Unique Acid Gas Enrichment Application

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ABSTRACT

Environmental regulations controlling the amount of H2S emissions require the Aquila Navasota Gas Plant to treat the acid gas from the main amine-treating unit to meet standard specifications. Originally, a batch process was installed to remove a portion of the H2S, bypassing the remaining gas, to meet the specifications. Operating cost of this batch process increased as the H2S content increased and became excessive. This required Aquila to investigate alternative processes. Process evaluations were requested from several sources and a large variance in unit designs was found. Due to the unique nature of the feed gas, 96+% CO2 and < 1000 ppm H2S at 10 psig, conventional design technology for amines required a higher circulation rate and excessive CO2 absorption. Since the recovered H2S would be sent to a flare, fuel consumption would be higher with the excess CO2. One design, provided by Huntsman Corporation, was found to offer the lowest capital investment along with lower operating cost. This design utilized specific design parameters in the absorber that allowed the circulation rate to be less than one-third of the other designs. Unit operating parameters will be reviewed and have been within original estimates. Design also allows for a wide range of operating conditions without much change in treated specifications. Design and operating characteristics will be reviewed.

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INTRODUCTION

Aquila operates and maintains the Navasota Treating Plant in Grimes County, Texas. The plant is a 160 MMscfd, 800 gpm, amine treating facility designed primarily for the removal of carbon dioxide (CO_2). In addition to approximately 6.5% CO_2, the inlet gas contains approximately 25 ppm H_2S. This presents complications due to the fact that the facility is limited to an H_2S emission rate of four pounds per hour. The facility begins to approach the four pounds per hour emission limit from the amine regeneration vent at an inlet gas rate of approximately 50 MMscfd and 25 ppm H_2S. Since the H_2S emission rate is limited to for four pounds per hour, a portion of the H_2S must be captured or converted to SO_2.

When Navasota was originally constructed, Sulfaguard, a liquid H_2S scavenger system, was installed and operated to maintain compliance with the four pounds per hour emission limit. Emissions were limited by routing a portion of the approximately 5.5 MMscfd CO_2 regenerator vent stream containing approximately 800 ppm H_2S through the Sulfaguard unit prior to venting to atmosphere. This process was effective, but expensive. Sulfaguard usage averaged about 12,000 gallons per month for an average cost in excess of $50,000 per month. This was an unacceptable operating cost!

Aquila set out to find an alternative to the Sulfaguard system. Traditional alternatives would include a flare or incinerator. However, fuel gas requirements to burn 5.5 MMscfd of CO_2 are excessive. Non-regenerable solid scavengers such as iron sponge result in the same elevated operating expenses as the Sulfaguard system in this application.

After reviewing the numerous alternatives, Aquila focused on a traditional regenerative amine system utilizing a specialized solvent and absorber design to selectively remove the H_2S from the vent stream. Aquila evaluated several alternative solutions, including differing selective amine treating designs, before selecting and implementing the chosen technology.

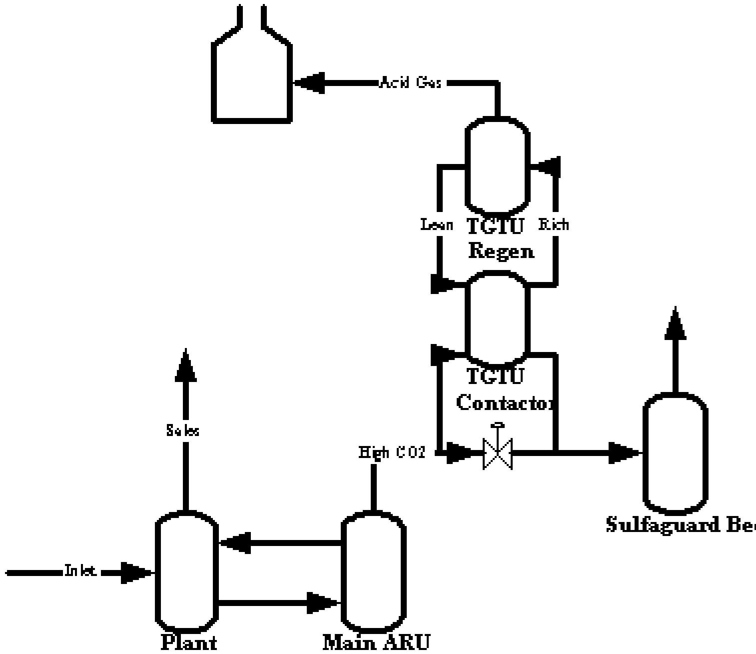
The remainder of this paper will address the following:

