

Evaporative Loss From External Floating–Roof Tanks

API PUBLICATION 2517
THIRD EDITION, FEBRUARY 1989

American Petroleum Institute
1220 L Street, Northwest
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Measurement Coordination Department

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FOREWORD

In 1957, the API Evaporation Loss Committee initiated an extensive effort to collect available petroleum industry data on evaporative losses from external floating-roof tanks. An intensive study was made of these data and resulted in correlations for estimating evaporative losses from external floating-roof tanks. These results were published in February 1962 as API Publication 2517.

By the mid-1970s, as a result of the national energy crisis and increased concern for the environment, additional emphasis was placed on the need to reduce evaporative losses from petroleum storage tanks. Accordingly, in 1976 the API Committee on Evaporation Loss Measurement began a review and analysis of the prior API work and of more recent work performed by oil companies, manufacturers, industry groups, and regulatory agencies. From this analysis, and in view of the considerable improvements that had been made in both the technology of floating-roof tank seals and the methods for measuring evaporative losses, the committee recommended that the evaporative-loss data be updated and combined with new data obtained from an extensive test program. API responded by sponsoring a broad program that included laboratory, test-tank, and field-tank studies. From this intensive effort, the mechanisms of evaporative loss were identified, and the effects of the relevant variables were more precisely quantified. The results were published in February 1980 as the second edition of API Publication 2517.

The second edition of API Publication 2517 dealt with evaporative loss from the floating-roof rim seal and the shell-wetting loss from lowering the stock level in external floating-roof tanks. In 1984, as the result of other related API test programs, the Committee on Evaporation Loss Measurement believed that sufficient evidence existed to warrant an additional test program to determine the magnitude of evaporative losses from floating-roof fittings. A survey of tank manufacturers and owners was conducted to establish the type and number of typical roof fittings used on tanks of various diameters. From this survey and an API-sponsored test program performed in 1984, methods were developed for calculating the evaporative loss from the various external floating-roof fittings. As a result, API Publication 2517 was updated with this information, and this third edition was published.

This edition contains the following information:

- a. Section 2 contains the equations necessary for estimating the evaporative loss or the equivalent atmospheric hydrocarbon emissions from the general types of external floating-roof tanks currently available.
- b. Section 3 describes current typical external floating-roof tanks, including types of floating roofs, rim-seal systems, and roof fittings.
- c. Section 4 discusses the mechanisms of evaporative loss and the development of the loss correlations.

The entire data base and the details of the data analysis are on file at API. This third edition supersedes all previous editions of API Publication 2517.

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Suggested revisions are invited and should be submitted to the director of the Measurement Coordination Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.



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CONTENTS

	Page
SECTION 1—SCOPE	1
SECTION 2—PROCEDURES FOR CALCULATING LOSSES	2
2.1 Loss Equations	2
2.1.1 General	2
2.1.2 Standing Storage Loss	2
2.1.3 Withdrawal Loss	2
2.1.4 Total Loss	3
2.2 Discussion of Variables	4
2.2.1 General	4
2.2.2 Standing Storage Loss Factors	4
2.2.2.1 Rim-Seal Loss Factor	4
2.2.2.2 Total Roof-Fitting Loss Factor	6
2.2.2.3 Vapor Pressure Function	6
2.2.2.4 Vapor Molecular Weight	12
2.2.2.5 Product Factor	13
2.2.2.6 Density of Condensed Vapor	13
2.2.3 Withdrawal Loss Factors	14
2.2.3.1 Significance	14
2.2.3.2 Annual Net Throughput	14
2.2.3.3 Clingage	14
2.2.3.4 Average Liquid Stock Density	15
2.3 Summary of Calculation Procedure	15
2.4 Sample Problem	15
2.4.1 Problem	15
2.4.2 Solution	16
2.4.2.1 Standing Storage Loss	16
2.4.2.2 Withdrawal Loss	18
2.4.2.3 Total Loss	19
SECTION 3—COMPONENTS OF EXTERNAL FLOATING-ROOF TANKS	34
3.1 External Floating-Roof Tanks	34
3.2 Floating Roofs	34
3.3 Rim Seals	34
3.3.1 General	34
3.3.2 Mechanical-Shoe Primary Seals	35
3.3.3 Resilient-Filled Primary Seals	37
3.3.4 Flexible-Wiper Primary Seals	38
3.3.5 Secondary Seals	38
3.3.6 Weather Shields	39
3.4 Roof Fittings	39
3.4.1 General	39
3.4.2 Access Hatches	39
3.4.3 Unslotted Guide-Pole Wells	39
3.4.4 Slotted Guide-Pole/Sample Wells	40
3.4.5 Gauge-Float Wells	40
3.4.6 Gauge-Hatch/Sample Wells	40
3.4.7 Vacuum Breakers	40
3.4.8 Roof Drains	41

3.4.9 Roof Legs.....	42
3.4.10 Rim Vents	43
SECTION 4—DETAILS OF LOSS ANALYSIS.....	43
4.1 Introduction	43
4.2 Loss Mechanisms	43
4.2.1 General.....	43
4.2.2 Rim-Seal Loss	44
4.2.3 Roof-Fitting Loss	45
4.2.4 Withdrawal Loss	45
4.3 Data Base for Loss Correlations.....	45
4.3.1 Standing Storage Loss Data	45
4.3.2 Withdrawal Loss Data	46
4.4 Development of Standing Storage Loss Correlation	46
4.4.1 General.....	46
4.4.2 Rim-Seal Loss Factors	46
4.4.3 Tank Diameter	46
4.4.4 Roof-Fitting Loss Factors	47
4.4.5 Vapor Pressure Function	47
4.4.6 Product Factors	47
4.4.7 Tank Paint Color.....	47
4.5 Development of Withdrawal Loss Correlation	47
SECTION 5—REFERENCES	48
APPENDIX A—DEVELOPMENT OF RIM-SEAL LOSS FACTORS	49
APPENDIX B—DEVELOPMENT OF RELATIONSHIP BETWEEN AIRFLOW RATE AND WIND SPEED	51
APPENDIX C—DEVELOPMENT OF DIAMETER FUNCTION	53
APPENDIX D—DEVELOPMENT OF ROOF-FITTING LOSS FACTORS	55
APPENDIX E—DEVELOPMENT OF VAPOR PRESSURE FUNCTION.....	57
APPENDIX F—DEVELOPMENT OF PRODUCT FACTORS.....	59
APPENDIX G—DEVELOPMENT OF CLINGAGE FACTORS	61
APPENDIX H—DOCUMENTATION RECORDS	63

