Methane to Markets

Reducing Methane Emissions with Vapor Recovery on Storage Tanks

IAPG & US EPA Technology Transfer Workshop

November 5, 2008
Buenos Aires, Argentina

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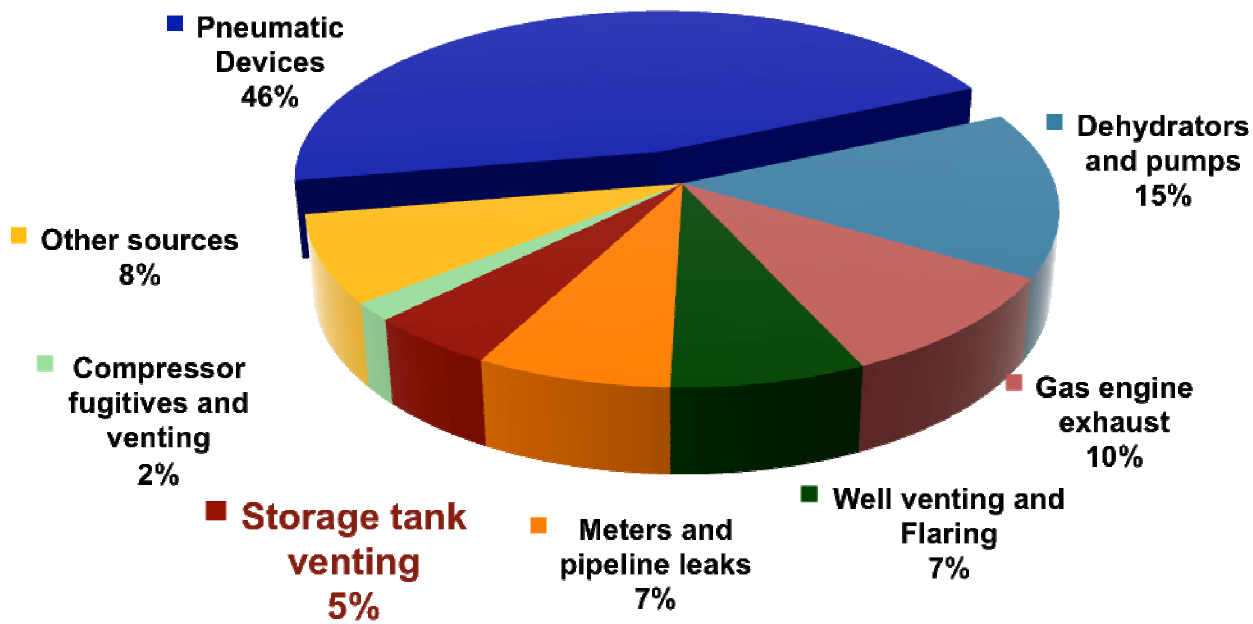
Vapor Recovery Units: Agenda

- Methane Losses
- Methane Savings
- Is Recovery Profitable?
- Industry Experience
- Project Summary for Argentina
- Discussion Questions

Methane Losses from Crude Oil and Condensate Storage Tanks

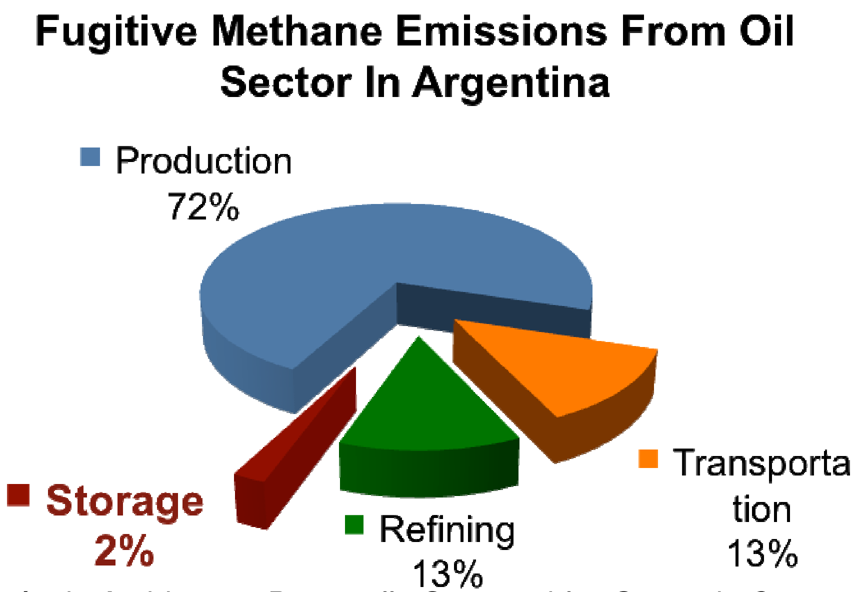
- Condensate storage tanks account for:
  - 5% of methane emissions in the U.S. production, gathering, and boosting sectors (excl. offshore operations)



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.

Methane Losses from Crude Oil and Condensate Storage Tanks

- In Argentina methane fugitive emissions account 90% (588,41 MtonCO_2e/year) from energy sector[1]
  - 12,45 MtonCO_2e fugitive methane emissions from oil sector
  - 0,28 MtonCO_2e fugitive methane emissions from storage systems (2% of Oil Sector)



[1] All data extracted from: Secretaría de Ambiente y Desarrollo Sustentable. *Segunda Comunicación Nacional de la República Argentina a la UNFCCC.* October, 2007. Fundación Bariloche and Argentina's Government .

