Natural Gas Dehydration: Agenda

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

- Dehydrators and pumps account for:
  - 15% of methane emissions in the U.S. production, gathering, and boosting sectors (excl. offshore operations)


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
  - Most use Triethylene Glycol (TEG)
- Glycol dehydrators generate 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
- Glycol Contactor
  - Dry Sales Gas
  - Driver
  - Glycol Energy Exchange Pump
    - Lean TEG
    - Pump
  - Rich TEG
- Fuel Gas
- Water/Methane/VOCs/HAPs To Atmosphere
- Glycol Reboiler/Regenerator
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](chart.png)

- **With FTS**: 80% for <1 MMcf/day, 70% for 1-5 MMcf/day, 60% for >5 MMcf/day
- **Without FTS**: 10% for <1 MMcf/day, 20% for 1-5 MMcf/day, 40% for >5 MMcf/day

Source: API

MMcf = Million cubic feet

Logic Flow Diagram (LFD)
FTS 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

Low Capital Cost/Quick Payback
Flash Tank Costs

- U.S. EPA 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

Glycol Contactor

Dry Sales Gas

Inlet Wet Gas

Glycol Reboiler/Regenerator

Rich TEG

Lean TEG

Gas Driver

Electric Motor Driven Pump

Fuel Gas

Water/Methane/VOCs/HAPs To Atmosphere
### 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>400 to 40,000 Mcf/year</td>
<td>Immediate</td>
</tr>
<tr>
<td>Install Flash Tank</td>
<td>$6,500 to $18,800</td>
<td>Negligible</td>
<td>700 to 10,500 Mcf/year</td>
<td>0.4 to 1.9 years</td>
</tr>
<tr>
<td>Install Electric Pump</td>
<td>$1,400 to $13,000</td>
<td>$165 to $4,300</td>
<td>360 to 36,000 Mcf/year</td>
<td>0.1 to 0.8 years</td>
</tr>
</tbody>
</table>

¹ – Gas price of $5/Mcf
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
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 gasses 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; 8°C @ 30 atm</td>
<td>Least expensive</td>
</tr>
<tr>
<td>Lithium chloride</td>
<td>&lt; 60°C @ 17 atm</td>
<td>More expensive</td>
</tr>
</tbody>
</table>

Source: Van Air
Desiccant Performance Curves at Maximum Pipeline Moisture Spec (3.2 kg water / MMcf)
Desiccant Dehydrator Schematic

- **Filler Hatch**
- **Drain Valve**
- **Support Grid**
- **Drying Bed**
- **Brine**
- **Desiccant Tablets**
- **Inlet Wet Gas**
- **Dry Sales Gas**

**Labels:**
- Maximum Desiccant Level
- Minimum Desiccant Level
- Minimum Desiccant Level
- Maximum Desiccant Level
Gas Vented from Glycol Dehydrator

Example:

GV = ?
F = 1 MMcf/day
W = 10-3.2 kg H₂O/MMcf
R = 25 L/kg
OC = 150%
G = 0.8 ft³/L

Calculate:

GV = \( \frac{F \times W \times R \times OC \times G \times 365 \text{ days/year}}{1,000 \text{ cf/Mcf}} \)

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)

Glycol Dehydrator Unit
Source: GasTech
Desiccant Dehydrator Savings: Gas Vented from Pneumatic Controllers

Example:

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

Where:

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

Calculate:

GE = EF * PD
GE = **504 Mcf/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 6.4 kg water/MMcf
  - Reboiler heat rate: 281 Btu/L 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 8°C to 16°C
  - Specific heat of natural gas: 0.441 Btu/kg-°C
  - Density of natural gas: 0.0228 kg/cf
  - Efficiency: 70%

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

Example:
GLD = ?
ID = 20 inch (0.508 m)
H = 76.75 inch (1.949 m)
%G = 45%
P₁ = 1 atm
P₂ = 31 atm
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 (atm)
P₂ = Gas pressure (atm)
T = Time between refilling (days)

