IMPROVING SULFUR RECOVERY AT GPM'S GOLDSMITH GAS PLANT

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Abstract

A conventional 3-stage Claus sulfur recovery unit located in GPM Gas Corporation's Goldsmith Gas Plant was successfully converted to a sub-dewpoint process plant using Amoco's **C**old **B**ed **A**dsorption (CBA) technology. The sulfur recovery efficiency was raised from about 96% to more than 98%. This allowed plant throughput to nearly double without increasing sulfur dioxide (SO_2) emissions.

Essentially all existing equipment items were reused in the CBA process retrofit. The conversion required the addition of a new reactor, modification of the existing third bed to serve as a CBA reactor, replacement of the last sulfur condenser, and the addition of a unique, cost-effective heater to regenerate the CBA beds. Some existing equipment items were modified and/or replaced to improve the overall economics and reliability of the operation, and the sulfur recovery unit instrumentation was converted to DCS (distributed control system) control.

Proven, highly reliable sulfur vapor valve assemblies were added to allow the existing third bed and the new reactor to cycle as CBA beds, with the DCS controlling these switching valves.

The project team included Ortloff Engineers, LTD, area contractors, and GPM's technical, purchasing, inspection, and maintenance personnel. Time from project approval and kickoff through startup was less than 12 months. Careful coordination of the conceptual design, detailed design, procurement, HAZOP, operator training, shutdown, and startup phases resulted in a very successful fast-track project. The Goldsmith Gas Plant is no longer capacity-limited by the SO_2 emission rate from the sulfur recovery unit.

Background – GPM Goldsmith Gas Plant

A block diagram of the Goldsmith Plant is shown in Figure 1. The facility includes inlet compression from low pressure gathering systems, DEA treating to remove CO_2 and H_2S, sulfur recovery, dehydration, treated gas compression, cryogenic NGL recovery, residue recompression, and the supporting utility systems.

The Goldsmith Sulfur Plant was originally constructed in 1973 for El Paso Natural Gas Company. In 1987 the plant was bought by Phillips Petroleum Company along with the rest of the El Paso Plant at Goldsmith. Currently, this plant is operated by GPM Gas Corporation.

In 1992, GPM desired to increase the facility throughput from a nominal 86 MMSCFD to 135 MMSCFD initially, and ultimately to 160 MMSCFD. Naturally, changes were planned for the other systems in the plant to support the higher plant throughput. The modifications to the cryogenic gas plant were presented at the national GPA Annual Convention last year. Only the changes to the sulfur plant and its resulting operation are discussed in this paper.

The Goldsmith Sulfur Recovery Upgrade Project was initiated to improve the overall sulfur recovery of the existing sulfur recovery unit (SRU). The original design was a straight-through Claus SRU using three Claus catalytic stages and one thermal conversion stage. All of the Claus reactor reheating was provided by in-line acid gas burners. Original design capacity of the SRU was for an inlet feed rate of 147 long tons per day (LT/D) of sulfur in an acid gas stream containing 56% H_2S. The SRU had remained in operation since its original installation with only minor changes made to the basic design and configuration.

In 1992, the Goldsmith SRU was processing an acid gas stream with a variable H_2S content (42-62%) at a total feed rate of 50-60 LT/D. The sulfur recovery efficiency of the existing plant was about 96%, giving SO_2 emissions in the range of 373-448 Lbs/hr. At that time, GPM was in the process of renewing the Sulfur Plant Operating Permit with the Texas Air Control Board (TACB, the predecessor of the Texas Natural Resources Conservation Commission). As a part of the renewed permit (issued in 1993), the TACB allowed GPM to raise the permitted sulfur production rate to 110 LT/D, but stipulated that the sulfur recovery efficiency be improved to 98%. These values correspond to an inlet sulfur capacity of 112.25 LT/D and an SO_2 emission rate of 419 Lbs/hr. Although this fit with GPM's plans for expanding the gas throughput rate at Goldsmith, it meant that the SO_2 emissions had to remain essentially the same as for the current operations. Therefore, the sulfur recovery efficiency of the Goldsmith SRU had to be improved in order to satisfy the new permit and to allow an increase its processing capacity.

GPM performed a sulfur recovery improvement study in August-September 1992. The study evaluated both SUPERCLAUS™ technology (licensed by Comprimo) and Cold Bed Adsorption technology (licensed by Amoco Production Company), and determined that the most cost-effective modification to improve the overall sulfur recovery was to convert the existing 3-stage Claus process into an Amoco Cold Bed Adsorption process. The upgraded SRU was to be designed by Ortloff to accept an inlet feed rate of up to 112.25 LT/D from an acid gas stream containing 50% H_2S (dry basis). With this new process, 110 LT/D of sulfur would be produced at an average overall sulfur recovery of 98% or higher.

Existing Sulfur Plant – The 3-Stage Claus Process

The basic Claus process utilizes the following chemical reactions to convert hydrogen sulfide to elemental sulfur:

(1) $H_2S + 3/2\ O_2 \rightleftharpoons SO_2 + H_2O$

(2) $2\ H_2S + SO_2 \rightleftharpoons 3/n\ S_n + 2\ H_2O$

The overall reaction for the process is:

(3) $3\ H_2S + 3/2\ O_2 \rightleftharpoons 3/n\ S_n + 3\ H_2O$

A simplified process flow diagram of the original Goldsmith 3-stage Claus SRU is shown in Figure 2. Acid gas and combustion air enter the burner on the Reaction Furnace where 1/3 of the H_2S is converted to SO_2 by reaction (1). At the high temperature existing in the furnace, a portion of the SO_2 formed will react with part of the remaining H_2S (thermal conversion) to form sulfur according to equation (2). This sulfur is condensed as the hot process gas is cooled by generating 200 PSIG steam in the H.P. Sulfur Boiler and

50 PSIG steam in Sulfur Condenser No. 1, and the condensed liquid sulfur is drained from the outlet of the condenser.

The process gas from the condenser is reheated in Reheater No. 1. This in-line heater heats the process gas by mixing it directly with the burner effluent that results from partial combustion of a portion of the inlet acid gas bypassing the Reaction Furnace. The heated stream enters the first Claus Reactor where the majority of the sulfur compounds are catalytically converted to elemental sulfur vapor by reaction (2). The sulfur vapor produced is then condensed in Sulfur Condenser No. 2 by generating additional 50 PSIG steam, recovering more of the inlet sulfur. After this condenser, the same process is repeated two more times through two more sets of Reheaters, Reactors, and Sulfur Condensers. The SRU tailgas then flows to the Tailgas Incinerator where all remaining sulfur compounds are converted to SO_2 before the effluent is dispersed to the atmosphere from the top of the stack.

