

THE LINDE GROUP

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Sulfur Process Technology



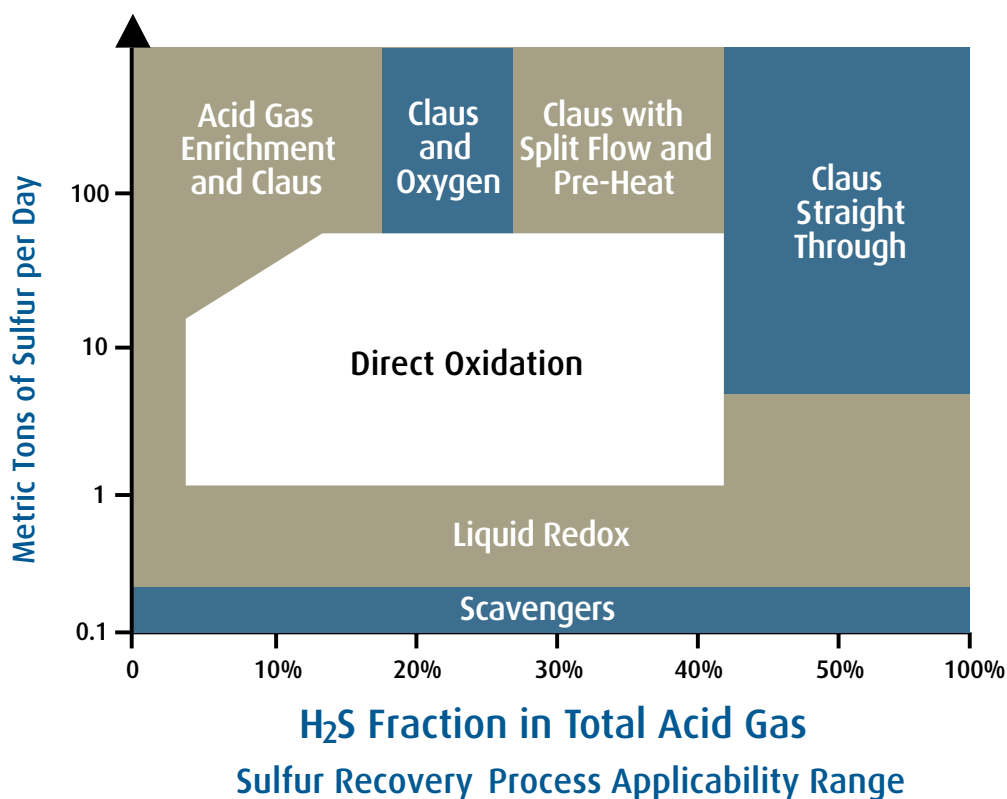


Sulfur is an extremely useful element. Its largest application is for the manufacture of fertilizers with other principal users including rubber industries, cosmetics, and pharmaceuticals. Sulfur is present in many raw industrial gases and in natural gas in the form of hydrogen sulfide. The noxious hydrogen sulfide fumes that characterize many gas processing, refinery operations, and petroleum production sites represent a genuine threat to our environment.

Concentration levels of H_2S vary significantly depending upon their source. H_2S produced from absorption processes, such as amine treating of natural gas or refinery gas, can contain 50-75% H_2S by volume or higher. Many other processes can produce H_2S with only ppm concentration, but in quantities which preclude the gases from being vented without further treatment.



Figure 1



HYDROGEN SULFIDE CONVERSION

The large variations in concentrations and flows require different methods for H₂S removal and sulfur recovery. For relatively small quantities of H₂S/sulfur, scavenger processes are often used. For sulfur quantities up to approximately 5 long tons per day (LTD) of sulfur, liquid reduction-oxidation (redox) processes are common. The sulfur is produced as an aqueous slurry. Direct oxidation can sometimes be utilized for low H₂S concentrations to produce high quality liquid sulfur.

The Claus Process is the most widely used process for conversion of H₂S to elemental sulfur. Variations of the Claus Process, Direct Oxidation, and Liquid Redox Processes, can overlap other processes' applicability ranges. Figure 1 is a Sulfur Recovery Process Applicability Chart which presents the relative ranges of technology applications.

CLAUS TECHNOLOGY

The Claus Process was invented in 1883 by the English scientist, Carl Friedrich Claus. The basic Claus Process mixed hydrogen sulfide with oxygen and passed the mixture across a pre-heated catalyst bed. The end products were sulfur, water and thermal energy. Because the process performed best at 400°F to 600°F, and the reaction heat could be removed only by direct radiation, only a small amount of H₂S could be processed at one time without overheating the reactor. The process was improved in 1938 by

I.G. Farbenindustrie A.G., a German company, by the addition of free-flame oxidation ahead of the catalyst bed and revising the catalytic step. This "Modified Claus Process" greatly increased the sulfur yield and is the basis of most Sulfur Recovery Units (SRU) in use today.

