Vapor Recovery Tower/ VRU Configuration

Lessons Learned from Natural Gas STAR

Occidental Petroleum Corporation and
California Independent Petroleum Association

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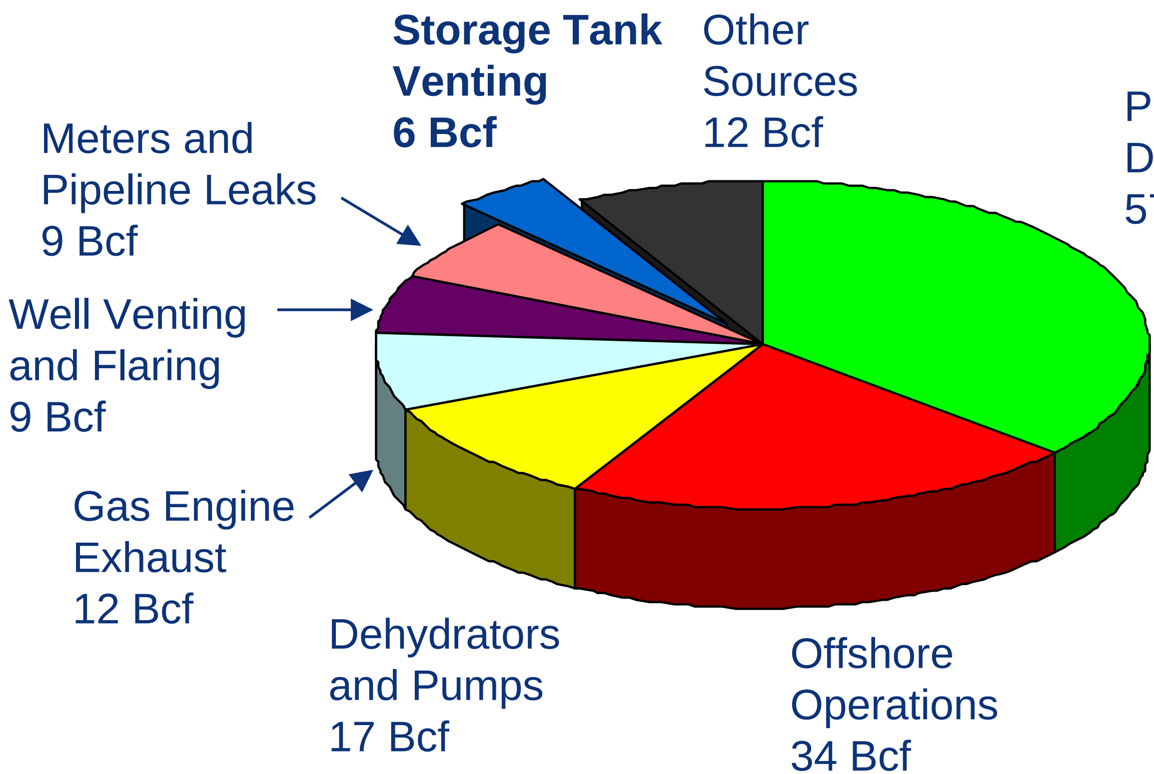
epa.gov/gasstar

Vapor Recovery: Agenda

- Methane Losses
- Methane Savings
- Is Recovery Profitable?
- Industry Experience
- Lessons Learned
- Discussion

Methane Losses from Storage Tanks

- Storage tanks are responsible for 4% of methane emissions in natural gas and oil production sector
  - 96% of tank losses occur from tanks without vapor recovery



Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990 - 2005

Bcf = billion cubic feet

Sources of Methane Losses

- A storage tank battery can vent 4,900 to 96,000 thousand cubic feet (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

