Addendum to Publication 2517— Evaporative Loss From External Floating-Roof Tanks

ADDENDUM TO API PUBLICATION 2517 (THIRD EDITION)
MAY 1994

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005

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Measurement Coordination

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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 of these data 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 prior API studies and more recent testing performed by oil companies, manufacturers, industry groups, and regulatory agencies. As a result of 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. This intensive effort identified the mechanisms of evaporative loss and precisely quantified the effects of the relevant variables. 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 floating-roof rim seals and 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. This information was included in the third edition of API Publication 2517.

In the early 1990s, with continuing environmental concerns and passage of the Clean Air Act Amendments, further emphasis was placed on the need to reduce evaporative emissions from tankage. API sponsored a program that included laboratory testing to validate the emissions loss factors for roof fittings previously tested and to test new equipment configurations to establish loss factors. This program also included testing to establish the effect of wind speed on evaporative losses.

The fourth edition of API Publication 2517 is forthcoming. In the interim, API is publishing this addendum to the third edition of Publication 2517 to release new, pertinent information regarding evaporative losses from slotted versus unslotted guide poles.

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

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SECTION 1—SCOPE

1.1 Purpose

The purpose of this addendum is to provide the users of the third edition of API Publication 2517 with improved data for calculating evaporative losses from guide-pole/sample wells. The test results reported in this addendum improve the basis for determining evaporative losses from these floating-roof fittings.

1.2 Comparison to Previous Data

The roof fitting loss factors reported in the third edition of API Publication 2517 were based on actual tests and supplemented with extrapolated data when actual test data were not available. The information provided in this addendum is based solely on actual tests of various guide-pole/sample well configurations under controlled conditions and has a higher reliability of providing data that is representative of actual operating conditions. Some of the guide-pole/sample well configurations tested for this addendum were duplicate configurations of the guide-pole/sample wells tested as the basis for the current edition of API Publication 2517. In tests of duplicate configurations, the results were similar.

1.3 Components Tested for Reducing Guide-Pole/Sample Well Emissions

Testing conducted included various combinations of four basic emission reduction components that can be incorporated into the design of a guide-pole/sample well: a sliding cover gasket or "well gasket," a float with a wiper, a guide-pole sleeve, and a pole wiper. Section 2 of this addendum describes the mechanics of evaporative loss for each of these designs. Sections 3 and 4 describe design criteria and data from these tests. Section 5 is provided to aid the reader in understanding the significance of individual and various combinations of improvements.

1.4 Use of Results

These results update the third edition of API Publication 2517 as to the anticipated losses from unslotted guide poles and slotted guide poles. Where the results reported in this addendum differ from anticipated losses reported in API Publication 2517, the data in this addendum should be used with the formulas in API Publication 2517 to compute total losses. Specifically, this addendum supersedes the guide-pole loss factors in Table 5 of the third edition of API Publication 2517. Also, due to the lack of test data at higher wind speeds, it is recommended that the table of factors not be used for wind speeds above 15 miles per hour.

Incorporating the generic loss reduction features of the tested components will result in a similar degree of loss reduction for operational tanks. However, this addendum follows the same format as API Publication 2517 in that:

a. These test results 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.
b. This publication is not intended to be used as a guide for equipment design, selection, or operation.
c. 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.

1.5 Definitions

1.5.1 A *guide-pole/sample well* is a device used in external floating-roof tanks to prevent the floating roof from rotating and guide the roof as it rises during tank filling. The guide pole is usually made from pipe and is positioned near the shell of the tank. In some cases the guide pole can also be used for sampling and gauging the tank contents. When used for these purposes, the pipe is slotted to prevent gauging errors that can occur due to the specific gravity variations.

1.5.2 A *gauge-pole/sample well* is a device used in external floating-roof tanks for sampling and gauging the tank's contents. When this fitting is used, some other fitting or device is used to prevent the floating roof from rotating and guide the roof as it rises during tank filling. Gauge-pole/sample wells are constructed the same as guide-pole/sample wells and have the same roof fitting loss factors.

1.5.3 A *guide-pole well* is the opening in the floating roof that encircles the guide pole and allows the roof to move vertically through the full operating range. This opening allows some movement of the roof but still prevents rotation.

1.5.4 A *sample well* is the guide pole used for sampling. This type of guide pole is usually slotted.

1.5.5 *Stilling well* is another term for a sampling or gauging well.

1.5.6 *Sliding cover* is the part of the guide-pole assembly that covers the guide-pole well and has the guide pole passing through its center.

1.5.7 A *float* is a device located inside a slotted guide pole that floats in the product to reduce the amount of exposed liquid surface in the guide pole or restrict the movement of vapors out of the guide pole.

1.5.8 A *well gasket* is a gasket placed between the top of the guide-pole well and the bottom of the sliding cover.

1.5.9 A *wiper* is a device that can be used on either the sliding cover or the float to provide a more effective seal.

1.5.10 *A guide-pole sleeve* is an optional component attached to the sliding cover. This sleeve extends into the product liquid to restrict the movement of vapors from the guide-pole well.

1.6 Referenced Publications

The most recent editions of the following standards, codes, and specifications are cited in this addendum:

API

Publ 2517	*Evaporative Loss from External Floating-Roof Tanks*
Publ 2517D	*Documentation File for API Publication 2517—Evaporation Loss From External Floating-Roof Tanks*
Publ 2519	*Evaporation Loss from Internal Floating-Roof Tanks*
Std 650	*Welded Steel Tanks for Oil Storage*
Std 653	*Tank Inspection, Repair, Alteration, and Reconstruction*

Section 6 contains a list of the numbered references cited in this addendum.

