The CONTACTOR™
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Efficient Sulphur Conversion: Hot Gas Bypass or Direct Reheat?

The Modified Claus Process uses a multi-step strategy of reheating the process gas, passing it through a catalyst to facilitate reaction, and then cooling it to condense the sulphur product. There are a variety of options available for the reheating step. Two of them are the focus of this edition of The Contactor™: hot gas bypass and direct reheat.

Hot Gas Bypass

Hot gas bypass is a method of reheating the process gas stream following its cooling by the condenser to remove the sulphur produced by reaction. Part of the hot gas from the first pass of the Waste Heat Boiler (WHB) is mixed with the cooler gas before entering the Claus Converter (Figure 1).

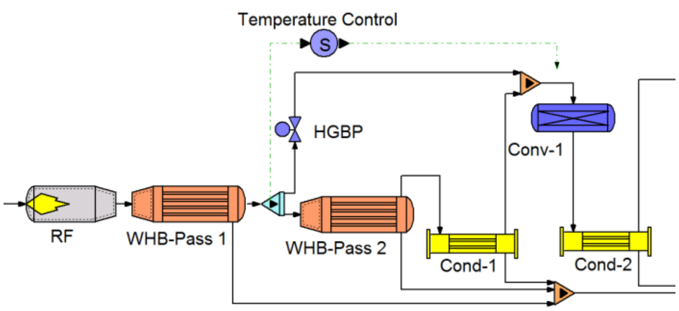

Figure 1. PFD of Hot Gas Bypass (HGBP)

This method can be very effective for reheating the cooler process gas stream by using the high temperature of the hot gas from the WHB. Usually only a small fraction of the gas is needed. The true flowrate, however, depends on a number of factors including the temperature of the two streams being mixed, the desired outlet temperature, and the gas rate through the unit. Because the heat is simply being diverted from the WHB to the converter inlet, it can be considered a "zero cost" heat source. However, if the SRU is exporting HP steam from the WHB, the heat truly does come with a cost, but the method is fairly simple and is cost efficient when compared to direct reheat.

As with almost everything, there are downsides to using hot gas bypass. By redirecting a portion of the hot gas to the converter inlet, the stage condensers are bypassed and so any sulphur produced in the thermal section is not condensed until later in the process. By leaving this produced sulphur in the process gas stream, the dew point of that stream is raised which increases the possibility of sulphur condensation in the catalyst pores which reversibly deactivates the catalyst. Hot gas bypass can also exhibit poor temperature control, especially at turndown. If the temperature of the hot gas varies, there is an inherent delay in responding to that variation which can result in converter inlet temperatures that for a short time are either too hot or too cold. Given the high temperature sulfide service, specialized valve designs are required, where internal steam purging is often employed to keep the valve parts cool and free of sulfur.

Direct Reheat

Direct reheat is a class of reheat that uses a burner with either fuel gas or acid gas as the fuel source. Hot gas bypass is also in the class of direct reheat, but unlike inline burners, hot gas bypass does not introduce auxiliary gas streams to the process; it simply uses what is already in the process. Figure 2 shows an example of direct reheat. Here, the fuel source is amine acid gas (AAG).

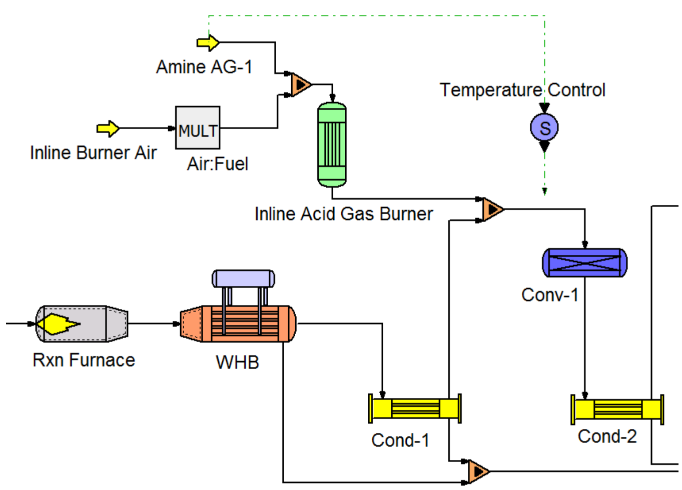

Figure 2. PFD of Direct Reheat using Amine Acid Gas

As Figure 2 shows, AAG is combusted with air, much like in the reaction furnace, to produce a hot gas stream. This is then mixed with the cooler process gas coming from the upstream condenser to increase the temperature of that stream sufficiently before entering the converter. Both AAG and natural gas direct reheat exhibit excellent temperature control, especially for the first converter where high temperatures may be required for COS and CS_2 hydrolysis. Natural gas though adds OpEx to the configuration because of its cost, whereas AAG is considered a "free" fuel source as it comes from the inlet to the SRU. Both fuel sources advantageously provide a short-term temperature increase for catalyst rejuvenation. In the case of natural gas, operational benefits can be realized by reducing the required time to remove sulfur from the unit on shutdown heat soak

Similar to the hot gas bypass, there are downsides. Whether it's with AAG or natural gas, the fuel source used for the direct reheat creates a secondary source for contaminants and failures do occur.

