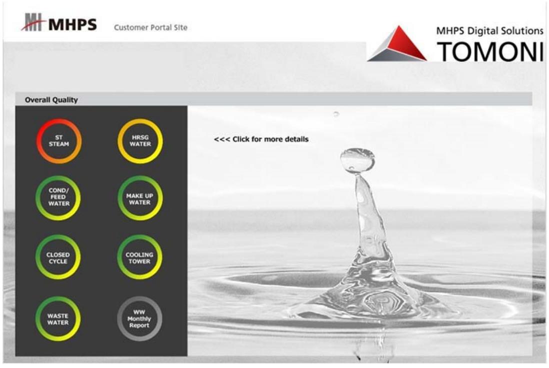
Development of Water Quality Diagnostic System Contributed to Reduce Environmental Impact and Operational Costs



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In thermal power plants, water treatment is conducted to prevent problems such as corrosion in the boiler/turbine systems, scale formation/deposition, and carryover to the turbine. Most plants have been in operation without incident, with the water quality criteria that were established based on reference standards such as the Japanese Industrial Standards (JIS).[1] To enable the early detection of signs that indicate the possible occurrence of a serious incident in the future, we have developed the "water quality diagnostic system." The execution of "appropriate water quality control" is considered important not only for decreased amounts of chemicals in use and wastewater to lower the environmental impact, but also from an economical point of view (such as shortening of plant startup time and operational cost reduction).

1. Introduction

The purpose of thermal power plant water treatment is to prevent problems such as corrosion in the boiler/turbine systems, scale formation and deposition, and the consequent carryover to the turbine. In recent years, there have been cases of abnormal water quality affecting the boiler/turbine systems extensively, which were caused by mismanaged operation or inadequate handling of the situation when, for example, aging facilities failed to maintain the required water quality or cooling water (seawater) leaked in the condenser. These resulted in serious problems such as leakage from boiler steam generating tubes. The causes of such water quality abnormalities can lie in raw water or facilities to supply make-up water (demineralized water) to the plant, rather than in the main water system. Therefore, to enable the early detection of signs of future serious incidents, we have developed the "water quality diagnostic system" with extended coverage for water quality monitoring, which will be presented in this report. Once installed, the system can be very useful for maintaining/realizing long-term plant soundness and performance, as well as for decreasing the amounts of chemicals used and wastewater to lower the environmental impact. It can also improve the plant economics in terms of shortening the plant startup time, reducing operational costs, etc.

2. Importance of water quality control in thermal power plants

Figure 1 is a typical diagram of water-related systems used at thermal power plants.[2] In the main water system, water circulates starting as condensate, followed by boiler feedwater, boiler water (in the boiler) and steam (in the turbine), and finally returning to condensate. The water that is lost during circulation is compensated for by supplying make-up water. In addition to the main system, the plant can also have the following water-related facilities: (1) the make-up water treatment system by which raw water such as industrial water is treated to produce/supply highly-purified water, (2) the chemical dosing and water-quality monitoring system through which

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water quality is monitored and adjusted to keep water non-corrosive, (3) the condensate treatment system in which circulating water in the plant is purified (mainly installed in once-through boilers) and (4) the wastewater treatment system to purify wastewater from the equipment and facilities of the plant.

Figure 2 shows water-induced problems and the sites where they occur. In recent years, there have been an increasing number of incidents in which the causes are contamination by impurities such as ion-exchange resins and chemicals from the demineralizer (e.g., hydrochloric acid). Some of them pertained to the affected properties of raw water as a result of contamination by organic compounds or aging water treatment facilities. There are also other water-induced or related problems such as pipe wall thinning due to flow-accelerated corrosion (FAC) and an increased drop in the feedwater heater pressure due to scale deposition. These issues indicate the increasing importance of water quality control.

Figure 3 gives a causality diagram regarding the possible causes of serious incidents and (early signs of) abnormalities in water quality which are detectable by monitoring and can be indicated by water quality diagnosis results.[3] Collation and analysis of the obtained data can prevent such serious incidents from occurring.