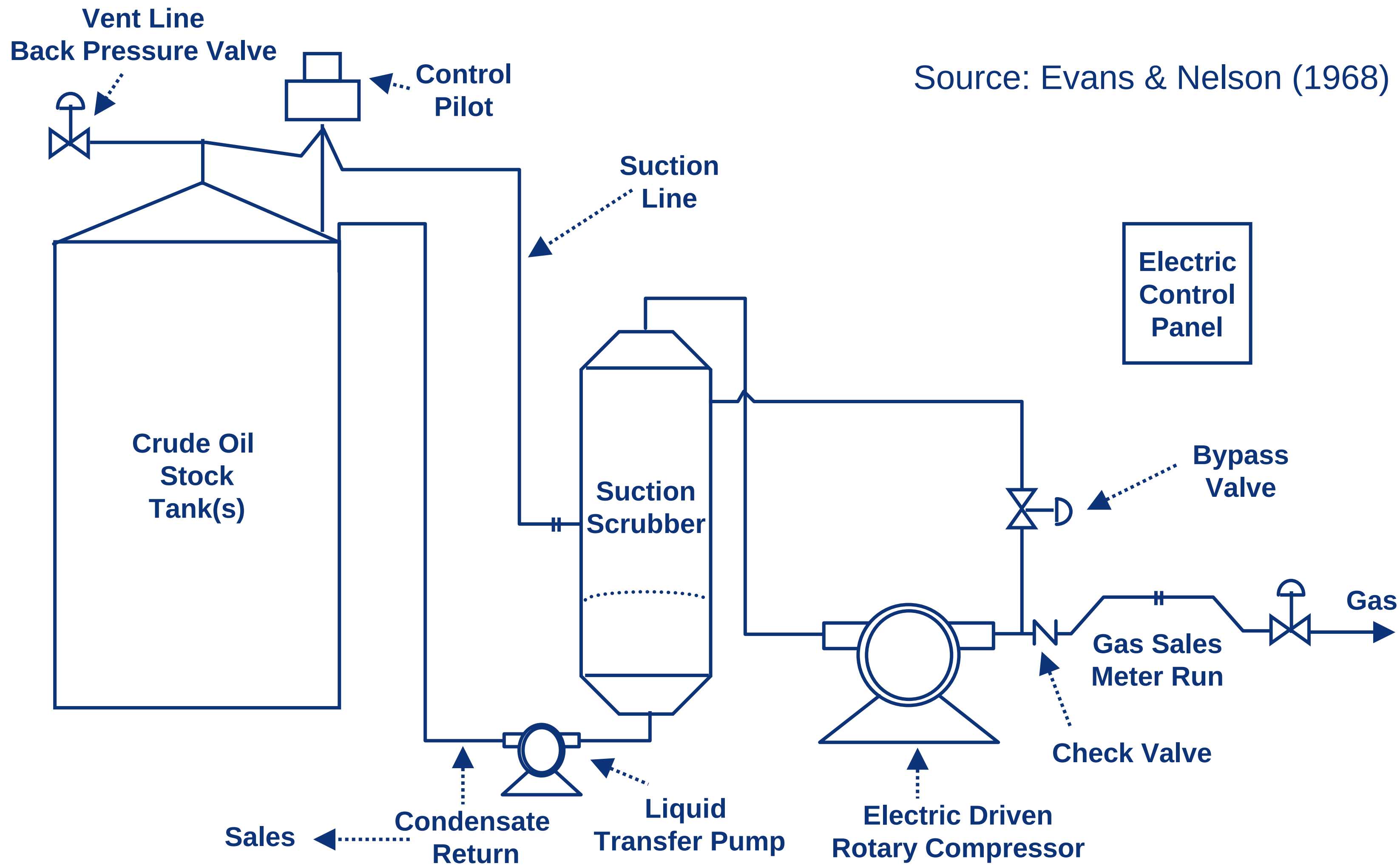
- Vapor recovery can capture up to 95% of hydrocarbon vapors from tanks
- Recovered vapors have higher heat content than pipeline quality natural gas
- Recovered vapors are more valuable than natural gas and have multiple uses
  - Re-inject into sales pipeline
  - Use as on-site fuel
  - Send to processing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

Types of Vapor Recovery Units

- Conventional vapor recovery units (VRUs)
  - Use rotary 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 a high pressure water motive

