

Manual of Petroleum Measurement Standards Chapter 19.2

Evaporative Loss from Floating-roof Tanks

MPMS CHAPTER 19.2
FOURTH EDITION, AUGUST 2020



Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be used. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

Classified areas may vary depending on the location, conditions, equipment, and substances involved in any given situation. Users of this document should consult with the appropriate authorities having jurisdiction.

Users of this document should not rely exclusively on the information contained in this document. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein.

API is not undertaking to meet the duties of employers, manufacturers, or suppliers to warn and properly train and equip their employees, and others exposed, concerning health and safety risks and precautions, nor undertaking their obligations to comply with authorities having jurisdiction.

Information concerning safety and health risks and proper precautions with respect to particular materials and conditions should be obtained from the employer, the manufacturer or supplier of that material, or the material safety data sheet.

Where applicable, authorities having jurisdiction should be consulted.

Work sites and equipment operations may differ. Users are solely responsible for assessing their specific equipment and premises in determining the appropriateness of applying the document. At all times users should employ sound business, scientific, engineering, and judgment safety when using this document.

The scenarios in this document are merely examples for illustration purposes only. [Each company should develop its own approach.] They are not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied for reliance on or any omissions from the information contained in this document.

All rights reserved. No part of this work may be reproduced, translated, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the Publisher, API Publishing Services, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001-5571.

Foreword

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

The verbal forms used to express the provisions in this document are as follows.

Shall: As used in a standard, “shall” denotes a minimum requirement to conform to the standard.

Should: As used in a standard, “should” denotes a recommendation or that which is advised but not required to conform to the standard.

May: As used in a standard, “may” denotes a course of action permissible within the limits of a standard.

Can: As used in a standard, “can” denotes a statement of possibility or capability.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 200 Massachusetts Avenue, Suite 1100, Washington, DC 20001. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 200 Massachusetts Avenue, Suite 1100, Washington, DC 20001.

Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, Suite 1100, Washington, DC 20001, standards@api.org.

Contents

	Page
1 Scope.....	1
2 Normative References	2
3 Symbols	2
4 Procedure for Estimating Loss.....	3
4.1 General	3
4.2 Standing Loss L_s	4
4.3 Working Loss L_w	22
5 Sample Problems	23
5.1 General	23
5.2 EFRT Sample Problem	23
5.3 IFRT Sample Problem	27
5.4 Domed EFRT Sample Problem	30
6 Equipment Descriptions	34
6.1 Components	34
6.2 Types of Floating-Roof Tanks	59
7 Loss Mechanisms	60
7.1 General	60
7.2 Standing Loss	61
7.3 Working Loss	63
8 Development of Estimation Methods	63
8.1 General	63
8.2 Standing Loss	63
8.3 Working Loss	68
Annex A (informative) Development of Rim-Seal Loss Factors.....	70
Annex B (informative) Development of Rim-Seal Relationship Between Airflow Rate and Wind Speed	74
Annex C (informative) Development of Diameter Function	76
Annex D (informative) Development of Deck-Fitting Loss Factors.....	78
Annex E (informative) Development of Vapor Pressure Function	85
Annex F (informative) Development of Product Factors.....	87
Annex G (informative) Development of Clingage Factors	89
Annex H (informative) Development of Fitting Wind-Speed Correction Factor	90
Annex I (informative) Development of Deck-Seam Loss Factors.....	93
Annex J (informative) Documentation Records.....	95

Contents

	Page
Annex K (informative) SI Units	96
Bibliography.....	97

Figures

1	EFRT with Pontoon Floating Roof	36
2	EFRT with Double-deck Floating Roof.....	37
3	IFRT with Noncontact Deck	38
4	Domed EFRT	39
5	Vapor-mounted Primary Seals	41
6	Liquid-mounted Primary Seals.....	43
7	Mechanical-shoe Primary Seals	44
8	Secondary Seals.....	46
9	Access Hatch	47
10	Fixed-roof Support Column.....	47
11	Gauge Float (Automatic Gauge).....	48
12	Gauge Hatch Sample Ports	49
13	Vacuum Breaker	50
14	Deck Drains	51
15	Deck Leg.....	52
16	Rim Vent	53
17	Vertical Ladder	54
18	Unslotted (Unperforated) Guidepole	55
19	Slotted (Perforated) Guidepole	56
20	Ladder/Guidepole Combination	57
C.1	Calculated Losses as a Function of Diameter Exponent	77
D.1	IFRT Deck Fitting Emission Factors—Effect of Ladder Sleeve on Emission Reduction.....	83

Tables

1	Symbols	2
2	Rim-Seal Loss Factors	6
3a	Deck-Fitting Loss Factors—Other-than-guidepole Deck Fittings	9
3b	Deck-fitting Loss Factors—Unslotted (Unperforated) Guidepoles	13
3c	Deck-fitting Loss Factors—Slotted (Perforated) Guidepoles.....	14
4	Typical Number of Columns N_{fc} for Tanks with Column-Supported Roofs	15
5	Typical Number of Vacuum-Breakers N_{rvb} and Deck Drains N_{fdl} for API 650 Annex C Decks (EFRTs and Domed EFRTs)	15
6	Typical Number of Deck Legs N_{fdl} for API 650 Annex C Floating Roofs	16
7	Deck-Seam Length Factors S_g	18
8	Clingage Factors C_L for Steel Tanks (bbl/1000 ft ²).....	22
9	Effective Column Diameter D_c for Typical Column Construction	23
D.1	Summary of Deck Fittings Selected for Data Regression, and Associated Loss Factors for Each	81
D.2	Net Liquid Surface Area for a Ladder/Guidepole Combination	82
D.3	Emission Factors for IFRT Ladder Sleeves	83

Contents

	Page
D.4 IFRT Emission Factor Comparison for a Ladder/Guidepole Combination	84
H.1 Assumed Distribution of Time for a Floating Roof in Each Height Range	91
H.2 Assumed Floating Roof Height Distribution versus Survey Results	91
I.1 Noncontact Deck Seams	94
I.2 Contact Deck Seams	94
J.1 Documentation Records	95

Evaporative Loss from Floating-roof Tanks

1 Scope

This standard contains methodologies for estimating the total evaporative losses of hydrocarbons from external floating-roof tanks (EFRTs), freely vented internal floating-roof tanks (IFRTs), and domed external floating-roof tanks (domed EFRTs).

The methodologies provide loss estimates for general equipment types based on laboratory, test-tank, and field-tank data.

Types of floating roofs, rim-seal systems, and deck fittings are described for information only.

The equations estimate average annual losses from floating-roof tanks for various types of tank construction, floating-roof construction, rim-seal systems, and deck fittings, as well as for various liquid stocks, stock vapor pressures, tank sizes, and wind speeds (EFRTs).

The equations were developed for:

- a) stocks with a true vapor pressure greater than ~0.1 psia;
- b) average wind speeds ranging from 0 miles per hour (mph) to 15 mph (EFRTs); and
- c) tank diameters greater than 20 ft.

The estimation techniques become more approximate when these conditions are not met.

When this standard is used to estimate losses from non-freely vented (closed vent) internal or domed external floating-roof tanks (tanks vented only through a pressure-vacuum relief vent, blanketed with an inert gas, vented to a vapor processing unit, or otherwise restricted from being freely vented), refer to the methodology in API TR 2569 ^[7].

