Natural Gas Dehydtration

Lessons Learned from the Natural Gas STAR Program

ConocoPhillips
The Colorado Oil and Gas Association, and
The Independent Petroleum Association of Mountain States

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epa.gov/gasstar
Natural Gas Dehydration: Agenda

- Methane Losses
- Methane Recovery
- Is Recovery Profitable?
- Industry Experience
- Discussion
Methane Losses from Dehydrators

Dehydrators and pumps account for:

- 17 Billion cubic feet (Bcf) of methane emissions in the production, gathering, and boosting sectors

- Offshore Operations: 34 Bcf
- Well Venting and Flaring: 9 Bcf
- Compressor Fugitives, Venting, and Engine Exhaust: 14 Bcf
- Storage Tank Venting: 6 Bcf
- Other Sources: 10 Bcf
- Meters and Pipeline Leaks: 9 Bcf
- Pneumatic Devices: 57 Bcf*

*Bcf = billion cubic feet


Natural Gas STAR reductions data shown as published in the inventory.
What is the Problem?

- Produced gas is saturated with water, which must be removed for gas transmission
- Glycol dehydrators are the most common equipment to remove water from gas
  - 36,000 dehydration units in natural gas production, gathering, and boosting
  - Most use triethylene glycol (TEG)
- Glycol dehydrators create emissions
  - Methane, Volatile Organic Compounds (VOCs), Hazardous Air Pollutants (HAPs) from reboiler vent
  - Methane from pneumatic controllers

Source: www.prideofthehill.com
Basic Glycol Dehydrator System
Process Diagram

- Inlet Wet Gas
- Motive Gas Bypass
- Dry Sales Gas
- Fuel Gas
- Water/Methane/VOCs/HAPs To Atmosphere
- Lean TEG
- Rich TEG
- Glycol Reboiler/Regenerator
- Glycol Contactor
- Glycol Energy Exchange Pump
- Pump
- Driver
Methane Recovery

- Optimize glycol circulation rates
- Flash tank separator (FTS) installation
- Electric pump installation
- Zero emission dehydrator
- Replace glycol unit with desiccant dehydrator
- Other opportunities
Optimizing Glycol Circulation Rate

- Gas pressure and flow at wellhead dehydrators generally declines over time
  - Glycol circulation rates are often set at a maximum circulation rate
- Glycol overcirculation results in more methane emissions without significant reduction in gas moisture content
  - Partners found circulation rates two to three times higher than necessary
  - Methane emissions are directly proportional to circulation
- Lessons Learned study: optimize circulation rates
Installing Flash Tank Separator (FTS)

- Methane that flashes from rich glycol in an energy-exchange pump can be captured using an FTS
- Many units are not using an FTS

![Bar chart showing MMcf/day processed with and without FTS.]

*Percent*

*MMcf/day processed*

MMcf = Million cubic feet

Source: API
Methane Recovery

- Recovers about 90% of methane emissions
- Reduces VOCs by 10 to 90%
- Must have an outlet for low pressure gas
  - Fuel
  - Compressor suction
  - Vapor recovery unit
Flash Tank Costs

Lessons Learned study provides guidelines for scoping costs, savings and economics

Capital and installation costs:
- Capital costs range from $3,500 to $7,000 per flash tank
- Installation costs range from $1,684 to $3,031 per flash tank

Negligible Operational & Maintenance (O&M) costs
Electric Pump Eliminates Motive Gas

Glycol Contactor

Dry Sales Gas

Inlet Wet Gas

Gas Driver

Electric Motor Driven Pump

Rich TEG

Pump

Lean TEG

Glycol Reboiler/Regenerator

Water/Methane/VOCs/HAPs To Atmosphere

Fuel Gas
Overall Benefits

- Financial return on investment through gas savings
- Increased operational efficiency
- Reduced O&M costs (fuel gas, glycol make-up)
- Reduced compliance costs (HAPs, BTEX)
- Similar footprint as gas assist pump
### Is Recovery Profitable?

