Methane to Markets

Production Sector Emission Reduction Opportunities

Advancing Project Development in India through Public Private Partnerships

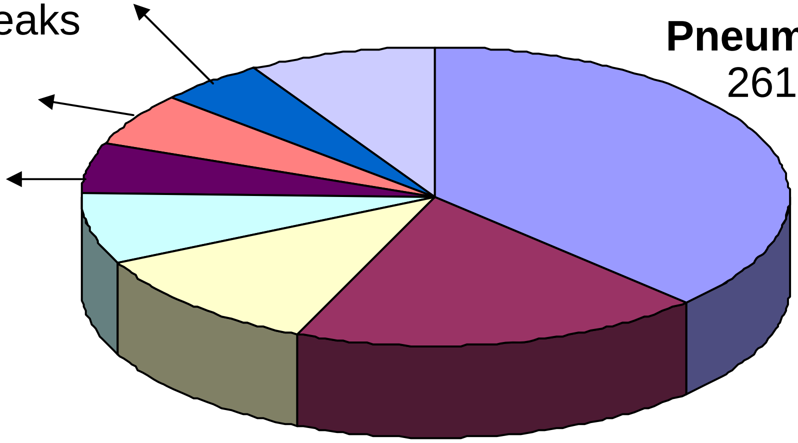
22 – 23 February, 2007

Production Sector Emission Reduction Opportunities: Agenda

- Indian Oil and Gas Production Sector Emissions
- Vapor Recovery Units (VRUs)
- Pneumatic Devices
- Dehydrators
- Discussion Questions

Indian Oil and Gas Production Sector Emissions

- An estimated 261 million m^3 from pneumatic devices, 79 million m^3 from dehydrators and pumps, and 31 million m^3 of methane from crude oil storage tanks is lost each year in India



Storage Tank Venting
31 million m^3
1.1 Bcf

Other Sources
60 million m^3
2.1 Bcf

Pneumatic Devices
261 million m^3
9.2 Bcf

Meters and Pipeline Leaks
40 million m^3
1.4 Bcf

Well Venting and Flaring
40 million m^3
1.4 Bcf

Gas Engine Exhaust
51 million m^3
1.8 Bcf

Dehydrators & Pumps
79 million m^3
2.8 Bcf

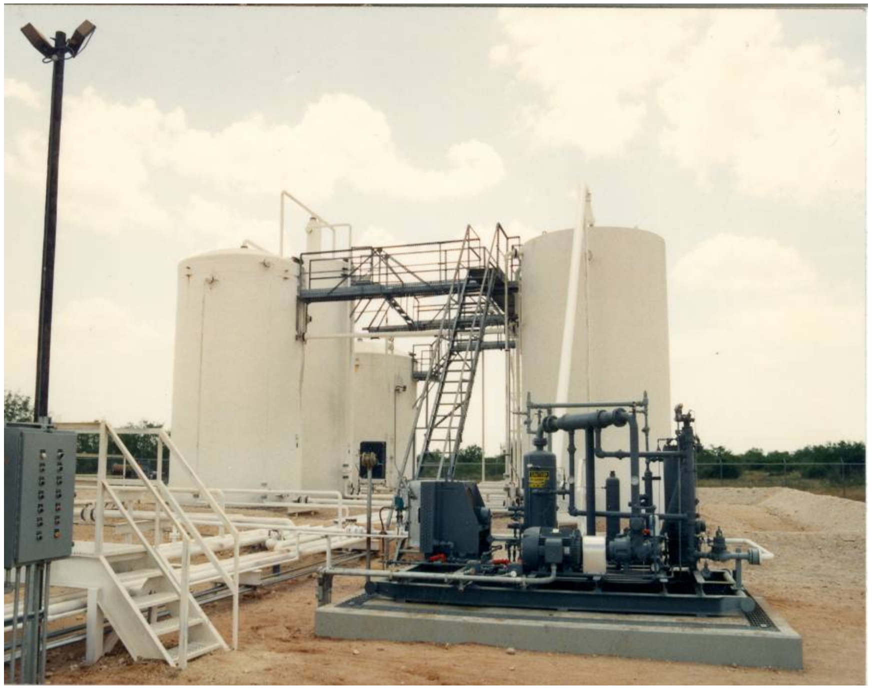
Offshore Operations
133 million m^3
4.7 Bcf

Sources: *US Natural Gas STAR program success points to global opportunities to cut methane emissions cost-effectively*, Oil and Gas Journal, July 12, 2004
Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004

Vapor Recovery Units (VRUs)

