

Manual of Petroleum Measurement Standards Chapter 19.1

Evaporative Loss from Fixed-roof Tanks

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Summary of Changes to API MPMS Chapter 19.1, Fourth Edition

- 1) Added guidance for estimating emissions from insulated and partially insulated tanks.
- 2) Added guidance for estimating standing (breathing) loss from underground tanks or fully insulated aboveground tanks due to cyclic heating of the stored liquid.
- 3) Added an explanation of what is meant by the term “true vapor pressure” as used in this document.
- 4) Edited the coefficients in the expressions for T_{LA} , T_V , and ΔT_V to use a uniform assumption of 0.5 for the tank height-to-diameter ratio and expressed the coefficients to one significant figure.
- 5) Added language to clarify, in the instances of alternative equations, which equations are preferred as being more accurate.
- 6) Added an upper limit of 1 to the vapor space expansion factor, KE .
- 7) Replaced the former equation for calculating T_B from ambient conditions with the equation developed in APIMPMMS Ch. 19.4, Annex I.

Evaporative Loss from Fixed-roof Tanks

1 Scope

This standard contains methodologies for estimating the total evaporative losses of hydrocarbons from fixed-roof tanks. The methodologies provide loss estimates for general equipment types based on laboratory, test-tank, and field-tank data.

Types of fixed-roof tanks and roof fittings described are for information only.

The equations estimate average annual losses from fixed-roof tanks for various liquid stocks, stock vapor pressures, tank sizes, meteorological conditions, and operating conditions.

The following special cases are addressed:

- a) horizontal tanks,
- b) higher volatility stocks (true vapor pressure greater than 0.1 psia),
- c) vent settings higher than 0.03 psia (0.5 oz/in.²),
- d) tanks that have either roof or shell insulation.

The estimation may be improved by using detailed field information, including climatic data and operational data for the appropriate time period.

The equations are not intended to be used in the following applications:

- a) to estimate losses from unstable or boiling stocks or from petroleum liquids or petrochemicals for which the vapor pressure is not known or cannot readily be predicted [to calculate emissions from tanks that contain material at or above its boiling point or the point at which material starts to flash, the API model E&P Tank (API 4697) can be used];
- b) to estimate losses from fixed-roof tanks that have an internal floating roof (API MPMS Ch. 19.2 ^[4] and API 2569 ^[13] address these);
- c) to estimate losses from cleaning fixed-roof tanks (API 2568 ^[12] addresses this);
- d) to estimate losses from tanks with air sparging operations.

The estimation procedures were developed to provide estimates of typical losses from fixed-roof tanks that are properly maintained and are in normal working condition. Losses from poorly maintained tanks may be greater. Because the loss equations are based on equipment conditions that represent a large population of tanks, a loss estimate for a group of fixed-roof tanks may be more representative than a loss estimate for an individual tank.

Evaporative loss considerations are not the only criteria for equipment selection. Many other factors not addressed in this standard, such as tank operation, maintenance, and safety, are important in designing and selecting tank equipment for a given application.

2 Normative References

The following documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API *Manual of Petroleum Measurement Standards (MPMS) Chapter 19.4, Evaporative Loss Reference Information and Speciation Methodology*, Third Edition, 2012, including Addendum 2

