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
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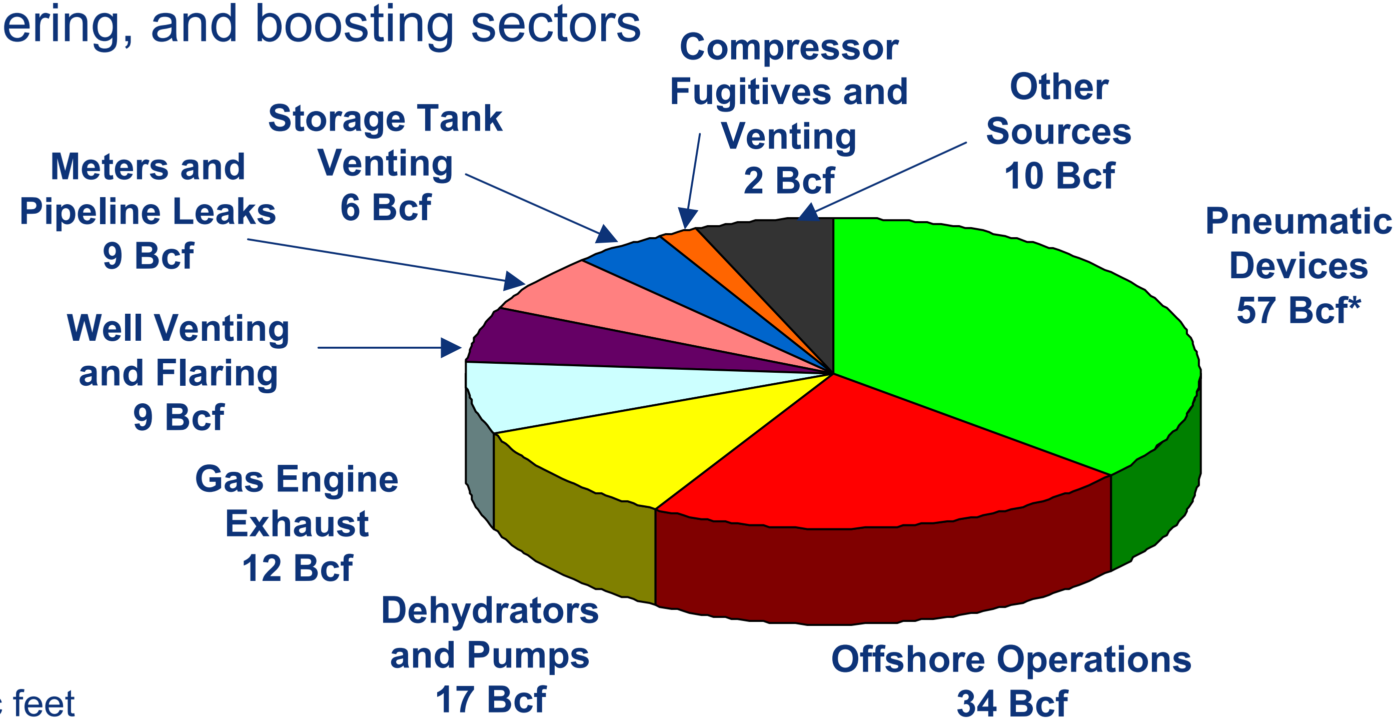
epa.gov/gasstar

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

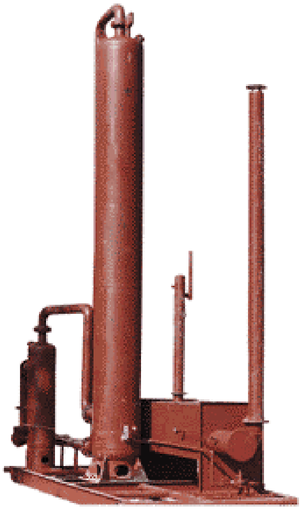


*Bcf = billion cubic feet

EPA. *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 – 2005.* April, 2007. Available on the web at: http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissions.html
Natural Gas STAR reductions data shown as published in the inventory.