- The design basis/parameters of the treating unit;
- Economics of each alternative technologies and absorber design options;
- Specific operating data is provided and operating issues discussed;
- Actual project economics; and,
- Conclusions.

DESIGN BASIS/FEED GAS

Amine regenerator vent stream parameters from the main plant at Navasota are as follows:

- 5.5 MMscfd;
- Temperature range: 90 – 110°F;
- Pressure: 8 –10 psig;
- Approximately 96% CO_2; 3.5% H_2O; 800 ppm H_2S; less than 1% hydrocarbons; less than 1% amine.



In order for this project to be a complete success, the proposed treater has to reduce the H_2S level in the 5.5 MMscfd of CO_2 to less than 190 ppm. The following figure is a simplified flow diagram to show how the plant was configured. The acid gas from the main ARU was sent to the Sulfaguardtreater. The new amine unit was installed between the main ARU and the Sulfaguard unit.

ECONOMICS OF ALTERNATE TECHNOLOGIES AND ABSORBER DESIGN OPTIONS

The options available for this project were broken down into three main concepts:

1. Continue Solid Bed Unit
2. IncinerateTotal Off-gas
3. Selective Amine Treating

Operating costs, associated with continuing the solid bed unit operations, were greater than $600,000 annually. Fuel requirements to incinerate the entire 5.5 MMscfd vent stream of CO_2 would exceed $1,000,000 annually even at $2.50/Mcf fuel prices. Therefore, Aquila focused their evaluation on the selective amine treating process.

Further complicating the economic evaluation is the various design possibilities of the selective amine process. Table 1 compares the cost of straight incineration (Case 1) with three separate selective amine-treating designs (Case 2, Case 3, and Case 4).

Table 1: Design Case Selection List

Parameter	Case 1	Case 2	Case 3	Case 4
Absorber Dia.	-NA-	4.5	4.5	4.5
Absorber # Trays	-NA-	20	9	-NA-
Absorber Packing (ft)	-NA-	-NA-	-NA-	12
Amine Circulation Rate	-NA-	185	100	40
Reboiler Duty (mmbtu/hr)	-NA-	8.78	4.62	1.85
Reboiler Fuel (MSCFD)	-NA-	213.1	114.8	45.8
Incinerator Fuel (MSCFD)	442.6	93.0	34.5	6.2

Total Fuel (MSCFD)	442.6	306.1	149.3	52.0
Fuel Cost @ $2.50 (966 Btu)	$390,141	$269,819	$131,604	$45,837
Fuel Cost @ $4.50 (966 Btu)	$702,254	$485,675	$236,888	$82,506
Capital Cost	-NA-	$1,284,000	$789,000	$521,000

As the data clearly shows, there are dramatic differences in the required circulation rates and fuel requirements based solely on the level of selectivity obtained in each design. It has long been known that MDEA (methyldiethanolamine) is selective for the removal of H_2S versus CO_2. While MDEA will react with CO_2, the reaction is such that several factors influence the amount of CO_2 removed. The reaction of H_2S with MDEA is via a proton transfer and is almost instantaneous. CO_2 does not react directly with MDEA and the reaction is relatively slow, resulting in selective removal of H_2S. Controlling the number of stages, contact time, temperature and partial pressure of the acid gas all influence the reactions with CO_2. One additional factor in selective treating is that if less amine is bound with CO_2, more is available to react with H_2S. Traditionally, absorbers have been designed utilizing 20 trays. In selective treating, fewer trays/stages may be utilized which increase the CO_2 slip. This factor is due to both equilibrium and kinetics. With fewer stages, less CO_2 is absorbed, allowing for more H_2S removal.