SECTION 2—MECHANICS OF EVAPORATIVE LOSS FROM GUIDE POLES

2.1 Introduction

Every liquid stock has a finite vapor pressure, depending on the surface temperature and composition of the liquid, that produces a tendency for the liquid to evaporate. Through evaporation, all liquids tend to establish an equilibrium concentration of vapors above the liquid surface. Under completely static conditions, an equilibrium vapor concentration would be established, after which no further evaporation would occur. However, external floating-roof tanks are exposed to dynamic conditions that disturb this equilibrium and lead to additional evaporation. These dynamic conditions are responsible for continued evaporation, resulting in stock loss and emissions to the atmosphere.

Fittings that penetrate the floating roof are potential sources of loss because they can require openings that allow for interaction between the stored liquid and the open space above the floating roof. Although such openings can be sealed, the design details of roof fittings generally preclude the use of a completely vapor-tight seal. As a result, evaporative losses can occur from a roof fitting penetration as discussed in 2.2 through 2.5.

One specific roof fitting penetration is the guide pole. This fitting may be either an unslotted guide-pole well (see Figure 1) or a slotted guide-pole/sample well (see Figure 2). For the unslotted guide-pole/sample well, there are two paths by which evaporative losses can escape to the atmosphere during standing storage: (a) gaps between the well and the sliding cover and (b) gaps between the guide pole and the sliding cover. In a slotted guide-pole/sample well, slots in the guide pole itself provide a third path (see Figure 3). Multiple driving forces cause the emissions, and certain interactions can affect the rate at which evaporative losses occur through these emission paths.

2.2 Wind Driven Emissions

Wind is the dominant force in inducing evaporative losses from an external floating-roof tank guide pole. As wind flows across the fitting, air enters and exits the well vapor space (see Figure 4). This air carries product vapors out of the well and releases them to the atmosphere. Besides this direct vapor carrying effect, replacing vapor-laden air with fresh air facilitates further evaporation of product in the well vapor space.

It is important to note that for the guide-pole designs shown in Figures 1 and 2, various emission paths exist (see Figure 3). As a result, wind-driven air can enter the well vapor space through an emission path in a higher-pressure area and exit in a lower-pressure area. An example of this effect is shown in Figure 4, where the air enters the well vapor space through the well and sliding cover on the upwind side then exits through and around the guide pole, where a lower pressure region exists.

2.3 Temperature and Pressure Driven Emissions

As the temperature and pressure in the well vapor space vary, the gas in that vapor space expands or contracts, causing breathing emissions. As the gas temperature increases or the barometric pressure decreases, emission-laden air is expelled from the well vapor space (see Figure 5). As the gas temperature decreases or the barometric pressure increases,

