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Data Quality in Estimating Storage Tank Releases to Air in the Oil and Gas Sector

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Introduction

- Oil & Gas sector on the rise in Alberta
  - 60% growth in investment- 2017
  - 6% growth in exports – 2017

    Alberta Government 2017 Budget Economic Outlook

- NPRI regulatory driver
  - Approx. half of AB sites reporting to NPRI are in the O&G sector
- U.S. EPA forthcoming revisions to AP-42?

Agenda

- Introduction
- Natural Gas Production Water - Flashing
- Crude Oils – Degassing
- Crude Oils – Nomograph Overestimates
- U.S. EPA TANKS 4.0.9d and Alternatives
- Capture Efficiency

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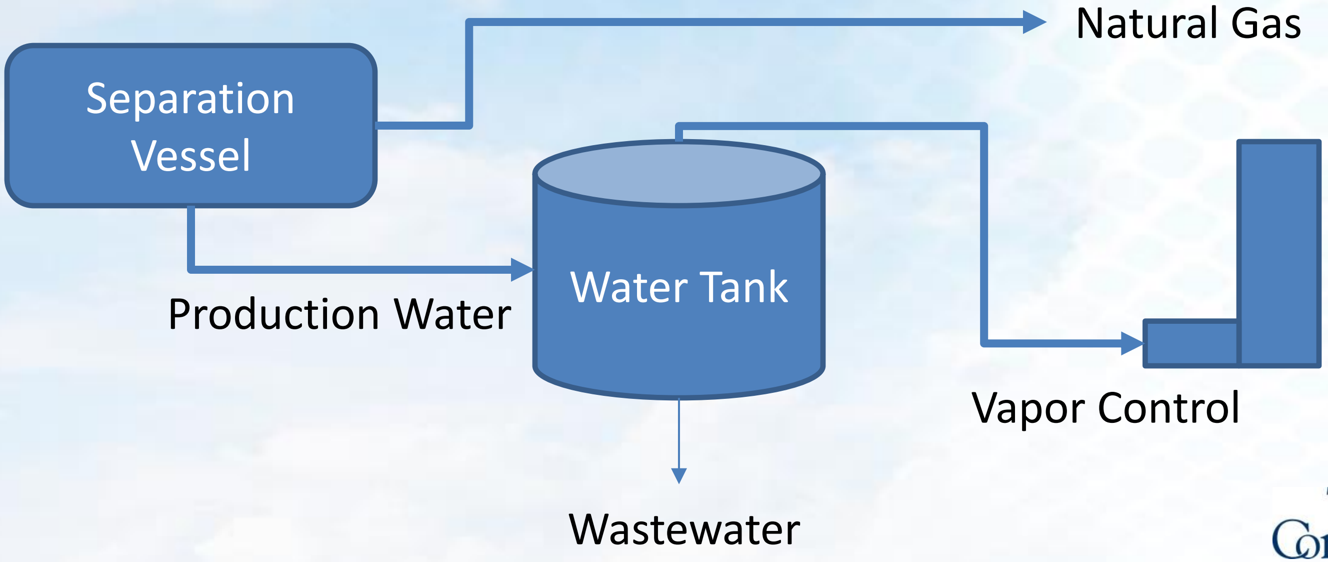
Natural Gas Midstream

- ‘Production Water’
  - Water that is used during production e.g. fracking
  - May condense out of produced natural gas
  - Contains hydrocarbon contamination but is mostly aqueous

Natural Gas Production Water

- Scenario: Production water tank at a dry gas well
- Onsite separator removes production water from natural gas