Sources of Methane Losses from Tanks

- A storage tank battery can vent 142 to 14.158 Mm^3 of natural gas and light hydrocarbon vapors to the atmosphere each year
  - Vapor losses are primarily a function of oil or condensate throughput, gravity, and gas-oil separator pressure
- Flash losses
  - Occur when crude oil or condensate is transferred from a gas-oil separator at higher pressure to a storage tank at atmospheric pressure
- Working losses
  - Occur when crude or condensate levels change and when liquid 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

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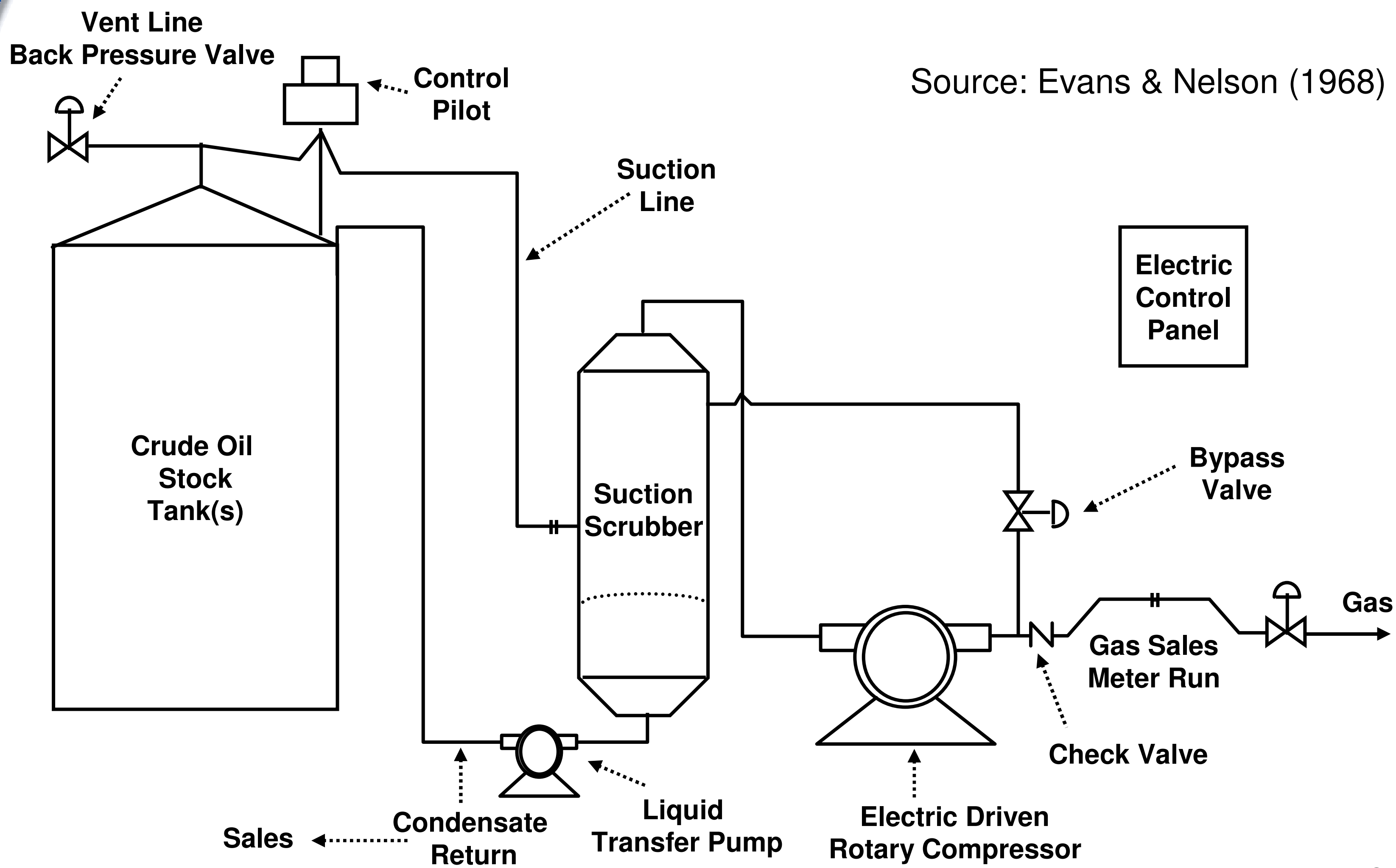
Types of Vapor Recovery Units

- Conventional vapor recovery units (VRUs)
  - Use screw or vane compressor to suck vapors out of atmospheric pressure storage tanks
  - Scroll compressors are new to this market
  - Require electrical power or engine driver
- Venturi ejector vapor recovery units (EVRU™) or Vapor Jet
  - Use Venturi jet ejectors in place of rotary compressors
  - Contain no moving parts
  - EVRU™ requires a source of high pressure motive gas and intermediate pressure discharge system
  - Vapor Jet requires high pressure motive water

Conventional Vapor Recovery Unit

Source: Evans & Nelson (1968)



