The CONTACTOR™

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Stability Limits for Amine Regenerators: Reboiler Duty

As pointed out in the July, 2011 issue of this publication, amine regeneration is possibly the most neglected part of gas treating plant operation, yet this is precisely where solvent lean loadings are determined. The ability of most plants to meet treating goals hinges directly and critically on solvent lean loadings.

Most amine regenerators are operated with enough boilup to provide a reasonable flow of condensable† stripping steam to every tray or all the packing in the column. Sometimes, however, regenerators are purposefully operated with such a low flow of energy to the reboiler that only the lowermost trays receive condensable stripping steam. This seems to be especially the norm for post-combustion carbon capture plant designs where absolute minimum stripping energy is paramount. It occurs frequently when the CO_2 section of an ammonia plant is retrofitted with activated (piperazine-promoted) MDEA — the regeneration column itself becomes almost superfluous.

As we will see, the transition from over-boiled to under-boiled can be rather sudden, leading to unexpected plant instability‡. The transition can from throttling reboiler energy (steam, hot oil) flow. It can equally well be caused, for by increased solvent load on the regenerator or by gradual loss of heat transfer efficiency in the cross exchanger, perhaps as a result of fouling, and leading to colder-than-intended rich amine entering the regenerator (see the July, 2011 issue). Here we look at the effect of reboiler duty on regenerator performance.

† As long as there is a vapor flow to a tray, the tray will see a nonzero water concentration; however, the water content may not be adequate to transfer any heat to the liquid via condensation. Normally, regenerator vapors have high water content and stripping energy is provided by steam condensation.

‡ Here instability does not imply inoperability. It means an unexpectedly large change in a performance variable caused by a change in a control variable.

The rigorously-fundamentals-based science and engineering used in the ***ProTreat***™ process simulator so accurately models a plant's internal workings as to make ***ProTreat*** itself a virtual plant. The simplest and most accurate way to explore such instability is by applying ***ProTreat*** simulation to the same example as in the July, 2011 issue.

Case Study

The 20-tray regenerator with kettle reboiler is stripping a 32,000 lb/hr, 50 wt% MDEA solvent loaded with H_2S and CO_2 to 0.28 and 0.23 mol/mol, respectively. This 2-ft diameter column is fed on the third tray from the top and operates at a head pressure of 0.95 kg/cm^2(g) (13.5 psig). We ask how performance responds to reduced energy input as measured by decreasing reboiler duty

The fixed feed temperature for this particular case is 210°F. Simulations were run with reboiler duties from 2.25 MMBTU/hr to 5.0 MMBTU/hr (660 kW to 1.46 MW). Figure 1 is a set of typical regenerator temperature profiles as a function of reboiler duty. It shows that when reboiler

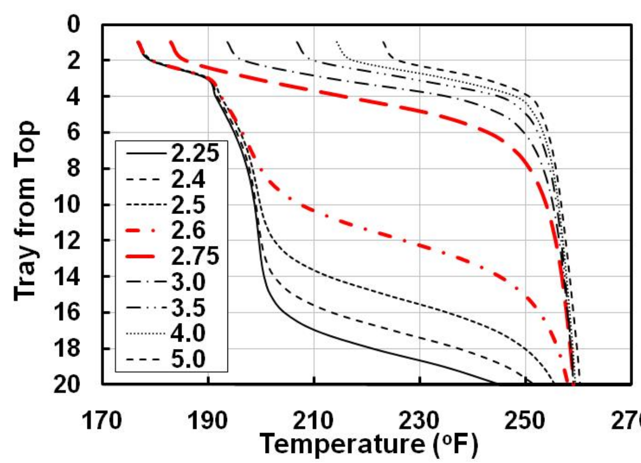

Figure 1 Effect of Reboiler Duty on Regenerator Temperature Profile

duty is lowered from 2.75 MMBTU/hr to 2.6 MMBTU/hr (805 to 761 kW), a reduction of 5%, the temperature profile starts to collapse. The collapse is essentially complete with a further 4% reduction.

Figure 2 shows how solvent lean loadings change in response. There is a very sharp rise in H_2S lean loading and a sharp drop in CO_2 loading, albeit by a small amount in absolute terms (0.0003 loading units). The rise in H_2S loading however is certainly enough to put most H_2S treaters out of compliance and ensure the produced gas is hugely off specification. The cause is the same as with regenerator feeds that are too cold. In the vicinity of the temperature collapse, the flow of condensable stripping steam (which supplies the heat required for stripping) is pretty much used up and there is nothing left to do any further stripping, or even to heat the feed to the bubble point. As a result, the feed flows down the column at the same temperature it had when it entered, until it finally meets a little steam and is able to begin to be heated. By this time, however, most of the column has been traversed by relatively cold amine. In fact, it is so cold it actually absorbs much of the H_2S that was stripped on the bottom trays and the reboiler.

Figure 2 Effect of Reboiler Duty on Solvent Lean Loadings

The abnormally high H_2S content of the solvent throughout most of the regenerator causes elevated CO_2 equilibrium vapor pressures. This enhances CO_2 stripping by increasing the partial pressure driving force. In other words, the improvement seen in Figure 2 is strictly the result of H_2S absorption in the stripper pushing CO_2 out, just as the vapor-liquid equilibrium says it must. However, the CO_2 loading is decreased by only a small absolute amount. Note that because it is the higher H_2S level in the solvent that causes elevated CO_2 vapor pressure (and better CO_2 regeneration), lower CO_2 lean loadings at lower regeneration energy levels will *not* occur in the absence of a substantial amount of H_2S in the solvent.

These results also provide a caveat for the general rule-of-thumb regarding desirable reflux ratio and stripping ratio values for various amine solvents. For example, for MDEA a common rule-of-thumb is to use enough reboiler energy to provide a reflux ratio of around 0.8 (reflux ratio is the molar flow of refluxed water divided by the molar flow of acid gases in the overhead vapor). In other words, reflux ratio is used to set the reboiler duty. For the current example, Table 1 shows this corresponds to a reboiler duty of a little under 3.5 MMBTU/hr, corresponding to a feed temperature of 210°F.

Table 1 Reflux Ratio vs. Reboiler Duty

Duty (MMBtu/hr)	Reflux Ratio	Stripping Ratio
2.5	0.301	0.337
3.0	0.529	0.565
3.5	0.866	0.901
4.0	1.198	1.234
5.0	1.858	1.893

Table 2 shows the effect of regenerator feed temperature at a reboiler duty of 3.0 MMBTU/hr. It is evident that low feed temperature has the same qualitative effect on reflux (and stripping) ratio as too little reboiler energy does. Quoting a rule-of-thumb for reflux ratio presumes the feed is sufficiently hot. *The Lesson*: make sure the conditions are right for the rule-of-thumb to apply.

Table 2 Reflux Ratio vs. Feed Temperature

Feed Temp (°F)	Reflux Ratio	Stripping Ratio
185	0.128	0.163
190	0.153	0.189
195	0.185	0.221
200	0.226	0.262
205	0.375	0.411
210	0.529	0.565
215	0.681	0.717

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To learn more about this and other aspects of gas treating, plan to attend one of our workshops in Houston and Abu Dhabi in 2011-12. **On-line registration is now open**. For details please visit www.ogtrt.com/seminars.

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