

# **COMPARISON OF GYPSUM DEWATERING TECHNOLOGIES AT FLUE GAS DESULFURIZATION PLANTS**

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## **KEYWORDS**

Flue gas desulfurization plants, wet systems, gypsum dewatering, gypsum recovery, vacuum belt filters, environmental, coal-fired power plant equipment, new technology for coal-fired power plants

## **ABSTRACT**

Recovering gypsum from flue gas desulfurization (FGD) plants is becoming more important as the technical feasibility of substituting FGD gypsum for natural gypsum in traditional applications such as wall board, cement and soil conditioners has been demonstrated. It is estimated that there are over 200 new coal-fired plants and over 1000 upgrades of existing coal-fired plants in various stages around the world. An important aspect of gypsum recovery is the solid-liquid separation technology that is used.

This paper discusses three technologies that are used by coal-fired power plants to dewater and dry gypsum. These are centrifuges, continuous belt filters (CBF) and continuous-indexing belt filters (CI-BF) and rotary vacuum filters. Each technology is examined for their ability to filter, wash and dry the gypsum to meet the moisture content for salable FGD gypsum as compared with natural gypsum. The paper continues with an analysis of the utilities required for each technology including electricity and water usage and the ability to reuse water in the process. Finally, maintenance, reliability, uptime and redundancy requirements are discussed as well as general overview of instrumentation and PLC controls and communication is covered.

The paper concludes by describing the important information that power plant engineers should review before deciding on a solid-liquid separation technology. These parameters include type of FGD process, type of coal, limestone purity, water analysis, operating data, composition of the gypsum slurry and other upstream or downstream equipment. Finally, to meet the plants overall environmental objectives, a unique approach is described that takes the wastewater treatment sludge and incorporates it with the gypsum for a cement product.

## INTRODUCTION

Environmental awareness has been increasing over the years. One area that has received a considerable amount of attention is the potential of acid rain that results from the generation of sulfur dioxide (SO<sub>2</sub>) during the combustion of fossil fuel. For coal-fired power plants (CFPPs), which represent a major source of SO<sub>2</sub>, this has been an important concern. There are several ways that CFPPs can reduce SO<sub>2</sub> emissions including conventional wet and dry scrubbing technologies. This paper will examine wet flue gas desulfurization (WFGD) systems and specifically techniques available for producing a by-product of salable gypsum for wallboard, cement and other manufacturing uses.

## TECHNICAL DESCRIPTION OF WFGD SYSTEMS

### WFGD TECHNOLOGY

A typical process flow diagram of a conventional wet scrubber including gas handling and SO<sub>2</sub> absorption is shown in Figure 1. In wet scrubbers, the flue gas enters a large vessel (spray tower or absorber), where it is sprayed with a water limestone slurry. The calcium in the slurry reacts with the SO<sub>2</sub> to form calcium sulfite.

Limestone with forced oxidation (LSFO) is a variation of the traditional wet scrubber in that it utilizes limestone instead of lime. In the LSFO process, the calcium sulfite initially formed in the spray tower absorber is nearly 100 percent oxidized to form gypsum (calcium sulfate) by bubbling compressed air through the sulfite slurry in the tower recirculation tank or in a separate vessel. Because of their larger size and structure, gypsum crystals settle and dewater better than calcium sulfite crystals, reducing the required size of by-product handling equipment. The gypsum slurry is fed to a hydrocyclone and filter for final dewatering. The high gypsum content has a commercial value, as a useful by-product.

