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Do Amine Absorbers Always Show a Temperature Bulge?

Normally, one expects an amine absorber to show a temperature bulge or peak. But is this always true, or are there operating conditions under which a bulge does not appear at all? What kinds of conditions are they? In The Contactor, *10* (7), July, 2016 we showed that a critical parameter especially determining the location of a temperature bulge is the Heat Transport Capacity Ratio (*HTCR*), defined as

$$HTCR = L\, c_p^L / V\, c_p^V$$

in which *L* and *V* are liquid and vapor flow rates and c_p is heat capacity, all in consistent units. In this issue of The Contactor we will use this parameter in a case study to explore one type of situation where there might not be a temperature *bulge* at all.

Case Study: H_2S and CO_2 Removal with MDEA

A very low H_2S gas with 2.33% carbon dioxide is to be treated using 50 wt% MDEA to meet pipeline specifications of < 4 ppmv H_2S and < 2% CO_2. On the face of it, this looks like a selective treating application, but it's not—at 6.38 ppmv H_2S, the raw gas itself almost meets the H_2S specification. The objective is to lower the CO_2 content from 2.33% to < 2.0% while removing only a couple of parts per million of hydrogen sulfide. The 60 barg, 60°C gas flows at 275 MMscfd.

The flowsheet is a completely conventional one, with the standard absorber, regenerator and cross-exchanger connected in the usual way. The *absorber* has 20 valve trays. It is to be designed for 70% jet flood and 70% downcomer choke flood. The *regenerator* also is being designed with 20 valve trays with the tower bottom at 14.5 psig. For this case study, the regenerator operating conditions are held constant.

This unit will be built in the Middle East where cooling is often problematic so the design assumes the lean amine is relatively hot at 65°C. Because so little acid gas needs to be removed from such a large gas flow, quite a low solvent rate will be adequate for its removal.

ProTreat® shows the target treated gas composition can be obtained with only 150 gpm solvent flow (Table 1). Higher solvent rates simply result in increased H_2S and CO_2 removal, at least until the solvent rate reaches about 300 gpm. For a reason to be discussed later, at that point the lean solvent H_2S loading jumps by a factor of nearly 20.

Table 1 Treating at Various Solvent Rates

Solvent (gpm)	H_2S (ppmv)	CO_2 (mol%)	Lean H_2S Loading	HTCR
100	4.61	2.06	0.0000004	0.084
150	3.65	1.92	0.0000008	0.129
200	2.67	1.79	0.0000016	0.175
250	1.65	1.66	0.0000042	0.221
275	1.22	1.60	0.0000094	0.246
300	3.91	1.56	0.00018	0.269
350	3.78	1.51	0.00019	0.318
500	3.35	1.41	0.00018	0.461
1000	3.33	1.38	0.00017	0.967

Figure 1 shows profiles of gas temperature at the indicted solvent rates. In every case, there is,

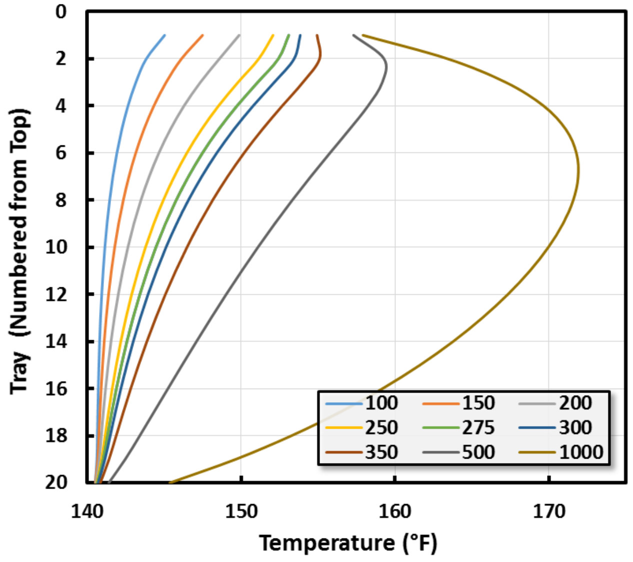

Figure 1 How Peak Gas Temperature and Profiles Depend on Solvent Rate

of course, a peak temperature but a true temperature *bulge* only starts to manifest at about 300 gpm and is fully in evidence by 350 gpm.

