Tanks Emissions for TRI Reporting

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Overview

- The Role Tanks Play in Toxic Release Inventory
- Calculation Methodology
- Data Collection Best Practices
  - Potential Pitfalls and Considerations

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The Role Tanks Play in TRI

- TRI is meant to cover any and all emissions generated from manufacturing / processing / otherwise used chemical operations.

- Movement of materials through tanks causes working and standing emissions which needs to be captured for TRI reporting.

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Calculation Methodology
Sources of Emissions

- **Working losses**
  - Fixed–Roof Tank: Filling loss
  - Floating–Roof Tank: Clingage loss
- **Standing losses**
  - Fixed–Roof Tank: Breathing loss
  - Floating–Roof Tank: vapors escaping past the Rim Seals, Deck Fittings and Deck Seams emissions loss

Calculation Methodology
Sources of Emissions

- Tank Cleaning
- Heated Tanks (Hot Stock), Insulated Tanks
- Flashing off losses
- Degassing losses
- Loading losses from Railcar, Truck, Marine Vessel loading

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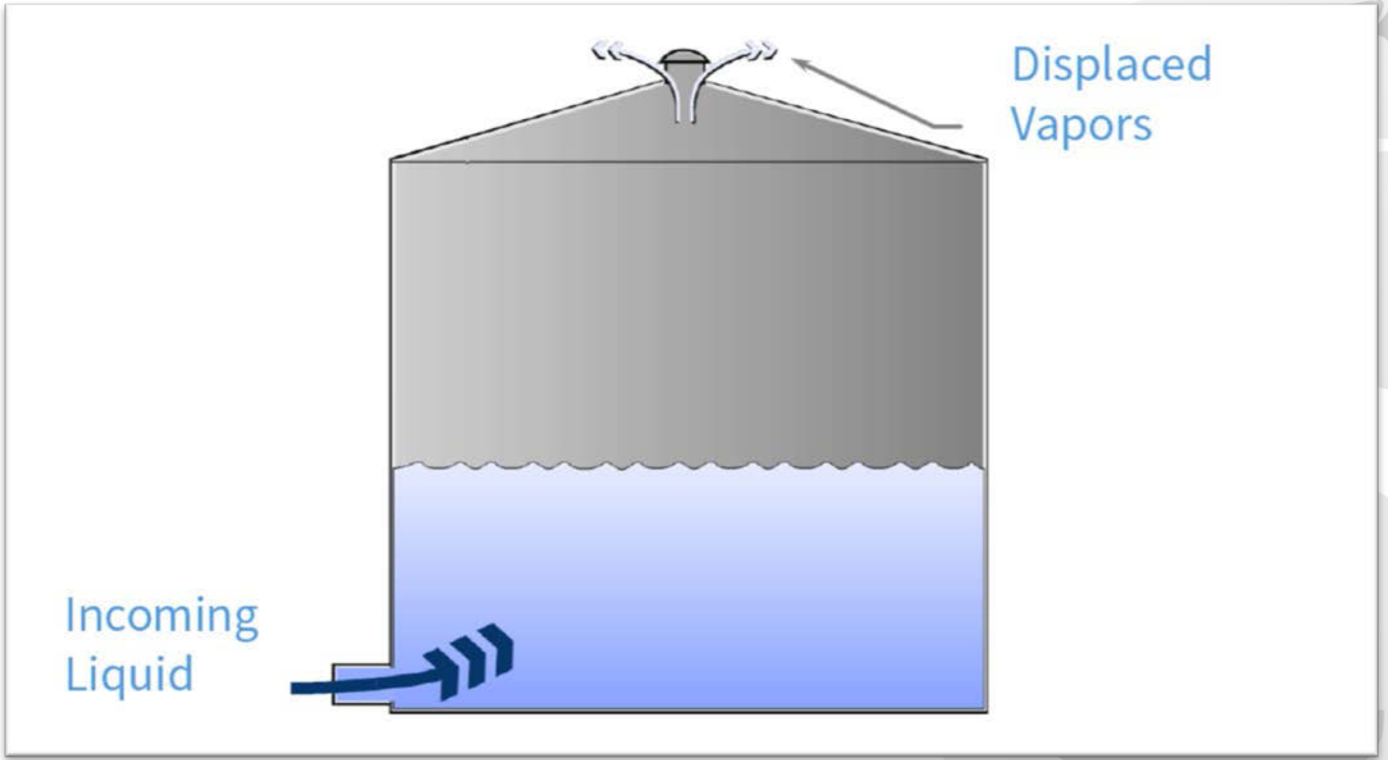
Working Losses – Fixed Roof