Vapor Recovery Installations

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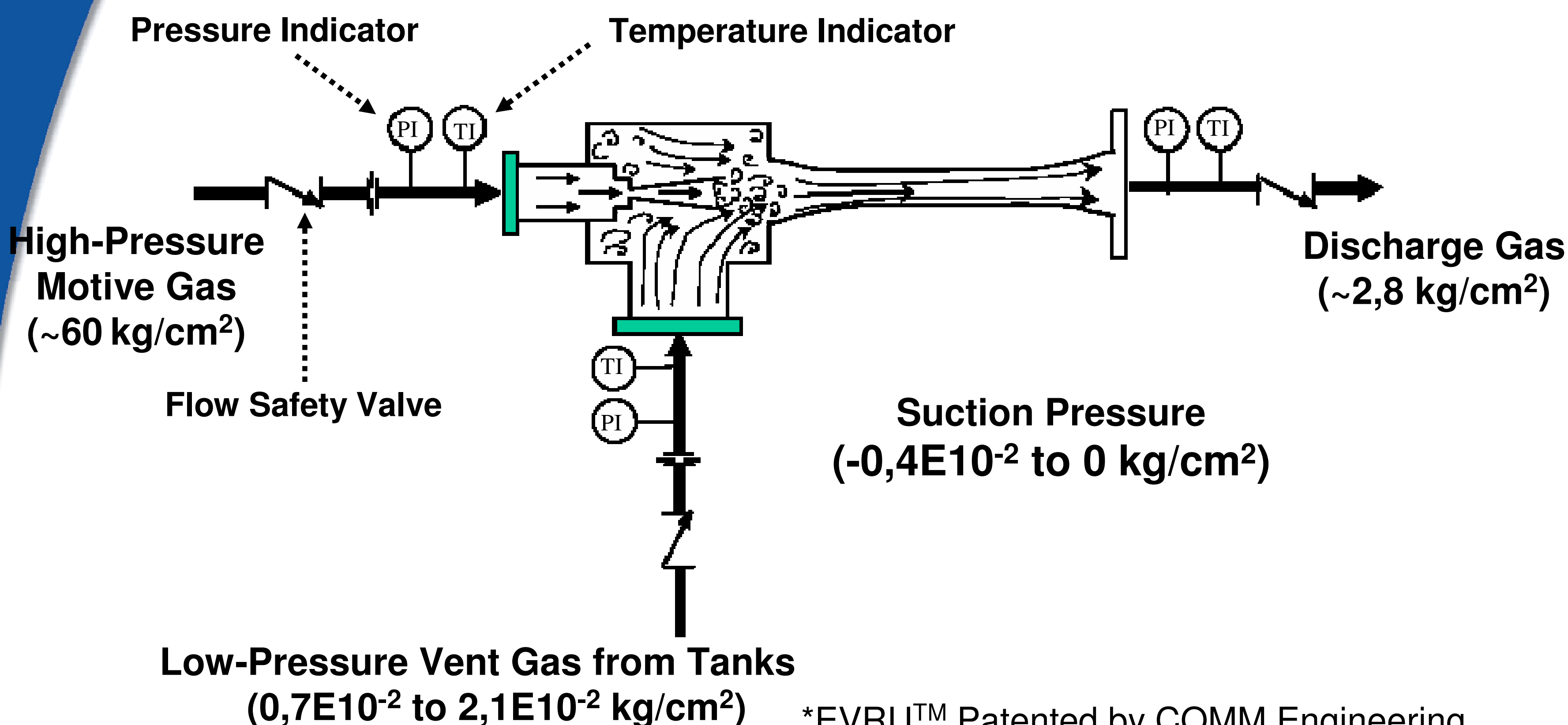
Venturi Jet Ejector*



