Improved Reliability of High-AVT (High-pH Water Treatment) Application to Combined Cycle Plants

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Generally in the water treatment of combined cycle plants, ammonia and hydrazine are used in the feedwater system and phosphates are used in the boiler system. However, in Mexico, the Tuxpan No. 2 and No. 5 power plants have adopted "High-AVT (high-pH water treatment)," in which ammonia is used to set the pH of feedwater higher than the conventional level, requiring no phosphates in the boiler system. Tuxpan No. 2 power plant started commercial operations in 2001. Since then, more than 10 years have passed with no problems having been found during equipment inspections. In response to such good operational results, we will introduce high-AVT as an option for the water treatment of combined cycle plants.

1. Introduction

Mainly for the water treatment of combined cycle plants, ammonia (NH3) and hydrazine (N_2H_4) are used in the feedwater system and phosphates are used in the boiler system.

In order to prevent the alkali corrosion caused by excessively injected or concentrated phosphates and also reduce the operator's workload, however, the Tuxpan No. 2 and No. 5 power plants (Mexico) adopted "high-AVT (high-pH water treatment)," which has been used in nuclear power plants. In this water treatment, ammonia is used to set the pH of feedwater higher than the conventional level, making phosphate boiler water treatment unnecessary.

High-AVT has been used in five combined-cycle plant units that we installed overseas. The operational results are good, as the high-AVT plant operation has continued without problems for more than 10 years since the initial application. This report provides a summary.

2. Outlines of power plants and water quality control facilities

Figure 1 shows the location of the Tuxpan No. 2 and No. 5 power plants. The Tuxpan power plants are situated in a suburb of Tuxpan, Veracruz, approximately 250 km to the northeast of Mexico City. Most of the electric power generated is transmitted to the capital (Mexico City).

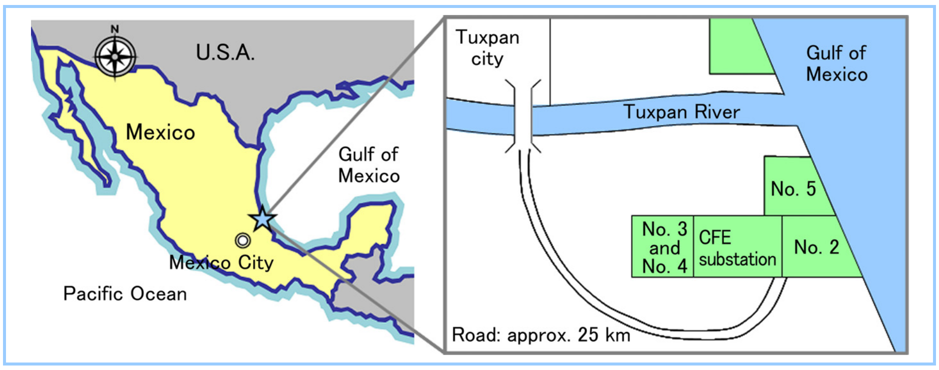

Figure 1 Location of the Tuxpan No. 2 and No. 5 power plants

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Exterior views of the Tuxpan No. 2 and No. 5 power plants are shown in **Figure 2**, and their major equipment specifications are listed in **Table 1**. Both are combined cycle plants with a power output of 495 MW and are equipped with a heat recovery steam generator (HRSG) that is of a horizontal triple-pressure design with reheat.

