Measures for Reduction of Radiation Exposure at Higashidori Nuclear Power Station

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I. INTRODUCTION

Tohoku Electric Power Company has made significant efforts to reduce the amount of radioactive material adhered to piping and components in its nuclear power plants, ranging from the Onagawa Nuclear Power Station (NPS) Unit 1 to the Higashidori NPS Unit 1, by taking various measures to reduce radiation exposure at various stages, including design, manufacturing, construction, commissioning and operation of nuclear power plants, and by taking rigorous water chemistry control measures. As a result, the total exposure dose during the first periodic inspection at the Higashidori Nuclear Power Station was successfully reduced to 0.14 man-Sv, which was one of the lowest values observed in the domestic nuclear power stations.

During the period from 2005 to 2007, the Higashidori NPS achieved the world's lowest annual average dose per BWR (boiling water reactor) unit, which was 0.10 man-Sv/unit-year.

The exposure reduction measures taken at the Higashidori NPS and the resulting performance were presented at the 2008 ISOE (Information System on Occupational Exposure) International ALARA Symposium, and the presentation won the Best Presentation Award.

The internationally recognized world's best performance of the Higashidori NPS was the result of steady efforts to reduce radiation exposure made by our company since the design phase of Onagawa Unit 1.

II. RADIATION EXPOSURE REDUCTION MEASURES

In order to reduce the radiation doses to nuclear power plant workers, it is important to shorten working hours and radiation levels in work areas.

Concerning the shortening of working hours, steadily improved results are being obtained through the adoption of remote handling and automatic equipment, such as automatic CRD replacing apparatus, and through labor-saving in maintenance and inspection by adopting forgings for reactor pressure vessels.

This paper describes specific measures to reduce radiation levels that were found effective at the Higashidori NPS, including measures to reduce crud, water chemistry control and material surface treatment.

II. A. Measures to reduce crud

The potential sources of radiation exposure include deposition-type sources and replacement-type sources. The deposition-type sources are various types of radioactive crud that are activated in reactor water and deposited at portions where water flow is stagnant or slow. The replacement-type sources are radioactive ions in reactor water that are incorporated in oxidized films on hot portions of the reactor piping.
To reduce the deposition-type sources, it is necessary to reduce crud.
The most noteworthy effort to reduce crud is the "Clean Plant Activities" that has been carried out in a consistent manner since the early stage of construction. With the aim of improving work environment, protecting, storing and managing piping and components (maintenance of inner surface cleanliness), controlling wash and storage water chemistry, and reducing the amount of waste generated during construction work, the Clean Plant Activities were carried out in an organized way by all employees engaged in construction.

Figure 1 Clean plant action (scene of general cleanup)

To improve the work environment, air guns, jet sprays and foot wiping mats were provided at building entrances and exits during construction to ensure removing mud and dust attached to the shoes of workers and vehicles that enter the building.

Another important goal of this action was to raise workers' clean plant awareness.
Raising the awareness made each worker to become more attached to the Higashidori NPS. It is believed that the raised consciousness of "my plant" leads to stable plant operation and reduced radiation exposure because during periodic inspection and daily operation at the

station, the workers have a feeling like, "We will carefully handle the plant that we have built."

II. B. Water chemistry control

The representative radionuclides that significantly contribute to radiation exposure include Co-60 and Co-58. Since these ions are incorporated into oxidized films on hot portions of the piping system and become replacement-type sources, it is important to reduce the concentration of radioactive ions and suppress their incorporation into the oxidized films.

At Onagawa Unit 1, the amount of Fe crud carried into the reactor via feedwater had been controlled in relation to the Ni ion concentration in the reactor water in order to allow for stable incorporation of cobalt ions into oxidized films on the fuel cladding surface. This was aimed at the Fe/Ni control to reduce the concentration of radioactive cobalt in reactor water and reduce the amount of crud adhered to piping and components located outside the core.

Oxidation treatment of the fuel cladding tubes was initially employed in BWR plants. Subsequently, however, since the fuel cladding tubes with no oxidation treatment were introduced, the effect of the Fe/Ni control in reducing the concentration of radioactive cobalt in the reactor water was lost. This led to an increase in the dose rate around piping systems located outside the reactor core.

To solve this problem, a water chemistry control method called "the Ultra Low Fe High Ni control" was developed. This involves suppression of the amount of Fe crud carried into the reactor via feedwater and raising of the concentration of nickel ions in the reactor, leading to formation of dense oxidized films on the surfaces of piping systems outside the core and suppression of incorporation of radioactive cobalt.

