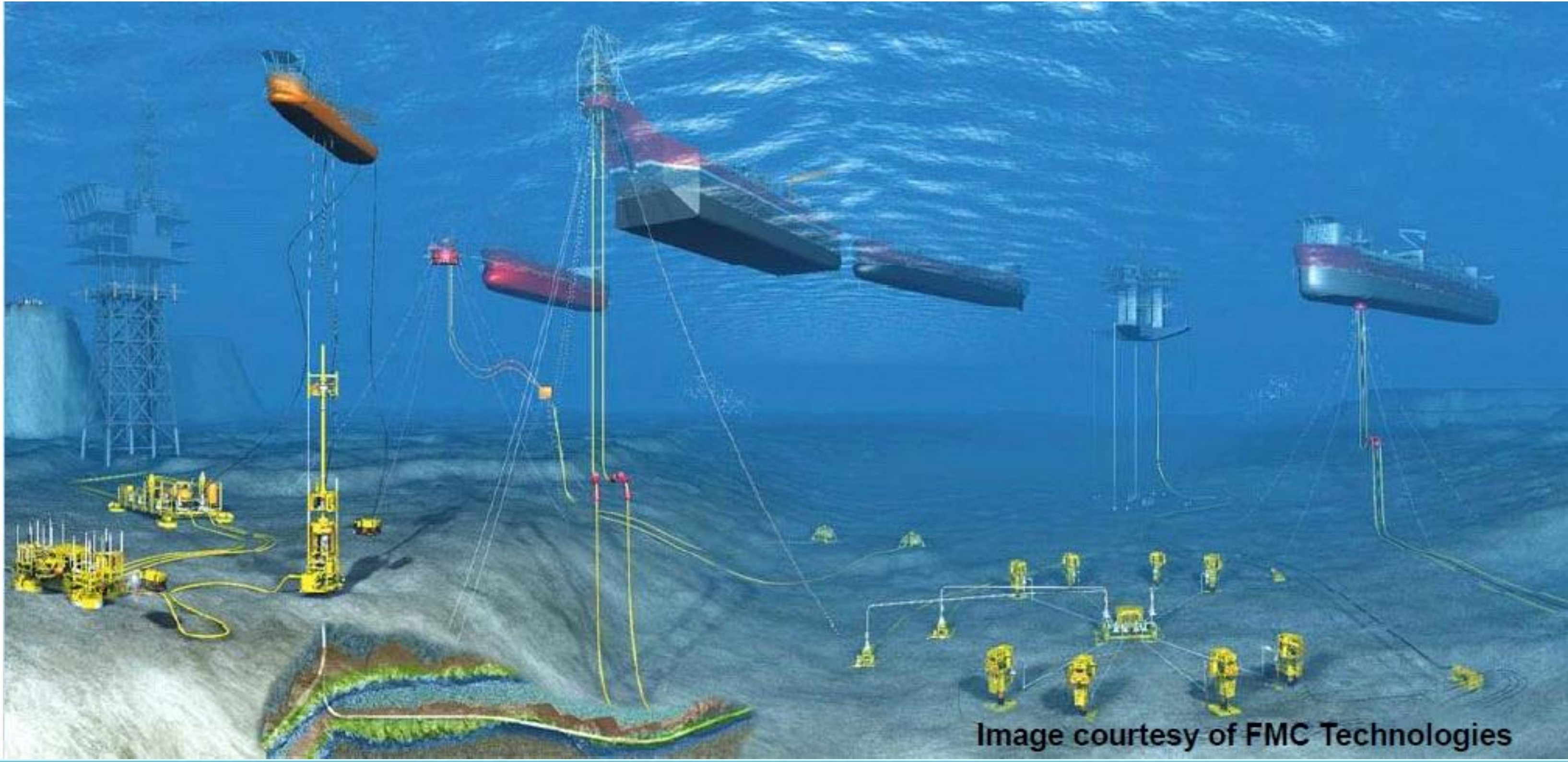
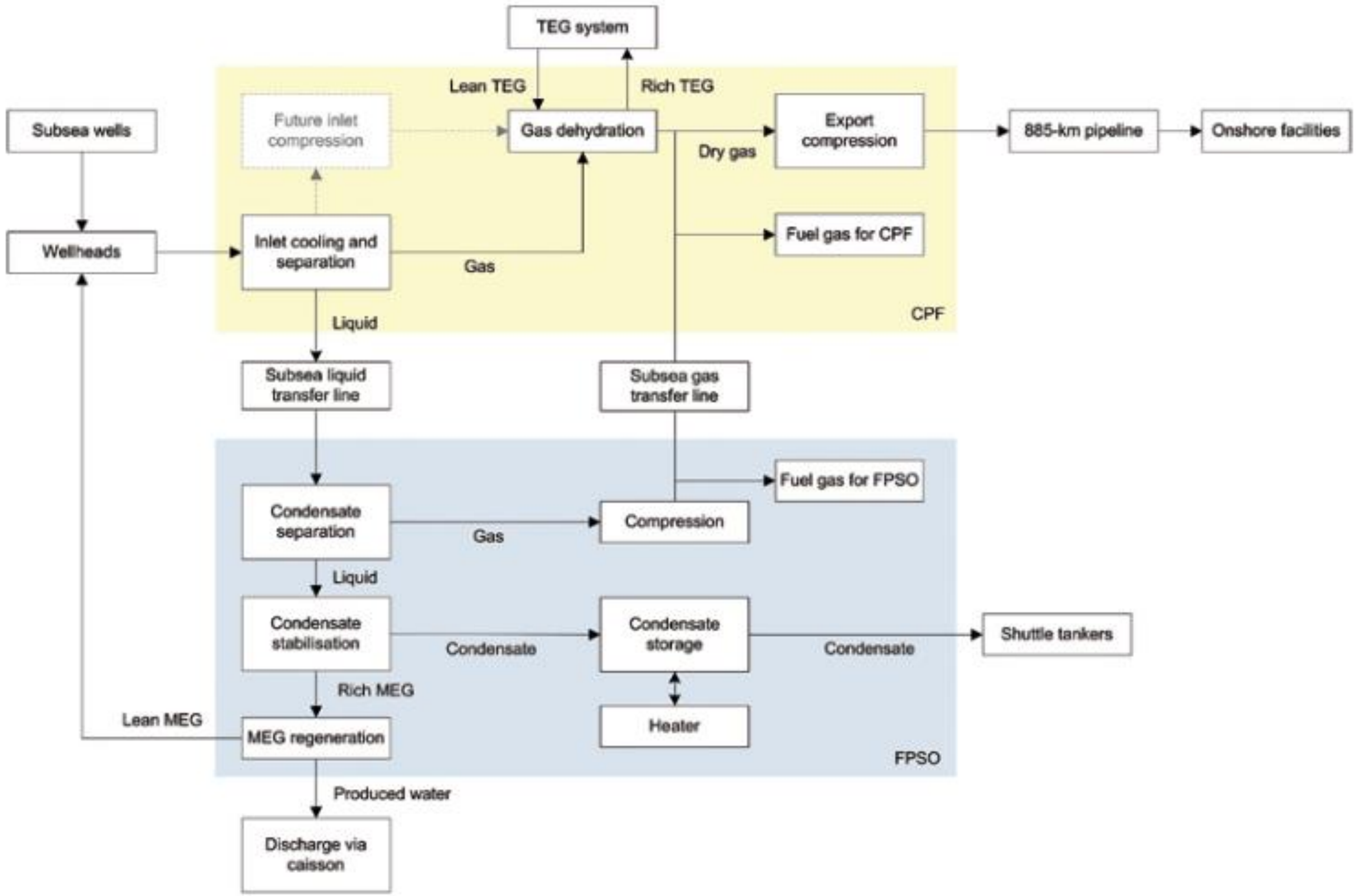


