

Operation Results of IHI Flue Gas Desulfurization System - Phase 1 Units Nos. 1 & 2 (300 MW each) of Waigaoqiao Thermal Power Station for Shanghai Electric Power -

TSUMITA Yoshimitsu : General Manager, Basic Design Department, Power Plant Division, Energy Plants Operations

TODA Koji : Manager, Basic Design Department, Power Plant Division, Energy Plants Operations

ENDO Takumi : Basic Design Department, Power Plant Division, Energy Plants Operations

FUJINO Yoshihisa : Basic Design Department, Power Plant Division, Energy Plants Operations

IHI Flue Gas Desulfurization (FGD) System was completed in July 2006 for the two 300 MW coal-fired thermal power plants at Waigaoqiao, one of the largest-capacity power plants in Shanghai. This FGD system is the first to be constructed in Shanghai and is now operating smoothly and achieving superior SO₂ removal efficiency. This system applied the latest design and new technologies to cope with the stringent local environmental regulations as follows.

- (1) Spiral spray nozzle
- (2) Dry type limestone milling system
- (3) Pneumatic transportation system of limestone powder

These technologies can reduce the installation and running cost compared with a conventional type FGD system.

1. Introduction

Recently, Shanghai has rapidly developed as the center of the Chinese economy, and its demand for electric power grows every year. The large-capacity Waigaoqiao Thermal Power Station supplies about 20% of the total electric energy of the Shanghai area. It is the policy of the government of China, which will hold the Games of the XXIX Olympiad Beijing 2008 and World Expo 2010 Shanghai, to increasingly strengthen environmental controls. On such a background, Shanghai Electric Power decided on a policy to install flue gas desulfurization systems for Phase 1 Units Nos. 1 and 2 of Waigaoqiao Thermal Station for the first time in the Shanghai area to complete its environmental preservation measures.

Under such circumstances, our company, with many achievements and experiences in the field of flue gas desulfurization systems for coal fired power plants, delivered one set of flue gas desulfurization systems for the Phase 1 Unit Nos. 1 and 2 of Waigaoqiao Thermal Power Station as the newest wet type flue gas desulfurization systems using its accumulated technologies, completed all the work processes in July 2006, and delivered them to the customer. **Figure 1** shows

the overall view of the flue gas desulfurization system of Waigaoqiao Thermal Power Station.

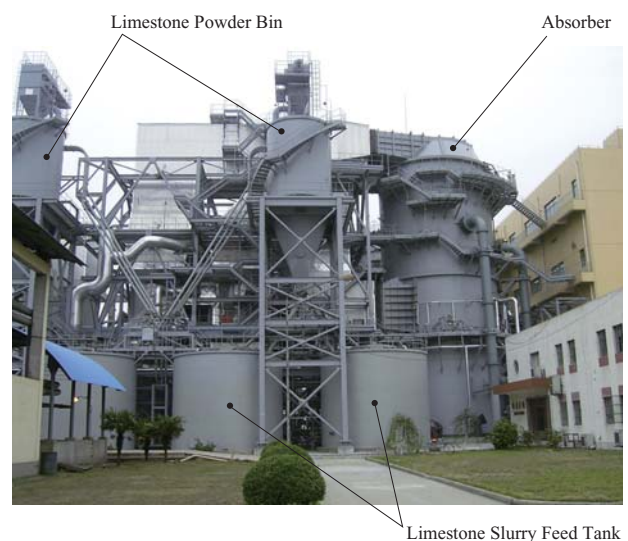


Fig.1 Overall view of FGD system of Waigaoqiao Thermal Power Station

2. Outline of phase 1 units Nos. 1 and 2 of Waigaoqiao thermal power station

The Phase 1 Units Nos. 1 and 2 of Waigaoqiao Thermal Power Station are outlined as follows.

Generator power	300 MW × 2
Boiler	
Type	Subcritical pressure forced circulation drum type
Fuel used	Coal
Evaporation	1 250 t/h/unit (at maximum continuous load)
Steam pressure	18.3 MPa
Steam temperature	538 °C /538 °C (main steam/reheat steam)
Combustion system	Single fuel firing by coal
Environmental preservation equipment	
Electrostatic precipitator (EP)	Low temperature electrostatic precipitator
Flue gas desulfurization system (FGD)	Wet type limestone-gypsum process

Waste water treatment system (WWTS)

Two-stage coagulation-sedimentation method/sand filter/neutralization process system

3. Wet type flue gas desulfurization system

3.1 Specifications

Main specifications are as follows. **Figure 2** and **Figure 3** show the general equipment arrangements.

