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Improved Program for Natural Gas Dehydration with TEG

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ABSTRACT

Natural gas production at North Sea and deep offshore locations often calls for dehydration below the conventional 4-7 lb/MMSCF water content limit. Most existing triethylene glycol (TEG) design and rating programs use outdated data and are not well suited for the high dew point depression applications.

Recent advances in the water-TEG equilibrium and saturation water content data in the hydrate forming regions have been incorporated into a new PC based computer program. This paper discusses the improvements in the data base that are utilized in the new program, the program's features, and comparisons of the program's predictions against actual operating data.

INTRODUCTION

The TEG-water equilibrium data provided in the recently issued GPSA Engineering Data Book (10th Edition, 1987) are too optimistic, especially in the low dew point range. A TEG unit for a North Sea location designed with this data set, therefore, might not meet operational requirements. Recently, several authors[1,2] have published newer data and revised correlations, which make possible a TEG design program utilizing more accurate equilibrium data.

PROCESS CALCULATION BASIS

This work is based largely on recently published TEG-water equilibrium correlations of Parrish[1], et. al. As for the dew point calculation, Parrish's correlation as well as Bukacek's[3] tabulation of natural gas dew point versus water content was utilized together with the hydrate region data of Aogagi, et. al.[4] The dew point data were correlated by using the empirical correlations of the type used by Behr[5].

The often used Kremser-Brown method is utilized for the multistage contactor calculation. This method is rather accurate for TEG dehydration applications because absorption factors are essentially constant over the entire column. The gas phase molal flow rate is virtually constant and the changes in the liquid molal flow rate are compensated by similar changes in the K values. The Kremser-Brown equation given below illustrates this point.

$$\frac{Y_{n+1}-Y_1}{Y_{n+1}-Y_o} = \frac{A^{n+1}-A}{A^{n+1}-1}$$

where,

Yn_{+1} = Mol fraction H_2O in inlet gas

Y_1 = Mol fraction H_2O in outlet gas

Y_o = Mol fraction H_2O in equil. with incoming lean TEG

A = Absorption factor = L/VK

L = Liquid rate, mol/time

V = Gas rate mol/time

N = Number of theoretical stages in absorber

X = Mol fraction H_2O in TEG

K = Y_{H_2O}/X_{H_2O}

As an option, a tray by tray calculation method is also provided in the program. However, a PC equipped with a math coprocessor is suggested for reduced computation time when using this option.

PROGRAM FEATURES

The program has the following modules:

1. Process Conceptualization,
2. Contactor Design or Rating,
3. Design of Reconcentrator/Heat Exchangers and Equipment Recommendation,
4. Design of Condensate Separator/Pumps/Filters and Equipment Recommendation,
5. Data Files for Process Parameters and Default Input Values, and
6. Equipment Files Containing Recommended Manufacturer's Equipment Lists and Specifications.

Of the six modules, only the Process Conceptualization and the Reconcentrator/Heat Exchanger Sections will be shown in this paper.

A process engineer, given a TEG dehydration unit design task, typically starts his design activities by seeking an optimum combination of glycol circulation rate, lean glycol concentration, number of trays in the contactor, etc. In many cases, the optimum is the combination which allows lowest heat requirement. The Process Conceptualization Module has a useful built-in feature which allows the engineer to make a quick comparison of up to five design options for his application (e.g., North Sea) as shown in Figure 1.

Once the processing option is selected (e.g., Option Number 2 or 3 of Figure 1), the rest of the program can be called upon to generate performance and mechanical data for the entire unit. A portion of the calculation results of Module 3 is shown in Figure 2.

Figure 1 – Quick Comparison of Processing Options

SUMMARY OF FUEL USAGE/HEAT DUTIES

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***********CONSTANTS*************

Design Gas Flowrate - 100.0 MMSCFD	Reboiler Thermal Efficiency - 60%
Operating Pressure - 1000 PSIG	Operating Temperature - 100 DEG F
Inlet Water Content - 58.9 LBS/MMCF	Design Water Removal - 237 LBS/HR
Outlet Water Content - 2.00 LBS/MMCF	Outlet Dewpoint - 9.8 DEG F
Temp. to Glycol Pumps - 195 DEG F	Design Reflux Rate - 15%
Theo. Plates - Stripping Column - 2.0	Dewpoint Depression - 90.2 DEG F