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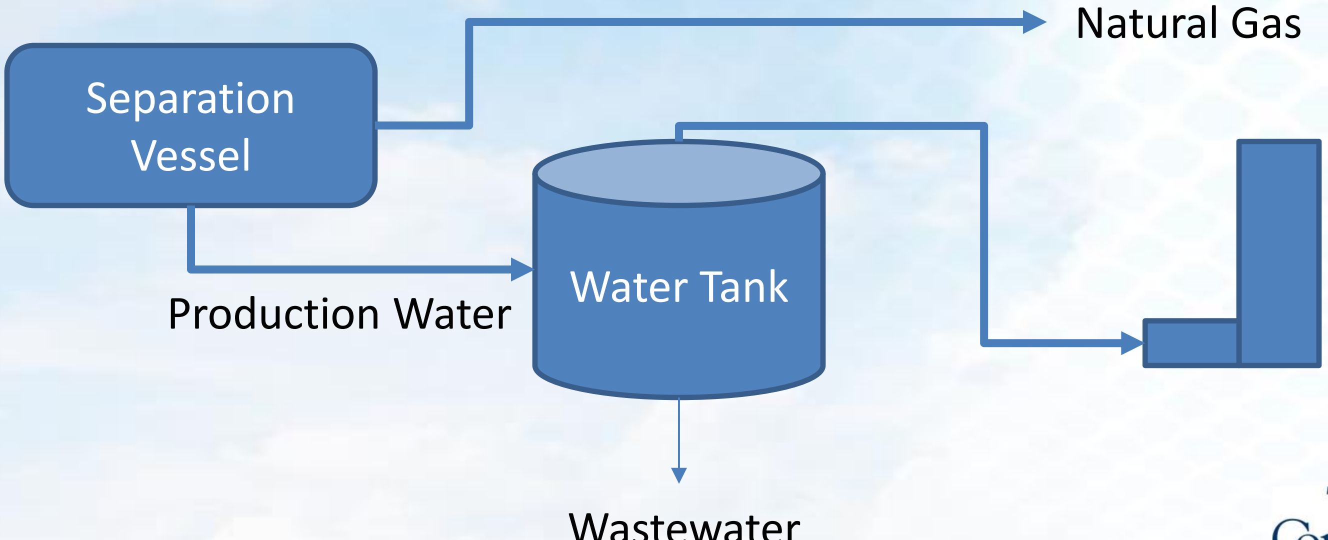
Natural Gas Production Water

- Best Practices
  - Take a pressurized sample from separator
    - Gas chromatograph data on compounds
    - Gas-oil ratio
    - Advantage: direct access by sampling the vapor products of flashing
    - Calculate working/breathing with TankESP or AP-42
  - If not available:
    - Simulate flashing using thermo calculations
    - API offers software tool
    - Need a reasonable assumption re: qty VOC flashed

Natural Gas Production Water

> Method A: Sampled Gas-Water Ratio

$$Release, \frac{metric\ tons\ VOC}{yr} = \left(\frac{bbl}{yr} \times \frac{GWR, scf/bbl}{379\ scf/lbmol} \times \frac{vapor\ MW, lb/lbmol}{2000 \frac{lb}{USton} \times 1.102 \frac{metric}{US\ ton}} \times vapor\ wt\%\ VOC\right)(100\% - \%DRE)$$



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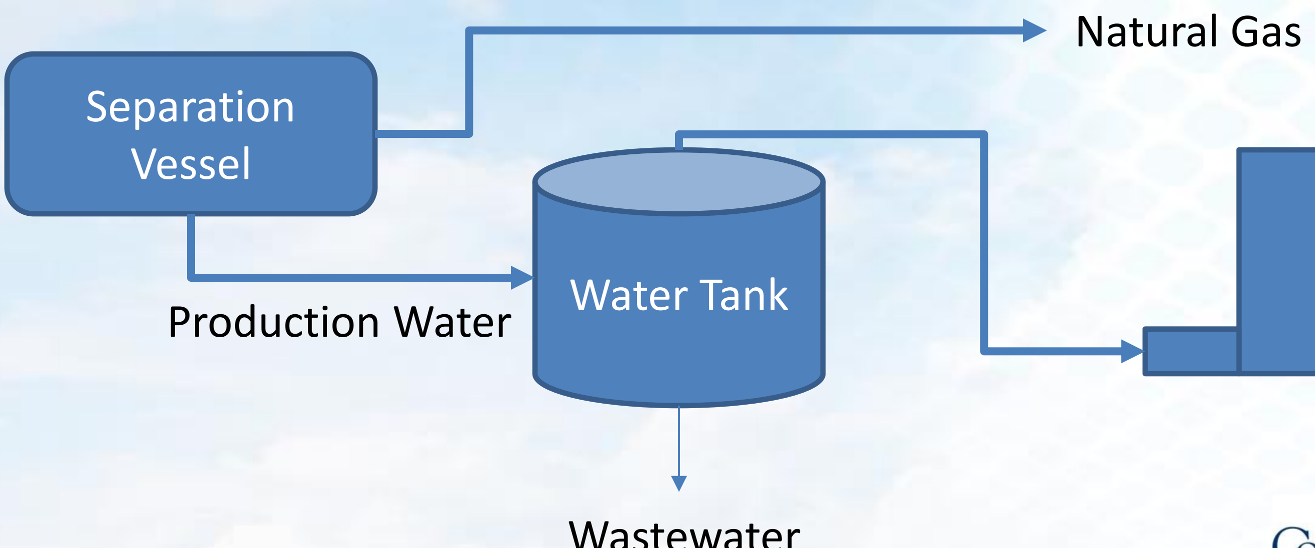
Natural Gas Production Water

