GLYCOL DEHYDRATOR DESIGN MANUAL

By: C, Richard Sivalls; SIVALLS TANKS, INC.; Odessa, Texas
1976 LAURANCE REID GAS CONDITIONING CONFERENCE

The dehydration of natural gas is defined as the removal of the water that is associated with the natural gas in the vapor form. It has long been recognized that the dehydration of natural gases is necessary to ensure efficient operation of gas transmission lines. The removal of the water vapor prevents the formation of gas hydrates and reduces corrosion in the pipelines. It also improves the efficiency of the pipelines by reducing liquid accumulations at low spots in the lines. One of the most popular methods of dehydration of natural gas now in use is an absorption process employing diethylene or triethylene glycol as the desiccant. In recent years triethylene glycol has emerged as the most popular chemical to be used due to its high affinity for the water vapor and other desirable properties such as non-corrosiveness, ease of regeneration and low chemical losses.

DESCRIPTION OF PROCESS

For the following description of the process and flow through a typical glycol dehydrator refer to Figure No. 1. The wet inlet gas stream first enters the unit through an inlet gas scrubber where any liquid accumulations are removed. A 2-phase or distillate-gas scrubber is illustrated in Figure No. 1. If any liquid water is in the gas stream, a three-phase scrubber may be used to discharge the distillate and water from the vessel separately. The mist eliminator aids in removing any entrained liquid particles from the wet gas stream leaving the top of the inlet scrubber.

The wet gas then enters the bottom of the glycol-gas contractor and flows upward through the trays as illustrated countercurrent to the glycol flowing downward through the column. The gas contacts the glycol on each tray and the glycol absorbs the water vapor from the gas stream.

The dry gas leaves the top of the contactor vessel through another mist eliminator which aids in removing any entrained glycol droplets from the gas stream. The gas then flows down through a vertical glycol cooler, usually fabricated in the form of a concentric pipe heat exchanger, where the outlet dry gas aids in cooling the hot regenerated glycol before it enters the contactor. The dry gas then leaves the unit from the bottom of the glycol cooler.

The dry glycol enters the top of the glycol-gas contactor from the glycol cooler and is injected onto the top tray. The glycol flows across each tray and down through a downcomer pipe onto the next tray. The bottom tray downcomer is fitted with a seal pot to hold a liquid seal on the trays.

The wet glycol which has now absorbed the water vapor from the gas stream leaves the bottom of the glycol-gas contactor column, passes through a high pressure glycol filter which removes any foreign solid particles that may have been picked up from the gas stream, and enters the power side of the glycol pump. In the glycol pump the wet high pressure glycol from the contactor column is used to pump the dry regenerated glycol into the column. The wet glycol stream flows from the glycol pump to the inlet of the flash separator. The low pressure flash separator allows for the release of the entrained solution gas which has to be used with the wet glycol to pump the dry glycol into the contactor. The gas separated in the flash separator leaves the top of the flash separator vessel and may be used to supplement the fuel gas required for the reboiler. Any excess vent gas is discharged through a back pressure valve.

The flash separator is equipped with a liquid level control and diaphragm motor valve which discharges the wet glycol stream through a heat exchange coil in the surge tank to preheat the wet glycol stream. If the wet glycol stream absorbs any liquid hydrocarbons in the contactor, it may be desirable to use a three phase flash separator to separate the glycol from the liquid hydrocarbons before the stream enters the reboiler. Any liquid hydrocarbons present in the reboiler will cause undue glycol losses from the stripping still.

The wet glycol stream leaves the heat exchange coil in the surge tank and enters the stripping still mounted on top of the reboiler at the feed point in the still. The stripping still is packed with a ceramic Intalox saddle type packing and the glycol flows downward through the column and enters the reboiler. The wet glycol passing downward through the still is contacted by hot rising glycol and water vapors passing upward through the column. The water vapors released in the reboiler and stripped from the glycol in the stripping still pass upward through the still column through an atmospheric reflux condenser which provides a partial reflux for the column. The water vapor then leaves the top of the stripping still column and is released to the atmosphere.

The glycol flows through the reboiler in essentially a horizontal path from the stripping still column to the opposite end. In the reboiler the glycol is heated to approximately 350 - 400 °F to remove enough water vapor to re-concentrate it to 99.5% by weight or more. In field dehydration units the reboiler is generally equipped with a direct fired firebox (reboiler) using a portion of the natural gas stream for fuel. In plant type units the reboiler may be fitted with a hot oil heated coil or steam coil. A temperature control in the reboiler operates a fuel gas motor valve to maintain the proper temperature in the glycol reboiler. The reboiler is also generally equipped with a high temperature safety overriding temperature controller to shut down the fuel gas system in case the primary temperature control should malfunction.

In order to provide extra dry glycol, 99% by weight plus, it is usually necessary to add some dry stripping gas to the reboiler. A valve and small pressure regulator are generally provided to take a small amount of gas from the fuel gas system and inject it into the bottom of the reboiler through a spreader system. This stripping gas will “roll” the glycol in the reboiler to allow any pockets of water vapor to escape which might otherwise remain in the glycol due to its normal high viscosity. This gas will also sweep the water vapor out of the reboiler and stripping still and, by lowering the partial pressure of the water vapor in the reboiler and still column, allow the glycol to be re-concentrated to a higher percentage.

The re-concentrated glycol leaves the reboiler through an overflow pipe and passes into the shell side of the heat exchanger surge tank. In the surge tank the hot re-concentrated glycol is cooled by exchanging heat with the wet glycol stream passing through the coil. The surge tank also acts as a liquid accumulator for feed for the lean glycol pump. The re-concentrated glycol flows from the surge tank through a strainer and into the lean glycol pump. From the pump it passes into the shell side of the glycol cooler mounted on the glycol-gas contactor. It then flows upward through the glycol cooler where it is further cooled and enters the contactor column on the top tray.

DEHYDRATOR DESIGN

Triethylene glycol dehydrators utilizing tray or packed column contactors may be sized from standard models by using the following procedures and associated graphs and tables. Custom design glycol dehydrators for specific applications may also be designed using these procedures. The following information must be available on the gas stream to be dehydrated.

1. Gas flow rate, MMScfd;
2. Specific gravity of gas;
3. Operating pressure, psig;
4. Maximum working pressure of contactor, psig;
5. Gas inlet temperature, °F;
6. Outlet gas water content required, lb/MMScf.

Having the above information, it is then necessary to select two points of design criteria.

1. Glycol to water circulation rate based on water removed. A value of 2 to 6 gal TEG/lb H_2O removed is adequate for most glycol dehydration requirements. Use 2.5 to 4 gal TEG/lb H_2O for most field dehydrators.
2. Lean TEG concentration from re-concentrator. 99.0 to 99.9% lean TEG is available from most glycol re-concentrators. A value of 99.5% lean TEG is adequate for most design considerations.

The following procedures may be used to size a glycol dehydrator for a specific set of conditions, evaluate performance and determine the gas capacity of a given size unit.

INLET SCRUBBER

A good inlet scrubber is essential for efficient operation of any glycol dehydrator unit. The required diameter of a vertical inlet scrubber may be selected using Figure No. 2 in the Appendix based on the operating pressure of the unit and gas capacity required. 2-phase inlet scrubbers are generally constructed with 7-1/2 foot shell heights. Additional data on typical standard vertical inlet scrubbers are contained in Tables 4A and 4B in the Appendix.

GLYCOL-GAS CONTACTOR

Select a contactor diameter based on the operating pressure required with the approximate required gas capacity from Figure 3 or 4 in the Appendix. Figure 3 is for glycol contactors using trayed columns and Figure 4 is for contactors using packed columns. The gas capacities as determined for a given diameter contactor from Figure 3 or 4 must be corrected for the operating temperature and gas specific gravity.

Calculate the gas capacity of the gas-glycol contactor selected for the specific operating conditions.

$$G_O = G_S\,(C_t)\,(C_g)$$

Where,

G_O = Gas capacity of contactor at operating o conditions, MMScfd
G_S = Gas capacity of contactor at standard conditions (0.7 sp. gr. and 100 °F), based on operating pressure, MMScfd
C_t = Correction factor for operating temperature
C_g = Correction factor for gas specific gravity

The temperature and gas specific gravity correction factors for trayed glycol contactors are contained in Tables 1A and 1B respectively. The temperature and specific gravity factors for packed glycol contactors are contained in Tables 2A and 2B respectively.

Next, determine the required dew point depression and the water removed for the glycol dehydration unit from the following:

Dew point depression, °F = (Inlet gas temp. °F - Outlet dew point temp. °F)

$$W_r = \frac{(W_i - W_o)(G)}{24}$$

Where,

W = Water removed, lb/hr
W_i = Water content of inlet gas, lb H_2O/MMScf

W_O = Water content of outlet gas, lb H_2O/ MMScf
G = Gas flow rate, MMScfd

The outlet dew point temperature can be found on the water vapor content graph, Figure 7[1], using the outlet gas water content required and the operating pressure. The dew point temperature is the temperature at which the remaining water vapor in the gas will start to condense. The inlet gas temperature is also the inlet dew point temperature since the gas is generally assumed to be water saturated before it is dehydrated. The water content of the inlet gas can be determined from the same water vapor content graph using the inlet gas temperature and the operating pressure.

If the natural gas stream contains appreciable amounts of either carbon dioxide and/or hydrogen sulfide, the water content of these sour gases should be taken into account in determining the total water content of the inlet gas stream. Since both carbon dioxide and hydrogen sulfide gases absorb considerably more water vapor than natural gas, they appreciably increase the total water content and dehydration requirements of the gas stream.

TRAYED CONTACTORS

Select the number of actual trays required from Figure 5 using the required dew point depression and the selected glycol to water circulation rate. The data contained in Figure 5 will give the approximate number of trays required for rapid sizing of field glycol dehydrators. A more detailed consideration of the actual number of trays required will give the accurate results needed for the most economical size contactor.

For a more detailed study, a modified McCabe-Thiele diagram 4 can be constructed to determine the number of theoretical trays for a triethylene glycol dehydrator. This number can be converted to the actual number of trays required by applying the tray efficiency.

First, determine the concentration of the rich TEG leaving the bottom of the glycol-gas contactor.

$$\rho_i = Sp.Gr.(8.34)$$

$$Rich\ TEG = \frac{(\text{Lean TEG})\ (\rho_i)}{\left(\rho_i + \frac{1}{L_W}\right)}$$

Where

ρ_i = Density of Lean TEG Solution, lb/gal
Sp. Gr. = Specific gravity of Lean TEG Solution at operating temperature of contactor

Rich TEG = Concentration of TEG in rich solution from contactor, %/100
Lean TEG = Concentration of TEG in lean solution to contactor, %/100
L_W = Glycol to water circulation rate, w gal TEG/lb H_2O

The Operating Line for the McCabe-Thiele diagram is based on connecting a line between a point indicating the top of the column and a point indicating the bottom of the column.

Top of Column: lb H_2O/MMScf in outlet gas and lean TEG, %
Bottom of Column: lb H_2O/MMScf in inlet gas and rich TEG, %

The Equilibrium Line on the McCabe-Thiele diagram can be constructed by determining the water content of the gas which would be in equilibrium with various concentrations of triethylene glycol. This can be done by filling in the following Table.