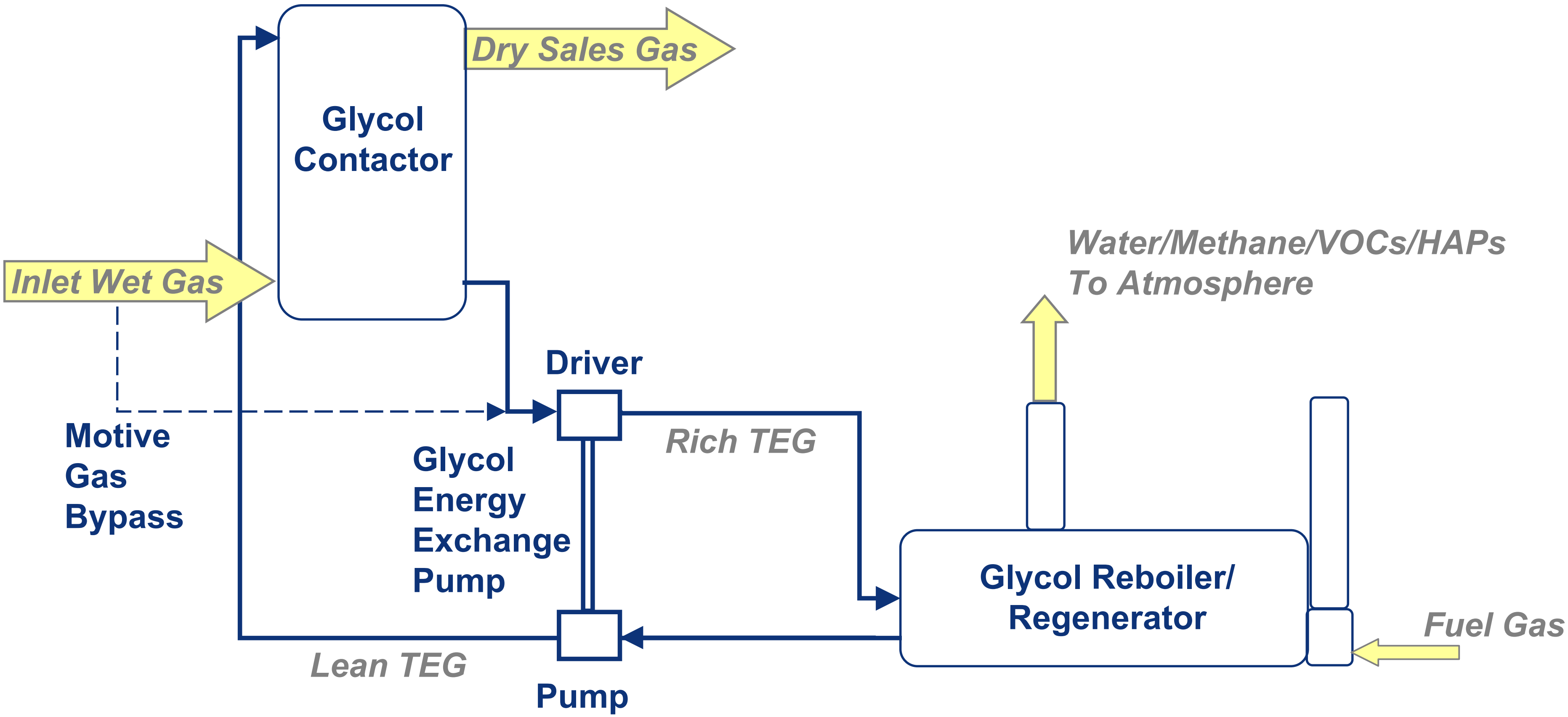
What is the Problem?

