PART 1

Guidelines for glycol dehydrator design

Properly sized equipment and better instrumentation enhances natural gas drying

W. P. Manning, Coastal Chemical Co., Inc., Houston, Texas, and **H. S. Wood,** Maloney-Crawford, Tulsa, Okla.

Better designs and instrumentation improve glycol dehydrator performance. These guidelines emphasize efficient water removal from natural gas. Water, a common contaminant in natural gas, causes operational problems when it forms hydrates and deposits on solid surfaces. Result: plugged valves, meters, instruments and even pipelines. Simple rules resolve these problems and reduce downtime and maintenance costs.

Under normal production conditions, natural gas is saturated with water (Fig. 1).[1,2] Water as a vapor is not the major problem. However, when water combines with the gas molecules, e.g., methane, ethane, propane and forms solid hydrates such as $CH_4.7H_2O$, $C_2H_6.8H_2O$ and $C_3H_8.18H_2O$,[3] then it becomes a problem. Below 200 psia, hydrates form at 32°F, at higher pressures temperature increases. These hydrates deposit and build up on solid surfaces. Eventually, they plug valves, meters and instruments and result in unnecessary maintenance and lost production.

Water, also, increases natural gases' corrosivity, especially when acid gases, e.g., hydrogen sulfide and carbon dioxide, are present. On cooling, water condenses in the pipeline and can accelerate pipeline corrosion and erosion rates and increases pipelines' pressure drop. These conditions are undesirable and can be prevented by drying the gas.

Several methods can dry natural gas: liquid desiccants (glycols), solid desiccants (alumina, silica gel, mole sieves) and calcium chloride. Glycol dehydration is preferred when attaining sales gas contracts' specs—typically 7 lb H_2O/MMscf—because:

- Process is continuous rather than batch or intermittent. Makeup is easy compared to emptying and refilling solid desiccant towers.
- Installation cost is about half that of solid desiccant plants.
- Pressure drop in the absorber is lower, 5 to 10 psi vs. 10 to 30 psi for solid desiccants.
- Less heat is needed for regeneration per pound of water removed.
- Glycol is more resistant to contaminants. Hydrocarbons and produced water quickly ruin solid desiccants.

Glycols. Ethylene glycols have the general formula $HO(C_2H_4O)_nH$. Ethylene, diethylene, triethylene and tetraethylene glycols correspond to values of 1, 2, 3 and 4 for n respectively. Triethylene glycol (TEG) is accepted as the most economical choice because of:

- Low equipment and operating costs[4]
- High thermal stability—the theoretical decomposition temperature is 404°F[5]
- Efficient regeneration at high reboiler temperatures. Concentrations up to 99.9% TEG are obtainable.
- Low vaporization losses.

TEG dehydration's major limitation is the minimum gas dew point. Values below −25°F are difficult to obtain. This is not low enough for cryogenic processing, which requires solid desiccants. Also, TEG is corrosive if contaminated or oxidized by air.

TEG process. Glycol dehydration involves: water absorption from the natural gas by glycol at high pressure and low temperature and reconcentration of glycol at low pressure and high temperature. In Fig. 2, drying occurs in the absorber. The other equipment removes water from glycol for recycle. The TEG process is well documented.[4,6-13]

Equipment selection and design depend on applications that can range from small wellhead units, e.g., 5 Mscfd, to gas transmission plants, e.g., up to 2 Bscfd. Standard (off the shelf) equipment is often used for small gas volumes where reliable unattended operation is preferred over design optimization and operating efficiency. However, the reverse is true for large gas volumes where economics

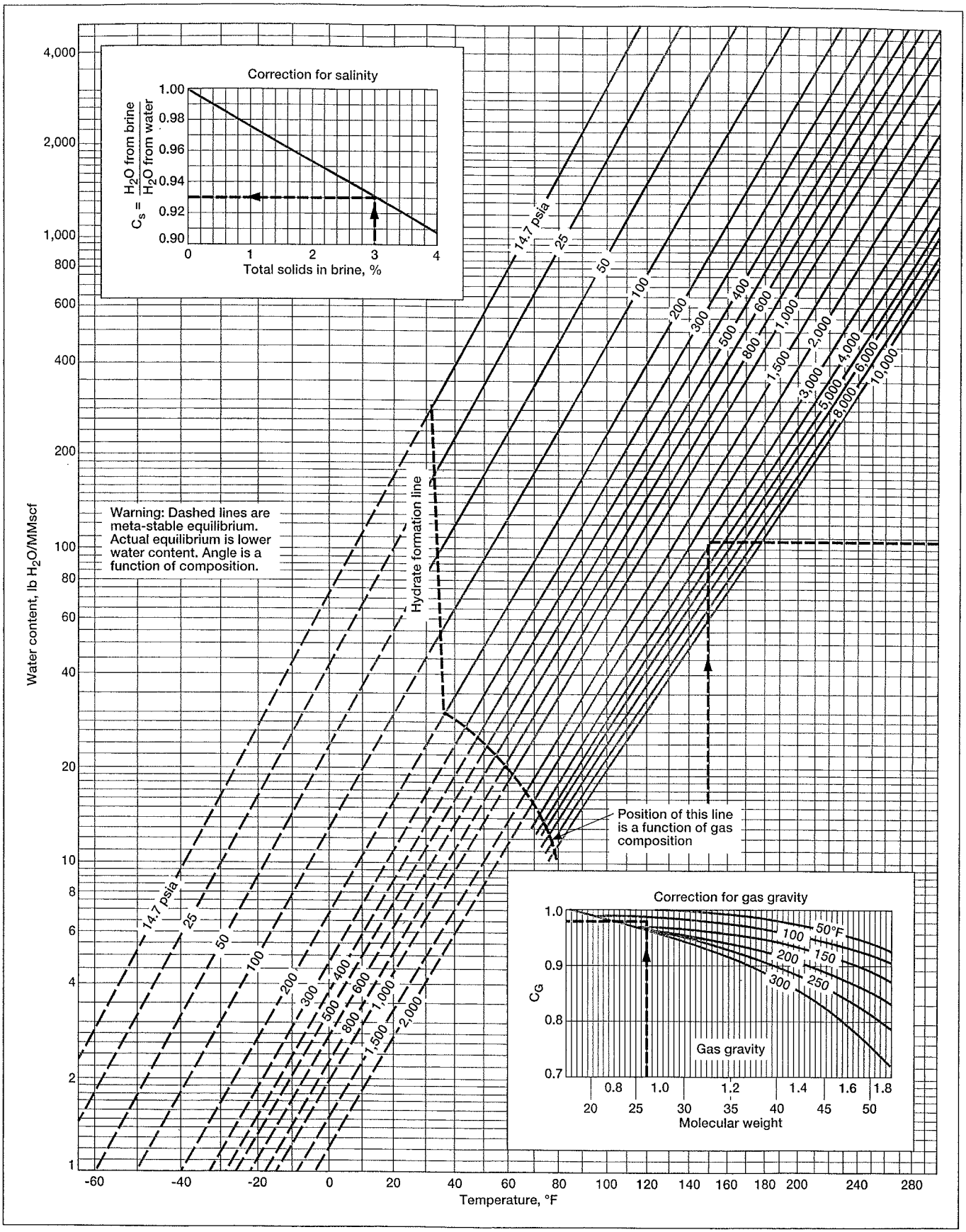
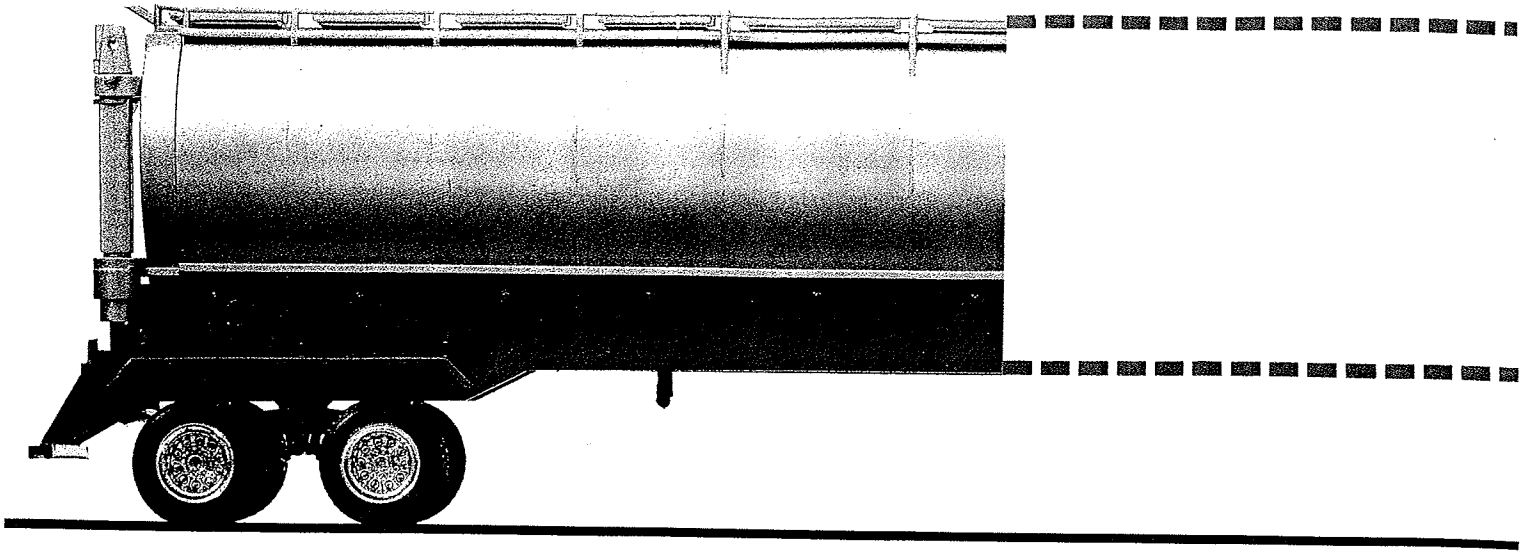


