United States Environmental Protection Agency
Air and Radiation (6202J)
EPA
October 2001

LESSONS LEARNED

FROM NATURAL GAS STAR PARTNERS

NaturalGas EPA POLLUTION PREVENTER

DESICANT DEHYDRATORS

Executive Summary

There are approximately *150,000* wells producing *90,000 Tcf* of high pressure natural gas in the United States emitting an estimated *90 Tcf* of methane from glycol dehydrators to the atmosphere. Producers, traditionally use Triethylene glycol (TEG) dehydrators to remove water from saturated gas. Glycol dehydrators vent and bleed methane, VOCs, and HAPs to the atmosphere from the reboiler/regenerator and pneumatic devices, and also require fuel gas to heat the glycol on the reboiler/regenerator and/or the gas if the temperature of the gas is too low for the glycol to absorb. This process wastes gas, costs money, and contributes to local air quality problems. Natural Gas STAR Partners have found that replacing these glycol dehydrators with desiccant dehydrators considerably reduces methane, VOC and HAP emissions and operating and maintenance costs.

Economics analyses demonstrate that replacing a glycol dehydrator with desiccant dehydrator can save up to $4,163/yr in gas and O&M cost and 617 Mcf/yr in methane savings for a gas that is processing 1 MMcfd. This Lessons Learned study describes how Partners can identify when and where desiccant dehydrators should be implemented to realize these economic and environmental benefits.

Method for Reducing Gas Loss[1]	Annual Methane Savings (Mcf)[2]	Annual volume of Gas Lost and Used (Mcf)[3]	Value of Gas Saved ($)	Capital and Installation Cost ($)[4]	O&M Cost ($)[5]	Payback (Years)
Replacing A Glycol Dehydrators with two Desiccant Dehydrators	617	1,146	3,438	20,750	725	5

[1] All the values for the gas are based on $3/Mcf and for a 1 MMcfd gas operating at 600 psig and 54 F.
[2] Based on the difference between the methane vented or lost from the glycol and desiccant dehydrators.
[3] Based on the difference between the gas lost and used from using glycol dehydrator and the gas vented using desiccant dehydrator.
[4] Installation cost is based on 75% of the capital cost and also 10% of salvage value is included in the value.
[5] Based on the difference between glycol and desiccant dehydrators operation and maintenance costs.

This is one of a series of Lessons Learned Summaries developed by the EPA in cooperation with the natural gas industry on superior applications of Natural Gas STAR Program Best Management Practices (BMPs) and Partner Reported Opportunities (PROs). This Lessons Learned Summary focuses on reducing methane emissions from using desiccant dehydrators for gas dehydration and is written for Production Partners.

LESSONS LEARNED

FROM NATURAL GAS STAR PARTNERS

DESICANT DEHYDRATORS

Technology Background

Produced natural gas normally is saturated with water that can condense and/or freeze in gathering, transmission and distribution piping causing pressure surges and corrosion. To avoid this problem, the gas is dehydrated before entering the pipeline or processing equipment. Triethylene glycol (TEG), less commonly diethylene glycol (DEG) and propylene carbonate have been used the most common dehydrating agents. Recently, deliquescing salt desiccants are being used in dehydrators by the oil and gas production sector.

Triethylene glycol (TEG) Dehydrator

In the TEG dehydrator process, or less common diethylene glycol (DEG), the TEG not only absorbs water, but also methane and other volatile organic compounds (VOCs), such as ethane through pentanes, and hazardous air pollutants (HAPs), such as benzene, toluene, ethylbenzene and xlyene, or BTEX. When this rich glycol goes through a reboiler/regenerator, methane, VOCs and HAPs are boiled out of solution in the water and vented to the atmosphere. (See the EPA Lesson Learned studies: *Installation of Flash Tank Separators, Reducing the Glycol Circulation Rates in Dehydrators*, and *Replacing Gas Assisted Pumps with Electric Pumps*).

Desiccant Dehydrator

"Natural Gas STAR Partners have reported success using an alternative method: desiccant dehydrator".

Desiccant

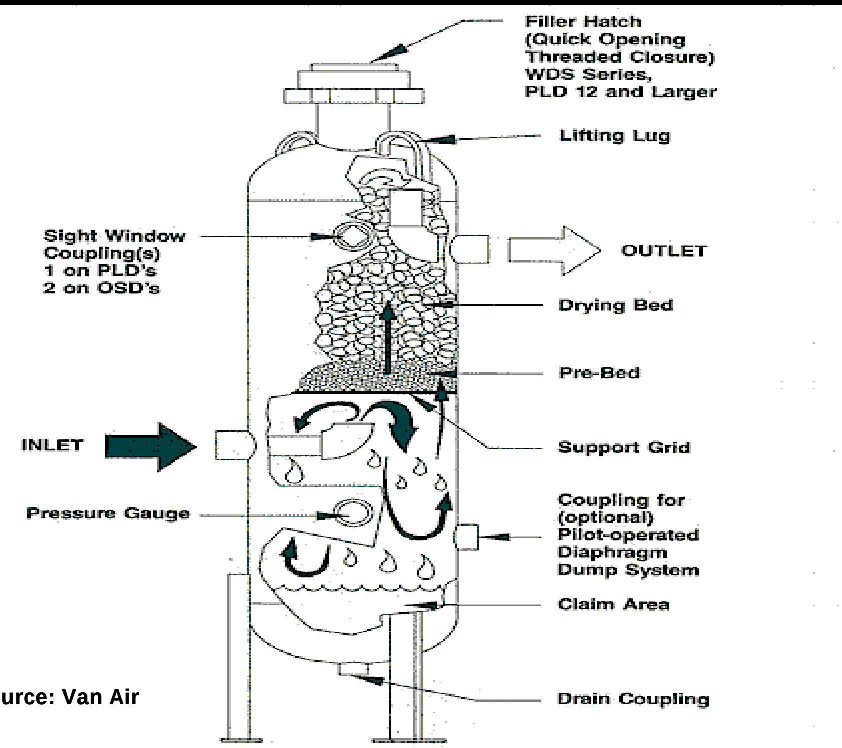
Desiccants have been used to dehydrate natural gas by the oil and gas industries for over 70 years. Desiccants are made up of hygroscopic salts, such as calcium chloride, lithium chloride and potassium chloride. Desiccants attract and adsorb moisture, which gradually dissolves the desiccants into brine. This process is called 'deliquescing'. The amount of moisture removed from the gas depends on the type of desiccant. Calcium chloride, the most common and least expensive desiccant, removes approximately 67% of moisture in natural gas. Lithium chloride, which is more expensive desiccant than calcium chloride, removes approximately 87% of moisture in natural gas. Desiccants are usually packed in dehydrator vessels in the form of tablets or pellets. The tablets are package in 25-50lb bags.

