Priority Subjects with Limited Terms — **Establishment of Optimal Risk Management**

Safety Assessment of LWR Systems

Background and Objective

In order to enhance the safety of nuclear power plants, it is necessary to reveal theirvulnerabilities through quantitative risk assessment and simulations using an analysis model which reproduces phenomena in as much detail as possible. It is also necessary to add and modify equipment which is effective in improving safety. To this end, we aim to sophisticate the evaluation system applied to improve safety measures, and develop a quantitative evaluation of the effectiveness of these measures.

Main results

1 Evaluation on characteristics of severe accident analysis codes

In order to investigate the differences in characteristics of MAAP5.01[*1] and MELCOR2.1[*2], severe accident (SA) analyses for a TBU[*3] sequence in a representative BWR plant were conducted for both these codes. The hydrodynamic responses inside a reactor pressure vessel (RPV) at an early phase (until the onset of fuel relocation) were relatively consistent. However, significant differences were observed in the onset timing of the major physical phenomena after the core support plate failure (Fig. 1). When direct containment heating (DCH) is considered to occur, the primary containment vessel (PCV) fails just after the RPV failure (Fig. 1). In this case, concrete ablation in the pedestal cannot be observed and hydrogen generation due to molten core – concrete interaction (MCCI) significantly decreases (Fig. 2)(L13006).

2 Development of BWR building hydrogen / vapor behavior evaluation method

Behavior of hydrogen, which flows into a reactor building through a reactor containment in an SA, was analyzed using a three-dimensional computational fluid dynamics (CFD) code. The lumped parameter (LP) model, which was developed to predict CFD calculation results, was expanded so as to also cover counter current flow through side openings such as blow-out panels (Fig. 3). The CFD calculations and LP evaluations were compared with various conditions and the results were in good agreement. This implies that the present LP model can save time and computational resources by predicting the results before CFD calculations.

3 Development of measurement technology for sophisticating the evaluation model used during reactivity initiated accidents (RIA)

A Reactivity Initiated Accident (RIA) is an event in which the reactor power increases rapidly and surface of a cladding tube dries up in less than 1 second. During an RIA, it is important to accurately evaluate the behavior of boiling bubble and fuel temperature from the perspective of considering reactivity feedback[*4]. In this study, a technology was developed to enable measurement of void fraction and transient temperature in a direct heating system which simulates RIA. A wire mesh sensor covered with insulating material and a thermocouple which a balance circuit were constructed, and it has become possible to measure two-phase flow with high temporal and spatial resolution (Fig. 4).

4 Development of level 1 PRA model for common cause failures due to external events

Based on the level 1 PRA model (probabilistic risk assessment model for the evaluation of core damage frequency) of the typical BWR plant for internal and seismic events developed in 2012, a prototype PRA model for additional effects of tsunami hazardswas developed. Additionally, for the development of fragility data to input in this model, tsunami fragilities[*5] of watertight doors and sea water pumps were studied and issues for investigation were identified for the methodology to link tsunami fragilities to tsunami hazards.

*1 MAAP: Severe accident analysis code under development by EPRI (U.S.). Mainly used by the electric utility side.
*2 MELCOR: Severe accident analysis code under development by U.S.NRC. Mainly used by regulatory bodies in Japan.
*3 Station blackout with no emergency power supply and no recovery of short and longterm A/C power
*4 The effect of suppressing reactor power corresponding to fuel temperature elevation at the occurrence of a reactivity initiated accident (RIA).
*5 Tsunami fragility: Conditional probability of loss of function of components in the event of a tsunami of a certain magnitude
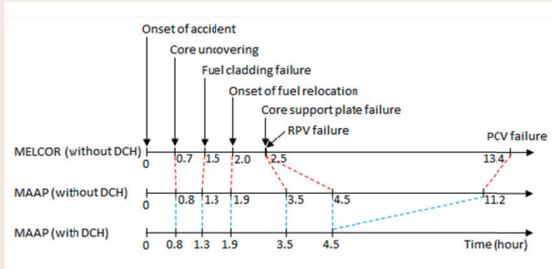
Fig. 1: Comparison of chronology in a TBU sequence