#### Three Options for Minimizing Glycol Dehydrator Emissions

<table>
<thead>
<tr>
<th>Option</th>
<th>Capital Costs</th>
<th>Annual O&amp;M Costs</th>
<th>Emissions Savings</th>
<th>Payback Period¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimize Circulation Rate</td>
<td>Negligible</td>
<td>Negligible</td>
<td>394 to 39,420 Mcf/year</td>
<td>Immediate</td>
</tr>
<tr>
<td>Install Flash Tank</td>
<td>$6,500 to $18,800</td>
<td>Negligible</td>
<td>710 to 10,643 Mcf/year</td>
<td>4 to 11 months</td>
</tr>
<tr>
<td>Install Electric Pump</td>
<td>$1,400 to $13,000</td>
<td>$165 to $6,500</td>
<td>360 to 36,000 Mcf/year</td>
<td>&lt; 1 month to several years</td>
</tr>
</tbody>
</table>

¹ – Gas price of $7/Mcf
Zero Emission Dehydrator

- Combines many emission saving technologies into one unit
  - Vapors in the still gas coming off of the glycol reboiler are condensed in a heat exchanger
  - Non-condensible skimmer gas is routed back to the reboiler for fuel use
  - Electric driven glycol circulation pumps used instead of energy-exchange pumps
Overall Benefits: Zero Emissions Dehydrator

- Reboiler vent condenser removes heavier hydrocarbons and water from non-condensables (mainly methane)
- The condensed liquid can be further separated into water and valuable gas liquid hydrocarbons
- Non-condensables (mostly methane) can be recovered as fuel or product
- By collecting the reboiler vent gas, methane (and VOC/HAP) emissions are greatly reduced
Replace Glycol Unit with Desiccant Dehydrator

Desiccant Dehydrator
\[\checkmark\] Wet gasses pass through drying bed of desiccant tablets
\[\checkmark\] Tablets absorb moisture from gas and dissolve

Moisture removal depends on:
\[\checkmark\] Type of desiccant (salt)
\[\checkmark\] Gas temperature and pressure

<table>
<thead>
<tr>
<th>Hygroscopic Salts</th>
<th>Typical T and P for Pipeline Spec</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium chloride</td>
<td>&lt;47°F @ 440 psig</td>
<td>Least expensive</td>
</tr>
<tr>
<td>Lithium chloride</td>
<td>&lt;60°F @ 250 psig</td>
<td>More expensive</td>
</tr>
</tbody>
</table>
Desiccant Performance

Desiccant Performance Curves at Maximum Pipeline Moisture Spec (7 pounds water / MMcf)

Source: Air & Vacuum Process, Inc.
Desiccant Dehydrator Schematic
Estimate Capital Costs

- Determine amount of desiccant needed to remove water
- Determine diameter of vessel
- Costs for single vessel desiccant dehydrator
  - Capital cost varies between $3,500 and $22,000
  - Gas flow rates from 1 to 20 MMcf/day
    - Capital cost for 20-inch vessel with 1 MMcf/day gas flow is $8,100
    - Installation cost assumed to be 75% of capital cost
- Normally installed in pairs
  - One drying, one refilled for standby
How Much Desiccant Is Needed?

Example:
D = ?
F = 1 MMcf/day
I = 21 pounds/MMcf
O = 7 pounds/MMcf
B = 1/3

Calculate:
D = F * (I - O) * B
D = 1 * (21 - 7) * 1/3
D = 4.7 pounds desiccant/day

Where:
D = Amount of desiccant needed (pounds/day)
F = Gas flow rate (MMcf/day)
I = Inlet water content (pounds/MMcf)
O = Outlet water content (pounds/MMcf)
B = Desiccant/water ratio vendor rule of thumb

Source: Van Air
Calculate Vessel Diameter

Example:
ID = ?
D = 4.7 pounds/day
T = 7 days
B = 55 pounds/cf
H = 5 inch

Where:
ID = Internal diameter of the vessel (inch)
D = Amount of desiccant needed (pounds/day)
T = Assumed refilling frequency (days)
B = Desiccant density (pounds/cf)
H = Height between minimum and maximum bed level (inch)

Calculate:

\[ ID = 12 \times \sqrt{\frac{4 \times D \times T \times 12}{H \times B \times \pi}} = 16.2 \text{ inch} \]

