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Containment Performance Analysis with Large Break LOCA for EU-APR1400

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1. Introduction

During a severe accident, as the last barrier of Defense-In-Depth strategy, the containment has an important role to limit the release of the radioactive material to environment. The containment should be able to maintain its structural integrity to prevent the release of the radioactive materials contained in it.

Regarding severe accident requirement, EUR [1] required that the containment system shall be designed in such a way it can withstand any of the severe accident considered in Design Extension Condition (DEC), without operator action during 12 hours from the beginning of the sever accident condition.

In this paper for containment performance analysis, the containment pressurization analysis is performed and thermo-hydraulic response analysis of containment structure is carried out to provide basic understanding of containment transient states under a severe accident sequence. Especially, in EU-APR1400 design, to reduce containment pressure and temperature, Severe Accident Containment Spray System (SACSS) is designed to be actuated automatically when Core Exit Temperature (CET) reaches 922 K (649 ℃).

2. Containment Performance Analysis

2.1 Analysis Approach

The objective of the Containment Performance analysis is to ensure that containment system can withstand any of severe accident without operator action during the first 12 hours from the beginning of the severe accident condition and that system, which is designed to remove decay heat from the containment during accident, can reduce containment pressure and temperature and keep them at a sufficiently low level.

In order to evaluate the containment performance, each of dominant sequences is analyzed to determine if it will lead to containment failure and the nature of its associated release is identified. The mode and timing of the containment failure and the nature of the releases are affected by the physical phenomena occurring inside the reactor vessel and inside containment during the progression of the accident. These phenomena, called parameters, are based on analyses of radionuclide release and transport, physical processes inside containment and off-site consequences. Each combination of consequence parameters defines a specific event sequence with unique consequences.

There is a relationship between the consequence parameters and plant system conditions. Thus, the core damage sequences, when coupled with the status of the containment safeguards systems, can be related to the plant damage.

Containment over-pressurization can be induced by hydrogen burns, rapid steam generation, direct containment heating, or a gradual buildup of steam and/or non-condensable gases.

It has also been postulated that the rapid generation of large amounts of steam could lead to the over-pressurization of containment. Core damage sequences initiated by LOCAs produce large amounts of steam inside containment prior to vessel failure. If, on vessel failure, the corium reacts with cooling water in the cavity, additional steam will be generated. Under proper conditions, the steam may be generated rapidly enough to cause a rapid over-pressurization of containment. The operation of the containment spray system would help condense the steam and thus reduce the potential for containment over-pressurization

2.2 Parameters affecting Steam Over-Pressurization

Steam over-pressurization of the containment is influenced by the debris to produce steam and the capability of the containment active systems to condense steam.

The contribution of non-condensable gases to containment failure is a function of the degree of core concrete attack, the distribution of corium within the containment, and the constituents of the basemat and structural concrete.

In EU-APR1400 a core-concrete attack phenomenon which affects the containment performance is significantly eliminated by means of Passive Ex-Vessel corium retaining and Cooling System (PECS). The only source of core-concrete interaction is corium interaction with Sacrificial Material (SM) in PECS. However, SM composition was determined to achieve several purposes and one of them is to reduce the release of hydrogen and non-condensable gases into the atmosphere during the accident, it is expected that the containment would not be affected largely by core-concrete attack.

The gas evolution due to corium-concrete interaction is directly related to the amount of corium in contact and/or close proximity to the core debris. Concrete not in close contact with the corium debris will not be heated to sufficiently high levels to start the dehydration process or begin the de-carboxylation process.

2.2 Selection of Severe Accident Scenario

This section provides a quantitative description of the containment performance for a selected severe accident sequence. Analysis is carried out to quantify the transient plant response and determine the containment performance characteristics for the sequence. As for the selection of accident sequence in terms of the containment performance during severe accident, the severity of the phenomenon is taken into account based on the core damage frequency which is obtained from the results of PSA Level I for APR1400 [2]. As a result of accident scenario selection, Large Break LOCA is selected in the containment performance as it makes reactor core meltdown earliest and corium with biggest decay heat drops down to the cavity.

