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Assess Claus Unit Performance by Simulation – Part 2

In Part 1, an operating SRU was modeled to assess the accuracy of the SulphurPro® simulator. In Part 2 we assess the effect of oxygen enrichment on the same unit's performance.

The base case discussed in Part 1 used 28.5% oxygen in the enriched air. The objective now is to determine exactly how enrichment actually affects several key performance parameters in the as-built plant. Note that this is not a design study; rather, the SRU under all the conditions being studied must operate within the physical constraints of the existing equipment and flowsheet configuration without modifications.

There are several "solver" (S) blocks that can be used in SulphurPro for the flowsheet solution process in this study. A Solver block in SulphurPro is intended to determine the value of a parameter within an operating block needed to achieve a specification parameter in a selected stream. In the following, refer to Part 1 for parametric details, and use the flow diagram found there to locate specific streams and Solver blocks:

- The function of the solver labeled *ADA* is to calculate the total enriched air flow to the Reaction Furnace (RF) needed to *maintain the* H_2S:SO_2 *ratio of about 2:1* in the tail gas vapor from the final condenser (Stream 20).
- Another solver (*Acid Gas Flow Control*) could be used to calculate the total flow rate of sulphur-bearing feeds into the SRU (Stream 46) to set the total flow rate of gas from the first condenser and into the converter/condenser bank (Stream 26). If no COPE[†] recycle is needed (corresponding to no or low enrichment), the gas flow from the first condenser (Stream 43) is often taken as a fair measure the SRU's gas handling capacity. However, if higher levels of enrichment are contemplated, COPE recycle is necessary to keep the RF outlet temperature below the thermal limits of the furnace refractory. If one is interested in high levels of oxygen enrichment, the gas flow in Stream 26 is the practical measure of capacity. Thus *Acid Gas Flow Control ensures the SRU is fed with the right amount of gas to keep it at full capacity* (Stream 26).
- With oxygen enriched air, furnace temperatures can become high enough to exceed the thermal limits of the furnace's refractory (usually 2,700°F) and of the material in the WHB, especially with regard to corrosion. In the original case, 28.5% enriched air together with COPE recycle was used to keep furnace effluent temperature at the (unnecessarily) low temperature of 2,400°F. For each case in the present study, the Solver block *COPE Recycle* was set up to calculate the recycle gas flow by solving for the split of first-condenser gas between the COPE recycle (Stream 8) and the feed to the first Reheater (Stream 26) that is necessary to keep the RF effluent at 2,700°F.

The study was done by using the ADA to keep the H_2S to SO_2 ratio close to 2:1, keeping the plant's *total* gas throughput into the converter system constant and holding the furnace effluent temperature to 2,700°F via adjusting the COPE recycle gas flow (Stream 8). This particular exercise was not to determine how to optimize each level of oxygen enrichment, but simply to compare each case on an apples-to-apples basis. Figure 1 shows the Reaction Furnace effluent temperature and the percentage COPE recycle needed to achieve this temperature for various levels of oxygen enrichment.

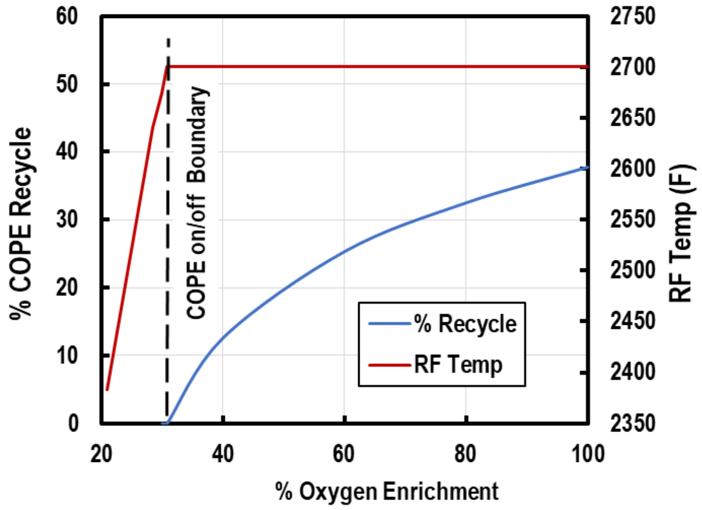

Figure 1 **O_2 Enrichment Needs Various levels of COPE Recycle to Keep RF Temperature under 2,700°F**

The SRU's acid gas processing capacity increases quite rapidly with enrichment level (Figure2). In principle at least, using pure oxygen instead of air can increase SRU capacity by nearly 250% in the case considered here. However, there are other factors that must be taken into consideration that can limit the real potential of enrichment, and that may require adjustments to be made to overcome them at least partially. One of the most important ones is the effect of increased throughput (i.e., reduced residence time in the RF) on ammonia destruction.

[†] Claus Oxygen-based Process Expansion (COPE). See for example: B. Gene Goar, R. L. Hull, and H. L. Vines, *Consider the COPE® Process for Improving Sulfur Plant Operations and Lowering Tail Gas Emissions*, Laurence Reid Gas Conditioning Conference Proceedings, Norman, OK, February, 1987.