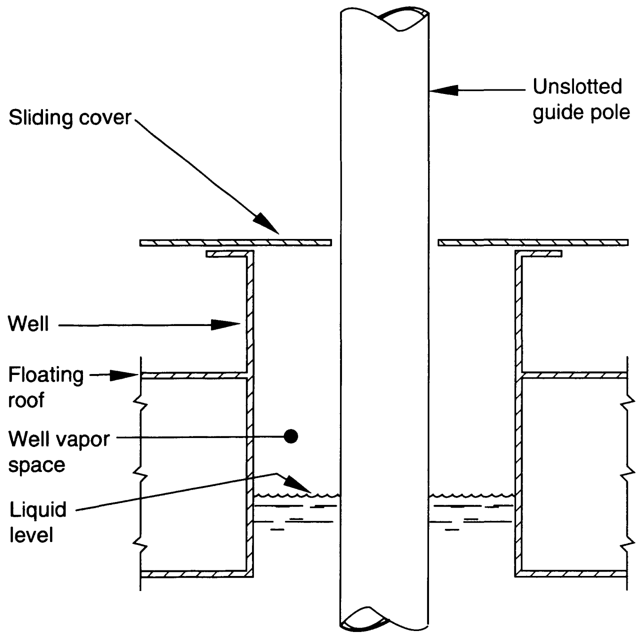

Figure 1—Unslotted Guide-Pole Well

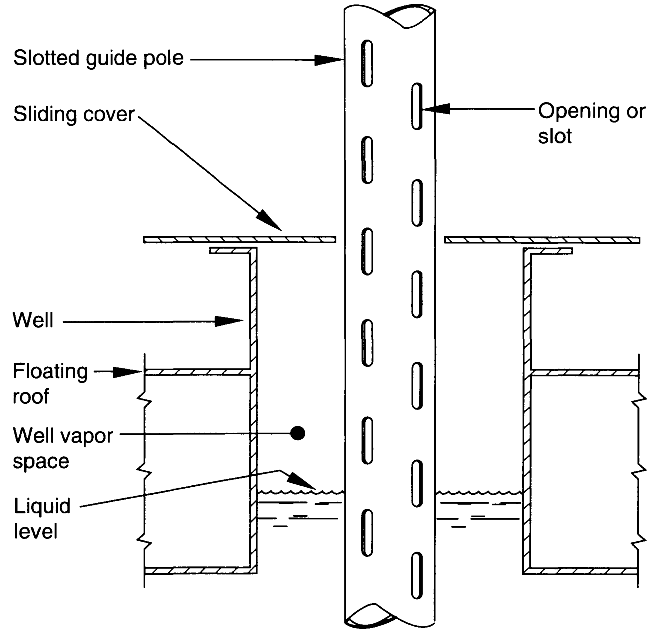

Figure 2—Slotted Guide-Pole/Sample Well

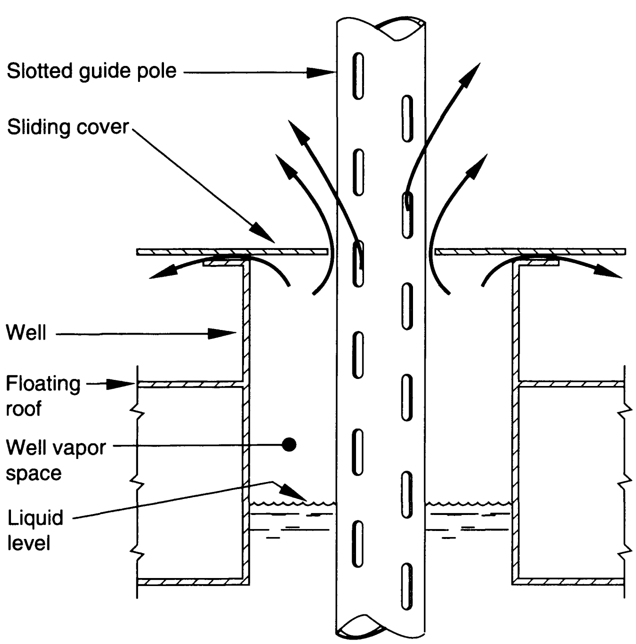

Figure 3—Emissions Loss Paths

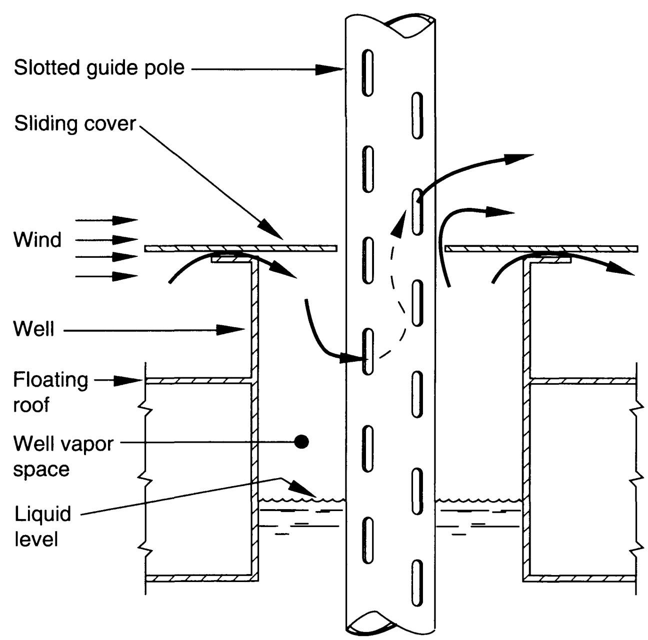

Figure 4—Wind Driven Emissions

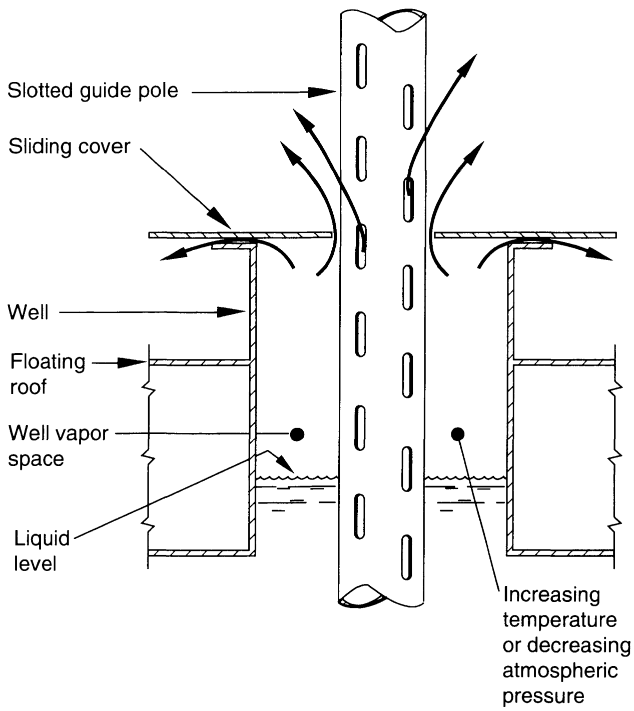

Figure 5—Breathing Emissions

the opposite occurs and fresh air is drawn into the well vapor space. This breathing effect creates a net evaporative loss. However, because of the relatively small size of the guide-pole well, this effect is minor.

2.4 Diffusion Driven Emissions

Evaporative loss can occur due to gaseous diffusion of the hydrocarbons through the air in the well vapor space even without the effects of wind, temperature, and pressure. This diffusion effect causes a net flow of hydrocarbons from a region of high concentration (such as near the liquid surface in the well vapor space) to regions of low concentration (such as the ambient air). The rate of these diffusion driven evaporative losses is generally low.

2.5 Withdrawal Driven Emissions of Stock

As the floating roof descends during stock withdrawal, some of the liquid stock clings to the exposed surface of the guide pole and is exposed to the atmosphere. This clingage usually evaporates before the exposed area is covered by the ascending floating roof during a subsequent filling, which results in evaporative loss.

2.6 Emissions Control Features

Construction features can be incorporated into guide-pole fittings to reduce the emissions resulting from the various mechanisms of evaporative loss. Figure 6 illustrates several emissions control features used in combination on a slotted guide-pole/sample well, including the following:

a. Well gasket.
b. Pole sleeve.
c. Pole wiper.
d. Float.
e. Float wiper.

A pole sleeve interrupts the wind driven air flow from the well vapor space into the slotted guide pole. The pole sleeve also interrupts air flow from the well vapor space into the slotted guide pole. Using a float inside the slotted guide pole reduces the amount of exposed liquid surface area inside the guide pole and restricts the exchange of vapors between the guide pole and the atmosphere. The various gaskets and wipers reduce the width of openings through which emissions can occur, and a pole wiper also has the potential to reduce clingage of stock to the guide pole during stock withdrawal.

