Causes of Corrosion Holes in Condensate Storage Tank Lining and Measures to Prevent Recurrence

Attachment

1. Overview of incident

During the process of shutting down Hamaoka Nuclear Power Station Reactor No. 5 (advanced boiling water reactor; rated output 1,380 MW) on May 14, 2011, damage to the main condenser tubes resulted in an inflow of seawater into the main condenser, and part of this seawater also infiltrated the condensate storage tank, increasing the concentration of chloride ions in the water in the tank.

Due to this incident, from October 21, 2011, the condensate water was drained from the tank, and cleaning of the tank and a visual inspection of the tank lining (made of stainless steel) were commenced.

As a result of this inspection, 40 holes were discovered in and around the welded sections of the lining (35 in the floor and 5 in the walls).

The 35 holes in the floor of the tank were divided into 26 spots of contiguous holes, and bubble tests were conducted successively in each spot as the holes were repaired, in order to check for leaks. Bubbles were observed in 11 of the 26 spots, and it was therefore judged on March 30, 2011 that the holes penetrated the lining in certain spots.

2. Results of inspection of condensate storage tank

(1) Results of visual inspection

- 40 holes were discovered in and around the welded sections of the lining (35 in the floor and 5 in the walls).
- Crud (main component: iron) had built up in the condensate tank.
  (Crud is formed by rust from the inner walls of the pipes, etc. being carried into the tank and settling on the floor. Crud is normally discovered during the periodic inspection of the tanks, and is not unique to this incident.)

(2) Results of detailed inspection of holes

- Holes in floor

  Bubble tests showed that bubbles emerged through holes in 11 of the 26 spots. Because of this, it was judged that the tank did not satisfy the requirement of the ministerial ordinance specifying technical standards for nuclear power generation facilities ("technical standards" below) for zero leaks.

- Holes in walls

  It was determined that none of the five holes in the walls penetrated the tank, and that the thickness of the remaining lining material satisfied the requirement of the technical standards for a plate thickness of at least 1.5 mm.

(3) Other

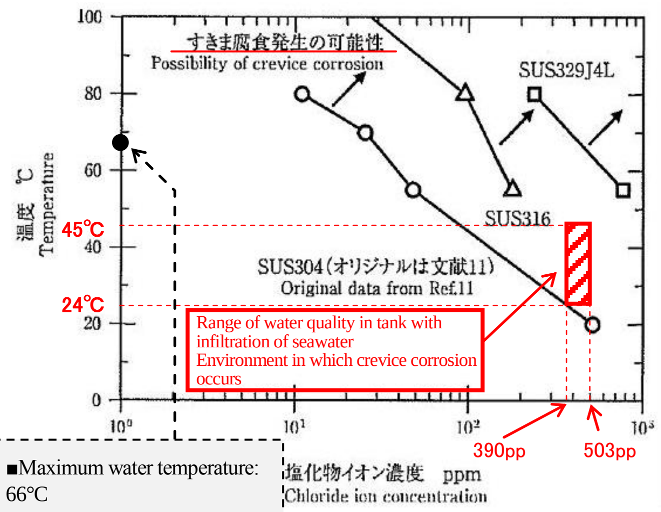
When the discharge valve of the condensate storage tank leak detection device was opened, it was found to contain approximately 40 ml of water. It was therefore assumed that the condensate storage tank was leaking.

3. Investigation of causes

It was possible to consider a variety of factors in the occurrence of corrosion holes, including water quality and welding defects, and the following investigations were therefore conducted.

(1) Corrosion originating in design factors

With regard to the possibility that corrosion may have been due to the selection of materials (SUS304) and inadequate setting of water quality standards, a survey of relevant studies[*1] indicated that at the maximum temperature for use of the condensate storage tank (66°C or below), the selected material would not corrode in water meeting the water quality standard set for normal operation (a chloride ion concentration of 10 ppb[*2] or less).



■Maximum water temperature: 66°C
■Corrosion does not occur at the water quality standard during normal operation（Chloride ion concentration: 10ppb or below）

(2) Corrosion originating in factors due to installation, etc.

With regard to the possibility that corrosion may have been due to errors in material specifications, defects in welding work, etc., examination of past records and other data indicated no problems.

(3) Corrosion originating in factors due to operation prior to infiltration of seawater

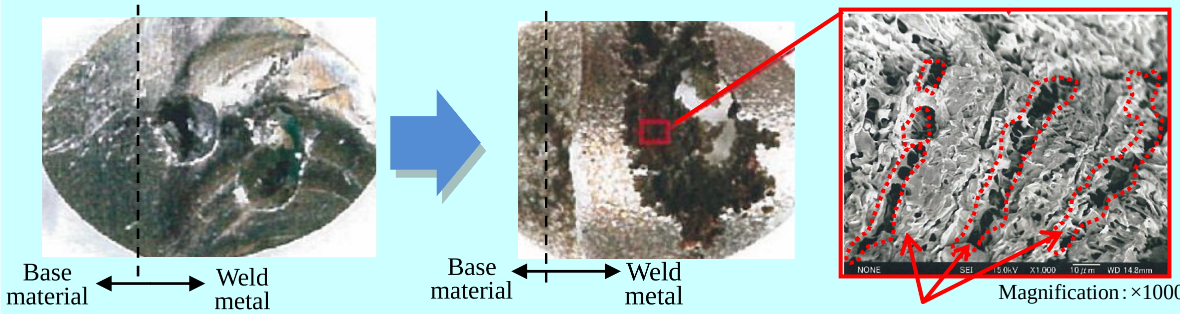
With regard to the possibility that corrosion may have been due to the infiltration of corrosive substances, etc., a study of the past water quality history showed that the condensate water satisfied water quality standards, and that no corrosion problem would have occurred.

