Process and Plant Design for 99% Sulfur Recovery from Sour Gas

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1. Introduction

Oil and gas industries employ sulfur recovery processes for limiting SO_x emissions. Such emissions have many dangerous impacts on the troposphere environment. In addition, world demand for sulfuric acid products is increasing due to continuous increases in world population and to support economical growth all over the world. From financial and environmental perspectives, investing in efficient sulfur recovery processes is a very promising project.

The objective of this work is designing a Modified Claus plant accompanied with a Tail Gas Treatment (TGT) process capable of producing 800 tonnes/day of sulfur from sour gas streams. Moreover, the process has to be efficient in recovering at least 99% of sulfur from sour gas. This report shows a Front End Engineering Design for the proposed sulfur recovery process. The major objective in this work is to provide an estimate for the cost of the project and assessing this estimate from an economical point of view. The expected error in this study is ± 30%.

2. Key Features

The modified Claus process is used to achieve a recovery of 97%. To achieve the desired 99% sulfur recovery, a Tail Gas Unit (TAIL GAS UNIT) must be added. In this section, the modified Claus process is analyzed from chemical and processing perspectives. Fig. 1 shows a schematic of the modified Claus process [1].

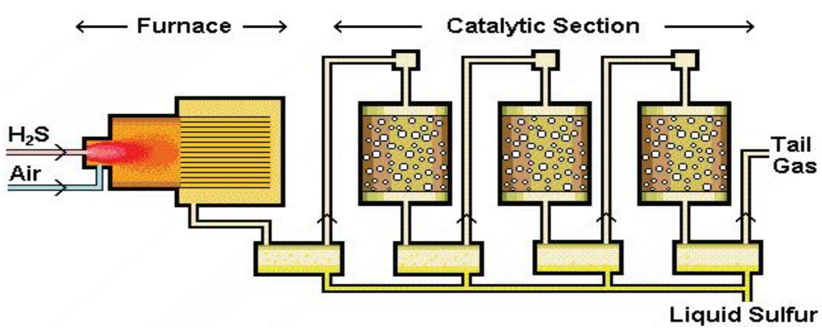

Fig. 1. Schematic of modified Claus process.

The modified Claus process consists of two basic reactors [1]. The first one is the reaction furnace. The unit is responsible for achieving 67% conversion to sulfur. The reaction furnace receives a mixture of acid gas and air at a pressure close to atmospheric. Many reactions happen within the furnace. They are classified as either oxidation reactions or anoxic reactions.

The reaction furnace produces the desired sulfur product in the form of S_2 gas. Effluents of the reactor leave at a temperature of 1200^o C. This temperature will have a direct effect on choosing material of construction of the furnace. The furnace is followed by a highly efficient heat exchanger where reactor effluents exchange heat with high pressure (300-600 psig) cooling water. Reactor effluents temperature exits at 370^o C. High pressure steam is generated in this process. This heat exchanger is called "Waste Heat Boiler". The condenser is used to condense sulfur in the form of S_8 which is collected in a sulfur holding vessel. Un-reacted gasses (H_2S SO_2, H_2O and CO_2, etc.) are reheated and then enter a series of gas phase packed bed reactors with alumina catalyst. Each reactor is followed by a condenser unit and a reheat unit. Catalytic converters are operated in isothermal conditions at the temperatures shown in Fig. 1. After the final reactor, sulfur is condensed and un-reacted gasses are separated and sent for further processing in the Tail Gas Unit. All sulfur condensers are cooled using cooling utility to produce low or medium pressure steam. All reheat units utilize the steam produced in the waste heat boiler. Liquid sulfur is degassed in a sulfur degassing pit with bubbling air to lower H_2S content to 10 ppm by weight.

A Super Claus Tail Gas Unit receives the tail gas coming from the Claus plant at an H_2S to SO_2 ratio of 2:1. The feed enters the first reactor and mixes with air before entering a selective oxidation reactor. In this reactor, the selective oxidation reaction takes place with an iron oxide catalyst on a silica base. The overall sulfur recovery reached by the Super Claus Process is 99.3%.

The HYSYS process simulator is used for case studies of the proposed design. Equipment costing and economic analysis is done based on the most promising design. Total Capital Investment (TCI) is estimated based on delivered purchased equipment cost using the factored estimate method. Delivering the purchased equipment composes 15% of the cost of purchasing the equipments.

The estimated Total Capital Investment is based on January 2002 prices. To estimate current prices, Total Capital Investment in January 2002 needs to be corrected using the Marshall & Swift price index of process industries for 2006 which is 1216. Thus, the Total Capital Investment based on 2006 prices is 18.75 million dollars. Legal expenses are set to zero since the government owns the proposed plant. Project Management is added as 5% of the Total Capital Investment. The Total Production Cost of the project is $3.46 million. Catalysts costs are added as a separate operating cost.

Economical analysis is conducted based on cash flow diagrams. Present worth of costs for the project is $61.25 million while the annual production cost is $25.35/tonne. Monte Carlo Simulation is used with ±30% as the incorporated uncertainty. Variables tested are the Total Capital Investment, Total Production Cost, and catalysts costs. The confidence interval calculated through the simulation on annualized production cost has a lower bound of $20.92 / tonne, an upper bound of $31.16 / tonne and an average of $25.8 / tonne.

3. Conclusions

This work has shown a feasibility study of a Sulfur Recovery plant project capable of producing 800 tonnes / day of sulfur. The following conclusions are derived:

1) A Modified Claus plant accompanied with a Tail Gas Treatment process capable of producing 800 tonnes / day of sulfur is designed.
2) The chosen process is a Modified Claus accompanied with either Super Claus Tail Gas Unit or Sub-dew point Tail Gas Unit.
3) HYSYS simulator is used to simulate the process.
4) Detailed design involved designing heat exchangers, reactors, pumps, compressors, and storage tanks.
5) All equipments costs are estimated based Jan 2002 prices
6) The Total Capital Investment for the project is $18.75 million while the Total Production Cost of the project is $3.46 million. Catalysts costs are added as a separate operating cost.
7) Economical analysis is conducted based on cash flow diagrams. Present worth of costs for the project is $61.25 million while the annual production cost is $25.35/tonne.
8) Monte Carlo Simulation is used with ±30% as the incorporated uncertainty. Variables tested were: the Total Capital Investment, Total Production Cost, and catalysts costs. Confidence interval calculated through the simulation on annualized production cost has a lower bound of $20.92 / tonne, an upper bound of $31.16 / tonne and an average of $25.8 / tonne.
9) The reader is referred to the chemical engineering graduation project report for the 2006 class at The Petroleum Institute in Abu Dhabi [2].

4. References and Bibliography

1. Clark, P., 2005, SOGAT Proceedings-Workshop, Abu Dhabi, UAE, November 29.
2. Chemical Engineering Graduation Project Report, Class of 2006, The Petroleum Institute, Abu Dhabi, UAE.

Author Biographies

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