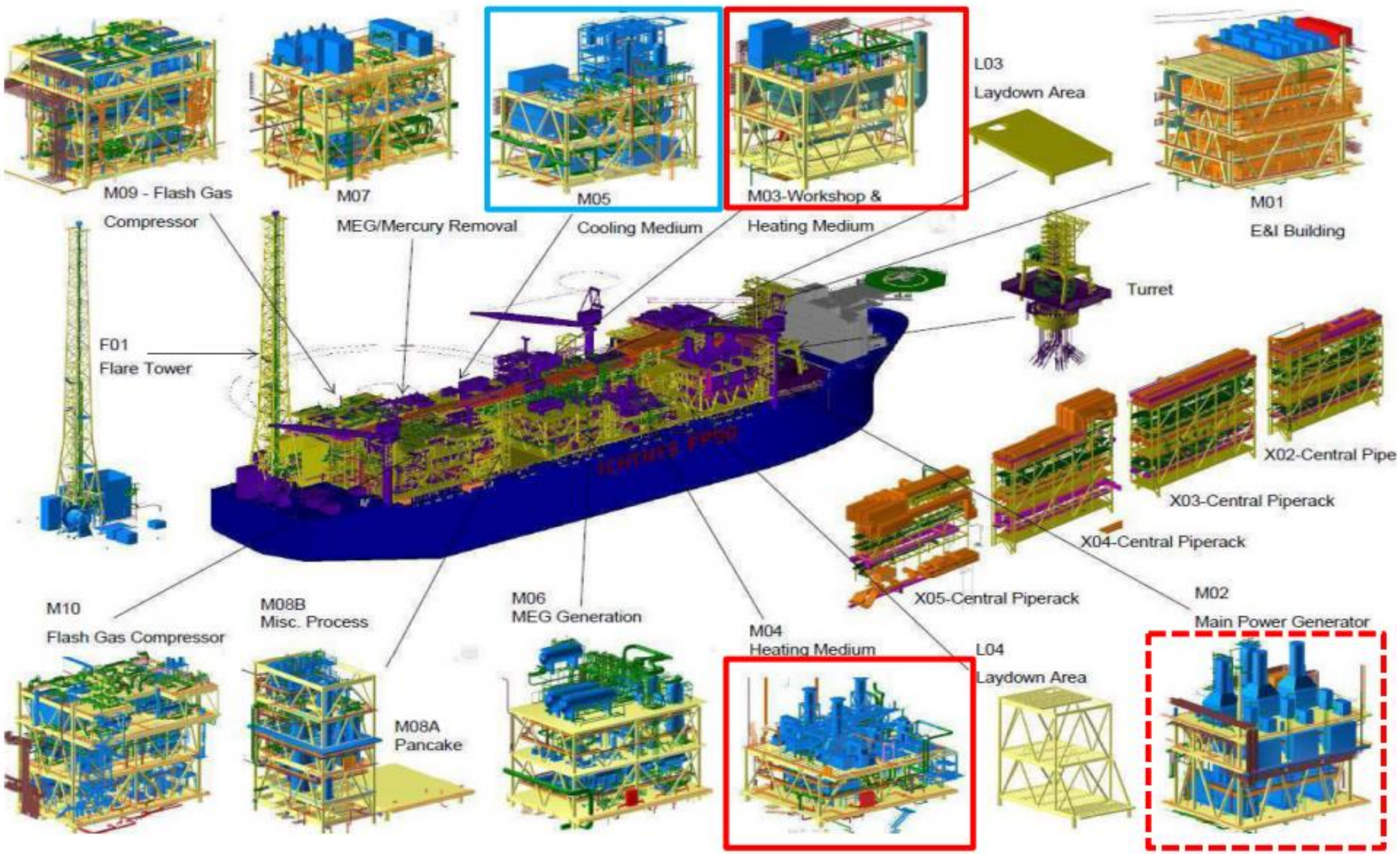
Offshore Equipment

Yutaek Seo

Offshore Process Flow Diagram



Offshore facilities on topside



- Specification for pipeline quality gas

US Pipelines					
Specs	Alliance USA	Empire	GLGT	Iroquois	Northern Border
Hydrogen Sulphide	Max. 1 grains/Ccf³	Max. 1 grains/Ccf³	Max. 1/4 grains/Ccf³	Max. 1/4 grains/Ccf³	Max. 0.3 grains/Ccf³
Total Sulphur	Max. 5 grains/Ccf³	Max. 20 grains/Ccf³	Max. 20 grains/Ccf³	Max. 1.25 grains/Ccf³	Max. 2 grains/Ccf³, (0.3 grains mercaptan/Ccf³)
Carbon Dioxide	Max. 2% by volume	Max. 2% by volume	Max. 2% by volume	Max. 2% by volume	Max. 2% by volume
Oxygen	Max. 0.4% by volume	Max. 1% by volume	Max. 1% by volume	Max. 0.2% by volume	Max. 0.4% by volume
Nitrogen	Not specified	Not specified	Max. 3% by volume	Max. 2.75% N_2+O2 4% N_2+ CO_2	Not specified
Temperature	Max. 122°F	Max. 120°F, Min. 40°F	Max. 120°F, Min. 20°F	Max. 120°F	Min. 32°F Max. 120°F
Heating Value	Min. 962 BTU/ft³	Min. 950 BTU/ft³ Max. 1200 BTU/ft³	Min. 967 BTU/ft³ Max. 1069 BTU/ft³	Min. 967 BTU/ft³ Max. 1110 BTU/ft³	Min. 967 BTU/ft³
Water	Max. 4 lbs/MMcf	Max. 7 lbs/MMcf	Max. 4 lbs/MMcf	Max. 4 lbs/MMcf at 14.73 psi & 60°F	Max. 4 lbs/MMcf
Hydrocarbon Dewpoint	Max. 14°F at opt. pres.	Not specified	Not specified	Max. 15°F or less	Max. -5°F (800psia), -10°F (1000 psia), -18°F at (1100 psia)
Interchangeability	Not specified	Not specified	Not specified	See Iroquois Tariff	Not specified

Water content determin

- McKetta-Wese PP correlation
- Example

: NG MW 26

: 3 % brine

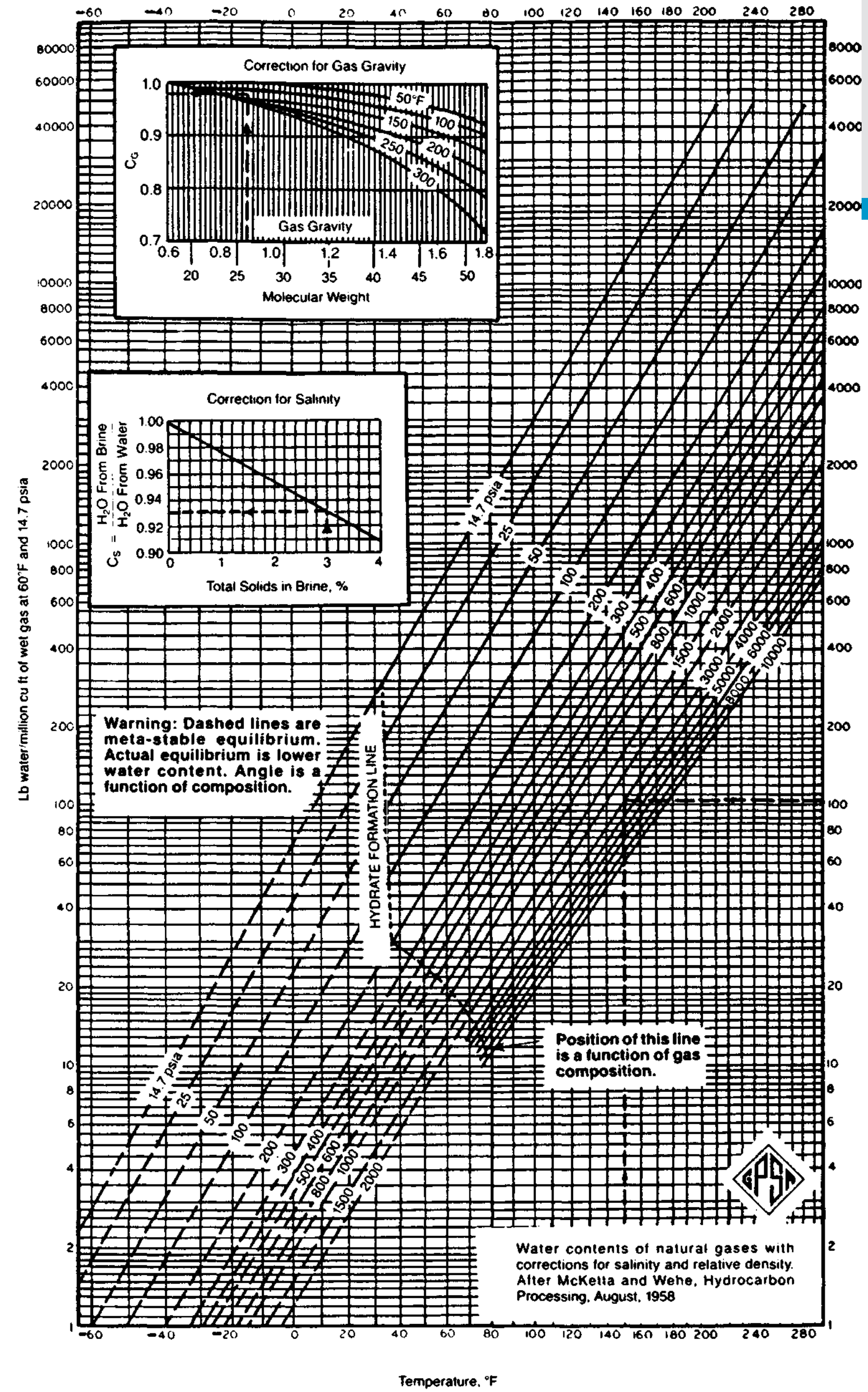
: 3000 pisa, 150 oF

→ 104 lb of water per MMscf of wet gas

: correction factor

salinity – 0.93, MW – 0.98,

→ 104 * 0.93 * 0.98 = 94.8 lb/MMscf



- Correction for acid gas when NG contains more than 5% CO2 and/or H2S.

: if 15% H2S, from Figure 8-3, water content for H2S is 400 lb/MMscf

: Effective water content is 0.85*94.8 + 0.15*400 = 141 lb/MMscf

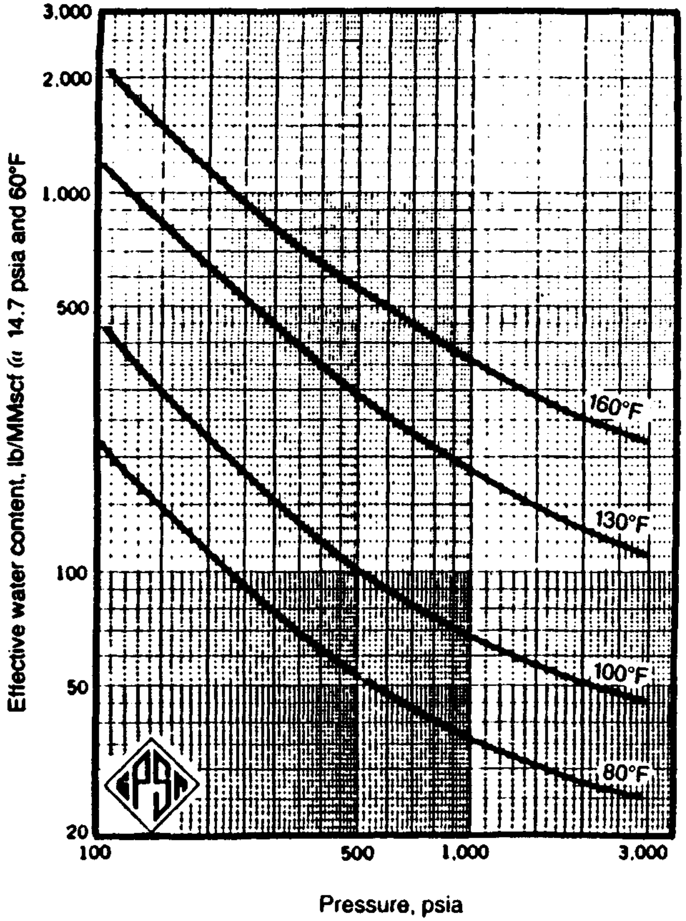


Figure 8-2. Effective water content of CO_2. (From Gas Processors Suppliers Association, *Engineering Data Book*, 10th Edition.)