HOW THE PROCESS WORKS

Feed gas for a Claus Sulfur Recovery Unit usually originates in an acid gas sweetening plant. The stream, containing varying amounts of H₂S and CO₂, is saturated with water and frequently has small amounts of hydrocarbons and other impurities in addition to the principal components.

In a typical unit, H₂S-bearing gas enters at about 8 psig and 120°F. Combustion air is compressed to an equivalent pressure by centrifugal blowers. Both inlet streams then flow to a burner which fires into a reaction furnace.

The free-flame Modified Claus reaction can convert approximately 50% to 70% of the sulfur gases to sulfur vapor. The hot gases, up to 2,500°F, are then cooled by generating steam in a waste heat boiler.

The gases are further cooled by producing low-pressure steam in a separate heat exchanger, commonly referred to as a sulfur condenser. This cools the hot gases to approximately 325°F, condensing most of the sulfur which has formed up to this point. The resultant liquid sulfur is removed in a separator section of the condenser and flows by gravity to a sulfur storage tank. Here it is kept molten, at approximately 280°F, by steam coils. Sulfur accumulated in this reservoir is pumped to trucks or rail cars for shipment.

TECHNOLOGIES

We offer the following for sulfur recovery and tail gas cleanup:

- Straight-Through Claus (page 6)
- Split-Flow Claus (page 6)
- Direct Oxidation (page 7)
- Acid Gas Enrichment (page 7)
- Oxygen Enrichment (page 8)
- Cold Bed Adsorption (page 9)
- Shell Claus Off-Gas Treating (SCOT) (page 11)

Catalytic Reaction Completes The Process

Any further conversion of the sulfur gases must be done by catalytic reaction. The gas is reheated by one of several means and is then introduced to the catalyst bed. The catalytic Claus reaction releases more energy and converts more than half of the remaining sulfur gases to sulfur vapor. This vapor is condensed by generating low-pressure steam and is removed from the gas stream. The remaining gases are reheated and enter the next catalytic bed.

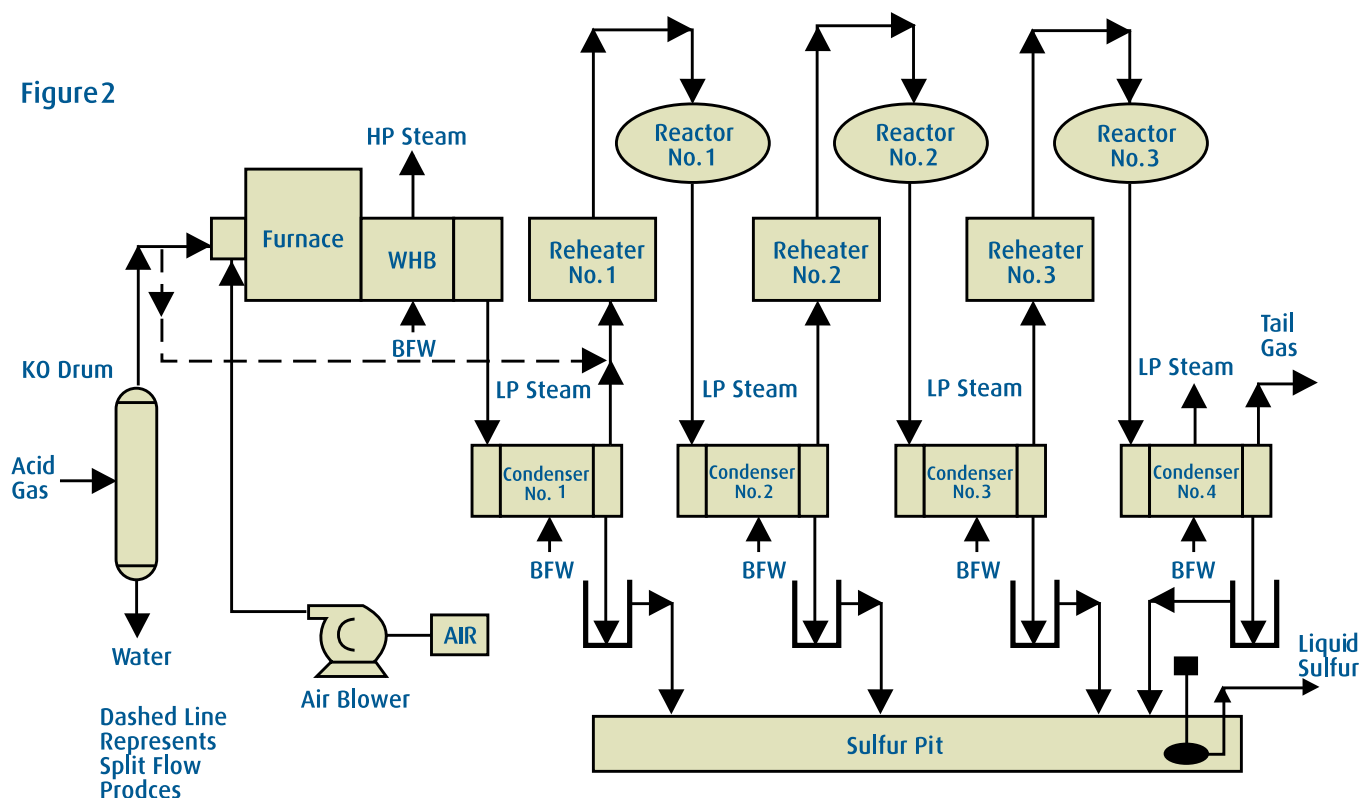
This cycle of reheating, catalytic conversion and sulfur condensation is repeated in two to four catalytic steps. A typical SRU has one free-flame reaction and three catalytic reaction stages. Each reaction step converts a smaller fraction of the remaining sulfur gases to sulfur vapor, but the combined effect of the entire unit is to reduce the hydrogen sulfide content to an acceptable level.