Fig. 1. Water content of natural gas.

requires high performance.

Fig. 2 shows an optimized TEG process. It includes features such as an external gas-glycol heat exchanger, controls of the still overhead temperature, split lean/rich glycol heat exchange to control the temperature of the flash separator and filters, and stripping gas to improve glycol reconcentration. Simpler designs do not include all of the equipment shown.

Carbon steel is the standard construction material. If the gas contains large amounts of carbon dioxide, series



300 stainless steels should be used for the rich side of the glycol-glycol heat exchanger, still and reflux condenser. High pressure components, i.e., inlet scrubber, absorber and gas-glycol heat exchanger, are code vessels (see ASME Section VIII). Flash tank and heat exchangers are also code construction. Flow velocities in the piping should be low, 2 ft/sec on the pump suction and 5 ft/sec on the pump discharge.[14]

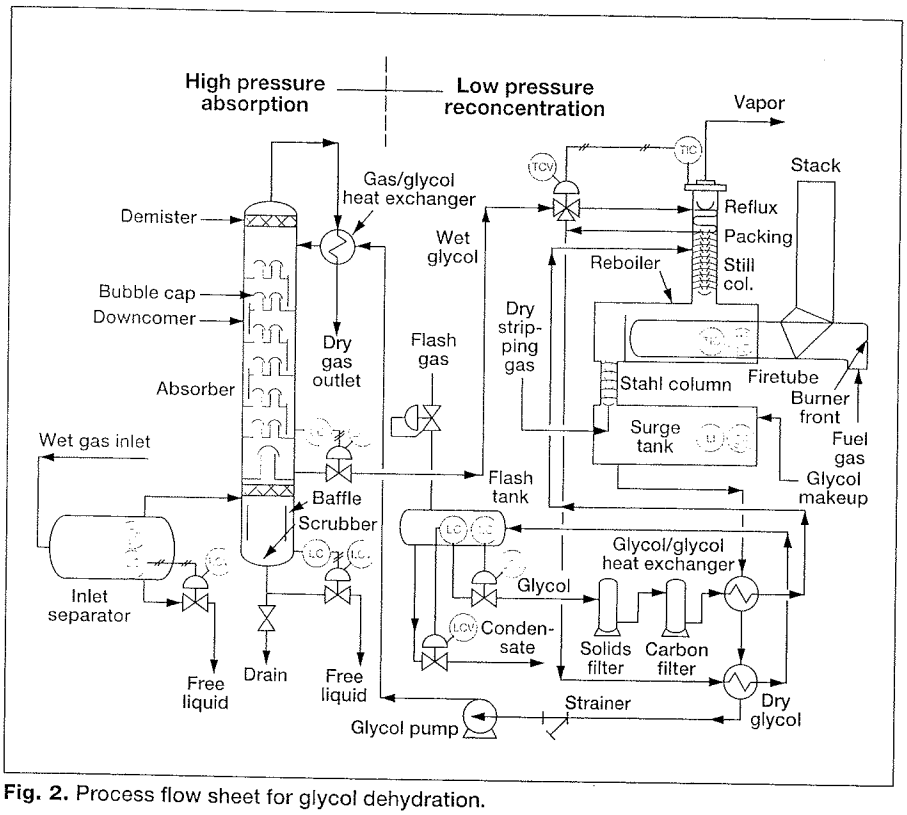


Fig. 2. Process flow sheet for glycol dehydration.

Inlet separator. Clean glycol provides efficient, trouble-free operation, while dirty or contaminated glycol causes most operational problems. Contaminants enter the system in the inlet gas stream. More common contaminants are water and hydrocarbon liquids—both produced and condensed, compressor lubricants, treating chemicals and solids, e.g., sand, pipeline scale and rust (fine iron sulfide, etc.). Liquids enter as vapor or entrained droplets.

A conventional separator—vertical or horizontal with a mist extractor or coalescing vanes—works well in containing mist contaminants. A filter separator may be needed if compressor oils or very fine solids are not removed sufficiently. If necessary, water-washing in a cyclone can remove micron and submicron solid particles.

The inlet separator should be close to the absorber. A high liquid-level shutdown handles system upsets such as slugs of produced water. Unfortunately, the inlet separator is often overlooked and, if it is included, design and instrumentation are frequently inadequate. A separator installed after the gas-glycol heat exchanger can collect glycol carryover. Glycol in this separator is the first sign of foaming. If it is not contaminated, the collected glycol can be reused as makeup. The outlet separator protects downstream equipment from glycol contamination.

Absorber or contactor consists of three sections: an integral scrubber at the bottom, a central trayed or packed drying section, and a demister at the top. The integral scrubber complements the inlet separator. Design should include a baffle, which initiates a tangential swirl in the gas and a gas flow reversal, and a mist extractor. The gas then flows through the chimney tray and contacts the glycol. Many integral scrubbers do not have a high liquid level controller shutoff for inlet gas flow. Sometimes the dump valve is not sized for slugs of produced water or hydrocarbons in the controller. Without proper instrumentation, the integral scrubber should not be used as a substitute for the inlet scrubber.

In the drying section, the gas flows countercurrently to the glycol. Bubble cap trays are preferred though they are less efficient (25% vs. 33%) than valve trays because they are suitable for viscous liquids and low liquid/gas flow ratios. Also, bubble caps do not weep, and turndown

ratios as high as 6:1 are obtainable. For smaller diameter towers, e.g., 12 in. or less, packing is used, e.g., ceramic saddles or stainless steel rings. The latter allow higher flowrates, are nonbreakable and don't crumble into small pieces, but they are more expensive. Tray spacing must be large enough to prevent splashing or entrainment of the glycol to the overhead tray. Industry standard is 24 in. Towers larger than 4 ft sometimes have a 30-in. spacing and manways on each tray. The top section provides space for the glycol to disengage from the gas. The distance between the top tray and the demister should be 1.5 times the tray spacing. For smaller units, the gas-glycol heat exchanger is often a helical coil located above the top tray.