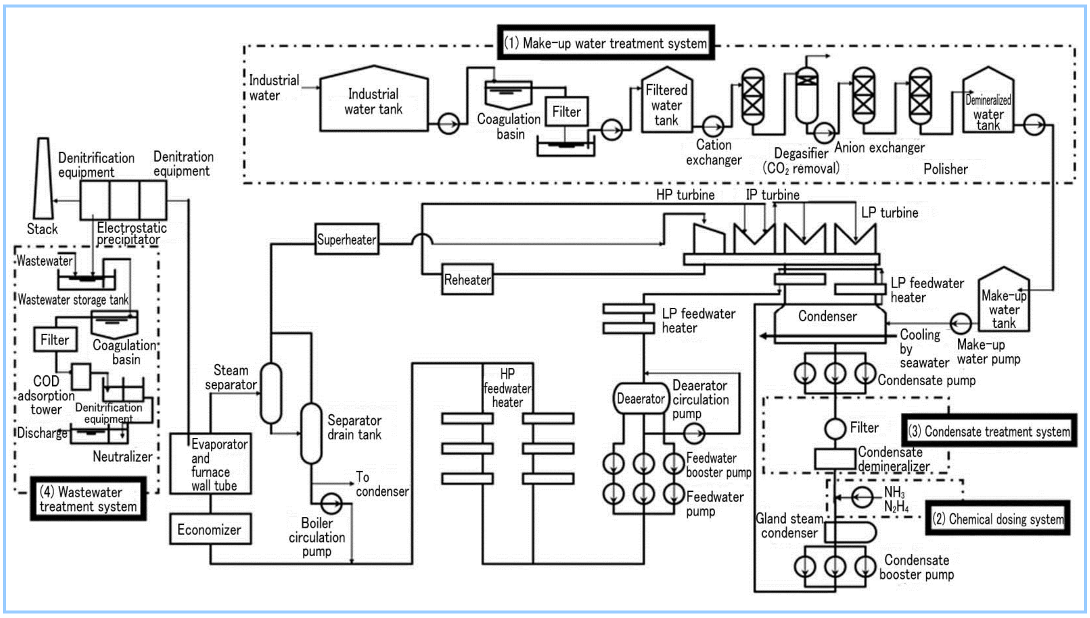


Figure 1 A typical water/steam system at thermal power plants

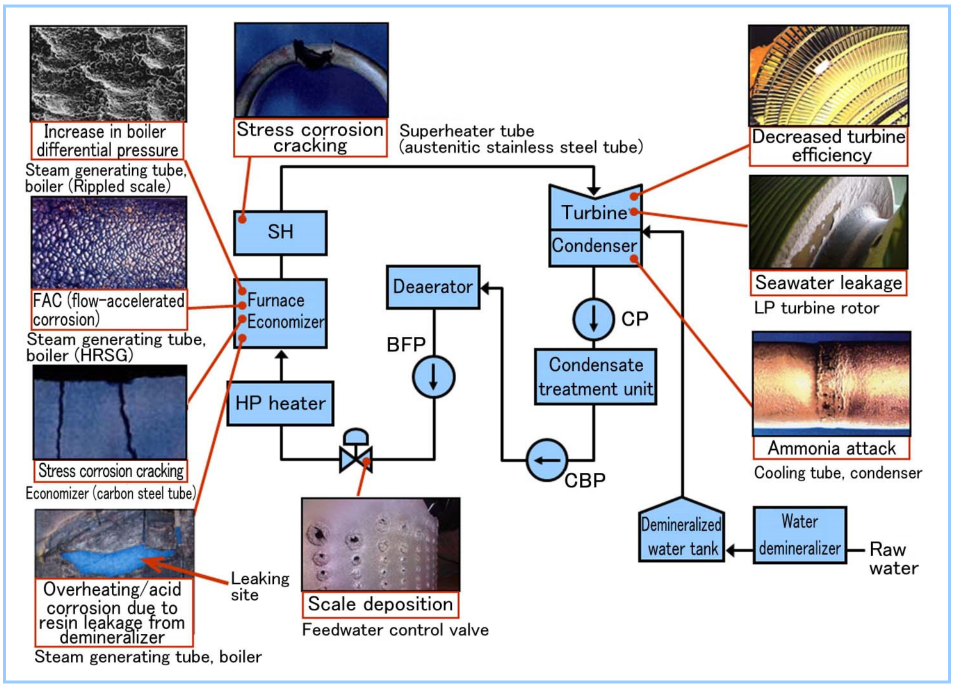


Figure 2 Water-induced problems and their occurrence sites

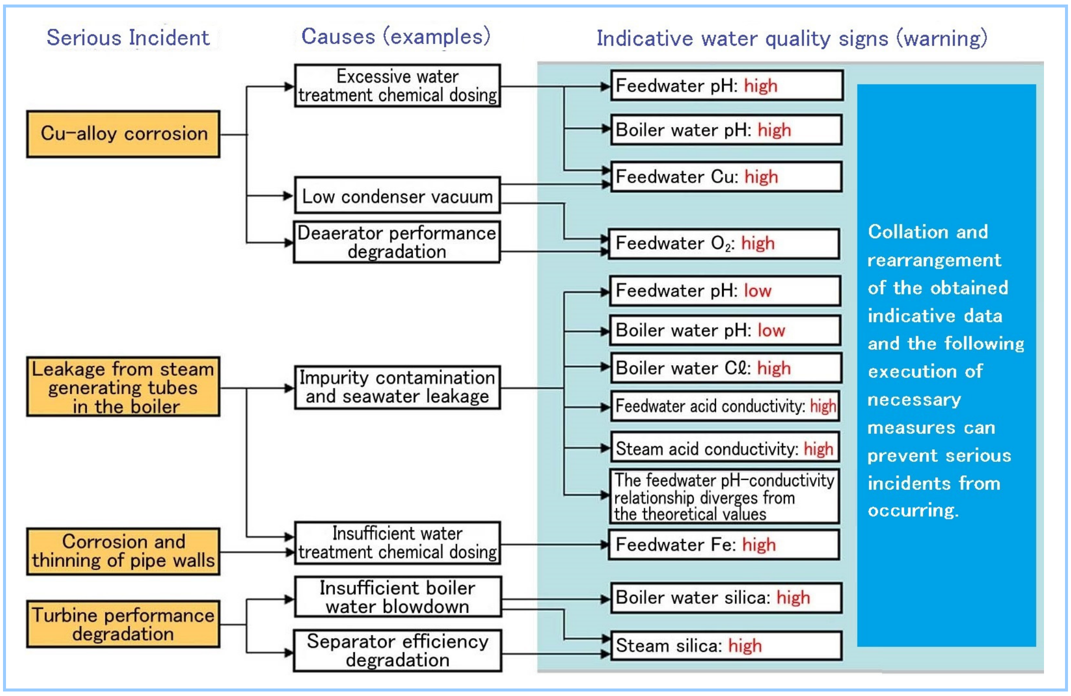


Figure 3　Incidents predictable by water quality monitoring and diagnosis results (example)

3. Brief description of our water quality diagnostic system

Figure 4 lists some of the plant water quality monitoring and diagnosis items. To prevent water-induced or related problems in thermal power plants, water quality diagnosis is conducted by collating and analyzing the data such as that collected by water quality monitoring devices, operational data (i.e., flow rate, pressure and temperature) and equipment-specific information (i.e., degree of valve opening and differential pressure), mainly in relation to (1) the boiler condensate/feedwater system, (2) the steam system, (3) the make-up water system (demineralized water production facility), (4) the circulating water system and (5) the wastewater treatment system. A simplified schematic of the water quality monitoring and diagnosis system is given in **Figure 5**. Principally provided as a Cloud-based service, our water quality diagnosis system can predict, based on (the signs of) abnormalities in water quality, serious incidents that are likely to happen if left unattended. It can also suggest additional inspections necessary to formulate appropriate measures and recommend the examination items to be carried out during the next regular inspection. The water quality simulator, which can be connected via the intranet, is installed to show the optimal water quality conditions, provide training for operational management at the time of abnormal water quality, and assist with daily water quality control.