Process Description

The desiccant dehydrator is a very simple process; it has no moving parts and needs no external power so that it can be used in offshore or remote sites.

As shown in Exhibit 1, wet natural gas enters the dehydrator vessel below the desiccant support grid. The support grid prevents the desiccant tablets from dropping into the claim area (brine sump). *Some vendors install a mist eliminator below the support grid so that the brine does not dissolve the packed desiccant tablets.* The wet gas flows upward through the support plate and pre–bed (which is usually 5-10mm activated alumina and gives additional support to the support plate) in the drying bed, where it interacts with the desiccant tablets. The moisture from the gas is adsorbed by the tablets and accumulates on the surface of the tablets.

Exhibit 1: Schematic of Single Vessel Desiccant Dehydrator



Source: Van Air

Gradually the moisture dissolves the desiccants into brine droplets, which trickle down into the claim area that is connected to a brine storage tank. When the desiccants reach equilibrium or the maximum amount of moisture they can adsorb, the 'dry' gas exits on the top of the vessel to the main gas line.

Operating Requirements

The amount of water removed by the desiccant tablets depends on the quality of the desiccant and the temperature and the pressure of the inlet gas. High temperature inlet gas will have high moisture content for the desiccants to remove to the desired moisture content. According to a vendor, the inlet temperature of the gas must be between 35F and 100F to utilize the desiccant dehydrator. If the inlet temperature of the gas is too high, the desiccants form hydrates in the solution that cause caking and drain problems. If the inlet temperature of the gas is too high or too low, the gas has to be cooled or heated before entering the dehydrator. Since saturated gas holds more water at low temperatures, high pressure gas result more moisture removal by the desiccant (the inlet gas pressure can be as high as 1400 psig). Desiccant tablets work best for a natural gas processing at high pressure and low temperature. (Appendix 1-Table1 provides the outlet water content in the gas at given temperatures and pressures for two types of desiccants). A single commercial dehydrator vessel (Exhibit 1) can dehydrate gas from 0.095 to 5.346 MMcfd between 35 –100 F and 100-1400 psig. The dimensions of the single vessels range from 10-3/4"outside diameter (OD) X 73-7/8" over all height of the vessel (HV) to 37-3/4"OD X 85-1/2"HV. These vessels can hold 48-583 lb of calcium chloride and 57-583 lb for lithium chloride desiccants.

Refilling Desiccants and Draining Brine

As the desiccant tablets adsorb moisture from the gas, the level of the desiccant tablets in the drying bed slowly decrease to the minimum desiccant tablet level. This level indicates the minimum level at which the desiccant tablets can dehydrate the gas to its desire outlet moisture content. Some manufacturers place a sight window on the vessel (see Exhibit 1), to show the operator the minimum desiccant level. When the desiccant level is below the sight window (at the minimum desiccant level), the operator needs to depressurize the vessel; manually open the filler hatch and refill the desiccants up to the maximum level. To depressurize the vessel, the inlet and the outlet valves must be closed and the drain valve has to be open to flash the gas left in the vessel. The brine in the claim area has to be drained when the brine reaches a certain level to prevent from flooding. Automatic or manually operated drain valves drain the brine to the brine storage tank. When the drain valve is operated manually, a liquid level indicator is necessary in order for the operator to know when it is time to drain the brine. The desiccant dehydrators can be designed (e.g. by using larger size or multiple dehydrators) for the operator not to refill the desiccant and drain the brine frequently.

Economic and Environmental Benefits

Using desiccant dehydrators as alternatives to glycol dehydrators can yield significant economic and environmental benefits, including:

- **Reduced capital cost** - The capital costs of desiccant dehydrators are low compared to the capital costs of TEG dehydrators. Unlike TEG dehydrators, desiccant dehydrators do not use pumps, contactors, and fired reboiler/regenerator. The only capital cost is for the vessel.
- **Reduced operation and maintenance cost** – Since most of the well heads and processing units are located in remote areas, it is important for the dehydrator units to be reliable and continuously accessible and with minimum oversight from operation and mainte-

nance personnel. Desiccant dehydrator operation and maintenance costs are favorable compare to glycol dehydrators. The primary operating and maintenance costs are for desiccants and labor for refilling the dehydrator. Maintenance costs are labor for draining and disposing the brine. If the drain valve is automatic, no labor is needed to drain the valve, maintenance cost for services the equipment must be considered

θ **Methane or high hydrocarbons are not emitted**– The desiccant tablets only adsorb water, therefore, methane and other hydrocarbons will not be vented to the atmosphere as with glycol dehydrators.

Decision Process

Operators can access the economics of replacing an existing glycol dehydrator with a desiccant using the these five steps.

Five Steps for Implementing A Desiccant Dehydrator
1. Identify possible locations for desiccant dehydrator; 2. Estimate the capital costs; 3. Estimate the operating costs; 4. Estimate savings; 5. Conduct economic analysis.

Step 1: **Identify possible locations for desiccant dehydrator.**

Desiccant dehydrators are an economic choice for natural gas dehydration under certain production condition. Desiccant dehydrators are installed where gas drying is needed such as prior to the gas entering transmission pipelines or processing plants. The wellhead gas temperature and pressure play a major role in determining the appropriate gas drying system. Glycol dehydrators work best for higher temperature gas. If the temperature of the gas is too low for the TEG to remove the moisture, operators have to heat the gas prior entering the dehydrator. Heating the gas requires more product burned as fuel. An alternative method is to install a desiccant dehydrator, which works best at higher pressure and low temperature. In addition, since most desiccant dehydrators are commonly manufactured for a maximum pressure of 500 psig and expanding the gas down to this pressure from a higher wellhead pressure will auto refrigerate the gas below wellhead temperature. Exhibit 2 shows the operating conditions of the gas to use either a desiccant or a glycol dehydrator.