Each of these construction features could be used by itself or in combination as shown in Figure 6. Other construction features not described here may also be useful in controlling emissions from guide poles. The degree to which the emissions are controlled or reduced depends not only on which construction features are applied but also on the combination of these features.

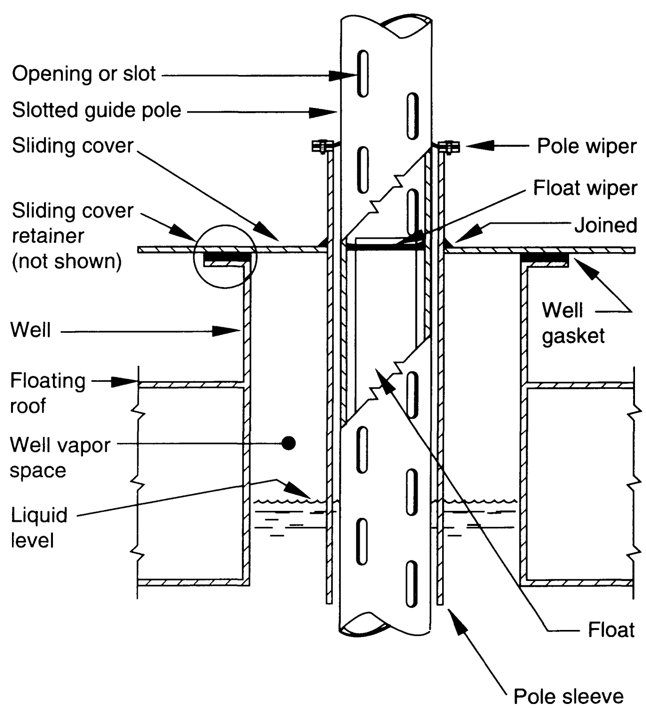

Figure 6—Emissions Control Features

SECTION 3—DESCRIPTION OF GUIDE-POLE MODIFICATIONS

3.1 Basic Guide Poles and Wells

Antirotation devices prevent floating roofs from rotating and damaging the rolling ladder, roof drain systems, and rim seals and from interfering with the operation of float gauges. One commonly used antirotation device is a guide pole fixed at the top and bottom of the tank. Openings at the top and bottom provide a means for hand gauging the tank level and for taking bottom samples.

3.1.1 UNSLOTTED GUIDE POLE

Figure 1 shows a typical unslotted guide pole used as an antirotation device and as an access for hand gauging the tank and sampling the product. One disadvantage of unslotted guide poles is that product enters the guide pole only from the bottom and does not exchange freely with the bulk liquid. Without this exchange, errors can occur due to differences in product specific gravity, composition, and temperature. Therefore, the product and its level in the guide pole may not be representative of the product in the tank at all levels. Unslotted guide poles can be used for single component products and products of fixed composition and of similar specific gravity for successive tank fills.

3.1.2 SLOTTED GUIDE POLE

Figure 2 shows a typical slotted guide pole. Except for the addition of slots, slotted guide poles are designed the same and perform the same function as unslotted guide poles. In this application, the slots allow the product inside the guide pole to mix freely with the product in the tank and thus have the same composition, temperature, and liquid level as the product in the tank.

3.1.3 GUIDE-POLE WELL

The guide pole passes through a guide-pole well, usually 17 inches to 22 inches in diameter (see Figures 1 and 2). A sliding cover or a combination fixed plate and sliding cover is placed over the guide-pole well in which there is a hole slightly larger than the guide pole's outside diameter. This sliding cover accommodates the limited radial movement of the floating roof as it changes position relative to the guide pole.

3.2 Emissions Sealing System

Tests were conducted on an emission sealing system (see Figure 6) composed of the following four basic components added to the standard guide-pole installation:

a. Well gasket.
b. Guide-pole sleeve.
c. Pole wiper.
d. Float with wiper.

3.2.1 WELL GASKET

In many installations the metal sliding cover slides directly on the top of the well. This metal-to-metal fit provides a path for air and vapor currents between the well and sliding cover (see Figures 3 through 5).

3.2.2 GUIDE-POLE SLEEVE AND POLE WIPER

Figures 3, 4, and 5 illustrate the free exchange of air and vapors from the well vapor space through the slots and up the guide pole. In an attempt to block this flow, a sleeve was placed around the guide pole for some tests (see Figure 6). This sleeve was configured differently, depending on whether a pole wiper was used.

In the testing where the pole wiper was not used, the sleeve was a solid metal pipe around the portion of the guide pole from 6 inches above the sliding cover to 12 inches below the surface of the product. The sleeve was welded to the sliding cover at the point it passed through the cover. A small gap was left between the guide pole and the sleeve to permit relative movement during floating-roof operations.

When the pole wiper was installed, the sleeve construction was tested in two configurations. In one configuration the pole sleeve extended up to the sliding cover, and the pole wiper was mounted on the sliding cover so that it projected over the top edge of the pole sleeve. In the second configuration the pole sleeve extended 6 inches above the sliding cover, and the pole wiper was mounted on the top edge of the pole sleeve.

In both configurations, the pole wiper consisted of a $^{1}/_{4}$-inch-thick neoprene gasket. The pole wiper served two functions: it covered the annular gap between the inside surface of the pole sleeve and the outside surface of the guide pole, and it also wiped stock clingage from the outside surface of the guide pole during tank emptying operations.

3.2.3 FLOAT WITH WIPER

In an attempt to prevent free communication of air and product vapors between the atmosphere and the vapor space inside a slotted guide pole, some tests included a float with wiper positioned inside the slotted guide pole. The body of the float was sized to have a $^{1}/_{4}$-inch gap all around between the float and the inside of the slotted guide pole. The bottom of the float was immersed in the product during all tests using the float.

