

Manual of Petroleum Measurement Standards Chapter 19.3—Evaporative Loss Measurement

Part A—Wind Tunnel Test Method for the Measurement of Deck-Fitting Loss Factors for External Floating-Roof Tanks

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FOREWORD

This standard provides rules for testing the deck fittings of external floating roofs under laboratory conditions to provide evaporative loss information. It was prepared by Task Group II of the API Environmental Technical Advisory Group (ETAG).

Testing programs conducted by API in 1984 and 1993 provided the information on which the current evaporative loss factors are based for common, generic types of external floating-roof deck fittings. These factors are published in the *API Manual of Petroleum Measurement Standards*, Chapter 19.2, for use in estimating the evaporative loss of petroleum stocks from floating-roof tanks. These factors and the test methods used to develop them have been widely accepted by oil companies, manufacturers, industry groups, regulatory agencies, and general interest groups. API has not, however, tested or developed evaporative loss factors for proprietary designs of individual manufacturers. By publishing a testing protocol, API is making the test method available to interested parties who wish to test particular deck fittings under the auspices of API.

API certification of an evaporative loss factor developed through this program is subject to the following three-step process:

- a. The testing shall be performed in laboratories licensed by API. The requirements to qualify for licensure are presented in the *API Manual of Petroleum Measurement Standards* (MPMS), Chapter 19.3, Part G.
- b. Testing and determination of test results shall be performed as specified herein.
- c. The evaluation of these test results and the certification of an evaporative loss factor for the item tested shall then be conducted in accordance with the API MPMS, Chapter 19.3, Part F.

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Chapter 19.3—Evaporative Loss Measurement

PART A—WIND TUNNEL TEST METHOD FOR THE MEASUREMENT OF DECK-FITTING LOSS FACTORS FOR EXTERNAL FLOATING-ROOF TANKS

0 Introduction

The purpose of this standard is to establish a uniform method for use in measuring the evaporative loss factors for deck fittings of external floating-roof tanks. These loss factors are to be determined in terms of loss rate and wind speed for certification purposes.

It is not the purpose of this standard to specify procedures to be used in the design, manufacture, or field installation of deck fittings. Furthermore, equipment should not necessarily be selected for use solely on the basis of evaporative-loss considerations. Many other factors—such as tank operation, maintenance, and safety—are important in designing and selecting tank equipment for a given application.

1 Scope

This test method may be used to establish evaporative loss factors for deck fittings of external floating-roof tanks. The test method involves measuring the weight loss of a test assembly over time. This standard specifies the test apparatus, the instruments, the test procedures, and the calculation procedures to be used. The variables that are to be measured are defined, and quality provisions are stipulated. The format for reporting the values of both the test results and their associated uncertainty are also specified.

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 References

The most recent editions of the following standards contain provisions that through reference in this text constitute provisions of this standard.

API

Manual of Petroleum Measurement Standards (MPMS)

Chapter 15, “Guidelines for the Use of the International Systems of Units (SI) in the Petroleum and Allied Industries”

Chapter 19.2, “Evaporative Loss From Floating-Roof Tanks”

Chapter 19.3, Part E, “Weight Loss Test Method for the Measurement of Deck-Fitting Loss Factors for Internal Floating-Roof Tanks”

Chapter 19.3, Part F, “Evaporative Loss Factor for Storage Tanks Certification Program”

Chapter 19.3, Part G, “Certified Loss Factor Testing Laboratory Registration”

Std 650 *Welded Steel Tanks for Oil Storage*

ASTM¹

D323 *Test Method for Vapor Pressure of Petroleum Products (Reid Method)*

E220 *Method for Calibration of Thermocouples by Comparison Techniques*

E230 *Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples*

3 Terminology

3.1 DEFINITIONS

For the purposes of this standard, the following definitions apply.

3.1.1 data acquisition: The process of receiving signals from the sensors, determining the values corresponding to the signals, and recording the results.

3.1.2 deck: That part of a floating roof which provides buoyancy and structure, and which covers the majority of the liquid surface in a bulk liquid storage tank. The deck has an annular space around its perimeter to allow it to rise and descend (as the tank is filled and emptied) without binding against the tank shell. This annular space is closed by a flexible device called a rim seal. The deck may also have penetrations, closed by deck fittings, which accommodate some functional or operational feature of the tank.