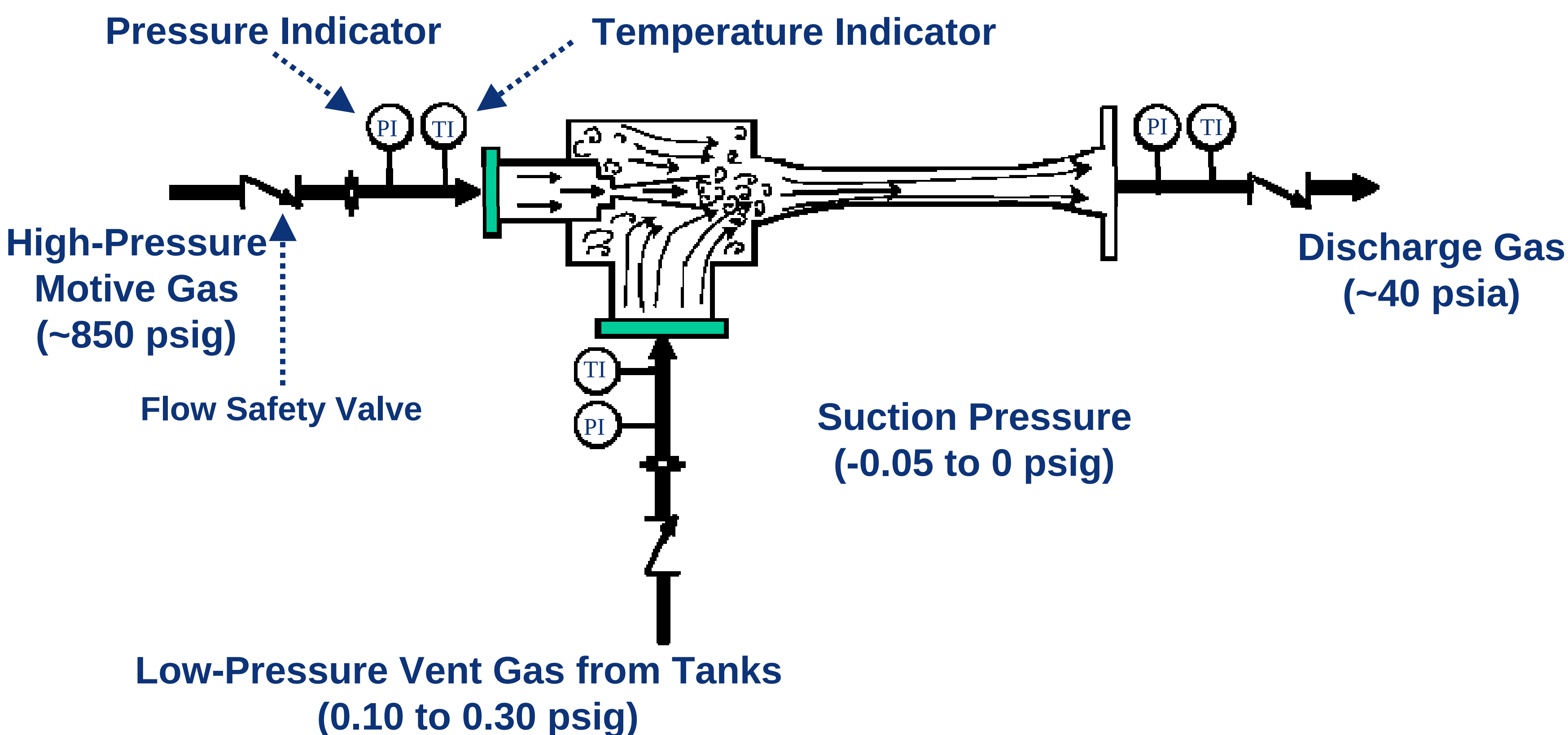
Conventional Vapor Recovery Unit

Source: Evans & Nelson (1968)