- Working Losses account for the emissions while liquid is being pumped in or out of a tank.
  - Fixed-Roof tank filling loss is due to displaced vapors flowing out of the vent



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Working Losses – Fixed Roof

$$L_W = N\, H_{LX} \left(\frac{\pi}{4}\right) D^2\, K_N\, K_P\, W_V\, K_B \qquad (3\text{-}35)$$

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 7.3-18

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 3-21

K_B = vent setting correction factor, dimensionless

for open vents and for a vent setting range up to $\pm$ 0.03 psig, $K_B = 1$

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Working Losses – Floating Roof

- Floating-Roof Tank withdrawal loss is due to Clingage loss
  - Evaporation from the wet shell as liquid level drops.

Withdrawal Loss - The withdrawal loss from floating roof storage tanks can be estimated using Equation 3-41.

$$L_{WD} = \frac{(0.943)QC_S W_L}{D}\left[1 + \frac{N_C F_C}{D}\right] \qquad (3\text{-}41)$$

where:

L_{WD} = withdrawal loss, lb/yr

Q = annual throughput (tank capacity [bbl] times annual turnover rate), bbl/yr

C_S = shell clingage factor, bbl/1,000 ft^2; see Table 7.3-10

W_L = average organic liquid density, lb/gal; see Note 1

D = tank diameter, ft

0.943 = constant, 1,000 $ft^3 \cdot gal/bbl^2$

N_C = number of fixed roof support columns, dimensionless; see Note 2

F_C = effective column diameter, ft (column perimeter [ft]/π); see Note 3

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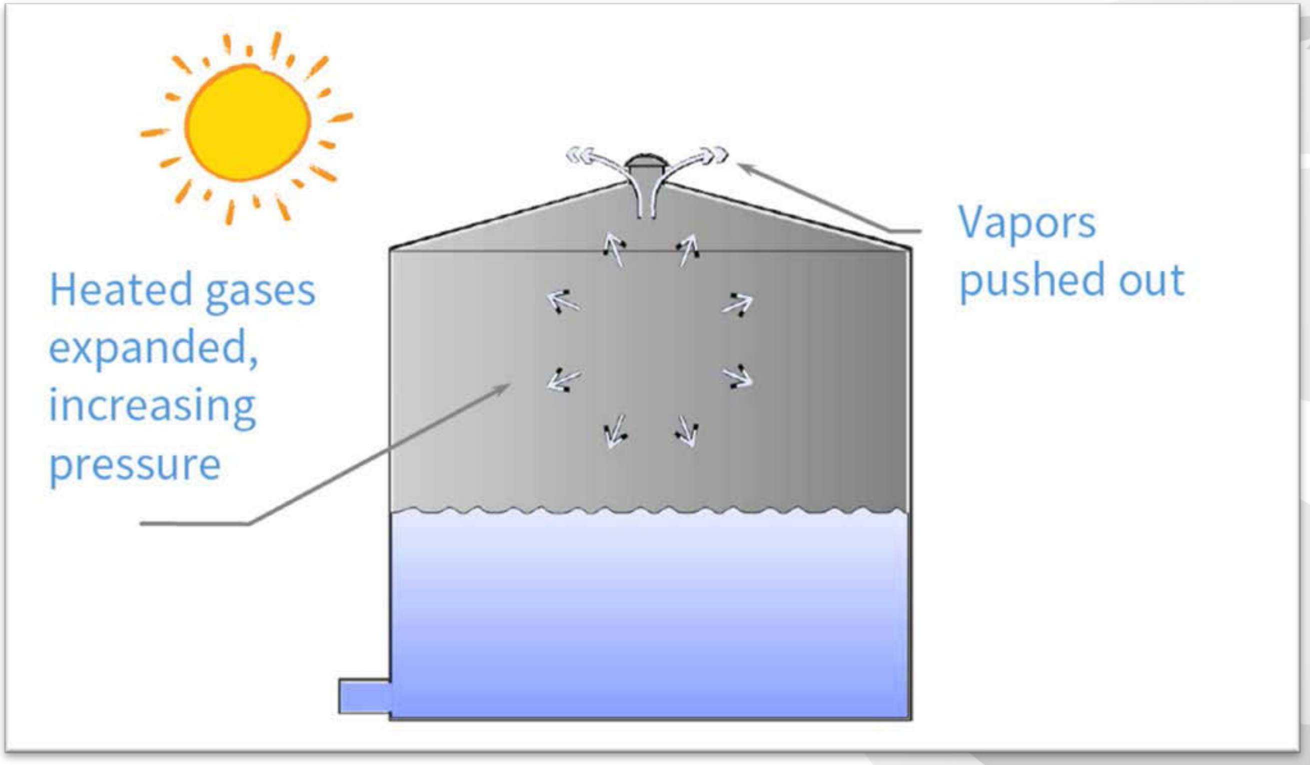
Standing Losses – Fixed Roof

