Operation Results of IHI Flue Gas Desulfurization System – Unit No.1 and 2 (600 MW × 2) of Wangqu Thermal Power Station for Shanxi Lujin Electric Power –

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An IHI flue gas desulfurization (FGD) system was completed for 600 MW×2 coal-fired thermal power plant at Wangqu Lujin, China, in August 2006, which was one of largest-capacity plants in Shanxi province. This was constructed as the first FGD system in the province and is now operating smoothly and demonstrating superior SO_2 removal efficiency with high operational reliability. The conventional design with proven technologies was applied to cope with the local stringent environmental regulations. IHI supplied the basic design for a local engineering company, which was in charge of the details and civil engineering design for the FGD system.

1. Introduction

In China, the air pollution legislation was revised in 2004 and air pollution control was strengthened against coal-fired power plants. For this reason, it is mandatory to install flue gas desulfurization systems for construction of new thermal power plants, and it is estimated that there will be a demand for flue gas desulfurization systems of 20 million kW per year in the future. In the environmental equipment market in China, however, there are many competing companies, and it is considered that it will be increasingly difficult for each company to obtain orders for EPC (work including design, procurement, and installation in the supply range). For this reason, our company established a policy to specialize in engineering mainly consisting of software by constructing a new model called basic design package supply aiming at developing environmental businesses in China.

Under such a policy, the wet type flue gas desulfurization system of Phase 1 Units Nos. 1 and 2 of Wangqu Thermal Power Station for Shanxi Lujin Electric Power was constructed making the best use of our company's many achievements and experiences in the field of flue gas desulfurization systems for coal-fired power plants and delivered as the latest system integrating our accumulated technologies, and all the construction processes were accomplished and the delivery to the customer completed in December 2006.

In this paper, we introduce the wet type flue gas desulfurization system of Phase 1 Units Nos. 1 and 2 of Wangqu Thermal Power Station for Shanxi Lujin Electric Power, the delivery of which was completed as the first step of the basic design package supply.

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

The Phase 1 Units Nos. 1 and 2 of Wangqu Thermal Power Station started their commercial operation in August 2006 as a new and powerful coal-fired power plant of the largest scale in Shanxi Province. Its outline is as follows.

Figure 1 shows the overall view of the wet type flue gas desulfurization system of Phase 1 Wangqu thermal power station.

Generator outpu	600 MW × 2
Boiler	
Type	Supercritical pressure boiler
Fuel used	Coal
Evaporation	1 944 t/h/unit (at maximum continuous load)
Steam pressure	24.2 MPa
Steam temperature	566°C/566°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)
No. 1 coagulation and sedimentation/sand filter

Fig. 1 View of FGD of Wangqu Thermal Power Station

3. Wet type flue gas desulfurization system

3.1 Specifications

Main specifications are as follows. **Figure 2** shows the general equipment arrangement.

Type — Wet type limestone-gypsum process (simultaneous desulfurization and oxidation)

Capacity

Flue gas flow rate (wet) at inlet
1 938 100 $m^3{}_N$/h (per boiler)

