The CONTACTOR™

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Characteristics of PCCC

Post-combustion carbon capture (PCCC) is a rather unique operation in gas treating for several reasons. First amongst them is the fact that although only about 90% of the CO_2 in the gas has to be removed, by gas treating standards the partial pressure of CO_2 at either end of the absorber is actually quite low. For example, to remove 90% of the CO_2 from a gas containing 5% CO_2 at one atmosphere total pressure, the CO_2 partial pressure in the treated gas will be 0.005 atm (0.07 psi). Compare this with the CO_2 partial pressure in the gas flowing to the compressor train in an LNG plant. If the treated gas is at 1,000 psi with 50 ppmv CO_2 the CO_2 partial pressure is 0.05 psi, fairly comparable to CO_2 capture.

At the gas inlet end of the absorber, however, the gas in the LNG plant is likely to be 10 mol% CO_2 with a CO_2 partial pressure of 100 psi, whereas, in a PCCC absorber, the CO_2 partial pressure in the raw gas might be only 1.5 psi — the average driving force for absorption in PCCC is vastly lower and the actual volumetric gas flow rate is enormously higher than most conventional gas treating situations. Therefore, solvent for PCCC needs to be much more favorably disposed to CO_2 absorption than in conventional gas treating.

Another difference between conventional gas treating and CO_2 capture is that conventional treating produces a valuable product (the treated gas) against which some of the costs of treating can be offset. CO_2 capture generally produces no such products so treating is just 100% costs without any possibility of recouping costs (unless there is a market for the CO_2 captured such as for use in enhanced oil recovery or beverage carbonation, or if carbon taxes are high enough).

CO_2 removal in PCCC is controlled and limited by using a low solvent flow rate and a high solvent loading. On the other hand, in conventional gas treating, CO_2 is controlled by lean loading. In other words, conventional CO_2 removal is lean end pinched — PCCC is always rich end pinched. The composition profiles in Figures 1 and 2 illustrate these differences. High solvent loading means rapid corrosion of carbon steel. This is especially the case in CO_2 removal because there is usually no H_2S present to passivate metal surfaces and mitigate corrosion rates. In

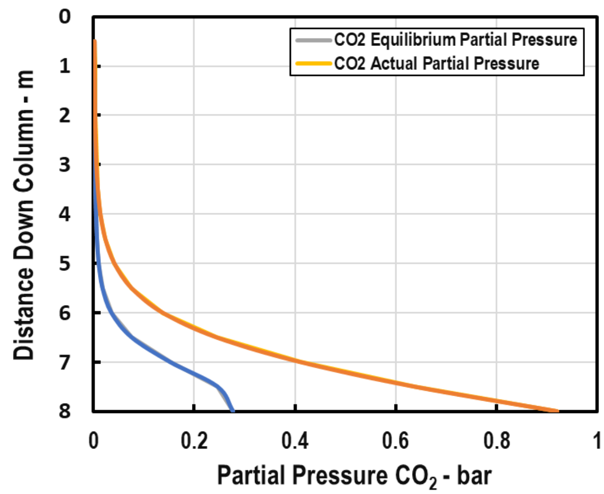

Figure 1 Typical CO_2 Partial Pressure Profiles in Conventional LNG Treating: Removal from 2% CO_2 gas at 62 barg with Piperazine + MDEA. Absorption rate is completely pinched (constricted) in the upper half of the absorber.

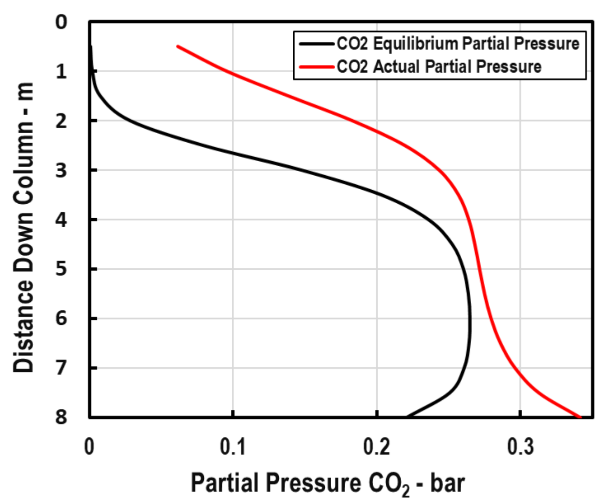

Figure 2 CO_2 Partial Pressure Profiles in PCCC: 90% CO_2 Removal from 40% CO_2 Landfill Gas at 0 barg Using Piperazine + MDEA. Absorption rate has low driving force in the bottom half of the column, so it's pinched there.

