Development of Energy-Saving Device for Hot Water Supply System in Europe

Authors: *Shigeru Iijima** and *Kazuhiro Shigyo**

Mitsubishi Electric Corporation developed a scale catching device to prevent scale deposits on our heating and hot water supply systems for Europe and evaluated their performance in a demonstration test. As a result, heating and hot water supply systems with scale catching devices and plate heat exchangers (P-HEXs) were introduced to the European market in 2014.

1. Background

In 2007, Mitsubishi Electric introduced air-to-water (ATW) systems for heating and hot water supply in the European market. ATW systems use heat pump outdoor units to efficiently convert heat in the air to heat energy that is used to heat water, and they have been remarked as energy-saving heat sources with reduced CO_2 emissions.

Europe, which is the main target of the ATW systems, has high calcium hardness in its tap water. As a result, calcium carbonate scale (hereafter, "scale") tends to adhere to the tap water circuits in heating and hot water supply systems, which can prevent the heat exchange and increase the pressure drop.

External P-HEXs for hot water supply were introduced into Mitsubishi Electric's ATW systems in a model change in 2014. As shown in Fig. 1, a P-HEX and pump were installed. The P-HEX heats the tap water in the storage tank with the circulating hot water through heat exchange. Small P-HEXs with high heat transfer efficiency have a low cost. However, when the heating surface of a P-HEX is covered with scale deposits, the cross section of the circuit becomes smaller and the increased pressure drop of the system may cause a pump failure or other faults.

Therefore, Mitsubishi Electric developed a scale catching device in order to introduce P-HEXs into ATW systems. This paper describes the structure of the scale catching device and the knowledge acquired through its development.

2. Structure of Scale Catching Device

Figure 2 illustrates the structure of the scale catching device. A copper pipe was used for the device and the inlet and outlet sections were reduced like a truncated cone to match the diameter of the peripheral pipes. Stainless steel spiral fibers were placed in the cylindrical section inside the copper pipe. In addition, the scale catching device was installed in the vertical direction as shown in Fig. 2. The water inlet was located at the bottom and the outlet was located at the top.

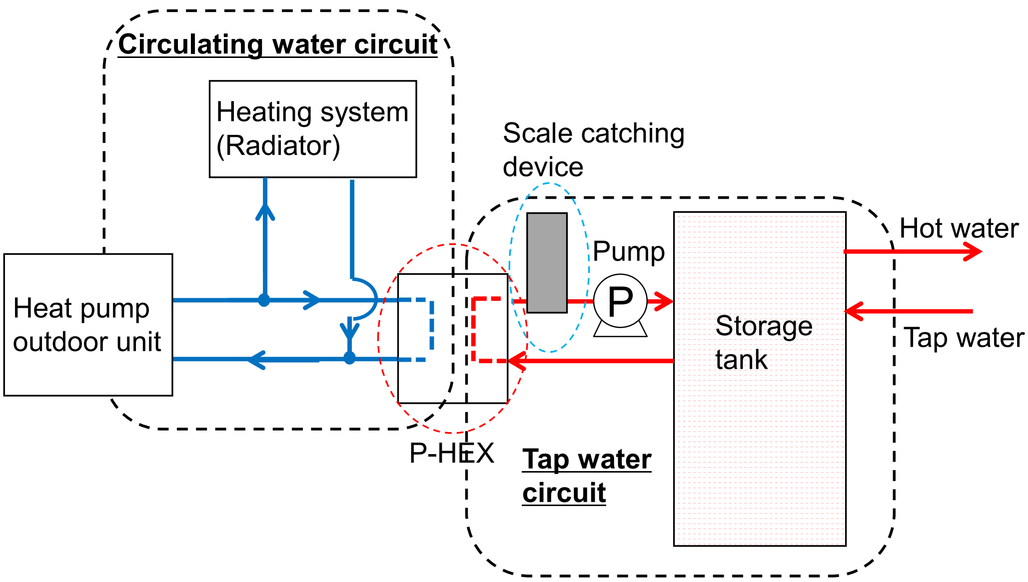

Fig. 1 Schematic of the 2014 ATW system

* *Advanced Technology R&D Center*

3. Scale Catching Device Demonstration Test

3.1 Test procedures

Demonstration tests using an actual ATW system were carried out to evaluate the performance of the scale catching device.