- Fixed-Roof Tank Breathing loss occurs when heated gases expand, raising the pressure within the tank which results in Vapors flowing out of the vent



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Standing Losses – Fixed Roof

$$L_S = 365 K_E \left(\frac{\pi}{4} D^2 \right) H_{VO} K_S W_V \tag{3-4}$$

where:

- L_S = standing storage loss, lb/yr
- K_E = vapor space expansion factor, dimensionless, see Equation 3-5, 3-6, or 3-7
- D = diameter, ft, see Equation 3-13 for horizontal tanks
- H_{VO} = vapor space outage, ft, see Equation 3-15; use $H_E/2$ from Equation 3-14 for horizontal tanks
- K_S = vented vapor saturation factor, dimensionless, see Equation 3-20
- W_V = stock vapor density, lb/ft^3, see Equation 3-21
- 365 = constant, the number of daily events in a year, (year)$^{-1}$

See reference 4

Standing Losses – Floating Roof

- Floating–Roof Tank: vapors escaping past the Rim Seals, Deck Fittings and Deck Seams emissions loss

Total losses from floating roof tanks may be written as:

$$L_T = L_R + L_{WD} + L_F + L_D \qquad (3\text{-}38)$$

where:

L_T = total loss, lb/yr
L_R = rim seal loss, lb/yr; see Equation 3-39
L_{WD} = withdrawal loss, lb/yr; see Equation 3-41
L_F = deck fitting loss, lb/yr; see Equation 3-42
L_D = deck seam loss (internal floating roof tanks only), lb/yr; see Equation 3-46

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Tank Cleaning

- Steps of the cleaning process:

  a) Normal Pumpout
  b) Standing idle
  c) Vapor space purge – “Forced Ventilation”
  d) Sludge removal
  e) Remain clean
  f) Refilling

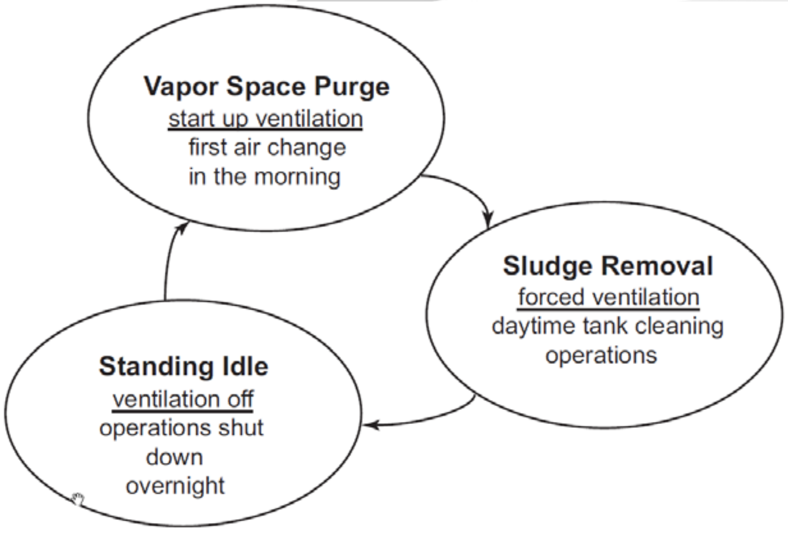

Figure 1—Daily Tank Cleaning Cycle

Normal Pumpout

- Removal of as much liquid as possible in a normal manner until no more can be removed.