Amoco's Cold Bed Adsorption (CBA) Sulfur Recovery Process

The Goldsmith SRU was retrofitted to use Amoco's CBA process as shown in Figure 3. This CBA unit is described in Amoco's terminology as a 4R/Rotate 3,4 configuration. This means the plant contains four catalytic reactor stages and that the flow arrangement changes on the third and fourth stages. In other words, the plant contains two conventional catalytic Claus stages, followed by two catalytic CBA stages. This configuration is typical of the schemes employed by most CBA plants in operation today. It was chosen because its simplicity results in an economic plant design, while the two CBA stages are sufficient to provide the desired sulfur recovery performance of 98%. The existing third Claus Reactor was converted to a CBA Reactor so that only one new CBA Reactor was required.

Cold Bed Adsorption Theory

The thermal and catalytic conversion in the conventional Claus portion of the sulfur plant (through Sulfur Condenser No. 3) recovers about 91-94% of the inlet sulfur. Adding more conventional Claus catalytic stages beyond this point would add some sulfur recovery, but would soon reach the point of diminishing returns. This is because the Claus reaction, equation (2), is an equilibrium reaction, and becomes limited by the concentrations of water and sulfur vapor in the gases flowing through the plant. The CBA portion of the sulfur plant overcomes this limitation through the use of "sub-dewpoint" conversion stages.

Although catalytic conversion of H_2S and SO_2 is higher at lower reactor temperatures, conventional Claus reactors must be operated at temperatures sufficiently high to keep the sulfur produced from condensing. Sulfur conversion catalyst will adsorb liquid sulfur in its pores, which blocks the active sites where the Claus reaction occurs. If the Claus reactor temperature is too low, the sulfur concentration in the vapor will exceed its dewpoint concentration, causing liquid sulfur to form and adsorb on the catalyst. Over time, this liquid sulfur will block all of the active sites in the catalyst and render the catalyst bed almost completely inactive.

A CBA reactor is operated in a cyclic fashion to avoid complete catalyst deactivation from liquid sulfur blocking the active sites. The CBA reactor is operated at low temperature (250-300°F) initially so that it is below the sulfur dewpoint of the reaction products (i.e., "sub-dewpoint") and the sulfur formed is condensed and adsorbed on the catalyst. After operating in this manner for a period of time, the CBA reactor is "regenerated" by routing hot gas (600-650°F) through the reactor to vaporize the adsorbed liquid sulfur, which is then condensed and removed in the downstream CBA Sulfur Condenser. This is very similar to the processing steps used when dehydrating gas streams with molecular sieves. There are normally two or more CBA reactors in series so that at least one can be operating sub-dewpoint while the other is being regenerated.

Not only does a CBA reactor benefit from a more favorable Claus reaction constant at its lower operating temperature, it also has the advantage of shifting the Claus reaction equilibrium. The Claus reaction is a vapor-phase reaction, so condensing the sulfur product removes it from the vapor, forcing the equilibrium in reaction (2) farther to the right, toward higher conversion. These two factors allow much higher sulfur conversion than in a conventional Claus reactor, resulting in overall sulfur recovery efficiencies in excess of 98-99% for most CBA plants.

CBA Adsorption Cycle

Figure 4 shows just the CBA section of the retrofitted SRU. The vapor from Sulfur Condenser No. 3 flows through the new Sulfur Separator for removal of any entrained sulfur droplets. (This separator was added to minimize the amount of liquid sulfur entering the CBA section of the SRU.) From the Sulfur Separator, the process gas flows through the CBA regeneration heater (consisting of the CBA Regeneration Burner and the CBA Regeneration Mixing Chamber) to the first CBA Reactor. During the adsorption cycle, no heating occurs in the heater and the gas enters the first, or "lead", CBA reactor at about 270-280°F. Nearly all of the remaining H_2S and SO_2 is converted into elemental sulfur, which condenses and is adsorbed on the catalyst. The gas leaves the first CBA Reactor and is cooled in the new CBA Sulfur Condenser by generating 20 PSIG steam. No sulfur is condensed at this point because most of the sulfur has been adsorbed on the catalyst in the first CBA Reactor.

The gas leaving the CBA Sulfur Condenser flows directly to the second CBA Reactor, where a portion of the remaining H_2S and SO_2 is converted to sulfur, which also condenses and is adsorbed on the catalyst. Gas leaves the second CBA Reactor and is routed to the Tailgas Incinerator. This SRU tailgas stream contains very little elemental sulfur because nearly all the sulfur has been adsorbed on the catalyst in the CBA Reactors.

CBA Regeneration Cycle

After operating in this manner for a period of time (12 hours at design flow rates), the first CBA Reactor must be regenerated to remove its adsorbed sulfur. During the regeneration cycle, the gas leaving Sulfur Condenser No. 3 is heated to 600-650°F by combining with the burner effluent generated by the CBA Regeneration Burner in the CBA Regeneration Mixing Chamber before entering the first CBA Reactor. The hot gas vaporizes the liquid sulfur held on the catalyst bed, which then leaves the reactor in the gas as sulfur vapor and is cooled, condensed, and separated in the CBA Sulfur Condenser. The remaining gas flows to the second CBA Reactor as before. The second CBA Reactor continues to operate in adsorption mode, converting nearly all of the remaining H_2S and SO_2 and adsorbing the sulfur produced. Gas leaves the second CBA Reactor as before and flows to the Tailgas Incinerator.