Figure 4　Plant water quality monitoring and diagnosis items (example)

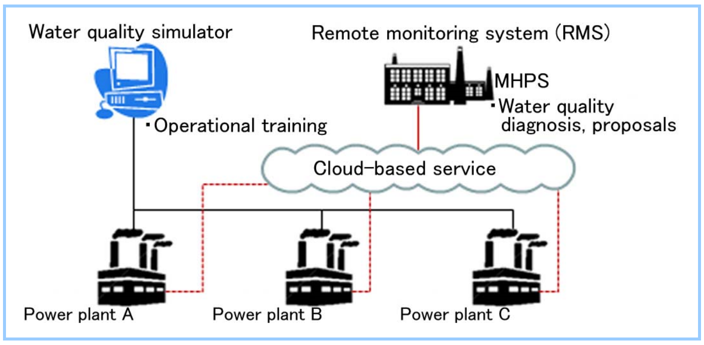


Figure 5 Schematic of water quality monitoring and diagnosis system (example)

3.1 Water quality diagnostic system for boiler condensate/feedwater and steam systems

Typical examples of water quality monitoring data analysis results are presented in **Figure 6**, while **Figure 7** shows an example of plant water quality diagnosis results. The diagnosis is made based on the reference criteria by assigning a rank from A to E, and a report similar to a medical checkup (as shown in Figure 7) will be composed. If required, additional inspections will be recommended. The make-up water system, which can be associated with abnormalities in water in the boiler condensate/feedwater and steam systems, is also assessed. Thus, causative factors and appropriate measures can be analyzed and considered simultaneously.

3.2 Water quality optimization in the circulating water system

Figure 8 illustrates the concept of water quality optimization for the circulating water system. The prevention of problems and better economy can be realized by optimizing the amounts of water and chemicals used through the water quality diagnosis and assessment system. Specifically, to keep the water quality optimized accordingly in response to seasonal fluctuations in raw water quality and varying degrees of cooling water cleanliness, the degree of valve opening for cooling tower blowdown is adjusted so that the amount of blowdown from the cooling tower and the chemical dosing pump discharge rate can be regulated. Less blowdown from the cooling tower results in less wastewater, which means the wastewater treatment system requires less load. This can eventually lead to a lower environmental impact. The use of less make-up water for cooling water management and decreased amounts of chemicals for water treatment can also contribute to operational cost reduction.