- Air flows into tank – therefore no emissions assumed.

Standing Idle

- During a standing period, vapors generated as residual material evaporates (No forced Ventilation).

Standing Idle Emissions

Fixed Roof Tanks	Internal Floating Roof Tanks with a Liquid Heel	External Floating Roof Tanks with a Liquid Heel	Drain-Dry Floating-Roof Tanks
Initial standing idle period upon emptying the tank (Section 4):			
Included with normal standing storage (breathing) losses (see API 19.1[3]) Thus $L_S = 0$	{equations 9 & 10} $L_S = n_d K_E \left(\frac{PV_V}{RT}\right) M_V K_S$ $\leq 5.9D^2 h_{le} W_l$	{equations 11 & 10} $L_S = 0.57\, n_d\, D\, P^*\, M_V$ $\leq 5.9D^2 h_{le} W_l$	{equations 12 & 13} $L_S = 0.0063\, W_l\, (\pi/4) D^2$ $\leq P\, V_V M_V S/(RT)$ where: $S = 0.6$
Subsequent (overnight) standing idle periods during the daily cleaning cycle (Section 6):			
$L_S = 0$	$L_S = 0$	$L_S = 0$	$L_S = 0$

See reference 7

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Vapor Space Purge

- Remaining vapors in the tank are forced out with “Forced ventilation”

Vapor Space Purge Emissions

{equation 14} $L_P = \left(\frac{PV_V}{RT}\right) M_V S$, where V_V and S are evaluated as shown below:

Fixed-Roof Tanks

{equation 7}

$V_V = H_{VO}\,(\pi D^2/4)$

Floating-Roof Tanks

{equation 6}

$V_V = (h_v)(\pi D^2/4)$)

Full Liquid Heel | Partial Liquid Heel | Drain-Dry Tanks

Initial vapor space purge upon commencing forced ventilation (Section 5):

Fixed-Roof Tanks	Full Liquid Heel	Partial Liquid Heel	Drain-Dry Tanks
{equations 15-17} $S = \frac{0.5 n_d + 1}{6}$ ≥ 0.25 ≤ 0.5	{equation 18; Table 6} IFRT $S = 0.6$; EFRT S is taken as $C_{sf}S = 0.6\left(1 - \frac{\frac{0.57DP^* RT}{PV_V} - K_E K_S}{K_E K_S + 0.6}\right)$	{equation 18; Table 6} IFRT $S = 0.5$; EFRT S is taken as $C_{sf}S = 0.5\left(1 - \frac{\frac{0.57DP^* RT}{PV_V} - K_E K_S}{K_E K_S + 0.5}\right)$	{Table 6} $S = 0$

Subsequent vapor space purge emissions during the daily cleaning cycle, after standing idle overnight (Section 6):

Fixed-Roof Tanks	Full Liquid Heel	Partial Liquid Heel	Drain-Dry Tanks
$S = 0.25$	$S = 0.6$	$S = 0.5$	$S = 0.5$

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See reference 7

Sludge Removal

- Volatile materials from the tank are removed while it is subject to "Forced ventilation".

Sludge Removal Emissions (Section 6) applicable to all tank types – {continued forced ventilation of the vapor space after the vapor space purge, for each day of the daily cleaning cycle}

vapor concentration method	{equations 19 & 21} $L_{SR} = 60\, Q_v\, n_{SR}\, t_v\, C_V \dfrac{P_a M_V}{RT}$ where: $C_V \leq P/P_a$	{equation 10} when a liquid heel is present: $L_{SR} \leq 5.9 D^2\, h_{le}\, W_l$	{equation 22} if drain-dry, or after the liquid heel has been vacuumed out: $L_{SR} \leq 0.49\, F_e\, D^2\, d_s\, W_l$

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See reference 7

Remain Clean

- Once the tank is clean, there are no emissions as long as the tank stays clean.