- 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



Methane Recovery

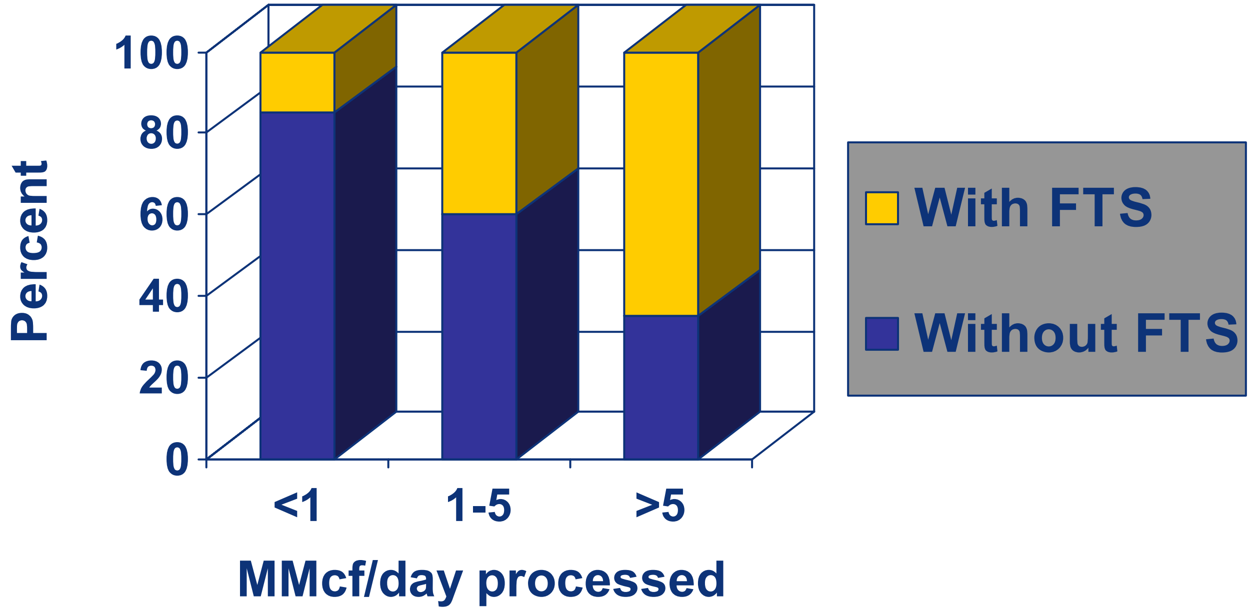
- Optimize glycol circulation rates
- Flash tank separator (FTS) installation
- Electric pump installation
- Zero emission dehydrator
- Replace glycol unit with desiccant dehydrator
- Other opportunities