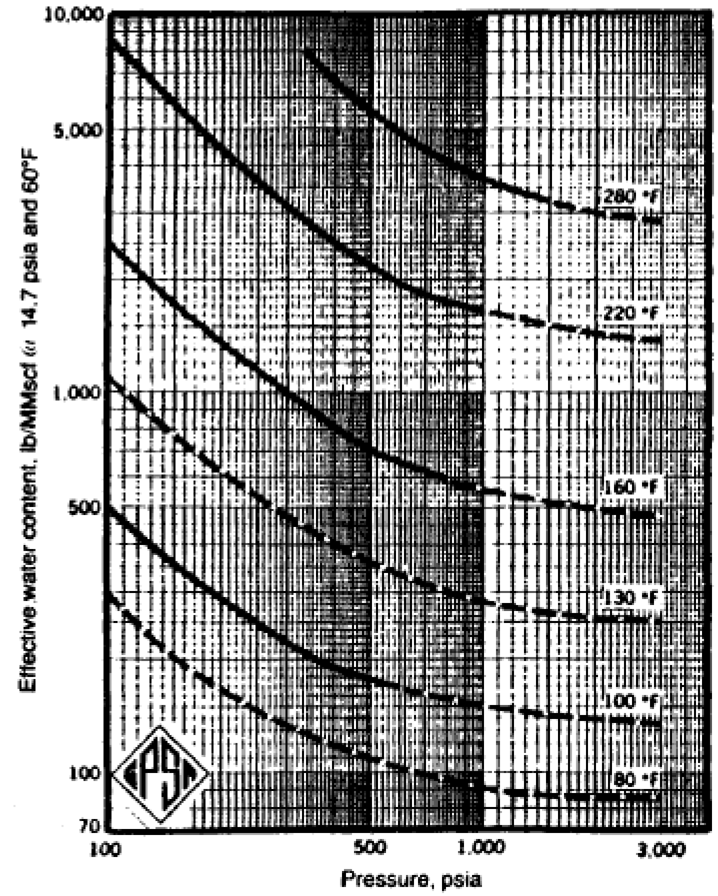


Figure 8-3. Effective water content of H_2S. (From Gas Processors Suppliers Association, *Engineering Data Book*, 10th Edition.)

Glycol dehydration

- This is an absorption process, where the water vapor in the gas stream becomes dissolved in a relatively pure glycol liquid solvent stream.
- Glycol dehydration is relatively inexpensive, as the water can be easily "boiled" out of the glycol by the addition of heat. This step is called "regeneration" or "reconcentration" and enables the glycol to be recovered for reuse in absorbing additional water with minimal loss of glycol.

- Most glycol dehydration processes are continuous. That is, gas and glycol flow continuously through a vessel (the "contactor" or "absorber") where they come in contact and the glycol absorbs the water.
- The glycol flows from the contactor to a "reboiler" (sometimes called "reconcentrator" or "regenerator") where the water is removed or "stripped" from the glycol and is then pumped back to the contactor to complete the cycle.

- Typical trayed contactor

: Counter-current flow

: Wet gas contacts the rich glycol at the bottom

: The gas encounters leaner and leaner glycol
(i.e. glycol with less and less water)

: At each successive tray the leaner glycol is able to absorb additional amounts of water vapor from the gas.

: The counter-current flow in the contactor makes it possible for the gas to transfer a significant amount of water to the glycol and still approach equilibrium with the leanest glycol concentration.

: Glycol contactors will typically have between 6 and 12 trays, depending upon the water dew point required. To obtain a 7 lb/MMscf specification, 6 to 8 trays are common.

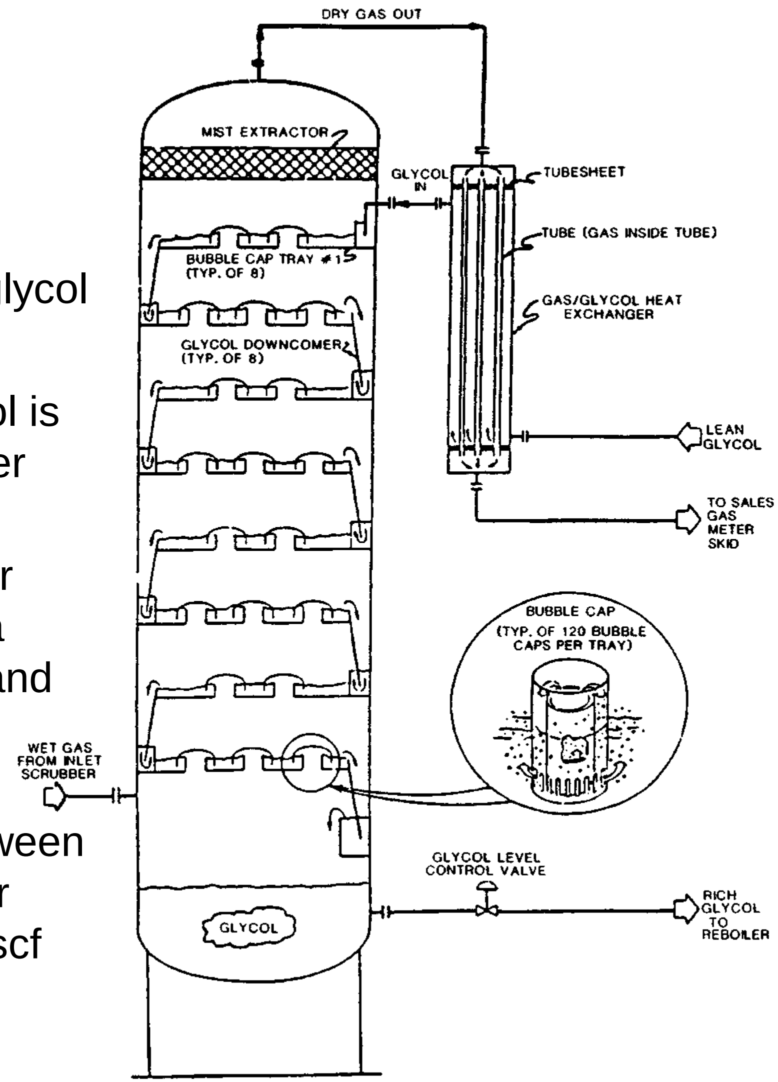
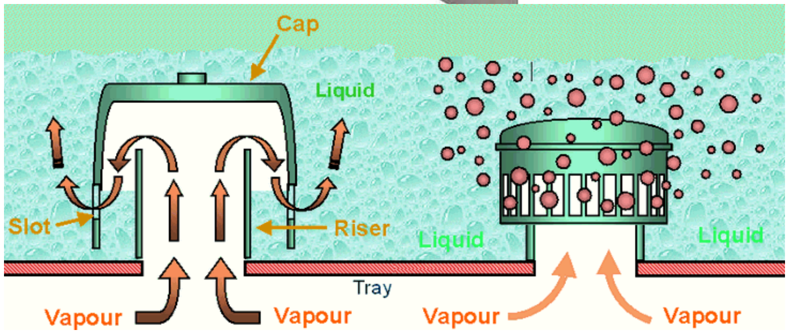
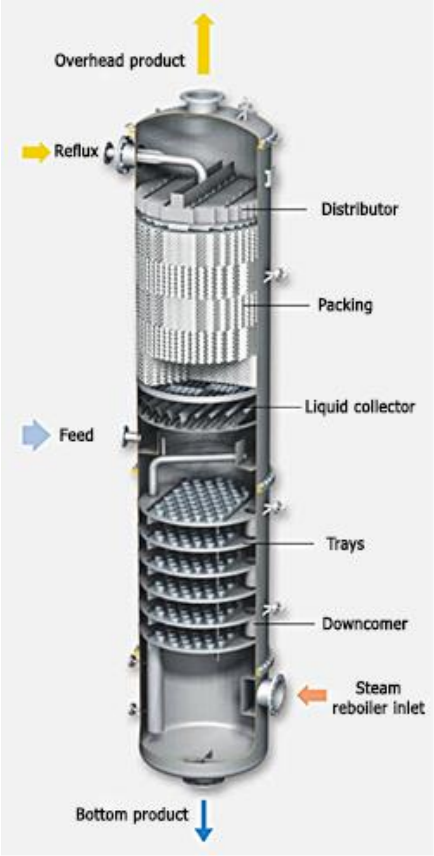


Figure 8-4. Typical glycol contactor in which gas and liquid are in counter-current flow.

- Contactors that are 12 ¾ in. and less in diameter usually use regular packing, while larger contactors usually use bubble cap trays to provide adequate contact at gas flow rates much lower than design.
- Structured packing is becoming more common for very large contactors.





- It is possible to inject glycol in a gas line and have it absorb the water vapor in co-current flow. Such a process is not as efficient as countercurrent flow, since the best that can occur is that the gas reaches near equilibrium with the *rich* glycol as opposed to reaching near equilibrium with the *lean* glycol as occurs in counter-current flow.
- Figure 8-5. Bottom of the contactor
- Partial co-current flow can be used to reduce the height of the glycol contactor by eliminating the need for some of the bottom trays.
- The glycol will absorb heavy hydrocarbon liquids present in the gas stream. Thus, before the gas enters the contactor it should pass through a separate inlet gas scrubber to remove liquid and solid impurities that may carry over from upstream vessels or condense in lines leading from the vessels.

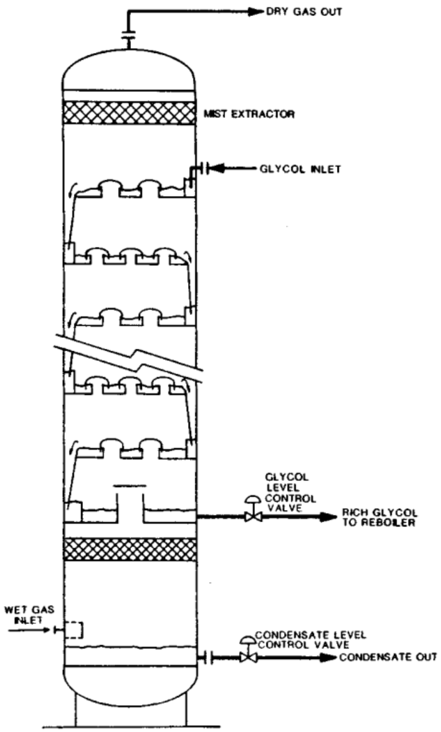
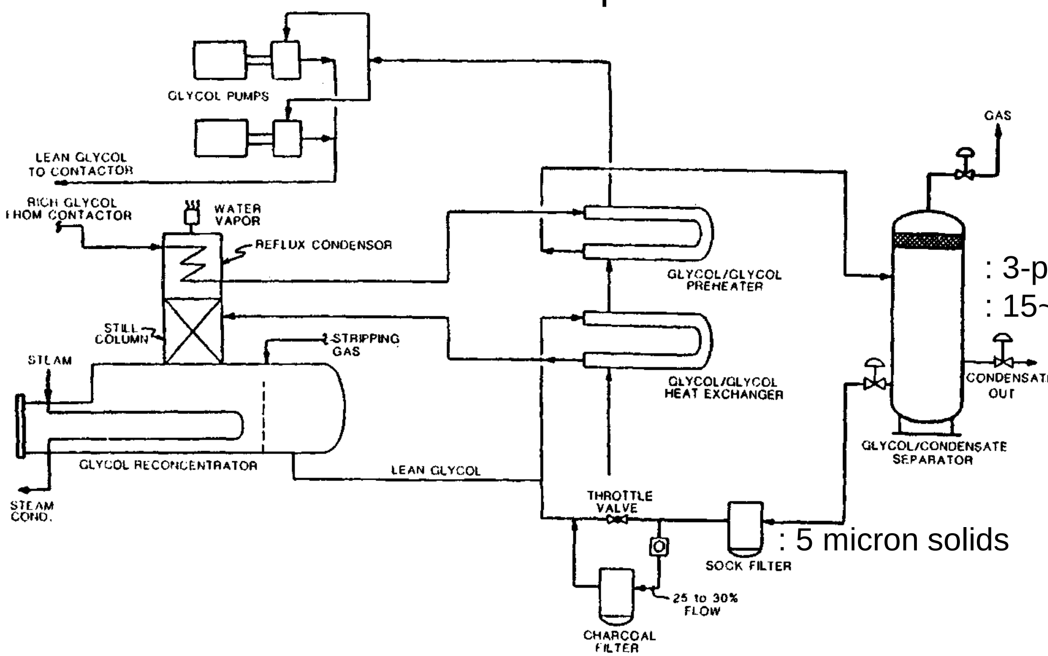


Figure 8-5. The bottom of the contactor is often used as a vertical inlet scrubber.

