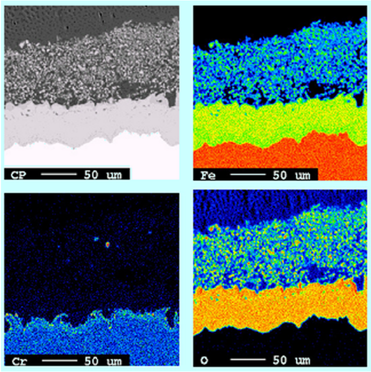
Achievement on OT (Oxygenated Feed-Water Treatment) Application and Introduction of Countermeasures for Powdered Scale Deposit



SENICHI TSUBAKIZAKI*1 MASAHARU TAKADA*2
TAKAYUKI SUTO*3 HIROTAKE KAWASHIMA*4
TARO ICHIHARA*2 AKITO YOSHIDA*5

OT (Oxygenated Feed-Water Treatment) using oxygenation methods for boiler feed water was first introduced at a thermal power utility plant in Japan in 1990 based on the success of OT applications in Europe. It is now operational at 53 Japanese electric utility thermal power plants, 20 years after its introduction. Recently, some OT plants have experienced increased iron concentrations in the drain system of the low-pressure feed-water heater. In addition, a powdered scale deposit has been generated and attached to the inside of the furnace wall tubes, contributing to an increase in the wall tube temperature. As a countermeasure, a high-temperature filter was used to remove the iron suspended in the drain system; the results validated the effectiveness of the filter.

1. Introduction

In domestic thermal power plants, boiler feed-water treatment is conducted to prevent obstructions such as corrosion in the boiler and turbine systems, scale generation and deposition, and carryover into the turbine.

The history of boiler feed-water treatment for domestic thermal power plants is shown in **Figure 1**.

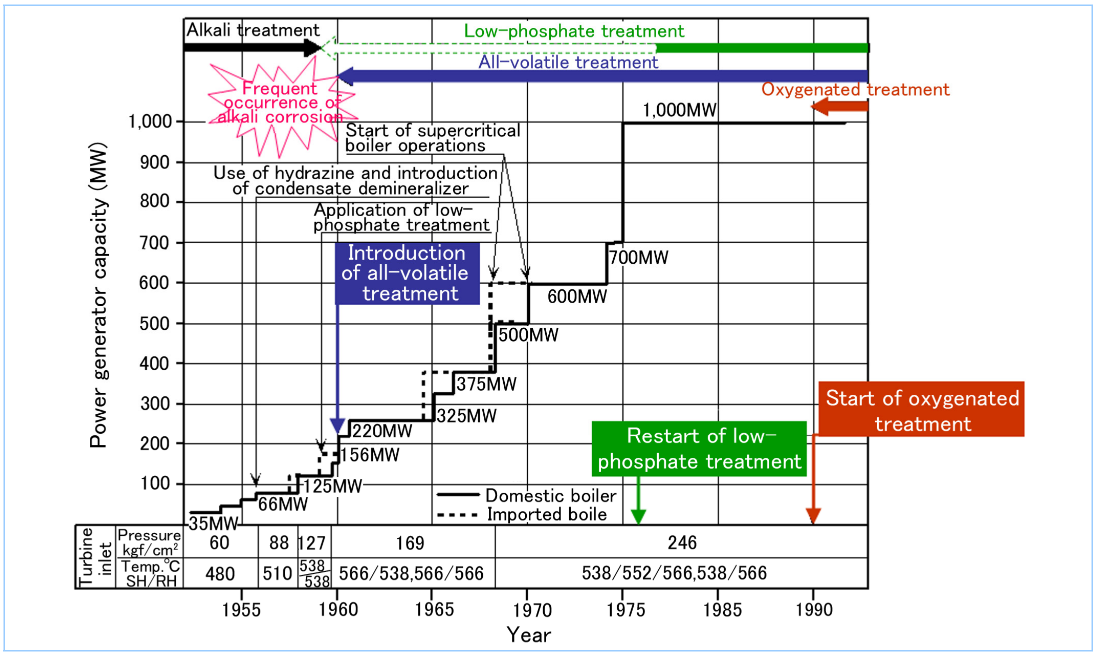


Figure 1 History of boiler feed-water treatment for domestic thermal power plants

*1 Engineering Manager, Power Systems Service Division, Power Systems
*2 Power Systems Service Division, Power Systems *3 Boiler Engineering Department, Power Systems
*4 Power Systems Project Engineering Department, Power Systems Project Management Division, Engineering Headquarters
*5 Group Manager, Power Systems Service Division, Power Systems

Domestic verification tests for a combined water treatment (CWT) using oxygenation methods were conducted based on success in Germany, Russia, and other nations. The tests resulted in Japanese Industrial Standard (JIS) B8223, the first water chemistry control criterion, in 1989. In 1990, the first CWT application in Japan was to a large once-through utility boiler. Because a condensate polishing plant (CPP) is required, there have been few CWT applications to drum boilers. However, after more than 20 years since its introduction, CWT is operational at 53 thermal power utility plants, resulting in satisfactory achievement records.

