The CONTACTOR™

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Layered Catalysts in the Sulfur Converter of a Claus SRU

The Claus converter is not restricted to using a single type of catalyst; in fact, different catalyst types activated using different protocols perform differently and they can even perform different tasks. The earliest catalyst used in sulfur converters was made of activated carbon stabilized with 6.6% silica. Activated carbon was followed by bauxite (the ore from which alumina is produced) as a catalyst but it was supplanted by activated Alumina (Al_2O_3) for a number of reasons, including higher mechanical strength, lower regeneration temperature, and better catalytic stability. Today, activated alumina is used in conjunction with catalysts based on titania (TiO_2). Although titania is more expensive than alumina, it is longer lived with better low-temperature reactivity toward high COS and CS_2 gases, e.g., Claus feeds generated from high CO_2 natural gas sources. The most recent addition is titania-CoMo catalyst. However, alumina is considerably cheaper than titania and is perfectly adequate for gases low in these contaminants so it continues to be used alone in much of the industry.

It has become common practice to layer different catalysts in the same bed. For example, expensive titania catalyst can be protected from catalyst poisons by placing a layer of alumina ahead of it. Figure 1 shows a three-converter layout using alumina and titania catalyst beds in a common vessel. The practice of layering different types of catalyst in a single Claus Converter vessel has been done for many years. Layering within a single converter can have several benefits.

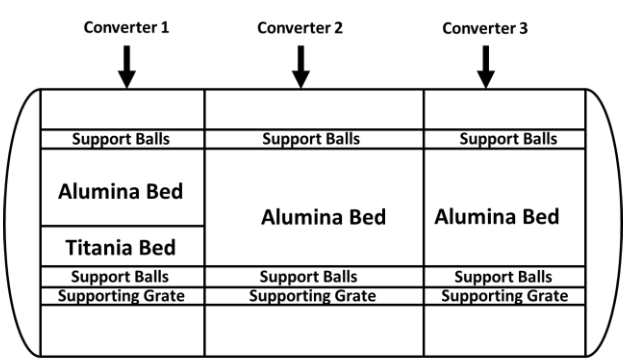

Figure 1 Single Shell Housing Three Converters, the First with a Layered Catalyst Bed

In Sulfur Recovery Units (SRUs) where CO_2 is a significant portion of the acid gas feed, such components as COS and CS_2 can become quite problematic. There are several strategies that could be put in place to deal with COS and CS_2. When using only alumina catalyst, one of these is to operate the first converter bed at an elevated temperature, using the first reheater to increase the temperature of the feed to the reactor. The preferred way of doing this is by indirect (steam) reheating which requires the availability of high pressure steam.

Reheaters are controlled based on the converter's inlet temperature. In this case, in order to achieve adequate or acceptable COS and CS_2 conversion using alumina catalyst, the first converter outlet temperature would need to be on the order of 650°F (343°C). The problem with this approach is the resulting low conversion of H_2S to elemental sulfur at such a high temperature in the first vessel, forcing the rest of the H_2S conversion to be achieved in the second and third (if the plant has a third) converter beds. While COS and CS_2 conversion is favored at high temperatures, the Claus H_2S conversion is favored at low temperatures. Thus, to deal with COS and CS_2, Claus conversion in the first converter is sacrificed. Figure 2 compares COS kinetics with alumina vs. titania catalysts at a high and a low temperature.

One way to get around the consequential sacrificing of first-bed Claus conversion is to use titania catalyst in the first converter bed. Titania catalyst is significantly more active towards COS and CS_2 and, as such, can achieve a similar conversion of these components at a lower temperature compared to alumina catalyst operating at a higher temperature. However, the relatively high cost of titania, makes filling the whole converter bed with only titania uneconomic. This suggests putting multiple types of catalyst into a single converter bed, i.e., layering the catalyst.

Titania is more active than alumina so less of it is needed to achieve a similar conversion. Thus, having a small layer of titania catalyst with alumina in the rest of the bed gives the benefit of higher COS and CS_2 conversion while still retaining the bulk of the converter bed with

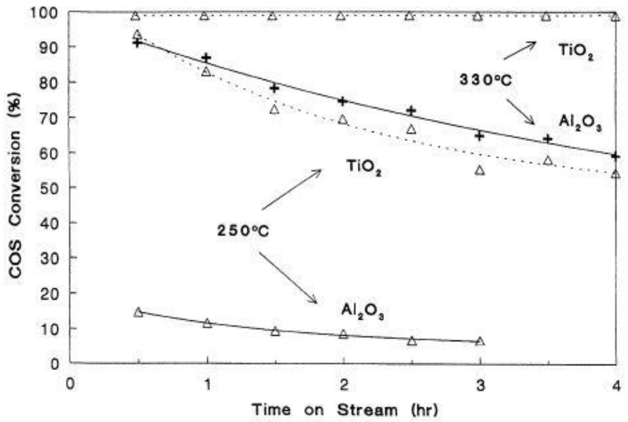

Figure 2 Effectiveness of Alumina vs. Titania in COS Hydrolysis†

more economical alumina catalyst. Where should the titania layer be placed?

There are several reasons for not using titania as the first layer:

- Although more active than alumina (see for example Figure 1), titania is also far more fragile and much more susceptible to deactivation. Contaminants entering the converter would contact the titania layer first and readily poison it. Titania is expensive so it would make sense to protect it from contaminants that may enter the converter. This suggests that it would be best to deal with the contaminants first by placing a layer of cheaper alumina ahead of the titania.
- Conversion of COS and CS_2 is favored by higher temperature for both alumina and titania. As the gas proceeds from the converter inlet the exothermic nature of the conversion reactions causes the gas temperature to rise through the bed. High temperatures benefit COS and CS_2 conversion rates, and if titania catalyst is present there, rates will be fastest and the amount of titania can be minimized.

For these reasons, the bottom of the converter is the most logical placement for the titania layer.

Catalysts used for the Claus conversion of H_2S, SO_2, COS and CS_2 to elemental sulfur have generated a wealth of literature and form a fascinating area for the study of their chemistry, reaction kinetics and mechanism of action. But their now broadly known fundamentals, have not been well applied to simulation. Catalytic converters still receive only a rather broad-brush treatment.

SulphurPro® is a kinetics and heat transfer rate-based sulfur recovery simulator. It currently models alumina catalysts using reaction kinetics and diffusion rate-based calculations that account for catalyst size, shape, pore size and level of activity. Currently we are developing a model for titania catalysts on the same basis. In its next release, SulphurPro will also have the ability to model the benefit of layering multiple catalyst types within a single converter bed, all on a kinetics and bulk plus pore diffusion basis to make the accurate simulation of sulfur converters easier than ever before.

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† From P.D. Clark, N.I. Dowling, M. Huang, *Conversion of CS_2 and COS over alumina and titania under Claus process conditions: Reaction with H_2O and SO_2*, Applied Catalysis B: Environmental 31 (2001) 107–112.