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USE OF TRIETHYLENE GLYCOL TO DEHYDRATE NATURAL GAS

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ABSTRACT

A chemical method of water removal from natural gas, obtained in the Niger Delta where water-cut is more than 20%, is presented. Triethylene glycol (TEG) which has a low vapour loss is used to lower the dew point of 20 MMSCF/D gas containing 6 Ib H_2O per MMSCF from 100^0 to 28^0F at an operating pressure of 1000 psig. The wet gas, after scrubbing, was allowed to flow at counter-current to the TEG in 7-trayed separation stages. Gycol absorbs acidic gases present in produced water: These gases are easily flashed in the separator thereby controlling corrosion. The ability of TEG to dry a gas increases with concentration. Glycol, of pH= 7.0-8.5 when reconcentrated to 99.5 weight percent improves dehydration efficiency and lowers plant operating cost. To achieve this the outlet temperature should be higher than inlet by 10-15^0F.

Key Words: Gas, Dehydration, Glycol, Hydrate.

INTRODUCTION

Dehydration of natural gas is important in order to avoid severe operational problems from hydrates formation, pipe erosion and corrosion. The desired water content is 0.5 – 7lb H_20/MMSCF (True, 1992). A change in the method employed for dehydration could offer great benefits in meeting sal... ...act and corrosion or hydrate control. Oil and gas fields in the Niger Delta in recent years have high water-cut in excess of 22% (Appah and Nwachukwu, 1998). Natural gas, by its source, is almost always associated with water usually in the range of 400-500 pounds in one million standard cubic feet of gas.

Methods of dehydrating natural gas include adsorption with solid desiccants such as silica gel, calcium chloride and activated alumina (ALCOA, 1986), and liquids desiccants such as methanol (Skopak and Philip, 1985), use of molecular sieves and expansion refrigeration (Campbell, 1984) but the results obtained are unsatisfactory. For example silica gel cannot be used where hydrogen sulphide concentration is more than 6 percent since sulphur will deposit and block the bead surfaces. The solid desiccant dehydrators have the following shortfalls: high capital cost, mechanical breaking of desiccant particles, high regeneration heat requirements and high pressure drop (Grace, 1988).

Removing water vapour from gas stream with triethylene glycol (TEG) occurs by absorption. TEG is non-corrosive, non-toxic and has a low vapour loss. Two types of structures are commonly used in gas processing (Olawoye, 1997). In type one the sodalite cages form a simple cubic structure with pores of 3-5 Angstrons (A). The second type is tetrahedral in structure, having a pore size of 10 A. TEG sufficiently lowers the dew-point of the gas to achieve dehydration, since water content depends on pressure, temperature, salt content and gas composition. The choice of TEG follows its general applicability and economics. For this work, TEG was used to treat 20 MMSCF/D gas having specific gravity 0.7 (at an operating pressure of 1000 psig) and water content 6 Ib per MMSCF at the bubble cap trays plant outlet. The maximum working pressure was 1,440 psig. This study illustrates the importance of dew point as one parameter, which determines dehydration efficiency in various gas treatment processes.

PRELIMINARY SIZING OF GAS PLANT

The primary variables involved in removing water from a gas stream are the gas flow rate, specific gravity, operating pressure, maximum working pressure, gas inlet temperature and outlet water content required in the gas. Design criteria are glycol-water circulation rate in the range 2-5 gal TEG per Ib water removed and concentration of the lean TEG from the regeneration system of 99.0 – 99.5%.

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TEG has a molecular weight of 150.17, specific weight of 9.375 lb/gal, boiling point of 550.4°f at 760mm Hg freezing point, of 24.3°F and heat of vapourisation of 174 Btu/Ib. Properties of the gas obtained from three Niger Delta wells OBF 3S, OBK 7T and OBF 4L (Table 1) were used in determining the quality of TEG needed for effective dehydration.

Glycol to water circulation rate was 3.5 gal TEG/lb H_2O and lean glycol concentration of 99.5% TEG. From Appendix 1 (Mcketta and Wehe chart), the water content of inlet gas at 1000 psig and 100 °F is 61 lb H_2O/mmscf gas, the dew point at outlet with 6 lbH_2O/mmscf is 28°F and the required dew point depression is (100 – 28) = 72 °F. The amount of water to be removed, W_r, is given by

$$W_r \frac{(W_i - W_o)q}{24} \quad (1)$$

where,

W_i is the inlet water in gas , W_o is the outlet water content, q-glass flow rate while 24 is a conversion factor for gas rate from day to hour.

