The CONTACTOR™

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CO_2 Absorbers in LNG Production — Design Pitfalls: Temperature Control in a Split-flow Absorber

To prepare gas for liquefaction, its CO_2 content typically is reduced to 50 ppmv or below by absorption into an amine treating solvent. Most solvents are based on *N*-methyldiethanolamine (MDEA) promoted with lesser amounts of piperazine, although 2-(2-aminoethoxy)ethanol, known commercially as Huntsman's DIGLYCOLAMINE® agent (DGA®) and BASF's ADEG, has found use in this application.

Split-flow plants can be especially sensitive to departures from normal operating conditions, to the extent that even a slight change in a crucial process parameter can lead to failure-to-treat by a very wide margin. In these cases, small changes do *not* lead to the expected small responses in performance. There are several pitfalls in designing the CO_2 removal system: One of them is excessive semi-lean solvent temperature.

Case Study: Split-flow LNG Plant

This particular case involves the CO_2 removal section of an LNG plant using piperazine-promoted MDEA to remove carbon dioxide from predominantly methane to below 50 ppmv. We will focus on the absorption side of the process. Although it could have been built as a single tower with a mid-tower solvent flow of semi-lean (partially stripped) amine, the absorption section was actually built as two towers in series, as shown in Figure 1.

Rich solvent flows through a cross-exchanger to the regenerator where it is contacted with steam stripping vapor generated in the regenerator's reboiler. The regeneration section is not shown, but the largest part of the solvent is withdrawn after flowing only part way down the regenerator. It is used in the absorber labeled **Bulk Removal**. This solvent has undergone only limited stripping so its carbon dioxide content is still fairly high. However, really well stripped solvent is unnecessary for *bulk* CO_2 removal where the objective is to remove most of the carbon dioxide without achieving anything like the <50 ppmv specification. The 50-ppmv specification is met by the **Polishing** absorber downstream where a relatively small flow of very *well-stripped* solvent is all that is needed to remove the remaining carbon dioxide and meet the final CO_2 specification.

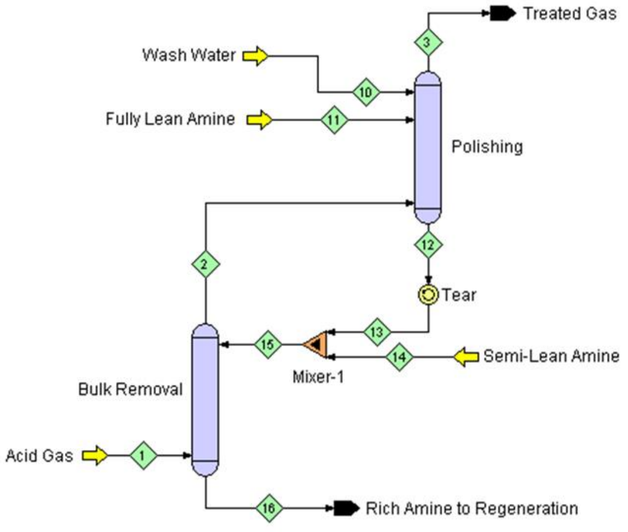

Figure 1 Absorption Side of a Split Flow Unit for Removing CO_2 to < 50 ppmv

The 4-m diameter **Polishing** column in this case contains two 5.5-m beds of 25-5 Hiflow Rings while two 1-pass bubble cap trays with 50-mm weirs serve as wash trays to remove entrained and vaporized amine from the final treated gas. Wash water usage is 4055 kg/h at a temperature of 50°C. The **Bulk Removal** absorber is 6-m diameter with two 5.5-m deep beds of 50-5 Hiflow Rings. Table 1 shows the flows, temperatures, pressures, and compositions of the four inlet streams. Solvent carbon dioxide loading is in moles of CO_2 per mole of total amine (MDEA + piperazine).

Table 1 Inlet Stream Flows & Compositions

	Raw Gas	Wash Water	Fully Lean	Semi Lean
Temp., °C	78.2	50	48	**Variable**
Pres., bar(g)	45	45	45	45
Flow - kg/h	328,000	4,055	768,800	4,477,000
Composition				
Water	Satur'd	100%	–	–
CO_2 (% / load)	17.5%	0	0.021	0.388
MDEA, wt%	0	0	37	37
Pip., wt%	0	0	3	3
CH_4, mol%	82.5	0	0	0

The plant was unable to meet the CO_2 specification by several *thousands* of ppm. The clue was an undersized semi-lean cooler combined with very hot ambient air (coolant) that resulted in a minimum attainable semi-lean temperature of about 80°C, some 10°C higher than the process licensor's recommended maximum of 70°C.