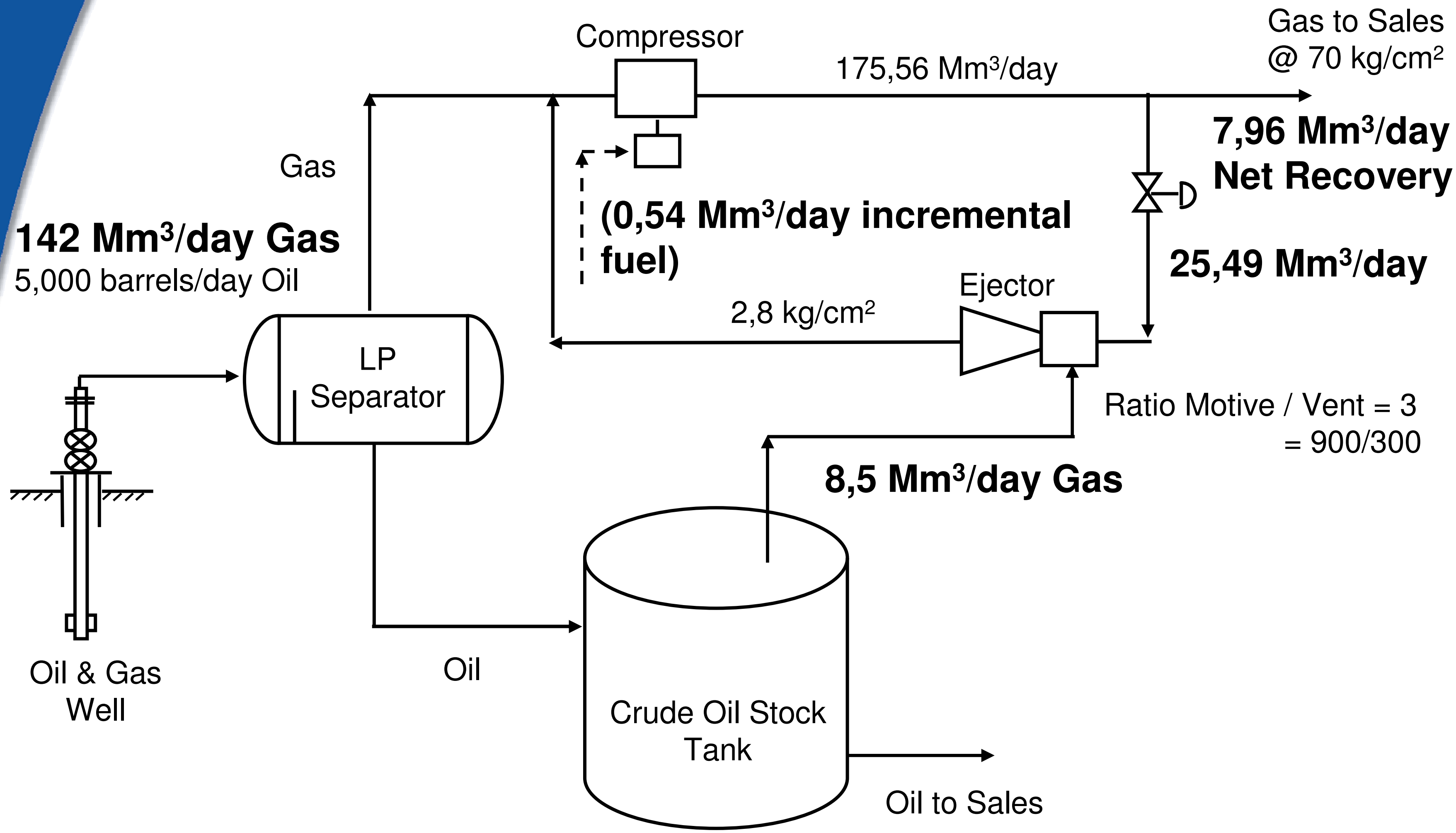
*EVRU™ Patented by COMM Engineering

Adapted from SRI/USEPA-GHG-VR-19

psig = pound per square inch, gauge

psia = pounds per square inch, atmospheric

Vapor Recovery with Ejector



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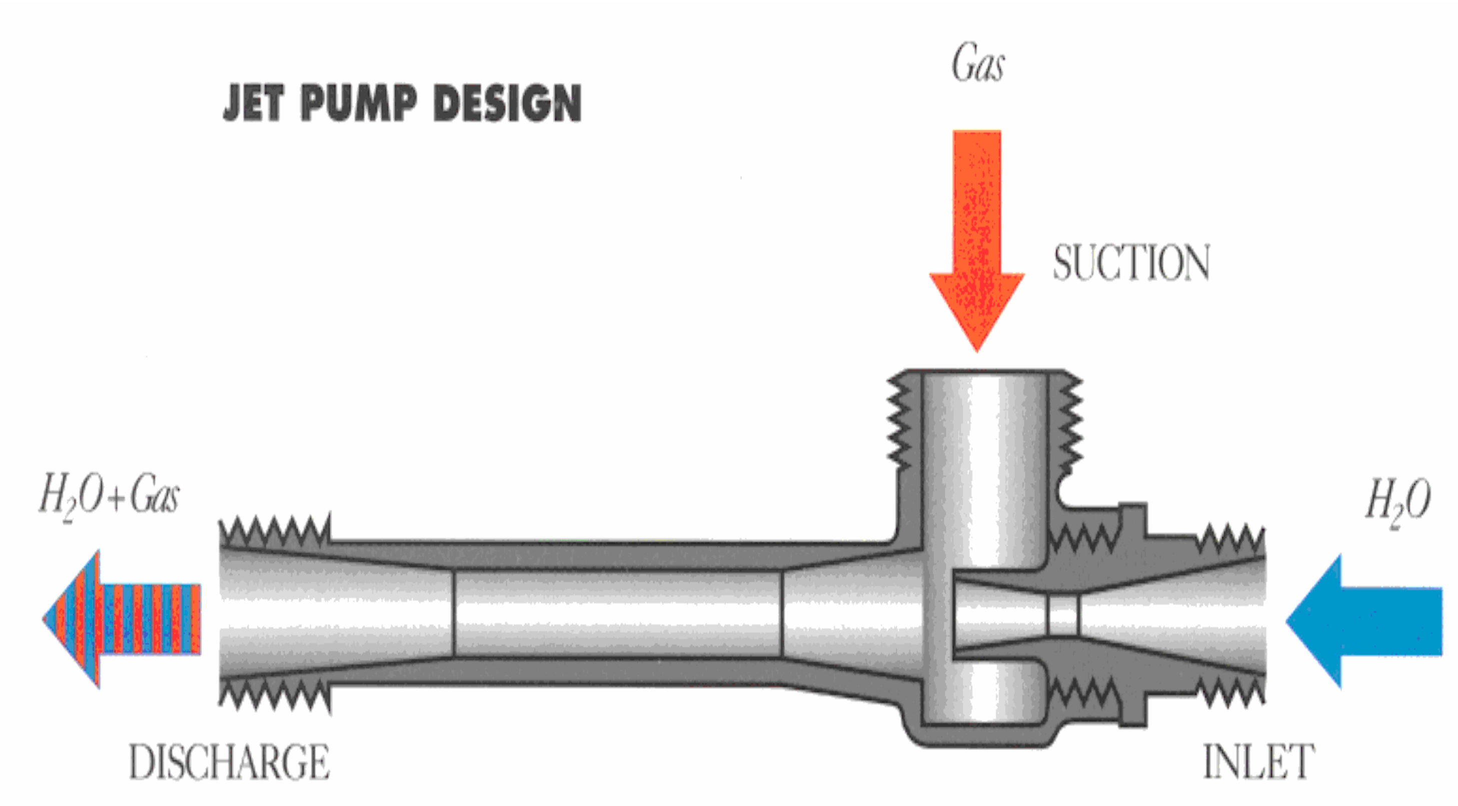
Vapor Jet System*



