KEPCO's First 5000 MW of Flue Gas Desulfurization

John R. Cline, Sr.
David W. Murphy
Robert W. Telesz
Babcock & Wilcox
Barberton, Ohio, U.S.A.

Presented to:
Power-Gen International '98
December 9-11, 1998
Orlando, Florida, U.S.A.

BR-1666

Abstract

In 1995, Babcock & Wilcox (B&W) licensed wet limestone in-situ forced oxidation (LSFO) technology for flue gas desulfurization (FGD) to Hyundai Heavy Industries (HHI). B&W worked very closely with HHI during their initial bidding process, in both design and execution of the proposal. Subsequently, HHI was awarded two major flue gas desulfurization contracts by Korea Electric Power Company (KEPCO) in December of 1995. Specifically, HHI was awarded contracts to supply flue gas desulfurization systems for six (6) 500 MW units at the Hadong Power Plant and four (4) 500 MW units at the Taean Power Plant. This is the largest flue gas desulfurization system order ever placed in the world. For these first FGD contracts in Korea, B&W is supplying the process design and many of the engineered products. For future contracts, HHI expects to provide the entire plant design with only technical support from B&W.

This paper presents the project execution methodology, including design, fabrication, and construction. Of particular note is the manner of shop modularization and field erection of the 500 MW alloy absorber modules. Finally, several unique features of the flue gas desulfurization process will be highlighted. These unique features include: an innovative, compact, spray header system; a proven lance oxidation air distribution system; a unique dual path hydroclone system; and the partial recirculation of solids from the waste water treatment system to the flue gas desulfurization process.

Introduction

The Babcock & Wilcox Company has had a relationship with Hyundai Heavy Industries for many years, stemming from HHI's first licensing B&W technology on utility boilers in January 1978. In 1981, HHI licensed B&W's industrial boiler technology. Thus, the two companies were well prepared to cooperate in the arena of flue gas desulfurization. A formal agreement between the two companies was concluded shortly before the Requests for Tender for FGD systems were released for the Hadong, Poyoung and Taean stations. The agreement included several weeks of technology transfer and training. These activities were concluded before the Requests for Tender were released.

Although all the units at the Hadong, Poyoung and Taean stations are 500 MW capacity, site-specific conditions resulted in HHI, with B&W as licensor and primary subcontractor, being awarded contracts to supply FGD systems for two of the three plants. Specifically, HHI was awarded contracts to supply flue gas desulfurization systems for six (6) 500 MW units at the Hadong Power Plant and four (4) 500 MW units at the Taean Power Plant. For these first contracts, B&W is supplying the process design and the engineered products key to the FGD system. Figure 1 shows the location of these stations.

Project Organization

B&W recognizes the importance of a single point contact with the customer on any project. In this case, B&W's customer is HHI. For this project, B&W assigned a single project manager for both the Hadong and the Taean projects. The project manager has several project engineers assigned to assist him in the engineering, procurement, fabrication and delivery of equipment. The project engineers mainly deal with coordination of internal engineering design groups, purchasing agents and vendors, but they also interface with HHI engineers. While the en-

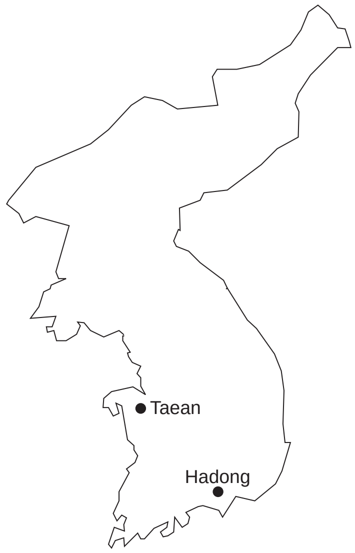

Figure 1 Station locations — Korea.

Figure 2 Absorber sections on barge.

Figure 3 Absorber sections on barge.

gineers may interface with HHI personnel directly, official correspondence is always funneled through the B&W project manager to the HHI project manager.

B&W's scope of supply for this project included the reagent preparation system, the absorber system and the dewatering system. B&W also supplied the control system hardware and the control philosophy for the equipment in B&W's scope of supply. HHI provided the control philosophy for equipment in their scope of supply. HHI provided the electrical components and the auxiliary systems, instrument air, service air and service water. In a separate contract, HHI had responsibility for the reagent receiving/handling system and the gypsum handling system.

