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Improve Deep CO_2 Removal with Intercooling

Plant capacity and energy usage are frequently optimized by using minimum operable solvent flow rate and running the regenerator with the lowest reboiler duty consistent with achieving adequate lean solvent loading for treating objectives. Special flow sheet arrangements are also used to minimize energy consumption. It is known that under such circumstances the absorber may be operating precariously close to an unstable region where only a relatively slight change in one operating condition or another in the wrong direction can cause treating to be missed *without warning* by a very wide margin. The primary manifestation of the onset of such a treating failure is the sudden development of a temperature bulge spanning a large part of the absorber's height.

In a tightly designed plant operation, small design errors and small excursions in flow or composition may force one to operate sufficiently far enough away from the original design point so that the instability will not manifest; thus, capacity may be unknowingly limited to less than the original design gas rate. Furthermore, a tight design may make it impossible to process a higher carbon dioxide content gas or to process at a higher throughput without significant and costly changes to equipment. This issue of The Contactor™ presents an inexpensive way to overcome the mass transfer limitation imposed by bulge pinching and to design a CO_2 removal section needing lower solvent flow rates and smaller equipment.

Case Study: CO_2 Removal in a Gas Plant

A very broad temperature bulge is an indication that the gas and liquid in the bulge region of the tower are very nearly in equilibrium with respect to their carbon dioxide content. A case in point is Figure 1 which shows the simulated temperature profile together with the actual and equilibrium carbon dioxide concentration profiles in a 25-tray column. The absorber is treating 75 000 kg/h of gas having 3% CO_2 in methane at 40°C and 65 barg. The solvent flow is 80 000 kg/h of 45 wt% MDEA and 5 wt% piperazine at 45°C.

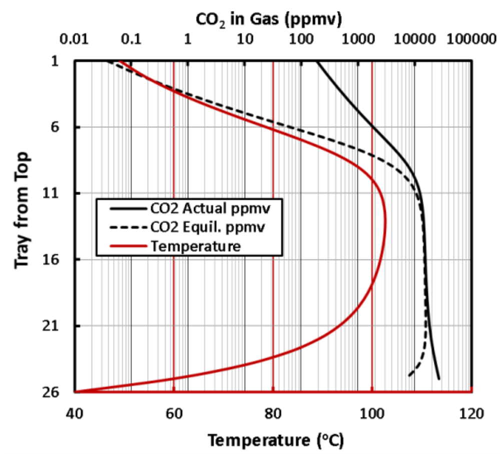

Figure 1 Temperature and CO_2 Profiles in a 25-tray Absorber without Intercooling

The peak temperature is over 100°C, and where the temperature is high (trays 10 through 20) the driving force for absorption is essentially zero. Away from the bulge region there is adequate concentration difference between the actual (solid line) and equilibrium (dashed line) carbon dioxide concentrations in the gas for there to be rapid absorption. However, the bulge region embraces 40% of the trays in the column. Thus, with only 60% of the trays remaining and actually active, the gas can be treated to only 186 ppmv CO_2, not nearly adequate for LNG. Sensitivity to solvent rate indicates the solvent rate is marginally too low. (In fact, the 50 ppmv CO_2 specification lies almost exactly in the region of greatest sensitivity

The root of the problem is the temperature bulge which, in this case, is itself caused by insufficient solvent flow rate. If the circulation pumps are already at capacity, circulation rate cannot be increased. A second approach might be to try to deal with the temperature bulge directly by using inter-tray solvent cooling. Although more costly than pump replacement, it is worth looking at this approach from a different perspective. The rich solvent is loaded to only 0.31 moles of CO_2 per mole of total amine so there is a lot of residual, unused solvent capacity. Would lowering the bulge temperature unload the absorber by permitting a much lower solvent flow rate and using more of the solvent's capacity? Would lowering the bulge temperature increase treating capacity? Such questions have been address qualitatively in the patent literature (US 8,790,453 B2 to Baburao & Schubert, 2014), but the best quantitative answers come from ProTreat® rate-based simulation.

