Reduce Emissions and Operating Costs with Appropriate Glycol Selection

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ABSTRACT

BTEX emissions from glycol dehydration units have become a major concern and some form of control is necessary in many cases. One method of reducing BTEX emissions that is often overlooked is in the selection of the proper dehydrating agent. BTEX compounds are less soluble in diethylene glycol (DEG) than triethylene glycol (TEG) and considerably less soluble in ethylene glycol (EG). If the use of DEG or EG achieves the required gas dew point in cases where BTEX emissions are a concern, a significant savings in both operating costs and the cost of treating still vent gases may be achieved. This paper compares plant operations using TEG, DEG, and EG from the viewpoint of BTEX emissions, circulation rates, utilities, and dehydration capabilities.

GLYCOL SELECTION CRITERIA

Glycol selection for natural gas dehydration applications may be based on a number of factors including dehydration capability, glycol losses in the contactor and regenerator, and absorption of volatile organic compounds (VOC's). The most commonly used glycol is triethylene glycol[1]. Diethylene glycol and ethylene glycol may also be used in dehydration applications; however, DEG and EG are often not considered due to dry gas water content requirements. TEG has a higher degradation temperature and can be regenerated to a higher lean concentration with no modifications to the standard regenerator reboiler. However, EG and DEG can meet water content specifications when used with enhanced regeneration systems. Enhanced regeneration is any system that improves glycol regeneration to achieve a "leaner" or more concentrated glycol solution. Enhanced regeneration could be the injection of stripping gas into the reboiler, azeotropic regeneration[2], or other proprietary processes.

Glycols absorb aromatic compounds such as benzene, toluene, ethylbenzene, and xylenes (BTEX) from natural gas. BTEX, along with other organic compounds considered to be pollutants, such as hexane, cyclopentane, heptane, cyclohexane, etc. are collectively known as volatile organic compounds. Regulatory agencies limit emissions from dehydration units to 10 tons/year of any one pollutant or 25 tons/year of total pollutants[3]. BTEX is generally of greatest concern since these compounds are often found in natural gas and are soluble in glycols. Use of EG or DEG reduces BTEX emissions since BTEX compounds are much less soluble in DEG and EG than in TEG. The following table displays the relative solubility of benzene and toluene in the three glycols.

Table 1. Solubility of Benzene and Toluene in Glycols[4].			
Compound	Solubility (weight % at 25° C)		
	In EG	In DEG	In TEG
Benzene	5.7	31.3	Completely Soluble
Toluene	2.9	17.2	24.8

Glycol losses must also be a consideration when selecting a glycol. Although BTEX compounds are less soluble in EG, the use of EG results in higher losses due to a higher volatility as compared with DEG or TEG. However, if a downstream hydrocarbon liquids recovery process also recovers EG from the process gas, losses can be reduced. Even if ethylene glycol is not recovered, the use of EG is cost effective if it allows sufficient savings elsewhere, such as in the cost of reducing dehydration unit emissions.

MINIMIZING VOC EMISSIONS

There are several strategies for reducing the amount of VOC emissions from the glycol still vent[1].

(1) Incinerating regenerator vent gases eliminates VOC emissions. Although effective, substantial cost may be associated with incinerator fuel consumption and capital cost.

(2) Condensing the regenerator vent stream to recover BTEX and VOC's decreases emissions. While not as costly as incineration, condensing and recovering BTEX and VOC's presents the problem of waste disposal of the water phase containing BTEX compounds.

(3) Maximizing the amount of vapor flashed upstream of the still by operating the flash at the lowest pressure and highest temperature possible also reduces VOC emissions. The flash gas must be incinerated or used as fuel since it contains significant VOC's.

(4) Removing the BTEX from the rich glycol in a BTEX stripping column utilizing stripping gas diminishes VOC emissions. A process recently developed by Latoka Engineering strips BTEX from the rich glycol using flash gas and additional sales gas if necessary. All stripping gas is used as reboiler fuel.

(5) Decreasing the glycol circulation rate also minimizes BTEX emissions since the lower circulation rate means less total BTEX is absorbed.

(6) Selecting a glycol that absorbs the least amount of BTEX also plays a major role in emission reduction.

(7) Decreasing absorber pressure and increasing absorber temperature tends to decrease VOC emissions. Although helpful in reducing emissions, reducing absorber pressure may not be feasible due to the cost of sales gas recompression.

All of these methods reduce VOC emissions. The most cost-effective method of VOC emission reduction is to reduce the amount of BTEX and VOC's absorbed initially since no additional equipment is required and no increase in energy consumption is necessary. This may be accomplished by using the lowest glycol circulation rate possible or by using the glycol in which BTEX compounds are least soluble. Thus DEG and especially EG can allow savings in the cost of treating still vent gases to meet emission requirements. DEG and EG have the added benefit of being less costly than TEG[5] and also require less energy for regeneration. Additional equipment for enhanced regeneration, if necessary, is minimal.