Type	Wet-type limestone-gypsum process (simultaneous desulfurization and oxidation)
Capacity	
Flue gas flow rate (wet) at FGD inlet	1 220 000 m ³ _N /h (per boiler)
Flue gas temperature at FGD inlet	127 °C
SO ₂ concentration	
At FGD inlet	741 mg/m ³ _N (O ₂ concentration : 6% conversion value)
At FGD outlet	37 mg/m ³ _N or lower (O ₂ concentration : 6% conversion value)

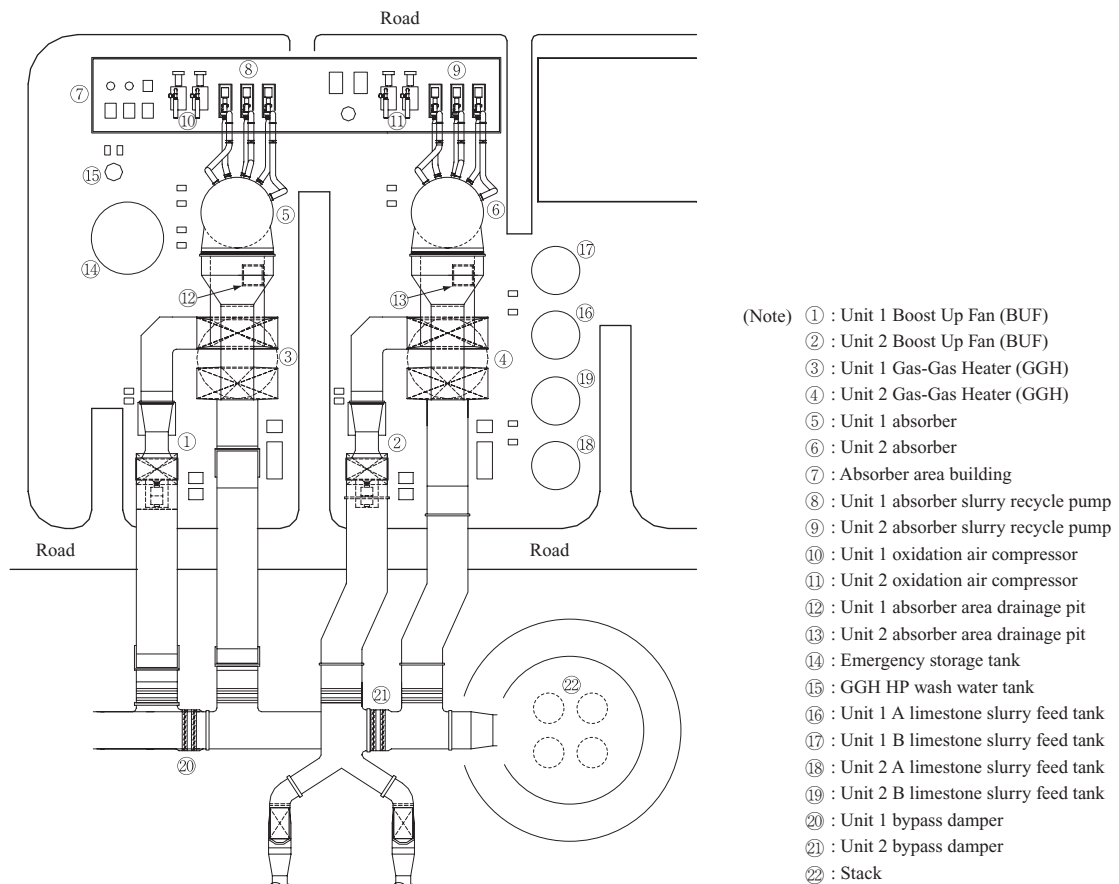
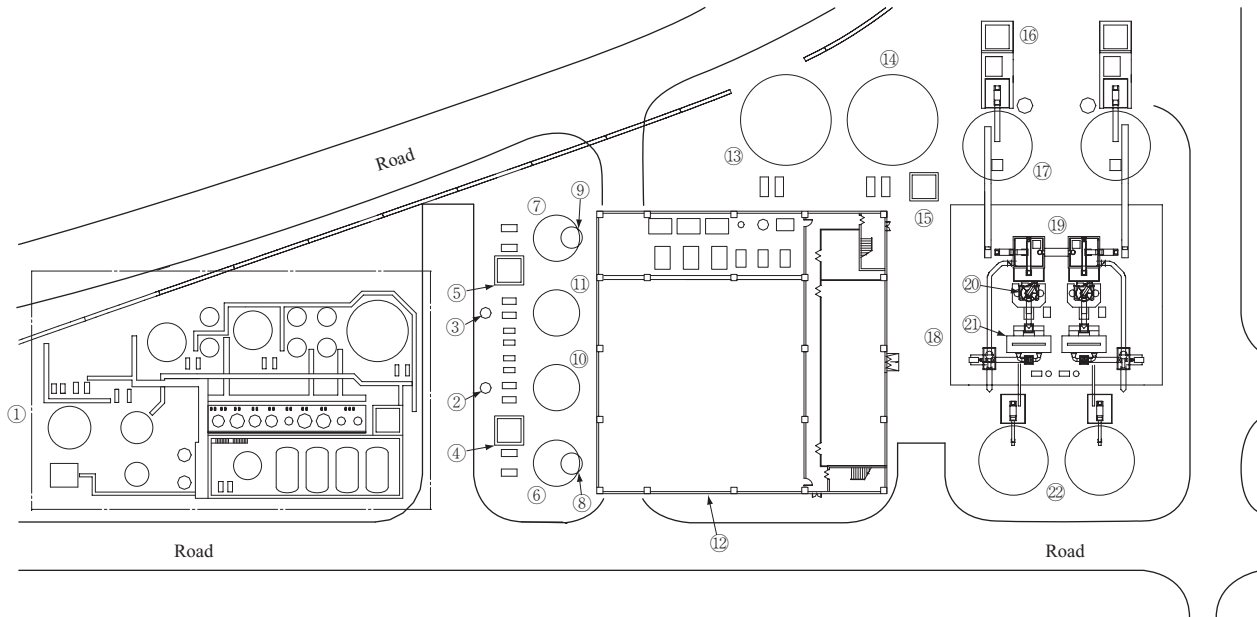


