Sulfur Filtration Improvements at Dofasco's No. 1 Byproducts Plant

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Reliable, continuous sulfur removal when cleaning coke oven gas can be achieved with an automated diaphragm pressure filter. This paper details the procurement, installation and commissioning of the filter and the construction of facilities to house the new equipment.

Dofasco's No. 1 byproducts plant cleans coke oven gas (COG) generated from the No. 1, 2 and 3 byproducts plants. The hydrogen sulfide (H_2S) is removed from the COG at the No. 1 byproduct plant in the two Stretford plants. This Stretford process strips the H_2S from the COG and chemically converts it to elemental sulfur. The sulfur must be removed from the stripping solution (called Stretford liquor) to complete the COG H_2S cleaning process. Stretford liquor is recycled back into the process after the sulfur has been removed.

The existing rotary drum filter and autoclave technology had reached the end of their useful lives and were unable to provide reliable continuous sulfur removal.

Benchmarking determined that a Verti-Press pressure filter from Filtra Systems Inc. was the best technology for the replacement. The liquor in the sulfur is squeezed out of the cake using a rubber diaphragm in a sealed horizontal chamber. The new filter press reduces the moisture in the cake from 70 percent to less than 20 percent. The operation of the filter press is completely automatic and requires very little operator attention. It is constructed completely of stainless steel to maximize the filter's life in the corrosive Stretford environment.

This paper reviews the engineering, equipment procurement, installation and commissioning of a Verti-Press automated diaphragm pressure filter and construction of the necessary facilities to house this new equipment.

Background

Dofasco's cokemaking facilities reduce coal to coke at its coke batteries. One of the products generated from this raw material conversion is coke oven gas. COG is used as an energy source at Dofasco's hot mill for steel production. Since COG contains many different chemical species, it is processed through the byproducts plant to extract different components, including hydrogen sulfide (H_2S), prior to being sent to the hot mill.

The No. 1 Stretford plant is a component of the No. 1 byproducts plant. After benzene, toluene and xylene (BTX) are extracted from the COG, the gas is sent to the No. 1 Stretford plant, where H_2S is removed to prevent plugging of lines and reduce atmospheric sulfur, which contributes to acid rain. At the No. 1 Stretford plant, the COG enters near the bottom of the H_2S tower and countercurrently interacts with Stretford liquor that is sprayed from the top of the tower. Stretford liquor is composed of water, vanadium, sodium thiocyanate, sodium thiosulfate anhydrous, 1.5-anthraquinone disulfonic acid disodium salt, anthraquinone disulfonic acid disodium salt, and sulfur. As the H_2S-containing COG interacts with the Stretford liquor droplets, the H_2S is absorbed by the Stretford liquor so that the COG is free from H_2S by the time it leaves the top of the tower. The Stretford liquor, which contains H_2S, is collected at the bottom of the tower and is sent to an oxidizer to separate the sulfur and to oxidize the Stretford liquor for reuse in the H_2S tower. The Stretford liquor is recycled to the pumping tank, while the sulfur slurry is sent to the sludge tank. Previously, the sulfur slurry was sent to a rotary drum filter that reduced the moisture content of the sulfur from approximately 70 to 45 percent. The filter cake was discharged into an autoclave, which melted



