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Quench Towers Are Mass Transfer Devices, Too

To comply with a plant's regulated sulfur emissions limit, gas from the sulfur plant is processed in a tail gas treating unit (TGTU) for removal of the hydrogen sulfide not recovered in the sulfur plant. However, first the gas passes through a vessel in which it is contacted directly with quench water to lower its temperature.

Usually this TGU quench tower is thought of only as a direct-contact heat transfer device. Despite its primary purpose being one of heat transfer, though, a substantial amount of water moves from the cooling water into the hot gas at the hot end of the column, with some of it going back into the water phase near the top of the column. A considerable amount of heat transfer occurs, not by heat conduction, but rather by diffusion of water holding a high latent heat of vaporization. For diffusion, read *mass transfer*.

We posit quench towers to be, in part, mass transfer devices. The diffusion or mass transfer rate of water vapor into and through the gas phase is not something incidental to cooling the gas; rather, it may actually *control* the quench rate. This process has a close parallel in the operation of cooling towers where the objective is to cool the water rather than the air. In this case, air is not the coolant but is the medium that drives and carries away water vapor formed by evaporative cooling. Cooling towers and humidification operations are mass transfer processes, too.

As is so often the case, the easiest route to understanding is a case study. Here we look at a specific example of a sulfur plant tail gas being quenched in a tower packed with random packing. Note that structured packing could be used as well, and indeed a quench tower using spray nozzles is also possible. Trays, however, are not recommended for used in quench applications because suddenly admitting cold water into a tower containing hot gas tends to buckle trays and rip them from support rings. This is a serious issue not just in quench towers but also in sour water strippers with pump-around condensers—hard to control and subject to tray damage.

Case Study — A TGU Quench Tower

Figure 1 shows the general configuration of the TGU quench unit in this ProTreat® simulation case study. As is common to most quench systems, the hot gas from the sulphur plant was first heat recovered against boiling water in an exchanger (not shown) immediately upstream of the quench column. It enters the quench column at about 350°F. Flow rate and other conditions are shown in Table 1. The quench water is cooled to 110°F and flows at 725 Std. (60°F) USgpm in the recirculating loop. Any water condensed from the hot tail gas in the quench is purged to keep recirculation constant.

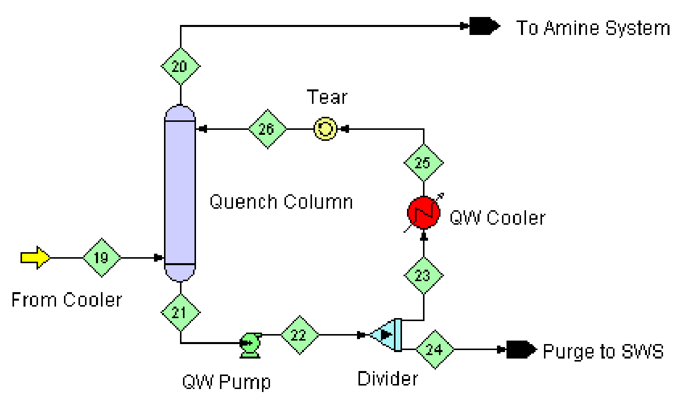

Figure 1 TGTU Quench Column with Quench Water Cooler

The column has 10 feet of Raschig Super-Rings®. Size was varied between #0.5 and #3. Because of limited space, individual results are not tabulated; however, all sizes smaller than #2 produce essentially the same quenched gas temperature of 110.0°F. The #3 rings cooled the gas to 114.8°F. These are large rings and have small specific surface area. Figure 2 shows the effect of packing depth on cooling for three different packing sizes. With #1 packing, the gas essentially reaches the cooling water temperature just before it exits the column. Larger packings need more than a 10-ft bed but achieving satisfactory cooling can be done in 10 feet regardless of packing size.

