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Evaluation of Ulchin 1&2 Containment Performance Against Severe Accident Challenges

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1. Introduction

In preparing plant-specific severe accident management guidances (SAMGs), it is important to investigate whether the containment integrity could be maintained under the conditions of high pressure and temperature after the reactor core was damaged. It is required to analyze how much high they will rise under a spectrum of accident scenarios and then to determine what a kind of strategy or action would be appropriate and to identify whether it is effective or not compared to the containment capability. Of course, all these results are included in the technical basis reports for plant-specific SAMGs.

Especially, during the licensing review process on the SAMGs for preceding operating plants, it was issued that the effectiveness of accident management strategies on the containment for accident sequences of interest and the assessment of positive and negative effects following the strategy action should be identified. It was also issued that the hydrogen control method for the plants which do not have hydrogen control measures should be presented.

The purpose of this study is to evaluate the Ulchin 1&2 containment performance against severe accident challenges in terms of pressure and hydrogen control. Since the design characteristics and SAMG organizations of Ulchin 1&2 are similar to those of preceding Westinghouse-like plants, the general approach[1] used to preceding plant evaluations is also applied. Major dominant sequences were selected and thermal-hydrodynamic analyses using MAAP4 code[2] were performed.

2. Evaluation Method

In order to evaluate the containment performance, five dominant accident sequences has been selected and the MAAP4 calculations were performed for those sequences.

2.1 Choice of the Accident Sequences

Level 1 and 2 Probabilistic Safety Assessment (PSA) results[3] were used to select accident sequences and, as a result, the five most probable sequences were selected with respect to plant damage state(PDS), as shown in Table 1. All of them represent typically high-pressure sequences. These five sequences occupy 52.28% and 78.3% of total core damage frequency(CDF) with respect to individual accident sequences and PDSs, respectively.

Table 1. Dominant Accident Sequences of Ulchin 1&2

No.	Sequence (PDS)	Frequency (/yr)	PDS Fraction (%)	Sequence Fraction (%)
1	SBO_S26 (PDS 3)	1.24E-06	25.9	15.31
2	TLOOP_S47 (PDS 6)	1.06E-06	275	13.17
3	SBO_S32 (PDS 5)	8.04E-07	10.8	10.00
4	SBO_S100 (PDS 9)	7.50E-07	9.6	9.33
5	LOHS_S9 (PDS 12)	3.56E-07	4.5	4.47
Total		4.21E-06	78.3	52.28

2.2 Hydrodynamic Calculation

The MAAP4 code calculations were performed for selected sequences. Referring to as MAAP4 parameter file, Reference 3 was utilized as plant model. Figure 1 presents the lumped-parameter nodalization for Ulchin 1&2 containment.

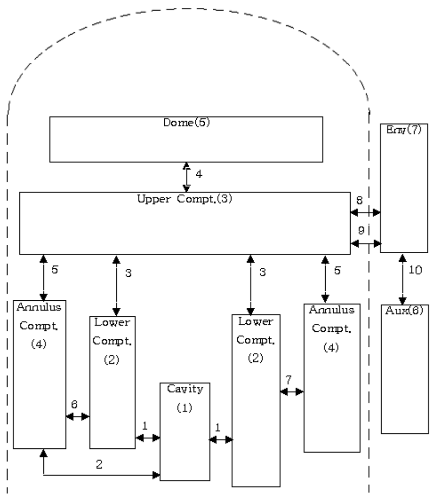

Figure 1. Containment Modeling in MAAP4

Table 2 presents the calculation results, which shows occurrence timings of major events during core melt progression. Generally, if the SG secondary side was available, the core damage occurred later from the accident initiation.