Therefore, $W_r = \frac{(61-6)20}{24} = 45.83 lbm/hr$

A 36 inch out diameter (O.D) vertical scrubber is required for a 1,440 psig maximum working pressure (Appendix 2). A two-phase scrubber with a 7.5 ft. Shell height was used. Given the glycol to water circulation rate (3.5) and dewpoint depression (72°F), the number of trays from Appendix 3 is 7 bubble – cap trays.

Glycol circulation rate, L, is given by

$$L = \frac{L_w(W_i)q}{24} \quad (2)$$

where, L_W is the glycol to water circulation rate

Therefore, $L = \frac{3.5 x 61 x 20}{24} = 177.92$gal/hr

The reboiler heat load, Q, is given by

$$Q = 2000L \quad (3)$$

= 2000 x 177.92
= 3.56 x 10^5 Btu/hr

The reboiler size (Appendix 4) = 30 x 10

From Appendix 5, pump model 21015 PV, with 28 strokes/mm pumping speed, is required for a glycol circulation rate of 177.92 gal/hr. Glycol flash separator is usually designed for a liquid retention time of at least 5 minutes. The setting volume in the separator, V, is given by

$$V = \frac{LT}{60} \quad (3)$$

where, T is the retention time (5 min) and L is the glycol circulation rate.

Therefore, V is calculated as

$$V = \frac{177.92 x 5}{60} = 14.8 gal$$
$$= 0.35 bbl.$$

From Appendix 5, a 20 O.D two-phase separation is required.

DEHYDRATION PROCESS USING TEG

The flow chart for the glycol dehydration plant is schematically shown in Fig. 1. The wet gas is first sent to a scrubber to remove water and solid matter. Scrubbed gas by counter-current flow to the TEG is sent upwards through a 7-trayed-type equilibrium separation stages. Glycol absorbs water vapour from the gas (1 scf gas/gal at 1000 psig operating pressure). The dry gas from the top of the contractor is sent to a gas-glycol heat exchanger to cool the regeneration glycol. After the heat exchange, the dried gas leaves the dehydration unit. The wet glycol leaves from the bottom of the contractor through a solid filter for preheat by heat exchange. Preheated wet glycol is then sent to the flash separator to remove dissolved or entrained gas. The glycol flows down in the stripping into the reboiler which still removes water, from the wet glycol, to the atmosphere. In the reboiler, glycol is heated to approximately 350-400°F to reconcentrate it to 99.5%.

Daily gas production rates obtained from three wells (OBF 3S, OBK 7T and OBF 4L) used for this work are shown in Table 1. The specific gravity (0.7), operating pressure (1000 psig) and temperature (100°F) were obtained from chemical laboratory report of gas to feed the dehydration plant.