% TEG	Equilibrium Dew Point Temp. at Contactor Operating Temp.*	Water Content of Gas at Dew Point Temp. and Contactor Operating Pressure, lb H_20/MMScf**
99		
98		
97		
96		
95		

*Determine from the chart of equilibrium water dew points of glycol solutions at various contact temperature, Figure 8[2]
**Determine from the chart of water vapor content of gas at various temperatures and pressures, Figure 7[1]

The modified McCabe-Thiele diagram can then be constructed with the operating line and equilibrium line and then stepped off by triangulation to determine the theoretical number of trays required. This procedure is best illustrated by an example which is included in the Appendix and Figure 9.

The actual number of trays then required can be determined using the tray efficiency.

No. Actual Trays = No. Theo. Trays / Tray Eff., fraction

Where,
Tray Efficiency = 25% for bubble cap trays
= 33-1/3% for valve trays

The number of actual trays required as determined from either Figure 5 or by construction of McCabe-Thiele diagram is based on both theoretical and actual test data using a typical natural gas. Select the next whole number of trays based on the above design procedures after the tray efficiencies have been considered. However, good operation of field dehydrators indicates that a minimum of four trays should be used in any glycol-gas contactor.

Standard field dehydration contactors normally have 24” tray spacing. Due to the tendency of glycol to foam in the presence of liquid hydrocarbons, it is recommended that no less than 24” tray spacing be used to prevent any field problems with the equipment. If any foaming problem does occur, closer tray spacing can result in carryover or entrainment of the glycol in the gas stream, and cause excessive glycol losses as well as decreased efficiency in dehydration of the gas.

PACKED CONTACTORS

The same procedures can be used for packed column contactors and the depth of packing required can be determined from Figure 5. It is determined in the same manner using the required dew point depression and the selected glycol to water circulation rate. If a more detailed consideration of the depth of packing is required a modified McCabe-Thiele diagram can be drawn based on the same procedures as described above. The depth of packing required can then be determined from the following empirical relation based on using 1" metal pall rings in the contactor.

$$\text{Depth Packing, feet} = \text{No. Theo. Trays}^{3}$$

Then select the next whole number of feet of packing for use in the contactor. However, good operation indicates that a minimum four feet of packing should be used in any gas-glycol contactor.

Additional specifications for standard tray type glycol-gas contactors are contained in Tables 5A and 5B in the Appendix. Data on packed column glycol-gas contactors is contained in Tables 6A and 6B in the Appendix.

GLYCOL RECONCENTRATOR

For the detailed considerations involved in sizing the various components of the glycol re-concentrator it is first necessary to calculate the required glycol circulation rate.

$$L = \frac{L_W\ (W_i)\ (G)}{24}$$

Where,

- L = Glycol circulation rate, gal/hr
- L_W = Glycol to water circulation rate, w gal TEG/lb H_2O
- W_i = Water content of inlet gas, lb H_2O /MMScf
- G = Gas flow rate, MMScfd

REBOILER

The required heat load for the reboiler can be estimated from the following equation:

$$Q_t = 2000\,(L)$$

Where,

Q_t = Total heat load on reboiler, Btu/hr

L = Glycol circulation rate, gal/hr

The above formula for determining the required reboiler heat load is an approximation which is accurate enough for most high pressure glycol dehydrator sizing. A more detailed determination of the required reboiler heat load may be made from the following procedure.

$$Q_1 = (L)(\rho_i)(C)(T_2 - T_1)$$

$$Q_W = \frac{(970.3)(W_i - W_o)(G)}{24}$$

$$Q_r = (0.25)(Q_W)$$

$$Q_{Loss} = 5{,}000 \text{ to } 20{,}000 \text{ Btu/hr depending on boiler size}$$

$$Q_t = Q_1 + Q_W + Q_r + Q_{Loss}$$

Where,

Q_1 = Sensible heat required for glycol, Btu/hr

Q_W = Heat of vaporization required for water, Btu/hr

Q_r = Heat to vaporize reflux water in still, Btu/hr

Q_{Loss} = Heat loss from reboiler and stripping still, Btu/hr

Q_t = Total reboiler heat load, Btu/hr

L = Glycol circulation rate, gal/hr

P_i = Glycol density at average temperature in reboiler, lb/gal = (sp gr) (8.34)

C = Glycol specific heat at average temperature in reboiler, Btu/lb - ^{o}F

T_2 = Glycol outlet temperature, °F

T_1 = Glycol inlet temperature, °F

970.3 = Heat of vaporization of water at 212 °F and 14.7 psia, Btu/lb

W_i = Water content of inlet gas, lb H_2O/MMScf

W_O = Water content of outlet gas, lb H_2O /MMScf

G = Gas flow rate, MMScfd

Note: For high pressure glycol dehydrators,

$$\rho_i = (C)(T_2 - T_1) \approx 1{,}200$$

If the size of the reboiler and stripping still is known or is estimated, the heat loss can be more accurately determined from the following equation.

$$Q_1 = (0.24)(A_S)(T_V - T_a)$$

Where,

Q_1 = Overall heat loss from reboiler and still, Btu/hr
0.24 = Heat loss from large insulated surfaces, Btu/hr-ft^2-°F
A_S= Total exposed surface area of reboilers and still, ft^2
T_V = Temperature of fluid in vessel, °F
T_a = Minimum ambient air temperature, °F

The actual surface of the firebox required for direct fired reboilers can be determined from the following equation which is based on a design heat flux of 7,000 Btu/hr - sq ft. By determining the diameter and overall length of the U-tube firebox required to give the total surface area as calculated, the general overall size of the reboiler can be determined.

$$A = \frac{Q_t}{7{,}000}$$

Where,

A = Total fire tube surface area, ft^2
Q_t = Total heat load in reboiler, Btu/hr

GLYCOL CIRCULATING PUMP

The required size of glycol circulating pump can be readily determined using the glycol circulation rate and the maximum operating pressure of the contactor. The most commonly used type of glycol pump for field dehydrators is the Kimray[3] glycol powered pump which uses the rich glycol from the bottom of the contactor to power the pump and pump the lean glycol to the top of the pressurized contactor. Sizing data for this type of glycol pump is contained in Table 8 3 of the Appendix. For electric motor driven positive displacement or centrifugal pumps, the manufacturers of these pumps should be consulted for exact sizing to meet the specific needs of the glycol dehydrator.

GLYCOL FLASH SEPARATOR

It is advisable to install a flash separator downstream from the glycol pump (especially when a glycol-powered type pump is used) to remove any entrained hydrocarbons from the rich glycol. A small, 125 psig working pressure, vertical 2-phase separator is adequate for this purpose. The separator should be sized based on a liquid retention time in the vessel of at least five minutes.

$$V = \frac{(L)(T)}{60}$$

Where

V = Required settling volume in separator, gal
L = Glycol circulation rate, gal/hr
T = Retention time = 5.0 minutes

Liquid hydrocarbon should not be allowed to enter the glycol gas contactor. Should this be a problem, a three phase glycol flash separator will keep these liquid hydrocarbons out of the reboiler and stripping still. A liquid retention time of 20 to 30 minutes should be used in the above equation to size a three phase flash separator.

The hydrocarbon gas released from the flash separator can be piped to the reboiler to use as fuel gas and stripping gas. The amount of gas available from a glycol pump can be determined from the data in Table 8 in the Appendix based on the glycol circulation rate and the operating pressure of the contactor.

STRIPPING STILL

The size of the packed stripping still for use with the glycol re-concentrator can be determined from Figure No. 6. The diameter required for the stripping still is normally based on the required diameter at the base of the still using the vapor and liquid loading conditions at that point. The vapor load consists of the water vapor (steam) and stripping gas flowing up through the still. The liquid load consists of the rich glycol stream and reflux flowing downward through the still column. The minimum cross sectional area and/or diameter required for the still as read from Figure No. 6 is based on the glycol to water circulation rate, gal TEG/lb H_2O and the glycol circulation rate, gal/hr.

Normally, one theoretical tray is sufficient for most stripping still requirements for triethylene glycol dehydration units. For conservative design the height of packing using 1-1/2” ceramic Intalox saddles is held at a minimum of 4 feet. Conservative design and field test data indicates that this height should be gradually increased with the size of the glycol re-concentrator to a maximum of approximately 8 feet for a 1,000,000 Btu/hr unit.

The amount of stripping gas required to re-concentrate the glycol to a high percentage will usually be approximately 2 - 10 Scf per gallon of glycol circulated. This stripping gas requirement has been considered in the size of the stripping still that is determined using Figure No. 6. Specifications for the main components of standard size glycol re-concentrators are contained in Table 7 in the Appendix.

EQUIPMENT OPERATION

Normal operational problems are generally minimal with a properly designed and maintained glycol dehydration unit. This type of equipment can be operated unattended in remote field locations. The main problem generally encountered is contamination of the triethylene glycol solution which reduces the efficiency in the contactor dehydrating the gas and resulting in excessive glycol losses from the contactor or stripping still column. Foaming caused by contamination of the glycol solution by liquid hydrocarbons can be minimized by the addition of small amounts of an anti-foam inhibitor. Of course, the unit should be designed and operated to minimize the occurrence of liquid hydrocarbons in the glycol-gas contactor or re-concentrator. The inlet dry glycol to the contactor should be maintained at a slightly higher temperature than the gas stream to prevent the condensing of any hydrocarbons in the vessel. Any liquid hydrocarbons entering the stripping still and reboiler will also cause a vapor flood condition in the stripping still due to the increased vapor load from the liquid hydrocarbons vaporized in the hot still column. This carries glycol out of the stripping still column with the gas and water vapor. Liquid hydrocarbons will also cause coking in the stripping still contacting element and on the firebox in the reboiler. Heavy end hydrocarbons may remain in the reboiler and hinder the re-concentration of the glycol to a high percentage. Total glycol losses from a properly designed and maintained dehydration unit - due to solubility of the glycol and the gas in the contactor and vaporization losses from the stripping still - should not exceed 0.1 gallon TEG per MMScf or 1 lb TEG per MMScf of gas treated.

SUMMARY

The main design items required for a triethylene glycol dehydration unit such as the glycol-gas contactor, glycol circulation pump, reboiler, and stripping still may be designed using the above described procedures and formulas. Standard dehydrator units based on manufacturer's catalog data can then be selected based on the minimum design criteria as determined. Also, the above procedures may be used in evaluating the performance or determining the maximum gas capacity of any given specific size glycol dehydration unit. To better illustrate the design procedures an example is contained in the Appendix for a typical field gas dehydration requirement.