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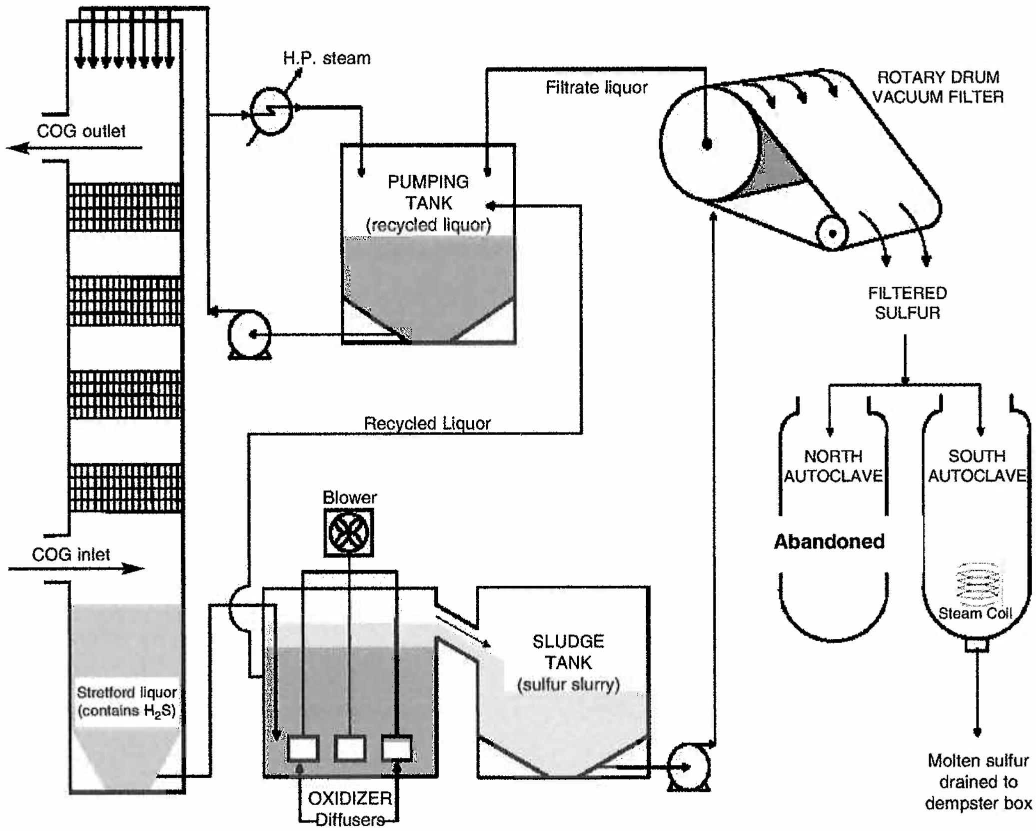
Figure 1



No. 1 Stretford plant process flow diagram before changeout.

the sulfur using steam, driving off moisture and some of the contaminants. The elemental sulfur byproduct from the autoclave, now with less than 1 percent moisture, was sent for disposal. Figure 1 provides a former process flow diagram of the No. 1 Stretford plant.

The rotary drum filter and autoclave had reached the end of their useful lives. The filter drum and the frame that supports it had corroded past the point of repair in the aggressive Stretford environment.

The autoclave had several steam leaks through the exterior shell of the vessel, caused by the interior pressure from the steam jacket and the corrosive Stretford environment. The vessel's shell had been patched several times to repair the steam leaks. However, the corrosion of the vessel had reached a point where the exterior shell was too thin to weld to, rendering it irreparable.

In 2000, the decision was made not to replace existing equipment in kind, but to look for alternate technologies for sulfur slurry processing.

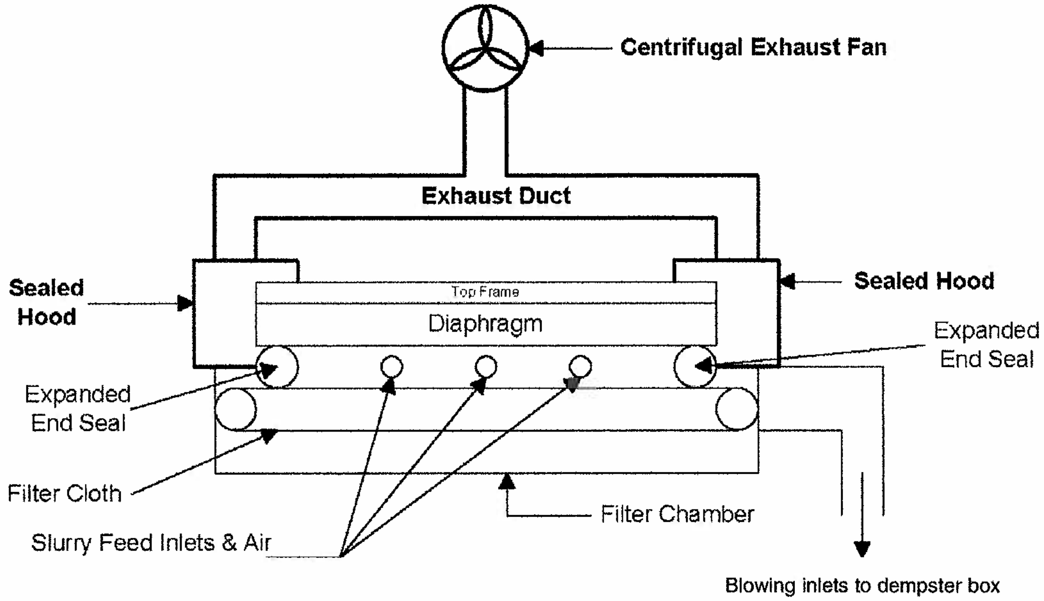
Pressure filtration systems supplied by two independent manufacturers were investigated. To better evaluate these options, in 2001 a benchmarking trip to California was organized to visit the Calpine geothermals power plant and the Tosco-Rodeo refinery, where the filter is utilized for processing sulfur from Stretford solution.