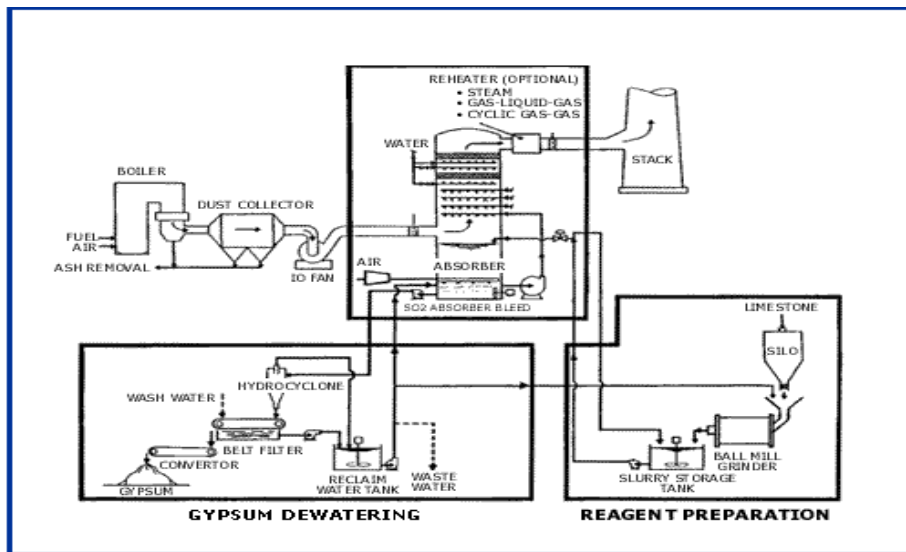


FIGURE 1: TYPICAL WET FLUE GAS DESULFURIZATION PLANT

## TYPICAL GYPSUM DEWATERING SYSTEM

The typical dewatering system is shown in Figure 2. It consists of both a primary and secondary dewatering system and a wastewater feed system all capable of 24 hours/day, 7-days/week operations. The primary dewatering system includes the gypsum dewatering hydrocyclones. The secondary dewatering system includes the vacuum belt filters. The dewatering system is required to continuously receive slurry from the absorbers and produce gypsum conforming to the guaranteed specification. Gypsum slurry is continuously pumped from the absorber by gypsum bleed pumps, which feed the gypsum dewatering feed tanks. The gypsum dewatering feed pumps feed slurry to the gypsum dewatering hydrocyclone clusters and vacuum belt filter trains.

The gypsum dewatering hydrocyclones separate and distribute the gypsum slurry suspended solids. The gypsum dewatering hydrocyclones have multiple sets of individual cyclones and a valve network, which can isolate flow to individual cyclones. 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 dewateres the gypsum. The dewatered cake falls from the filter cloth into the discharge chute, which directs it onto a conveyor for final storage and distribution.