High Yields Plus Energy

Claus sulfur plants can normally achieve high sulfur recovery efficiencies. For lean acid gas streams, the recovery typically ranges from 93% for two-stage units (two catalytic reactor beds) up to 96% for three-stage units. For richer acid gas streams, the recovery typically ranges from 95% for two-stage units up to 97% for three-stage units. Since the Claus reaction is an equilibrium reaction, complete H_2S and SO_2 conversion is not practical in a conventional Claus plant. The concentration of contaminants in the acid gas can also limit recovery. For facilities where higher sulfur recovery levels are required, the Claus plant is usually equipped with a tail gas cleanup unit to either extend the Claus reaction or capture the unconverted sulfur compounds and recycle them to the Claus plant.

All Claus SRU's produce more heat energy as steam than they consume. This is particularly true for those plants equipped with waste heat boilers on the incinerator. The steam produced can be used for driving blowers or pumps, reboiler heat in the gas treating or sour water stripping (SWS) plants, heat tracing, or any of a number of other plant energy requirements.

Figure 2



Typical Straight Through Sulfur Plant

TECHNOLOGY OVERVIEW

This booklet presents an overview of the technologies available through Linde Process Plants, Inc. (LPP).

TYPES OF PLANTS

Claus Sulfur Recovery Units are generally classified according to the method used for the production of SO_2 and the method used to reheat the catalyst bed feeds. The various reheat methods can be used with any SO_2 production method, whereas the technique used for the production of SO_2 is determined by the H_2S content of the acid gas feedstock.

Most sulfur recovery plants utilize one of three basic variations of the Modified Claus Process “straight-through,” “split-flow,” or “direct-oxidation.” “Acid gas enrichment” can be applied ahead of the SRU to produce a richer acid gas stream and “oxygen enrichment” may be used in combination with any of these variations.

These three varieties of the Modified Claus Process differ in the method used to oxidize H_2S and produce SO_2 ahead of the first catalytic reactor. The first two processes use a flame reaction furnace ahead of the catalytic stages. The third process reacts oxygen directly with the H_2S in the first catalytic reactor to produce the SO_2 .

Straight-Through Process

A “straight-through” unit (shown on Figure 2) passes all the acid gas through the combustion burner and reaction furnace. The initial free-flame reaction usually converts more than half of the incoming sulfur to elemental sulfur. This reduces the amount which must be handled by the catalytic sections and thus leads to the highest overall sulfur recovery.

The amount of heat generated in the reaction depends on the amount of H_2S available to the burner. With rich acid gas (60% - 100% H_2S), the reaction heat keeps the flame temperature above 2200°F. When the gas is leaner, the flame temperature is reduced; the greater mass is heated to a lower temperature. If the temperature falls below a critical point, approximately 1800°F to 2000°F, the flame becomes unstable and cannot be maintained.

This point is usually reached when the acid gas has an H_2S content of 50% or less. The problem can be overcome, within limits, by preheating the acid gas and/or air before it enters the burner. However, the lower the H_2S content, the higher the preheat requirement becomes; when the gas composition falls below about 40% H_2S , this approach ceases to be practical.

