Manual of Petroleum Measurement Standards Chapter 19.3—Evaporative Loss Measurement

Part C—Weight Loss Test Method for the Measurement of Rim-Seal Loss Factors for Internal Floating-Roof Tanks

FIRST EDITION, JULY 1998

Reaffirmed 3/2002

STEP

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Measurement Coordination

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FOREWORD

This standard provides rules for testing the rim seals of internal floating roofs under laboratory conditions to provide evaporative rim-seal loss factors. It was prepared by Task Group II of the API Environmental Technical Advisory Group (ETAG).

Testing programs conducted by API, which began in the mid-1970s and extended through 1982, provided the information on which the current evaporative rim-seal loss factors are based for common, generic types of external, covered, and internal floating-roof rim seals. These rim-seal loss factors are published in API Publication 2517, *Evaporative Loss From External Floating-Roof Tanks*; API Publication 2519, *Evaporation Loss From Internal Floating-Roof Tanks*; and in API *Manual of Petroleum Measurement Standards*, Chapter 19.2, "Evaporative Loss From Floating-Roof Tanks," for use in estimating the evaporative loss of petroleum stocks from external, covered, and internal floating-roof tanks. These rim-seal loss 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 rim-seal loss factors for proprietary designs of individual manufacturers. By publishing this test method, API is making the test method available to interested parties who wish to test particular rim seals 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 API *Manual of Petroleum Measurement Standards*, Chapter 19.3, Part G, "Certified Loss Factor Testing Laboratory Registration;"
(b) Testing and determination of test results shall be performed as specified herein; and
(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 API *Manual of Petroleum Measurement Standards*, Chapter 19.3, Part F, "Evaporative Loss Factor for Storage Tanks Certification Program."

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CONTENTS

Chapter 19.3—Evaporative Loss Measurement

PART C—WEIGHT LOSS TEST METHOD FOR THE MEASUREMENT OF RIM-SEAL LOSS FACTORS FOR INTERNAL FLOATING-ROOF TANKS

0 Introduction

The purpose of this standard is to establish a uniform method for measuring evaporative rim-seal loss factors of rim seals used on internal floating-roof tanks. These rim-seal loss factors are to be determined in terms of loss rate and seal gap area 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 rim seals. Furthermore, equipment should not 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 rim-seal loss factors for rim seals used on internal 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 procedure, 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 Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

2.1 API NORMATIVE STANDARDS

API

Manual of Petroleum Measurement Standards, Chapter 19.2, "Evaporative Loss From Floating-Roof Tanks"

MPMS Chapter 19.3, Part F, "Evaporative Loss Factor for Storage Tanks Certification Program"

MPMS Chapter 19.3, Part G, "Certified Loss Factor Testing Laboratory Registration"

Publ 2517 *Evaporative Loss from External Floating-Roof Tanks*

Publ 2519 *Evaporation Loss from Internal Floating-Roof Tanks*

2.2 ASTM NORMATIVE STANDARDS

ASTM[1]

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

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 deck seam: Certain types of internal floating roofs are constructed of deck sheets or panels that are joined by mechanical means at deck seams. Such mechanically joined seam devices have an associated deck seam loss. Other types of internal or external floating roofs are constructed of metal

[1]ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428.

sheets that are joined by welding. Such seam devices do not have an associated deck seam loss.

3.1.5 evaporative loss factor: An expression used to describe the evaporative loss rate characteristics of a given floating roof device. In order to obtain the standing storage evaporative loss rate for a bulk liquid storage tank equipped with a floating roof, the evaporative loss factor for each evaporative loss contributing device 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, a vapor molecular weight, and a product factor.

3.1.6 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.

3.1.7 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 preprogrammed to record data at prescribed intervals, to analyze the data that has been received, and to electronically store the results.

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

3.1.9 internal floating roof: A floating roof that is not exposed to the ambient environmental conditions by virtue of being in a bulk liquid storage tank that has a fixed roof at the top of the tank shell. Internal floating roofs are thus distinguished from external floating roofs by their use of a fixed roof to protect the internal floating roof from environmental exposure. Internal floating roofs are typically designed in accordance with Appendix H of API Standard 650, *Welded Steel Tanks for Oil Storage*.

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

3.1.11 rim seal: A flexible device that closes the annular rim space between the tank shell and the perimeter of the floating roof deck. Effective rim seals close the annular rim space, accommodate irregularities between the floating roof and the tank shell, and help to center the floating roof, yet permit normal floating roof movement.