*Patented by Hy-Bon Engineering

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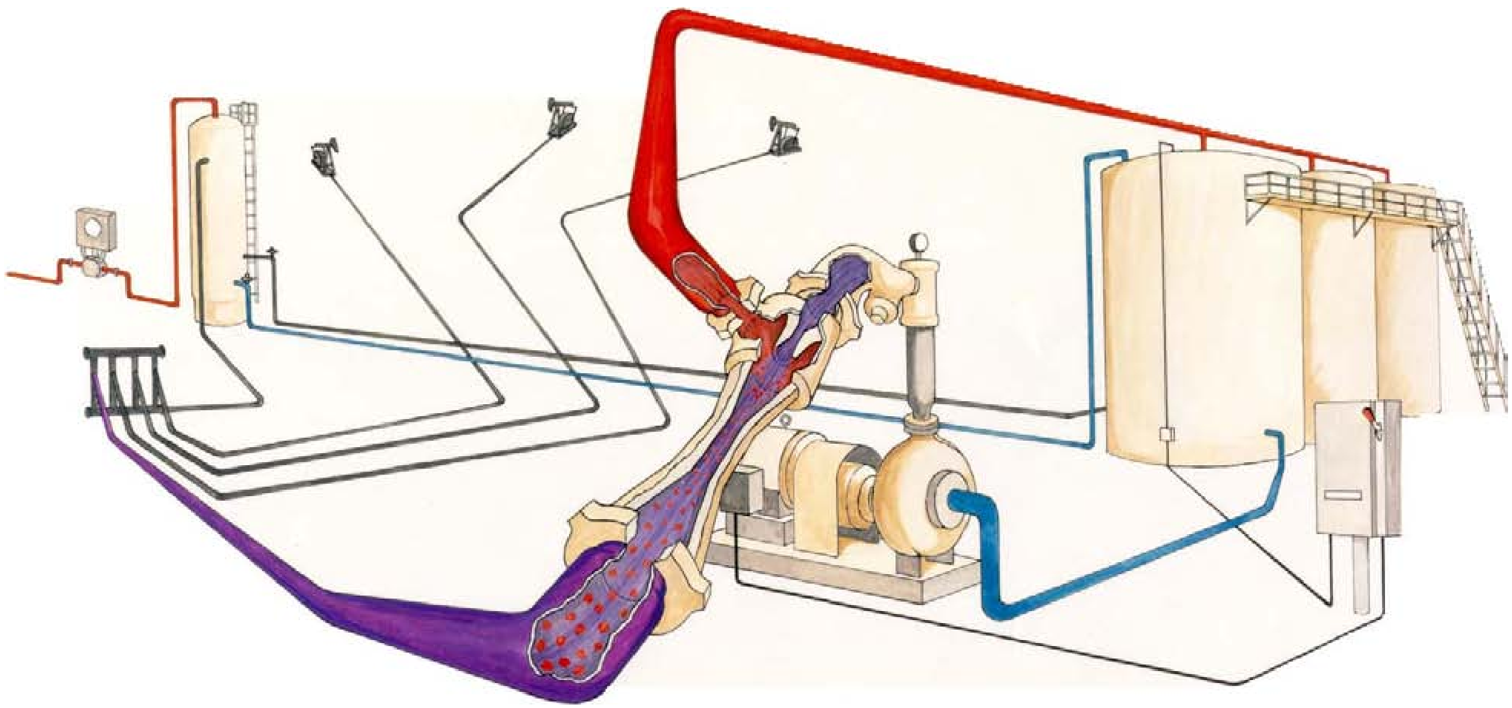
Vapor Jet System*



- Utilizes produced water in closed loop system to effect gas gathering from tanks
- Small centrifugal pump forces water into Venturi jet, creating vacuum effect
- Limited to gas volumes of 2 Mm^3/ day and discharge pressure of 3 kg/cm^2