In this paper, we present countermeasures against obstruction from powdered scale deposition, which is an important issue for domestic CWT plants.

2. CWT Plant Operation

2.1 Boiler feed-water treatments for once-through boilers

Figure 2 shows current boiler feed-water treatments for once-through boilers in domestic thermal power utility plants.

Boiler type		Once-through boiler		
Water treatment type		All volatile treatment	Oxygenated treatment	
		AVT	NWT	CWT
pH	(at 25 °C)	9.0–9.7	≒7	8.0–9.3
Cation conductivity	(mS/m)	≦0.025	≦0.02	
Dissolved oxygen	(μg/L)	≦7	20–200	
Chemicals		Ammonia Hydrazine	Oxygen	Ammonia Oxygen

AVT: all-volatile treatment
NWT: neutral water treatment
CWT: combined water treatment

Figure 2 Boiler feed-water treatments for once-through boilers

In conventional all-volatile treatment (AVT), the water quality is adjusted using ammonia to control pH and hydrazine as a deoxidant. Because dissolved oxygen is thought to be a corrosive component, its concentration is minimized and the boiler feed-water pH is adjusted to prevent corrosion.

Oxygenated treatment (OT), on the other hand, is based on the theory that slightly soluble oxides adhered to the surface of steel can prevent steel corrosion and elute corrosion products into water. OT includes neutral water treatment (NWT), in which dissolved oxygen is allowed to coexist in neutral water, and CWT, in which dissolved oxygen is allowed to coexist in weak alkaline water adjusted to a range of pH 8.0 to 9.3 by ammonia.

The solubility of hematite, generated during CWT, is approximately a hundred trillion times lower than that of magnetite, generated during AVT; thus, hematite reduces iron elution from the system. CWT applications have been promoted in domestic thermal power utility plants (mainly once-through boilers) as a means of preventing scale deposition in equipment and boilers.

2.2 CWT track record and effectiveness

In Japan, CWT has been applied to 57 thermal power utility plants, and is operated in 53 plants as of March 2011.

CWT in Japan has effectively (1) reduced the frequency of chemical cleanings by lowering the build-up rate of scale, (2) alleviated the increase of boiler pressure loss by preventing rippled scale build-up, (3) improved environmental conservation by reducing ammonia usage, (4) reduced scale deposition on equipment surfaces, and (5) reduced flow-accelerated corrosion (FAC).

As shown in **Figure 3**, CWT has slowed the build-up rate of rippled scale compared with AVT, alleviating the increase of boiler pressure loss. Thus, the increase in feed-water pressure at the boiler inlet (i.e., the increase in feed-water pump power) has been curbed.

In addition, the slower build-up rate via CWT allows the boiler chemical cleanings (scale removal) to be deferred from 2–4 years to more than 10 years. With this effect and others, it has contributed in some boilers to a savings of more than 50 million yen per year for a 600–MW plant.