When emissions are a concern, the primary focus should be placed on meeting emissions requirements. The system must, of course, meet water dew point requirements as well. Finding the optimum system that minimizes capital and operating costs is the primary goal in designing a dehydration unit. A process simulator may be used as a tool for determining the optimum design. Concerns such as sales gas water content, VOC emissions, glycol

losses, and reboiler duties may be tabulated for a number of operating conditions.

Two case studies are presented in this paper. In the first case, the BTEX content in the incoming gas is relatively low when compared with the second case. In each case, the performance data, including BTEX emissions, were collected from an operating unit that was designed and constructed with a special BTEX stripper. The following comparisons and analyses were then performed.

1. The performance data from the operating unit were compared with results from the process simulation package, PROSIM® [6] for the particular glycol used in the unit.
2. PROSIM results were then used to compare the performance of the unit for alternative glycols including EG, DEG, and TEG.
3. Using PROSIM results, the performance and emissions of the glycol unit with the special BTEX stripper were compared to a standard glycol unit with no special BTEX facilities.

In each of the cases, stripping gas was used in the reboiler as needed to meet a water specification of 7 lb water/MMSCF in the dry gas.

CASE STUDY 1

This dehydration unit is located on a natural gas pipeline near Bloomfield, New Mexico. TEG is used for dehydration and the unit is capable of processing 50 MMSCFD. Table 2 lists the inlet gas BTEX composition.

Table 2. BTEX Composition of the Inlet Gas for Case 1.	
Compound	Mole %
Benzene	0.0005
Toluene	0.0007
Ethylbenzene	< 0.0001*
Xylenes	< 0.0001*
*0.0001 was used as the inlet composition in the PROSIM simulations.	

The operating conditions for Case 1 are given in Table 3, and the process flow diagram including the BTEX stripper is shown in Figure 1.

| Table 3. Operating Conditions for Case 1	
Wet Gas Flow Rate	29.2 MMSCFD
Wet Gas Temperature	69° F
Contactor Pressure	305 psia
Separator Pressure	47 psia
Stripper Temperature	166° F
Stripper Pressure	31 psia
Reboiler Temperature	355° F
Glycol Circulation Rate	2.34 gpm
Lean Glycol Temperature	133° F
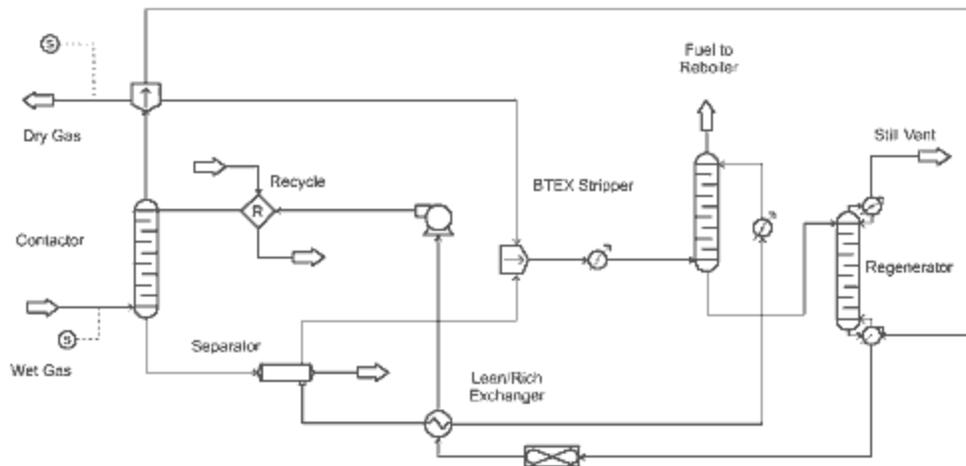
Figure 1. TEG Dehydration Unit (PROSIM flowsheet for Case 1a).

As illustrated in Figure 1, the wet gas enters the bottom of the contactor column where it is contacted by lean glycol entering the top of the column. The dry sales gas exits the top of the contactor with a water content of 3 lb/MMSCF and is sent to a pipeline. The rich glycol exits the bottom of the contactor and enters a three phase separator. The flash gas from the separator is combined with a portion of the dry sales gas for use as stripping gas in the BTEX stripper. The rich glycol is heated to 165° F before being fed to the top of the BTEX stripper. The plant uses the patented Latoka Engineering BTEX stripper system[7]. The rich glycol containing BTEX is heated and stripped in a column using flash gas and additional gas as necessary. The stripping gas containing VOC compounds is used as fuel in the reboiler fire box, eliminating the BTEX emission problem while saving reboiler fuel costs. Enough fuel gas is added to the reboiler fire box to satisfy the duty requirement. After exiting the bottom of the BTEX stripper, the rich glycol is fed to the regenerator. Lean glycol is then recycled to the absorber.