During the initial stages of regeneration, no sulfur is vaporized in the CBA Reactor as the hot gas heats the reactor. Once the liquid sulfur begins to vaporize, the bulk of the sulfur is removed during the "plateau" phase where the reactor outlet temperature remains relatively constant. After this bulk sulfur removal, the reactor outlet temperature again begins to climb as the reactor enters the "heat soak" phase, which is maintained until the outlet temperature reaches 600-650°F (the same as the feed temperature). Once the CBA

Reactor reaches this temperature and stabilizes, it is then cooled by turning off the CBA Regeneration Burner so that the gas from the Sulfur Separator once again enters the reactor without being heated. At normal flow rates, the heating cycle for the CBA Reactor is set for 9 hours.

After the first CBA Reactor has been cooled (3 hours at normal flow rates), it is placed into the "cleanup" position by changing the positions of the appropriate switching valves. What was the second CBA Reactor (in the "cleanup" position) now becomes the first bed in the "lead" position, and what was the first CBA Reactor (in the "lead" position) becomes the second bed in the "cleanup" position. By operating in this manner, the final ("cleanup") bed always has the lowest sulfur content and keeps the sulfur concentration in the sulfur plant tailgas as low as possible. At normal flow rates, the CBA Reactors are set to switch every 24 hours (adsorbing 12 hours, heating 9 hours, and cooling 3 hours). The operation of the CBA switching valves, as well as the operation of the CBA Regeneration Burner, is controlled by the new DCS according to the time schedule shown in Figure 5.

Retrofit of the Goldsmith Sulfur Plant with Amoco's CBA Process

Nearly all existing equipment items were reused in the CBA process retrofit. The conversion from a 3-stage Claus SRU to the CBA process required the addition of the following new items:

1. **Sulfur Separator**
   A new vertical Sulfur Separator was installed in the sulfur vapor line from Sulfur Condenser No. 3 to the CBA Regeneration Heater to ensure that liquid sulfur carryover to the CBA Reactors is minimized. This was necessary because the separator section at the outlet of Sulfur Condenser No. 3 was too short for good separation (a common deficiency in many sulfur plants).

2. **CBA Regeneration Heater**
   A new in-line burner type heater firing fuel gas was installed to heat the process gas stream leaving the Sulfur Separator to 650°F. This heater replaced the existing Reheater No. 3 which fired acid gas to heat the feed to the third Claus bed. The burner on the new heater is not in operation during adsorption and cooling modes; the process gas stream flows through it without heating. (The pilot flame can remain

lit at all times.) The DCS automatically ramps up the main burner during the heating cycle to regenerate a CBA bed, then ramps down the main burner at the conclusion of the heating cycle.

3. **CBA Reactor**

   A new CBA Reactor was installed in parallel with the existing No. 3 Claus Reactor so that there are two CBA reactors. One is the existing No. 3 Claus Reactor (converted to CBA service) and the other is a new CBA Reactor. No structural work was required for this existing reactor. It was inspected to make sure the refractory was in good condition and that the proper amount of catalyst was installed.

4. **CBA Sulfur Condenser**

   A new CBA Sulfur Condenser was installed which includes an efficient sulfur separator section on the outlet from the condensing tubes. This boiler replaced the existing Sulfur Condenser No. 4, which was too small for the new service – cooling the CBA regeneration gas that is laden with sulfur vapor and condensing this sulfur vapor to produce liquid sulfur. The separator section of the new boiler has a high efficiency mist extractor to prevent any liquid sulfur carry-over into the second CBA reactor.

5. **20 PSIG Steam Condensers**

   Two new air-cooled 20 PSIG Steam Condensers were installed. One condenses the steam generated in Sulfur Condenser No. 3 and the other condenses the steam generated in the CBA Sulfur Condenser. Operating these sulfur condensers at a steam pressure of 20 PSIG instead of 50 PSIG minimizes the amount of sulfur vapor in the feeds to the CBA beds and in the SRU tailgas.

6. **Sulfur Vapor (Switching) Valves**

   Eight new automated steam-jacketed sulfur vapor valve assemblies were installed to allow the existing third Claus bed and the new CBA Reactor to cycle as CBA beds. The new DCS controls these switching valves.

7. **Steam-Heated Piping**

   Steam-heating was added to the piping to and from the two CBA Reactors.

Key Items for CBA Process Reliability

Like any other sulfur plant, a CBA plant requires close attention to detail (both in the design phase and during operations) to have a truly reliable operation. In addition, however, the following three key items are essential for cost effective, successful use of the CBA process:

1. **Sulfur Vapor (Switching) Valves**

   New sulfur vapor valve assemblies were installed to permit the required CBA catalyst bed switching. (GPM specified that Ortloff's proprietary valve assembly design be used for these switching valves because of their critical nature to the process.) The automated valves used in these assemblies are customized steam-jacketed high-performance trunnion valves. These valve assemblies have given continuous, trouble-free service for over 10 years in CBA switching valve service. The CBA process cannot succeed without good switching valves, as the switching valves must operate reliably and seal properly for the process to work efficiently and give the required recovery performance.

2. **CBA Regeneration Heater**

   Another piece of equipment critical to the CBA process is the CBA Regeneration Heater used to heat the regeneration gas to 600-650°F. This heater must be reliable under severe operating conditions, as it is exposed to thermal cycling and to high temperatures in corrosive service. After an economic evaluation, a fuel gas fired in-line burner type heater was selected for installation at Goldsmith. It is believed to be the first direct-fired regeneration system used in a CBA unit.

