The CONTACTOR™

Published Monthly by Optimized Gas Treating, Inc.
Volume 12, Issue 1, January, 2018

Sulphur Condenser Turndown Operations

With crude oil prices remaining low and the presently large amount of low sulphur shale oil, refineries are being pushed into processing lower sulphur crudes. This significantly reduces the overall sulphur available for processing in the SRU and forces the unit to operate at turndown conditions. Another scenario that all too often happens is that a sulphur unit is designed and built based on a specified feed gas rate and composition; however, upon starting the unit, the original design basis is no longer valid and the unit is severely under-loaded. These are just two of the many reasons that a Sulphur Recovery Unit (SRU) might be operating at turndown. This issue of The Contactor focuses on the operation of the final Sulphur Condenser, specifically its pressure drop, mass velocity, sulphur conversion and recovery, and it shows how these variables change as the throughput is reduced.

The primary purpose of a Sulphur Condenser is to remove the sulphur being produced upstream. This is a critical step for furthering the Claus reaction (Le Chatelier's principle). Without this step, the reaction would only proceed as far as the first occurrence of equilibrium.

Mass velocity plays an important role in the operation of a Sulphur Condenser. If the mass velocity is too low, excessive cooling of the process gas occurs, and the sulphur being condensed may tend to remain suspended in the gas as there is not enough force to cause the smaller liquid sulphur molecules to collide and coalesce out of the gas; this is often referred to as fogging. At the other extreme, if the mass velocity is too high, the velocity of the gas is high enough that the liquid sulphur running out of the condenser tubes can entrain with the gas; this is often referred to as misting. In either of these two cases, excessive sulphur entrainment can be expected which may lead to increased emissions (if it occurs at the final condenser), liquid sulphur on the catalyst which may lead to deactivation of the catalyst, elevated sulphur dew point temperatures in the catalyst beds, and reduced conversion in the converter beds.

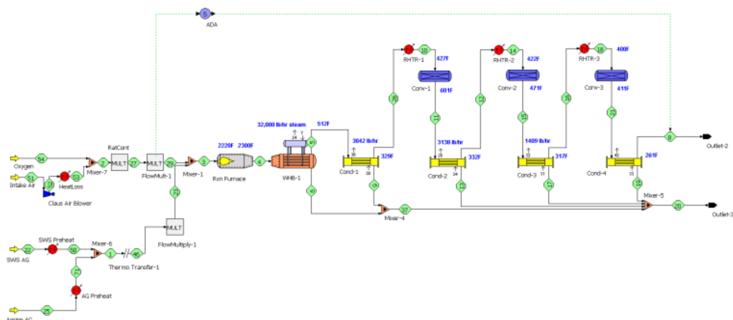
Case Study: An SRU on 28% Oxygen Enrichment

The sulphur unit is a three (3) bed Claus unit under low level oxygen enrichment processing both sour water gas and amine acid gas operating at a rate of 125 LTPD. The acid gas inlet stream flow rate and key component dry basis compositions can be seen in Table 1 while Figure 1 shows flowsheet details.

Table 1. Conditions of Sour Gas Inlets

Stream	Flow Rate (lbmol/hr)	H_2S mol%	CO_2 mol%	NH_3 mol%
Amine AG	386	91.9	6.7	---
SWAG	68	44.75	---	55.25

Figure 1. Flowsheet for Case Study



The exchangers, which include the WHB and the four (4) condensers, are all calculated in rating mode. Here the tube count, tube diameter, and tube length are obtained from the equipment data sheets and are used to calculate the outlet temperature as well as the mass velocity and pressure drop for the final condenser. Having the ability to rigorously rate exchangers allows for studies, such as turndown effects, to be much more reliable and closer to reality than ever before. Table 2 shows the base case operations for the exchangers, and lists the outlet temperatures and the mass velocities of the WHB as well as the four condensers. Table 3 shows the calculated conversion and sulphur recovery. When discussing things such as sulphur recovery, it is always best to define the calculations. In this study, recovery is defined as the liquid sulphur atoms leaving an exchanger (specifically S_2, S_6, and S_8) over the sulphur atoms entering the system (H_2S in the acid gas).