A simulation study of this plant was carried out using the ProTreat® mass transfer rate-based simulator. As the simulation results of Figure 2 show, there is a critical temperature of about 76.8°C above which treating is predicted to fail precipitously. At that temperature the **Bulk Removal** absorber becomes thoroughly rich end pinched to the extent that it is fully saturated with dissolved carbon dioxide. The approach to equilibrium at the rich end of the absorber reaches virtually 100%. Any further increase in semi-lean solvent temperature reduces the solvent's capacity and the excess CO_2 that cannot be absorbed spills over into the **Polishing** column. Unfortunately, the spill-over is of such an amount that the **Polishing** column cannot quite cope with the extra carbon dioxide, and the treated gas quickly fails to meet specifications. This happens without warning!

The reason for the failure is shown in Figure 3. It can be seen that as the semi-lean temperature rises, the CO_2 profile in the **Polishing** column goes from a typical lean-end pinched shape (72, 74, 76°C), where most absorption occurs close to the column base, to a typical rich-end pinched form at 76.85 and 77°C. At 76.75°C the CO_2 profile is changing position in the column extremely rapidly. "Inadequate column internals" was the first reaction of the process operators, but the real cause was a lot more subtle. One does not normally expect a temperature change of a few degrees to cause a huge performance loss. The mantra of small-change-small-effect is affirmed by the flatness of the curve to the left of 76°C in Figure 2 and by the very small response of the carbon dioxide profile to temperature changes below 76°C in Figure 3. But, there is an extremely rapid change from lean-end to rich-end pinch conditions around the cut-off temperature. This unheralded, causative change is revealed by ProTreat's rate-based simulations.

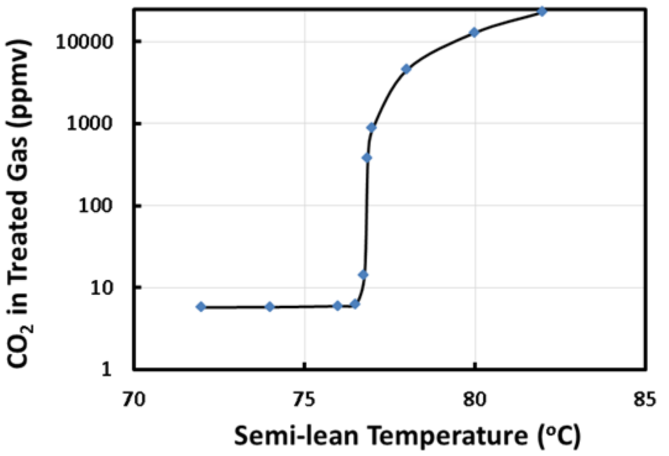

Figure 2 **Effect of Semi-lean Temperature on Treated Gas CO_2 Content**

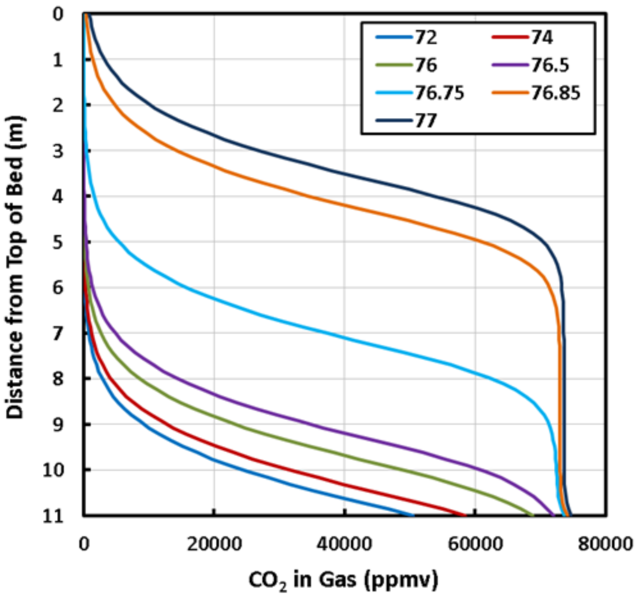

Figure 3 **Effect of Semi-lean Temperature on Treated Gas CO_2 Content**

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