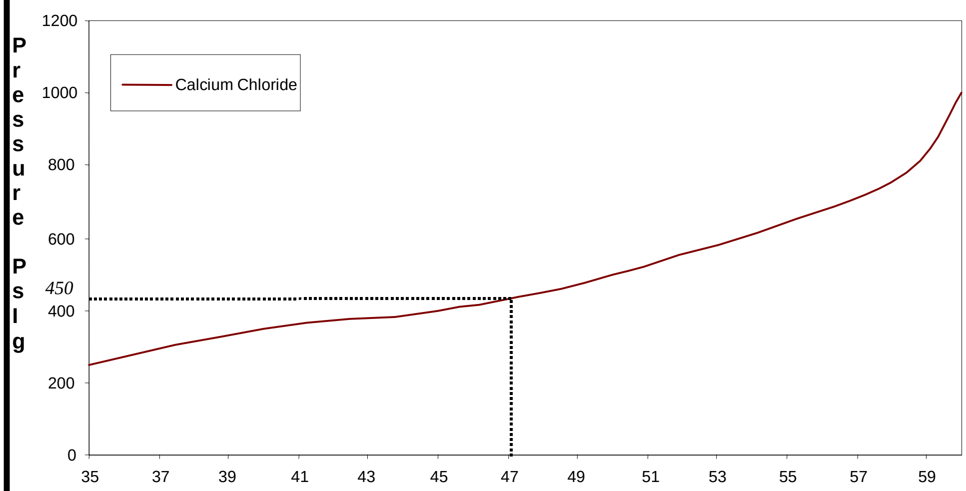
Exhibit 2. Optimum Operating Conditions for Dehydration Technologies

	Low Pressure	High Pressure
Low Temperature	Desiccant / Glycol[1]	Desiccant
High Temperature	Glycol	Glycol / Desiccant[2]

[1] The gas needs to be heated to apply glycol dehydrators or, the gas has to be compressed to apply desiccant dehydrators.
[2] The gas needs to be cooled to apply desiccant dehydrators

Producers mostly dehydrate the gas up to the maximum pipeline moisture requirement of 7 lb./MMcf of gas processed. Exhibit 7 shows the temperature and pressure requirement of the inlet gas for the calcium chloride to remove moisture to 7 lb./MMcf. Calcium chloride performance declines rapidly for the gas above 60 F. For example, if the inlet gas is at 450 psig, the temperature of the gas has to be 47 F or less for calcium chloride desiccant to remove to pass the pipeline moisture requirement.

Exhibit 3. Calcium Chloride Performance Curves at Maximum Pipeline Moisture Content Requirement (7 lb. of water/MMcf)



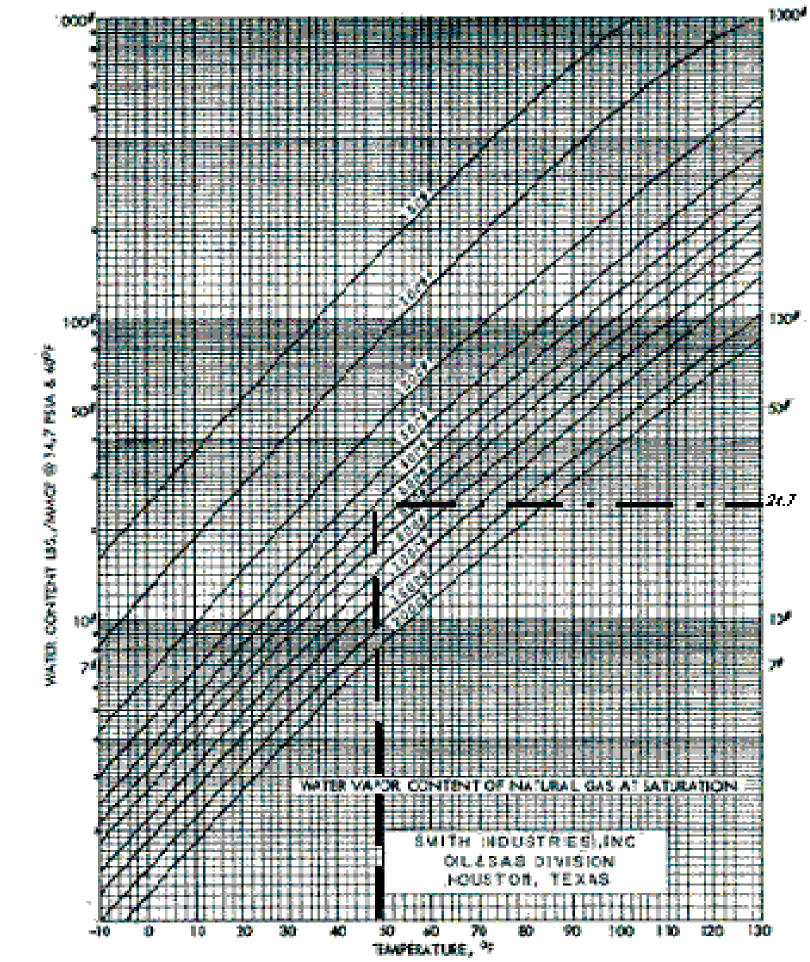
Source:VanAir

Step 2: Estimate the capital costs.

Capital cost of a single vessel desiccant dehydrator that also include the initial fill of the desiccant ranges between $2,000 and $46,000 for gas volume rates from 1 to 20 MMcf/d. The first step in determining the capital cost is based on the gas operating conditions

The first step in determining the capital cost is to calculate how many desiccants is used to remove the moisture based on the gas operating conditions. For example, for a gas stream with a flow rate of 1 MMcf/d flow rate at inlet temperature and pressure of 47 F and 450psig, the moisture content in the inlet gas is 24.7 lb./MMcf (See Exhibit 4).