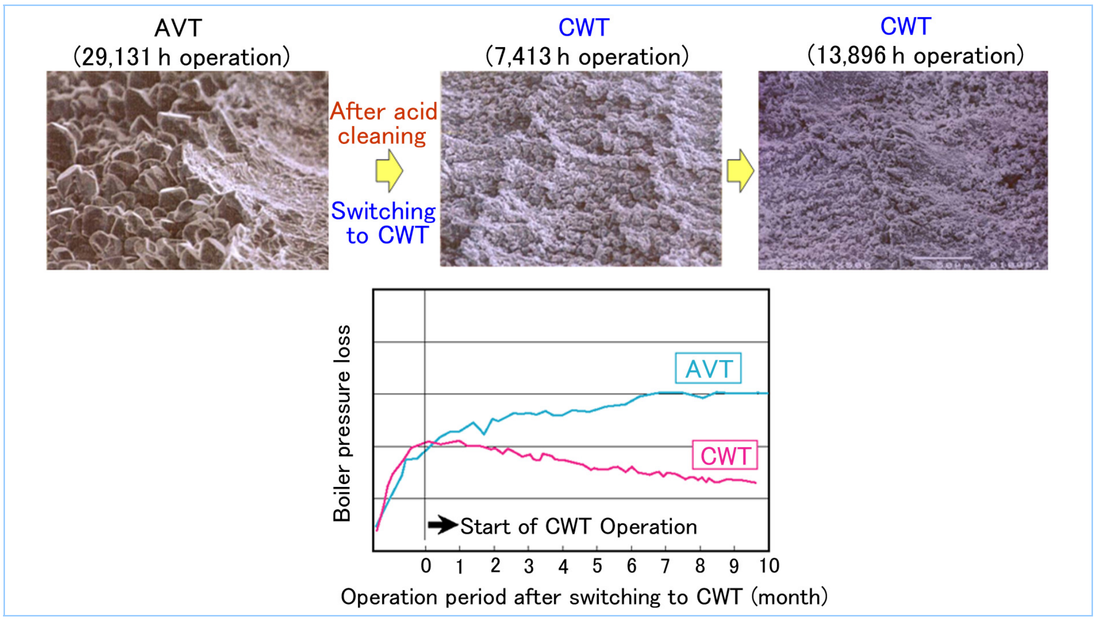


Figure 3 CWT effect of reduced rippled scale build-up

2.3 Example problems at inspected CWT plants

The problems identified at inspected CWT plants are shown in **Figure 4**. It is not clear whether all these events have a cause-and-effect relationship with CWT, but all are listed herein.

Almost all the events were addressed during CWT introduction, and there are currently no reports of operational problems.

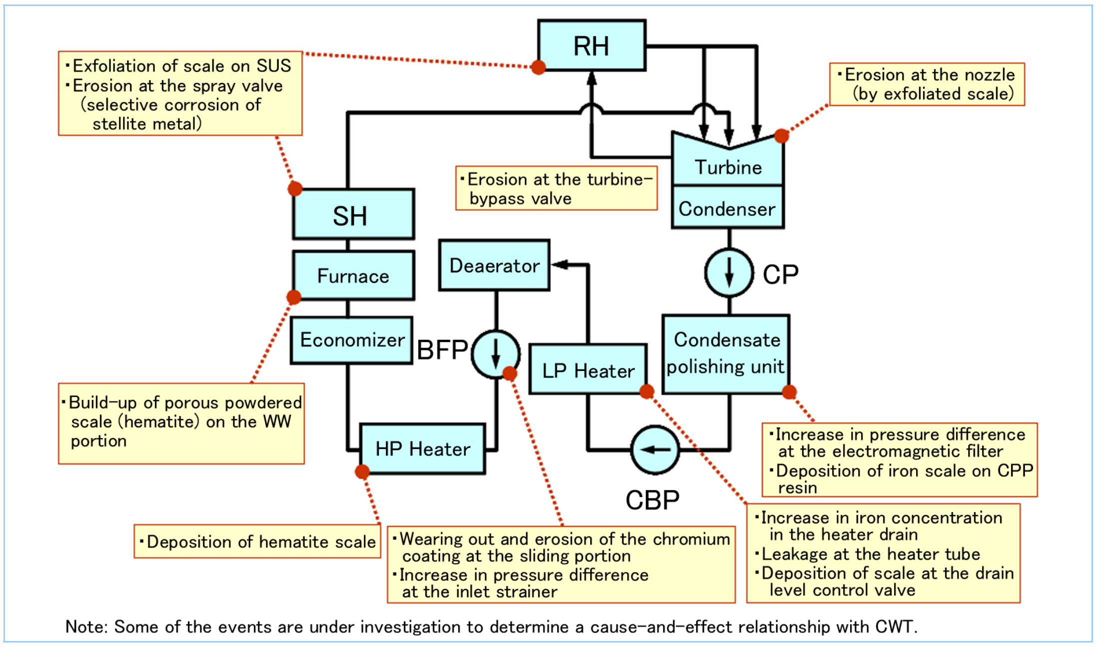


Figure 4 Example problems at inspected CWT plants

2.4 Powdered scale deposition

In recent years, an increased amount of iron transferred into the boiler and the deposition of hematite scale on the inside surfaces of the boiler furnace wall tubes in some CWT plants has caused the temperature of the metal furnace wall tubes to increase.

The deposited hematite scale, called "powered scale", has low thermal conductivity and a porous structure consisting of small particles. **Figure 5** shows powdered scale deposited on the inside surfaces of boiler furnace wall tubes.