Refilling

- As the tank is refilled, vapors are generated by the incoming stock which displaces those vapors

Refilling Emissions (Section 7)

{equation 23} $L_F = \left(\frac{PV_V}{RT}\right) M_V S$, where $S = 0.15$ and V_V is evaluated as shown below:

Fixed-Roof Tanks	Floating-Roof Tanks
included with normal working losses (see API 19.1) Thus $L_F = 0$	{equation 6} $V_V = (h_v)(\pi D^2/4)$

See reference 7

Heated Tanks (Hot Stock)

- Heat-up losses that occur during the operation of reactors, distillation equipment, and similar types of processing equipment may be estimated by application of the Ideal Gas Law and vapor-liquid equilibrium principles.
- The equation below is derived from performing material balances around the vessel headspace for the non-condensable component and for component *i* during the heating:

$$E_{n-i,out} = N_{avg} \ln\left(\frac{p_{nc,1}}{p_{nc,2}}\right) - \left(n_{i,2} - n_{i,1}\right)_{vessel}$$

Where: $N_{avg} = \frac{1}{2}\left(n_1 + n_2\right)$

Gas Law: $n = \frac{PV}{RT}$, also $n_i = \frac{p_i V}{RT}$ for a single component, i, in the gas space.

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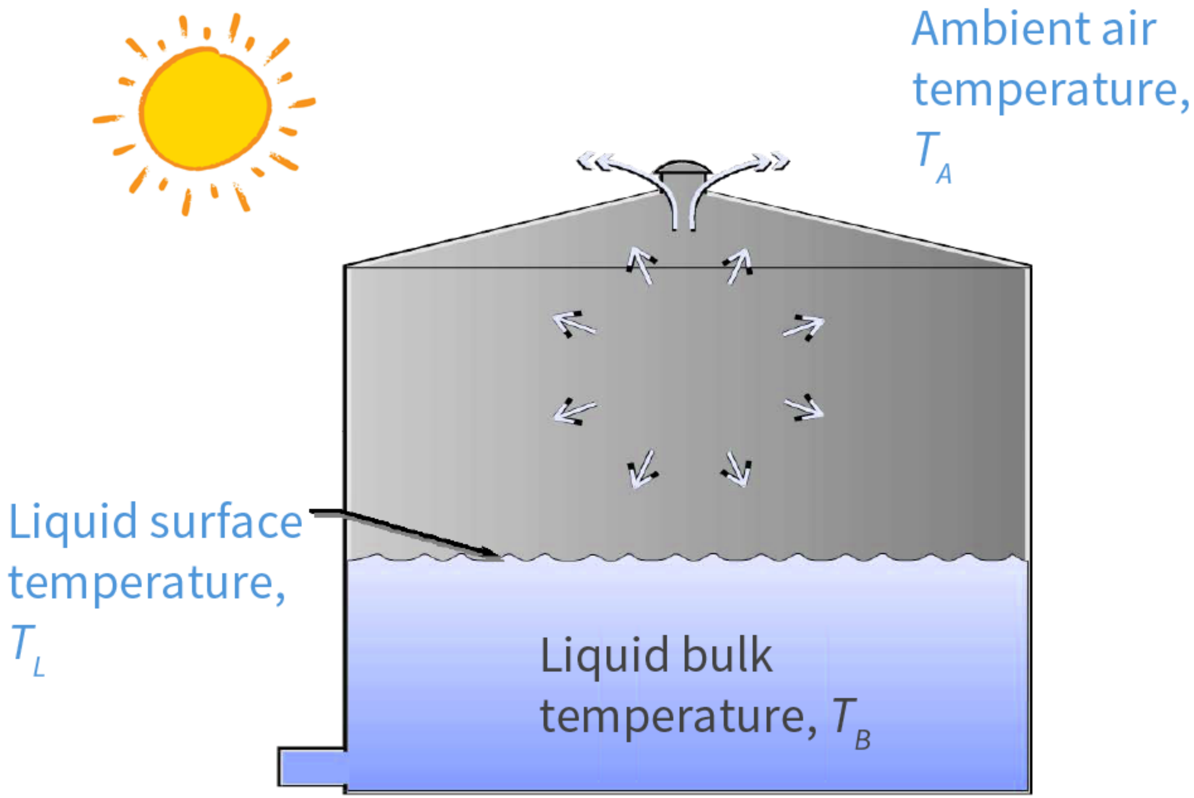
See reference 4

Heated Tanks (Hot Stock), Not insulated Tanks

Liquid bulk temperature may be affected by:

- The variation in vapor space temperature drives the vapor space expansion and contraction, which depends on the fluctuation in ambient temperature.