*Patented by Hy-Bon Engineering

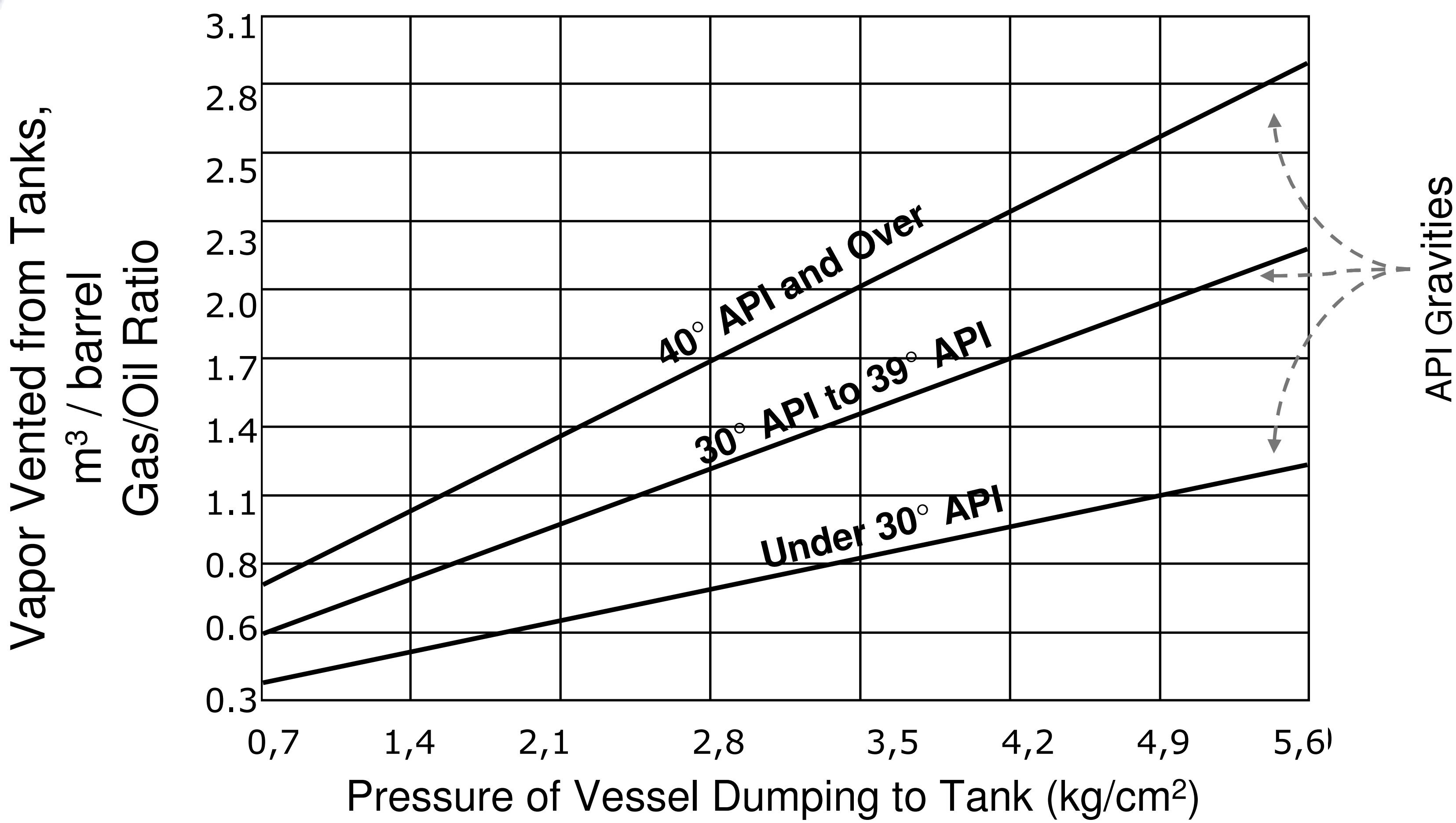
Criteria for Vapor Recovery Unit Locations

- Steady source and sufficient quantity of losses
  - Crude oil stock tank
  - Flash tank, heater/treater, water skimmer vents
  - Gas pneumatic controllers and pumps
  - Dehydrator still vent
  - Pig trap vent
- Outlet for recovered gas
  - Access to low pressure gas pipeline, compressor suction, or on-site fuel system
- Tank batteries not subject to air regulations

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

Estimated Volume of Tank Vapors



° API = API gravity

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What is the Recovered Gas Worth?

- Value depends on heat content of gas
- Value depends on how gas is used
  - On-site fuel
    - Valued in terms of fuel that is replaced
  - Natural gas pipeline
    - Measured by the higher price for rich (higher heat content) gas
  - Gas processing plant
    - Measured by value of natural gas liquids and methane, which can be separated
- Gross revenue per year = (Q x P x 365) + NGL
  - Q = Rate of vapor recovery (Mm^3 per day)
  - P = Price of natural gas ($US\$/Mm^3$)
  - NGL = Value of natural gas liquids

Value of Natural Gas Liquids

	1 kCal/L	2 MkCal/L	3 US$/L	4 US$/MkCal[1,2] (=3/2)
Methane	3.978	3,98	0,11	0,03
Ethane	4.927	4,93	0,40	0,08
Propane	6.107	6,11	0,53	0,09
n Butane	6.909	6,91	0,66	0,09
iso Butane	6.669	6,67	0,66	0,10
Pentanes+*	6.990	6,99	0,81	0,12