The visits revealed that the Verti-Press pressure filter has been operating in these plants for 20+ years. The track record of the filter, lab testing, Dofasco's own observations and industry opinion helped Dofasco conclude that the Verti-Press pressure filter is the best available technology for filtering, dewatering and washing the Stretford sulfur in its Stretford process.

Operation

The Verti-Press pressure filter is designed for the filtration of finely divided, suspended solids from liquid and efficient washing of the dewatered filter cake. Separation is accomplished using pressures up to 100 psi and a permanent media belt. Dewatering is accomplished through a combination of diaphragm squeezing and compressed air blowing at pressures up to 90 psi. The horizontal filter chambers are closed by hydraulically pressurizing seals across each end of the filter chambers to 200 psi. The feed pump then pumps the slurry into the filter chambers. Suspended solids are retained on the "filter belt," and the filtered solution drains into a lower drip tray

Figure 2



Cross-section of filter chamber and vapor collection system.

and flows from the filter by gravity to the pumping tank. Figure 2 illustrates the main components of the filter press.

At the end of the feed cycle, air pressure is used to remove all free liquid from the filter chamber and cake. Wash water is then metered into the filter for the cake wash. A rubber diaphragm in the filter chamber is pressurized hydraulically to 100 psi pressure. This pushes all the wash water through the filter cake. After the diaphragm is retracted, the filter cake is blown with compressed air to remove any residual cake moisture.

The end seals are then retracted and the belt is advanced to discharge the filter cake. During the cake discharge cycle, the belt is washed with a spray header located at the drive end of the filter. The belt assembly moves one complete revolution during the cake discharge cycle. A sulfur cake between $^3/4$ and 1 inch thick is discharged to the dempster box, which is disposed of on a daily basis. Figure 3 provides a process flow diagram incorporating a Verti-Press pressure filter.

The end seals are washed with water to remove any remaining particles that would prevent proper sealing in the filter in the next cycle. The cycle automatically repeats every 10–15 minutes until the filter is shut down by the operator. The No. 1 Stretford plant Verti-Press pressure filter operates approximately 16 hours each day.