Since Tohoku Electric Power Company adopted a hollow fiber membrane filter for the condensate filtration unit, conducted operation with the Ultra Low Fe High Ni control and had good records at Onagawa Units 2 and 3, this water chemistry control method was adopted at Higashidori Unit 1 as well.

The operational performance of Higashidori Unit 1 showed that the concentration of Fe crud in feedwater was maintained at 0.1 ppb or less and that the integrated amount of Fe carried into the reactor during the first operating cycle was suppressed to approximately 2.9 kg. This suggests that the same level of operation with the Ultra Low Fe High Ni control as that of Onagawa Units 2 and 3 was achieved at Higashidori Unit 1.

II. C. Material surface treatment

Since increased chromium ion levels have been observed at BWR plants that recently started operation, suppression of the generation of chromium ions has become an issue to be addressed.

Because the main source of increased chromium ions is feedwater heater tubes, and the incorporated chromium ions turn into chromic acid, it is believed that this condition makes the in-core environment an oxidizing atmosphere under which the elution of radioactive cobalt attached to the fuel cladding surface is enhanced and the concentration of cobalt radioactivity in the reactor water is increased.

The domestic BWR-owner companies performed a common study among utilities, which was called the "study on the suppression of elution of chromium from feedwater heater tubes," and confirm that surface treatment of oxidized stainless steel has an effect on the elution of chromium.

Tohoku Electric Power Company decided to reflect the result of this study in Higashidori Unit 1, and performed surface oxidation of the heat transfer tubes of second high-pressure feedwater heater, which is the final stage feedwater heater, to suppress the level of chromium ions carried in via feedwater for the first time in an operating BWR unit (Figure 2).

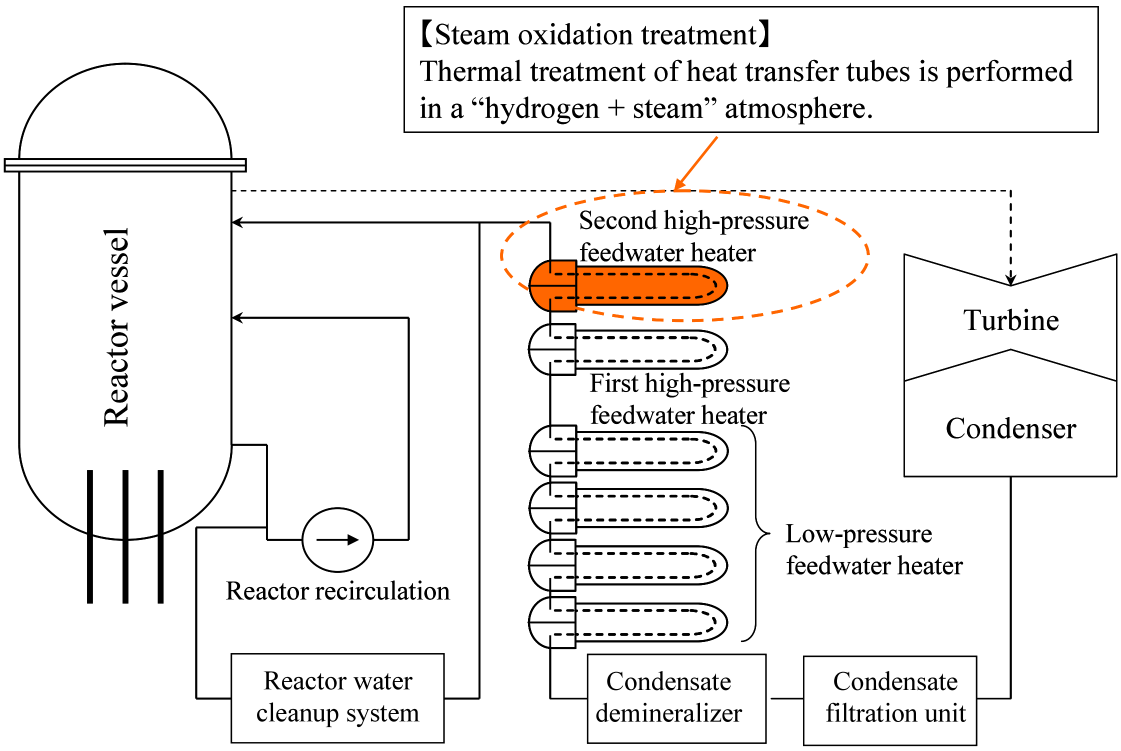

Figure 2 Surface oxidation treatment of feed water heater tubes

As a result, the total amount of chromium ions carried into the reactor via feedwater during the first operating cycle was about two-fifths of that for Onagawa Units 2 and 3. This suggests that the surface oxidation of feedwater heater tubes contributed significantly to suppression of the elution of chromium ions.

