The CONTACTOR™

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Supersaturation in TGU Quench Towers

The cooled gas leaving a quench tower can be supersaturated with water vapor. This is an interesting situation predicted when the ProTreat® mass and heat transfer rate model is used to simulate the quench column. The prediction is of something that really can occur.

Condensation can leave the inside of transfer lines wringing wet and subject to increased corrosion. There is a further issue that may be equally important—the heat associated with a significantly supersaturated vapor will have to be removed in downstream heat exchange equipment; whereas, if it is only saturated, the heat of supersaturation must be removed in the quench system exchangers. Thus, the extent of supersaturation affects heat exchanger sizing in the downstream TGTU.

Prior to entering the amine section of the tail gas treating unit (TGTU), gas from the hydrogenation reactor in the Sulphur Recovery Unit (SRU) is quenched by direct contact with cooling water in a packed column. A certain amount of cooling is done by conductive and convective transfer of heat itself, but a substantial portion of the heat is transferred by rate-limiting diffusion of water vapor to the water surface where it condenses, and where its latent heat of condensation is released.

If the gas phase is water *saturated* at the local coolant temperature, it should be evident that there can be no diffusional water flux because there is no driving force. Net diffusion of water vapor towards the interface requires the gas to be supersaturated relative to the vapor pressure of water over the liquid at the interface. This creates a driving force for diffusion. In other words, it *requires* a supersaturated gas.

At the bottom of a quench tower the gas is superheated, and therefore cooling water immediately evaporates. However, as the gas travels up through the packed bed it meets colder water and its water content diminishes. The gas passes from the superheated state into a subcooled one. A subcooled gas is actually supersaturated[†].

There are several questions to be considered: (1) How much supersaturation can one expect? (2) How and where should the supersaturation of the quenched gas be removed? (3) What impact might this decision have on exchanger sizing? (4) Is TGTU absorber performance impacted? The precise answers to these questions depend on the specifics of the particular system. In the short space available here the best we can do is to discuss these issues using a case study.

Case Study: TGU Quench and TGTU

The system we will use as the basis for the discussion (Fig. 1) has a 12-ft diameter quench tower with 9-ft bed of Mellapak® 250X packing, followed by a conventional TGTU. The absorber is 12-ft diameter with 25 feet of FLEXIPAK® 250Y packing. The regenerator is 9-ft diameter with 30 FLEXITRAYS®, the upper six being wash trays.

The SRU tail gas is at 312ºF flowing at 120,000 lb/h and containing 44% water with slightly over 3% CO_2 and 0.6% H_2S. The balance is nitrogen with 120 ppmv ammonia and sundry other trace components. The quenched tail gas is treated with 600 gpm of 43 wt% MDEA.

The cross-exchanger, **X-Exch**, is designed to produce a rich amine temperature to the regenerator of 220°F and the trim cooler is operated to give a 106°F lean amine stream to the absorber

Figure 2 shows the water vapor concentration profiles across the quench tower's 9-ft packed bed. At the right is the *actual* water content of the gas, and the left-hand line shows the water in *equilibrium* with the quench water. There are two observations: (1) a 9-ft bed has about twice as much

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[†] Supersaturation does not refer to the presence of micro droplets of liquid suspended in the gas, i.e., mists. If mist is formed, the latent heat of condensation was already released when the droplets first appeared. Droplets are liquid. They no longer contain latent heat associated with the phase change.

packing as necessary, and (2) the *equilibrium* water content of the cooled gas is 16.4 mol% but the gas *actually* has 29.1 mol% water vapor—it is *very* significantly supersaturated. There is a decision to be made: (A) desaturate the gas immediately or (B) let the TGTU absorber remove the supersaturation‡.