   Several types of regeneration heaters have been used in CBA plants, including gas/gas exchangers and indirect fired heaters. A gas/gas exchanger in this type of thermally cyclic service requires exotic metallurgy (such as 321 S.S.) for reliable service. A carbon steel gas/gas exchanger will last only about 3-5 years due to the constant "shedding" of the normally protective iron sulfide film caused by the thermal cycling. An indirect fired heater where the regeneration gas flows through the tube side of a cabin-type heater also requires exotic metallurgy for the tubes. Both gas/gas exchangers and indirect fired regeneration heaters have been used successfully in CBA plants, but both are very expensive options.

For the Goldsmith SRU, an indirect heater would have an installed cost of about $550,000, versus the installed cost of about $100,000 for the in-line burner used. In addition, the in-line burner is inherently more fuel efficient than an indirect heater and does not require forced-draft or recirculation fans. Altogether, the in-line burner saves more that $15,000 per year in utilities.

Due to its significantly lower cost compared to the other alternatives, an in-line burner type of regeneration heater was selected for Goldsmith. However, in-line burners are more difficult to design and trickier to control. They must operate at slightly sub-stoichiometric conditions to prevent sulfur fires in the catalyst beds, but too little air can cause soot that will coke the catalyst beds. Overall, however, the in-line heater was a unique, cost-effective regeneration heater option for the Goldsmith plant that has proven to be very acceptable throughout two years of operation.

3. Steam-Heated Piping

Another innovation applied in the Goldsmith SRU retrofit was the use of strap-on steam heating elements instead of steam-jacketing to heat the cyclic sections of process piping around the CBA switching valves and the CBA Reactors. This piping must be heated to prevent sulfur solidification and to prevent corrosion (due to water condensation) since these lines are stagnant during portions of the CBA bed switching cycle. Steam-jacketing is frequently used to keep critical SRU lines hot; however, the lines requiring heat in the Goldsmith SRU were very large – 20" and 24" pipe. It would have been very expensive to install 20" x 24" and 24" x 30" steam-jacketed pipe, and it is also more difficult to design jacketed piping for the differential thermal expansion of the lines exposed to the thermal cycling inherent in the CBA process.

The strap-on heating elements proved to be a cost-effective alternative to steam-jacketing. These strap-on heating elements are fabricated from carbon steel boiler tubes with a concave heating surface formed to the radius of the outer diameter of the process pipe, giving a large amount of heat transfer surface per unit length. The strap-on installation allowed for the cyclic thermal expansion of these lines. And, since these heating elements could be strapped onto the existing piping around the third Claus bed, much of this piping was reused instead of being replaced with jacketed pipe. Thus, using strap-on heating elements reduced design, material, and installation costs for the CBA retrofit.

Other SRU Upgrade Modifications

In addition to the modifications required for converting the SRU to the CBA process, some existing equipment items and instrumentation were modified and/or replaced to improve the overall economics and reliability of the operation:

1. A new distributed control system (DCS) was installed.

2. A new H_2S analyzer was installed on the acid gas feed to improve the response of the air:acid gas flow ratio control to changes in inlet acid gas composition and flow rate.

3. New PLC-based burner management systems were installed on all the burners in the SRU and Incinerator.

4. Other minor equipment repair and replacements were performed to correct existing plant deficiencies.

5. A new steam-jacketed startup vent with an automated sulfur vapor valve assembly was installed on the Sulfur Condenser No. 1 gas outlet line to allow a cold catalyst bed startup procedure to be used in the SRU. The CBA switching valves are used as SRU tailgas block valves with appropriate logic in the control system. This vent (plus a few other modifications) allows the Reaction Furnace warmup combustion products to be vented to the atmosphere instead of through the catalyst beds. This simplifies the furnace warmup procedure and avoids both the possibility of coking the catalyst beds with soot and potential sulfur fires in the beds. This design also makes it easy to keep the SRU on hot standby when acid gas is not available. Since most corrosion damage in sulfur plants occurs when the plants are allowed to cool and stand cold, this design can greatly extend the service life of sulfur plants which require considerable standby time. The net result is simpler, quicker startups and longer catalyst life. Cold bed startup capability is a standard feature in Ortloff-designed sulfur plants, and Ortloff's design for successful use of this important operating procedure is unique in the industry.

Project Schedule and Management

GPM obtained both AFE approval and TACB approval for the Goldsmith SRU upgrade project by the end of May 1993 and the project was kicked off June 23, 1993. This was less than 12 months before the "must complete" date of June 1, 1994. Ortloff was also involved in the Goldsmith cryogenic plant upgrade project which was approved in late December 1993 with the same "must complete" date. The two projects were managed in similar fashion and involved the same contractors.

The basic engineering package Ortloff provided for the SRU upgrade included process design and process engineering, mechanical flow sheets, equipment specifications, purchase orders, job data books, project management and review of all detailed engineering tasks, drawing reviews, operator training, operating manuals, and startup assistance.

Ortloff functioned as the detailed design consultant and project manager, coordinating all detailed engineering work. The process and mechanical design work was done by Ortloff personnel. The civil/structural and detailed piping design work was done by HPF Consultants, Inc. of Midland, with review and approval by Ortloff. Instrument and electrical design was done by Lauren Engineers, Inc. of Abilene (formerly of Midland), with review and approval by Ortloff.

GPM and Phillips purchased and expedited all equipment and materials. Excellent coordination and cooperation between the GPM/Phillips procurement personnel and the contractors helped keep this project on schedule. GPM's operating, engineering, and maintenance personnel actively reviewed the design documents as soon as they were issued. Questions were resolved very quickly to avoid any late changes. All of the detailed engineering and design personnel were located within 35 miles of the plant, so communication between the project design team members was not a problem. The number of people involved in the project was also kept to a minimum by all parties.