conventional treating one usually stays away from high loadings (<0.4). This strategy is not always possible in PCCC because operating with high CO_2 loadings can be integral to how the process is controlled and prevented from absorbing more than the nominal 85–90% of the CO_2 presented. In a conventional treating plant, columns processing high pressure gas are usually of reasonable diameter (up to 10 meters, so having to clad the inside of such a vessel adds to its cost but may not be a crippling investment in terms of the overall plant). Such vessels in PCCC plants however, are enormous and cladding can become prohibitive. In fact, the sheer size of a PCCC absorber points to concrete as a viable material of construction.

CO_2 absorption is controlled by the liquid-side resistance to mass transfer and chemical reaction lowers this resistance in proportion to the (square root of) the reaction rate constant. Because of the low CO_2 partial pressures throughout the absorber, fast reaction kinetics is needed for providing fast enough mass transfer (absorption) rates of CO_2 into the solvent. Without reaction, using a tertiary amine such as MDEA or a hindered amine such as AMP (used in CESAR1 solvent — now a ProTreat® option) provides mass transfer rates that are far too low to be effective for CO_2 absorption in PCCC. They would require an enormously tall column. The key in PCCC is lowered liquid-side, mass-transfer resistance through very fast reaction.

In conventional treating, the dominant concern is treated gas composition. In PCCC the dominant concern is cost, particularly of energy, and there's usually no product of value to absorb any of the cost. Fast reaction usually means piperazine as an additive to a tertiary (MDEA) or hindered (AMP) amine. Piperazine is fairly volatile so it is necessary to water wash the treated gas. Piperazine and other secondary amines also degrade in the presence of NO_X to carcinogenic nitrosamines. Furthermore, oxygen degradation and flue gases necessarily contain significant oxygen levels because of the need to use excess air in combustion processes. Therefore, attention must be paid to piperazine degradation.

Energy conservation through heat integration is very important in gas treating but it plays and even more important part in PCCC because energy consumption completely dominates operating cost. Many of the improvements to PCCC processes are the result of tweaks and improvements to process configurations that reduce operating costs.

Large gas flows necessarily mean higher solvent losses through vaporization and entrainment. Vaporization losses are directly tied to component vapor pressures which are a function of the reactive components in the (aqueous) solvent. The ideal solvent has active ingredients with zero vapor pressure. There is a whole class of such species, namely ionic components or salts. Examples are amino acids which, when activated with caustic soda or caustic potash, can be highly reactive towards CO_2, and they're ionic so have zero vapor pressure. Despite being completely nonvolatile, however, water washing the treated gas is one way to recover **entrained** solvent. And because absorbers are large diameter with high velocity gas flows, entrainment is anything but negligible.

The preferred tower internal is a large structured type packing. This keeps the pressure drop low and provides enough wetted surface area to effectively absorb CO_2. Unlike conventional treating where pressure drop is supplied by the gas, which is at high pressure itself, in PCCC the gas arrives at the treating plant at essentially atmospheric pressure (or the discharge pressure entering the power plant's stack. Pressure drop through the absorber, although measured in inches of water, must be supplied by a blower and because of the very high gas flow rates, the power requirement can be surprisingly high.

Flue gas from any source is hot and contaminated with combustion products, possibly ash in the case of coal firing, together with SO_2, nitrogen oxides, and oxygen. Oxygen causes amine degradation while SO_2 reacts irreversibly with amines permanently disabling their reactivity. SO_X are precursors of aerosols which can lead to greatly increased solvent losses, far exceeding losses through degradation and volatilization. Bag filters and so on can remove a substantial portion of the particulates but some invariably pass through to the amine system. Fine solids and other contaminants are a source of foaming so one should expect foaming might be an ongoing issue in a coal-fired PCCC plant. Corrosion is another issue and, in fact, hot amine solutions are more corrosive at low CO_2 loads than at high.

PCCC presents much the same raft of challenges as conventional gas treating, but in some cases some of the inherent weaknesses may be exacerbated. Critical characteristics include the inevitable presence of oxygen and more concerning, corrosion, as well as acidic contaminants such as SO_2 which permanently degrade the amine.

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