1-16 Estimation of the Failure Time and Location of the Pressure Vessel Lower Head in Severe Accidents
— Development of Failure Evaluation Methods for the Pressure Vessel Lower Head —
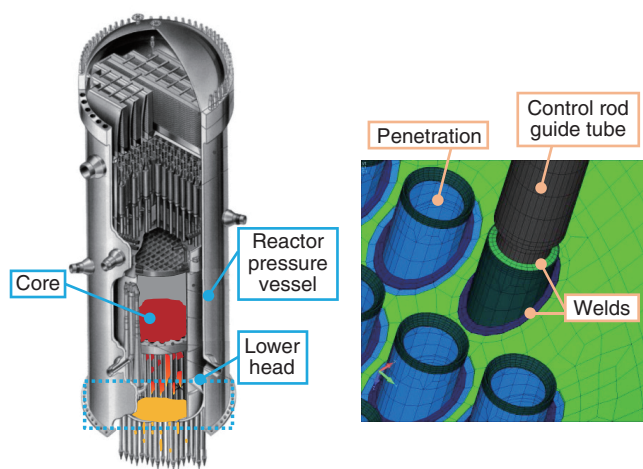

Fig.1-37 Analysis model of RPV lower head
The RPV lower head of a BWR, similar to 1F, has a complicated geometry since there are many penetrations and welds for connecting the control rod guide tubes. It is expected that failure location and time of the lower head after relocation of molten fuel are affected by this complicated geometry. We have developed a 3D model that includes these welds to assess the rupture behavior of the lower head during the accident in detail.

Fig.1-38 An example of the temperature distribution
This figure illustrates an example of temperature distribution obtained from thermal-hydraulic analyses with a detailed 3D model. The yellow region in the top left figure corresponds to relocated molten fuel and materials. Through this region is heated up, the temperatures of the materials comprising the RPV lower head are also raised, resulting in creep deformation of the lower head.

To gain better awareness of the situation within the reactor pressure vessel (RPV) of the TEPCO's Fukushima Daiichi NPS (1F) and improve the current severe accident (SA) analysis codes, e.g. THALES2 developed by JAEA, we are conducting research and development to assess the rupture behavior of the RPV lower head due to relocation of the molten core. Since simple evaluation methods and models are used for rupture evaluations in the current SA analysis codes, failure time and location obtained from the current codes may include a large uncertainty (scatter). For more accurate evaluations of the rupture behavior of the lower head of boiling water reactors (BWRs) like 1F, it is necessary to develop methods to estimate local failure by considering geometrically complicated structures (Fig.1-37).

In this study, we are developing a coupled analysis method of thermal-hydraulics (TH) and structural analyses, which are to be applied to the behavior of a molten core and to the thermal-elastic-plastic-creep behavior of the structures, r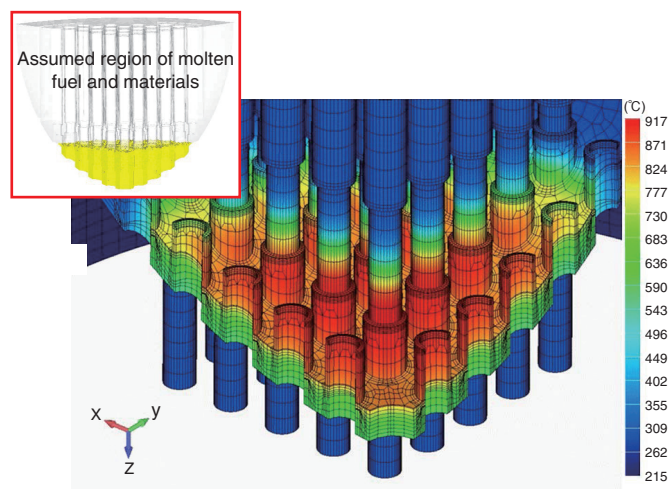espectively. We are also developing methods for evaluating the failure time and locations of the RPV lower head due to creep-deformation.

Fig.1-38 illustrates an example of analysis results obtained by using a three-dimensional (3D) model that considers the penetrations of a BWR (Fig.1-37). As an initial condition, we assumed that 10% of the reactor core has been melted and relocated to the lower head, and that the coolant water in the reactor is completely evaporated. Here, this scenario differs from the accident at 1F. The relocated core is heated by decay heat and the temperature of the lower head also increases. Using the developed failure-evaluation methods considering creep-deformation, we estimated that ruptures would occur at the penetrations because the damage index showed maximal values at those points.

In future, through experiments whose details are described in Topic 1-17, we will improve the failure-evaluation methods and contribute to the estimation of rupture time and the location of RPV in 1F and the improvement of SA analysis codes.

Reference
Katsuyama, J. et al., Development of Failure Evaluation Method for BWR Lower Head in Severe Accident; (3) Creep Damage Evaluation Based on Thermal–Hydraulics and Structural Analyses, Proceedings of 23rd International Conference on Nuclear Engineering (ICONE 23), Chiba, Japan, 2015, ICONE23–1534, 7p., in DVD–ROM.