The CONTACTOR™
Published Monthly by Optimized Gas Treating, Inc.
Volume 11, Issue 10, October, 2017

Packing Size and Ammonia Syngas Absorber Temperatures

In the August, 2016 issue of The Contactor (Vol 10, No 8) we showed some surprising effects of packing size on the performance of a CO_2 absorber in LNG service where only a moderate solvent rate was need to lower the raw gas 2% CO_2 level to a few parts per million. The critical parameter determining the location of a temperature bulge was identified as the Heat Transport Capacity Ratio (*HTCR*), defined by

$$HTCR = L\, c_p^L / V\, c_p^V$$

L and *V* are liquid and vapor flow rates and c_p is heat capacity, all in consistent units. In this issue of The Contactor the same parameter is used in a case study of a CO_2 absorber in ammonia production to see how HTCR affects temperature bulges and profiles when the solvent to gas flow rate ratio is quite large.

Case Study: CO_2 Removal with Piperazine-MDEA

Ammonia syngas is typically 18% CO_2 in a hydrogen-nitrogen mixture. Perhaps the most widely used solvent for this application is a mixture of piperazine with MDEA, although MEA, DGA®, ADEG®, and promoted hot potassium carbonate are still used in some ammonia plants. To facilitate more direct comparison with the LNG example discussed in the August, 2016 issue, the same packing series is used, namely IMTP® random packing, in a bed of the same 40-ft (12-m) depth. A common treating pressure for syngas is 350 psig (24.3 barg). The gas flow in this case is 250 MMSCFD (280,000 Nm³/h), being treated with 40 wt% MDEA plus 3 wt% piperazine to ensure the treating goal of < 1,000 ppmv CO_2 can be met in a 40-ft packed absorber bed. The required solvent flow is about 4,500 USgpm (1,022 m³/h). The flowsheet in this case study is a conventional absorber-regenerator lineup. A cross exchanger transfers heat between the recirculating rich and lean amine streams for energy conservation, and there is the usual assortment of trim coolers, pumps and sundry other equipment items.

There are two scenarios to consider: (1) revamp of an existing absorber and (2) designing a new one. Each tells a different story but the primary difference is that the tower dimensions are fixed in the revamp and percentage flood varies with packing size; whereas, the opposite is true in the design case.

Figure 1 shows temperature profiles for these packings as predicted by ProTreat® simulation for the ***Revamp Case***. There are three main observations:

- All packing sizes exhibit almost the same bulge temperature (small packings are only slightly lower)
- Peak temperatures are all located close to the bottom of the absorber.
- Temperature profiles become moderately broader with increasingly large packings.

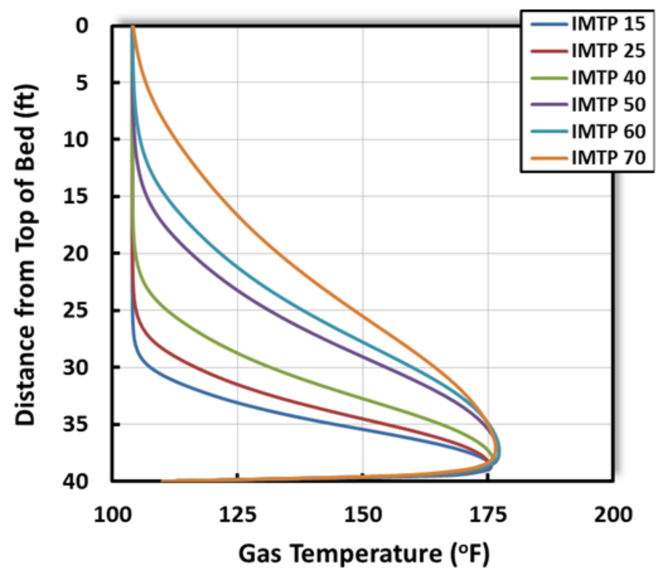

Figure 1 Temperature Profiles Depend on Packing Size — Revamp Case

The reason for peak broadening is evident from Figure 2 which shows rapid CO_2 absorption in the bottom half of the IMTP #15 (small packing size) bed and absorption that takes more and more of the packed depth as packing size increases. This is as it should be: the interfacial gas-liquid area in a short bed of small packings can be equaled only by a much deeper bed of large packing. Figure 2 also shows that the 1,000 ppmv CO_2 treating specification will be greatly exceeded if excessively small packing sizes are used. Their high interfacial area allows the gas to be brought into equilibrium with the entering lean solvent. In such cases, the lean solvent loading sets the treating level—the absorber is called rich end pinched. With large packings, however, treating is mass transfer rate controlled. Precise and reliable simulation of mass transfer rate-controlled processes is the ProTreat® simulator's forté.

