Reducing Methane Emission with Vapor Recovery on Storage Tanks

Lessons Learned from the
Natural Gas STAR Program

Producers Technology Transfer Workshop

Newfield Exploration Company,
Anadarko Petroleum Corporation,
Utah Petroleum Association,
Interstate Oil & Gas Compact Commission,
Independent Petroleum Association of Mountain States

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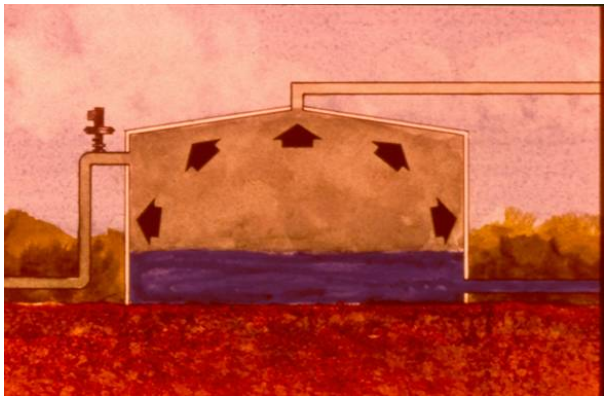
epa.gov/gasstar

Vapor Recovery Units: Agenda

- Methane losses
- Methane savings
- Is recovery profitable?
- Industry experience
- Discussion questions

Tank Operations



As the oil resides in the tanks, it gives off vapors, thereby increasing the pressure inside the tank.

Sources of Methane Losses from Tanks

- A storage tank battery can vent 5 to 500 thousand cubic feet (Mcf) of natural gas and light hydrocarbon vapors to the atmosphere each day
  - 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.
- Standing losses
  - Occur with daily and seasonal temperature and barometric pressure changes.

Why Let Money Escape into the Air?

Besides being an environmental hazard, escaping vapors result in the loss of a major revenue source for the oil company. Hundreds of oil companies have added significant money to their bottom line by capturing this valuable gas stream.

Methane Savings: Vapor Recovery

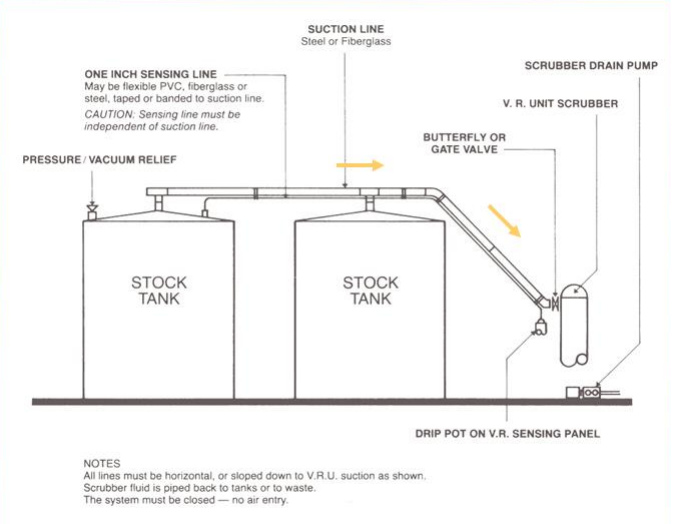
- Vapor recovery can capture up to 95% of hydrocarbon vapors from tanks
- Recovered vapors have higher heat content than pipeline quality natural gas
- Recovered vapors are more valuable than natural gas and have multiple uses
  - Re-inject into sales pipeline
  - Use as on-site fuel
  - Send to processing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