(4) Corrosion originating in infiltration of seawater

A review of relevant studies[*1] indicated that the water quality environment following the infiltration of seawater (Chloride ion concentration: 390-503 ppm[*2]; Water temperature: 24-45°C) and the build-up of crud would create an environment promoting crevice corrosion.

A sample of a corrosion hole was taken and its structure was observed. The results of these observations showed a dendritic crystal morphology characteristic of crevice corrosion.

Results of observation of structure of corrosion holes



Surface of sampled hole — Underside of sampled hole — Dendritic crystal morphology observed in corrosion in crevices, etc.

4. Conjectured cause

It is believed that the infiltration of seawater into the condensate storage tank while the tank had a build-up of crud resulted in the formation of an environment that promoted corrosion in the crevices between the crud and the lining. Corrosion proceeded in these crevices until holes penetrated the lining.

A survey of relevant studies indicated that the welded sections are more prone to corrosion than the lining.

5. Repair of corrosion holes

Following the removal of sufficient salt by cleaning of the interior of the condensate tank, the following repair measures were applied to the corrosion holes (35 in the floor and five in the walls of the tank) based on the Rules on Design and Construction for Nuclear Power Plants and the Rules on Welding for Nuclear Power Plants in the JSME Codes for Nuclear Power Generation Facilities.

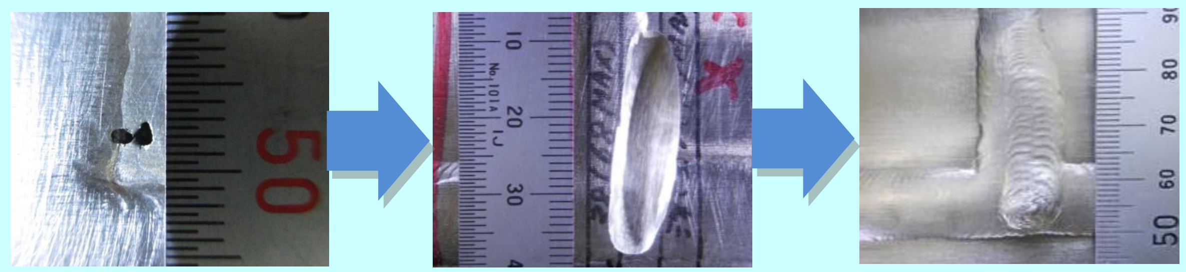
(1) Holes that do not penetrate the lining

Depending on the remaining plate thickness of the lining in the spots for removal of holes, the surface was either rendered smooth (abraded), or repaired by welding.

(2) Holes that penetrate the lining

Repair by welding or attachment of a reinforcing plate by welding.

【Example of repair welding】



At inspection (Two holes) — Removal of hole — Repair welding

6. Measures to prevent the reoccurrence of errors

The cause of the present incident was the infiltration of seawater into the condensate storage tank as a result of an inflow of seawater due to damage to the tubes of the main condenser in a number of spots. Given this, the following measures will be implemented in order to prevent the recurrence of the incident.

(1) Clarification of response procedures during infiltration of seawater

Seeking to control the infiltration of seawater into the facility and the spread of its negative effects to the greatest possible extent, based on the present incident, while retaining our existing operating procedures for responding to miniscule leaks of seawater from the tubes, we have also added procedures for shutting off the water supply to the condensate tank and transitioning to emergency shutdown operations when an incident occurs that results in a significant swing in the readings of the conductivity meters in the feedwater channels to the reactor to our existing operating procedures for responding to miniscule leaks of seawater from the tubes.

(2) Prevention of infiltration of seawater into main condenser

The damage to the main condenser tubes was caused by the rupture of a pipe. We intend to modify the structure of these pipes to prevent a recurrence of the incident.

7. Future responses

Based on a plan submitted to the Nuclear and Industrial Safety Agency (Reported April 25, 2012) the equipment that was infiltrated by seawater will be opened and disassembled for inspection, and its soundness will be evaluated.

*1 Matsuho Miyasaka, Corrosion Prevention – Corrosion of Seawater Pumps and Preventive Technologies," *Ebara Jiho*, No. 224 (2009-7), Japan Society of Corrosion Engineering, *Materials and Environment*, Vol. 41 (1992), pp. 833-835, etc.
*2 1 g in 1,000 kg represents 1 ppm, and 0.001 g in 1000 kg represents 1 ppb.