Tuxpan No. 2 power plant   Tuxpan No. 5 power plant

Figure 2 Exterior views of the power plants

Table 1 Major specifications of equipment (Tuxpan No. 2 and No. 5 power plants)

Plant	Tuxpan No. 2 power plant	Tuxpan No. 5 power plant
Operating company	Electricidad Aguila de Tuxpan (EAT)	Electricidad Sol de Tuxpan (EST)
Power generation method	Combined cycle (thermal) system	
Plant output	495 MW	
Plant configuration	2-on-1 GTCC	
Gas turbine type	M501F	
Steam turbine type	TC2F-29.5	
HRSG type	Reheating, triple-pressure, horizontal, natural circulation	
Fuel	Natural gas, oil	Natural gas
Manufacturer	Mitsubishi Heavy Industries, Ltd.	
Commencement of operations	December 2001	September 2006

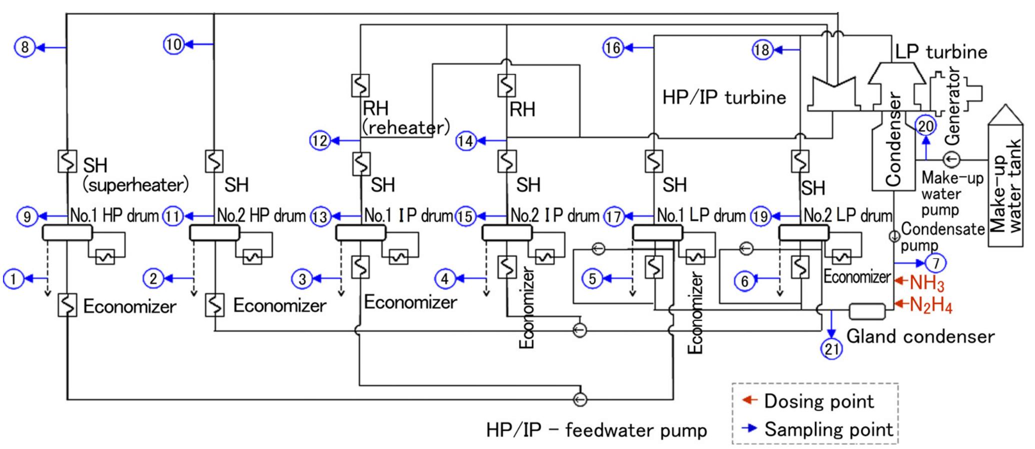

Figure 3 Schematic diagram of the system: chemical dosing and sampling points

Figure 3 is a schematic diagram of the system (with an indication of points for chemical dosing and sampling). **Table 2** gives the water-quality monitoring devices installed at each sampling point. **Figures 4** and **5** show photographs of the sampling rack and dosing equipment, respectively (both taken at the No. 5 power plant).

In this HRSG system configuration, LP drum water is fed into the IP and HP drums. Ammonia and hydrazine are injected at the outlet of the condensate pump.

With regard to water-quality control, analytical devices were installed for continuous monitoring measurements (pH, electrical conductivity, cation conductivity and dissolved oxygen), while analytical devices were not installed for the items that can be manually measured for routine control (hydrazine and silica).

Table 2 Sampling points and installed water-quality monitoring devices

No.	Sample name	pH	Electrical conductivity	Cation conductivity	Dissolved oxygen	Grab Sampling
1	No. 1 HP drum water	○	○	○		○
2	No. 2 HP drum water	○	○	○		○
3	No. 1 IP drum water	○	○	○		○
4	No. 2 IP drum water	○	○	○		○
5	No. 1 LP drum water	○	○			○
6	No. 2 LP drum water	○	○			○
7	CP outlet		○	○	○	○
8	No. 1 HP steam			○		○
9	No. 1 HP saturated steam					○
10	No. 2 HP steam			○		○
11	No. 2 HP saturated steam					○
12	No. 1 IP steam			○		○
13	No. 1 IP saturated steam					○
14	No. 2 IP steam			○		○
15	No. 2 IP saturated steam					○
16	No. 1 LP steam			○		○
17	No. 1 LP saturated steam					○
18	No. 2 LP steam			○		○
19	No. 2 LP saturated steam					○
20	Make-up water		○			○
21	Discharge of gland condenser	○	○	○	○	○