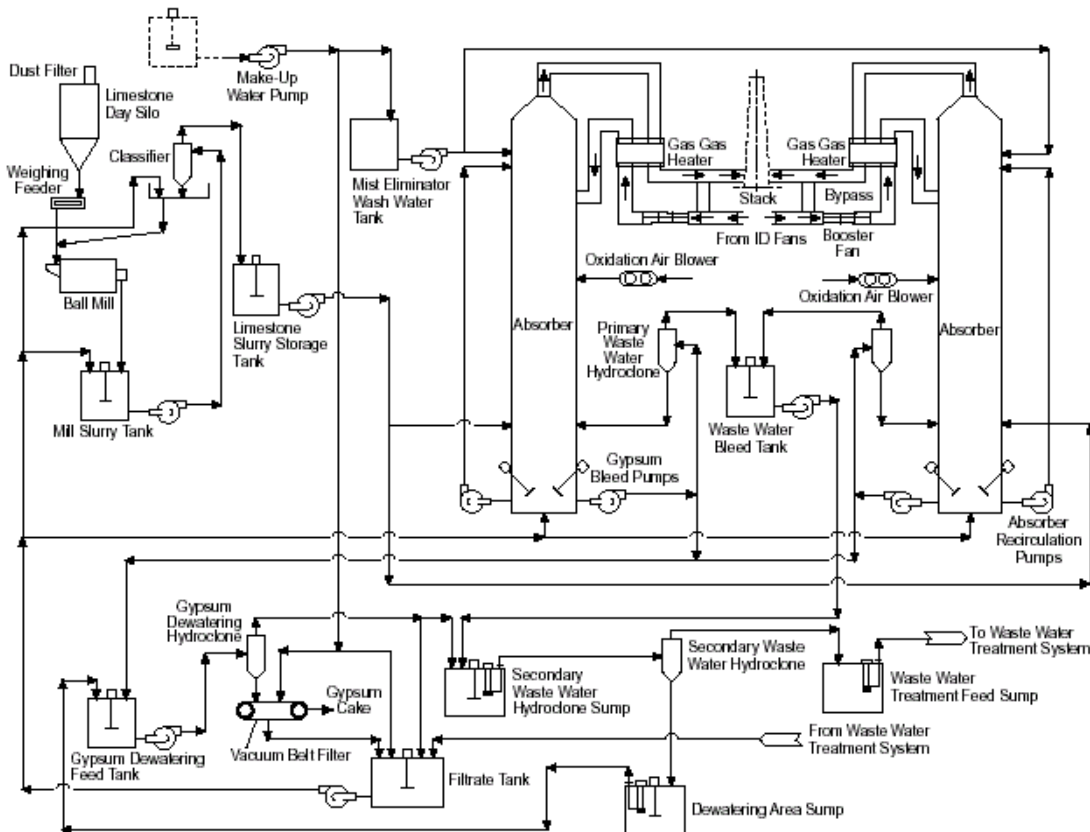


FIGURE 2: GYPSUM DEWATERING SYSTEM

## **COMPARISON OF GYPSUM DEWATERING SYSTEMS**

There are several types of solid-liquid separation systems that can be used to dewater and dry the gypsum slurry. These include belt filters (CBF continuous and CI-BF continuous-indexing), vertical basket centrifuges and rotary vacuum filters.

### **VACUUM BELT FILTERS**

There are two types of vacuum belt filters that can be used in the WFGD process: Continuous-CBF and Continuous-Indexing CI-BF. While both types can filter and wash the gypsum, their operational characteristics are very different.

The filtration cycle begins when vacuum is applied to the slurry that has been distributed on the vacuum belt filters. There are two distinct operations in the filtration cycle: cake formation and cake dewatering. Cake formation occurs as the free water is removed from the slurry. The end of the cake formation portion of the cycle is visually noted by the free water disappearing from the surface of the cake. The cake formation occurs very quickly after vacuum is applied. The cake wash water displaces dissolved contaminants from the formed cake. Cake wash water may be either recycled cloth wash water or make-up water. After cake formation and cake washing, cake dewatering begins and continues through the remainder of the cycle. In this portion of the cycle, water is removed from between the gypsum particles or crystals. The filter cloth and dewatered cake pass over a small radius discharge roller that separates the dewatered cake from the cloth for discharge. The vacuum belt filter design includes a cloth wash after cake discharge.

In terms of operational characteristics, there are several main differences between CBFs and CI-BFs as shown in Table 1. One main difference is the need for a carrier or grooved rubber belt. The CBFs need a rubber belt for the operation. The belt lies in the vacuum box. Two narrow sealing belts run between the main rubber belt and the sides of the vacuum box. These belts must be sealed to each other and cooled by a continuous flow of water. The belts require high maintenance and increase the water usage at the plant.

CI-BFs are continuous-indexing designs that eliminate the need for rubber carrier belts. The filter cloth is moved intermittently in steps. During the cloth movement, the vacuum is switched on and off to allow the cloth to move (index). The entire operation is pneumatic and is easily controlled. Water usage for sealing is eliminated and only one belt, rather than three (3) belts need to be maintained.

### **VERTICAL BASKET CENTRIFUGES**

Vertical basket centrifuges are also used for gypsum dewatering. A typical cycle is basket acceleration to 800 RPM followed by slurry feeding, cake washing, spinning for cake drying and then speed reduction to 40 RPM for cake discharge. The centrifuges are operated on a batch basis with an overall cycle time of 8 – 10 minutes per batch. The basket centrifuges, while they produce a dry cake, require very high maintenance due to the high rotational speeds and generally require twice as many centrifuges as compared with the number of belt filters for an equivalent production rate. Table 2 provides

additional technical comparisons of vertical basket centrifuges to CI-BFs and Table 3 compares the economics of the two technologies.