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

- a) to estimate losses from unstable or boiling stocks (i.e. stocks with a true vapor pressure greater than the atmospheric pressure at the tank location) or from petroleum liquids or petrochemicals for which the vapor pressure is not known or cannot readily be predicted;
- b) to estimate losses from tanks in which the materials used in the rim seal, deck fittings, or deck seams have either deteriorated or been significantly permeated by the stored stock;
- c) to estimate losses from storage tanks that do not have a floating roof (API MPMS 19.1^[53] addresses this);
- d) to estimate losses from landing floating roofs (API MPMS 19.6.1 ^[8] addresses this);
- e) to estimate losses from cleaning storage tanks (API MPMS 19.6.2 ^[9] addresses this).

The estimation procedures were developed to provide estimates of typical losses from floating-roof tanks that are properly maintained and in normal working condition. Losses from poorly maintained tanks can 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 floating-roof tanks will be more accurate than a loss estimate for an individual tank. The estimation can be improved by using detailed field information, including climatic data and operational data for the appropriate time period.

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 referenced 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. *MPMS* Chapter 19.3

API. *MPMS* Chapter 19.4, *Evaporative Loss Reference Information and Speciation Methodology*, 3rd Edition

3 Symbols

Table 1—Symbols

Symbol	Description	Units	See Section
A_{fi}	liquid surface area within type/deck fitting	in ²	4.2.2.3
C_L	clingage factor	bbl/1000 ft ²	4.3.3
D	tank diameter	ft	4.2.2, 4.3.1
D_C	effective column diameter	ft	4.3.6
F_d	total deck-seam loss factor	lb-mole/yr	4.2.2.4
F_f	total deck-fitting loss factor	lb-mole/yr	4.2.2.3
F_r	total rim-seal loss factor	lb-mole/yr	4.2.2.2
ΣH_Q	annual sum of the decreases in liquid level	ft/yr	4.3.2
i	fitting type number (1, 2, ..., k)	dimensionless	4.2.2.3
I	average daily total insolation on a horizontal surface	Btu/(ft ² day)	4.2.3.2
k	total number of different types of deck fittings	dimensionless	4.2.2.3
K_C	product factor	dimensionless	4.2.3.4
K_d	deck-seam loss per unit seam length factor	lb-mole/ft-yr	4.2.2.4
K_{fai}	zero-wind-speed loss factor for type i deck fitting	lb-mole/yr	4.2.2.3 and Table 3
K_{fbi}	wind-dependent loss factor for type i deck fitting	lb-mole/mph ^{n} -yr	4.2.2.3 and Table 3
K_{fi}	loss factor for type i deck fitting	lb-mole/yr	4.2.2.3
K_r	rim-seal loss per unit length factor	lb-mole/ft-yr	4.2.2.2
K_{ra}	zero-wind-speed rim-seal loss factor	lb-mole/ft-yr	4.2.2.2 and Table 2
K_{rb}	wind-dependent rim-seal loss factor	lb-mole/mph ^{n} -ft-yr	4.2.2.2 and Table 2
K_v	fitting wind-speed correction factor	dimensionless	4.2.2.3
l	length of a deck panel	ft	4.2.2.4 and Table 7
L_S	standing loss	lb/yr	4.2
L_{seam}	total length of deck seams	ft	4.2.2.4
L_T	total loss	lb/yr	4.1
L_W	working loss	lb/yr	4.3
m_i	wind-dependent loss exponent for type i deck fitting	dimensionless	4.2.2.3 and Table 3
M_V	average molecular weight of stock vapor	lb/lb-mole	4.2.3.3
n	wind-dependent rim-seal loss exponent	dimensionless	4.2.2.2 and Table 2
N_{fah}	number of access hatches	dimensionless	4.2.2.3 and Table 3

Table 1—Symbols (Continued)

Symbol	Description	Units	See Section
N_{fc}	number of fixed-roof support columns	dimensionless	4.2.2.3, and Tables 3 and 4, 4.3.5
N_{fdd}	number of deck drains	dimensionless	4.2.2.3, and Tables 3 and 5
N_{fdl}	number of deck legs	dimensionless	4.2.2.3, and Tables 3 and 6
N_{fgf}	number of gauge floats (automatic gauge)	dimensionless	4.2.2.3 and Table 3
N_{fi}	number of type i deck fittings	dimensionless	4.2.2.3
N_{fl}	number of vertical ladders	dimensionless	4.2.2.3 and Table 3
N_{flg}	number of ladder/guidepole combinations	dimensionless	4.2.2.3 and Table 3
N_{frv}	number of rim vents	dimensionless	4.2.2.3 and Table 3
N_{fsgp}	number of slotted (perforated) guidepoles	dimensionless	4.2.2.3 and Table 3
N_{fsp}	number of gauge hatch/sample ports	dimensionless	4.2.2.3 and Table 3
N_{fugp}	number of unslotted (unperforated) guidepoles	dimensionless	4.2.2.3 and Table 3
N_{fvb}	number of vacuum breakers	dimensionless	4.2.2.3, and Tables 3 and 5
P^*	vapor pressure function	dimensionless	4.2.3.2
P_A	average atmospheric pressure at the tank site	psia	4.2.3.2
P_{VA}	stock true vapor pressure at the daily average liquid surface temperature	psia	4.2.3.2
Q	annual stock throughput	bbl/yr	4.3.2
Q_N	net stock throughput associated with decreasing the liquid level in the tank	bbl/yr	4.3.2
S_d	deck-seam length factor	ft/ft ²	4.2.2.4 and Table 7
T_{AA}	average daily ambient temperature	°R	4.2.3.2
T_{AN}	average daily minimum ambient temperature	°R	4.2.3.2
T_{AX}	average daily maximum ambient temperature	°R	4.2.3.2
T_B	average liquid bulk temperature	°R	4.2.3.2
T_{MAX}	average daily maximum ambient temperature	°F	4.2.3.2
T_{MIN}	average daily minimum ambient temperature	°F	4.2.3.2
T_{LA}	average liquid surface temperature	°R	4.2.3.2
V	average ambient wind speed at the tank site	mi/hr	4.2.2.2, 4.2.2.3
w	width of deck sheet or panel	ft	4.2.2.4 and Table 7
W_L	average stock liquid density at 60 °F	lb/gal	4.3.4
α	tank surface solar absorptance	dimensionless	4.2.3.2

4 Procedure for Estimating Loss

4.1 General

The total loss L_T is the sum of the standing loss L_S and the working loss L_W :

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

4.2 Standing Loss L_S

4.2.1 Overview

Standing loss pertains to evaporative loss of stock liquid from beneath the floating roof while it is floating. The standing loss L_S can be estimated as follows:

$$L_S = (F_r + F_f + F_d)P^*M_vK_C \quad (2)$$

where

- F_r is the total rim-seal loss factor, in pound-moles per year;
- F_f is the total deck-fitting loss factor, in pound-moles per year;
- F_d is the total deck-seam loss factor, in pound-moles per year;
- P^* is the vapor pressure function, dimensionless;
- M_v is the average molecular weight of stock vapor, in pounds per pound-mole;
- K_C is the product factor, dimensionless.

The loss factors F_r , F_f , and F_d pertain to the design of the tank and floating roof, and are designated equipment-related factors. The loss factors P^* , M_v , and K_C pertain to the characteristics of the stored stock liquid, and are designated stock-related factors. While the equipment-related factors are expressed in units of pound-moles per year, they have to be multiplied by the dimensionless stock-related factors P^* and K_C to determine actual pound-moles per year of evaporative loss for a given liquid product. To convert the actual pound-moles per year to pounds per year, multiply by the molecular weight of the product in its vapor phase, M_v , with molecular weight having units of pounds per pound-mole.

