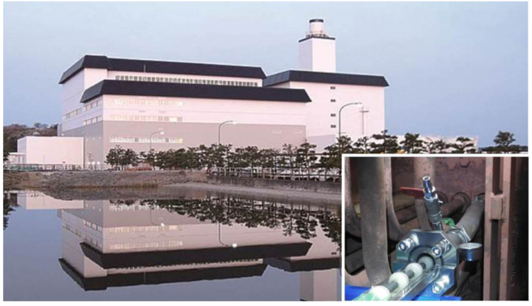
Development of Inspection Technology for Caustic Gouging of Combined Cycle HRSG (Pneumatic Transfer ECT)



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In heat transfer tubes of combined cycle Heat Recovery Steam Generators (HRSG) for thermal power plants, corrosion thinning caused by caustic gouging may occur on the tube inner surface. Mitsubishi Heavy Industries, Ltd. (MHI) and Mitsubishi Hitachi Power Systems, Ltd. (MHPS) developed the Pneumatic transfer Eddy Current Testing (ECT) inspection system as a technology which allows corrosion-thinned parts of heat transfer tubes to be measured without removing scale. In addition, to evaluate the performance of this technology, a verification test was conducted using the HRSG at Sendai Thermal Power Station No. 4 of Tohoku Electric Power Co., Inc. and satisfactory results were obtained.

1. Introduction

In heat transfer tubes of combined cycle HRSG for thermal power plants, corrosion thinning caused by caustic gouging (**Figure 1**) may occur on the tube inner surface. MHI has established ECT technology as an inspection method for the corrosion-thinned section of the tube inner surface, by which the entire length/circumference of the tube is inspected without being affected by scale produced by corrosion. The conventional inspection system adopted a hydraulic transfer method using water pressure, and it was a large-scale system that required much time for preparation before inspection and cleanup, including the transportation and installation of a large pump, a cable conveying device and a water tank. Therefore, we made a study of a Pneumatic transfer system as the system to be adopted instead of a hydraulic transfer system. This report describes the Pneumatic transfer ECT inspection system and the results of the verification test conducted using the actual HRSG unit at Sendai Thermal Power Station No. 4 of Tohoku Electric Power Co., Inc.

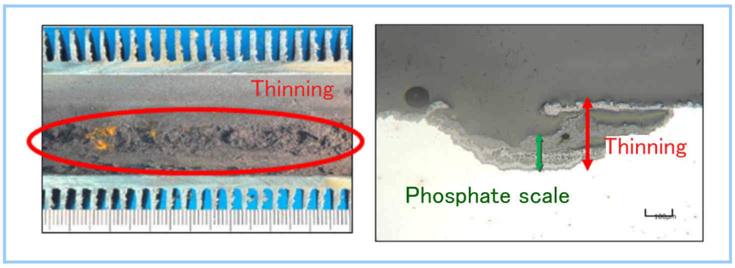

Figure 1 Example of caustic gouging

2. Development of Pneumatic transfer ECT inspection system

Figure 2 shows Pneumatic transfer ECT inspection system and the conventional hydraulic transfer ECT inspection system. In the Pneumatic transfer ECT inspection system, the developed

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ECT probe is inserted into the heat transfer tube by pneumatic pressure and the inside of the tube is inspected for thinning over its entire circumference and length while the probe is moved by manual operation. The transfer device has an air inlet opening and a cable insertion opening and has a simple structure using a hose band for connection to the tube to be inspected. The conventional hydraulic transfer system required a large hydraulic pump, a cable conveying device and a water storage tank, and the setup of the system had to be conducted using heavy equipment outside the HRSG furnace. On the other hand, the developed Pneumatic transfer system can be installed inside the furnace because of its compact system composition and the system installation time can be reduced. A resin ball is attached to the signal cable, thereby reducing contact friction and buckling of the cable during transfer. Thus, smooth transfer by pneumatic pressure is possible.

