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Best configuration of a low H_2S content sulfur recovery unit (SRU)

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ABSTRACT

The modified Claus process is the most common method for the conversion to sulphur of hydrogen sulphide contained in sour oil and natural gas. In low H_2S feed concentration, which are usually in gas plants, flame stability has an important rule in overall plant recovery and thus, special consideration for thermal stage should be done to meet requested efficiency. The purpose of this work was to study different configurations in low H_2S feed content by using two parameters, feed and air preheating and also adjusting a bypass around burner (thermal stage) to maximize sulphur recovery. Using PROMAX, a suitable SRU process simulation, shows us that regarding plant chemical and mechanical constrains, we can enhance sulphur recovery by adjusting these two items.

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KEYWORDS

SRU;
Sulphur recovery;
Process configuration;
H_2S.

INTRODUCTION

Many of the catalysts used for the treatment of hydrocarbons in the petrochemical industry are highly susceptible to poisoning by sulphur compounds. It is thus essential to separate hydrogen sulphide from feedstocks such as sour natural gases or crude oil[1]. The Claus process is employed to convert waste H_2S of many industrial processes to elemental sulphur. This process was developed by Carl Friedrich in 1883[2]. Several modifications were developed on the process to increase the overall conversion of sulphur and produce a tail gas which satisfies the environmental regulations. All requirements to be met by Claus plants are dictated by the operating conditions of modern, flexible refineries and natural gas plants and increasingly stringent emission control regulations[3]. Therefore, Sulfur recovery units (SRUs) do not directly increase the net present value of the refinery because of low sulfur market price; nevertheless, they are necessary to match all stringent environmental regulations[4].

The modified Claus process consists of a high temperature front-end reaction furnace, followed by catalytic reaction stages. This process continues to be the most widely used process for the conversion of H_2S to sulfur[3]. Generally, Byproduct gases originating from physical and chemical gas and oil treatment units in refineries, natural gas processing and gasification plants are also routed to Claus unit[3].

The reactions occurring in the furnace are numerous. Several authors have attempted to delineate the important ones[5-7]. The overall reaction characterizing the process is as follows[4]:

$$2H_2S + O_2 \Rightarrow S_2 + 2H_2O \quad (1)$$

A key reaction that occurs in front-end reaction furnace is a two step sequence, 1/3 of the acid gas is oxidized to SO_2 using air:

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

This combustion generate a large amount of heat. Further, the combustion products undergo Claus reaction between H_2S and SO_2.

$$2H_2S + SO_2 \Rightarrow 3/2\, S_2 + 2H_2O \quad (3)$$

Reaction 3 is a reversible exothermic reaction. Thus, processing under adiabatic condition greatly increases temperature, which lowers equilibrium conversion to about 75%. Effluent gas from the reaction furnace passes through a waste heat boiler to recover heat and produce high-pressure steam. Likewise, a large amount of elemental sulphur (S_2) are produced during of thermal decomposition H_2S. In fact, Elemental sulfur produced in the furnace is about 50-60% of the total sulfur production of the plant.

Some other reactions occur in the furnace are as follow[8,9]:

$$H_2S + 1/2\, O_2 \Rightarrow S + H_2O \quad (4)$$

$$2H_2S + SO_2 \Rightarrow 3/2\, S_2 + 2H_2O \quad (5)$$

$$3H_2S + 3/2\, O_2 \Rightarrow 3/2\, S_2 + 3H_2O \quad (6)$$

In the second step or catalytic reaction stage, remain unreacted H_2S are combined with SO_2, over an alumina catalyst to form elemental sulfur in fixed bed reactors by the following reaction[1,8]:

$$2H_2S_{(g)} + SO_{2(g)} \Rightarrow 3/n\, S_{n(g)} + 2H_2O_{(g)} \quad (7)$$

High conversions for this exothermic, equilibrium-limited reaction call for low temperatures, the use of which, however, leads to low reaction rates, so that a catalyst must be employed. Even so, high sulphur yields still necessitate a multistage process with interstage cooling and sulphur condensation[1].

Although the modified Claus process has remained relatively unaltered since its introduction, further modifications to the basic process have been introduced in order to increase the plant capacity or efficiency[10].