The still vent gas contains only 2.46 tons/year of total BTEX emissions as determined by analysis of the lean and rich glycol solutions. Table 4 shows a comparison of the TEG plant data with PROSIM predictions for dry gas water content and BTEX emissions.

| Table 4. Comparison of PROSIM Predictions to TEG Plant Data for Case 1.		
	Data	**PROSIM**
Water Content of Dry Gas (lb/MMSCF)	3	6
Benzene Emissions (tons/year)	0.47	0.47
Toluene Emissions (tons/year)	1.17	1.41
Ethylbenzene Emissions (tons/year)	0.06	0.41
Total Xylene Emissions (tons/year)	0.76	0.57
Total BTEX Emissions (tons/year)	2.46	2.86
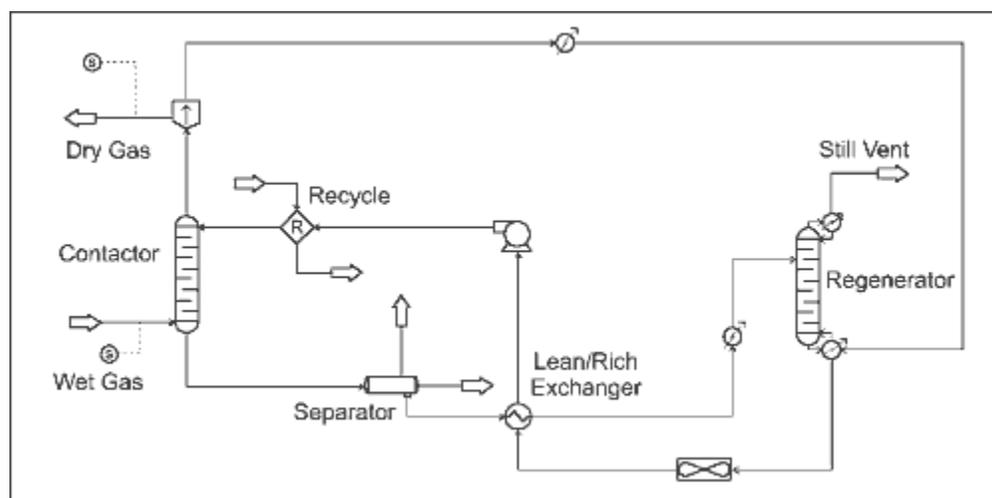
Figure 2. Standard TEG Dehydration Unit (PROSIM flowsheet for Case 1b).

After verifying PROSIM results, the simulation model was used to investigate and compare the effect of glycol selection and circulation rate on dehydration, BTEX and VOC emissions, and reboiler duty for the following cases.

- **Case 1a** – Glycol unit with special BTEX stripper as shown in Figure 1
- **Case 1b** – Standard glycol unit as shown in Figure 2

Simulations were performed using EG, DEG, and TEG for glycol circulation rates of 2 to 4 gal/lb water removed at an inlet gas rate of 50 MMSCFD (plant capacity) and a pressure of 300 psia. If needed to meet the water specification, stripping gas was used in the simulation.

As shown in Tables 5a and 5b, and in Figures 3 and 4, BTEX and VOC emissions are greatly affected by glycol selection. Compared to TEG, DEG shows a 26% decrease in BTEX emissions and a 44% decrease in total VOC emissions with the BTEX stripper. Without the BTEX stripper, DEG results in a 22% decrease in BTEX and 42% decrease in VOC's.

Compared to TEG, EG shows an 84% decrease in BTEX emissions and a 71% decrease in total VOC emissions with the BTEX stripper. Without the BTEX stripper, EG results in an 82% decrease in BTEX and 70% decrease in total VOC's.

