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Where to Add Regenerator Energy

There are two distinct ways to increase the heat flow into the regeneration end of an amine unit: preheating the rich amine feed to a higher temperature, and putting more heat into the reboiler to increase boilup rate. Which is the most effective in promoting deeper stripping? Is the answer different if cost effectiveness is a concern?

Where Stripping Takes Place

To begin answering these questions, we have to decide where stripping is actually taking place. More often than not, the hot rich feed to an amine regenerator is at a higher pressure than the tower—it is somewhat superheated because it flashes upon entry to the column. A flashing feed is frequently the case even when the feed is at only 190°F (88°C) and the column pressure is at the typical value of 12–18 psig (0.8–1.2 barg) because the partial pressure of dissolved acid gases can be substantially higher than the vapor pressure of water at the same conditions†. Cold reflux water from the condenser sometimes mixes with the rich amine feed but by the time they are even contacted, the feed has already flashed. It flashes as it leaves the feed nozzle and distribution pipes. Mixing with cold reflux will cool the preheated feed and it may require several trays or feet of packing to bring the mixture up to the boiling point and, all the while, acid gases may be undergoing *absorption.* After that, stripping of acid gases can really take place, and it continues down the rest of the stripping column.

Most of the heat is added to the column in the reboiler where stripping is completed and where steam containing (in a well stripped solvent) a little acid gas is generated. It turns out that in practice a large fraction of acid gas stripping takes place in the reboiler; however, one would be well advised to limit stripping in the reboiler, unless stainless metallurgy is used.

As the vapor flows through the regenerator it continues to strip acid gases from the solvent so that by the time it approaches the feed tray or distributor its acid gas concentration should be fairly high. If the combined feed and reflux is too cold, water vapor may condense into the solvent taking already stripped acid gases with it and generating a local solvent stream that is actually more heavily loaded than the feed. This sets up an internal recycle of acid gases that must be repeatedly stripped and the stripping steam then gets used to heat the feed instead of stripping out acid gases as intended.

Feed Preheating

Heating the rich amine feed is usually done in a cross exchanger where the hot lean amine transfers heat into the cold rich feed. The amount of heat that can be transferred, i.e., the extent to which the rich feed can be heated, is limited by the surface area in the exchanger. So once a plant is built there is little or no opportunity to adjust feed preheating. However, in the design phase, heat exchanger area can be adjusted to achieve the desired preheat, but only with a resulting increase in capital expense. Only rigorous simulation and careful economic evaluation of each individual case will reveal whether such an approach is cost effective. However, such an approach will certainly result in deeper stripping simply because more energy is being applied to the system. But is that an effective place to apply it? Again, rigorous mass-transfer rate-based simulation is the most reliable tool to help answer this question. There are no rules-of-thumb; answers are very much dependent on system specifics.

Increasing Reboiler Energy

When more energy is fed into the reboiler, the extra vapor generated acts on the liquid flowing across every tray in the tower, and over every piece of packing. This increases stripping rates not only in the reboiler, but everywhere else in the tower, too.

† Flashing will occur when the total pressure exerted by the solution exceeds the system pressure. The total pressure of the solution is the sum of the partial pressure of all its components, including water, amine, acid gases, and dissolved hydrocarbons and inert gases.

However, as the following example shows, sometimes regenerator operation can be extremely sensitive to both feed preheat, and reboiler energy input, making rules-of-thumb hard to apply.

Case Study

The plots shown below are for a particular instance of CO_2 removal in which the plant was being operated under three scenarios:

- Design conditions (Design)
- Maximum throughput (Case 1), and
- Maximum throughput *and* with minimal reboiler energy flow (Case 2).

In Case 1, the gas processing rate was increased by 10% over design and the steam flow to the reboiler was decreased by 3%. The increased gas processing rate caused the temperature of the now higher amine flow to drop by 15°F and the simulated temperature profile changed from the solid to the dotted curve. The change in temperature profiles may not seem like a large amount; however, the effect on stripping was substantial. As Figure 2 shows, solvent loading actually *increased* over the top two stripping trays. This is a harbinger of things to come. Nevertheless, the final lean amine loading leaving the reboiler rose from 0.13 to only 0.14 mol CO_2 / mole amine, a fairly small change in the context of the operation of this plant.

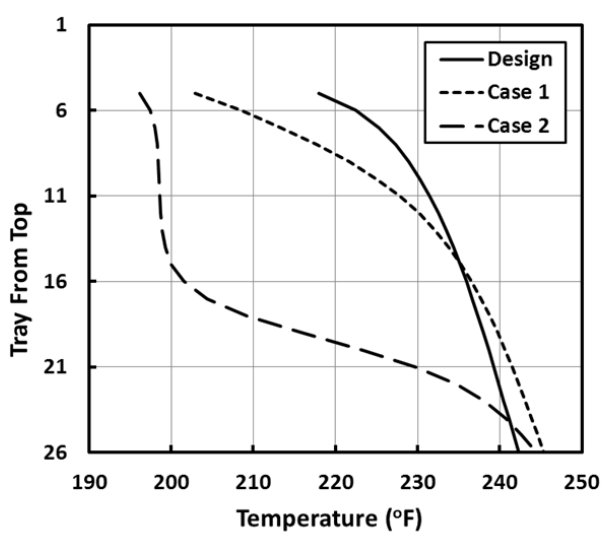

Figure 1 Regenerator Temperature Profiles

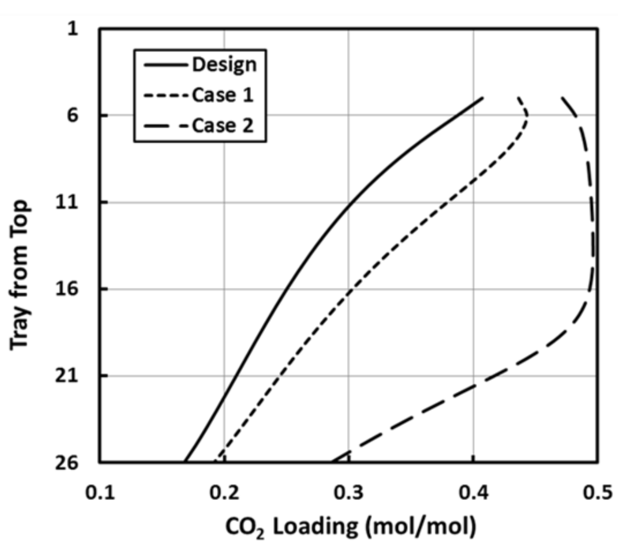

Figure 2 Regenerator CO_2 Loading Profiles

The effect of decreasing the reboiler energy input by a further 5% (8% decrease from the original design value) in Case 2 was more telling. Figure 1 shows that the temperature profile collapsed and Figure 2 shows the loading *actually increased* over the top ten stripping trays. Only by tray 18 (from the top) had solvent loading fallen to the value that first existed on the feed tray. The lean amine loading leaving the reboiler was now 0.2 mol/mol. Operating the regenerator under these conditions was unsatisfactory from the standpoint of CO_2 stripping, and it turned out to be problematic from a corrosion standpoint, too.

This example demonstrates that rich amine preheat is not something that's easy to control and adjust except by manipulating other process variables such as solvent flow rate. Varying solvent flow rate can have a measurable effect on gas processing rates, and it can also affect how cleanly one can strip the solvent. But reboiler duty is more likely to influence stripping to a greater extent than rich amine feed temperature. All of these effects however, can only be determined reliably using a high fidelity process simulation tool applied to the particular case at hand. The ProTreat® mass transfer rate-based simulator is the premier tool for this kind of task.

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