Vapor Recovery Installations

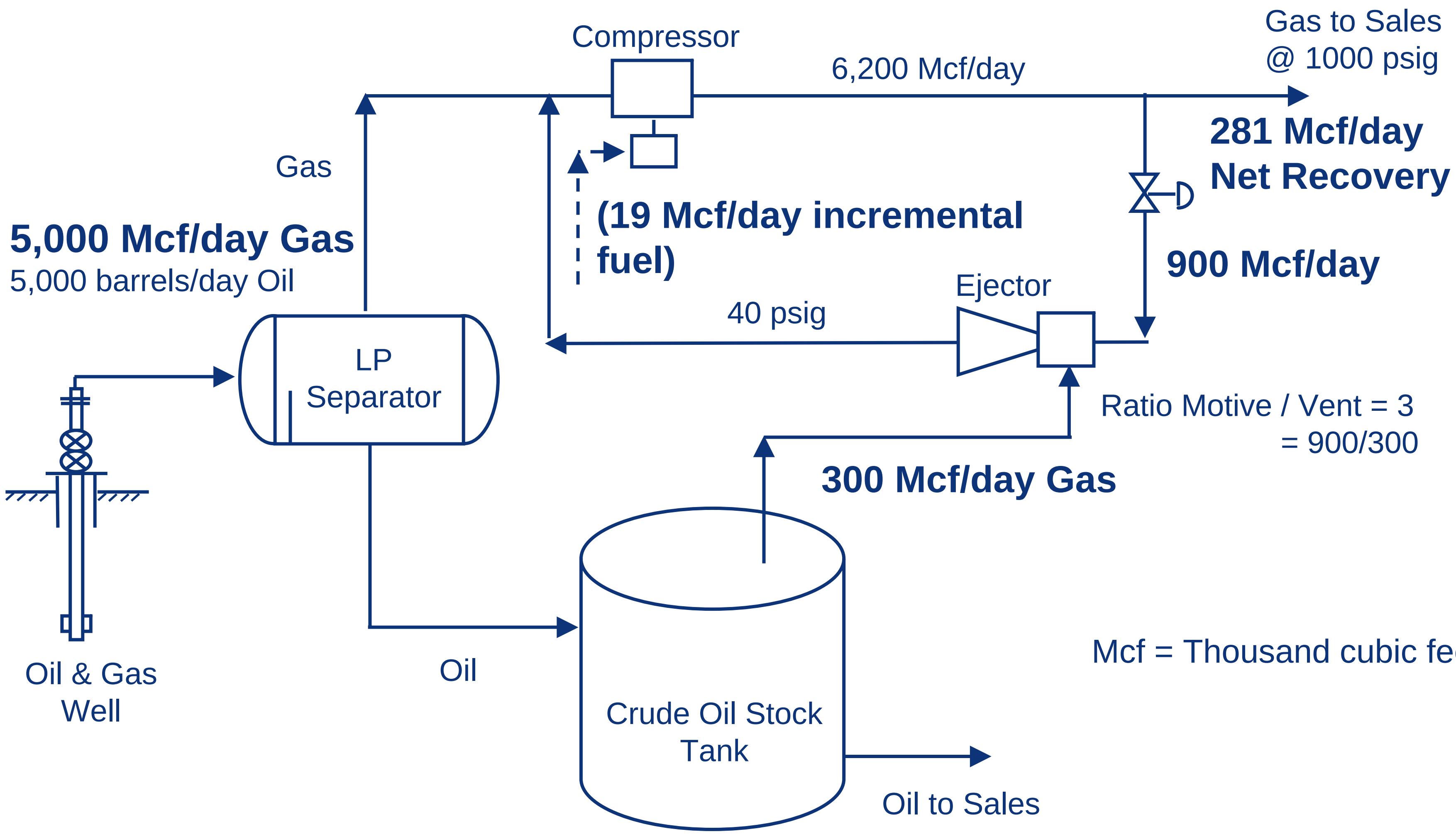
Venturi Jet Ejector*



*EVRU[TM] Patented by COMM Engineering

