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Division XI

LARGE-SCALE MODIFICATION WORK OF SUPPRESSION CHAMBER AND INTERNAL STRUCTURES AT ONAGAWA NPP

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ABSTRACT

The suppression chamber and its internal structures, that is a vent system consisted of vent pipe, vent header, and downcomer at Onagawa Nuclear Power Plant Unit 2 of Tohoku Electric Power Co., Inc., were subjected to a significant increase in the acceleration response level applying to the seismic design due to the enforcement of the new regulatory standards in 2013. In order to ensure seismic resistance to the acceleration response level, a large-scale modification work of the components was required in addition to the upgrading of the evaluation method.

The main features of this modification work were followings. First, it was a large-scale modification work that our company or other companies had never done before. Second, the feasibility of the modification was carefully examined by using full-scale mock-up models. Third, the work plan was elaborated in consideration of the specific characteristics of the on-site work environment, and the work was conducted systematically under thorough management in preparation for the plant's restart.

Based on these efforts, the modification work has been completed with the cooperation of the plant manufacturer (Toshiba Energy Systems & Solutions Corporation), who is in charge of the design and work, to complete the work as planned, while paying attention to safety work.

INTRODUCTION

The suppression chamber and its internal structures are installed to provide a water source for depressurization of Primary Containment Vessel and water injection to the reactor in case of an accident. An overview of the components are shown in Figure 1.

Since the components are categorized as seismic class S, the highest in the seismic design classification, they are required to ensure seismic resistance to the design basis ground motion Ss.

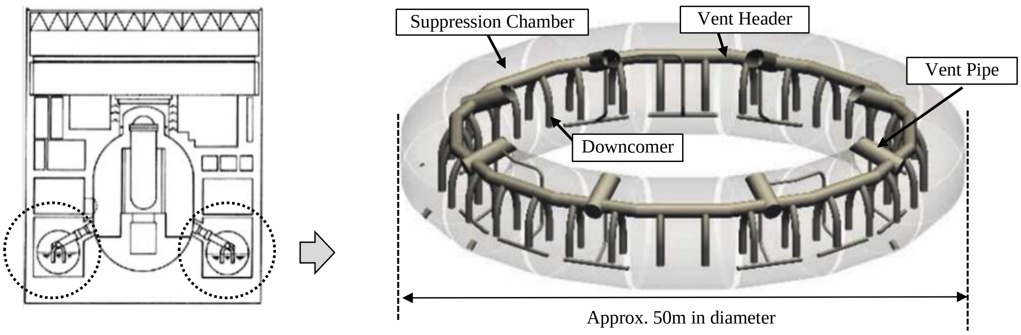

Figure 1: Overall view of the suppression chamber and vent system

SEVERE SEISMIC EVALUATION CONDITIONS

The design basis ground motion Ss of Onagawa NPP was revised as a result of the stricter requirements for natural hazards due to the enforcement of the new regulatory standards in 2013. As a result, the acceleration response level (maximum acceleration of 1,000 gals) applied for the seismic design of the components was significantly higher than that when constructing the plant (maximum response acceleration of 375 gals).

In addition, the external water injection scenario in the event of a severe accident was revised, resulting in an increase the evaluation water level and the overall mass of the suppression chamber, which had a significant impact on its seismic resistance. (See Figure 2).

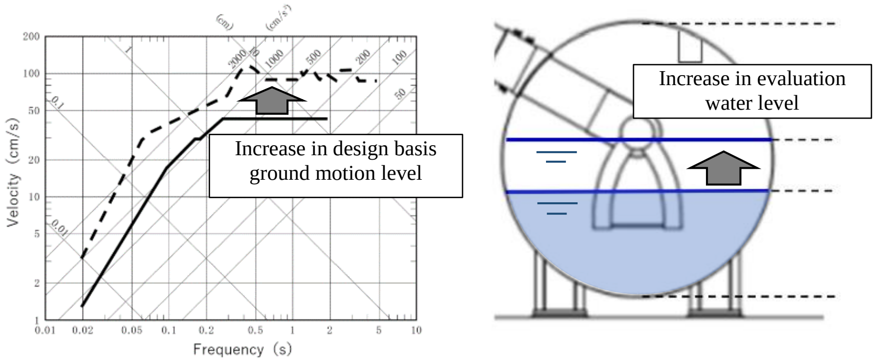

Figure 2: Image of the increase of severity in evaluation.

UPGRADING OF EVALUATION METHODS

In response to significantly stricter conditions for seismic evaluation, such as increase in seismic motion and volume of internal water, the evaluation method has been upgraded to ensure that the seismic resistance is satisfied with these conditions.