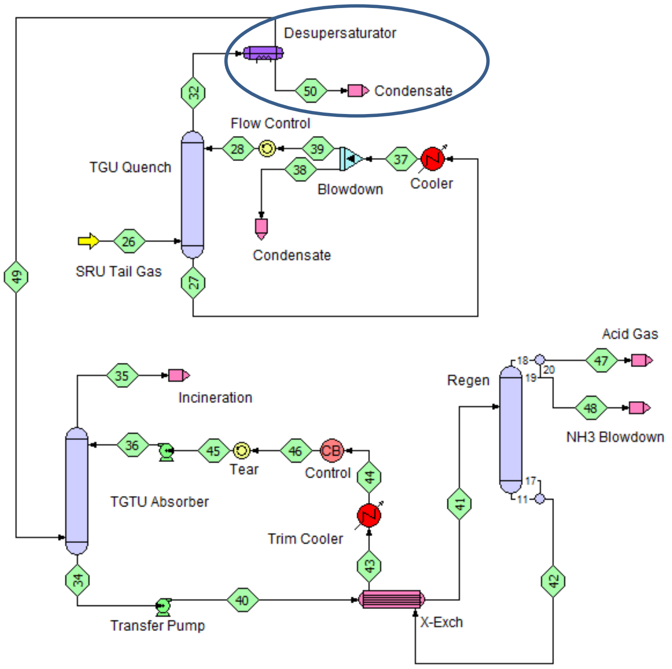

Figure 1 TGU Quench Column with TGTU

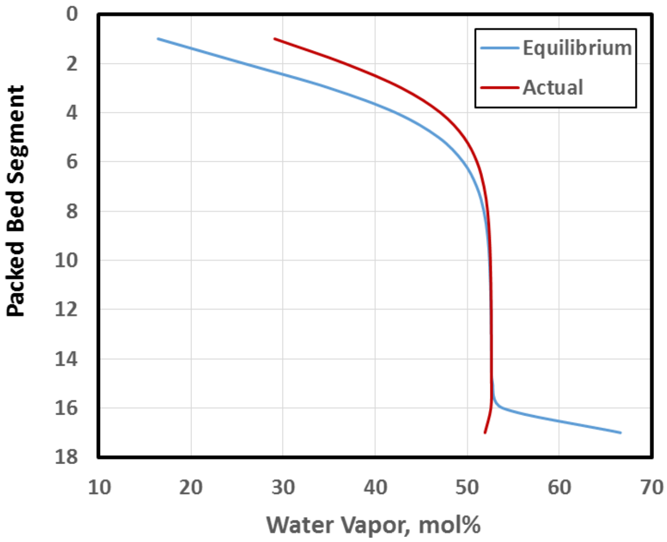

Figure 2 Quench Tower Water Vapor Profiles: Equilibrium and Actual

Case A: The **Desupersaturator** circled in the flowsheet drawing (a TP-flash) equilibrates the gas at the tower top temperature.

Case B: The overhead from the quench tower goes directly to the **TGTU Absorber** without equilibration

One might surmise that in Case A, because excess water has already been removed, the exchangers labeled **X-Exch** and **Trim Cooler** will be unloaded and can be made smaller. However, what does the simulation say?

The quenched gas to the **TGTU Absorber** is the same temperature (134°F) in both cases but the excess water vapor in Case B puts extra heat into the absorber, producing a hotter (160°F) rich amine bottoms stream than Case A (133°F). This has the effect of ruining the H_2S leak which goes from 47 ppmv (A) to 1,760 ppmv (B). The higher rich amine inlet temperature has an interesting consequence for the cross-exchanger. **X-Exch** is intended to produce a rich amine at 222°F so in Case A there is a larger temperature rise across the exchanger. Thus, the cross-exchanger must have more area in Case A than in Case B, *not less*. The heat duty and exchanger size go up by 40%! The LMTD in the two cases is nearly the same—39.2°C vs. 39.5°C in Cases A and B, respectively

The heat removed in the **Desupersaturator** in Case A must instead be removed in the **Trim Cooler** in Case B so in terms of energy flow, neither scheme has any advantage over the other. However, in Case A there is an additional piece of equipment needed vs. a larger **Trim Cooler** in Case A. The circulation rate is slightly higher in Case B because of the additional condensate from desupersaturation in the absorber; however, because this condensate has to be added back to maintain solvent strength in Case A, the water makeup requirement is higher.

The decision concerning what to do about supersaturation of the quenched gas has significant consequences for the design of the exchangers in the TGTU. ProTreat simulation is the first step to making sound technical and economic decisions.

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‡ The real problem with this quench tower is a too low cooling water rate to sufficiently cool the gas. Sensitivity to the quench water flow rate will be the subject of a future issue of The Contactor.