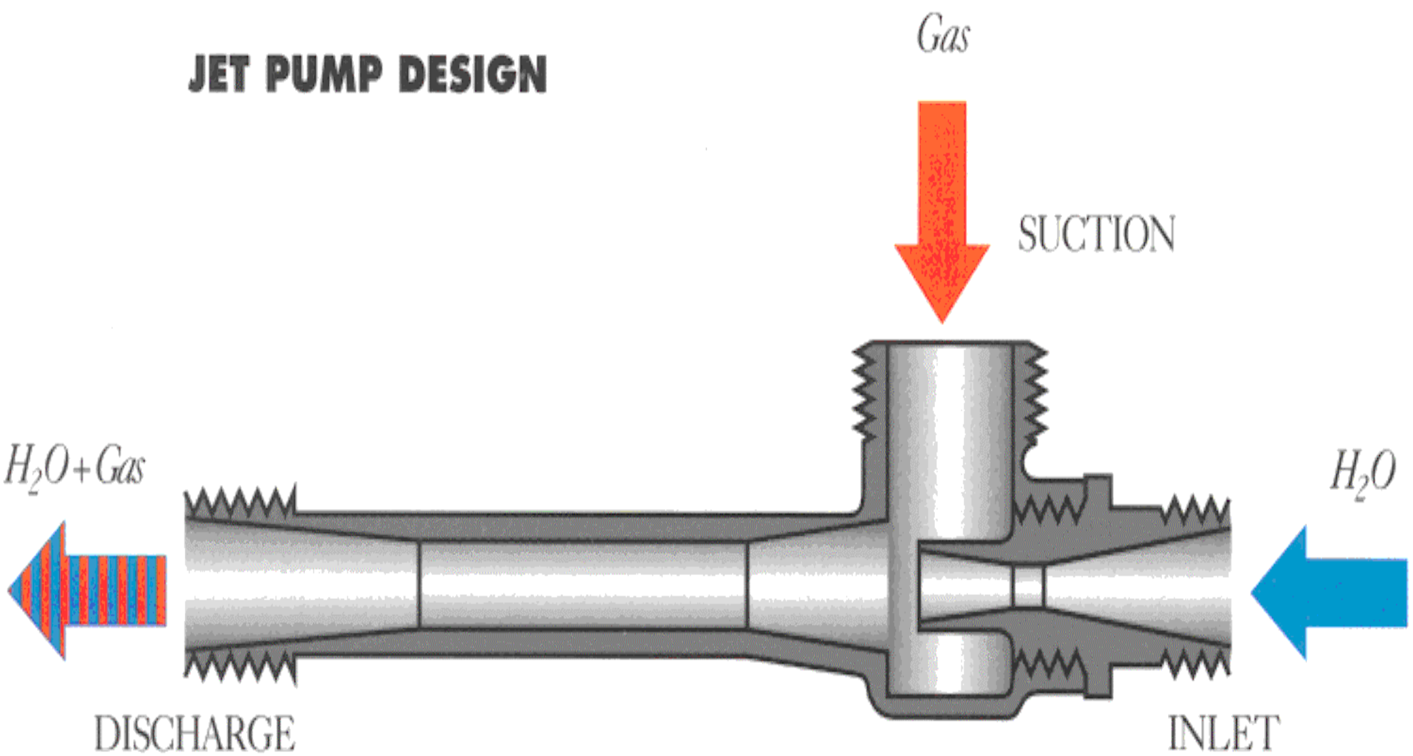
Adapted from SRI/USEPA-GHG-VR-19
psig = pound per square inch, gauge
psia = pounds per square inch, absolute