Figures

1—Rim-Seal Loss Factor for a Welded Tank With a Mechanical-Shoe Primary Seal	7
2—Rim-Seal Loss Factor for a Welded Tank With a Liquid-Mounted Resilient-Filled Primary Seal.....	8
3—Rim-Seal Loss Factor for a Welded Tank With a Vapor-Mounted Resilient-Filled Primary Seal.....	9
4—Rim-Seal Loss Factor for a Riveted Tank With a Mechanical-Shoe Primary Seal.....	10
5—Roof-Fitting Loss Factor for Access Hatches.....	14
6—Roof-Fitting Loss Factor for Unslotted Guide-Pole Wells.....	15
7—Roof-Fitting Loss Factor for Slotted Guide-Pole/Sample Wells	16
8—Roof-Fitting Loss Factor for Gauge-Float Wells	17
9—Roof-Fitting Loss Factor for Gauge Hatch/Sample Wells	18
10—Roof-Fitting Loss Factor for Vacuum Breakers	19
11—Roof-Fitting Loss Factor for Roof Drains.....	20
12—Roof-Fitting Loss Factor for Adjustable Roof Legs	21



13—Roof-Fitting Loss Factor for Rim Vents	22
14—Total Roof-Fitting Loss Factor for Typical Fittings on Pontoon Floating Roofs	24
15—Total Roof-Fitting Loss Factor for Typical Fittings on Double-Deck Floating Roofs	25
16—Vapor Pressure Function	26
17A—True Vapor Pressure of Refined Petroleum Stocks With a Reid Vapor Pressure of 1–20 Pounds per Square Inch.....	27
17B—Equation for True Vapor Pressure of Refined Petroleum Stocks With a Reid Vapor Pressure of 1–20 Pounds per Square Inch	29
18A—True Vapor Pressure of Crude Oils With a Reid Vapor Pressure of 2–15 Pounds per Square Inch	28
18B—Equation for True Vapor Pressure of Crude Oils With a Reid Vapor Pressure of 2–15 Pounds per Square Inch.....	29
19—External Floating-Roof Tank With Pontoon Floating Roof.....	35
20—External Floating-Roof Tank With Double-Deck Floating Roof	36
21—Mechanical-Shoe Primary Seal	37
22—Resilient-Filled Primary Seal.....	37
23—Flexible-Wiper Primary Seal	38
24—Mechanical-Shoe Primary Seal With Shoe-Mounted Secondary Seal.....	38
25—Resilient-Filled Primary Seal With Rim-Mounted Secondary Seal....	39
26—Access Hatch	39
27—Unslotted Guide-Pole Well	39
28—Slotted Guide-Pole/Sample Well.....	40
29—Gauge-Float Well	40
30—Gauge-Hatch/Sample Well.....	41
31—Vacuum Breaker	41
32—Overflow Roof Drain	42
33—Roof Leg.....	42
34—Rim Vent	43
C-1—Calculated Losses as a Function of Diameter Exponent	54

Tables

1—Summary of Procedure for Calculating Standing Storage Loss	3
2—Summary of Procedure for Calculating Withdrawal Loss	5
3—Rim-Seal Loss Factors, K_r and n	5
4—Average Annual Wind Speed (V) for Selected U.S. Locations	11
5—Roof-Fitting Loss Factors, K_{fa} , K_{fb} , and m , and Typical Number of Roof Fittings, N_f	13
6—Typical Number of Vacuum Breakers, N_{fb} , and Roof Drains, N_{fd}	23
7—Typical Number of Roof Legs, N_{fl}	23
8—Physical Properties of Selected Petrochemicals	30
9—Average Annual Ambient Temperature (T_a) for Selected U.S. Locations.....	32
10—Average Annual Stock Storage Temperature (T_s) as a Function of Tank Paint Color.....	34
11—Average Clingage Factors, C	34

Evaporative Loss From External Floating-Roof Tanks

SECTION 1—SCOPE

This publication contains an improved method for estimating the total evaporative losses or the equivalent atmospheric hydrocarbon emissions from external floating-roof tanks that contain multicomponent hydrocarbon mixtures (such as crude oils and gasolines) or single-component stocks (such as petrochemicals). This publication was developed by the API Committee on Evaporation Loss Measurement. The equations presented are based on recent laboratory, test-tank, and field-tank data. These equations are intended to provide loss estimates for general equipment types, since it is not within the scope of this publication to address specific proprietary equipment designs.

Typical currently available types of floating roofs, rim-seal systems, and roof fittings are described for information only. This publication is not intended to be used as a guide for equipment design, selection, or operation.

The equations are intended to be used to estimate annual losses from external floating-roof tanks for various types of tank construction, floating roofs, rim-seal systems, and roof fittings, as well as for various liquid stocks, stock vapor pressures, tank sizes, and wind speeds. The equations are applicable to properly maintained equipment under normal working conditions. The equations were developed for liquids that are not boiling, stocks with a true vapor pressure ranging from approximately 1.5 to less than 14.7 pounds per square inch absolute, average wind speeds ranging from 2 to 15 miles per hour, and tank diameters greater than 20 feet. Without detailed field information, the estimation techniques become more approximate when used to calculate losses for time periods shorter than 1 year.

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

- a. To estimate losses from unstable or boiling stocks or from mixtures of hydrocarbons 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, roof fittings, or both have either

deteriorated or been significantly permeated by the stored stock.

Section 2 includes a complete guide for estimating evaporative stock loss or the equivalent total atmospheric emissions from volatile stocks stored in external floating-roof tanks.

Note: The calculated pounds per year of total hydrocarbon losses may include both reactive and nonreactive compounds. To obtain reactive hydrocarbon emissions, the weight fraction of reactive hydrocarbons in the vapor must be applied.

Detailed equations are given in 2.1, and a description of how to determine specific values for the variables included in the equations is given in 2.2. References are made to tables and figures that include information about the most common (typical) values to use when specific information is not available. The loss-estimation procedures are summarized in 2.3 (Tables 1 and 2), and a sample problem is presented in 2.4.

Section 3 describes the typical equipment types covered in Section 2.

Section 4 describes the bases and development of the loss-estimation procedures presented in Section 2. The estimation procedures were developed to provide estimates of typical losses from external floating-roof tanks that are properly maintained and in normal working condition. Losses from poorly maintained equipment 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 external floating-roof tanks will be more accurate than a loss estimate for an individual tank. It is difficult to determine precise values of the loss-related parameters for any individual tank.

Equipment should not be selected for use based solely on evaporative-loss considerations. Many other factors not addressed in this publication, such as tank operation, maintenance, and safety, are important in designing and selecting tank equipment for a given application.