Agenda

- Methane Losses
- Methane Recovery
- Lessons Learned



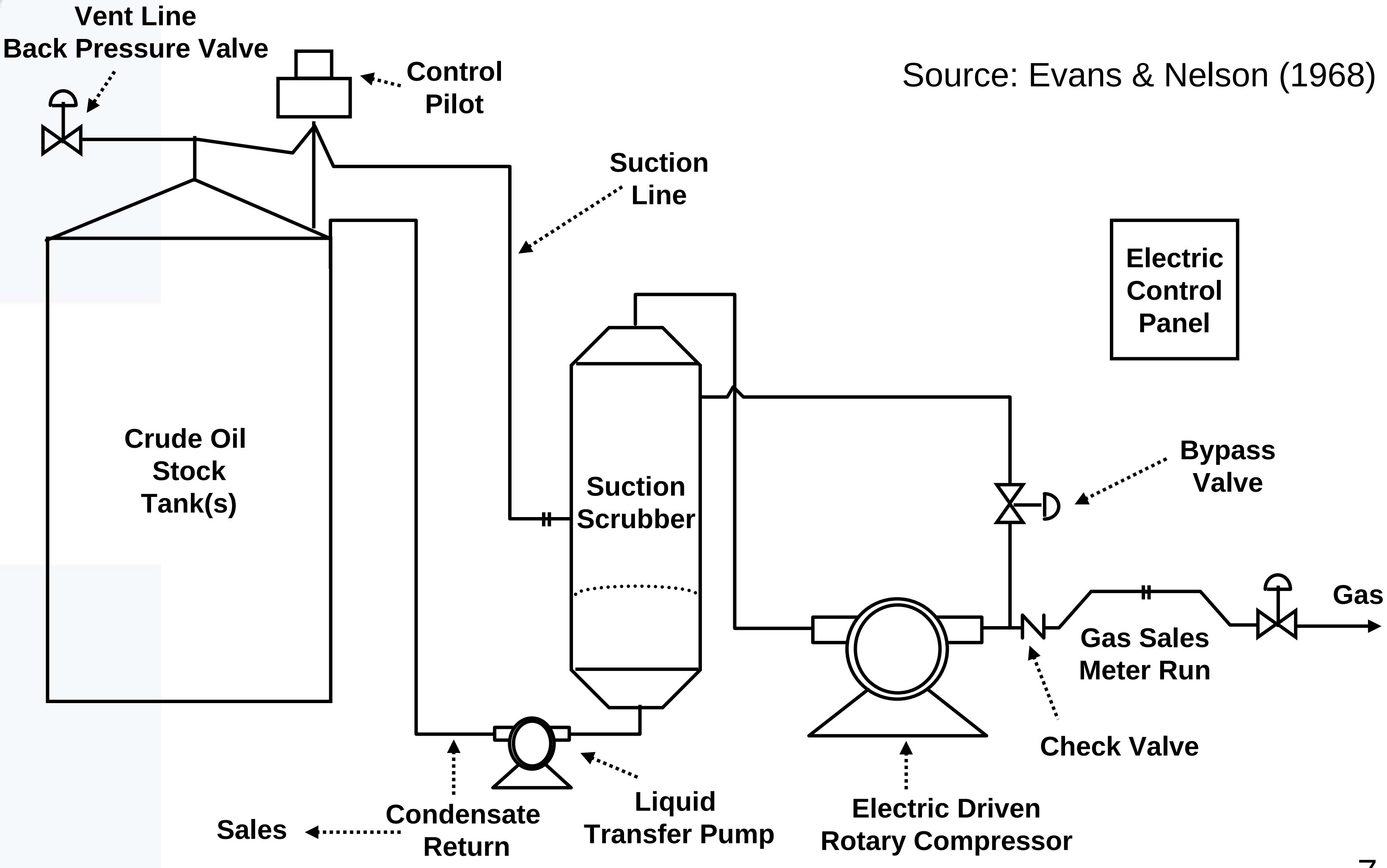
Methane Losses from Storage Tanks

- A production storage tank battery can vent 140 to 2,720 thousand m^3 (4,900 – 96,000 Mcf) of natural gas and light hydrocarbon vapors to the atmosphere each year
  - Vapor losses are primarily a function of oil throughput, gravity, and gas-oil separator pressure
- Flash losses
  - Occur when crude is transferred from a gas-oil separator at higher pressure to a storage tank at atmospheric pressure
- Working losses
  - Occur when crude levels change and when crude in tank is agitated
- Standing losses
  - Occur with daily and seasonal temperature and barometric pressure changes

Methane Savings: Vapor Recovery

- Vapor recovery can capture up to 95% of hydrocarbon vapors from tanks
- Recovered vapors have higher heat content than pipeline quality natural gas
- Recovered vapors are more valuable than natural gas and have multiple uses
  - Re-inject into sales pipeline
  - Use as on-site fuel
  - Send to processing plants for recovering valuable natural gas liquids

Conventional Vapor Recovery Unit



Source: Evans & Nelson (1968)