Standard ID available = 20 inch

Source: Van Air
Operating Costs

- **Operating costs**
  - Desiccant: $2,556/year for 1 MMcf/day example
    - $1.50/pound desiccant cost
  - Brine Disposal: Negligible
    - $1.40/bbl brine or $20/year
  - Labor: $2,080/year for 1 MMcf/day example
    - $40/hour

- **Total: about $4,656/year**
Savings

- Gas savings
  - Gas vented from glycol dehydrator
  - Gas vented from pneumatic controllers
  - Gas burned for fuel in glycol reboiler
  - Gas burned for fuel in gas heater

- Less gas vented from desiccant dehydrator

- Methane emission savings calculation
  - Glycol vent + Pneumatics vents – Desiccant vents

- Operation and maintenance savings
  - Glycol O&M + Glycol & Heater fuel – Desiccant O&M
Gas Vented from Glycol Dehydrator

Example:
GV = ?
F = 1 MMcf/day
W = 21-7 pounds H₂O/MMcf
R = 3 gallons/pound
OC = 150%
G = 3 cf/gallon

Calculate:
GV = (F * W * R * OC * G * 365 days/year) / 1,000 cf/Mcf

GV = 69 Mcf/year

Where:
GV = Gas vented annually (Mcf/year)
F = Gas flow rate (MMcf/day)
W = Inlet-outlet H₂O content (pounds/MMcf)
R = Glycol/water ratio (rule of thumb)
OC = Percent over-circulation
G = Methane entrainment (rule of thumb)
Gas Vented from Pneumatic Controllers

Example:
GE = ?
PD = 4
EF = 126 Mcf/device/year

Calculate:
GE = EF * PD
GE = 504 Mcf/year

Where:
GE = Annual gas emissions (Mcf/year)
PD = Number of pneumatic devices per dehydrator
EF = Emission factor (Mcf natural gas bleed/pneumatic devices per year)

Source: norriseal.com

Norriseal
Pneumatic Liquid Level Controller
Gas Burned as Fuel for Glycol Dehydrator

Gas fuel for glycol reboiler:
- 1 MMcf/day dehydrator
- Removing 14 lb water/MMcf
- Reboiler heat rate: 1,124 Btu/gal TEG
- Heat content of natural gas: 1,027 Btu/scf

Fuel requirement: 17 Mcf/year

Gas fuel for gas heater:
- 1 MMcf/day dehydrator
- Heat gas from 47ºF to 90ºF
- Specific heat of natural gas: 0.441 Btu/lb-ºF
- Density of natural gas: 0.0502 lb/cf
- Efficiency: 70%

Fuel requirement: 483 Mcf/year
Gas Lost from Desiccant Dehydrator

Example:
GLD = ?
ID = 20 inch (1.7 feet)
H = 76.75 inch (6.4 feet)
%G = 45%
P₁ = 15 Psia
P₂ = 450 Psig
T = 7 days

Where:
GLD = Desiccant dehydrator gas loss (Mcf/year)
ID = Internal Diameter (feet)
H = Vessel height by vendor specification (feet)
%G = Percentage of gas volume in the vessel
P₁ = Atmospheric pressure (Psia)
P₂ = Gas pressure (Psig)
T = Time between refilling (days)

Calculate:
GLD = \( \frac{H \times ID^2 \times \pi \times P_2 \times %G \times 365 \text{ days/year}}{4 \times P_1 \times T \times 1,000 \text{ cf/Mcf}} \)

GLD = \( \boxed{10 \text{ Mcf/year}} \)

Desiccant Dehydrator Unit
Source: usedcompressors.com
Natural Gas Savings

Gas vented from glycol dehydrator: 69 Mcf/year
Gas vented from pneumatic controls: +504 Mcf/year
Gas burned in glycol reboiler: + 17 Mcf/year
Gas burned in gas heater: +483 Mcf/year
Minus desiccant dehydrator vent: - 10 Mcf/year
Total savings: 1,063 Mcf/year

Value of gas savings (@ $7/Mcf): $7,441/year
## Desiccant Dehydrator and Glycol Dehydrator Cost Comparison