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Heated Tanks (Hot Stock), Not insulated Tanks

- Stock being heated in the tank (daily average liquid surface temperature, TLA, is unknown), liquid bulk temperature is calculated using the following equation:

$$T_{LA} = 0.44T_{AA} + 0.56T_B + 0.0079\ \alpha\ I \quad (3\text{-}26)$$

where:

T_{LA} = daily average liquid surface temperature, °R

T_{AA} = daily average ambient temperature, °R; see Note 4

T_B = liquid bulk temperature, °R; see Note 5

α = tank paint solar absorptance, dimensionless; see Table 7.3-6

I = daily total solar insolation factor, Btu/(ft^2 day); see Table 7.3-7

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See reference 4

Heated Tanks (Hot Stock), Insulated Tanks

Types of Insulated tanks covered:

- Stock being heated external to the tank and circulated through the tank (Tank receiving hot stock from a process unit)
- Insulated tank
- Tank Maintained at a constant temperature

If sufficiently insulated, then thermal exchange with ambient is insignificant. Therefore tank will not experience ΔTV associated with diurnal ambient temperature cycle. In this case all regions inside the tank may be assumed to be at the same temperature:

✓ $TB = TL = TV$

If TB is maintained at a "constant" temperature, then no breathing loss occurs

✓ $\Delta TV = 0$

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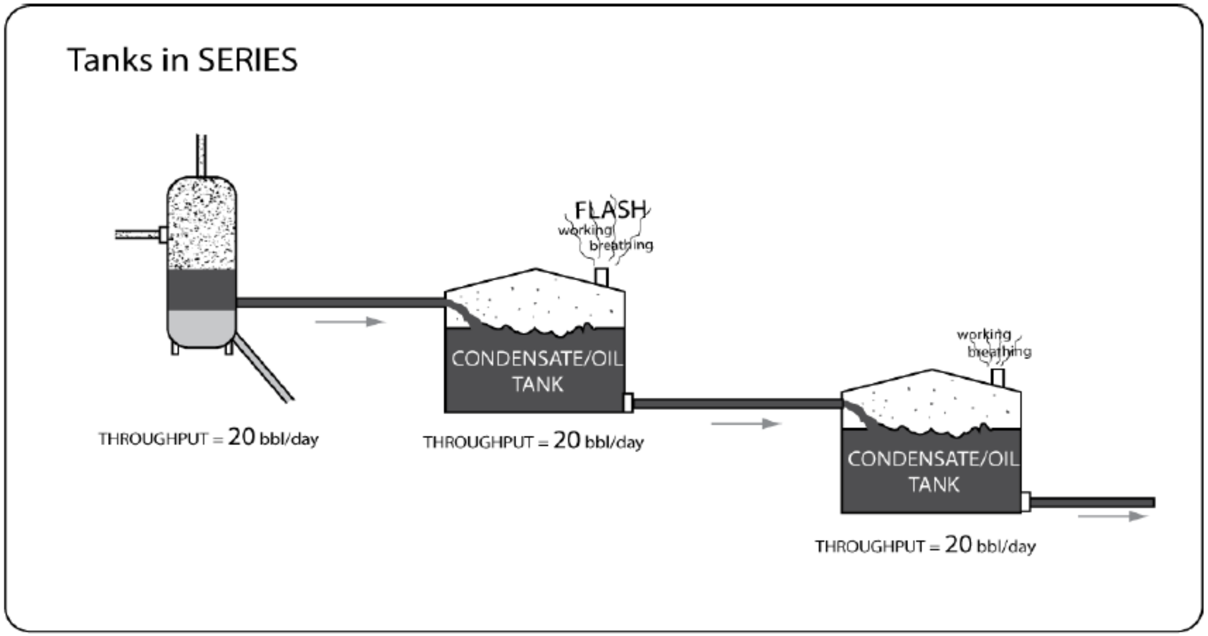
Flashing Loss

- Flashing loss applies to tanks storing live oil liquid, where the unstable components bubble (boil) out of solution.