4.2.2 Equipment-Related Factors

4.2.2.1 General

The equipment-related factors F_r , F_f , and F_d in the standing loss equation are dependent only on the characteristics of the tank and floating roof, and are independent of the stored stock liquid. These factors are considered to represent average loss rates for common types of floating roof construction. Loss factors for specific details of construction may be developed in accordance with the test methods and procedures given in API MPMS Ch. 19.3.

4.2.2.2 Rim-Seal Loss Factor F_r

The rim seal loss factor F_r can be estimated as follows:

$$F_r = K_r D \quad (3)$$

where

- K_r is the rim seal loss per unit length factor (lb-mole/ft-yr);
- D is the tank diameter (ft).

The rim seal loss factor K_r can be estimated as follows:

$$K_r = K_{ra} + K_{rb} V^n \quad (4)$$

where

- K_{ra} is the zero-wind-speed rim-seal loss factor (lb-mole/ft-yr)—see Table 2.

- K_{rb} is the wind-dependent rim-seal loss factor (lb-mole/(mi/hr)ⁿ-ft-yr)—see Table 2;
- V is the average ambient wind speed at the tank site (mi/hr);
- n is the wind-dependent rim-seal loss exponent—see Table 2.

Table 2—Rim-Seal Loss Factors

Tank Construction and Rim-seal System	Average-fitting Seals				Tight-fitting ^a Seals			
	Zero-wind Speed Loss Factor	Wind-dependent Loss Factor	Wind-	Rim-seal Loss Factor K_r (lb-mol/ft-yr)	Zero-wind Speed Loss Factor	Wind-dependent Loss Factor	Wind-dependent Loss Factor	Rim-seal Loss Factor K_r (lb-mol/ft-yr)
	K_{ra} (lb-mol/ft-yr)	K_{ro} [(lb-mol/(mph) ⁿ)-ft-yr]	n	0 5 10 15	K_{ra} (lb-mol/ft-yr)	K_{ro} [(lb-mol/(mph) ⁿ)-ft-yr]	n	0 5 10 15
Welded tanks								
Mechanical-shoe seal								
Primary only	5.8 ^{b c}	0.3 ^c	2.1 ^c	5.8 15 44 94	1.5	0.4	1.9	1.5 10 33 70
Shoe-mounted secondary	1.6	0.3	1.6	1.6 5.5 14 24	1.0	0.4	1.5	1.0 5.5 14 24
Rim-mounted secondary	0.6	0.4	1.0	0.6 2.6 4.6 6.6	0.4	0.4	1.0	0.4 2.4 4.4 6.4
Liquid-mounted seal								
Primary only	1.6	0.3	1.5	1.6 5.0 11 19	1.0	0.08	1.8	1.0 2.4 6.0 11
Weather shield	0.7	0.3	1.2	0.7 2.8 5.5 8.4	0.4	0.2	1.3	0.4 2.0 4.4 7.2
Rim-mounted secondary	0.3	0.6	0.3	0.3 1.3 1.5 1.7	0.2	0.4	0.4	0.2 1.0 1.2 1.4
Vapor-mounted seal								
Primary only	6.7 ^d	0.2	3.0	6.7 32 210 680	5.6	0.2	2.4	5.6 15 56 139
Weather shield	3.3	0.1	3.0	3.3 16 100 340	2.8	0.1	2.3	2.8 6.9 23 54
Rim-mounted secondary	2.2	0.003	4.3	2.2 5.2 62 340	2.2	0.02	2.6	2.2 3.5 10 25
Riveted tanks								
Mechanical-shoe seal								
Primary only	10.8	0.4	2.0	11 21 51 100	e	e	e	
Shoe-mounted secondary	9.2	0.2	1.9	9.2 14 25 44	e	e	e	
Rim-mounted secondary	1.1	0.3	1.5	1.1 4.5 11 19	e	e	e	

^a "Tight-fitting" means that the floating roof is maintained with no gaps more than $1/8$ in. wide between the rim seal and the tank shell.

^b When no specific information is available, a welded tank with an average-fitting mechanical-shoe primary seal only can be assumed to represent the most common or typical construction and rim-seal system in use on domed EFRTs.

^c When no specific information is available, a welded tank with an average-fitting mechanical-shoe primary seal only can be assumed to represent the most common or typical construction and rim-seal system in use on EFRTs.

^d When no specific information is available, a welded tank with an average-fitting vapor-mounted primary seal only can be assumed to represent the most common or typical construction and rim-seal system in use on IFRTs.

^e No evaporative-loss information is available for riveted tanks with consistently tight-fitting rim-seal systems.

The rim-seal loss factors may only be used for ambient wind speeds from 0 mph to 15 mph. If the average ambient wind speed V at the tank site is not available, wind-speed data from the nearest local weather station or values from API *MPMS* Ch. 19.4, 3rd Edition, Table 2 may be used as an approximation. For IFRTs and domed EFRTs, ambient wind speed is not a significant parameter and the value of V is set equal to zero. The equation then becomes:

$$K_r = K_{ra} \quad (5)$$

Rim-seal systems are described in 6.1.3. The loss factors for average-fitting seals are applicable for typical rim-seal conditions and should be used except when a rim-seal system is known to be consistently tight-fitting (that is, when there are no gaps more than $1/8$ in. wide between the rim seal and the tank shell), in which case the loss factors for tight-fitting seals are applicable. If the rim seal fit is unknown, use factors for average-fitting seals.

4.2.2.3 Deck-Fitting Loss Factor F_f

The deck-fitting loss factor F_f can be estimated as follows:

$$F_f = N_{f1} K_{f1} + N_{f2} K_{f2} + \dots + N_{fk} K_{fk} \quad (6)$$

where

N_{fi} is the number of type i deck fittings. If N_{fi} is unknown, determine N_{fi} from Table 3;

i is the fitting type number 1, 2, ..., k ;

k is the total number of different types of deck fittings;

K_{fi} is the loss factor for type i deck fitting (lb-mole/yr)—see Table 3.

The deck fitting loss factor K_{fi} can be estimated as follows:

$$K_{fi} = K_{fai} + K_{fbi} (K_v V)^{m_i} \quad (7)$$

where

K_{fai} is the zero-wind-speed loss factor for type i deck fitting (lb-mole/yr)—see Table 3;

K_{fbi} is the wind-dependent loss factor for type i deck fitting (lb-mole/(mi/hr) ^{m_i} -yr)—see Table 3;

K_v is the fitting wind-speed correction factor, given a value of 0.7;

V is the average ambient wind speed at the tank site (mi/hr);

m_i is the wind-dependent loss exponent for type i deck fitting (dimensionless)—see Table 3.