AAG burners pose a risk of oxygen breakthrough, bypass sulphur around conversion stages, increase the converter bed dew points, increase COS and CS_2 formation, and are not suitable for lean acid gases. If the AAG contains an appreciable amount of ammonia or aromatic hydrocarbons, such as BTEX, this has the potential to create problems downstream of the burner. There is also a fairly large associated CapEx from the equipment plus a maintenance cost for refractory lined equipment and additional instrumentation.

Natural gas burners also pose the risk of oxygen breakthrough, and an even higher risk of soot formation and hydrocarbon breakthrough. Refinery fuel gas should never be used because its composition and heating value are unknown. Similar to AAG burners, there are substantial CapEx and OpEx associated with the equipment.

Hot Gas Bypass and Direct Reheat at Turndown

At first glance, these two reheat methods may appear to be quite similar. However, a subtle difference between them reveals itself at turndown conditions. The WHB is designed to meet an outlet temperature at normal rates. When the unit is turned down, the boiler becomes oversized for the feed rate and it over cools the gas being used to reheat the converter inlet. This requires more gas to provide the same converter inlet temperature, bypassing more converted sulphur around the first-stage condenser.

Case Study

The case study is intended to demonstrate the effect on operations and sulfur recovery efficiency (SRE) of both hot gas bypass and direct reheat under turndown conditions, and to compare the results with the base case where indirect steam reheat is used. As shown in Tables 1–3, the individual stage and cumulative conversions are fairly similar amongst all three cases—the real difference is in the recovered sulphur. Between the steam reheat base case and the AAG inline burner case, there is little difference. However, the hot gas bypass case shows a shift in where the sulphur condensing load is being placed. As the unit is turned down, there is more gas being bypassed to Converter 1 inlet to provide heat due to overcooling of the gas in the first pass of the waste heat boiler. This causes more of the converted sulphur to make its way around the first condenser and end up in the second condenser.

In the end, there are only minor differences in the way these three units actually perform provided they are being operated properly. Because these reheat options are being used only on the first stage, the second stage is able to pick up the remainder and bring the unit to a similar overall performance. The decision between which method to use really comes down to what the objectives of the plant are, the available utilities, and the feed conditions.

	Thermal Stage		**1st Stage**	**2nd Stage**
	WHB	**C1**	**C2**	**C3**
Conversion %	58.3		71.91	42.59
Cum. Conv. %	58.3		88.29	93.28
Recovery %	6.48	50.47	30.14	5.32
Cum. Recov. %	6.48	56.95	87.09	92.41

Table 1. Steam Reheat at 30% Turndown

	Thermal Stage		**1st Stage**	**2nd Stage**
	WHB	**C1**	**C2**	**C3**
Conversion %	58.3		71.74	42.60
Cum. Conv. %	58.3		88.22	93.24
Recovery %	5.22	40.56	41.18	5.36
Cum. Recov. %	5.22	45.78	86.95	92.31

Table 2. Hot Gas Bypass Reheat at 30% Turndown

	Thermal Stage		**1st Stage**	**2nd Stage**
	WHB	**C1**	**C2**	**C3**
Conversion %	58.3		71.63	45.30
Cum. Conv. %	58.3		87.29	93.05
Recovery %	6.27	50.65	32.18	6.08
Cum. Recov. %	6.27	56.92	86.07	92.15

Table 3. AAG Inline Burner Reheat at 30% Turndown

The objectives of the plant may dictate that the first converter inlet needs to be at a temperature that is beyond what high pressure (HP) steam can achieve. There could also be poor availability of HP steam. Heat soaks to remove liquid sulphur from catalyst becomes difficult to do with HP steam because of temperature limitations. These are just a few reasons why using either hot gas bypass or direct reheat may be a better option. If the incoming feed has a high level of contaminants, such as BTEX, then perhaps steam reheat is the option to use.

Using a reaction kinetics and rigorous heat transfer rate-based sulphur simulator, SulphurPro®, can help assess these different options and much more.

In the upcoming May issue of the Contactor™, we will investigate this subject a little further by including the different reheat options on all conversion stages rather than simply the first stage. Doing this will further highlight the key differences between the three options already discussed here.

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