The absorber diameter can be obtained from manufacturers' charts,[7,8,10] Fig. 3 or from Eq. 1.

$$V = 600\,[(\rho_L - \rho_G)/\,\rho_G]^{0.5} \qquad (1)$$

where V = maximum gas superficial velocity, ft/hr
ρ_L = glycol density, lb/ ft^3
ρ_G = gas density, lb/ ft^3

Flash tank. The flash tank separates dissolved hydrocarbon gases from glycol. Operating pressures range from 50 to 75 psig. Removal of the flash gas from wet glycol reduces subsequent vapor flow in the still column. Flash gas quantity depends on the type of glycol pump used. A reciprocating pump has no significant gas flow with the glycol from the absorber. TEG absorbs 1 scf of natural gas per gallon at 1,000 psig and 100°F.[12,15] Most of this gas evolves when the glycol flashes at 75 psig. Though heavier hydrocarbons are more soluble, the amount of flash gas is less than 2 scf/gal TEG. When a glycol-powered pump is used, the amount of "pump gas" used is significantly more than the dissolved gas, e.g., 3 scf/gal at 500 psig and 6 scf/gal at 1,000 psig.[10]

For lean gases, a two-phase separator with a 10-minute retention time is adequate. No liquid hydrocarbon phase accumulates. However, heavier hydrocarbons collect when rich gas is dried and a three-phase separator is needed. Heavy hydrocarbons form stable emulsions and foams. These are broken at 150°F and a retention time of 20 minutes.

Separation temperature can be controlled by using the rich glycol stream from the absorber to provide the reflux for the still column and by splitting the glycol-glycol heat exchanger duty. Glycol should not be heated over 200°F because the solubility of heavier hydrocarbons in the TEG increases with temperature. Guidelines for vertical and horizontal designs are:[13]

Vertical:
Height, ft = 3.4 + 0.4 gpm
Minimum height = 4 ft
Maximum height = 10 ft
Minimum diameter = 1.5 ft
Horizontal:
Length/diameter ratio = 3 preferred
Minimum length = 3 ft
Minimum diameter = 2 ft

Filters. Good filtration cannot be overstated. Filtration includes the removal of solid particles and dissolved impurities. The solids' content in the glycol should be kept below 0.01 wt% to prevent pump wear, plugging of the heat exchangers, fouling of the absorber trays and still packing, deposition on the firetube and TEG foaming.[16]

Filters made from fabrics, paper or fiberglass remove particles of 5 microns and larger. Placing the filter after the flash tank takes advantage of the viscosity reduction from a higher temperature (compared with the absorber temperature). These filters are designed for an initial pressure drop of 3 to 5 psi and should be changed at 20 psi.

Nearly all glycol systems including standard units have a solids filter. A common design consists of 3 in. × 36 in. cylindrical elements in a housing. Solids' filter should have full flow and sized for 1 to 2 gpm per element. On change out, do a visual inspection of the filter's core. If the element is still clean on the inside, problems such as incorrect sizing or paraffin plugging are present.[6,16]

Rigid filter elements last longer, don't collapse and don't release filtered solids back into the glycol. Though these elements cost more, total filtration cost, i.e., elements, labor, glycol loss and disposal, are often less.[17]

Activated carbon filters remove dissolved impurities, e.g., high boiling hydrocarbons, surfactants, well treating chemicals, compressor lubricants and TEG degradation products. Canister filters, which seldom rupture or bleed, are widely used. Hard, dense coal-based carbons are preferred over wood-based carbons that are light, soft and create dusting problems. The allowable flowrates are low, 1 gpm per cartridge. Canister filters are often located in a side stream. The carbon filter should be located after the sock filter so that it is not used as a solids filter.

Preferably, a carbon filter vessel handling the full glycol flow can be used. The length to diameter ratio should be at least five. Granular, 8 to 30 mesh, 30 lb/ft^3, coal-based carbon is recommended. The flowrate should be 2 to 3 gpm/ft^2 of bed area. A retention time of 15 to 20 minutes is recommended to obtain the full carbon capacity. The carbon should be replaced when it no longer removes color from the glycol. New carbon should reduce foaming and hydrocarbon content. Replace carbon on a regular planned maintenance schedule.

Glycol-glycol heat exchanger. This heat exchanger transfers heat from the hot reconcentrated glycol to the cold wet glycol and reduces the reboiler duty. Many small, standard designs use a helical, horizontal coil in the surge tank. This is economical fabrication and inefficient operation. Even when the entire coil is submerged, the rich glycol cannot be heated above 200°F. The glycol level in the surge tank is critical because the coil must be submerged to be functional.

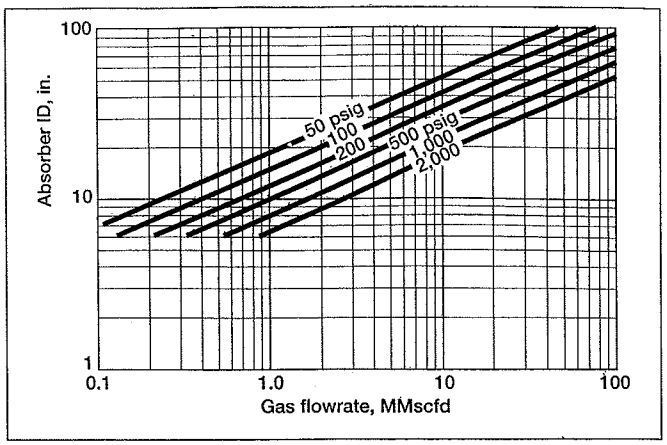


Fig. 3. Absorber diameter.

A well-designed, insulated heat exchanger, such as a double pipe with a finned inside pipe or shell and tube or plate and frame, heats the glycol to 300°F. This is an approach of 60°F to 90°F to the reboiler temperature. A 100°F improvement in heat transfer reduces the reboiler duty by 600 Btu/gal, a savings of 15% to 20%. Temperatures above 300°F "boil" the wet glycol. Vaporization results in excessive liquid/gas velocities to the still column. In Fig. 2, two or more exchangers in series can be used to control the rich glycol's temperature to the flash tank and filters, and prevent temperature cross.

In designing the exchanger, add 10% to the duty to cover fouling and flow variations. Use a rich glycol temperature of 300°F to maximize the duty. For small units with a coil in the surge tank, size the shell volume for a 30 minute retention time.

Still column. Reconcentration of the glycol occurs in the still column and reboiler. Water separation from the glycol is easy because there is a large difference in the boiling points and the relative volatility is very high. Reconcentration requires three theoretical stages: the reboiler, the still and the reflux condenser. These are the premises for many design programs. The still or stripping column is a vertical pipe filled with a minimum of 4 ft of ceramic saddles or stainless steel rings. This should be raised to 8 ft when the reboiler duty reaches 1 MMBtu/hr.[10] Trays are sometimes used in very large units. In some small units, the still column's lower section is insulated. The upper part is bare and sometimes has vertical fins. Atmospheric cooling provides the reflux.

The serious drawback to this economical design is that "mother nature" controls the amount of reflux, not the operator. In calm summer days, insufficient reflux causes high glycol vapor losses. And on rainy winter days, excessive reflux overloads the reboiler and results in inadequate glycol reconcentration.

Reflux should be controlled by installing a cooling coil in the top of the still column. Wet glycol flows through the coil and controls the temperature at the top of the still:

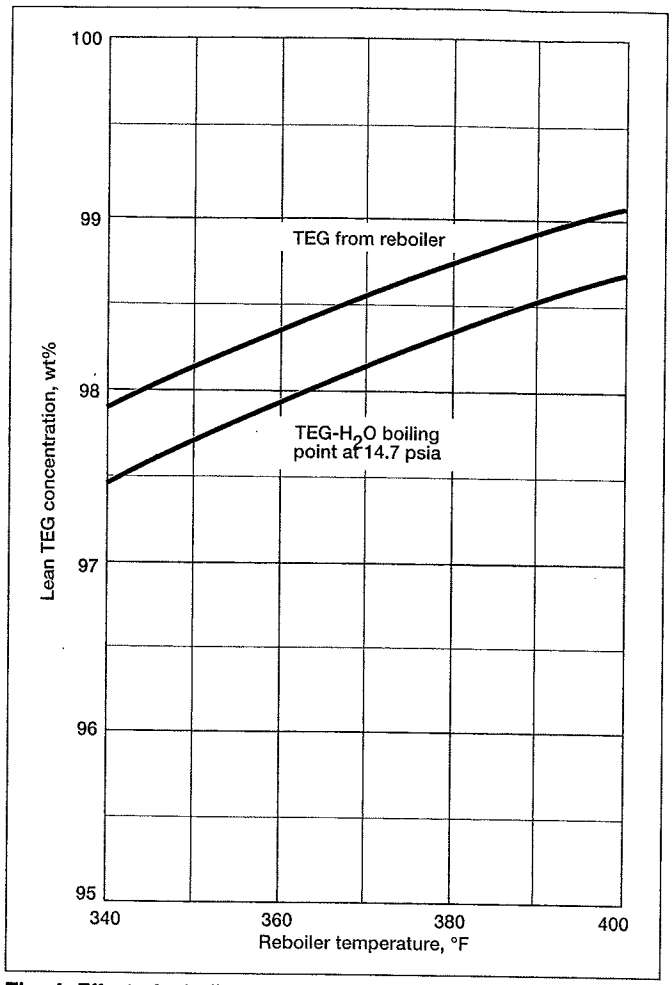


Fig. 4. Effect of reboiler temperature on lean TEG concentration.

