2-⑥ Development of evaluation methods of seismic performances of RPV and PCV and the impacts of the damages

Project objectives

The seismic resistances of RPV, PCV, and other major plant components shall be evaluated through assessment in consideration of effects of the falling of highly heated fuel debris at the time of the accident, the aging degradation accompanying the corrosion of steel, and the water leak repairs performed, and the facilities added prior to fuel debris retrieval. In addition, the effects in the event of damage shall be predicted, and the measures that may be taken to prevent or mitigate the consequences shall be determined. Furthermore, the effectiveness shall also be verified for the safety scenarios developed on the basis of the proposed prevention/mitigation measures.

1. Project details and progress

The following outcomes have been achieved based on the results of "2. Related projects" below.

(1) Producing the scenarios of safety in the event of a severe earthquake

The facility improvement measures to be implemented were determined, as were the emergency action plans to be made ready before the beginning of fuel debris retrieval to address the consequences of damage to large components that may be induced by a severe earthquake, and safety scenarios were developed (each indicating the flow of a series of actions to be taken to maintain safety functions or to restrict effects from the accident).

(2) Development of approaches to evaluating seismic resistance and determining impacts from damage in the process of producing safety scenarios

① Development of an approach to evaluating the seismic resistance of suppression chamber (S/C) supports and determining impacts from damage

- By performing the elastic time-history response analyses of vent pipes and S/C system coupled model (**Fig. 1**), the seismic resistance of the structure after the injection of sealant into S/C was assessed.
- In addition, elastoplastic analyses (by the double gradient method) were also performed for critical components, such as the column supports, to determine the maximum allowable quantity of sealant that may be injected into S/C.

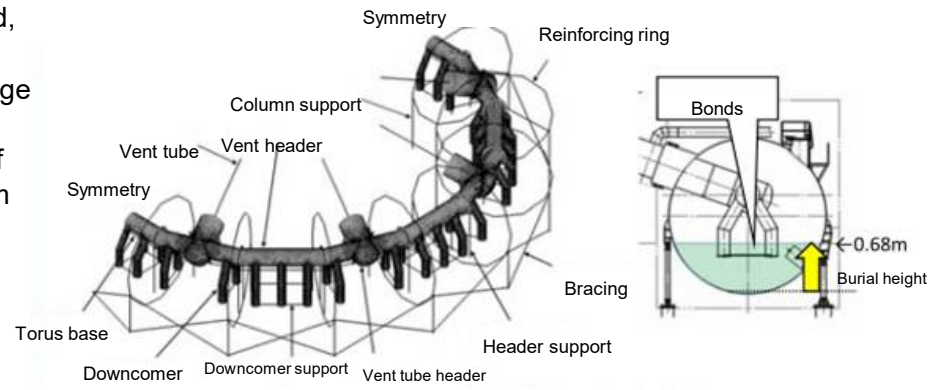


Fig. 1: Vent tube - S/C system coupled analysis model (Unit 1)

② Development of an approach to evaluating the seismic resistance of pedestals and determining impacts from damage

An assessment approach was developed and material data was collected as described below to enable prediction of the distribution of temperature in the pedestal when it was exposed to high temperature and the impact of erosion by fuel debris:

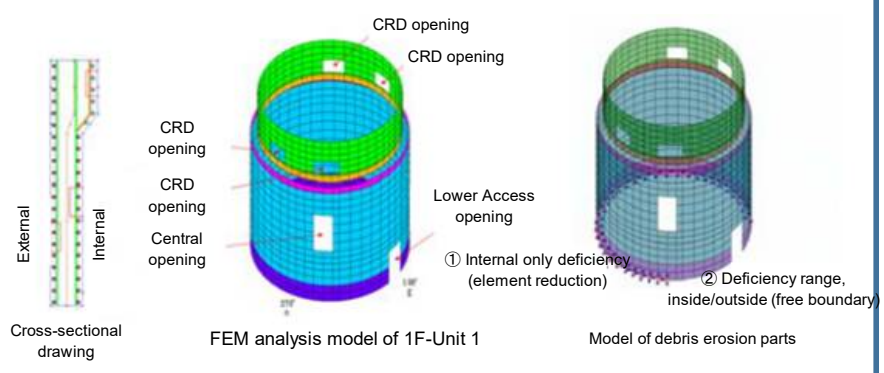


Fig. 2: 3-D FEM elastic-plastic analysis model of RPV pedestal

- Performing elastoplastic analyses by three-dimensional finite element method (FEM) (**Fig. 2**) and evaluating strength and rigidity using a fiber model
- Coupled response analysis method for evaluating how changes in pedestal strength or rigidity may impact the seismic resistance of large components such as PCV and RPV
- Degree of heat-induced corrosion and strength reduction of reinforcement bars that have a history of being exposed to high temperatures

(3) Supporting the advancement of safety scenarios

In order to support the advancement of assessment approaches mentioned above, the approaches to verification by analyses, tests, etc., were reviewed, and detailed analyses and material tests were performed in connection with the following:

- Assessment of S/C supports at Unit 1 by performing elastoplastic time-history response analyses
- Collection of data from PCV material tests performed to determine the effects of the history of being exposed to high temperature at the time of the accident

Implemented by International Research Institute for Nuclear Decommissioning (IRID) (FY 2013 -)

2. Related projects

The following describes the results of previous related projects.