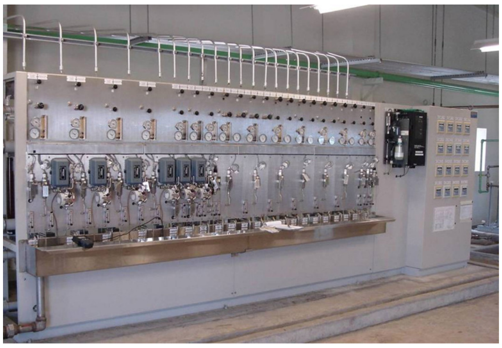

Figure 4 Sampling rack (taken at the No. 5 power plant)

Figure 5 Dosing equipment (taken at the No. 5 power plant)

3. Plant water treatment methods

3.1 Methods of water treatment for combined cycle plants

Table 3 is a list of water treatment methods used in combined cycle plants.

Table 3 List of water treatment methods used in combined cycle plants

No.	Water treatment method: Feedwater	Water treatment method: Boiler water	Dosing chemicals: Feedwater: NH_3	N_2H_4	O_2	Dosing chemicals: Boiler water: Na_3PO_4	Na_3PO_4+ Na_2HPO_4	NaOH	Note
1	AVT(R)	PT	○	○	—	—	○	—	Used in domestic HRSGs
2	AVT(O)	PT	○	—	—	—	○	—	Verification test using an actual domestic plant under way
3	AVT(O)	PC	○	—	—	○	—	○ May be used in conjunction	IAPWS[*1] guidance
4	AVT(O)	CT	○	—	—	—	—	○	IAPWS guidance
5	OT (CWT)		○	—	○	—	—	—	Need to install a condensate demineralizer
6	High-AVT(O)	PT	○	—	—	—	○ (HP : —)	—	FAC, hydrazine-free (See papers published by KEPCO)
7	High-AVT(R)		○	○	—	—	—	—	Used in the Tuxpan power plants, Mexico

[*1] IAPWS stands for the International Association for the Properties of Water and Steam.

AVT(O): All Volatile Treatment (Oxidizing conditions)
AVT(R): All Volatile Treatment (Reducing conditions)
PT: Coordinated Phosphate Treatment
PC: Phosphate Continuum
CT: Caustic Treatment
OT: Oxygenated Treatment

The combination of water treatment methods given in No. 1 is AVT(R) for feedwater (all-volatile treatment with hydrazine in use) and PT for boiler water (phosphate treatment using Na_3PO_4 and Na_2HPO_4), which has been mainly used in commercial combined-cycle plants in Japan. In No. 2, feedwater is treated by AVT(O) (all-volatile treatment without the use of hydrazine) and boiler water by PT. In response to the recent designation of hydrazine as a "mutagenic substance" and the consequent demand for the realization of hydrazine-free water treatment, verification testing for No. 2 is currently under way using an actual domestic plant.

The combinations shown in No. 3 to No. 5 are mainly used in overseas plants. Particularly in No. 5, there was a case in which a plant with a once-through boiler being installed in the HRSG high-pressure system adopted it for the oxygenated treatment (OT) of feedwater/boiler water.

In No. 6, feedwater is treated by high-AVT(O), which represents hydrazine-free all-volatile treatment in addition to the use of feedwater with a high pH, while boiler water is treated by PT. Based on the water treatment method used in No. 2, No. 6 is characterized by an increased amount of ammonia injection and feedwater with a higher pH. Verification testing using an actual plant has been conducted by Kansai Electric Power Co. Inc. (KEPCO) since 2008.

Both feedwater and boiler water are treated by high-AVT(R) in No. 7. High-AVT(R) denotes all-volatile treatment with hydrazine and the use of feedwater with a high PH, and has been commercially used in Tuxpan No. 2 power plant since it commenced operation in December 2001. As the pH level can be maintained sufficiently high only by the injection of ammonia into the feedwater, the boiler water is not dosed with phosphates.

3.2 High-AVT

High-AVT is an all-volatile treatment method for feedwater with a pH level exceeding the Japanese feedwater quality control standards (upper limit: pH 9.7) provided by JIS B 8223:2006, and is mainly used in nuclear power plants.