The iron concentration in the drain system of the low-pressure feed-water heater has increased at plants with powdered scale deposition on the inside surfaces of the boiler furnace wall tubes after CWT. It is thought that dissolved oxygen in the drain system of the low-pressure feed-water heater was transferred to the vapor side (the condenser side), shifting the drain to low oxygen conditions, similar to AVT, and to pH conditions of 8.5 to 9.0, lower than that of AVT. Thus, the iron concentration in the drain increased because the hematite-formation reaction was delayed due to low temperatures.

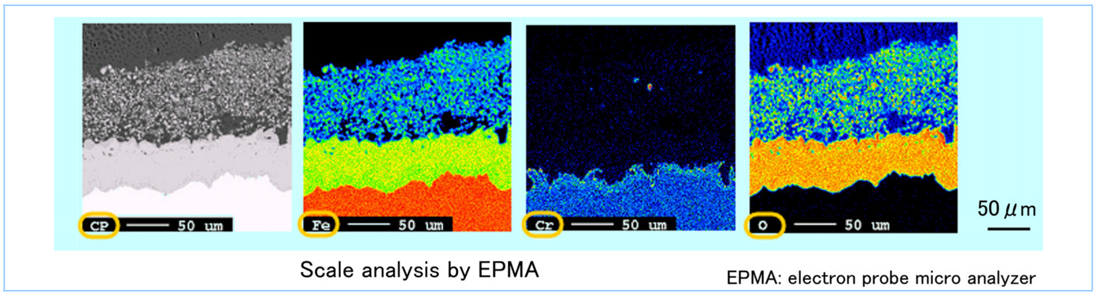


Figure 5　Powdered scale deposited on the boiler generating tube

3. Countermeasures against Powdered Scale Deposition

3.1 Measures for lowering the iron concentration in low-pressure feed-water heater drain systems (measures for normal operation)

Test results of material balance of iron in the plant systems indicated that iron removal and transfer are primary sources of powdered scale and therefore it is thought that reducing the transfer of iron particles into the boiler will reduce powdered scale deposition by decreasing the iron concentration in the drain system of the low-pressure feed-water heater. The following countermeasures were studied and introduced in the plants:

(1) Replacing the low-pressure feed-water heater material with SUS (reducing iron elution);
(2) Shifting the pH value of the feed water (lowering iron solubility);
(3) Shifting the pH value in the low-pressure feed-water heater drain system by injecting ammonia (lowering iron solubility);
(4) Injection of oxygen into the low-pressure feed-water heater drain system (accelerating hematite formation);
(5) Closed operation of the vent valve of the low-pressure feed-water heater (accelerating hematite formation);
(6) Installation of a high-temperature filter for removing suspended iron in the low-pressure feed-water heater drain system (lowering iron concentration).

Figure 6 shows an example in which implementing countermeasures (2)–(4), i.e., controlling water quality and lowering the iron concentration of the low-pressure feed-water heater drain system, reduced powdered scale deposition. Test results of suspended iron removal in the drain system via installation of a high-temperature filter are also presented.

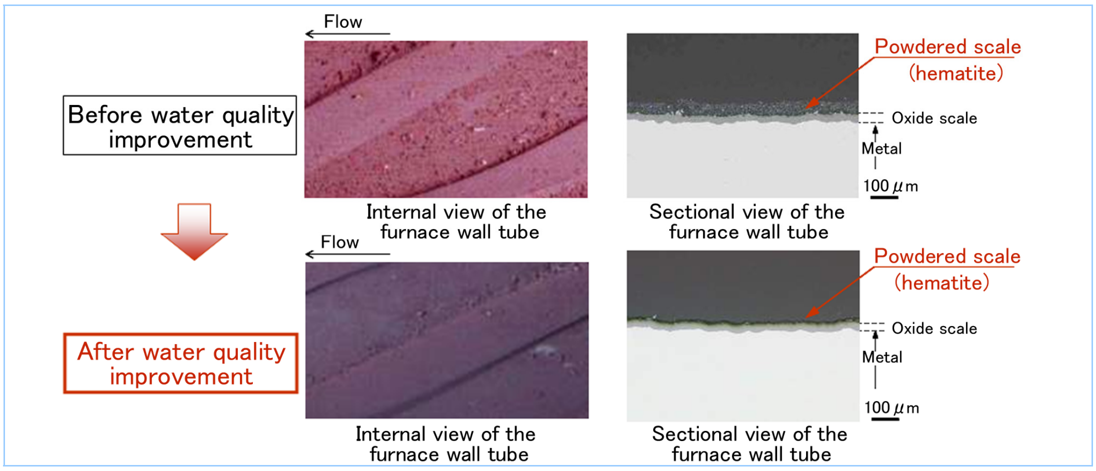


Figure 6　Powdered scale reduction via optimized water quality during normal operations

3.2 Suspended iron removal test in the low-pressure feed-water heater drain system (measures for start-up operation)

Figure 7 shows an external view of the suspended iron removal test unit with a high-temperature filter for the low-pressure feed-water heater drain system.