○ Development of evaluation methods for the structural integrity of RPV and PCV (FY 2011 - 2013)

(1) Evaluating the seismic resistance of major plant component such as RPV, PCV, and pedestal

Evaluation was conducted on the seismic margins of major plant components at present and at the time of fuel debris retrieval (considering the impacts of thinning by corrosion, the additional load from the weight of fuel debris retrieval devices, etc.). It was concluded that major parts of the components may retain seismic resistances of a satisfactory level, but some components required more detailed analysis of seismic resistance.

(2) Evaluation of the effects that hot debris may have had as they fell inside the pedestal

A literature search, etc., on the molten core-concrete interactions (MCCI) was used to prepare basic data that would contribute to the prediction of erosion suffered by the pedestal.

○ Development of evaluation methods for the structural integrity of RPV and PCV (FY 2014 - 2015)

(1) Evaluating the feasibility of fuel debris retrieval by the subversion method considering the aseismic integrity of PCV/RPV

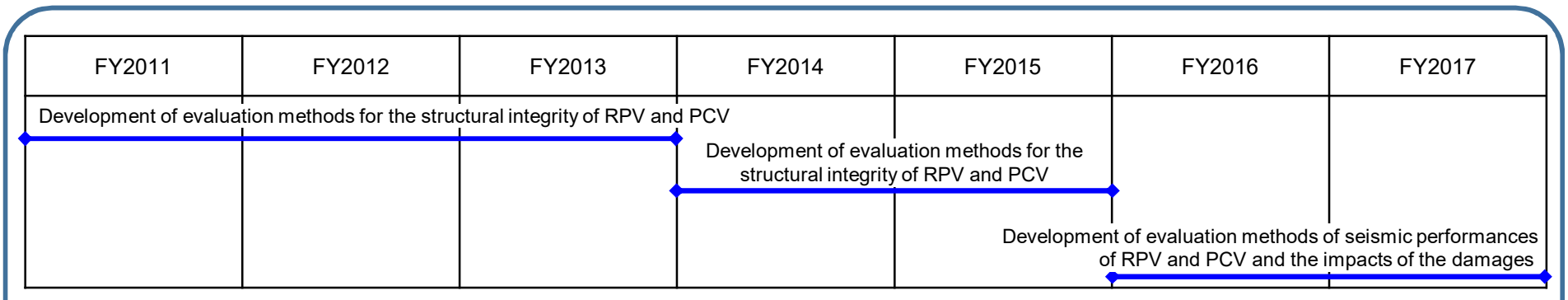
Based on the results of evaluating the seismic resistance of PCV, RPV and other major plant components under plant conditions at the time of fuel debris retrieval, the feasibilities of fuel debris retrievals by the partial submersion method or the full submersion top access method were studied, and detailed evaluation was performed for the seismic resistance of components and parts that demonstrated small seismic margin in the earlier evaluation.

(2) Simplified evaluation of seismic resistance of components in consideration of PCV repairs and water level increase

The parameters (such as the D/W water level) that would impact seismic response analysis were identified or selected, and then seismic response analysis was performed using different assumptions on the parameter values. Based on the results obtained, it was determined how changes in parameter values would impact seismic response, and a simple method of seismic resistance evaluation was developed. Then, the validity of the simple evaluation method was demonstrated by comparing results from the simple evaluation method with results from the method that is normally used, the dynamic analysis method.

(3) Estimating the impacts of erosion suffered by the pedestal

The knowledge required for estimating or discussing pedestal strength in real units was obtained by collecting concrete strength data from the testing of cylindrical specimens, block specimens, and scaled pedestal specimens, etc., that were heated to high temperature and then left in air or in water as well as reinforcement bar corrosion data.


FY2011
FY2012
FY2013
FY2014
FY2015
FY2016
FY2017
Development of evaluation methods for the structural integrity of RPV and PCV
Development of evaluation methods for the structural integrity of RPV and PCV
Development of evaluation methods of seismic performances of RPV and PCV and the impacts of the damages