A unique aspect of the FGD design centered around the absorber modules. Typically, absorber towers are fabricated in the field from rolled plate. This was the approach taken for the Hadong station because site-specific conditions prevented the Hadong absorbers from being modularized. However, to ease space limitations and to accelerate the construction schedule, portions of the absorbers for the Taean station were constructed in modular form.

The Taean absorber towers were built in four sections. The first section consisted of the absorber reaction tank. The second section was the absorber inlet area. The third section included the absorber tray, absorber spray headers, mist eliminators and mist eliminator spray headers. The fourth section was the absorber outlet transition. The first section, the absorber reaction tank, was field fabricated. The remaining sections were constructed in modular form at HHI's shipyard and barged to the job site. Figures 2 and 3 show the absorber sections on the barge. Figure 4 depicts the stacked absorber sections ready for final welding.

B&W has designed and constructed 3600 MW of modularized absorber towers prior to this project. The combination of B&W's design experience and HHI's construction expertise was an excellent match for this type of construction. This offered the customer a unique opportunity to benefit from B&W's experience in designing modularized absorber towers and HHI's knowledge of Korean construction practices.

Construction of the FGD systems proceeded very smoothly. B&W and HHI are providing technical advisors for the startup of the equipment in their respective scope. KEPCO is responsible for operating the units and providing consumables. The first units at Taean and Hadong are in beginning stages of startup at the writing of this paper.

Project Description

Absorber System

A single dedicated SO_2 absorber system is provided per boiler unit for a total of four SO_2 absorber systems for Taean and six SO_2 absorber systems for Hadong. The absorbers utilize a wet limestone process with in-situ forced oxidation to remove flue gas SO_2 and produce a gypsum byproduct.

Each absorber utilizes a perforated absorber tray and two absorber spray levels for SO_2 removal. The two spray levels include one undertray spray level and one upper spray level. Two interspatial spray headers comprise each of the two levels. A dedicated absorber recirculation pump feeds each header, for a total of four recirculation pumps per absorber. Figure 5 illustrates a cut-away of a typical absorber tower.

The SO_2 removal process starts as hot flue gas enters the absorbers, and is cooled and saturated by absorber slurry sprayed

Figure 4 Stacked absorber sections.

from the undertray spray level and absorber slurry falling from the tray. The flue gas then flows through the absorber tray. The absorber tray, shown in Figure 6, uniformly distributes flue gas and absorber slurry from the upper spray level across the absorber cross sectional area. As the gas passes through the layer of absorber slurry on the absorber tray, the increased gas velocity, caused by the tray perforations, generates a fierce bubbling action thereby assuring optimal liquid-gas contact. The flue gas then passes through the upper absorber spray zone, where absorber slurry spraying countercurrent to the flue gas flow completes the sulfur dioxide removal process. The gas then flows upward to the two stage mist eliminator located near the top of each absorber. After passing through the second stage mist eliminators, the flue gas exits the absorber through the outlet hood.

The absorber slurry and mist eliminator wash water that are sprayed into the absorber pass down through the absorber and are collected in the lower section of the absorber which is referred to as the absorber reaction tank. Four side-entering agitators on each absorber reaction tank keep the absorber slurry solids in suspension. Each absorber reaction tank is supplied with an absorber overflow seal box that is designed to protect the absorber and the absorber inlet ductwork from flooding.

Absorber slurry pH is controlled by the addition of fresh limestone slurry to the absorber. The amount of limestone slurry added to each absorber is a function of expected boiler load, sulfur dioxide loading, and actual absorber slurry pH. Two redundant in-line pH probes are provided in the discharge piping of the gypsum bleed pumps to measure absorber slurry pH.

As the hot inlet flue gas is quenched, water is evaporated and carried out of the absorber. In addition, the sulfur dioxide removal process forms solid products. These two processes result in an increase of absorber slurry density. Absorber slurry density is controlled by the addition of mist eliminator and filtrate water to the absorber. A non-nuclear density meter, located in a bleed line off the gypsum bleed pumps discharge piping, measures absorber slurry density. A signal from the absorber slurry density meter opens or closes the absorber density control valve. The absorber is designed to operate at an absorber slurry density equivalent to 15 percent suspended solids.