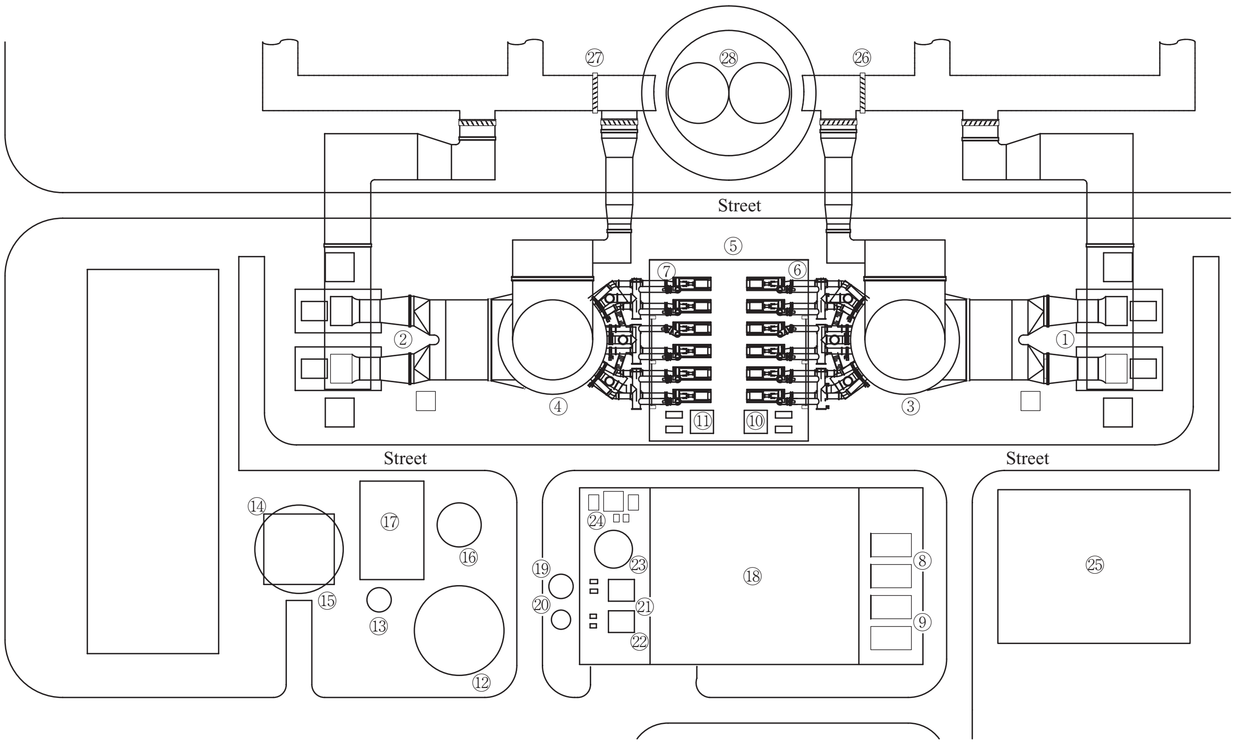
Flue gas temperature at inlet
121°C

SO_2 concentration

At FGD inlet — 1 246 mg/$m^3{}_N$ (O_2 concentration : 6% conversion value)

At FGD outlet — 33 mg/$m^3{}_N$ or less (O_2 concentration : 6% conversion value)

Gypsum moisture content
10 wt% or less



(Note)
① : No. 1 unit boost up fan (BUF)
② : No. 2 unit boost up fan (BUF)
③ : No. 1 unit absorber
④ : No. 2 unit absorber
⑤ : Circulating pump room
⑥ : No. 1 unit absorber slurry recycle pump
⑦ : No. 2 unit absorber slurry recycle pump
⑧ : No. 1 unit oxidation air fan
⑨ : No. 2 unit oxidation air fan
⑩ : No. 1 unit absorption system drain pit
⑪ : No. 2 unit absorption system drain pit
⑫ : Emergency blow tank
⑬ : Eliminator washing water tank
⑭ : Limestone slurry pit
⑮ : Limestone silo
⑯ : Filtrate tank
⑰ : Small pump room
⑱ : Vacuum belt filter room
⑲ : Primary hydrocyclone overflow tank
⑳ : Washing water tank
㉑ : No. 1 unit vacuum pump
㉒ : No. 2 unit vacuum pump
㉓ : Secondary hydrocyclone overflow tank
㉔ : Gypsum system drain pit
㉕ : Desulfurization control room
㉖ : No. 1 unit bypass damper
㉗ : No. 2 unit bypass damper
㉘ : Stack

Fig. 2 General arrangement

Gypsum purity	97.2 wt% or more
Main equipment (quantity for 2 boilers)	
Absorber	
Type	Spray type
Quantity	2 units
Outside dimensions	17.0 m (diameter) × 30.0 m (height)
Boost up fan (BUF)	
Type	Variable pitch axial flow fan
Capacity	30 360 m^3/min × 3.083 kPa
Quantity	4 units
Motor output	2 500 kW
Absorber slurry recycle pump	
Type	Centrifugal type (impeller : anti-corrosion alloy, casing : rubber lining)
Capacity	113.0 m^3/min
Quantity	
1st bank	4 units
2nd bank	4 units
3rd bank	4 units
Motor output	
1st bank	630 kW
2nd bank	710 kW
3rd bank	710 kW
Vacuum belt filter (common to units 1 and 2)	
Type	Vacuum belt filter
Capacity	42 m^2 (filter area)
Quantity	2 units (1 unit in operation + 1 unit as spare)
Limestone silo (common to units 1 and 2)	
Capacity	1 300 m^3
Quantity	1 unit
Waste water treatment system (common to units 1 and 2)	
Type	No. 1 coagulation and sedimentation + sand filter
Capacity	Maximum 240 t/d
Quantity	1 set
Absorbent and byproduct (design value for 1 boiler)	
Limestone powder consumption	11.0 t/h
Gypsum	22.0 t/h
Utilities (design value for 1 boiler)	
Industrial water	70.5 t/h
Waste water	7.5 t/h
Maximum power consumption	10 200 kW (for 2 boilers)