3 Symbols

Symbol	Description	Units	Source
B	vapor pressure constant	$^{\circ}\text{R}$	Table 3 of 19.4
D	tank diameter	ft	Eq. (3a), (3b)
D_H	cylindrical diameter of a horizontal tank	ft	user
D_V	cylindrical diameter of a vertical tank	ft	user
H_L	average liquid height	ft	Eq. (5a), (5b)
H_{LN}	minimum liquid height	ft	user
H_{LX}	maximum liquid height	ft	user or Eq. (25)
H_R	domed tank roof height	ft	user
H_{RO}	roof outage (or shell height equivalent to the volume under the roof)	ft	Eq. (6a) to (6f)
H_S	tank shell height	ft	user
H_{VO}	vapor space outage (or height)	ft	Eq. (4a), (4b)
I	daily total insolation on a horizontal surface	$\text{Btu}/(\text{ft}^2 \text{ day})$	Table 1 of 19.4
K_B	vent setting correction factor	dimensionless	Eq. (27a), (27b)
K_C	product factor	dimensionless	Eq. (26a) to (26c)
K_E	vapor space expansion factor	1/day	Eq. (13a) to (13c)
K_N	turnover factor	dimensionless	Eq. (23a), (23b)
K_S	vented vapor saturation factor	dimensionless	Eq. (7)
L_H	end-to-end length, horizontal tanks	ft	user
L_S	standing loss	lb/yr	Eq. (2a), (2b)
L_T	total loss	lb/yr	Eq. (1)
L_W	working loss	lb/yr	Eq. (21)
M_V	stock vapor molecular weight	lb/lb-mole	Section 4.5 of 19.4
N	stock turnover rate	turnovers/yr	Eq. (24a), (24b)
N_{hc}	number of heating cycles	cycles/yr	user
P_A	atmospheric pressure at the tank site	psia	user
P_{BN}	breather vent minimum pressure setting (negative if a vacuum setting)	psig	user
P_{BX}	breather vent maximum pressure setting (always positive)	psig	user
P_{VA}	stock true vapor pressure at the daily average liquid surface temperature	psia	4.2.4
P_O	normal operating pressure	psig	Eq. (28)
P_{VN}	stock true vapor pressure at the daily minimum liquid surface temperature	psia	4.2.5 b)
P_{VX}	stock true vapor pressure at the daily maximum liquid surface temperature	psia	4.2.5 b)
Q	stock throughput	bbl/yr	user
R	ideal gas constant (10.731)	$\text{psia ft}^3/(\text{lb-mole } ^{\circ}\text{R})$	
S_R	tank cone roof slope	dimensionless	User
T_{AA}	average daily ambient temperature	$^{\circ}\text{R}$	Eq. (9)
T_{AN}	average daily minimum ambient temperature	$^{\circ}\text{R}$	Eq. (11)
T_{AX}	average daily maximum ambient temperature	$^{\circ}\text{R}$	Eq. (10)
T_B	average liquid bulk temperature	$^{\circ}\text{R}$	User or Eq. (12)
T_{LA}	average daily liquid surface temperature	$^{\circ}\text{R}$	Eq. (8a), (8b)
T_{LN}	average daily minimum liquid surface temperature	$^{\circ}\text{R}$	Eq. (16a), (16b)
T_{LX}	average daily maximum liquid surface temperature	$^{\circ}\text{R}$	Eq. (17a), (17b)

Symbol	Description	Units	Source
T_{MAX}	average daily maximum ambient temperature	°F	Table 1 of 19.4
T_{MIN}	average daily minimum ambient temperature	°F	Table 1 of 19.4
T_V	average vapor temperature	°R	Eq. (20a), (20b)
V_Q	stock throughput associated with increasing the liquid level in the tank	ft ³ /yr	Eq. (22a), (22b)
W_V	stock vapor density	lb/ft ³	Eq. (19)
α	tank surface solar absorptance	dimensionless	Section 4.8 of 19.4
ΔP_B	breather vent pressure setting range	psi	Eq. (18)
ΔP_V	daily stock vapor pressure range	psi	Eq. (15a), (15b)
ΔT_V	average daily vapor temperature range	°R	Eq. (14a), (14b)
ΣH_Q	annual sum of the increases in liquid level	ft/yr	user
π	constant (3.14159)	dimensionless	—

NOTE 1 "19.4" refers to API MPMS Ch. 19.4.
NOTE 2 The term "average" refers to average over the period (i.e. year) being considered.

4 Procedure for Estimating Loss

4.1 General

The total loss L_T (lb/yr) is the sum of the standing loss L_S and the working loss L_W :

$$L_T = L_S + L_W \quad (1)$$

where

L_S (lb/yr) is determined in 4.2;

L_W (lb/yr) is determined in 4.3.