The deck-fitting loss factors may only be used for ambient wind speeds from 0 mph to 15 mph. If the average ambient wind speed V at the tank site is not available, wind-speed data from the nearest local weather station or values from API *MPMS* Ch. 19.4, 3rd Edition, Table 1 may be used as an approximation. For IFRTs and domed EFRTs, ambient wind speed is not a significant parameter and the value of V is set equal to zero. The equation then becomes:

$$K_{fi} = K_{fai} \quad (8)$$

The most common types of deck fittings are listed in Table 3, along with loss factors for various types of construction details. These common deck fittings are described in 6.1.4. For deck-fitting configurations that are

not listed in Table 3, loss factors may be estimated at the zero-miles-per-hour wind speed condition (IFRTs and domed EFRTs) from the following:

$$K_{fai} = 0.27 (A_{fi})^{0.86} \quad (9)$$

where

A_{fi} is the liquid surface area within type i deck fitting (square inches), which is the area inside the deck fitting well or leg sleeve, less any area occupied by an obstruction in the deck-fitting well or leg sleeve (such as a fixed-roof support column, unslotted guidepole, guidepole float, or deck support leg).

The coefficient, 0.27, has units of pound-moles per (square inch)^{0.86}-year, and the exponent, 0.86, is dimensionless.

Equation (9) is only applicable when the distance from the liquid surface to the top of the deck-fitting well or leg sleeve is 12 in. or greater. Shorter deck-fitting wells or leg sleeves can result in higher loss rates. There are no similar algorithms available for estimating loss factors for shorter deck-fitting wells or leg sleeves.

Equation (9) is for an uncontrolled deck fitting. Effective deck-fitting controls would be expected to result in lower loss factors than would be estimated by this equation, but there are no algorithms available for estimating the effectiveness of deck-fitting controls.

Equation (9) is for the zero-miles-per-hour wind speed condition. There are no algorithms available for estimating loss factors at nonzero wind speeds (EFRTs).

Table 3a—Deck-Fitting Loss Factors—Other-than-guidepole Deck Fittings

Deck-fitting Type and Construction Details	Zero-wind Speed Loss Factor K_{e0} (lb-mol/yr)	Wind-dependent Loss Factor K_{w0} [lb-mol/(mph) ^{<i>n</i>} •yr]	Wind-dependent Loss Exponent <i>m</i> (dimensionless)	Typical Number of Deck Fittings N_f (dimensionless)	Deck-fitting Loss Factor K_f (lb-mol/yr)			
					0 (mph)	5 (mph)	10 (mph)	15 (mph)
<u>Access hatches</u> Unbolted cover, ungasketed Unbolted cover, gasketed Bolted cover, gasketed	36	5.9	1.2	$N_{dh} = 1$	36	63	97	140
	31	5.2	1.3		31	58	96	140
	1.6	0.0	0.0		1.6	1.6	1.6	1.6
<u>Fixed-roof support columns</u> Round pipe, ungasketed sliding cover Round pipe, gasketed sliding cover Round pipe, flexible fabric sleeve seal Built-up column, ungasketed sliding cover Built-up column, gasketed sliding cover	31			N_{fc} ; note ^a , Table 4	31			
	25				25			
	10				10			
	51				51			
	33				33			
<u>Gauge floats (automatic gauge)</u> Unbolted cover, ungasketed Unbolted cover, gasketed Bolted cover, gasketed	14	5.4	1.1	$N_{gf} = 1$	14	35	60	86
	4.3	17	0.38		4.3	32	40	46
	2.8	0.0	0.0		2.8	2.8	2.8	2.8

Table 3a—Deck-Fitting Loss Factors—Other-than-guidepole Deck Fittings (Continued)

Deck-fitting Type and Construction Details	Zero-wind Speed Loss Factor K_{ws} (lb-mol/yr)	Wind-dependent Loss Factor K_{wb} [(lb-mol/(mph) ^m ·yr]	Wind-dependent Loss Exponent m (dimensionless)	Typical Number of Deck Fittings N_f (dimensionless)	Deck-fitting Loss Factor K_f (lb-mol/yr)			
					0 (mph)	5 (mph)	10 (mph)	15 (mph)
<u>Gauge hatch/sample ports</u> Weighted mechanical actuation, ungasketed	2.3	0.0	0.0	$N_{fsp} = 1$	2.3	2.3	2.3	2.3
Weighted mechanical actuation, gasketed	0.47	0.02	0.97		0.5	0.5	0.6	0.7
Slit fabric seal (10 % open area)	12	^b	^b		12			
<u>Vacuum breakers</u> Weighted mechanical actuation, ungasketed	7.8	0.01	4.0	N_{fsg} ; note ^c , Table 5	7.8	9.3	32	130
Weighted mechanical actuation, gasketed	6.2	1.2	0.94		6.2	10	14	17
<u>Deck drains (opening that drains directly into the product)</u> 3-in. diameter, open	1.5	0.21	1.7	N_{fdd} ; note ^d , Table 5	1.5	3.3	7.2	13
3-in. diameter (10 % open area)	1.8	0.14	1.1		1.8	2.4	3.0	3.7
1-in. diameter	1.2	^b	^b		1.2			
<u>Deck legs</u> Adjustable (API 650, Annex H type)	7.9	^b	^b	N_{fll} ; notes ^e and ^f , Table 6	7.9			
<u>Adjustable (API 650, Annex C-type, double-deck roofs and center area of pontoon roofs)</u> Ungasketed, no sock	0.82	0.53	0.14		0.8	1.5	1.5	1.6
Gasketed, no sock	0.53	0.11	0.13		0.5	0.7	0.7	0.7

Table 3a—Deck-Fitting Loss Factors—Other-than-guidepole Deck Fittings (Continued)

Deck-fitting Type and Construction Details	Zero-wind Speed Loss Factor K_{w0} (lb-mol/yr)	Wind-dependent Loss Factor K_{w0} [(lb-mol/(mph) ^m ·yr]	Wind-dependent Loss Exponent m (dimensionless)	Typical Number of Deck Fittings N_f (dimensionless)	Deck-fitting Loss Factor K_f (lb-mol/yr)			
					0 (mph)	5 (mph)	10 (mph)	15 (mph)
With sock, no gasket	0.49	0.16	0.14		0.5	0.7	0.7	0.7
Adjustable (API 650, Annex C-type, pontoon area of pontoon roofs)								
Ungasketed, no sock	2.0	0.37	0.91					
Gasketed, no sock	1.3	0.08	0.65					
With sock, no gasket	1.2	0.14	0.65					
Fixed	0.0	0.0	0.0		0	0	0	0
Rim vents				$N_{fv} = 1$, note ^h				
Weighted mechanical actuation, ungasketed	0.68	1.8	1.0		0.7	7.0	13	20
Weighted mechanical actuation, gasketed	0.71	0.10	1.0		0.7	1.1	1.4	1.8
Ladders				$N_{ff} = 0$, note ⁱ				
Sliding cover, ungasketed	98	^b	^b		98			
Sliding cover, gasketed	56	^b	^b		56			

Table 3a—Deck-Fitting Loss Factors—Other-than-guidepole Deck Fittings (Continued)

Deck-fitting Type and Construction Details	Zero-wind Speed Loss Factor K_{s0} (lb-mol/yr)	Wind-dependent Loss Factor K_{w0} [(lb-mol/(mph)) ^m ·yr]	Wind-dependent Loss Exponent m (dimensionless)	Typical Number of Deck Fittings N_f (dimensionless)	Deck-fitting Loss Factor K_f (lb-mol/yr)		
					0 (mph)	5 (mph)	10 (mph)
Ladder/guidepole combinations Sliding cover, ungasketed Ladder sleeve with ungasketed sliding cover Ladder sleeve with gasketed sliding cover	98	b	b	$N_{fg} = 0$, note ^a	98		
	65	b	b		65		15 (mph)
	60	b	b		60		