Fig.2 General layout (flue gas and absorption area)



- (Note)
- ① : Waste water treatment system
 - ② : Unit 1 filtrate wash water tank
 - ③ : Unit 2 filtrate wash water tank
 - ④ : Unit 1 gypsum area drainage pit
 - ⑤ : Unit 2 gypsum area drainage pit
 - ⑥ : Unit 1 reclaim water tank
 - ⑦ : Unit 2 reclaim water tank
 - ⑧ : Unit 1 waste water hydrocyclone
 - ⑨ : Unit 2 waste water hydrocyclone
 - ⑩ : Unit 1 waste water storage tank
 - ⑪ : Unit 2 waste water storage tank
 - ⑫ : Gypsum dewatering building
1F : Gypsum storage room, Electric room, Compressor room
2F : Waste water hydrocyclone feed tank, Waste water storage tank, Vacuum receiver, Gypsum conveyor, Electric room
3F : Vacuum belt filter, Gypsum hydrocyclone, Vacuum pump, Control room
 - ⑬ : Unit 1 gypsum slurry tank
 - ⑭ : Unit 2 gypsum slurry tank
 - ⑮ : Limestone area drainage pit
 - ⑯ : Limestone unloading hopper
 - ⑰ : Limestone silo
 - ⑱ : Limestone preparation building
 - ⑲ : Limestone intermediate silo
 - ⑳ : Limestone mill
 - ㉑ : Bag filter
 - ㉒ : Limestone powder silo

Fig.3 General layout (gypsum dewatering, limestone preparation and waste water treatment area)

Gypsum moisture content	10 wt% or less	Capacity	96 m ³ /min
Gypsum purity	95 wt% or more	Quantity	1st bank 2 units 2nd bank 2 units 3rd bank 2 units
Main equipment (quantity for 2 boilers)		Motor output	1st bank 355 kW 2nd bank 400 kW 3rd bank 450 kW
Absorber		Vacuum belt filter (common to units 1 and 2)	Type Vacuum belt filter Active filter area 18 m ² Quantity 2 units (1 unit in operation + 1 unit as spare)
Type	Spray type	Limestone mill (common to units 1 and 2)	Type Dry type vertical roller mill Capacity 7.6 t/h Quantity 2 units (1 unit in operation + 1 unit as spare)
Quantity	2 units	Waste water treatment system (common to units 1 and 2)	Type Two-stage coagulation-sedimentation + sand filter Capacity Maximum 328 t/d Quantity 1 set
Outside dimensions	11.6 m (diameter) × 30.1 m (height)		
Boost up fan (BUF)			
Type	Variable pitch axial-flow fan		
Capacity	34 940 m ³ /min × 4.70 kPa		
Quantity	2 units		
Motor output	3 300 kW		
Gas-gas heater (GGH)			
Type	Vertical-axial rotary regenerative type		
Quantity	2 units		
Heating surface	18 820 m ²		
Absorber slurry recycle pump			
Type	Centrifugal type (Impeller : anti-corrosion alloy, Casing : carbon steel + rubber lining)		

Absorbent and byproduct (design values for 1 boiler)	
Limestone powder consumption	1.5 t/h
Quantity of gypsum produced	2.7 t/h
Utilities (design values for 1 boiler)	
Industrial water	22.5 t/h
Waste water	2.7 t/h
Maximum power consumption	6 840 kW (for 2 boilers)

3.2 Processes

This equipment consists of 5 systems :① flue gas system to send exhaust gas from the boiler to the absorber and introduce treated gas to the stack, ② absorption system to collect SO₂ from the exhaust gas and produce gypsum, ③ gypsum dewatering system to recover the produced gypsum as a byproduct, ④ limestone preparation system to prepare the limestone slurry as an absorbent, and ⑤ waste water treatment system to treat the waste water from the gypsum dewatering system. **Figure 4** shows the processes of flue gas desulfurization system.