POSSIBLE CONFIGURATIONS

Processing a lean acid gas requires some special consideration be given to the operation of the burner. A Claus furnace feed containing a relatively low concentration (less than 50 percent) of H_2S may be incapable of producing a stable flame. Also, incomplete combustion of hydrocarbons in the feed can lead to deterioration of the catalyst in the reactors due to soot or carbon deposition[9].

There are several configuration available to treat lean streams, including a four-bed Claus with acid gas preheat and fuel gas burner, the all-catalytic Selectox process, acid gas bypass around the furnace, and oxygen enrichment of the combustion air feed to the Claus plant.

Having a stable flame in the burner needs using acid gas preheated to about 500 °F and fuel gas burned separately using a special burner.

Alternatively, bypassing a portion of the feed around the furnace can solve the problem of insufficient combustibles in a lean acid gas. The bypassed gas is mixed with the burner effluent prior to the waste heat boiler. The amount of oxygen fed to the burner is the same as the amount that would be required to burn the entire stream, resulting in an increased flame temperature. Ideally, a flame temperature in the range of 1850-2200 °F should be maintained.

One consequence of bypassing gas around the burner is that any hydrocarbons in the bypassed gas are not combusted, which may lead to problems in the downstream catalyst beds[9,10].

OPTIMUM CONDITION OF STRAITE THROUGH ARRANGMENT WITH PREHEAT

In order to obtain feed heating effect on the recovery of the plant, first of all a sample SRU plant for gas refinery is considered. Schematic diagram of such a modified two stage SRU plant is shown in figure 1. In design case, feeds and combustion air are fed to plant without any preheating. Increasing temperature of feed and air simultaneously has been studied by simulating the process with PROMAX simulator and recoveries obtained are showed in figures 2 and 3.

In more close range, it shows heating effect on increasing sulphur recovery. But it should be notice that there are some important constraints which limits feed preheating. One of them that should be considered is maximum allowable burner outlet temperature. It is directly affected by the feed temperature. Other limitations dictated by the constructors. Variation of Burner outlet temperature is shown in figure 4.