3.2 Process

This wet type flue gas desulfurization system consists of 5 systems : ① boiler air and gas system to send exhaust gas from the boiler to the absorber and introduce treated gas to the stack, ② absorption system to collect SO_2 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 a absorbent, and ⑤ waste water treatment system to treat the waste water from the gypsum dewatering system. **Figure 3** shows the processes of this wet type flue gas desulfurization system.

3.2.1 Boiler air and gas system

Untreated gas discharged from the boiler passes through the gas air heater, electrostatic precipitator, and induced draft fan (IDF), and is increased in pressure by the boost up fan (BUF) and sent to the absorber for desulfurizing and dust removal. Then the mist carried in the treated gas is removed by the mist eliminator installed in the absorber and the gas is discharged into the atmosphere through the stack.

3.2.2 Absorption system

SO_2 in the untreated gas introduced into the absorber is absorbed and removed by spray solution containing limestone sprayed into the absorber. The absorbed SO_2 is forcefully oxidized by oxygen in the air blown into the absorption slurry at the bottom of the absorber and immediately becomes gypsum. The main reactions in this process are as follows.

$$SO_2 + CaCO_3 + 1/2O_2 + 2H_2O \rightarrow CaSO_4 \cdot 2H_2O + CO_2 \uparrow$$

The gypsum slurry produced through the reactions in the absorber is intermittently sent to the gypsum dewatering system from the absorber. **Figure 4** shows the outline of the absorber of this wet type flue gas desulfurization system.

3.2.3 Gypsum dewatering system

The bleed slurry from the absorber is sent to the gypsum hydrocyclone and separated into underflow and overflow by centrifugal force. The underflow (solids relatively large in particle size containing much gypsum) of the primary 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 mainly containing limestone and soot/dust) of the primary hydrocyclone is stored in the tank and then sent to the secondary hydrocyclone by the pump and separated again into underflow and overflow by centrifugal force.

The underflow (solids relatively large in particle size containing much limestone) of the secondary hydrocyclone is returned to the absorber and the unreacted limestone in the liquid is effectively reused. On the other hand, the overflow (solids relatively small in particle size containing much soot/dust) of the secondary hydrocyclone is sent to the waste water treatment system and treated on SS (suspended solid) and heavy metal.

Figure 5 shows the processes of the gypsum dewatering system of this wet type flue gas desulfurization system and **Fig. 6** the classifying principle of the two-stage hydrocyclone.