- Method B: Material Balance

$$Release, \frac{metric\ tons\ VOC}{yr} = \left(\frac{bbl}{yr} \times 42\frac{gal}{bbl} \times 0.003785412\ \frac{m^3}{gal} \times liquid\ wt\%\ VOC\right)(100\% \ - \%DRE)$$



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Natural Gas Production Water

Result	Method A, GWR	Method B, Mat'l Balance
Throughput, m^3/yr	20,700	20,700
Liquid wt%	--	1% (conservative est.)
GWR, scf/bbl	4.01, analytical	--
Vapor Molar Mass, g/mol	31.02, analytical	--
Vapor wt% VOC	52.51 wt%, analytical	--
Vapor Capture/Control	98%	98%
VOC Release, metric tons/yr	0.20	4.14
% Difference	--	2034% (!!)

Environment and Climate Change Canada, *Guide for Reporting to the National Pollutant Release Inventory (NPRI): 2016 and 2017*, Cat. No. : En81-1E-PDF, 2016.

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Natural Gas Production Water

- Site-related variances in analytical results
  - Vapor wt% VOC from 1% to 50%
    - VOC release quantity proportional to vapor wt%
  - Gas-Water Ratio up to 7 bbl/scf
    - VOC release quantity proportional to GWR

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Crude Oil Vapor Pressure

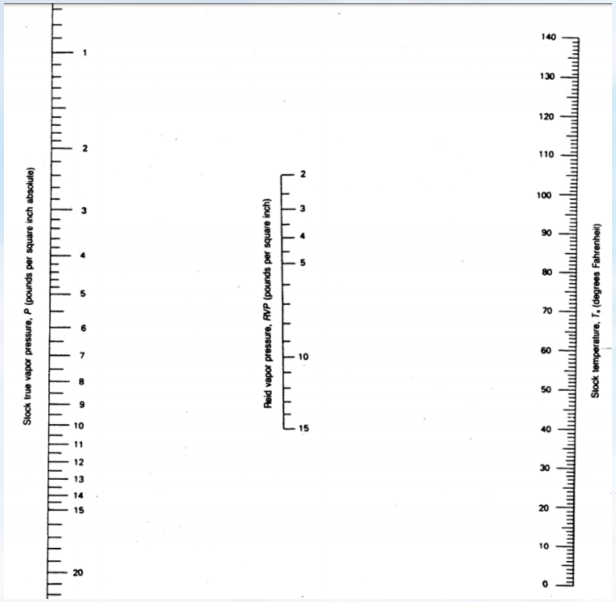
- Scenario: Crude oil storage

Crude Oil Vapor Pressure

- Best Practices
  - Use ASTM D6377 to quantify TVP
    - Advantage: discovers TVP of crude without using RVP to TVP correlations that overstate TVP
  - Instructions for lab analysis:
    - Measure the TVP at various temperatures
      - E.G., 5 C° increments from 5 to 40 °C
    - Use a Vapor to Liquid (V / L) ratio of 4.0
  - Then, use results to regress TVP as function of temperature

Crude Oil Vapor Pressure

- Relationship between nomographs and degassing
  - Nomograph gives one TVP for each (RVP, T)



From U.S. EPA, AP-42 emission factor guide, section 7.1, “Organic Liquid Storage Tanks”

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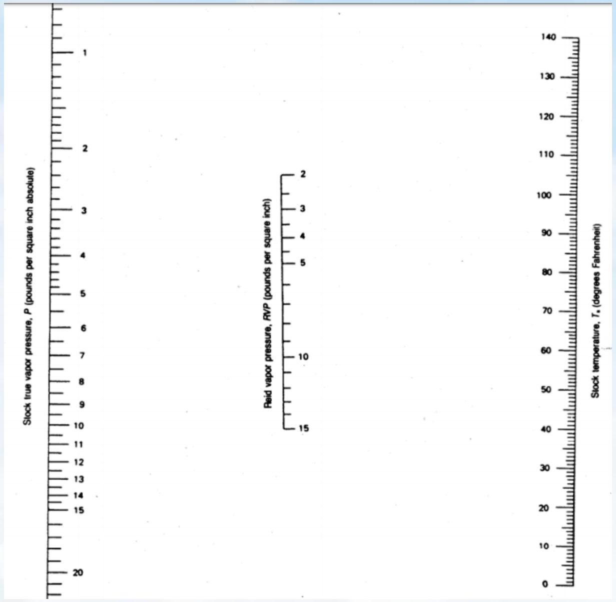
Crude Oil Vapor Pressure

