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Reduced Sulfur Emissions from Existing Claus Sulfur Recovery Unit-Case Study

Hasan Asharif[1], Aboujila Ajwade[2*]
[1]Chamical Engineering Department, University of Zawia, Zawia, Libya
[2]Mellitah Oil and Gas Company, Onshore Sulphur Plant, Mellitah, Libya
*Corresponding Author: abojila.jwade@yahoo.com

Abstract

Hydrogen sulfide is a byproduct of processing natural gas, and considered as one of the most noxious industrial gases and highly toxic gas.H_2S removal from natural gas is particularly required for reasons of environment, safety, and corrosion problems. The most common conversion method used is the Claus process. This method has been developed for the removal of hydrogen sulfide from gaseous emissions. Mellitah plant, which is the focus of this study from the sulfur emission point view. The bottleneck of the Mellitah-complex, is the acid gas stream, which is treated carefully at sulphur plant in order to convert all the associated H_2S gas to liquid sulphur. Since emissions from raw gas are controlled at sulfur plant, Claus unit is the source of all H_2S and SO_2 emissions. In this paper, the effect of various operating parameters on the emissions of H_2S/SO_2 from the existing Claus unit was studied. In order to achieve this objective, the existing Claus unit was simulated by using process simulator Aspen-HYSYS® V8.8. Acid Gas was used as fluid package to determine various operating parameters such as air/feed ratio, burner temperature and overall sulfur recovery, have the greatest impact on the emissions of H_2S/SO_2 ratio in tail gas leaving Claus unit. A series of simulations were carried out by increasing air flow rate/acid gas feed ratio. The emissions of H_2S/SO_2 controller set at 2 which is optimum value. A tail gas ratio of 2 is used for the remainder of the simulations. Also the overall efficiency of the unit is related to the ratio of H_2S/SO_2 in tail gas, is related to the control of air flow rate/feed ratio and the ratio between the two variables. Higher recovery efficiency means less sulfur compounds are emitted in tail gas.

Keywords: Claus unit; acid gas feed; burner temperature; sulfur recovery.

1. Introduction

Sulfur recovery unit (SRU) is an important unit in natural gas processing units. It removes H_2S from acid gas feed ratio before they can be released into the environment.

In general, Claus process is a process in which 1/3 of H_2S in the acid gas feed ratio with air is burned to SO_2 which is then reacted with the remaining H_2S to produce sulfur.

Mellitah plant was originally designed to treat raw gas and condensate streams produced from offshore gas field where it is treated in several process units in the gas plant and the sulfur plant, to meet the international sales and emission standards.

The sulphur recovery unit at "Mellitah Plant" which is the focus of this study from the sulphur emission point view. The function of the sulphur plant is to treat the Amine Acid Gas (AAG) coming from gas sweetening units and convert the H_2S into elemental sulphur. The resulting tail gases are thermally oxidized in the incinerator unit.

In this paper. At first. The simulation of existing sulfur recovery unit was done by using pro-

cess simulator Aspen-HYSYS®. The actual total feed flow rate, feed composion and actual operation conditions of sulfur plant was utilized in the simulation of sulfur recovery unit. Then, the obtained results were compared to plant actual data. After matching plant data many operating parameters was studied such as burner temperature, sulphur recovery have the greatest impact on H_2S/SO_2ratio in tail gas.
In this case also Claus unit operating parameter settings which yield the highest overall sulphur recoveries are determined by performing a series of simulation based on increasing air flow rate/acid gas feed ratio.

2. Methodology

The methodology consist of a review on increase air flow rate/feed ratio (in tail gas ratio of 2) effect on the reaction furnace temperature and sulphur recover of Claus unit using process simulator Aspen-HYSYS®.
Figure (2.1) shows the flow diagram of the sulfur recovery unit that could be used with air and acid gas feed are preheated at 250 ° C before interring into thermal reactor to accomplish the complete oxidation to burn approximately one-third of the total H_2S in the feed acid gas to SO_2. The main reactions take place during the combustion of acid gas occurs with air according to main Claus reaction.

$$H_2S + 1.5\ O_2 \rightarrow SO_2 + H_2O + \text{heat} \ldots\ldots \text{ main reaction in thermal reactor.}$$

$$H_2S + 0.5O_2 \rightarrow H_2O + 0.5\ S_2$$

Also side reactions involving HC and CO_2 in the acid gas feed ratio can results in the formation of carbon sulphide COS and carbon disulphide CS_2 in the reaction furnace.