**TABLE 1: DIFFERENCES BETWEEN CONTINUOUS AND CONTINUOUS-INDEXING BELT FILTERS**

COMPONENT	CBF	CI-BF	BENEFITS OF CI-BF FOR GYPSUM DEWATERING
Rubber belt and sealing belts	Required	Not required	-30% less water usage -Lower maintenance -Rubber belt damage stops the entire operation
Filter Cloth Life	Short life due to constant contact with moving rubber belt and sealing surfaces	Long life	Lower maintenance and higher up-time
Vacuum Level	-0.5 bar	-0.8 bar	Higher vacuum means better dewatering and lower final moisture content for the gypsum
Energy Usage	Motor for rubber belts	Pneumatics	Lower energy costs
Cake Washing	Continuous, cannot alter residence time	Residence time can be altered	-Better displacement washing as cake is stationary -Lower water usage -Can use higher temperature water for reducing final moisture content -Can use steam for reducing final moisture content
Filter Media Washing	Continuous, cannot alter residence time	Residence time can be altered	-Better cloth cleaning for longer filter life -Lower water usage
Cloth Tracking	Needs three trackers for rubber belt, sealing belts and filter media	One set of trackers	Lower maintenance because cloth remains smooth

**TABLE 2: DIFFERENCES BETWEEN VERTICAL BASKET CENTRIFUGES AND CONTINUOUS-INDEXING BELT FILTERS**

COMPONENT	VERTICAL BASKET CENTRIFUGE	CI-BF	BENEFITS OF CI-BF FOR GYPSUM DEWATERING
Operation	Batch	Continuous	-Matches the plant operation -Need twice as many units to meet production requirements
Cake washing	-Channeling can occur -Needs larger volumes of wash water	Can alter residence time	-Better displacement washing as cake is stationary -Lower water usage -Can use higher temperature water for reducing final moisture content -Can use steam for reducing final moisture content
Cake discharge	Batch; may leave a heel	100% discharge	Maximum recovery and economics
Energy Usage	Motor for centrifugal forces	Pneumatics	Lower energy costs

**TABLE 2: DIFFERENCES BETWEEN VERTICAL BASKET CENTRIFUGES AND CONTINUOUS-INDEXING BELT FILTERS (CONTINUED)**

Maintenance	Very high due to high operating speeds	Very low	Lower costs and higher uptime
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**TABLE 3: ECONOMIC DIFFERENCES BETWEEN VERTICAL BASKET CENTRIFUGES AND CONTINUOUS-INDEXING BELT FILTERS BASED UPON A PRODUCTION RATE OF 22 TONS/HOUR OF DRY GYPSUM**

COMPONENT	VERTICAL BASKET CENTRIFUGE	CI-BF
Capacity per machine	5 tons/hour	11 tons/hour
Number of machines with standby	6	3
Residual Moisture	6%	6% (with steam dewatering)
Additional equipment	Thickener, rundown tank, conveyor	None
Relative Capital Costs (Estimated)	1.8	1
Relative Maintenance Costs (Estimated)	1.2	1
Relative Water Costs (Estimated)	1.33	1
Relative Energy Costs (Estimated)	1.1	1 (including vacuum pumps)
Total Costs/Ton of Dry Gypsum (Estimated)	1.13 – 1.24	1

**ROTARY VACUUM FILTERS**

Rotary vacuum filters (RVFs) are another alternative for gypsum dewatering. RVFs are typically fed from by a pump from a mix tank. The flow rate is controlled by an in-line throttling valve to maintain a slurry overflow to the RVF. The solids must be kept suspended for good cake buildup. An inadequate suspension will limit cake build up and reduce the RVF capacity. As the drum rotates, generally up to 40 RPM, the drum submergence should be between 10 – 30%. The designs of RVFs vary with either compartmentalized vacuum sections or one continuous vacuum section. Depending upon cake buildup, these designs may have dead-zones where no filtration occurs due to solids blinding.

After filtration, the gypsum is washed and dewatered. Washing gypsum in an RVF requires elevated wash temperatures and three washes. Water usage is high as the wash liquid only affects the top half of the drum and excess wash water then runs into the slurry trough. Dewatering of the cake continues via vacuum. The cake is discharged pneumatically by a blowback valve which is positioned inside of the filter drum at an extreme close proximity to the inside drum surface to prevent vacuum loss. There is a tradeoff among blowback pressure, cake moisture, percent of cake discharged and filter media life.

**COMPARISON SUMMARY**

The paper has discussed continuous belt filters (CBF), continuous-indexing belt filters (CI-BF), vertical basket centrifuges and rotary vacuum filters (RVFs). The technical comparisons in Tables 1 and 2 including maintenance requirements, energy and water usage, and product quality along with the

economic analysis in Table 3 leads to the conclusion that CI-BFs typically are the most cost-effective solution for gypsum dewatering. Figure 3 shows a typical CI-BF unit installed with 12 m<sup>2</sup> of filter area producing 9000 kilograms/hour of dry gypsum.