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

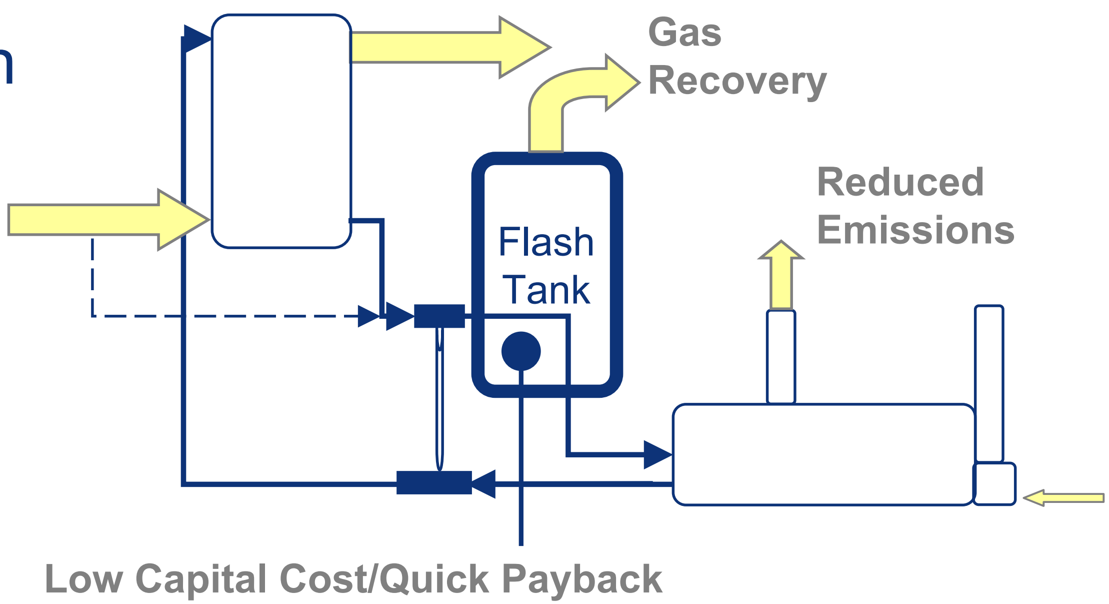


MMcf = Million cubic feet

Source: API

Methane Recovery

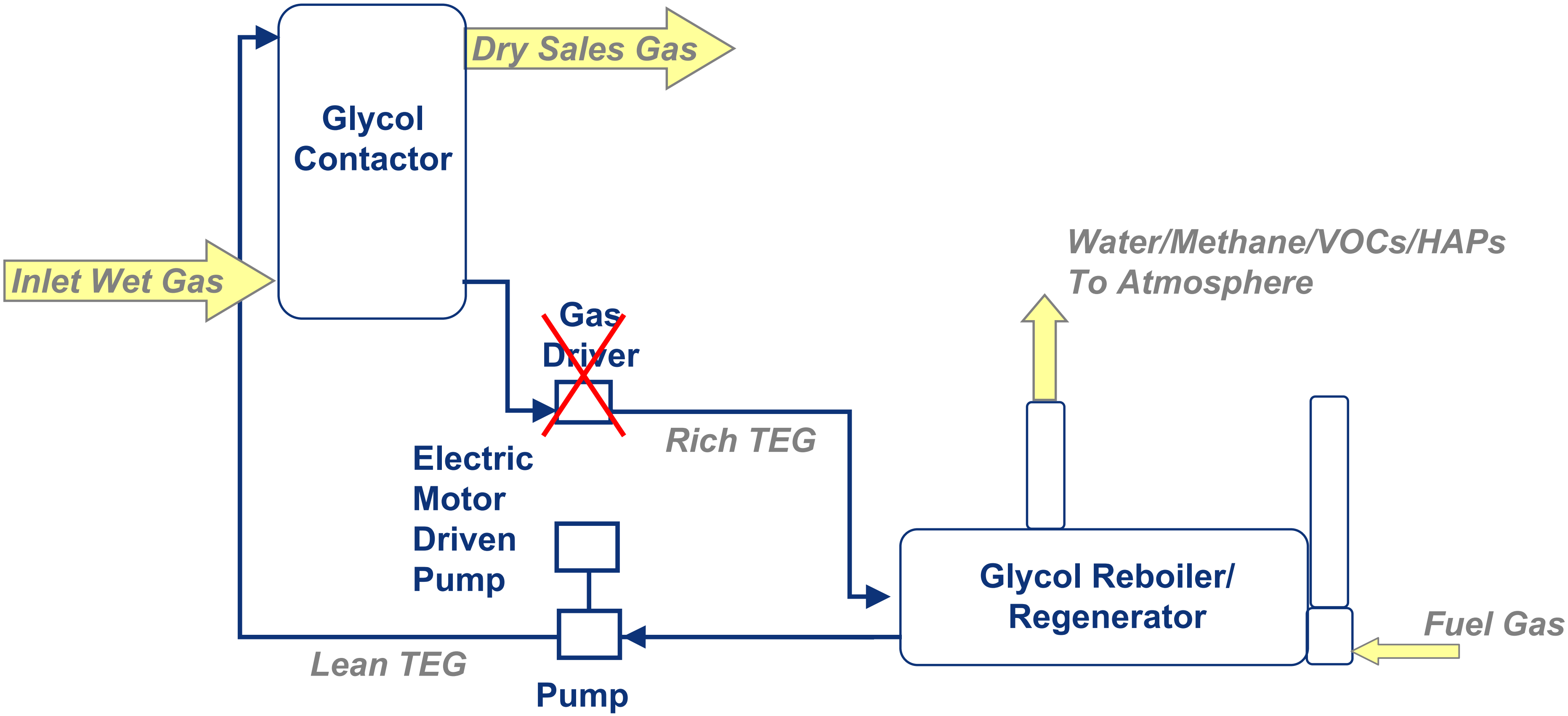
- Recovers about 90% of methane emissions
- Reduces VOCs by 10 to 90%
- Must have an outlet for low pressure gas
  - Fuel
  - Compressor suction
  - Vapor recovery unit