Figure 6 shows the relationship between pH levels and flow-accelerated corrosion (FAC) rates (dissolution of iron). As higher pH levels decrease the rate of FAC, the thinning of pipe walls caused by FAC is expected to be suppressed.

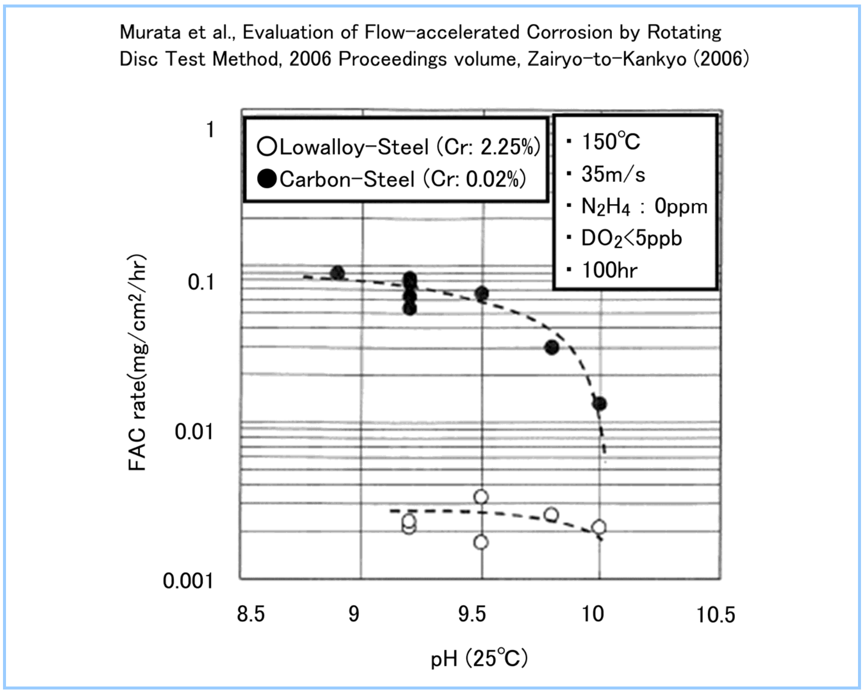

Figure 6 Relationship between pH levels and FAC rates (iron dissolution)

3.3 Criteria for water quality control

Based on the estimation of ammonia balance, the water quality control criteria (for the No. 5 power plant in **Table 4**) were determined by evaluating/verifying the data obtained through the plant's test operations (the sample Nos. correspond to the sampling point Nos. in Figure 3).

In high-AVT, the ammonia levels are approximately 10 times higher than the conventional JIS method, thus quickly exhausting ion-exchange resins in the cation conductivity detector.

However, the increased quantities of loaded ion-exchange resins and the use of resins with a pH indicator function by changing the color can successfully reduce the frequency of resin replacement.

Table 4 Water quality control criteria

Sample No.	Sample name	pH	Electrical conductivity	Cation conductivity	Dissolved oxygen (DO)	Iron (Fe)	Hydrazine (N_2H_4)	Silica (SiO_2)	Note
		at 25℃	μS/cm	μS/cm	μg/l	μg/l	μg/l	mg/l	
1, 2	HP drum water	9.0～10.0	2～28	≦12				≦0.5	
3, 4	IP drum water	9.0～10.0	2～28	≦12				≦20	
5, 6	LP drum water	9.5～10.1	8～35					≦0.5	
7	CP outlet	9.0～10.2	2～44	≦0.5	≦20 (≦7)				
8-11	HP steam/ saturated steam			≦0.3				≦0.02	
12-15	IP steam/ saturated steam			≦0.3				≦0.02	
16-19	LP steam/ saturated steam			(*)				≦0.02	*Alarm level >0.5μS/cm
20	Make-up water							≦0.02	
21	Discharge of gland condenser	9.8～10.2 (10)	10～44 (30)	≦0.5	≦20 (≦7)	≦20	≧10 (20～30)		

( ): Target value

4. Data from actual plant operation

4.1 Water quality during operation

Figure 7 shows both the target and measured pH values of each component of the system (the measured pH values were obtained at the No. 2 and No. 5 power plants in August 2007, and were calculated from data on electrical conductivity and ammonia concentrations).