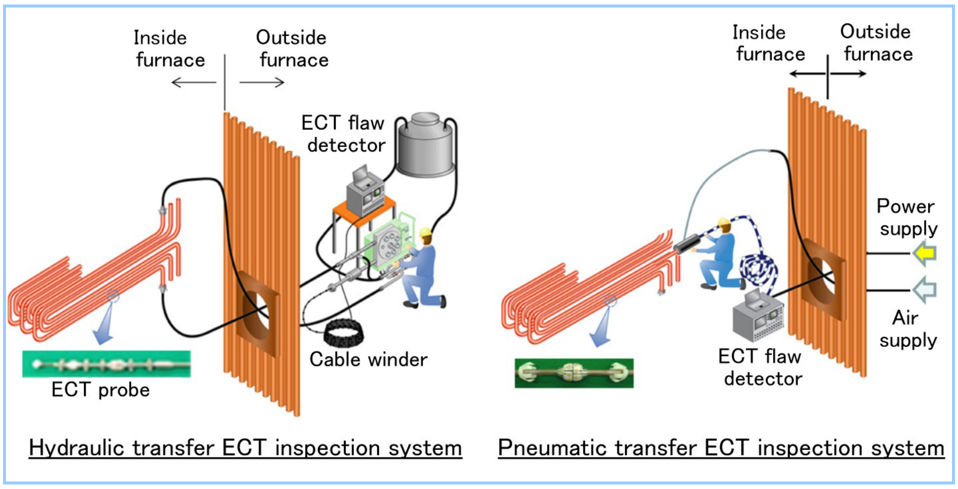

Figure 2 Pneumatic transfer ECT inspection system and conventional hydraulic transfer ECT inspection system

Figure 3 presents the developed ECT probe. There are various types of sensor coils, and this probe adopts the differential coil method in which the effect of the magnetism of the carbon steel tubes, etc., used in HRSG and noise generated by the sensor tilt are small and the defect detectability is high. This means that to detect the difference between the signal components in the tube circumferential direction and in the tube axial direction, noise can be reduced while signals generated by defects are maintained. The coil part of this probe has a flexible structure, allowing the probe to smoothly pass through discontinuous portions such as welding penetrations or tube bends.

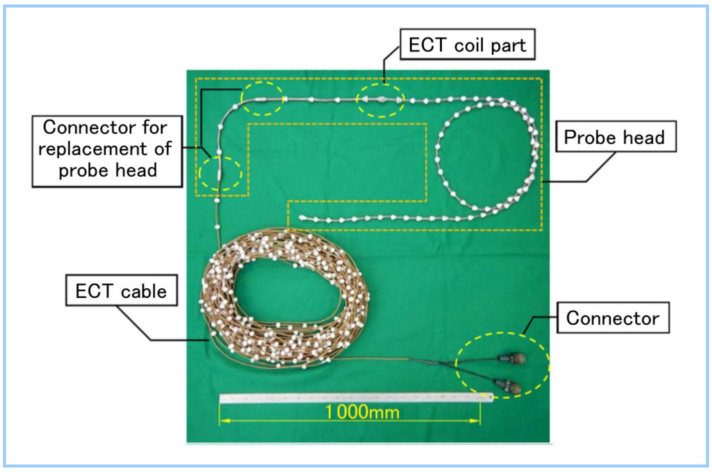

Figure 3 Developed ECT probe

Figure 4 gives the results of the verification test using a mock-up panel. With the use of the Pneumatic transfer system, verification was conducted for the passibility of the probe through the panel (overall length of 40m), which simulates the HRSG heat transfer tube. As a result, it was confirmed that the probe can pass through bend sections with a bending radius of 65 mm. The required air flow rate during passage was about 1000 NL/min, and it was found that the probe is applicable to the flow rate of general air compressors used in thermal power plants.

