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
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
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

\[
Release, \frac{\text{metric tons VOC}}{\text{yr}} = \left( \frac{\text{bbl}}{\text{yr}} \times \frac{\text{GWR, scf/bbl}}{379 \text{ scf/lbmol}} \times \frac{\text{vapor MW, lb/lbmol}}{2000 \frac{\text{lb}}{\text{US ton}}} \times 1.102 \frac{\text{metric}}{\text{US ton}} \times \text{vapor wt\% VOC} \right) (100\% - \%DRE)
\]
Natural Gas Production Water

> Method B: Material Balance

\[
\text{Release, \( \frac{\text{metric tons VOC}}{\text{yr}} \)} = \left( \frac{\text{bb}l}{\text{yr}} \times 42 \frac{\text{gal}}{\text{bb}l} \times 0.003785412 \frac{m^3}{\text{gal}} \times \text{liquid wt\% VOC} \right) (100\% - \%DRE)
\]
## Natural Gas Production Water

<table>
<thead>
<tr>
<th>Result</th>
<th>Method A, GWR</th>
<th>Method B, Mat’l Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput, m³/yr</td>
<td>20,700</td>
<td>20,700</td>
</tr>
<tr>
<td>Liquid wt%</td>
<td>--</td>
<td>1% (conservative est.)</td>
</tr>
<tr>
<td>GWR, scf/bbl</td>
<td>4.01, analytical</td>
<td>--</td>
</tr>
<tr>
<td>Vapor Molar Mass, g/mol</td>
<td>31.02, analytical</td>
<td>--</td>
</tr>
<tr>
<td>Vapor wt% VOC</td>
<td>52.51 wt%, analytical</td>
<td>--</td>
</tr>
<tr>
<td>Vapor Capture/Control</td>
<td>98%</td>
<td>98%</td>
</tr>
<tr>
<td>VOC Release, metric tons/yr</td>
<td>0.20</td>
<td>4.14</td>
</tr>
<tr>
<td>% Difference</td>
<td>--</td>
<td>2034% (!!)</td>
</tr>
</tbody>
</table>

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
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)

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
# Crude Oil Vapor Pressure

<table>
<thead>
<tr>
<th>Result</th>
<th>Method A, ASTM D6377</th>
<th>Method B, API 19.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reid Vapor Pressure, kPa</td>
<td>48.09</td>
<td>48.09</td>
</tr>
<tr>
<td>True Vapor Pressure, kPa, 37.8 °C, Degassed</td>
<td>61.02</td>
<td>61.32</td>
</tr>
<tr>
<td>True Vapor Pressure, kPa, 37.8 °C, Not Degassed</td>
<td>128.1</td>
<td>--</td>
</tr>
</tbody>
</table>

Standing Loss (VFR)

> Related to several variables

\[ L_S = 365K_E \left( \frac{\pi}{4} D^2 \right) H_{VO} K_S W_V \]  

(1-4)

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 \( H_b/2 \) 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
Working Loss (VFR)

> AP-42 7.1, Equation 1-35

\[
L_W = N \ H_{LX} \left( \frac{\pi}{4} \right) D^2 \ K_N \ K_P \ W_v \ K_B
\]

(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 \( \leq 36 \), \( K_N = 1 \)
- \( K_P \) = 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 \( P_{vap} \) (\( W_v \))
## Crude Oil Vapor Pressure

<table>
<thead>
<tr>
<th>Release Scenarios</th>
<th>Vertical Fixed-Roof Tank</th>
<th>Large Internal Floating Roof Storage Tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank Diameter, m</td>
<td>3.05</td>
<td>42.67</td>
</tr>
<tr>
<td>Tank Height, m</td>
<td>6.10</td>
<td>16.57</td>
</tr>
<tr>
<td>Capacity, m³</td>
<td>40.03</td>
<td>23690</td>
</tr>
<tr>
<td>Turnovers</td>
<td>25/yr</td>
<td>2/yr</td>
</tr>
<tr>
<td>Color</td>
<td>White</td>
<td>White</td>
</tr>
<tr>
<td>Roof Type</td>
<td>Cone, 0.0625 m/m slope</td>
<td>Internal Floating, Mechanical Shoe Seal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shoe-Mounted Secondary</td>
</tr>
<tr>
<td>Location</td>
<td>Fargo, ND</td>
<td>Fargo, ND</td>
</tr>
</tbody>
</table>

Trinity Consultants
## Crude Oil Vapor Pressure

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.

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

> Relationship between nomographs and real-world pressures

- Nomograph is conservative overestimate
Crude Oil Vapor Pressure

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

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.”
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
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.
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
Questions?

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