A $^{1}/_{16}$-inch-thick neoprene wiper with the same outside diameter as the inside diameter of the guide pole was mounted at the top of the float. This float wiper remained in all-around contact with the guide pole during the tests. The float was maintained in a fixed position so that its wiper was either 1 inch above the sliding cover or at the same level as the sliding cover, depending on the test. In addition to preventing free exchange of air and vapors, the wiper's function was to wipe product from the inside surface of the guide pole if the floating roof was lowered.

3.2.4 LOW CLEARANCE FLOAT WITHOUT WIPER

An additional test was performed using a float that had a smaller clearance within the guide pole. A float with a body 1/4 inch smaller in diameter than the inside diameter of the slotted guide pole was used to determine the loss from a tighter float without a float wiper and without a pole sleeve. The top of the float extended 1 inch above the top of the sliding cover.

This type of tightly fitting float may not be practical in some tanks because of protrusions and seams in the guide pole that would cause a tightly fitting float to bind.

SECTION 4—DEVELOPMENT OF ROOF FITTING LOSS FACTORS FOR GUIDE POLES

4.1 Introduction

API Publication 2517 lists roof fitting loss factors for guide poles of the following construction:

a. Unslotted guide-pole well (8-inch-diameter unslotted pole, 21-inch-diameter well):
   1. Ungasketed sliding cover.
   2. Gasketed sliding cover.

b. Slotted guide-pole/sample well (8-inch-diameter slotted pole, 21-inch-diameter well):
   1. Ungasketed sliding cover, without float.
   2. Ungasketed sliding cover, with float.
   3. Gasketed sliding cover, without float.
   4. Gasketed sliding cover, with float.

Roof fitting loss factors for the above roof fittings are based on evaporative loss tests that were performed from 1984 through 1985 [1] on guide poles and other roof fittings. Appendix D of API Publication 2517 describes the construction features of the guide poles that were tested as the basis for the roof fitting loss factors in API Publication 2517. These construction features were representative of typical guide-pole construction on field tanks at that time.

As a result of the 1985 API-sponsored test program [1, 2], the importance of evaporative loss from guide poles was recognized. Along with this recognition, the petroleum industry identified improvements in construction details that were expected to result in lower roof fitting loss factors.

In 1992, API initiated a test program to measure the roof fitting loss factors of improved roof fittings, including guide poles. This recent test program [3] was completed in December 1993 and demonstrated that the improved construction features significantly reduced the roof fitting loss factors of guide poles. In addition to determining new roof fitting loss factors, existing fitting factors were verified at wind velocities of 5, 10, and 15 miles per hour, and tests were also performed at 0 miles per hour to establish a baseline for wind speeds below 5 miles per hour.

4.2 Mathematical Development of Roof Fitting Loss Factors

The evaporative loss from the roof fittings on floating roofs is the sum of the losses from each type of roof fitting. The losses for each type of fitting can be estimated as follows:

$$L_f = N_f K_f P^* M_v K_c \quad (1)$$

Where:

L_f = evaporative loss from the type of roof fitting being considered, in pounds per year.
N_f = number of roof fittings of the type being considered (dimensionless).
P^* = vapor pressure function (dimensionless).
M_v = average stock vapor molecular weight, in pounds per pound-mole.
K_c = product factor (dimensionless).
K_f = roof fitting loss factor, in pound-moles per year.

The roof fitting loss factor, K_f, for each type of fitting can be estimated as follows:

$$K_f = K_{fa} + K_{fb} V^m \quad (2)$$

Where:

K_{fa} = loss factor for a particular type of roof fitting, in pound-moles per year.
K_{fb} = loss factor for a particular type of roof fitting, in pound-moles (miles per hour)^m per year.
V = wind speed, in miles per hour.
m = loss factor for a particular type of roof fitting (dimensionless).

After each roof fitting has been considered, the total roof fitting loss is the sum of the losses from each type of roof fitting.

4.3 Database for Roof Fitting Loss Factors

Experimental data were used to determine the roof fitting loss factors of guide poles [1, 3]. Tests were performed in a wind tunnel constructed for this purpose. Four roof fittings could be tested simultaneously in this facility. Each roof fitting was mounted on an independent product reservoir that rested on a digital platform scale. The top of each roof fitting extended into the wind tunnel. Air was passed over the roof fitting at a known velocity to simulate the wind on an actual external floating roof. Evaporative loss was measured by a weight change method using a computer-controlled data acquisition system that automatically recorded the weight of each test fixture, the product temperature, the air temperature, and the wind speed at specified time intervals. The wind tunnel was operated at wind speeds of 4.3, 8.5, and 11.9 miles per hour. The resulting loss data for each roof fitting were fitted to an equation assumed to have the form of Equation 2 (see [3] and API Publication 2517D).

The wind speeds measured in the wind tunnel used for loss factor measurement were assumed to represent both the local wind speed at a particular roof fitting and the wind speed at the tank location. This assumption was considered conservative in that the wind speed at any fitting on a floating-roof was expected to be less than the wind speed at the tank location. Recently, wind tunnel tests on model external floating-roof tanks were performed [4, 5] to measure the local wind speed on the floating roof at roof fitting locations relative to the wind speed at the tank location. The results of this testing are expected to be incorporated into a future revision of API Publication 2517.

The earlier test program [1] was performed on roof fittings where both single-component hydrocarbons (*n*-hexane) and mixtures of propane and *n*-octane were tested. This earlier test data did not show a weathering effect for mixtures. As a result, the recent test program [3] was performed using only a single-component hydrocarbon (*n*-hexane).