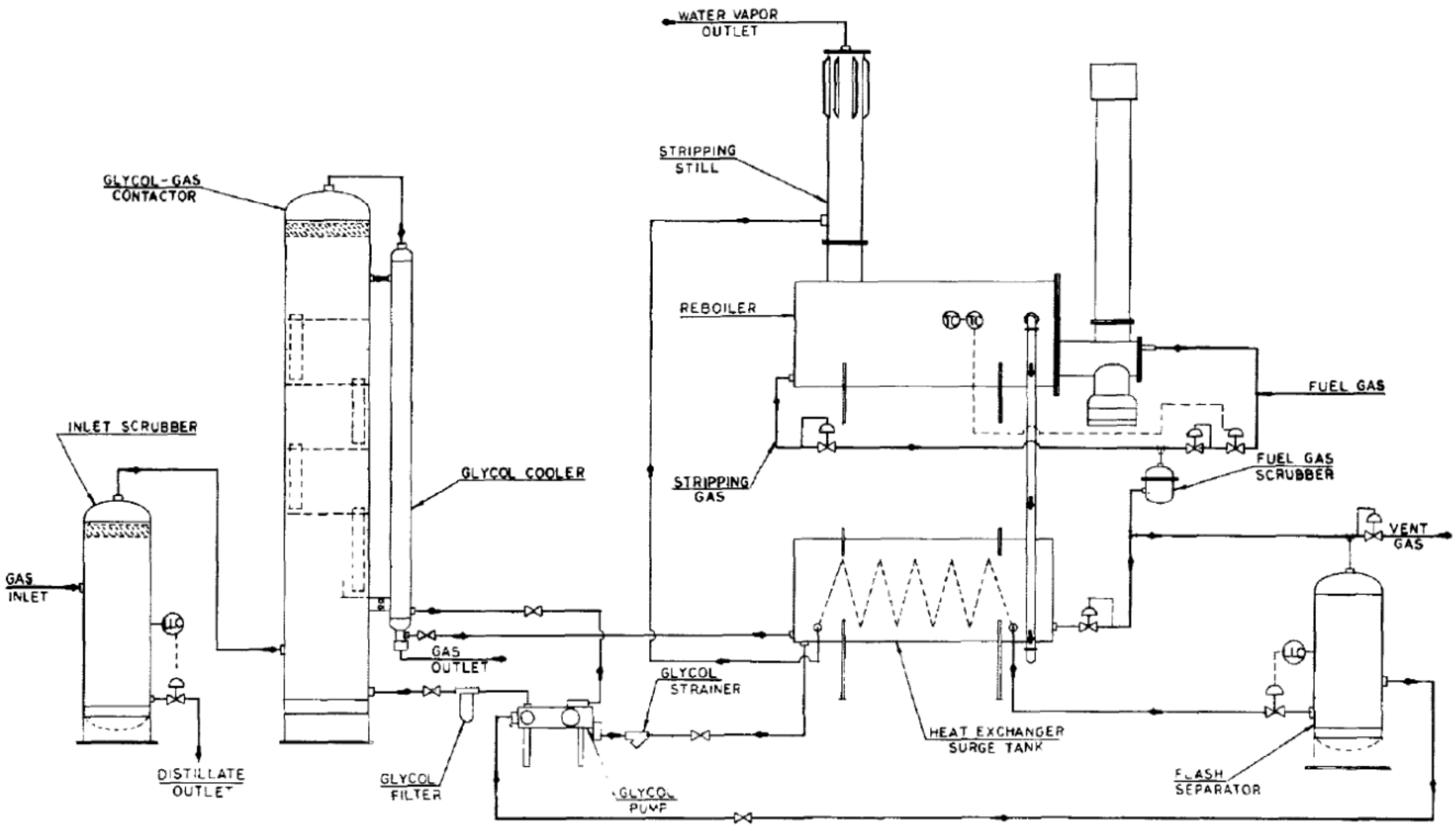
REFERENCES

1. McCarthy, E. L., Boyd, W. L., and Reid, L. S. “Water Vapor Content of Essentially Nitrogen-free Natural Gas Saturated at Various Conditions of Temperature and Pressure”, Trans. AIME (1950) 189, 241.
2. Dingman, J. C. and LaBas, C. L. “Determination of Water Vapor Dew Points of Aqueous Triethylene Glycol Solutions by A Chromatographic Method”, California Natural Gasoline Association, Anaheim, California, 1963.
3. Kimray, Inc., “Equipment Catalog” Section G, pp. 3 - 7.
4. Kohl, A. L. and Riesenfeld, F. C., “Gas Purification”, McGraw-Hill, 1960; pp 360 - 362.
5. Union Carbide Corporation, “Gas Treating Chemicals”, 1967 pp 3 - 30.

APPENDIX

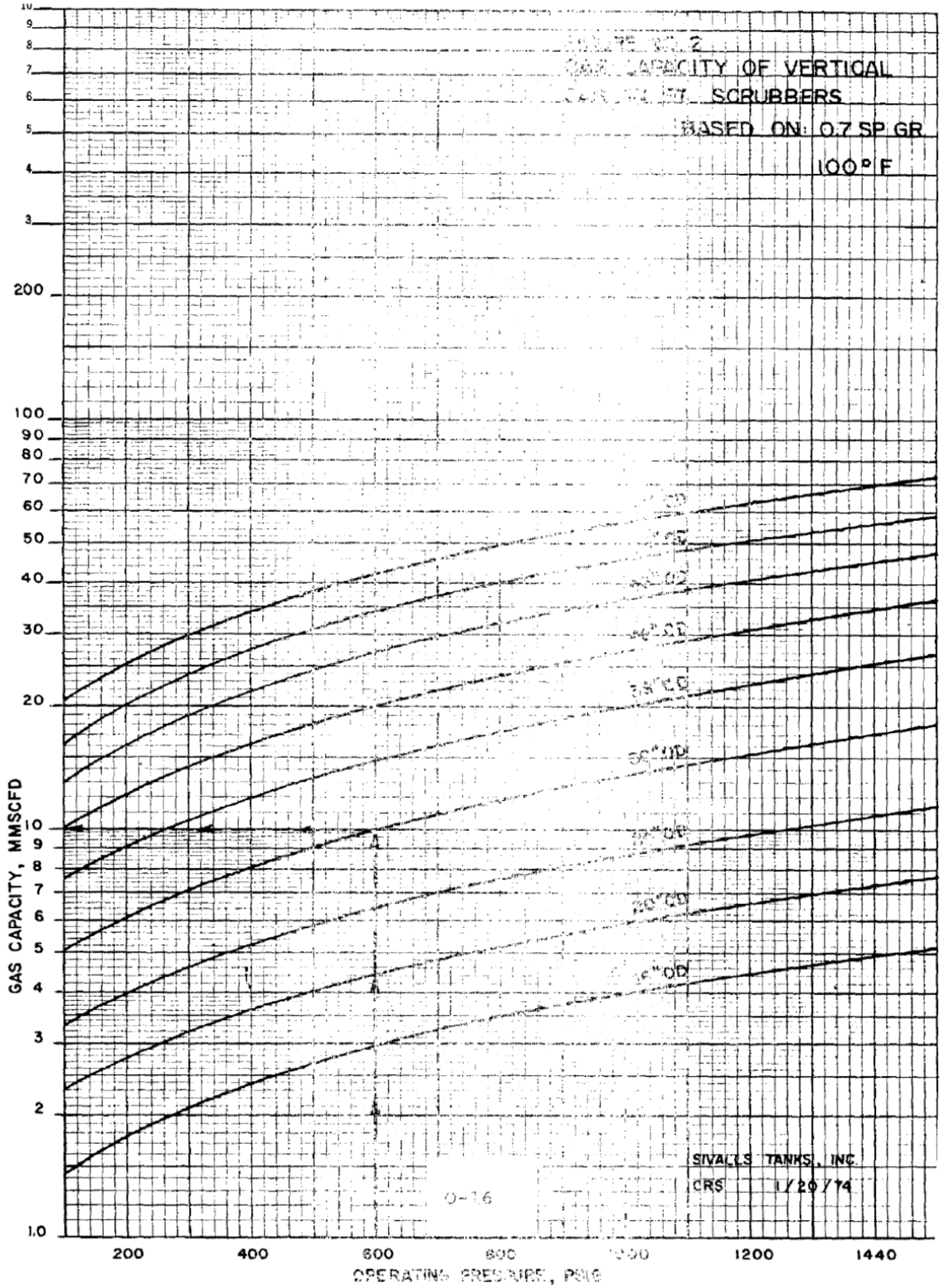
FIGURE NO. I

GLYCOL DEHYDRATOR FLOW DIAGRAM



SIVALLS TANKS, INC.

CRS 1/20/74


CAPACITY OF VERTICAL
SCRUBBERS
BASED ON: 0.7 SP GR
100° F
GAS CAPACITY, MMSCFD
OPERATING PRESSURE, PSIG
200
400
600
1200
1440
1.0
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
200
SIVALLS TANKS, INC.
CRS 1/20/74

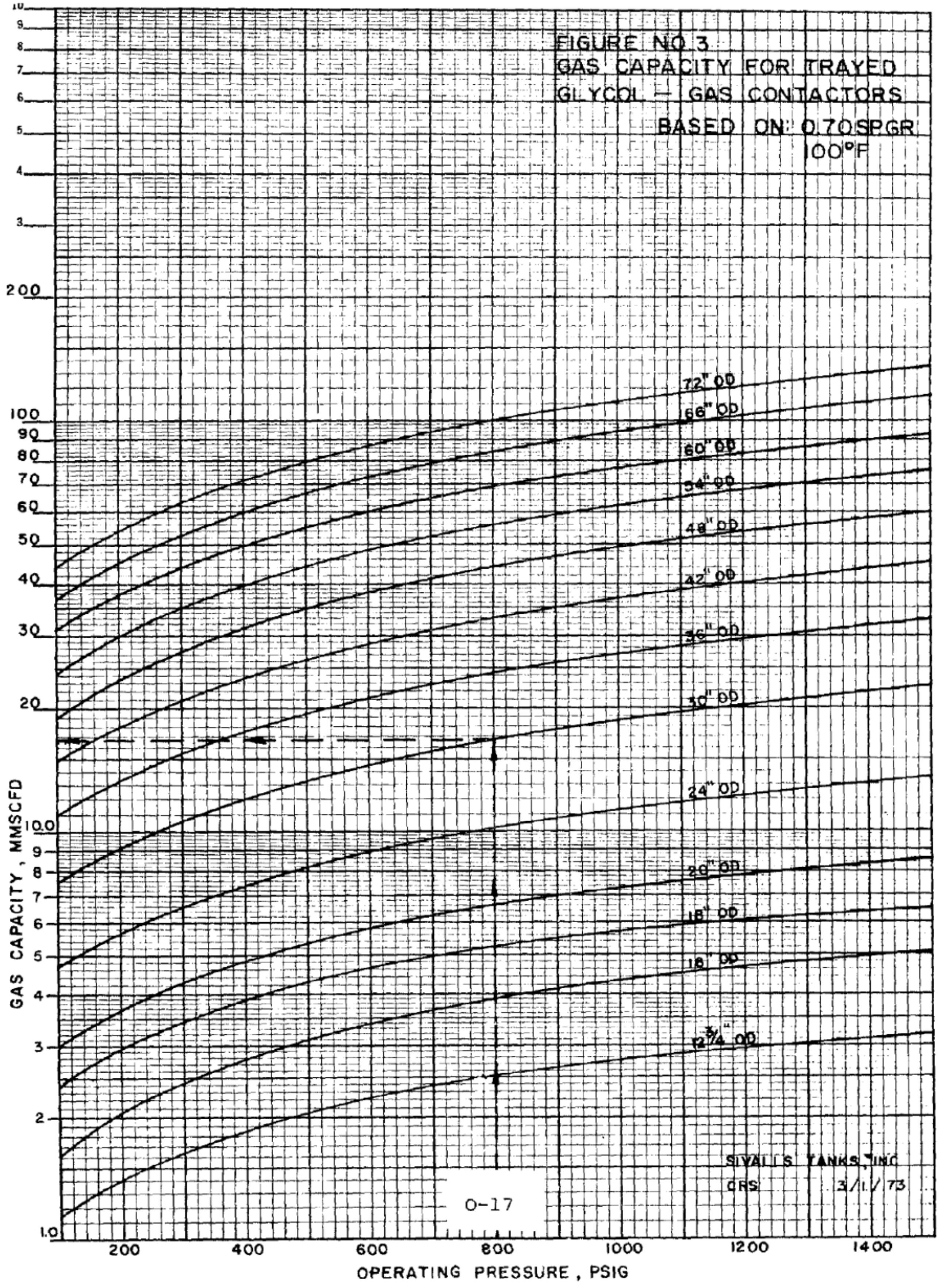


FIGURE NO 3
GAS CAPACITY FOR TRAYED
GLYCOL - GAS CONTACTORS
BASED ON: 0.70 SPGR
100°F
72" OD
66" OD
60" OD
54" OD
48" OD
42" OD
36" OD
30" OD
24" OD
20" OD
18" OD
16" OD
12¾" OD
GAS CAPACITY, MMSCFD
OPERATING PRESSURE, PSIG
SIVALLS TANKS, INC
CRS
3/1/73
O-17