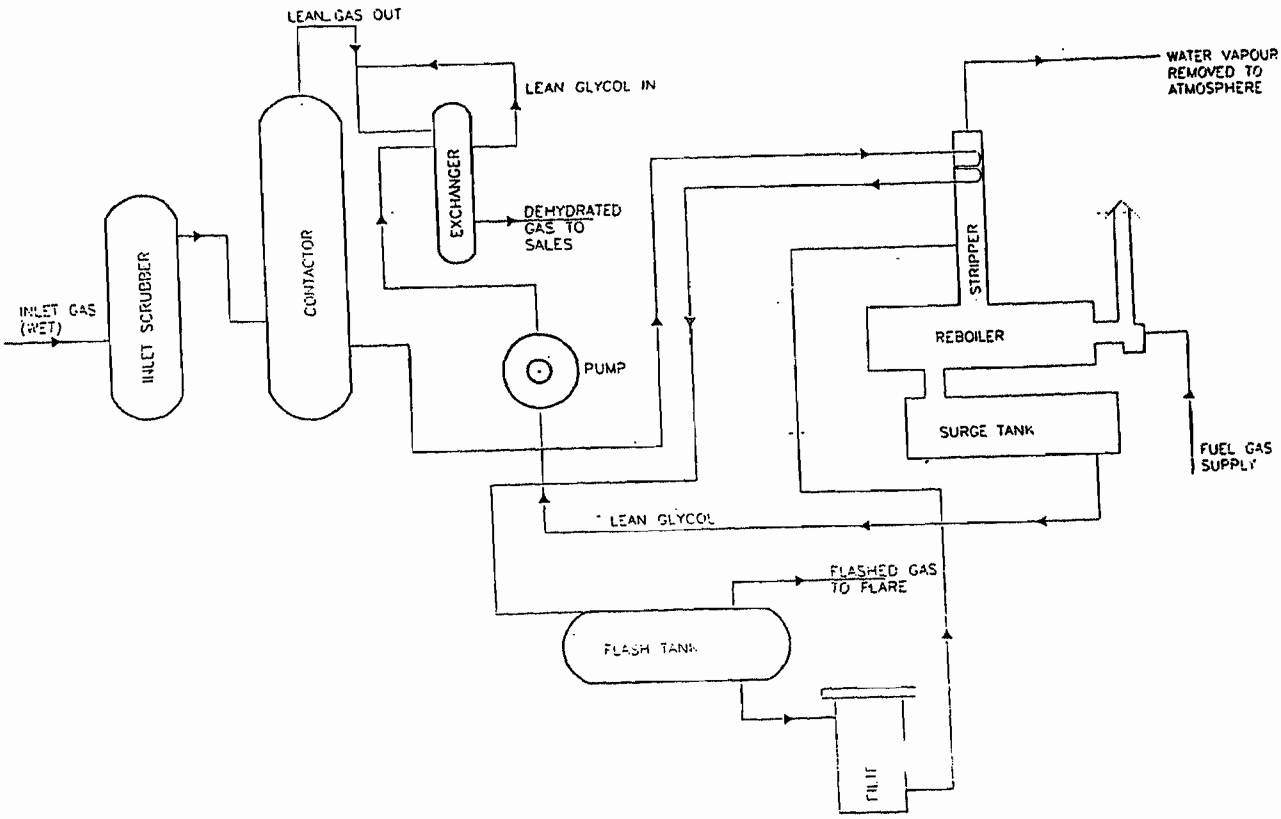

FIGURE .1 A GLYCOL PLANT FLOW PROCESS

DISCUSSION OF RESULTS

The lean glycol concentration (99.5 per cent TEG) was chosen to achieve the optimum dew point depression (72°F) and glycol to water circulation rate of 3.5 gal TEG/lb H20. For this case, operating above the maximum flow capacity of 23 mmscf/d and working pressure of 1440 psig would lead to inadequate scrubbing. The bubble-cap trays, as chosen, are suitable for viscous liquids and they can handle low flow of 16-20 per cent of the calculated rate. The trays were spaced at least 18 inches apart, since TEG tends to foam. Calculations were carried out to allow the contractor handle flowrates of 15% above capacity, while capabilities of other units, such as pumps and reboilers, were considered. Water content and quantity to be picked up, in the glycol-gas contractor, by the glycol depend on the inlet gas temperature and pressure. An increase in the inlet-gas temperature or decrease in inlet-gas pressure increases the load on the unit. Sudden changes in pressure and temperature affect glycol flow in the absorber and break down comer seals.

Ability of TEG to dry gas increases with concentration. At 100°F, the equilibrium water dew points of the gas in contact with 98,99, 99.5 and 99.7 weight percent TEG are 32, 16, 0 and –16°F respectively. The equilibrium water dew point decreases with decreasing temperature, but cooling the glycol increases its viscosity and its tendency to foam. The chosen glycol-powered pump, Model 21015 PV, with 28 strokes/min pumping speed facilitates the water picked up by the glycol. Dehydration increases with increasing temperature, higher circulation rates and number of contractor trays. For the purpose of this research, 3.5 gal/lb H_2O was adequate. The condensate-glycol separation is best a 100°F and 75 psig.