Specifically, the internal water had been conservatively treated as a rigid body that behaves together with the vessel and used the total mass of the internal water. However, since the effective mass of the internal water that loaded actually in seismic is only a partial, the seismic load was calculated taking this effect into account.

The effective mass concept is common in seismic design for other industries. However, because the suppression chamber has a particular shape like a doughnut, and for the purpose of accurately figuring out the actual phenomena, a scale model was fabricated and vibration tests were conducted on a shaking table to replicate the effect caused by the oscillation of the water in the suppression chamber. It was verified that the results of the tests generally conform to those obtained by fluid analysis, thus the effective mass by fluid analysis was applied to the actual seismic design. (See Figure 3).

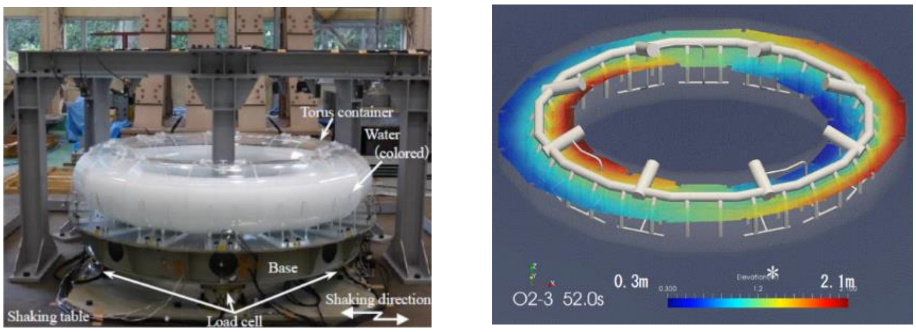

Figure 3: Example of vibration test and flow analysis using a reduced model

LARGE-SCALE MODIFICATION WORK

Outline of modifications

Taking into account the upgrading of the evaluation method described in the previous section, we conducted an evaluation of seismic resistance and, after various studies, came to the conclusion that a large-scale modification for reinforcement was necessary to ensure seismic resistance. Figure 4 shows a schematic diagram of the modification scope.

The modifications include welding with the reinforcing parts such as plates, ribs, and supports to each part of the suppression chamber and vent system. Reinforcing parts were installed in each part to constraint vibration by adding the support points, to suppress deformation by improving the stiffness, and to distribute the load at stress concentrations.

The number of the reinforcing parts to be installed was huge (approximately 4,000), as a result of dividing the parts into sections in consideration of ease of handling and installation. Since all of these parts were to be installed by welding, automatic welding machines were adopted to the full extent possible to reduce the burden on welders and shorten the welding process (see Figure 5). This is the largest scale modification since its plant construction.

The suppression chamber will be the source of water in the event of an accident, and we have confirmed that the addition of these parts will not affect the internal water flow or safety functions.

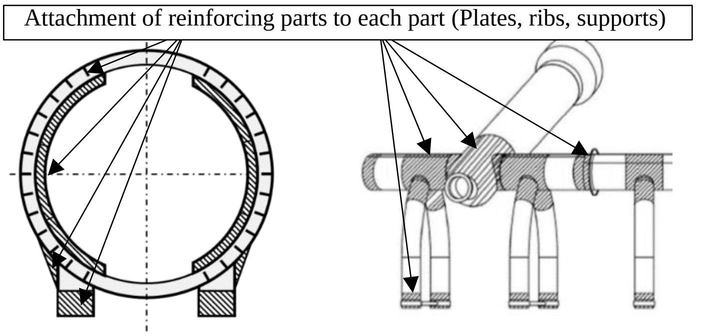

Figure 4: Schematic diagram of the modification scope
(Left: suppression chamber, Right: vent system)

Figure 5: Example of modification work in progress
(Left: suppression chamber, Right: vent system)

Verification of feasibility using mock-up

Although the basic concept of this modification is to add general reinforcing parts such as plates, ribs, and supports, this is a specific project with no past experience in welding significant amounts of steel to significant components in a confined environment as inside the suppression chamber. Therefore, in addition to ensuring accessibility or workability, it is necessary to verify in advance any influences such as welding deformation. In addition, in order to complete the work in a short period of time for the early restart of the plant, it is important to improve the efficiency of the work procedures while taking safety and quality into consideration.

To address these issues, a full-scale steel mock-up was fabricated to verify the feasibility of the modification work from various perspectives before the actual work is carried out on site. The mock-up was fabricated separately for the main body of the suppression chamber and the vent system (see Figure 6), and various types were fabricated, including an elemental specimen for welding that reproduced only part of the component and a full-scale mock-up that replicated the entire component for accessibility or workability. The main items to be checked using the mock-up are listed below.