Types of Vapor Recovery Units

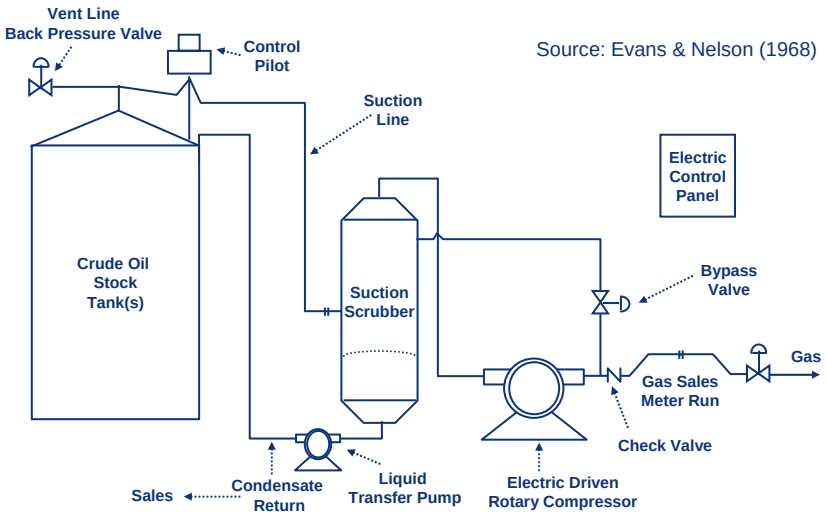
- Conventional vapor recovery units (VRUs)
  - Use specially designed packages configured to capture
  - low pressure, wet gas streams with no oxygen ingress
  - Use rotary screw or rotary vane compressor for wet gas
  - Scroll compressors are new to this market & also work well
  - Require electrical 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

Vapor Recovery Systems



Conventional VRU



Source: Evans & Nelson (1968)

Rotary Vane VRUs

Rock Springs, Wyoming

Rotary vane VRU installation

Used in VRU service for 50+ years

Photos Courtesy of Hy-bon Engineering

Rotary Screw VRUs

Eni installed vapor recovery systems in their Dacion East and West facilities in Venezuela, each designed to move 1.4 MMcf/day of gas at pressures to 230 psig.

Eni Oil & GasDacion Field, Venezuela; 2004

Rotary screws used in VRU service for 15+ years

Project Overview – Eni Dacion (Venezuela)

- Rotary screw vapor recovery units were installed to capture up to 1.4 MMcf/day per site
- White paper was written shortly after installation on the economic success of the project; denoting economic payback of less than 12 months
- 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.

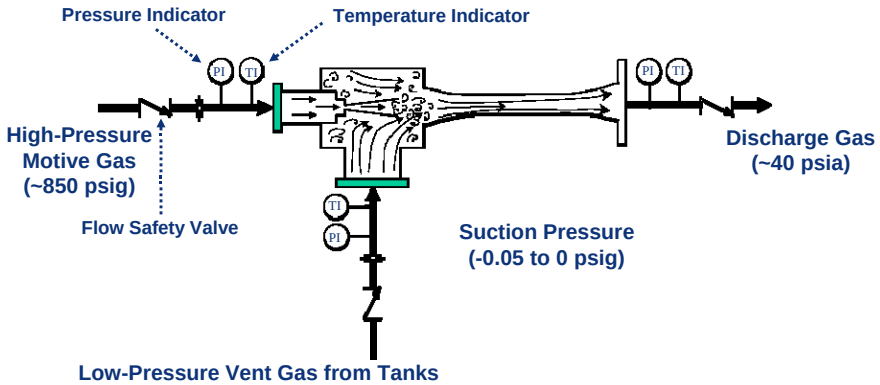
Scroll VRUs

- Scroll compressors first used in VRUs in 2004
  - Over 70 now installed in U.S. in VRU service
  - Devon case study using scrolls in Gas STAR website