Table 2. Base Line at Original Operating Capacity

Parameter		WHB	Cond 1	Cond 2	Cond 3	Cond 4
T Out (F)	**Calc**	512.6	333.5	333.9	313.2	260.8
	Meas	512	329	332	317	261
Mass Velocity ($lb/s\text{-}ft^2$)		2.0	3.0	3.0	2.7	2.8

Table 3. Recovery at Original Operating Capacity

	Thermal Stage		1st Stage	2nd Stage	3rd Stage
	WHB	Cond 1	Cond 2	Cond 3	Cond 4
Recovery	17.89	37.58	30.92	9.02	2.28
Cumula-tive	17.89	55.47	86.38	95.40	97.69

Results

In this study, the SRU was placed in a turndown state at 75% and 50% of the original operating capacity. This reduced the throughput from 125 LTPD to 93.75 LTPD and 62.5 LTPD respectively. Normally, oxygen would be removed during turndown operations due to cost; however, for this study, the enrichment level was held constant for simplicity. Focusing on the cumulative sulphur recovery, we can see from Table 4 and Table 5 that with the exception of the WHB and Condenser 1, the overall unit did not recover all that much more, or less, sulphur.

Table 4. Recovery at 75% Capacity

	Thermal Stage		1st Stage	2nd Stage	3rd Stage
	WHB	Cond 1	Cond 2	Cond 3	Cond 4
Recovery	28.71	26.43	31.17	9.15	2.28
Cumula-tive	28.71	55.14	86.31	95.46	97.74

Table 5. Recovery at 50% Capacity

	Thermal Stage		1st Stage	2nd Stage	3rd Stage
	WHB	Cond 1	Cond 2	Cond 3	Cond 4
Recovery	37.00	17.51	31.83	9.15	2.25
Cumula-tive	37.00	54.51	86.35	95.50	97.75

As the throughput to the unit is reduced, the majority of the sulphur being condensed in the thermal stage shifts from the first condenser to the WHB. This can be attributed to the fact that because of the decreased throughput, the operating temperature of the WHB is noticibly lower than in the original operating temperatures. This leads to more sulphur being removed in the WHB at both 75% and 50% capacity leaving less to be condensed in the first condenser as can be seen from Tables 3, 4, and 5 above. However, in both turndown cases, the overall sulphur recovery does not have a significant shift one way or the other. Looking at this purely from a process chemistry perspective, for this particular unit, the performance of the unit does not depend as heavily on rate as one might expect. In this case, performance of the unit in turndown conditions would be dominated by other factors such as heat loss, due to a lower thermal mass of the process gas, and fogging due to lower mass velocities.

The turndown limit for a sulphur condenser really depends on the mass velocity as well as a number design specific variables. These can be accounted for in Protreat® through the entrainment specification. For this study, entrainment was considered constant. Table 6 shows how the mass velocity through the final condenser changes as the throughput to the SRU is reduced.

Table 6. Mass velocity through Final Condenser at Turndown Conditions

% of Original Operating Case	100%	75%	50%
Calculated Mass Velocity (lb/ft^2-s)	2.80	2.08	1.39

The final parameter that is highly important in an SRU is pressure drop. ProTreat® is able to calculate the pressure drop through the exchangers allowing this parameter to be studied. If we look at the pressure drop, specifically through the final condenser, we can see from Table 7 that as throughput is decreased, pressure drop through the exchanger also decreases.

Table 7. Conditions of Sour Gas Inlets

% of Operating Rate	100%	75%	50%
Calculated Pressure Drop (psi)	0.52	0.30	0.14

Conclusions

There are many reasons that an SRU may be operating in a turndown state; partial loss of feed gas due to problems in the unit upstream, changes in feed gas rate after the unit was built, adding oxygen enrichment, etc. However, being able to know and understand the limitations and capabilities of the SRU is crutial to reliable operations. Through the use of a true kinetic rate and heat transfer based sulphur simulator, the turndown conditions and impact on the recovery, pressure drop, and mass velocity can be studied. A newly developed spreadsheeting tool is available on ProTreat's downloads page for calculating the sulphur conversion and recovery. It was found that the recovery does not change dramatically as the unit is turned down and pressure drop becomes almost negligable. For this case, practical considerations, such as heat loss to the environment and fogging in the condenser tubes would probably be the deciding factor as to just how far the throughput can be reduced. However, there are many other factors that affect the turndown causing the devil to be in the details.

~·~·~·~·~·~·~·~·~·~·~·~·~~·~·~·~·~·~

To learn more about this and other aspects of gas treating and sulphur recovery, plan to attend one of our training seminars. Visit www.protreat.com/seminars for details.