Table 5a. Effect of Glycol Selection and Circulation Rate for Case 1a.									
Dehydration Unit with BTEX Stripper									
Glycol:	EG			DEG			TEG		
Circulation Rate (gal/lb)	2	3	4	2	3	4	2	3	4
Water Content of Dry Gas (lb/MMSCF)	7	7	7	7	7	7	7	6.2	5.8
Reboiler Stripping Gas Rate (SCF/gal)	9	6	5	6.1	3.6	2.8	0.7	0	0
Total BTEX Emissions (tons/yr)	0.2	0.5	0.7	1.7	2.9	4.0	2.3	3.9	5.28
Total VOC Emissions, Including BTEX Emissions (tons/yr)	4.8	7.1	8.7	8.3	14.1	19.5	14.2	25.2	35
Glycol Losses from Absorber (lb/hr)	1.49	1.54	1.59	0.18	0.19	0.2	0.064	0.068	0.071
Glycol Losses from BTEX Stripper (lb/hr)	1.15	1.25	1.34	0.32	0.36	0.4	0.096	0.11	0.12
Glycol Losses from Regenerator (lb/hr)	0.92	1.26	1.41	0.03	0.042	0.046	0.003	0.004	0.005
Total Glycol Losses (lb/hr)	3.6	4	4.4	0.55	0.63	0.6	0.16	0.18	0.2
Reboiler Temperature (° F)	285	285	285	290	290	290	355	355	355
Reboiler Duty (MBtu/hr)	128	148	167	107	127	146	160	211	258
Reflux Ratio	0.25	0.25	0.25	0.1	0.1	0.1	0.1	0.1	0.1

Table 5b. Effect of Glycol Selection and Circulation Rate for Case 1b.

Standard Dehydration Unit with no BTEX Stripper									
Glycol:	EG			DEG			TEG		
Circulation Rate (gal/lb)	2	3	4	2	3	4	2	3	4
Water Content of Dry Gas (lb/MMSCF)	7	7	7	7	7	7	7	6.2	5.8
Reboiler Stripping Gas Rate (SCF/gal)	9.1	6.1	5	6.1	3.6	2.9	0.7	0	0
Total BTEX Emissions (tons/yr)	0.57	0.87	1.4	2.6	3.9	5.0	3.3	5.0	6.4
Total VOC Emissions, Including BTEX Emissions (tons/yr)	6.6	9.3	11.5	12.0	18.7	24.8	20.2	32.3	42.5
Glycol Losses from Absorber (lb/hr)	1.5	1.54	1.6	0.18	0.19	0.2	0.064	0.068	0.071
Glycol Losses from Regenerator (lb/hr)	1.0	1.3	1.5	0.03	0.045	0.049	0.003	0.004	0.005
Total Glycol Losses (lb/hr)	2.5	2.9	3.1	0.19	0.24	0.26	0.067	0.072	0.076
Reboiler Temperature (° F)	285	285	285	290	290	290	355	355	355
Reboiler Duty (MBtu/hr)	128	149	168	108	128	147	161	212	259
Reflux Ratio	0.25	0.25	0.25	0.1	0.1	0.1	0.1	0.1	0.1

The results also indicate that the BTEX stripper system significantly reduces emissions. As illustrated in Tables 5a and 5b as well as Figures 3 and 4, the BTEX stripper reduced total BTEX emissions by 18-30% for TEG, 20-35% for DEG and 42-65% for EG in this case. The highest reductions are a result of the BTEX stripping gas rate being held constant for all the runs, regardless of the circulation rate.
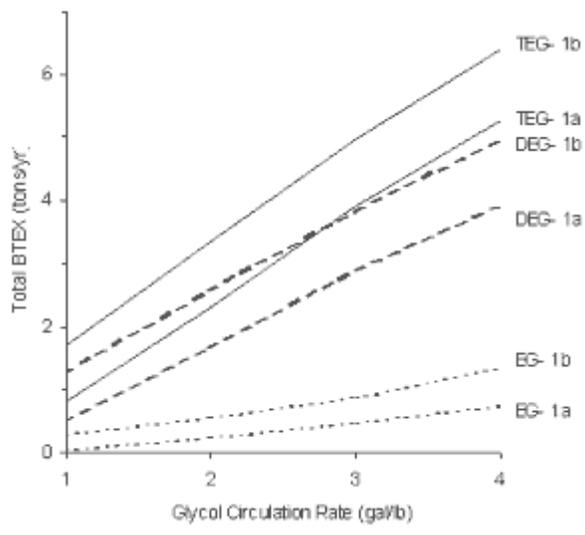

Figure 3. Comparison of BTEX Emissions for Cases 1a and 1b.
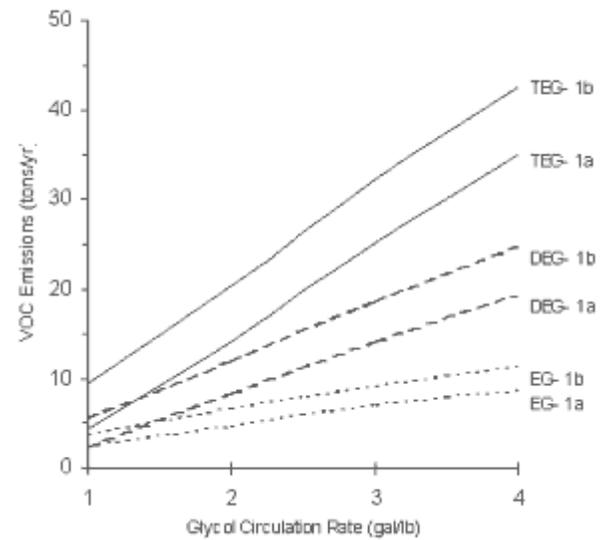
Figure 4. Comparison of Total VOC Emissions (Including BTEX) for Cases 1a and 1b.