The target pH value for feedwater is 10.1. In the No. 2 and No. 5 power plants, feedwater is maintained at a pH level of 10.2 and 10.1, respectively. This allows for a pH level of 9.5 or higher throughout the system, verifying that the water quality during operation is controlled as designed.

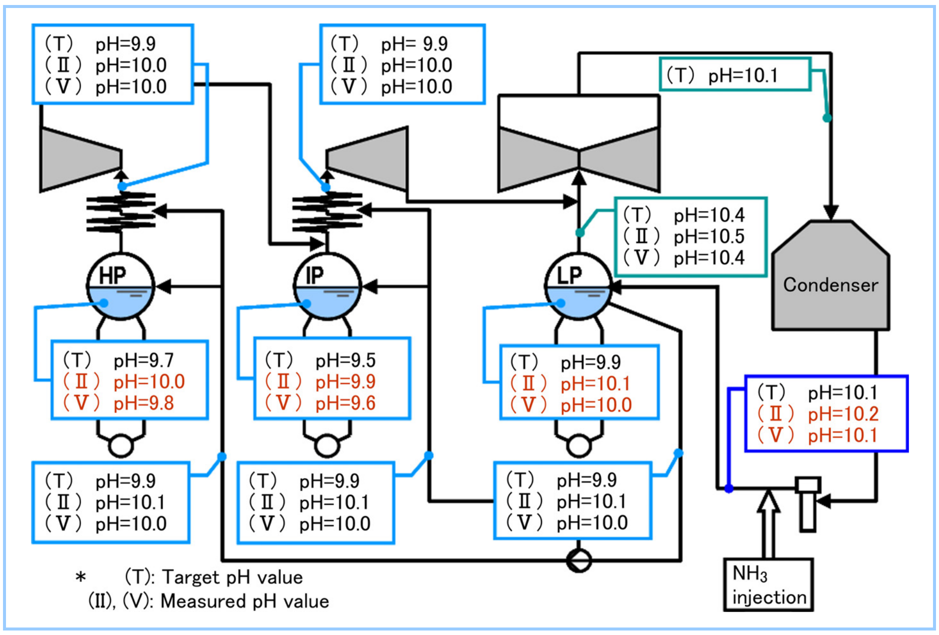

Figure 7 Target and measured pH values of each system component (obtained at the No. 2 and No. 5 power plants in August 2007)

4.2 Results of equipment inspections (No. 2 power plant)

In the No. 2 power plant, the insides of the HRSG drums were inspected in August 2007, which is 6 years after the start of commercial operations. No abnormalities such as corrosion were found. **Figure 8** shows the LP turbine during overhaul inspection, which also indicated no abnormalities.

With regard to the application of high-AVT to existing or newly-built combined cycle plants, sufficient preliminary assessment and demonstration using an actual plant are indispensable, because each plant will be operated under different conditions in terms of factors such as HRSG pressure, feedwater system configuration, operational schedule (continuous operation or start-up/shut-down). However, the application is sufficiently viable.

Last-stage rotating blade of LP steam turbine   Last-stage stationary blade of LP steam turbine

Figure 8 Low-pressure steam turbine during overhaul inspection (No. 2 power plant, August 2007)

5. Conclusions

High-AVT (high-pH water treatment) has been used in overseas nuclear power plants and was adopted by the Tuxpan No. 2 and No. 5 power plants. No problems have been caused throughout the course of plant operation. With the application of high-AVT, only ammonia is used to manage the plant during outages, and thus advantages such as shortened start-up times can be expected.

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