Air Permit Reviewer Reference Guide

APDG 6419

Short-term Emissions from Floating Roof Storage Tanks

Air Permits Division
Texas Commission on Environmental Quality

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Short-term Emissions from Floating Roof Tanks

Introduction

The purpose of this document is to clarify current TCEQ Air Permits Division guidance on estimating short-term emissions from floating roof tanks during routine operations. The parameters and methods herein are recommended for the purpose of establishing conservative emission rates that may be relied upon for health impacts analyses and other permitting requirements. The emission calculation procedures are generally based on equations found in EPA AP-42 Chapter 7 (November 2019 version). Note that this guidance does not address calculation of annual emissions. For guidance on estimating annual emissions, please refer to EPA AP-42 Chapter 7 or contact the Air Permits Division at (512) 239-1250.

This publication illustrates an acceptable method for estimating short-term emissions from floating roof tanks. Please refer to Appendix A for the example calculation. Please note that other software or spreadsheet programs may also be used to estimate short-term emission rates, provided the methodology is based on current EPA AP-42 equations using the worst-case parameters described below.

The most conservative value for short-term emissions can be determined using the maximum pump rate for withdrawal losses and the vapor pressure corresponding to the maximum liquid surface temperature. The maximum liquid surface temperature (T_{LX}) can be assumed to be 95°F (554.67°R) or the actual temperature, whichever is higher, for consistency with the guidance for fixed roof tanks (APDG 6250). As an alternative, a maximum liquid surface temperature can be determined from on-site monitoring of the actual temperature. As a third alternative, applicants can continue to calculate emissions using the "worst month" approach, which is equivalent to using the average daily liquid surface temperature (T_{LA}) from the month that produces the highest emission rate. In the "worst month" approach, T_{LA} is calculated using equations and the monthly meteorological data (Table 7.1-7) from the current EPA AP-42, Chapter 7.

The following short-term calculation procedures are intended to cover routine emissions from the most common floating roof tank scenarios. For special cases that may require unique considerations, please contact the Air Permits Division at (512) 239-1250.

Total Short-term Losses

Total short-term losses from floating roof tanks are a combination of withdrawal (working) losses and standing losses. Based on Equations 2-1 and 2-2 of EPA AP-42 Chapter 7, annual floating roof tank losses may be expressed as follows:

$$L_T = L_{WD} + L_R + L_F + L_D \text{ (Equation 1)}$$

- L_T is Total Loss (lb/year)
- L_{WD} is Withdrawal Loss (lb/year)
- L_R is Rim Seal Loss (lb/year)
- L_F is Deck Fitting Loss (lb/year)
- L_D is Deck Seam Loss (lb/year)

To obtain a short-term (lb/hr) emission rate, AP-42 equations for each loss type are used with certain worst-case parameters. For withdrawal loss, the equation is adjusted for maximum throughput. For standing losses (rim seal, deck fitting, and deck seam), the equations are adjusted to account for the vapor pressure corresponding to the maximum liquid surface temperature.

Withdrawal Loss

Withdrawal loss does not depend on the stock vapor pressure. It is the only component of total short-term losses that depends on the fill/withdrawal rate. In order to simulate worst-case conditions, we first determine a maximum annual throughput based on the maximum pumping rate and assuming throughput occurs on a continuous basis:

$$Q_{MAX} = PR_M \times (8760\ hr/yr) \text{ (Equation 2)}$$

- Q_{MAX} is Maximum Throughput (bbl/year)
- PR_M is Maximum Pumping Rate (bbl/hr)

Note: For internal floating roof tanks, use the greater of the maximum fill rate or maximum withdrawal rate; for external floating roof tanks, use the maximum withdrawal rate.

Withdrawal loss is then calculated as follows:

$$L_{WD} = \frac{0.943 Q_{MAX} C_S W_L}{D}\left[1 + \frac{N_C F_C}{D}\right] \text{ (Equation 3)}$$

- L_{WD} is Withdrawal Loss (lb/year)
- 0.943 is Constant ($10^3\ ft^3\ gal/bbl^2$)
- Q_{MAX} is Maximum Throughput (bbl/year)

- C_S is Shell Clingage factor (bbl/10^3 ft^2 – See Table 7.1-10 from AP-42)
- W_L is Liquid Density (lb/gal)
- N_C is Number of Fixed Roof Support Columns (Table 7.1-11 from AP-42); N_C = 0 for self-supported or cable-suspended roof
- F_C is Effective Column Diameter (ft)
- D is Tank Diameter (ft)