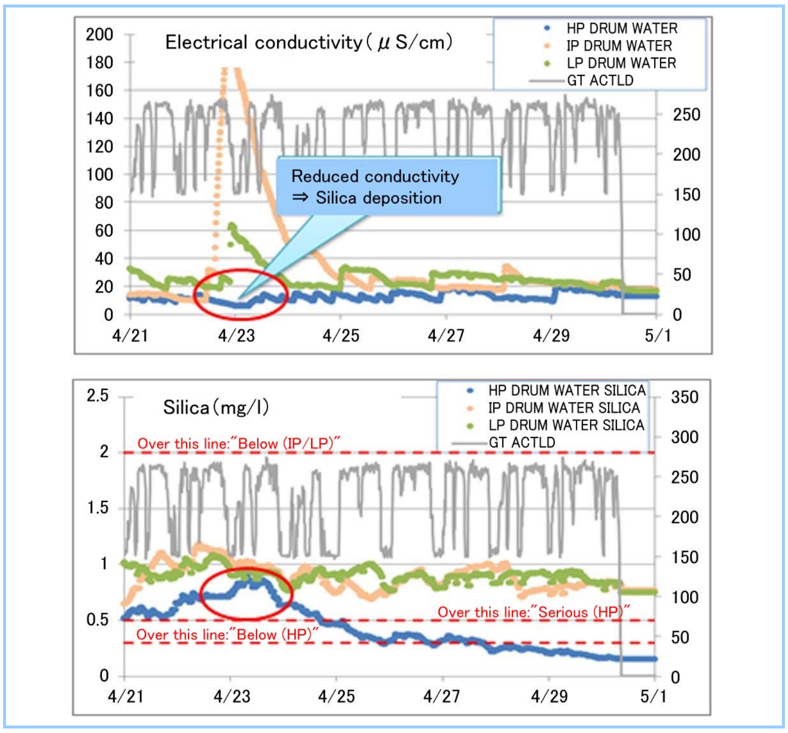
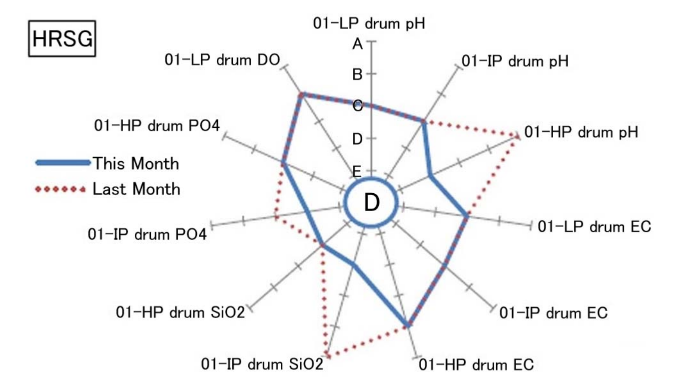


Figure 6 Water quality monitoring data analysis results (example)



	Reference criteria
A	No abnormalities detected. Maintain the current conditions.
B	Some abnormalities detected.
C	A couple of small problems detected. Regular check−ups are recommended.
D	Serious problems detected.
E	Many serious problems detected. Measures are urgently required.

Figure 7　Plant water quality diagnosis results (example)

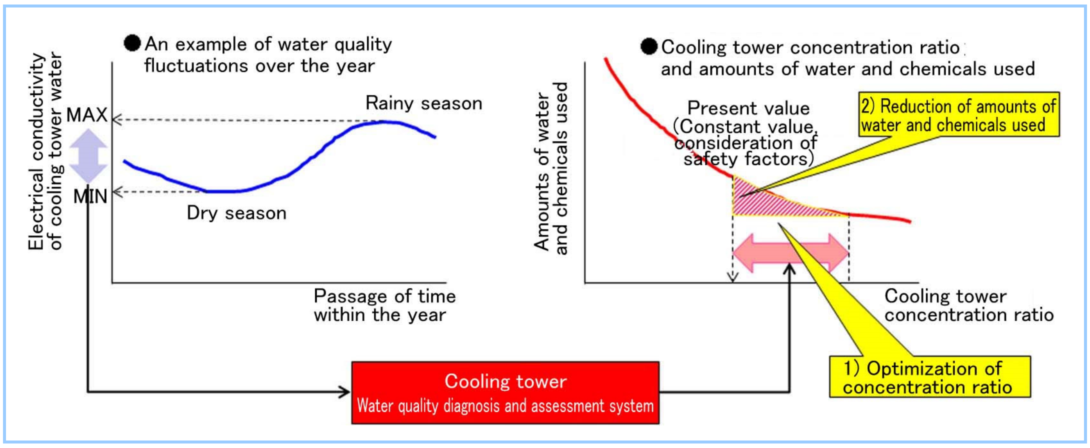


Figure 8　Concept image of water quality optimization for the circulating water system

4. Case examples of abnormal deviation correction based on water quality diagnosis

Given below are examples of cases in which the water quality diagnosis (i.e., monitored water quality data and operational data analyses) enables abnormal deviation to be corrected.