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 $1,200 to $2,500 per flash tank
- Negligible Operational & Maintenance (O&M) costs

Electric Pump Eliminates Motive 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

Option	Capital Costs	Annual O&M Costs	Emissions Savings	Payback Period[1]
Optimize Circulation Rate	Negligible	Negligible	394 to 39,420 Mcf/year	Immediate
Install Flash Tank	$6,500 to $18,800	Negligible	710 to 10,643 Mcf/year	4 to 11 months
Install Electric Pump	$1,400 to $13,000	$165 to $6,500	360 to 36,000 Mcf/year	< 1 month to several years

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

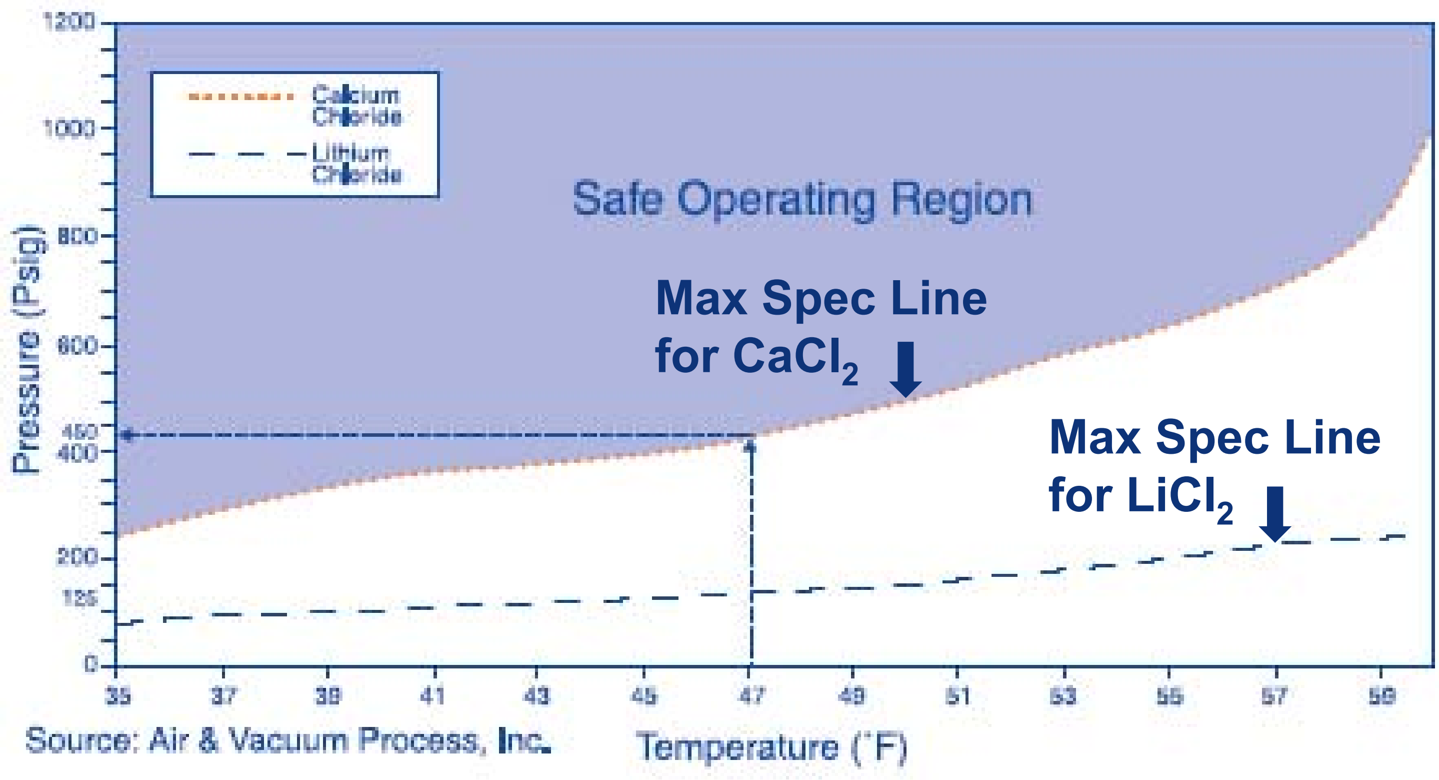
Replace Glycol Unit with Desiccant Dehydrator