3.1.12 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.

3.1.13 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.

3.1.14 vapor pressure function: A dimensionless factor, used in the loss estimation procedure, that is a function of the ratio of the vapor pressure of stored liquid to the 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.

3.1.15 weight loss test method: The method of determining a loss factor by measuring the weight loss of a test assembly over time as test liquid evaporates from the test assembly.

3.2 UNITS OF MEASUREMENT

3.2.1 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 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 C, Metric Units.

3.2.2 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 °F, or the degree Rankine, designated °R. The unit of electromotive force is the volt, designated *v*.

3.2.3 Pressure

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

3.2.4 Rim-Seal Loss Factors

The unit of reporting rim-seal loss factors is the pound-mole per foot of tank diameter per year, designated lb-mole/ft yr.

The units of the rim-seal loss factor, K_r, do not actually indicate pound-moles of vapor loss over time, but rather are units of a factor that must be multiplied by the tank diameter and other factors (which are dimensionless) to determine the actual pound-moles of evaporative loss over time for a given liquid product. To convert the pound-mole per foot of tank diameter per year units of the rim-seal loss factor to a loss rate in terms of actual pound-moles per foot of tank diameter per year, the rim-seal loss factor, K_r, is multiplied by the dimensionless coefficients P^*, which is a function of the product vapor pressure and atmospheric pressure, and Kc, the product factor.

A pound-mole, designated lb-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 then convert the actual pound-moles per foot of tank diameter per year to pounds per year of a given liquid product, the loss rate ($K_r P^* K_c$) is multiplied by the tank diameter, D, and the molecular weight of the liquid product in its vapor phase, M_v, with molecular weight having units of pounds per pound-mole. Additional information on this formula may be found in API Publications 2517 and 2519, and in API *MPMS*, Chapter 19.2.

3.3 NOMENCLATURE

Table 1 provides a description of the symbols and units.

Note: See Section 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 is suspended from load cells and is fitted with a test rim seal. Spacers are placed between the test rim seal and the simulated tank shell of the test assembly to create a specified rim-seal gap area. The area below the test rim seal is filled to an appropriate height with a volatile hydrocarbon test liquid of known properties, such as normal-hexane or isohexane. The weight loss of the test assembly over time is measured. The test data is 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 and the length of the test rim seal in order to determine an evaporative rim-seal loss factor for the test rim seal at that seal gap area.

5 Significance and Use

This test method establishes a procedure for measuring the evaporative rim-seal loss factor of rim seals that are used on internal floating-roof tanks. The testing is to be performed in a laboratory that has been approved by the API for this purpose in accordance with the API *MPMS*, Chapter 19.3, Part G, "Cer-

Table 1—Description of the Symbols and Units

Symbol	Description	Units
A_g	Rim-seal gap area	in^2
A_p	Constant in the vapor pressure equation	dimensionless
B_p	Constant in the vapor pressure equation	° R
D	Tank diameter	ft
F_g	Rim-seal gap area factor	in^2/ft
K_c	Product factor	dimensionless
K_r	Rim-seal loss factor	lb-mole/ft yr
L	Rim-seal loss rate	lb/hr
L_c	Length of the test assembly shell plate	ft
L_r	Rim-seal loss rate	lb/yr
L_s	Length of test rim seal	ft
Mv	Molecular weight of test liquid vapor	lb/lb-mole
P	Vapor pressure of the test liquid	psia
P_a	Atmospheric pressure	psia
P^*	Vapor pressure function	dimensionless
t	Time	hr
T	Stock liquid temperature	°R or °F
W	Weight loss of the test rim seal	lb

tified Loss Factor Testing Laboratory Registration." The values determined by this method are to be evaluated in accordance with the API *MPMS*, Chapter 19.3, Part F, "Evaporative Loss Factor for Storage Tanks Certification Program," to assign API-certified loss factors to the particular rim seal tested. The laboratory approval procedure, the test method, and the evaluation method together constitute a procedure by which manufacturers of floating roof rim seals may obtain API-certified loss factors for rim seals 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 API *MPMS* Chapter 19.3, Part F.

6.2 LOW LOSS RATES

This test method is not valid for rim seals that have a loss rate lower than the specified tolerance of the instruments, or lower than the observed range of drift of the load cells.