Exhibit 4: Water content of natural gas at given temperatures & Pressures



Calcium chloride desiccant removes 17.7 lb./MMcf of the moisture in the gas to meet the outlet gas moisture content of 7 lb./MMcf as shown in Exhibit 3. Multiplying the moisture removed with the pound of moisture removed by the desiccant and the flow rate of the gas, results 5.90 lb. of calcium chloride per day is needed for 1 MMcf of gas. Exhibit 5 summarizes this example.

> **Vendor's Rule of Thumb**
> One pound of desiccant removes three pounds of moisture from the gas

Exhibit 5: Determine the amount of desiccant needed to remove the desired water content

Where:

F =**Gas flow rate (MMcf/d)**
I =**Inlet water content (lb/MMcf)**
O =**outlet water content (lb/MMcf)**
B =**desiccant-to-water ratio (lb desiccant/lb water)**
D =**the amount of desiccant needed to remove the desired moisture content (lb desiccant/day)**

Given:

F	**=1 MMcf/d**
I	**=24.7 lb/MMcf**
O	**=7 lb/MMcf**
B	**=1 lb desiccant/3 lb water (vendor's rule-of-thumb)**
D	**=the amount of desiccant needed to remove the desired moisture content (lb desiccant/day)**

Calculate:

D $= F * (I-O) * B$

$= 1 * (24.7-7) * 1/3$

=5.90 lb desiccant/day

After determining the amount of desiccant used to remove the moisture content to 7 lb./ MMcf, the next step is to size the vessel. To determine the size of the vessel, the size of the working and minimum beds, the outside diameter of the vessel, the refilling time of the desiccants and the bulk density of the desiccant have to be known. The height between the support bed and the minimum level (the drying bed) and the height between the minimum level and the maximum level (the working bed) are commercially fixed around 18" and 5", respectively. The bulk density of the calcium chloride desiccant according to the vendor is around 55 lb/cf and the refilling time of the desiccants depends on how often the operator wants to change the desiccant (for this example we have assumed every week). Using these parameters and the equation for volume of a cylinder, the outside diameter of the vessel has to be 18.18". Exhibit 6 summarizes this example.

Exhibit 6: Determine the out side diameter of the vessel

Where:

D	**=The amount of desiccant needed to remove the desired moisture content (lb desiccant/day)**
T	**= Refilling time (day)**
B	**= The bulk density (lb/cf^3)**
OD	**= Outside diameter of the vessel (ft)**
H	**= the height between the maximum bed level and maximum bed level (ft)**

Given:

D	**= 5.90 lb desiccant/day**
T	**= 7 days**
B	**= 55 (lb/cf^3)**
H	**= 0.4167 ft ~ 5 in**

Calculate:

$$OD = \sqrt{\frac{4*D*T}{H*\Pi*B}}$$

= 1.515 ft ~ 18.18 in

Now the desired sized of the vessel is determined, the last step in estimating the capital costs is to select the dehydrator from the vendors standardize that is compatible with the example's design. Exhibit 7 shows different sizes of dehydrators based on the capacity and the pressure of the gas (more dehydrator specifications are provided in Appendix A. Table 2). If the pressure of gas at the transmission line for the example has to be 450 psig, the best choice is to pick the dehydrator that has outside diameter of 20" dehydrator with the capital cost of *$6, 500* gives. The installation cost for this study is assumed to be 75% of the capital cost, which is about $4,875. Changing the outside diameter to 20" dehydrator changes the refilling time to every 8.47 days.

Exhibit 7. Cost of Desiccant dehydrators
Maximum Capacity – Mscf
Maximum Working Pressure – 500 Psig

Outside Diameter (in)	100 Psig	200 Psig	300 Psig	350 Psig	400 Psig	450 Psig	500 Psig	Cost ($)[1]
10	95	177	260	301	342	383	424	
12	32	247	362	419	476	533	590	
16	214	400	587	680	773	866	959	
20	311	620	909	1054	1199	1344	1489	6,500
24	481	900	1319	1528	1738	1948	2158	
30	760	1422	2085	2416	2747	3078	3409	
36	1191	2230	3270	3789	4308	4827	5346	

[1] The capital cost includes the initial fill of calcium chloride desiccant tablets.

Source : VanAir

Step 3: Estimate the operating costs.

The operating cost of the desiccant dehydrator is the cost of refilling desiccants. In order to calculate the cost of the refilling desiccants, the amount of refill desiccants must be determined. A 20" outside diameter dehydrator holds about 171 lb. calcium chloride desiccant tablets. Based on Exhibit 5, 5.90 lb. of calcium chloride per day is used to remove moisture from 1 MMcf gas up to the maximum pipeline requirement. The refilling time is every 8.47 days. By multiplying the refilling time by the desiccant and the amount of the desiccants used per day and subtracting the results from the amount of desiccant tablets in maximum level bed, results the amount of desiccant tablets minimum bed level of 121 lb desiccant.

Depending on the vendor the cost of calcium chloride can range $0.65 to $1.2 per lb. Using $1.2 /lb. for the cost of calcium chloride the total cost for refilling 50 lb. every 8.47 days is $2,586/yr. Exhibit 8 summarizes this example.

Exhibit 8: Determine the cost of desiccant refill	
Where:	
D_{max}	= Amount of desiccant tablets at the maximum bed level (lb desiccant)
D_{min}	= Amount of desiccant tablets at the minimum bed level (lb desiccant)
D	=The amount of desiccant needed to remove the desired moisture content (lb desiccant/day)
T	= Refilling time (day)
P	= Price of the desiccant ($/lb desiccant)
C	= Total cost per year
Given:	
D_{max}	= 135 lb desiccant
T	= 8.47 day
D	= 5.9 lb desiccant/day
P	= $1.2/ lb of calcium chloride
Calculate:	
D_{min}	= D_{max} – (D*T) =(171 – (5.90*8.47) = 121 lb desiccant
C	= ((D_{max} - D_{min}) * P * 365 days/yr) / T = ((171 – 121) * 1.2 * 365) / 8.47 = $2,586/ yr

Step 4: Estimate savings. Replacing a glycol dehydrator with a desiccant dehydrator significantly saves gas and reduces operating and maintenance costs.