4.2 Standing Loss, L_S

4.2.1 Aboveground and Underground Tanks

- a) For uninsulated aboveground tanks, the standing loss L_S (lb/yr) due to the diurnal ambient temperature cycle is as follows:

$$L_S = 365(\pi D^2/4)H_{VO}K_S K_E W_V \quad (2a)$$

where

D , H_{VO} , K_S , K_E , and W_V are determined in 4.2.2 through 4.2.6, respectively;

constant 365 has units of days/yr.

- b) For insulated aboveground tanks, assume no standing loss occurs due to the diurnal ambient temperature cycle. For purposes of estimating emissions, a storage tank should be deemed insulated only if the roof and shell are both sufficiently insulated so as to minimize heat exchange with ambient air. If only the shell is insulated, and not the roof, there will be heat exchange only through the roof. The partially insulated scenario may be evaluated by a more detailed heat exchange model as given in API MPMS Ch. 19.4, Third Edition (including Addendum 1), Annex I, or this partially insulated scenario could be approximated by an assumption of an uninsulated tank using Equation (2a). Equation (2a) addresses only temperature

differentials in the vapor space resulting from the diurnal ambient temperature cycle. In the case of cyclic heating of the bulk liquid, see Equation (2b).

- c) For underground tanks, assume no standing loss occurs due to the diurnal ambient temperature cycle because the insulating nature of the earth limits the diurnal temperature change in the tank.
- d) For underground tanks or fully insulated aboveground tanks that undergo cyclic heating of the bulk liquid, the standing loss L_S (lb/yr) due to the heating cycles is:

$$L_S = N_{hc}(\pi D^2/4)H_{VO}K_S K_E W_V \quad (2b)$$

where

N_{hc} is the number of heating cycles per year (cycles/year).

For uninsulated tanks or for tanks with an insulated shell but an uninsulated roof, the effect of bulk liquid heating cycles on standing loss may be neglected because temperature swings in the vapor space of tanks with an uninsulated roof may be dominated by heat exchange with ambient air. Also, it can be random as to whether cycles of heating the bulk liquid add to or subtract from the vapor space temperature variation driven by the diurnal ambient temperature cycle.

In a fully insulated tank, however, the temperature of the vapor space will be approximately equal to the liquid bulk temperature. Thus, if the bulk liquid is subject to cyclic heating, the vapor space will cycle through the same temperature range as the bulk liquid. Cyclic heating may occur by occasionally receiving hot stock, which then cools over time until the next receipt of hot stock, or as a result of the tank being heated by some means that is periodically turned on and off.

4.2.2 Tank Diameter, D

The tank diameter D (ft) is as follows.

- a) For vertical tanks:

$$D = D_V \quad (3a)$$

where

D_V is the cylindrical diameter of a vertical tank (ft).

- b) For horizontal tanks:

$$D = \sqrt{\frac{4L_H D_H}{\pi}} \quad (3b)$$

where

L_H is the end-to-end length of a horizontal tank (ft);

D_H is the cylindrical diameter of a horizontal tank (ft).

4.2.3 Vapor Space Outage, H_{VO}

The vapor space outage H_{VO} (ft), the height of a cylinder of diameter D whose volume equals the vapor space volume of a fixed-roof tank, is as follows.

a) For vertical tanks (see Figure 1):

$$H_{VO} = H_S - H_L + H_{RO} \quad (4a)$$

where

H_S is the tank shell height (ft);

H_L is the average liquid height (ft). If H_L is unknown, use:

$$H_L = (H_{LX} + H_{LN})/2 \quad (5a)$$

where

H_{LX} is maximum liquid height (ft);

H_{LN} is minimum liquid height (ft) (height of remaining heel when emptied).

If H_{LX} or H_{LN} is unknown, use:

$$H_L = H_S/2 \quad (5b)$$

H_{RO} is the roof outage (ft), the shell height equivalent to the volume contained under the roof.

$$1) \text{ For flat roofs: } H_{RO} = 0 \quad (6a)$$

$$2) \text{ For cone roofs: } H_{RO} = H_R/3 \quad (6b)$$

$$\text{where } H_R = S_R D_V/2 \quad (6c)$$

$$\text{If the roof slope } S_R \text{ is unknown, use } H_{RO} = D_V/96 \quad (6d)$$

(this assumes the roof slope is $3/4$ in. on 12 in.).

$$3) \text{ For dome roofs: } H_{RO} = H_R/2 + 2H_R^3/(3D_V^2) \quad (6e)$$

$$\text{If the roof height } H_R \text{ is unknown, use } H_{RO} = 0.0686D_V \quad (6f)$$

(this assumes the roof radius equals the tank diameter).

