D'GAASS™ Sulfur Degasification Process Update

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ABSTRACT

Claus unit product sulfur normally contains 250-350 ppmw H_2S in the form of dissolved H_2S and chemically bound polysulfides, H_2S_X. The H_2S is released from the sulfur product during storage, handling, and transportation. Storage and handling operations can emit noxious odors and release toxic and explosive mixtures of H_2S in air. Historically, sulfur has not been degassed to remove H_2S. There are a few countries that have implemented limits on the residual H_2S concentration allowed in liquid sulfur shipments, Western Canada has limited residual H_2S in formed sulfur shipped through Vancouver to 30 ppmw for odor control, and some companies are implementing sulfur degassing to control odor and improve safety and/or meet customer product specifications.

The Goar, Allison & Associates, Inc. D'GAASS™ Process was developed to provide a cost effective, small footprint process for sulfur degassing. The D'GAASS Process has been in service at the Sulconam Plant in Montreal since September 1996. The process has received world wide acceptance by the sulfur recovery industry. There are currently 38 licensed degassing trains with 19 in operation.

Since the Sulconam Unit start-up, Goar Allison has collected extensive data to confirm and update our design methods. Degassing process performance has been very good; however, there have been a few unexpected problems, which is typical of new processes. Goar, Allison has worked with the local plants to develop solutions to improve unit reliability. Goar, Allison has also developed several process and mechanical options to best fit the local plant situation.

INTRODUCTION

All product sulfur from modified Claus process sulfur recovery units (SRU's) contains residual H_2S; some as dissolved H_2S and some in the form of loosely chemically bound polysulfides, H_2S_x. The total residual H_2S concentration is influenced by the H_2S vapor concentration (partial pressure) and the temperature at which the sulfur product condensed. As SRU's are pushed to and beyond their design capacities, the H_2S content of product sulfur increases.[1] Oxygen enrichment in the SRU also results in higher residual product H_2S.[2] The H_2S concentration in SRU product sulfur can range from 200 to 450 ppmw. Some H_2S is released during sulfur storage, handling, and transportation. The released H_2S results in safety hazards from the toxic H_2S gas and potentially explosive concentrations of H_2S and air.[3] Solid sulfur product formed from undegassed liquid sulfur is more friable (prone to fracture and create dust). The release of H_2S from solid or liquid product results in noxious odors. Undegassed sulfur is also more corrosive. Degasification of liquid sulfur controls most of the above listed problems.

Several factors contribute to the release of H_2S from liquid product sulfur (degassing). The primary factors that occur during normal storage and handling are low H_2S

concentration in the gas above the liquid sulfur, mechanical agitation, cooling, and time. The equilibrium ratio of H_2S and H_2S_x is dependent on temperature; the ratio of H_2S/H_2S_x is about 1.5 at 155°C (311°F) and 10 at 125°C (257°F).[1,4,5] Over time, dissolved H_2S will desorb into the gas phase; physical desorption is favored by low H_2S gas concentrations. As H_2S is desorbed, some H_2S_x is converted to H_2S to maintain the equilibrium H_2S/H_2S_x ratio. The overall degassing rate is primarily controlled by the rate H_2S_x is converted to H_2S.

BASIS OF D'GAASS PROCESS

Earlier commercial degassing processes were designed to strip H_2S from liquid sulfur at atmospheric pressure by passing stripping gas (normally air) through the sulfur product or passing product sulfur through a stripping gas stream. These processes are designed to be carried out in the sulfur rundown pit to promote the physical desorption of H_2S into the stripping air stream using a combination of mechanical agitation to increase the surface area between the sulfur and stripping gas and maintaining a low H_2S concentration in the gas phase by continuous removal and replenishment of the stripping gas (air) stream. The physical desorption of H_2S is relatively easy and fast. However, H_2S_x is a high molecular weight compound that is not volatile and therefore is not removed by physical desorption. The commercial processes required from several hours up to a few days sulfur residence time to achieve less than 10 ppmw residual H_2S/H_2S_x. The primary reason for the long residence time was to allow conversion of H_2S_x to H_2S which could then be removed by physical desorption. Some processes utilize a chemical catalyst/additive to aid in the decomposition of H_2S_x to H_2S and reduce the required degassing time.

The established degassing processes all use air as the stripping medium. Several other gas streams have been utilized/tested/proposed. These include gases such as SRU tail gas, CO_2, and nitrogen. Steam has also been utilized in several locations. The results using these stripping alternates have not been as effective as using air. In general, air is preferred; steam is next in effectiveness, and inert gases are least effective.

Research by Alberta Sulphur Research Ltd. (ASRL) has identified the primary advantage of air stripping to be the direct oxidation of some of the H_2S/H_2S_x directly to sulfur.[1,6] ASRL has also determined the oxidation reaction to be primarily a liquid phase reaction.[7] Steam stripping is thought to be more effective than inert gas stripping because small quantities of the boiler water treating chemicals are carried with the steam and catalytically promote decomposition of H_2S_x to H_2S. Plants that have implemented steam stripping have often experienced very significant corrosion in the sulfur pit.

The patented D'GAASS Sulfur Degasification Process[8] was developed by Goar, Allison & Associates, Inc. (GAA) to provide a simple, compact process that maximizes the advantages of air stripping. The other commercial degassing processes operate at or near atmospheric pressure. The D'GAASS Process operates at elevated pressure to

increase the partial pressure of oxygen and concentration of dissolved oxygen in the liquid sulfur. The higher oxygen concentration increases the oxidation reaction rate of H_2S and H_2S_x to sulfur and SO_2. The SO_2 can then react with H_2S via the Claus reaction to form additional sulfur. Another objective of the D'GAASS Process was to avoid the use of catalyst injection to increase the rate of H_2S_x decomposition.

D'GAASS PROCESS DESCRIPTION (Figure 1)

Degasification is carried out in a vertical vessel in which the undegassed sulfur is contacted with pressurized process air. Air and sulfur flow counter-currently across fixed column internals using a specially designed air distributor. The upward flow of air provides oxygen for the reaction, agitation of the sulfur, and stripping of H_2S.

