Core/Reactor Vessel Damage Measurement Strategies during Severe Accidents in NPP

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1. Introduction

Since the Fukushima accidents in Japan, worldwide nuclear societies have been particularly concerned about the reliability of instruments during severe accidents (SA) [1]. Recent studies reveal that the chance of survival of instruments located in containment is very low under the severe accident circumstance [2]. In addition, there is no instruments for measurement of integrity of reactor core and reactor pressure vessel during severe accidents.

This study suggests the alternative measurement methodologies in order to monitor the core/reactor vessel damage according to the severe accident propagation

2. Measurement Methodology

According to IAEA and TEPCO reports, one of the main reasons of the Fukushima accident why the accident could not be mitigated immediately is no reactor monitoring method due to harsh environments in terms of high temperature, high radiation and no electricity.

In order to overcome these ultimate conditions, alternative measurement systems to sustain high radiation and temperature that would be mounted next to a reactor. We suggest the alternative measurement systems including an ex-vessel temperature detecting array system (EVTDAS) and a high resolution radiation detecting array system (HRRDAS).

Figure 1 shows the conceptual diagram of the core/reactor damage monitoring systems.

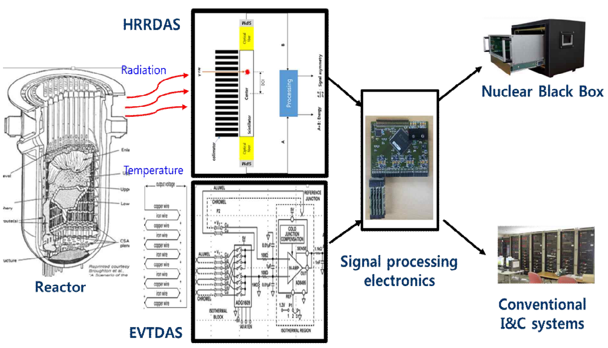

Fig. 1 Conceptual diagram for the core/reactor damage monitoring system

The function of the EVTDAS is to indirectly monitor the severe accident entry condition, core melting, corium relocation and reactor vessel failure. The temperature detectors of the EVTDAS are installed on the ex-vessel having array structure with radial and axial direction sensing elements. Each sensing element measure the ex-vessel temperature of specified point. The function of the HRRDAS is to indirectly monitor the core coolant, core melting, corium relocation and reactor vessel failure. The radiation detectors of the EVTDAS are vertically installed near the reactor vessel.

Signal processing electronics gathers each signal, makes the temperature and radiation profile of ex-vessel, and determine the core/reactor vessel status.

3. Feasibility Study

3.1 Ex-vessel Temperature Analysis

The relationship between core temperature and ex-vessel temperature was analyzed under the severe accident scenarios initiated by two events; station black out (SBO) and small break loss of coolant accident (SBLOCA), using MELCOR Code. Seven point ex-vessel temperatures are evaluated; three axial points and four radial points.

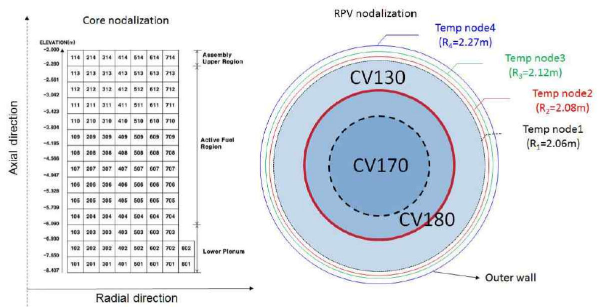

Fig. 2 Core and reactor vessel Nodalization

To evaluate the temperature propagation effect from core to ex-vessel, the reactor vessel modeling was performed (See Fig. 3).

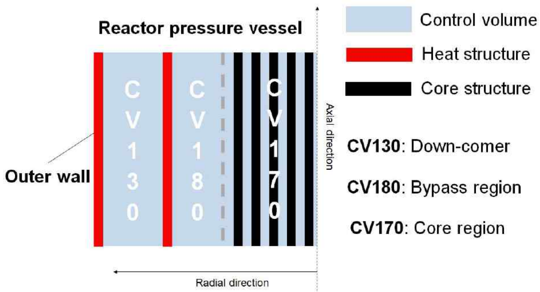

Fig. 3 Reactor Vessel Modeling

Fig. 4 show the temperature behaviors of peak cladding temperature (PCT), core exit temperature (CET), hot leg temperature (HLT) and ex-vessel temperature during SBO initiated event.