Reaction products formed by SO_2 removal, along with the addition of limestone slurry and density control water, cause a build-up of liquid within the absorber reaction tanks. The liquid level of each absorber reaction tank is controlled by bleeding gypsum slurry to the gypsum dewatering system.

The sulfur dioxide removal process includes an in-situ forced oxidation system. This oxidation system converts calcium sulfite ($CaSO_3 \cdot {}^1/_2H_2O$) formed by the sulfur dioxide removal process to calcium sulfate ($CaSO_4 \cdot 2H_2O$). Two oxidation air blowers per absorber supply the air used for oxidizing the absorber slurry. The oxidation air enters the absorbers through air lances located below the absorber slurry level in the absorber reaction tank to ensure that proper oxidation is achieved.

Dewatering System

The dewatering system at each plant consists of both a primary and secondary dewatering system and a waste water feed system, all capable of 24 hours/day, 7 days/week operation. Please refer to Figure 7 for a flow diagram of the FGD systems. The primary dewatering system includes the gypsum dewatering hydrocyclones. The secondary dewatering system includes the vacuum belt filters. The waste water feed system includes a secondary waste water hydrocyclone and a waste water feed sump. The dewatering system is capable of continuously receiving slurry from the absorbers and producing gypsum conforming to the guaranteed specification. The dewatering system is designed as a common system for the four units at the Taean plant and the six units at the Hadong plant. Spare dewatering trains are provided for each plant. Each train consists of one gypsum dewatering feed pump, one gypsum dewatering hydrocyclone cluster, and one vacuum belt filter.

Gypsum slurry is continuously pumped from each of the absorbers by the gypsum bleed pumps which feed the gypsum dewatering feed tanks. The gypsum dewatering feed tanks are cross-tied via both the dewatering tank feed header and the gypsum dewatering feed pump suction piping. The gypsum dewatering feed pumps feed slurry to the gypsum dewatering hydrocyclone clusters and vacuum filter trains. The hydrocyclone underflow (approximately 45 weight % suspended solids) drops directly onto the vacuum belt filter. The hydrocyclone overflow flows to the filtrate tanks with a chloride bleed stream feeding the secondary waste water hydrocyclone feed sump. The chloride level in the absorber is maintained below 20,000 ppm at all times via the normal gypsum slurry blowdown or the primary waste water hydrocyclone.