Vapor Recovery with Ejector



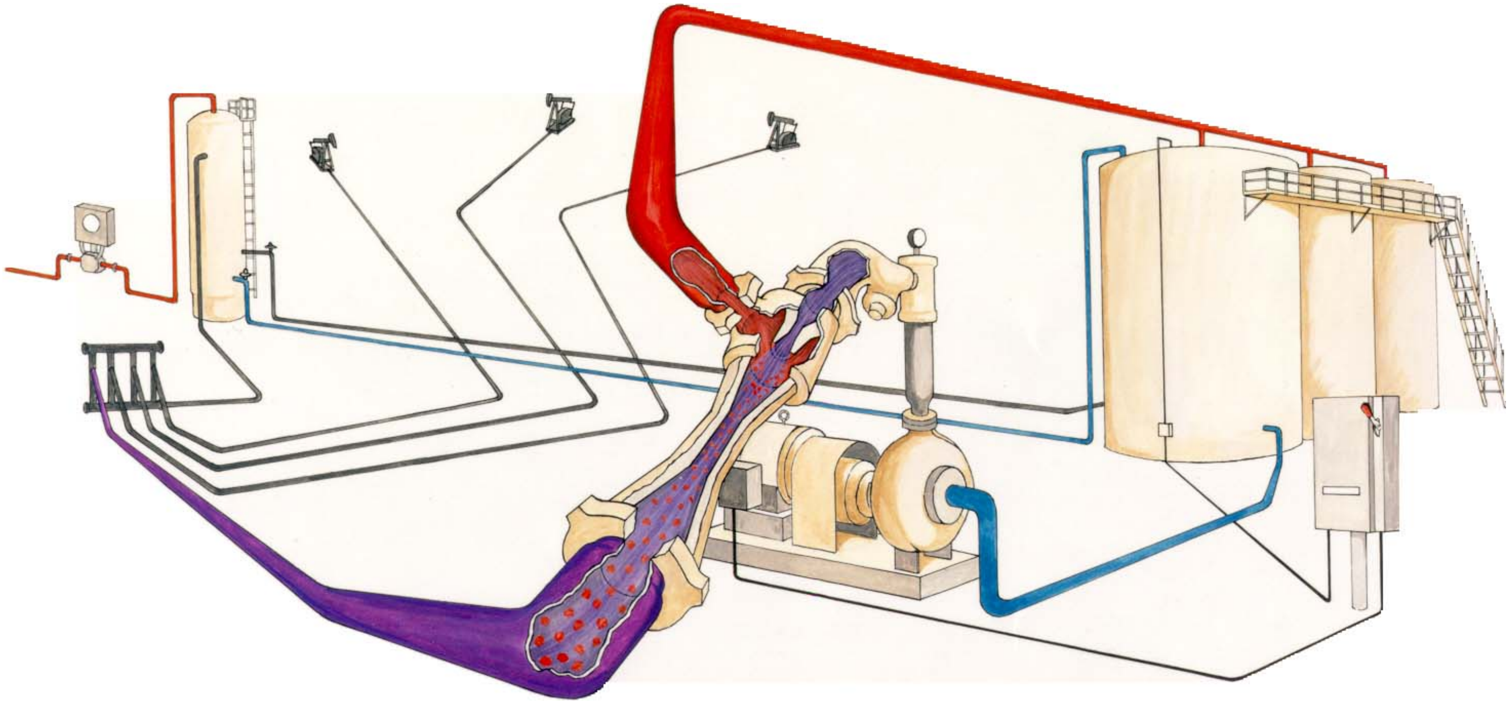
Mcf = Thousand cubic feet

Vapor Jet System*



*Patented by Hy-Bon Engineering

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 77 Mcf/day and discharge pressure of 40 psig