^a Columns are not used on tanks with self-supporting fixed roofs (typical of domed EFRTs), or on tanks without fixed roofs (EFRTs).
^b This feature is not typically used on API 650, Annex C decks, and no information is available for wind-dependent evaporative loss from this fitting construction (EFRTs).
^c The number of vacuum breakers on API 650, Annex H decks (IFRTs) can be assumed to be:
 $N_{v0} = 1$
^d The number of deck drains on API 650, Annex H decks (IFRTs) can be assumed to be:
 $N_{d0} = 0$, for welded decks;
 $N_{d0} = D^2/125$ for bolted decks, where D = tank diameter (ft).
^e The number of deck legs on API 650, Annex H decks (IFRTs) can be assumed to be:
 $N_{l0} = (5 + D/10 + D^2/600)$, where D = tank diameter (ft).
^f The deck legs tested for API 650, Annex H decks (IFRTs) had 12-in. tall leg sleeves. The deck legs tested for API 650, Annex C decks (EFRTs and domed EFRTs) had 30-in.-tall leg sleeves for the pontoon area of pontoon roofs, and 48-in.-tall leg sleeves for double-deck roofs and for the center area of pontoon roofs.
^g Ladder/guidepole combinations that penetrate the deck are not typically used on open-top tanks with API 650, Annex C decks (EFRTs).
^h Rim vents are used only with some mechanical-shoe primary seals.
ⁱ Vertical ladders that penetrate the deck are not typically used on open-top tanks with API 650, Annex C decks (EFRTs). The number of ladders on API 650, Annex H decks (IFRTs) can be assumed to be:
 $N_v = 1$

Table 3b—Deck-fitting Loss Factors—Unslotted (Unperforated) Guidepoles^j

Unslotted (Unperforated) Guidepoles:				Zero-wind Speed Loss Factor K_{fs} (lb-mol/ yr)	Wind-dependent Loss Factor K_{fb} [lb-mol/ (mph) ^m ·yr]	Wind-dependent Loss Exponent m (dimensionless)	Deck-fitting Loss Factor K_r (lb-mol/yr)			
Well Gasket (YES/NO)	Float with Wiper ^k (YES/NO)	Pole Wiper ^p (YES/NO)	Pole Sleeve (YES/NO)				0 (mph)	5 (mph)	10 (mph)	15 (mph)
NO	NO	NO	NO	31	150	1.4	31	900	2300	4100
YES	NO	NO	NO	25	13	2.2	25	230	970	2300
NO	NO	NO	YES	25	2.2	2.1	25	56	160	330
YES	NO	NO	YES	8.6	12	0.81	9	42	67	89
YES	NO	YES	NO	14	3.7	0.78	14	24	31	37

^j The quantity and type of guidepole should be confirmed for a given tank, rather than applying a default assumption.

^k Floats are not used in unslotted guidepoles.

^l Float wiper positioned at an elevation 1 in. above the sliding cover. No further reductions in emissions were achieved by positioning the float wiper at the same elevation as the sliding cover.

^m Limited data do not support differentiation for the presence or absence of well gaskets for these construction details.

ⁿ No evaporative-loss information is currently available for these construction details without well gaskets.

^o Tests were conducted with the float wiper at the same elevation as, 1 in. above, and 5 in. below the sliding cover. The data do not support differentiating between float wiper elevations when a float is used with a pole sleeve.

^p Tests were conducted with the pole wiper at the same elevation as and 6 in. above the sliding cover. The data do not support differentiating between pole wiper elevations.

^q The loss factors for a slotted guidepole equipped with a well gasket, float with wiper, and pole wiper may also be used for a slotted guidepole equipped with a gasketed cover over the opening through the deck and a flexible enclosure that surrounds the guidepole from the gasketed cover at the deck opening up to an elevation on the guidepole above all slots or holes through the guidepole. EPA's Storage Tank Emission Reduction Partnership Program granted the flexible enclosure system equivalency to the pole float system. [65 FR 19891(04/13/00)]

Table 3c—Deck-fitting Loss Factors—Slotted (Perforated) Guidepoles^j

Slotted (Perforated) Guidepoles:				Zero-wind Speed Loss Factor K_{fa} (lb-mol/yr)	Wind-dependent Loss Factor K_b [lb-mol/ (mph) $m \cdot \text{yr}$]	Wind-dependent Loss Exponent m (dimensionless)	Deck-fitting Loss Factor K_f (lb-mol/yr)			
Well Gasket (YES/NO)	Float with Wiper (YES/NO)	Pole Wiper p (YES/NO)	Pole Sleeve (YES/NO)				0 (mph)	5 (mph)	10 (mph)	15 (mph)
YES or NO ^m	NO	NO	NO	43	270	1.4	43	1600	4200	7300
YES or NO ^m	YES ⁱ	NO	NO	31	36	2.0	31	470	1800	4000
YES ⁿ	NO	YES	NO	41	48	1.4	41	320	770	1300
YES ⁿ	NO	NO	YES	11	46	1.4	11	280	710	1200
YES ⁿ	YES ^{i,q}	YES	NO	21	7.9	1.8	21	100	280	570
YES ⁿ	NO	YES	YES	8.3	4.4	1.6	8	41	110	200
YES ⁿ	YES ^o	YES	YES	11	9.9	0.89	11	41	67	91

^j The quantity and type of guidepole should be confirmed for a given tank, rather than applying a default assumption.

^k Floats are not used in unslotted guidepoles.

ⁱ Float wiper positioned at an elevation 1 in. above the sliding cover. No further reductions in emissions were achieved by positioning the float wiper at the same elevation as the sliding cover.

^m Limited data do not support differentiation for the presence or absence of well gaskets for these construction details.

ⁿ No evaporative-loss information is currently available for these construction details without well gaskets.

^o Tests were conducted with the float wiper at the same elevation as, 1 in. above, and 5 in. below the sliding cover. The data do not support differentiating between float wiper elevations when a float is used with a pole sleeve.

^p Tests were conducted with the pole wiper at the same elevation as and 6 in. above the sliding cover. The data do not support differentiating between pole wiper elevations.

^q The loss factors for a slotted guidepole equipped with a well gasket, float with wiper, and pole wiper may also be used for a slotted guidepole equipped with a gasketed cover over the opening through the deck and a flexible enclosure that surrounds the guidepole from the gasketed cover at the deck opening up to an elevation on the guidepole above all slots or holes through the guidepole. The EPA's Storage Tank Emission Reduction Partnership Program granted the flexible enclosure system equivalency to the pole float system. [65 FR 19891(04/13/00)]

Table 4—Typical Number of Columns N_{fc} for Tanks with Column-Supported Roofs

Tank Diameter Range D (ft)		Typical Number of Columns N_{fc}
$< D$	$D \leq$	
0	85	1
85	100	6
100	120	7
120	135	8
135	150	9
150	170	16
170	190	19
190	220	22
220	235	31
235	270	37
270	275	43
275	290	49
290	330	61
330	360	71
360	400	81

NOTE This table was derived from a survey of users and manufacturers. The actual number of columns in a particular tank can vary greatly depending on tank age, fixed-roof construction, roof design loads, and manufacturing preferences. There are no columns on tanks with self-supporting fixed roofs (typical of domed EFRTs) or on tanks without fixed roofs (EFRTs). This table should not supersede actual tank data.