RESULTS - KREMSER CALCULATIONS

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OPTION NUMBER	1	2	3	4	5
Reboiler Temperature (Deg F)	400	400	400	390	400
Lean Glycol Concentration (%)	99.40	99.40	99.50	99.50	99.70
Stripping Gas Req'rd (SCF/gal)	0.268	0.268	0.451	0.671	1.117
Number of Trays	8	9	8	8	6
Tray Efficiency (%)	30	30	30	30	30
Glycol Circ.Rate(Gal/Lb H2O Rem)	3.73	2.89	2.81	2.81	3.49
Lean Glycol Rate (Gal/Hr)	883	684	666	666	828
Reboiler Heat Duty (MBTU/Hr)	836	723	713	712	805
Fuel Gas (SCFH @ Thermal Above)	1394	1205	1188	1187	1342
Stripping Gas Rate (SCFH)	236	183	300	447	925
Total Fuel Required (SCFH)	1630	1388	1488	1634	2267
Glycol/Glycol Exch.Duty(MBTU/HR)	1111	860	837	792	1038
Glycol Temp. to Still (Deg F)	320	318	318	308	320

COMPARISON WITH ACTUAL DATA

The most complete operating unit data published to date are those by M. S. Worley of BS&B in 1967[6]. Other operating data obtained through personal communications with oil company personnel and with manufacturers of TEG dehydration equipment indicate that the BS&B data are quite accurate, particularly for TEG concentrations less than 99.9%.

The results of the program GLYCOL (in dotted lines) are compared to the BS&B data (in solid lines) in Figures 3 and 4. Here, the calculated values are based on the Kremser-Brown method with overall tray efficiency of 30%. The agreement is remarkably good. The discrepancy of up to 7 °F for the 99.9% - 8 tray case is an exception. Scarcity of operating data for such high dew point depression operations make confirmation of Worley's data for this case not possible at this time. Results of the tray by tray calculations (not shown here) are not substantially different from the Kremser-Brown calculations.

SUMMARY

A PC based TEG dehydration program that is based on recently published equilibrium data has been developed. The results of the program compare well with available data from operating units. This user-friendly program would be a useful tool to an engineer who wishes to design and optimize a TEG unit and who wishes to prepare performance and mechanical specifications for the unit.

REFERENCES

1. Parrish, W. R., Won, K. W., Baltatu, M. E., "Phase Behavior of the Water System for Extremely Low Dew Point Requirements", Proceedings of the Sixty-Fifth Annual Convention, Gas Processors Association, March 10-12, 1986.

2. Hubbard, R. A., "Method Advanced for Evaluating TEG Systems", Oil and Gas Journal, September 11, 1989.

Figure 2 – Reconcentrator and Heat Exch. Design Calculations

Type	Heat Duty (BTU/HR)*	Calculated Area (SQ FT)	Bundle Length	Suggested Sizes
Direct Fired	649001	86.5	----	----------------------

(25.96 Mscfd Fuel Gas @ 60% Thermal/1000 BTU/FT3)
Includes 20% excess heat duty

Column	Diameter Calculated	Diameter Selected	Packing Description Size	Packing Description Height	Packing Description Type
Still	12.9"	14.0"	2"	10'	PALL RINGS - metal
Sparge	9.5"	10.0"	.5"	6'	RASCHIG RINGS - ceramic

EXCHANGER CALCULATIONS

Exchanger	Heat Duty (BTU/HR)	Area (SQ.FT.) Calc.	Area (SQ.FT.) Selct.	No.	Type Exch.	Mfg.== Holland Suggested Model
Glycol/Glycol	891545	577.9	690.0	2	Mlt-tbe	8B55-15-00-SS-6A6
Alternate Choice	-----	577.9	734.0	2	Mlt-tbe	10B85-10-00-SS-6A6
Reflux Coils	34484	18.0	------	----		---------------------

TEMPERATURE PROFILES (DEG F)

Exchanger	Side	In	Intermediate	Out	Remarks
Reflux Coils - Steam	(Shell)	200	---	200	
- Glycol	(Tubes)	100	---	162	15% of rich flow
Glycol/Glycol- Lean	(Shell)	400	309	180	MTD - glycol/glycol
- Rich	(Tubes)	110	226	330	exchs == 70.1 DEG F

Design Reflux Rate - 15.0 %
Direct Fired Reboiler - Design Firetube Flux Rate - 7500 BTU/HR/SQ. FT.