Split-Flow Process

The second method of SO_2 production, known as the “split-flow” technique, is used to process leaner acid gases with 15% to 50% H_2S content. In these units, at least one-third of the acid gas flows into the combustion burner and the balance usually bypasses the furnace entirely. Enough H_2S is burned to provide the necessary 2:1 ratio of H_2S to SO_2 in the catalyst beds. The flame temperature is kept above the minimum, since the constant amount of heat supplied is absorbed by a lower mass of gas. The free-flame Claus reaction is reduced or eliminated entirely by this approach, since little or no H_2S is available to react in the furnace. This results in a slight reduction of the overall sulfur recovery.



Split-Flow Process For Ammonia Destruction

A variation of the split-flow process is often applied in refinery SRU's that must process sour water stripper (SWS) off-gas and destroy the ammonia it contains. Efficient ammonia destruction is critical for SRU's in refineries, since ammonia can combine with the sulfur compounds in the process gas to form salts that precipitate in the lower temperature section of the Claus unit. Accumulation of such ammonium salts would lead to unreliable operation and unacceptable maintenance costs.

Figure 2 shows the special split-flow furnace design used when processing SWS gas along with acid gas from an amine unit. All of the SWS gas is routed to the combustion burner along with a portion of the amine acid gas, so that at least 1/3 of the total H_2S is supplied to the burner. This creates a high temperature combustion zone at the inlet end of the reactor furnace where the ammonia breaks down into nitrogen and water by thermal decomposition. The remainder of the amine acid gas is injected into the middle part of the reactor furnace where it mixes with the burner combustion products. The outlet end of the furnace provides residence time for the SO_2 produced by the burner to react with the H_2S in the bypass acid gas and form sulfur, and for any hydrocarbons in the bypass acid gas to oxidize. An optical pyrometer is typically used to monitor the temperature in the inlet section of the furnace, and is often used to adjust the amount of bypass acid gas to control the temperature at the desired value.

Direct Oxidation Process

When the H_2S concentration is below about 15% in the acid gas, the direct oxidation version of the Modified Claus Process may be used. Rather than using a burner to combust H_2S to form SO_2 , the direct oxidation process catalytically reacts oxygen with H_2S by mixing the air and acid gas upstream of a catalytic reactor. As SO_2 forms, it then reacts with the remaining H_2S via the Claus reaction to form sulfur. The direct oxidation is typically followed by one or more standard Claus reactors to produce and recover additional sulfur. The direct oxidation process is sensitive to catalyst deactivation by contaminants in the acid gas feed (particularly hydrocarbons), so it is not used as much as the other Claus process varieties.

Acid Gas Enrichment

When the acid gas produced by the gas treating system is low in H_2S concentration, it is sometimes advantageous to "enrich" the acid gas by contacting it with a second solvent. The second solvent is typically a selective solvent designed to absorb essentially all of the H_2S from the acid gas while letting most of the remainder (generally carbon dioxide, CO_2) "slip" through. The enriching process can often raise the H_2S concentration of the SRU feed gas by a factor of 5 or more. Not only does this allow using smaller equipment in the SRU, but can often allow a more reliable SRU process to be used, such as a straight-through Claus Process instead of a direct oxidation Claus process.

Oxygen Enrichment

Since air is approximately 79% nitrogen and 21% oxygen, the introduction of air to supply the oxygen for combustion of H_2S to SO_2 also introduces a large quantity of nitrogen. When air is used as the oxygen source, approximately 5.6 moles of nitrogen are introduced into the gas flow for every mole of H_2S that is burned. Nitrogen does not react and the added mass of the nitrogen lowers the adiabatic flame temperature in the reaction furnace. The nitrogen must also be heated, cooled and reheated through the combustion, sulfur condensation, and reheat ahead of the reactors.

Pure oxygen or enriched sources of oxygen can be used instead of air in the Claus Process. Higher flame temperatures can be achieved with lower H_2S concentrations. In addition, the relative equipment sizes can be reduced in proportion to the amount of nitrogen that is not introduced with oxygen for combustion.

Reheat Methods

Gas leaving the sulfur condenser is at its sulfur dew point temperature. Since the catalytic reaction requires a higher temperature for proper operation, the gas must be reheated before entering the reactor. This can be done directly (internally) or indirectly (externally). The method chosen is an important characteristic of any Sulfur Recovery Unit.

Direct Reheat

Two direct reheat methods are commonly employed: “inline burning” and “hot gas bypass.” The first of these burns fuel or acid gas with air in an inline burner, allowing the combustion products to mix directly with the process gas flow. The second method bypasses a portion of the hot boiler outlet gas around the sulfur condenser and mixes it with the reactor feed stream.