- Desiccant Dehydrator
  - Wet 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

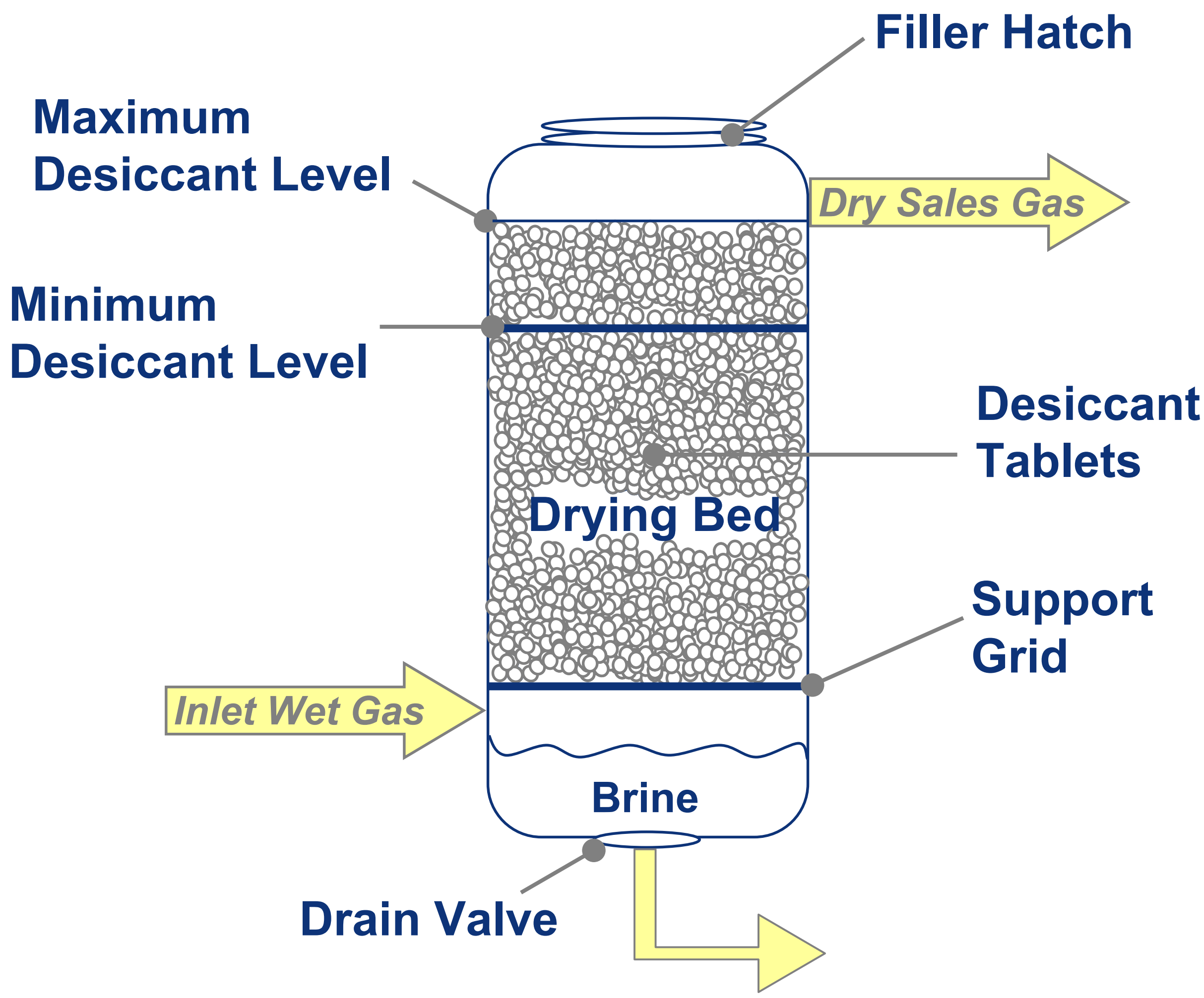
Hygroscopic Salts	Typical T and P for Pipeline Spec	Cost
Calcium chloride	<47^{o}F @ 440 psig	Least expensive
Lithium chloride	<60^{o}F @ 250 psig	More expensive