(1)　Impurity contamination

An example of water quality diagnosis results is given in **Figure 9**, in which the relationship between feedwater electrical conductivity and pH is plotted, along with the theoretical pH as a function of electrical conductivity (represented by the black line) and those taking the pH meter measurement error of ±0.1 into consideration (the red and blue lines). As the measured pH values fall within the target water quality range, the conventional monitoring system would conclude no abnormalities detected in this regard and proceed without a warning. With the new system, however, the analysis results can indicate the diverging tendency of pH-conductivity relationship from the theoretical values. Especially regarding the data out of the ±0.1 range, inspection will be recommended because there is a possibility of impurity contamination into feedwater.

Figure 10 lists some of the possible causes for deviation of the measured pH values from the theoretical pH values calculated from electrical conductivity. Such deviation can occur, as a result of (1) improper calibration or deterioration of pH meters, (2) contamination of organic compounds from make-up water, (3) slight leakage of Na from make-up water (demineralizer regeneration chemical: NaOH), (4) slight leakage of Cl from make-up water (demineralizer regeneration chemical: HCl) and (5) seawater leakage (in small or large quantities). Additional inspections, which can be recommended in accordance with the water quality diagnosis results, include microanalysis of feedwater (e.g., Na and Cl), organic compounds in the make-up water system, corrosive factors (e.g., Na and Cl) and examination of presence/absence of seawater leakage (e.g., chemical analysis, and leakage inspection).

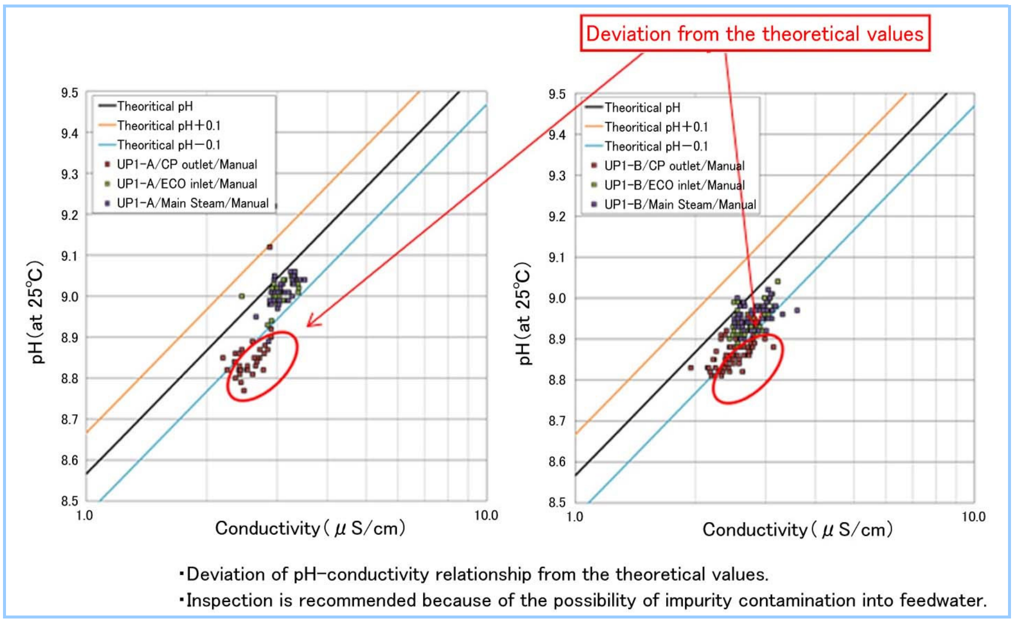


Figure 9 Water quality diagnosis results (example)