$$H_2S + CO_2 \rightarrow COS + H_2S$$

$$2H_2S + CO_2 \rightarrow CS_2 + 2H_2O$$

The effluent gas from the main burner (reaction furnace) passes through the first pass waste heat boiler to recover heat and produce high pressure steam. The second pass waste heat boiler is where the redistribution of S_2 to S_8 is the primary reaction. Process gases leaving the waste heat boiler, is further cooled down in the first condenser to condense and recover the liquid sulfur.
The process gases leaving first condenser is preheater in the first reheater and sent to catalytic converter where Claus reaction occurs at lower temperatures. This leds to higher equilibrium conversion because Claus reaction is exothermic.

$$2\ H_2S + SO_2 \rightarrow 2\ H_2O + 3/8\ S_8$$

Typically, COS and CS_2 are also hydrolyzed in the first catalytic converter according to the following exothermic reactions.

$$COS + H_2O \rightarrow H_2S + CO_2$$

$$CS_2 + 2H_2O \rightarrow 2H_2S + CO_2$$

Usually, the catalyst based on alumina γ-$Al_2O_3$is use in this process.
Sulphate is formed on γ-Al_2O_3 catalyst when a mixture of H_2S and SO_2, separately, passes on the catalyst at operation conditions. Sulfur is recovered after each catalyst stage by cooling converter effluent gases in sulfur condensers. Finally, effluent gas from the process is incinerated and vented to the atmosphere.

Table 2.1: Comparison Between the Actual Plant Data and the Obtained Result from the Simulation.

Components	Acid gas composition actual data		Combustion Air actual data		Process gas leaving thermal reactor (WHB). Mole%		Tail gas from SRU. Mole%	
	Kgmole/h	Mole%	K mole /h	Mole%	Actual data	Hysys	Actual data	Hysys
H2S	246.5	28.65			7.967	7.021	0.625	0.615
SO2					4.67	4.97	0.304	0.348
H2					0.78	0.77	0.0078	0.008
H2O (vap)	33.69	7.79	14.8	1.87	11.39	13.13	21.21	21.21
N2			425.68	77.98	29.25	29.66	29.66	31.29
CO2	550.4	66.56			40.88	40.84	44.71	43.96
COS					0.35	0.333	Trace	Trace
CS2					0.35	0.333	Trace	Trace
O2			113.12	20.47				
HC	Trace	Trace	Trace	Trace	Trace	Trace	Trace	Trace
TATAL	871.4	100	552.84	100	100	100		
T ° C	45		28					
P (Bar)	1.6		1					
Burner Temperature ° C					989	1005		
Recovery%							97.41	97.8
H_2S/SO_2							2.37	1.76

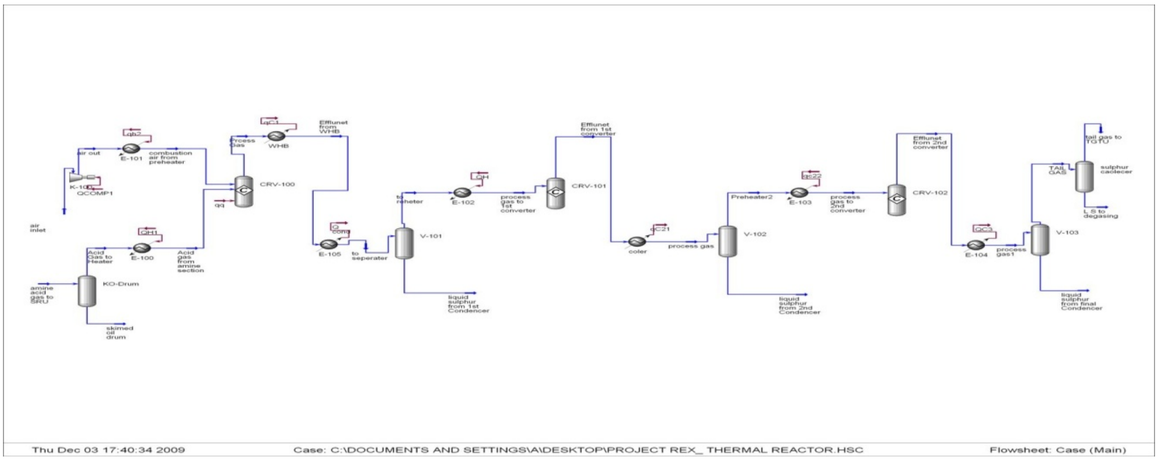

Figure 2.1: Flow Sheet of Simulated Claus Process, Adapter from HYSYS® Simulation

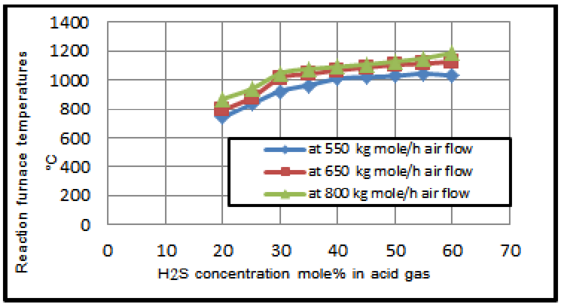

Figure 3.1: Concentration of H_2S in acid gas feed ratio VS. The reaction furnace temperature. At different air flow rate.