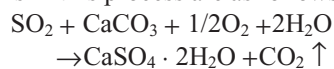
3.2.1 Flue gas system

Untreated gas discharged from the boiler passes through the gas air heater, electrostatic precipitator, and induced draft fan, and is increased in pressure by the booster up fan (BUF), and sent to the gas-gas heater (GGH). Here it is heat-exchanged with wet low-temperature treated gas in the absorber outlet, and the untreated gas itself is cooled and the treated gas is heated. This effectively disperses the flue gas and prevents white smoke.

Then the untreated gas coming out from the gas-gas heater is sent to the absorber for desulfurization and dust removal. Subsequently, mist included in the treated gas is removed by the mist eliminator installed in the absorber. The treated gas coming from the mist eliminator is sent again to the gas-gas heater and heated, and then it is discharged into the atmosphere through the stack.

3.2.2 Absorption system

SO₂ in the untreated gas sent to the absorber is absorbed and removed by the spray solution containing limestone. The absorbed SO₂ is forcefully oxidized by oxygen in the air blown into the absorption slurry at the bottom of the absorber and immediately becomes gypsum. Main reactions in this process are as follows.



The gypsum slurry produced through the reactions in the absorber is intermittently supplied to the gypsum dewatering system from the absorber. **Figure 5** shows the outline of the absorber.

3.2.3 Gypsum dewatering system

The liquid from the absorber is sent to the waste water hydrocyclone and separated into underflow and overflow by centrifugal force. The underflow (solids relatively large in particle size containing much gypsum) of the gypsum hydrocyclone is supplied to the gypsum dewatering system, dewatered, and recovered as gypsum with moisture content of not more than 10%.

On the other hand, the overflow (solids relatively small

in particle size containing must limestone and dust) of the gypsum hydrocyclone is stored in the tank and then sent to the waste water hydro cyclone by the pump and separated again into underflow and overflow by centrifugal force.

The underflow of the waste water hydrocyclone is returned to the absorber and the unreacted limestone in the liquid is effectively reused. On the other hand, the overflow of the waste water hydrocyclone is sent to the waste water treatment system and treated on SS (suspended solid), heavy metal, and COD (chemical oxygen demand). **Figure 6** shows the processes of the gypsum dewatering system and **Fig. 7** the classifying principle of the two-stage hydro cyclone.

3.2.4 Limestone preparation system

The limestone (4 to 7 mm in particle size), absorbent, is transported by truck to the limestone unloading hopper, and then stored in the limestone silo by means of bucket conveyor. The limestone stored is crushed into 325 mesh (about 44 μm) or smaller and then transported for storage in the limestone powder silo by screw conveyor. The limestone powder stored is pumped for storage in the limestone powder bin by cellar pump (pneumatic type), and the necessary quantity is delivered by rotary feeder and prepared as limestone slurry in the limestone slurry feed tank. **Figure 8** shows the processes of the limestone preparation system.

3.2.5 Waste water treatment system

The overflow of the waste water hydrocyclone is sent to the waste water treatment system, and SS in the waste water is roughly removed by the pre-clarifier. In the No. 1 and No. 2 reaction tanks, NaOCl and NaOSO₃ are added, respectively, and COD is removed. In the subsequent No. 1 coagulation tank, PAC and polymer are added while the pH is adjusted, and SS in the waste water is formed for easy precipitation/separation in the subsequent No. 1 clarifier.

The waste water with less SS is sent to the No. 2 coagulation tank, and chelate and polymer are added and soluble components in the waste water are solidified. The treated waste water containing solidified soluble components is sent to the No. 2 clarifier for further precipitation/separation.

The treated supernatant liquid is sent to the sand filter in which final SS removal is made, and final pH adjustment is made in the neutralization tank, thus creating properties dischargeable outside the system. The concentrated SS content from the bottom of each clarifier is separately treated.