3.1.3 deck fitting: The device which substantially closes a penetration in the deck of a floating roof in a bulk liquid storage tank. Such penetrations are typically for the purpose of accommodating some functional or operational feature of the tank.

3.1.4 external floating roof: A floating roof that is exposed to the ambient environmental conditions by virtue of being in a bulk liquid storage tank that does not have a fixed roof at the top of the tank shell. External floating roofs are thus distinguished from internal floating roofs, which are located in tanks that do have a fixed roof to protect the floating roof from environmental exposure. External floating roofs are typically designed in accordance with Appendix C of API Standard 650.

¹American Society for Testing and Materials, 100 Bar Harbor Drive, West Conshohocken, Pennsylvania 19428.

3.1.5 floating roof: A device that floats on the surface of the stored liquid in a bulk liquid storage tank. A floating roof substantially covers the liquid product surface, thereby reducing its potential for exposure to evaporation. Floating roofs are comprised of a deck, a rim seal, and miscellaneous deck fittings.

3.1.6 indicator: An instrument that displays or records signals received from a sensor. The indicator is typically constructed to express the signal in units that are useful to describe the observed value of measurement. For example, an electronic signal may be received by the indicator as volts, but then displayed as pounds. An indicator may be incorporated into an electronic data acquisition system. An electronic data acquisition system typically has the capability to be pre-programmed to record data at prescribed intervals, to analyze the data that has been received, and to electronically store the results.

3.1.7 instrument: A device used in the measurement process to sense, transmit, or record observations.

3.1.8 loss factor: An expression used to describe the evaporative loss rate characteristics of a given floating-roof device. In order to obtain the total standing-storage evaporative loss rate for a bulk liquid storage tank equipped with a floating roof, the sum of the evaporative loss factors for each of the individual devices is modified by certain characteristics of both the climatic conditions and the stored liquid. The characteristics of the stored liquid are expressed as a vapor pressure function, the stock vapor molecular weight, and a product factor.

3.1.9 product factor: A factor that describes the evaporative loss characteristics of a given liquid product. The product factor, the stock vapor molecular weight, and the vapor pressure function are multiplied by the sum of the loss factors of the individual floating roof devices to determine the total standing-storage evaporative loss rate of a bulk liquid storage tank equipped with a floating roof.

3.1.10 sensor: An instrument that senses the attribute or measurement information that is to be obtained in a measurement process. This information is then transmitted to the indicator to be displayed or recorded.

3.1.11 standing-storage evaporative loss: Loss of stored liquid stock by evaporation past the floating roof during normal service conditions. This does not include evaporation of liquid that clings to the tank shell and is exposed to evaporation when the tank is being emptied (withdrawal loss); nor does it include vapor loss that may occur when the liquid level is sufficiently low so as to allow the floating roof to rest on its support legs. This does include, however, evaporative losses from the rim seal, deck seams, and deck fittings.

3.1.12 vapor pressure function: A dimensionless factor, used in the loss estimation procedure, that is a function of

the ratio of the vapor pressure of the stored liquid to average atmospheric pressure at the storage location. The vapor pressure function, the stock vapor molecular weight, and the product factor are multiplied by the sum of the loss factors of the individual floating roof devices to determine the total standing-storage evaporative loss rate of a bulk liquid storage tank equipped with a floating roof.

3.2 UNITS OF MEASUREMENT

3.2.1 Basic Units

The unit of length is either the mile, designated *mi*, the foot, designated *ft*, or the inch, designated *in*. The unit of mass is the pound mass, designated *pound* or *lb*. The unit of force is the pound force, designated *pound-force* or *lbf*. The unit of time is either the hour, designated *hr*, or the year, designated *yr*. The unit of temperature is the degree Fahrenheit, designated $^{\circ}F$, or the degree Rankine, designated $^{\circ}R$. The unit of electromotive force is the volt, designated *V*.

3.2.2 Loss Factors

The unit of reporting loss factors is the pound-mole per year, designated *lb-mole/yr*.

The pound-mole per year units of the loss factor K_f do not actually indicate pound-moles of vapor loss over time, but rather are units of a factor that must be multiplied by certain coefficients (which are dimensionless) in order to determine actual pound-moles of evaporative loss over time for a given liquid product. To convert the pound-mole per year units of the loss factor to a loss rate in terms of actual pound-moles per year, the loss factor K_f is multiplied by the dimensionless coefficients P^* , which is a function of the product vapor pressure, and K_c , the product factor.