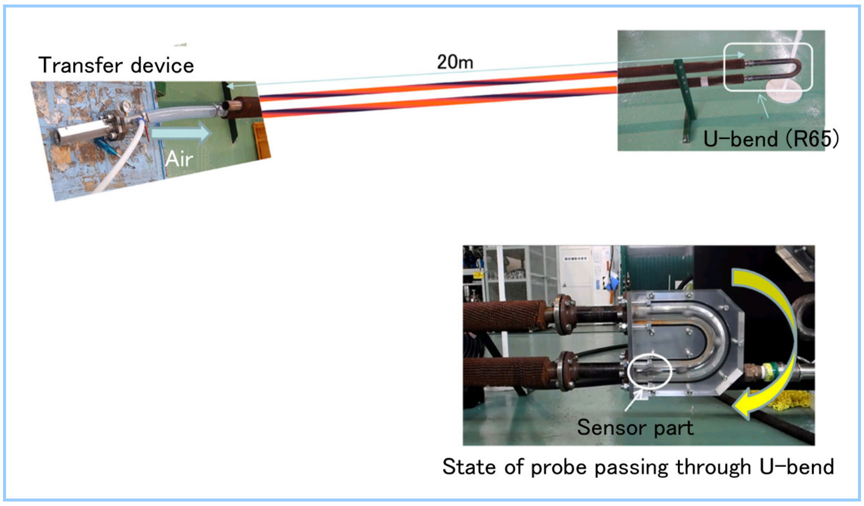

Figure 4 Results of verification test using a mock-up panel

Next, in order to evaluate the thinning detectability of the developed ECT probe, a verification test was conducted using samples with artificial flaws processed on the tube inner surfaces. **Figure 5** illustrates the detected state of the artificial flaws. The artificial flaws had the same depth (0.5 mm) and varied in width and length. The developed ECT probe was able to detect all the artificial flaws. In this system, the inspection results are displayed with a color tone view of the tube inner surface developed by our proprietary analysis system, enabling the thinning distribution to be visualized. Furthermore, the thinning depth can be evaluated from the obtained signal amplitude, etc.

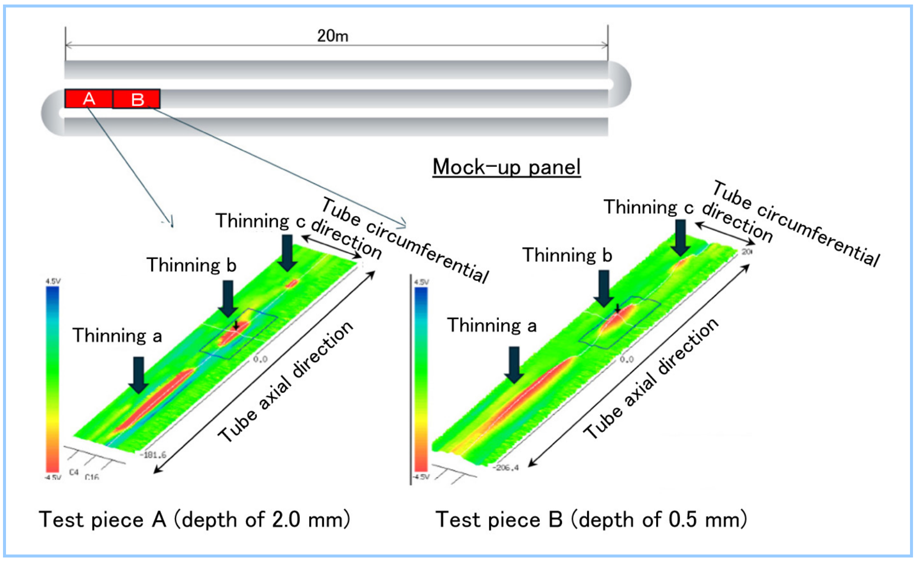

Figure 5 Example of detection of artificial flaws

3. Verification test at Sendai Thermal Power Station

In order to evaluate the practicality of the developed Pneumatic transfer system, a verification test was conducted using an actual heat transfer tube during the preventive maintenance and inspection period at Sendai Thermal Power Station No. 4 of Tohoku Electric Power Co., Inc. **Figure 6** depicts the appearance of Sendai Thermal Power Station and the high pressure evaporator tube to be verified. The verification items were the passibility of the ECT probe, the inspection time and a comparison between the cross section observed on the removed tube and the ECT signal. As a result of the insertion test, it was verified that the probe was able to pass through a tube with a length of 20m including welds without issue. **Figure 7** gives the comparison results of the ECT signal and the state of the tube inner surface. In the visual inspection using a fiberscope, white streaky scale adhering to the tube inner surface was observed, whereas in the ECT inspection, no thinning signal was detected in any tube. **Figure 8** presents the results of the inspection of the removed tube where the white streaky scale was observed on the inner surface. The white streaks were removed by blasting, and the tube inner surface was checked for thinning. As a result, a slight thinning of about 0.1 mm in depth was observed. This is less than the minimum limit value of detection (0.5 mm) of the developed ECT probe, and the validity of the ECT results (no thinning signal) was confirmed. In addition, based on the fact that no undesired noise was detected in the ECT signal, it was verified that the developed ECT inspection system has no issues as an inspection device.