- Dry gas from the top of the gas/glycol contactor flows through an external gas/glycol heat exchanger. This cools the incoming dry glycol to increase its absorption capacity and decrease its tendency to flash in the contactor and be lost to the dry gas. In some systems, the gas passes over a glycol cooling coil inside the contactor instead of the external gas/glycol heat exchanger.
- The glycol reconcentration system is shown in Figure 8-6.

: glycol/glycol preheater heated by the hot lean glycol to 170oF to 200oF.

: Reboiler heated to 340 oF to 400 oF to provide the heat for the still column



: 3-phase separator

: 15~30 min retention time

Figure 8-6. Glycol reconcentration system.

- The glycol then flows through the glycol/glycol heat exchanger to the still column mounted on the reconcentrator, which operates at essentially atmospheric pressure
- As the glycol falls through the packing in the still column, it is heated by the vapors being boiled off the liquids in the reboiler.
- The falling liquid gets hotter and hotter. The gas flashing from this liquid is mostly water vapor with a small amount of glycol. Thus, as the liquid falls through the packing it becomes leaner and leaner in water.
- Before the vapors leave the still, they encounter the reflux condenser. The cold rich glycol from the contactor cools them, condensing the glycol vapors and approximately 25 to 50% of the rising water vapor.
- The water vapor exiting the top of the still contains a small amount of volatile hydrocarbons and is normally vented to atmosphere at a safe location. OR the water vapor can be condensed in an aerial cooler and routed to the produced water treating system to eliminate any potential atmospheric hydrocarbon emission.
- Since there is a large difference between the boiling point of triethylene glycol (546°F) and water (212°F), the still column can be relatively short (10 to 12 ft of packing).

- If a very lean glycol is required, it may be necessary to use stripping gas. A small amount of wet natural gas can be taken from the fuel stream or contactor inlet stream and injected into the reboiler.
- For higher "wet" gas flow rates greater than 500 MMscfd, the "cold finger" condenser process is often attractive. A cold finger condenser tube bundle with cold rich gas from the contactor is inserted either into the vapor space at the reboiler or into a separate separator.

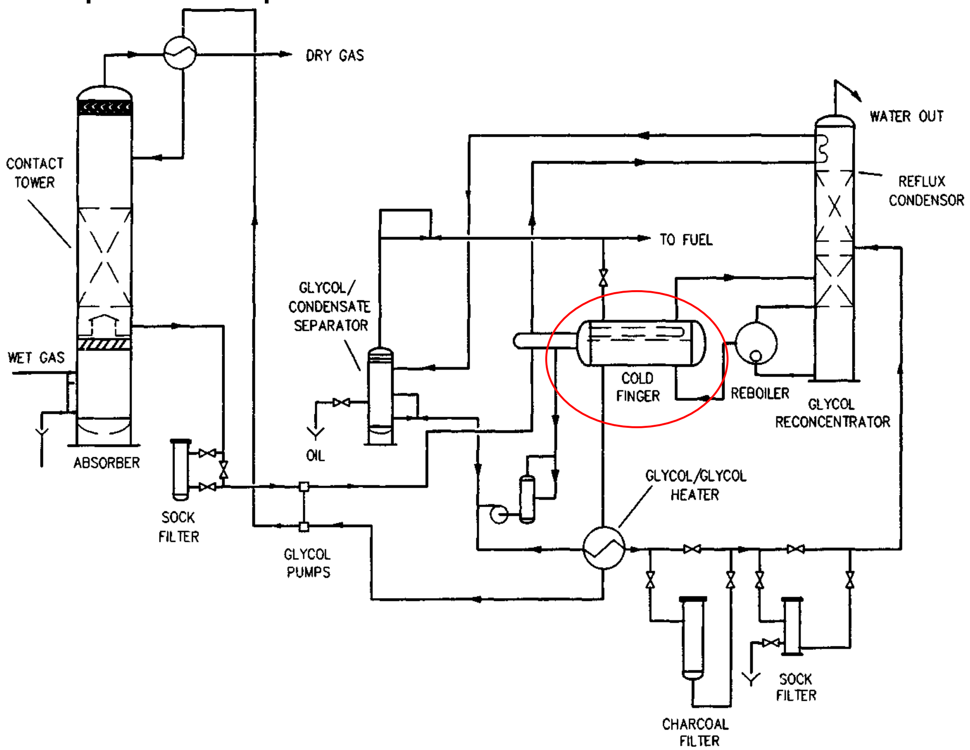


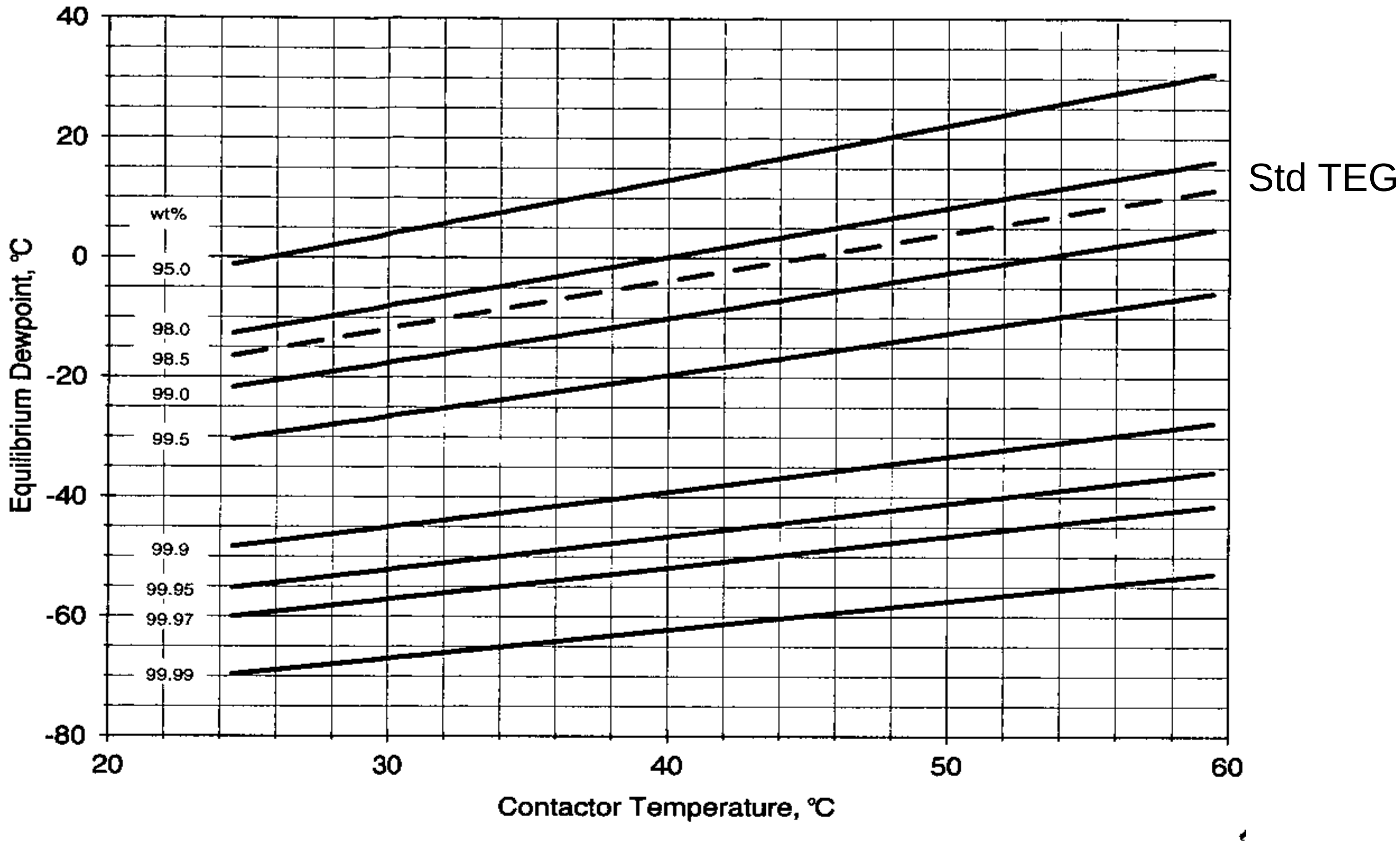
Figure 8-7. Cold finger condenser process.

