The Optimum Sulfur Recovery Process From North Gas Company Sour Acid Gas: A Case Study and Simulation

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Abstract—**The North Gas Company in Kirkuk, Iraq produces a sour gas stream that is loaded with considerable amounts of H_2S and CO_2, at concentrations of 2.95% and 2.54%, respectively. A previous study successfully treated this sour gas stream and produced a sweet gas stream by adopting a natural gas sweetening process using ProMax process simulation software. However, this process also produced an acid gas stream that was loaded with a considerable amount of H_2S. The acid gas stream is processed to a (sulfur recovery units) sulfur recovery unit to protect the environment. The Claus process is the major technology used to produce elemental sulfur from H_2S and SO_2 gases. This study examines this process to treat the acid gas stream and recover the elemental sulfur, using ProMax simulation software developed by Bryan Research and Engineering, LLC. Moreover, the simulation model was successful in reducing the amount of H_2S from 872.5 kg/h to 60.5 kg/h by adopting two Claus bed reactors to increase the process efficiency. Furthermore, process optimization was also adopted to find out the optimum Claus reactor bed operating temperature at 215°C.**

Index Terms—**Air pollution, Claus process, Environment protection, Gas sweetening, Gas treatment, Natural gas, Oil and gas industry, Sulfur recovery.**

I. Introduction

The majority of the world's energy demand is provided by fossil fuels (Taghizadeh and Bahadori, 2018). Air pollution may have several effects on the natural environment (Afifa, et al., 2024). Furthermore, many researchers have mentioned that air pollution may cause several human lung diseases and affect public health (Hashemi, et al., 2019). Indeed, oil and gas exploration and production may be considered one of the most obvious air pollution sources that contribute to many environmental and economic effects (Seyed, Bastani and Eslampanah, 2023). Natural gas has several advantages over other types of fossil fuels, for example, cleanliness, high thermal value, and environmentally friendly fuel, and the demand for this energy source will also increase in the future (Alzamzam and Shalhi, 2019). About 25% of natural gas is produced from sources and wells that require a sweetening process to participate in production processes; therefore, impurities should be eliminated, such as H_2S and CO_2 (Hashemi, et al., 2019). Acid gas containing H_2S and CO_2 may naturally exist in natural gas (Saeid, Poe and Mak, 2019). The acid gases, such as H_2S and CO_2 emissions from oil and gas facilities, are limited by global environmental legislations (Abdulrahman and Zangana, 2020). Indeed, acid gas stream flaring causes several environmental problems. H_2S is a very toxic and dangerous gas, and it can be converted into SO_2 by combustion, causing acidic rain and significant environmental issues (Seyed, Bastani and Eslampanah, 2023). Moreover, the massive emission of SO_2 has caused serious harm to the atmosphere, soil, and human beings (Zheng, et al., 2023). Engineers can convert these toxic gases, such as hydrogen sulfide (H_2S), to useful products, for example, the element sulfurs (Saeid, Poe and Mak, 2019). The produced sulfur will also increase the financial income of the plant. Element sulfur is an important raw material for many industries, for example, medicines and fertilizers. The sulfur element can be produced through the Claus process in sulfur recovery units (SRUs) (Singh and Raj, 2025). Indeed, the Claus process may be considered the most popular and commercial sulfur recovery process in the world. The H_2S can be converted in the Claus unit to the element sulfur (Ibrahim, Rahman and Raj, 2022). The main objective of the Claus process is to convert the hydrogen sulfide gas to the sulfur element