As previously stated, total VOC emissions must not exceed 25 tons/year. Figure 4 shows that for Case 1, EG meets the specification with or without the BTEX stripper. All of the DEG scenarios meet the specification with or without the BTEX stripper; however, the emissions are approaching the 25 tons/yr limit at a circulation rate of 4 gal/lb. For TEG circulation rates below 3 gal/lb, the specification is achieved only when the BTEX stripper is in use. For TEG circulation rates above 3 gal/lb, the stripping gas rate in the BTEX stripper would have to be increased to reduce emissions in the regenerator to an acceptable level. As expected, doubling the glycol circulation rate doubles the emissions.

Figure 5 is a comparison of the glycol losses. As expected, the losses are considerably higher for EG due to a lower boiling point. Since most of the losses occur in the absorber (see Tables 5a and 5b), EG could possibly be recovered. The BTEX stripper also contributes to EG losses.
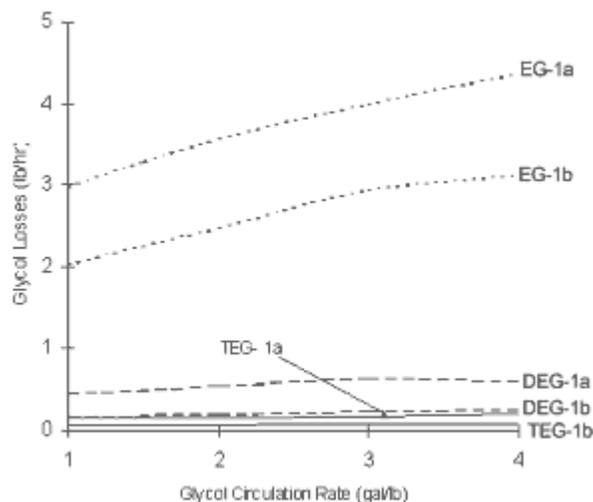
Figure 5. Comparison of Glycol Losses for Cases 1a and 1b.
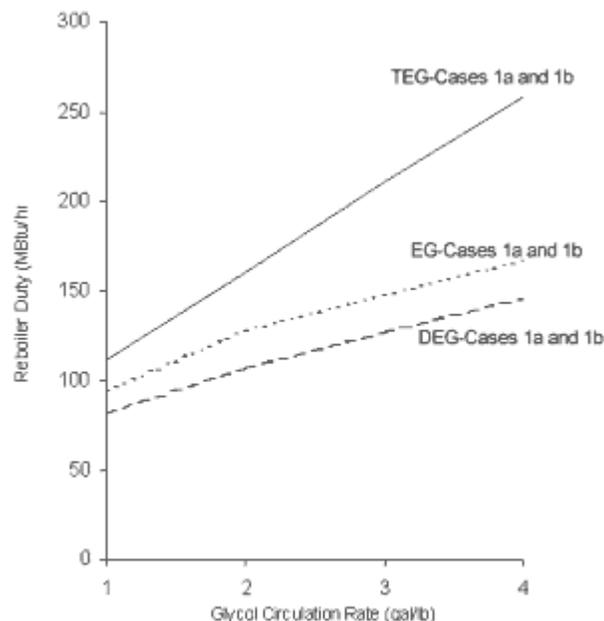
Figure 6. Comparison of Reboiler Duty for Various Glycols in Cases 1a and 1b.

Figure 6 compares reboiler duties for the three glycols. EG duties are higher than those for DEG due to a higher reflux ratio (0.25 vs. 0.1) in addition to higher stripping gas rates. A higher reflux ratio for EG helps to reduce losses in the regenerator. Overall, TEG has the highest reboiler duties (over 50% higher than EG at a circulation rate of 4 gal/lb).

CASE STUDY 2

The second dehydration unit is an installation located in south central New Mexico that uses DEG for dehydration. Although VOC's other than BTEX are present in the regenerator still vent gas, only BTEX emissions are presented for this case. The unit processes 20 MMSCFD. Table 6 displays a representative inlet gas BTEX composition.