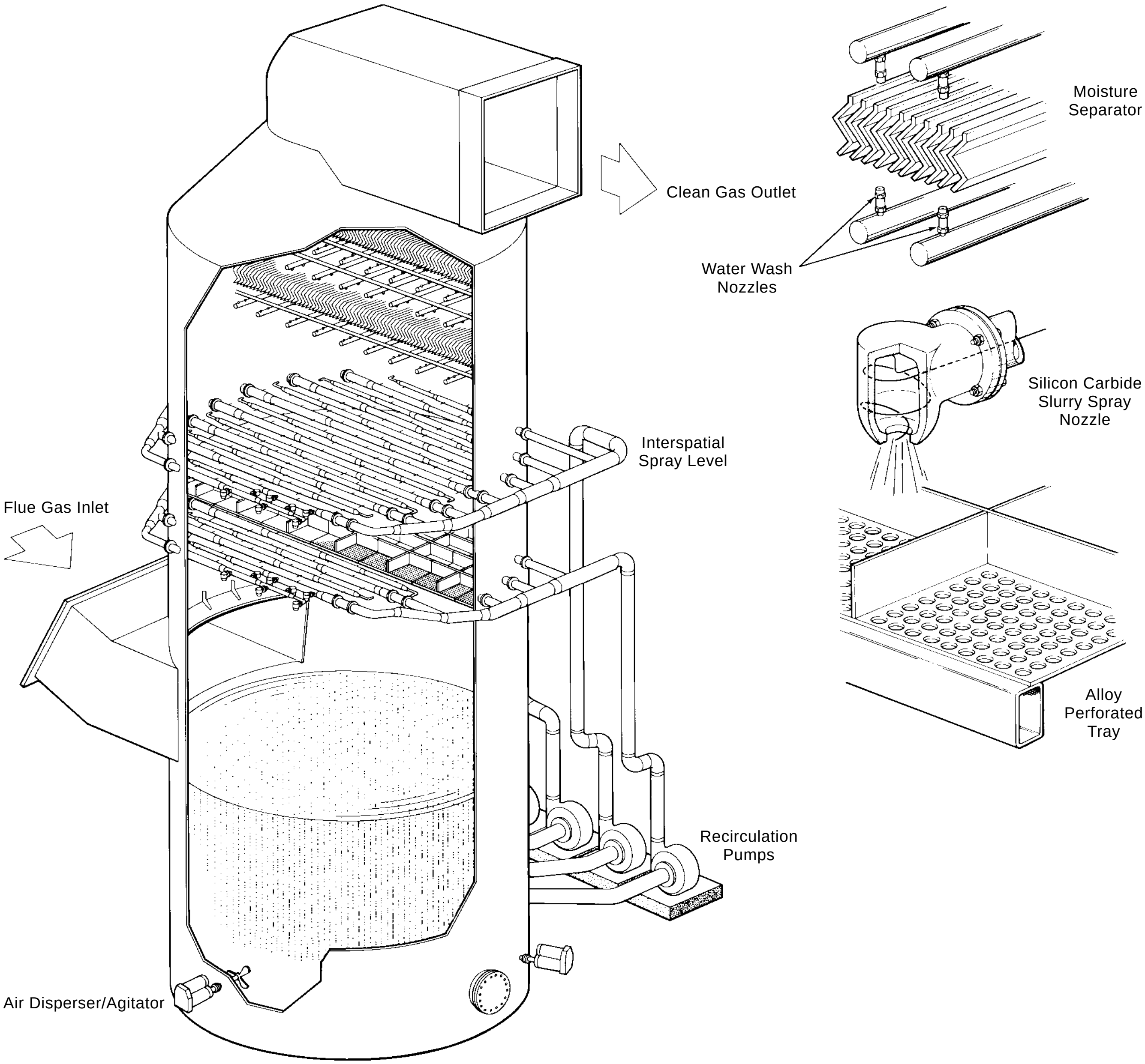

Figure 5 Typical B&W absorber tower.

The secondary waste water hydrocyclone feed sump receives the chloride bleed streams from each of the gypsum dewatering hydrocyclones or from the waste water bleed pumps. The secondary waste water hydrocyclone feed sump pumps feed the secondary waste water hydrocyclone. The chloride bleed is treated by the secondary waste water hydrocyclone to further reduce the solids concentration. The dilute overflow is collected in the waste water treatment feed sump and pumped to the FGD waste water treatment system by the waste water treatment feed sump pumps. Underflow from the secondary waste water hydrocyclone cluster is directed to the dewatering area sump and pumped back to the gypsum dewatering feed tank by the dewatering area sump pumps. Underflow from the #1 thickener

Figure 6 Absorber tray from below.