SECTION 2—PROCEDURES FOR CALCULATING LOSSES

2.1 Loss Equations

2.1.1 GENERAL

This section outlines procedures for estimating the total annual evaporative stock loss or the equivalent atmospheric hydrocarbon vapor emissions from volatile stocks stored in external floating-roof tanks. The total loss, L_t , is the sum of the standing storage loss, L_s , and the withdrawal loss, L_w . In some cases, the withdrawal loss may be negligible (see 2.2.3.1); in these cases, the total loss is approximately equal to the standing storage loss.

2.1.2 STANDING STORAGE LOSS

The following minimum information is needed to calculate the standing storage loss, L_s :

- The true vapor pressure of the stock (or the Reid vapor pressure and average storage temperature of the stock).
- The type of stock.
- The tank diameter.
- The average wind speed at the tank site.

Improved estimates of the standing storage loss can be obtained through a knowledge of some or all of the following additional information:

- The type of tank construction (welded or riveted).
- The type of rim-seal system.
- The type and number of roof fittings.
- The type of floating-roof construction (pontoon or double-deck).
- The molecular weight of the stock vapor.

The standing storage loss, L_s , includes losses from the rim seal and the roof fittings. The standing storage loss can be estimated as follows:

$$L_s = (F_r D + F_t) P^* M_v K_c \quad (1)$$

Where:

L_s = standing storage loss, in pounds per year.

F_r = rim-seal loss factor, in pound-moles per foot-year.

D = tank diameter, in feet.

F_t = total roof-fitting loss factor, in pound-moles per year.

P^* = vapor pressure function (dimensionless).

M_v = average molecular weight of stock vapor, in pounds per pound-mole.

K_c = product factor (dimensionless).

The standing storage loss is converted from pounds per year to barrels per year as follows:

$$L_s \text{ (barrels per year)} = \frac{L_s \text{ (pounds per year)}}{42W_v} \quad (2)$$

Where:

W_v = density of the condensed vapor, in pounds per gallon.

The procedures used to calculate the standing storage loss are summarized in Table 1.

Equation 1 was derived by adding together the two equations that represent the independent loss contributions of the rim seal and the roof fittings. The following equations can be used to estimate the independent contributions:

$$L_r = F_r D P^* M_v K_c \quad (3)$$

$$L_t = F_t P^* M_v K_c \quad (4)$$

Where:

L_r = rim-seal loss, in pounds per year.

L_t = total roof-fitting loss, in pounds per year.

The other variables are as defined for Equation 1.

2.1.3 WITHDRAWAL LOSS

The withdrawal loss, L_w , can be calculated from the following information:

- The annual net throughput (associated with lowering the liquid stock level in the tank).
- The type of stock.
- The average liquid stock density.
- The tank diameter.
- The condition of the tank shell.

The withdrawal loss, L_w , pertains to the evaporation of liquid stock that clings to the tank shell while the stock is withdrawn. The withdrawal loss can be estimated as follows:

$$L_w = \frac{0.943 Q C W_l}{D} \quad (5)$$

Where:

L_w = withdrawal loss, in pounds per year.

Q = annual net throughput (associated with lowering the liquid stock level in the tank), in barrels per year.

C = clingage factor, in barrels per 1000 square feet.

Table 1—Summary of Procedure for Calculating Standing Storage Loss

Standing Storage Loss Equations			
L_s (pounds per year) = $[(F_r D) + (F_i)]P^*M_sK_s$			(1)
L_s (barrels per year) = $\frac{L_s \text{ (pounds per year)}}{42W_1}$			(2)
Variable	Definition	Units of Measurement	Source
F_r	= Rim-seal loss factor = $K_r V^n$ (Equation 9)	Pound-moles per foot-year	Figures 1–4 or Equation 9
K_r	= Rim-seal loss factor	Pound-moles per (miles per hour) ⁿ -foot-year	Table 3
V	= Average wind speed	Miles per hour	User specified or Table 4
n	= Rim-seal-related wind-speed exponent	(Dimensionless)	Table 3
D	= Tank diameter	Feet	User specified
F_i	= Total roof-fitting loss factor = $[(N_0 K_0) + (N_a K_a) + \dots + (N_k K_k)]$ (Equation 10)	Pound-moles per year	If no specific information about the type and number of fittings is available: Figure 14 for a pontoon floating roof Figure 15 for a double-deck floating roof If specific information about the type and number of fittings is available: Equations 10 and 11, using values from Tables 5–7 or Figures 5–13
N_0	= Number of roof fittings of a particular type	(Dimensionless)	
K_0	= Roof-fitting loss factor for a particular type of fitting = $K_{fi} + K_{bi} V^{m_i}$ (Equation 11)	Pound-moles per year	
K_{fi}	= Roof-fitting loss factor	Pound-moles per year	
K_{bi}	= Roof-fitting loss factor	Pound-moles per (miles per hour) ^{m_i} -year	
m_i	= Roof-fitting loss factor	(Dimensionless)	
i	= 1, 2, ..., k	(Dimensionless)	
V	= Average wind speed	Miles per hour	
k	= Total number of different types of roof fittings	(Dimensionless)	

W_1 = average liquid stock density at the average storage temperature, in pounds per gallon.

D = tank diameter, in feet.

The constant, 0.943, has dimensions of (1000 cubic feet) × [gallons per (barrel squared)].

The withdrawal loss is converted from pounds per year to barrels per year as follows:

$$L_w \text{ (barrels per year)} = \frac{L_w \text{ (pounds per year)}}{42W_1} \quad (6)$$

Where:

W_1 = average liquid stock density at 60°F, in pounds per gallon.

The procedures used to calculate withdrawal loss are summarized in Table 2.

2.1.4 TOTAL LOSS

The total loss, L_t , in pounds per year and barrels per year, can be estimated as follows:

Table 1—Continued

Standing Storage Loss Equations			
L_s (pounds per year) = $[(F_r D) + (F_l)]P^*M_sK_c$			
L_s (barrels per year) = $\frac{L_s \text{ (pounds per year)}}{42W_v}$			
Variable	Definition	Units of Measurement	Source
P^*	= Vapor pressure function	(Dimensionless)	Figure 16 (or Equation 12)
P	= True vapor pressure	Pounds per square inch absolute	Figure 17 for refined petroleum stocks Figure 18 for crude oils Table 8 for selected petrochemicals
RVP	= Reid vapor pressure (Figures 17 and 18)	Pounds per square inch	User specified
T_s	= average storage temperature of stock (Figures 17 and 18)	Degrees Fahrenheit	User specified or Tables 9 and 10
M_s	= Average molecular weight of stock vapor	Pounds per pound-mole	User specified or 64 for gasoline 50 for U.S. midcontinent crude oil Table 8 for selected petrochemicals
K_c	= Product factor	(Dimensionless)	1.0 for refined stocks 0.4 for crude oil 1.0 for single-component stocks
W_v	= Density of condensed vapor = Liquid stock density for pure compounds	Pounds per gallon	User specified or 0.08 M_s for refined petroleum stocks and crude oils Table 8 for selected petrochemicals

$$L_t \text{ (pounds per year)} = (L_s + L_w) \text{ (pounds per year)} \quad (7)$$

$$L_t \text{ (barrels per year)} = (L_s + L_w) \text{ (barrels per year)} \quad (8)$$

Where:

L_t = total loss.