**Implementation Costs**

<table>
<thead>
<tr>
<th>Type of Costs and Savings</th>
<th>Desiccant ($/yr)</th>
<th>Glycol ($/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Costs</td>
<td>16,097</td>
<td>24,764</td>
</tr>
<tr>
<td>Desiccant (includes the initial fill)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glycol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other costs (installation and engineering)</td>
<td>12,073</td>
<td>18,573</td>
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<tr>
<td>Total Implementation Costs:</td>
<td>28,169</td>
<td>43,337</td>
</tr>
</tbody>
</table>

**Annual Operating and Maintenance Costs**

<table>
<thead>
<tr>
<th>Type of Costs and Savings</th>
<th>Desiccant ($/yr)</th>
<th>Glycol ($/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desiccant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of desiccant refill</td>
<td>2,556</td>
<td>206</td>
</tr>
<tr>
<td>($1.50/pound)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of brine disposal</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Labor cost</td>
<td>2,080</td>
<td></td>
</tr>
<tr>
<td>Glycol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of glycol refill</td>
<td></td>
<td></td>
</tr>
<tr>
<td>($4.50/gallon)</td>
<td>206</td>
<td></td>
</tr>
<tr>
<td>Material and labor cost</td>
<td>6,240</td>
<td></td>
</tr>
<tr>
<td>Total Annual Operation and Maintenance Costs:</td>
<td><strong>4,656</strong></td>
<td><strong>6,446</strong></td>
</tr>
</tbody>
</table>

Based on 1 MMcf per day natural gas operating at 450 psig and 47°F. Installation costs assumed at 75% of the equipment cost.
## Desiccant Dehydrator Economics

**NPV = $19,208  IRR = 51%  Payback = 21 months**

<table>
<thead>
<tr>
<th>Type of Costs and Savings</th>
<th>Year 0</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital costs</td>
<td>-$28,169</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avoided O&amp;M costs</td>
<td>$6,446</td>
<td>$6,446</td>
<td>$6,446</td>
<td>$6,446</td>
<td>$6,446</td>
<td>$6,446</td>
</tr>
<tr>
<td>O&amp;M costs - Desiccant</td>
<td>-$4,656</td>
<td>-$4,656</td>
<td>-$4,656</td>
<td>-$4,656</td>
<td>-$4,656</td>
<td>-$4,656</td>
</tr>
<tr>
<td>Value of gas saved(^1)</td>
<td>$7,441</td>
<td>$7,441</td>
<td>$7,441</td>
<td>$7,441</td>
<td>$7,441</td>
<td>$7,441</td>
</tr>
<tr>
<td>Glycol dehy. salvage value(^2)</td>
<td>$12,382</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 – Gas price = $7/Mcf, Based on 563 Mcf/year of gas venting savings and 500 Mcf/year of fuel gas savings
2 – Salvage value estimated as 50% of glycol dehydrator capital cost
Partner Experience

- One partner routes glycol gas from FTS to fuel gas system, saving 24 Mcf/day (8,760 Mcf/year) at each dehydrator unit
- Texaco (now Chevron) has installed FTS
  - Recovered 98% of methane from the glycol
  - Reduced emissions from 1,232 - 1,706 Mcf/year to <47 Mcf/year
Other Partner Reported Opportunities

- Flare regenerator off-gas (no economics)
- With a vent condenser,
  - Route skimmer gas to firebox
  - Route skimmer gas to tank with VRU
- Instrument air for controllers and glycol pump
- Mechanical control valves
- Pipe gas pneumatic vents to tank with VRU (not reported yet)
Lessons Learned

- Optimizing glycol circulation rates increase gas savings, reduce emissions
  - Negligible cost and effort
- FTS reduces methane emissions by about 90 percent
  - Require a low pressure gas outlet
- Electric pumps reduce O&M costs, reduce emissions, increase efficiency
  - Require electrical power source
- Zero emission dehydrator can virtually eliminate emissions
  - Requires electrical power source
- Desiccant dehydrator reduce O&M costs and reduce emissions compared to glycol
- Miscellaneous other PROs can have big savings
Discussion

- Industry experience applying these technologies and practices
- Limitations on application of these technologies and practices
- Actual costs and benefits