Undegassed sulfur from the sulfur collection pit is pumped to the D'GAASS contactor. The pumping rate is flow controlled at the sulfur production rate. The sulfur feed rate may be controlled using a sulfur pit level controller to provide a cascade set point for the flow controller. The degassed sulfur from the contactor flows to sulfur storage, sulfur forming, or directly to truck or rail car loading. The degassed sulfur pressure exiting the process is adequate to transfer the sulfur to the forming unit, a storage tank, or loading rack(s) without additional pumping. A return line from the bottom of the contactor to the sulfur pit is provided to drain the system and to allow recycling to the pit during start-up or if there are problems with the downstream facilities.

The Claus sulfur product temperature is normally above the optimum temperature for sulfur degassing. Cooling the feed sulfur before it enters the contactor is required to achieve 10 ppmw residual H_2S in the degassed sulfur. Cooling the sulfur in a shell and tube exchanger using boiler feedwater as a cooling medium has proven to be a good method.

The major unit controls are: (1) flow control of the sulfur feed rate to the D'GAASS Unit at the SRU sulfur production rate; (2) temperature control of the feed sulfur; (3) flow control of the process air based on the maximum rated capacity; (4) level control of the contactor by regulating the flow of degassed sulfur leaving the vessel; and (5) unit pressure control by regulating the overhead vapor effluent flow.

The overhead stream is air with small amounts of H_2S, SO_2, and sulfur vapor. The overhead stream can be sent to the incinerator. As an alternate, the elevated D'GAASS operating pressure allows sending the overhead vapor stream to the thermal stage of the SRU or to a tail gas unit burner. The routing of the overhead air stream is discussed in more detail later in the paper.

PROCESS PERFORMANCE FACTORS

There are many factors that influence the performance of the D'GAASS Process, as well as other degassing processes. Included in these factors are feed and product H_2S/H_2S_x concentration, degassing temperature, degassing pressure, sulfur and air residence time, and air rate.

The major degassing performance factors are the concentration of H_2S/H_2S_x in the undegassed feed and the degassed product. ASRL has shown air degassing to be a pseudo-first order reaction.[1]   A simple way to consider the effects of H_2S/H_2S_x feed and product concentrations is to utilize half-life. This concept should apply to both atmospheric processes and the D'GAASS Process. Using this concept, the time required to reduce the H_2S/H_2S_x concentration from 300 ppmw to 150 ppmw is the same as the time required to reduce the concentration from 20 ppmw to 10 ppmw.

The key feature of the D'GAASS Process is the use of pressure to increase the partial pressure of oxygen and therefore the liquid sulfur dissolved oxygen concentration. If Henry's Law is assumed to apply, the equilibrium concentration of oxygen in sulfur at 90 psig is seven times the concentration at atmospheric pressure. Higher dissolved oxygen concentration in the liquid sulfur results in a greater overall kinetic reaction rate. This feature allows the D'GAASS Process sulfur residence time to be minutes compared to hours for the atmospheric pressure degassing processes. Higher oxygen partial pressure also increases the transfer rate of oxygen from the gas phase to the liquid.

The importance of temperature in sulfur degassing performance has been known for several years. ASRL presented research data, Figures 2 and 3, indicating the optimum degassing temperature for their laboratory air sparge degassing testing apparatus was between 130 and 140°C (266-284°F).[1]   Most sulfur condensers generate 50 psig (350 kPag) steam to cool the process gas and condense sulfur. This results in condenser outlet temperature of 320-350°F (160-175°C) for most SRU's. Sulfur pits are usually equipped with steam coils to offset heat losses and maintain the sulfur as a liquid. Normally, 50 psig steam is also used in the coils. The sulfur pit product temperature is typically 300-320°F (150-160°C). Therefore, cooling is normally required for efficient degassing in all processes. The D'GAASS Process utilizes a conventional shell and tube heat exchanger to cool the sulfur feed to the degassing contactor. GAA has found preheating SRU boiler feedwater works very well for the sulfur cooler. The degassing contactor feed temperature is controlled by regulating the boiler feedwater flow through the cooler. This provides very precise control of the temperature at the optimum temperature, which is not possible with the in-pit systems.

The importance of sulfur residence time is probably obvious. As discussed above, ASRL has shown air degassing to be a pseudo-first order reaction. For example, to reduce the residual H_2S in undegassed sulfur from 300 ppmw to 9 ppmw in the degassed product, it requires 5 half-lives. This is equivalent to 10 hours if the half-life

time is 120 minutes. If the degassing unit capacity allowed only 4 half-lives residence time, the resulting product residual would be 19 ppmw.

The air residence time may not be as obvious, but it is very important. The effect of pressure on the equilibrium oxygen concentration of oxygen in sulfur was discussed above. However, oxygen does not immediately dissolve in liquid sulfur. The transfer of oxygen to sulfur can be the rate limiting step; equilibrium dissolved oxygen concentration may not be achieved. Mass transfer from a gas phase to a liquid phase has been compared to heat transfer with film resistances to mass transfer similar to heat transfer film resistance. The overall transfer of mass (oxygen) is dependent on the driving force (oxygen partial pressure) and area (bubble surface area). Because the system is dynamic, the longer the bubble is in contact with the sulfur the more oxygen will be transferred.

The other major factor is the air rate. With the major advantage of the D'GAASS Process (higher pressure with greater liquid sulfur oxygen concentration), the process air rate is much lower than for the atmospheric processes.

The D'GAASS process design optimizes the application of the factors discussed above. The feed temperature is controlled at optimum temperature. The operating pressure is maximized within economic limits. The D'GAASS contactor fixed vessel internals and air distributor are designed to maximize process air utilization. Correct application of all these factors is necessary for effective, economical degassing.

DESIGN VARIATIONS

As of August 2005, there are 38 licensed D'GAASS Units. Each location has specific local factors that have resulted in several different process configurations being implemented. Some factors are local process limits, and some are economic. Design variations are discussed below.

Process Air Supply:

The process air feed may be supplied by a compressor dedicated to the D'GAASS Process or from the plant air (or instrument) air system. If adequate volume and available pressure allow usage from the plant air system, it will normally reduce the installed cost of the D'GAASS Unit. The plant air header pressure will typically be lower than the pressure from a dedicated compressor. To offset the lower pressure, additional process air flow can be utilized. About half of the units have employed dedicated compressors and half have used plant air.

