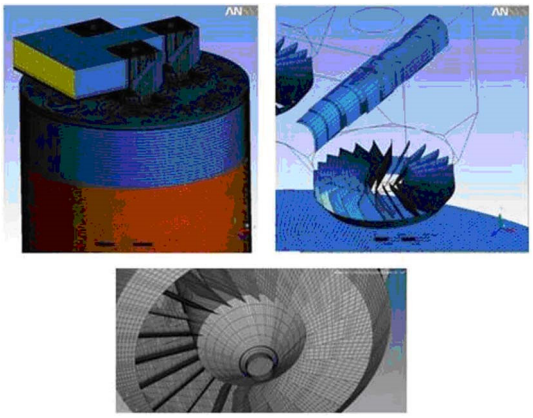
Development of Wastewater Spray Dryer (WSD) for Desulfurization Plants



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In recent years, as the idea of Best Available Techniques (BAT) is widely accepted in various industries, regulations on wastewater (especially desulfurized wastewater) from thermal power plants are becoming stringent mainly in Europe and the U.S., increasing the demand for dry flue gas treatment technology and zero wastewater technology. Mitsubishi Hitachi Power Systems, Ltd. (MHPS) has commercialized several zero wastewater technologies such as the Wastewater Evaporation System (WES) and the Waste Water Concentration and Solidification System (WCS). This report summarizes the technological development of our new zero wastewater technology for thermal power plants (i.e., the Wastewater Spray Dryer or WSD), which is designed based on the temperature reducing tower of our proven refuse incinerator.

1. Introduction

In recent years, the U.S. and Europe are taking on the idea of BAT, which is similar to our concept of "Practically Best Technology," and have started implementing environmental conservation measures that are tailored to local environmental situations. Along with this trend, more stringent regulations on flue gas and wastewater from thermal power plants are being put into effect around the world. The major flue gas regulations in the U.S. are the Mercury and Air Toxics Standards (MATS).

When it comes to pollutant-containing wastewater, discharge into a river or territorial waters is controlled by the Clean Water Act (CWA), setting the water quality standards. The Act was enacted as the Federal Water Pollution Control Act in 1948. Through the drastic changes in 1972 and minor alterations in 1977, as well as the later amendments of related ordinances, it has prescribed the pollutant standards for the protection of human beings, wild animals, aquatic life and other organisms. The U.S. Environmental Protection Agency (EPA) has issued more than 50 industrial guidelines (such as for power plants and ironworks) and, on a regular basis, updates or makes new guidelines. The Effluent Limitation Guidelines and Standards, which are EPA regulations to control the discharge of wastewater from industrial establishments, provide the criteria of technically removable pollutant quantities with the aim to maintain health and improve water quality.

In Europe, the European IPPC Bureau was organized to create opportunities for information exchange among experts in EU member countries and representatives of industrial/environmental groups, and the drafting of BAT reference documents (BREF). Nearly 30 BREF were thus prepared, which cover approximately 50 industrial categories and will be operative in 2016.

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2. Zero wastewater technology

The filtrate obtained after the dehydration of gypsum is a by-product of the wet desulfurization system. Normally, pollutants in the filtrate (such as heavy metals) are removed by coagulating sedimentation with the use of chemicals in the wastewater treatment system, and then the detoxified filtrate is discharged as wastewater. However, as mentioned above, the future enforcement of wastewater regulations is expected to increase the need for dry flue gas treatment technology and zero wastewater technology.

As a means of reducing the amount of wastewater (to achieve zero wastewater) from the flue gas desulfurization equipment, MHPS developed WES, in which wastewater from the wet flue gas desulfurization equipment is sprayed into flue gas at the inlet of the precipitator to evaporate the water in the wastewater using the heat of the flue gas, and the residual solids are collected by the precipitator (**Figure 1**). WES has been installed in 10 plants since 1980.