A pound-mole is an amount of a substance the mass of which, when expressed in pounds, is equal to the numerical value of the molecular weight of the substance. To convert the actual pound-moles per year loss rate to pounds per year of a given liquid product, the loss rate ($K_f P^* K_c$) is multiplied by the molecular weight of the product in its vapor phase, M_v , with molecular weight having units of pounds per pound-mole. Additional information may be found in the API MPMS, Chapter 19.2.

3.2.3 Pressure

The unit of pressure is the pound-force per square inch absolute, designated *psia*.

3.2.4 System of Units

This standard employs the inch-pound units of the English system. Values shall be referenced to the U.S. National Institute of Standards and Technology (NIST) values (formerly the U.S. National Bureau of Standards). The text of this stan-

standard does not include equivalent International System of Units (SI) values, which is the system adopted by the International Organization of Standardization (ISO), but guidance for conversion to SI and other metric units is provided in Appendix D.

3.2.5 Velocity

The unit of velocity is the mile per hour, designated *mi/hr* or *mph*.

3.3 NOMENCLATURE

Table 1 provides a description of the symbols and Units.

Table 1—Description of the Symbols and Units

Symbol	Description	Units
A_p	Constant in the vapor pressure equation	dimensionless
B_p	Constant in the vapor pressure equation	°R
K_c	Product factor	dimensionless
K_f	Deck-fitting loss factor	lb-mole/yr
L	Deck-fitting loss rate	lb/hr
L_f	Deck-fitting loss rate	lb/yr
M_v	Molecular weight of stock vapor	lb/lb-mole
P	True vapor pressure of the stock	psia
P_a	Atmospheric pressure	psia
P^*	Vapor pressure function	dimensionless
T	Stock liquid temperature	°R or °F
V	Wind speed	mi/hr

Note: See 3.2 for definitions of abbreviations for the units.

4 Summary of Test Method

The test method described in this standard uses a weight loss procedure to measure a rate of evaporative loss. A test assembly containing a volatile test liquid of known properties, such as normal hexane (n-hexane), is mounted on a scale and inserted into a wind tunnel. At a prescribed level of wind speed, the weight loss over time is measured. The data is then corrected for variations in temperature and atmospheric pressure during the period of the test, and a loss rate is determined. The loss rate is then factored for the properties of the test liquid in order to determine an evaporative loss factor for that test assembly at that level of wind speed.

5 Significance and Use

This test method establishes a procedure for measuring the evaporative loss factor for deck fittings of external floating-roof tanks. The testing is to be performed in a laboratory that has been approved by API for this purpose, in accordance with the API MPMS 19.3, Part G. The values determined by this method are to be evaluated in accordance with the API

MPMS, Chapter 19.3, Part F, in order to assign an API-certified loss factor to the particular deck fitting tested. The laboratory approval procedure, the test method, and the evaluation method together constitute a procedure by which manufacturers of floating roofs may obtain API-certified loss factors for deck fittings of their proprietary design.

6 Limitations to Test Method

6.1 EVALUATION OF RESULTS

The results of this test method are not intended to be used apart from their evaluation in accordance with the API MPMS, Chapter 19.3, Part F.

6.2 LOW LOSS RATES

This test method is not valid for deck fittings that have a loss rate lower than the specified tolerance of the instruments, or lower than the observed range of drift of the scales.

7 Test Apparatus

7.1 TEST APPARATUS SCHEMATIC

Figures 1 and 2 are schematics of the test apparatus to be used to obtain the measurements necessary for developing a certified evaporative loss factor for a deck fitting of an external floating roof. The test apparatus is comprised of certain test equipment and instrumentation arranged in a test room.

7.2 TEST ROOM

The test room is to be large enough to house the test equipment, instrumentation, and personnel required for the test method, except that the blower need not fit into the test room. The test room shall be constructed and controlled such that the air temperature in the test room is capable of being maintained within $\pm 5^\circ\text{F}$ of a selected test room temperature.

7.2.1 Insulation

The test room should be insulated to aid in the control of the air temperature within the room.

7.2.2 Air Temperature Control System

The test room shall have a dedicated temperature controller for maintaining the air temperature in the test room. The test room may also have a dedicated heater and air conditioner.

7.2.3 Circulation Fan

The test room shall be equipped with a fan that circulates the air within the test room to reduce air temperature variations in the test room. The fan shall be positioned so as not to cause a disturbance that affects the scale weight readings.