TEG process comparison

TEG Technology	TEG Conc. WT %	Water Dewpoint Depression (°C)	Water Dewpoint (°C) @ 40°C OpT
Standard	98.75	45	-5
Stripping Gas	99.2 to 99.98	55 to 83	-15
ECOTEG	99.2 to 99.98	55 to 83	-15
Vacuum	99.9	55 to 83	-15
Coldfinger	99.96	55 to 83	-15
DRIZO	99.99+	100 to 122	-60

- Coldfinger and vacuum not considered due to operational concerns (equilibrium and air ingress respectively).
- ECOTEG may be worth further investigation but has not been considered for this review

Absorption system

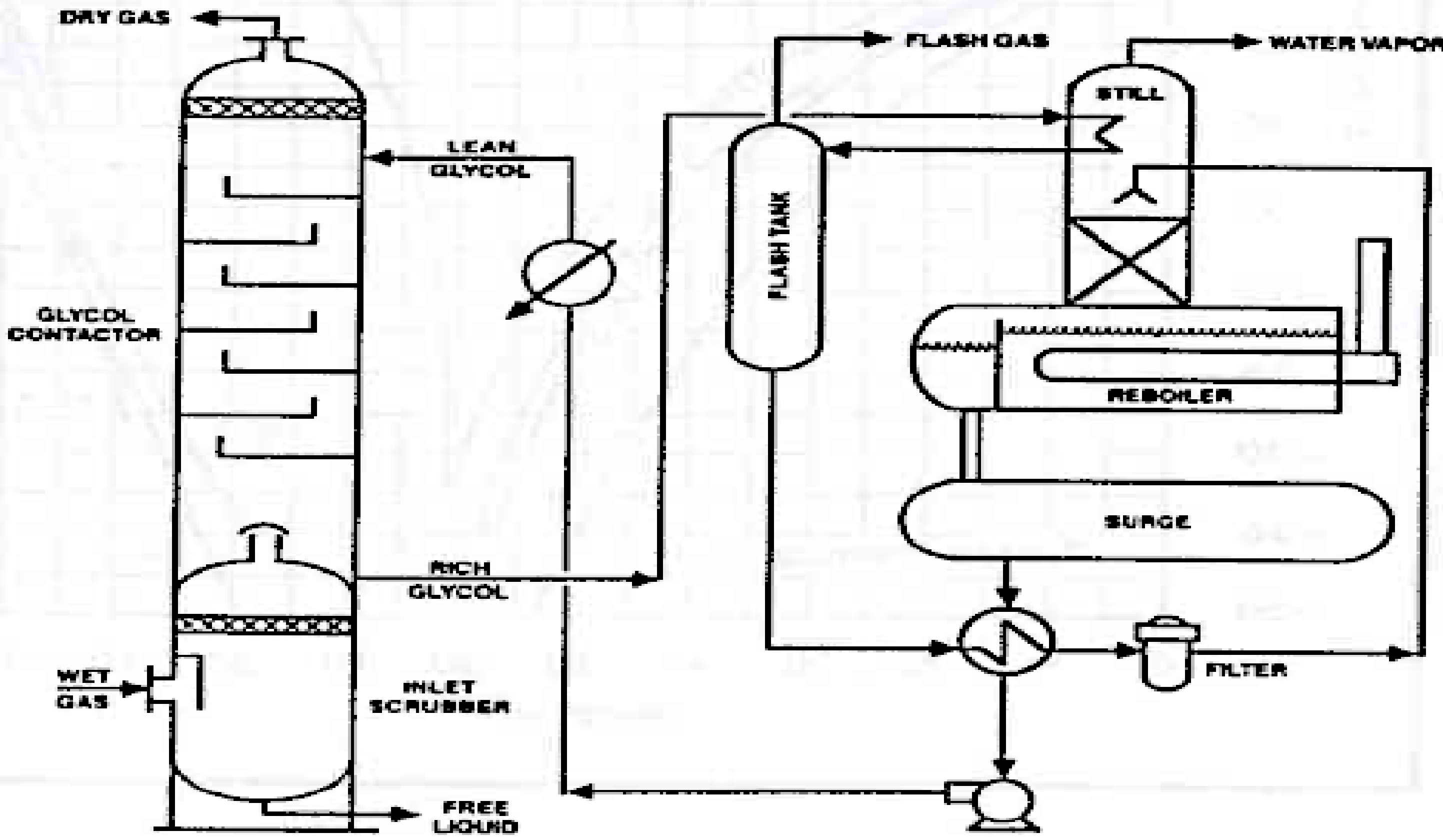


(a)

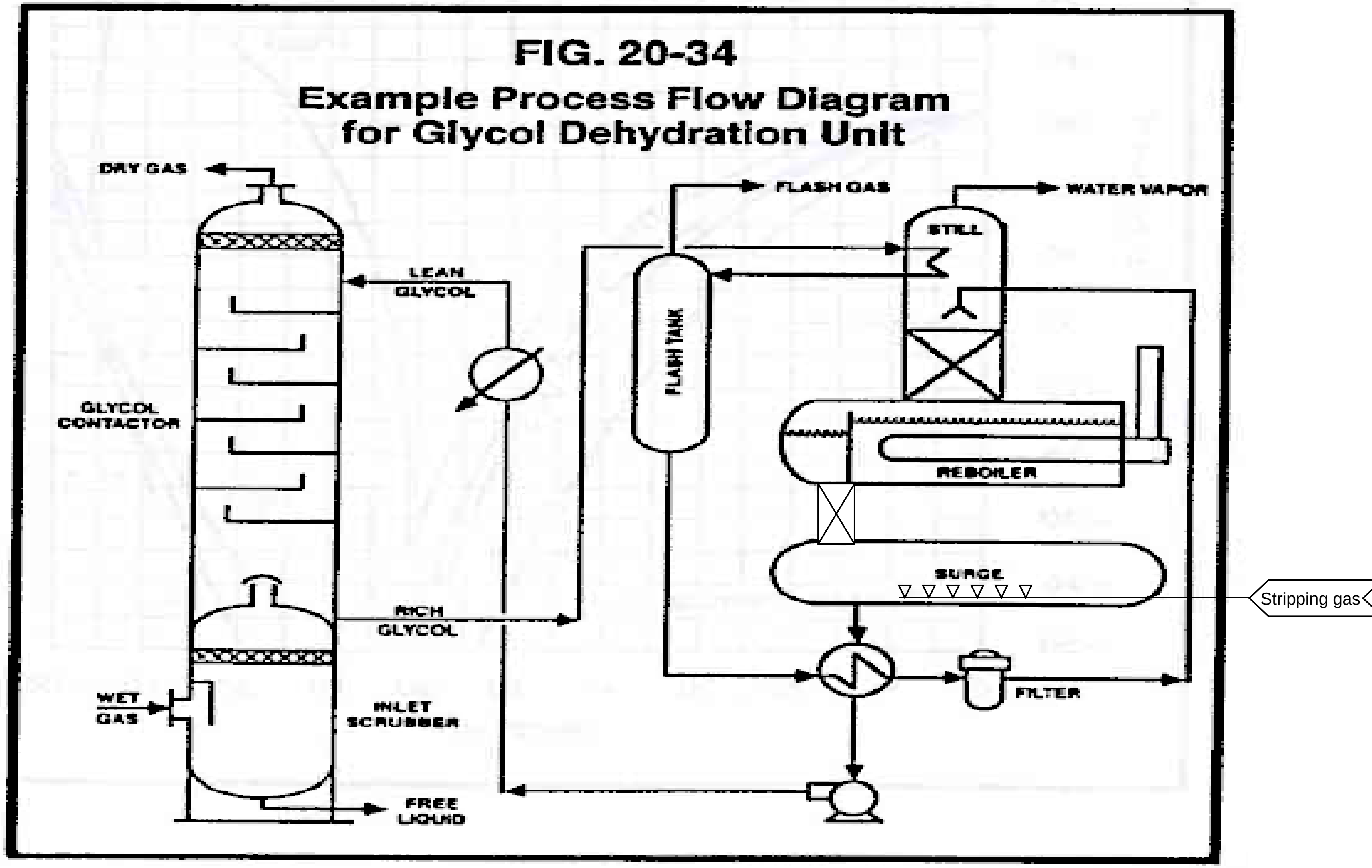
Standard TEG unit not suitable at 50°C

FIG. 20-34

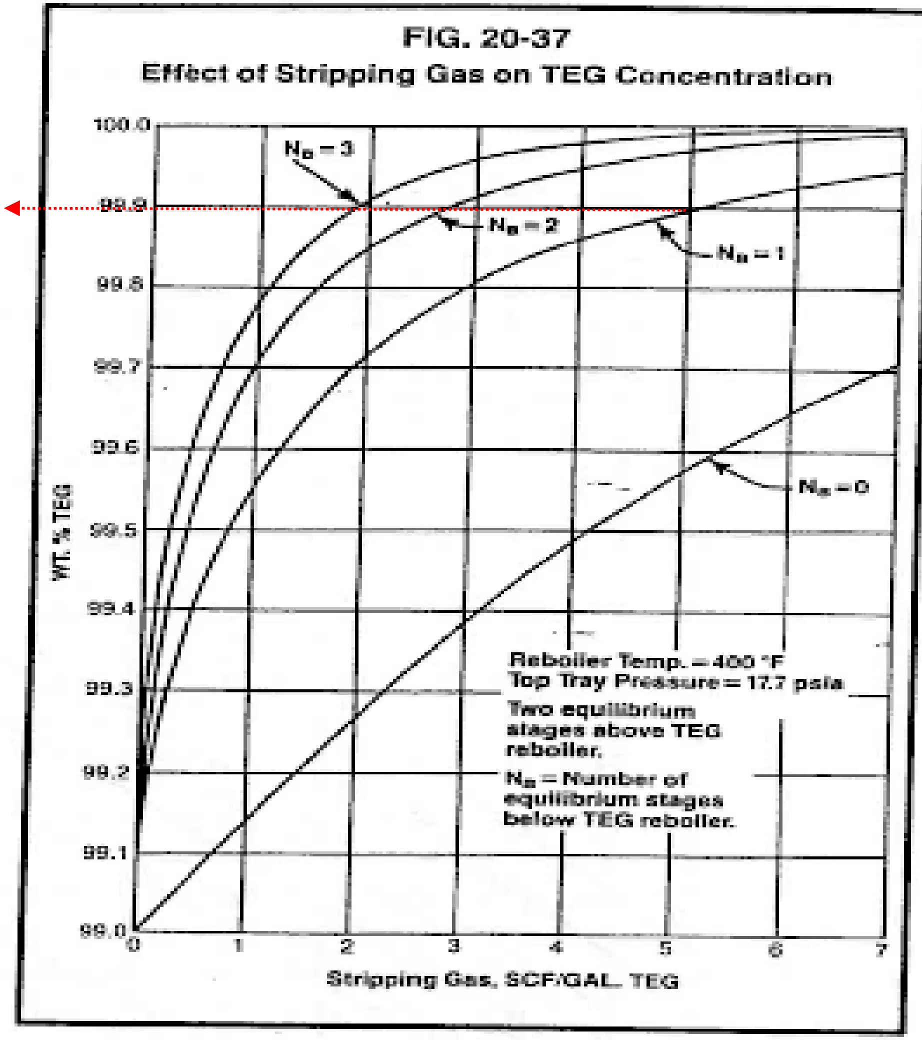
Example Process Flow Diagram for Glycol Dehydration Unit