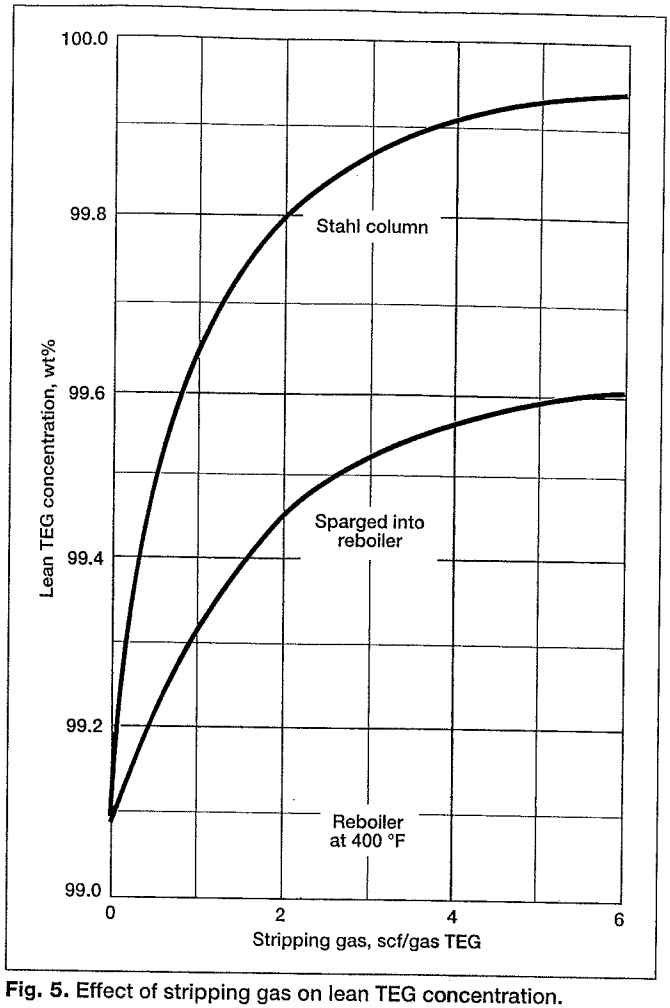


Fig. 5. Effect of stripping gas on lean TEG concentration.

210°F with no stripping gas down to 190°F depending on the amount of stripping gas. Glycol losses in the water vapor leaving the still are minimal with a reflux equal to 30% of effluent water vapor.

The diameter of the stripping column can be estimated:

$$\text{Diameter, in.} = 0.6\ (\text{TEG circulation, gph})^{0.5} \qquad (2)$$

Glycol absorbs some aromatics in the natural gas and the overhead vapors from the still, which contains benzene and toluene. The vapors are piped to ground level and then condensed in a drum. Condensate disposal must comply with benzene regulations. Incineration is another disposal approach that handles the wet gas containing hydrogen sulfide or mercaptans.

Reboiler. The reboiler supplies heat to reconcentrate the glycol. This includes heating the glycol to the reboiler temperature, vaporizing water in the still effluent, supplying the reflux duty and overcoming heat losses. Reboilers are typically horizontal, cylindrical, have a heat source—firetube, steam or hot oil bundle—and a weir to control the glycol level. For many applications, temperature control of the reboiler obtains a specified degree of reconcentration. In Fig. 4, concentrations up to 99.1% TEG are attainable at 400°F. Note that the reconcentration is about 0.4% higher than what would be predicted from the atmospheric boiling point curve. This is due the desorption effect of dissolved hydrocarbons and, to a lesser extent, operation at altitudes above sea level. There are applications where the process conditions, e.g., high gas temperature or low gas pressure, require higher TEG reconcentration and the use of stripping gas.

The reboiler temperature should not exceed 400°F and a high temperature shutdown is mandatory. The reboiler's design should keep the maximum film temperature below 430°F. This requires control of the heat flux to 6,000 Btu/hr ft^2 when the reboiler temperature is 400°F and 8,000 Btu/hr ft^2 when the reboiler is at 360°F.[10,12,13]

In a well-designed firetube, the length to diameter ratio is high to limit the radiant heat flux. There should be no flame impingement. The burner is adjusted to release the combustion heat slowly and limit the maximum heat flux to twice the average. A long, rolling, yellow-tipped flame is desirable.[5,13,18] Larger reboilers have tube bundles heated by steam or a heat transfer fluid. The heat flux is controlled by the temperature of the heat medium—450°F is preferred but sometimes 500°F can be used. Whatever the heat source, the glycol level should be 6 in. over the top tube.

Good operation—fast startup and quick response to changes in the gas flowrate or water content—requires that the available heat duty be 25% greater than the design or steady state requirement. This should be possible without overheating the glycol. Reboiler duty can be estimated from the amount of water removed:[13]

$$\text{Duty, Btu/lb } H_2O = 900 + 950\ (\text{gal TEG/lb } H_2O) \qquad (3)$$

Use a heat flux of 14,000 Btu/hr ft^2 in calculating the vapor disengagement area. The desired configuration is:[13]

Length/diameter ratio = 5 preferred
Minimum diameter = 1.5 ft
Minimum length = 3.5 ft

Usually, a stripping gas sparger is installed into the reboiler's bottom, e.g., a perforated pipe. The highest reconcentration is obtained by contacting the effluent glycol from the reboiler countercurrently with dry sales gas as it flows into the surge tank (Fig. 2). This is the crux of the Stahl column, which is a 2 ft to 4 ft long downcomer packed with ceramic saddles and stainless steel rings.[19] Stripping gas should be preheated.

Fig. 5 quantifies the advantage of using stripping gas. Sparging in the reboiler increases the glycol concentration from the 99.1% to 99.5% at 400°F. A Stahl column makes much better use of the stripping gas and can achieve concentrations as high as 99.9%. Stripping gas is an additional cost and should only be used when necessary, and then at less than 3 scf/gal TEG.

Surge tank. The surge tank contains surges in the glycol flowrate without upsetting the operation, holds a complete draindown of glycol from the absorber trays and provides capacity during startup for the glycol to expand when heated from ambient to operating temperature. For small units the surge tank is an extension of the reboiler.

Glycol spills over a weir from the section with the firetube to the surge section in which the helical glycol-glycol heat exchange coil is located. In these designs, the surge tank also serves as the storage tank. Large units have a separate surge tank (Fig. 2). Some large designs have a separate storage tank. The surge tank should have a level indicator, a low level shutdown and insulation to protect operators and conserve heat. Dimension guidelines are the same as those for reboilers.

Next month—Part 2. More guidelines on calculating the glycol circulation rate, pumps, heat exchangers and instrumentation in a TEG process. Also, an example of how these guidelines can be used to improve the sizing of absorbers and reconcentrators. ■

The authors

William Manning *is a principal process engineer with Coastal Chemical Co., Houston. He has over 30 years of experience in process development, project management, plant operation and troubleshooting in oil and gas production. Dr. Manning holds 15 patents and 20 publications and has served as an adjunct professor at Tulsa University. He holds a BS and PhD degree in chemical engineering from McGill University and is a registered professional engineer in Oklahoma.*

Harold Wood *is chief engineer for Maloney-Crawford, Tulsa, Okla. He has over 40 years of experience in the oil and gas industry, particularly in oil refining, chemical plants and lease production facilities. He specializes in the design of glycol dehydrators and holds three patents. Mr. Wood holds a BS degree and an MS degree in chemical engineering from Cornell University and is a registered professional engineer in Oklahoma.*

PART 2

Guidelines for glycol dehydrator design

Step by step, here's how to properly size a TEG absorber and reconcentrator

W. P. Manning, Coastal Chemical Company, Inc., Houston, Texas, and **H. S. Wood,** Maloney-Crawford, Tulsa, Okla.

Design guidelines can reduce hydrate-pluggage problems in the triethylene glycol (TEG) absorption process, thus eliminating downtime and lost production caused by water in natural gas. In addition, equipment can be properly sized by following prescribed troubleshooting tips. Use these guidelines along with the instrumentation list to help you correctly size an absorber and reconcentrator.

