The CONTACTOR™

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Acid Gas Fired Reheater Control: Part 1

Modified-Claus based Sulphur Recovery Units (SRUs) require successive cooling and reheating of the process gas stream as it passes through several catalytic converter stages. Between each converter, the gas is cooled to condense and remove elemental sulphur, then reheated to allow production of additional elemental sulphur in the next stage.

Common methods to reheat the stream are (1) indirect steam heat, (2) electric heaters, (3) hot oil, (4) gas/gas exchange, and (5) direct-fired reheaters. Here we focus on direct-fired reheaters, positioned between the sulphur condenser and the next converter bed and using some of the SRU's acid gas feed as fuel (Acid Gas Fired Reheater, or AGFR). the main process stream is heated to the desired converter temperature by mixing it with the hot combustion gases from the burner.

Reheaters being burners, they require a strategy to control the flow rate of air and fuel (acid gas). The heat needed to produce the desired temperature rise in the process stream sets the total amount of H_2S combustion needed in the reheater.

After setting the temperature requirement, there is still a degree of freedom left in the control philosophy:

- Should we feed the stoichiometrically required amount of acid gas such that it is all burned?
- Should we feed an excess amount of acid gas so that the combustion products contain a 2:1 ratio of H_2S: SO_2? or,
- Is the best answer somewhere between these two?

Here we use a rate-based simulation to explore the process implications of the choice. Specifically, the question to be answered is what effect does the reheater's air-to-acid-gas ratio has on overall sulphur recovery and COS generation?

Process Description

The chemistry pertaining to AGFRs is generally similar to the chemistry in the SRU's Thermal Reactor (TR), although the process objectives are not identical. One of the primary objectives for the TR is to create the stoichiometric amount of SO_2 that will allow the overall conversion of H_2S to elemental sulphur to proceed as far as possible through the Claus reaction (Equation 1). This objective causes the optimal H_2S:SO_2 ratio in the TR to be close to 2:1 to match Claus reaction stoichiometry. In contrast, the primary process objective in a fired reheater is simply to liberate enough heat of combustion with a stable flame to achieve the required temperature increase in the process stream.

$$2\ H_2S + SO_2 \leftrightarrow \frac{3}{2}\ S_2 + 2\ H_2O \qquad (1)$$

As per the TR flame control strategy, to maintain reliable AGFR operation, it is imperative to have a proper air control system that maintains flame stability to satisfy the required temperature control setpoint. The control scheme should be programmed to allow for independent feed flow measurement on all feed streams to the AGFR Burner; including amine acid gas, and where applicable, all fuel gas streams with steam moderation cascaded to fuel gas flow. Each feed stream will have an air demand multiplier that can be adjusted based on composition so as to provide the total flow target based on the cascade temperature control setpoint. Air demand requirement for each stream is then fed to a summation block to allow for ratio air control. In gas plants, it is common to have amine acid gas (AAG) with less than 50% H_2S. For lean amine acid gas and/or turndown operation (refinery applications included), it may be necessary to co-fire the burners with supplemental fuel gas to sustain a stable flame.

Other important differences from the TR are vessel size and residence time. TRs typically accommodate most of the acid gas fed to the SRU and provide enough residence time that slower reactions (including the Claus reaction) can approach thermodynamic equilibrium. Since fired reheaters will typically take only a small percentage of the total acid gas flow, they are designed with much shorter residence times. As a consequence of shorter residence time, kinetically controlled reactions (such as the Claus reaction) will not typically be able to achieve equilibrium in a fired reheater before the hot gases are cooled by mixing with the main process stream.

In reality there are several kinetically controlled reactions taking place in AGFRs in addition to the Claus reaction; for example, thermal splitting of H_2S into H_2 and S_2. For the present study we will use Claus as a proxy for all of them. The extent of Claus conversion taking place in a reheater depends on the size and configuration of the equipment. If the residence time is long enough, the reaction will proceed to equilibrium. Conversely if the residence time is very short, the Claus reaction may not occur to any appreciable extent at all.

Our study starts in this Part 1 with a base case which is burning enough H_2S to achieve the temperature targets. The amount of acid gas fed to the burner (% stoichiometric air-to-fuel ratio) is varied along with the extent that the Claus reaction is allowed to proceed. In Part 2, we discuss the primary design and operating decisions needed to address the question as to whether the air and acid gas should be fed in stoichiometric proportions, or should the acid gas should be fed in excess? How much does the design of the particular reheater vessel influence this decision?