Significant differences are observed in the onset timing of the major physical phenomena after the core support plate failure between analytical results of MAAP and MELCOR. When the DCH is considered to occur in the TBU sequence, the PCV fails just after the RPV failure.
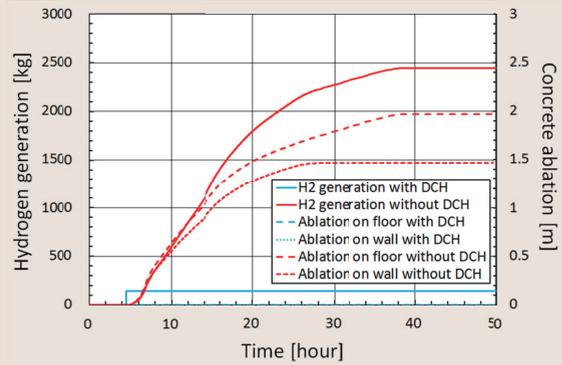
Fig. 2: Effect of DCH on hydrogen generation and concrete ablation in the pedestal in a TBU sequence

In the case of a TBU sequence, pressure in the RCS at the time of a RPV failure remains high. Hence, high temperature molten debris is discharged from the RPV to PCV with pressurized steam. This leads to the occurrence of DCH and results in the generation of thermal and mechanical loads to the PCV. When the DCH is considered to occur, most of the molten debris is discharged to the drywell from the pedestal. Consequently, concrete ablation in the pedestal cannot be observed and hydrogen generation due to MCCI significantly decreases. However, when the DCH is not considered, all of the molten debris remains in the pedestal, resulting in the occurrence of large scale MCCI.
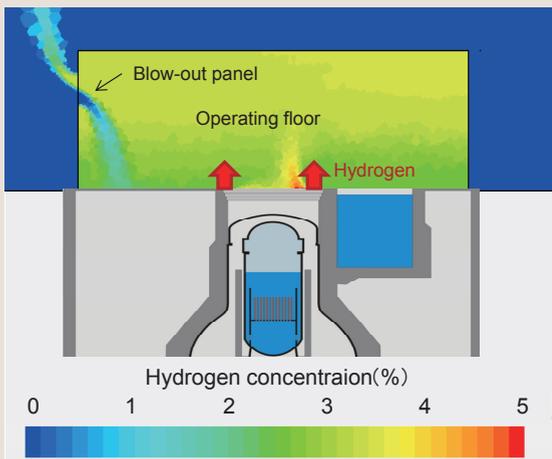
Fig. 3: Hydrogen behavior analysis in a reactor building

Behavior of hydrogen, which flows into the reactor building from the reactor containment in a severe accident, was calculated using a three-dimensional computational fluid dynamics (CFD) code. The lumped parameter model was expanded to cover the counter-current flow (upper figure), in which the gas is emitted through the upper half of a blow-out panel and enters from the lower half.
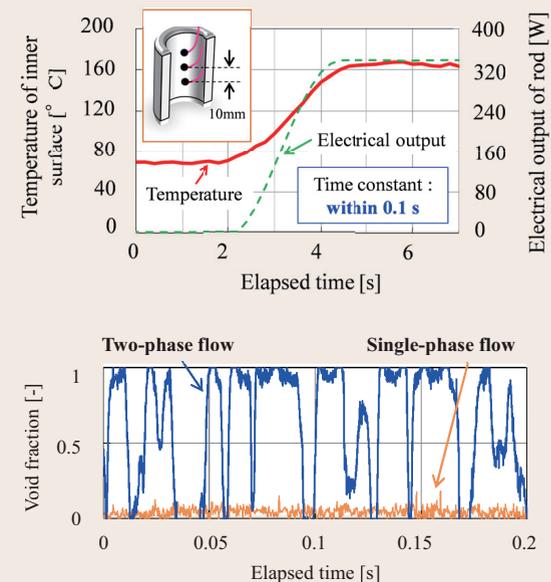
Fig. 4: Development of an RIA measurement method

A technology enabling measurement of void fraction and transient temperature in direct heating system which simulates RIA was developed. A wire mesh sensor covered with insulating material and a thermocouple which has balance circuit were constructed, and it has become possible to measure two-phase flow with a high degree of accuracy.