	5 kCal/m^3	6 MkCal/m^3	7 US$/$m^3$ (=4*6)	8 US$/MkCal	9 Vapor Composition	10 Mixture (MkCal/m^3)	11 Value (US$/$m^3$) (=8*10)
Methane	9.006	9,01	0,26	0,03	82%	7,38	0,21
Ethane	15.778	15,78	1,28	0,08	8%	1,26	0,10
Propane	22.462	22,46	1,93	0,09	4%	0,90	0,08
n Butane	29.110	29,11	2,76	0,09	3%	0,87	0,08
iso Butane	29.021	29,02	2,86	0,10	1%	0,29	0,03
Pentanes+	38.979	38,98	4,54	0,12	2%	0,78	0,09
Total						11,49	0,59

1 – Natural Gas Price assumed at US$0,03/MkCal as on Mar 16, 2006 at Henry Hub
2 – Prices of Individual NGL components are from Platts Oilgram for Mont Belvieu, TX July 11, 2008

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Cost of a Conventional VRU

Vapor Recovery Unit Sizes and Costs				
Capacity (Mm^3/day)	Compressor Horsepower	Capital Costs (US$)	Installation Costs (US$)	O&M Costs (US$/year)
0,71	5 to 10	20.421	10.207 to 20.421	7.367
1,42	10 to 15	26.327	13.164 to 26.327	8.419
2,83	15 to 25	31.728	15.864 to 31.728	10.103
5,66	30 to 50	42.529	21.264 to 42.529	11.787
14,16	60 to 80	59.405	29.703 to 59.405	16.839
Cost information provided by United States Natural Gas STAR companies and VRU manufacturers, 2006 basis.				

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Is Recovery Profitable?

Financial Analysis for a Conventional VRU Project						
Peak Capacity (Mm^3/day)	Installation & Capital Costs[1] (US$)	O&M Costs (US$/year)	Value of Gas[2] (US$/year)	Annual Savings (US$)	Simple Payback (months)	Internal Rate of Return
0,71	35.738	7.367	77.106	69.739	10	121%
1,42	46.073	8.419	154.213	145.794	6	204%
2,83	55.524	10.103	308.425	298.322	4	352%
5,66	74.425	11.787	616.850	605.063	3	537%
14,16	103.959	16.839	1.542.125	1.525.28 6	2	974%

1 – Unit cost plus estimated installation of 75% of unit cost
2 – US$0,59 x ½ peak capacity x 365, Assumed price includes MkCal enriched gas (11,49 MkCal/m^3)

Industry Experience: EnCana Oil & Gas

- Vapor recovery unit installed in Frenchie Draw, WY, U.S.
- Captures vapors from
  - Separators
  - Crude oil storage tank
  - Non-condensable dehydrator still gas
- VRU designed to handle 14 Mm^3/day
  - Additional capacity over the estimated 8 Mm^3/day of total gas from all emission sources

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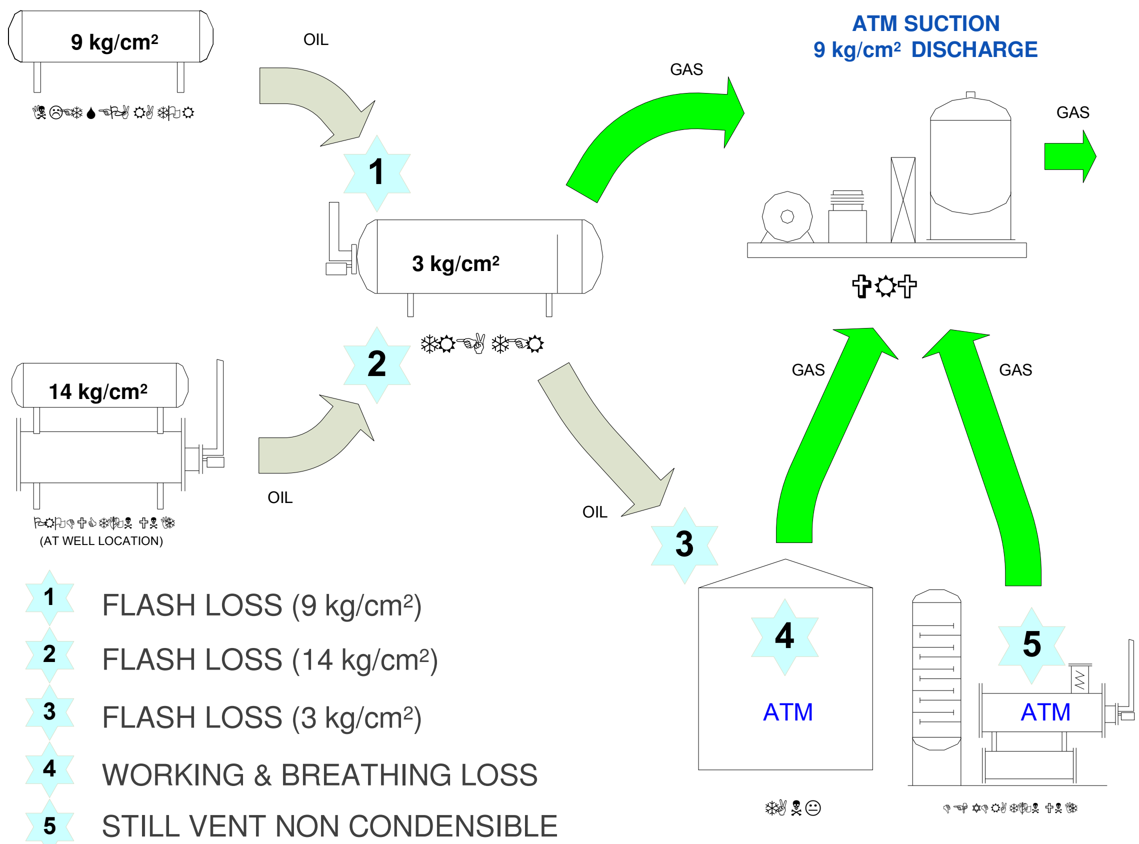
Industry Experience: EnCana Oil & Gas

- Quantify the volume of vapor emissions

Total Emissions- 8Mm^{3}D



Source: EnCana Oil & Gas (USA) Inc.