Vapor Recovery Installations

Source: Hy-Bon Engineering

Criteria for Vapor Recovery Unit Locations

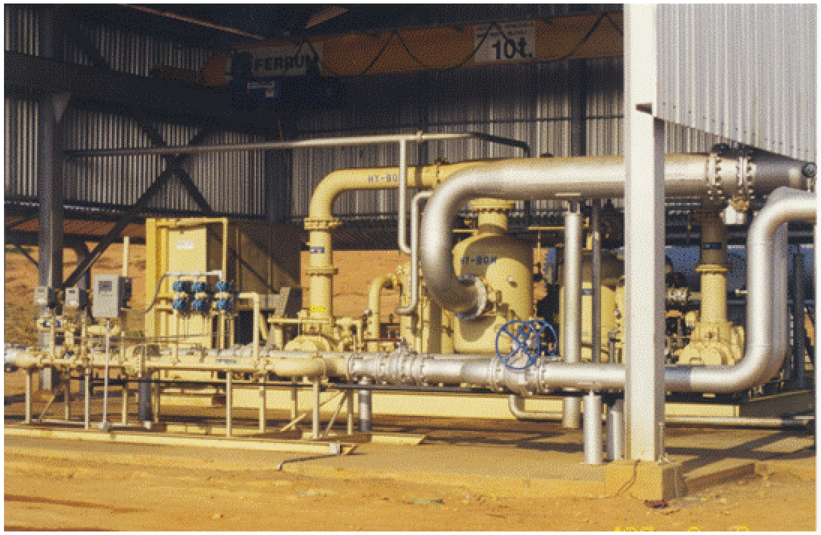
- Steady source and sufficient quantity of losses
  - Crude oil stock tank
  - Flash tank, heater/treater, water skimmer vents
  - Gas pneumatic controllers and pumps
- Outlet for recovered gas
  - Access to low pressure gas pipeline, compressor suction, or on-site fuel system

Dual VRU bound for Venezuela - one of 17 units capturing gas currently for Petroleos de Venezuela. Flooded screw compressor for volumes to 5.0 million cubic feet per day; up to 200 pounds per square inch, gauge (psig).

Methane to Markets

Quantify Volume of Losses

- Estimate losses from chart based on oil characteristics, pressure, and temperature at each location (± 50%)
- Estimate emissions using the E&P Tank Model (± 20%)
- Engineering equations – Vasquez-Beggs (± 20%)
- Measure losses using recording manometer and well tester or ultrasonic meter over several cycles (± 5%)
  - This is the best approach for facility design

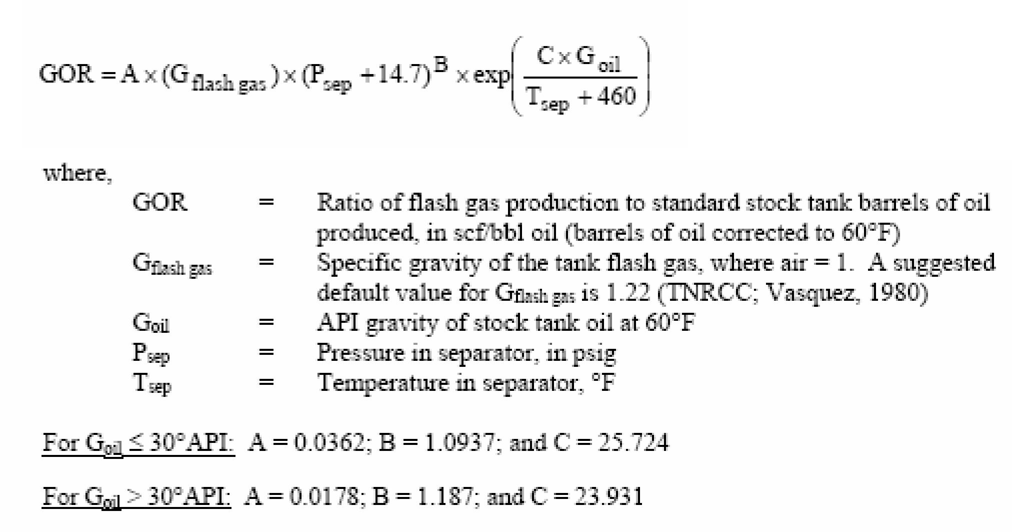


PDVSA has installed vapor recovery in the majority of their production facilities in Eastern Venezuela.

Final Stage of Separation

- Atmospheric tanks may emit large amounts of tank vapors at relatively low separator pressure

Vasquez-Beggs Equation



$$GOR = A \times (G_{flash\ gas}) \times (P_{sep} + 14.7)^{B} \times \exp\left(\frac{C \times G_{oil}}{T_{sep} + 460}\right)$$

where,

GOR = Ratio of flash gas production to standard stock tank barrels of oil produced, in scf/bbl oil (barrels of oil corrected to 60°F)

$G_{flash\ gas}$ = Specific gravity of the tank flash gas, where air = 1. A suggested default value for $G_{flash\ gas}$ is 1.22 (TNRCC; Vasquez, 1980)

G_{oil} = API gravity of stock tank oil at 60°F

P_{sep} = Pressure in separator, in psig

T_{sep} = Temperature in separator, °F

For $G_{oil} \leq 30°$API: A = 0.0362; B = 1.0937; and C = 25.724

For $G_{oil} > 30°$API: A = 0.0178; B = 1.187; and C = 23.931

Example for Bombay Crude

- G_{oil} – 39.2º API
- $G_{flash\ gas}$ – 1.22
- T_{sep} – 38º C (100ºF)
- P_{sep} – 1.2 atm (3 psig)
- GOR = **1 m^3/tonne**
  = **3.5 scf/bbl**

psig – pounds per square inch, gauge
scf – standard cubic feet
bbl – barrels

Is Recovery Profitable?