Rim Seal Loss

Rim seal loss depends on the vapor pressure of the material being stored and is not affected by the fill/withdrawal rate.

$$L_R = \left(K_{Ra} + K_{Rb} v^n\right) D P^* M_V K_C \quad \text{(Equation 4)}$$

- L_R is Rim Seal Loss (lb/year)
- K_{Ra} is Zero Wind Speed Loss Factor ((lb-mole)/(ft·yr))
- K_{Rb} is Wind Dependent Loss Factor ((lb-mole/((mph)^n (ft·yr)))
- For K_{Ra}, K_{Rb}, and n, Use Table 7.1-8 from AP-42, Chapter 7
- v is Worst Month Wind Speed (mph)[(1)(2)] – Use Data from Site, Local Weather Station, or EPA AP-42 Table 7.1-7

  [(1)]NOTE: v = 0 for internal or domed external floating roof tank.

  [(2)]NOTE: While AP-42 indicates average ambient wind speed for annual calculations, please use the worst month wind speed for short-term calculations.
- n is Wind Dependent Loss Exponent (dimensionless)
- D is Tank Diameter (ft)
- P* is Vapor Pressure Function (Eqn. 5, dimensionless)
- M_V is Vapor Molecular Weight (lb/lb-mol)
- K_C is Product Factor (0.6 crude oil[(3)]; 1.0 other)

  [(3)]NOTE: For the crude oil product factor (K_C), use 0.6 for short-term (lb/hr) calculations and 0.4 for annual (tpy) calculations as recommended by API Technical Report 2576.

$$P^* = \frac{P_{VA}/P_A}{\left[1 + \left(1 - \left(P_{VA}/P_A\right)\right)^{0.5}\right]^2} \quad \text{(Equation 5)}$$

- P_{VA} is Vapor Pressure at Maximum Liquid Surface Temperature, psia
- P_A is Atmospheric Pressure, psia

Deck Fitting Loss

Deck fitting losses depend on the vapor pressure of the stored material. Applicants should provide a completed Table 7(c) and/or Table 7(d) with the permit application to summarize tank fittings. If there are tank fittings not found in Table 7(d), use the values from AP-42 (Table 7.1-12) to calculate long-term emissions from floating roof tanks. Tables 7(c) and 7(d) are available on the TCEQ website. (www.tceq.texas.gov/permitting/air/forms/newsourcereview/tables/nsr_table2.html)

$$L_F = F_F P^* M_V K_C \quad \text{(Equation 6)}$$

- L_F is Deck Fitting Loss (lb/year)
- F_F is Fitting Loss Factor[(1)(2)] – calculated from Form 7(d) (lb-mol/yr) or AP-42 Table 7.1-12
- K_C is Product Factor (0.6 crude oil; 1.0 other)

[(1)]NOTE: Please note that wind speed will affect the calculation of F_F for external floating roof tanks. See AP-42 Chapter 7, Equations 2-13 through 2-16 and AP-42 Chapter 7, Sample Calculations, Example 3.

[(2)]NOTE: Please note that actual tank fitting types must be used when calculating the fitting loss factor (F_F). Fittings must also be in compliance with rules and current BACT.

Deck Seam Loss

Deck seam losses are zero for external floating roof tanks and for welded decks on internal floating roof tanks. For bolted decks on internal floating roof tanks, the losses depend on the vapor pressure of the stored material and the square of the diameter of the tank.

$$L_D = K_D S_D D^2 P^* M_V K_C \quad \text{(Equation 7)}$$

- L_D is Deck Seam Loss (lb/year)
- K_D is Deck Seam Loss per Unit Seam Length Factor (lb-mol/ft·yr)
  = 0.0 for Welded Deck; = 0.14 for Bolted Deck
- S_D = Deck Seam Length Factor (ft/ft^2)
  = L_{seam}/A_{deck} (ft^{-1})

  Where: L_{seam} = total length of deck seams (ft)

  A_{deck} = area of deck (ft^2) = $\left(\frac{1}{4}\right)\pi D^2$

Seasonal Adjustments

Please note that if the material characteristics vary by month or season due to regulatory requirements (such as Reid Vapor Pressure limits at gasoline terminals), the worst-case month for emissions may not necessarily correspond to the warmest ambient conditions. In the case of external floating roof tanks, please note that both temperature and wind speed will affect standing losses, and the highest ambient temperature and highest wind speed may not necessarily occur in the same month. These and other variable factors may be accounted for by calculating emissions for each month separately (using Q_{MAX}) and choosing the month with the highest emissions as the basis for the short-term emission rate. The variables should be considered regardless of the calculation method used (hand method or other AP-42 based program).