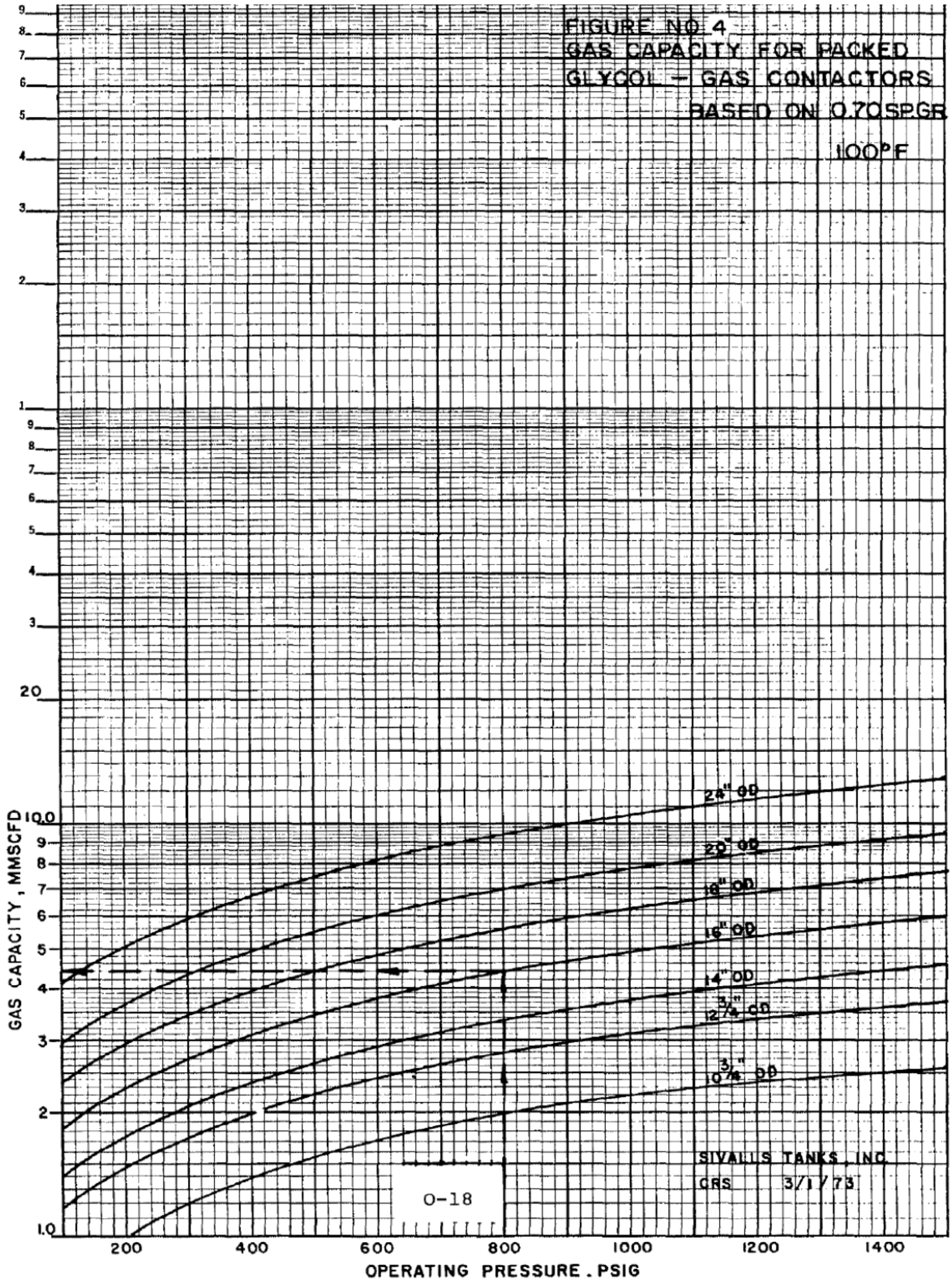


FIGURE NO. 4
GAS CAPACITY FOR PACKED
GLYCOL - GAS CONTACTORS
BASED ON 0.70 SP.GR.
100°F
24" OD
20" OD
18" OD
16" OD
14" OD
12 3/4" OD
10 3/4" OD
SIVALLS TANKS, INC.
CRS 3/1/73
O-18
GAS CAPACITY, MMSCFD
OPERATING PRESSURE, PSIG
200
400
600
800
1000
1200
1400
1.0
2
3
4
5
6
7
8
9
10.0
20

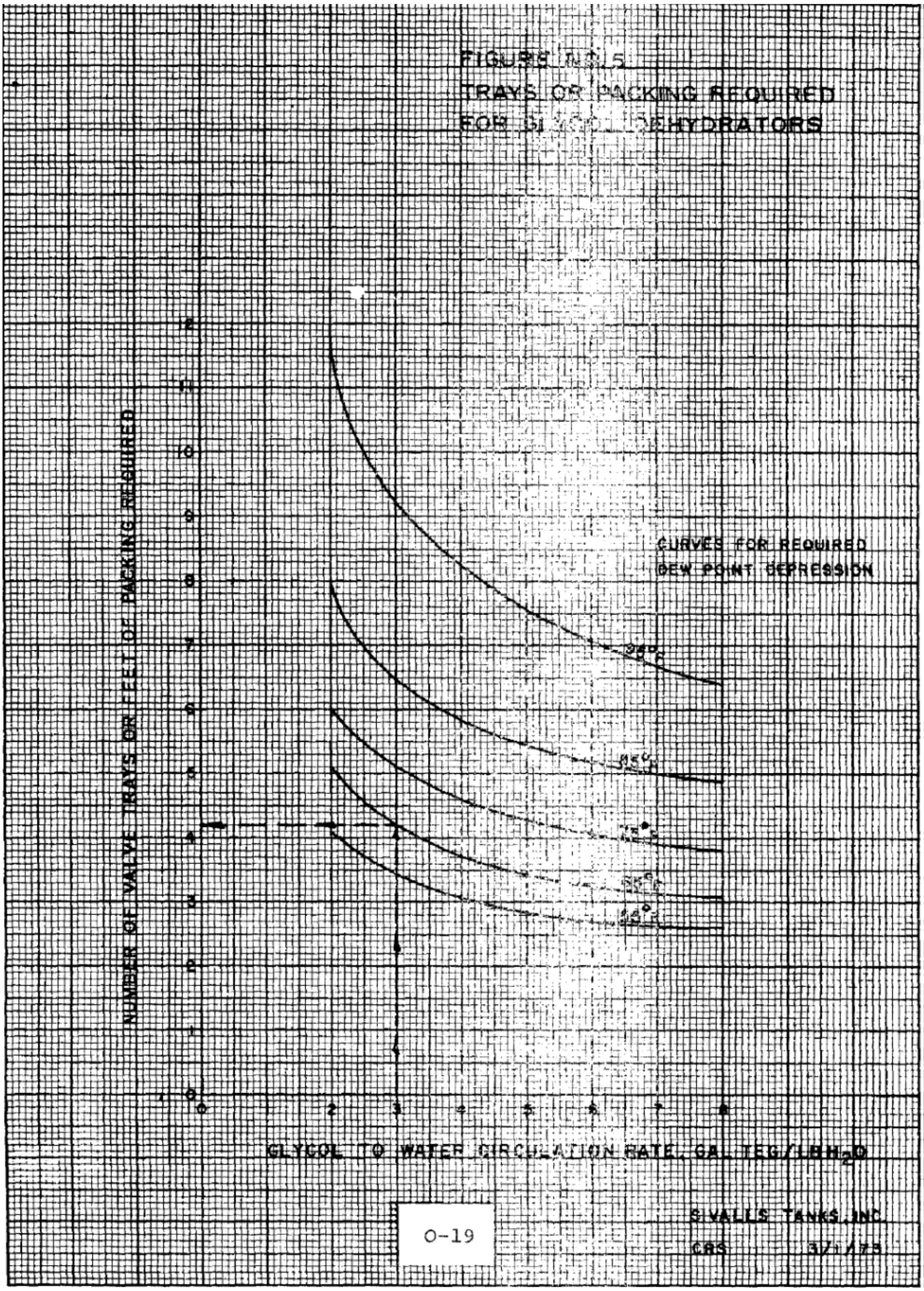
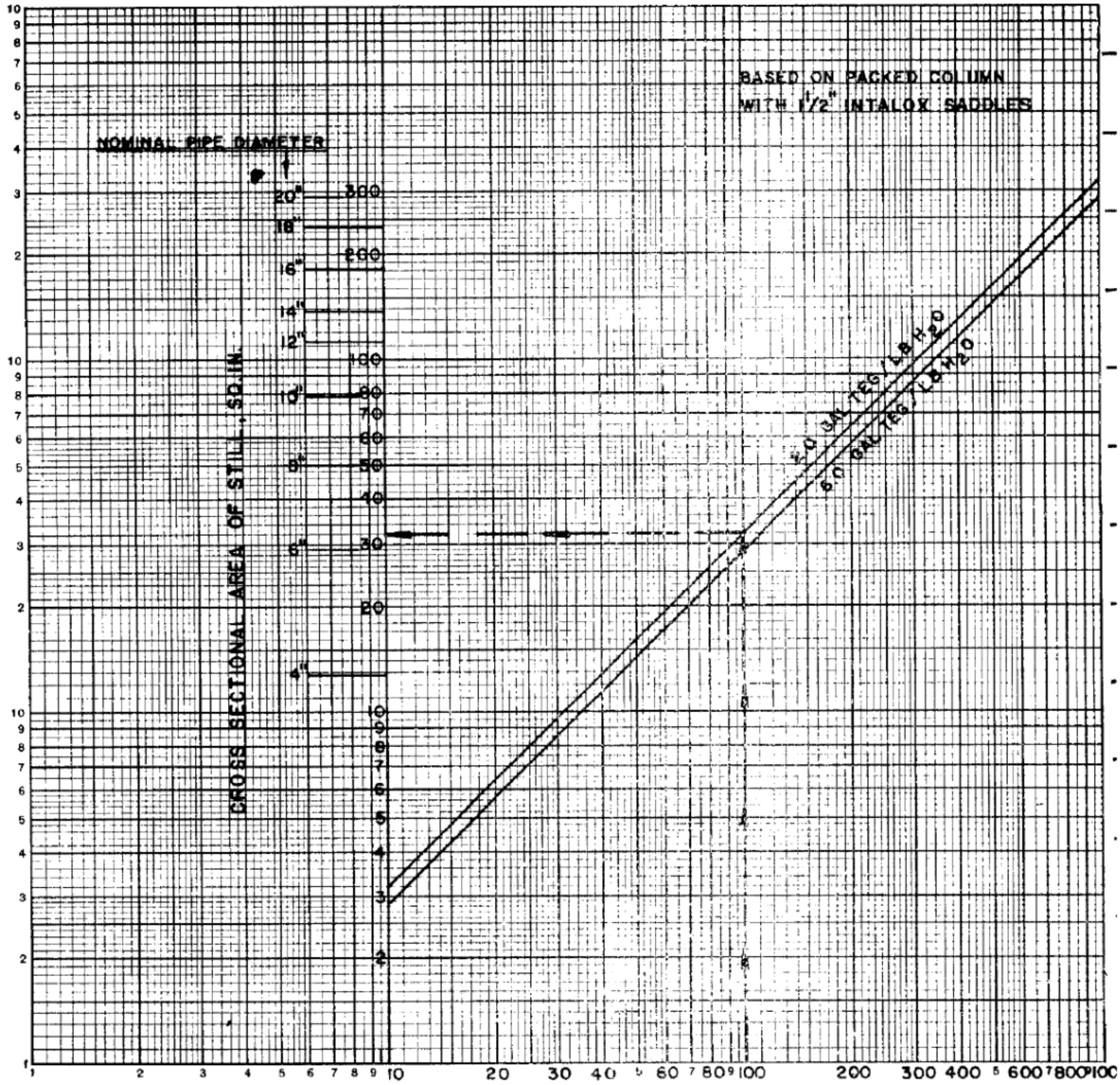