Scroll VRU Installation

Courtesy of Hy-bon Engineering

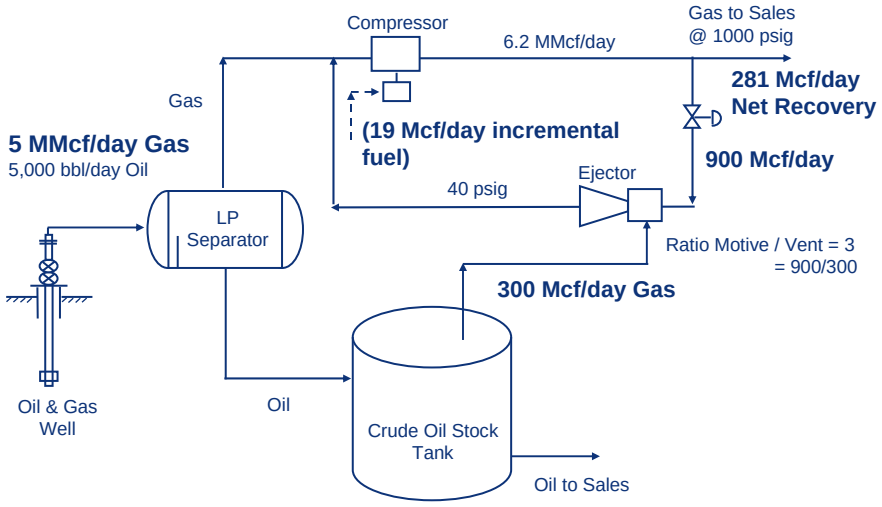
Venturi Jet Ejector*



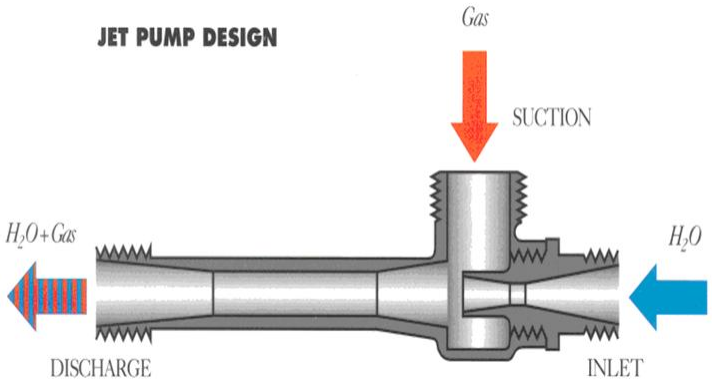
*EVRU™ Patented by COMM Engineering

Adapted from SRI/USEPA-GHG-VR-19
psig = pound per square inch, gauge
psia = pounds per square inch, absolute

Vapor Recovery with Ejector



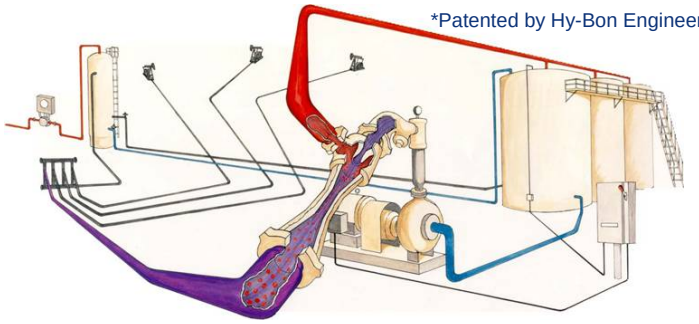
Vapor Jet System*



*Patented by Hy-Bon Engineering

Vapor Jet System*

*Patented by Hy-Bon Engineering



- 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 77 Mcf/day and discharge pressure of 40 psig

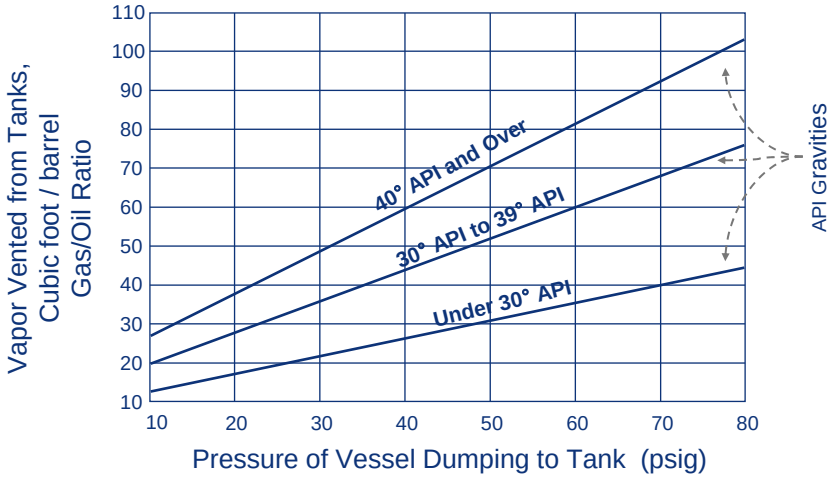
Criteria for Vapor Recovery Unit Locations

- 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

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, turbine meter or ultrasonic meter over several cycles (± 5%)
  - This is the best approach for facility design

Estimated Volume of Tank Vapors



° API = API gravity

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 (MMBtu per day)
  - P = Price of natural gas ($/MMBtu)
  - NGL = Value of natural gas liquids

