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Severe accident environment simulation system to evaluate the equipment survivability

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1. Introduction

IAEA report [1] represents that severe accident is acknowledged as an event with an extremely low probability of occurrence and it was somewhat overlooked. However, the importance of severe accident has been realized due to the three mile island (TMI) and Fukushima accident. The severe accident causes significant damage to the reactor core. After the accidents in TMI and Fukushima, not only design basis accident (DBA) but also beyond design basis accident (BDBA) and severe accident caused by natural disaster such as earthquake are considered more important from the safety point of view.

To reflect the real accidental situation, many regulations of equipment survivability (ES) are enacted and revised. According to 10CFR50.34(f) [2], the equipment which is necessary for maintaining containment integrity should perform its function in environmental conditions of severe accident with hydrogen generated by the equivalent of 100% clad-water reaction. And the mitigation equipment must be designed to operate in the severe accident environment over the time span for which they are needed. ES should be ensured in accidental events (earthquake, blackout, etc.) and environment of severe accident (pressure, temperature, radiation) according to SECY-90-016 and SECY-93-087 [3, 4].

Severe accident management guideline is prepared based on ES assessment. However, the regulatory requirement on ES assessment describes that the equipment and instrument, which are selected for managing the severe accident, should be alive. However, that requirement does not suggest the ways to evaluate the ES.

Environmental factor of severe accident (temperature, pressure, radiation, etc.) can cause damage to essential equipment. The severe accident could cause hydrogen generation due to cladding-water reaction. And the concentrated hydrogen in containment could combust and could cause significant increment of temperature. But, test equipment for empirical ES assessment is difficult to be prepared because the technology to simulated harsh environment during severe accident is difficult to be achieved. The test equipment that can simulate severe accident environment is essential to evaluate the ES through the type test [5].

Therefore, in this study, equipment for ES assessment was developed and the performance of equipment was verified. By verification test, the test equipment was confirmed to make the temperature profile of severe accident properly for assessment of ES.

2. Experimental

The temperature profile for assessment of ES can be divided into three state following the time step of severe accident as shown in fig 1. In initial state, from initiation of accident to 10 seconds, the temperature is rapidly increased. Explosive increase of temperature is occurred in this state due to hydrogen combustion. Next state is transient state, which is from 10 seconds to 600 seconds. In the steady state, from 600 seconds to 24 hours, temperature is maintained at 460 K due to decay heat of radioactive materials.

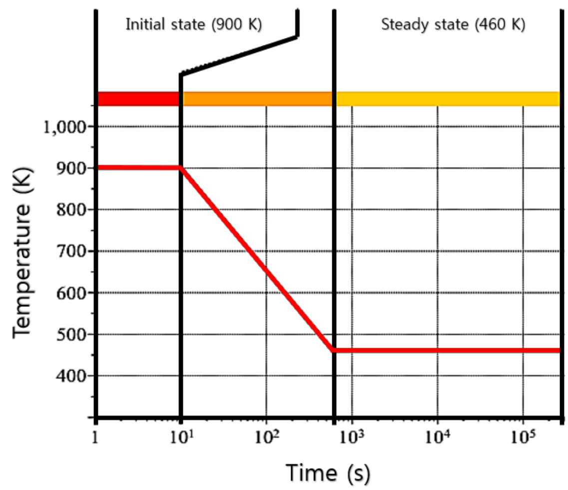

Fig. 1 Temperature profile of severe accident for ES [6]

KIMM has develop an equipment which can simulate the temperature profile of severe accident for the assessment of ES, which is called KIMM-SAES (KIMM-Severe Accident environment simulation system for evaluation of ES). The equipment consists of furnace and actuator. It is hard to simulate the sharp initial temperature profile right after the severe accident started because of hydrogen burn. To simulate this profile, peak temperature was generated by furnace and rapid profile was generated by thermal gradient of the tube furnace by moving the specimen from center of furnace (heat zone) to relatively lower temperature section.

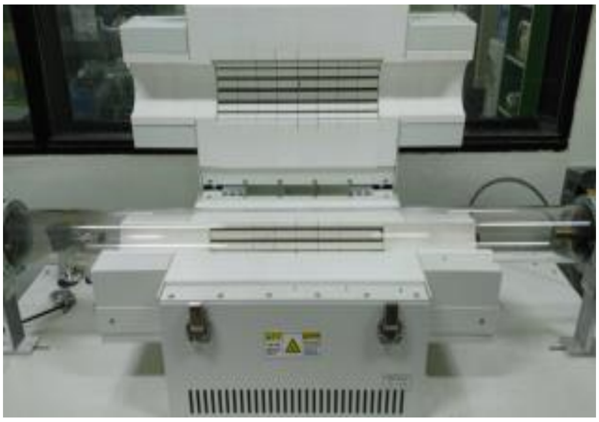

Fig. 2 Severe accident environment simulation equipment for ES evaluation (KIMM-SAES)

3. Results and Discussion

To evaluate the performance of test equipment to simulate temperature profile of severe accident, the performance test was conducted. Total 14 points in the furnace were measured with 5 cm interval between each point, from center to 65 cm. The temperature of center and 5 cm region were maintained constant temperature of 900 K. The temperature was decreased to 460 K at the 60cm region from the center.

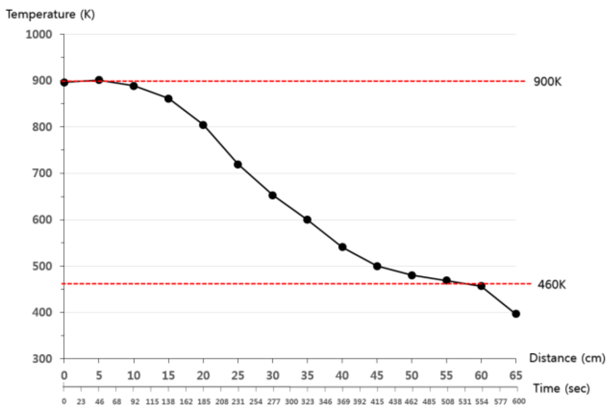

Fig. 3 Result of performance verification test of KIMM-SAES

As the result of the test, in comparison with temperature profile of severe accident as shown in fig 1, section from the center of the furnace to 5 cm, 5 ~ 60 cm can be matched to initial state and transient state, respectively. By placing the specimen 60 cm from the center of the furnace, it is possible to simulate the temperature profile in a steady state where the temperature of 460 K was kept constant.

4. Conclusions

To evaluate the ES in severe accident environment, the equipment should simulate the environment of severe accident. To do this, KIMM developed the equipment for ES assessment. And, performance test was conducted.

According to the result of the performance test, temperature profile of severe accident for ES assessment was successfully simulated by using the developed equipment, as shown in temperature profile in fig 3. It seems that the ES assessment test can be performed by using this equipment. For example, operating environment and temperature profile of emergency reactor depressurization valve (ERDV) during the severe accident is similar to that of fig 2, and it should be simulated to conduct ES assessment of the ERDV.

5. Future work

Due to size of the tube furnace and manual operating concept of actuator, the equipment has several improvement issues. Specimen which are smaller than furnace can be tested by using the developed equipment in this study. To compensate this problem, IR-lamp and motor-operated actuator system will be installed to achieve more rapid thermal gradient. Such equipment improvements will improve equipment reliability.

Using the equipment for ES assessment, verification test for thermal lag analysis will be conducted.

Acknowledgment

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