3.2.4 Limestone preparation system

The limestone (particle size 250 mesh : about 50µm),

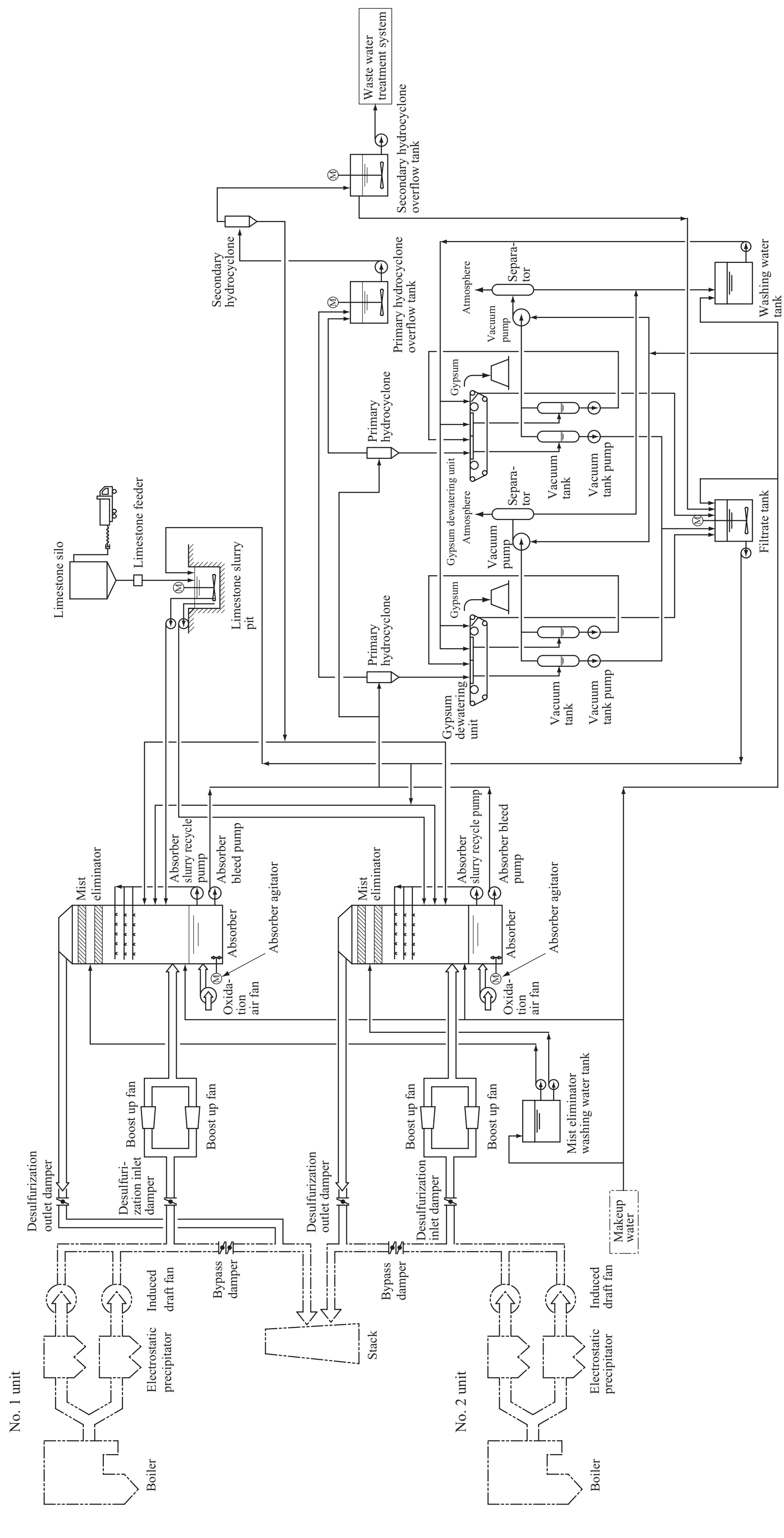
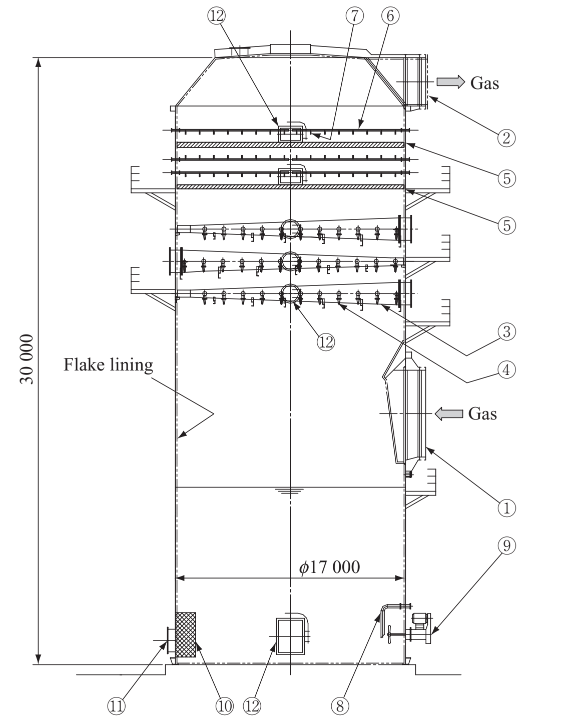


Fig. 3 Process flow of FGD



(Note) ① : Gas inlet nozzle
② : Gas outlet nozzle
③ : Recycle spray piping
④ : Recycle spray nozzle
⑤ : Mist eliminator
⑥ : Mist eliminator washing water piping
⑦ : Mist eliminator washing spray nozzle
⑧ : Oxidation air piping
⑨ : Absorber agitator
⑩ : Absorber internal strainer
⑪ : Recycle liquid outlet nozzle
⑫ : Manhole

Fig. 4 Schematic drawing of absorber (unit : mm)

absorbent, is transported into the plant by jet pack vehicle, pumped into the limestone powder silo and stored, and then the necessary quantity is charged into the limestone slurry pit by a rotary feeder and prepared as limestone slurry.