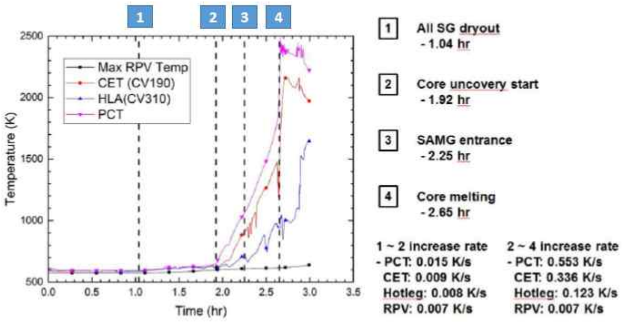

Fig. 4 Temperature behaviors during SBO initiated severe accident

Fig. 5 shows the enlarged temperature behaviors of three axial ex-vessel points. After SAMGs entrance, ex-vessel temperatures of each point show the meaningful changes.

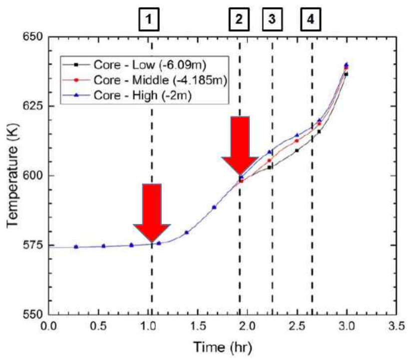

Fig. 5 Temperature behaviors of each axial ex-vessel point during SBO initiated severe accident

3.2 Ex-vessel Radiation Analysis

The ex-vessel radiation behavior was analyzed to investigate the gamma ray change of radial direction due to the coolant and corium status using MCNP Code. Fig. 6 and 7 show the core/reactor vessel radiation shielding modeling in this study.

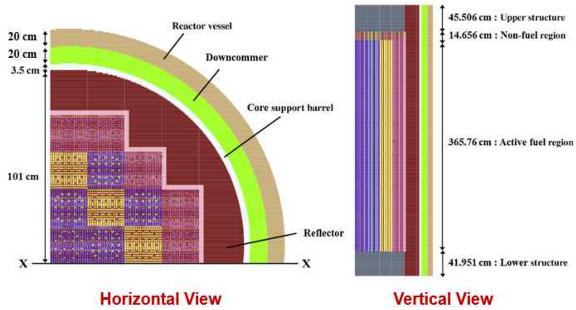

Fig. 6 Core/reactor vessel shielding modeling

Fig. 7 show the photon flux behavior due to the change of core coolant level. It is noted that there is big radiation change depending on the coolant level.

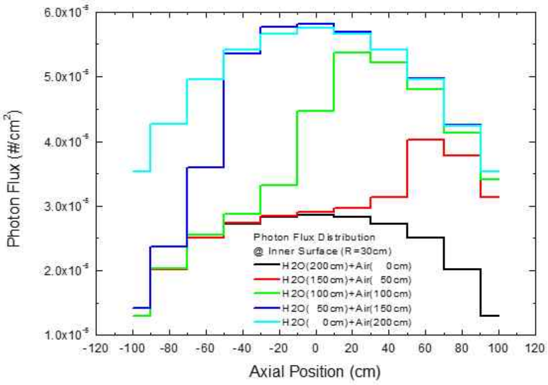

Fig. 7 The photon flux behavior depending on core coolant level

4. Conclusion

The new alternative reactor monitoring under the severe accident circumstance is suggested. As the feasibility study, ex-vessel temperature is changed by core condition, and gamma energy from the core is also changed depending on the core coolant status and corium relocation. It, therefore, is feasible to develop the suggested alternative system.

Acknowledgement

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REFERENCES

[1] "Recommendations for Enhancing Reactor Safety in the 21st Century, The near-term task force review of insights from the Fukushima Dai-ichi Accident", July, 2011

[2] IAEA, Accident Monitoring Systems for NPPs, IAEA Nuclear Energy Series No NP-T-3.16, 2015.