*Patented by Hy-Bon Engineering

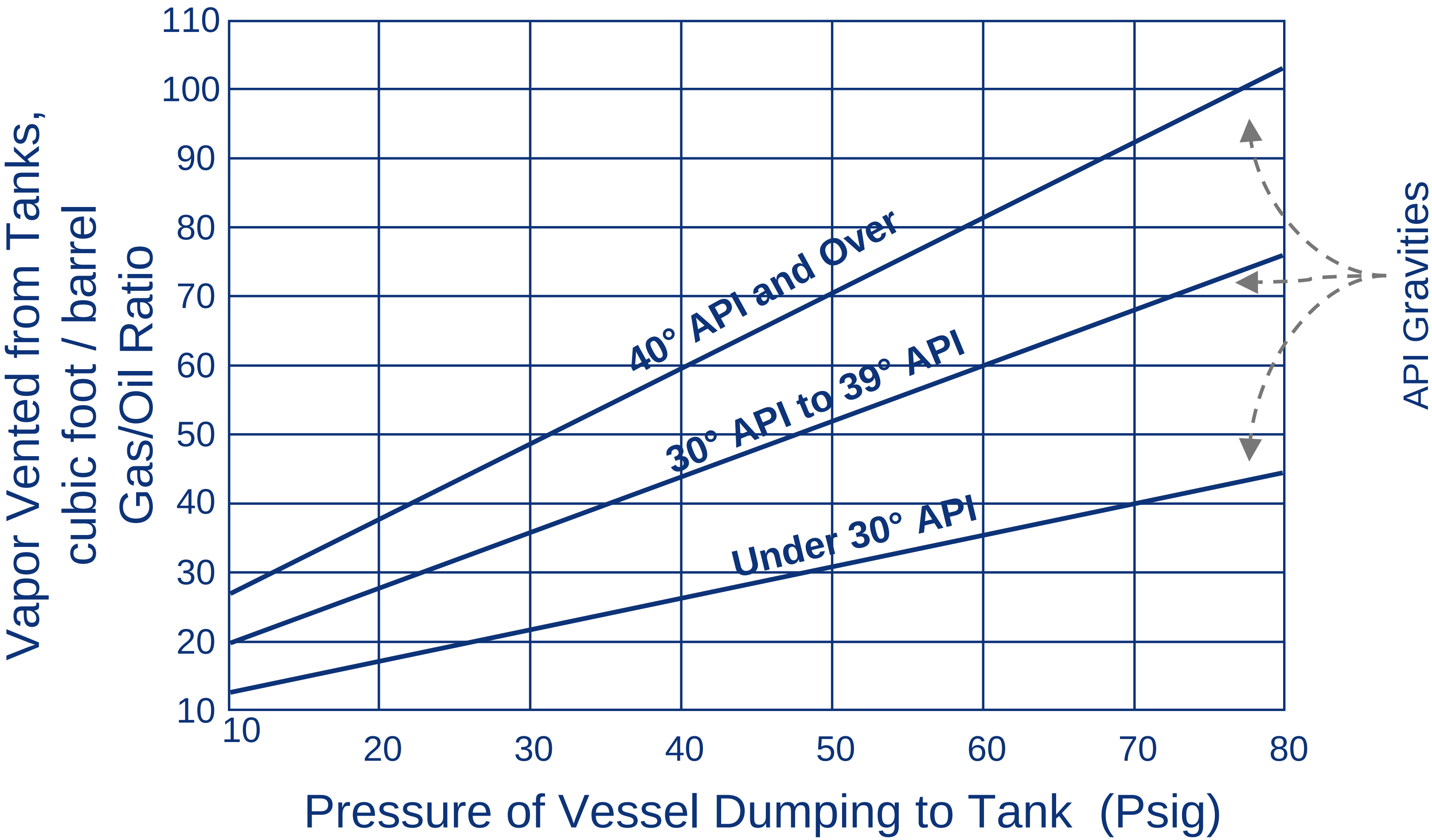
Criteria for Vapor Recovery Unit Locations

- Steady source and sufficient quantity of losses
  - Crude oil stock tank
  - Flash tank, heater/treater, water skimmer vents
  - Gas pneumatic controllers and pumps
- 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

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 Huntington Beach Crude

- G_{oil} – 20.7º API
- $G_{flash\ gas}$ – 1.22
- T_{sep} – 100ºF
- P_{sep} – 3 psig
- GOR = **2.6 scf/bbl**

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

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

Value of Recovered Gas

- Gross revenue per year = (Q x P x 365) + NGL
  - Q = Rate of vapor recovery (Mcf per day)
  - P = Price of natural gas
  - NGL = Value of natural gas liquids

Value of Natural Gas Liquids

	1 Btu/gallon	2 MMBtu/ gallon	3 $/gallon	4 $/MMBtu[1,2,3] (=3/2)
Methane	59,755	0.06	0.43	7.15
Ethane	74,010	0.07	0.64	9.14
Propane	91,740	0.09	0.98	10.89
n Butane	103,787	0.10	1.32	13.20
iso Butane	100,176	0.10	1.42	14.20
Pentanes+	105,000	0.11	1.50	13.63

	5 Btu/cf	6 MMBtu/Mcf	7 $/Mcf (=4*6)	8 $/MMBtu	9 Vapor Composition	10 Mixture (MMBtu/Mcf)	11 Value ($/Mcf) (=8*10)
Methane	1,012	1.01	$7.22	7.15	82%	0.83	$5.93
Ethane	1,773	1.77	$16.18	9.14	8%	0.14	$1.28
Propane	2,524	2.52	$27.44	10.89	4%	0.10	$1.09
n Butane	3,271	3.27	$43.16	13.20	3%	0.10	$1.32
iso Butane	3,261	3.26	$46.29	14.20	1%	0.03	$0.43
Pentanes+	4,380	4.38	$59.70	13.63	2%	0.09	$1.23
Total						1.289	$11.28