III. RADIATION EXPOSURE REDUCTION EFFECT

As the combined effect of the operation with the Ultra Low Fe High Ni control and the surface oxidation of feedwater heater tubes, incorporation of radioactive materials into piping and components outside the reactor core was successfully suppressed, and the dose rate on the primary loop recirculation (PLR) system piping measured during the first periodic inspection was 0.06 mSv/h, an extremely low value among the domestic BWRs. The dose rate measured during the second periodic inspection remained at a low level of 0.16 mSv/h (Figure 3).

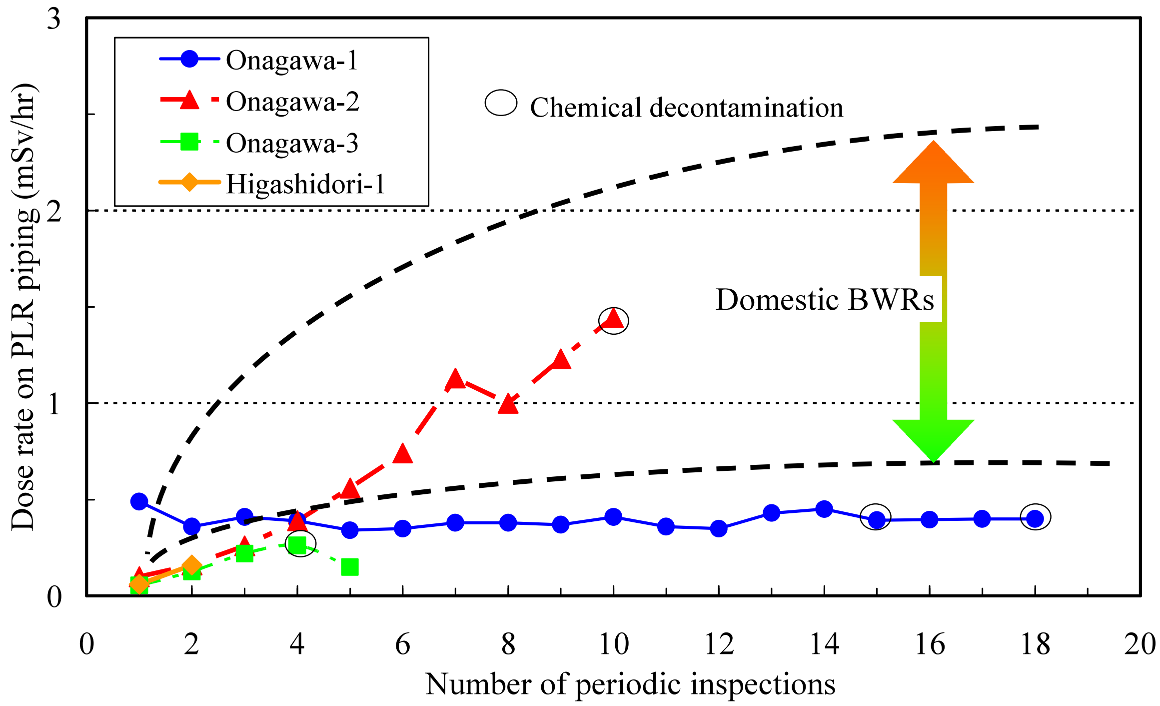

Figure 3 Transition of dose rate on PLR piping in domestic BWRs

IV. SUMMARY

The steady efforts of Tohoku Electric Power Company to reduce exposure were started at Onagawa Unit 1 and succeeded by Higashidori Unit 1, which eventually achieved the world's best record.

We will keep the Onagawa and Higashidori NPSs at low exposure levels as clean plants by making additional efforts to reduce exposure and careful checking the quality of reactor water at each plant. We believe that this will lead to gaining the trust of local communities.

REFERENCES

M. SATO, J. SATO, “Exposure reduction measures at Higashidori Nuclear Power Station”, Proceedings of 2008 Meeting of Thermal and Nuclear Power Engineering Society.