➢ Gas savings

Desiccant dehydrators have a smaller amount of gas loss that occurs when depressurizing the vessel to refill the desiccant. The amount of gas saved is calculated by comparing an existing glycol dehydrator to a desiccant dehydrator. The EPA's previous Lesson Learned studies about glycol dehydrators, shows that a glycol dehydrator unit has a contactor, an electric or energy exchange pump, a reboiler/regenerator, and if necessary, a gas heater, a flash tank separator and/or a condenser. (See the EPA's Lesson Learned studies: *Installation of Flash Tank Separators and Glycol Dehydrator, Reducing the Glycol Circulation Rates in Dehydrators*, and *Replacing Gas Assisted Pumps with Electric Pumps*). Operators can determine the gas savings by following these five steps.

Determine The Gas savings:
1. Gas vented from glycol dehydrator;
2. Gas vented from pneumatic controllers;
3. Gas burner for fuel in glycol reboiler;
4. Gas burner for fuel in gas heater;
5. <u>Less</u> gas vented from desiccant dehydrator.

1. Gas vented from glycol dehydrator

The amount of entrained gas depends on the TEG circulation rate and the type of pump the dehydrator uses. In this case, an energy exchange pump without a flash tank separator is assumed and the rule of thumb is for every one gallon of TEG circulated 3 cubic ft of methane is absorbed and vented from the reboiler/regenerator. The TEG circulation rate of7.2 gal of TEG /hr is aggregated from EPA's Lesson Learned Study. Methane emission of 189 Mcf/yr is vented from a 1 MMcf/d gas processed in a glycol dehydrator. Exhibit 9 summarizes this example.

Exhibit 9. Gas vented from the reboiler/regenerator

Where:

L	**= TEG Circulation Rate (gal/ hr)** [1]
G	**= Methane Entrainment Rate (ft/gal)** [1]
GV	**=Amount of Gas Vented Annually (Mcf/yr)**

Given:

L	**= 7.2 gal TEG/hr (circulation rate for 1 MMcfd gas processed)**
G	**=rule of thumb: 3 cubic ft/gal for energy exchange pumps; 1 cubic ft/gal for electric pumps**

Calculate:

GV	**=(L * G * 8,760 (hours per year))/(1000cf/Mcf)**
	=(7.2 * 3 * 8,760) / 1000
	=189 Mcf/yr

[1] EPA's Lesson Learned study, Reducing the Glycol Circulation Rates in Dehydrators, Exhibit 2 and 3.

2. Gas vented from pneumatic controllers

A glycol dehydrator unit (excluding a flash tank separator and a condenser) with a gas heater, assume four bleeding pneumatic controllers: level controllers on the contractor and reboiler, and temperature controller on the reboiler and gas heater. These pneumatic devices bleed gas to the atmosphere. Based on EPA's GRI study, *Methane Emissions form the Natural Gas Industry, Volume 3*, the annual emission factor for pneumatic devices in the production sector is estimated to be 126 Mcf/device. For the four pneumatic devices, the methane emission is 504 Mcf/yr. Exhibit 10 summarizes this example.

Exhibit 10: Gas vented from pneumatic controllers.

EF	**= Emission Factor (Mcf natural gas leakage/ pneumatic device per year)** [1]
PD	**= Number of pneumatic devices**
GE	**= Gas Emissions**

Given:

EF	**= 126 Mcf/device/yr**
PD	**= 4 Pneumatic device/ dehydrator**

Calculate:

GE	**= EF * PU**
	= 126* 4
	= 504 Mcf/yr

[1] EPA's GRI study, Methane Emissions form the Natural Gas Industry, Volume 3

3. Gas burner for fuel in glycol reboiler

The glycol dehydrator uses natural gas on the re-boiler/regenerator to boil off water from the rich glycol. Assuming that the heat duty is 37,500 Btu/hr with 70% efficiency, the gas used by the reboiler is 224 Mcf/yr. Exhibit 11 summarizes this example.

Exhibit 11: Gas burner for fuel in glycol reboiler

Where:

H	**= Heat duty (Btu/hr)**
HV	**= Heating value of natural gas (Btu/cf)** [1]
E	**= Heat Transfer Efficiency**
FGR	**= Fuel Gas for Reboiler (Mcf/yr)**

Given:

H	**= 37,500 (Btu/hr)**
HV	**= 1,027 (Btu/cf)**
E	**= 70%**

Calculate:

MU	**= (H * E * 8,760 (hours per year))/ (HV * 1000cf/Mcf)**
	= (37,500* 0.7*8,760) / (1,027 * 1,000)
	=224 Mcf/yr

[1] Energy information Administration (EIA), Monthly Energy Review, Table A4.

4. Gas burner for fuel in gas heater

TEG does not perform well on low temperature gas. Producers heat the gas prior entering the dehydrator unit when the gas is below 90 F. Natural gas is used to fuel the gas heater. The amount of fuel gas used to heat the gas should be include in the total gas saving. Exhibit 12 shows an example to determine how much gas is used to heat 1 MMcfd gas from 47 F to 90 F, which is 237 Mcf/yr.

Exhibit 12: The amount of fuel gas used to heat the gas

Where:

HV	**= Heating value of natural gas (Btu/cf)**
CV	**= Specific heat at constant volume (Btu/lb F)** [1]
D	**= Density of natural gas (lb/cf)** [1]
ΔT	**= (T_2 – T_1) change in temperature (F)**
F	**= Flow rate (cf/yr)**
E	**= Efficiency**
MU	**= Methane Used (Mcf/yr)**

Given:

HV	**= 1,027 Btu/cf)**
CV	**= 0.441 (Btu/lb F)**
D	**= 0.0502 (lb/cf)**
ΔT	**= 43 F (90 – 47) F**
F	**= 41,667 (cf/hr)**

E = **70%**

Calculate:

MU = $\underline{(F * CV * D * \Delta T * E * 8{,}760 \text{ (hours per year)})}$
(HV * 1000cf/Mcf)

= (0.441 * 0.0502* 36 * (0.70 * 8,760) / (1,027 * 1,000)

= 237 Mcf/yr

5. <u>Less</u> gas vented from desiccant dehydrator

The gas loss from a desiccant dehydrator is determined by calculating the amount of gas flashed out through the brine valve when the vessel is de-pressurized the vessel during the refilling process. The 20" OD desiccant dehydrator that was used in Exhibit 7 has an overall height of 76.75". Based on a vendor, 45% of the volume of the vessel is filled with gas. Using Bolye's Law, the amount of gas vented to the atmosphere during depressurizing of the vessel is 8.15 Mcf/yr. Exhibit 13 summarizes this example.