Both methods have an adverse effect on overall sulfur recovery. In the case of the inline burner, it is difficult to maintain precise control of the overall air/ H_2S ratio. Any excess or deficiency of oxygen to the inline burner can cause undesirable reactions in the catalyst beds. Too little oxygen can lead to carbon deposits on the catalyst, reducing its activity. Too much oxygen can lead to catalyst deactivation, increased corrosion and, in extreme cases, fire in the reactor. All of these result in reduced sulfur recovery.

The “hot gas bypass” method allows a portion of the sulfur-bearing process gas to skip one or more catalytic reaction and sulfur condensing steps. When this happens, the sulfur gases have less opportunity to convert to sulfur vapor and the overall sulfur recovery drops. With both methods, the recovery loss is more pronounced in a lean acid gas unit than it is in a rich gas SRU.

Indirect Reheat

The indirect reheat method uses an outside heat source to raise the temperature of the acid gases in a heat exchanger. Although this requires additional equipment, it eliminates the conversion loss problems associated with direct reheat. There are three common variations of indirect reheat: “gas-gas exchange,” “fuel gas firing,” and “steam reheat.”

Gas-gas exchangers use sulfur condenser feed to reheat the sulfur condenser outlet gas. This exchange works well as long as the temperature of the heating gas is maintained above a minimum level. If the upstream catalyst bed has lost some of its efficiency, however, the drop in conversion will lower the outlet temperature. Less heat energy will be available for reheat. As a result, the following catalyst bed will perform less efficiently and overall sulfur recovery will decrease.

Steam reheat and fuel gas fired heaters have none of the problems associated with the gas-gas exchange method above. Fuel gas firing uses a conventional fired heater; the acid gases are heated in tubes and the combustion products are vented to the atmosphere. For this reason, fuel gas firing usually involves higher utility costs than the other indirect methods.

Steam reheat can usually be accomplished by utilizing a portion of the steam produced by the SRU itself, often in the same vessel with the source of steam production. Steam reheat is the method commonly preferred in better quality sulfur plant designs.

Recovery and Emissions Levels

Most Sulfur Recovery Units are installed to meet mandated air pollution requirements. The U.S. Environmental Protection Agency (EPA) has issued standards for acceptable emissions from new and modified SRU's in natural gas production. Under these standards, the volume of H_2S concentration of the acid gas stream determine the minimum sulfur recovery level required. Small natural gas SRU's with low H_2S concentrations are allowed to have lower recovery levels than larger plants with higher concentrations.

The chart in [Figure 3](#) shows these mandated recovery levels as a function of total sulfur and H_2S concentration in the acid gas to be processed.

Also shown in [Figure 3](#), as the plant size and H_2S concentration increase, the required recovery level begins to exceed what can be accomplished with just a Claus SRU. This will normally require the addition of a tail gas cleanup process downstream of the Claus SRU.

Figure 3

**ONSHORE NATURAL GAS SRU'S
PERCENT RECOVERY REQUIREMENTS**

Sulfur Feed Rate, LT/D	Mole Percent H ₂ S In Acid Gas									
	10		20		40		60		80	
	A	B	A	B	A	B	A	B	A	B
1,000	97.6	97.1	98.5	97.7	99.3	98.8	99.8	99.3	99.8	99.7
555	97.1	96.2	97.9	97.1	98.8	98.0	99.2	98.5	99.6	98.8
100	95.4	93.9	96.2	94.7	97.0	95.6	97.5	96.1	97.9	96.4
10	93.2	90.8	94.0	91.6	94.8	92.4	95.3	92.9	95.6	93.3
5	92.5	89.9	93.3	90.7	94.2	91.5	94.6	92.0	95.0	92.4
Below 5	79.0	74.0	79.0	74.0	79.0	74.0	79.0	74.0	79.0	74.0

A: Efficiencies with fresh catalyst (initial requirements).

B: Efficiencies with degraded catalyst (continuous requirements).

Tail Gas Cleanup

If a three-stage or four-stage Sulfur Recovery Unit cannot meet the minimum EPA recovery levels, further processing is required. This involves a Tail Gas Cleanup Unit (TGCU), which can either be integrated with the SRU at the design stage or added to an existing SRU. Tail Gas Cleanup Units are divided into two general types: dry bed processes and wet scrubbing processes.

Dry bed processes such as the Amoco Cold Bed Adsorption (CBA) process use the same catalytic Claus reaction as the standard SRU, except that they are operated below the sulfur dew point temperature. As the sulfur forms it is deposited on the catalyst. Once the catalyst bed has adsorbed a sufficient quantity of sulfur, it is regenerated to strip the sulfur from the catalyst and recover it. This type of process can achieve overall sulfur recoveries of 99.0% or better.