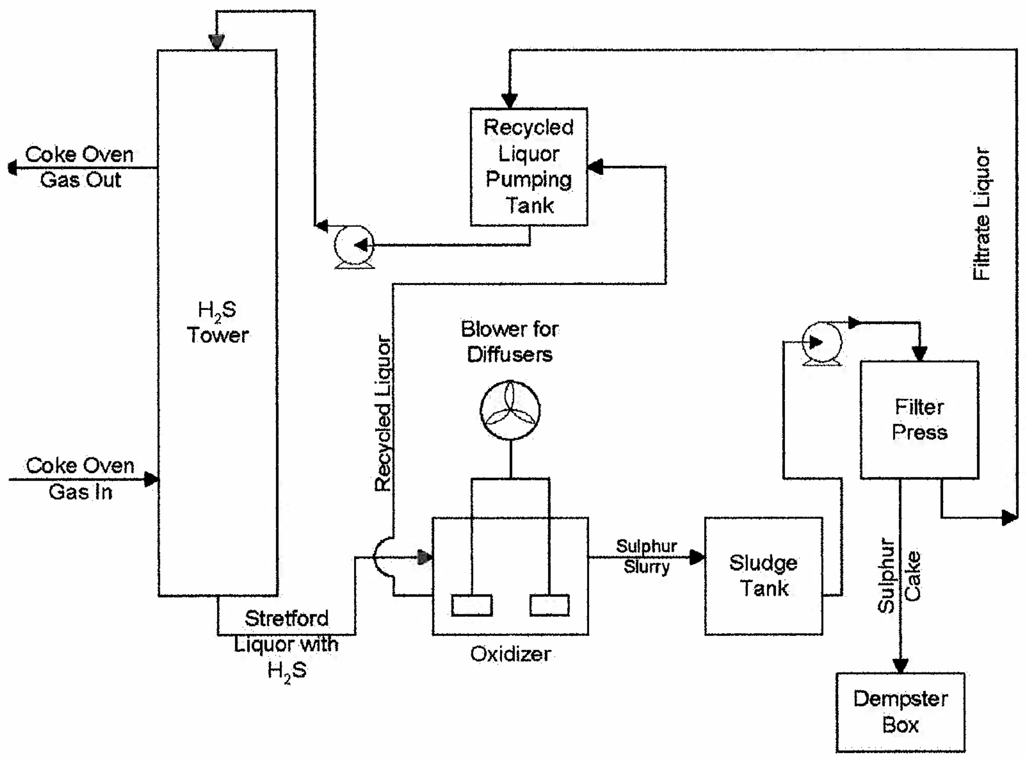
Design Considerations

Sizing — The Verti-Press pressure filter selection was based on laboratory testing with a representative slurry sample from Dofasco's Stretford plant. The sizing was based on filtering, dewatering and cake washing 3.0–4.0 tons/day of dry sulfur. The filter test program yielded an average filtration rate of about 25 pounds per square feet per hour of dry sulfur. The resultant filter cake was approximately 80 percent dry solids. Therefore, it was established that the required filter size would be about 20–22 square feet. The filter currently installed has 25 square feet of filter area. The filter cycle to achieve this includes a physical press of the material with the machine's diaphragm, cake washing to remove vanadium, and other filter function steps, from discharge to discharge.

Cake Thickness — A uniform cake thickness, maintained between $^3/4$ and 1 inch, ensures optimum filter performance. One significant advantage of the Verti-Press system is the program will adjust the filter cycle to maintain a specific cake thickness. The volume of hydraulic water used to pressurize the diaphragm is monitored. A change in volume from the previous cycle indicates the cake thickness has changed because of a variation in the feed slurry solids content. The program will react to the variation by adjusting the slurry pumping time to ensure the specified cake thickness is met. Dofasco's original design specification did not include this option.

Operating Features — The initial bid package prepared by Dofasco listed the specifications that were to be met by the successful bidder. Although the original package was quite

Figure 3



No. 1 Stretford plant process flow diagram.

detailed, only the significant criteria are discussed below.

Filter System — The filter was completely shop assembled, piped and wired. Prior to shipment, a complete functional test of all filter operations was to be conducted. The filter end seals were be hydraulically operated using 200 psig water as a working fluid. The filter diaphragm was to be hydraulically operated using 100 psig water as a working fluid. The water was to be provided from the supplied, closed-loop water station.

All portions of the filter chamber wetted by the process slurry, including all process piping and the main frame, were to be fabricated using 316L stainless steel.

One water station was to consist of a closed-loop system for automatic operation of the filter end seals. The water station skid was to be supplied with a 304L stainless steel tank complete with cover. The tank was to be equipped with a level indicator, a manual water makeup valve and manual drain valve. The water station skid was to be housed under filter frame.

Process Control — The filter system is designed to be monitored by the No. 1 byproduct I/A data control system (DCS). The filter press program is connected to the DCS through a DH+ to RS-232 communications module. All phases of the filter function are to be controlled by a programmable controller PLC to eliminate the need for a full-time operator. The enclosure is outfitted with a graphic display to indicate complete filter operation, auxiliary equipment interlocks and alarm conditions. The enclosure has an alarm horn mounted on the panel to signal that an alarm condition exists.

The filter is fed from the No. 1 sludge tank through a slurry feed pump at a rate of 35–50 gpm at 40 pisg. A recirculation line is required to reticulate slurry when the filter is out of service. The filtrate, including the belt wash drainage, discharges to the sump on the No. 1 Stretford pad, and it is recycled back into the process.

Service Requirements — A filter building was elevated to allow for a filter cake discharge chute through the floor and truck access to the dempster box, which is placed in line with the discharge chute under the building. The building was built for the corrosive Stretford environment.

Lake water is used for filter cloth, end seal cleaning and cake cleaning. City water is an operating fluid for operation of the filter end seals and diaphragm.

Construction and Installation

Scope — The scope of this project was completed in two phases.

Figure 4

Filter press building.