7.2.4 Wind Tunnel Air

The air that is directed through the wind tunnel may be drawn from an area of the building outside of the test room in order to avoid disturbing the control of the air temperature within the test room. The temperature of the air in the wind tunnel shall be maintained within $\pm 10^{\circ}\text{F}$ of the temperature of the air in the test room.

7.3 WIND TUNNEL

The wind tunnel shall be a straight length of duct that air may be directed through by means of a blower, as illustrated in Figure 1. The duct should have a rectangular cross section so as to readily accommodate openings. There will typically be openings in the bottom to insert items to be tested, in the top for access hatches, and in the sides for viewing ports.

7.3.1 Wind Tunnel Size

The wind tunnel shall have a minimum cross section of 3 feet by 3 feet and shall be of sufficient length to accommodate measuring stations for performing tests and a suitable means for air flow control.

7.3.2 Measuring Stations

The wind tunnel may have one or more pairs of measuring stations, as shown in Figures 1 and 2. The measuring stations shall be arranged in series along the length of the wind tunnel. Each measuring station shall occupy a section of the wind tunnel at least 5 feet long. There shall be sufficient room beneath each measuring station for a scale. A frame shall be provided for supporting the scale that accommodates leveling the scale and adjusting its elevation. There shall be an opening in the bottom of the wind tunnel at each measuring station to allow the item to be tested to rest on the scale below. There may be an access hatch in the top of the wind tunnel to facilitate placement of the test items, and a window in the side for viewing the test item while the test is in progress.

7.3.3 Transformation Piece

A transformation piece shall be installed between the wind tunnel and the connection to the air blower. An access hatch may be installed in this transformation piece to facilitate inspection and cleaning of the air flow distribution mechanism.

7.3.4 Air Flow Control

The air flow pattern shall be controlled by an air flow distribution mechanism and air flow straighteners.

7.3.4.1 Air Flow Distribution Mechanism

An air flow distribution mechanism, such as a perforated plate or a screen, shall be installed in the wind tunnel to pro-

vide proper flow patterns. This distribution mechanism shall be located upstream of the measuring stations to insure a substantially uniform flow ahead of the measuring stations.

A velocity survey in the empty wind tunnel shall be performed at each measuring station at wind speeds of 5, 10, and 15 miles per hour. The maximum velocity recorded in this velocity survey at each measuring station shall not exceed the average velocity by more than 40 percent.

The wind tunnel shall have an access hatch immediately upstream of the air flow control section to allow inspection and cleaning of the distribution mechanism. This access hatch may be located in the transformation piece.

7.3.4.2 Air Flow Straighteners

Air flow straighteners shall be installed in the wind tunnel upstream of each pair of measuring stations. The upstream end of the upstream air flow straightener shall be located at least 6 inches downstream from the air flow distribution mechanism, as shown in Figures 1 and 2. The air flow straightener sections shall be at least 2 feet long and shall consist of air flow straightening devices, such as a bank of 2-inch diameter tubes.

7.4 AIR BLOWER

Air movement in the wind tunnel shall be provided by an air blower located at the upstream end of the wind tunnel. The air blower shall be capable of providing variable air flow rates corresponding to wind tunnel wind speeds ranging from 0 to 15 miles per hour. The air blower shall be capable of maintaining wind speed at a constant level within ± 10 percent during a test period.

7.5 VIBRATION DAMPING

The transmission of vibrations to the scales and data acquisition system shall be minimized by installing vibration-damping equipment on the air blower. The air blower shall be mounted on vibration isolation dampers, and a flexible fabric section shall be installed between the discharge of the blower and the transformation piece of the wind tunnel.

7.6 TEST VESSELS

An item to be tested shall be mounted in the lid of a test vessel which shall rest on the scales. The test vessel, including its lid, shall be leaktight. The test vessel shall contain the test liquid.

7.6.1 Test Vessel Size

The size of the test vessel may vary to accommodate different sizes of test items. The test vessel shall be deep enough to allow the level of the test liquid surface to be within ± 1 inch of a specified level. The level of the liquid surface is determined from the reference distance described in 8.3.