- Economics of installing vapor recovery units are attractive, particularly for larger units

Financial Analysis for a conventional VRU project[1]

Capacity		Installation & Capital Costs[2]	Operating & Maintenance	Value of Gas[3]	Payback	Internal Rate of Return
(m^3/day)	(Mcf/day)	($)	($/Year)	($/Year)	(Months)	(%)
700	25	35,738	7,367	30,300	19	58
1,400	50	46,073,	8,419	60,600	11	111
2,800	100	55,524	10,103	121,360	6	200
5,600	200	74,425	11,787	242,725	4	310
14,100	500	103,959	16,839	606,810	3	567

1 - All costs and revenues are represented in U.S. economics
2 - Unit Cost plus estimated installation at 75% of unit cost
3 - $7 x 1/2 capacity x 365 x 95%

Methane to Markets

Project Summary for India

- Install Vapor Recovery on Crude Oil Storage Tanks

Project Description: 2,800 m^3 per day (100 Mcf/day) of vapor recovery capacity installed on a crude oil stock tank battery.

Gas Saved:	491,000 cubic meters per year (17,300 Mcf per year)
Sales Value[1]:	$51,900
Capital and Installation Cost[2]:	($67,700)
Operating and Maintenance Cost[2]:	($400) per year
Payback Period:	16 months

1 – Gas price in India $3/Mcf ($106/thousand m^3)

2 – All costs have been converted to an Indian basis using the methodology described in *US Natural Gas STAR program success points to global opportunities to cut methane emissions cost-effectively*, Oil and Gas Journal, July 12, 2004

Lessons Learned

- Vapor recovery can yield generous returns when there are market outlets for recovered gas
  - Recovered high heat content gas has extra value
  - Vapor recovery technology can be highly cost-effective in most general applications
  - Venturi jet models work well in certain niche applications, with reduced operating and maintenance costs
- VRU should be sized for maximum volume expected from storage tanks (rule-of-thumb is to double daily average volume)