Table 6. BTEX Composition of the Inlet Gas for Case 2.	
Compound	Mole %
Benzene	0.008
Toluene	0.016
Ethylbenzene	0.002
Xylenes	0.002

This plant also uses the BTEX stripper system patented by Latoka Engineering. The process flow diagram is shown in Figure 7 and is very similar to the process described in Case 1a. The operating conditions are shown in Table 7.

Table 7. Operating Conditions for Case 2.	
Wet Gas Flow Rate	22 MMSCFD
Wet Gas Temperature	120° F
Contactor Pressure	850 psia

|	
Separator Pressure	50 psia
Stripper Temperature	275° F
Stripper Pressure	31 psia
Reboiler Temperature	285° F
Glycol Circulation Rate	4.22 gpm
Lean Glycol Temperature	130° F
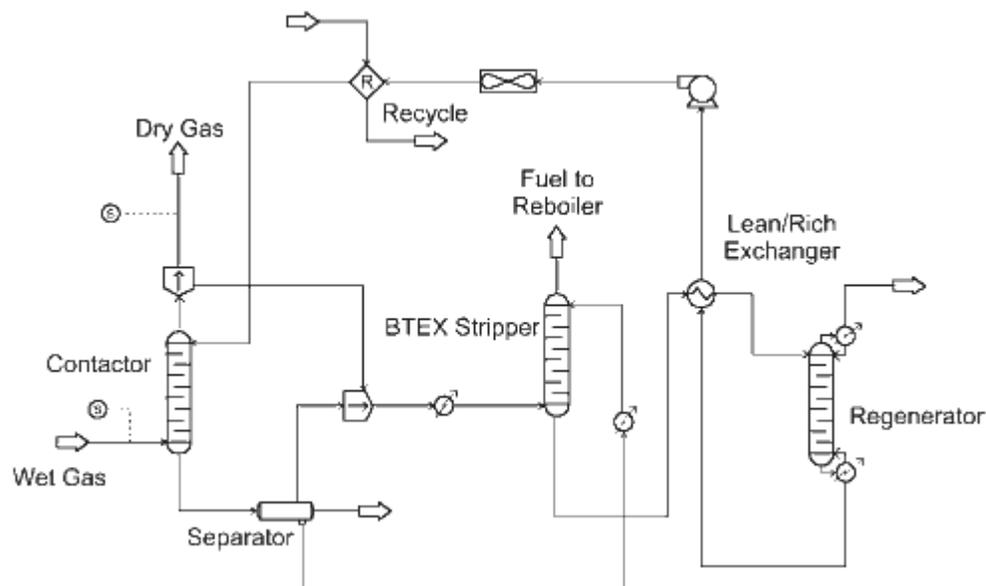
Figure 7. DEG Dehydration Unit (PROSIM flowsheet for Case 2a).

The regenerator still vent gas contains 14.96 tons/year total BTEX as determined by an analysis of the rich and lean glycol. Table 8 shows a comparison of the measured BTEX emissions with PROSIM predictions. Differences in individual emissions were most likely due to the inlet composition sample being taken in January 1996 while the lean/rich analyses were performed in July 1996. The overall BTEX emissions are suitable to provide a basis for comparison.

| Table 8. Comparison of PROSIM Predictions to Plant Data for Case 2.		
	Data	**PROSIM**
Benzene Emissions (tons/year)	2.83	0.97
Toluene Emissions (tons/year)	6.72	6.03
Ethylbenzene Emissions (tons/year)	0.54	6.39
Total Xylene Emissions (tons/year)	4.87	3.20
Total BTEX Emissions (tons/year)	14.96	16.59
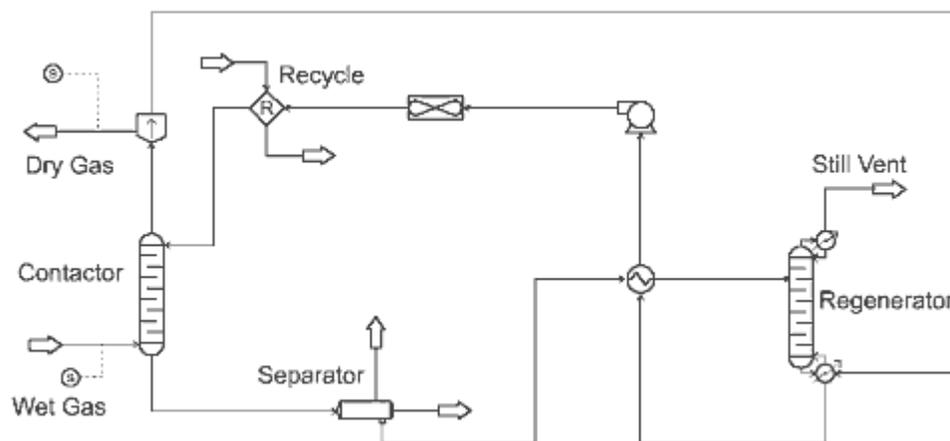
Figure 8. DEG Dehydration Unit (PROSIM flowsheet for Case 2b).