Table 1 Hot Tail Gas Into Quench Column

Flow Rate (MMscfd)	20
Temperature (°F)	350
Pressure (psia)	15.9
Composition	
Water (mole %)	27.1
Hydrogen Sulfide (mole %)	1.4
Carbon Dioxide (mole %)	8.8
Carbonyl Sulfide (ppmv)	45.1
Hydrogen (mole %)	2.8
Carbon Monoxide (ppmv)	270.7
Nitrogen (mole %)	59.9

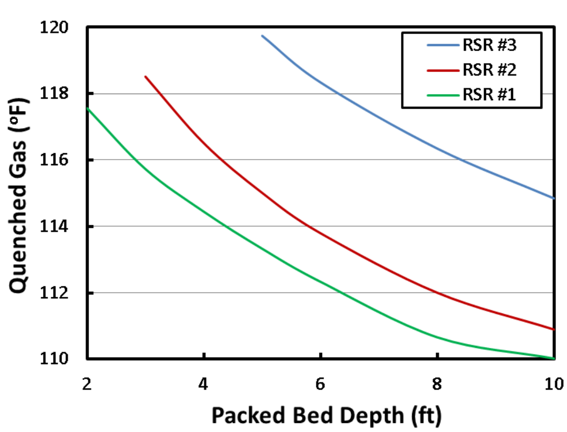

Figure 2 Variation in Gas Temperature with Packing Size and Depth in Bed

The gas and quench water temperature profiles shown in Figure 3 indicate that the gas experiences a very large drop in temperature in the first foot or so of packing. Figure 4 shows this is achieved by the vaporization of a very large amount of quench water. After the first foot of packing, the gas and liquid temperatures track each other, with the gas leaving only a few degrees warmer than the incoming quench water.

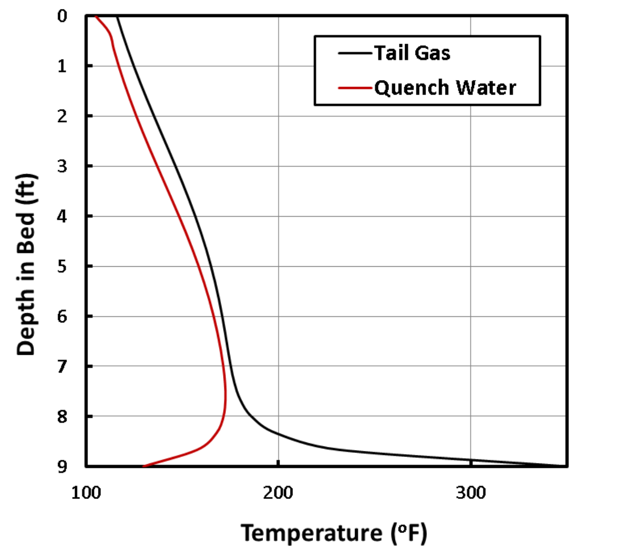

Figure 3 Temperature Profiles with #3 Raschig Super-Rings

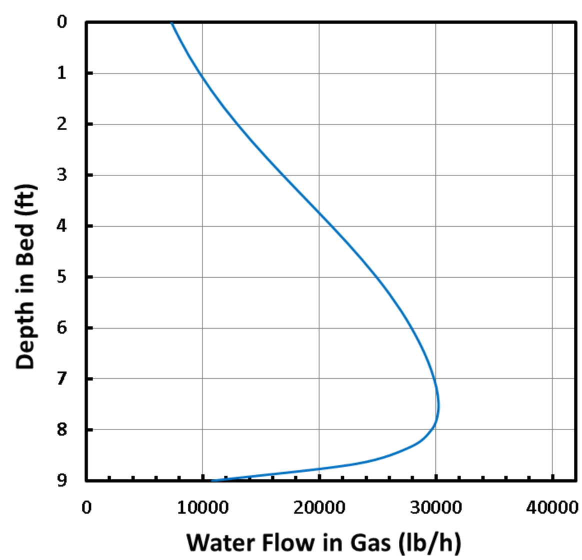

Figure 4 Water-vapor Flow in Quench Tower

Evaporation of water is obviously a heat transfer process in which heat diffuses from the bulk liquid to the interface where water evaporates. However, the now evaporated water must then diffuse away from the interface into the bulk gas.

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