Table 1 also lists the Heat Transport Capacity Ratio, HTCR, at each solvent rate. Its value is always less than unity and is quite small indeed before there is any hint of a temperature bulge. At a value of HTCR of about 0.25 the temperature profiles shows a slight inflection and when HTCR reaches 0.46 a bulge is evident on the second tray. At a solvent flow of 1,000 gpm with HTCR at 0.97 there is a bulge temperature of 172°F on Tray 7. When the heat carrying capacity of the two phases are roughly in balance, the temperature bulge is somewhat centrally located. In the present example, the maximum is slightly above the mid-point in the absorber because the entering solvent is a little hotter than the entering gas.

Perhaps one surprise is how quickly the tower internal temperature appears to rise as the temperature bulge moves in towards the center of the tower. Figure 2 shows how the peak temperature (whether at the very top of the tower or internally away from its ends) rises with the absorption rate of CO_2, which itself is an increasing function of the solvent rate The left-most point in this plot corresponds to a solvent rate of 100 gpm and the right-most point is 1,000 gpm. As soon as temperature actually peaks *inside* the tower (see arrow in Figure 2), the temperature rise starts to depart from linearity with CO_2 absorption rate. Prior to this, the gas flow is so large relative to solvent flow that the gas pushes a great deal of the heat of absorption right out the top of the tower. However, once a temperature bulge develops inside the tower, the liquid flow is high enough to drive some of the heat of absorption back into, and down, the tower. Released heat of absorption starts getting trapped inside the column, and the higher the solvent rate the more heat gets trapped.

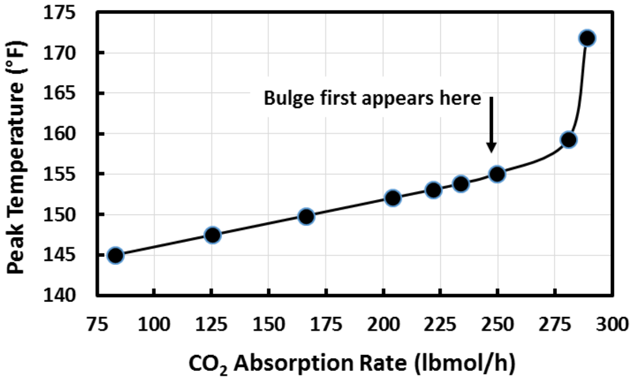

Figure 2 **Peak Temperature Correlates with CO2 Absorption Rate**

The other interesting revelation in Table 1 is that at 300 gpm the H_2S leak suddenly rises from 1.22 to 3.91 ppmv. Hydrogen sulfide absorption is lean end pinched, being set by the H_2S loading of the lean solvent. Loading experiences a factor of 20 rise when the solvent flow reaches 300 gpm. This is a consequence of the regenerator being asked to strip ever higher solvent flow with exactly the same reboiler duty (BTU/h). Eventually, the steam flow in the regenerator collapses, first becoming barely sufficient to heat the rich feed to its bubble point at regenerator pressure, then failing to raise the liquid much above the feed temperature. Figure 3 shows how the flow rate of stripping steam is affected by the unmet energy demand of higher solvent flow.

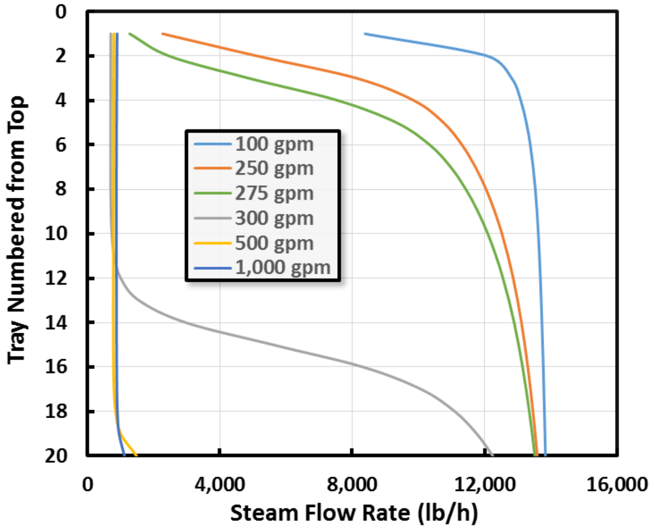

Figure 3 **Stripping Steam Flow in the Regenerator at Several Liquid Loads**

The reason for the sudden increase: the solvent flow has reached the point where the limited reboiler duty can't sustain adequate flow of stripping steam through much of the tower. Stripping falters and lean H_2S loading rises. The change is sudden because the collapse of the steam flow is rapid.

Lessons: (1) At the low liquid rates needed for minimal acid gas removal there may not be a temperature bulge at all; (2) HTCR is a good indicator of where and whether a temperature bulge may appear; (3) The ProTreat® mass transfer rate model can reveal a lot about unusual treating situations.

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