Ortloff prepared a Construction Bid Package complete with construction drawings. This allowed GPM to obtain a lump sum construction contract for the SRU upgrade. Ref-Chem Corporation of Odessa was awarded the construction contract and started site work in February 1994. Tie-ins were completed during a plant shutdown in May 1994 and the SRU was started up on schedule in June 1994.

Startup and Initial Operations

Like the startup of any new or retrofitted plant or unit, there were a few minor problems to be solved when the retrofitted SRU was placed back in service.

Burner Assembly Operating Problems

The Goldsmith SRU experienced some flame-failure burner shutdowns at all three new in-line burner assemblies (the two Reheater Burners and the CBA Regeneration Burner) while pilot burner fuel and air pressures/mixtures were being optimized to achieve reliable operation. Solid sulfur films formed on the viewports, flame scanner nozzles, pilot orifices, etc. during these shutdown periods due to inadequate purge systems for the connections on the burner. (The solid sulfur precipitates out of the process gas stream, which continues to flow through these burner systems during a burner shutdown).

Since a good inert purge medium such as nitrogen is not available at the Goldsmith plant, air from the main combustion air line is used in the purge system. Unfortunately, the purge air supply point was initially designed and installed downstream of the combustion air shutdown valve. The air purge piping has now been modified to take air from upstream of the ESD valve, which allows purge air to continue for a few minutes after each burner shutdown to minimize this problem.

CBA Sulfur Condenser Steam Pressure Control

The new 20# Steam Condenser No. 2 (an aerial cooler) was installed to maintain the CBA Sulfur Condenser steam pressure at 20 PSIG. This aerial cooler worked fine during the regeneration portion of the CBA cycle when the inlet gas to the CBA Sulfur Condenser is relatively hot. During the adsorption phase, however, the CBA Sulfur Condenser inlet gas is fairly cool and it was difficult to maintain the steam pressure above 15 PSIG, even with the fan shut off and the louvers closed. Although there was concern with the possibility of sulfur solidifying and plugging in the CBA Sulfur Condenser tubes, this problem never developed (most likely due to the very low sulfur content of the process gas leaving the CBA Reactors). The steam side of the system did freeze up during the winter, however, causing minor damage to the aerial cooler. Installing a steam coil directly under the Steam Condenser tube bundle corrected this problem.

Emissions Results

A plant performance test was performed in September 1994, about three months after startup, to ensure that the upgraded SRU using Amoco's CBA process could achieve a sulfur recovery efficiency of 98%. The performance test results showed that the upgraded SRU recovered 98.1% of the inlet sulfur when processing an acid gas stream containing 59 LT/D of sulfur with an H_2S concentration of 61% (dry basis).

The Goldsmith SRU has maintained this high level of sulfur recovery. A recent performance test (February 1996) showed that the SRU was recovering 98.6% of the inlet sulfur when processing an acid gas stream containing 46 LT/D of sulfur with a concentration of 60% H_2S (dry basis).

Conclusions

1. Upgrading the Goldsmith SRU to Amoco's Cold Bed Adsorption process increased the average sulfur recovery level from about 96% to more than 98%. This allowed the "effective" SRU capacity to nearly double without increasing SO_2 emissions.

2. Ortloff's proprietary sulfur vapor valve assemblies have provided reliable service as the CBA switching valves. No leaking has been experienced, and no operational failures have occurred.

3. The cold catalyst bed startup procedure allowed by the automated sulfur vapor valve assemblies in the process piping has significantly improved the ease and safety of startup operations.

4. DCS operation of the CBA switching cycle (controlling the CBA Regeneration Heater and switching valves) works well and requires very little operator attention.

5. Use of the in-line direct-fired type of CBA Regeneration Heater was very cost-effective and has provided satisfactory service.

6. Careful coordination of the conceptual design, detailed design, procurement, HAZOP, operator training, shutdown, and startup phases resulted in a very successful fast-track retrofit project.