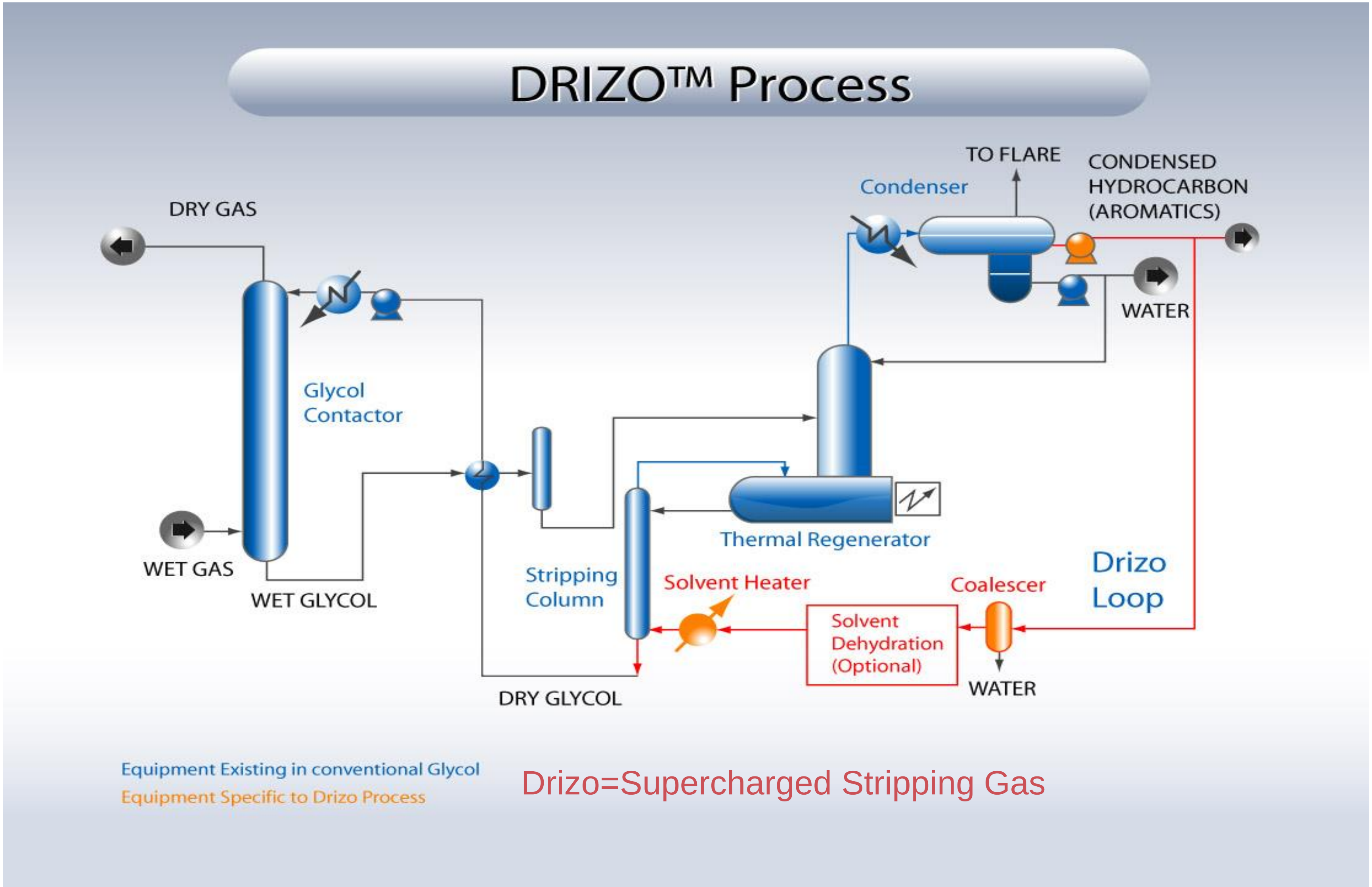
TEG with Stripping gas



- DEW POINTS BELOW -15°C POSSIBLE W/ STRIPPING GAS
- REQUIRES MORE STRUCTURD PACKING WITHIN TEG REGEN SYSTEM
- REQUIRES MORE STRIPPING GAS



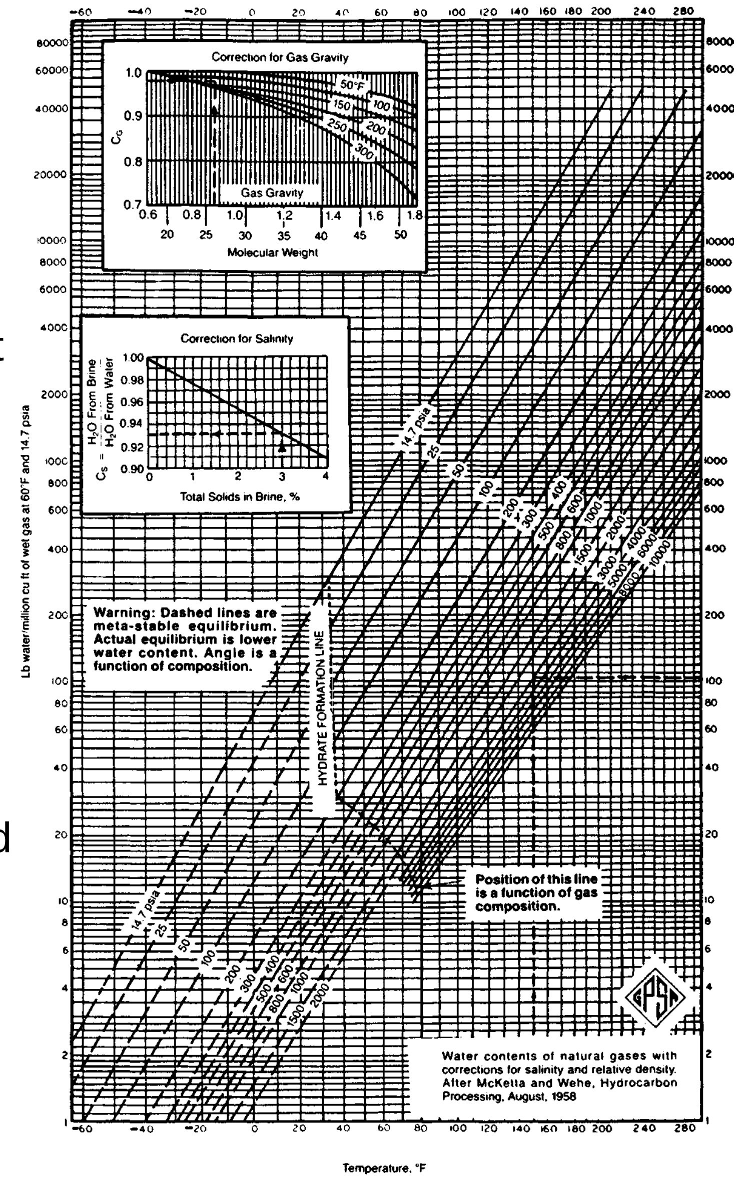
DRIZO process



Design considerations

Inlet gas temperature

- At constant pressure, the water content of the inlet gas increases as the inlet gas temperature increases.
- For example, at 1,000 psia and 80 oF gas holds about 34 lb/MMscf, while at 1,000 psia and 120 oF it will hold about 104 lb/MMscf.
- An increase in gas temperature may result in an increase in the required diameter of the contact tower due to increased gas velocity.
- Inlet gas temperatures above 120 oF result in high triethylene glycol losses. It is more common to cool the gas below 120 oF before entering the contactor.
- The minimum inlet gas temperature is normally above the hydrate formation temperature and should always be above 50 oF. Below 50 oF glycol becomes too viscous. Below 60 oF to 70 oF glycol can form a stable emulsion with liquid hydrocarbons in the gas and cause foaming in the contactor.
- Typically designed to operate at 80 ~ 110 oF



Contactor

Contactor pressure

- Contactor pressures have little effect on the glycol absorption process as long as the pressures remain below 3,000 psig.
- At a constant temperature the water content of the inlet gas decreases with increasing pressure, thus less water must be removed if the gas is dehydrated at a higher pressure.
- In addition, a smaller contactor can be used at high pressure as the actual velocity of the gas is lower, which decreases the required diameter of the contactor.
- Typically, dehydration pressures of 500 to 1,200 psi are most economical.

Number of contactor trays

- Theoretically, 4 actual trays are specified. In bubble cap towers, tray spacing is normally 24 in.
- The more trays the greater the dew-point depression for a constant glycol circulation rate and lean glycol concentration. By specifying more trays, fuel savings can be realized because the heat duty of the reboiler is directly related to the glycol circulation rate.
- Most contactors designed for 7 lb/MMscf gas are sized for 6 to 8 trays.