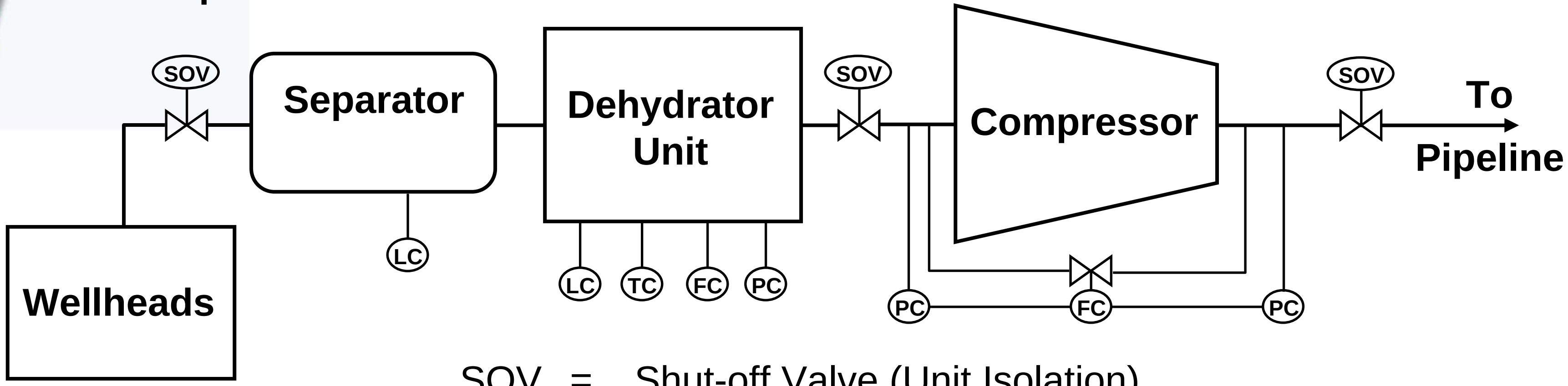
Pneumatic Devices

Agenda

- Methane Losses
- Methane Recovery
- Lessons Learned
- Recommendations

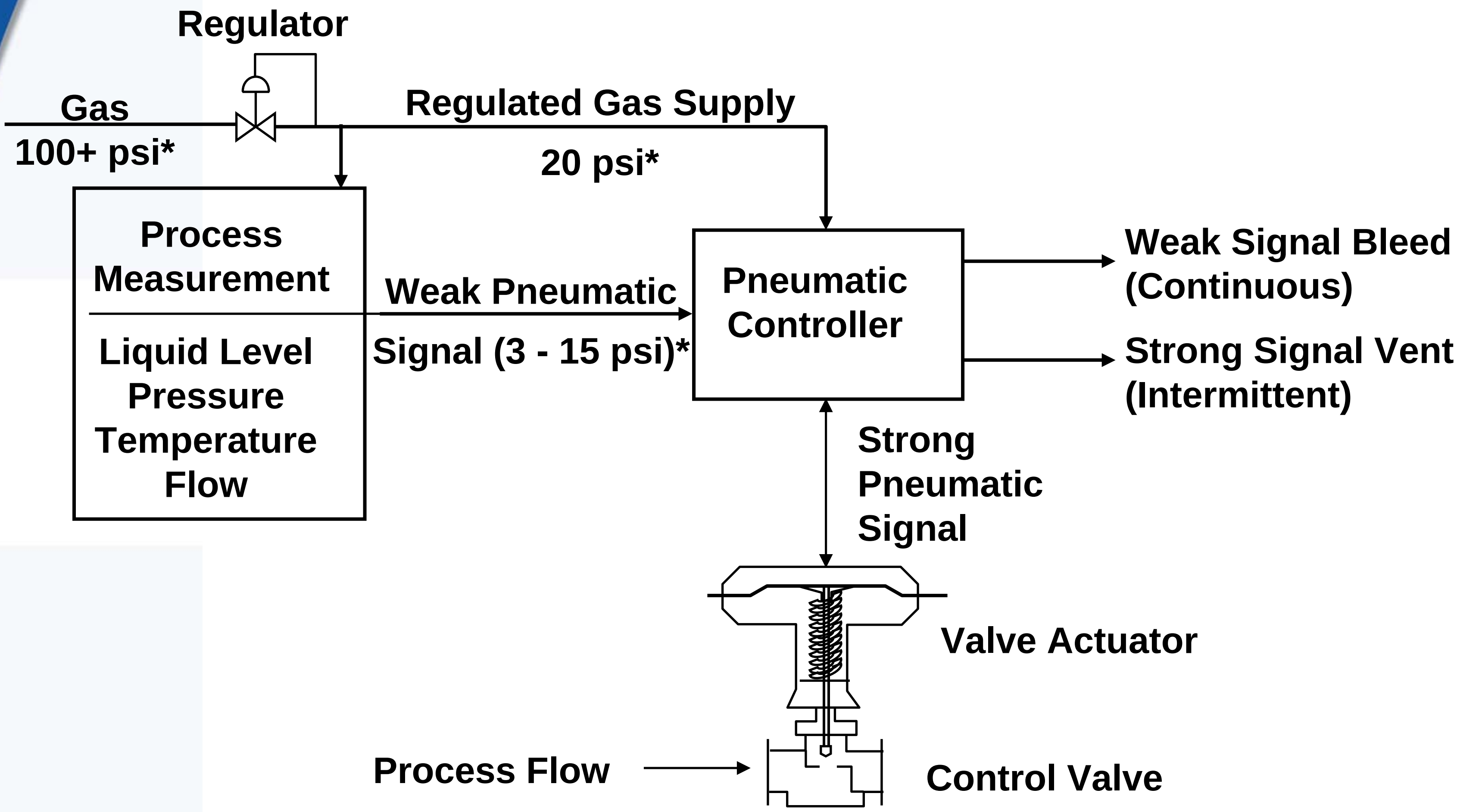
Methane Losses from Pneumatic Devices

- Pneumatic devices account for an estimated 37% of methane emissions in the Indian oil and gas production sector



SOV = Shut-off Valve (Unit Isolation)
LC = Level Control (Separator, Contactor, TEG Regenerator)
TC = Temperature Control (Regenerator Fuel Gas)
FC = Flow Control (TEG Circulation, Compressor Bypass)
PC = Pressure Control (FTS Pressure, Compressor Suction/Discharge)

How Gas Pneumatic Devices Work



* 14.7 pounds per square inch (psi) = 1 atmosphere

Methane Emissions

- As part of normal operations, pneumatic devices release natural gas to atmosphere
- High-bleed devices bleed in excess of 4 m^3 per day (6 cf/hour)
  - Equates to >1,460 m^3/year (>50 Mcf/year)
  - Typical high-bleed pneumatic devices bleed an average of 3,965 m^3/year (140 Mcf/year)
- Actual bleed rate is largely dependent on device's design

Methane Recovery from Pneumatic Devices

- Option 1: Replace high-bleed devices with low-bleed devices
  - Replace at end of device's economic life
  - Typical cost range from $700 to $3000* per device
- Option 2: Retrofit controller with bleed reduction kits
  - Retrofit kit costs ~ $675*
  - Payback time ~ 6 months
- Option 3: Maintenance aimed at reducing losses
  - Field survey of controllers
  - Re-evaluate the need for pneumatic positioners
  - Cost is low

Field experience shows that up to 80% of all high-bleed devices can be replaced or retrofitted with low-bleed equipment

*All costs represented in U.S. economics

Five Steps for Reducing Methane Emissions from Pneumatic Devices

LOCATE and INVENTORY high-bleed devices

ESTABLISH the technical feasibility and costs of alternatives

ESTIMATE the savings

EVALUATE economics of alternatives

DEVELOP an implementation plan

Suggested Analysis for Replacement

- Replacing high-bleed controllers at end of economic life
  - Determine incremental cost of low-bleed device over high-bleed equivalent
  - Determine gas saved with low-bleed device using manufacturer specifications
  - Compare savings and cost
- Early replacement of high-bleed controllers
  - Compare gas savings of low-bleed device with full cost of replacement