Phase 1: Equipment Procurement and Construction Engineering

- Procure a Verti-Press pressure filter from the filter manufacturer.
- Engineer a new building to house the filter, complete with necessary services, including water, steam and air piping, electrical requirements, and instrumentation to connect the filter to the No. 1 byproducts plant DCS.
- Plan for demolition activities.
- Construction tender packages.
- Pre-start health and safety review.
- Local consulting firm was contracted to do all the construction engineering activities.

Phase 2: Construction

- A new steam-heated building to house the pressure filter complete with emergency eyewash/shower and monorail.
- Electrical services, process and service piping, including new sludge pumps and new lake water pumps.
- New sludge tank level instrumentation and a communication link between the filter PLC program and the No. 1 byproducts plant DCS.
- Commissioning assisted by filter press supplier.
- Training by filter press supplier.
- Demolition of the existing rotary drum filter and autoclaves, and all necessary repairs to the existing filter building.

In January 2003, the contract was awarded to a local contractor, and construction began in March 2003. Project delays were primarily encountered due to inclement weather, incomplete engineering, assumptions/interpretations of scope of work made by the contractor during the bid process, and "brownfield" surprises. Despite various challenges, installation was completed at the end of July 2003, and equipment was turned over to the start-up team. Figure 4 illustrates the filter press building.

Throughout the construction phase of the project, weekly meetings were held between Dofasco and the prime contractor. The purpose of these meetings was to update all concerned parties as to the status of the project and to go over any problems that arose. The meetings also became the forum for discussing design changes that had either been overlooked or discovered as the construction progressed.

Start-up Preoperational Testing and Training

When construction was approximately 85 percent complete, Dofasco conducted successful preoperational testing to confirm both functionality and reliability of the equipment and systems. Coincidentally, just before completion of the construction, the autoclave experienced structural failure and had to be taken out of service permanently. This meant that actual commissioning time would be limited.

Throughout the assembly phase of the project, the preliminary operator orientation and training continued. Operators were taken to the job site in groups of two to be become familiar with the new filter press. This up-front involvement precipitated early operator buy-in on the project.

In general, the pre-training was successful. The nature of the operating panel meant that most operators could quickly master the operation of the filter press.

Commissioning — During preoperational testing, most of the deficiencies of the equipment and systems were found and corrected. In turn, the hot commissioning was virtually uneventful and resulted in a vertical start-up.

During the dewatering cycle of the first sulfur cake, it became apparent that vapors from the filter chamber were being displaced into the building. The vapor emissions often consisted of a complex mixture of many aromatic compounds. Vapor emission intensity is directly related to the upstream processes, which are influenced by upsets and/or out-of-control operations. For example, if the benzol scrubbers or the ammonia absorbers do not work efficiently, the carryover of the high levels of benzene and ammonia in the COG will manifest itself and overconcentrate the Stretford process. Consequently, the vapors emitted from the various vessels and pieces of equipment in the Stretford operation, including the filter press, contain varied levels of benzene and ammonia.

Vapor collection hoods were installed to capture these vapors, without impeding either operation or maintenance of the equipment. The hoods are ducted to the fan. The new hoods, ducting and associated fittings were fabricated completely of stainless steel with the intention to withstand the corrosive Stretford environment. Figure 5 illustrates the existing filter press complete with the vapor collection system.

Figure 5

Filter press complete with vapor collection system.

Maintenance — The critical task for the operators is routine cleaning of the filter once per shift. This includes end seal openings, the filtrate tray, belt scraper and belt wear bars. Thorough washing of the filter belts on a daily basis will improve belt life and filter performance. To ensure reliable operation of the filter press, the studs for the diaphragm hold-down plate must be retorqued annually.

Current Status and Future Work — The Verti-Press pressure filter meets Dofasco's No. 1 Stretford plant sulfur processing requirements, and it is tolerant of upstream process upsets. The pressure filter operation is completely automated and requires very little operator attention. The pressure filter has remained fully operational since installation with minimum downtime, continuing to produce sulfur cake with less than 20 percent moisture. By all accounts, this part of the project is entirely successful.

In order to maintain filter consistency, the filter manufacturer recommended adding a program that will control the cake thickness by monitoring the volume of water used to pressurize the diaphragm. An increase in diaphragm water would indicate a decrease in cake thickness, and during the next cycle, the slurry feed stage would be adjusted to maintain cake thickness (likely to be averaged over three cycles to avoid overcontrol). A proposal for instrumentation to measure slurry density has been received from the filter manufacturer. Dofasco is considering implementation of this feature.

Acknowledgments

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