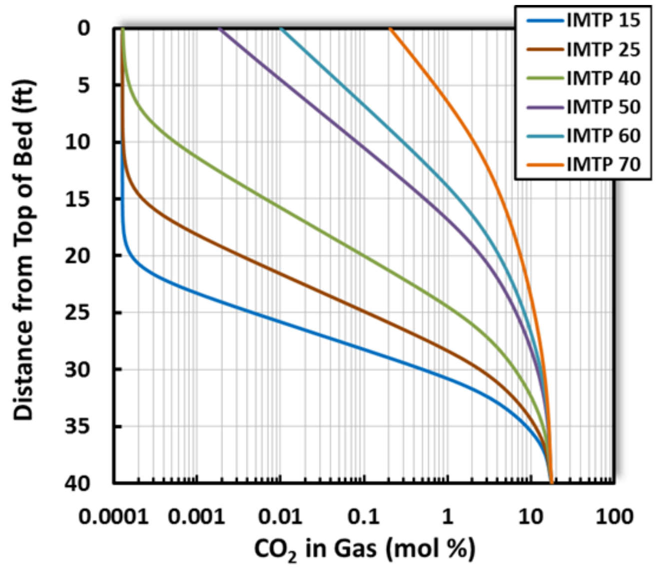

Figure 2 CO$_2$ Concentration Profile Dependence on Packing Size — Revamp Case

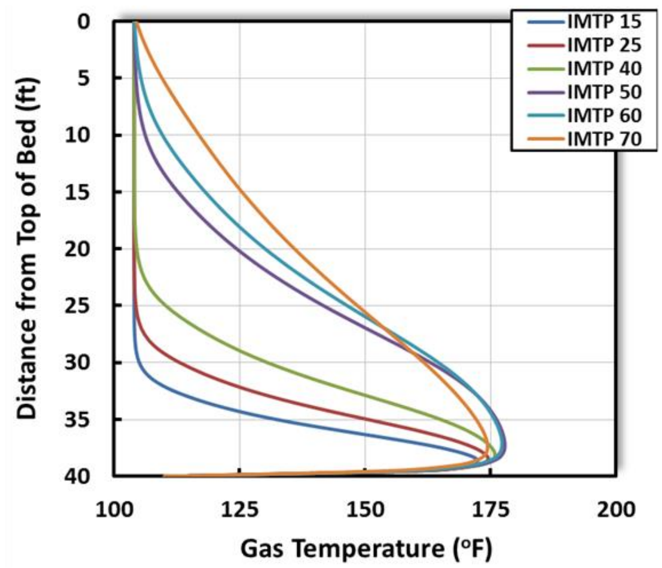

Figure 3 Temperature Profiles Depend on Packing Size — Design Case

The value of the temperature peak changes hardly at all with packing size because the solvent rate is so high (the HTCR value is 12) the heat of absorption is driven out the bottom of the column. The small gas flow cannot return much of the released heat to the tower and raise the bulge temperature. This should be contrasted with the LNG case referenced above where HTCR = 1.4. There, the temperature profile spreads much more broadly, and the bulge temperature itself increases with packing size fairly strongly. In the LNG case study, heat conveyance by vapor and liquid are much more in balance so that heat released into the liquid is carried downwards where the gas picks it up and carries it back up the column. But before the gas leaves, it transfers heat back into the incoming cold solvent which drags it back down again. The up and down conveyance of heat allows the heat of reaction to build up inside the absorber. This does not happen in the syngas case because heat conveyance by the solvent completely dominates.

In the green-field ***Design Case***, tower diameter is allowed to vary with packing size to maintain a fixed 70% flood condition†. Figure 3 shows the temperature bulge remains at about 175°F (80°C) without much dependence on packing size. However, Figure 4 shows that in the design case IMTP #60 barely meets the 1,000 ppmv CO_2 specification, and IMTP #70 now takes the gas to only about 9,000 ppmv CO_2, whereas, in the Revamp Case, the treated gas reached 2,000 ppmv. In the design case, the tower diameter has been sized on the basis of 70% hydraulic flood which with IMTP #70 results in completely unsatisfactory treating. The same is true for IMTP #60 which in the revamp case achieved 100 ppmv CO_2 but in the design case barely makes 1,000 ppmv. The revamp could be done quite successfully with #70 packing in a large *diameter* tower but designing for hydraulic flood would need quite a bit *taller* column.

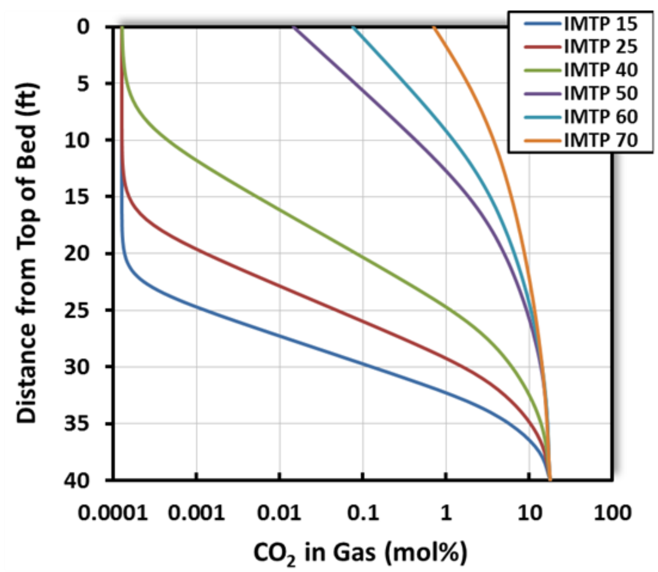

Figure 4 CO$_2$ Concentration Profile Dependence on Packing Size — Design Case

Packing size can have some quite obvious effects on absorber hydraulic and mass transfer performance. It can also have more subtle effects, effects in fact that can jeopardize a design or a revamp if too much attention is paid to hydraulics and not enough to mass transfer. ProTreat® attends to both.

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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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† Incidentally, in both Revamp and Design cases, regenerator geometry and operating conditions are fixed throughout.