2.3 Analysis Tool

The Modular Accident Analysis Program (MAAP) 4.07 code [3] is used for this analysis. MAAP code is a computer code which simulates light water reactor system and containment performance for severe accident events.

2.4 Thermal Hydraulic Analysis for LB LOCA Accident

Thermal hydraulic responses on two cases in terms of the containment performance are analyzed; the first case is that SACSS is not actuated and the second case is that SACSS is actuated. In the latter, SACSS is actuated when CET reaches 922 K.

2.5 Result of Containment Pressure in LBLOCA

After initiation of the accident, the containment pressure increase due to release steam from RCS. The core uncovery starts at 215.4 sec. and reactor fails at 7201.1 sec. by instrumentation tube ejection in lower head. If SACSS is not actuated, the containment pressure increases continuously and then reaches at the instance when the containment cannot withstand anymore. Dot line in Fig.1 shows the case that SACSS is not actuated. If SACSS is actuated at 1800.5 sec., the relative cold water injected into the containment remove the heat of the containment atmosphere and then reduces the pressure to a sufficient low level. Solid line in Fig.1shows that SACSS is actuated.

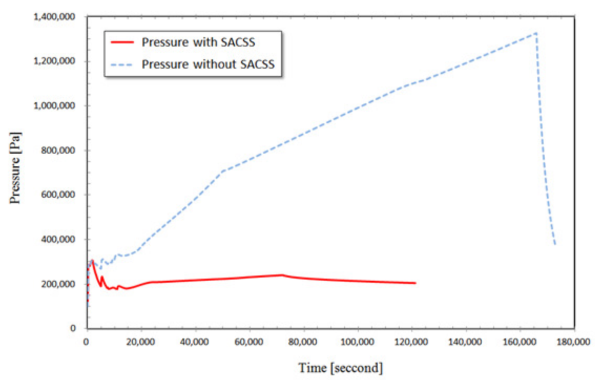

Fig.1 Containment Pressure in LBLOCA

2.6 Result of Containment Temperature in LBLOCA

Regarding temperature in containment, after initiation of the accident, the containment temperature increase due to released steam from RCS. If SACSS is actuated at 1800.5 sec., temperature decreases to 370 K.

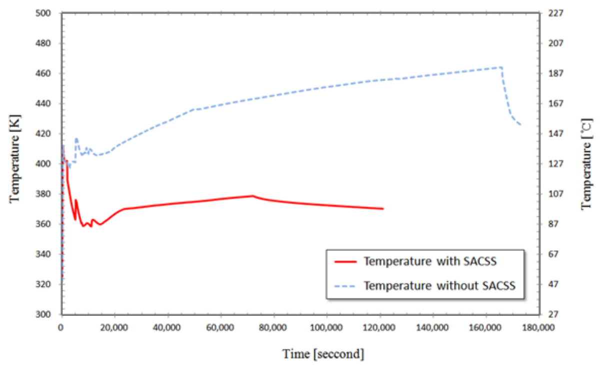

Fig.2 Containment Pressure in LBLOCA

3. Conclusions

The containment performance analysis was carried on LBLOCA sequence for EU-APR1400 with SACSS through MAAP code. If SACSS is actuated when CET reaches 922 K (649 ℃), the containment pressure and temperature decrease to a sufficient low level.

The predicted atmospheric pressure of containment will not exceed the ultimate pressure capacity (UPC) and have a sufficient margin to it even though the UPC of the reference plant (Shin-Kori Units 3&4) is used instead because the UPC calculation for EU-APR1400 has not been completed.

The largest load on the containment by LBLOCA is estimated at 306.1 kPa. Thus the margin to UPC is estimated to be 330 % in comparison with 1.329 MPa as UPC for the reference plant.

Acknowledgement

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