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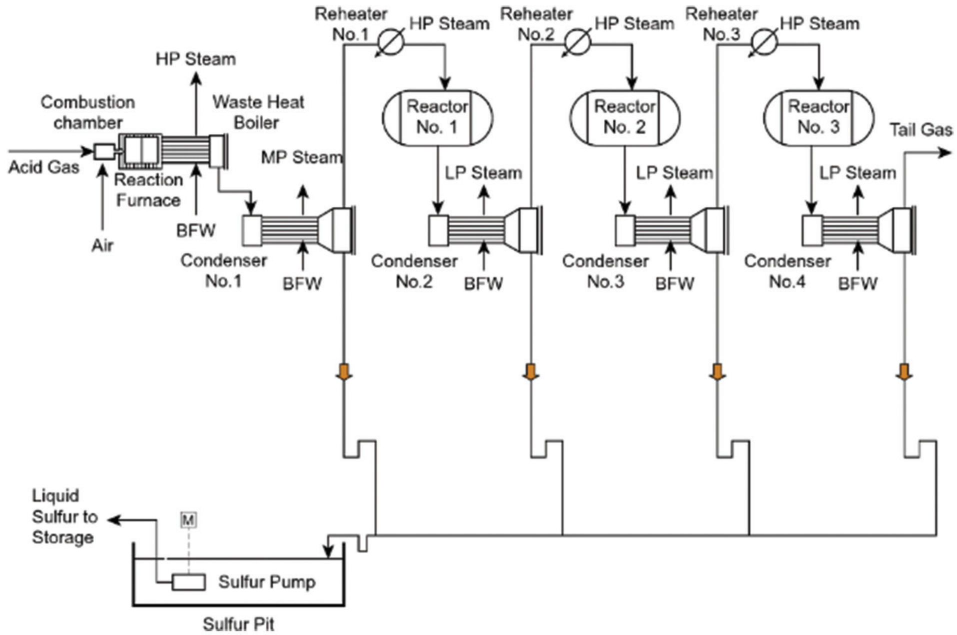

Fig. 1. Typical process flow schematic of three stages Claus sulfur recovery unit (Seyed Heydar, Bastani and Hamidreza, 2023).

through chemical reactions between hydrogen sulfide and sulfur dioxide, yielding elemental sulfur and water vapor (Blázquez, et al., 2019):

$$2H_2S(g) + SO_2(g) \rightarrow (3/n)\ Sn(g) + 2H_2O(g) \quad (1)$$

The sulfur recovery process may contain a multistage Claus sulfur-recovery process. Fig. 1 shows a typical sulfur recovery process.A sufficient amount of H_2S in the feed gas is oxidized to Sulfur dioxide (SO_2) in the process furnace. More than 97% of the sulfur is recovered by two or three stages (Abdulrahman and Zangana, 2020). The reactions involved in the process are shown below:

$$H_2S + 1/2O_2 \rightarrow S + H_2O \quad (2)$$

$$H_2S + 2/3O_2 \rightarrow SO_2 + H_2O \quad (3)$$

$$2H_2S + SO_2 \rightarrow 3S + 2H_2O \quad (4)$$

H_2S is partially oxidized with air and converted into SO_2 in the Claus furnace. The products from this reaction are sulfur dioxide, water, and unreacted hydrogen sulfide. This tail gas normally requires further cleanup to obtain higher recovery (Alzamzam and Shalhi, 2019). The catalytic Claus reactor is achieved through two or three stages. First, the reheater step that raises the temperature of the gas from the sulfur condenser to avoid condensation of sulfur vapor when the sulfur forming at the clause reactor (Taghizadeh and Bahadori, 2018). Second, the hydrogen sulfide reacts with sulfur dioxide over an activated alumina catalyst. Some SRUs use more than one Claus reactor, for example, two or three to increase the process efficiency.

The Claus reactions (Selim, Gupta and Al Shoaibi, 2013):

$$2H_2S + SO_2 \rightarrow 3/6\ S_6 + 2H_2O \quad (5)$$

TABLE I
NGC Amine Sweetening Acid Gases Stream Composition

Component	Mole%
H_2S	64
H_2O	1
CO_2	30
CH_4	3
C_2H_6	2

$$2H_2S + SO_2 \rightarrow 3/8\ S_8 + 2H_2O \quad (6)$$

Third, the sulfur condenser is used to remove liquid sulfur, the product of the reaction. The sulfur recovery process efficiency depends on feed composition, age of the catalyst, and the number of reactor stages (Saeid, Poe and Mak, 2019).

II. Case study of Kirkuk North Gas Company (NGC) and Simulation

The NGC processes the majority of the associated gas in Iraq's northern oil fields, specifically within the Kirkuk field. The gas stream processed at the NGC plant is classified as sour gas, containing significant amounts of hydrogen sulfide (H_2S) and carbon dioxide (CO_2) at concentrations of 2.95% and 2.54%, respectively. At present, a diethanolamine system is employed to reduce these sour component concentrations to below 5 parts per million (ppm) for H_2S and 2% for CO_2. The NGC sour gas stream has been treated in a previous study (Abdulrahman and Zangana, 2020). However, the acid gas stream emitted from the amine sweetening process has not been treated and was loaded with huge quantities of hydrogen sulfide. Therefore, this study aims to process the acid gas stream using an appropriate SRU by utilizing ProMax simulation