Calculate:
\[ GLD = \frac{H \times ID^2 \times \pi \times P₂ \times %G \times 365 \text{ days/year}}{4 \times P₁ \times T \times 1,000 \text{ cf/Mcf}} \]

\[ GLD = 10 \text{ Mcf/year} \]
## Natural Gas Savings

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas vented from glycol dehydrator:</td>
<td>69 Mcf/year</td>
</tr>
<tr>
<td>Gas vented from pneumatic controls:</td>
<td>+504 Mcf/year</td>
</tr>
<tr>
<td>Gas burned in glycol reboiler:</td>
<td>+17 Mcf/year</td>
</tr>
<tr>
<td>Gas burned in gas heater:</td>
<td>+483 Mcf/year</td>
</tr>
<tr>
<td>Minus desiccant dehydrator vent:</td>
<td>-10 Mcf/year</td>
</tr>
<tr>
<td>Total savings:</td>
<td>1,063 Mcf/year</td>
</tr>
</tbody>
</table>

Value of gas savings (@ $5/Mcf): $5,315/year
## Desiccant Dehydrator and Glycol Dehydrator Cost Comparison

Based on 1 MMcf per day natural gas operating at 30 atm and 8°C
Installation costs assumed at 75% of the equipment cost

### Type of Costs and Savings

<table>
<thead>
<tr>
<th>Type of Costs and Savings</th>
<th>Desiccant ($/yr)</th>
<th>Glycol ($/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Implementation Costs</strong></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>12,073</td>
<td>18,573</td>
</tr>
<tr>
<td>Other costs (installation and engineering)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Implementation Costs:</strong></td>
<td>28,169</td>
<td>43,337</td>
</tr>
<tr>
<td><strong>Annual Operating and Maintenance Costs</strong></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>
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<tr>
<td>Labor cost</td>
<td>1,040</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>3,054</td>
</tr>
<tr>
<td><strong>Total Annual Operation and Maintenance Costs:</strong></td>
<td><strong>3,610</strong></td>
<td><strong>3,260</strong></td>
</tr>
</tbody>
</table>

Based on 1 MMcf per day natural gas operating at 30 atm and 8°C
Installation costs assumed at 75% of the equipment cost
Desiccant Dehydrator Economics

- Payback = 3.3 years
  - Without potential carbon market benefits

<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 (US$)</td>
<td>-28,169</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avoided O&amp;M costs (US$)</td>
<td></td>
<td>3,260</td>
<td>3,260</td>
<td>3,260</td>
<td>3,260</td>
<td>3,260</td>
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<tr>
<td>O&amp;M costs - Desiccant (US$)</td>
<td>-3,610</td>
<td>-3,610</td>
<td>-3,610</td>
<td>-3,610</td>
<td>-3,610</td>
<td>-3,610</td>
</tr>
<tr>
<td>Value of gas Saved¹ (US$)</td>
<td>5,135</td>
<td>5,135</td>
<td>5,135</td>
<td>5,135</td>
<td>5,135</td>
<td>5,135</td>
</tr>
<tr>
<td>Glycol dehy. salvage value² (US$)</td>
<td>12,382</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (US$)</td>
<td>-15,787</td>
<td>4,785</td>
<td>4,785</td>
<td>4,785</td>
<td>4,785</td>
<td>4,785</td>
</tr>
</tbody>
</table>

¹ Gas price = US$5/Mcf
² Salvage value estimated as 50% of glycol dehydrator capital cost
Industry Experiences

▪ One Partner installed flash tank separators on its glycol dehydrators
  – Recovers 98% of methane from glycol degassing
  – 1,200 to 1,700 Mcf/year reductions per dehydrator
  – US$5,925 to US$8,295/year\(^1\) savings per dehydrator

▪ Another Partner routes gas from flash tank separator to fuel gas system
  – 8.75 MMcf/year reductions per dehydrator
  – US$43,750/year\(^1\) savings per dehydrator

\(^1\) Gas valued at $5/Mcf
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