Simulations were performed with EG, DEG and TEG for glycol circulation rates of 2-4 gal/lb water removed to examine the effect of glycol selection on dehydration, BTEX emissions, and reboiler duty for the following cases.

- **Case 2a** – Glycol unit with special BTEX stripper as shown in Figure 7
- **Case 2b** – Standard glycol unit as shown in Figure 8

Each of the three glycols meet the water content specification if stripping gas or another type of regeneration enhancement is used for EG and DEG. (Stripping gas was used in these simulations.)

For the case reported in Table 9a, the constant parameters include a regenerator condenser duty of −18,000 Btu/hr and a 10° F approach temperature in the lean/rich exchanger. Also, the glycol and gas are both preheated to 275° F before entering the BTEX stripper. For the case reported in Table 9b, a constant regenerator reflux ratio of 0.1 was specified along with a 10° F approach temperature in the lean/rich exchanger.

Tables 9a and 9b, along with Figures 9 and 10, show that using EG or DEG instead of TEG reduces BTEX emissions. Compared to TEG, DEG decreases BTEX emissions by 45% when the BTEX stripper is employed. Without the BTEX stripper, DEG results in a 38% decrease in emissions.

Table 9a. Effect of Glycol Selection and Circulation Rate for Case 2a.									
Dehydration Unit with BTEX Stripper									
Glycol:	EG			DEG			TEG		
Circulation Rate (gal/lb)	2	3	4	2	3	4	2	3	4
BTEX Stripping Gas Rate (SCF/gal)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Water Content of Dry Gas (lb/MMSCF)	7	7	7	7	7	7	6.1	5.2	4.8
Reboiler Stripping Gas Rate (SCF/gal)	6.9	4.5	3.4	5.7	3.2	2.2	0	0	0
Total BTEX Emissions (tons/yr)	1.4	2.3	3.1	14.5	22.8	30.4	26.7	42.1	54.9
Total Glycol Losses (lb/hr)	4.7	6.2	7.4	1.1	1.5	1.7	0.3	0.4	0.5
Reboiler Temperature (° F)	290	290	290	295	295	295	375	375	375
Reboiler Duty (MBtu/hr)	58.7	61.0	63.3	56.1	57.8	59.7	56.0	59.8	63.6

Table 9b. Effect of Glycol Selection and Circulation Rate for Case 2b.									
Standard Dehydration Unit with no BTEX Stripper									
Glycol:	EG			DEG			TEG		
Circulation Rate (gal/lb)	2	3	4	2	3	4	2	3	4
Water Content of Dry Gas (lb/MMSCF)	7	7	7	7	7	7	6.1	5.2	4.7
Reboiler Stripping Gas Rate (SCF/gal)	9.3	6.2	4.7	6.9	4	2.8	0	0	0
Total BTEX Emissions (tons/yr)	7.0	10.5	14.1	32.2	48.4	63.2	56.6	76.5	97.5