Sulfur Cooler:

As discussed above, the undegassed sulfur feed is normally hotter than the optimum temperature for degassing. If boiler feedwater is available at acceptable conditions, it is the preferred cooling medium. Preferred BFW conditions are:

- The pressure of the BFW is equal to or greater than the feed sulfur pressure. This insures that if there is any leakage, BFW will leak into the sulfur instead of sulfur into the BFW.
- The BFW temperature is about 250°F, which is above the sulfur melting point but below the optimum degassing temperature.

At several locations, the BFW did not meet the above preferred conditions. When the BFW is too cold, the BFW has been preheated in a separate heat exchanger or by using steam jacketed piping for the BFW; by recirculating and mixing a portion of the heated BFW exiting the sulfur cooler with the cool BFW, and by injecting higher pressure steam into the BFW using a special mixing valve.

The other primary method of cooling the feed sulfur has been by generating low pressure (~15 psig) steam in the shell of an exchanger similar to the final sulfur condenser in many SRU's. The low pressure steam can be exported if it can be utilized or it can be condensed and returned to the sulfur cooler in a closed loop system. The cooling medium for the steam condenser can be air, cooling water, or cool BFW.

Sulfur Feed:

When the degassing unit is fed from a single sulfur rundown pit, the feed rate is generally controlled by the pit level controller providing a remote set point to the feed flow controller; the feed rate is equal to the sulfur production rate. However, when feeding the degassing unit from multiple sources, a different control system must be utilized. Each rundown pit may be operated using the individual level controllers and pumping from each pit. This requires high head feed pumps be installed in each pit. Some locations have transferred sulfur from one or more pits to a primary feed pit from which the degassing unit is fed. This requires a single set (operating plus spare) of feed pumps. In one location, the degassing unit was fed from three SRU's. The local operations personnel did not want pump directly from the pits, but wanted to continue batch transfer from the rundown pits. A large feed surge drum was installed to accommodate this unit.

For small units, a variable speed gear pump can be used, which eliminates the requirement for a feed control valve.

Overhead Gas Stream:

The overhead stream is air with ppm levels of H_2S, SO_2, and sulfur vapor. The stream has been routed to the SRU incinerator, thermal stage, tail gas unit RGG burner, and SBS type tail gas unit. If the stream is routed to any of the locations other than the incinerator, the sulfur compounds are recovered and do not directly contribute to the overall plant sulfur emissions. The overhead stream has also been used to sweep the feed surge drum discussed above and has been routed to the sulfur pit to contribute to the pit sweep air.

The stream pressure is sufficient that it can also be utilized as the motive fluid for the pit sweep air system eductor. This option results in saving the steam normally used to drive the eductor and fuel savings in the incinerator because the air contributes to combustion, but the steam requires heating from about 300°F to 1200°F (150-650ºC)[9,10].

Plant Construction:

About half of the D'GAASS Units have been retrofits and half associated with new SRU's. Most of the units have been field constructed with the contactor and sulfur cooler mounted on independent foundations with field installed piping, instrument cable, electric power, etc. However, some of the retrofits have utilized modular construction. Modular construction has the advantage that much of the construction work can be performed in a fabrication shop where labor rates are often significantly lower, and labor is generally much more efficient. Modular construction reduces field construction time which also has the advantage minimizing the time external work is being performed near an operating unit.

Two different modular concepts have been utilized. The unit that has the feed surge drum discussed above has a three stacked modules. The lower module has the air compressors, feed pumps, and junction boxes. The feed drum is mounted above this module with a middle module containing mostly piping. The upper module has the sulfur cooler and sulfur and air flow and overhead pressure control loops. The contactor vessel is mounted on a separate foundation adjacent to the modules. The other units used vertical modules in which the contactor vessel, sulfur cooler, and all major controls were mounted, Figure 4. The complete module was trucked to the field and set on a prepared foundation. If dedicated compressors were required, they were mounted on a separate module.

Sulfur service piping must be heated to maintain the pipe wall above the sulfur freezing temperature. Sulfur piping has traditionally been heated with 50 psig steam in the annular space of jacketed piping. Crosses for rodding were provided at each change of direction. Several of the D'GAASS Units have used non-jacketed piping that is heated using ControTrace elements from Controls Southeast. The ControTrace piping is less expensive and has the advantage of isolation of the steam and sulfur streams. When properly installed, the ControTrace systems have worked well; however, the elements must be tightly banded to the piping with heat transfer cement between the element and pipe. Since the D'GAASS Unit operates with flows pressured through the piping, plugging is not as likely as with traditional gravity flow sulfur piping. Crosses are a source of heat loss since two legs are always dead flow areas and have been eliminated from the piping. Rodding of pressurized piping is also a significant safety hazard and should not be done without special precautions.

Catalyst:

The Sulconam (first) D'GAASS Unit contactor was tested with two internal beds, a bed to enhance vapor-liquid contacting and a fixed catalyst bed. Testing of the Sulconam unit indicated no significant improvement in performance with the catalyst bed, and that the catalyst was not required to achieve less than 10 ppmw residual $H_2S + H_2S_x$. The single bed design simplifies the contactor construction and also avoids problems with incorrect operation of the unit that could damage catalyst. Some operators have performed steam-out of the contactor even though they have been told to not introduce water either liquid or steam to the contactor. At one location, the operators completely filled the contactor with water.

Injection of a chemical catalyst was also tested. The degassing performance using the chemical catalyst was very good; however, it is possible to achieve less than 10 ppmw residual $H_2S + H_2S_x$ in a relatively small contactor without injecting catalyst. Chemical catalyst injection has the disadvantages of catalyst cost, the catalyst destroys the polymeric sulfur which greatly reduces the strength of any solid form product unless several hours hold up is provided to allow the polymeric sulfur to reform, and many purchasers do not want sulfur that has had a catalyst additive because any excess/residual catalyst may cause problems with units processing the sulfur.

INDUSTRY ACCEPTANCE

The D'GAASS Process has been well accepted by sulfur processing industry since it was first introduced to the industry at the Brimstone Symposium in 1997 with a steady increase in the number of D'GAASS Units, Figures 5 and 6. There are currently 38 licensed units with a total processing capacity of over 22,500 MTPD; five additional units are in engineering with final details on the license agreement pending. The units are located in 9 countries on 4 continents.

