This paper describes the events developed to analyze spent fuel risk. In this section, the initiating events treated, the event trees for sequences leading to pool heat up, and modeling approach are described. In order to develop a complete risk model of loss of spent fuel pool cooling up to the point of pool boiling, the risks from the two groups of scenarios should be considered; those that involve the fuel in the spent fuel pool, and those that involve the fuel in the core and spent fuel pool. In this paper, only the risk model for spent fuel pool boiling is described.

2.1 Initiating Events

Identification of spent fuel pool initiating events methods is similar to those applied to the at-power PSA models. Three-tiered approach is used: (1) develop a master logic diagram, (2) complete system load reviews, and (3) review LPSD literature.

Loss of Spent Fuel Pool Cooling System event includes loss of the SFPC system due to equipment failures and human errors and loss of cooling to the SFPC heat exchangers. However, this event is negligible than other events below listed in the viewpoint of the contribution for overall spent fuel pool boiling frequency based on the references for SFP PRA.

In this paper, four initiating events derived from the list of initiating events in other reference [1, 2] are as follows:

- Loss of Offsite Power (LOOP)
- Large Loss of Spent Fuel Pool Inventory (LINVC)
- Small Loss of Spent Fuel Pool Inventory (LINCS)
- Seismic Events (EQE)

Loss of Offsite Power events includes the LOOP and SBO events. The initiating event frequency of LOOP is applied as 3.12E-2/yr based on the KSNP full power PSA report [3].

Loss of Spent Fuel Pool Inventory event includes losses of inventory from leaks from the failure of piping or gates/seals. Only leaks for which the outgoing flow rate exceeds the normal makeup flow rate are considered. The initiating frequencies of these events based on the reference[1] are determined as follows:

- Initiating frequency of small leak =3.0E-3/ry
- Initiating frequency of large leak =2.0E-3/ry.

Seismic events covers seismically induced losses of offsite power, SFPC piping integrity, and spent fuel pool boundary integrity. The initiating event frequency of seismic events is assumed as 4.59E-5/yr based on the initiating event frequency of seismic induced LOOP of KSNP seismic PSA[3].

The event trees for 4 initiating events were developed and, Figure 2 shows the LOOP event tree for the spent fuel pool as an example.

2.2 Human Reliability Data

Because of the very limited number of automatic equipment actions that are typically functional during shutdown, operator actions are more dominant during shutdown than during at-power conditions. Therefore, the large numbers of sequences of four event trees related to SFP boiling frequency contain multiple human error probabilities. HRA dependency analysis is critical to realistic shutdown analysis. Many of the sequences take many hours to lead to spent fuel pool boiling leaving significant time for operators to perform required tasks. In keeping with the simple modeling approach used in other parts of the analysis, a simple human reliability analysis (HRA) technique is applied. This technique is a worksheet-based approach developed for the ASP program.

2.3 Quantification Results

The annual probability of spent fuel pool (SFP) boiling events is order of 1E-6. Figure 4 shows the results for the spent fuel pool boiling frequency. Three initiating events contribute almost 97% of frequency of SFP boiling; they are loss of offsite power (LOOP), small loss of inventory (LINCS), and large loss of inventory (LINVC). These contribute 52%, 32%, and 13%, respectively, to the frequency of boiling.

The above conclusions are the result of a limited scope study. Key modeling simplification, use of a simplified human reliability analysis, and the lack of recovery analysis for dominant sequences.

3. Conclusions

The following conclusions regarding the likelihood of spent fuel pool boiling are based upon the calculation.

- The dominant contribution comes from LOOP event, and the contribution from loss of SFP inventory events is also significant.
- Weaknesses may be seen in the completeness with regard to initiating events, system analysis, and human reliability analysis.
- Simplifying assumptions and models need further analysis.

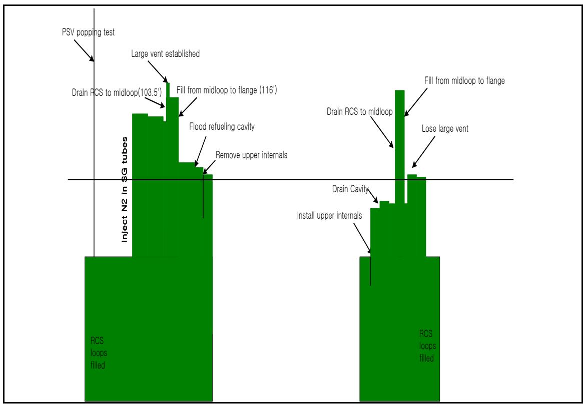

Fig.1The risk profiles during refueling outage for the typical KSNP

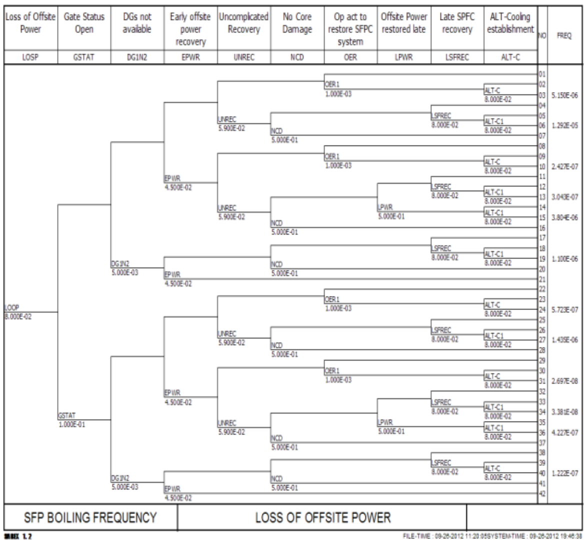

Fig.2 Loss of Offsite Power Event Tree for the SFP

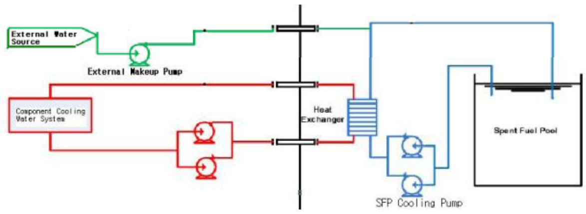

Fig.3 Drawing related to the SFP cooling system and alternative Make-up system

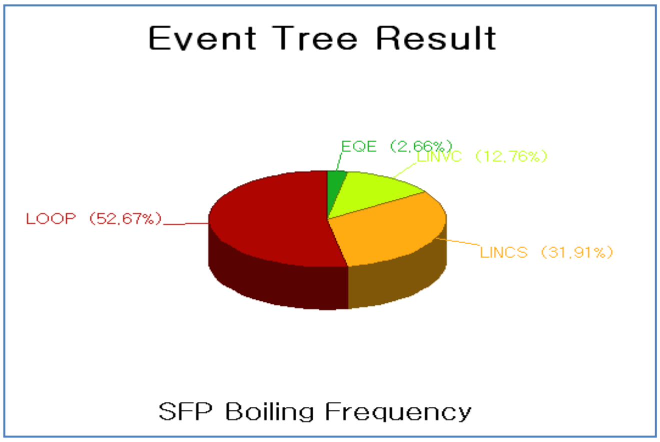

Fig.4 Risk Profile for the SFP boiling Frequency

REFERENCES

[1] "Loss of Spent Fuel Pool Cooling PRA", INEL-96/0344, 1996

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[3] Ulchin 5&6 PSA report, KHNP, 2002