The CONTACTOR™

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Internals for Claus TGTU Absorbers

Tail Gas Treating Units (TGTUs) are intended to remove relatively small amounts of H_2S from the back end of sulfur recovery units (SRUs) SRUs almost always have several converter-condenser pairs in series to convert H_2S and SO_2 into elemental sulphur and recover the elemental sulfur from each condenser. After passing through the final condenser in the series the final gas (tail gas) consists of mostly nitrogen, water vapor, CO_2, and unrecovered H_2S. To meet sulfur emission regulations the residual H_2S must be captured from the tail gas and returned to the SRU for conversion to sulfur.

After treating in the TGTU, the effluent gas typically contains 10–100 ppmv of H_2S in mostly nitrogen and this stream is then incinerated. The amine solvent (usually MDEA either alone, or spiked with an additive to enhance the solvent regeneration step) needs to remove only relatively small concentrations of H_2S, typically 2–3 mol%. The diluent is mostly nitrogen, usually with 2–3 mol% CO_2, and a similar amount of hydrogen with trace levels of inert gases such as argon and sometimes ammonia depending on the source of the original SRU feed.

Amine-based solvents have high chemical capacity for acid gases so gas with low H_2S content needs only a fairly small solvent flow to treat a large total gas volume. In other words, the L/G ratio in a TGTU is typically quite a bit lower than found in most acid gas removal units in natural gas service. Hydraulically, packing tends to be better suited to low L/G ratios than trays and additionally packing performs with much lower pressure drop, an important consideration with tail gas because inherently it is at not much more than 1–2 psig at its source. So at first glance one might lean towards packing as the preferred tower internal for a TGTU. But is this always the best choice?

Case Study

Table 1 lists the inlet gas and solvent composition, and their flowrates, temperature and pressure for a typical TGU. We will treat this as a design case with various specified column internals and columns sized for 70% of flood in all cases. The absorber was taken to contain 12 valve trays on 2-ft spacing or an equal depth (24 ft.) of random or structured packing. This is sufficient tray count or packed depth for the H_2S treating to be lean-end pinched and both types of internals produce a treated gas with 50-60 ppmv H_2S. The CO_2 slip however varies markedly with tower internals details, ranging from 81% with 350-size structured packing to 96% with multipass trays.

Although trays and packing are radically different in appearance, all tower internals nevertheless are intended to provide surfaces to support and facilitate the intimate contact between two phases, in this case a gas and a liquid. Trays provide a horizontal surface to support the liquid and perforations to allow passage of the gas through the liquid. Packing provides inclined surfaces to support a liquid film flow and to allow contact with the gas that flows adjacent and countercurrent to it.

Table 1 Stream Properties

Tail Gas Feed to TGTU	
Flow, MMscfd	12
Temp., F	100
Pres., psig	2
Composition (mol%):	
H_2O	Saturated
CO_2	3
H_2S	3
H_2	2
CO	0.01
N_2	91.99
Solvent Data	
Flow, gpm	400
Temp., F	120
MDEA, wt%	37

In all cases the objective is to provide a large interfacial area separating the phases, encouraging high transfer rates of material between them. The flux (rate per unit area) of components is determined directly by (1) the turbulence levels in the phases (because these affect phase mass transfer coefficients) and by diffusion coefficients, and (2) the concentration differences of components between the phases because these differences correspond to mass transfer driving forces. The transfer rate of components depends additionally on the interfacial area across which components must diffuse that exists within a local volume of packing or volume of froth between the trays.

Table 2 compares CO_2 slip and H_2S leak for several tower internals, along with the calculated diameter at 70% flood.

Table 2 Performance of Selected Tower Internals

Tower Internal	Diameter (ft)	CO_2 Slip (%)	H_2S Leak (ppmv)
1-Pass Valve Tray	6.11	92.2	53
2-Pass Valve Tray	5.69	94.7	49
3-Pass Valve Tray	5.57	96.2	49
Mellapak M125.X	4.16	94.2	131
Mellapak M170.X	4.48	91.3	51
Mellapak M250.X	5.06	85.8	48
Mellapak M350.X	5.28	81.1	47

These results are for a fixed flowsheet configuration (single absorber and regenerator combination) with all parameters (flow rates, reboiler duty, pressures, etc.) kept constant. At first glance the results don't look all that different from case to case. Certainly the H_2S leak from the absorber is fairly constant with the exception of the largest size (125.X) structured packing. Tower diameters are comparable although because of lower pressure drop, structured packing needs slightly smaller diameters, as expected. The performance parameter that varies the most significantly however, is CO_2 slip. Interestingly, 125.X packing shows the same excellent CO_2 slip as a 2-pass tray but its H_2S leak is nearly three times higher, mainly because there is insufficient contact area to put the absorber fully into a lean-end H_2S-pinch condition.