Wet scrubbing processes, such as the Shell Claus Off-Gas Treating (SCOT) process, include a front-end section to convert all of the sulfur compounds in the SRU tailgas back into H₂S. After cooling, the H₂S-containing process gas is contacted with a solvent to remove the H₂S, much like in a conventional gas treating plant. The solvent is then regenerated to strip out the H₂S, which is then recycled to the upstream SRU for subsequent conversion and recovery. This type of process can achieve overall sulfur recoveries of 99.9% or better and can reduce the sulfur emissions to less than 250 ppm in the incinerator effluent.

Amoco Cold Bed Adsorption (CBA) Process

The conventional Claus sulfur recovery process is limited by reaction equilibrium considerations to sulfur recoveries in the range of 94-97%. Very high (99.8%+) sulfur recoveries can be achieved by adding an amine-based tail gas cleanup process on the Claus effluent. A good example of this technology is the SCOT process licensed by Shell, which is often employed in refineries to reduce sulfur dioxide emissions to very low levels. However, amine-based tail gas cleanup units are not only expensive to build (often 80% or more of the cost of the upstream Claus plant), but expensive to operate as well.

A better choice of technology for the intermediate sulfur recovery range of 98-99.5% is the so-called "sub-dew point" Claus process. This process extends the capability of the Claus process by operating the Claus reaction at a lower temperature, so that the sulfur produced by the reaction condenses. Since the Claus reaction occurs in the gas phase, this liquid sulfur does not inhibit the reaction like sulfur vapor does, resulting in a favorable shift in the reaction equilibrium and higher sulfur conversion.

Amoco Corporation (now BP) developed and licenses the most widely used sub-dew point Claus process. The Amoco Cold Bed Adsorption (CBA) process has been used in more than 15 sulfur plants, including two 40 LTD sulfur plants constructed by The Ortloff Corporation at the Amerada Hess facility near Seminole, Texas. These sulfur plants have been consistently performance-tested at higher than 99% sulfur recovery. Due to the extremely favorable performance of the Seminole plants, Amerada Hess commissioned Ortloff Engineers, Ltd. to



design a 225 LTD CBA sulfur plant for their facility in Tioga, North Dakota, which was placed in operation in 1991. It too has consistently performed above its required recovery level of 98.8% sulfur recovery. Three other Ortloff-designed CBA sulfur plants have been started up within the past few years, including a unit recently placed in operation at a refinery in Louisiana.

A CBA sulfur plant consists of a conventional Claus section and a CBA section. The thermal and catalytic conversion in the conventional Claus portion of the sulfur plant usually recovers 90-95% of the inlet sulfur. Adding more conventional Claus catalytic stages beyond this point would not add much sulfur recovery because the Claus reaction 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-dew point" conversion stages.

Although catalytic conversion of H_2S and SO_2 is greater at lower reactor temperatures, conventional Claus reactors must be operated at temperatures sufficiently high to keep the sulfur produced from condensing. Sulfur 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 dew point 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/120-150°C) initially so that it is

below the sulfur dew point of the reaction products (i.e., "sub-dew point") 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 flowing hot gas through the reactor to vaporize the adsorbed liquid sulfur, which is then condensed and removed in a down-stream sulfur condenser. This process is analogous 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-dew point 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 the Claus reaction further 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 98-99.5% for CBA plants.

The cyclic nature of the CBA process requires process gas switching valves that must perform in very demanding sulfur vapor services. This has caused significant operation and maintenance problems in CBA plants designed by other engineering companies and contractors. Ortloff's Proprietary Sulfur Vapor Valve Assemblies have functioned flawlessly without operational or leakage problems in the CBA plants designed by LPP/Ortloff. The dependability of these valve assemblies is the key factor in allowing LPP/Ortloff to design and install CBA SRU's that will perform as expected without problems with switching valve failures and/or sulfur vapor leakage.

Shell Claus Off-Gas Treating (SCOT) Process

When very high overall sulfur recoveries are required, even the extended capability of the sub-dew point Claus process may not be adequate. For these types of facilities, the amine-based SCOT tailgas cleanup process from Shell is often the best choice. The SCOT process is widely recognized as the most economical process for achieving overall sulfur recoveries of 99.7% or higher, and has more industrial applications than any other process of this type.