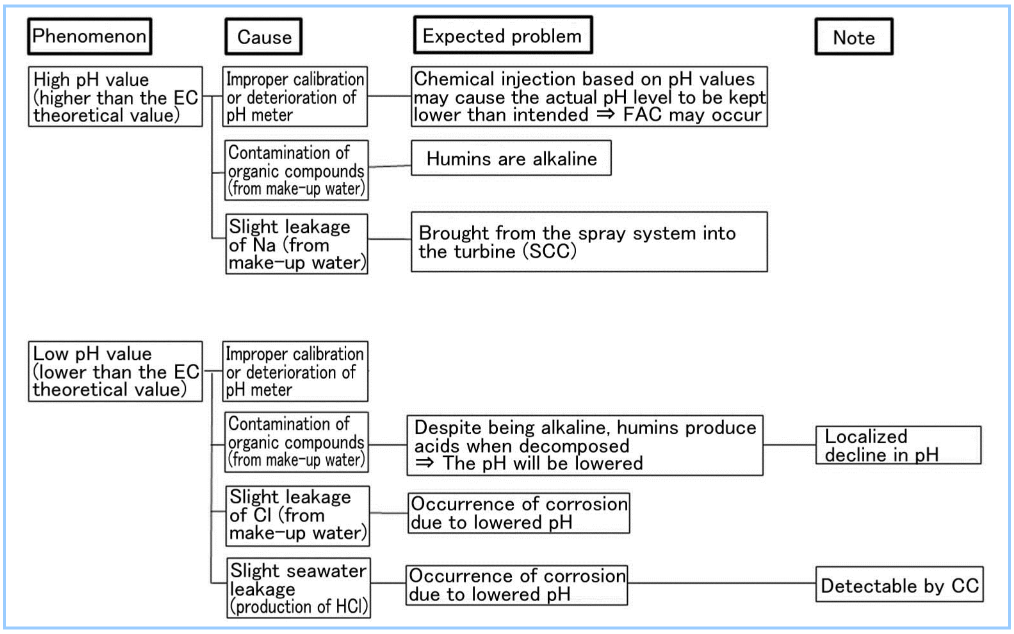


Figure 10 Possible causes for deviation of the measured pH values from the theoretical pH values calculated from electrical conductivity (example)

(2) Increased pressure drop caused by scale deposition on the feedwater heater

Figure 11 shows a water quality diagnosis result and the following adjustments for deviation correction, in response to an increased high-pressure heater differential pressure. The increased differential pressure due to scale deposition on the high-pressure heater is detected at the time of issuing a warning or during a regular inspection overhaul. The problem will be addressed by removing scale with highly-pressurized water (jet cleaning) on a regular basis.

In this case, the upward trend in differential pressure is kept monitored, and water quality is optimized while the plant is in operation (water quality conditions settings were based on past actual data) in such a way that the pressure that has been increased can be offset (stopping the rise). Even before a warning is issued, the situation is successfully handled without shutting down the plant, and scale is removed during regular inspections.

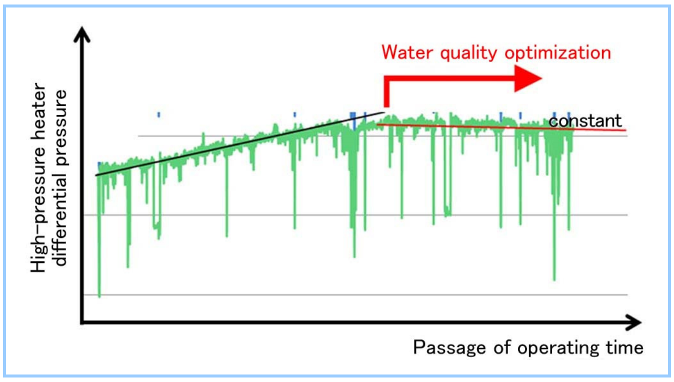


Figure 11 A case of successful correction of abnormal deviation based on water quality diagnosis results (increased high-pressure heater differential pressure)

5. Conclusion

As a means of the early detection of signs of future serious incidents based on the water quality control data of thermal power plants, we have developed the “water quality diagnostic system.” Plant water quality diagnosis can prevent the occurrence of serious incidents, as well as help maintain long-term plant soundness and performance. The system can be very useful for lowering the environmental impact by cutting the amounts of chemicals used and wastewater, while it can also improve the plant economics in terms of shortening the plant startup time, reducing operational costs, etc.

We will build a diagnosis system that can further contribute to reducing environmental impact and operational costs, by incorporating new sensor data such as pipe wall thinning monitoring (thin-film UT) and chemical analysis results that are not stored/managed by plant computer systems.

References

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