4.4 Guide-Pole Roof Fittings Tested

Sixteen different guide-pole roof fittings were tested in the recent loss factor test program, with five of the tests performed on unslotted guide poles and eleven performed on slotted guide poles [3]. Each guide pole was constructed of an 8-inch diameter, Schedule 40 pipe that penetrated a 21-inch inside diameter fitting well. The liquid level in the fitting well was 18 inches below the level of the sliding cover.

The test program evaluated the emission control effectiveness of the following guide-pole construction features:

a. Sliding cover.
b. Well gasket.
c. Pole sleeve.
d. Pole wiper.
e. Float (two diameters).
f. Float wiper.

The well gasket was placed between the top of the fitting well and the bottom of the sliding cover. The pole sleeve consisted of a tube with a 9¼-inch inside diameter that was joined to the sliding cover and extended downward 12 inches below the liquid surface in the fitting well. The pole wiper was used to seal the gap between the sliding cover or top of the pole sleeve and the guide pole. The pole wiper was tested at two elevations: 6 inches above the sliding cover and at the same elevation as the sliding cover. The float wiper was used to seal the gap between the top of the float and the inside surface of the slotted guide pole. The float wiper was tested at two elevations: 1 inch above the sliding cover and at the same elevation as the sliding cover.

4.5 Analysis of Guide-Pole Roof Fittings Loss Data

A computer-controlled data acquisition system recorded the test data from the wind tunnel. The test results were documented in the form of plots of product loss versus net time. Least-squares regressions were performed on all the test data to determine the slope of the product loss data plots for each roof fitting at the beginning of each test, which corresponds to the initial loss rate. Whenever possible, the loss data were fitted to a first-order polynomial and the loss rate was determined by evaluating the first derivative of the polynomial. In several of the tests, however, the loss rate changed significantly as the test progressed. In these cases, the test data were fitted to a second-order polynomial and the initial loss rate was determined by evaluating the first derivative of the polynomial at the beginning of the test. The second-order fit was used for all tests in which the liquid level changed significantly during the test. Only the initial loss rate was used to calculate the roof fitting loss factor for a test.

For each roof fitting test, the roof fitting loss factor, K_f, was determined from the initial loss rate (in pound-moles per year) and the product vapor pressure.

The roof fitting loss factor of slotted guide-pole/sample wells was found to depend upon the orientation of the slot relative to the wind direction. Tests were performed at orientations of 0 degrees, 45 degrees, and 90 degrees relative to the wind direction. The roof fitting loss factors determined at these three orientations were averaged to result in a single average roof fitting loss factor at the wind speed of the test.

For each guide-pole roof fitting, the roof fitting loss factors, K_{fa}, K_{fb}, and m in Equation 2, were determined from the measured loss factors at the various wind speeds of the tests. The resulting roof fitting loss factors are summarized in Table 1. Using the roof fitting loss factors listed in Table 1, the resulting loss factors at wind speeds of 0, 5, 10, and 15 miles per hour were determined and are listed in Table 2.

4.6 Comparison of Guide-Pole Roof Fittings Loss Factors

The guide-pole loss factors resulting from the current test program [3] were compared with those listed in API Publication 2517.

The same vane anemometer wind speed instrument was used in the current test program [3] that was also used in the previous test program [1]. As a result of extensive calibrations and comparisons with pitot tube wind speed instruments, it was found that the wind speed indicated by the pitot tubes was 85 percent of that indicated by the vane anemometer. Thus, in comparing the results of the current test program with API Publication 2517, the wind speed needed to be corrected when using the roof fitting loss factors listed in API Publication 2517.

Table 3 is a comparison of the roof fitting loss factor results from the current test program to those predicted in API Publication 2517 at a wind speed of 10 miles per hour. The roof fitting loss factor test results of the current test program compared favorably with those predicted in API Publication 2517 for guide poles of the same construction. Some of the loss factors shown in API Publication 2517 were not based on loss factor tests of that specific fitting but rather were scaled from values of tests on other roof fittings. In these cases, the comparison between the current test program and the API Publication 2517 values was not as close. In particular, the results of the current test program for unslotted guide poles indicated significantly larger roof fitting loss factors than those predicted by API Publication 2517. This comparison highlights the difficulty in scaling loss factor results of external floating-roof fittings from one roof fitting to another due to the complex wind-induced loss mechanisms that occur. It also highlights the need to base roof fitting loss factors on actual test data measured on specific roof fittings.

Comparisons were also made to evaluate the effectiveness of the emissions control construction features used on guide poles. Table 2 summarizes the roof fitting loss factors from the current test program at wind speeds of 0, 5, 10, and 15 miles per hour for the improved construction features that were tested. First, the results indicate that when these construction features are combined, they can be very effective in emissions control. Second, the test results indicate that evaporative losses from unslotted guide poles and slotted guide poles can be reduced to the same levels by incorporating appropriate construction features. Third, the test results show that emissions from guide poles can be significantly reduced by incorporating appropriate construction features so that the guide-pole losses are no longer a major portion of evaporative losses from floating-roof tanks.