Adjustment for Material Temperature

If the floating roof tank or its material is heated, or if the material enters the tank above ambient temperature, the short-term standing loss calculations should be adjusted to account for the vapor pressure at the worst-case liquid surface temperature. This approach may also be used for ambient temperature tanks when a more conservative assumption is selected (e.g., using 95^{o}F for the liquid surface temperature).

For the short term calculation, the worst-case vapor pressure is plugged into the vapor pressure function equation (Equation 5, or AP-42 Equation 2-4).

The material temperature adjustment for floating roof tank scenarios is further illustrated in *Appendix A, Example Calculations*.

Note: In cases where mixtures are stored, please also account for any variations in vapor phase molecular weight (Mv) due to heating.

Best Available Control Technology (BACT)

All new or modified storage tanks must meet current Best Available Control Technology (BACT) requirements. Current BACT requirements are listed in the TCEQ NSR Form PI-1 General Application located at the following link:

https://www.tceq.texas.gov/permitting/air/guidance/newsourcereview/nsrapp-tools.html

For more information on current or historical BACT requirements for storage tanks, please contact the TCEQ Air Permits Division at (512) 239-1250.

Equation References

Equation 1: AP-42, Chapter 7.1.3.2.1, Equations 2-1 and 2-2
Equation 2: TCEQ Draft RG-166, Equation V-2
Equation 3: AP-42, Chapter 7.1.3.2.1, Equation 2-19
Equation 4: AP-42, Chapter 7.1.3.2.1, Equation 2-3
Equation 5: AP-42, Chapter 7.1.3.2.1, Equation 2-4
Equation 6: AP-42, Chapter 7.1.3.2.1, Equation 2-13
Equation 7: AP-42, Chapter 7.1.3.2.1, Equation 2-18

APPENDIX A
Short-term Emissions from Floating Roof Tanks
Example Calculations

Short-term emissions from floating roof tanks may be calculated using equations from AP-42 Chapter 7 with some value substitutions to reflect worst-case parameters and conditions. TCEQ recommends the following calculation steps:

EXAMPLE SCENARIO: Internal Floating Roof (IFR) Tank - heated such that the maximum liquid surface temperature = 100°F.

Given:	General	= AAAA Corporation located in Galveston, Texas.
	Tank Type	= Internal Floating Roof Tank
	Diameter	= 60 ft
	TC_G	= 846,100 gal
	Q	= 10,000,000 gal/yr
	Q_{MAX}	= PR_M (gal/hr) x 8,760 hr/yr
	PR_M	= 5,000 gal/hr (needed for Q_{MAX})
	Roof	= Not Self Supporting
	No. Columns	= 1
	Column Dia.	= 1 ft
	Internal Shell	= Light Rust
	Shell Col/Shade	= White/White
	Shell Cond.	= Good
	Roof Col/Shade	= White/White
	Roof Cond.	= Good
	Primary Seal	= Liquid-Mounted
	Sec. Seal	= None
	Deck Type	= Welded
	Deck Fittings	= See Below
	Contents	= 100% n-Heptane
	M_V	= 100.204 lb/lbmol
	Heated?	= Yes
	T_{MAX}	= Maximum Liquid Surface Temperature = 100°F
	VP_{MAX}	= Vapor Pressure at T_{MAX} = 1.62 psia
	W_L	= Liquid Density at 100°F = 5.597 lb/gal

Deck Fitting Information

Deck Fitting	Status	Quantity
Access Hatch (24-in. Diam.)	Bolted Cover, Gasketed	1
Automatic Gauge Float Well	Bolted Cover, Gasketed	1
Column Well (24-in. Diam.)	Built-Up Col.-Sliding Cover, Gasketed	1
Ladder Well (36-in. Diam.)	Sliding Cover, Gasketed	1
Roof Leg or Hanger Well	Adjustable	17
Sample Pipe or Well (24-in. Diam.)	Slit Fabric Seal 10% Open	1
Vacuum Breaker (10-in. Diam.)	Weighted Mech. Actuation, Gask.	1

Find: Worst-case short-term VOC emission rate (lb/hr).