Table 5—Typical Number of Vacuum-Breakers N_{fvb} and Deck Drains N_{fdd} for API 650 Annex C Decks (EFRTs and Domed EFRTs)

Tank Diameter D (ft) ^b	Number of Vacuum Breakers N_{fvb}		Number of Deck Drains N_{fdd}	
	Single-Deck Pontoon Roof	Double-Deck Roof	Single-Deck Pontoon Roof	Double-Deck Roof
50	1	1	0	1
100	1	1	0	1
150	2	2	0	2
200	3	2	0	3
250	4	3	0	5
300	5	3	0	7
350	6	4	0	—
400	7	4	0	—

^a This table was derived from a survey of users and manufacturers. The actual number of vacuum breakers can vary greatly depending on throughput and manufacturing preferences. The actual number of deck drains can vary greatly depending on the design rainfall and manufacturing preferences. For tanks greater than 300 ft in diameter, actual tank data or the manufacturer's recommendations may be needed for the number of deck drains. This table should not supersede actual tank data.

^b If the tank diameter is between the diameters listed, the closest diameter listed should be used. If the tank diameter is midway between the diameters listed, the next larger diameter should be used.

Table 6—Typical Number of Deck Legs N_{fdl} for API 650 Annex C Floating Roofs

Tank Diameter D (ft) ^b	Single-Deck Pontoon Floating Roof		Double-Deck Floating Roof
	N_{fdl} in pontoon area	N_{fdl} in center (single-deck) area	N_{fdl}
30	4	2	6
40	4	4	7
50	6	6	8
60	9	7	10
70	13	9	13
80	15	10	16
90	16	12	20
100	17	16	25
110	18	20	29
120	19	24	34
130	20	28	40
140	21	33	46
150	23	38	52
160	26	42	58
170	27	49	66
180	28	56	74
190	29	62	82
200	30	69	90
210	31	77	98
220	32	83	107
230	33	92	115
240	34	101	127
250	35	109	138
260	36	118	149
270	36	128	162
280	37	138	173
290	38	148	186
300	38	156	200
310	39	168	213
320	39	179	226
330	40	190	240
340	41	202	255
350	42	213	270
360	44	226	285

Table 6—Typical Number of Deck Legs N_{fdl} for API 650 Annex C Floating Roofs (Continued)

Tank Diameter D (ft) ^b	Single-Deck Pontoon Floating Roof		Double-Deck Floating Roof
	N_{fdl} in pontoon area	N_{fdl} in center (single-deck) area	N_{fdl}
370	45	238	300
380	46	252	315
390	47	266	330
400	48	281	345
^a This table was derived from a survey of users and manufacturers. The actual number of deck legs can vary greatly depending on the tank age, floating roof construction, roof design loads, and manufacturing preferences. This table should not supersede actual tank data. ^b If the tank diameter is between the diameters listed, the closest diameter listed should be used. If the tank diameter is midway between the diameters listed, the next larger diameter should be used.			

4.2.2.4 Deck-Seam Loss Factor F_d

Deck-seam loss factors only apply to API 650, Annex H decks (IFRTs) that are of bolted construction. The deck-seam loss factor F_d can be estimated as follows:

For EFRTs:

$$F_d = 0 \quad (10)$$

For IFRTs:

$$F_d = K_d S_d D^2 \quad (11)$$

where

K_d is the deck-seam loss per unit seam length factor (lb-mole/ft-yr);

S_d is the deck-seam length factor (ft/ft²);

D is the tank diameter (ft).

The deck-seam loss per unit seam length factor K_d can be estimated as follows:

$K_d = 0$ for a welded deck; $K_d = 0.14$ for a bolted deck.

If the deck construction is unknown, $K_d = 0$ for tanks with self-supporting roofs and $K_d = 0.14$ for tanks with column-supported fixed roofs.

The deck-seam length factor S_d can be estimated as follows:

$$S_d = L_{seam} / (\pi D^2 / 4) \quad (12)$$

where L_{seam} is the total length of deck seams (ft).

If L_{seam} is unknown, determine S_d using Table 7. If the deck construction is unknown, $S_d = 0.20$.

This calculation is based on the assumption that losses from deck seams occur continuously or from discrete, localized points that are distributed along the entire length of the seam. This assumption may be more applicable to some seam designs than others, but it is judged to be the most reasonable and conservative (potentially overestimating loss) for determining general deck-seam loss factors. Deck-seam losses from specific designs can vary significantly and can originate from joints or seam details that are not proportional to the total seam length.

No information is available for other deck types (for example, adhesively-joined seams).

Table 7—Deck-Seam Length Factors S_d

Deck Construction	S_d (ft/ft ²)
Continuous sheet construction, $S_d = 1/w$, where w = width of deck sheet or panel (ft)	
5 ft wide sheets	0.20
6 ft wide sheets	0.17
7 ft wide sheets	0.14
Panel construction, $S_d = (l + w)/(l \times w)$, where l = length of a deck panel (ft)	
5 × 7.5 ft rectangular panels	0.33
5 × 12 ft rectangular panels	0.28

4.2.3 Stock-Related Factors

4.2.3.1 General

The stock-related factors P^* , M_v , and K_C in the standing loss equation pertain to the properties of the stored stock liquid at the actual storage conditions. As such, these factors depend upon the location of the tank and the physical characteristics of the tank, as well as the properties of the stored stock liquid.

4.2.3.2 Vapor Pressure Function P^*

The vapor pressure function P^* can be estimated as follows:

$$P^* = \frac{P_{VA}/P_A}{\left\{1 + \left[1 - (P_{VA}/P_A)\right]^{0.5}\right\}^2} \quad (13)$$

where

P_{VA} is the stock true vapor pressure (psia) at the average liquid surface temperature T_{LA} . Use API *MPMS* Ch. 19.4, 3rd Edition, Section 4.2 to determine vapor pressure at a given temperature.

P_A is the average atmospheric pressure (psia) at the tank site. If P_A is unknown, use 14.7 psia.

The average liquid surface temperature T_{LA} (°R) may be determined (in order of decreasing accuracy) from measurements, from API *MPMS* Ch. 19.4, 3rd Edition, Addendum 2, Annex I, or from the following equations, which are derived from API *MPMS* Ch. 19.4, 3rd Edition, Addendum 2, Annex I:

For internal and domed external floating roof tanks:

$$T_{LA}^{(14)} = \frac{[2.86(H_S/D) + 1.43]T_{AA} + [3.52(H_S/D) + 3.79]T_B + 0.027\alpha_R I + 0.017(H_S/D)\alpha_S I}{6.38(H_S/D) + 5.22}$$

where

H_s	is the tank shell height (ft);
D	is the tank diameter (ft);
T_{AA}	is the average daily ambient temperature (°R);
T_B	is the liquid bulk temperature (°R);
α_R	is the tank roof surface solar absorptance (dimensionless);
α_S	is the tank shell surface solar absorptance (dimensionless);
I	is the average daily total insolation factor (Btu/(ft ² day));

The constants 2.86, 1.43, 3.52, 3.79, 6.38, and 5.22 are dimensionless. The constants 0.027 and 0.017 have units of degrees Rankine square-foot day per British thermal unit.

