The CONTACTOR™

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Confidence in Design — But the Column's Packed: What Now?

For many years, packing has had a bad reputation in absorption and distillation at high pressure. Part of the reason is inattention to proper distributor design. Another is the persistent and still unresolved difficulty in translating ideal stages to actual packed bed depths and the selection of a particular commercial packing. However, packing is now being used increasingly in gas processing for several reasons. For a given size, packed columns tend to permit higher throughput than trays. And in offshore operations such as FPSO and FLNG, columns using structured packing are much less susceptible to the effects of rocking motion caused by wave action. It is particularly critical to select the *right* packing type and size in FLNG because of severe weight and footprint restrictions, so the need for reliability and accuracy is even higher.

It is no longer necessary to engage in any form of guesswork when it comes to designing towers containing one or more of a large range of packing types and sizes. The key is to simulate the column as the mass transfer device it really is. This entails a mass transfer rate approach. Although rate calculations require knowledge of the mass transfer characteristics of the internals (mass transfer coefficients for both phases, and the interfacial area) this kind of information is available in the literature as well as within the ProTreat® amine treating simulator. As we shall see, ProTreat simulation makes packing performance just as easy *to predict* as trays. The emphasis here is on *prediction* because absolutely no parameters need to be guesstimated by the engineer to come up with the right answer. The simulation is out-of-the-box reliable and accurate.

Packed columns seem always to have presented a challenge to designers, perhaps because there are so many varieties, types, and sizes of packing and perhaps even more because the experience base is so small, especially in gas treating with amines. However, today there is no reason why packed columns cannot be designed with just as much certainty and confidence as trays. The processes taking place in absorption and regeneration towers are *mass transfer* processes, and as long as one has access to the basic mass transfer characteristics as embodied in mass transfer coefficient correlations for the particular internals of interest, packed columns are no harder to specify and design than the trayed variety. The fundamental correlations contained within the ProTreat® simulator's information base have been developed from literature, vendor and research data and have been shown repeatedly to allow very accurate and reliable *predictions* of column performance without recourse to guestimating artificial parameters such as tray efficiencies or fictitious residence times in theoretical stages. Although far from a proof, perhaps the best demonstration of this statement is in a commercial example.

Comparison with Commercial Data

The test case involves the revamp of the amine section of an LNG plant using GAS/SPEC 2020 solvent to treat a feed gas with 2.24% CO_2 at about 4 MPa. The unit was built originally with trayed columns but was unable to achieve more than 70% of the nameplate capacity, purportedly because of foaming. The process flowsheet was completely conventional with the usual absorber-regenerator combination connected via a flash tank, cross exchanger, trim cooler and pumps. On-site analysis of the treated gas (27.7°C) showed 21.2 ppmv CO_2. Using all the known plant conditions plus the tray details, ProTreat *predicted* 18.2 ppmv at 27.7°C. This was what one might call an "out-of-the-box" prediction in which absolutely no parameters were guessed or estimated. The simulation data consisted of tray and column vendor drawings along with process flow, temperature and pressure measurements taken directly from the DCS. This was certainly a very encouraging result.

The cause of foaming (if indeed there really was foaming) was never determined. However, even at only 70% of the design capacity, the regenerator was running very close to the recommended 85% hydraulic flood limit so there was a question as to whether the tower was being prevented from operating at full capacity because it was perhaps hydraulically undersized. Regardless of the real cause of the capacity bottleneck, the decision was taken by plant operations to replace both towers with somewhat larger diameter versions, and to replace the trays with structured packing. The packing was of local manufacture and, although its appearance was similar to several well-known commercial brands, all there was to go on was a few photographs without the benefit of a linear scale, or even knowing whether the packing in the photographs was intended for the absorber (1200 mm diameter) or the regenerator (1400 mm diameter). The packing is shown in the accompanying photograph.

Full-capacity plant performance data were taken in mid-2012, again using GAS/SPEC 2020 solvent. The treated gas was reported to be 7 ppmv CO_2. Out-of-the-box ProTreat® simulation indicated the unit should have been producing between 1 and 2 ppmv CO_2 with the absorber and regenerator running at 23% and 36% of flood, respectively. Based on past experience, this was more discrepancy than we are used to seeing, although for a 50 ppmv CO_2 specification on the gas going to liquefaction, all these numbers more than meet requirements. Nevertheless, we looked for possible causes.

The CO_2 absorber was running in the completely mass transfer rate controlled regime—it was neither lean-end nor rich-end pinched. When mass transfer rate controls absorption, and all the process parameters such as flow rates, compositions and temperatures have been verified, the reason for discrepancies must be sought in mass transfer. All that could be determined for this particular version of packing was an *estimated* crimp size (roughly 25 mm) and that the packing sheets were perforated and embossed, a treatment that promotes liquid spreading. Given the fast chemical reaction between CO_2 and the solvent, interfacial area controls the entire process and is the most likely culprit. It would have to be lower in the plant than what we estimated from photographs. Inability to estimate packing parameters accurately is the most likely explanation for the 5 ppmv CO_2 discrepancy.

The simulation results are pure predictions, and are certainly close enough to actual measured performance to give us considerable confidence in the ability of ProTreat® simulation to predict the effect of packing type and size, for example, on CO_2 removal using reactive amines. Packed absorption columns can operate in various modes of pinching or be mass transfer rate controlled throughout. There is just no way to tell beforehand which mode will prevail, and with what packing type and size. This makes it almost impossible to develop a design that is as truly optimized as it should be in FPSO and FLNG applications using any approach other than one with a mass transfer *rate* basis. Currently, only the ProTreat simulator has this proven capability, as witnessed through repeated validation against real plant data—not by using the data to fit the model but rather, by using the model itself to *predict* the data.

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