L_s = standing storage loss.

L_w = withdrawal loss.

2.2 Discussion of Variables

2.2.1 GENERAL

Information is summarized below on how to determine specific values for the variables in the loss equations given in 2.1. Tables, figures, and the range of values of the variables for which the loss equations are applicable are cited for reference.

To obtain the most accurate estimate, the detailed quantities, sizes, and other information pertinent to the specific tank or tanks under consideration should be used. The typical quantities and sizes included in the tables and figures should be used only when actual detailed information is not available. More detailed discussions of the development, definition, and effects of these variables are given in Section 4 and the appendixes.

2.2.2 STANDING STORAGE LOSS FACTORS

2.2.2.1 Rim-Seal Loss Factor

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

$$F_r = K_r V^n \quad (9)$$

Where:

K_r = rim-seal loss factor, in pound-moles per (miles per hour) ^{n} -foot-year.

V = average wind speed, in miles per hour.

n = rim-seal-related wind-speed exponent (dimensionless).

The rim-seal loss factors, K_r and n , are given in Table 3 as a function of tank construction and rim-seal system. There are three basic types of primary seals: mechanical shoe, resilient filled, and flexible wiper. Resilient-filled primary seals can be either vapor mounted or liquid mounted. Vapor-mounted primary seals are mounted on the floating roof so that a vapor space exists between the liquid stock and the bottom of the primary seal. Liquid-mounted primary seals are mounted so that the bottom of the primary seal touches the liquid. In addition to the primary seal, some rim-seal systems are also equipped

Table 2—Summary of Procedure for Calculating Withdrawal Loss

Withdrawal Loss Equations			
$L_w \text{ (pounds per year)} = \frac{0.943QCW_i}{D}$			
$L_w \text{ (barrels per year)} = \frac{L_w \text{ (pounds per year)}}{42W_i}$			
Variable	Definition	Units of Measurement	Source
Q	= Annual net throughput (associated with lowering the liquid stock level in the tank)	Barrels per year	User specified
C	= Clingage factor	Barrels per 1000 square feet	Table 11
W_i	= Average liquid stock density at average stock storage temperature (Equation 5)	Pounds per gallon	User specified or 6.1 for gasoline Table 8 for selected petrochemicals
D	= Tank diameter	Feet	User specified
W_i	= Average liquid stock density at 60°F (Equation 6)	Pounds per gallon	User specified or 6.1 for gasoline Table 8 for selected petrochemicals

with a secondary seal. For mechanical-shoe primary seals, the secondary seal can be either shoe mounted or rim mounted. For resilient-filled primary seals, the secondary seal is only rim mounted.

The 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 $\frac{1}{8}$ inch wide between the rim seal and the tank shell), in which case the factors for tight-fitting seals are applicable.

The development of these average and tight factors is described in Appendix A. Average factors were devel-

Table 3—Rim-Seal Loss Factors, K_r , and n

Tank Construction and Rim-Seal System	Average-Fitting Seals		Tight-Fitting Seals ^a	
	K_r [lb-mole/(mi/hr) ⁿ -ft-yr]	n (dimensionless)	K_r [lb-mole/(mi/hr) ⁿ -ft-yr]	n (dimensionless)
Welded Tanks				
Mechanical-shoe seal				
Primary only	1.2 ^b	1.5 ^b	0.8	1.6
Shoe-mounted secondary	0.8	1.2	0.8	1.1
Rim-mounted secondary	0.2	1.0	0.2	0.9
Liquid-mounted resilient-filled seal				
Primary only	1.1	1.0	0.5	1.1
Weather shield	0.8	0.9	0.5	1.0
Rim-mounted secondary	0.7	0.4	0.5	0.5
Vapor-mounted resilient-filled seal				
Primary only	1.2	2.3	1.0	1.7
Weather shield	0.9	2.2	1.1	1.6
Rim-mounted secondary	0.2	2.6	0.4	1.5
Riveted Tanks				
Mechanical-shoe seal				
Primary only	1.3	1.5	c	c
Shoe-mounted secondary	1.4	1.2	c	c
Rim-mounted secondary	0.2	1.6	c	c

Note: The rim-seal loss factors K_r and n may only be used for wind speeds from 2 to 15 miles per hour.

^aCriteria for seal tightness are defined in 2.2.2.1.

^bIf 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.

^cNo evaporative-loss information is available for riveted tanks with consistently tight fitting rim-seal systems.

oped because it was not possible to quantify parameters for all rim-seal conditions that affect loss. It was thus not possible to determine an exact relationship between the rim-seal loss and rim-seal conditions.

The rim-seal loss factor, F_r , can be calculated using Equation 9 or read directly from Figures 1–4.

The rim-seal loss factors are only applicable for wind speeds from 2 to 15 miles per hour. If the average wind speed, V , at the tank site is not available, wind-speed data from the nearest local weather station or values from Table 4 may be used as an approximation.

If no information is available on the specific type of tank construction and rim-seal system, a welded tank with a mechanical-shoe primary seal may be assumed to represent the most common type currently in use. However, calculations based on such assumed data should be used only as a preliminary indication of evaporative losses. Losses from specific tanks must be based on the actual tank characteristics.

2.2.2.2 Total Roof-Fitting Loss Factor

If information is available on the specific type and number of roof fittings, the total roof-fitting loss factor, F_t , can be estimated as follows:

$$F_t = [(N_{t1}K_{t1}) + (N_{t2}K_{t2}) + \dots + (N_{tk}K_{tk})] \quad (10)$$

Where:

F_t = total roof-fitting loss factor, in pound-moles per year.

N_{ti} = number of roof fittings of a particular type (dimensionless).

K_{ti} = loss factor for a particular type of roof fitting, in pound-moles per year.

$i = 1, 2, \dots, k$ (dimensionless).

k = total number of different types of roof fittings (dimensionless).

The loss factor for a particular type of roof fitting, K_{ti} , can be estimated as follows:

$$K_{ti} = K_{fai} + K_{fbi}V^{m_i} \quad (11)$$

Where:

K_{fai} = loss factor for a particular type of roof fitting, in pound-moles per year.

K_{fbi} = loss factor for a particular type of roof fitting, in pound-moles per (miles per hour) ^{m_i} -year.

m_i = loss factor for a particular type of roof fitting (dimensionless).

$i = 1, 2, \dots, k$ (dimensionless).

