How to design glycol dehydrators

... for 100°F.-plus dew-point depression

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UNTIL about 2 years ago, glycol dehydration was never seriously considered when dew-point depressions in excess of 75°F. were required except in a few plant units where vacuum regeneration was used. However, glycol dehydration units are now being built by several manufacturers for dew-point depressions greater than 100°F. This has caused gas-process men to reconsider the type of dehydration to be used where high-dew-point depressions are required.

A number of developments have contributed to this breakthrough of the old 75°F. depression limit for glycol dehydration. Most important of these is the fact that glycol dehydration equipment is being designed far more completely and thoroughly than ever before. Gone are the days of rule-of-thumb design of glycol dehydration equipment such as “four tray contractors and 98% glycol”; instead, dry glycol concentrations are being accurately calculated and increased. Required absorber transfer units are being carefully determined.

Another important contribution to high-dew-point depressions is the development of the glycol-powered pump, which provides a small quantity of accurately measured gas proportioned to the glycol circulation.

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How it works. Fig. 1 shows a typical glycol-dehydration flowsheet, in which lean glycol is pumped into the top of an absorber column countercurrent to the gas stream to be dehydrated. The rich glycol stream leaves the bottom of the absorber, passes through the power side of a glycol-powered pump (or level controller and motor valve), and into a flash chamber, or gas-glycol separator. Here, entrained and dissolved gas is removed from the glycol; (this gas may then be used for the stripping of the glycol).

The rich glycol passes through a heat exchanger, (countercurrent to the hot, lean glycol), through a filter, and into the stripping still. Water vapor and stripping gas (if any) are removed from the top of the stripping still through a partial reflux condenser. Lean glycol leaves the reboiler, passes through the heat exchanger countercurrent to the rich glycol, and through the pump back into the absorber column.

In a typical dehydration design problem, the process engineer will be given the inlet-gas conditions (pressure, temperature, and degree of saturation), and the required dryness of the outlet gas. He must then design the most economical plant which will provide the desired performance.

The first step in a design problem should be to assume a glycol circulation rate and estimate the dry glycol concentration. Next, the absorber column should be sized. Once these two steps have been completed, the remainder of the process design is routine, such as heat exchange, line sizing, filter sizing, and so forth.

It is extremely important that a complete material and heat balance be made around each piece of equipment. Reboilers, stripping columns, and heat exchangers are frequently undersized by design engineers using rule-of-thumb design data. Also, accurate material balances are absolutely essential in the use of the data presented below.

Regeneration System

Design of the glycol reconditioning still should be done in a conventional manner to determine the number of theoretical trays required to provide the desired outlet dry glycol concentration. However, a number of problems arise in the design of the reconditioning still: accurate equilibrium data for water-triethylene glycol systems at higher temperatures are not readily available; also, the glycol temperature should never exceed 400°F. to prevent excessive decomposition.

Since 100% triethylene glycol has a vapor pressure of only 65 mm. mercury at this temperature, it is necessary that the reboiler operating pressure be reduced to increase dry glycol concentration above that shown on boiling point curves. This may be done by gas stripping or vacuum regeneration.

Dry glycol concentrations may be accurately predicted from vapor-pressure curves for units using vacuum
regeneration. However, design of a still using gas stripping is quite complex when reflux rates and theoretical trays are considered, since the partial pressure of the stripping gas varies through the column due to changes in water-vapor concentration. Data presented below may be used to predict dry-glycol concentrations when gas stripping is used. These values may be increased somewhat by increasing reflux ratios and the number of theoretical trays in the stripping section of the column.

Stripping-still column cross-sectional areas can be determined from flood point correlations as presented in published literature from vapor and liquid loadings and the type of packing used. Most process engineers design glycol stripping stills to operate at between 60 and 80% of flood point of the column.

Direct-fired reboilers for triethylene glycol normally are designed with heat fluxes of 8,000 to 10,000 B.t.u./hr.-sq. ft. Steam-heated reboilers and the heat exchangers should be designed in accordance with the Standard of Tubular Exchanger Manufacturers Association.

Vacuum regeneration. Reconcentration of glycol under vacuum has been successfully used in plants for some years. Vacuum is usually maintained by steam ejectors or motor-driven vacuum pumps. This type of reconcentration should be employed wherever possible where high concentrations of glycol are required. With the price of gas increasing each year, gas stripping of glycol normally cannot be economically used in the larger units.