UNIT PERFORMANCE

The 19 operating units have all met their performance guarantee. Design sulfur feed concentrations have ranged from 250 to 700 ppmw $H_2S + H_2S_x$ with feed temperatures as high as 380°F. However, some units have had lower than desirable on-stream performance. This has been a result of corrosion in the vapor area of the contactor and overhead piping upstream of the pressure control valve.

Observations:

The corrosion products have been primarily sulfates. The presence of sulfates indicates the corrosion is most likely from the presence of dissolved SO_3 in the feed sulfur or liquid water. There are other possibilities but are less likely.

GAA has not found a published correlation or data on the dew point of SO_3 and water at pressures above about 15 psig. However, extrapolation of published correlations indicates that SO_3 concentrations in the overhead gas stream as low as 1 ppmv at the contactor overhead operating conditions can result in condensation as sulfuric acid. The source of the SO_3 is most likely a poorly performing burner, particularly an acid gas fired reheat burner. However, SO_3 can also be formed by reaction of NO_2 from an inefficient mixing burner or poorly controlled front-side split ammonia destruction process and SO_2. The SO_3 formation reaction is very fast and has been reported to have caused corrosion of SRU condenser tubes.[11] Significant excess oxygen feed to a selective oxidation unit can also result in formation of small quantities of SO_3.

Liquid water with sulfur, H_2S, SO_2, O_2, and possibly SO_3 can result in corrosion through several paths. Sulfur and iron in the presence of liquid water will form iron sulfide which will then react with other components. The overhead gas stream components will normally remain in the vapor state; however, if liquid water is present, H_2S, SO_2, and SO3 are all very soluble in water. Sulfurous, thiosulfuric, and sulfuric acids, all strong acids, can form. The presence of oxygen aggravates the situation.

Normally, liquid water would not be expected at the contactor overhead conditions. However, any point on the contactor or overhead piping that is significantly below the bulk temperature can be below the water dew point with one or a combination of the acidic gas components. The vapor section of the contactor in several early units was not heated, but was supposed to have been fully insulated. In analyzing the source of corrosion, some units were found to have significant areas of the contactor that were uninsulated. These areas included lifting lugs, top blind flanges, and instrument nozzles. Piping flanges are also often left uninsulated. The uninsulated areas result in large heat loss with resulting metal temperatures well below the dew point, particularly in cold climate areas. It is very important to keep all portions of a sulfur recovery unit above the sulfur freezing point, but it is imperative to keep the overhead area of the degassing unit warm enough to avoid water and H_2S, SO_3, and SO_2 dew point conditions.

At least one unit located in a warm climate area did not insulate the process air piping between the air compressor and contactor. Water condensed and collected in low points in the air piping. When it accumulated enough, a slug of water was sent to the contactor. The water accumulated as a layer on the liquid sulfur. Acid gases dissolving in the water resulted in corrosion at the normal liquid level interface.

It was observed that degassing units operating with dry air did not experience as many problems with corrosion. This included plants using dried plant air, plants located in cold climates that experienced less corrosion in the winter when the air dew point was already low, and plants using two-stage compressors with intercoolers and knockout between stages.

Corrosion Prevention:

GAA has worked with the local plants to develop plans and methods for preventing and/or minimizing corrosion. GAA also hired a metallurgical consultant to develop recommendations for corrosion resistant materials. Based on the metallurgist recommendations and findings from units that had experienced corrosion, GAA has developed design modifications and recommendations for D'GAASS Units.

- Heat the upper, vapor section of the contactor vessel including all nozzles using medium pressure (150 psig) steam
- Remove or heat any contactor lifting lugs
- Fully insulate all areas of the contactor vessel including nozzles, flanges, lifting lugs, etc.
- Heat the overhead piping between the contactor outlet nozzle and pressure control valve using medium pressure steam
- Fully insulate the overhead piping including all flanges
- Use acid resistant metals (Haynes International Hastelloy® C-22 or C-2000 or equal) in the vapor section of the contactor and overhead piping upstream of the pressure control valves
- Use corrosion resistant materials in the overhead pressure control valve
- Use dry plant air or install dryers on the process air from dedicated process air compressors

MECHANICAL PROBLEMS

Level Probes:

The most common method of level measurement in the D'GAASS contactor vessel has been with capacitance probes. Earlier unit probes were stainless steel rods inserted into the sulfur. However, some of the mounting nozzles were extended to as much as 18" to extend above an upper platform, and were unheated with uninsulated flanges. The heat loss from the nozzle and probes resulted in corrosion of the probe in the vapor area and ultimately failure of the probe. All nozzles are now specified to be steam jacketed, fully insulated, and the level probes are fully Teflon coated.

Pump Installation:

In all D'GAASS Retrofits, new, higher head, lower volume sulfur pumps have been required. In at least two locations, the new pumps have been installed into a pit containing a significant liquid sulfur level. When the pumps were installed, they were simply lowered into the liquid sulfur. When the pumps were started, the pump either tripped on overload or did not pump. The problem was ultimately identified as differential expansion between the pump shaft and steam jacketed shaft case. When the pump is lowered into the liquid sulfur, the case heats and expands quicker than the

shaft. This jams the pump case against the impeller and either prevents the impeller from turning causing overload; or the nut holding the impeller on the shaft is broken, and the impeller is forced off the shaft.

The pump must be very slowly lowered into the liquid sulfur allowing the case and shaft to heat evenly.

Pump Bearing Clearance:

In three units, the SRU's experienced problems with pit fires after the D'GAASS Unit start-up. This was very puzzling because there was no change in the undegassed sulfur in the rundown pits. The only significant change was that the pit was maintained at a lower level. It was finally discovered that the bearings which are lubricated and cooled by the sulfur did not have adequate clearance to allow adequate lubrication and cooling of the bearings. The bearings overheated and ignited the sulfur. When the bearing clearance was increased from 0.012-0.014" to 0.020", the sulfur fires stopped. GAA is not sure why this had not been a problem before unless there is a difference in the clearance for the original high volume, low head sulfur transfer pumps and the new low volume, high head feed pumps. The other possibility is that the short tine that was required to pump down the pit was not long enough to build sufficient heat to ignite the sulfur.