(1) Workability and feasibility of components
Workability such as the ability of the welding torch to fit into narrow areas, ability to attach parts, and sufficient space for work is checked. In addition, a series of workability checks are conducted, including the shape of the working scaffold, fitting and tack welding method of the reinforcing parts, applicability of the automatic welding machine, and nondestructive inspection. If any problems are found, countermeasures such as modification of procedures, minor structural modification of parts, etc., should be considered.

(2) Influence of fabrication tolerance
In accordance with the range of fabrication tolerances at the time of plant construction, the actual dimensions of the existing components were varied. Due to this, it was assumed that the dimensions of the reinforcing parts would not fit perfectly and they would not be able to be installed accurately by welding. As a countermeasure, the actual components were measured in 3D laser scanner and the reinforcing parts would be accurately machined to the measured shape to fit the existing components perfectly. The feasibility of this method has confirmed in a mock-up test.

(3) Influence of welding
Since many reinforcing parts would be installed by welding, welding deformation was a concern. If this influence became a problem, we had to review the welding procedure and consider a jig to prevent deformation as countermeasures. In addition, the extent to which the heat input from the welding affects the existing coating should be investigated, and the peeling and re-coating should be optimized.

(4) Review of installation procedures
Based on the above test results, a more work-efficient procedure was studied to shorten the on-site work process.

(5) Assessing work time
Based on the above test results, assessing the work time of each procedure required for reinforcing work, and ensure an accurate on-site process.

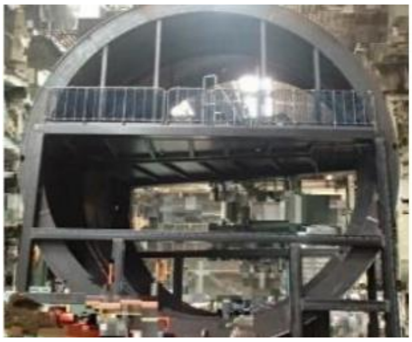


Figure 6: Full-scale mock-up (Left: suppression chamber, Right: vent system)

Working environment

One of the major characteristics of the work environment inside the suppression chamber is that it is a confined space in a radiation controlled area, and the entry inside the suppression chamber is possible only by climbing down two openings (maintenance holes) of approximately 1.5 m in diameter (see

Figure 7). Therefore, it is necessary to plan the work carefully considering sufficient ventilation, securing the traffic lines for workers to carry in reinforcing parts, machines or scaffoldings, and interference with each work area.

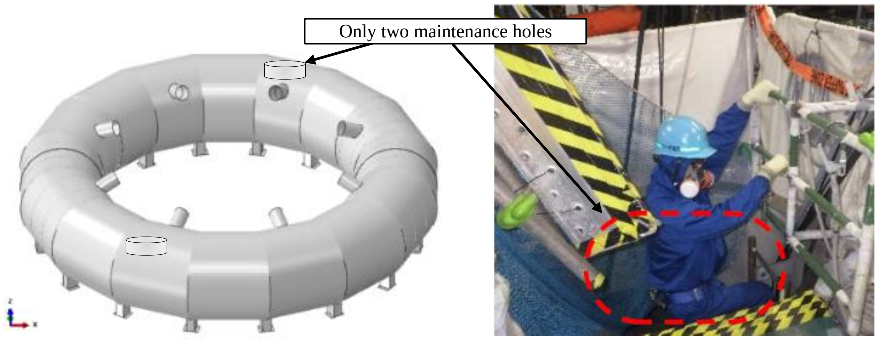

Figure 7: Accessibility to the inside of the suppression chamber

(1) Ventilation

Considering that a large amount of welding, painting, and other work in a confined space, oxygen must be supplied to workers entering the area, a large-capacity ventilation system and safety control are necessary. Figure 8 shows an image of the ventilation system.

Since maintenance holes are used for access for workers and materials, ventilation ducts are laid using vent pipes to the drywell.

Specifically, ventilation ducts are installed in two of the eight vent pipes connected to the suppression chamber (these cannot be used for the access passage because of their narrowness), and temporary fans are used to exhaust air to the drywell. Ventilation fans are also installed in each section of the suppression chamber to circulate internally.

Oxygen meters are placed in each section and constantly monitored to ensure maximum safety.