V = average wind speed, in miles per hour.

The most common roof fittings are listed in Table 5, along with the associated roof-fitting-related loss fac-

tors, K_{fa} , K_{fb} , and m , for various types of construction details. These factors are applicable for typical roof-fitting conditions. The roof-fitting loss factors may only be used for wind speeds from 2 to 15 miles per hour. The loss factor for a particular type of roof fitting may be calculated using Equation 11 or read directly from Figures 5–13.

Since the number of each type of roof fitting can vary significantly from tank to tank, N_f values for each type of roof fitting should be determined for the tank under consideration. If this information is not available, typical N_f values are given in Tables 5, 6, and 7.

If no information is available about the specific type and number of roof fittings, a typical total roof-fitting loss factor, F_t , can be read from Figure 14 or 15. These figures show the total roof-fitting loss factor, F_t , as a function of tank diameter, D , for pontoon and double-deck floating roofs, respectively.

2.2.2.3 Vapor Pressure Function

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

$$P^* = \frac{P/P_a}{\{1 + [1 - (P/P_a)]^{0.5}\}^2} \quad (12)$$

Where:

P = true vapor pressure at the average stock storage temperature, in pounds per square inch absolute.

P_a = average atmospheric pressure at the tank location, in pounds per square inch absolute.

Alternatively, P^* can be read directly from Figure 16, which is based on an atmospheric pressure, P_a , of 14.7 pounds per square inch absolute.

True vapor pressures can be determined from Figures 17A and 17B for refined stocks (gasolines and naphthas) and from Figures 18A and 18B for crude oils by knowing the Reid vapor pressure, RVP , and the average stock storage temperature, T_s , in degrees Fahrenheit. Vapor pressures of selected petrochemical stocks are given in Table 8.

If the average stock storage temperature, T_s , is not known, it can be estimated from the average annual ambient temperature, T_a , in degrees Fahrenheit (given for selected U.S. locations in Table 9), and the tank paint color, using Table 10.

The loss equations are applicable for nonboiling stocks down to a true vapor pressure of at least 1.5 pounds per square inch absolute. The loss equations can be applied at lower vapor pressures with some loss

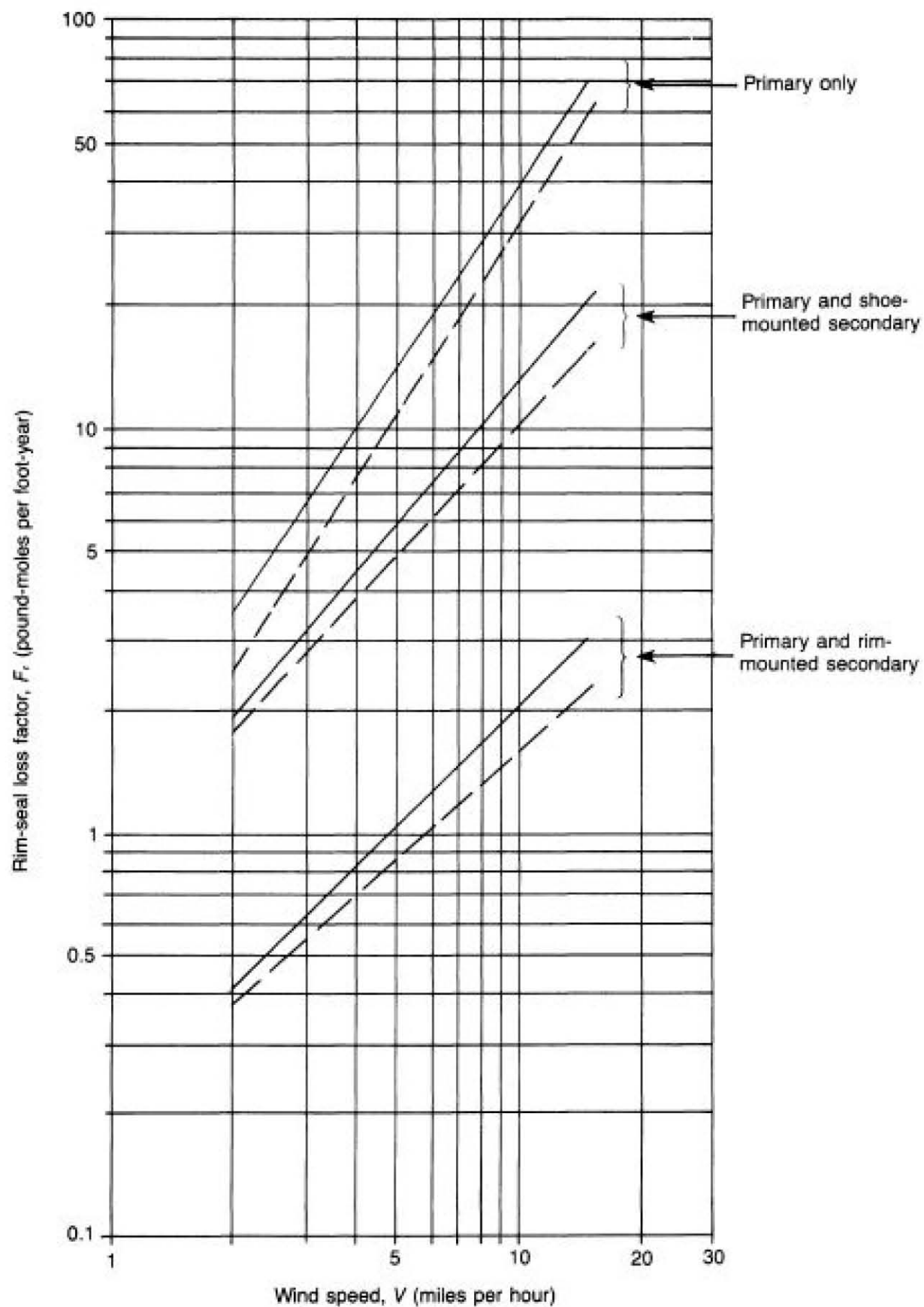
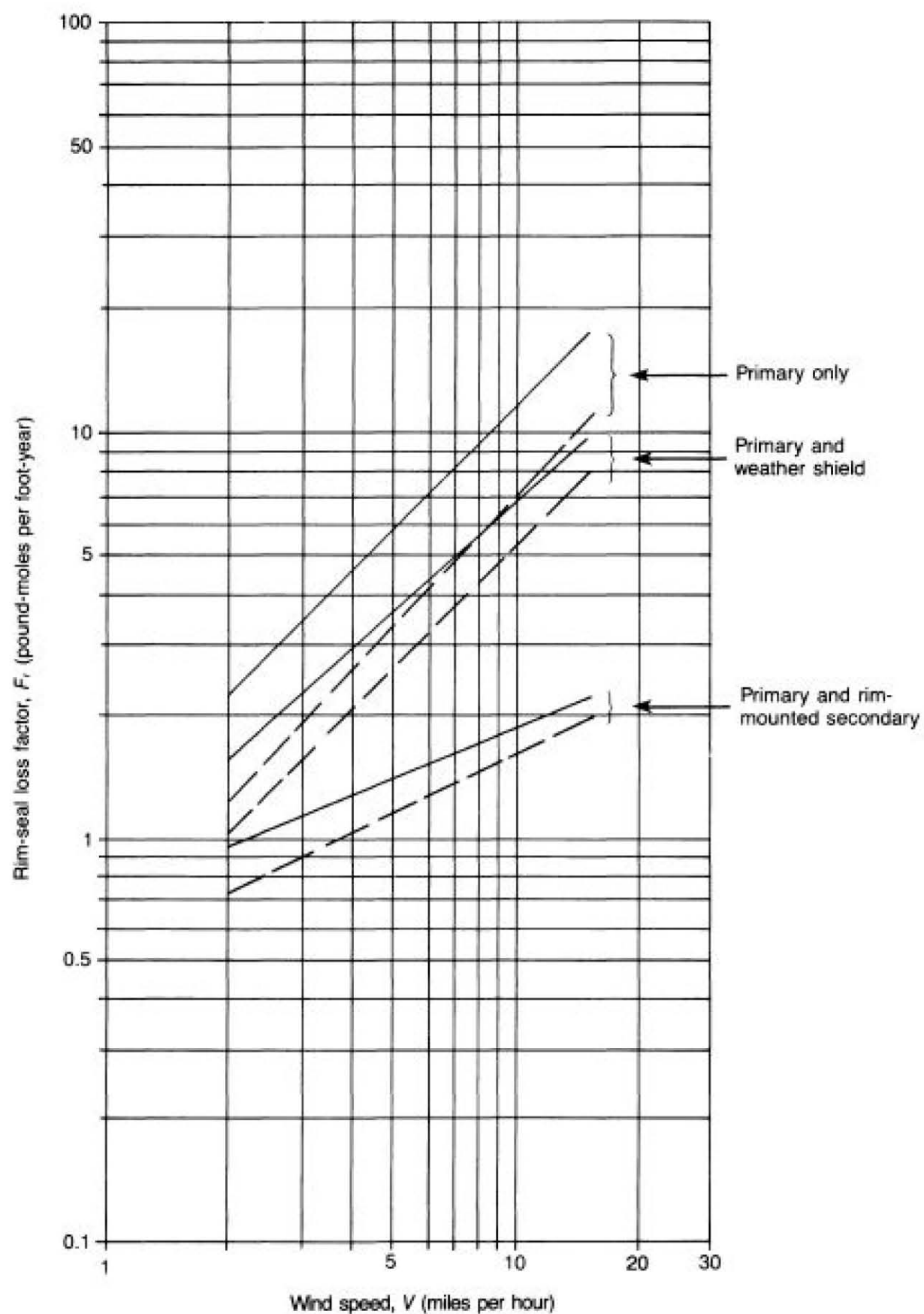