FIGURE NO. 5
TRAYS OR PACKING REQUIRED
FOR GLYCOL DEHYDRATORS
CURVES FOR REQUIRED
DEW POINT DEPRESSION
NUMBER OF VALVE TRAYS OR FEET OF PACKING REQUIRED
GLYCOL TO WATER CIRCULATION RATE, GAL TEG/LB H2O
SIVALLS TANKS, INC.
CRS

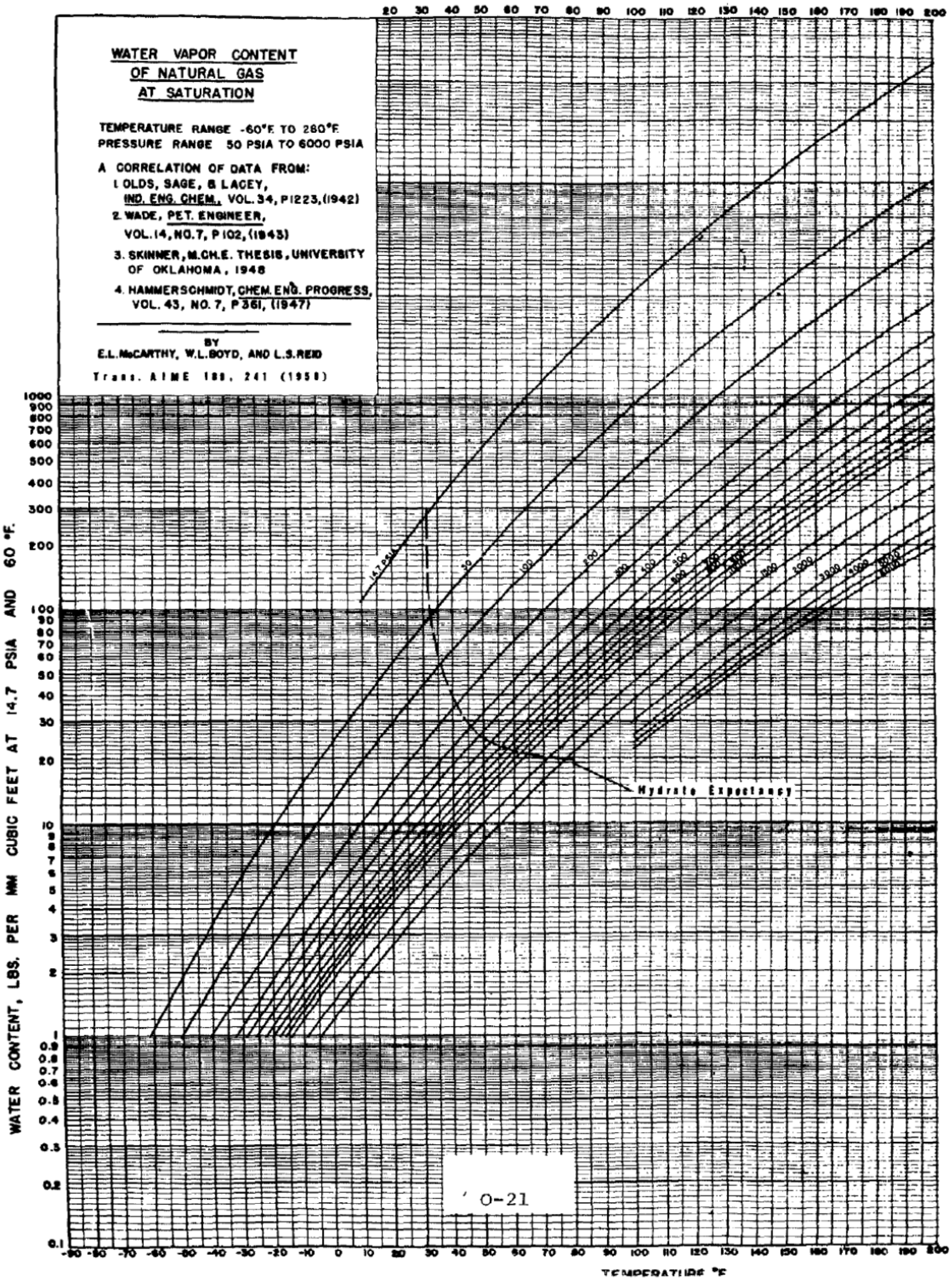
O-19

FIGURE NO. 6
STRIPPING STILL SIZE FOR
GLYCOL DEHYDRATORS



SIVALLS TANKS, INC.
3/1/73 CRS

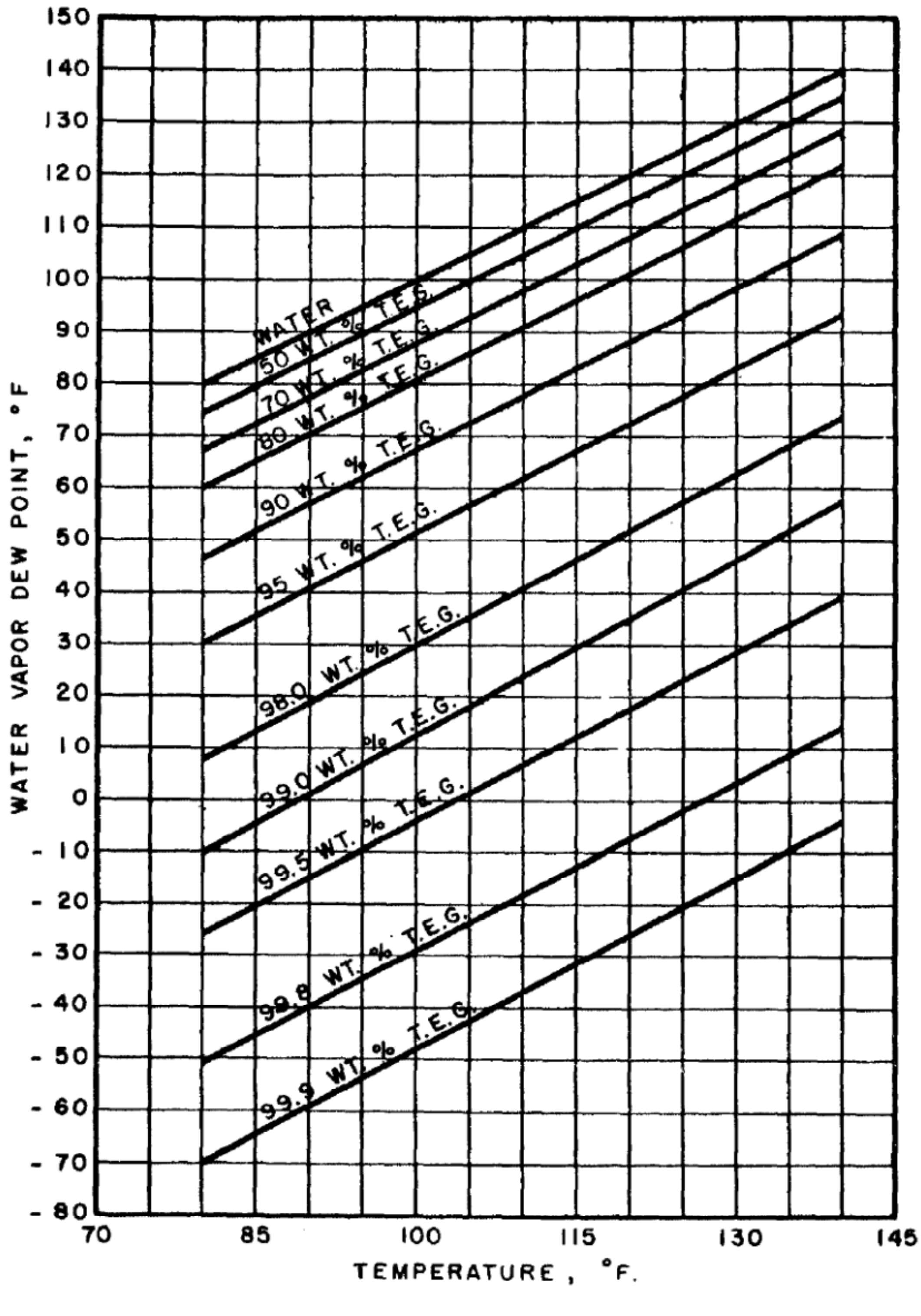
FIGURE NO. 7



’ O-21

FIGURE NO. 8

DEW POINTS OF AQUEOUS TRIETHYLENE GLYCOL SOLUTIONS VERSUS TEMPERATURE



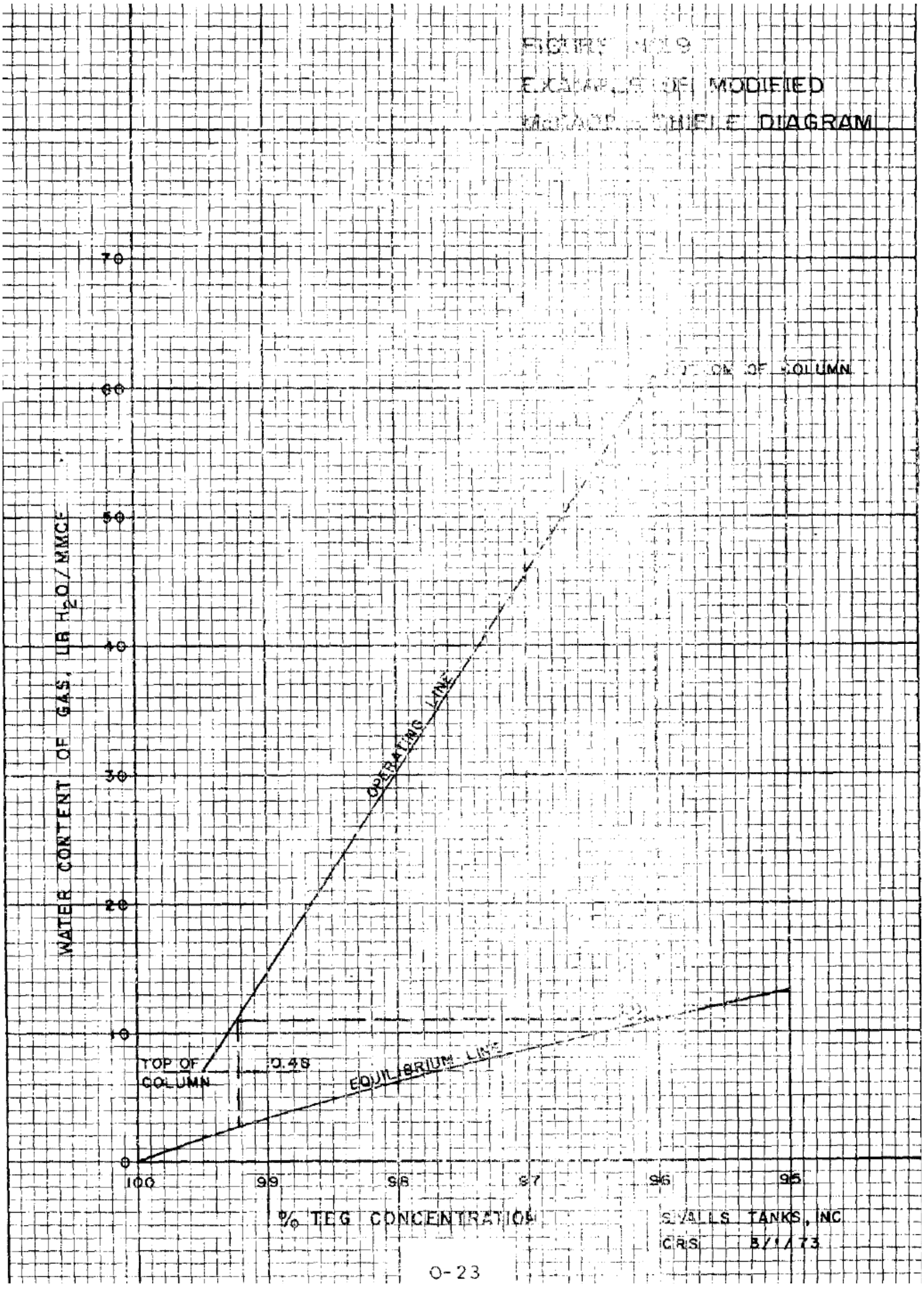


DIAGRAM
OF COLUMN
70
60
50
40
30
20
10
0
WATER CONTENT OF GAS, LB H_2O/MMCF
OPERATING LINE
TOP OF COLUMN
0.48
EQUILIBRIUM LINE
100
99
98
97
96
95
% TEG CONCENTRATION
SIVALLS TANKS, INC
CRS
O-23

APPENDIX A

GAS CONVERSION EQUATIONS

From the basic laws the following useful conversion equations can be derived.

At Standard Conditions of 14.7 psia and 60° F:

Molecular weight of gas = 28.97 (sp gr)

$$\text{Density of gas, lb/cu ft} = 0.0764\ (\text{sp gr}) = \frac{\text{mol wt}}{379} = \frac{28.97\ (\text{sp gr})}{379}$$

$$\text{Specific volume of gas, cu ft/lb} = \frac{13.08}{\text{sp gr}} = \frac{379}{\text{mol wt}}$$

$$\text{Gas flow, mol/day} = \frac{\text{Gas flow, cu ft/day}}{379}$$

Mass flow rate, lb/hr = 3185 (MMSCFD) (sp gr)

At Conditions Other Than Standard:

$$\text{Density of ideal gas, lb/cu ft} = \frac{2.703\ (\text{sp gr})\ (\text{Pressure, psia})}{(\text{Temp, F} + 460)}$$

$$\text{Density of actual gas, lb/cu ft} = \frac{2.703\ (\text{sp gr})\ (\text{Pressure, psia})}{(\text{Temp, F} + 460)\ (Z)}$$

$$\text{Ideal gas flow, cu ft/day} = \frac{(\text{Gas flow, SCFD})\ (14.7)\ (\text{Temp F} + 460)}{(\text{Pressure, psia})\ (520)}$$

$$\text{Actual gas flow, cu ft/day} = \frac{(\text{Gas flow, SCFD})\ (14.7)\ (\text{Temp F} + 460)\ (Z)}{(\text{Pressure, psia})\ (520)}$$

$$\text{Actual gas flow, cu ft/sec} = \frac{0.327\ (\text{MMSCFD})\ (\text{Temp, F} + 460)}{(\text{Pressure, psia})}\ (Z)$$

$$\text{Volume of mol, cu ft/mol} = \frac{379\ (\text{Temp, F} + 460)\ (14.7)}{(520)\ (\text{Pressure, psia})}$$

Where: Z = Compressibility factor

APPENDIX A
PHYSICAL AND CHEMICAL PROPERTIES OF GLYCOLS [5]

TABLE 3A

	Ethylene Glycol	Diethylene Glycol	Triethylene Glycol
Molecular Weight	62.07	106.12	150.17
Specific Gravity @ 68°F	1.1155	1.1184	1.1255
Specific Weight, lb/gal.	9.292	9.316	9.375
Boiling Point @ 760 MMHg, °F	387.7	474.4	550.4
Freezing Point, °F	9.1	18.0	24.3
Surface Tension @ 77°F, dynes/cm	47.0	44.8	45.2
Heat of Vaporization @ 760 MMHg, BTU/lb	364	232	174

TABLE 3B
100% Diethylene Glycol

Temp. °F	Sp Gr	Viscosity, cps	Sp Heat BTU/lb-F	Thermal Conductivity BTU/hr-Sq ft-°F/ft
50	1.127	72	0.53	0.146
75	1.117	45	0.54	0.14
100	1.107	18	0.56	0.135
125	1.098	12.7	0.57	0.13
150	1.089	7.3	0.58	0.125
175	1.076	5.5	0.59	0.12
200	1.064	3.6	0.60	0.115
225	1.054	2.8	0.61	0.11
250	1.043	1.9	0.63	0.105
275	1.032	1.6	0.62	
300	1.021	1.3	0.66	

TABLE 3C
100% Triethylene Glycol

Temp. °F	Sp Gr	Viscosity	Sp Heat BTU/lb-F	Thermal Conductivity BTU/hr-Sq ft-°F/ft
50	1.134	88	0.485	0.14
75	1.123	56	6.50	0.138
100	1.111	23	0.52	0.132
125	1.101	15.5	0.535	0.130
150	1.091	8.1	0.55	0.125
175	1.080	6.1	0.57	0.121
200	1.068	4.0	0.585	0.118
225	1.057	3.1	0.60	0.113
250	1.034	1.9	0.635	