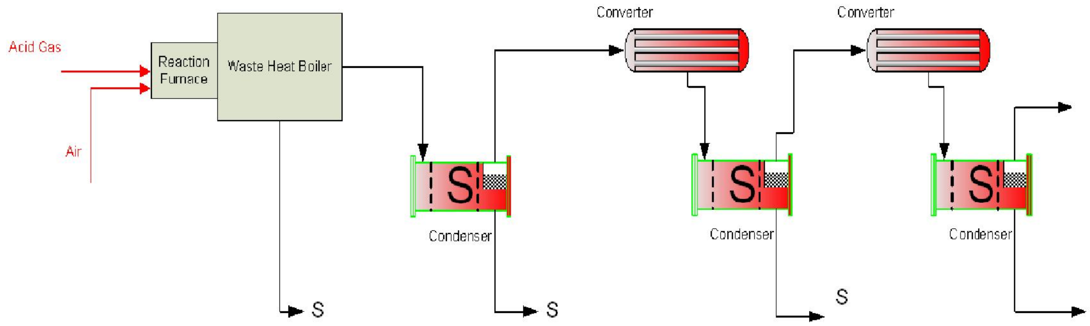

Figure 1 : Schematic modified two stages claus process

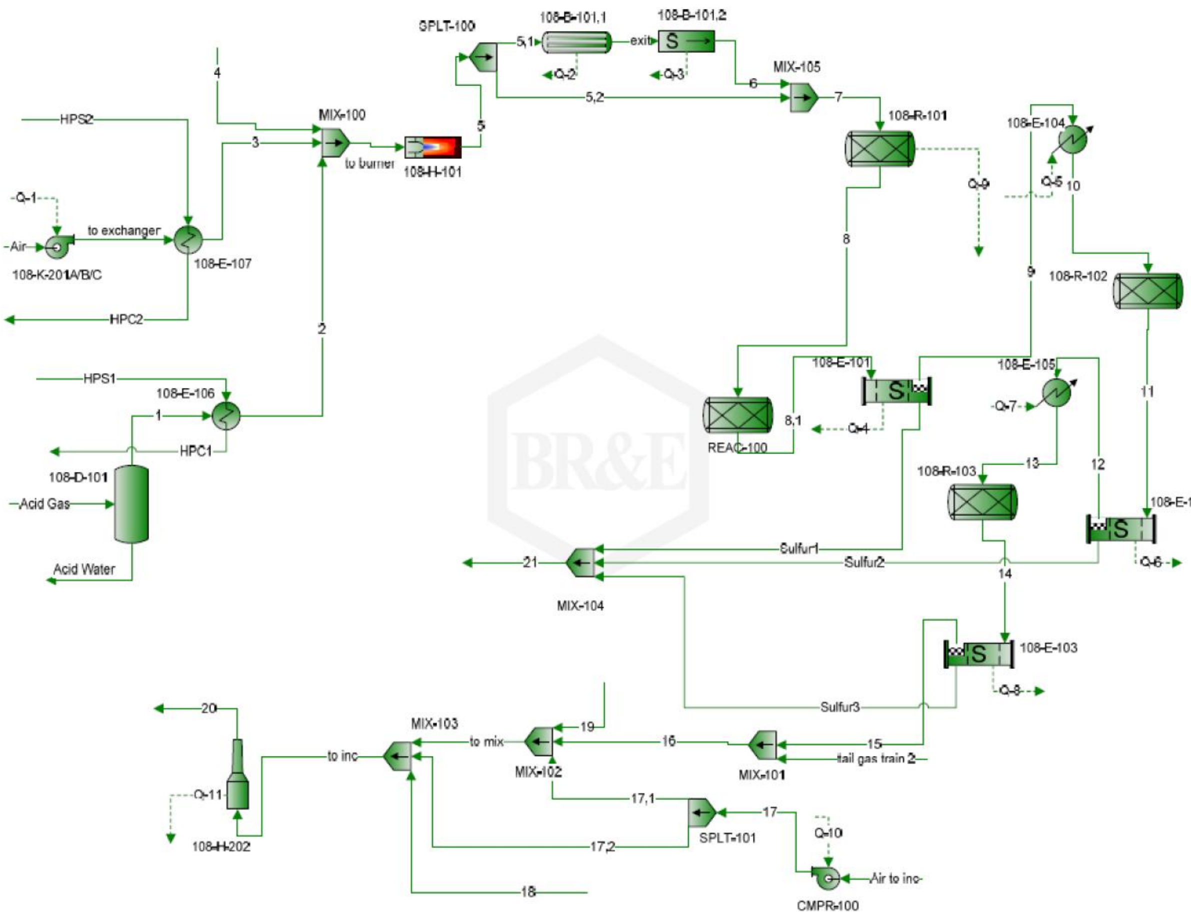

Figure 2 : SRU process simulation by PROMAX

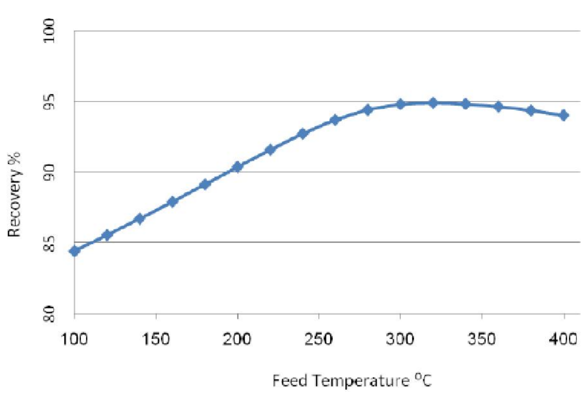

Figure 3 : SRU process recovery obtained by feed preheating

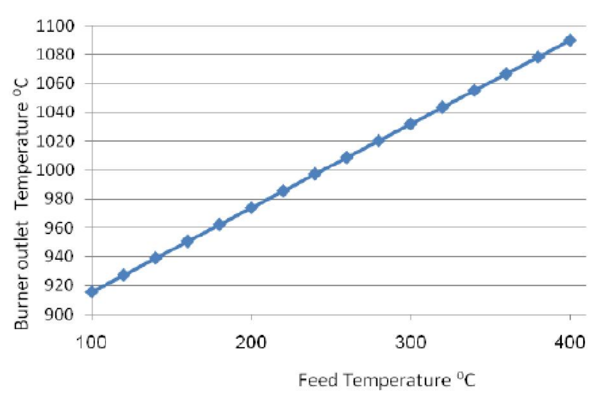

Figure 4 : Burner outlet temperature via feed temperature

OPTIMUM CONDITION OF SPLIT FLOW ARRANGEMENT

Partial feed bypassing around the furnace can be another way to increase sulphur recovery in low H_2S concentration feeds. To do this, some cases with different amounts of split flow have been studied. Bypass flow have been mixed with burner effluent stream goes to the waste heat boiler. In all cases, by fixing feed temperature, plant recovery obtained and compared with each other. Figure 5 shows the results.

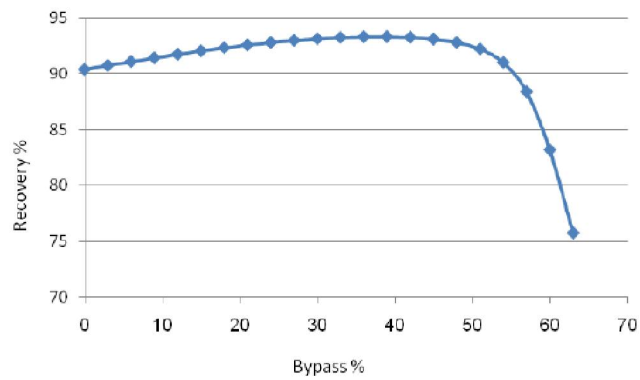

Figure 5 : SRU process recovery via split flow around furnace at feed temperature 220 °C