Overall Heat Transfer Coefficients (BTU/HR/SQ FT/DEG F)

Glycol/Glycol (Bare) -	22.0
Glycol/Glycol (Finned) -	9.0
Reflux Coils	- 30.0

Figure 3 – Approximate Glycol Flow Rate 6 Actual Trays

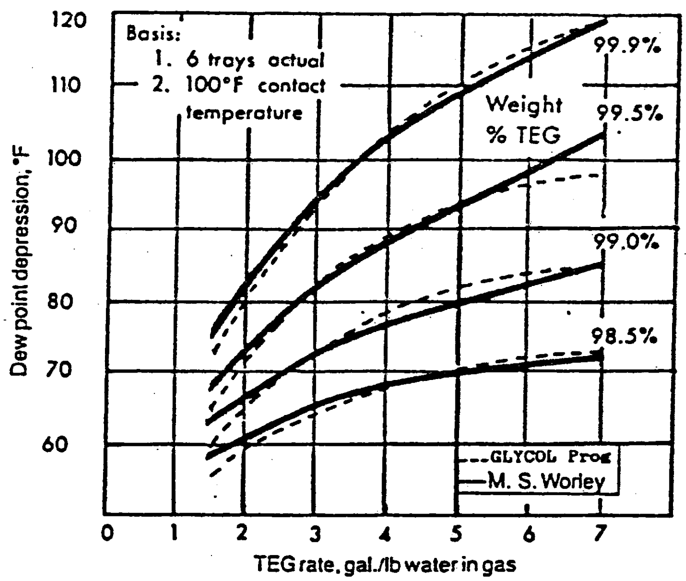
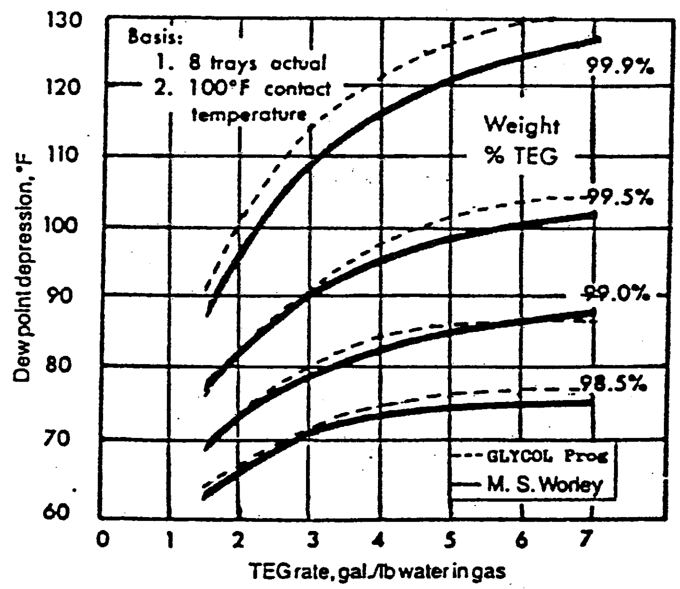


Figure 4 – Approximate Glycol Flow Rate 8 Actual Trays



3. Bukacek, R. F., "1982 Annual Book of ASTM Standards", Part 26, ASTM, Philadelphia, PA., p. 48.

4. Aogagi, K., Song, K. Y., Sloan, E. D., Dharmawardhana, P. B., Kobayashi, R., "Improved Measurement and Correlation of the Methane Gas in Equilibrium with Hydrate", Proceedings of the Fifty Eighth Annual Convention, Gas Processors Association, San Antonio, Texas, 1979.

5. Behr, W. R., "Correlation eases absorber-equilibrium-line calculations for TEG-natural gas dehydration", Oil & Gas Journal, p. 96, Nov. 7, 1983

6. Worley, M. S., "Super Dehydration with Glycol", Proceedings of the Gas Conditioning Conference, The University of Oklahoma, Norman, OK, 1967.