The average daily ambient temperature T_{AA} can be estimated as follows:

$$T_{AA} = (T_{AX} + T_{AN})/2 \quad (15)$$

where

$$T_{AX} = T_{MAX} + 459.67 \quad (16)$$

T_{MAX} is the average daily maximum ambient temperature (°F), obtained from weather records or from historical averages given in API *MPMS* Ch. 19.4, 3rd Edition, Table 1;

$$T_{AN} = T_{MIN} + 459.67 \quad (17)$$

T_{MIN} is the average daily minimum ambient temperature (°F), obtained from weather records or from historical averages given in API *MPMS* Ch. 19.4, 3rd Edition, Table 1.

The constant 459.67 converts degrees Fahrenheit to degrees Rankine.

The average liquid bulk temperature T_B may be determined (in order of decreasing accuracy) from measurements, from API *MPMS* Ch. 19.4, 3rd Edition, Addendum 2, Annex I, or from the following equation, which is derived from API *MPMS* Ch. 19.4, 3rd Edition, Addendum 2, Annex I:

$$T_B = T_{AA} + 0.003\alpha_S I \quad (18)$$

The constant 0.003 has units of degrees Rankine square-foot day per British thermal unit.

Equation (14) may be simplified by assigning a default value of $H_s/D = 0.5$ and an assumption of $\alpha_R = \alpha_S$, resulting in the equation shown below for an uninsulated internal or domed external floating roof tank:

$$T_{LA} = 0.3T_{AA} + 0.7T_B + 0.004\alpha I \quad (19)$$

where the constants 0.3 and 0.7 are dimensionless, the constant 0.004 has units of degrees Rankine square-foot day per British thermal unit, and:

α is the average tank surface solar absorptance (dimensionless).

The average daily liquid surface temperature, T_{LA} , for external floating roof tanks is independent of H_s/D for a given value of T_B . Different expressions for T_{LA} are given below for the two common types of external floating roof deck. If the type of external floating roof deck is unknown, assume the deck to be the steel peripheral pontoon type.

For external floating roof tanks with a steel peripheral pontoon deck (single deck center area):

$$T_{LA} = 0.7 T_{AA} + 0.3 T_B + 0.008 \alpha_R I \quad (20)$$

where the liquid bulk temperature, T_B , is preferably determined from measurements or estimated from process knowledge, but otherwise may be estimated as follows:

$$T_B = T_{AA} + [0.71 \alpha_R I + 0.485 (H_s/D) \alpha_s I] / (170 H_s/D + 57) \quad (21)$$

For default $H_s/D = 0.5$, when $\alpha_R = \alpha_s$:

$$T_B = T_{AA} + 0.007 \alpha I \quad (22)$$

For external floating roof tanks with a steel double deck:

$$T_{LA} = 0.3 T_{AA} + 0.7 T_B + 0.009 \alpha_R I \quad (23)$$

where the liquid bulk temperature, T_B , is preferably determined from measurements or estimated from process knowledge, but otherwise may be estimated as follows:

$$T_B = T_{AA} + [0.39 \alpha_R I + 0.485 (H_s/D) \alpha_s I] / (170 H_s/D + 45) \quad (24)$$

For default $H_s/D = 0.5$, when $\alpha_R = \alpha_s$:

$$T_B = T_{AA} + 0.005 \alpha I \quad (25)$$

The equations for liquid surface temperature and liquid bulk temperature derived from API *MPMS* Ch. 19.4, 3rd Edition, Addendum 2, Annex I are summarized as shown below, where the simplified equations are obtained by assigning a default value of $H_s/D = 0.5$ and an assumption of $\alpha_R = \alpha_s$:

Internal floating-roof tank and domed external floating-roof tank

Liquid surface temperature [from Equation (14)]

Variable H_s/D :

$$T_{LA} = \frac{[2.86(H_s/D) + 1.43] T_{AA} + [3.52(H_s/D) + 3.79] T_B + 0.027 \alpha_R I + 0.017 (H_s/D) \alpha_s I}{6.38(H_s/D) + 5.22}$$

Default H_s/D [from Equation (19)]:

$$T_{LA} = 0.3 T_{AA} + 0.7 T_B + 0.004 \alpha I$$

Liquid bulk temperature

Variable H_s/D : Not applicable

Default H_s/D [from Equation (18)]:

$$T_B = T_{AA} + 0.003 \alpha_s I$$

External floating-roof tank—steel peripheral pontoon deck

Liquid surface temperature

Variable H_s/D : Not applicable

Default H_s/D [from Equation (20)]:

$$T_{LA} = 0.7T_{AA} + 0.3T_B + 0.008\alpha_R I$$

Liquid bulk temperature

Variable H_s/D [from Equation (21)]:

$$T_B = T_{AA} + [0.71\alpha_R I + 0.485(H_s/D)\alpha_S I]/(170H_s/D + 57)$$

Default H_s/D [from Equation (22)]:

$$T_B = T_{AA} + 0.007\alpha I$$

External floating-roof tank—steel double deck

Liquid surface temperature

Variable H_s/D : Not applicable

Default H_s/D [from Equation (23)]:

$$T_{LA} = 0.3T_{AA} + 0.7T_B + 0.009\alpha_R I$$

Liquid bulk temperature

Variable H_s/D [from Equation (24)]:

$$T_B = T_{AA} + [0.39\alpha_R I + 0.485(H_s/D)\alpha_S I]/(170H_s/D + 45)$$

Default H_s/D [from Equation (25)]:

$$T_B = T_{AA} + 0.005\alpha I$$

4.2.3.3 Stock Vapor Molecular Weight M_v

For selected petroleum liquids (multicomponent stocks), the stock vapor molecular weight M_v is given in API *MPMS* Ch. 19.4, 3rd Edition, Table 2. For single component stocks, the stock vapor molecular weight M_v is equal to the molecular weight of the stock liquid. Molecular weights of selected petrochemicals are given in API *MPMS* Ch. 19.4, 3rd Edition, Table 3.

4.2.3.4 Product Factor K_C

The product factor accounts for the effect of different stocks on standing loss. The product factor K_C is:

$K_C = 0.4$ for crude oil stocks, except if the true vapor pressure of the crude oil is determined by the HOST method,
 $K_C = 1.0$ (see API *MPMS* Ch. 19.4, 3rd Edition, Annex E);

$K_C = 1.0$ for refined petroleum stocks;

$K_C = 1.0$ for single component petrochemical stocks.

4.3 Working Loss L_w

4.3.1 Overview

Working, or withdrawal, loss pertains to the evaporation of stock liquid that clings to the tank shell (and any fixed-roof support columns) while the stock is withdrawn (i.e. while the liquid level is decreased). The working loss L_w can be estimated as follows:

$$L_w = \frac{0.943 Q_N C_L W_L}{D} \left(1 + \frac{N_{fc} D_C}{D} \right) \quad (26)$$

where

Q_N is the net stock throughput associated with decreasing the liquid level in the tank (bbl/yr);

C_L is the clingage factor (bbl/1000 ft²);

W_L is the average stock liquid density at 60 °F (lb/gal);

N_{fc} is the number of fixed-roof support columns (dimensionless);

D_C is the effective column diameter (ft);

D is the tank diameter (ft).

The constant 0.943 has units of thousand cubic foot-gallons per barrel².

4.3.2 Net Stock Throughput Q_N

The net stock throughput Q_N is:

$$Q_N = 0.1781 (\Sigma H_Q) (\pi D^2 / 4) \quad (27)$$

where ΣH_Q is the annual sum of the decreases in liquid level (ft/yr).

The constant 0.1781 has units of barrels per cubic foot.

