The CONTACTOR™

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Pumparound Condensers in Sour Water Strippers: Why, When and Simulation

For a number of reasons, most modern sour water stripper condensing systems are pump around type rather than overhead condenser type. Pumparounds avoid salts deposition in the overhead system. Typical deposits include ammonium carbamate, ammonium bicarbonate, and especially ammonium bisulfide.

Ammonium Bisulfide: $NH_3 + H_2S \rightarrow NH_4 \cdot HS$

Ammonium Carbamate: $2NH_3 + CO_2 \rightarrow NH_4 \cdot CO_2 \cdot NH_2$

Ammonium Bicarbonate: $NH_3 + CO_2 + H_2O \rightarrow NH_4.HCO_3$

Pumparounds do not guarantee avoiding corrosion issues in heat exchanger tubes because both types of condenser involve heat transfer across bundles of tubes, whether fin fan or shell and tube type. Even SS316 tubes are subject to chloride stress corrosion cracking. However, pumparound coolers work on a single-phase water system and hence tend to operate at lower process fluid velocity.

The main disadvantage of an overhead condenser system is the risk of plugging by very high concentrations of NH_4SH through salt deposition. Corrosion is also an issue, especially if there is cyanide (CN^-) or formate ($HCOO^-$) present in the system. Pumparound condensers lessen plugging problems; however, they are not without their disadvantages.

Figure 1 shows schematically a typical sour water stripper pumparound system drawn in the ProTreat® simulator. Pumparound condenser performance and behavior are sensitive to operating conditions because ultimately everything in the system is very easily taken into the liquid phase. This means that startup can be tricky; during the initial startup period, boilup has filled the column with vapor. If cold reflux is not introduced slowly, massive condensation of vapor can occur, creating a vacuum, with vapor rushing upward to fill it. The result can be very seriously buckled trays. If the column is packed rather than trayed, the distributor tray may buckle instead. In either case, serious damage to tower internals is a distinct possibility and an all too frequent occurrence.

Overhead temperature is controlled by controlling the pumparound rate and the pumparound temperature. The rest of this issue of The Contactor is a case study to investigate through simulation just how these parameters affect SWS performance. The focus is on a trayed stripper although the conclusions pertain equally to a packed column design.

Case Study

The purpose of the SWS is to produce stripped water, free to the extent possible from ammonia and hydrogen sulfide. The SWS feed (Stream 11 in Figure 1) is a typical refinery sour water with composition shown in Table 1. Sour water at 125°F and 35 psig is being treated at 135 USgpm in a 6-ft diameter tower containing Nutter trays — 4 pumparound trays and 30 stripping trays. The stripper head pressure is 11 psig. Boil-up is provided by a steam heated kettle reboiler.

Table 1 Sour Water Composition

Component	Concentration
Carbon Dioxide	200 ppmw
Hydrogen Sulfide	1.56 wt%
MDEA	100 ppmw
Ammonia	0.89 wt%
Formate	20 ppmw
Sodium Ion	15 ppmw

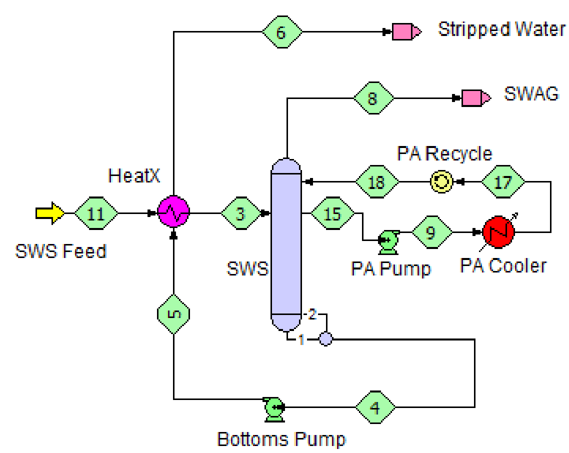

Figure 1 SWS with Pumparound Condenser

Controlling Overhead Temperature

The purpose of controlling the SWS overhead temperature, i.e., the temperature of the Sour Water Stripper Acid Gas (SWAG) is to control its water content. In a refinery, the SWAG is fed to a Sulfur recovery Unit (SRU). Water is just a diluent. It unnecessarily loads the SRU in much the same way that nitrogen left over from combustion air, or a high CO_2 level in the acid gas dilutes the feed, making the SRU furnace harder to operate and lowering the SRU's capacity for processing sulfur.

There are two ways to control overhead temperature using a pumparound condenser: (1) control the operation of the PA Cooler (Figure 1), and (2) control the pumparound flow rate by controlling the liquid flow being drawn from the bottom pumparound tray. As shown in Figure 2, there is a wide range of condensing stream (Stream 18) temperatures and flowrates that provide reasonable SWAG overhead gas temperatures.

