Air Permit Reviewer Reference Guide

APDG 6250

Estimating Short Term Emission Rates from Tanks

Air Permits Division
Texas Commission on Environmental Quality

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Estimating Short Term Emission Rates from Fixed Roof Tanks

Scope

The goal of this document is to provide a methodology to calculate the worst case short term emissions from a vertical fixed roof tank (VFR tank). All calculations and derivations for short term emissions also apply to horizontal tanks. However, this calculation methodology does not apply to pressure vessels capable of handling 29.72 psia or greater, constant level or "surge" tanks (i.e., tanks that have inflow and outflow at the same time), and certain cases where a tank contains mixed phase materials (i.e., water with dense non aqueous phase liquid or crude with dissolved methane) or may otherwise have flash emissions.

Calculation Procedure

Emission from loading a VFR tank should be calculated using Equation 1:

Equation 1

$$L_{MAX} = \frac{M_V \times P_{VA}}{R \times T} \times FR_M$$

Equation 1

- MV (lb/lbmol) is the vapor molecular weight of the VOC
- PVA (psia) is the vapor pressure of the tank contents at the worst case temperature
- FRM (gal/hr) is the maximum filling rate
- R ((Psia × gal)/(lbmol × °R)) is the ideal gas constant (80.273 for the selected units)
- T (Rankine) is the worst case liquid surface temperature. It is TCEQ practice to use either 95°F (554.67°R) or the actual temperature, whichever is higher

Using these units in Equation 1 gives emissions as a lb/hr rate.

Engineering Derivation

This section derives and explains Equation 1 listed above. Working losses are emissions of VOC that occur during the filling of a VFR tank. In an atmospheric vessel with fixed volume, a rising liquid level causes the displacement of vapors between the liquid surface and the vessel roof (the "headspace"). Emissions can be calculated by taking note of the fact that the total tank volume (liquid volume plus headspace) is a constant, and writing down its derivative, as is done in Equation 3.

$$V_{LIQUID} + V_{HEADSPACE} = Constant$$

Equation 2

$$\frac{d}{dt}V_{LIQUID} + \frac{d}{dt}V_{HEADSPACE} = 0$$

Equation 3

The rate at which the tank liquid volume increases (the derivative of VLIQUID with respect to time) is equal to its filling rate, FR, and the rate at which the headspace volume decreases (the derivative of VHEADSPACE with respect to time) is equal to the volumetric emission rate, ERVOL. Substituting and rearranging Equation 3, we have:

Equation 4

$$FR = ER_{VOL}$$

The mass emission rate is equal to the volumetric emission rate times the density of the vapor space, W_V. This is expressed in Equation 5 when Equation 4 is substituted.

Equation 5

$$ER = W_V \times FR$$

Assuming that the vapor space is of constant density, the vapor VOC density may be rewritten using the ideal gas law:

Equation 6

$$W_V = \frac{M_V \times P_{VA}}{R \times T}$$

All calculations for working losses are based on the relationship in Equation 5. Additional complexities such as incomplete saturation of the vapor space,[1] or pressure differentials between the vessel and the atmosphere introduced by tank breather settings, are accounted for with the use of various correction factors.

Relation Between Historical and Current Calculation Methodologies

TCEQ draft guidance document, RG-166[2](p. 11), prescribes Equation 7 for calculating short-term losses (in lb/hr) from VFR tanks:

Equation 7

$$L_{MAX} = \frac{L_W \times FR_M}{N \times T_{CG}}$$

LW (lb/yr) is specified as "working loss calculated using AP-42... at maximum liquid surface temperature, lbs/yr (NOTE: LW must be calculated using a turnover factor, KN, of 1)." FRM (gal/hr) is the maximum filling rate. N is the number of annual turnovers, and TCG (gallons) is the tank capacity. The product N × TCG is equal to the annual throughput, Q, (gal/yr). AP-42, chap. 7 (p. 7.1-18) provides Equation 8 for calculating LW:

$$L_W = .0010 \times M_V \times P_{VA} \times Q \times K_N \times K_P$$

Equation 8

Q is the annual throughput (bbl). KN and KP are correction factors: KN accounts for incomplete saturation of the vapor space when turnovers are frequent, and KP accounts for lower releases from crude oil tanks than from organic liquid tanks (KP = 1 for the latter)[3]. The constant 0.0010 is equal to 1/(R × T), where R is the universal gas constant, 1.911 (bbl × psia)/(lbmol × °R) and T is arbitrarily set at 522.67 °R (i.e., 63°F), but need not be. Equation 8 may therefore be rewritten as Equation 9:[4]

Equation 9

$$L_W = \left(\frac{M_V \times P_{VA}}{R \times T}\right) \times Q$$

Substituting Equation 9 into Equation 7, as RG-166 prescribes, yields the following:

Equation 10

$$L_{MAX} = \frac{\left(\frac{M_V \times P_{VA}}{R \times T}\right) \times Q \times FR_M}{N \times T_{CG}}$$

Q, the annual throughput, is by definition equal to N × TCG, so these terms cancel, leaving Equation 11:

$$L_{MAX} = \frac{M_V \times P_{VA}}{R \times T} \times FR_M$$ **Equation 11**

It will be noted that Equation 11 (which is identical to Equation 7 and Equation 1) can also be obtained by plugging Equation 6 into Equation 5.

Endnotes

1When the partial pressure of VOC in the vessel vapor space is equal to its vapor pressure, the vapor space is saturated. When the partial pressure of the VOC in the vessel space is less than its vapor pressure, the vapor space is incompletely saturated.

2 Technical Guidance Package for Chemical Sources: Storage Tanks (Feb. 2001). TCEQ Air Permits Division

3 It is TCEQ practice to conservatively set KP = 1 for all liquids when performing worst case emissions calculation.

4 Assuming KN = KP = 1, which is true for worst case short term emissions from organic liquids.