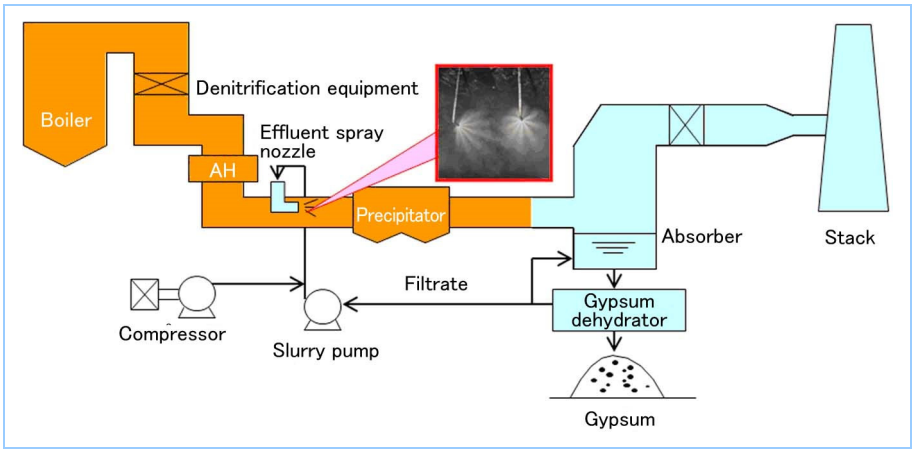


Figure 1 WES process flow

MHPS has developed a new treatment technology for zero wastewater, based on the temperature reducing tower that is a component of a refuse incinerator developed by Mitsubishi Heavy Industries Environment and Chemical Engineering Co., Ltd. This new technology employs WSD, characterized by the spray-drying of desulfurized wastewater. In this system, the heat for drying is derived from the high temperature of the flue gas which diverges from the upstream side of the air heater (AH). Therefore, when installed, WSD can be independent from the system of the main flue. The salts obtained after the drying of filtrate are collected by the downstream precipitator (**Figure 2**). In WSD, as evaporation/drying take place in the auxiliary process that branches away from the upstream side of AH, it can be easily cut off as a segregated sub-system. Therefore, unlike the aforementioned WES in which the main flue is involved in the process, WSD can be independently carried out when necessary.

Table 1 compares different types of wastewater treatment processes.

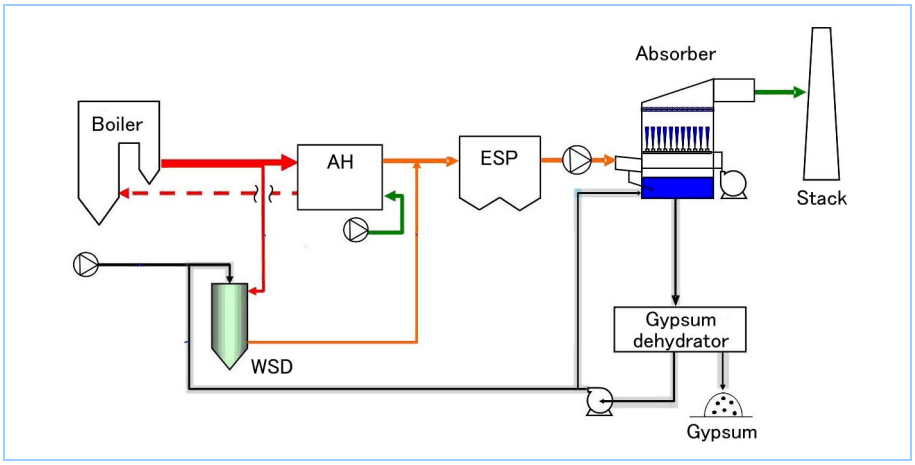
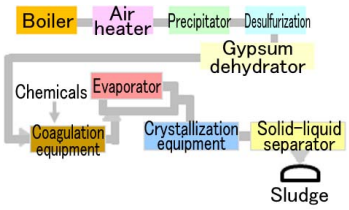
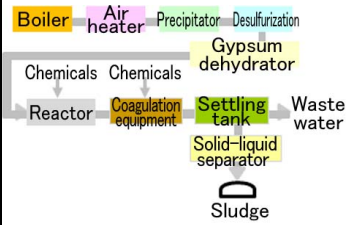


Figure 2 WSD process flow

Table 1 Process comparison

	New	Conventional	
	WSD process	Evaporation/solidification process	Wastewater treatment process
Process flow			
Features	[Pros] - Inexpensive facility/operational costs - No need for chemical/biological treatment - Small installation space - No need for continuous operation (bypass) - Able to manage high dissolved-salt levels [Cons] - Slightly-lowered power generation efficiency (≈0.5%) - Slightly-increased particulate matter levels in the precipitator (<5%)	[Pros] - Able to retrofit - Able to manage high dissolved-salt levels - Separation of all dissolved salts from water [Cons] - Large energy consumption - Need for chemical (pre)treatment - Expensive facility/operational costs	[Pros] - Proven operational performance [Cons] - Large installation space (unable to retrofit) - Need for chemical treatment (Future stringent regulations will necessitate biological treatment.) - Expensive facility/operational costs - Unable to manage high dissolved-salt levels

3. Pilot tests

Using the pilot test facility of Mitsubishi Heavy Industries, Ltd. Research & Innovation Center (**Figure 3**), the evaporation/drying properties of desulfurized filtrate were examined with WSD, and the design parameters necessary for a zero wastewater wet desulfurization system were obtained. As a result, it became possible to design WSD to meet the volume of wastewater on the scale of a desulfurization plant. **Figure 4** shows the scanning electron microscope (SEM) images of WSD dried salts. These salts take a shape similar to a seed husk with a hollow inside, and their diameter ranges between 10 μm and 60 μm. The moisture trapped in the hollow is the cause of the prolonged evaporation process. The dryer should be designed to overcome this problem. Calcium chloride ($CaCl_2$), which is a salt precipitated when desulfurized filtrate is dried, exhibits a strong deliquescent property. From the perspective of ensuring fluidity, therefore, it is important to understand the tendencies caused by varying salt concentrations and flow temperatures (**Figure 5**).