A 36 x 10, 400,000 Btu/hr reboiler with indirect heating is specified. Indirect heating, to boil water out of the glycol, is preferred since direct-fire heaters often constitute an open flame hazard. A 400,000 Btu/hr heat load helps to keep TEG temperature below 400°F (350-400°C) to avoid thermal decomposition of glycol. The concentration of water in the lean glycol leaving the reboiler varies with the reboiler temperature and pressure. The reboiler is operated at atmospheric pressure.

It is recommended that glycol pH be 7.0-8.5, boiler temperature below 400°F to avoid glycol overheating and thermal degradation where the gas stream content should be below 2500 ppmul. Inlet gas should be

TABLE 1. CHROMATOGRAPHIC ANALYSIS OF GAS (MOLE %)

SAMPLING DATE: WELL & CHOKE SIZE SAMPLING POINT		20/01/97 WELLHEAD OBF 3S	20/01/97 WELLHEAD OBK 7T	20/01/97WELL HEAD OBF 4L
TEMPERATURE:	°F	100		
PRESSURE	Psig	1000		
Methane	C_1	84.98	85.57	86.61
Ethane	C_2	6.68	6.37	5.83
Propane	C_3	3.44	3.52	2.97
iso-Botane	i-C_4	0.66	0.59	0.57
normal-Butane	n-C_4	0.18	0.86	0.70
iso-Pentane .	i-C_5	0.26	0.24	0.24
normal-Pentane	n-C_5	0.19	0.18	0.17
Hexanes plus	C_6+	0.43	0.45	0.61
Carbon Dioxide	CO_2	2.450	2.140	20200
Nitrogen	N_2	0.100	0.08	0.10
TOTAL		100.00	100.0.	100.00

PHYSICAL PROPERTIES CALCULATION (ISO/DIS 6975)
15C @ 1.013250bar

MOLECULAR WEIGHT		19.84	19.72	19.56
DENSITY	[Air=1]	0.70012	0.7023	0.7001
VOLUMIC MASS	Kg/m³	0.8406	0.8354	0.8278
SUPERIOR CALORIFIC VALUE	Kcal/m³	12079	10293	10188
INFERIOR CALORIFIC VALUE	Kcal/m³	9302	9314	9217
COMPRESSIBILITY FACTOR		0.9969	0.9969	0.9970

properly scrubbed to avoid hydrocarbon condensation while outlet gas temperature should be higher than inlet by 10-15°F. Excessive high gas flow rate in the contractor, presence of contaminants such as particles, salts and corrosion inhibitors cause foaming. Defoamers such as silicon emulsion breakers, block polymers of ethylene and propylene should be injected at inlet gas stream to the contractor.

CONCLUSION

Five important conclusions can be dr~ from this study:

1. Dew point or hydrate formation temperature of the natural gas has been lowered from 100° to 28°F. The amount of water vapour in the gas is, therefore, always less than the amount required to saturate the gas.

2. The outlet-gas water content of 6 lb H_20/MMSCF gas obtained using glycol, meets sales gas contract and pipeline specifications.

3. Use of glycol instead of methane for gas

dehydration removes corrosion caused by CO_2 and H_2S in produced water. These acid gases are soluble in glycol and easily flashed in the separator.

4. Reconcentration of glycol (pH 7.0-8.5) to 99.5 weight percent improves dehydration efficiency and lowers plant operation cost.

5. A higher outlet temperature than inlet by 10-15°F enhances scrubbing and injection of defoamers at inlet gas stream controls foaming caused by high flow rate and solid contaminants.

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SI Metric Conversion Factors