4. Technologies adopted

4.1 Spray nozzle of new type (Spiral type)

The conventional spray nozzle has demonstrated its superior desulfurization performance adopting flow 700 l/min × pressure 0.07 MPa. In this construction work, we adopted a newly developed spray nozzle of new type (spiral type) of flow 2 130 l/min and low pressure to reduce equipment cost by decreasing the number of spray

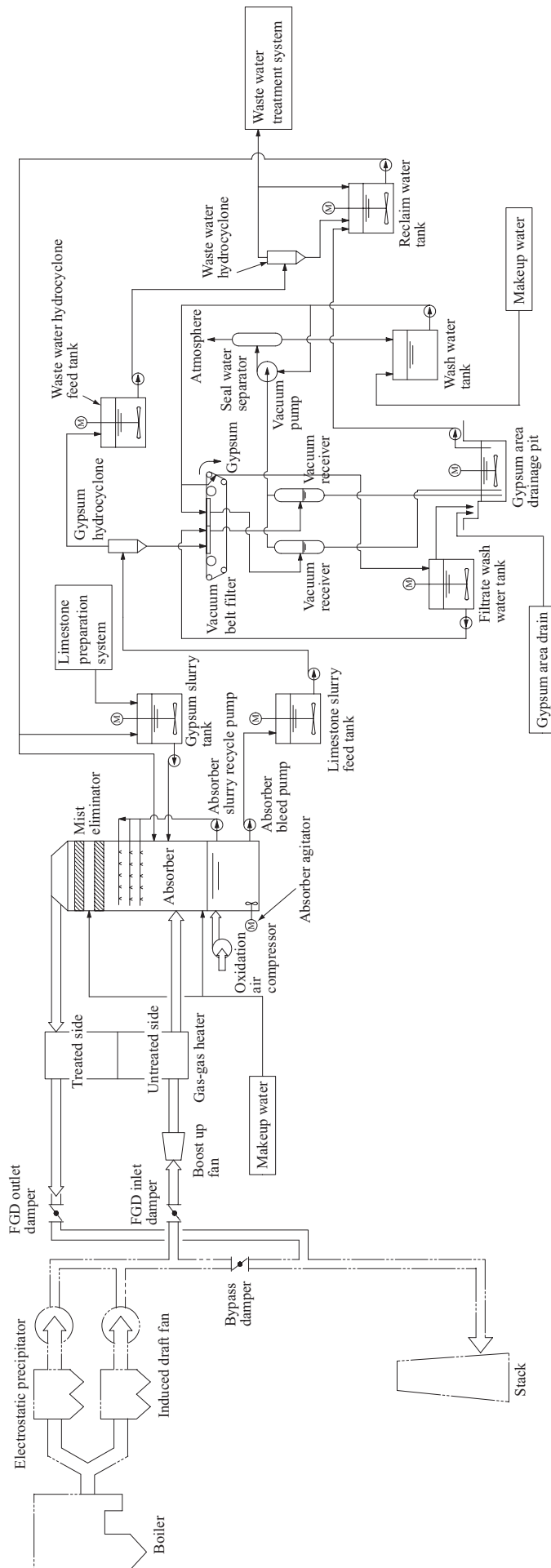


Fig.4 Process flow of FGD

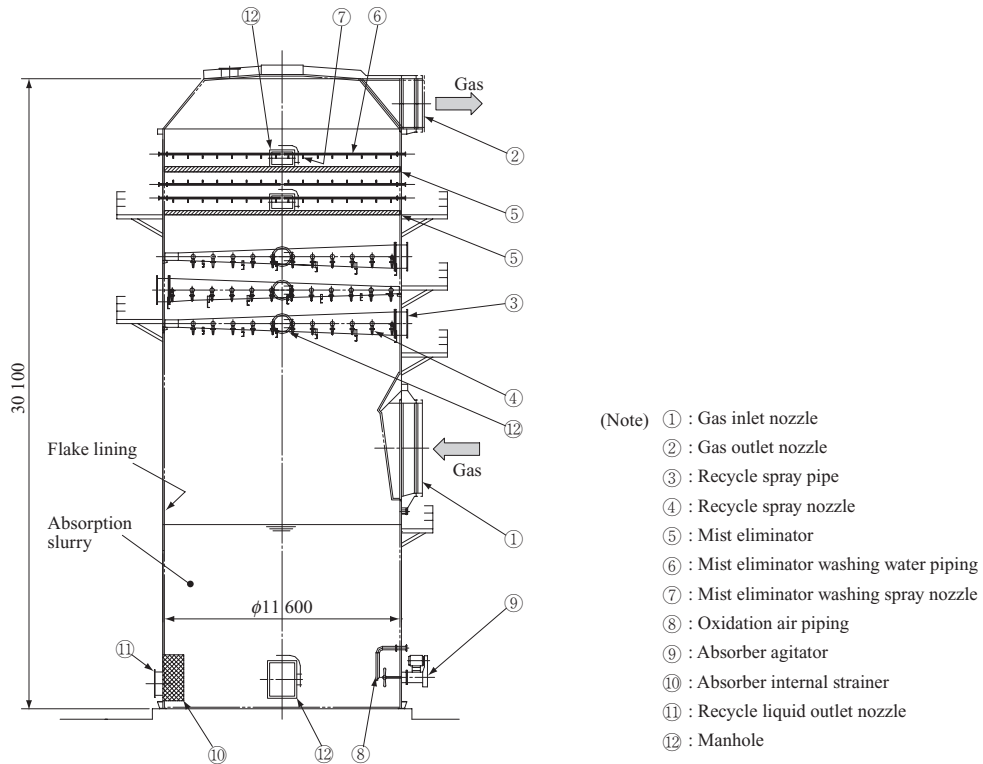


Fig.5 Schematic drawing of absorber (unit : mm)