Horizontal Pump Seals:

One location uses horizontal centrifugal sulfur feed pumps. They had a lot of problems with pump seal failures. The pump vendor recommends using 35 psig steam for the seal jacket. We suspect this is because they were considering the viscosity of pure sulfur and wanted to avoid the high viscosity temperature region. However, undegassed sulfur viscosity is much lower than pure sulfur. We believe the 35 psig steam (about 280°F) did not provide adequate heat input to the seal to avoid freezing sulfur in the spare pump.


SUMMARY

Overall, the first 9 years operating experience of the D'GAASS Process has been very good. All operating units have met degassing performance guarantees. Units that have experienced corrosion in the contactor overhead section and piping have been provided recommendations to mitigate the problem including heating these sections using medium pressure steam, insuring everything is fully insulated, using dry process air, and using alternate metallurgy. Current D'GAAS designs all specify using dry process air, medium pressure steam (if available) heating for the vapor section of the contactor and overhead piping, completely insulating all vessel and piping components, and alloy metallurgy for the upper section of the contactor and overhead piping. The overall upgrades to improve reliability only add a small increment to the overall installed cost of the degassing unit.

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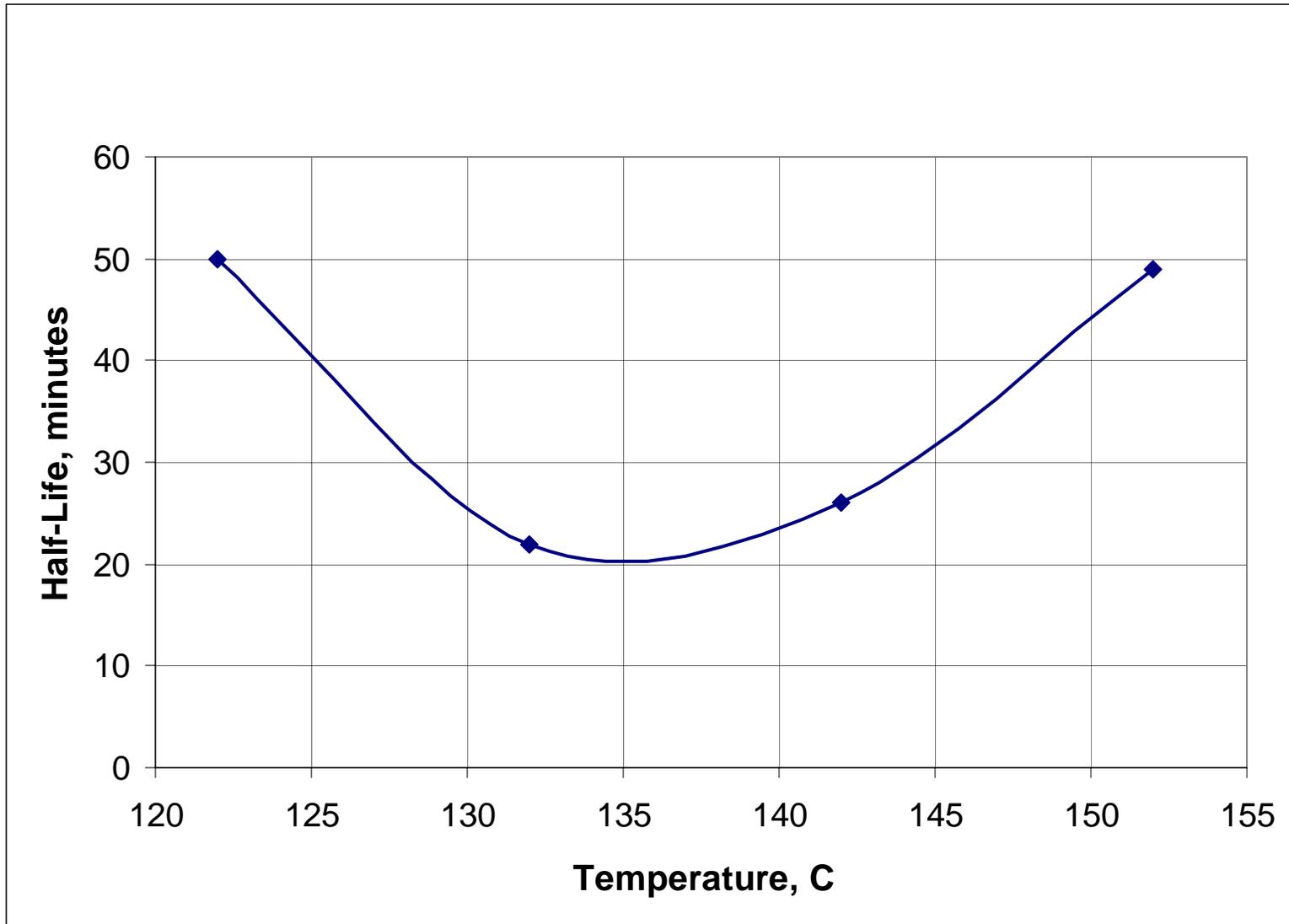
Figure 1, Typical D'GAASS Flow Diagram
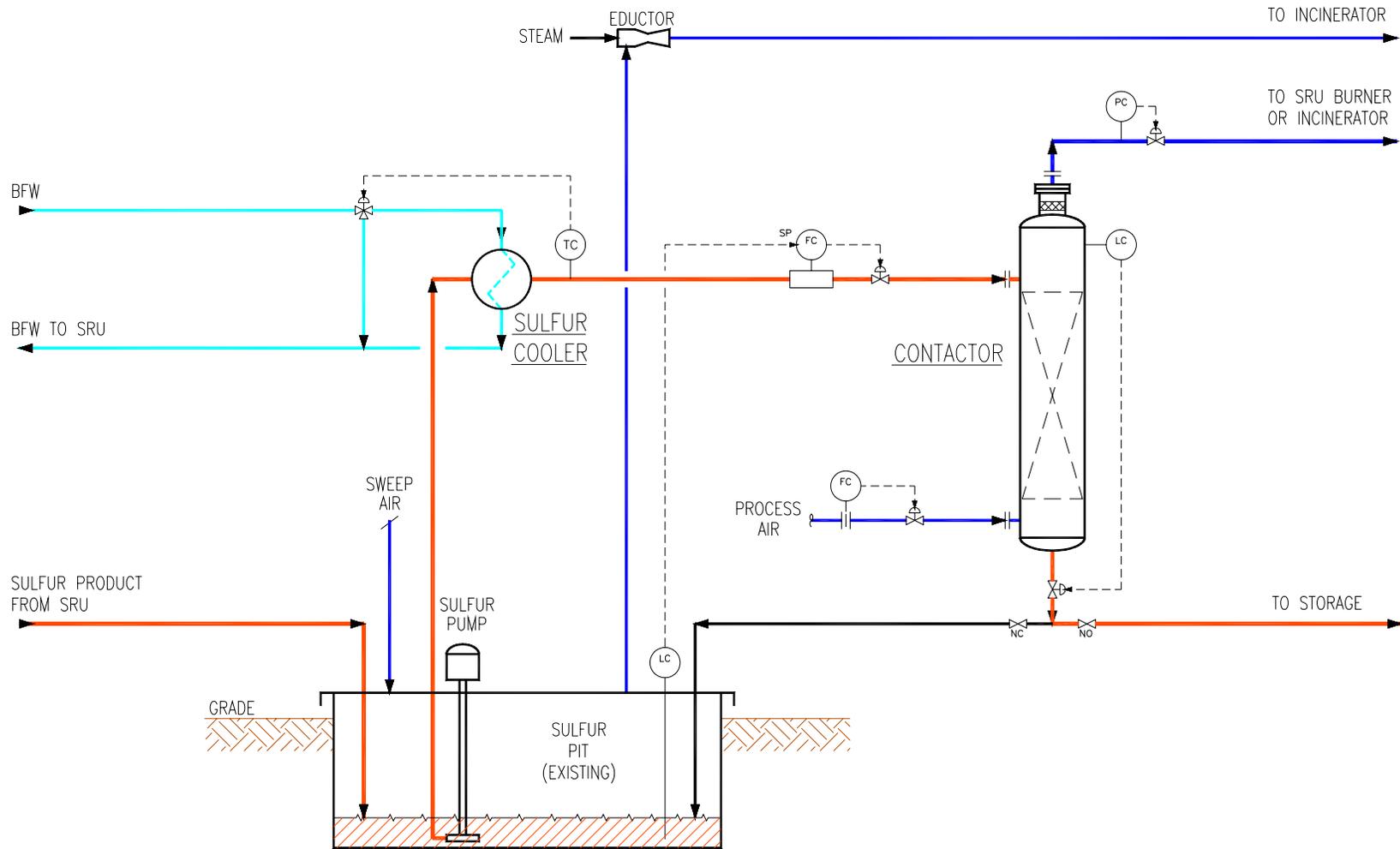
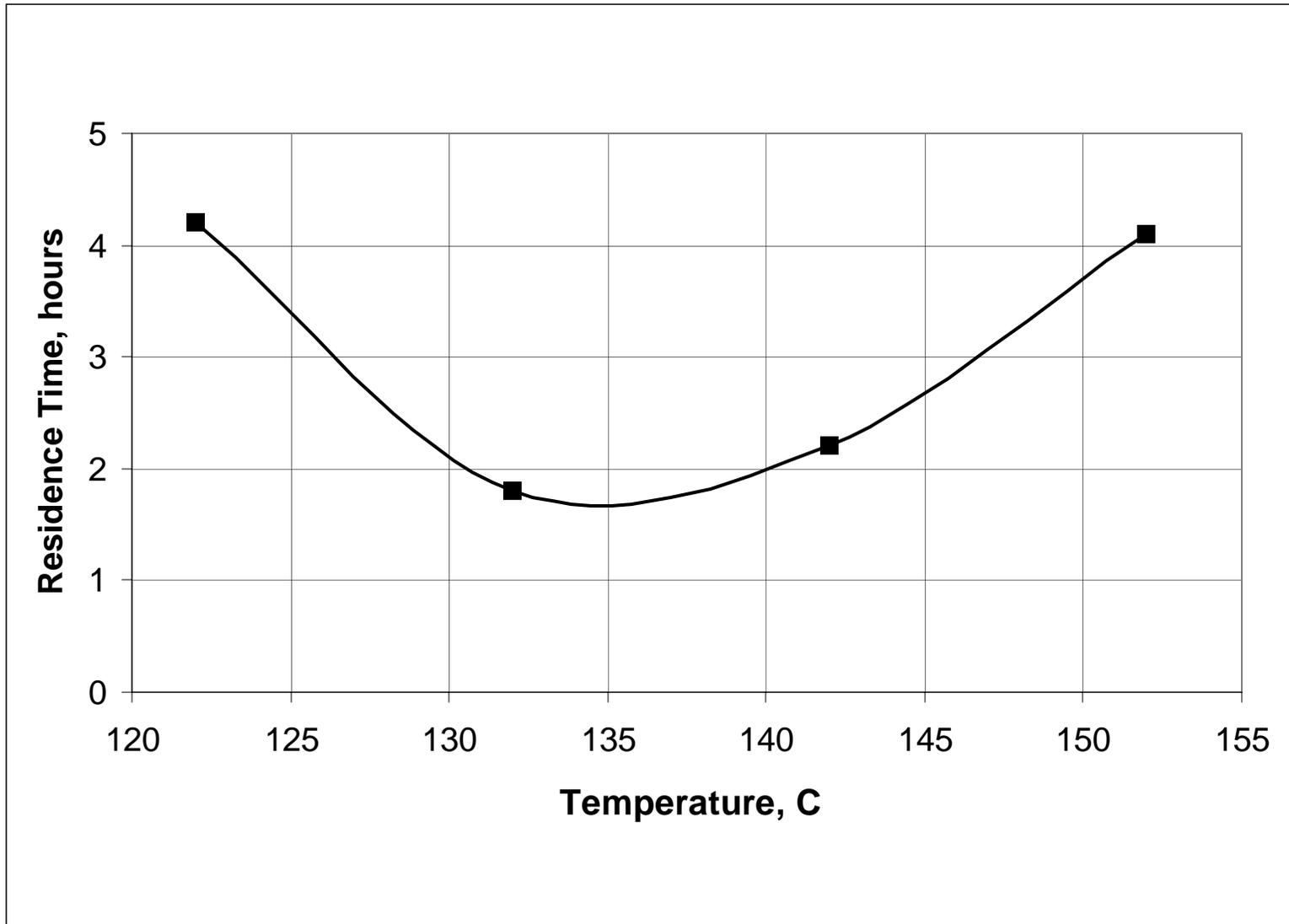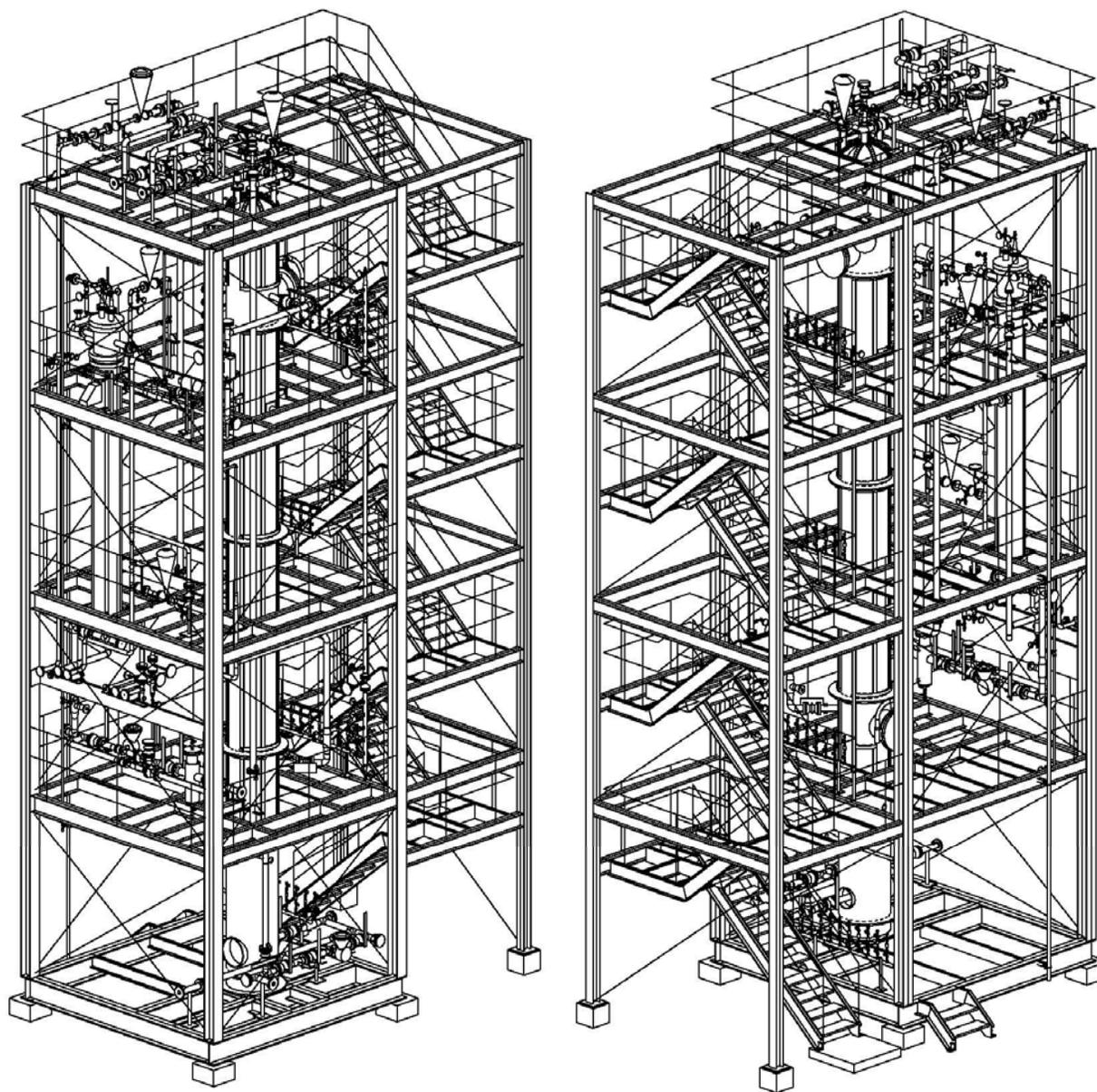**Figure 2, Effect of Temperature on Sulfur Degassing Half-Life**