Case Study

The case study is based on a typical refinery SRU shown in Figure 1. The unit feed and operating conditions are given in Table 1. Two amine acid gas compositions were used: Test Run 1 with 92% H_2S and Test Run 2 with 83% H_2S. The model includes only the conversion section of the SRU. It does not include the Tail Gas Treating Unit (TGTU).

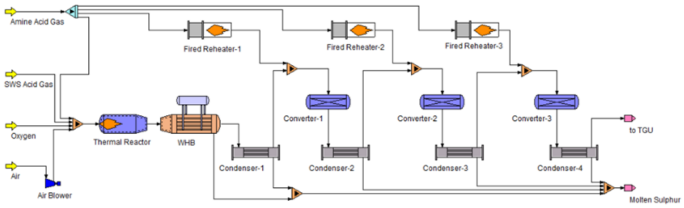

Figure 1 Flowsheet for Case Study

To explore the process implications of reheater operation, we ran a rate-based sulphur plant simulation in SulphurPro® with varying burn strategies from 30% to 90% of stoichiometric air-to-fuel ratio. The heat release requirement for a reheater does not change very much with burn strategy. Therefore, the air supply to each reheater also does not change very much; instead, we change the amount of excess acid gas sent to the reheater beyond the amount required to consume all the oxygen.

As already mentioned, it is difficult to know the extent of Claus conversion that will occur in a reheater because it is a strong function of the size and configuration of the equipment. From a modelling perspective, the uncertainty was bounded by running the models in two different reaction modes to represent the two limiting cases. One limiting case allows all reactions to come to equilibrium by Gibbs energy minimization which simulates a large reheater with residence time of 0.5 seconds or more. The other limiting case prevents the Claus reaction from occurring at all, representing a small reheater with a residence time of 0.1 sec or less. The behavior of a real reheater is bounded by these two extremes.

Effect on Flame Temperature

The most immediate consequence of differing air-to-fuel ratio in the reheater is on the adiabatic flame temperature, as shown in Figure 2. As expected, the hottest temperature is at the stoichiometric air-to-fuel ratio since *deviation* from this ratio implies the presence of additional unreacted gas which will act as a heat sink. The Claus reaction is endothermic at flame temperatures, so models which inhibit the Claus reaction show slightly higher flame temperatures. Note that for this case study, air-to-acid-gas ratios above 50% lead to flame temperatures that can lead to refractory and burner damage.

Table 1 Operating Conditions for Case Study

AAG feed rate	450 lbmol/h	
AAG composition (wet basis)	Test Run 1 composition H_2S = 92% CO_2 = 5% CH_4= 0.5	Test Run 2 composition H_2S = 83% CO_2 = 14% CH_4= 0.5
SWAG feed rate	81 lbmol/h	
BTEX in SWAG	1900 ppmv	
Oxygen enrichment	29%	
1st Converter Outlet	650°F	
2nd Converter Outlet	~ 485°F*	
3rd Converter Outlet	~ 420°F*	
*Temperatures of 2nd and 3rd converters set to maintain 25°F approach to sulphur dew point		

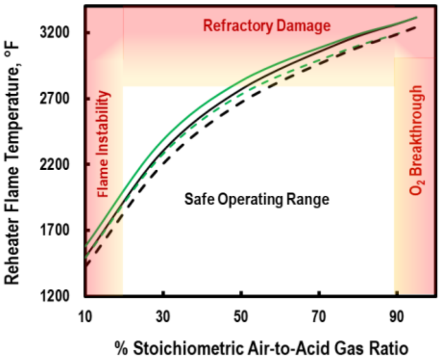

Figure 2 Reheater flame temperature changes with burn strategy. Green lines represent cases with no Claus reaction. Black lines represent cases with Claus reaction proceeding to equilibrium. Solid lines represent Test Run 1 with higher H_2S concentration in Amine Acid Gas, dashed lines represent Test Run 2 with lower H_2S concentration. Shaded regions indicate approximate ranges where undesirable effects may occur.

In Part 2 (July, 2021 issue) we will discuss the effect of burn strategy on sulphur conversion in the SRU and on COS formation. The later is important to the downstream TGTU and total sulphur emmission.

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