Exhibit 13: Gas lost from the desiccant dehydrator

Where:

H	**= Height of the dehydrator vessel**
D	**= Outside diameter of the vessel**
P_1	**= Atmospheric pressure (Psig)**
P_2	**= Pressure of the gas (Psig)**
PI	**= pi**
% G	**= Percent of gas volume in the vessel**
GLD	**= Gas loss from the desiccant dehydrator (Scf/yr)**

Given:

H	**= 76.75 in (6.40 ft)**
D	**= 20 in (1.67 ft)**
P_1	**= 450 Psig**
P_2	**= 15 Psig**
PI	**= 3.14**
T	**= 8.47**
%G	**= 45%**

Calculate:

GLD = $((H * D^2 * PI)/4) * \%G * (P_1/P_2) * 365 \text{ days/yr}) / (T)$

= 8.15 Mcf/yr

<u>Total Methane Emissions and Gas Savings</u>

Natural gas contain consists 90% methane. The total methane emissions savings is determined by taking 90% of the summation of the gas loss from the reboiler/regenerator and of the gas bleed from the pneumatic devices and subtracting the results by 90% of the gas loss by the dehydrator, which is 624 Mcf/yr. The total fuel gas savings is determined by adding the fuel gas used in the reboiler and the gas heater, which 461 Mcf/yr. The value of the gas savings is determined by multiplying the total gas savings (the sum of Exhibit 9, 10, 11 and 12 and minus Exhibit

13) by the price of gas (*EPA' default value* of $3.00 per Mcf), which results $3,462 per year. Exhibit 14 summarizes this example.

Exhibit 14: Total Methane Emission and Gas Savings	
Calculate:	
TME	**=Total Methane Emissions (Mcf/yr)** **90% *(Exhibit 9+ Exhibit 10 - Exhibit 13)** **=(170+454- 7.3) Mcf/year** **= 617 Mcf/yr**
Calculate:	
FGS	**=Total Fuel Gas Savings (Mcf/yr)** **(Exhibit 11 + Exhibit 12)** **=(224 + 237) Mcf/year** **= 461 Mcf/yr**
Calculate:	
TGS	**= Total Gas Savings (Mcf/yr)** **= GV (Exhibit 9) + GE (Exhibit 10) – GLD (Exhibit 13)+FGS** **=(189 + 504 –8.15 + 461)** **=1,146 Mcf/yr**
Value of Gas Savings	
Calculate:	
GVS	**= Gas Value Savings** **= (TGS * Price of gas)** **= (1,146 Mcf/yr)* $ 3/Mcf** **= $ 3,438/yr**

➢ "Other savings"

Other savings include the difference between the operating and maintenance cost (labor cost) of glycol dehydrator and desiccant dehydrator.

- Operating and maintenance costs of a glycol dehydrator
  - ♦ The operating costs include the refill cost of the glycol and from Exhibit 8, to refill the 50 lb. of desiccant every 8.47days cost $ 2,586/ yr.
  - ♦ Maintenance costs (labor costs) are assumed based on one hour for one person to close the gas inlet and outlet valves, to depressurize the vessel, to input 50 lb of desiccant and to pressurize back the vessel, which is around $300/yr.
- Operating and maintenance costs of a glycol dehydrator
  - ♦ The operating costs include the initial and make-up glycol. For the operation conditions of the example the initial cost is based on 100 gallons glycol tank that cost $4.50/gal of TEG, which results $450 According to a vendor, about 0.1 gal /MMcf

of glycol is lost in the glycol dehydrator process. The annual glycol lost will be 37gal and the make up cost will be $164/yr.

- Maintenance costs (labor costs) are assumed two people cleaning and changing the systems, repairing pump and fire-tube of the reboiler and maintaining of the efficiency glycol, contactor, reboiler and pump, which is around $3,447/yr.

Step 5: **Conduct Economic Analysis*.*** The installation, capital and operating costs of a desiccant dehydrator are favorable compare to glycol dehydrators. Exhibit 15 shows the cost comparison of the two types of dehydrators to dehydrate 1 MMcfd natural gas at 450 psig pressure and 47 F temperature.

Exhibit 15: Cost Comparison of Desiccant Dehydrator and Glycol Dehydrator

1 MMcfd natural gas at operating 450 psig and 47 F

Type of costs and savings	Desiccant ($/yr)	Glycol ($/yr)
Implementation costs:		
Capital Cost		
Desiccant[1] (includes the initial fill)	13,000	
Glycol[2]		20,000
Other cost (Installation & Engineering)[3]	9,750	15,000
Salvage Value[4]		2,000
Total Implementation Costs:	22,750	35,900
Annual Operating and Maintenance Costs		
Desiccant		
Cost of Desiccant refill[5] ($1.11/lb)		2,586
Maintenance Cost[6]		300
Glycol		
Cost of Glycol initial and refill[6] ($4.5/gal)	614	
Maintenance Cost[6]	3,447	
Total Annual O & M Costs	4,061	2,886
Gas Use		
Fuel[7]	1,383	
Gas Loss		
Pneumatic Devices	1,512	
Vents	567	24.45
Total Gas Used and Loss[7]	3,462	24.45
Methane Emission (Mcf/yr)[7]	624	8.15

[1] The capital of the desiccant dehydrator is based on two desiccant dehydrators that are used alternately, See Exhibit 7.
[2] The capital cost of the glycol is only for comparison. The initial fill costs of glycol $450 for is not included.
[3] Estimated installation cost of 75% of the unit cost.
[4] Based on 20% of the glycol dehydrator.
[5] The values are obtained from Exhibit 8
[6] The values are obtain from Step 4 , Section "Other Savings". The makeup glycol is $164/yr.
[7] The values are obtained from Exhibit 14, the gas price is assumed to be $3/Mcf).

Estimated Savings

Savings achieved by STAR Partners implementing desiccant dehydrators instead of glycol dehydrators. The analysis of replacing an exiting glycol dehydrator of 1 MMcf at 450 psig and 75 F gas with a desiccant dehydrator. Exhibit 16 shows the economic analyzes for replacing a glycol dehydrator with a desiccant dehydrator.