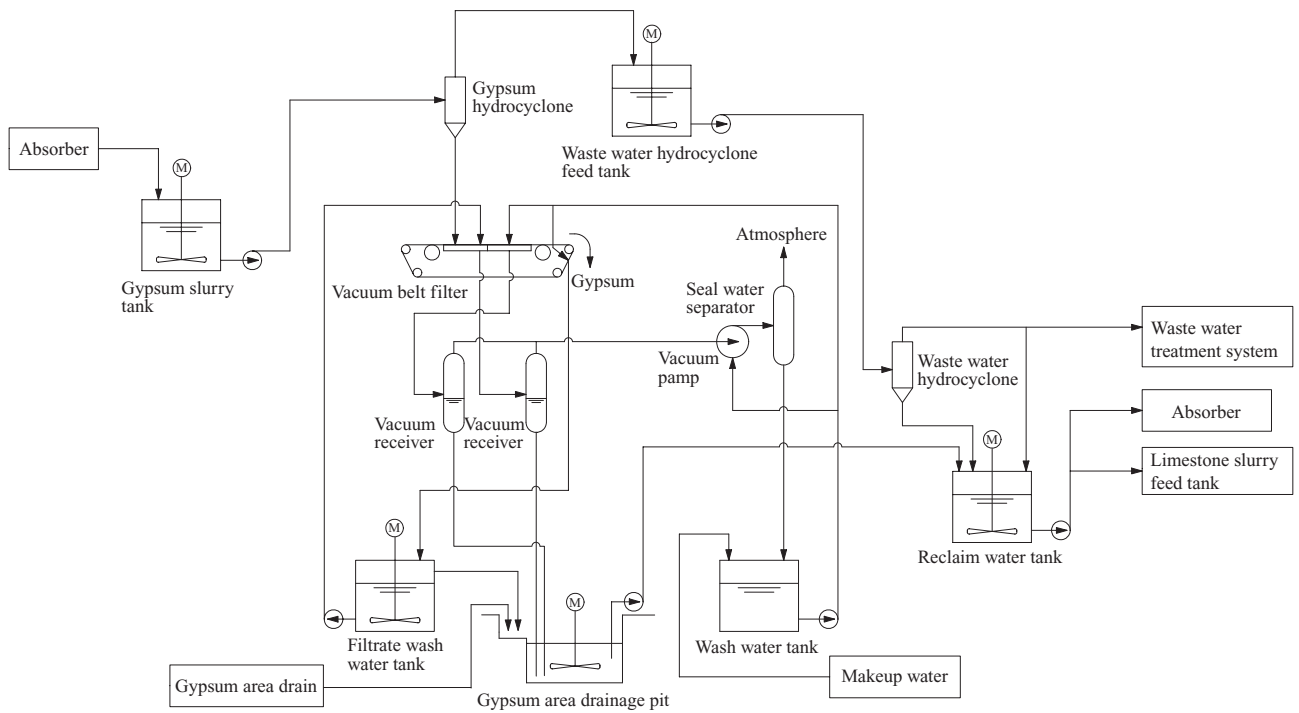


Fig.6 Process flow of gypsum dewatering system

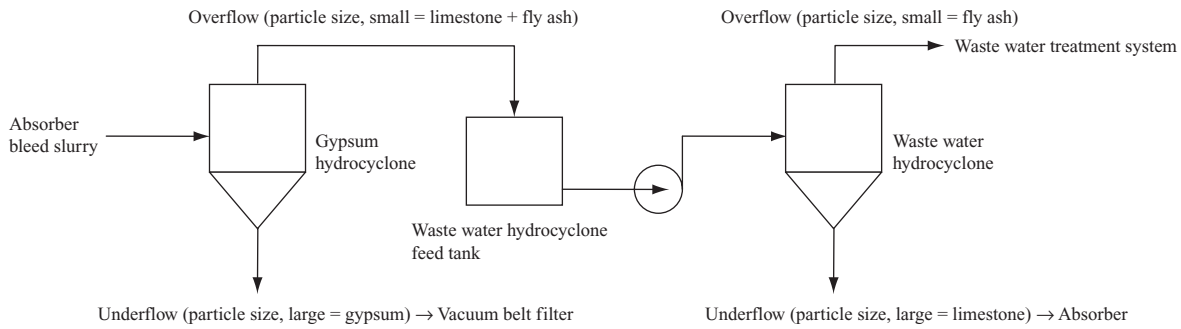


Fig.7 Classification theory of two-stage hydrocyclone

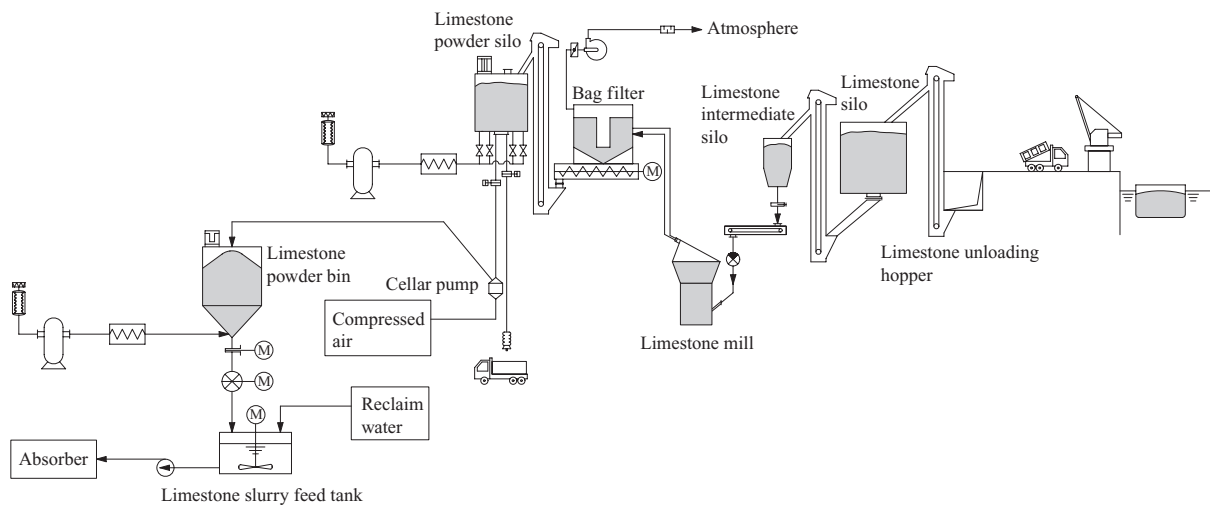


Fig.8 Process flow of limestone preparation system

nozzles and reduce operation cost by decreasing power consumption of pumps.

Since this spray nozzle greatly affects the desulfurization performance, we considered the following points in designing when we adopted this spray nozzle.

(1) Securing droplet diameter of 2 500 μm or smaller

By making the droplet diameter 2 500 μm or smaller, the specific surface area of the droplet increases, and as a result, the gas-liquid contact area increases, making it possible to obtain high desulfurization performance.

(2) Securing sufficient spray diameter

By adopting a certain value or larger for the spray diameter per spray nozzle, uniform spraying to the cross section of the absorber can be done, thus realizing high desulfurization performance.

As a result, we were able to decrease the number of nozzles (equipment cost) to about 1/3 and reduce the recycle pump power (operation cost) to about 80% in comparison with the conventional equipment.

4.2 Dry type limestone mill and pneumatic transfer of limestone powder

With this equipment, the limestone (4 ~ 7 mm in particle size), absorbent, is crushed to 325 mesh (about 44 μm)

using a dry-type vertical roller mill and transported to the limestone powder bin installed on the limestone slurry feed tank about 800 m away.

As to the crushing behavior of limestone produced in China, we obtained samples in the initial design stage in cooperation with the customer and conducted sufficient prior verification through crushing tests in cooperation with the mill maker to decide the equipment specifications.

For the mill itself, we adopted a product made in Japan, but as to the cellar pump to mix/pump air and limestone, the main component of the equipment to pneumatically pump limestone for the distance of 800 m, we adopted a product made in China.

In adopting it, we carefully conducted quality control and performance checking at the factory of the Chinese manufacturer, ensuring highly reliable equipment. In the trial test process, we mutually checked with the customer on the limestone receiving timing and number of times in the early stage, realizing the smooth adjustment of the trial operation.

4.3 Long-distance transportation of gypsum slurry

In the long-distance transportation of slurry, we have conventionally adopted the design philosophy of maintaining a constant or increased slurry flow velocity in the piping to

avoid blocking due to accumulated slurry in the piping and prevent air pocket in the piping.