The SCOT process consists of a catalytic reduction section, a feed conditioning section, and a solvent contacting/regenerating section. In the reduction section, reducing gas (hydrogen and/or carbon monoxide) is mixed with the SRU tailgas and passed through a catalyst bed so that all of the sulfur compounds are reduced to H_2S . In the feed conditioning section, the hot gas leaving the catalyst bed is cooled, first in a waste heat boiler (typically), followed by direct contact with quench water. The cooled gas can then be contacted with a selective gas treating solvent in the solvent section, so that nearly all of the H_2S is absorbed while most of the carbon dioxide remains in the gas. The treated gas flows to the incinerator for oxidation of the few remaining sulfur compounds. The rich solvent is regenerated to strip out the H_2S , which is then recycled back to the sulfur plant feed gas. With the SCOT Tail Gas Treating Unit (TGPU) to capture nearly all of the unrecovered sulfur leaving the Claus SRU, nearly complete sulfur recovery is possible even though the SRU only recovers 94-97% of the sulfur in its feed gas. If required, the SCOT process can achieve overall sulfur recoveries in excess of 99.9%, resulting in SO_2 concentrations in the incinerator effluent of 250 ppm or lower.

Superior Design Features

The technical expertise we use in the design and construction of Claus Sulfur Recovery Units was developed through experience in building Sulfur Recovery Units. A significant number of the design features employed in these SRU's enhance their quality and reliability to such an extent that they are widely considered to be the best in the industry.

Ammonia Destruction

Claus process refinery SRU's must be designed to accept acid gas streams containing significant amounts of ammonia. This ammonia must be completely destroyed at the entrance to the SRU to prevent the formation of ammonium salts in the lower temperature sections of the Claus unit, since the accumulation of such salts would lead to unreliable operation and unacceptable maintenance costs. Formation of SO_3 in the unit is consistent with the Claus Reaction furnace operating conditions. Therefore, we routinely incorporate this technique in our sulfur plant design.

The reactor furnace for ammonia destruction consists of two zones separated by a refractory checker wall. The sour water stripper gas stream containing ammonia enters the first zone along with a portion of the amine acid gas feed stream.

All of the process air also enters the first zone. This zone is controlled at about 2500°F (1370°C) by adjusting the amount of amine acid gas that bypasses the burner. The ammonia is destroyed and the effluent mixes with the bypassed acid gas prior to entering the second zone. The second zone provides residence time for the sulfur forming reactions to occur.

Acid Gas Preheater

Preheating the amine acid gas with low pressure steam produced from the sulfur condenser is an integral part of our ammonia destruction process and control system design, as this minimizes the possibility of ammonia salts forming when the amine acid gas mixes with the SWS gas, since ammonium hydrosulfide normally precipitates at temperatures below 100°F (40°C). In addition, the net effect of preheating with low pressure steam is to export more high pressure steam from the system. This shift in steam credits alone often provides a simple economic justification for the pre-heater investment.

Waste Heat Boiler Design

LPP's SRU's utilize unique designs developed by Orloff for the successful elimination of hot-end tube and tube sheet attachment failures due to high temperature sulfide corrosion. Special attention is paid to both the heat flux mechanisms and the heat shielding of these attachments. This is the kind of meticulous attention to detail which has allowed us to build sulfur recovery systems with performance records that far exceed the industry average.

Indirect Reheat

In LPP's SRU's, the catalyst bed feed gas systems are usually heated to the desired reaction initiation temperatures by indirect use of the high pressure steam generated within the sulfur recovery plant. This design feature results in higher overall sulfur recovery and simplified process control when compared with units using other reheat schemes. In addition, optimum operating conditions can be easily maintained and corrosion problems minimized.

Cold Bed Startup

For many years, it has been known that most damage occurs in Sulfur Recovery Units during startup and shutdown operations. Since refinery SRU's are usually required to shut down and start up more frequently than those in production treating facilities, our engineers developed design features which would minimize the risk of damage during these periods.

Our design allows the sulfur recovery system to be started up without first warming the reactor catalyst beds. This has several advantages. First, the free oxygen and hydrocarbons found in most gases used for reactor warmup are not

passed through the catalyst bed. As a result, there is far less chance of starting fires in the catalyst bed during warmup, which can lead to overheating damage to both catalyst and equipment. Second, our cold bed startup reduces catalyst sulfation and thus keeps the catalyst active longer.

Experience has proven that sulfur recovery systems can be successfully started up in this manner, if the heat exchange surfaces are brought to operating temperature before introducing process gas to the unit. Our design, incorporating the successful use of this important operating procedure, is unique in the industry.

Ortloff's Proprietary Sulfur Vapor Block Valve Assemblies are key elements in this design. Warmup block and vent valves are provided that are experience-proven to be both operationally and functionally reliable.

Sulfur Drain Seal Assemblies

We have also designed sulfur drain seal assemblies to serve the needs of the operator. Our standard practice is to provide one sump assembly per sulfur drain source.