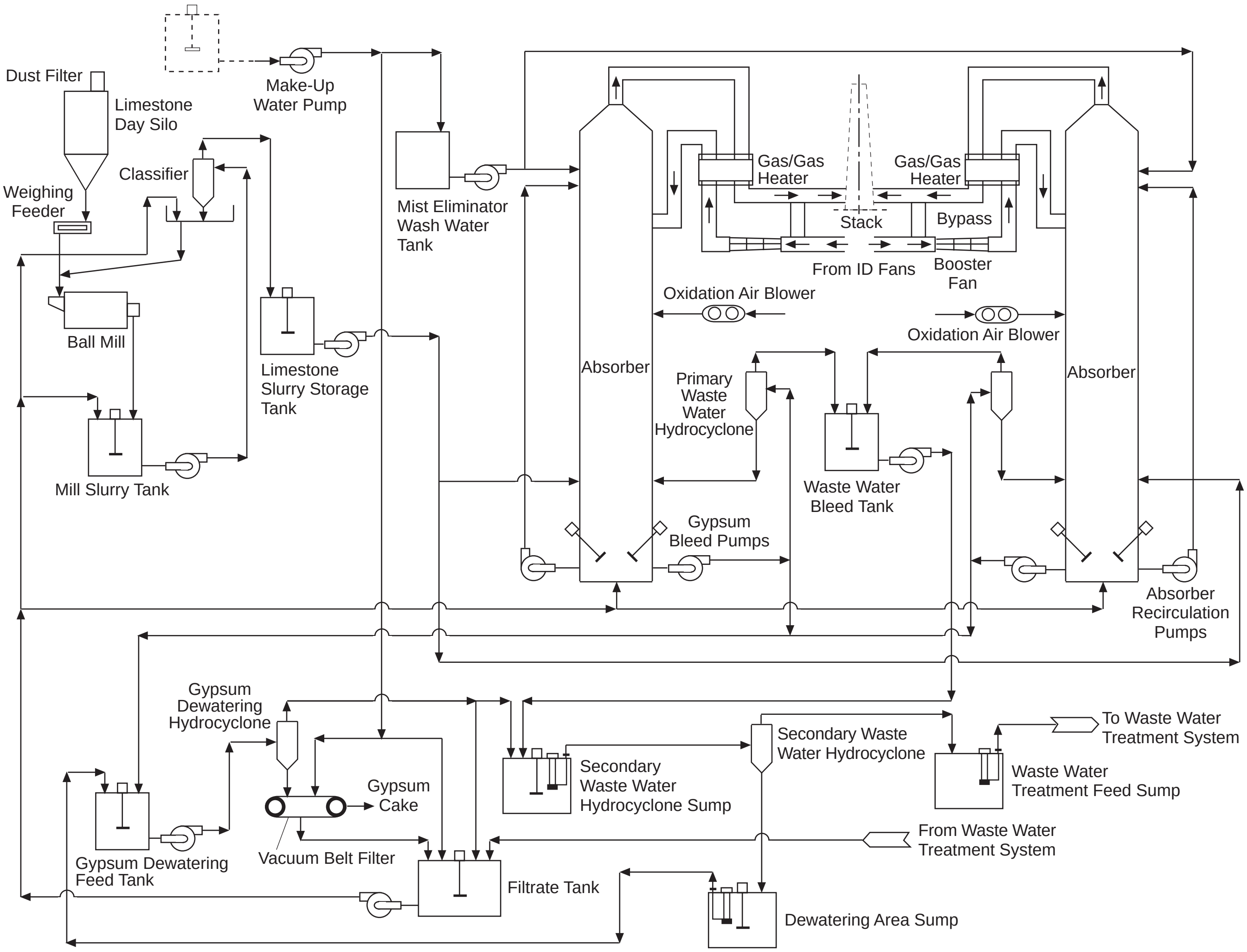

Figure 7 Taean station FGD flow diagram.

in the waste water treatment system is pumped back to the FGD system and returned to the filtrate tank. The recycle stream returns much of the calcium products in order to reduce the solids loading on the waste water treatment system.

The gypsum slurry from each gypsum dewatering hydrocyclone underflow flows by gravity to a dedicated vacuum belt filter. The hydrocyclone is located directly above the filter. The vacuum belt filter dewaters the gypsum to a maximum 10% free moisture. Make-up water is used to wash gypsum cake in the vacuum belt filter to reduce chlorides in the gypsum cake. The filtrate collected off the vacuum filter is sent to the filtrate tank by means of the primary filtrate pumps.

Limestone Slurry Preparation System

Wet ball mill trains are supplied common to the multiple units at each plant. Each limestone slurry preparation train consists of one limestone day silo, one weighing feeder, one wet ball mill with all required accessory equipment, one classifier, and one mill slurry tank with agitator and pump. For Taean, storage is provided by two limestone slurry storage tanks. For Hadong, intermediate storage is provided by two limestone slurry hold-

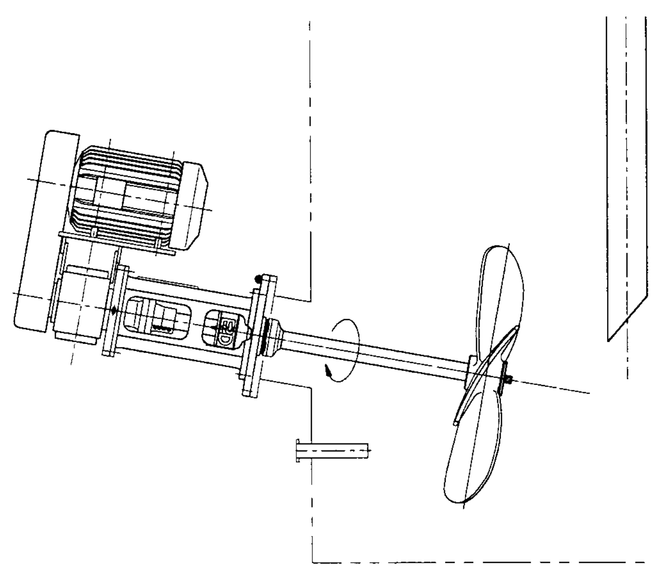

Figure 8 Oxidation air lance.

ing tanks. The holding tanks at Hadong feed three limestone slurry storage tanks. Each slurry storage tank is supplied with limestone slurry pumps as well, each with common discharge to two absorber modules.