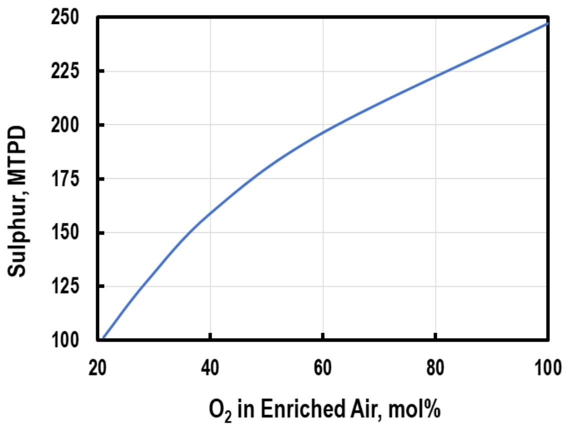

Figure 2 How Oxygen Enrichment Affects Sulphur Processing Capacity

The inlet gas is of a mixture of AAG and SWAG. SWAG almost always has a high ammonia concentration, 55% NH_3 in this example. The mixed feed is 6.65% ammonia on a dry basis. An often quoted guideline is that the RF effluent should be below 150 ppmv ammonia. As Figure 3 shows, NH_3 can be several times higher than the recommended maximum when high levels of oxygen enrichment are used <u>even when the RF outlet is kept at 2,700°F</u>. The problem with high NH_3 levels is the propensity for ammonia to form salts in downstream equipment, especially in sulphur condensers towards the end of the converter sequence. Ammonium salts cause higher pressure drop, thus reducing plant throughput, eventually plugging lines, and necessitating deceased throughput or a shutdown to clear.

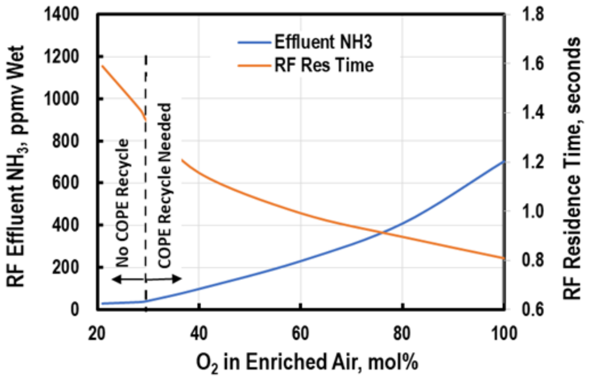

Figure 3 Effect of Oxygen Enrichment on Residence Time and Effluent NH_3 in Furnace

For this particular case, since the SRU is an existing plant, and equipment sizes are fixed, so there are limited ways to increase ammonia destruction in the RF. Ammonia destruction is determined by reaction kinetics driven by three primary factors: the RF temperature (quite high here); the RF residence time (also shown in Figure 3, and which COPE causes to decrease with higher enrichment); and the mixing characteristics of the burner. High efficiency burners are essential for good reliability and operability of the SRU under oxygen enrichment.

Higher RF temperatures increase ammonia destruction. This means reducing the amount of COPE gas recycled from the first condenser, also requiring the throughput of acid gas to the SRU to be decreased to keep the hydraulic load at or below the plant's capacity. Reducing throughput to permit higher reaction furnace temperatures would also increase the residence time in the reaction furnace so there are two beneficial outcomes. However, the maximum recommended RF temperature is 2,700°F so monitoring the effect of altered COPE on the rest of the plant would be crucial to ensuring operability.

High temperatures expose the WHB to increased risk of catastrophic failure, especially from a high temperature near the tube-sheet and its associated sulphidic corrosion. Figure 4 shows that with a high level of enrichment, even with COPE recycle, the peak tube-wall average temperature (at the tube sheet) in the WHB can become dangerously high, and the peak heat flux can rise to 175% of the unenriched value. This is highly concerning because the actual peak tube-wall temperature is directly linked to the sulphidic corrosion rate. Removing the inert nitrogen concentrates H_2S in the RF effluent. This combined with higher temperatures at the entry of the WHB tubes can drive the corrosion rate up by a factor of 10 at 100% oxygen. Although the peak heat flux might be below the recommended maximum (where a transition from nucleate boiling to a Leidenfrost mechanism —vapor blanketing— occurs), an increase of this magnitude would require a closer look at the utilities system of the WHB and further CFD analysis to ensure this change does not push the equipment to the point of failure.

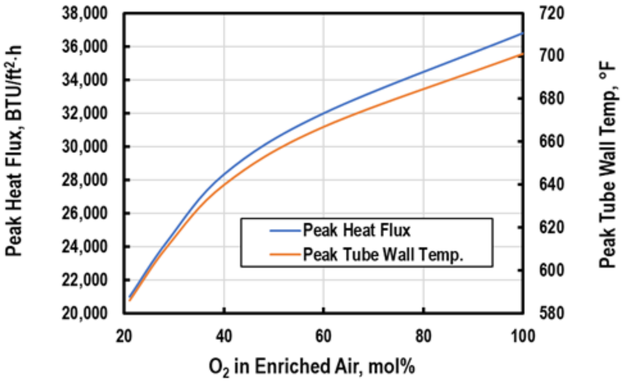

Figure 4 Effect of Enrichment on Peak Heat Flux and Peak Tube Wall temperature in the WHB

The SulphurPro® SRU simulator is based on fundamental reaction kinetics and on heat transfer as a rate process. To assess reliably the effect of a planned change in process conditions, a fundamentals-based simulator that addresses all the nuances of process chemistry is far superior to one that uses heuristics and curve fits, even if the fits are to a plethora of plant performance measurements.

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

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