Exhibit 16: Economics of Retrofitting a Desiccant Dehydrator

Type of costs and savings[1]	Year (0) ($/yr)	Year (1) ($/yr)	Year (2) ($/yr)	Year (3) ($/yr)	Year (4) ($/yr)	Year (5) ($/yr)
Capital & Installation Costs	(22,750)					
Avoided O&M Cost		3,611	3,611	3,611	3,611	3,611
O&M costs ($/yr)		(2,886)	(2,886)	(2,886)	(2,886)	(2,886)
Value of Gas Saved		3,438	3,438	3,438	3,438	3,438
Salvage Value	2,000					
Total ($)	(20,750)	4,163	4,163	4,163	4,163	4,163

NPV (Net Present Value)[2] =(6,335)
IRR (Internal Rate of Return)[3] = (3%)
Payback Period (yr) = 5

[1]All the cost values are obtained from Exhibit 14, the gas price is assumed to be $3/Mcf).
[2] The NPV is calculated based on 10% discount over five years.
[3] The IRR is calculated based on 5 years.

Lessons Learned

Desiccants Dehydrators can cost effectively reduce methane emissions for gas dehydration. Partners offer the following lessons learned:

- Desiccant dehydrators can provide significantly economic benefits, such as increased operating efficiency, decreased capital and maintenance costs for low flow rate gas at high pressure and low temperature.
- Operating costs of desiccant dehydrators are slightly higher than the cost from glycol dehydrator. The desiccants dissolve in water and they have to be replaced, while the glycol are recycled/circulated.
- Desiccant dehydrators are an effective method for eliminating emissions of methane, VOCs, and HAPs to the atmosphere, resulting in both economic and environmental benefits.
- The brine in the storage tank is often diluted with the produced water and injected back to the ground or dumped into water disposal pits.
- For high temperatures and low pressures and large volume gas, glycol dehydrators are more economical gas drying method.

Partner's Experiences from Implementing Desiccant Dehydrators

In one of their production fields in Wyoming, Natural Gas STAR partner BP has installed 12 desiccant dehydrator units for well site dehydration. As a result of these implementations, BP has reported reducing 8,860 Mcf/yr of methane emissions from these units. Assuming $2 per Mcf, the gas value savings is approximately $ 17,770 for 12 units. In addition to the methane emission reduction, desiccant dehydrator reduced all other emissions, such as VOCs, HAPs and BTEX, from both the glycol dehydrator overhead and the glycol reboiler. The net present value of the desiccant dehydrator is equal to or slightly less than of the glycol dehydrator.

Appendix A

Table 1: Moisture content of natural gas after drying with desiccants in lb./ MMcf

Type Calcium Chloride Deliquescent Desiccant Tablets

	10 PSIG	25 PSIG	50 PSIG	75 PSIG	100 PSIG	125 PSIG	150 PSIG	175 PSIG	200 PSIG	225 PSIG	250 PSIG	275 PSIG	300 PSIG	350 PSIG	400 PSIG	500 PSIG	750 PSIG	1000 PSIG
80°F	344	219	134	98	77	64	55	48	43	39	35	33	30	27	23.6	19.7	14.3	11.6
75°F	292	186	113	83	65	54	46	41	36	33	30	28	26	22.5	20.1	16.8	12.2	9.9
70°F	246	157	96	70	55	46	39	43	31	27	25	23.4	21.7	19.1	17.1	14.3	10.4	8.5
65°F	207	132	81	59	47	39	33	29	26	23.5	21.4	19.8	18.4	16.2	14.5	12.1	8.9	7.3
60°F	174	111	68	50	39	33	29	24.5	21.9	19.8	18.1	16.8	15.5	13.7	12.3	10.3	7.6	6.2
58°F	162	103	63	46	36	31	26	22.8	20.3	18.4	16.8	15.6	14.4	12.9	11.4	9.6	7	5.8
56°F	150	96	59	43	34	29	24.1	21.2	18.9	17.1	15.7	14.5	13.4	11.8	10.6	8.9	6.6	5.4
54°F	140	89	55	40	32	26	22.5	19.8	17.6	16	14.6	13.5	12.6	11.1	9.9	8.3	6.2	5.1
52°F	130	83	51	37	29	24.5	21	18.4	16.4	14.9	14.4	12.6	11.7	10.3	9.3	7.8	5.8	4.7
50°F	121	77	47	35	27	22.8	19.5	17.1	15.3	13.9	12.7	11.7	10.9	9.6	8.6	7.2	5.4	4.4
45°F	100	64	39	29	22.7	18.9	16.2	14.3	12.7	11.5	10.6	9.8	9.1	8	7.2	6.1	4.5	3.7
40°F	83	53	32	24	18.8	15.6	13.4	11.8	10.5	9.6	8.8	8.1	7.5	6.7	6	5	3.8	3.1
35°F	68	44	27	19.6	15.5	13	11.1	9.8	8.7	7.9	7.2	6.7	6.2	5.5	5	4.2	3.1	2.6