| Total Glycol Losses (lb/hr)	4.1	5.2	6.1	0.5	0.5	0.6	0.1	0.1	0.2
Reboiler Temperature (° F)	290	290	290	295	295	295	375	375	375
Reboiler Duty (MBtu/hr)	66.5	71.2	75.9	68	74	79.6	66	76.9	86.7
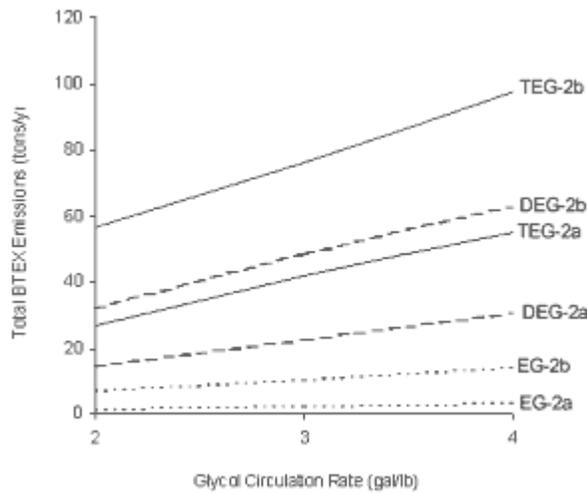
Figure 9. Comparison of BTEX Emissions for Cases 2a and 2b.   Figure 10. Comparison of Glycol Losses for Cases 2a and 2b.
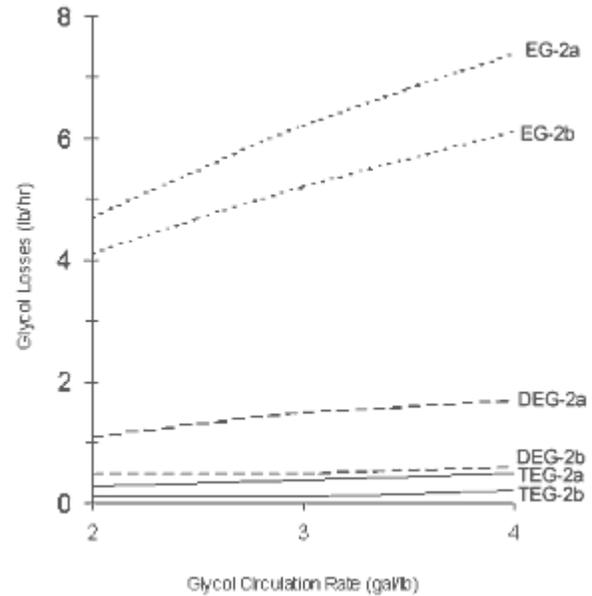
In Case 2a, a 94% decrease in BTEX emissions is observed when EG is used in place of TEG. In Case 2b, EG results in an 86% decrease in BTEX.

Similar to Case 1, use of the BTEX stripper system once again reduces emissions as shown in Tables 9a and 9b and in Figure 9. In Case 2a, the BTEX stripper reduces emissions by 44-53% for TEG, 52-55% for DEG and up to 80% for EG.

The inlet gas in this case contains considerably more BTEX than the inlet gas in Case 1. Figure 9 illustrates that emissions specifications should not be exceeded when EG is used. However, when DEG and TEG are in circulation, the specification will likely be exceeded unless the lowest possible circulation rate is used in conjunction with the BTEX stripper.

OPERATING COSTS

The previous case studies indicate that EG is the best choice for minimizing BTEX emissions; however, glycol losses are significantly higher. Since most of the glycol losses occur in the absorber, a downstream liquids recovery process that retrieves an aqueous phase containing the EG could reduce losses. If EG is used, it must be determined if the cost of glycol replacement is less than the cost of treating the regenerator vent gases. If enhanced regeneration is necessary, that expense should also be considered. As illustrated in Figures 6 and 11, reboiler duties for EG and DEG are generally lower when compared with TEG, resulting in lower utility cost.
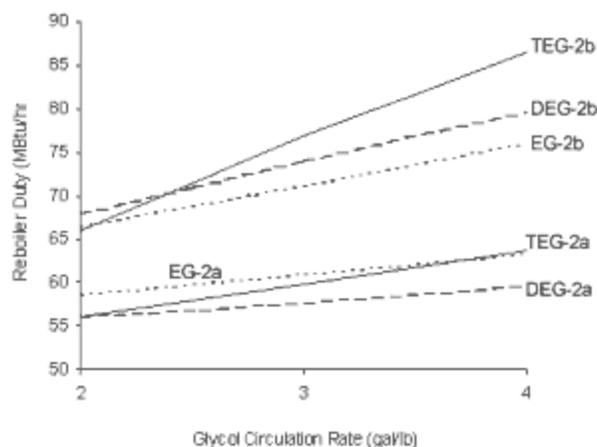
Figure 11. Comparison of Reboiler Duty for Various Glycols in Cases 2a and 2b.

In Figure 11, TEG duties are lowest at lower circulation rates because no stripping gas is required in the reboiler to meet dry gas water content specifications. The Latoka glycol stripper system uses the stripping gas as reboiler fuel, further reducing utility costs.

SUMMARY

Selection of the appropriate glycol for dehydration unit applications must be based on dehydrating capabilities, glycol losses, and VOC emissions. Using DEG and especially EG instead of TEG when BTEX is a concern can greatly reduce BTEX emissions, and thus costs of reducing emissions from the glycol still vent. The system must be optimized to be the most cost effective. The use of a process simulator can simplify the glycol selection process. Based on the results in this study, using a glycol that absorbs less VOC's requires no additional equipment and can actually reduce operating costs in many cases. The costs associated with the use of EG or DEG would be increased glycol makeup and some form of enhanced regeneration to obtain a more concentrated glycol to achieve the dry gas water content, if necessary. A number of dehydration units using DEG and EG are operating successfully in Louisiana, New Mexico, Texas, Colorado, and Oklahoma.

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