Pump. Reciprocating or glycol-powered pumps are used. A full-flow standby pump minimizes downtime due to pump failure. Include an in-line strainer on the pump suction. Glycol-powered pumps use effluent from the chimney tray of the absorber as the energy source. These pumps are used when electricity is not available. Adjusting the pump speed controls the flowrate.[20] The major drawback to glycol-powered pumps is gas consumption. This varies from 2 scf/gal TEG at an absorber pressure of 300 psig to 6 scf/gal TEG at 1,000 psig.[10,15] Consequently, there is more pump gas that can be used for fuel or for stripping.

Larger units use electric driven pumps because they are more economical. Flow control is done either by varying the pump speed or with a bypass around the pump. Good flow control is desirable because excessive glycol circulation increases the reboiler duty. The bypass valve around the pump should discharge to the surge tank. Full flow around the pump cools the packing and reduces leaks. Use the manufacturer's catalog when selecting glycol-powered pumps.[20] Quick estimates for the horsepower and the electric consumption for a reciprocating pump are:[13]

$$\text{Pump, bhp} = (0.000012)(\text{gph})(\text{psig}) \quad (3)$$

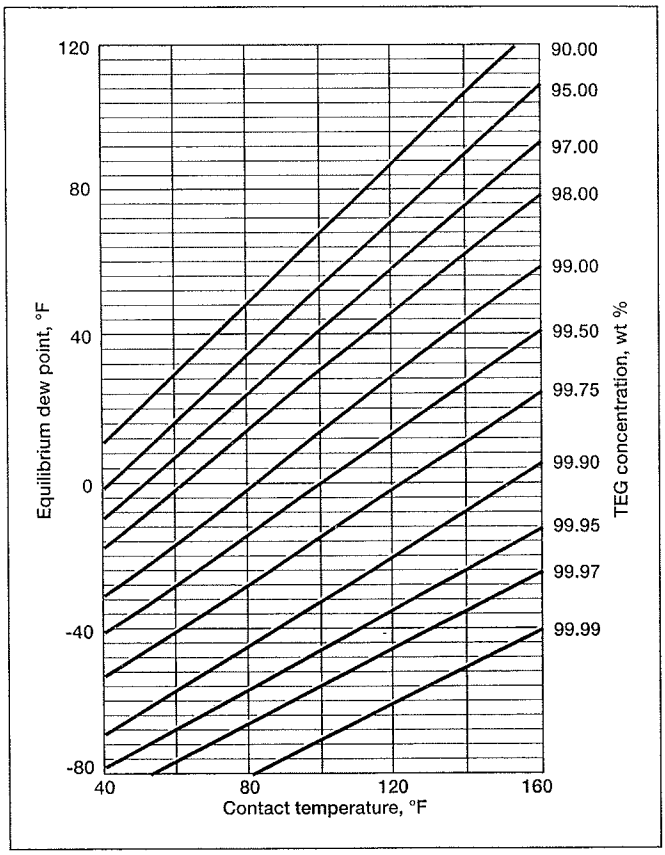


Fig. 6. Dew points for TEG-water system.

$$\text{Motor, kW} = (0.000011)(\text{gph})(\text{psig}) \quad (4)$$

Gas-glycol heat exchanger. Lean glycol should be cooled 10°F warmer than effluent gas from the absorber. Otherwise, the top tray acts as a heat exchanger and the glycol's temperature on the top tray rises. This increases the effluent gas' water content. Heat exchange with the dry gas is preferred because it prevents cooling the glycol below the effluent gas temperature. Small units normally use a helical coil installed in absorber above the top tray and below the demister. Large units use a double pipe or shell and tube

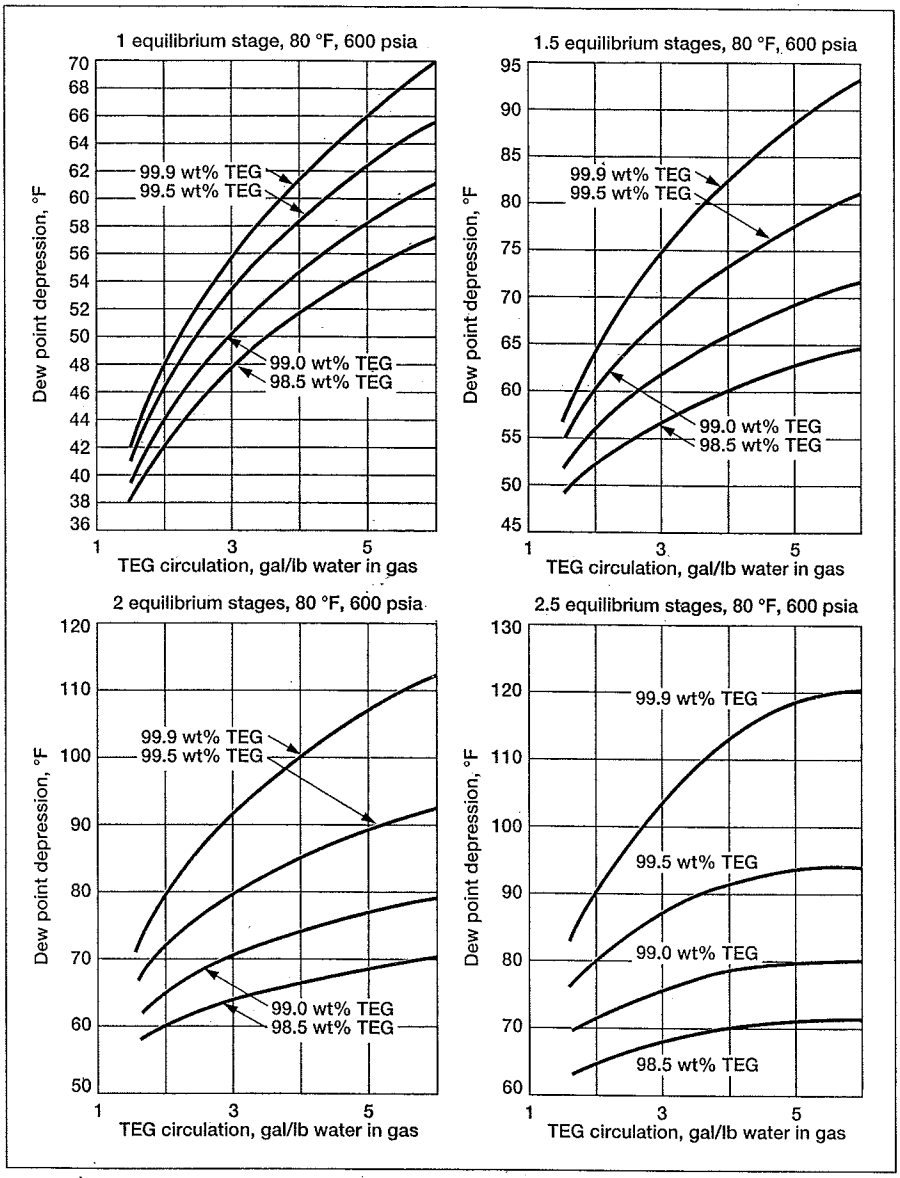


Fig. 7. Predicted dew point depression at 80°F and 600 psia.

heat exchanger mounted vertically next to the absorber. For very large units, a forced-draft air heat exchanger or a water-cooled shell and tube heat exchanger may be needed. External heat exchangers allow measuring the inlet lean glycol's temperature. Size the heat exchanger to cool the glycol from 200°F to 10°F above the gas temperature. Add 10% to the duty to compensate heat transfer loss from fouling and variations in the glycol circulation rate.

Instrumentation. Here's a list for fully monitoring a glycol dehydrator. Few units have the entire list. Keeping the control system as simple as possible is advisable:[13,21]

Inlet separator: thermometer, gauge glasses, level indicating controller and high level shutdown.

Absorber: pressure gauge, back pressure controller on exit gas line, thermometer, gauge glasses and level controllers on chimney tray and integral scrubber.

Flash tank: thermometer, gauge glasses and level indicating controllers for glycol and hydrocarbon streams, high level and low level shutdowns on the glycol stream.