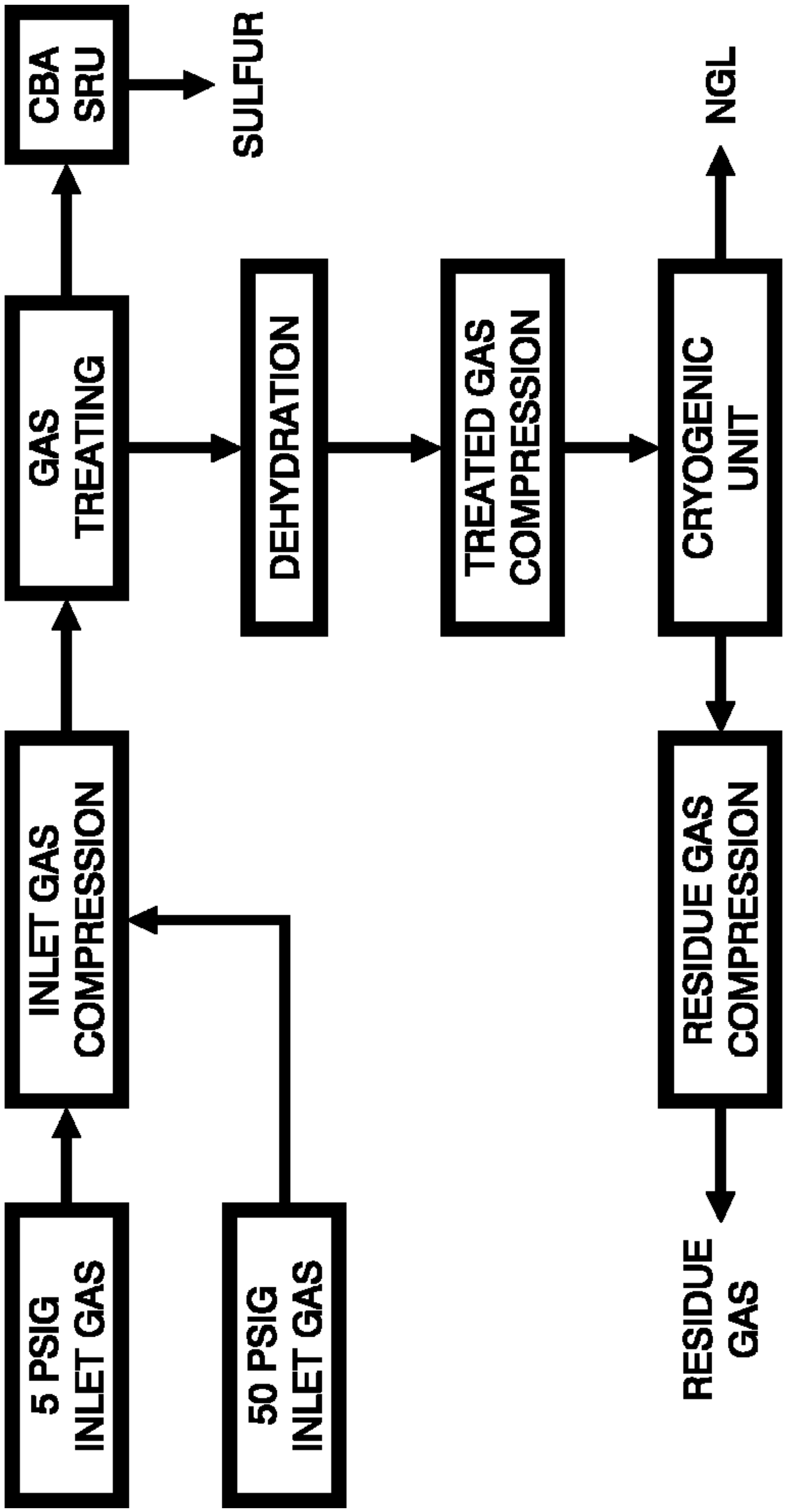


Figure 1 — The Goldsmith Gas Plant

