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Assess Claus Unit Performance by Simulation – Part III

In Part I, an operating SRU was simulated, and the unit measurements were used to assess the accuracy of the SulphurPro® simulator. In Part II, the effect on the SRU's performance of oxygen enrichment applied via a COPE® Recycle scheme was assessed. In Part III, we summarize the findings and delve into more detail on some important considerations when modeling these types of processes, with an introduction to the SURE™ process.

Summary

Increasing the oxygen content in the combustion air to an SRU is a great way to increase the plant's capacity and allow a higher volume of acid gas to be processed. This is done by adding pure oxygen while proportionately backing out combustion air containing diluent nitrogen. Thus, the concentration of the reactant (oxygen) is increased while leaving the recovered hydraulic capacity available for additional acid gas. There are precautions that need to be taken, however, when increasing the oxygen content.

One of the pitfalls of oxygen enrichment is failing to account for the much higher reaction furnace (RF) temperatures that result from more concentrated reactants. Furnace temperatures can easily exceed the thermal limits of the furnace's refractory lining and the Waste Heat Boiler's (WHB's) tubesheet protection system. In a traditional process configuration, the allowable concentration of oxygen is quite limited, mostly by the permissible RF temperature which limits the level of enrichment allowed. Without mitigation measures to limit the RF temperature, levels of oxygen are usually kept below a maximum of 28-30% with typical refinery acid gas feeds. Beyond this, changes to the process equipment often need to be made.

The cutoff concentration of oxygen is not the same for every plant. It is determined by a number of factors, one being the acid gas quality (the concentration of H_2S is in the feed gas entering the plant). Low quality acid gas (less than 30% H_2S) can have high levels of oxygen enrichment applied without the need for temperature mitigation of any kind. In fact, when processing low quality gas to improve contaminants destruction, one way to boost the temperature within the reaction furnace is by adding oxygen; however, this is a topic for another discussion. Processing H_2S-rich acid gas with oxygen does require steps to limit temperature.

SulphurPro SRU simulation uses a completely fundamental modern approach that allows the effect of process changes on a whole host of performance metrics to be reliably assessed. Heretofore, one had to rely exclusively on extrapolations (and interpolations) of curve-fits to measured performance data.

SRU performance has always been challenging to assess accurately due to sample reactivity in a plugging service. This in itself has led to simulation models that are empirical. They are truly reliable only for the conditions for which the simulation tool was actually regressed. When the opposite approach is taken and first-principles reaction kinetics together with modern reactor theory and heat transfer fundamentals are used in modeling, greatly improved reliability and simulation accuracy result.

With the fundamentals approach predictions are based on what the science says, devoid of the errors inherent in making, interpreting, and correlating error-prone plant measurements and making unnecessary assumptions. Interactions between variables are not ignored; rather, they are automatically accounted for, and the detailed performance of an SRU is actually predicted, and to a high degree of reliability.

Reliable simulation is an excellent way to assess the possible consequences of proposed process changes before the changes are actually made. Simulation reliability is crucial because when changes to process conditions are being contemplated, decisions with significant downside potential sometimes must be made. Our contention is that simulation based on measured fundamental reaction kinetics for all the important reactions taking place in the SRU while also accounting for the interplay between radiative and convective heat transfer with reaction kinetics in condensers and waste heat boilers is the best possible approach.

More on Oxygen Enrichment Processes

There are several licensed processes available for implementing Oxygen Enrichment at varying levels. With high levels of oxygen enrichment, there are special considerations that need to be given to managing the high associated heat release and temperatures. Two proprietary high-level enrichment processes are COPE® Recycle and SURE™ Double Combustion.

COPE is an acronym for Claus Oxygen-based Process Expansion. The current licensor is Fluor Technologies. COPE was initially developed by Goar, Allison and Associates (GAA) with Elmo Nasato being one of the lead inventors. This technology works by recycling a portion of the process gas from the first condenser outlet back to the front of the RF in order to dilute the acid gas and cool the exothermic reactions. With this approach, COPE permits processing with any level of oxygen enrichment from 21% (base air) to 100% oxygen in the combustion air. As shown and discussed in Part II of this series, COPE can hugely increase the sulphur processing capability with more than doubling of plant capacity being easily achieved. More detail can be found in Part II.

SURE™ Double Combustion technology is a process licensed by both Comprimo and Linde AG, and is capable of oxygen enrichment levels up to 100%. As the name implies, this technology works by splitting the thermal release between two separate RF/WHB units, each with its own oxygen injection system (Figure 1). The acid gas is fed to the burner of the first RF/WHB unit along with combustion air and a portion of the oxygen. After passing through the first WHB, the partially combusted (and cooled) process gas is fed into a secondary thermal reactor and mixed with oxygen, then passes to a secondary WHB. In several instances, the secondary thermal reaction has been successfully accomplished in the turnaround section between the two WHB passes.

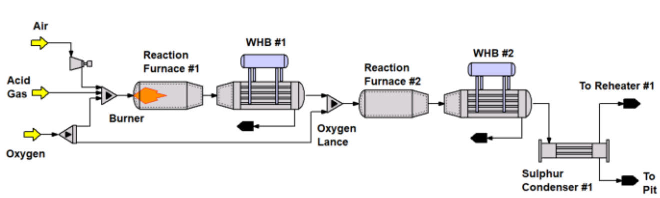

Figure 1. SURE™ Double Combustion

After leaving the second RF/WHB, the process gas continues through the typical Claus process of sulfur condensation, gas reheating, and catalytic conversion to elemental sulfur. Note that in SURE there is no liquid withdrawal from the first WHB but a discharge point is needed by the SulphurPro WHB model, even if the flow is zero.

Modeling Considerations

When modeling high-level oxygen enrichment, it is vital to get every aspect of the process right. Quite possibly the most important aspect is having the reactions occurring in the right pieces of equipment in the process. Otherwise, the Reaction Furnace temperature and WHB inlet heat flux are misrepresented by the simulator. This is true even for modeling Claus units operating on atmospheric combustion air alone, but becomes increasingly vital as the level of oxygen goes up. Heat release and consumption are key considerations when looking at oxygen enrichment and, if these are not taken into account in the right step of the process, the design of the equipment can be problematic and cause operational predicaments and bottlenecks when implemented. Undersized WHB's, excessive corrosion, incorrect furnace temperatures and under-predicted combustion air/oxygen flowrates are all possible with the wrong simulation technology.

SulphurPro® is a kinetics and heat transfer rate-based simulator for accurately modeling nearly every aspect of the modified Claus process, including accurately representing high levels of oxygen enrichment in processes such as COPE® Recycle and SURE™ Double Combustion. SulphurPro includes detailed first principles-based reaction modeling at each important step in the process, enabling it to achieve a very high level of accuracy.

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