Figure 1—Rim-Seal Loss Factor for a Welded Tank With a Mechanical-Shoe Primary Seal



Note: Solid line indicates average-fitting seal; broken line indicates tight-fitting seal; $F_r = K_r V^n$.

Figure 2—Rim-Seal Loss Factor for a Welded Tank With a Liquid-Mounted Resilient-Filled Primary Seal

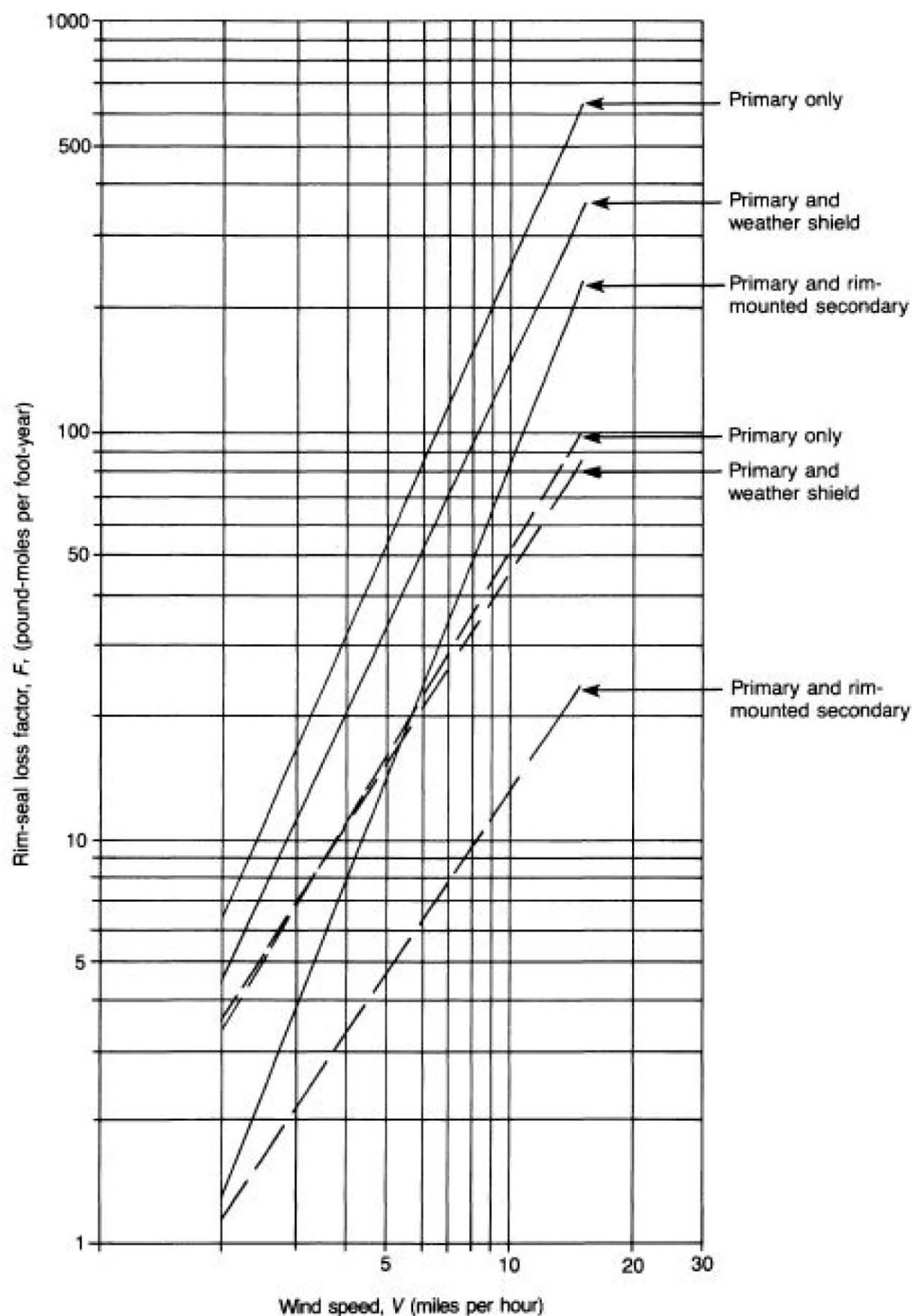
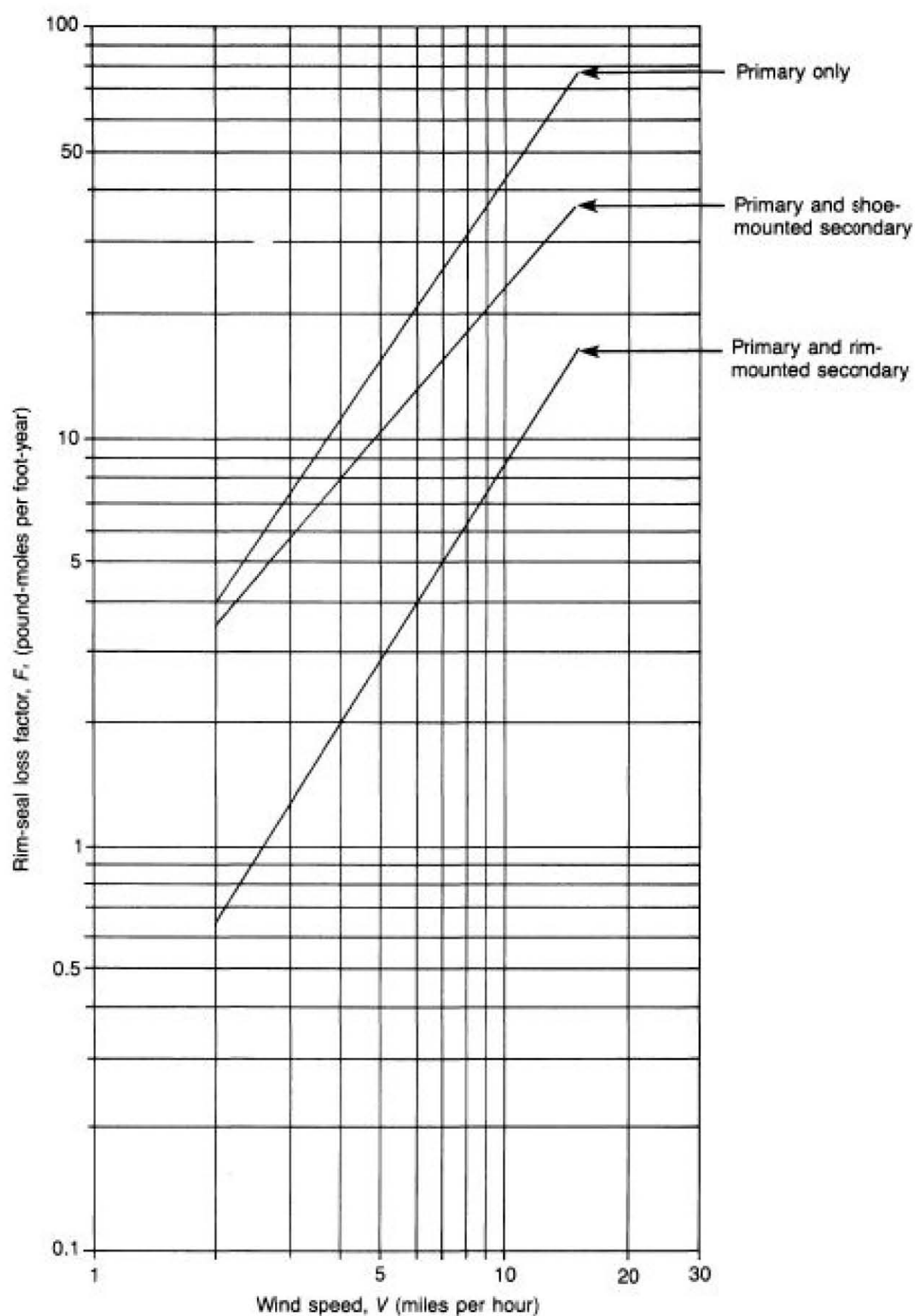


Figure 3—Rim-Seal Loss Factor for a Welded Tank With a Vapor-Mounted Resilient-Filled Primary Seal



Note: Solid line indicates average-fitting seal; $F_r = K_r V^n$.

Figure 4—Rim-Seal Loss Factor for a Riveted Tank With a Mechanical-Shoe Primary Seal