Filters: pressure differential for both the solids and charcoal filters.

Glycol-glycol heat exchanger: thermometers on inlet and outlet of both lean and rich glycol streams.

Still: pressure gauge and temperature indicating controller on the overhead vapor.

Reboiler: pressure gauge, relief valve, temperature indicating controller, high-temperature shutdown and flame sensor to shut down the burner.

Surge tank: gauge glass and low level shutdown.

Pump: thermometer and pressure gauge on discharge.

Gas-glycol heat exchanger: thermometer on effluent glycol.

Operating conditions. Pressure and temperature of the inlet gas control the water content and water amount to be removed. High pressures and low temperatures are preferred operating conditions because they reduce water content, equipment size and fabrication costs. Note that cooling TEG increases foaming tendency, so an inlet gas temperature below 60°F is not recommended. For most applications, the pressure and temperature of the inlet gas are fixed. However, if the gas is very hot, e.g., after sweetening w' amine or potassium carbonate so tions, cooling to 120°F is advised. Similarly, compression may be needed for very low pressure gas, e.g., stock tank vapors or landfill gas. Here are some suggested operating temperatures:

Inlet gas	80 to 100°F
Lean glycol to absorber	5 to 15°F warmer than gas
Flash tank, filters	100 to 200°F, 150°F preferred
Glycol to still	200 to 300°F, 300°F preferred
Reboiler	350 to 400°F, 380°F preferred
Glycol to pump	< 200°F, < 180°F preferred
Still overhead	210°F, lower with stripping gas

Dew point depression. The TEG drying capability is limited by the vapor-liquid equilibrium (VLE) between the water contents of the gas and glycol (Fig. 6).[16] The dew point of natural gas in equilibrium with TEG decreases dramatically as the TEG concentration increases, e.g., 32, 15, 0 and −32°F for 98, 99, 99.5 and 99.9 wt% TEG respectively at 100°F. And the dew point follows the gas temperature, e.g., 30, 15, 0, and −15°F at 120, 100, 80 and 60°F, respectively, for 99 wt% TEG.

The dew point depression obtained in the absorber c be correlated in terms of the lean TEG concentration, t TEG circulation rate and the number of equilibrium stages—one stage is equivalent to four actual trays. The effect of pressure is secondary—the dew point decreases 0.9°F for every 100 psi increase in pressure. Worley's data for 4, 6 and 8 trays at 100°F and from 1.5 to 7 gal TEG/lb

H_2O in inlet gas have been published.[12]

Worley's graphs are based on the Worley VLE data and are optimistic. Olbrich and Manning developed similar charts[13,22] (Figs. 7 and 8) using the Parrish VLE data for the following absorber conditions:

Absorber trays	4	to	12
Lean TEG concentration, wt%	98.5	to	99.5
Circulation, gal TEG/lb H_2O	1.5	to	6
Temperature, °F	80	to	100
Pressure, psia	300	to	1,400

The Olbrich data are 2°F to 15°F more conservative than Worley's. Up to two additional trays are suggested for the absorber. This explains why some manufacturers add one tray to the Worley data.[14,23]

Design problem. Here's an example of how to select standard sizes of absorbers and reconcentrators:

- Obtain design information such as: inlet gas flowrate, pressure and temperature; required dew point or water content of the gas inlet; gas analysis or gravity; available utilities and regulations for discharging still overhead.
- Select an appropriate combination of lean glycol concentration, circulation rate and number of absorber trays using the Olbrich data. For small units, use a circulation rate of 3 gal TEG/lb H_2O. For larger units, use a lower circulation rate to reduce the size of the equipment and conserve energy.

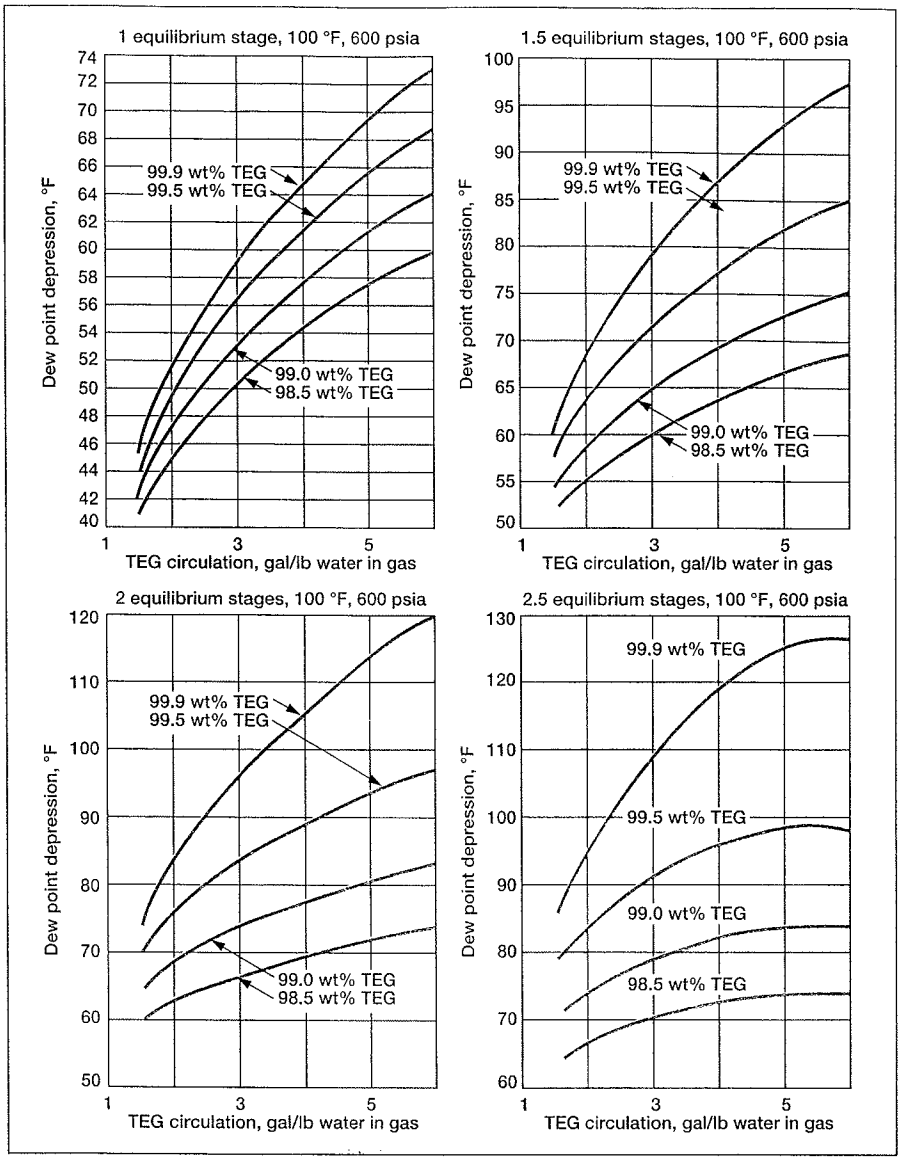


Fig. 8. Predicted dew point depression at 100°F and 600 psia.

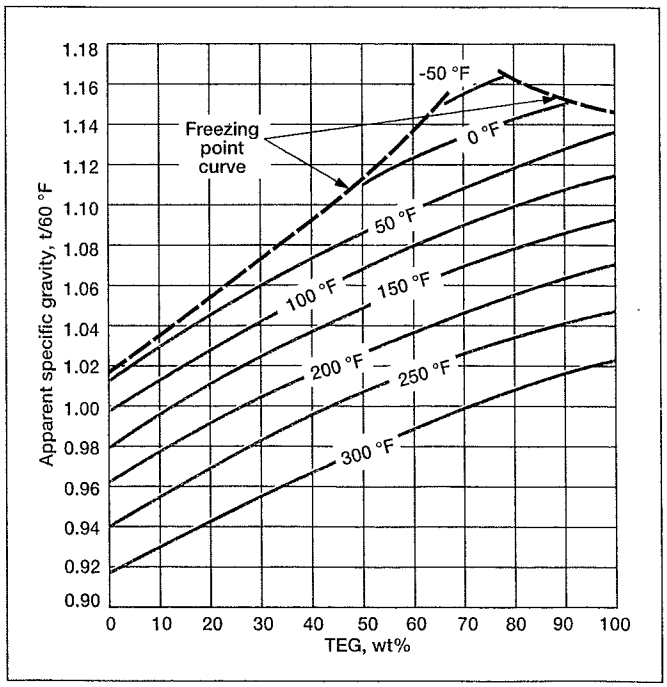


Fig. 9. Density of TEG.