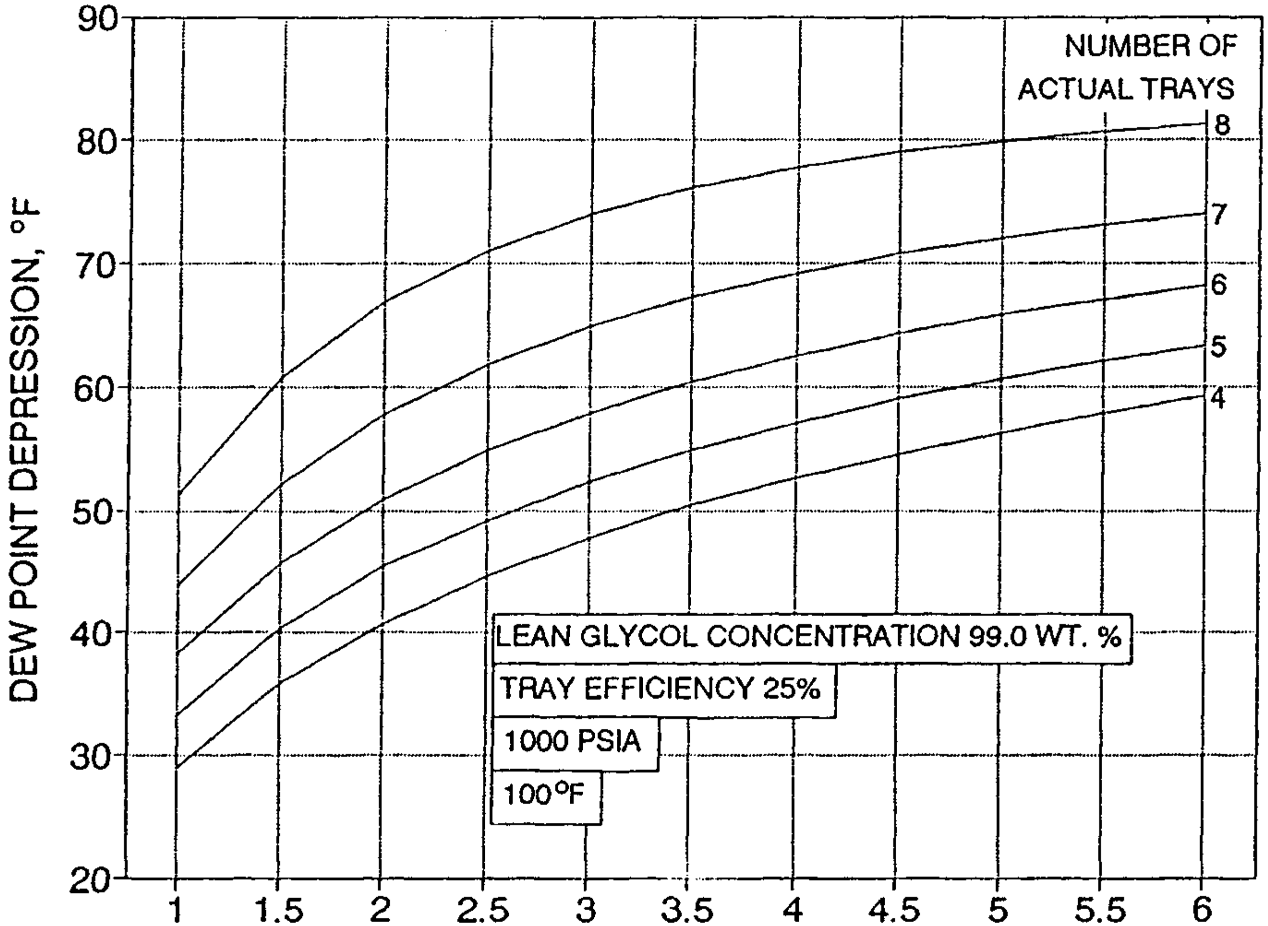


Figure 8-8. The number of trays can have a greater effect on dew-point depression than the circulation rate.

Contactor

Lean Glycol temperature

- The temperature of the lean glycol entering the contactor has an effect on the gas dew-point depression and should be held low to minimize required circulation rate.
- High glycol losses to the gas exiting the contactor may occur when the lean glycol temperature gets too hot.
- On the other hand, the lean glycol temperature should be kept slightly above the contactor gas temperature to prevent hydrocarbon condensation in the contactor and subsequent foaming of the glycol.
- Most designs call for a lean glycol temperature 10 oF hotter than the gas exiting the contactor.

Contactor

Glycol concentration

- The higher the concentration of the lean glycol the greater the dewpoint depression for a given glycol circulation rate and number of trays.

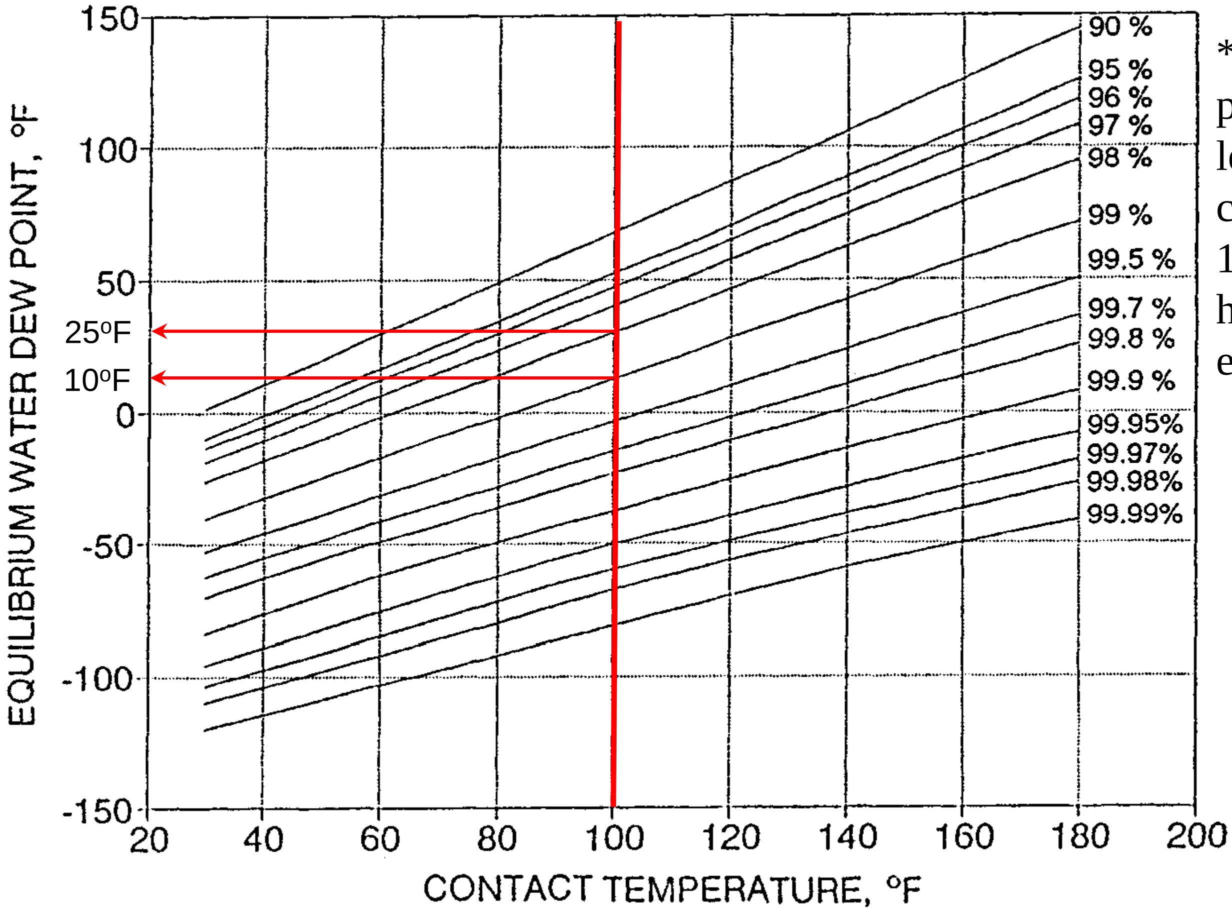


Figure 8-9. Equilibrium water dew points at different temperatures for gases.

* Actual dew points of gas leaving the contactor will be 10 ºF to 20 ºF higher than equilibrium.

Contactor

- Figure 8-10 shows that increasing the lean glycol concentration can have a much greater effect on dew-point depression than increasing the circulation rate.
- To obtain a 70ºF dew-point depression a circulation rate of 6.2 gal/lb at 99.95%, 8.2 gal/lb at 99.5% or in excess of 12 gal/lb at 99% is required.
- The lean glycol concentration is determined by the temperature of the reboiler, the gas stripping rate, and the pressure of the reboiler.
- Glycol concentrations between 98 and 99% are common for most field gas units.

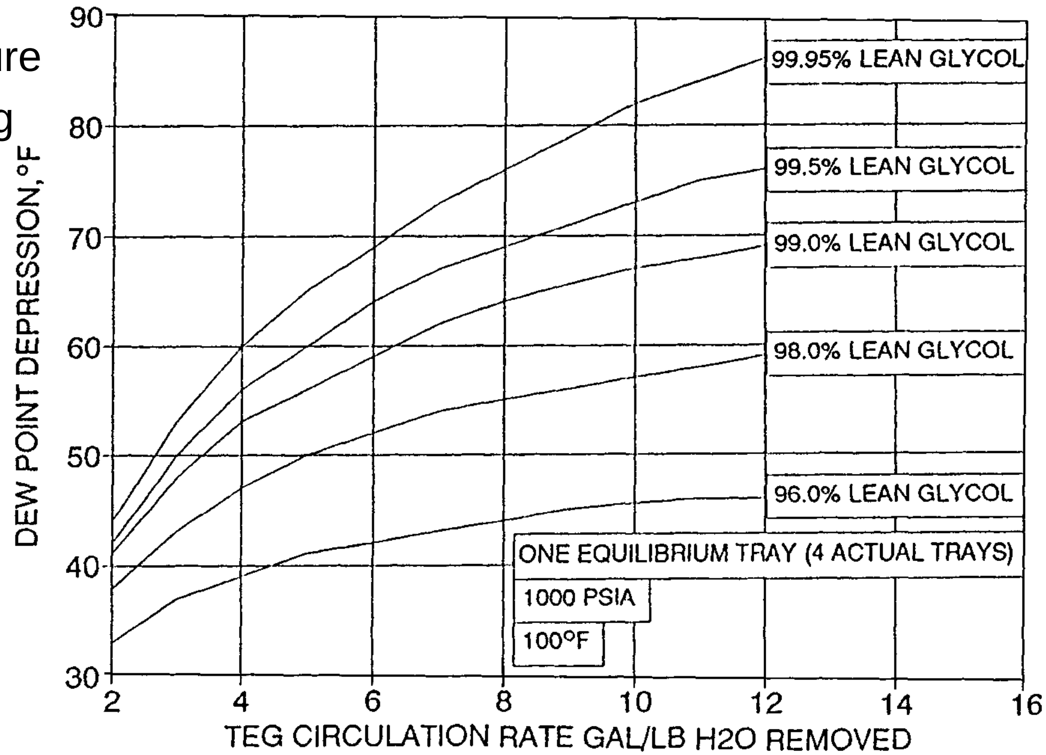


Figure 8-10. Increasing glycol concentration has a greater effect on dew-point depression than increasing the circulation rate.

Reboiler

Glycol reboiler temperature

- The reboiler temperature controls the concentration of the water in the lean glycol. The higher the temperature the higher the concentration.
- When higher lean glycol concentrations are required, stripping gas can be added to the reboiler, or the reboiler and still column can be operated at a vacuum.