> Method A: ASTM D6377
  - Analytical sampling at specified Gas-Oil Ratio (GOR) and temperature curve

> Method B: API 19.2 Nomographs



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Crude Oil Vapor Pressure

Result	Method A, ASTM D6377	Method B, API 19.2
Reid Vapor Pressure, kPa	48.09	48.09
True Vapor Pressure, kPa, 37.8 °C, Degassed	61.02	61.32
True Vapor Pressure, kPa, 37.8 °C, Not Degassed	128.1	--

Crude analytical data sourced from: Hannes Pickner, "Validation of True Vapour Pressure Measurement in Crude Oil and Refined Products," *Petro Industry News Annual Buyer's Guide 2017*.

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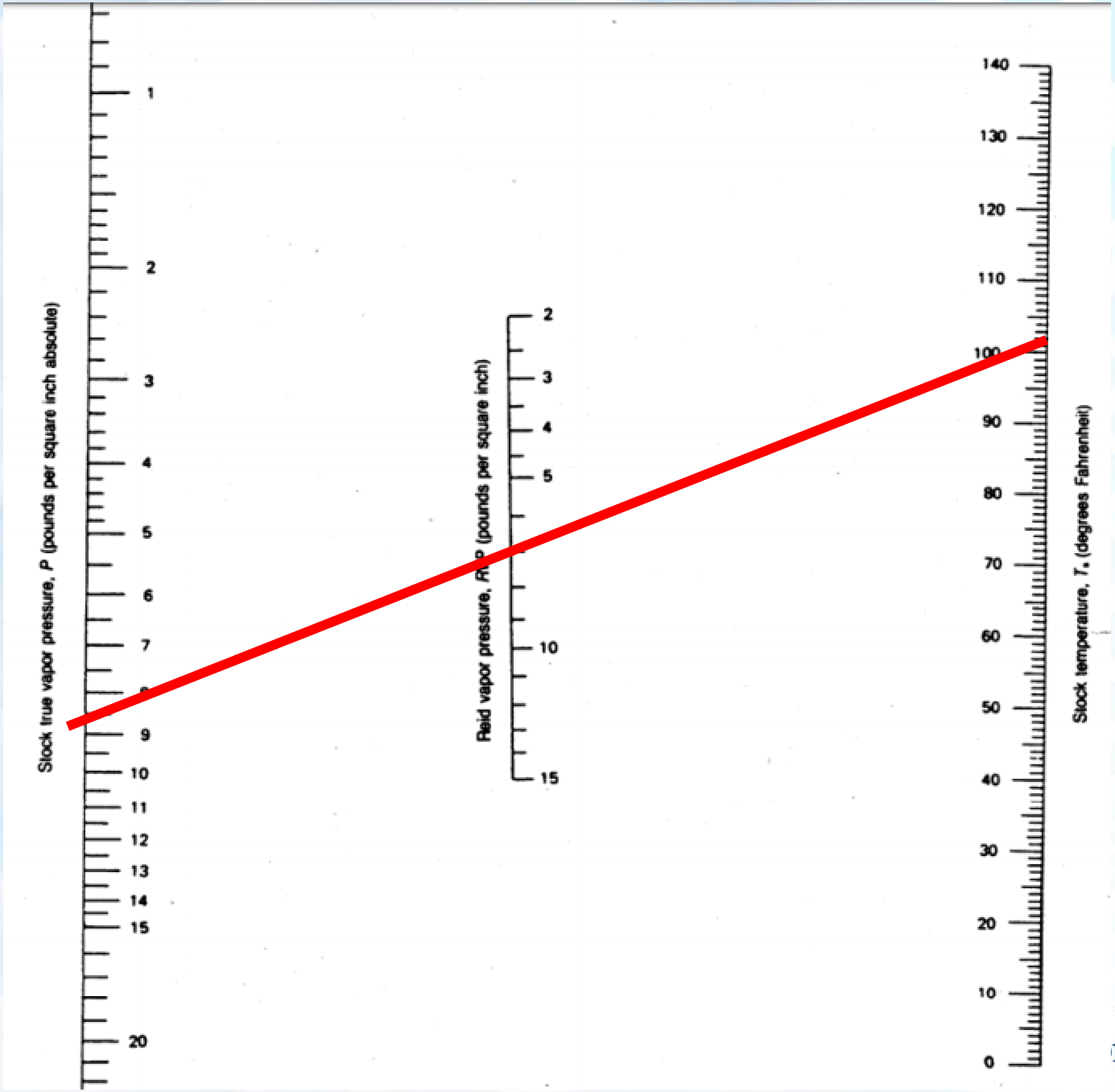