**Figure 3: Continuous-Indexing Belt Filter with 12 m<sup>2</sup> of Filter Area Installed for a Gypsum Dewatering System Producing 9000 Kilograms/Hour of Dry Gypsum**

## **INSTRUMENTATION AND CONTROLS SYSTEMS FOR CONTINUOUS-INDEXING (CI-BF) BELT FILTERS**

### **SCOPE OF WORK**

A typical installation includes an Allen-Bradley SLC 5/04 control system designed to control one or more of the CI-BFs as well as the associated vacuum and liquid pumps, tanks and valves. The control system includes Local Control and PLC Panels.

### **PLC CONTROL SYSTEM**

The PLC Panel includes the PLC control hardware, 24-Volt DC power supply, terminals, wire ways, circuit protection, and relays with a 120-volt AC power supply. The PLC Panel contains terminals to accept signals from instrumentation on the CI-BFs. The total PLC discrete and analog points generally include 10-15% spares. The discrete inputs typically include an emergency stop, valve controls

(vacuum valves, vent valves, and cloth rinse valves), pump controls (vacuum pumps, filtrate pumps, cloth rinse pumps) and belt filter controls (movement-indexing and cloth tracking). The discrete outputs include monitoring of the filtrate tanks and pumps, belt filter operation, as well as feed pressures and liquid flows to and from the CI-BFs. Finally, the PLC system is programmed to provide manual and automatic control of the CI-BFs as well as all emergency and safety interlocks. Communication to the plant Distributed Control System (DCS) is handled in several ways including data highways and data files.

## **PROCESS PARAMETERS TO CONSIDER WHEN SPECIFYING A CI-BF FOR GYPSUM DEWATERING**

When specifying a dewatering system for a WFGD plant, the engineer must examine process, operational and mechanical characteristics and parameters. These are described in Table 4.

**TABLE 4: QUESTIONS FOR SPECIFYING A CI-BF FOR GYPSUM DEWATERING**

A. Process:
1. Type of coal used (i.e. brown (soft) coal or hard coal)?
2. Type of water used (fresh or saline) ?
3. What kind of WFGD process is used?
4. What kind of limestone is used and what is its purity?
5. Are hydrocyclones installed?
6. What will be done with the overflow of the gypsum hydrocyclone ?
B. Operating data:
1. Temperature?
2. PH-Value?
3. Flow rates to the gypsum dewatering system?
C. Composition of the gypsum slurry:
1. Type of calcium sulfate?
2. Are chlorides present?
3. Is fly ash present?
4. Are there inerts present?
5. What is the particle size distribution of the solids in the slurry?
6. What are the shapes and form of the solids in the slurry?
D. Water analysis?
E. Standard equipment specifications for the plant?

## **HOLISTIC APPROACH FOR MEETING OVERALL ENVIRONMENTAL OBJECTIVES**

In some cases, a plant may choose to take the wastewater treatment sludge (with about 30 – 35% solids) and send it along with the gypsum slurry to be processed or dewatered. For this method of operation, the dewatered gypsum would be used as a cement product rather than gypsum for wallboard. In this mode, the gypsum may become thixotropic leading to cloth blinding. Attention to cake washing and vacuum levels will minimize the potential of this problem. Further recycling of water is also shown in Figure 2. In this plant, water from the wastewater treatment system is sent back to the filtrate tank to be



used as cake wash water or cloth wash. With careful planning during the design phase of a CI-BF gypsum project, water usage can be minimized to improve the system economics.

## **CONCLUSION**

This paper examined gypsum dewatering systems at WFGD plants. The technical and economic analyses of several types of solid-liquid separation systems concluded that continuous-indexing belt filters (CI-BFs) are the preferred method for dewatering as compared to vertical basket centrifuges, continuous belt filters and rotary vacuum filters. The paper further described methods to minimize water usage at WFGD plants with the use of CI-BFs. Finally, the improved economics and reliability of CI-BFs in conjunction with minimized water and energy usage will allow engineers at WFGD plants to have a cost-effective solution for gypsum dewatering and recovery for a salable gypsum product.

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