See reference 2,3

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Flashing Loss

- This is most common when an E&P (Exportation & Production) fixed-roof tank receives a liquid under pressure into an atmospheric tank.
  - Live oil means some components have TVP > Storage pressure, these components are unstable as liquid.

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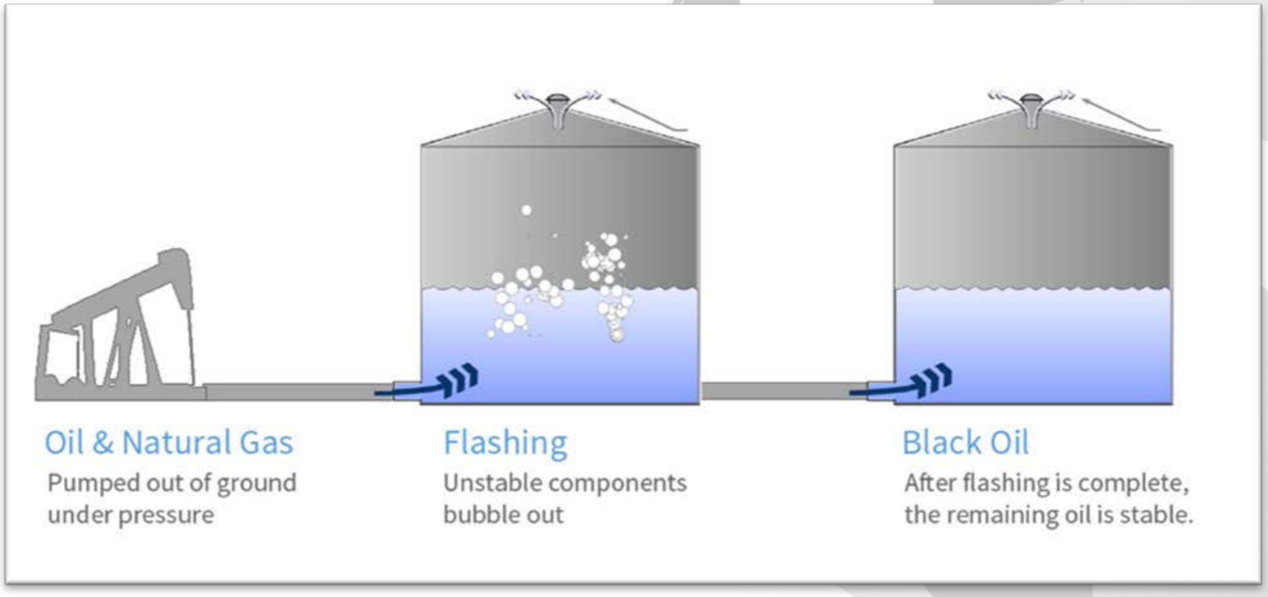
See reference 2,3

Flashing losses

- Flashing loss also applies to Tank Batteries in Production
  - Oil & gas is pumped out of the ground and under pressure until
  - Flashing occurs where the unstable components (Primarily Natural gas) bubble out.
  - Once stable, the Black oil is pumped to a secondary tank.

See reference 2,3



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Degassing losses

Degassing of large stationary storage tanks that contain volatile organic compounds is of great significance in industrial areas because of the potential for large emissions of the vapors in the tanks.

- Fixed-Roof Tank:
  - You need to Calculate emissions from one turnover with the turnover factor (Kn) = 1 to account for vapors displaced during filling and then add the emissions from 1 turnover calculated as if the tank had a floating roof to account for clingage.
- Floating-Roof Tank:
  - You need to Calculate emissions for one turnover then add the emissions from the tank assuming it has a fixed roof with a height equal to the height of the legs (about 6 or 7 ft.) to approximate the vapor displaced from the space under the floating roof.

Loading loss from Railcar, Truck, Marine Vessel

- Loading losses are primary emissions from rail tank car, tank truck, and marine vessel operations. Loading losses occur as organic vapors in "empty" cargo tanks are displaced to the atmosphere by the liquid being loaded into the tanks. These vapors are a composite of
  - (1) vapors formed in the empty tank by evaporation of residual product from previous loads,
  - (2) vapors transferred to the tank in vapor balance systems as product is being unloaded, and
  - (3) vapors generated in the tank as the new product is being loaded.

