The CONTACTOR™
Published Monthly by Optimized Gas Treating, Inc.
Volume 13, Issue 9, September, 2019

Sulphur Processing Operations during Startup, Shutdown, and Turndown—Part I

Sulphur recovery units (SRU's) are designed to meet a specific set of targets given an initial set of premises such as feed flowrates, feed composition, feed temperatures, and pressure. During the design phase, considerations are generally given to different scenarios such as varying feed quality, feed rate (turndown), equipment aging (exchanger fouling), and catalyst aging to help assess the robustness of the design. However, startups and shutdowns arguably cause the most damage to an SRU through thermal cycling of the process equipment, and it is these very conditions that are often overlooked or not given much thought. Thermal cycling affects the reliability of the Waste Heat Boiler (WHB) most notably by degrading the tubesheet system, which includes the refractory, ferrules, the tubesheet itself, the tube-to-tubesheet joints, and the tubes. Through proper design, operating practices, and maintenance procedures, the Reaction Furnace and WHB system can have life expectancy in excess of 20 years. However, with an inadequate design, poor operating practices, and poor maintenance, it could be as short as two to three years[1, 2]. Being able to model accurately varying feed quality, feed rate, exchanger fouling, and catalyst aging can provide better understanding of the effects of these parameters.

Startup Operations

Procedures for starting up an SRU vary slightly between bringing an existing unit back online after a shutdown versus a green unit that has never before seen sulphur. In overly-simplistic terms, the following steps are usually taken:

1. Light the pilot
2. Light the main burner
   a. If the unit has never seen sulphur, or if the refractory is "green", then excess air is typically used to control the rate of refractory heat up per the manufacturer guidelines with regard to the maximum temperature change per hour for the refractory to minimize the potential for refractory thermal shock and the consequent damage. Considerations in some jurisdictions for maintaining a TGU downstream in operation that is always "coupled" to the SRU may preclude excess air operations to prevent damage to the Co/Mo catalyst if presulfiding has been previously conducted.
   b. If the unit is being brought back online after processing sulfur previously, then excess air is forbidden in order to prevent sulfur fires. The procedure involves firing natural gas and air at 90% to 95% of stoichiometric at a hydraulic load corresponding to *at least* 30% of the design operating rate on acid gas. A convenient average hydraulic load for the SRU that is often taken for a basis is the molar flowrate as measured at the outlet of the first condenser. The natural gas will then gradually be replaced with acid gas until the unit is running on only acid gas and air at the 30% design rate.
3. Bring in acid gas when the unit is properly heated up and stable.

Most flowmeters start losing accuracy at flows below 25% turndown so setting the limit for startup at 30% ensures flowrates will be well within the range of most instruments. Having some hydraulic back pressure on the unit also helps to maintain feed gas and air control valves in operable positions. Burner backfiring is a serious issue at turndown because it causes damage to the burner tip which can then lead to an irregular flame pattern, hot spots, and ultimately burn a hole in the Reaction Furnace wall.

Shutdown Operations

Simplistically, shutdown procedures can be considered the direct opposite of startup. The unit is first turned down to approximately 30% of the design rate and the acid gas is gradually replaced with natural gas until the unit is operating on only natural gas, tempering steam and air. This period of operation is also referred to as hot standby. The purpose here is to keep the equipment hot and remove the elemental sulfur from the plant equipment either in preparation for a true shutdown or to keep the system idling.

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Turndown Operations

It is normal for an SRU to operate at below design flowrates. More often than not, the initial operating conditions (which include flowrates) change after construction and commissioning, as well as during operation of the unit. Ensuring that the unit will perform adequately under these non-design conditions is crucial to successful operation.

Heat losses from plant equipment also become more significant at turndown, and separations equipment may not perform as advertised either. In a sulfur condenser, for example, fogging has been reported at low mass velocities (<1 lb/sec·ft^2) [3, 4]. Fogging is a phenomenon in which submicron mist is formed in the bulk vapor versus normal film condensation on the condenser tubes. This mist is so fine it evades conventional mist elimination devices.

An important part of turndown operations is knowing whether the plant equipment is operating safely and reliably. Here, we use an example of how process simulation can complement plant operations.

Case Study

A series of case studies was performed to analyze startup and shutdown operations as well as the effects of turndown on the SRU. The Claus Unit analyzed was a typical 2-stage unit in a refinery setting processing both sour water acid gas and amine acid gas at a combined design flowrate of 125 TPD (Figure 1 and Table 1). The heat exchange units, such as WHB and condensers, were simulated in rating mode to assess accurately the effects of operating at off-design rates. All cases were simulated using SulphurPro®, a reaction rate and heat transfer rate-based sulphur recovery simulator.

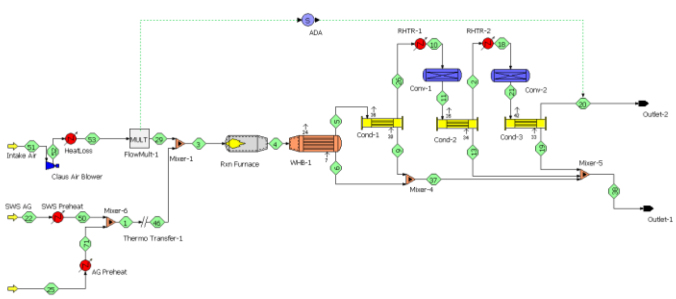

Figure 1. SulphurPro® PFD for 2 Stage Claus Unit

For the first case study, the unit simulation was run in two turndown scenarios; one at 75 TPD (60% of design) and the other at 40 TPD (30% of design). The performance of the unit, and specifically the exchangers, was assessed at each turndown step.

	Amine Acid Gas	Sour Water Acid Gas
H_2O	5.28%	22.19%
H_2S	87.14%	35.01%
CO_2	6.63%	-----
NH_3	-----	42.79%
CH_4	0.947%	-----

Table 1. Feed Conditions for Amine Acid Gas and Sour Water Acid Gas (mole %)

For the second case study, the unit was assessed at a point midway between the startup/shutdown procedures. Natural Gas and Acid Gas (from both Amine Acid Gas and Sour Water Acid Gas sources) were both sent to the Claus unit in equal amounts (50% each) at a combined hydraulic load that was equal to the hydraulic load at 30% of the design rate on acid gas only. This gave a point midway between hot standby (natural gas only) and turndown on acid gas (40 TPD or 30% of design).

In Part II of this series, we will present and discuss the results of the case studies. These case studies were conducted using OGT's SulphurPro® simulator which is based on reaction kinetics and heat transfer rates.

References

1. *Factors Affecting Claus Waste Heat Boiler Design and Operations,* Elmo Nasato, Nathan Hatcher, Simon Weiland and Steven Fulk, Sulphur 2018.
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4. *Design Considerations for Modified Claus Sulphur Recovery Plants*, B. Gene Goar, Proceedings of the Comprimo/Western Research Seminar on Gas Sweetening and Sulphur Recovery, November 1985, Amsterdam, The Netherlands.

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