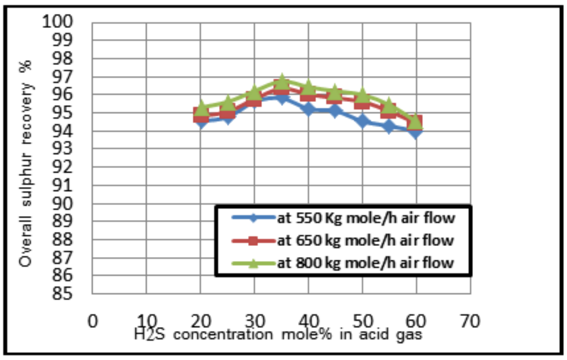

Figure 3.2: Concentration of H_2S in acid gas feed VS. Overall sulphur recovery at different air flow rates.

3. Results and discussion

The sulphur recovery unit was analyzed by a process simulation program "HYSYS® Software", using a simulator is a good method as it is valuable tool to aid in the analysis either by evaluating and predicting the optimum operation conditions and their sensitivity parameters on H_2S/SO_2 ratio in tail gas leaving Claus unit.
Table (2.1) Simulation results were the priority of the work to get best simulation result and to provide a basis for the accuracy of the program's predictions. As seen in the figure (3.1) by increasing air flow rate/feed ratio into simulated sulfur recovery unit. Temperature of the main burner have much more increasing. It was noticed that in 35 mol% of H_2S concentration in feed ratio. temperature of main burner is 932 °C at (550 kg

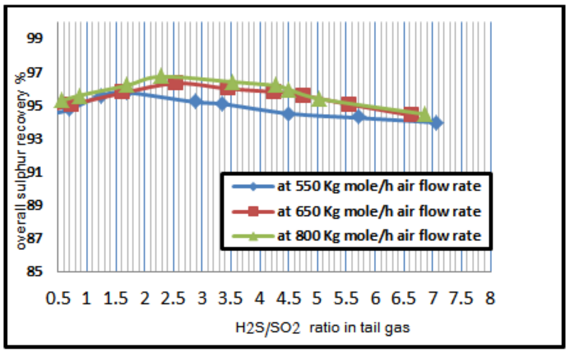

Figure 3.3: H_2S/SO_2 Ratio in tail gas VS. The Overall Sulphur Recovery.

mole/h air flow), 1026 °C at (650 kg mole/h air flow) and 1047 °C at (800 kg mole/h air flow) respectively.
Also the effect of increasing air flow rate/feed ratio on sulfur recovery rate, while changing the temperature of main burner has been studied. Optimal temperature of reaction furnace is a temperature in which more sulphur recovery is obtained. So, in this study the changes of the rate of sulphur recovery were studied with respect to increases air flow rate /feed ratio. As shown on figure (3.2). Sulfur recovery efficiency was increased relatively and then decreased with change the ratio between two variables (air/ feed ratio). It was noticed that in 35mol% of H_2S concentration in feed ratio and 800 kg mole/h air flow rate yields the highest overall sulphur recovery 96.75.
H_2S/SO_2ratio in tail gas leaving unit was studied in Figure (3.3) results shows the optimum of H_2S/SO_2 ratio equal 2.22 for highest overall sulphur recovery 96.75.

4. Conclusion

The first role of the reaction furnace in the simulation Claus unit is to partially oxidize one third of H_2S in the acid gas feed ratio to $SO_2$and it will also produce a significant amount of the total produced sulfur. This will ensure that these compounds do not break through the downstream process unit. For a Claus unit the optimum value of the H_2S/SO_2 ratio is equal to 2.
A change in the H_2S/SO_2 rates will have the following effects:
Increasing the value above the optimum range results in excess H_2S content in the tail gas and the Claus unit efficiency will decrease. However, reducing the value below the optimum range, results in SO_2 content in the tail gas will increase and small decrease in plant efficiency.
Due to the difficulty for the process to meet environmental emission requirements, the tail gas treatment unit (TGTU) have to be employed to reduce the percentage of the sulphur compounds before disposals to atmosphere.

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