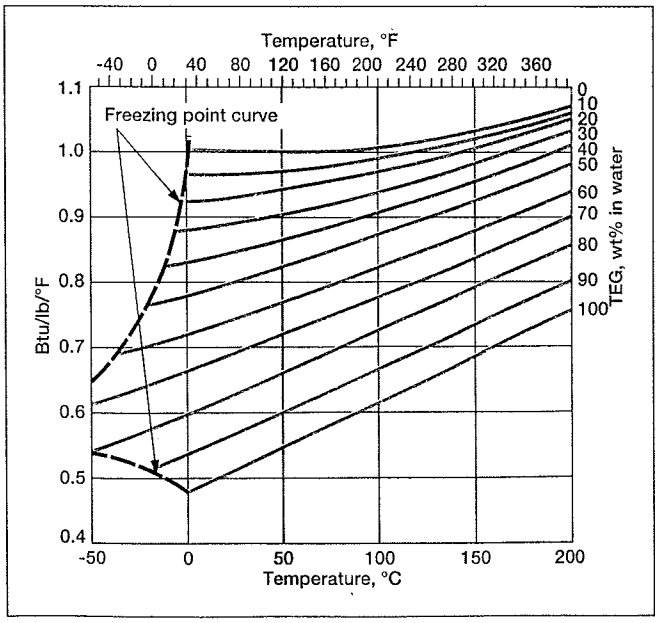


Fig. 10. Specific heat of TEG.

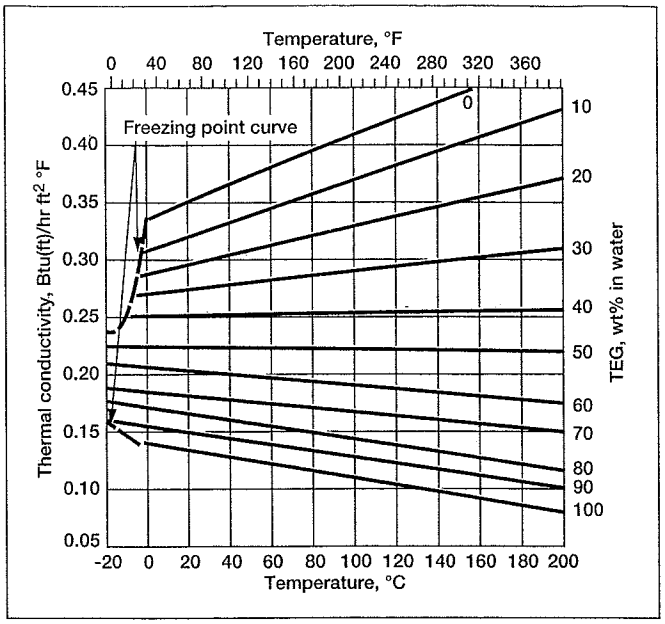


Fig. 11. Thermal conductivity of TEG.

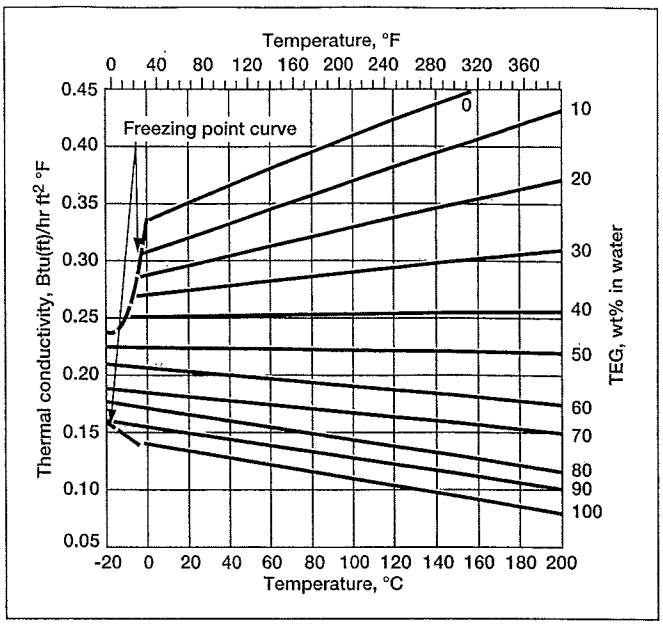


Fig. 12. Viscosity of TEG.

Table 1. Mass and heat balances

		Absorber Gas in	Absorber Gas out	Absorber TEG in	Absorber TEG out	Gas-TEG HX Gas	Gas-TEG HX TEG	Reflux coil	TEG HX Stage 1	Flash gas
Gas	lb/hr	76,333	76,321	—	12	76,321	—	12	12	8
Water	lb/hr	87	12	16	91	12	16	91	91	—
TEG	lb/hr	—	14	1,632	1,618	14	1,632	1,618	1,618	—
Total	lb/hr	76,420	76,347	1,648	1,721	76,347	1,648	1,721	1,721	8
Temp. in	°F	90	—	100	—	90	185	90	110	—
Temp. out	°F	—	90	—	90	92	100	110	150	148
ΔT	°F					1.8	85	20	40	
Cp	Btu/lb°F					0.56	0.57	0.57	0.59	
Q	Btu/hr					76,960	79,850	19,620	40,620	
		Flash tank	**Filter**	**TEG HX Stage 2**	**Still overhead**	**Reflux**	**Reboiler**	**Surge tank**	**TEG HX Stage 1,2**	**Pump**
Gas	lb/hr	4	4	4	4	—				
Water	lb/hr	91	91	91	75	23	16	16	16	16
TEG	lb/hr	1,618	1,618	1,618	2	—	1,616	1,632	1,632	1,632
Total	lb/hr	1,713	1,713	1,713	81	23	1,632	1,648	1,648	1,648
Temp. in	°F	150	148	145	—	—	300	390	380	180
Temp. out	°F	148	145	300	210	—	390	380	180	185
ΔT	°F	2	3	155	—	—	90	5	200	5
Cp	Btu/lb °F	—	—	0.66	—	—	0.73	—	0.68	0.57
Q	Btu/lb	—	—	175,240	75,000	22,500	107,220	—	224,130	4,700

- Make material and heat balances.
- Size or obtain bids for equipment.

The physical properties of TEG are needed for design calculations.[12,24,25] Union Carbide's graph was selected for Figs. 9 through 12 because they include equations that can be used in computer programs.

Some design engineers include these additional safety factors:

- Add one more tray to the absorber
- Select the pump and pipe size so that circulating rate can be increased by 15%
- Add more than 25% to the reboiler duty
- Add more than 10% to the heat exchanger ratings
- Include equipment to use stripping gas and perhaps a Stahl column.

Technically, this is an overkill unless drastic changes in design conditions are anticipated. Economically, it is not disastrous because these modifications are low cost.

Example.

1. Design data.

Gas flowrate	40 MMscfd
Gas gravity	0.60, mol wt 17.4
Gas pressure	800 psia, 786 psig at 1,000 ft elevation
Gas temperature	90°F
Inlet gas humidity	Saturated
Sales gas specification	7 lb H_2O/MMscf

The relation between dew point depression and water removed can be obtained from Fig. 1. From the data, the 62°F dew point depression corresponds to 45 lb H_2O/MMscf to be removed.

	Inlet	Outlet
Pressure, psia	800	796
Temperature	90	92
Condition	Saturated	Dried
Dew point, °F	90	28
Water content, lb H_2O MMscf	52	7

2. Glycol circulation rate. Select a circulation rate of 2 gal TEG/lb H_2O in the inlet gas to obtain an efficient design. A lean TEG concentration of 98.9% is achievable with a reboiler temperature of 390°F with no stripping gas (Fig. 4). Use Olbrich charts and start with 6 trays or 1.5 equilibrium stages.

Dew point depression (Fig. 7)	56.0°F at 80°F
Dew point depression (Fig. 8)	58.0°F at 100°F
Average	57.0°F at 90°F

With the correction for pressure, (0.9)(2.0) = 1.8°F, the expected dew point depression is 58.8°F. Similarly, for eight trays (two equilibrium stages) the depression is 68.3°F. So seven trays will work. Note the effect of stripping gas on the circulation rate, specifically, 3 scf/gal TEG sparged directly into the reboiler or using a Stahl column.