Implementation[a]	Replace at End of Life	Early Replacements	
		Level Control	Pressure Control
Cost ($)	150 – 250[b]	513	1,809
Annual Gas Savings (m^3)	1,400 – 5,660	4,700	6,460
Annual Gas Savings (Mcf)	50 – 200	166	228
Annual Value of Saved Gas ($)[c]	350 – 1,400	1,165	1,596
IRR (%)	138 – 933	226	84
Payback (months)	2 – 9	6	14

[a] All data based on Partners' experiences and represented in U.S. economics
[b] Range of incremental costs of low-bleed over high bleed equipment
[c] Gas price is assumed to be $7/Mcf ($250/thousand m^3)

Suggested Analysis for Retrofit

- Retrofit of low-bleed kit
  - Compare savings of low-bleed device with cost of conversion kit
  - Retrofitting reduces emissions by average of 90%

	Retrofit[a]
Implementation Costs[b]	**$675**
Bleed rate reduction (m^3/device/year)	**6,200**
Bleed rate reduction (Mcf/device/year)	**219**
Value of gas saved ($/year) [c]	**1533**
Payback (months)	**6**
Internal Rate of Return	**226%**

[a] On high-bleed controllers

[b] All data based on Partners' experiences and represented in U.S. economics.

[c] Gas price is assumed to be $7/Mcf ($250/thousand m^3)

Suggested Analysis for Maintenance

- For maintenance aimed at reducing gas losses
  - Measure gas loss before and after procedure
  - Compare savings with labor (and parts) required for activity

	Reduce supply pressure	Repair & retune	Change settings	Remove valve positioners
Implementation Cost ($)[a]	**207**	**31**	**0**	**0**
Gas savings (m^3/year)	**4,960**	**1,250**	**2,500**	**4,470**
Gas savings (Mcf/year)	**175**	**44**	**88**	**158**
Value of gas saved ($/year)[b]	**1,225**	**308**	**616**	**1,106**
Payback (months)	**3**	**2**	**<1**	**<1**
IRR	**592%**	**994%**	**--**	**--**

[a] All data based on Partners' experiences and represented in U.S. economics

[b] Gas price is assumed to be $7/Mcf ($250/thousand m^3)

Project Summary for India

- Replacing high bleed pneumatics with low bleed

Project Description: Early replacement of a high bleed pressure controller with a low bleed controller

Gas Saved:	7,400 cubic meters per year (260 Mcf per year)
Sales Value[1]:	$780
Capital and Installation Cost[2]:	($2,200)
Operating and Maintenance Cost[2]:	($0) per year
Payback Period:	3 years

[1] – Gas price in India $3/Mcf ($106/thousand m^3)

[2] – All costs have been converted to an Indian basis using the methodology described in *US Natural Gas STAR program success points to global opportunities to cut methane emissions cost-effectively*, Oil and Gas Journal, July 12, 2004

Lessons Learned

- Most high-bleed pneumatics can be replaced with lower bleed models
- Replacement options save the most gas and are often economic
- Retrofit kits are available and can be highly cost-effective
- Maintenance is a low-cost way of reducing methane emissions

Recommendations

- Evaluate all pneumatics to identify candidates for replacement and retrofit
- Choose lower bleed models in new facilities where feasible
- Identify candidates for early replacement and retrofits by doing economic analysis
- Improve maintenance
- Develop an implementation plan