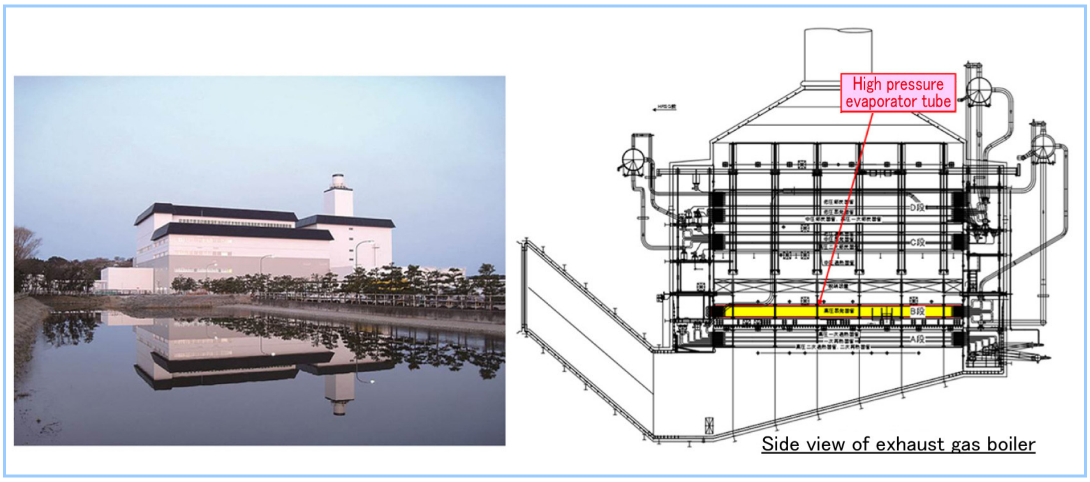

Figure 6　Appearance of Sendai Thermal Power Station and high pressure evaporator

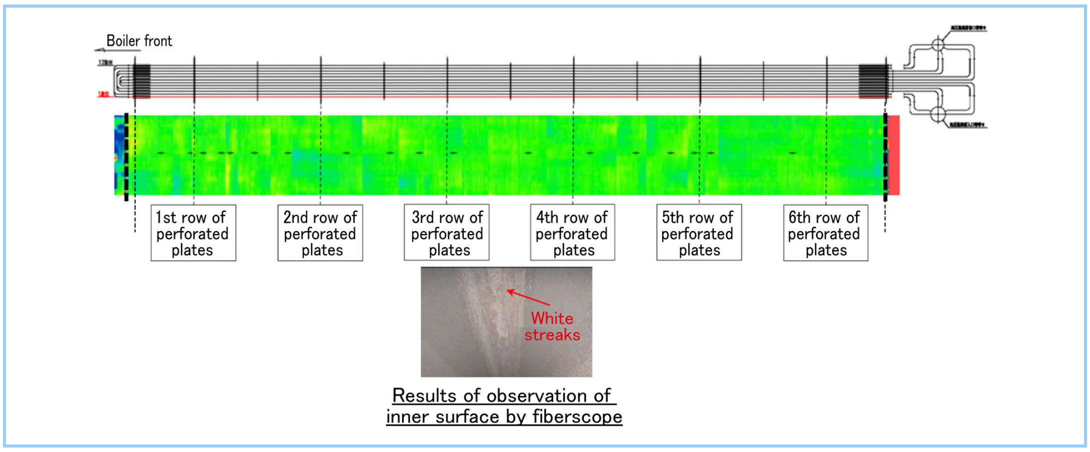

Figure 7　Comparison results of ECT signal and state of tube inner surface

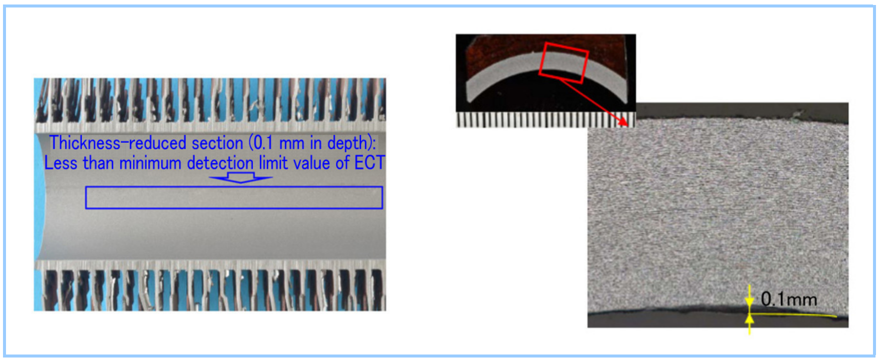

Figure 8　Results of inspection of removed tube

Figure 9 shows the states of the field installation of the hydraulic transfer system and the Pneumatic transfer system. The hydraulic transfer system is large and is installed outside the HRSG furnace, while the Pneumatic transfer system is compact and can be installed inside the furnace. Figure 10 is the inspection time of both systems. The simplification of the system reduced the preparation time for inspection to about one third and increased the inspection speed by about 1.5 times. With these effects, it is expected that the total number working hours can be reduced by 45%

in the Pneumatic transfer system. In the hydraulic transfer system, the tube had to be cut at two points of the probe, one at the inlet and the other at the outlet, to secure a water circulating passage, while in the Pneumatic transfer system, the tube is cut at only one point for the probe inlet, and related work can be reduced.

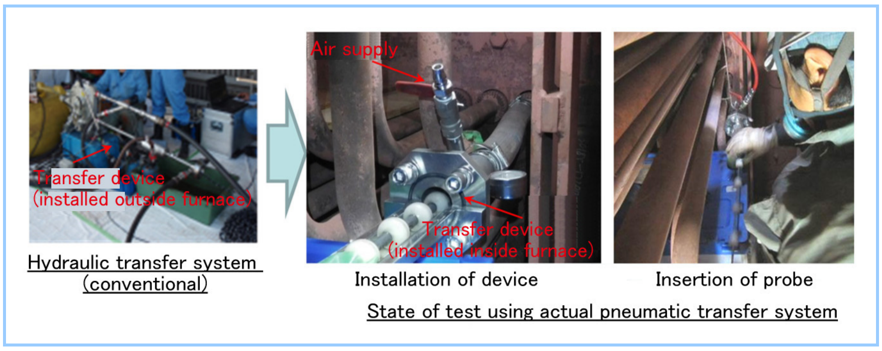