Figure 3, Residence time Required to Reduce H$_2$S from 100 ppmw to 6.25 ppmw

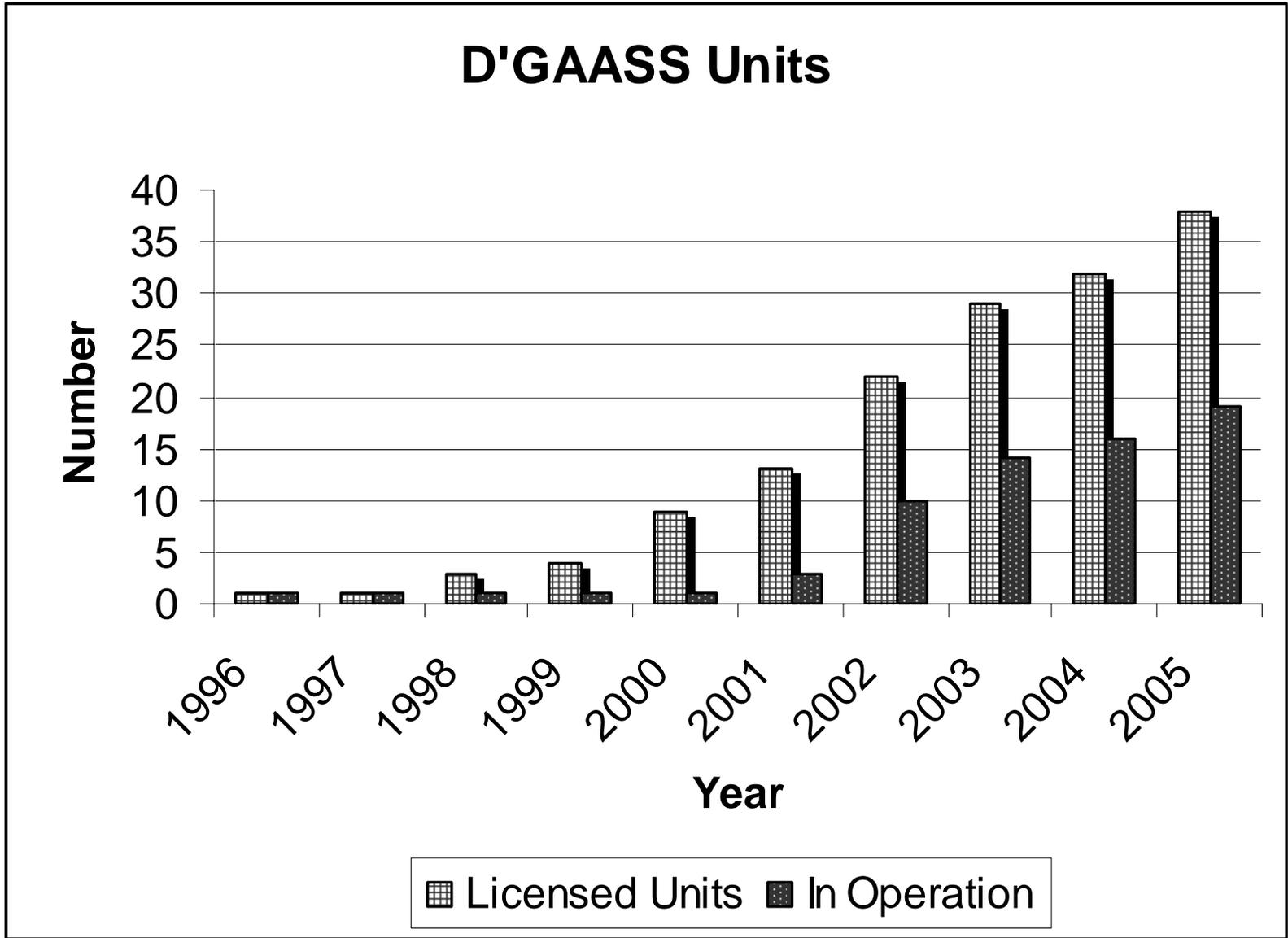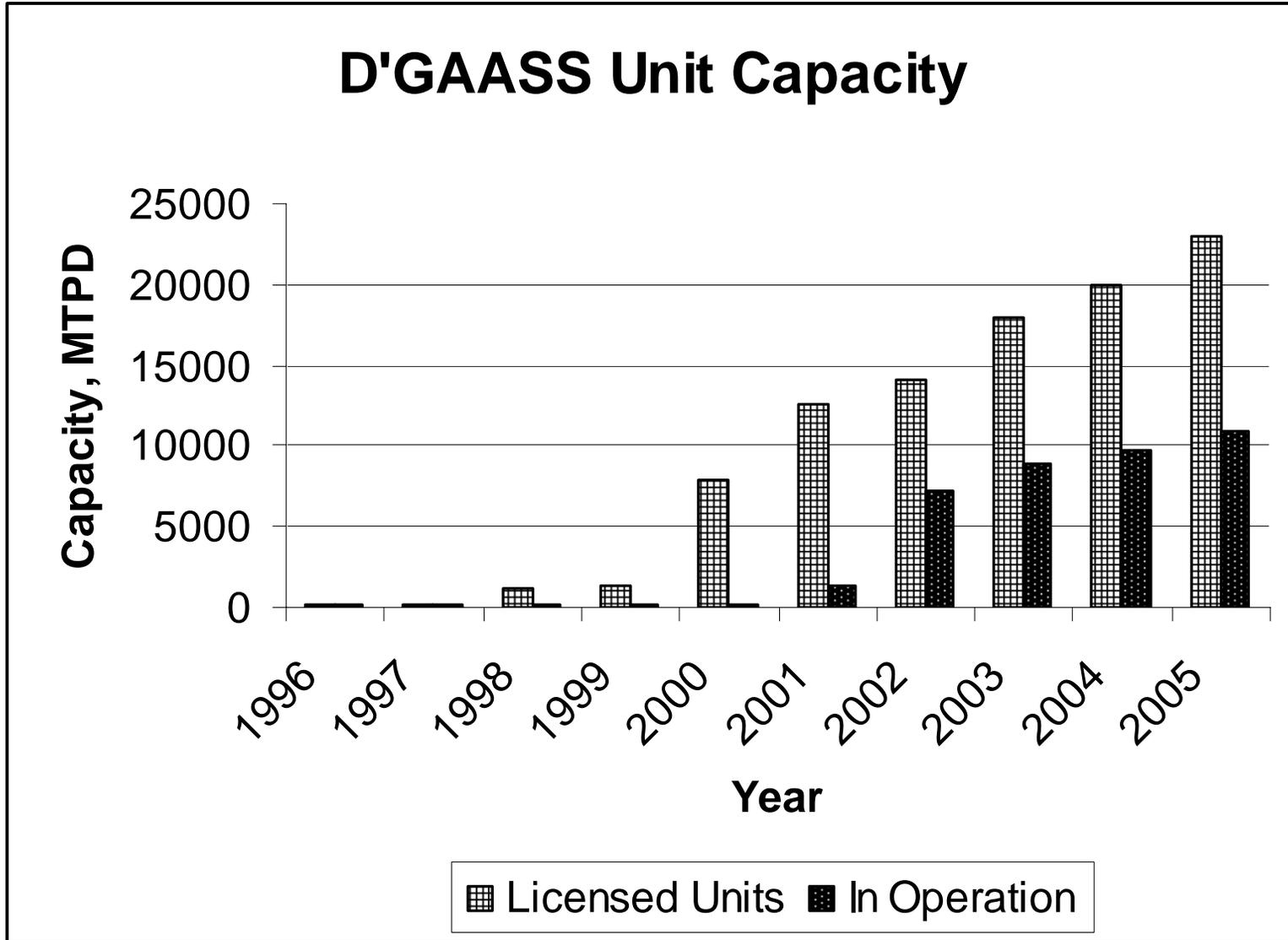**Figure 4: D'GAASS Sulfur Degassing Process Module**

Figure 5: Licensed D'GAASS Units

Figure 6: D'GAASS Unit Capacity