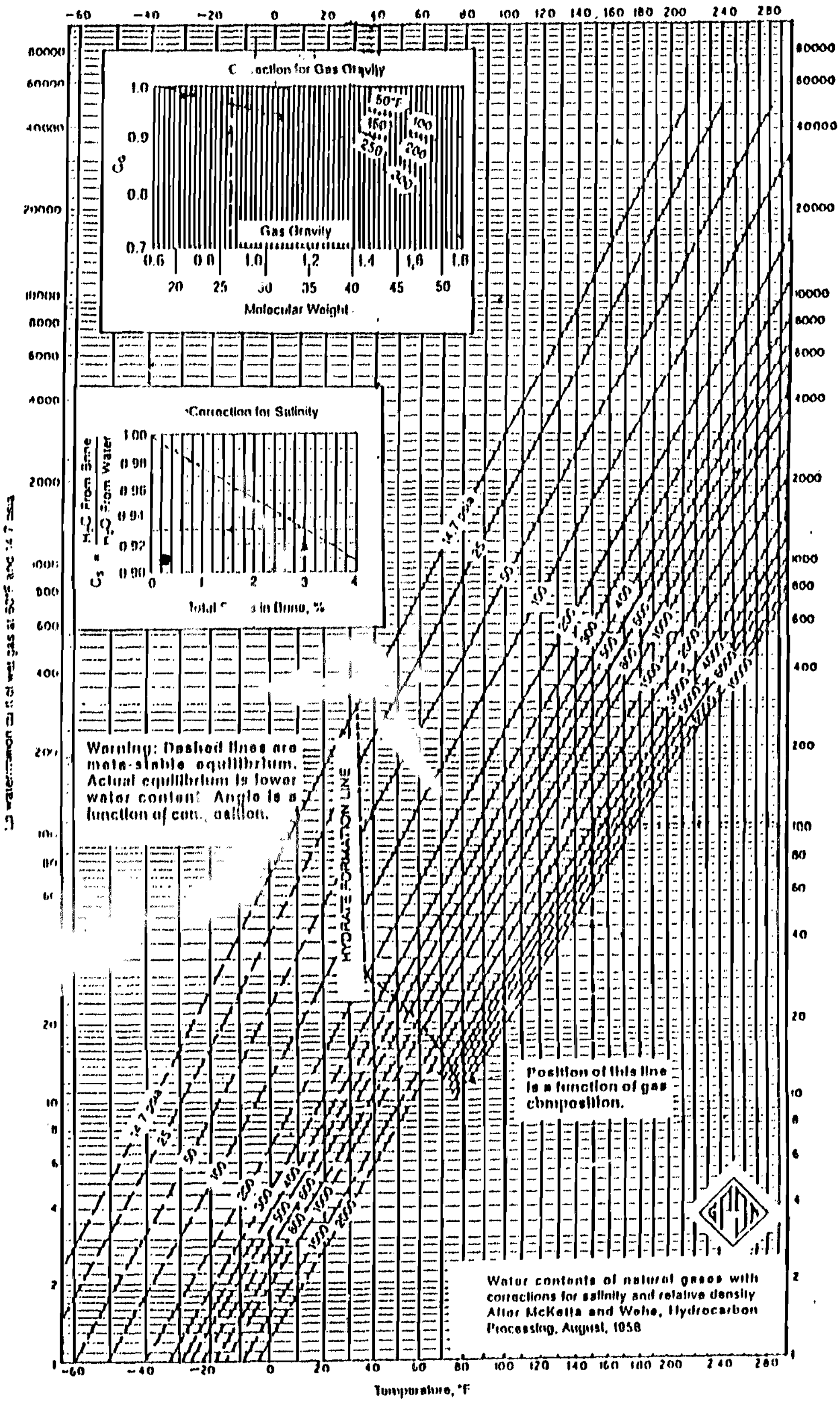
The list below includes SI Metric conversion factors for common engineering units. The units given in the paper are those currently used in petroleum studies and approved by Soc. Of Petroleum Engineering along with the SI units.

Bbl x 1.589 873	E-01	= m^3
Ft x 3.048*	E-01	= m
°F (°F-32)/1.8		= °C
°F (°F + 459.67)/1.8		= K
gal x 3.785 412	E-03	= cm
in. X 2.5*	E + 00	= cm
psi x 6.894 757	E + 00	= kPa
Btu x 1.055 056	E + 00	= kJ
Lb x 4.535 924	E – 01	= Kg

*Conversion factor is exact

Appendix 1 Dew Point of Natural Gas (Olawoye, 1997)