Figure 3 Pilot test facility (Mitsubishi Research and Innovation Center in Hiroshima)

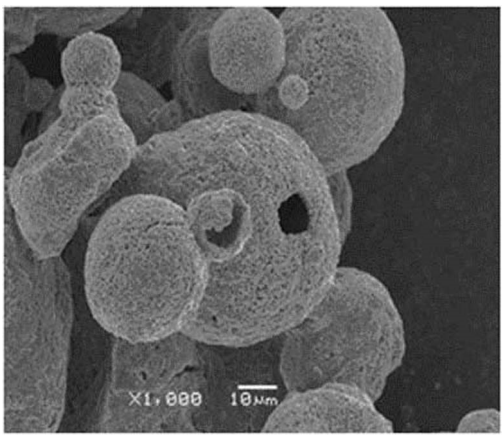


Figure 4 Observation of WSD dried salts (SEM)

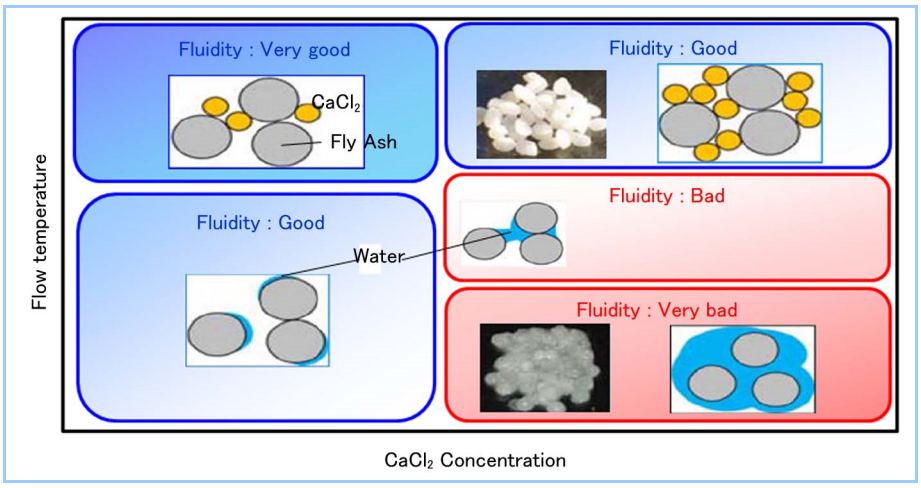


Figure 5 Change in dried salt fluidity under varying $CaCl_2$ level and flow temperature condition

4. Our direction in the future

In wet desulfurization with no wastewater, the key process to be successfully compliant with the recent stringent wastewater regulations lies in the stabilization of fuel-derived heavy metals contained in desulfurized wastewater (the prevention of elution). It is necessary to take suitable measures according to the types of heavy metals (**Figure 6**). Regarding arsenic (As), mercury (Hg) and tetravalent selenium (Se^{4+}), their immobilization is relatively easy, whereas hexavalent selenium (Se^{6+}) is difficult to immobilize. To inhibit the formation of Se^{6+}, it is effective to keep the oxidation reduction potential (ORP) within a certain range during operation (Reference (1)).

MHPS is currently examining the effects of a variety of agents such as additives to allow us to offer processes that can accommodate the requirements of the strengthened regulations.

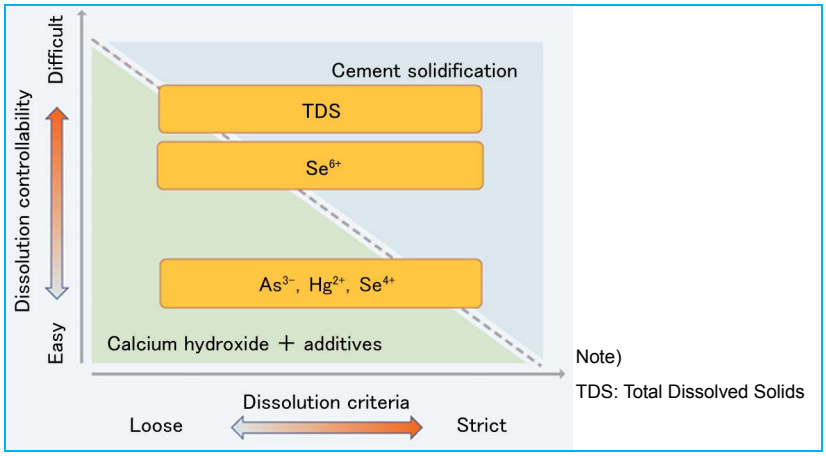


Figure 6 Dissolution controllability measures for heavy metals

5. Conclusion

Through component tests and pilot tests, we have established a zero wastewater process of wet desulfurization with WSD. The obtained findings are utilized in the calculation of computational fluid dynamics (CFD) for the process design. The long-term stability and reliability will be evaluated through demonstration tests. MHPS will continue to offer technologies that can meet the demands of strengthened regulations and fulfil the environmental responsibility that is of increasing importance.

Reference

1. Kikkawa, H. et al., Highly-Efficient Removal of Toxic Trace Elements and Particulate Matter in Flue Gas Emitted from Coal-fired Power Plants by Air Quality Control System (AQCS), Mitsubishi Heavy Industries Technical Review Vol. 52 No. 2 (2015) pp. 89-96