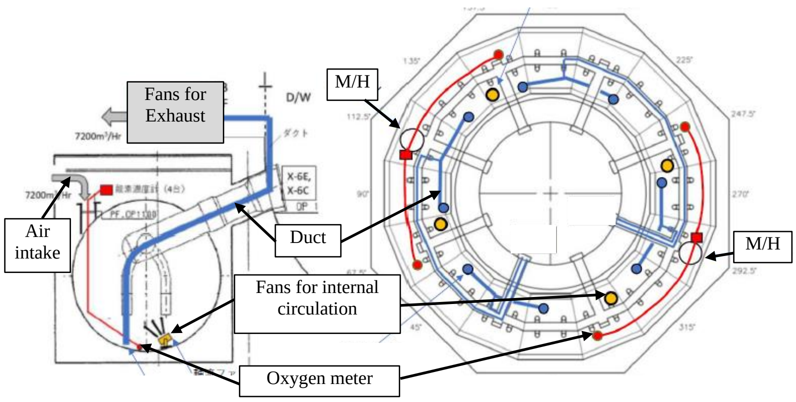

Figure 8: Overview of ventilation system

(2) Area control

The key to implementing large-scale modification work in the suppression chamber in a short period of time must be the precise area coordination. This work has many restrictions such as the following.

- ✓ A large number of reinforcing parts must be installed at the same time in narrow spaces.
- ✓ Fire-protection shall be required for welding with the curing materials.
- ✓ The installation sequence should be followed as verified by mock-up test.
- ✓ To take into account the manufacturing schedule of the parts in the factory.

In addition to the above, the suppression chamber has only two access openings, and the narrow internal space limits the options for the handling of materials and the access of workers, but if these accesses are obstructed by other work, the work will not proceed smoothly. Therefore, in a closed environment such as this work, it is very important to secure the accesses, the work near the passages should always be planned so that own work area, scaffolding, fire-protection with curing materials, and material storage areas do not obstruct the accesses.

And since flammable gas is generated during non-destructive inspection and painting of welds, even if the ventilation as mentioned above are ensured, welding work cannot be performed in the vicinity of the welding area to avoid the risk of a fire accident.

Taking the above complicated conditions into consideration, we are working to complete the large-scale modification work in a short period of time by carefully planning the work by drawing the work area visually to the process chart (see Figure 9).

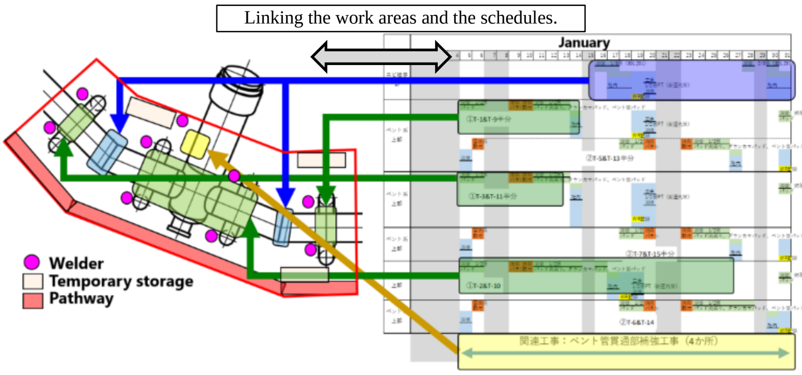

Figure 9: Example of area adjustment with visually drawing

THOROUGH MANAGEMENT OF WORK PROGRESS

Planned completion of the work in a short period of time, while placing the highest priority on safety and quality control, is an extremely important factor for the early start-up of the plant. On the other hand, as mentioned above, this work is meticulously organized under very complicated conditions, and any delay in a single task might affect the entire subsequent process.

Therefore, since reliable progress control is extremely important, a wide variety of process charts were prepared with high accuracy based on the master schedule, including detailed on-site work, mock-up tests, factory fabrication of parts, welding inspections, and related work in the vicinity. The progress of these processes was also monitored on a regular basis to check for any delays or problems, or signs of them, and thorough management was carried out to ensure that the construction work proceeded in a planned schedule.

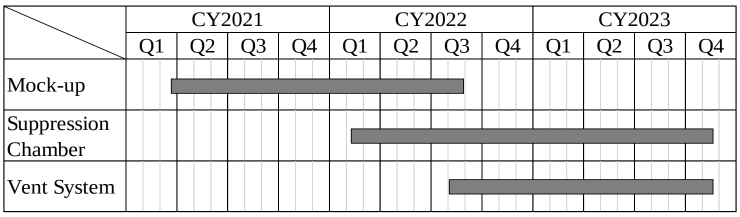

Figure 10: Overall work schedule

CONCLUSION

In order to complete the unprecedented large-scale modification work in a short period, we faced not only technical issues, but also issues related to the work environment and process. While resolving these issues one by one with discussion of the plant owner and the plant manufacturer, we have completed the main work in October 2023 as planned.

We believe that the various safety measures taken at Onagawa NPP Unit 2, including this work, must make a significant contribution to enhancing safety after plant start-up.