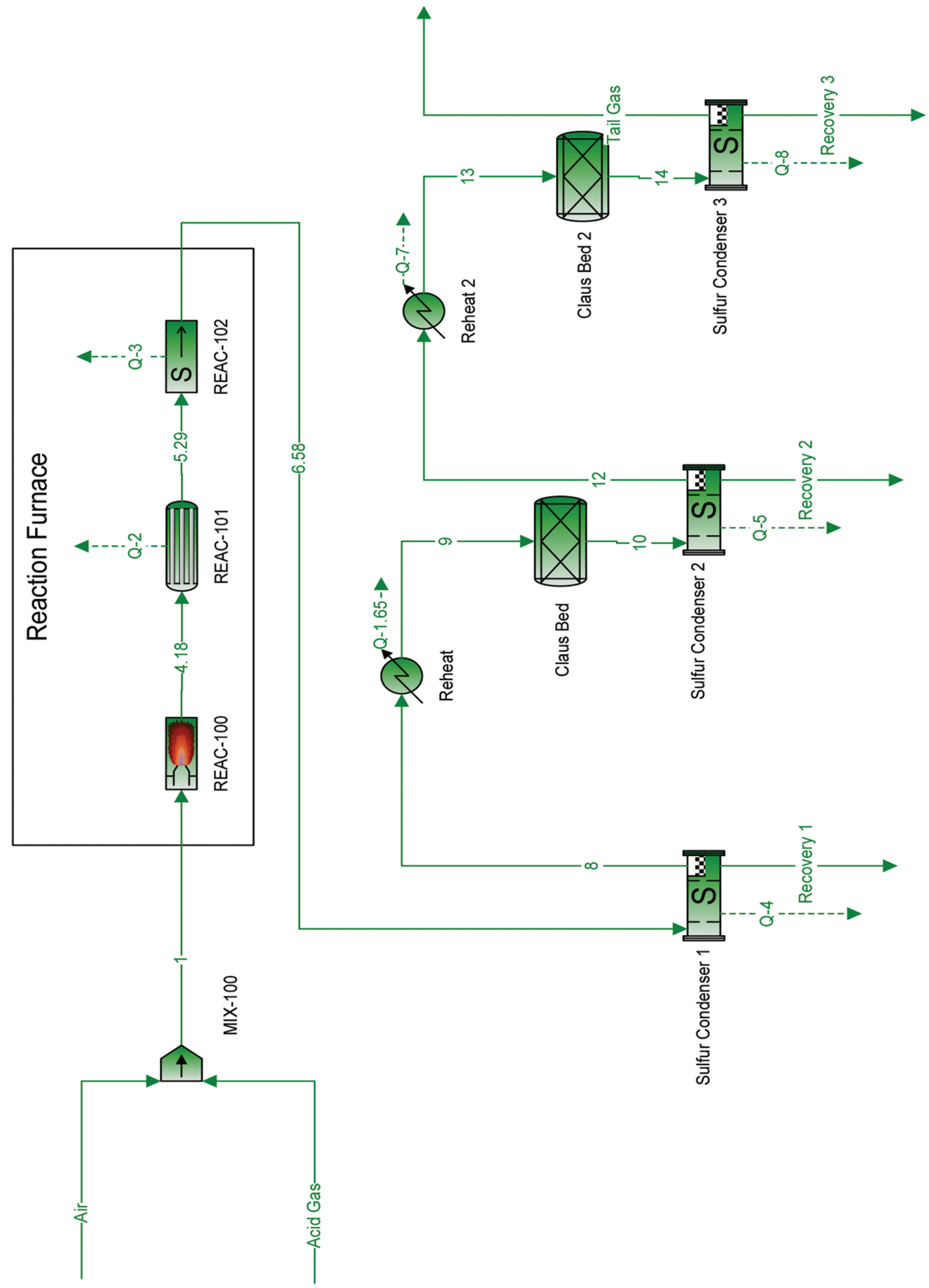

Fig. 2. North Gas Company sulfur recovery process by ProMax simulation.

software version 6.0. Table I presents the composition of the NGC acid gas stream produced from the gas sweetening process, while Table II outlines the operational conditions of the acid gas stream.