Figure 2 shows the cooling configuration used to study these questions. Simulations were run with hot solvent drawn from any one of several trays from Tray 12 through Tray 20, as enumerated

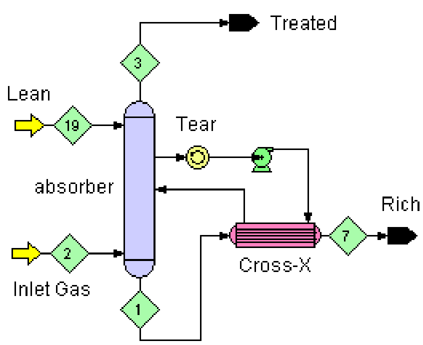

Figure 2 Inter-tray Cooling Arrangement

from the top of the column, cooled, and then returned to the tray immediately below. Preliminary investigation via ProTreat® simulation indicated that drawing the entire solvent flow from mid-column and returning it at 50°C would allow the solvent flow to be reduced by 25% while achieving a treated gas with only 10 ppmv CO_2. Although not studied for this brief note, the reduced solvent flow will have the added benefit of substantially lowered reboiler duty as well as smaller equipment — a reduction in both CAPEX and OPEX. Furthermore, using the absorber bottoms as the exchange medium does not burden utilities cost because it entails no additional cooling water. The only requirement is a cross exchanger. Solvent circulation can even be gravity driven. It remains to locate the draw tray.

Figure 3 shows how insensitive treating is to draw tray location. At a flow of 60 000 kg/h, drawing from anywhere in the bulge region is effective in producing a gas well below the 50 ppmv CO_2 specification, *and using 25% less solvent*. Even at only 55 000 kg/h (31% less solvent), a satisfactorily treated gas still can be produced. Coincidentally, in these two cases, the solvent is also being much more effectively used—the rich loadings are now 0.41 and 0.45 mol/mol, respectively.

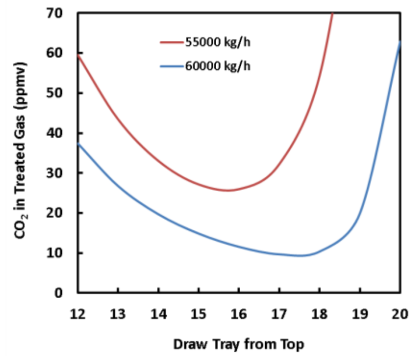

Figure 3 Sensitivity to Draw Tray Location

Lowering the size of a temperature bulge by properly applying inter-tray solvent cooling can be used to improve treating greatly. Figure 4 shows that solvent cooling works by lowering the equilibrium partial pressure of CO_2 over the solvent in the region of the temperature bulge, i.e., by generating more favourable equilibrium conditions. This results in the creation of good concentration driving force for absorption where previously there was none. There is now absorption over the whole column, and peak temperature is much reduced. A huge benefit can be enjoyed at almost trivial cost.

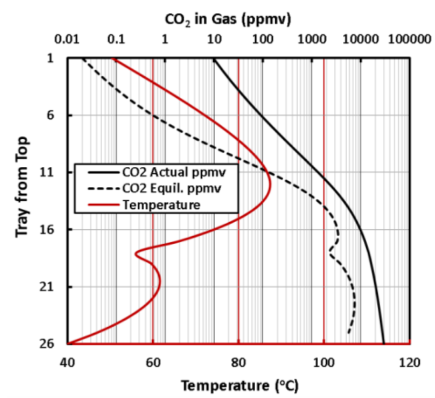

Figure 4 Profiles with Intercooling to 50°C at a Solvent Rate of 60 000 kg/h

This kind of study requires mass transfer rate-based simulation of the performance of absorbers in deep carbon dioxide removal applications using piperazine-promoted MDEA. ProTreat® is virtually the only commercially available simulator with a proven performance record modeling piperazine-activated MDEA in LNG and syngas applications.

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

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