The CONTACTOR™

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Pinch Analysis of a TGTU Absorber

Acid gas absorbers in amine treating systems very often operate in what is called a pinched condition. The pinch may occur at the lean end (top) of the absorber or at the rich, or bottom end, or even in the middle. It all depends on the specifics of the solvent and on the operating conditions of the unit.

An absorber's operation is pinched when the driving force for absorption virtually disappears somewhere inside the tower. In many cases involving the simultaneous absorption of carbon dioxide and hydrogen sulfide a selective solvent is used remove as much of the H_2S as possible and reject or slip most of the CO_2. In such cases, the absorber will tend to operate in a **lean end pinched** state *with respect to H_2S*. This means the difference between the actual concentration of H_2S in the gas and its concentration in the gas that is in equilibrium with the solvent—at the same elevation in the column—is so small absorption can no longer take place. Absorption has become pinched off.

Systems using solvents for deep CO_2 removal (e.g., MDEA promoted with piperazine for ammonia syngas and LNG treating) need a solvent that is highly reactive towards CO_2. In such cases, absorbers can become lean end pinched with respect to CO_2. They can also become pinched around the temperature bulge in the middle of the column.

In CO_2 capture, a rich end pinch is common because this is the way that fractional CO_2 removal is limited and controlled. Solvent flow rate is throttled back so the rich solvent is saturated to limit removal. In other words, the capacity of the solvent is manipulated via flow rate to control the total fraction of CO_2 that can absorb. If too much CO_2 is being removed the solvent flow (i.e., solvent capacity) is choked off a little which allows more CO_2 to pass uncaptured through the system.

In this issue of The Contactor™ we use the ProTreat® simulator in a case study to analyze the behavior of a TGTU absorber when solvent flow is varied over a fairly modest range. Performance goes from mass transfer rate controlled everywhere, to lean-end pinched in H_2S. Simulated temperature profiles, which is an excellent tool to start diagnosing absorber problems, show great sensitivity to solvent flow, and the treated gas H_2S level ranges from about 1 ppmv to 2,000 ppmv as solvent flow is varied. The solvent used for the study is a specialty solvent formulated specifically for selective hydrogen sulfide removal. The study originated with a ProTreat user.

Case Study: H_2S Removal Using a Formulated Solvent

Tail gas with 2.5% H_2S and 8% CO_2 (dry basis) enters the absorber at 38.5°C and 0.10 barg, water saturated from passing through the tail gas quench system. The gas flows at 22,500 Nm^3/h. The solvent is 45 wt% formulated amine and enters the absorber at 38°C. Its flow rate varies from 70,000 to 90,000 kg/h. The 2.4-m diameter absorber contains 8 metres of FLEXIPAC® 250Y structured packing. The regenerator is a 23-tray 1.5-m diameter column with a kettle reboiler at 1.28 barg and energy input constant at 5 MW.

The ProTreat® simulator was used to assess the absorber's performance and its response to various solvent flow rates, all other operating conditions remaining constant. Figure 1 shows how the treating level is simulated to respond to solvent

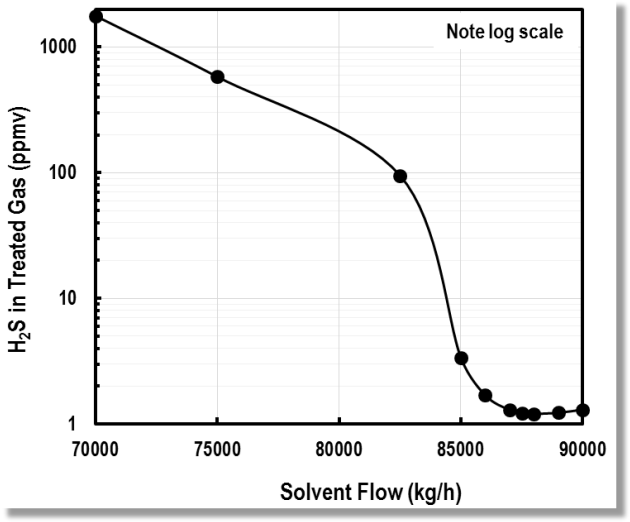

Figure 1 Effect of Solvent Rate on H_2S Removal

rate. There is a sharp decrease in H_2S leak from the absorber that starts at around 82,500 kg/h and starts tapering off above about 85,000 kg/h. Below 82,500 kg/h there is a slow steady response to increasing solvent rate just as one might expect (higher solvent flow implies more capacity for H_2S and larger interfacial area for absorption, hence, increased H_2S absorption). Above 86,000 the H_2S leak is unresponsive to solvent flow rate, remaining steady at an amazingly low value of between 1 and 2 ppmv.

The region between 82,500 and 86,000 kg/h contains what might be called an operation cliff because the transition between extremely satisfactory operation and completely unsatisfactory performance occurs over a pretty narrow range of solvent flow rates. It might be beneficial to elaborate on what causes the sudden change.

Figure 2 shows temperature profiles at five solvent flow rates. At high flows the temperature profiles taper off asymptotically to a linear rate of decrease at the top of the column. In fact, from about 85,000 to 90,000 kg/h temperatures approach and, at the top of the absorber, coincide with the temperatures that are simulated to exist in the complete absence of H_2S, i.e., with CO_2 absorption alone. This would indicate that H_2S absorption has virtually ceased in the top part of the column—absorber performance has become lean-end pinched.