3.2.5 Waste water treatment system

The overflow of the secondary hydrocyclone is sent to the tank and then to the waste water treatment system, and SS in the waste water is roughly removed in the initial settling tank. The treated supernatant liquid is sent to the sand filter in which final SS removal is made, thus creating properties dischargeable outside the system.

4. Technologies adopted and order receiving form

4.1 Technologies adopted

The process selection of this wet type flue gas desulfurization system, absorber size and performance and equipment specifications were decided based on our company's design and past technological achievements of desulfurization system plants. The basic design was made in due consideration of fully meeting the customer's requirements for a system to ensure stable operation and easy maintenance while maintaining sufficient desulfurization efficiency to satisfy the environmental control values. It was, however, decided not to install the GGH (gas-gas heater) normally installed for domestic wet type flue gas desulfurization systems to prevent diffusion of flue gas and white smoke, in accordance with the customer's intention. For this reason, we made design considerations on material selection at the inlet/outlet of the absorber, method of

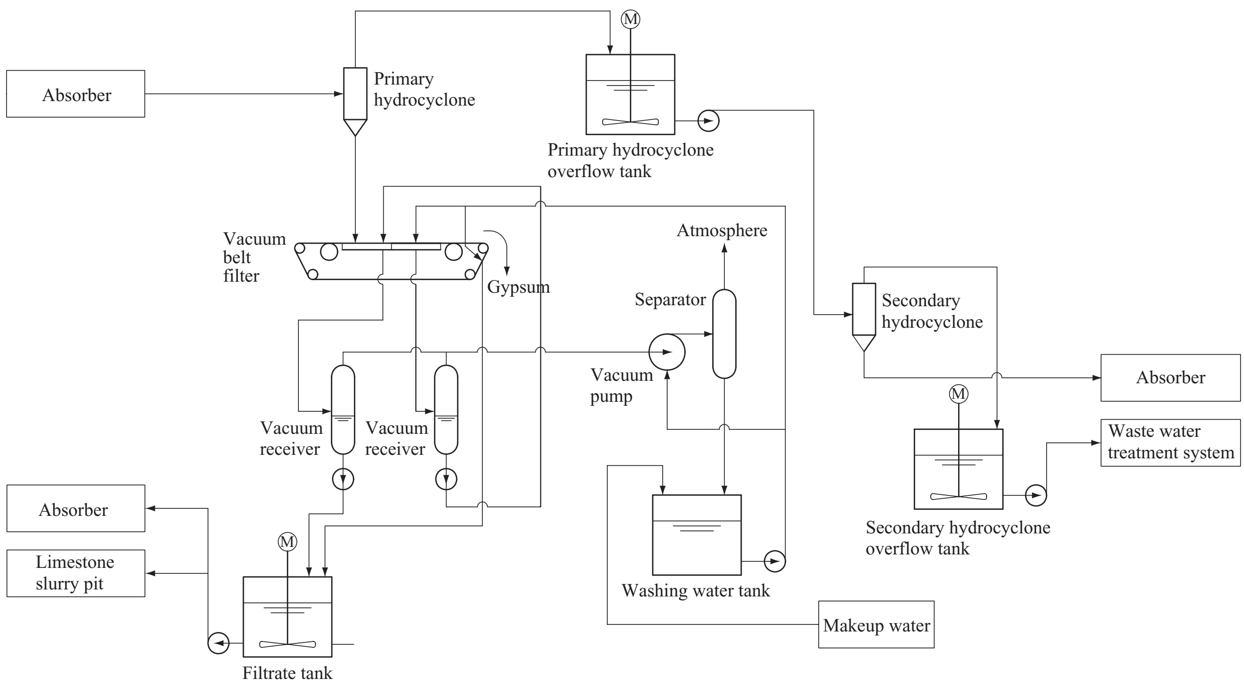


Fig. 5 Process flow of gypsum dewatering system

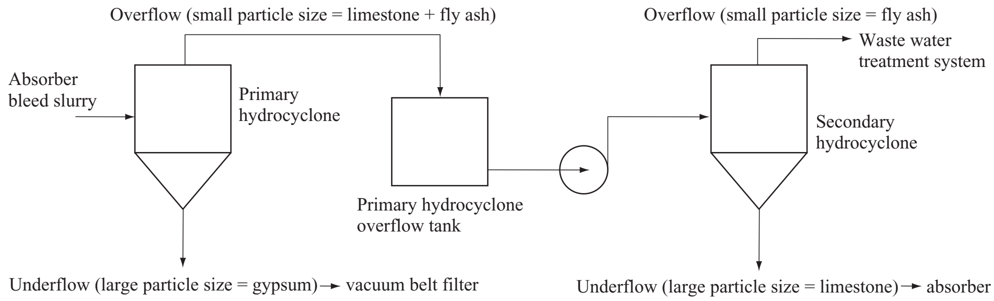


Fig. 6 Principle of two-stage hydrocyclone classifier

treating condensed water produced in the flue, and maintenance when the plant is stopped.

4.2 Order receiving form

This work was the first for which our company received an order for the basic design package supply.

IHI took charge of the basic design of the wet type flue gas desulfurization system mainly consisting of process selection, decision on absorber size and performance, decision on equipment specifications and basic arrangement of apparatuses, and the project management. An engineering company in China was in charge of the purchase of apparatuses and detailed designing of flue, piping, and supports in China and another engineering company in China was in charge of the planning of foundation works of the building and equipment. The work ranges of the companies were decided based on the drawings issued, and efforts were made to strictly control them, including costs.

5. Operation results