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Loading loss from Railcar, Truck, Marine Vessel

The quantity of evaporative losses from loading operations is, therefore, a function of the following parameters:

- Physical and chemical characteristics of the previous cargo;
- Method of unloading the previous cargo;
- Operations to transport the empty carrier to a loading terminal
- Method of loading the new cargo; and
- Physical and chemical characteristics of the new cargo.

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Loading loss from Truck

Emissions from loading petroleum liquid can be estimated (with a probable error of ±30 percent)[4] using the following expression:

$$L_L = 12.46 \frac{SPM}{T} \quad (1)$$

where:

L_L = loading loss, pounds per 1000 gallons (lb/10^3 gal) of liquid loaded

S = a saturation factor (see Table 5.2-1)
P = true vapor pressure of liquid loaded, pounds per square inch absolute (psia) (see Section 7.1, "Organic Liquid Storage Tanks")
M = molecular weight of vapors, pounds per pound-mole (lb/lb-mole) (see Section 7.1, "Organic Liquid Storage Tanks")
T = temperature of bulk liquid loaded, °R (°F + 460)

Emissions from controlled loading operations can be calculated by multiplying the uncontrolled emission rate calculated in Equation 1 by an overall reduction efficiency term:

$$\left(1 - \frac{eff}{100}\right)$$

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See reference 8

Loading loss from Truck, Marine Vessel

Table 5.2-1. SATURATION (S) FACTORS FOR CALCULATING PETROLEUM LIQUID LOADING LOSSES

Cargo Carrier	Mode Of Operation	S Factor
Tank trucks and rail tank cars	Submerged loading of a clean cargo tank	0.50
	Submerged loading: dedicated normal service	0.60
	Submerged loading: dedicated vapor balance service	1.00
	Splash loading of a clean cargo tank	1.45
	Splash loading: dedicated normal service	1.45
	Splash loading: dedicated vapor balance service	1.00
Marine vessels[a]	Submerged loading: ships	0.2
	Submerged loading: barges	0.5

[a] For products other than gasoline and crude oil. For marine loading of gasoline, use factors from Table 5.2-2. For marine loading of crude oil, use Equations 2 and 3 and Table 5.2-3.

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See reference 8

Data Collection Best Practices

- **Potential Pitfalls**
  - Accounting for material composition
  - Accounting for temperature variations
  - Accounting for chemical speciation
- **Considerations for TRI**
  - Processing
  - Emissions
  - Waste

Data Collection Best Practices

- **Account for total wt% of the chemical composition of the material:**
  - User needs to assure that 100% wt. content of the material being handled is accounted for
  - Otherwise the emission calculations ratios will be affected by the missing components

- **Best practice:**
  - Obtain the copy of Material composition claims for the original analysis

Data Collection Best Practices

- **Account for temperature variation:**
  - If annual throughput is used, temperature variations due to seasonal changes in temperature could not be accounted for. This caused incorrect emission calculation.
  - To account for temperature variation, at least monthly throughput records are required, and the minimum data collection interval.

Data Collection Best Practices

- **Account for the TVP of each chemical within a given product:**
  - Tanks emissions are directly related to each individual chemical and its TVP.
  - TVPs can be calculated using the Antoine and Riedel factors
  - In case the factors for these two equations are unavailable for a given chemical, the alternate solution would be to provide two or more TVPs *(the more TVPs are provided in the working temperatures interval, the more accurate the approximation becomes)*. Other TVPs could be approximated by using the linear interpolation from the given TVP's
  - The total TVP for products can only result in total VOC emission calculation. It is not useful when comes to TRI reporting since the emissions need to be quantified for each chemical not the product as a whole.

Data Collection Best Practices

- **Account for the waste shipped offsite**
  - Even though no emission credit to be gained for tracking waste generated by tanks cleaning, it is a necessary component of the TRI reporting.
  - TRI requires the speciation of the waste components and what has been shipped, where and how it was disposed of.
  - Generator should know the profile for its waste being shipped offsite, this can be accomplished either by testing or use of the MSDS for the primary material stored in the tank.

References

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