Desiccant Performance

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



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

$B = 1/3$

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

Calculate:

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

$D = 1 * (21 - 7) * 1/3$

D = **4.7 pounds desiccant/day**

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:

$$ID = 12 * \sqrt{\frac{4*D*T*12}{H*B*\pi}} = 16.2 \text{ inch}$$

Standard ID available = **20 inch**

Source: Van Air

cf = cubic feet

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 H_2O/MMcf

R = 3 gallons/pound

OC = 150%

G = 3 cf/gallon

Where:

GV= Gas vented annually (Mcf/year)

F = Gas flow rate (MMcf/day)

W = Inlet-outlet H_2O content (pounds/MMcf)

R = Glycol/water ratio (rule of thumb)

OC = Percent over-circulation

G = Methane entrainment (rule of thumb)

Calculate:

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

GV = **69 Mcf/year**

Glycol Dehydrator Unit
Source: GasTech

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 bleed/ pneumatic devices per year)

Calculate:

GE = EF * PD

GE = 504 Mcf/year

Norriseal Pneumatic Liquid Level Controller

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 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%

P_1 = 15 Psia

P_2 = 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

P_1 = Atmospheric pressure (Psia)

P_2 = Gas pressure (Psig)

T = Time between refilling (days)

Calculate:

$$GLD = \frac{H * ID^2 * \pi * P_2 * \%G * 365 \text{ days/year}}{4 * P_1 * T * 1{,}000 \text{ cf/Mcf}}$$

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

Type of Costs and Savings	Desiccant ($/yr)	Glycol ($/yr)
Implementation Costs		
Capital Costs		
Desiccant (includes the initial fill)	16,097	
Glycol		24,764
Other costs (installation and engineering)	12,073	18,573
Total Implementation Costs:	28,169	43,337
Annual Operating and Maintenance Costs		
Desiccant		
Cost of desiccant refill ($1.50/pound)	2,556	
Cost of brine disposal	14	
Labor cost	2,080	
Glycol		
Cost of glycol refill ($4.50/gallon)		206
Material and labor cost		4,680
Total Annual Operation and Maintenance Costs:	**4,650**	**4,886**

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= $13,315 IRR= 39% Payback= 25 months

Type of Costs and Savings	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Capital costs	-$28,169					
Avoided O&M costs		$4,886	$4,886	$4,886	$4,886	$4,886
O&M costs - Desiccant		-$4,650	-$4,650	-$4,650	-$4,650	-$4,650
Value of gas saved [1]		$7,441	$7,441	$7,441	$7,441	$7,441
Glycol dehy. salvage value [2]	$12,382					
Total	-$15,787	$7,677	$7,667	$7,667	$7,667	$7,667

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 an practices
- Actual costs and benefits