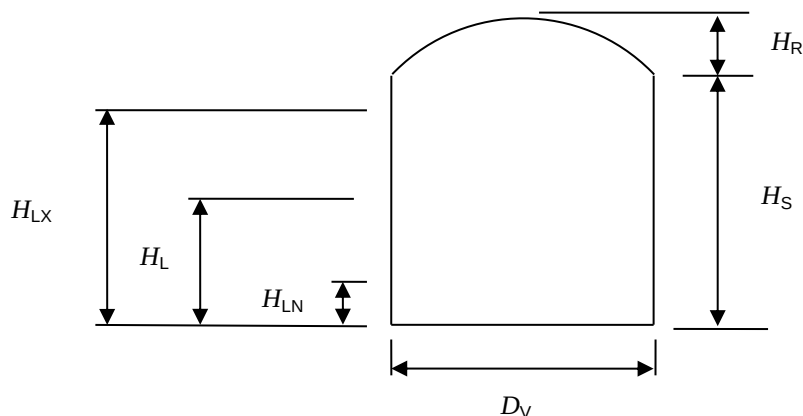


Figure 1—Fixed-roof Tank Geometry

b) For horizontal tanks:

$$H_{VO} = \pi D_H / 8 \quad (4b)$$

where

D_H is the cylindrical diameter of a horizontal tank (ft).

4.2.4 Vented Vapor Saturation Factor, K_S

The vented vapor saturation factor K_S (dimensionless) accounts for the degree of stock vapor saturation in the vented vapor:

$$K_S = 1 / (1 + 0.053 P_{VA} H_{VO}) \quad (7)$$

where

H_{VO} is determined in 4.2.3;

constant 0.053 has units of 1/(psia-ft);

P_{VA} is the stock true vapor pressure (psia) at the average liquid surface temperature T_{LA} (use API MPMS Ch. 19.4, Third Edition, Section 4.2 to determine vapor pressure P_V at a given temperature T).

NOTE True vapor pressure is defined in various ways for different purposes within the industry, such as "bubble point" for transportation specifications, but for the purposes of these emissions estimating methodologies, it is the sum of the equilibrium partial pressures exerted by the components of a volatile organic liquid [$P_V = \sum (P_i \cdot x)$, where P_i is the true vapor pressure of individual component, i , and x is the liquid-phase mole fraction of that component in the volatile organic liquid].

where

T_{LA} is the daily average liquid surface temperature ($^{\circ}\text{R}$), which may be taken as equal to the average liquid bulk temperature T_B for a fully insulated tank; see 4.2.1 b) for a discussion of insulated tanks.

$$T_{LA} = T_B \quad (8a)$$

T_{LA} is determined as follows for a tank that is not fully insulated:

$$T_{LA} = 0.4 T_{AA} + 0.6 T_B + 0.005 \alpha I \quad (8b)$$

$$T_{AA} = (T_{AX} + T_{AN}) / 2 \quad (9)$$

$$T_{AX} = T_{MAX} + 459.67 \quad (10)$$

T_{MAX} is the daily maximum ambient temperature ($^{\circ}\text{F}$), obtained from meteorological records or from historical averages given in API MPMS Ch. 19.4, Third Edition, Table 1.

$$T_{AN} = T_{MIN} + 459.67 \quad (11)$$

T_{MIN} is the daily minimum ambient temperature ($^{\circ}\text{F}$), obtained from meteorological records or from historical averages given in API MPMS Ch. 19.4, Third Edition, Table 1.

constant 0.005 has units of $^{\circ}\text{R ft}^2 \text{ day/Btu}$.

T_B is the liquid bulk temperature ($^{\circ}\text{R}$), preferably obtained from tank records.