EnCana Oil & Gas: Project Costs

- Determine the cost of VRU project

Installation (US$)

VRU Unit (14 Mm^3d) -	90.000
Generator-	85.000
Vent Header-	25.000
Labor-	200.000
TOTAL	400.000

O & M (US$)

VRU Unit (14 Mm^3d) -	15.000
Generator-	18.000
Fuel-	73.000
TOTAL	106.000

EnCana Oil & Gas: Project Economics

- Evaluate VRU economics

Capacity–	14 Mm^3d
Installation Cost -	US$400.000
O&M-	US$106.000/year
Value of Gas*-	US$788.400/year
Payback-	7 months
Return on Investment-	170%

*Gas price assumed to be US$268,39/$Mm^3$ by EnCana

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Industry Experience: Anadarko

- Vapor Recover Tower (VRT)
  - Add separation vessel between heater treater or low pressure separator and storage tanks that operates at or near atmospheric pressure
    - Operating pressure range: 0,1 – 0,4 kg/cm^2
  - Compressor (VRU) is used to capture gas from VRT
  - Oil/Condensate gravity flows from VRT to storage tanks
    - VRT insulates the VRU from gas surges with stock tank level changes
    - VRT more tolerant to higher and lower pressures
    - Stable pressure allows better operating factor for VRU

Industry Experience: Anadarko

- VRT reduces pressure drop from approximately 3,5 kg/cm^2 to 0,1-0,4 kg/cm^2
  - Reduces flashing losses
  - Captures more product for sales
  - Anadarko netted between US$7 to US$8 million from 1993 to 1999 by utilizing VRT/VRU configuration
- Equipment Capital Cost: $11.000
- Standard size VRTs available based on oil production rate
  - 51cm x 11 m
  - 122 cm x 11 m
- Anadarko has installed over 300 VRT/VRUs since 1993 and continues on an as needed basis

VRT/VRU Photos

Courtesy of Anadarko

Project Overview - PDVSa

This dual flooded screw package for PDVSA is designed for volumes to 0,14 MMm^3D; moving tank vapors from 0 to 14 kg/cm^2 in Eastern Venezuela.

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Project Overview - PDVSa

At this location, three vru compressor packages were set in tandem to move 0,42 MMm^{3}D of 630-655 kCal tank vapors.

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Project Overview – PDVSa Gas Anaco (Venezuela)

- Vapor recovery units currently capture over 2,12 million cubic meter of previously vented and flared gas across 7 facilities
- Gas Anaco project, begun in 2006, targets over one billion cubic meter of gas across eastern Venezuela
- Conversion of much of the power and transportation infrastructure to natural gas is underway

Eni Dacion-Venezuela

Eni installed vapor recovery systems in their Dacion East and West facilities in Venezuela, each designed to move 40 Mm^3D of gas at pressures to 16 kg/cm^2

Eni Oil & Gas

Dacion Field, Venezuela

2004

Project Overview – Eni Dacion (Venezuela)

- Vapor recovery units were installed to capture up to 40 Mm^3D per site
- White paper was written shortly after installation on the economic success of the project
- A highly valuable 70 API gravity condensate was recovered from the gas stream and used to blend with the primary low API gravity oil production – at an approximate daily rate of 100 to 150 barrels of condensate per unit.

Oxy - Colombia

- Initial project will be capturing approximately 350 mcfd of vent gas from the Caricare oil storage and production facility.
- Purpose of the project will be incremental capture of natural gas liquids from this gas stream.
- Two additional sites are planned following successful installation of the first project.
- Subsequent project to utilize flare gas is also being evaluated by Oxy Colombia.

Oxy Colombia April 2008

Servipetrol/ Petrobras Bolivia

- Installing vapor recovery units in Caranda, Bolivia field later this year.
- 2.000 bopd; 40 api gravity crude; 3,5 kg/m^2 seperator pressure
- Anticipate average of 4 Mm^3d gas capture
- US$252.000 incremental revenue per year, plus value of condensate produced

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
- Potential for reduced compliance costs can be considered when evaluating economics of VRU, EVRU™, or Vapor Jet

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Lessons Learned (continued)

- VRU should be sized for maximum volume expected from storage tanks (rule-of-thumb is to double daily average volume)
- Rotary vane, screw or scroll type compressors recommended for VRUs where Venturi ejector jet designs are not applicable
- EVRU™ recommended where there is a high pressure gas compressor with excess capacity
- Vapor Jet recommended where there is produced water, less than 2 Mm^3 per day gas and discharge pressures below 2,8 kg/cm^2