Stock true vapor pressure, P (pounds per square inch absolute)
1
2
3
4
5
6
7
9
10
11
12
13
14
15
20
Reid vapor pressure, RVP (pounds per square inch)
2
3
4
5
10
15
Stock temperature, T_s (degrees Fahrenheit)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

Standing Loss (VFR)

> Related to several variables

$$L_S = 365 K_E \left(\frac{\pi}{4} D^2 \right) H_{VO} K_S W_V \qquad (1\text{-}4)$$

where:

L_S = standing storage loss, lb/yr

K_E = vapor space expansion factor, dimensionless, see Equation 1-5, 1-6, or 1-7

D = diameter, ft, see Equation 1-13 for horizontal tanks

H_{VO} = vapor space outage, ft, see Equation 1-15; use $H_E/2$ from Equation 1-14 for horizontal tanks

K_S = vented vapor saturation factor, dimensionless, see Equation 1-20

W_V = stock vapor density, lb/ft^3, see Equation 1-21

365 = constant, the number of daily events in a year, (year)$^{-1}$

> L_s varies close to directly with P_{vap}

- Subject to some assumptions

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Working Loss (VFR)

- AP-42 7.1, Equation 1-35

$$L_W = N\ H_{LX} \left(\frac{\pi}{4}\right) D^2\ K_N\ K_P\ W_V\ K_B \tag{1-35}$$

where:

L_W = working loss, lb/yr
N = number of turnovers per year, $(\text{year})^{-1}$
H_{LX} = maximum liquid height, ft
D = diameter, ft
K_N = working loss turnover (saturation) factor, dimensionless; see Figure 7.1-18
  for turnovers > 36, $K_N = (180 + N)/6N$
  for turnovers ≤ 36, $K_N = 1$
K_P = working loss product factor, dimensionless
  for crude oils $K_P = 0.75$
  for all other organic liquids, $K_P = 1$
W_V = vapor density, lb/ft^3, see Equation 1-21
K_B = vent setting correction factor, dimensionless
  for open vents and for a vent setting range up to ± 0.03 psig, $K_B = 1$

- L_W directly proportional to Pvap (W_V)

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Crude Oil Vapor Pressure

Release Scenarios	Vertical Fixed-Roof Tank	Large Internal Floating Roof Storage Tank
Tank Diameter, m	3.05	42.67
Tank Height, m	6.10	16.57
Capacity, m^3	40.03	23690
Turnovers	25/yr	2/yr
Color	White	White
Roof Type	Cone, 0.0625 m/m slope	Internal Floating, Mechanical Shoe Seal Shoe-Mounted Secondary
Location	Fargo, ND	Fargo, ND

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Crude Oil Vapor Pressure

Result	Degassed	Not Degassed
Reid Vapor Pressure, kPa	48.09	48.09
True Vapor Pressure, kPa, 37.8 °C (reference)	61.02	128.1
Atmospheric Pressure, kPa	98.25	98.25
Flashing?	No	Yes – not in TANKS 4.0.9d
VOC Release, Small VFR, metric tons/yr working	0.95	1.52
% Difference	-37.7%	--
VOC Release, Large IFR, metric tons/yr total	2.63	9.85
% Difference	-73.3%	--

Emissions calculated with U.S. EPA TANKS 4.0.9d tool; excludes flashing emissions for non-degassed crudes. Cannot calculate VFR standing losses for non-degassed crude because K_E calculates incorrectly to zero.