Methane to Markets

Minimizing Emissions from Dehydrators

Agenda

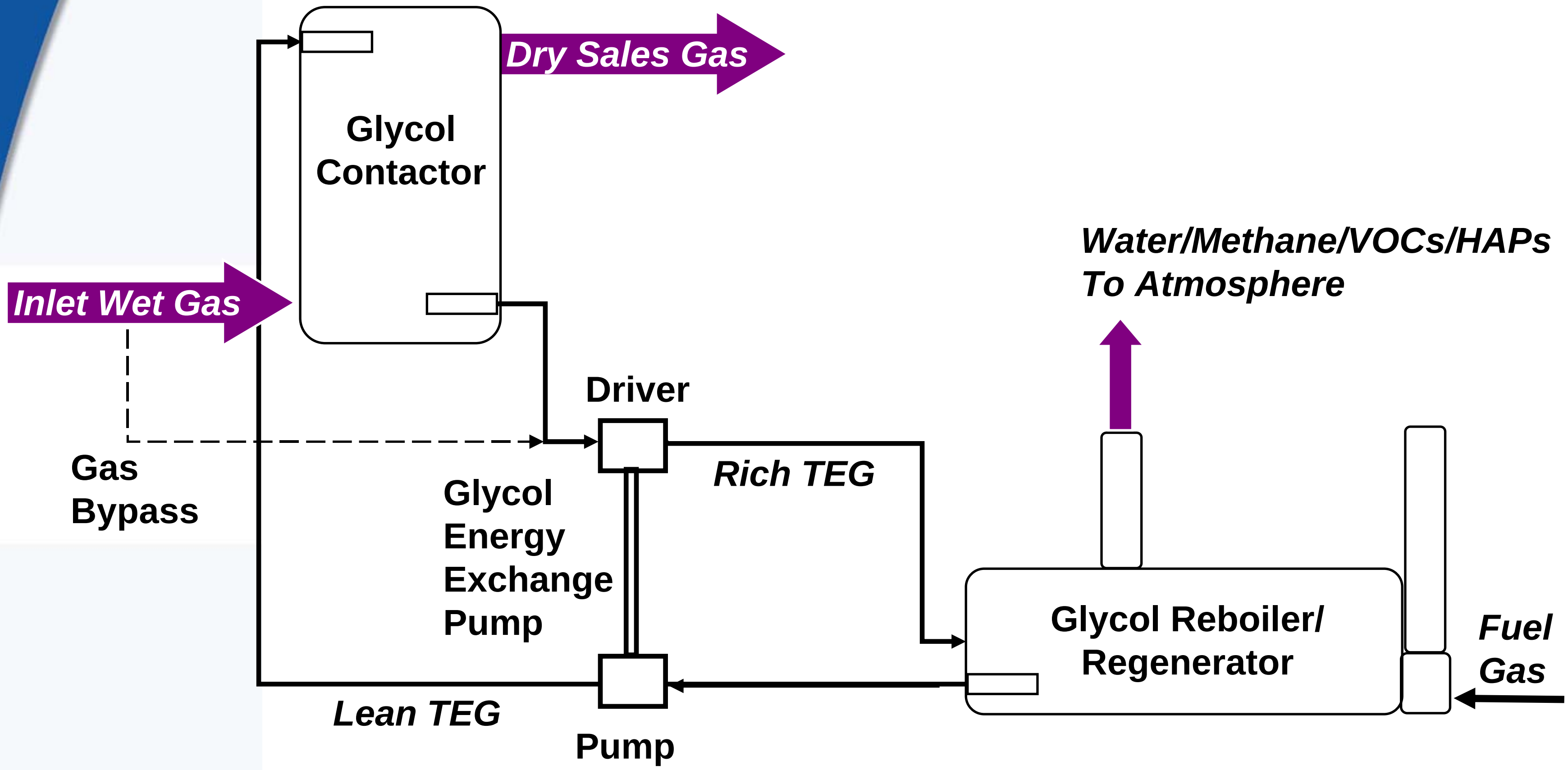
- Methane Losses
- Methane Recovery
- Recovery Options and Benefits

Methane Losses from Dehydrators

- Triethylene Glycol (TEG) is the common technology for removing moisture from produced natural gas
- Glycol also absorbs methane, reactive hydrocarbons (VOCs) and aromatics (HAPs)
- Glycol reboilers vent absorbed water, methane, VOCs, HAPs to the atmosphere
  - Wastes gas, costs money, reduces air quality
- On average in the U.S., 17,000 m^3 (600 Mcf) methane per glycol dehydrator is emitted each year from ~36,000 dehydrators

Methane to Markets

Basic Glycol Dehydrator System Process Diagram



Methane Recovery Options and Benefits

- Optimize glycol circulation rates
  - Methane emissions are directly proportional to glycol circulation rate
- Install flash tank separator (FTS)
  - Recovers all methane bypassed and most methane absorbed by glycol
- Install electric pump
  - Eliminates need to bypass gas for motive force; eliminates lean glycol contamination by rich glycol

Optimize Glycol Circulation Rate

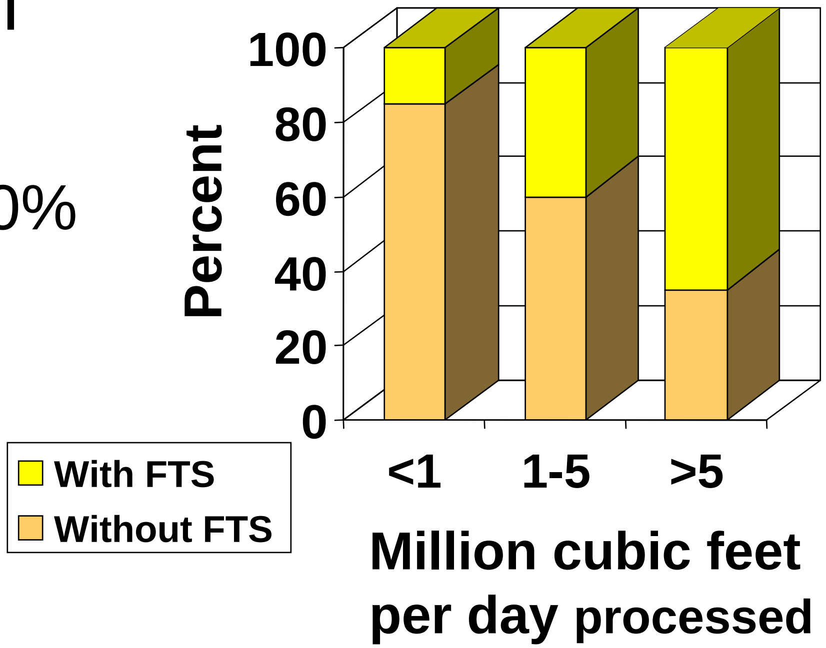
- Gas well’s initial production rate decreases over its lifespan
  - Glycol circulation rates designed for initial, highest production rate
- Glycol overcirculation results in more methane emissions without significant reduction in gas moisture content
  - Natural Gas STAR partners found circulation rates two to three times higher than necessary
  - This means two or three times more methane emissions than necessary