Specifications for Glycol Reconcentrators*



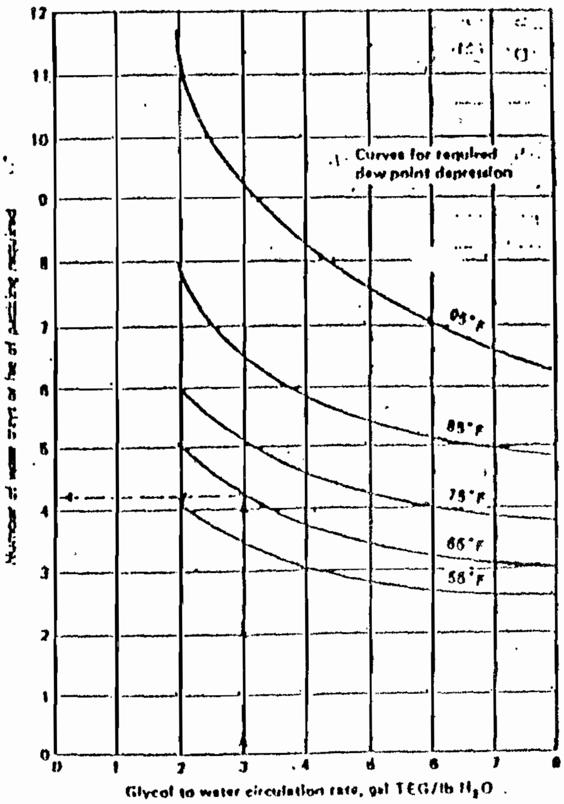
APPENDIX 2 Specifications for Vertical Inlet Scrubbers

Nominal WP Psig	Size OD	Nominal Gas Capacity MMscfd	Gas Inlet and Outlets Size	Glycol Inlet and Outlet Size	Glycol Cooler Size
1000	12¾	2.7	2"	½"	2"* 4"
	16"	4.3	2"	¾"	2"* 4"
	18"	5.5	3"	1"	3"* 5"
	20"	7.3	3"	1"	3"* 5"
	24"	11.3	3"	1"	3"* 5"
	30"	18.4	3"	1½"	3"* 5"
	36"	27.5	4"	1½"	4"* 6"
	42"	37.1	4"	2"	4"* 6"
	48"	49.6	6"	2"	6"* 8"
	54"	62.0	6"	2"	6"* 8"
	60"	77.5	6"	½"	6"* 8
1200	12¾	3.0	2"	¾"	2"* 4"
	16"	4.7	2"	¾"	2"* 4"
	18"	6.0	3"	1"	3"* 5"
	20"	7.8	3"	1"	3"* 5"
	24"	12.0	3"	1"	3"* 5"
	30"	20.1	3"	1½"	3"* 5"
	36"	29.8	4"	1½"	4"* 6"
	42"	41.4	4"	2"	4"* 6"
	48"	54.1	6"	2"	6"* 8"
	54"	68.4	6"	2"	6"* 8"
	60"	85.0	6"	1½"	6"* 8"
1440	12¾	3.1	2"	¾"	2"* 4"
	16"	4.9	2"	¾"	2"* 4"
	18"	6.5	3"	1"	3"* 5"
	20"	8.3	3"	1"	3"* 5"
	24"	43.3	3"	1"	3"* 5"
	30"	22.3	3"	1½"	3"* 5"
	36"	32.8	4"	1½"	4"* 6"
	42"	44.3	4"	2"	4"* 6"
	48"	58.3	6"	2"	6"* 8"
	54"	74.0	6"	2"	6"* 8"
	60"	91.1	6"	2"	6"* 8"

· Olawoye, 1997
.. Gas capacity based on 100°F, 0.7sp gr and contactor working pressure.

Appendix 3

Tray Selection for Glycol-Gas Contractors



Appendix 4
Specifications for Glycol Reconcentrators

Reboller Capacity, Btu/hrs	Glycol Capacity, gph**	Reboller Size Dia . x Len
75,000	20	18" x 3", 6"
75,000	35	18" x 3"
125,000	40	18" x 5 "
125,000	70	18" x 5"
175,000	90	24" x 5"
175,000	100	24" x 5"
250,000	150	24" x 7"
350,000	210	24" x 10"
400,000	250	30" x 10"
500,000	315	36" x 10"
750,000	450	36" x 15"
850,000	450	42" x15"
1,000,000	450	48" x 16"

Appendix 5
Specifications for Standard High-Pressure Glycol Pumps*

Model Number	Circulation Rate-Gallons/Hours 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
1715P V	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	48.5	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						

* Olawole, 1997

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