Q_N is the stock throughput associated with decreasing the liquid level in the tank. If Q_N is unknown, use the stock throughput Q for Q_N . Note that Q overestimates Q_N if product is pumped into and out of the tank simultaneously.

4.3.3 Clingage Factor C_L

The clingage factor C_L is given in Table 8.

Table 8—Clingage Factors C_L for Steel Tanks (bbl/1000 ft²)

Product Stored	Shell Condition		
	Light Rust	Dense Rust	Gunite Lining
Gasoline	0.0015	0.0075	0.15
Single-component stocks	0.0015	0.0075	0.15
Crude oil	0.0060	0.030	0.60

4.3.4 Stock Liquid Density W_L

For selected petroleum liquids (multicomponent stocks), the stock liquid density W_L is given in API *MPMS* Ch. 19.4, 3rd Edition, Table 2. The stock liquid density W_L of selected petrochemicals (single component stocks) is given in API *MPMS* Ch. 19.4, 3rd Edition, Table 3.

4.3.5 Number of Fixed-Roof Support Columns N_{fc}

If the number of fixed-roof support columns N_{fc} is unknown, N_{fc} may be determined from Table 4. Only tanks with column-supported fixed roofs have columns (typical of IFRTs). Tanks with self-supporting fixed roofs (typical of domed EFRTs) and tanks without fixed roofs (EFRTs) do not have fixed-roof support columns.

4.3.6 Effective Column Diameter D_C

The effective column diameter D_C is given in Table 9:

$$D_C = (\text{column perimeter in ft})/\pi \quad (28)$$

Table 9—Effective Column Diameter D_C for Typical Column Construction

Column description	Effective Column Diameter D_C (ft)
9 in. × 7 in. built-up column	1.1
8" pipe	0.7
Unknown	1.0

5 Sample Problems

5.1 General

The total evaporative loss is the sum of the standing loss and the working loss.

Sample problems are provided that illustrate the procedure for estimating evaporative loss. An EFRT problem is given in 5.2, an IFRT problem in 5.3, and a domed EFRT problem in 5.4. Estimated emissions are expressed to two significant figures, in that greater precision cannot be supported due to limitations in the precision of the empirically-derived emission factors.

5.2 EFRT Sample Problem

5.2.1 Overview

Estimate the total annual evaporative loss, in pounds per year, given the following information.

A welded EFRT in good condition has the following characteristics:

- a diameter of 100 ft;
- a shell painted an aluminum color, with a specular (shiny) finish in average condition;
- a pontoon (single-deck) floating roof;
- a mechanical-shoe primary seal, with no secondary seal;
- an unslotted guidepole with no controls (that is, no well gasket, pole wiper, or pole sleeve);

f) construction details for all other deck fittings are as indicated in the calculations below.

The motor gasoline stored in the tank has the following characteristics (no vapor or liquid composition is given):

- a) a Reid vapor pressure of 10 psi;
- b) a stock liquid density of 6.1 lb/gal;
- c) an average net throughput of 1.5 million bbl/yr.

The ambient conditions are as follows:

- a) an average annual ambient temperature of 60 °F;
- b) an atmospheric pressure of 14.7 psia;
- c) an average annual ambient wind speed of 10 mph;
- d) an average daily total insolation on a horizontal surface of 1300 Btu/(ft² day).

5.2.2 EFRT Standing Loss

Estimate the standing loss from Equation (2):

$$L_s = (F_r + F_f + F_d)P^*M_vK_C$$

The variables in Equation (2) can be determined as follows:

Total Rim-Seal Loss Factor

$$F_r = K_r D$$

= 4400 lb-mol/yr [from Equation (3) for an average-fitting primary only mechanical-shoe seal, with $V = 10$ mph].

where

$$K_r = 5.8 + (0.3)(10)^{2.1},$$

44 (lb-mol/ft-yr) [for a welded tank with a mechanical-shoe primary seal, from Equation (4) and Table 2, or directly from Table 2],

$$D = 100 \text{ ft (given).}$$

Total Deck-Fitting Loss Factor

$$F_f = N_{f1}K_{f1} + N_{f2}K_{f2} + \dots + N_{fk}K_{fk}$$

= 2500 lb-mol/yr [from Equation (6), with $V = 10$ mph].

where

$$N_{fah}K_{fah} = (1)[(1.6) + (0)(0.7 \times 10)^0]$$

1.6 lb-mol/yr [for bolted, gasketed access hatches, from Equation (7) and Table 3, or directly from Table 3].

$$N_{fc}K_{fc} = (\text{not used on EFRTs})$$

0 lb-mol/yr (for fixed-roof support columns).

$$N_{fgf} K_{fgf} = (1)[(14) + (5.4)(0.7 \times 10)^{1.1}]$$

60 lb-mol/yr [for unbolted, ungasketed gauge floats, from Equation (7) and Table 3, or directly from Table 3].

$$N_{fsp} K_{fsp} = (1)[(0.47) + (0.02)(0.7 \times 10)^{0.97}]$$

0.6 lb-mol/yr [for gasketed gauge hatch/sample ports, from Equation (7) and Table 3, or directly from Table 3].

$$N_{fvb} K_{fvb} = (1)[(6.2) + (1.2)(0.7 \times 10)^{0.94}]$$

14 lb-mol/yr [for gasketed vacuum breakers, K_{fvb} , from Equation (7) and Table 3, or directly from Table 3, N_{fvb} from Table 5].

$$N_{fdd} K_{fdd} = (\text{not typically used on pontoon (single-deck) floating roofs})$$

0 lb-mol/yr (for open deck drains).

$$N_{fdl} K_{fdl} = (17) [(2.0) + (0.37)(0.7 \times 10)^{0.91}] + (16) [(0.82) + (0.53)(0.7 \times 10)^{0.14}]$$

95 lb-mol/yr [for deck legs, K_{fdl} from Equation (7) and Table 3, or directly from Table 3, N_{fdl} from Table 6].

$$N_{frv} K_{frv} = (1)[(0.71) + (0.10)(0.7 \times 10)^{1.0}]$$

1.4 lb-mol/yr [for gasketed rim vents, from Equation (7) and Table 3, or directly from Table 3].

$$N_{fl} K_{fl} = (\text{not typically used on EFRTs})$$

0 lb-mol/yr (for vertical ladders).

$$N_{fugp} K_{fugp} = (1)[(31) + (150)(0.7 \times 10)^{1.4}]$$

2300 lb-mol/yr [for unslotted guidepoles with no well gasket, pole wiper, or pole sleeve, from Equation (7) and Table 3, or directly from Table 3].

$$N_{fsgp} K_{fsgp} = (\text{not present in this example})$$

0 lb-mol/yr (for slotted guide-poles).

Total Deck-Seam Loss Factor

$$F_d = K_d S_d D^2$$

$$= (0.0)(0.0)(100)^2$$

$$= 0 \text{ lb-mol/yr [from Equation (11) for a welded deck].}$$

Vapor Pressure Function

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

$$P^* = \frac{5.8/14.7}{\left\{ 1 + \left[1 - (5.8/14.7) \right]^{0.5} \right\}^2}$$

$$= 0.125 \text{ [for } P = 5.8 \text{ psia, from Equation (13)].}$$

where

$$T_{AA} = 60 \text{ }^\circ\text{F (given);}$$

$$T_{LA} = 0.7 T_{AA} + 0.3 T_B + 0.008 \alpha /$$