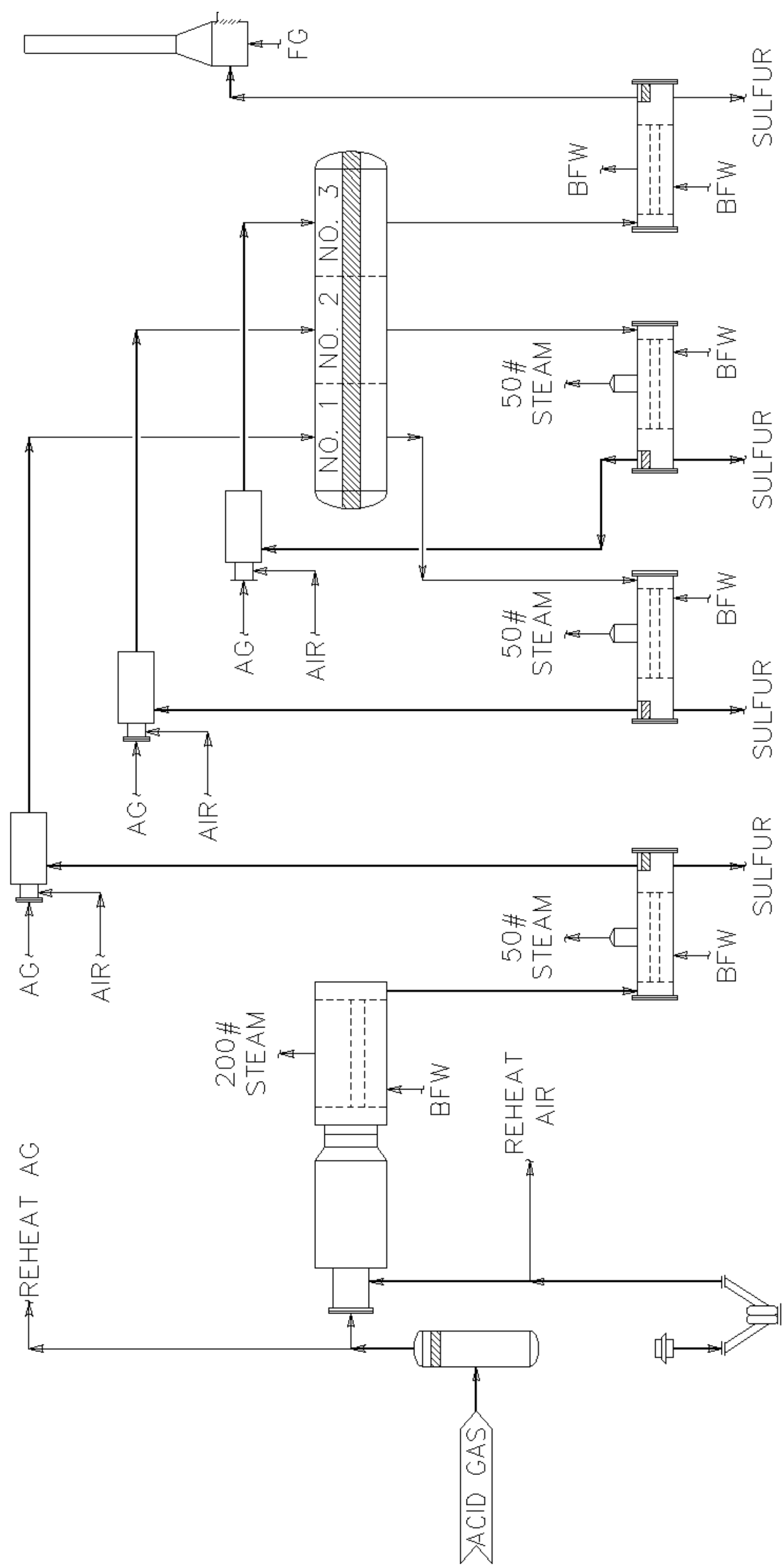
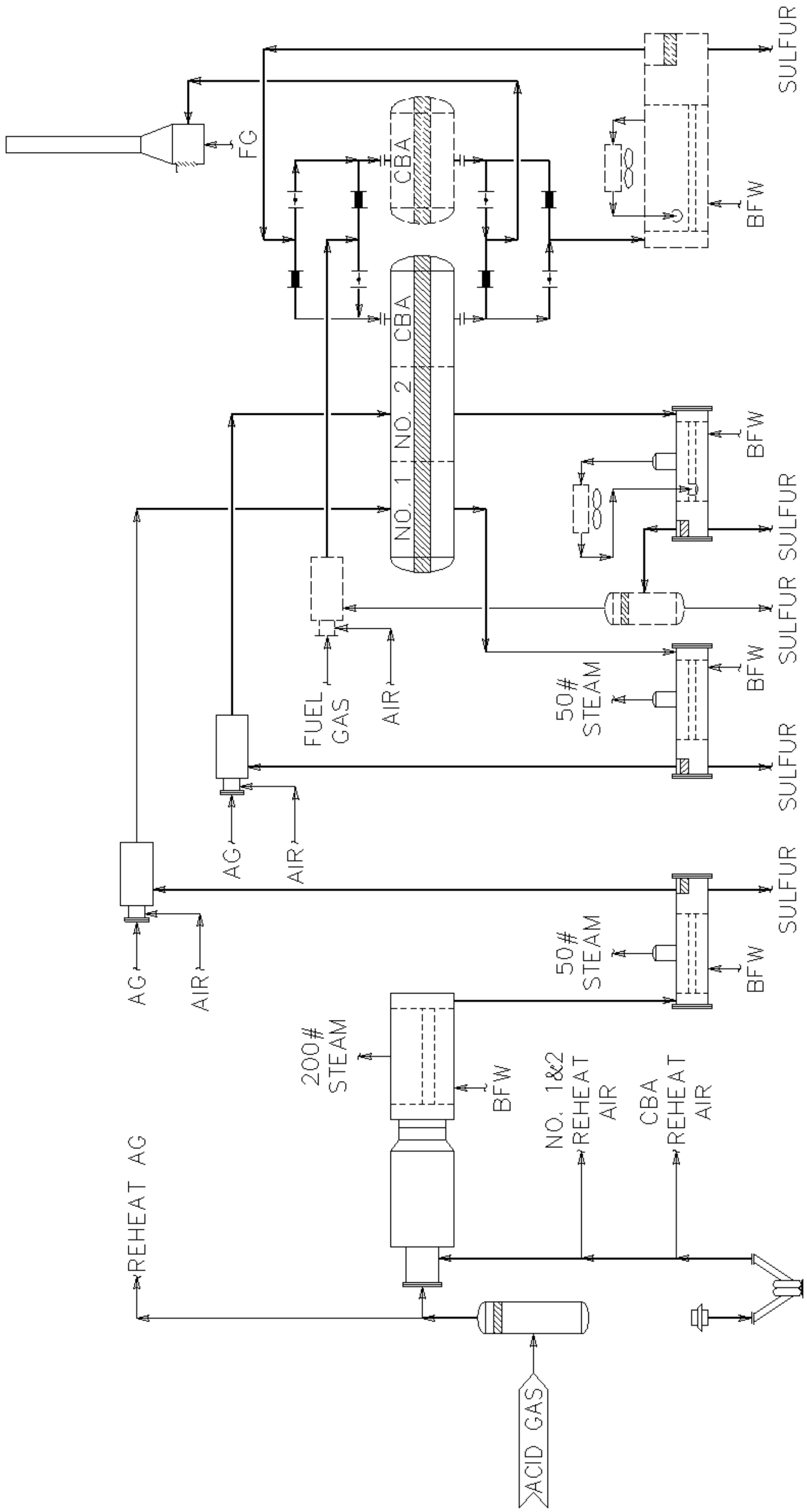