As mentioned before, there are some important plants constraints such as burner outlet temperature which should be attend not to pass the maximum sustainable burner temperature given by vendor. In above case study, variations of burner outlet temperature via bypass stream percent are shown.

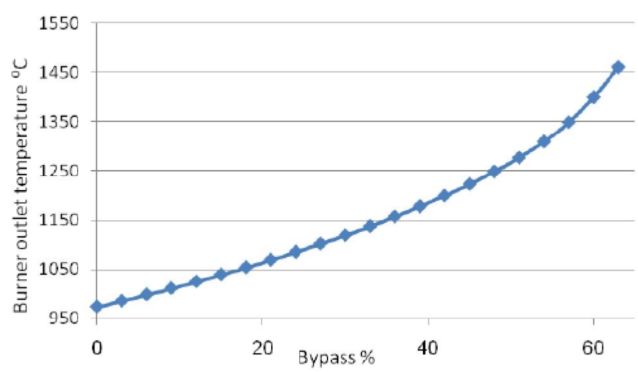

Figure 6 : Burner outlet temperature via bypass flow percent at feed temperature 220 °C

CONCLUSIONS

By Combination of these two parameters we can reach the best configuration of SRU. Regarding to maximum burner outlet temperature and some other chemical and mechanical constrains such as flame stability and maximum sustainable temperature of feed composition and burner refractory, optimum feed temperature and bypass flow can be obtained to achieve maximum possible recovery. Process recovery via bypass flow in different feed temperature has been shown in figure 7.

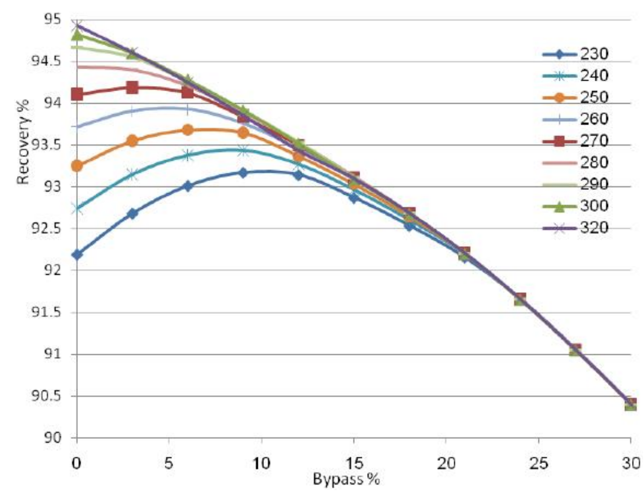

Figure 7 : SRU process recovery bypass flow percent in different feed temperature

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