Table 1—Roof Fitting Loss Factors, K_{fa}, K_{fb}, and m, for Guide Poles

Guide-pole Descriptions								
Slots (Y/N)	Well Gasket (Y/N)	Float (Y/N)	Float Wiper (Y/N)	Pole Sleeve (Y/N)	Pole Wiper (Y/N)	K_{fa} (lb-mole/year)	K_{fb} [lb-mole/ (mi/hr)^m yr]	m (dimensionless)
N	N	N	N	N	N	31.1	372	1.03
N	Y	N	N	N	N	25.0	1.05	3.26
N	N	N	N	Y	N	25.0	0.0267	4.02
N	Y	N	N	Y	N	8.63	13.8	0.755
N	Y	N	N	N	Y[d]	13.7	5.78	0.587
Y	N	N	N	N	N	45.4	698	0.974
Y	Y	N	N	N	N	40.7	311	1.29
Y	N	Y	Y[a]	N	N	35.7	102	1.71
Y	Y	Y	Y[a]	N	N	25.8	9.08	2.54
Y	Y	N	N	N	Y[d]	41.2	130	1.23
Y	Y	N	N	Y	N	16.3	132	1.19
Y	Y	Y[e]	N	N	Y	13.8	13.7	1.94
Y	Y	Y	Y[b]	N	Y[d]	17.9	54.2	1.10
Y	Y	Y	Y[a]	N	Y[d]	24.2	6.14	1.95
Y	Y	Y	Y[b]	Y	Y[d]	19.2	6.19	1.25
Y	Y	Y	Y[a]	Y	Y[c]	9.09	13.4	0.512

[a]Float wiper is 1 inch above the sliding cover.
[b]Float wiper is at the same elevation as the sliding cover.
[c]Pole wiper is 6 inches above the sliding cover.
[d]Pole wiper is at the same elevation as the sliding cover.
[e]Float with no wiper and 1/8 inch clearance.

Table 2—Roof Fitting Loss Factors, K_f, at Various Wind Speeds for Guide Poles

Guide-pole Descriptions						K_f, Roof Fitting Loss Factor, (lb-mole/yr)			
Slots (Y/N)	Well Gasket (Y/N)	Float (Y/N)	Float Wiper (Y/N)	Pole Sleeve (Y/N)	Pole Wiper (Y/N)	0 mi/hr	5 mi/hr	10 mi/hr	15 mi/hr
N	N	N	N	N	N	31.1	1980	4020	6080
N	Y	N	N	N	N	25.0	224	1940	7190
N	N	N	N	Y	N	25.0	42.2	305	1450
N	Y	N	N	Y	N	8.63	55.1	87.1	115
N	Y	N	N	N	Y[d]	13.7	28.6	36.0	42.0
Y	N	N	N	N	N	45.4	3390	6620	9800
Y	Y	N	N	N	N	40.7	2520	6100	10300
Y	N	Y	Y[a]	N	N	35.7	1630	5270	10500
Y	Y	Y	Y[a]	N	N	25.8	567	3170	8840
Y	Y	N	N	N	Y[d]	41.2	982	2250	3680
Y	Y	N	N	Y	N	16.3	912	2060	3330
Y	Y	Y[e]	N	N	Y	13.8	325	1210	2630
Y	Y	Y	Y[b]	N	Y[d]	17.9	336	700	1080
Y	Y	Y	Y[a]	N	Y[d]	24.2	166	571	1230
Y	Y	Y	Y[b]	Y	Y[d]	19.2	65.5	129	202
Y	Y	Y	Y[a]	Y	Y[c]	9.09	39.6	52.7	62.7

Note: Numbers are rounded to three significant digits.
[a]Float wiper is 1 inch above the sliding cover.
[b]Float wiper is at the same elevation as the sliding cover.
[c]Pole wiper is 6 inches above the sliding cover.
[d]Pole wiper is at the same elevation as the sliding cover.
[e]Float with no wiper and 1/8 inch clearance.

Table 3—Comparison of Current and API Publication 2517 Roof Fitting Loss Factors, K_f at 10 Miles Per Hour Wind Speed, for Guide Poles

Guide-pole Descriptions						K_f, Roof Fitting Loss Factor, (lb-mole/yr) at 10 mi/hr Wind Speed	
Slots (Y/N)	Well Gasket (Y/N)	Float (Y/N)	Float Wiper (Y/N)	Pole Sleeve (Y/N)	Pole Wiper (Y/N)	Current Results	API Publication 2517 Results[a]
N	N	N	N	N	N	4020	750
N	Y	N	N	N	N	1940	94.6
N	N	N	N	Y	N	305	—
N	Y	N	N	Y	N	87.1	—
N	Y	N	N	N	Y[d]	36.0	—
Y	N	N	N	N	N	6620	5970
Y	Y	N	N	N	N	6100	5010
Y	N	Y	Y[b]	N	N	5270	4010
Y	Y	Y	Y[b]	N	N	3170	3150
Y	Y	N	N	N	Y[e]	2250	—
Y	Y	N	N	Y	N	2060	—
Y	Y	Y[f]	N	N	Y	1210	—
Y	Y	Y	Y[c]	N	Y[e]	700	—
Y	Y	Y	Y[b]	N	Y[e]	571	—
Y	Y	Y	Y[c]	Y	Y[e]	129	—
Y	Y	Y	Y[b]	Y	Y[d]	52.7	—

Note: Numbers are rounded to three significant digits.
[a]The wind speed used with the API Publication 2517 loss factors, K_{fa}, K_{fb}, and m, is 10.0/0.85 = 11.8 miles per hour to account for the correction in the wind tunnel wind speed measurements discussed in 4.6.
[b]Float wiper is 1 inch above the sliding cover.
[c]Float wiper is at the same elevation as the sliding cover.
[d]Pole wiper is 6 inches above the sliding cover.
[e]Pole wiper is at the same elevation as the sliding cover.
[f]Float with no wiper and 1/8 inch clearance.

SECTION 5—HIERARCHIES OF EVAPORATIVE LOSS FROM GUIDE POLES

5.1 Loss From Tank Guide Poles

Product evaporation from storage tank guide poles or gauge poles is believed to be influenced by several factors. Of these, the most notable effects are caused by changes in wind velocity; wind direction; the presence or absence of slots; and equipment modifications such as the addition of well gaskets, floats, pole sleeves, and pole wipers. Studies have shown that when applying various modifications to the guide pole, the amount of emissions is dependent on the type of modification installed and whether it is used in combination with any other fitting modifications. To simplify the review of modifications, the K_f factor (as defined in API Publication 2517 or in 4.2) for emissions will be used throughout this discussion.