Solution: Using Hand Calculation Method (Heated IFR Tank)

1) Withdrawal (Working) Loss (L_{WD})

Calculate the maximum throughput (Q_{MAX}), based on the worst-case hourly pump rate (PRM):

Q_{MAX} (bbl/yr) = PR_M (bbl/hr) × 8,760 (hr/yr)

In this example:

Q_{MAX} (bbl/yr) = (5,000 gal/hr) × (1 bbl/42 gal) × 8,760 hr/yr

= 1,042,857.14 bbl/yr (or 43,800,000 gal/yr)

Note: For internal floating roof tanks, use the greater of the maximum fill rate or maximum withdrawal rate for PRM; for external floating roof tanks, use the maximum withdrawal rate for PRM.

Using an estimation method incorporating AP-42, Chapter 7.1, Equation 2-19 and Q_{MAX} as indicated above, calculate worst-case working (withdrawal) losses ($L_{WD\ MAX}$):

$L_{WD\ MAX}$ (lb/yr) = $[(0.943)(Q_{MAX})(C_S)(W_L)/D] \times [1 + (N_C F_C)/D]$

Where: 0.943 = constant (10^3 ft^3 gal/bbl^2)

Q_{MAX} = maximum throughput (bbl/yr, see above)
C_S = shell clingage factor (bbl/10^3 ft^2, AP-42 Table 7.1- 10)
W_L = liquid density (lb/gal)
N_C = number of fixed roof support columns (AP-42 Table 7.1- 11)
= 0 for self-supported or cable-suspended roof
F_C = effective column diameter (ft)
D = tank diameter (ft)

$L_{WD\ MAX}$ (lb/yr) = [(0.943 (10^3 ft^3 gal/bbl^2))(1,042,857.14 bbl/yr)(0.0015 bbl/10^3 ft^2)(5.597 lb/gal)/60 ft] × [1 + (1)(1 ft)/(60 ft)]

$L_{WD\ MAX}$ = 139.90 lb/yr

2) Rim Seal Loss (L_R)

From AP-42, Chapter 7, Equation 2-3:

L_R (lb/yr) = $(K_{Ra} + (K_{Rb}\ v^n))\ D\ P^*\ M_V\ K_C$

Where: K_{Ra} = Zero Wind Speed Loss Factor ((lb-mole)/(ft·yr))

K_{Rb} = Wind Dependent Loss Factor ((lb-mole/((mph)^n (ft·yr)))
For K_{Ra}, K_{Rb}, and n use Tbl 7.1-8
v = Worst Month Wind Speed (mph)

Use Data from Site, Local Weather Station, or EPA AP-42 Table 7.1-7

NOTE: v = 0 for internal or domed external floating roof tank.
n = Wind Dependent Loss Exponent (dimensionless)
D = Tank Diameter (ft)

P^*	=	Vapor Pressure Function (based on maximum liquid surface temperature, see note below)
P_{VA}	=	Vapor Pressure at Maximum Liquid Surface Temperature, psia (needed for P*)
P_A	=	Atmospheric Pressure, psia (needed for P*)
M_V	=	Vapor Molecular Weight (lb/lb-mol)
K_C	=	Product Factor (0.6 crude oil; 1.0 other)

IMPORTANT NOTE: For P*, use the vapor pressure at the maximum liquid surface temperature. In this example, the tank is heated to 100°F, with a corresponding vapor pressure of 1.62 psia:

$$P^* = \frac{[1.62 \text{ psia}/14.7 \text{ psia}]}{[1 + (1 - (1.62 \text{ psia}/14.7 \text{ psia}))^{0.5}]^2}$$

$$= 0.02918$$

$$L_R = [1.6\ ((\text{lb-mole})/(\text{ft}\cdot\text{yr})) + 0.3\ ((\text{lb-mole})/((\text{mph})^n\ (\text{ft}\cdot\text{yr}))]\ (60 \text{ ft})(0.02918)(100.204 \text{ lb/lbmol})(1.0)$$

$$L_R = 280.70 \text{ lb/yr}$$

3) Deck Fitting Loss (L_F)

From AP-42, Chapter 7, Equation 2-13:

$$L_F \text{ (lb/yr)} = F_F\ P^*\ M_V\ K_C$$

Where:

F_F	=	Total Fitting Loss Factor (lb-mol/yr)
P^*	=	Vapor Pressure Function (based on maximum liquid surface temperature, see above)
M_V	=	Vapor Molecular Weight (lb/lb-mol)
K_C	=	Product Factor (0.6 crude oil; 1.0 other)

IMPORTANT NOTE: Please note that actual tank fitting types must be used when calculating the fitting loss factor (F_F). Fittings must also be in compliance with rules and current BACT.

