The CONTACTOR™

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Optimal Circulation Rate in a TGTU Quench System

The subject of this month's Contactor is at the suggestion of John Corley, ExxonMobil Baytown Refinery, Baytown, Texas. It is a case study in which we look at how quench water rate through a TGTU quench tower affects the temperature and water content of the gas going to the TGTU amine system. It also demonstrates how the performance of even a quench tower, which we normally think of as a heat transfer device, can be cold-end, and even mid-tower, pinched.

Case Study

Figure 1 shows the general configuration of the TGTU quench unit in this ProTreat® simulation case study. The hot gas from the sulphur plant has already been heat recovered against boiling water (not shown) and enters the quench column at 350°F. Gas flow and other conditions are shown in Table 1. Water enters with the gas at 10,800 lb/h.

The recirculating quench water is cooled against a fixed coolant (water) flow rate of 800 gpm entering the cross-exchanger at 110°F. The exchanger itself has a surface area of 14,000 ft^2. To be specific, a constant shell-side heat transfer coefficient (HTC) of 200 BTU/hr·ft^2·°F is assumed. The circulation rate of quench water through the tube side is to be varied over the range 300,000–600,000 lb/h, and we also assume a tube-side HTC of 200 BTU/hr·ft^2·°F when the circulation rate is 500,000 lb/h. The overall HTC is calculated from the sum of resistances formula:

$$\frac{1}{U_o} = \frac{1}{U_{Shell}} + \frac{1}{U_{Tubes}}$$

and we further assume that the tube-side HTC depends on Reynolds number according to:

$$U_{Tubes} \propto Re^{0.8} \propto (Flow\ Rate)^{0.8}$$

Over the circulation range of interest the overall HTC varies from 80 to 107 BTU/hr·ft^2·°F. The tower contains 10 feet of #2 Raschig Super-Rings®.

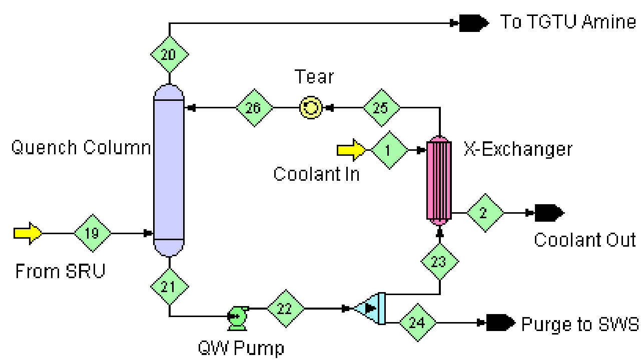

Figure 1 TGTU Quench Column with Quench Water Cooler

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 shows the ProTreat® simulated effect of quench water flow rate on the outlet temperature of the quenched gas. The effect on gas temperature is not dramatic, although it is certainly unmistakable, and clearly there is an optimum. Perhaps the more obvious effect is on the rate of water removal from the gas (Figure 3).

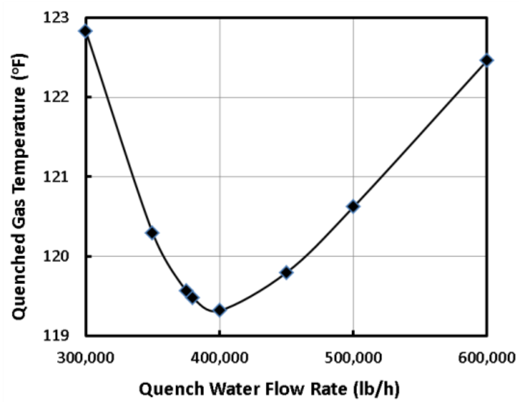

Figure 2 Effect of Quench Water Rate on Quenched Gas Temperature

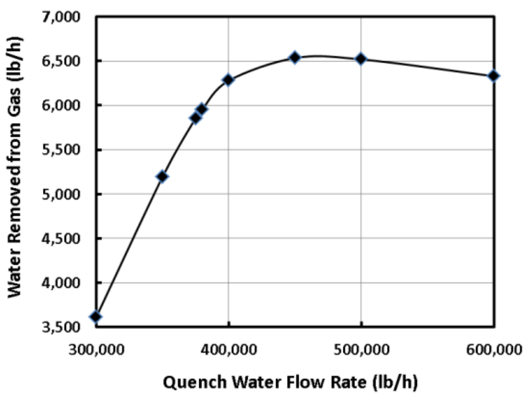

Figure 3 Effect of Quench Water Rate on Water Removal from Gas

It is noteworthy that with fixed equipment and coolant flow there is a recirculation rate that provides the lowest possible quenched gas temperature. Furthermore, if water removal is also a concern, there is another, different, maximizing circulation rate. Across the board, the higher the circulation rate, the higher the temperature of the quench water returning to the top of the tower.

Maxima and minima always result from competing factors. What is at play here is a competition between the LMTD across the exchanger and the LMTD in the contactor. Lower circulation results in a hotter bottoms temperature which gives a higher LMTD in the exchanger; however, this lowers the LMTD in the column. At high circulation rates, the exchanger area and the fixed cooling water flow combine to limit the possible extent of quench water cooling.

Temperature profiles in the column at low, intermediate, and high circulation rates are revealing (Figure 4). At the high rate all the possible heat removal has been achieved well before the gas leaves the column, indicating cold end pinching. At the low rate, however, the bottom half of the column is essentially inactive (pinched) and increasing the bed height will merely extend the pinched region across more of the bed.

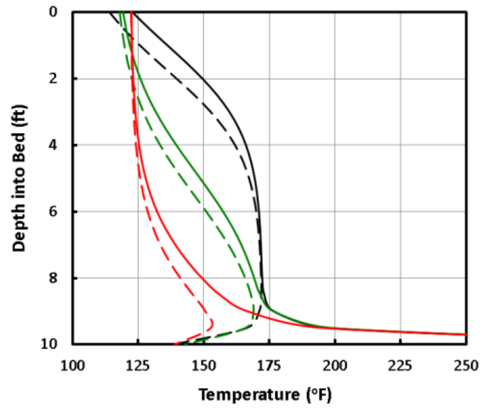

Figure 4 Temperatures in Quench Tower At 300,000; 400,000, 600,000 lb/h Gas: ———, Liquid: ----------

If one is interested in the water content of the gas, Figure 5 shows that at low circulation rates the flow of water rapidly increases to a very large, almost constant value before finally decreasing in the upper half of the tower. At high rates, removal is essentially completed in the lower half of the column. These cold-end and bulge pinches are typical of mass transfer rate-limited processes.

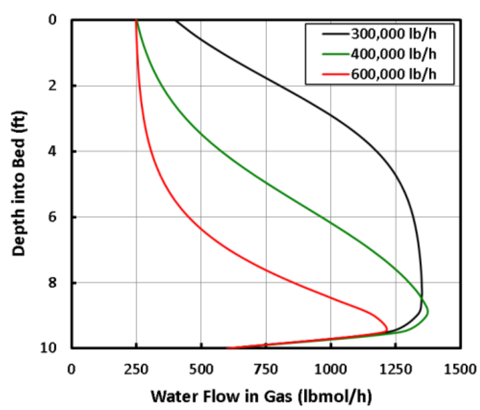

Figure 5 Water Flow Rates in the Gas

We thank John Corley for pointing out this interesting aspect of recirculating TGTU quench systems. There are indeed optimal quench water circulation rates The way to optimization is PreTreat® rate-based simulation.

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