Figure 2 — Original SRU Design

Figure 3 — CBA Retrofit Design



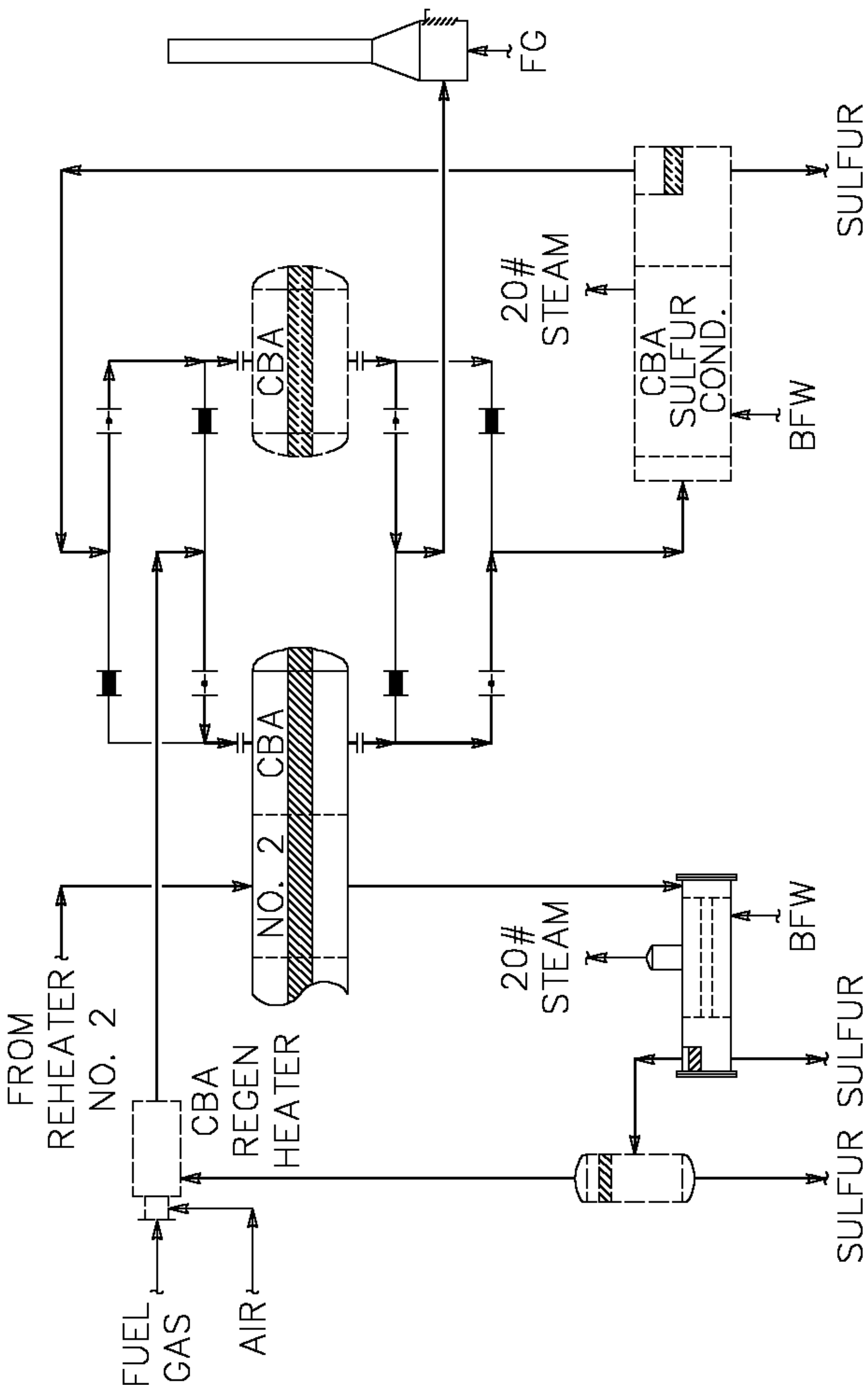


Figure 4 — CBA Section of Retrofit SRU Design

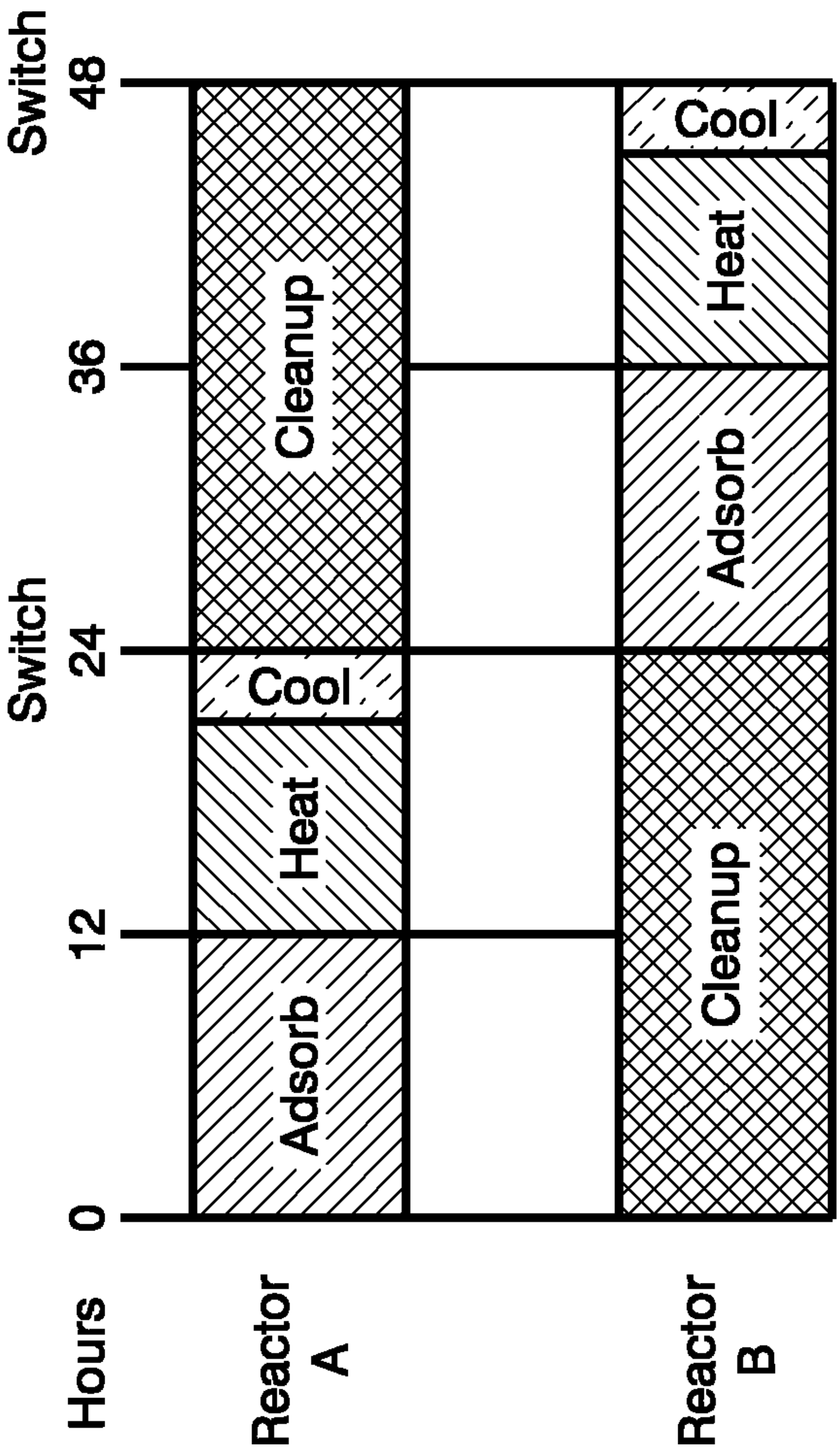


Figure 5 — CBA Cycle Times