The interfacial (wetted) areas of the packings (in m^2/m^3) are close to, but not identical with, the numerical designation of the packing size (which is why the packings were designated as such in the first place). The interfacial areas of the froth between trays on the same per-unit-volume basis are only about 1/3rd to 1/6th of the packing areas. Therefore, one might expect to see packing remove up to several times the amount of CO_2 that the trays manage to capture. This is exactly what the slip results in Table 2 show. For example, 250.X packing removes 14.2% of the CO_2 but a 2-pass valve tray removes only 5.3% or roughly 1/3rd as much. Carbon dioxide is a diluent in the SRU feed and is also associated with COS formation in the reaction furnace of the SRU. Therefore keeping the CO_2 content of SRU feed as low as possible is beneficial, especially in an SRU fighting a capacity limit. H_2S removal, on the other hand, is nearly independent of what internal is used in the absorber. This is because H_2S treating in a tail gas unit is almost completely controlled by the solvent lean loading with respect to H_2S, not by mass transfer as it is for CO_2.

Incidentally, the physical (non-reacting) gas- and liquid-side mass transfer coefficients are about twice the value for trays as for structured packing in this example. So from a mass flux standpoint trays want to absorb acid gases with about twice the mass flux as packing; however, their interfacial areas are several time lower so the overall effect is for trays to absorb CO_2 at a slower rate, reject more CO_2 and therefore recycle less to the SRU. This means less COS formation and slightly reduced parasitic load on the SRU from non-sulfur containing species.

As Table 2 shows, trays with multiple passes can perform much better than a single pass tray and better than structured packing under the low L/G ratios typical of TGU absorbers. This is a consequence of the sprays that form on trays operating at low liquid loads. As discussed elsewhere[†], sprays have mass transfer characteristics that correspond to rigid drops with turbulent gas flows around them. This reduces liquid-side mass transfer coefficients and enhances gas side coefficients.

Table 3 shows that random packings such as the Intalox® family perform in this application at a level between a 2-pass tray and the high surface area (350.X) structured packing. Again, H_2S treating is lean-end pinched so it's unaffected by mass transfer. To get the best CO_2 slip, the largest packing should be used consistent with meeting the H_2S specification. Of course, performance will vary with the specific packing used.

Table 3 Performance of Some IMTP® Tower Packings

Packing Size	Diameter (ft)	CO_2 Slip (%)	H_2S Leak (ppmv)
25	6.0	80.4	48
40	5.7	85.5	48
50	5.1	89.5	48
60	5.0	91.5	49
70	4.8	94.1	51

Structured packing has been used successfully for many years in tail gas treating. However, that there is an associated cost seems not to have been as well-known as perhaps it should have been. On the positive side, structured packing shows very low pressure drop, important in low pressure treating such as TGTUs (and even more important in vacuum distillation). On the negative side, however, structured packing recycles a lot more CO_2 to the reaction furnace and places unnecessary load on the SRU as a whole compared with treatment using trays. In any event, TGU absorbers tend to be quite short (a dozen or fewer trays or 20 feet of packing) so pressure drop is usually not a truly serious constraint. The right size random packing, too, can offer performance similar to a multipass tray in this application. Random packing spans a range of CO_2 slips similar to structured packing. Another consideration is the effect of contamination by DEA and MMEA, reactive impurities commonly found in refinery amine systems. They have a quite profound effect on CO_2 slip although not on H_2S leak; but that a subject for another time. So what's the right internal?

The answer to this question depends on the detailed specifics of your unique application. What we've looked at here is just a typical case. But, with a database of 39 distinct trays and packings in every size manufactured, ProTreat® is perfectly placed to help you decide just what particular packing (or tray) and exactly what size should be selected to get the very best treating performance possible from your TGTU. And heat stable salts, phosphoric acid and amine contaminants offer no limitation because ProTreat simulates the effect of them all.

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

† Weiland, R.H. & Hatcher, N.A., *Overcoming Challenges in Treating Shale Gas*, Hydrocarbon Processing, January, 2012.