The sulfur recovery unit has been simulated by using ProMax simulation software version 6.0. Fig. 2 shows the NGC sulfur recovery process:

TABLE II

NGC Amine Sweetening Acid Gases Stream Operation Conditions

North Gas Company Kirkuk Gas sweetening produced acid gases stream	
Temperature	70°C
Pressure	78.675 kPa (g)
Std vapor volumetric flow	947.617 m^3/h

III. Results and Discussion

The Claus process may be considered the most commercial and successful sulfur recovery method. Indeed, in this study, SRU adopted two Claus reactors to increase the sulfur recovery amounts and process efficiency as well. Moreover, the optimization study has examined the effects of both Claus reactors' temperatures on the produced sulfur in (Kg/h) for both reactors.

Fig. 3 shows the relationship between the first Claus temperature and the amount of the produced Sulfur from

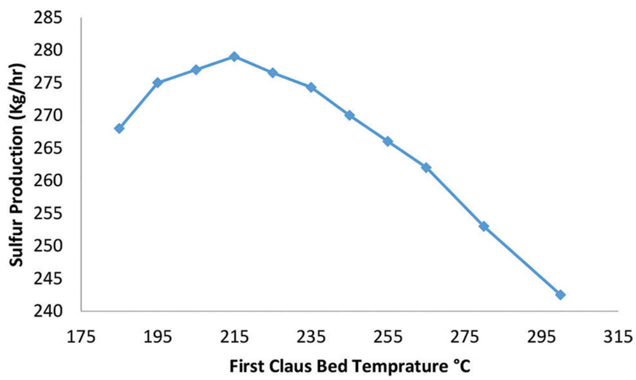

Fig. 3. Relationship between the first Claus bed temperature and Sulfur production.

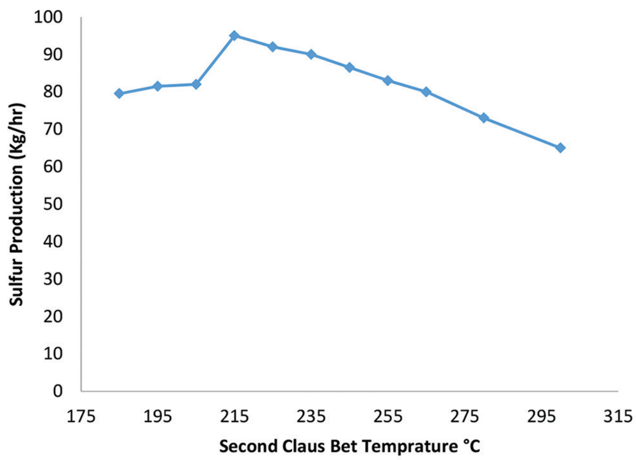

Fig. 4. Relationship between the second Claus bed temperature and Sulfur production.

the first Claus reactor. It seems from the mentioned figure that increasing the reactor temperature to 215°C leads to an increased amount of the produced sulfur. However, increasing the reactor temperature above that will decrease the amount of sulfur. Thus, it may be argued that maintaining the first Claus bed reactor at 215°C may be considered the optimum reactor temperature that produces optimum sulfur 279 Kg/h.

Fig. 4 shows the relationship between the second Claus temperature and the amount of the produced Sulfur from the first Claus reactor. It seems from the mentioned figure that the optimum second Claus bed reactor temperature is 215°C. Furthermore, too low a temperature may affect the bed reactions and cause sulfur condensation on the reactor and poison the catalyst.

IV. Conclusion

Acid gas stream flaring causes several environmental problems and negatively impacts public air quality. Engineers can convert these toxic gases, such as hydrogen sulfide, into useful products, for example, the sulfur element. The produced sulfur will also enhance the financial income of gas plants. Elemental sulfur is a crucial raw material for many industries, including pharmaceuticals and fertilizers. Indeed, the Claus process is widely regarded as the most popular sulfur recovery method in the world. This study utilized ProMax® Version 6.0 to accurately model and optimize the SRU system employed by NGC. The Claus process is the primary technology for producing elemental sulfur from H_2S and SO_2 gases. The research examined this process to treat the acid gas stream and recover elemental sulfur. Furthermore, the simulation model successfully reduced the amount of H_2S from 872.5 kg/h to 60.5 kg/h by implementing two Claus bed reactors, thereby increasing the process efficiency and productivity of raw sulfur. The process simulation also analyzed the temperatures within the Claus reactors through process optimization. It can be argued that operating both Claus bed reactors at 215°C may yield optimal sulfur production while maintaining process efficiency. However, further studies are recommended to optimize other process parameters and operational conditions.

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