Continued

Stripping gas	TEG concentration, wt%	Number of trays	Gal TEG lb H_2O in gas
None	98.9	7	2.0
Reboiler	99.5	7	1.7
Stahl	99.8	7	1.5

3. Material and heat balances.

Basis 1 hr
Gas flow = (940/24) = 1.67 MMscf/hr
Water content = (1.67)(52) = 86.7 lb/hr
TEG circulation = (2)(86.7) = 173.4 gal/hr
= (173.4)(9.41) = 1,632 lb/hr

Table 1 shows the material and heat balances. While the actual operating temperatures depend on the equipment selected, there should be no significant differences from Table 1.

4. Equipment. Here are some preliminary specifications. Alternatives such as vertical or horizontal heat exchangers can be used. The specifications show how the sizing guidelines can be used:

Inlet separator	Vertical, 42 or 48-in. OD by 7 ft 6 in. long 1,200 psig working pressure 6-in. gas connections
Absorber	ID = 44 in. (Fig. 3) Check using equation: $V = 600 [(\rho_L - \rho_G)/\rho_G]^{0.5}$ L = 69.3 lb/ft^3 and G = 2.60 lb/ft^3 V = 3,039 ft/hr = 50.6 ft/min Gas volume = 480 acfm (90°F, 800 psia) Area = (480/50.6) = 9.5 ft^2 ID = 42 in. Use 48-in. ID or 54-in. OD by 25-ft (27-ft) long 7 (8) trays with 24-in. spacing 1,200 psig working pressure 6-in. gas connections 2-in. glycol connections
Flash tank	Horizontal Two phase. Lean gas. 24-in. OD by 5-ft long 125 psig working pressure Retention time 15 min.
Solids filter	Full flow 9-in. ID by 3 ft 6 in. long Three 3 in. by 36-in. elements alternately 3-in. ID by 6 ft 6 in. long Six 12-in. elements
Carbon filter	Full flow 14-in. ID by 7-ft long Flowrate 2.7 gpm/ft^2 Retention time 15 min
Glycol-glycol heat exchanger	Double pipe 1-in. finned pipe in 2.5-in. jacket Duty 250,000 Btu/hr Area 110 ft^2 Split either 55 and 55 ft^2 Or better 30 and 80 ft^2
Still column	Use equation: ID = 0.6 (gph TEG)$^{0.5}$ ID = 7.9 in. 8-in. pipe by 6-ft long packed with 1-in. rings or 10-in. pipe by 6-ft long packed with 1-in. saddles
Reflux	Helical coil 0.75-in. ss tubing Duty 23,000 Btu/hr Area 4 ft^2
Reboiler	Duty from equation: Duty = 900 + (950) (gal TEG/lb H_2O) = 900 + (950) (173.4/75) = 3,096 Btu/lb H_2O = (3,096)(75) = 232,000 Btu/hr Check using Table 1 = 107.2 MBtu/hr heat glycol 75.0 vaporize still overhead 22.5 reflux, 30% still overhead 10.0 heat losses 214.7 MBtu/hr total 24-in. OD by 10-ft long 8-in. firetube, 44-ft^2 area Duty 275 MBtu/hr Heat flux 6,250 Btu/hr ft^2
Surge tank	24-in. OD by 7 ft 6 in. or 10-ft long Mounted below reboiler
Pump	Reciprocating 3 to 5 gpm Pump bhp = 1.73 Motor kW = 1.58
Gas-glycol heat exchanger	Shell and tube 8-in. ID by 6-ft long 55 (0.75 in.) tubes OD Duty 90 MBtu/hr Area 60 ft^2
Piping	Gas: 6-in. sch 80 Glycol: 1-in. sch 80 pump discharge 2-in. sch 40 pump suction

The authors

William Manning *is a principal process engineer with Coastal Chemical Co., Houston. He has over 30 years of experience in process development, project management, plant operation and troubleshooting in oil and gas production. Dr. Manning holds 15 patents and 20 publications and has served as an adjunct professor at Tulsa University. He holds a BS and PhD degree in chemical engineering from McGill University and is a registered professional engineer in Oklahoma.*

Harold Wood *is chief engineer for Maloney-Crawford, Tulsa, Okla. He has over 40 years of experience in the oil and gas industry, particularly in oil refining, chemical plants and lease production facilities. He specializes in the design of glycol dehydrators and holds three patents. Mr. Wood holds a BS degree and an MS degree in chemical engineering from Cornell University and is a registered professional engineer in Oklahoma.*

LITERATURE CITED

1 McCarthy, E. L., Boyd, W. L. and Reid, L. S., "Water Vapor Content of Saturated Natural Gas," Trans. AIME, Vol. 189, p. 241, 1950.
2 McKetta, J. J. and Wehe, A. H., "Water Contents of Natural Gas," *Petroleum Refiner,* Vol. 37, No. 8, p. 153, 1958.
3 Herrin, J. P., "Fundamentals of Gas Dehydration," Gas Conditioning Conf., Univ. of Okla., 1980.
4 Kohl, A. L. and Riesenfeld, F. C., *Gas Purification,* Fourth Ed., Gulf Pub. Co., Houston, Texas, 1985.
5 Ballard, D., "How to Operate a Glycol Plant," *Hydrocarbon Processing,* Vol. 45, No. 6, pp. 171–188, 1966.
6 Ballard, D., "The Fundamentals of Gas Dehydration," Gas Conditioning Conf., Univ. of Okla., 1979.
7 Black, Sivalls and Bryson, "Product Section 34 Dehydrators," Oklahoma City, Okla., 1960.
8 Natco, "Glycol Dehydration Systems," TSL Catalog, Tulsa, Okla., 1984.
9 Pearce, R. L., "Fundamentals of Gas Dehydration," Gas Conditioning Conf., Univ. of Okla., 1973.
10 Sivalls, Inc., "Glycol Dehydration Design Manual," Odessa, Texas, 1976.
11 Worley, S., "Super-Dehydration with Glycols," Gas Conditioning Conf., Univ. of Okla., 1967.
12 Gas Processors Suppliers Assn., *Engineering Data Book,* Section 20, Tenth Ed., Tulsa, Okla., 1987.
13 Manning, F. S. and Thompson, R. E., *Oil Field Handling of Natural Gas,* PennWell, 1991.
14 Harrell, B. E., Personal communication, Natco, Tulsa, Okla., 1991.
15 Guenther, J. D., "Natural Gas Dehydration," Seminar in Denmark, Lummus Engr., Houston, Texas, 1979.
16 Ballard, D., "Operator Talk...Glycol Dehydration," *Hydrocarbon Processing,* Vol. 56, No. 4, pp. 111–118, 1977.
17 Ballard, D. and von Puhl, S. A., "Improved Filtration Lowers Cost," Petroenergy, Houston, Texas, 1988.
18 Simmons, Jr., C. V., "Avoiding Excessive Glycol Costs," *Oil & Gas J.,* Vol. 79, No. 38, p. 121, 1981.
19 Stahl, W., "Method and System for Reconcentrating Ethylene Glycols," U.S. Pat. #3,105,748, Oct. 1963.
20 Kimray, Inc., "Equipment Catalog," Section G, Oklahoma City, Okla., 1960.
21 Landes, S. H., "Fat vs. Lean Instrument Designs," *Oil & Gas J.,* Vol. 81, No. 46, pp. 165–170, 1983.
22 Olbrich, M. E., "Improved Design Charts for TEG Contactors," MS Thesis, Univ. of Tulsa, 1988.
23 Manning, F. S., Personal communication, Univ. of Tulsa, Tulsa, Okla.
24 Dow Chemical Co., "Gas Conditioning Fact Book," Midland, Mich., 1962.
25 Union Carbide Corp., "Triethylene Glycol Catalog," Danbury, Conn., 1989.
26 Parrish, W. R., Won, K. W. and Baltatu, M. E., "Phase Behavior of the TEG-Water System," 65th Annual GPA Conv., San Antonio, Texas, 1986.
27 Pearce, R. L. and Sivalls, C. R., "Fundamentals of Gas Dehydration," Gas Conditioning Conf., Univ. of Okla., 1984.

End of series. Part 1, January 1993, page 106.