Type Lithium Chloride Deliquescent Desiccant Tablets

	10 PSIG	25 PSIG	50 PSIG	75 PSIG	100 PSIG	125 PSIG	150 PSIG	175 PSIG	200 PSIG	225 PSIG	250 PSIG	275 PSIG	300 PSIG	350 PSIG	400 PSIG	500 PSIG	750 PSIG	1000 PSIG
80°F	128	81	50	36	29	23.7	20.2	17.8	15.8	14.3	13	12	11.1	9.8	8.7	7.3	5.3	4.3
75°F	108	69	42	31	24.2	20	17.2	15.1	13.4	12.1	11.1	10.2	9.5	8.3	7.4	6.2	4.5	3.7
70°F	91	59	36	26	20.4	17	14.5	12.7	11.3	10.3	9.4	8.7	8	7.1	6.3	5.3	3.8	3.1
65°F	77	49	30	21.9	17.2	14.3	12.2	10.8	9.6	8.7	7.9	7.3	6.8	6	5.4	4.5	3.3	2.7
60°F	65	41	25	18.4	14.5	12.1	10.3	9.1	8.1	7.4	6.7	6.2	5.7	5	4.5	3.8	2.8	2.3
58°F	60	38	23.4	17.1	13.5	11.2	9.6	8.4	7.5	6.8	6.2	5.7	5.3	4.7	4.2	3.5	2.6	2.1
56°F	56	37	21.7	15.9	12.5	10.5	8.9	7.8	7	6.3	5.8	5.4	5	4.4	3.9	3.3	2.4	2
54°F	52	33	20.3	14.8	11.7	9.7	8.3	7.3	6.5	5.9	5.4	5	4.6	4.1	3.7	3.1	2.3	1.8
52°F	48	31	18.9	13.8	10.9	9	7.7	6.8	6.1	5.5	5	4.7	4.3	3.8	3.4	2.9	2.1	1.7
50°F	45	29	17.5	12.8	10.1	8.4	7.2	6.4	5.6	5.1	4.7	4.4	4	3.5	3.2	2.7	2	1.6
45°F	37	23.8	14.5	10.7	8.4	7	6	5.3	4.7	4.3	3.9	3.6	3.3	2.9	2.6	2.2	1.6	1.3
40°F	30	19.6	12	8.7	6.9	5.8	4.9	4.4	3.9	3.6	3.2	3	2.8	2.4	2.2	1.8	1.4	1.1
35°F	25	16.1	9.9	7.2	5.7	4.8	4.1	3.6	3.2	2.9	2.7	2.5	2.3	2	1.8	1.5	1.1	0.9

Source: Van Air

Table 2: Cost of Desiccant dehydrators
Maximum Capacity – Mscf

Model	10 PSIG	25 PSIG	50 PSIG	100 PSIG	200 PSIG	250 PSIG	500 PSIG	720 PSIG	1000 PSIG	1450 PSIG	Desiccant Required (lbs.) TYPE (1) SP	10BF	PREBED (2)
IGD 4-2.5	3	5	8	15	25	35	–	–	–	–	4.5	6.5	1.5
IGD 4-7.2	3	5	8	15	25	35	70	100	–	–			
IGD 4-14.5	2	5	8	15	25	35	70	100	140	220			
PLD 8-2.5	15	25	40	65	120	150	–	–	–	–	30	35	15
PLD 8-7.2	15	25	40	65	120	150	300	420	–	–			
PLD 8-14.5	15	25	40	65	120	150	300	420	600	870			
PLD 12-2.5	30	50	80	140	265	325	–	–	–	–	70	80	35
PLD 12-7.2	30	50	80	140	265	325	630	900	–	–			
PLD 12-14.5	30	50	80	140	265	325	630	900	1260	1830			
PLD 16-2.5	50	80	125	225	415	510	–	–	–	–	100	120	50
PLD 16-7.2	50	80	125	225	415	510	1000	1450	–	–			
PLD 16-14.5	50	80	125	225	415	510	1000	1450	2000	2900			
PLD 20-2.5	75	125	200	350	660	810	–	–	–	–	175	200	90
PLD 20-7.2	75	125	200	350	660	810	1575	2250	–	–			
PLD 20-14.5	75	125	200	350	660	810	1575	2250	3150	4675			
PLD 24-2.5	110	175	285	500	935	1150	–	–	–	–	250	300	120
PLD 24-7.2	110	175	285	500	935	1150	2230	3200	–	–			
PLD 24-14.5	110	175	285	500	935	1150	2230	3200	4460	6470			
PLD 30-2.5	175	275	450	800	1490	1850	–	–	–	–	400	460	190
PLD 30-7.2	175	275	450	800	1490	1850	3600	5130	–	–			
PLD 30-14.5	175	275	450	800	1490	1850	3600	5130	7200	10440			
PLD 36-2.5	275	415	675	1200	2230	2750	–	–	–	–	600	700	275
PLD 36-7.2	275	415	675	1200	2230	2750	5360	7700	–	–			
PLD 36-14.5	275	415	675	1200	2230	2750	5360	7700	10720	15544			

Source: VanAir

Sources Consulted

Reid Smith
Senior Environmental Specialist
Health, Safety & Environment
BP Amoco Exploration
Western Gas Business Unit
Mail Code 2.4470
501 WestLake Park Blvd.
Houston, TX 77079-2696
Tel: (281) 366-7515 Fax: (281) 366-7922

Duane Zavadil
Health, Safety & Environment Manager
1515 Arapaheo Street
Tower 3, Suite 1000
Denver, Colorado 80202
Tel: (303) 606-4396 Fax: (303) 629-8265

Charles Eskrigge
Air and Vacuum Process inc
5216 Cedar
Bellaire, TX 14.314.3401
Tel: (713) 645-0208 Fax: (713) 645-814.398
Internet: http://www.airvacuumprocess.com

Curt Murray, Sr.
Pride of the Hills MFG., Inc
President-CEO
8140 S.R. 514
Big Priairie, OH 44611-9692
Tel: (330) 567-3108 Fax: (330) 567-3854
Internet: www.prideofthehills.com

The Hanover Compressor Company
12001 N. Houston Rosslyn
Houston, Texas 14.314.3086
Tel: (281) 447-8787, Fax: (281) 447-8781

Paul Gunning, Natural Gas STAR Program
United States Environmental Protection Agency CD (6202J)
1200 Pennsylvania Avenue, NW
Washington, DC 20445
Tel: (202) 564-9736, Fax: (202) 565-2254
Email: gunning.paul@epa.gov

End Notes

Murray, Curt. *Practical Methods of Dying Natural Gas*. Pride of the Hills MFG., Inc.

Bowman. Bob. *Benefits of Using Deliquescing Desiccants for Gas Dehydration.* Society of Petroleum Engineers (SPE 45170)

U.S. Environmental Protection Agency. Lessons Learned: Reducing the Glycol Circulation Rates in Dehydrators (EPA430-B-97-014, May 1997).

U.S. Environmental Protection Agency. Lessons Learned: Installation of Flash Tank Separators (EPA430-B-97-008, October 1997).

U.S. Environmental Protection Agency. Lessons Learned: Replacing Gas – Assisted Glycol Pumps with Electric Pumps. (EPA430-B-00-006, December 2000).