For this wet type flue gas desulfurization system, we started the site installation of both No. 1 and No. 2 units in April 2005, conducted trial operation of each unit after receiving power in April and June 2006, 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 or controllability of any of the equipment, and completed the gas supply to the flue gas desulfurization system for No. 1 unit and No. 2 unit in August and November 2006, respectively. We then conducted 168 hour continuous operation (operation required in the specification) with actual gas. We completed the performance test of No. 1 unit and No. 2 unit in September and December 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 starting the trial operation with actual gas.

(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 boiler air and gas system when switching is done from the IDF rotor blade opening follow-up control when the bypass damper is “OPEN” to the 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 test

To confirm that this wet type flue gas desulfurization system satisfied the performance as planned, we conducted performance tests at boiler loads of 100% and 75%. **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 boiler 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. We also confirmed that it had high operational reliability, satisfying guarantee items related to reliability required of this work.

5.4 Load following test

Corresponding to load changes of the boiler, we

Table 1 Results of performance tests

Guarantee item	Unit	Guaranteed value	Performance test result		
			Boiler load / Boiler classification	100%	75%
Stack inlet SO_2 concentration	mg/m^3_N (dry, 6% O_2)	≤71.5	No. 1 unit	15.3	13.8
			No. 2 unit	19.8	11.3
Desulfurization efficiency	%	≥97.2	No. 1 unit	99.0	99.0
			No. 2 unit	98.8	99.3
Limestone stoichiometric ratio (in gypsum)	—	≤1.03	No. 1 unit	1.03	—
			No. 2 unit	1.00	—
Power consumption	kW·h	≤10 200	No. 1 unit	6 915	—
			No. 2 unit	5 156	—
Absorber outlet mist concentration	mg/m^3_N	≤75	No. 1 unit	48.8	36.1
			No. 2 unit	42.6	38.8
Stack inlet gas temperature	°C	≥45	No. 1 unit	46.4	44.0
			No. 2 unit	46.0	43.0
Gypsum purity	%	≥90	No. 1 unit	92.8	—
			No. 2 unit	91.2	—
Gypsum moisture	%	≤10	No. 1 unit	10.0	—
			No. 2 unit	10.0	—
Plant reliability (90 day continuous operation rate)	%	≥98	No. 1 unit	100	—
			No. 2 unit	100	—

conducted load following tests at the loads of 100, 75, 60 and 40% and confirmed good characteristics of load following of the desulfurization performance, BUF volume control, absorber bleed control, 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 determined the effects on the desulfurization/oxidation performance and waste water properties and obtained various data useful for optimal future equipment operation, 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 wet type 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 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.

— Acknowledgements —

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.