The high-temperature filter (spec.: 80 °C) of the test unit was installed in the sample line, located in the sample rack, of the drain system.

Because the suspended iron concentration in the drain system showed a strong increasing trend during start-up operations, the test was conducted during start-up and normal operations. The tests results for start-up operations are shown in **Figure 8**. The suspended iron concentrations at the filter outlet were approximately 50 µg Fe/L, even when the transient iron concentrations were over 90,000 µg Fe/L at the inlet of the filter installed in the drain system, and were maintained at less than approximately 10 µg Fe/L.

Because the target water quality in the treated drain was less than 50 µg Fe/L during start-up operations, the high-temperature filter, when installed, enabled the suspended iron concentration in the drain to be reduced to less than the target value in the initial stages of the water-feeding operation (reduction in start-up time). It is also expected to reduce the amount of removed iron particles flowing into the boiler, which contribute to powered scale deposition.

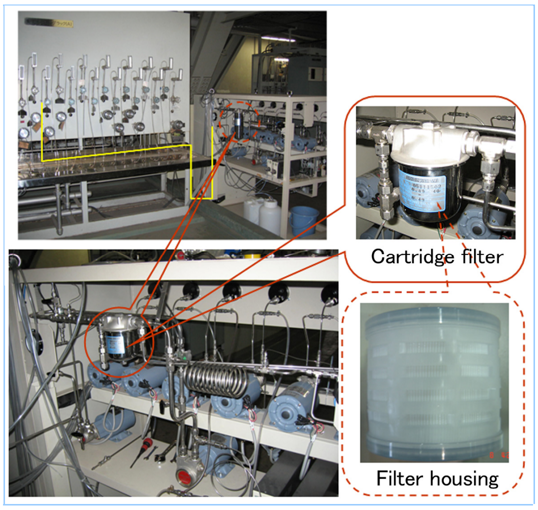


Figure 7 External view of the suspended iron removal test unit with a high-temperature filter for the low-pressure feed-water heater drain system

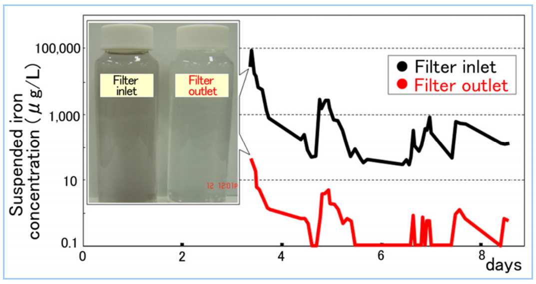


Figure 8 Suspended iron removal in the low-pressure heater drain using a high-temperature filter during start-up operations

4. Conclusion

CWT is superior to AVT for a once-through boiler. Although powdered scale deposition remains a problem, the suspended iron removal unit with a high-temperature filter in the low-pressure feed-water heater drain system reduced the iron concentration in the feed-water drain system.

We believe that these data can be used to reduce the amount of iron particles flowing into boilers during start-up operations. Future tests in commercial plants are necessary to verify these results.

References

1. Water conditioning for Boilerfeed Water and Boiler Water JIS B8223-2006
2. Thermal and Nuclear Power Engineering Society, Introductory technology course 34: Water Quality and Chemical Management in Thermal and Nuclear Power Plant, 2008
3. Zaitsu. N, Energy Conservation through Change of Boiler Feedwater Treatment Method at Shinkokura Power Station Unit No. 5, Journal of Japan Boiler Association, No. 312, 2002
4. Tsubakizaki. S, Learn from the Experts “Cycle Chemistry” Part 2, The Journal "The Thermal and Nuclear Power", Vol. 59 No. 1, 2008
5. Tsubakizaki. S, Subjects and Countermeasures for Oxygenated Treatment, 20th Anniversary of Oxygenated Feed-water Treatment for Boilers in Japan, 2010
6. Takada. M, Manjo. S, Asada. H, Consideration of Countermeasures for Powder Scale Deposit Problems in CWT Operation Plants, Conference Proceedings of Thermal and Nuclear Power, 2011