Limestone is fed to the limestone day silos by means of belt conveyors. Limestone exits each silo and is fed by a weighing feeder to the horizontal wet ball mill, where the limestone is crushed by a charge of steel balls. Filtrate water is fed into the wet ball mill circuit via the classifier underflow and the mill slurry tank. The limestone slurry gravity-feeds from the ball mill to the mill slurry tank. From the mill slurry tank, the limestone slurry is pumped by means of the mill slurry pump to a classifier consisting of radially oriented cyclones. Fine product slurry, 95% passing 325 mesh, is separated from slurry containing oversized limestone. The fine product continues to the limestone slurry storage tanks. The oversized limestone recycles to the ball mill inlet.

The limestone slurry is supplied to the absorber modules through limestone slurry feed loops via the limestone slurry feed pumps. The feed loops continually recycle back to the limestone slurry storage tanks which permits a continuous flow at various operating loads.

Flue Gas System

The flue gas exits the ID fans (50% capacity each) on each unit and flows to the new ductwork for the FGD system. This ductwork directs the non-treated, hot flue gas to the two dry axial booster fans (50% capacity each) supplied for each unit. These fans boost flue gas pressure to enable the flue gas to flow through the FGD system and exhaust though the chimney. Two bypass ducts exist, coming off the ductwork between each ID fan and booster fan and going directly to the stack inlet flue. Booster fan inlet in conjunction with FGD outlet dampers isolate the FGD system, in order to maintain boiler operation while the FGD system is off line for maintenance, inspection, or other reasons.

The flue gas exits each booster fan, and combines before flowing up into the regenerative gas/gas heater (GGH). Heat is extracted from the dirty, hot flue gas to reheat the clean gas flowing in the opposite direction. The flue gas then passes to the inlet of the absorber and flows upward through a series of sprays and a tray where the flue gas is cooled and saturated as well as scrubbed of SO_2. The clean cool flue gas exits the absorber tower and flows downward through the GGH. After leaving the GGH, the reheated flue gas splits into two paths and continues through ductwork to the stack breeching of the existing chimney where the clean flue gas is discharged into the atmosphere.

The outlet duct of each booster fan is equipped with an automatic emergency quenching system. This system protects the GGH, and all items downstream of the GGH in the flue gas path, from gas temperature excursions. The emergency quenching system is connected to the fire protection system of the plant.

Water Systems

The main water systems within the FGD system are the make-up water and filtrate return water systems. The make-up water system is primarily used for mist eliminator washing and flushing of process lines. The filtrate return water system is primarily used as process water for limestone slurry preparation and density control in the absorber.

Only make-up water is utilized for flushing slurry service process piping and mist eliminator washing. The mist eliminator wash system is composed of one mist eliminator wash water tank per two absorbers with two mist eliminator wash water pumps per absorber as well as on/off valves which are sequenced one at a time for a specified “on” time. Each of these valves directs make-up water to one of four mist eliminator quadrants. Washing in quadrants provides the minimum instantaneous demand for wash water.

The filtrate water system provides process water for FGD systems where fresh water is not required. Two of the significant uses of filtrate water within the FGD system are absorber density control and limestone ball mill feed. The filtrate water system consists of two filtrate water tanks, common among the absorbers at each plant. The filtrate water tanks are supplied with cross-piped filtrate return pumps. The filtrate tanks provide surge volume to allow batch operation of the limestone slurry preparation and vacuum filter systems. Make-up water can be added to the filtrate tank, for start-up and low tank level conditions.

Conclusion

The 5000 MW of FGD provided to KEPCO for the Hadong and Taean plants reflects proven design and high quality construction. The success of the B&W and HHI team in providing FGD to ten (10) units for KEPCO is high testimony to the tireless efforts of many people. We are confident that their superior design will allow these units to be successfully commissioned.