In the demonstration test, a circulation circuit with an ATW system was used. Simulated water was sent to the circulation circuit and continuous heating operation was carried out to reproduce the adhesion of scale to the P-HEX and the scale catching device. The water quality of the simulated water was similar to that of the hard tap water in Europe. The calcium hardness and M alkalinity were selected as parameters for the water quality. To maintain the water quality of the simulated water, it was replaced with newly prepared simulated water twice a week. In addition, the water quality was measured before and after each replacement and the weight of the scale deposits was calculated based on variations of the calcium hardness.

Usually, an ATW system is operated for approximately one hour per day to supply hot water for an ordinary household. However, in the demonstration test, the system was continuously operated to supply hot water for 24 hours per day to accelerate the deposit of scale. The longest operation time in the demonstration test was converted to a service period of 17 years for an ordinary household.

3.2 Test results

The scale catching device was tested for an operation time equivalent to the service period of 17 years for an ordinary household. The test results are shown below.

The total weight of the scale captured by the scale catching device was 190 g and the scale was evenly distributed on the stainless steel spiral fibers. On the other hand, the weight of the scale on the P-HEX was 3.0 g. Figure 3 shows the scale adhesion ratio for the heat exchanger and scale catching device to the weight of the scale on the entire system. Figure 3 shows that the scale adhesion ratio for the P-HEX was 1.0% to the weight of the scale on the entire system while that for the scale catching device was 81%. These results show that the scale catching device captured most of the scale, which reduced the weight of the scale on the P-HEX.

Figure 4 shows the changes in the weight of the scale on the P-HEX for the demonstration test time of the scale catching device. The values on the horizontal axis are the test times converted to the service periods for ordinary households. In addition, the slopes in the figure show the deposition rate of the scale on the P-HEXs. Installing a scale catching device decreased the deposition rate of scale on the P-HEX to 1/56, from 6.2 to 0.11 g/yr.

The above results show that the scale catching device is efficient and reduces the weight of the scale on P-HEXs. In addition, the device does not require maintenance during its service period. Therefore, Mitsubishi Electric introduced the ATW systems with P-HEXs and scale catching devices to the European market in 2014.

4. Mechanism of Scale Catching Devices

The mechanism of the developed scale catching device is described below. Figure 5 shows a model of the mechanism.

As shown in Fig. 5 (1), scale particles formed in the water enter the scale catching device. Particles that come into contact with the catching material get caught on the surface of the material. The catching material consists of 3D spiral fibers. The diameter of the openings in the spiral section is in the order of mm, which is sufficiently larger than the diameter of the scale particles (μm order) formed in the water. Therefore, the particles