In this work, however, operation turndown (long-term, low-load operation) was required, and it was difficult to avoid low flow velocity of slurry and up/down of the piping arrangement because the equipment was to be added within the existing power station, thus posing the risks of slurry accumulation and blocking.

We, therefore, assumed the accumulation of slurry in the piping and adopted a design that allows the removal of slurry accumulation during operation. That is, in the conventional design, a flow control valve is used for controlling the slurry flow and the control valve is slightly opened in the low-flow operation of slurry, which occurs at a low-load, and the slurry accumulation tends to occur especially in a pocket portion of the piping.

In this work, therefore, we changed the control valve to a cylinder valve (ON/OFF) so that the slurry flow in the piping can be instantly changed from minimum flow to maximum flow to allow the instant removal during maximum flow of slurry accumulation in the piping, which occurs during minimum flow. As a result, it became possible to transport the slurry stably even during the long-term low-load operation. For the flow control, we used a computer to integrate by time, thus realizing the specified flow control.

5. Operation results

For this equipment, we started the site installation of both the No. 1 and No. 2 units, in February 2004, conducted trial operation of each unit after receiving power in June 2005, and confirmed that the performance and reliability of each unit were sufficiently satisfied.

Subsequently, we conducted the general water operation including sequence test and interlock test and confirmed there was no problem with the safety and controllability of any of the equipment, and completed the gas supply to the flue gas desulfurization system in December 2005 for the No. 1 unit and April 2006 for the No. 2 unit. Subsequently, we conducted 168 hour continuous operation (operation required in the specification), completed the performance test of the No. 1 unit and No. 2 unit in April 2006 and July 2006, respectively, and confirmed that this equipment satisfied the performance and function requirements as planned.

5.1 Trial operation of each unit and general water operation

In the testing of each unit, we checked on the following items and made adjustments and confirmed there was no problem.

- (1) Performance of unit
- (2) Conditions during operation (vibration of unit, noise, temperature of lubricating oil, etc.)
- (3) Controllability

In the general water operation, we mainly checked on the following items and made adjustments and confirmed that there was no problem in stating the

actual gas commissioning.

- (1) Starting and stopping through master sequence
- (2) Alarm/interlock tests
- (3) Draft balance test
- (4) Absorber spray test
- (5) Mist eliminator automatic washing and spray test
- (6) Material balance and water balance

5.2 Adjustment of draft control system

As to the controllability of the draft of the flue gas system when switching is done from the IDF (Induced Draft Fan) rotor blade opening follow-up control when the bypass damper is "OPEN" to bypass damper/draft differential pressure control when the damper is "CLOSE", we made the following adjustments and confirmed good controllability through the draft balance test.

- (1) Adjustment of Closing timing and speed of the bypass damper blade
- (2) Adjustment of timing of starting mode changing from IDF rotor blade opening follow-up control to bypass damper/draft differential pressure control

5.3 Performance tests

To confirm that this equipment satisfied the performance as planned, we conducted performance tests at boiler loads of 100, 80, 60 and 40%. **Table 1** shows the results of the performance tests. The results were good, showing that the desulfurization efficiency sufficiently satisfied guaranteed values in the entire load range.

The byproduct gypsum satisfied the guaranteed values of purity, moisture, and limestone stoichiometric ratio and is effectively reused as a cement additive. In the 90 day continuous operation of the equipment, 100% operation was achieved at the operation rate of each unit, proving that it also has high operational reliability.

5.4 Load following test

Corresponding to load changes of the boiler, we conducted load following tests at the loads of 100, 80, 60 and 40% and confirmed good characteristics of load following of the desulfurization performance, Booster Up Fan (BUF) gas flow control, flow control of absorber bleed, and limestone supply control in both load increasing and decreasing.

5.5 Tests changing absorber conditions

Changing operation conditions of the absorber (operation pH, liquid level of absorber, etc.), we grasped effects on the desulfurization/oxidation performance and obtained various data useful for optimal equipment operation in the future, including selection of proper operation conditions of the absorber in accordance with the FGD inlet gas conditions.

6. Conclusion

This project has drawn much attention within China because it concerned a large flue gas desulfurization system, the first of its kind in the Shanghai area, but as a result of the trial operation and performance tests, we confirmed high desulfurization performance and also good load following characteristics and high operational reliability. We received good customer satisfaction not

only in the equipment performance and operation but also for our support in the progress course of the project.

In the future, we will intend to do our best in promoting our desulfurization technologies in the FGD market of China by taking advantage of our experience obtained through this project.

– Acknowledgments–

In this project, we received extensive cooperation from the government of China, many enterprises, and people concerned from the design stage. We hereby express our heartfelt thanks to them.