1 – Natural Gas Price assumed at $7.15/MMBtu as on Mar 16, 2006 at Henry Hub
2 – Prices of Individual NGL components are from Platts Oilgram for Mont Belvieu, TX January 11, 2006
3 – Other natural gas liquids information obtained from Oil and Gas Journal, Refining Report, March 19, 2001, p. 83
Btu = British Thermal Units, MMBtu = Million British Thermal Units, Mcf = Thousand Cubic Feet

Cost of a Conventional VRU

Vapor Recovery Unit Sizes and Costs				
Capacity (Mcf/day)	Compressor Horsepower	Capital Costs ($)	Installation Costs ($)	O&M Costs ($/year)
25	5 to 10	20,421	10,207 to 20,421	7,367
50	10 to 15	26,327	13,164 to 26,327	8,419
100	15 to 25	31,728	15,864 to 31,728	10,103
200	30 to 50	42,529	21,264 to 42,529	11,787
500	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.				

Is Recovery Profitable?

Financial Analysis for a Conventional VRU Project						
Peak Capacity (Mcf/day)	Installation & Capital Costs[1] ($)	O&M Costs ($/year)	Value of Gas[2] ($/year)	Annual Savings ($)	Simple Payback (months)	Internal Rate of Return
25	$35,738	$7,367	$51,465	$44,098	10	121%
50	$46,073	$8,419	$102,930	$94,511	6	204%
100	$55,524	$10,103	$205,860	$195,757	4	352%
200	$74,425	$11,787	$411,720	$399,933	3	537%
500	$103,969	$16,839	$1,029,300	$1,012,461	2	974%

1 – Unit cost plus estimated installation of 75% of unit cost
2 – $11.28 x ½ peak capacity x 365, Assumed price includes Btu enriched gas (1.289 MMBtu/Mcf)

Industry Experience

- Top five United States companies for emissions reductions using VRUs in 2005

Company	2005 Annual Reductions (Mcf)
Company 1	1,346,208
Company 2	313,753
Company 3	160,650
Company 4	54,597
Company 5	31,239

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 psi to 5 psi
  - 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 50 psig to 1-5 psig
  - Reduces flashing losses
  - Captures more product for sales
  - Anadarko netted between $7 to $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
  - 20” x 35’
  - 48” x 35’
- Anadarko has installed over 300 VRT/VRUs since 1993 and continues on an as needed basis

VRT/VRU Photos

Courtesy of Anadarko

VRT/VRU Photos

Courtesy of Anadarko

Industry Experience: Oxy

- Oxy Case Study - Vapor Recovery
  - Wasson Tank Battery (CDU 1 & 2)
  - Denver City, Texas
  - Installed in 2004
- Oxy purchased two vapor recovery units in August 2004 for capturing vapors from two separate tank batteries at their Wasson facility
- Each battery produces approximately 450 Mcf/day of tank vapors, which Oxy needed to gather and compress into a 45 psig sales line
- Due to the low discharge pressure, Oxy selected rotary vane compressor packages capable of moving 500 Mcf/day
- In order to minimize maintenance, Oxy selected electric drive units
  - 75 horsepower electric motors on each unit

Oxy Wasson Tank Battery 1 – CDU 1

Industry Experience: Oxy

	Cost per site	Total Cost
Capital Cost:	$92,500	$185,000
Installation Cost:	$9,500	$19,000
Installed Cost:	$102,000	$204,000
Gas Volume (Mcf/day):	450	900
Value at $7/Mcf:	$3,150	$6,300
Annual Revenue: (with no BTU adjustment and no liquid sales)	$1,149,750	$2,299,500
Monthly Incremental Revenue:	$95,812	$191,625
Payback (in months):	1.06	1.06

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 per day gas and discharge pressures below 40 psig

Discussion

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