Figure 9　States of field installation of hydraulic transfer system and pneumatic transfer system

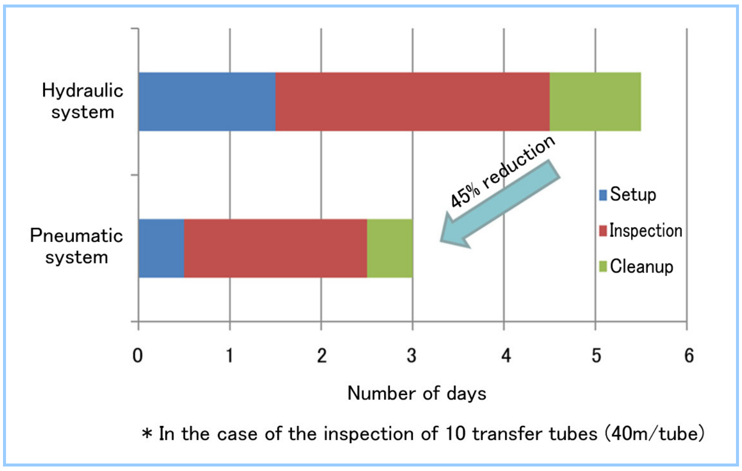

Figure 10　Comparison results of inspection time

4. Conclusion

This report described an overview of the Pneumatic transfer ECT inspection system, by which the thinning depth can be quantitatively assessed, and the results of the performance verification test conducted at Sendai Thermal Power Station of Tohoku Electric Power Co., Inc. In the ECT system, caustic gouging produced on the inner surface of a heat transfer tube of combined cycle HRSG for thermal power plants is inspected over the entire length/circumference of the tube. The system utilizes MHI's proprietary high-efficiency inspection technology and allows corrosion thinning produced on the inner surface of a tube made with magnetic material to be quantitatively assessed without the removal of scale. It is recommended that plants where caustic gouging may occur be checked for corrosion thinning using this inspection technology, and if any signs of thinning are observed, measures such as the optimization of water treatment should be carried out. In the future, we will continue inspections using this system to establish an inspection system with higher reliability.