In this application, as in many process designs, most parameters are fixed. As such, any difference in design is based on those variables that are readily changeable. In this design, acid gas partial pressure, the gas flow-rate, and to a lesser extent the temperatures are all fixed. Although the amine flow-rate is variable, the circulation rate is based on obtaining the proper amount of amine to meet the treated gas specification. The main variables that could be changed and have an effect on the selectivity are the number of trays/stages and contact time (tray/stage residence time).

Conventional tray design dictates a contact/residence time on the tray determined by the tray hydraulics. For a fixed tower diameter, reducing circulation rate can increase tray residence time, thus increasing CO_2 removal. Increasing circulation rate decreases the residence time, however, more amine is present to remove CO_2. These factors reduce the tower's ability to slip CO_2. Understanding the contributing factors is key to realizing how selectivity can be increased. The main criteria are to reduce the circulation rate and contact time, effectively reducing CO_2 removal.

Packed towers can offer an improvement in several areas for this application. First, pack towers can have a smaller diameter for a given gas volume, increasing gas velocity through the tower. Secondly, residence time, with regard to liquid traffic, is not as dramatically changed relative to the circulation rate as it is with trays. The packing hold-up time changes less dramatically than trays and is especially true of packing with low transfer efficiency. While many applications may utilize packing to gain additional capacity due to improved efficiency, selective treating can benefit from utilizing the opposite effect of specific packing.

One of the main problems with packing is getting accurate data with regard to computer modeling. Huntsman Corporation utilized the Bryan Research & Engineering's TSWEET® program to evaluate this design. Huntsman's working knowledge of amine systems and computer modeling allowed the design of this unit to be made with considerable certainty. Utilizing JEFFTREAT® MS-100, a formulated MDEA based solvent for selective treating, and specific design knowledge of packed towers, Huntsman was able to design a unit with minimum investment, circulation and fuel gas requirements.

SPECIFIC OPERATING DATA AND ISSUES

Table 2 shows selected operating data from the Aquila Navasota plant. The H_2S content in the acid gas from the main treating unit, which is vented to atmosphere, must remain below approximately 190 ppm in order to meet the four pounds per hour H_2S emission limit. To increase operating flexibility, the Sulfaguard system was maintained in the operating unit in the event that the amine-treating unit was down or upset. If the H_2S emission rate rises above four pounds per hour, a portion of the acid gas is routed to the Sulfaguard unit to meet the H_2S emission limit. The H_2S content is measured after the portion of gas exiting the Sulfaguard unit joins with the remainder of the treated gas. Therefore, the table only includes dates when the Sulfaguard unit was not in use since the amount of removal attributed directly to the Sulfaguard unit could not be determined.

Table 2: Operating Data

	Design	11/2/99	11/28/99	1/2/00	1/25/00
H_2S in pipeline		29 ppm	27 ppm	24 ppm	21 ppm
H_2S out pipeline		0 ppm	0 ppm	0 ppm	.05 ppm
Amine Conc.	45 wt%		30 wt%		45 wt%
Total lean loading	0.007		.016 m/m		.013 m/m
Stripper OH Temp	227 F	209 F	212 F	215 F	214 F
Lean amine temp to Abs.	100 F	101 F	98 F	100 F	88 F
Circulation Rate	40 gpm	37.5 gpm	33 gpm	34 gpm	
Treated gas ppm of H_2S	166	144	169	170	130
Pipeline inlet MMSCFD		115.6	107	127	133
Pipeline Outlet MMSCFD		108.4	101	120.3	125
Treated MMSCFD	5.5	4.59	4.38	4.83	5.1
LB-mole H_2S / day to TGTU	11.85	8.85	7.62	8.04	7.35