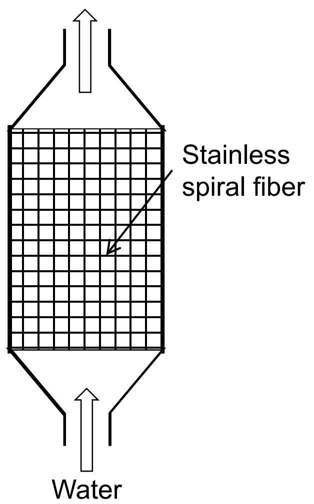

Fig. 2 Schematic of the scale catching device

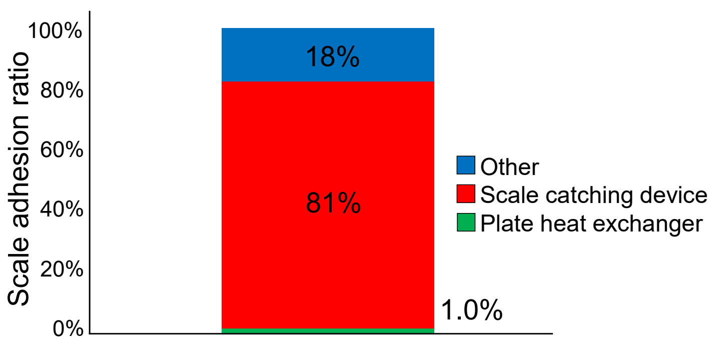

Fig. 3 Rate of scale deposition in the scale catching device demonstration test

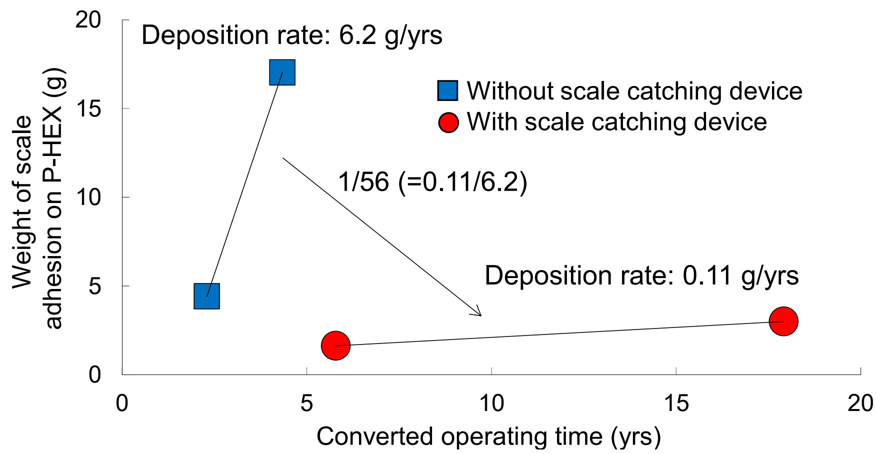

Fig. 4 Results of demonstration test (Comparison between with and without scale catching device)

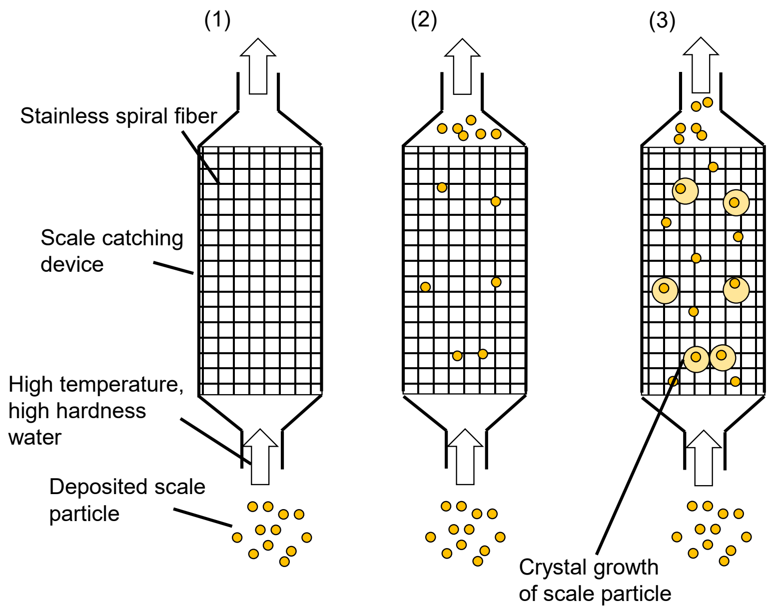

Fig. 5 Concept of scale capture process in the scale catching device

easily pass through the spiral section and come into contact evenly with the catching material at a certain probability. They get caught on the material that covers the area from the inlet to the outlet at a certain probability as shown in Fig. 5 (2). The high-temperature and high-hardness water flowing in the circulation circuit flows around the scale particles caught on the spiral fibers, as shown in Fig. 5 (3). Crystals start growing from the scale particles on the spiral fibers and they efficiently catch the scale components in the water.

As a future task, the performance of the scale catching device needs to be enhanced and the cost reduced.