The curves in Fig. 2 may be used to predict outlet triethylene glycol concentrations for vacuum reconcentration systems. When using vacuum regeneration, the stripping still should be designed to provide sufficient reflux and rectification to hold glycol losses within tolerable limits.

Gas-stripping regeneration. In order to allow the process engineer to estimate dry triethylene glycol concentrations obtainable with gas stripping, a generalized correlation, based on published triethylene glycol-water vapor pressure data, was calculated and plotted in Fig. 3. This correlation is based on one theoretical tray in the stripping section of the still and includes parameters for stripping gas, tray temperature, and absolute reboiler pressure.

In using this graph, start with the concentration of "Rich Glycol Feed" and follow the procedure illustrated by the dotted arrows. If the absolute reboiler pressure is 760 mm., follow a line vertically through this intersection to the "Outlet Dry Glycol Concentration"; if the absolute reboiler pressure is other than 760 mm., follow a line horizontally from this intersection to the reboiler pressure and then vertically again to the "Outlet Dry Glycol Concentration." If a stripping still contains a whole-number multiple of theoretical trays, this graph may be used for a tray to
Mole Fraction Water Vapor in Gas x 10^4

Bottom of Column

Operating Line

Equilibrium Line

Top of Column

Mole Fraction H_2O in Triethylene Glycol

0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1

0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1

MODIFIED McCabe-Thiele diagram showing a graphical calculation of required theoretical transfer units. Fig. 5.

tray calculation, in which the “Outlet Dry Glycol Concentration” from each tray represents the “Rich Glycol Feed” to the tray below it. The stripping gas parameter lines are drawn for standard cubic feet of gas per gallon of glycol, and therefore, would remain the same throughout the column. Average temperature of each tray must be known to make this tray-to-tray calculation.

Absorber Column

The absorber column should be designed according to standard process-design procedures. The required cross-sectional area may be calculated with the Brown and Saunders equation for tray-type columns:

\[
G = C \left( \frac{P_v}{P_L - P_v} \right)^{1/2}
\]

where:

- \(G\) = mass velocity of vapor through column, lb./hr.-sq. ft.
- \(C\) = a constant depending on surface tension.
- \(P_v\) and \(P_L\) = densities of vapor and liquid, respectively, lb./cu. ft.

Capacities of tray-type columns with various tray spacings are plotted in Fig. 4. Capacity of the glycol mist extractor in column should be checked against these capacities to be certain that the mist extractor area is sufficient. For most high-efficiency wiremesh mist extractors, the capacity of the mist extractor will exceed the column capacity. Slot area, chimney area, and downcomer size should be calculated by conventional tray-design methods.

Cross-sectional areas required for packed columns may be determined from generalized or specific published flood-point correlations. Columns should be designed 60% to 80% of flood-point rates, depending on the reliability of the flood-point data used.

Theoretical transfer units required may be calculated using a modified McCabe-Thiele diagram, in which the mole fraction of water in the glycol is plotted versus the mole fraction of water in the gas at equilibrium on a log-log graph. Fig. 5

THEORETICAL transfer units for triethylene glycol at varying concentrations and circulation rates are shown in these figures. Pressure variation between 500 and 1,000 psi has no effect on these values, but temperature changes do have a slight effect. Figs. 6-9.
presents a typical graphical calculation of the number of transfer units required for a specific dehydration problem.

Using this method, the required theoretical transfer units for various circulation rates of dry triethylene glycol at different concentrations were calculated and plotted in Figs. 6 through 9. These correlations are based on 700 psi and 100°F. Variation of the pressure between 500 and 1,000 psi has no effect on these values; however, temperature variations do have a slight effect on the theoretical trays required. These values should be increased approximately 3% for each 10°F decrease in temperature and decreased 3% for each 10°F rise.

Tray efficiencies for triethylene glycol-gas systems range from 20 to 40%, depending on tray design, loading, etc.; however, an efficiency of from 25 to 30% is recommended for average design work in converting theoretical to actual trays. For packed columns, very few HTU (Height of a Transfer Unit) data are available specifically for gas-glycol systems. In the absence of specific data, one may use a generalized correlation, if available, to determine the HTU of the packing material under consideration; for safe design purposes, one should use a 100% safety factor with theoretical HTU value obtained from a generalized correlation.

References