We believe it is essential to provide the operator a means to visually observe the sulfur drain from each separator chamber. We also use rundown lines of three inch size or larger to minimize the possibility of plugging.

Sulfur Tank Ventilation

The sulfur entering the storage tank contains a small quantity of dissolved H_2S . While the sulfur remains in the tank, this H_2S weathers off into the vapor space above the sulfur. Therefore, the sulfur tank must be ventilated to maintain a non-explosive concentration in the vapor space. Our design incorporates a natural draft ventilation system to sweep air through the tank.

We also provide stripping systems to remove the dissolved H_2S from the produced liquid sulfur.

Turndown and Optimum Plant Design

Designs have been developed for SRU's which operate successfully under very low turndown conditions. Dual range measurement and control instrumentation, plus special features designed into several equipment items, result in highly successful and exceptionally easy operation even at low rates. Utility costs are also extremely low in comparison with competitive designs, due to the special energy saving features we routinely incorporate.

SRU Tailgas Incinerator Waste Heat Boiler

LPP has a long history of successful tailgas incinerator systems installed in SRU's from 6 LTD up to very large units. Packaged waste heat recovery systems can be provided as an integral part of a new SRU, or as an addition to an existing SRU.





Material Specifications

LPP's Sulfur Recovery Units are designed to use carbon steel in nearly all services through the system. We have determined that it is more effective, economically and operationally, to properly design the SRU to eliminate those conditions corrosive to carbon steel, rather than experiment with exotic corrosion resistant materials.

We have eliminated high temperature sulfide corrosion through design techniques which keep the temperature of critical metal surfaces low. Designing to minimize the quantity of SO_3 in the system eliminates that source of corrosion. We have demonstrated, through many years of operating success, that proper attention to design details and concept can result in carbon steel delivering a very acceptable service life in all critical areas of the sulfur recovery system.

EXPERIENCE

Since 1969, LPP and our process design consultants, Ortloff Engineers, LTD, have designed and constructed more than 70 sulfur recovery plants based on the modified Claus and CBA (Cold Bed Adsorption) processes. These systems, processing off-gases from amine units, sour water strippers, and pulp/paper mills, range in size from 6 to 1,280 Long Tons per Day (LTD).

LPP, as a world leader in plant modularization, has modularized sulfur recovery and tail gas cleanup units with capacities up to 100 LTD and prepared designs for modular sulfur recovery plants up to 250 LTD capacity. LPP also has decades of experience supplying more conventional "stick built" plants.

Plants Designed For Easy Installation

Most sulfur recovery plants are required additions for existing plants. Getting the new sulfur recovery facilities with only the least interruption to existing facilities is always desired. Since most of our process plant manufacturing takes place inside our modern fabrication facility rather than outdoors at some remote site, SRU's and Tail Gas Cleanup Units can generally be completed faster and at a lower cost than site-built plants. Problems with weather delays, shortages of skilled labor, and on-site quality control are eliminated. In addition, we employ sequential staging, scheduling and materials control techniques to create what amounts to "assembly line" efficiency. Once the unit is completed, it is simply set in place on your site, ready for tie-in, testing, and start-up.



ABOUT LPP

LPP is a member of The Linde Group, a firm with over a century of experience providing gas processing systems to the industry. LPP has been providing world-class fabrication, proprietary technology, engineering, and design services since 1969.

ENGINEERING

Engineers are available with all of the disciplines required to provide turnkey plant installations using proprietary technology or the client's design.

FABRICATION

LPP is a leader in the field of engineering and fabrication of turnkey process systems. In addition to road and rail transportation, our fabrication facilities have access to the Port of Catoosa on the Arkansas River, which can transport prefabricated plants on oceangoing barges to global markets.

TECHNOLOGY

For the processes offered by LPP either in-house or licensed technology is used.

With LPP's Experience And Resources You Are Assured Success

While there are other firms that can fabricate process units, only LPP has the combination of proven experience, the specialized skills, an impressive track record, and extensive fabrication facilities to successfully deliver major turnkey process units to global markets.

Access To Major Waterway

Our Tulsa facility has easy access to the Port of Catoosa on the Arkansas River. This major waterway allows oceangoing barges access to the Gulf of Mexico to deliver units to global clients.

Rail And Inland Transportation

Rail service is also available at the facility, as well as easy access to major highways which allows us to optimize transportation to any point in North America or the world.

Processes Offered By LPP

- Cryo-Plus[®], Recovers C₃⁺
- Cryo-Plus C₂[≡], Recovers C₂⁺
- Sulfur Recovery
- Natural Gas Processing
- Nitrogen Rejection
- Helium/Hydrogen Liquifiers

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