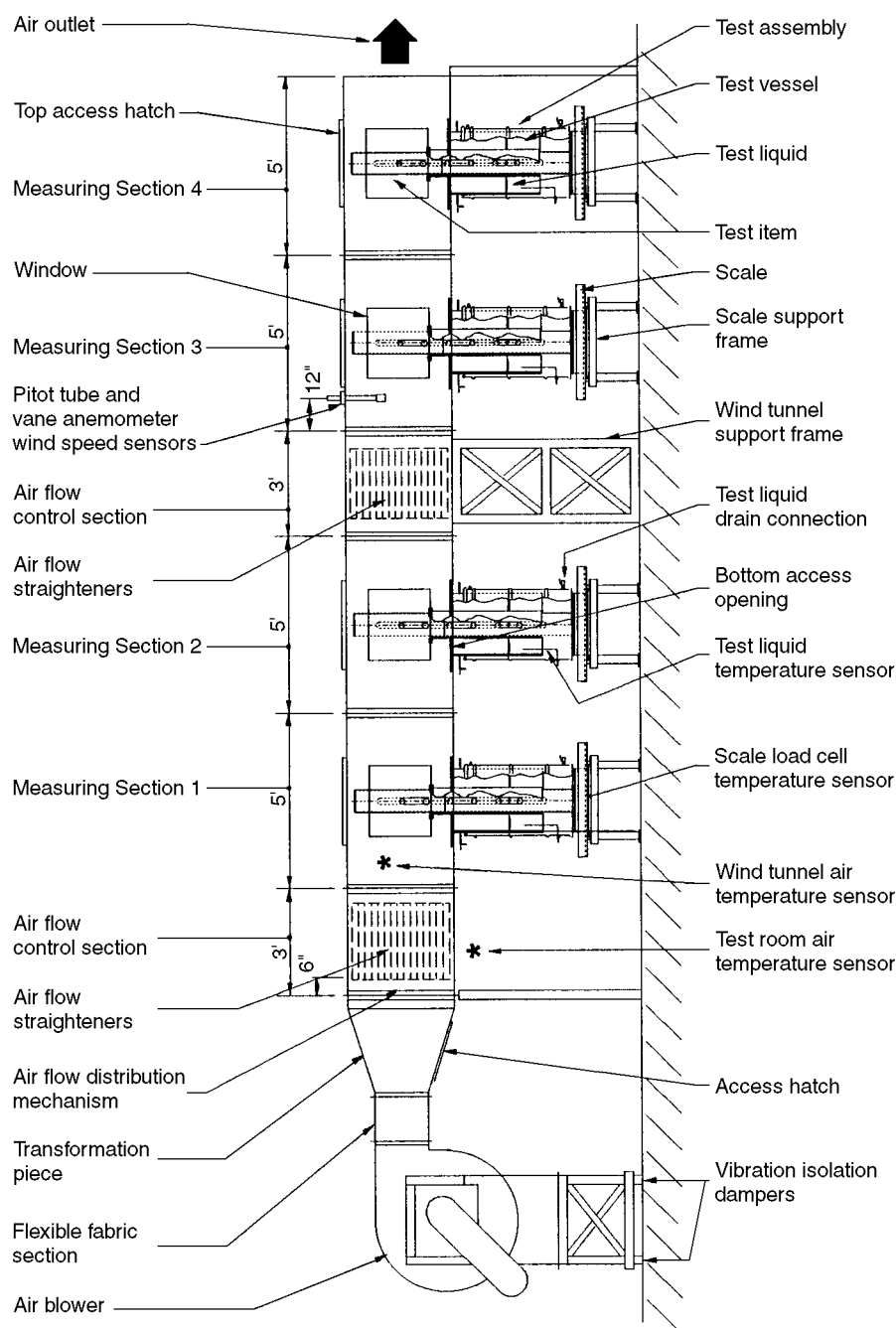


Figure 1—Elevation View of a Typical Wind Tunnel Test Facility

The test vessel shall be of sufficiently large diameter that the evaporative loss of test liquid that occurs during the test does not result in a change in the elevation of the test liquid surface of more than 1 inch during the course of the test.

Test items that exhibit very low loss rates will require scales that are capable of sensing smaller changes in weight than would be required for testing items with greater loss rates. This requirement may result in the use of a scale with a reduced load capacity for testing low loss rate items, thereby

limiting the size of the test vessel. This may generally be accomplished by using a test vessel of a smaller diameter, in that the low loss rate will result in a minimal change in the level of the test liquid surface.

7.6.2 Test Liquid

The test liquid shall be n-hexane or isohexane, technical grade or better. During a test, the temperature of the test liquid