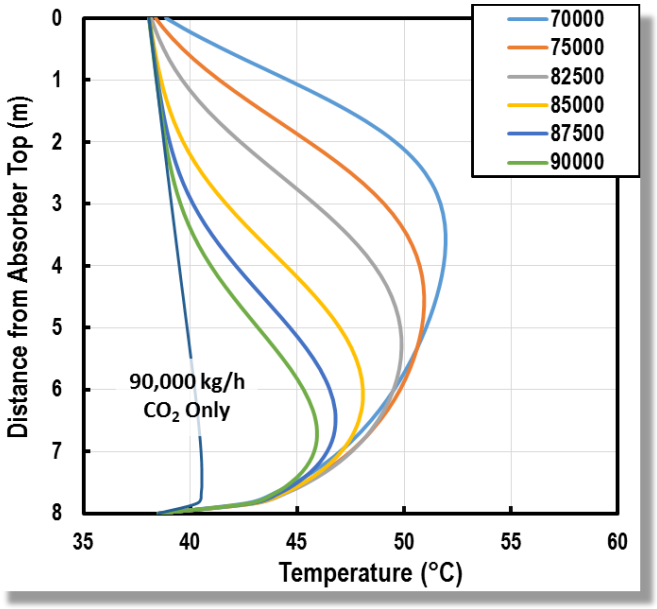

Figure 2 Temperature Profiles vs. Solvent Rate

At low solvent flows on the other hand, temperatures no longer asymptote to the CO_2-only case—and they are always higher. Thus, H_2S is being absorbed right across the entire column, and the absorber is not in a pinched condition.

The kind of behavior of tower internal temperatures described here is only indicative of mass transfer pinching. The term pinch refers to the situation when the actual and equilibrium partial pressures of a particular component approach each other so closely mass transfer can no longer take place—the concentration difference driving force for mass transfer disappears.

Figures 3 and 4 show vapor-phase H_2S concentration profiles at high and low solvent rates, respectively. At 90,000 kg/h (Figure 3) the pinch at the very top of the absorber is quite apparent and even at 86,000 kg/h there is barely a 0.1 ppmv concentration difference driving the absorption. At low solvent rates (Figure 4) there is a healthy concentration difference driving mass transfer and the absorber is certainly not pinched, at least not at the lean end. There is evidence of a pinch, however,

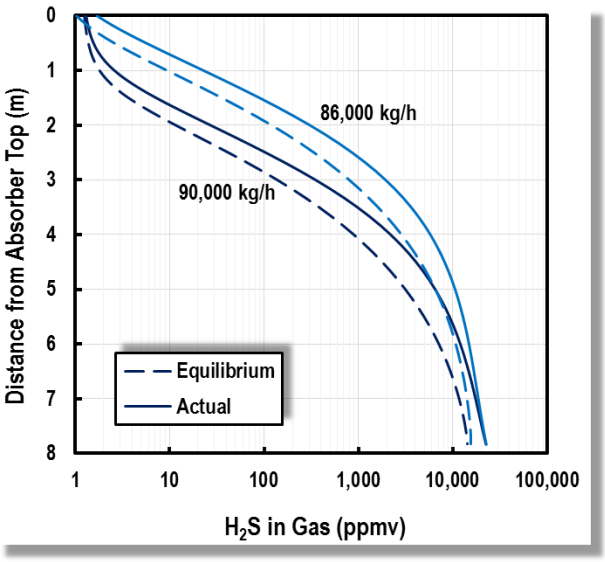

Figure 3 Lean-end Pinch at High Solvent Rates

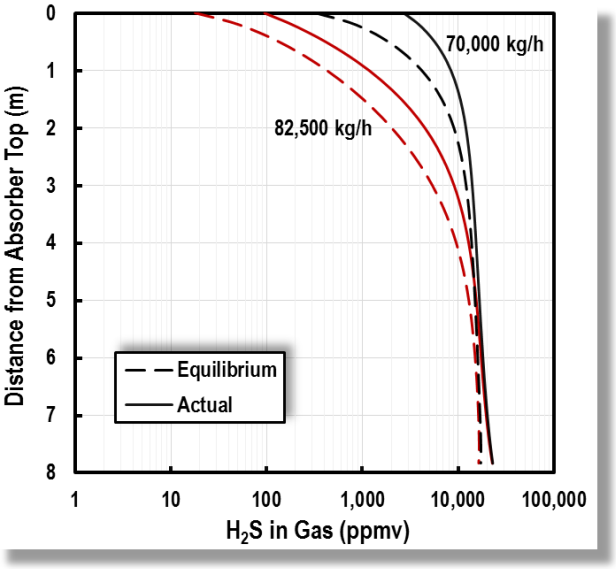

Figure 4 Mas Transfer rate Controlled (Not Pinched) at Low Solvent Rates

in the lower third of the tower.

As the solvent flow is decreased, operation slowly moves away from a lean pinched state (lower part of curve in Figure 1) and becomes mass transfer rate controlled. Near 82,500 kg/h H_2S pickup becomes strictly controlled by solvent capacity. Pinch analysis using ProTreat® simulation allows the performance curve to be predicted and understood.

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