Table 4—Average Annual Wind Speed (V) for Selected U.S. Locations

Location	Wind Speed (miles per hour)	Location	Wind Speed (miles per hour)	Location	Wind Speed (miles per hour)
Alabama		Delaware		Louisiana (continued)	
Birmingham	7.3	Wilmington	9.2	New Orleans	8.2
Huntsville	8.1	District of Columbia		Shreveport	8.6
Mobile	9.0	Dulles Airport	7.5	Maine	
Montgomery	6.7	National Airport	9.3	Caribou	11.2
Alaska		Florida		Portland	8.7
Anchorage	6.8	Apalachicola	7.9	Maryland	
Annette	10.6	Daytona Beach	8.8	Baltimore	9.2
Barrow	11.8	Fort Myers	8.2	Massachusetts	
Barter Island	13.2	Jacksonville	8.2	Blue Hill Observatory	15.4
Bethel	12.8	Key West	11.2	Boston	12.4
Bettles	6.7	Miami	9.2	Worcester	10.2
Big Delta	8.2	Orlando	8.6	Michigan	
Cold Bay	16.9	Pensacola	8.4	Alpena	7.9
Fairbanks	5.4	Tallahassee	6.5	Detroit	10.2
Gulkana	6.8	Tampa	8.6	Flint	10.3
Homer	7.2	West Palm Beach	9.5	Grand Rapids	9.8
Juneau	8.4	Georgia		Houghton Lake	8.9
King Salmon	10.7	Athens	7.4	Lansing	10.1
Kodiak	10.6	Atlanta	9.1	Muskegon	10.7
Kotzebue	13.0	Augusta	6.5	Sault Sainte Marie	9.4
McGrath	5.1	Columbus	6.7	Minnesota	
Nome	10.7	Macon	7.7	Duluth	11.2
St. Paul Island	18.3	Savannah	7.9	International Falls	9.0
Talkeetna	4.5	Hawaii		Minneapolis-Saint Paul	10.5
Valdez	6.0	Hilo	7.1	Rochester	12.9
Yakutat	7.4	Honolulu	11.6	Saint Cloud	8.0
Arizona		Kahului	12.8	Mississippi	
Flagstaff	7.3	Lihue	11.9	Jackson	7.4
Phoenix	6.3	Idaho		Meridian	6.0
Tucson	8.2	Boise	8.9	Missouri	
Winslow	8.9	Pocatello	10.2	Columbia	9.8
Yuma	7.8	Illinois		Kansas City (City)	9.9
Arkansas		Cairo	8.5	Kansas City Airport	10.7
Fort Smith	7.6	Chicago	10.3	Saint Louis	9.7
Little Rock	8.0	Moline	10.0	Springfield	10.9
California		Peoria	10.1	Montana	
Bakersfield	6.4	Rockford	9.9	Billings	11.3
Blue Canyon	7.7	Springfield	11.3	Glasgow	10.8
Eureka	6.8	Indiana		Great Falls	12.8
Fresno	6.4	Evansville	8.2	Havre	9.9
Long Beach	6.4	Fort Wayne	10.2	Helena	7.8
Los Angeles (City)	6.2	Indianapolis	9.6	Kalispell	6.6
Los Angeles International Airport	7.5	South Bend	10.4	Miles City	10.2
Mount Shasta	5.1	Iowa		Missoula	6.1
Oakland	8.2	Des Moines	10.9	Nebraska	
Red Bluff	8.6	Sioux City	11.0	Grand Island	12.0
Sacramento	8.1	Waterloo	10.7	Lincoln	10.4
San Diego	6.8	Kansas		Norfolk	11.8
San Francisco (City)	8.7	Concordia	12.3	North Platte	10.3
San Francisco International Airport	10.5	Dodge City	13.9	Omaha	10.6
Santa Maria	7.0	Goodland	12.6	Scotts Bluff	10.6
Stockton	7.5	Topeka	10.2	Valentine	10.0
Colorado		Wichita	12.4	Nevada	
Colorado Springs	10.1	Kentucky		Elko	6.0
Denver	8.8	Cincinnati Airport	9.1	Ely	10.4
Grand Junction	8.1	Jackson	7.0	Las Vegas	9.2
Pueblo	8.7	Lexington	9.5	Reno	6.5
Connecticut		Louisville	8.3	Winnemucca	7.9
Bridgeport	12.0	Louisiana		New Hampshire	
Hartford	8.5	Baton Rouge	7.7	Concord	6.7
		Lake Charles	8.7	Mount Washington	35.1

Table 4—Continued

Location	Wind Speed (miles per hour)	Location	Wind Speed (miles per hour)	Location	Wind Speed (miles per hour)
New Jersey		Oregon (continued)		Texas (continued)	
Atlantic City	10.2	Portland	7.9	Houston	7.8
Newark	10.2	Salem	7.0	Lubbock	12.4
New Mexico		Sexton Summit	11.8	Midland–Odessa	11.1
Albuquerque	9.1	Pennsylvania		Port Arthur	9.9
Roswell	8.7	Allentown	9.2	San Angelo	10.4
New York		Avoca	8.4	San Antonio	9.4
Albany	8.9	Erie	11.2	Victoria	10.0
Binghamton	10.3	Harrisburg	7.7	Waco	11.3
Buffalo	12.1	Philadelphia	9.5	Wichita Falls	11.7
New York (Central Park)	9.4	Pittsburgh International		Utah	
New York (JFK Airport)	12.2	Airport	9.2	Salt Lake City	8.8
New York (La Guardia		Williamsport	7.9	Vermont	
Airport)	12.3	Puerto Rico		Burlington	8.8
Rochester	9.8	San Juan	8.5	Virginia	
Syracuse	9.7	Rhode Island		Lynchburg	7.8
North Carolina		Providence	10.6	Norfolk	10.5
Asheville	7.6	South Carolina		Richmond	7.5
Cape Hatteras	11.4	Charleston	8.7	Roanoke	8.3
Charlotte	7.5	Columbia	6.9	Washington	
Greensboro–High Point	7.6	Greenville–Spartanburg	6.7	Olympia	6.7
Raleigh	7.8	South Dakota		Quillayute	6.1
Wilmington	8.9	Aberdeen	11.2	Seattle International	
North Dakota		Huron	11.7	Airport	9.1
Bismarck	10.3	Rapid City	11.2	Spokane	8.7
Fargo	12.5	Sioux Falls	11.1	Walla Walla	5.3
Williston	10.1	Tennessee		Yakima	7.1
Ohio		Bristol–Johnson City	5.6	West Virginia	
Akron	9.8	Chattanooga	6.2	Beckley	9.3
Cleveland	10.7	Knoxville	7.1	Charleston	6.4
Columbus	8.7	Memphis	9.0	Elkins	6.2
Dayton	10.1	Nashville	8.0	Huntington	6.5
Mansfield	11.0	Oak Ridge	4.4	Wisconsin	
Toledo	9.4	Texas		Green Bay	10.1
Youngstown	10.0	Abilene	12.2	La Crosse	8.8
Oklahoma		Amarillo	13.7	Madison	9.8
Oklahoma City	12.5	Austin	9.3	Milwaukee	11.6
Tulsa	10.4	Brownsville	11.6	Wyoming	
Oregon		Corpus Christi	12.0	Casper	12.9
Astoria	8.5	Dallas–Fort Worth	10.8	Cheyenne	12.9
Eugene	7.6	Del Rio	9.9	Lander	6.9
Medford	4.8	El Paso	9.2	Sheridan	8.1
Pendleton	9.0	Galveston	11.0		

Note: The data in this table are taken from *Comparative Climatic Data Through 1984*, National Oceanic and Atmospheric Administration, Asheville, North Carolina, 1986.

in accuracy, but they should not be applied at vapor pressures at which it is possible for the stock to reach a boiling state at the liquid surface. The vapor pressure of some mixtures of hydrocarbons or petrochemicals cannot be readily predicted; in these cases, the loss equations cannot be applied.

2.2.2.4 Vapor Molecular Weight

The molecular weight of the vapor, M_v , can be determined by analysis of vapor samples or by calculation

from the composition of the liquid. In the absence of this information, a typical value of 64 pounds per pound-mole can be assumed for gasoline, and a value of 50 pounds per pound-mole can be assumed for U.S. mid-continent crude oils (including both reactive and non-reactive fractions). Since a large variability in molecular weights has been observed in foreign crude oils, no average value has been developed for these stocks. For single-component stocks, the molecular weight of the vapor is equal to the molecular weight of the liquid stock, which is given in Table 8 for selected petrochemicals.