300	1.022	1.5	0.65	

GAS CAPACITY CORRECTION FACTORS FOR TRAYED GLYCOL-GAS CONTACTORS

TABLE 1A
TEMPERATURE CORRECTION FACTORS, C_t

Operating Temperature °F	Correction Factor C_t
40	1.07
50	1.06
60	1.05
70	1.04
80	1.02
90	1.01
100	1.00
110	0.99
120	0.98

TABLE 1B
SPECIFIC GRAVITY CORRECTION FACTORS C_g

Gas Specific Gravity	Correction Factor C_g
0.55	1.14
0.60	1.08
0.65	1.04
0.70	1.00
0.75	0.97
0.80	0.93
0.85	0.90
0.90	0.88

GAS CAPACITY CORRECTION FACTORS FOR PACKED GLYCOL-GAS CONTACTORS

TABLE 2A
TEMPERATURE CORRECTION FACTORS, C_t

Operating Temperature °F	Correction Factor C_t
50	0.93
60	0.94
70	0.96
80	0.97
90	0.99
100	1.00
110	1.01
120	1.02

TABLE 2B
SPECIFIC GRAVITY CORRECTION FACTORS, C_g

Gas Specific Gravity	Correction Factor C_g
0.55	1.13
0.60	1.08
0.65	1.04
0.70	1.00
0.75	0.97
0.80	0.94
0.85	0.91
0.90	0.88

APPENDIX B
EXAMPLE PROBLEM - DEHYDRATOR DESIGN

Size a glycol dehydrator for a field installation from standard models to meet the following requirements.

1. Gas flow rate: 10.0 MMSCFD
2. Gas specific gravity: 0.70
3. Operating line pressure: 1000 psig
4. Maximum working pressure of contactor: 1440 psig
5. Gas inlet temperature: 100°F
6. Outlet gas water content: 7 lb H_2O/MMSCF

Select additional design criteria.

1. Glycol to water circulation rate: 3.0 gal TEG/lb H_2O
2. Lean glycol concentration: 99.5% TEG
3. Use trayed type contactor with valve trays

Contactor Size:

From Figure No. 3 select a contactor diameter with the approximate gas capacity at operating pressure.

G_s for 24" O.D. contactor at 1000 psig = 11.3 MMSCFD

Correct for operating conditions from Tables No. 1A and 1B

$G_o = G_s\ (Ct)\ (C_g)$
$G_o = 11.3\ (1.0)\ (1.0) = 11.3$ MMSCFD

Required Dew Point Depression and Water Removed:

From Water Content Chart at 1000 psig

	Dew Pt Temp	Water Content lb H_2O/MMCF
Inlet	100°F	61
Outlet	33°F	7
	67°F	54 lb H_2O/MMCF

Number of Trays Required:

From Figure No. 5 at 3 gal. TEG/lb H_2O and 67°F dew point depression, No. actual trays = 4.5

For a more detailed study, construct a modified McCabe-Thiele diagram.

Density of lean glycol at $100^{o}F$, $\rho_L = (Sp\ gr)\ (8.34)$

$$= (1.111)\ (8.34)$$

$$= 9.266\ lb/gal.$$

$$\text{Rich TEG} = \frac{(\text{Lean TEG})\ (\rho_L)}{\rho_L + \frac{1}{L_W}}$$

$$= \frac{(0.995)\ (9.266)}{9.266 + \frac{1}{3.0}} = 0.960 = 96.0\%$$

Operating line points:

Top of Column: 7.0 lb H_2O/MMCF & 99.5% TEG
Bottom of Column: 61 lb H_2O/MMCF & 96.0% TEG

Equilibrium line points:

%TEG	Equilibrium Dew Point Temp. at $100^{o}F$	Water Content of Gas at Dew Point Temp. & 1000 psig
99	12	3.2 lb H_2O/MMCF
98	30	6.3
97	40	9.0
96	47	11.7
95	51	13.3

Construct a McCabe-Thiele diagram and determine the number of theoretical trays required. See Figure No. 9.

$$\text{No. Actual Trays} = \frac{\text{No. Theo. Trays}}{\text{Tray Eff.}}$$

$$= \frac{1.48}{0.333} = 4.44$$

The results from the McCabe-Thiele diagram are close to that determined from the approximation curve, Figure No. 5. In either case the next whole number of trays should be used.

No. Actual Trays Required = 5

Reconcentrator:

Determine the required glycol circulation rate.

$$L = \frac{L_w (W_i)\ (G)}{24}$$

$$= \frac{3.0\ (61)\ (10.0)}{24} = 76.25 \text{ gal./hr}$$

Reboiler Duty:

Determine the heat load required.