Wind velocity is one of the main factors driving guide-pole evaporative loss. As the velocity across a guide pole increases, evaporation increases. However, the magnitude of the increase is not as significant when modifications are made to the guide pole. When comparing an unmodified guide pole to a modified guide pole over the wind speed range, the percent increase in emissions of the two may be similar. However, the total emissions of the modified guide pole is considerably less than the unmodified guide pole. For example, the K_f factor for an unmodified slotted guide pole ranges from 3390 pound-moles per year at 5 miles per hour to 9800 pound-moles per year at 15 miles per hour. However, if the slotted guide pole is fully modified, the K_f factor would range from 39.6 pound-moles per year at 5 miles per hour to 62.7 pound-moles per year at 15 miles per hour.

An additional wind related phenomenon is wind direction. Because wind direction pertains only to slotted guide poles, it will be addressed in 5.2.

Another factor to consider is whether the guide pole is slotted or unslotted. When the slotted guide pole and the unslotted guide pole are compared to each other without any modification applied, the slotted guide pole has higher emissions than the unslotted guide pole. This is due primarily to the migration of vapors through and out of the guide pole's slots. However, with modification, emissions from slotted guide poles can be lowered to a level at or below those from unslotted guide poles.

One important consideration when modifying guide poles is whether the modifications are simple or require major changes to the tank. Potentially, guide-pole modifications could be considered major repairs under API Standard 653.

In many cases, additions such as adding a float in the guide pole can be made while the tank is in service, as long as the guide pole is in good condition and not coated with a heavy incrustation from years of service or storage of a corrosive product. For this reason, the design and age of the tank and the design and function of the improvements to the guide pole should be considered when determining the most appropriate modification to the guide pole.

5.2 Slotted Guide Poles

There are several modifications that can be made to slotted guide poles to reduce emissions. Due to the various combinations of modifications, a hierarchy of modifications will be provided to aid the reader in determining the most appropriate modifications. The review of the modifications is prioritized from minimum to maximum emission reduction benefit.

Before the various improvements can be reviewed, two preliminary issues—wind direction and gasketed sliding covers—need to be addressed. Testing has indicated that a gasketed sliding cover minimally affects an unmodified slotted guide pole. For example, an ungasketed slotted guide pole has a K_f factor of 6620 pound-moles per year at 10 miles per hour, and a gasketed slotted guide pole has a K_f factor of 6100 pound-moles per year at 10 miles per hour. However, as modifications are made to the slotted guide pole, the gasket does play an important role. For this reason, the review of modifications concentrates on slotted guide poles with gasketed sliding covers.

Research has shown that wind direction is another factor affecting slotted guide-pole emissions. Testing on unmodified slotted guide poles indicates that when the direction of the wind is parallel to the slots in the guide pole, the emissions are actually lower than when the wind is perpendicular to the slots. On a modified slotted guide pole, this difference is much smaller. Additional studies [4, 5] have indicated that the direction of the wind generally is parallel to the shell within a few feet of the shell. On most tanks, the slotted guide pole is located within this area along the shell. This suggests that emissions from a slotted guide pole can be reduced by aligning the slots parallel to the shell. Since other modifications can be made more cheaply and result in a more significant reduction in emissions, turning the slotted guide pole may not prove as beneficial as other modifications. However, aligning the slots parallel to the shell on a new tank, if it does not interfere with other equipment, could provide some benefit. In most cases additional modifications can be made more easily than turning the slotted guide pole.

Adding a float to a gasketed, slotted guide pole resulted in a significant reduction in emissions at low wind velocities. The reduction was significant at wind speeds up to 10 miles per hour but was not as dramatic at higher wind speeds (15 miles per hour). Similar results were noted when a float was used with other improvements. The reduction in the K_f factor for a slotted guide pole modified with only a gauge-pole float was approximately 3000 pound-moles per year at 10 miles per hour. As more modifications were made, the float provided similar benefits but also made the emissions from the slotted guide pole less dependent on wind direction.

Adding a pole sleeve or pole wiper resulted in significant emissions reductions. When tested separately, the pole sleeve and pole wiper each showed a reduction in the K_f factor of approximately 4000 pound-moles per year at 10 miles per hour. If the performance over the total range of wind speeds is considered, these two devices individually provide the greatest benefit without additional modifications.

Two additional combinations tested were a pole wiper with float and a pole sleeve with pole wiper and float. When these modifications were made, the K_f factor for each set of conditions was reduced by approximately 5500 pound-moles per year at 10 miles per hour. The combination that provided the most benefit over the entire range of wind speeds was the pole sleeve with pole wiper and float. This combination provided a reduction in the K_f factor of up to 10,000 pound-moles per year at 15 miles per hour.

Some of the tests on the pole wiper and float combination were conducted with the float wiper at the same elevation as the sliding cover and some with the float wiper 1 inch above the sliding cover. The difference in the two emissions rates was insignificant as compared to the total emissions for this fitting combination. Therefore, the height of the float wiper as compared to the sliding cover is not critical.

5.3 Unslotted Guide Poles

As noted in 5.2, only guide poles with gasketed sliding covers are discussed due to the performance noted as modifications are made to the guide pole. Because there are no slots in an unslotted guide pole, emissions from the guide pole are not affected by wind direction. Also, a float inside the unslotted guide pole is not helpful in controlling evaporative loss. For these reasons, only two basic modifications can be made to reduce the emissions from unslotted guide poles: the pole sleeve and the pole wiper. Either of these devices will lower the K_f factor by approximately 2000 pound-moles per year at 10 miles per hour.

SECTION 6—REFERENCES

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