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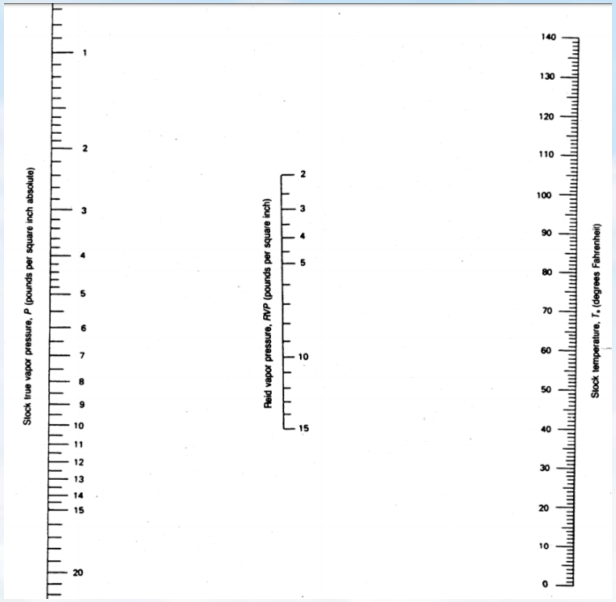
Crude Oil Vapor Pressure

- Relationship between nomographs and real-world pressures
  - Nomograph is conservative overestimate



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Crude Oil Vapor Pressure

Result	Nomograph	Equation of State
VPCR, kPa	74.46	74.46
True Vapor Pressure, kPa, 37.8 °C (reference)	103.4	79.29
True Vapor Pressure, kPa, 5.8 °C (Fargo ann. avg.)	41.93	33.98
VOC Release, Small VFR, metric tons/yr total	0.90	0.70
% Difference	28.4%	--
VOC Release, Large IFR, metric tons/yr total	1.55	1.19
% Difference	29.7%	--

Vapor pressures extrapolated at Fargo, ND temperatures based on curves provided in Cameron Konecnik, "Proposal for an Improved Method of Crude Oil Vapor Pressure Determination," CCQTA 3rd Annual LDAR-BWON-Tanks-Flares Conference, February 19, 2013, figure titled "Vapor Pressure Project Results – P1."

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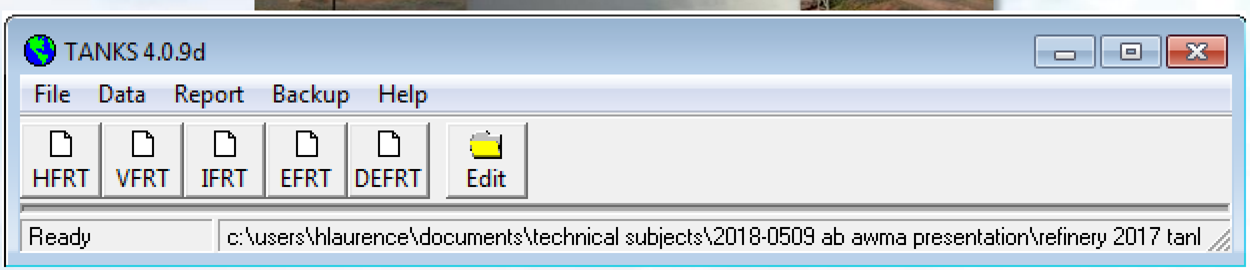
U.S. EPA TANKS 4.0.9d



U.S. EPA TANKS 4.0.9d

- Many reasons to avoid if possible
  - AP-42 revisions
  - Annual vs. monthly calculations
  - Working losses in VFRs – inaccurate calculation method

U.S. EPA TANKS 4.0.9d

- Specific reasons to avoid in oil & gas sector
  - Crude oil approach may underestimate (TCEQ has disallowed TANKS since 2011)
  - No flashing emissions
  - No roof landing / tank cleaning emissions
  - Monthly variance is inaccurate, but needed for:
    - Tanks with throughput changes
    - Tanks with seasonal regulatory requirements

Tank Emission Calculation Tools

- TankESP by Rob Ferry, now with Trinity
  - Captures flashing, roof landing, AND cleaning!
- Trinity Tanks Tool
  - Captures roof landing and cleaning
  - Spreadsheet
  - High degree of customization for advanced users
- API E&P TANK
  - Captures flashing

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Closing Remark – Capture %

- 100% capture for tanks with cover and closed vent system
- < 100% if tank is overpressurized and vapors released w/o control
- Small changes in capture % = large changes in release quantities
  - 99% to 98% = double
  - 98% to 97% = 1.5x
  - Etc.

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Conclusions

- Analytical data are gold standard
  - NG prod water: pressurized sample
  - Crude ASTM D6377
  - Validate assumptions behind data use
- Calculate flashing, degassing, and non-steady-state releases
  - Consider alternatives to TANKS 4.0.9d
- API 19.2 nomograph may overestimate Pvap and releases

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Questions?

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