Approximate heat load, $Q_t = 2000\ (L)$

$= 2000\ (76.25) = 152,500$ BTU/hr

Detailed calculation of heat required.

$$Q_l = L\ (1200) = 76.24\ (1200) = 91,488$$

$$Q_w = \frac{970.3\ \ (W_i - W_o)\ (G)}{24} = \frac{970.3\ (61-7)\ (10)}{24} = 21,832$$

$$Q_r = 0.25\ (Q_w) = 0.25\ (21,832) = 5,458$$

$$Q_l = 10,000 = 10,000$$

$$Q_t = 128,778 \text{ BTU/hr}$$

Stripping Still:

Determine the diameter of the packed column required from Figure 6 based on:

$L = 76.25$ gal./hr
$L_w = 3.0$ gal. TEG/lb H_2O
$A \approx 24$ sq in.

Minimum I. D = 5.5 in.

Standard Size Unit Required:

Summary of requirements:

Glycol-Gas Contactor: 23" O. D. with 5 trays, 1440 psi W. P.
Glycol Pump: 76.25 gal./hr
Reboiler: 128,778 BTU/hr
Stripping Still: 5.5 in. I. D.

Standard Size Unit:

Contactor: 24" O. D. x 14', 1440 psi W. P. with 5 valve trays
Glycol Reconcentrator: 175,000 BTU/hr reboiler, 9015-PV pump, 8-5/8" O. D. x 4'-6" stripping still

APPENDIX C
TABLE 4A
VERTICAL INLET SCRUBBERS

SPECIFICATIONS

Nominal W. P. psig	Size O. D.	Nominal Gas Capacity MMSCFD[1]	Inlet & Gas Outlet Conn	Std Oil Valve	Shipping Weight lb
230	16"	1.8	2"	1"	900
	20"	2.9	3"	1"	1000
	24"	4.1	3"	1"	1200
	30"	6.5	4"	1"	1400
	36"	9.4	4"	1"	1900
	42"	12.7	6"	2"	2600
	48"	16.7	6"	2"	3000
	54"	21.1	6"	2"	3500
	60"	26.1	6"	2"	4500
500	16"	2.7	2"	1"	1000
	20"	4.3	3"	1"	1300
	24"	6.1	3"	1"	2100
	30"	9.3	4"	1"	2700
	36"	13.3	4"	1"	3800
	42"	18.4	6"	2"	4200
	48"	24.3	6"	2"	5000
	54"	30.6	6"	2"	5400
	60"	38.1	6"	2"	7500
600	16"	3.0	2"	1"	1100
	20"	4.6	3"	1"	1400
	24"	6.3	3"	1"	2200
	30"	9.8	4"	1"	2800
	36"	14.7	4"	1"	3900
	42"	20.4	6"	2"	4500
	48"	27.1	6"	2"	5100
	54"	34.0	6"	2"	6000
	60"	42.3	6"	2"	8100
1000	16"	3.9	2"	1"	1100
	20"	6.1	3"	1"	1600
	24"	8.8	3"	1"	2500
	30"	13.6	4"	1"	3200
	36"	20.7	4"	1"	4400
	42"	27.5	6"	2"	6300
	48"	36.9	6"	2"	8400
	54"	46.1	6"	2"	9700
	60"	57.7	6"	2"	14500

Nominal W. P. psig	Size O. D.	Nominal Gas Capacity MMSCFD[1]	Inlet & Gas Outlet Conn	Std Oil Valve	Shipping Weight lb
1200	16"	4.2	2"	1"	1150
	20"	6.5	3"	1"	1800
	24"	6.5	3"	1"	2600
	30"	15.3	4"	1"	3400
	36"	23.1	4"	1"	4700
	42"	31.0	6"	2"	6700
	48"	40.5	6"	2"	8500
	54"	51.4	6"	2"	11300
	60"	62.3	6"	2"	14500
1440	16"	4.8	2"	1"	1500
	20"	6.7	3"	1"	2100
	24"	11.2	3"	1"	2800
	30"	17.7	4"	1"	3900
	36"	25.5	4"	1"	5400
	42"	34.7	6"	2"	7800
	48"	45.3	6"	2"	9200
	54"	56.1	6"	2"	12900
	60"	69.6	6"	2"	16000

1. Gas capacity based on 100°F, 0.7 sp gr, and vessel working pressure.

TABLE 4B

Size O. D.	Two Phase Scrubber			Three Phase Scrubber			
	Shell Height	Settling Volume, bbl[1]	Liquid Capacity bbl/day[2]	Shell Height	Settling Volume bbl[1]	Liquid Capacity bbl/day[3]	
						Oil	Water
16"	5'	0.27	340	7-1/2'	0.72	100	100
20"	5'	0.44	530	7-1/2'	1.15	160	160
24"	5'	0.66	760	7-1/2'	1.68	240	240
30"	5'	1.13	1180	7-1/2'	2.78	400	400
36"	5'	1.73	2000	7-1/2'	4.13	590	590
42"	5'	2.52	3000	7-1/2'	5.80	830	830
48"	5'	3.48	4000	7-1/2'	7.79	1120	1120
54"	5'	4.65	5000	7-1/2'	10.12	1450	1450
60"	5'	6.01	6000	7-1/2'	12.73	1830	1830

1. Based on nominal 1000 psig W. P. scrubber.
2. Based on 1.0 minute retention time.
3. Based on 5.0 minute retention time.

TABLE 5A
TRAY TYPE GLYCOL/GAS CONTACTORS

SPECIFICATIONS

Nominal W. P. psig	Size O. D.	Nominal Gas Capacity MMSCFD[1]	Gas Inlet & Outlet Size	Glycol Inlet & Outlet Size	Glycol Cooler Size	Shipping Weight lb
250	12-3/4"	1.5	2"	1/2"	2" x 4"	800
	16"	2.4	2"	3/4"	2" x 4"	900
	18"	3.2	3"	3/4"	3" x 5"	1100
	20"	4.0	3"	1"	3" x 5"	1400
	24"	6.1	3"	1"	3" x 5"	2000
	30"	9.9	4"	1"	4" x 6"	2400
	36"	14.7	4"	1-1/2"	4" x 6"	3200
	42"	19.7	4"	1-1/2"	4" x 6"	4400
	48"	26.3	6"	2"	6" x 8"	6300
	54"	32.7	6"	2"	6" x 8"	7700
	60"	40.6	6"	2"	6" x 8"	9600
500	12-3/4"	2.0	2"	1/2"	2" x 4"	1000
	16"	3.2	2"	3/4"	2" x 4"	1200
	18"	4.3	3"	3/4"	3" x 5"	1500
	20"	5.3	3"	1"	3" x 5"	1700
	24"	8.3	3"	1"	3" x 5"	2900
	30"	13.1	3"	1"	3" x 5"	3900
	36"	19.2	4"	1-1/2"	4" x 6"	6000
	42"	27.4	4"	1-1/2"	4" x 6"	7700
	48"	35.1	6"	2"	6" x 8"	10000
	54"	44.5	6"	2"	6" x 8"	12000
	60"	55.2	6"	2"	6" x 8"	15300
600	12-3/4"	2.2	2"	1/2"	2" x 4"	1100
	16"	3.4	2"	3/4"	2" x 4"	1300
	18"	4.5	3"	3/4"	3" x 5"	1600
	20"	5.5	3"	1"	3" x 5"	1800
	24"	8.5	3"	1"	3" x 5"	3000
	30"	14.3	3"	1"	3" x 5"	4000
	36"	21.2	4"	1-1/2"	4" x 6"	6300
	42"	29.4	4"	1-1/2"	4" x 6"	8400
	48"	39.2	6"	2"	6" x 8"	11300
	54"	49.3	6"	2"	6" x 8"	13400
	60"	61.3	6"	2"	6" x 8"	16500

Nominal W. P. psig	Size O. D.	Nominal Gas Capacity MMSCFD[1]	Gas Inlet & Outlet Size	Glycol Inlet & Outlet Size	Glycol Cooler Size	Shipping Weight lb
1000	12-3/4"	2.7	2"	1/2"	2" x 4"	1300
	16"	4.3	2"	3/4"	2" x 4"	1600
	18"	5.5	3"	3/4"	3" x 5"	2100
	20"	7.3	3"	1"	3" x 5"	2600
	24"	11.3	3"	1"	3" x 5"	4200
	30"	18.4	3"	1"	3" x 5"	5500
	36"	27.5	4"	1-1/2"	4" x 6"	8500
	42"	37.1	4"	1-1/2"	4" x 6"	11800
	48"	49.6	6"	2"	6" x 8"	16200
	54"	62.0	6"	2"	6" x 8"	20200
	60"	77.5	6"	2"	6" x 8"	26300
1200	12-3/4"	3.0	2"	1/2"	2" x 4"	1500
	16"	4.7	2"	3/4"	2" x 4"	1900
	18"	6.0	3"	3/4"	3" x 5"	2300
	20"	7.8	3"	1"	3" x 5"	3000
	24"	12.0	3"	1"	3" x 5"	4900
	30"	20.1	3"	1"	3" x 5"	6400
	36"	29.8	4"	1-1/2"	4" x 6"	10000
	42"	41.4	4"	1-1/2"	4" x 6"	13100
	48"	54.1	6"	2"	6" x 8"	18400
	54"	68.4	6"	2"	6" x 8"	23500
	60"	85.0	6"	2"	6" x 8"	29000
1440	12-3/4"	3.1	2"	1/2"	2" x 4"	1800
	16"	4.9	2"	3/4"	2" x 4"	2200
	18"	6.5	3"	3/4"	3" x 5"	2800
	20"	8.3	3"	1"	3" x 5"	3500
	24"	13.3	3"	1"	3" x 5"	5800
	30"	22.3	3"	1"	3" x 5"	7500
	36"	32.8	4"	1-1/2"	4" x 6"	11700
	42"	44.3	4"	1-1/2"	4" x 6"	14400
	48"	58.3	6"	2"	6" x 8"	20000
	54"	74.0	6"	2"	6" x 8"	25800
	60"	91.1	6"	2"	6" x 8"	32000

1. Gas capacity based on 100°F, 0.7 sp gr and contactor working pressure.

TABLE 5B

Size O. D.	Standard Shell Height[1]	Standard Glycol Cooler Height[1]	Add to Height For Add. Tray, ea.	Glycol Charge, gal	
				Standard[1]	For Each Add. Tray
12-3/4"	13'	9'	2'	10	1.5
16"	13'	9'	2'	13	2.2
18"	13'	9'	2'	16	2.8
20"	13'	9'	2'	19	3.4
24"	13'	9'	2'	25	5.0
30"	13'	9'	2'	38	8.2
36"	13'	9'	2'	53	11.8
42"	13'	9'	2'	73	16.8
48"	13'	9'	2'	90	20.9
54"	13'	9'	2'	112	26.6
60"	13'	9'	2'	137	32.6

1. For Standard Four Tray Contactor.

TABLE 6A
PACKED COLUMN GLYCOL/GAS CONTACTORS

SPECIFICATIONS

Nominal W. P. psig	Size O. D.	Nominal Gas Capacity MMSCFD[1]	Gas Inlet & Outlet Size	Glycol Inlet & Outlet Size	Glycol Cooler Size	Shipping Weight lb
250	10-3/4"	1.1	2"	1/2"	2" x 4"	500
	12-3/4"	1.6	2"	1/2"	2" x 4"	600
	14"	1.9	2"	1/2"	2" x 4"	650
	16"	2.5	2"	1/2"	2" x 4"	800
	18"	3.4	3"	3/4"	3" x 5"	900
	20"	4.0	3"	3/4"	3" x 5"	1100
	24"	5.5	3"	1"	3" x 5"	1800
500	10-3/4"	1.5	2"	1/2"	2" x 4"	600
	12-3/4"	2.2	2"	1/2"	2" x 4"	700
	14"	2.6	2"	1/2"	2" x 4"	750
	16"	3.4	2"	1/2"	2" x 4"	900
	18"	4.4	3"	3/4"	3" x 5"	1000
	20"	5.5	3"	3/4"	3" x 5"	1500
	24"	7.5	3"	1"	3" x 5"	2500