The requirement for supplemental treating of the gas with the Sulfaguard unit has occurred during the summer months. This is due to the limitation of the lean amine cooler, which uses air as the cooling medium. When the lean amine temperature to the absorber rises above 100 - 105ºF, the equilibrium for H_2S absorption is adversely affected and the Sulfaguard unit is needed to maintain the H_2S emission specification. If the lean amine temperature could be maintained below 100ºF at all time, the Sulfaguard system would be unnecessary. Huntsman and Aquila are currently addressing the temperature issue with possible solvent formulation adjustment and/or supplemental cooling of the lean amine.

Unfortunately, the plant has no measurements of the fuel gas supplied to the incinerator or the regenerator reboiler. The regenerator overhead temperature is lower than design, resulting in a higher lean loading / lower fuel usage than predicted by simulation models. However, the unit has still been able to meet the H_2S specifications with the higher lean loading with the exception of the earlier noted temperature effects.

ACTUAL PROJECT ECONOMICS

After several months of operations, economics of the unit were reviewed. The evaluation was based on actual operating data. Sulfaguard consumption was found as shown in Table 3.

Table 3: Navasota - Tail-Gas Treater
Actual Savings Resulting from Project

Month	**Sulfaguard Use (gal.)**	**Average Historical Sulfaguard Use (gal.)**	**Average Price ($/gal.)**	**Savings ($/mo.)**
Sep-99	6000	12000	$4.50	$27,000
Oct-99	6000	12000	$4.50	$27,000
Nov-99	0	12000	$4.50	$54,000
Dec-99	0	12000	$4.50	$54,000
Jan-00	0	12000	$4.50	$54,000
Feb-00	0	12000	$4.50	$54,000
Mar-00	0	12000	$4.50	$54,000
Apr-00	2000	12000	$4.50	$45,000
				$369,000

Average Savings per month: $46,125

Total operating costs and project Internal Rate of Returns (IRRs) for the unit are shown in Table 4 and are based on actual operating data.

Table 4: Economics for Adding Tail-Gas Treating Unit
Based on Actual Savings

Capital Cost ($K)	
Equipment and Installation	$521
Operating Cost ($K/mo.)	
Fuel for Amine Still	$14.80
($4.50/MMBTU, 4.5 MMBTU/hr):**	
Fuel for Flare ($4.50/MMBTU):**	$5.20
Chemical Usage (actual):	$0.30
Water Usage (based on actual):	$2.68
Electricity:	$0.60
Maintenance, etc:	$0.50
Total:	$24.08
Revenues ($K/mo.)	
SulfaGuardSavings:	$46.00
Total:	$46.00
NET SAVINGS ($K/mo.):	$22
Months to Payback Investment:	23.8
Before Tax irr(%):	47%
After Tax irr(%):	28%

**NOTE: Fuel prices were approximately $2.50/MMBTU during the evaluation of this project. $4.50/MMBTU is assumed in these economics to represent an “average” fuel price over the first 12 months of operation of this unit. Also, note that the heat rate for the amine still is conservatively assumed as the equipment’s max-firing rate.

As illustrated by the IRR rates presented in Table 4 above, the project is an economic success. In addition, the economics will improve by addressing the elevated lean amine temperatures, and therefore reducing Sulfaguard usage and operating costs even more, prior to the summer of 2001. Overall the project is an operational and economic success.

CONCLUSION

Unique treating applications such as acid gas enrichment present several distinct engineering challenges. Careful examination of alternatives can achieve the best design with acceptable economics. Extreme care and knowledge of selective technology must be utilized to provide a unit design that will provide the both operational and economic balance. In particular, application of knowledge and experience with regard to designing highly selective treating units is critical. This project is considered a success both operationally and economically.

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