Overall Benefits

- Methane gas savings
- Reduced emissions of VOCs and HAPs
- Lower operating costs
  - Reduced glycol replacement costs
  - Reduced fuel costs
- Immediate payback
- No capital costs

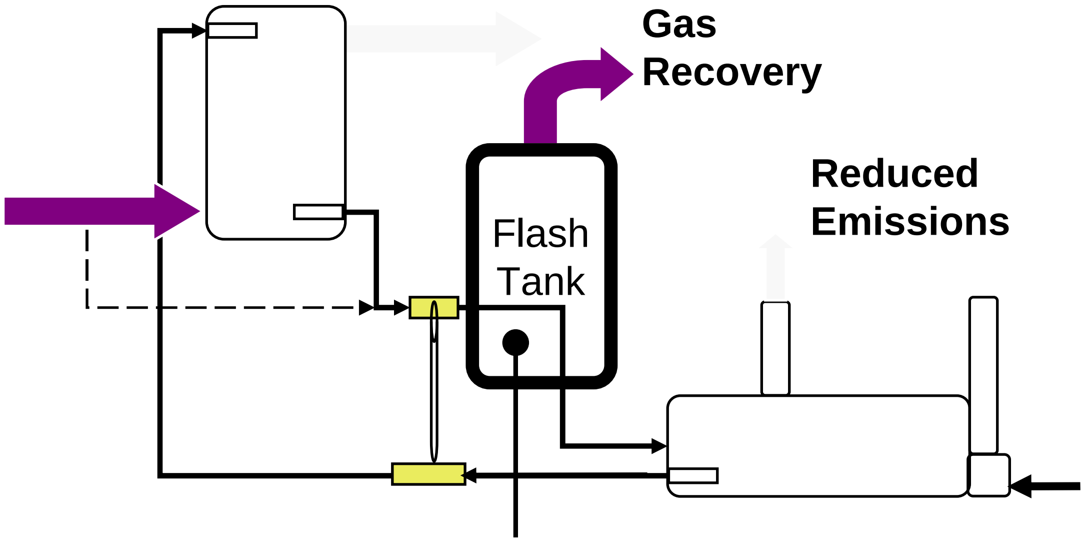
Install Flash Tank Separator (FTS)

- Most dehydrators send glycol/gas mixture from the pump driver to regenerator
- Flash tank separator operating at fuel gas system or compressor suction pressure recovers ~ 90% of methane
  - Recovers 10 to 40% of VOCs
- Many smaller units in U.S. are not using a FTS



Overall Benefits

- Gas recovery
- Reduced methane and VOC emissions
- Low capital cost; low operating costs



Gas Recovery

Reduced Emissions

Low Capital Cost/Quick Payback

Install Electric Pump

- Gas-assist pumps require additional wet production gas for mechanical advantage
  - Removes gas from the production stream
  - Largest contributor to emissions
- Gas-assist pumps leak and contaminate lean glycol with rich glycol
- Electric pump installation eliminates motive gas and lean glycol contamination
  - Economic alternative to flash tank separator
  - Requires electrical power

Overall Benefits

- Financial return on investment through gas savings
- Increased operational efficiency
- Reduced O&M costs
- Reduced air pollutants (VOCs and HAPs)

Is Recovery Profitable?

- **Three Options for Minimizing Glycol Dehydrator Emissions**

Option	Capital Costs[1]	Annual O&M Costs[1]	Emissions Savings	Payback Period)[2]
Optimize Circulation Rate	Negligible	Negligible	11,160 – 111,600 m^3/year	Immediate
Install Flash Tank	\$6,500 - \$18,800	Negligible	20,100 – 301,400 m^3/year	4 – 11 months
Install Electric Pump	\$1,400 - \$13,000	\$165 - \$6,500	10,200 – 102,000 m^3/year	< 1 month – several years

1 – All costs represented in U.S. economics

2 - Gas price of \$7/Mcf (\$250/thousand m^3)

Project Summary for India

- Installing a flash tank separator on a glycol dehydrator

Project Description: A dehydrator with an energy-exchange pump circulating glycol at 0.6 m^3/hour (150 gallon/hour)

Gas Saved:	100,500 cubic meters per year (3,548 Mcf per year)
Sales Value[1]:	$10,600
Capital and Installation Cost[2]:	($9,160)
Operating and Maintenance Cost[2]:	($0) per year
Payback Period:	10 months

1 – Gas price in India $3/Mcf ($106/thousand m^3)

2 – All costs have been converted to an Indian basis using the methodology described in *US Natural Gas STAR program success points to global opportunities to cut methane emissions cost-effectively*, Oil and Gas Journal, July 12, 2004

Methane to Markets

Discussion Questions

- To what extent are you implementing these technologies?
- How can these technologies be improved upon or altered for use in your operation(s)?
- What is stopping you from implementing these technologies (technological, economic, lack of information, manpower, etc.)?