Value of Natural Gas Liquids

	1 Btu/gallon	2 MMBtu/ gallon	3 $/gallon	4 $/MMBtu[1,2] (3/2)	5 Btu/cf	6 MMBtu/Mcf
Methane	59,755	0.06	0.18	6.92	1,012	1.01
Ethane	74,010	0.07	0.37	5.00	1,773	1.77
Propane	91,740	0.09	0.68	7.41	2,524	2.52
n Butane	103,787	0.10	0.86	8.29	3,271	3.27
iso Butane	100,176	0.10	0.91	9.08	3,261	3.26
Pentanes+*	105,000	0.11	1.01	9.62	4,380	4.38

	7 $/Mcf (4*6)	8 $/MMBtu	9 Vapor Composition	10 Mixture (MMBtu/Mcf)	11 Value ($/Mcf) (= 8*10)
Methane	$7.00	6.92	82%	0.83	$5.74
Ethane	$8.86	5.00	8%	0.14	$0.71
Propane	$18.71	7.41	4%	0.10	$0.75
n Butane	$27.10	8.29	3%	0.10	$0.81
iso Butane	$29.62	9.08	1%	0.03	$0.30
Pentanes+	$42.13	9.62	2%	0.09	$0.84
Total				1.29	$9.15

1 – Natural gas price assumed at $7/Mcf
2 – Prices of Individual NGL components are from Platts Oilgram for Mont Belvieu, TX February 17, 2009

Is Recovery Profitable?

Financial Analysis for a conventional VRU project[1]

	Installation and Capital Costs[2]	Operating and Maintenance	Value of Gas[3]	Payback	Internal Rate of Return
(Mcf/day)	($)	($/year)	($/year)	(Months)	(%)
25	35,738	7,367	39,000	14	84%
50	46,073	8,419	79,000	8	152%
100	55,524	10,103	158,000	5	266%
200	74,425	11,787	317,000	3	410%
500	103,959	16,839	793,000	2	747%

1 - All costs and revenues are represented in U.S. economics
2 - Unit cost plus estimated installation at 75% of unit cost
3 - $9.15/Mcf x 1/2 capacity x 365 x 95%
Mcf = thousand cubic feet

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: 1 – 5 psig
- 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

VRT/VRU Photos

Courtesy of Anadarko

Industry Experience: Anadarko

- VRT reduces pressure drop from approximately 50 psi to 1 – 5 psi
  - Reduces flashing losses
  - Captures more product for sales
  - Anadarko netted between U.S.$7 to U.S.$8 million from 1993 to 1999 by utilizing VRT/VRU configuration
- Equipment Capital Cost: $11,000 (VRT cost only)
- Standard size VRTs available based on oil production rate
  - 20” x 35’
  - 48” x 35’
- Anadarko has installed over 300 VRT/VRUs since 1993 and continues on an as needed basis

Industry Experience: ConocoPhillips

- Vapor recovery units installed in Baker, MT
- Anticipated multiple sites, so detailed technical review of options, was conducted
- Volumes per site ranged from 30 Mcf/day to 300 Mcf/day
- Pipeline pressure ranged from 20 to 40 psig
- Captures vapors from
  - Crude oil storage tanks
  - Produced water tanks
  - All manifolded together in closed loop system
  - Gas blanket system used to backfill tanks

Industry Experience: ConocoPhillips

- Evaluated rotary screw, rotary vane, vapor jet and EVRU™
- Selected rotary vane VRU's due to wide range of volumes of gas and low discharge pressure across the sites
- Pilot project on 3 locations, then added 6 additional sites
- Designed for optimum gas capture
  - Pressure transmitter on the tanks
  - Sloping lines to the VRU
  - Package specifically designed for vapor recovery service
  - Automated liquid handling and bypass systems

Baker, MT ConocoPhillips VRU installation; Picture Courtesy of Hy-bon Engineering

Baker, MT ConocoPhillips VRU installation; Picture Courtesy of Hy-bon Engineering

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Industry Experience: ConocoPhillips

- Payback economics – project for 9 tank batteries
  - Purchase price for 9 VRUs $ 475,000
  - Estimate install cost $ 237,500
  - Total capital costs $ 712,500
- Approx Gas Revenue
  - 1,050 Mcf/day x $6/Mcf x 30 days = $189,000/ month
  - Payback on capital investment < 4 months
  - Installed in 2005 & early 2006 – all locations continue to generate incremental revenue and meet environmental compliance goals today

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

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 75 Mcf/day gas and discharge pressures below 40 psig.

Discussion

- Industry experience applying these technologies and practices
- Limitations on application of these technologies and practices
- Actual costs and benefits

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