Natural Gas Dehydration

Lessons Learned from the Natural Gas STAR Program

Anadarko Petroleum Corporation and the Domestic Petroleum Council

Producers Technology Transfer Workshop
College Station, Texas
May 17, 2007

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
- Venting: 2 Bcf
- Compressor Fugitives and Venting: 12 Bcf
- Gas Engine Exhaust: 12 Bcf
- Meters and Pipeline Leaks: 9 Bcf
- Storage Tank Venting: 6 Bcf
- Pneumatic Devices: 57 Bcf*
- Other Sources: 10 Bcf
- Dehydrators and Pumps: 17 Bcf

*Bcf = billion cubic feet

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
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.

![Graph showing percent of MMcf/day processed with and without FTS](image)

**Percent of MMcf/day processed with and without FTS**
- **With FTS**: Dark yellow bars.
- **Without FTS**: Dark blue bars.

**Legend**
- **With FTS**
- **Without FTS**

**Source:** API

**Note:**
- MMcf = Million cubic feet
- Source: API

---

7
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

Gas Recovery

Low Capital Cost/Quick Payback

Reduced Emissions
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 $1,200 to $2,500 per flash tank

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

- Inlet Wet Gas
- Gas Driver
- Electric Motor Driven Pump
- Pump
- Rich TEG
- Dry Sales Gas
- Lean TEG
- Glycol Contactor
- Glycol Reboiler/Regenerator
- Fuel Gas
- Water/Methane/VOCs/HAPs To Atmosphere
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-condensable 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
  - Wet gases pass through drying bed of desiccant tablets
  - Tablets absorb moisture from gas and dissolve

- Moisture removal depends on:
  - Type of desiccant (salt)
  - 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)

Max Spec Line for CaCl₂
Max Spec Line for LiCl₂

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

- Filler Hatch
- Maximum Desiccant Level
- Minimum Desiccant Level
- Drying Bed
- Desiccant Tablets
- Support Grid
- Inlet Wet Gas
- Brine
- Drain Valve
- Dry Sales Gas
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:

\[
\begin{align*}
D &= ? \\
F &= 1 \text{ MMcf/day} \\
I &= 21 \text{ pounds/MMcf} \\
O &= 7 \text{ pounds/MMcf} \\
B &= 1/3
\end{align*}
\]

Calculate:

\[
D = F \times (I - O) \times B \\
D = 1 \times (21 - 7) \times 1/3 \\
D = 4.7 \text{ pounds desiccant/day}
\]

Where:

\[
\begin{align*}
D &= \text{Amount of desiccant needed (pounds/day)} \\
F &= \text{Gas flow rate (MMcf/day)} \\
I &= \text{Inlet water content (pounds/MMcf)} \\
O &= \text{Outlet water content (pounds/MMcf)} \\
B &= \text{Desiccant/water ratio vendor rule of thumb}
\end{align*}
\]

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 = Inside 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:**

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

Standard ID available = 20 inch

cf = cubic feet

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/bbl brine or $14/year
  - Labor: $2,080/year for 1 MMcf/day example
    - $40/hour

**Total: about $4,650/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
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 47°F to 90°F
- Specific heat of natural gas: 0.441 Btu/lb-°F
- 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 = Inside 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 = 10 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

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

<table>
<thead>
<tr>
<th>Type of Costs and Savings</th>
<th>Desiccant ($/yr)</th>
<th>Glycol ($/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Desiccant (includes the initial fill)</td>
<td>16,097</td>
<td>24,764</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>
</tr>
<tr>
<td>Total Implementation Costs:</td>
<td>28,169</td>
<td>43,337</td>
</tr>
<tr>
<td>Annual Operating and Maintenance Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Desiccant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of desiccant refill ($1.50/pound)</td>
<td>2,556</td>
<td></td>
</tr>
<tr>
<td>Cost of brine disposal</td>
<td>14</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 ($4.50/gallon)</td>
<td></td>
<td>206</td>
</tr>
<tr>
<td>Material and labor cost</td>
<td></td>
<td>4,680</td>
</tr>
<tr>
<td>Total Annual Operation and Maintenance Costs:</td>
<td><strong>4,650</strong></td>
<td><strong>4,886</strong></td>
</tr>
</tbody>
</table>
Desiccant Dehydrator Economics

NPV = $13,315  IRR = 39%  Payback = 25 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></td>
<td>$4,886</td>
<td>$4,886</td>
<td>$4,886</td>
<td>$4,886</td>
<td>$4,886</td>
</tr>
<tr>
<td>O&amp;M costs - Desiccant</td>
<td>-$4,650</td>
<td>-$4,650</td>
<td>-$4,650</td>
<td>-$4,650</td>
<td>-$4,650</td>
<td>-$4,650</td>
</tr>
<tr>
<td>Value of gas saved¹</td>
<td></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 value²</td>
<td>$12,382</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-$15,787</td>
<td>$7,677</td>
<td>$7,667</td>
<td>$7,667</td>
<td>$7,667</td>
<td>$7,667</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 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