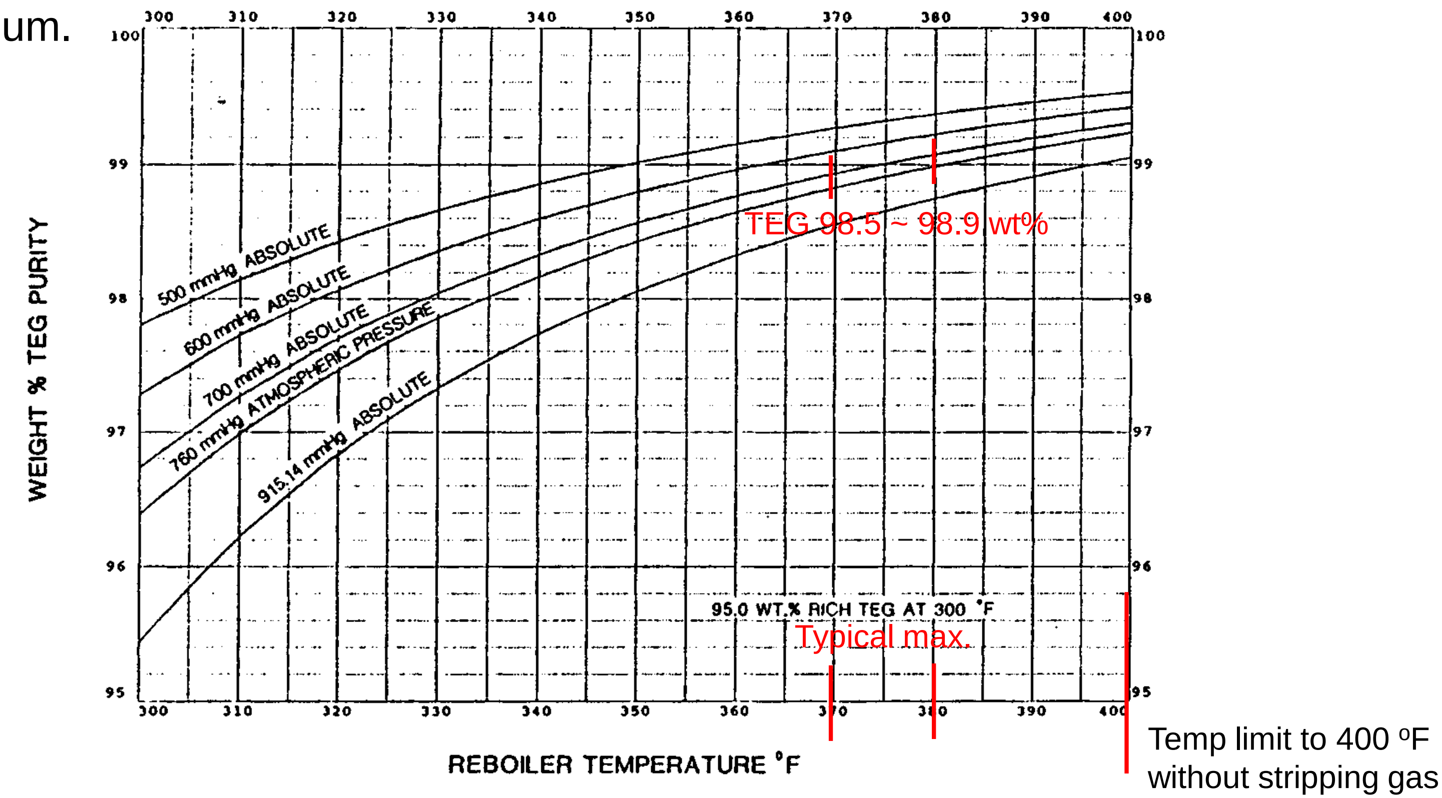


Figure 8-11. The higher the temperature the greater the lean glycol concentration.

Reboiler

Reboiler pressure

- Pressures above atmospheric in the reboiler can significantly reduce lean glycol concentration and dehydration efficiency.
- The still column should be adequately vented and the packing replaced periodically to prevent excess back pressure on the reboiler.
- At pressures below atmospheric the boiling temperature of the rich glycol/water mixture decreases, and a greater lean glycol concentration is possible at the same reboiler temperature.
- Reboilers are rarely operated at a vacuum in field gas installations, because of the added complexity and the fact that any air leaks will result in glycol degradation.
- In addition, it is normally less expensive to use stripping gas. However, if lean glycol concentrations in the range of 99.5% are required, consider using a reboiler pressure of 500 mm Hg absolute (approximately 10 psia) as well as using stripping gas.
- Sometimes the addition of a vacuum will help extend the range of an existing glycol system.

Stripping column

Stripping gas

- The lean glycol concentration leaving the reboiler can be lowered by contacting the glycol with stripping gas. Often, wet gas that is saturated with water vapor at ambient temperature and 25 to 100 psig is used. At 25 psig and 100 oF this gas is saturated with 1,500 lb/MMscf of water vapor.
- At atmospheric pressure and the temperatures in the reboiler the gas can absorb over 100,000 lb/MMscf.

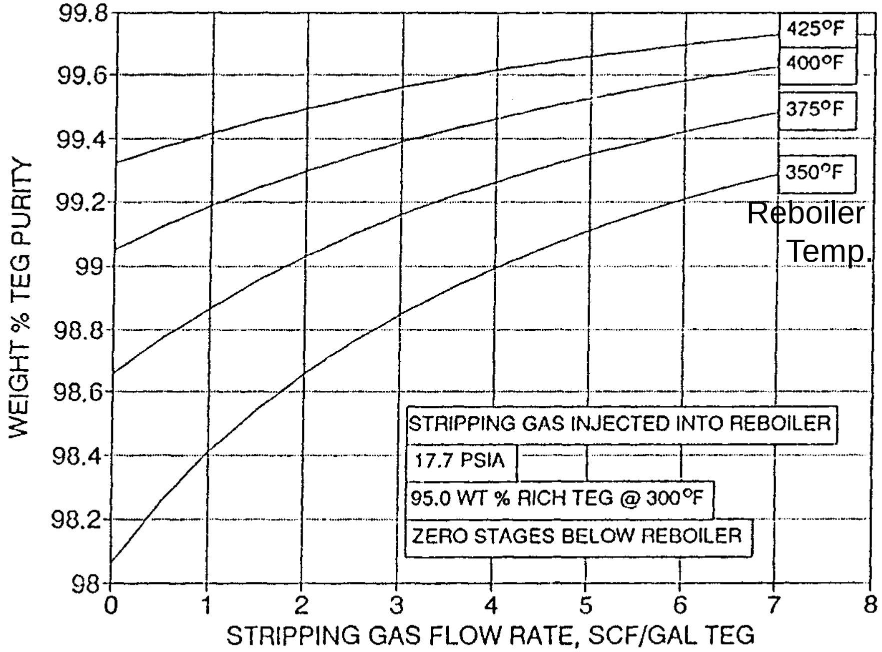


Figure 8-12. Effect of stripping gas on glycol concentration.

- Thus, it is normally desirable to use stripping gas only to increase lean glycol concentration above 98.5 to 98.9%.
- Greater purities are possible if stripping gas contacts the lean glycol in a column containing one or more stages of packing before entering the reboiler.

Stripping column/Reboiler/TEG concentration

Glycol circulation rate

- When the number of contactor trays and lean glycol concentration are fixed, the dew-point depression of a saturated gas is a function of the glycol circulation rate.
- The more glycol that comes in contact with the gas, the more water vapor is stripped out of the gas. Whereas the glycol concentration mainly affects the dew point of the dry gas, the glycol rate controls the total amount of water that can be removed.
- The minimum circulation rate to assure good glycol-gas contact is about two gallons of glycol for each pound of water to be removed. Seven gallons of glycol per pound of water removed is about the maximum rate.
- Most standard dehydrators are designed for approximately three gallons of glycol per pound of water removed.
- The heat required by the reboiler is directly proportional to the circulation rate. Thus, an *increase* in circulation rate may decrease reboiler temperature, decreasing lean glycol concentration, and actually *decrease* the amount of water that is removed by the glycol from the gas.

Stripping column

Stripping still temperature

- A higher temperature in the top of the still column can increase glycol losses due to excessive vaporization.
- The boiling point of water is 212 ^{o}F and the boiling point of TEG is 546 ^{o}F.
- The recommended temperature in the top of the still column is approximately 225 ^{o}F. When the temperature exceeds 250 ^{o}F the glycol vaporization losses may become substantial.
- Stripping gas will have the effect of requiring reduced top still temperature to produce the same reflux rate.

System sizing

Contactor sizing

- Bubble cap contactors are the most common. The minimum diameter can be determined using the equation derived for gas separation in vertical separators

$$d^2 = 5{,}040 \frac{TZQ_g}{P} \left[\left(\frac{\rho_g}{\rho_1 - \rho_g} \right) \frac{C_D}{d_m} \right]^{1/2}$$

where d = column inside diameter, in.
d_m = drop size, micron
T = contactor operating temperature, °R
Q_g = design gas rate, MMscfd
P = contactor operating presssure, psia
C_D = drag coefficent
ρ_g = gas density, lb/ft^3
ρ_g = 2.7 SP/TZ (Volume 1, Chapter 3)
ρ_1 = density of glycol, lb/ft^3
Z = compressibility factor (Volume 1, Chapter 3)
S = specific gravity of gas relative to air

- Reasonable choices of contactor diameter are obtained when the contactor is sized to separate 120-150 micron droplets of glycol in the gas.
- The density of glycol can be estimated as 70 lb/ft3.

- The diameter of packed towers may differ depending upon parameters developed by the packing manufacturers and random packing.
- Conventional packing will require approximately the same diameter as bubblecap towers.
- Structured packing can handle higher gas flow rates than bubble cap trays in the same diameter contactor while requiring half the height. (See Table 8-1.)
- The height per equivalent theoretical tray normally ranges from 8 ft for low dewpoints to 4 ft for moderate dewpoints. Adequate mist eliminator and glycol distribution is needed for high gas flow rates.

Table 8-1
Example Contactor Sizes for Dehydrating 50 MMscfd at 1,000 psig and 100°F

Tower Internals	Tower Diameter (inch)	Tray/Packing Height (feet)
A. Tray		
Bubble Cap	48	16
B. Structural Packing (Figures 6-9, 8-14)		
B1-300	36	8
B1-100	30	8
Flexipac #1	42	6
Flexipac #2	30	8
C. Random Packing (Figure 8-15)		
2″ Pall Ring	48	16

Reboiler heat duty

- The reboiler duty is the sum of

  : the sensible heat required to raise the wet glycol to reboiler temperature,

  : the heat required to vaporize the water in the glycol,
  : the heat required for the reflux (which is estimated at 25 to 50% of the heat required to vaporize the water in the glycol)

  : and losses to atmosphere.

Table 8-2
Approximate Reboiler Heat Duty

Design Gallons of Glycol Circulated /lb H_2O Removed	Reboiler Heat Duty Btu/Gal of Glycol Circulated
2.0	1066
2.5	943
3.0	862
3.5	805
4.0	762
4.5	729
5.0	701
5.5	680
6.0	659

Size at 150% of above to allow for start-up, increased circulation, fouling.

Thank you, Question?