Table 2. The Occurrence Timing for the events

Event	SBO _S26	TLOOP _S47	SBO _S32	SBO _S100	LOHS _S9
Core Uncovery	36,671	73,578	36,671	23,727	12,557
Max. Core Temp. exceeds 1,200 ℉	38,690	76,180	38,690	26,750	14,840
Corium Relocation into Lower Head	47,076	N/A	47,076	33,134	20,536
Reactor Vessel Failure	47,952	N/A	47,950	N/A	24,352

3. Analysis Results

3.1 Peak Pressure Analysis

The peak pressure analysis was performed to identify the possibility of containment failure due to overpressure. Comparing it with the target value of SAMG strategy criteria, we can get the insight whether the containment would undergo pressure the higher than it could stand up to. In this study, the controllable target pressure of SAMG strategy is 0.71 MPa according to Ulchin 1&2 PSA result[3], which corresponds to the containment failure probability of 5% from plant-specific containment fragility curve.

In general, the containment pressure would increase, if the containment heat removal function is failed. Among the analyzed sequences, LOHS_S9 sequence showed the highest containment pressure and its maximum pressure reaches almost 0.54MPa at 24 hour after accident initiation, as shown Figure 2. Since this peak value was lower than the containment performance criteria, it could be concluded that the containment integrity would be maintained against almost all of the sequences. In addition, it seems from the same reasons that the containment venting strategy needs not be applied for Ulchin 1&2 plant, unless the primary and ultimate functions of safety class containment heat removal remain to be failed during long time of accident progression.

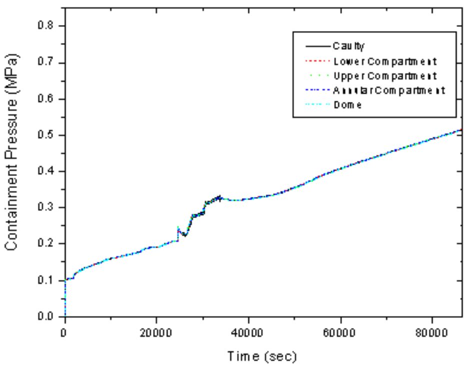

Figure 2. Containment Pressures in LOHS_S9 Sequence

3.2 Hydrogen Behavior Analysis

For design basis accident(DBA), Ulchin 1&2 plant has Combustible Gas Control System, which is composed of hydrogen recombiner, hydrogen monitoring system and post accident hydrogen venting system. In the severe accident, there would exist the circumstance of hydrogen concentration higher than 5% may occur and those subsystems may not cope with it. Therefore, it is very important to evaluate the containment risks related the severe accident hydrogen behavior, and to clarify the options of the hydrogen control strategy under the situation on which dedicated hydrogen control system is not equipped against the severe accident challenges. The purpose of this task is to prepare the information about the hydrogen behavior specified for Ulchin 1&2.

Table 3 presents the consequences on hydrogen generation and concentration for five accident sequences. Two sequences, SBO_26 and SBO_32 show high long-term hydrogen concentration, which exceeds 10 CFR 50.34 requirements of 10%. This is resulted from relative characteristics between free volume containment and amount of zircaloy cladding.

Table 3. Hydrogen Behavior Analysis Results

Event	SBO _S26	TLOO P_S47	SBO _S32	SBO _S100	LOHS _S9
Hydrogen Generation(kg)					
In-Core	496	534	496	405	380
Ex-Core	31	0.0	63	0.0	430
Long-term H_2 (vol%)					
Cavity compartment	12.1	4.6	12.7	8.3	5.9
SG compartment	11.9	4.2	12.5	7.8	5.5
Upper compartment	12.1	3.6	12.7	8.4	5.5
Annular compartment	12.1	4.6	12.7	8.3	5.4
Dome	12.2	3.5	12.8	8.6	5.5

4. Conclusion

In this study, the containment pressure and hydrogen distribution analyses were performed for selected accident sequences using MAAP4 code in order to support plant-specific SAMG development. The peak pressures were the lower than containment performance criteria so that Ulchin 1&2 containment integrity would be maintained for almost all accident sequences. For hydrogen behavior within the containment, long-term hydrogen concentrations were found to exceed 10 vol %, which requires specialized hydrogen control strategy in the course of SAMG development.

REFERENCES

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[3] Probabilistic Safety Assessment for Ulchin Units 1&2, KHNP, 2005, 12.