From AP-42 Chapter 7, Equation 2-14:

$$F_F = [(N_{Fi}K_{Fi}) + (N_{F2}K_{F2}) + (N_{Ff}K_{Ff})]$$

Where:

N_{Fi}	=	Number of Fittings of a Particular Type (dimensionless)
K_{Fi}	=	Deck Fitting Loss Factor for a Particular Type (lb-mol/yr) – See AP-42, Chapter 7, Equation 2-7.

From AP-42 Chapter 7, Equation 2-15:

$$K_{Fi} = K_{Fai} + K_{Fbi}(K_V v)^{m_i}$$

Where:

K_{Fi}	=	Deck Fitting Loss Factor for a ParticularType (lb-mol/yr)
K_{Fai}	=	Zero Wind Speed Loss Factor for a Particular Type Fitting (lb-mol/yr)
K_{Fbi}	=	Wind Speed Dependent Loss Factor for a Particular Type Fitting (lb-mol/((mph)^{m}yr)
m_i	=	Loss Factor for a Particular Type Fitting (dimensionless)
i	=	1, 2, n (dimensionless)
K_V	=	Wind Speed Correction Factor (dimensionless)

v = Worst Month Wind Speed (mph)

For *Internal* Floating Roof Tanks, v = 0, so, from AP-42, Chapter 7, Equation 2-16:

K_{Fi} = K_{Fai}

Using AP-42, Chapter 7, Table 7.1-12:

F_F = [(1)(1.6) + (1)(2.8) + (1)(33) + (1)(56) + (17)(7.9) + (1)(12) + (1)(6.2)] lb-mol/yr
F_F = 245.9 lb-mol/yr
L_F = (245.9 lb-mol/yr)(0.02918)(100.204 lb/lb-mol)(1.0)
L_F = 719.00 lb/yr

4) Deck Seam Loss (L_D)

From AP-42, Chapter 7, Equation 2-18:

L_D (lb/yr) = $K_D\ S_D\ D^2\ P^*\ M_V\ K_C$

Where: L_D = Deck Seam Loss (lb/year)

K_D = Deck Seam Loss per Unit Seam Length Factor (lb-mole/ft-yr)
= 0.0 for Welded Deck;
= 0.14 for Bolted Deck

For D, P* (max), and K_C, see above.

S_D = Deck Seam Length Factor (ft/ft^2)
= L_{seam}/A_{deck} (ft^{-1})

Where:

L_{seam} = total length of deck seams (ft)
A_{deck} = area of deck (ft^2) = $\left(\frac{1}{4}\right)\pi D^2$

This example indicates a welded deck. Therefore, K_D = 0.0, and thus:

L_D = 0.00 lb/yr

5) Combine Losses

Add the worst-case working losses and worst-case standing losses:

$L_{T\ MAX}$ (lb/yr) = $L_{WD} + L_R + L_F + L_D$

In this example:

$L_{T\ MAX}$ (lb/yr) = 139.90 lb/yr + 280.70 lb/yr + 719.00 lb/yr + 0.00 lb/yr
= 1,139.60 lb/yr

To obtain the worst-case lb/hr:

$L_{T\ MAX}$ (lb/hr) = $L_{T\ MAX}$ (lb/yr)/(8,760 hr/yr)
$L_{T\ MAX}$ (lb/hr) = (1,139.60 lb/yr)/ (8,760 hr/yr)

$L_{T\ MAX}$ (lb/hr) = 0.13 lb/hr VOC

NOTE: The above example assumes a heated tank at constant temperature. For ambient storage scenarios, calculations may be performed for multiple months to determine worst-case short-term emissions.

Summary of Changes to Guidance

Revision Date	Description of Changes
February 2020	Removed references to EPA Tanks 4.09D emission estimation software, which relied on equations and meteorological data rendered obsolete by November 2019 update of EPA AP-42. Performed typographical corrections and additional updates for consistency with November 2019 version of EPA AP-42.
February 2018	Original publication of short-term floating roof tank guidance document.