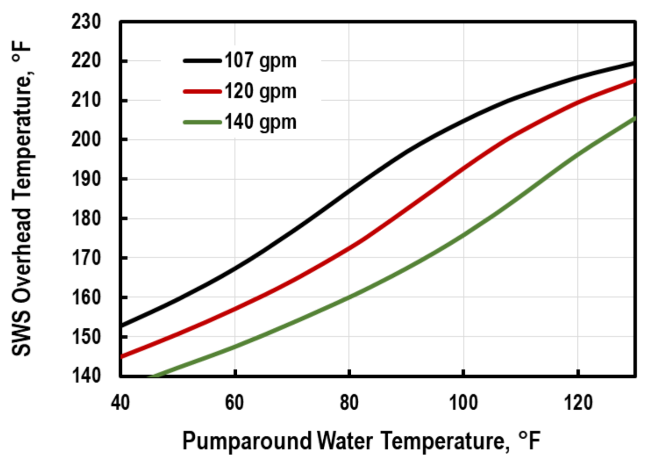

Figure 2 SWS Overhead Temperature Control

Low pumparound temperatures at high flow rates provide the lowest SWAG temperatures as is to be expected. There are no surprises here. Of course the SWAG temperature is not nearly equal to the coolant temperature if only because of differences in flow rates between the two streams. The real question though is whether the water content of the SWAG can be calculated on an equilibrium basis from its known temperature and acid gas content. The plots in Figure 3 say 'no'.

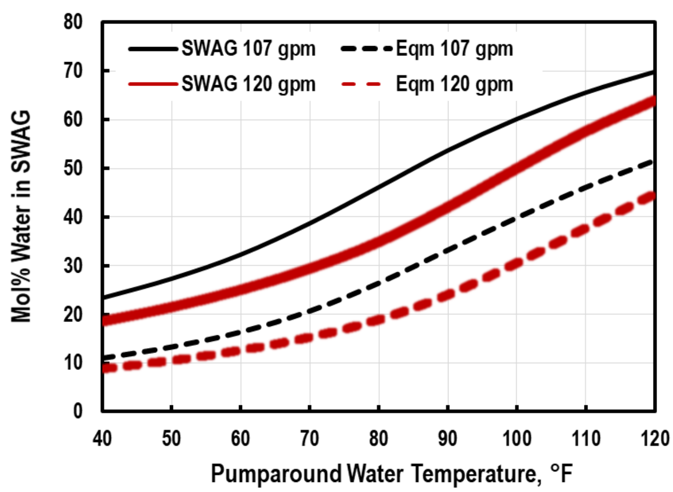

Figure 3 Actual and Equilibrium SWAG Water Content at Pumparound Flows of 107 and 120 USgpm

The solid lines in Figure 3 are the simulated SWAG water content leaving the SWS. The dashed lines are the water conent of the vapor that would be in equilibrium with the coolant on the top tray in the condensing section. The actual temperature lags considerably behind equilibrium, i.e., the SWAG has a much higher moisture content than its equilibrium value. In fact, there is a fully 15–20 percentage point difference between actual and equilibrium water content.

For those used to thinking in terms of condensing steam, such a huge difference between actual and equilibrium water conent of the gas possibly seems absurb. However, we are not dealing with the condensation of a pure component (water). Rather, the system consists of roughly equal parts water, ammonia, and hydrogen sulfide. Ammonia and hydrogen sulfide are not condensible, although they will certainly absorb into liquid water. But to condense water, the *water vapor first has to be moved by diffusion to the gas-liquid interface before it can condense and enter the liquid*. Diffusion is a **mass transfer rate** process. It is the **finite rate** of the diffusion process that is entirely responsible for the lag shown by the actual water content of the vapor with respect to equilibrium. Mass transfer rates are at work once again.

The SWAG contains 15–20 mol% more water than it should. It is **supersaturated** with water vapor as it leaves the SWS. As the SWAG flows through the piping from the SWS and joins the Amine Acid Gas (AAG), water will tend to drop out of the gas (like dew) and collect on the pipe walls. If there is a pressure letdown after the SWS of course, this will remove some (but probably not all) of the supersaturation.

The lesson here is, "Do not be fooled by equilibrium calculations into believing you know the actual water content of the SWAG anywhere in the pumparound system, and especially not in the overhead line from the SWS". Often a pumparound system will simple **not** be capable of achieving the lowest water content possible in the acid gas. And the water that condenses on pipe walls will absorb acid gases and lead to plugging and corrosion downstream! On the other hand, an overhead condenser system will more than likely come very close to providing the lowest possible water content, but it does so at the risk of condenser plugging if the system is not carefully designed and operated.

ProTreat's *real* mass and heat transfer rate model is the best tool available for assessing these kinds of issues and for providing answers with an extraordinary degree of accuracy and reliability. Does the simulator you're using allow these traits of sour water stripping to be investigated? ProTreat does.

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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.