Nominal W.P. psig	Size O.D.	Nominal Gas Capacity MMSCFD[1]	Gas Inlet & Outlet Size	Glycol Inlet & Outlet Size	Glycol Cooler Size	Shipping Weight lb
600	10-3/4"	1.7	2"	1/2"	2" x 4"	650
	12-3/4"	2.4	2"	1/2"	2" x 4"	750
	14"	2.9	2"	1/2"	2" x 4"	800
	16"	3.8	2"	1/2"	2" x 4"	950
	18"	4.8	3"	3/4"	3" x 5"	1100
	20"	6.0	3"	3/4"	3" x 5"	1700
	24"	8.1	3"	1"	3" x 5"	2700
1000	10-3/4"	2.3	2"	1/2"	2" x 4"	900
	12-3/4"	3.3	2"	1/2"	2" x 4"	1000
	14"	4.0	2"	1/2"	2" x 4"	1100
	16"	5.2	2"	1/2"	2" x 4"	1300
	18"	6.6	3"	3/4"	3" x 5"	1800
	20"	8.2	3"	3/4"	3" x 5"	2300
	24"	11.8	3"	1"	3" x 5"	3500
1200	10-3/4"	2.5	2"	1/2"	2" x 4"	1200
	12-3/4"	3.6	2"	1/2"	2" x 4"	1300
	14"	4.1	2"	1/2"	2" x 4"	1500
	16"	5.4	2"	1/2"	2" x 4"	1700
	18"	6.9	3"	3/4"	3" x 5"	2200
	20"	8.5	3"	3/4"	3" x 5"	2800
	24"	12.3	3"	3/4"	3" x 5"	4000
1440	10-3/4"	2.6	2"	1/2"	2" x 4"	1300
	12-3/4"	3.7	2"	1/2"	2" x 4"	1400
	14"	4.5	2"	1/2	2" x 4"	1600
	16"	5.9	2"	1/2"	2" x 4"	1900
	18"	7.5	3"	3/4"	3" x 5"	2500
	20"	9.3	3"	3/4"	3" x 5"	3100
	24"	12.7	3"	1"	3" x 5"	4500

1. Gas capacity based on 100°F, 0.7 sp gr and contactor working pressure.

TABLE 6B

Size O.D.	Standard Shell Height	Standard Glycol Cooler Height	Standard Contacting Element[1]	Glycol Charge gal.
10-3/4"	9'	7'	1" x 4"	6
12-3/4"	9'	7'	1" x 4'	7
14"	9'	7'	1" x 4'	8
16"	9'	7'	1" x 4'	10
18"	9'	7'	1" x 4'	12
20"	9'	7'	1" x 4'	14
24"	9'	7'	1" x 4'	18

1. Standard contacting element is carbon steel metal pall rings of size listed in Table.

TABLE 7
GLYCOL RECONCENTRATORS

SPECIFICATIONS

Reboiler Capacity Btu/hr	Glycol Capacity gph*	Reboiler Size Dia. x Len.	Heat Exchanger Surge Tank, Size Dia. x Len.	Stripping Still Size, Dia. x Ht.	Reflux Condenser Size, Dia. x Ht.	Flash Separator Size Dia. x Ht.
75,000	20	18" x 3'-6"	18" x 3'-6"	6-5/8" x 4'-6"	6-5/8" x 2'-0"	12" x 48"
75,000	35	18" x 3'-6"	18" x 3'-6"	6-5/8" x 4'-6"	6-5/8" x 2'-0"	12" x 48"
125,000	40	18" x 5'	18" x 5'	6-5/8" x 4'-6"	6-5/8" x 2'-0"	16" x 48"
125,000	70	18" x 5'	18" x 5'	6-5/8" x 4'-6"	6-5/8" x 2'-0"	16" x 48"
175,000	90	24" x 5'	24" x 5'	8-5/8" x 4'-6"	8-5/8" x 2'-0"	16" x 48"
175,000	100	24" x 5'	24" x 5'	8-5/8" x 4'-6"	8-5/8" x 2'-0"	16" x 48"
250,000	150	24" x 7'	24" x 7'	8-5/8" x 5'-0"	8-5/8" x 2'-0"	16" x 48"
350,000	210	24" x 10'	24" x 10'	10-3/4" x 5'-0"	10-3/4" x 2'-6"	20" x 48"
400,000	250	30" x 10'	30" x 10'	10-3/4" x 6'-0"	10-3/4" x 2'-6"	20" x 48"
500,000	315	36" x 10'	36" x 10'	12-3/4" x 7'-0"	12-3/4" x 2'-6"	24" x 48"
750,000	450	36" x 15'	36" x 10'	14" x 8'-0"	14" x 3'-0"	30" x 48"
850,000	450	42" x 15'	36" x 10'	14" x 8'-0"	14" x 3'-0"	30" x 48"
1,000,000	450	48" x 16'	36" x 10'	16" x 8'-0"	16" x 3'-0"	30" x 48"

Heat Exchange Coil		Glycol Pump Model	High Pressure Glycol Filter Size	Glycol Charge gal.	Shipping Wt lb
Size	Coil Area, sq ft				
1/2"	12.9	1715PV	1"	75	2100
1/2"	12.9	4015PV	1"	75	2100
1/2"	23.3	4015PV	1"	105	2200
1/2"	23.3	9015PV	1"	105	2250
1/2"	31.1	9015PV	1"	190	3200
1/2"	31.1	21015PV	1-1/2"	190	3200
3/4"	44.6	21015PV	1-1/2"	260	3700
3/4"	64.8	21015PV	1-1/2"	375	4000
3/4"	64.8	45015PV	2"	445	4500
1"	82.1	45015PV	2"	680	6500
1"	102.6	45015PV	2"	990	7000
1"	102.6	45015PV	2"	1175	7500
1"	102.6	45015PV	2"	1425	10000

*Glycol capacity is based on circulating 2.5 gal. TEG/lb H_2O and is controlled by the reboiler capacity or pump capacity whichever is smaller.

APPENDIX C
TABLE 8
GLYCOL PUMPS (3)

STANDARD HIGH PRESSURE PUMPS

CIRCULATION RATE — Gallons/Hour

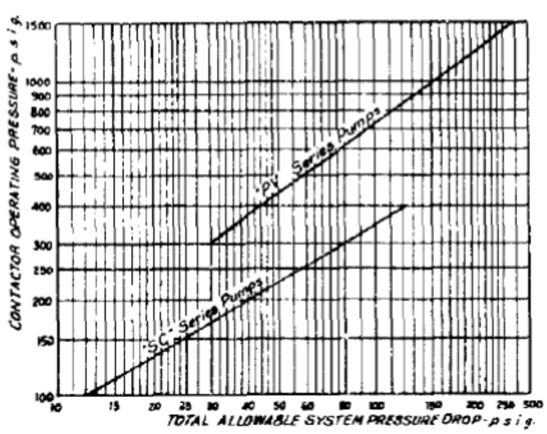
Model Number	*Pump Speed — Strokes/Minute. Count one stroke for each discharge of pump. 8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
1715 PV	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
4015 PV			12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
9015 PV			27	31.5	36	40.5	45	49.5	54	58.5	63	67.5	72	76.5	81	85.5	90
21015 PV		66	79	92	105	118	131	144	157	171	184	197	210				
45015 PV		166	200	233	266	300	333	366	400	433	466						

*It is not recommended to attempt to run pumps at speeds less or greater than those indicated in the above table.

GAS CONSUMPTION

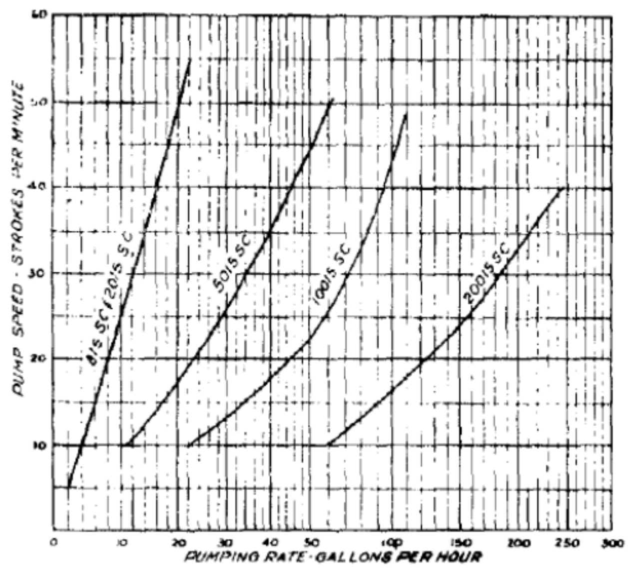
Operating Pressure—p.s.i.g.	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
Cu. Ft. Gallon @ 14.4 & 60°F.	1.7	2.3	2.8	3.4	3.9	4.5	5.0	5.6	6.1	6.7	7.2	7.9	8.3

PRESSURE DROP



Pump Model	Pump Conn.	Size Strainer	High Press. Filter Size	High Press. Filter Elements	Low Press. Filter Size	Low Press. Filter Elements
315PV	1/4"	1/2"	1"	1-2-3/4"x9-3/4"	1/2"	1-3" x 18"
1715PV & 815SC	1/2"	3/4"	1"	1-2-3/4"x9-3/4"	1/2"	1-3" x 18"
4015PV & 2015SC	1/2"	3/4"	1"	1-2-3/4"x9-3/4"	1/2"	1-3" x 18"
9015PV & 5015SC	3/4"	1"	1"	2-2-3/4"x9-3/4"	3/4"	1-3" x 36"
21015PV & 10015SC	1"	1"	1-1/2"	4-2-3/4"x9-3/4"	1"	4-3" x 18"
45015PV & 20015SC	1-1/2"	1-1/2"	2"	8-2-3/4"x9-3/4"	1-1/2"	4-3" x 36"

SMALL BORE PUMPS FOR LOW PRESSURES



GAS CONSUMPTION

Operating Pressure—p.s.i.g.	100	200	300	400
Cu. Ft./Gal. @ 14.4 & 60°F	1.0	1.9	2.8	3.7

MODEL 315PV SMALL PUMP

CIRCULATION RATE—Gallons/Hour

*Pump Speed — Strokes / Minute. Count one stroke for each discharge of pump.																
20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
2.5	3.2	3.9	4.5	5.2	5.8	6.5	7.1	7.8	8.4	9.1	9.7	10.4	11.0	11.7	12.3	13.0

* Do not operate at speeds in excess of 100 strokes per minute. Count ONE stroke for each discharge of pump.

GAS CONSUMPTION

Operating Pressure — p.s.i.g.	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
Cu. Ft./Gallon @ 14.4 & 60°F	0.9	2.0	2.9	3.9	4.8	5.7	6.7	7.6	8.5	9.5	10.3	11.2	12.2	13.1	14.0