If it is determined that the loss rate of the test rim seal is less than the detection limit of the instrumentation or the drift rate of the load cells, the report of test results shall state a de minimis value for the rim-seal loss factor that is based on the instrumentation detection limit and the drift rate of the load cells.

7 Test Apparatus

7.1 TEST APPARATUS SCHEMATIC

Figures 1, 2, and 3 are schematics of the test apparatus that is to be used to obtain the measurements necessary for developing a certified evaporative rim-seal loss factor for a test rim seal of an internal floating roof. The test apparatus is comprised of certain test equipment and instrumentation arranged in a test room and a data acquisition 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 data acquisition system is housed in a separate room, as described in Section 7.4. The test room shall be constructed and controlled such that the air temperature in the test room is capable of being maintained within ±5°F of a selected test room temperature for the duration of the test period.

7.2.1 Insulation

The test room should be insulated to aid in the control of the air temperature within the test 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 Air Ventilation System

The test room shall be equipped with an air ventilation system to provide sufficient ventilation of the test room to limit buildup of evaporated test liquid within the test room. The test room shall be equipped with a ventilation blower to withdraw a steady stream of ventilation air from the test room. However, the flow rate of ventilation air must be limited to about two air changes per hour so as to not create a condition significantly different than that inside the vapor space above an internal floating roof.

7.2.4 Access Doors

The test room shall be equipped with an equipment access door that is large enough to permit installation or removal of a test assembly. The test room shall also be equipped with a smaller personnel access door to permit inspection of a test assembly during a test period.

7.2.5 Support Frame

The test room shall be equipped with a support frame for use in supporting a test assembly during the test period. The test assembly is to be suspended from load cells that are attached to the support frame.

7.2.6 Spill Pan

It is advisable to place a spill pan under the test assembly to collect any spillage of the test liquid that may occur during filling and emptying operations.

7.3 TEST ASSEMBLY

A rim seal to be tested shall be mounted on the test assembly which shall have at least three suspension points so that it may be suspended from load cells.

7.3.1 Test Assembly Construction

Figure 3 is a schematic of a test assembly. The test assembly simulates a portion of the rim of an internal floating roof and includes a bottom plate, rim plate, shell plate and end plates. A stiffener plate may be used to help maintain the proper contour of the shell plate. The shell plate shall be curved to simulate the shell of a tank with a 50-foot radius. The test assembly may be constructed of aluminum to reduce its weight. The length of the test assembly shall be sufficient to permit mounting a section of the test rim seal that has an arc length of at least 10 feet.

The test assembly shall be fitted with a thermocouple to measure the temperature of the test liquid within 3 inches below the test liquid surface.

The test liquid is contained in the simulated rim space that is between the shell plate and rim plate.

The height of the rim plate shall be sufficient to allow the level of the test liquid surface to be at a distance below the top of the rim plate that is within ±1 inch of a specified level, which shall be that which is typical of industry practice for the rim seal being tested.

The test assembly shall have at least 3 support points so that it may be suspended from load cells and its orientation adjusted to permit it to be in a horizontal position during the test period.

Test rim seals that exhibit very low loss rates will require load cells that are capable of sensing smaller changes in weight than would be required for testing rim seals with greater loss rates. This requirement may result in the use of load cells with reduced load capacity, thereby limiting the weight of the test assembly.

7.3.2 Rim Seals

The rim seal to be tested shall be mounted on the simulated floating roof rim using the assembly and installation procedures normally used for the rim seal, as specified by the rim seal manufacturer. The only exception to this use of normal procedures involves the sealing method for the ends of the test rim seal. At each end of the section of test rim seal, the test rim seal must be joined and sealed to the end plate of the test assembly to eliminate emission end effects. Sealing details for these end joints shall be documented in the report of test results and should be installed in a manner so as to not affect the emission characteristics of the test rim seal.

The surfaces of the test rim seal and the test assembly shell plate shall be clean and free from oil or other material that may affect the rim-seal loss factor test results.

A leak-tightness test may be performed on the test rim seal to ensure that there are no leak paths through the two end joints. An example of such a leak-tightness test consists of applying a slight gas pressure in the vapor space under the rim seal. A leak detection liquid (typically a soap-like liquid that will form bubbles at vapor leaks) may then be applied at the end joints. If no bubbles are detected, it can be assumed that no significant end joint emission leaks are present.

7.3.3 Test Liquid

The test liquid shall be maintained at a level relative to the test rim seal that corresponds to that which is typical of industry practice for the rim seal being tested.

The test liquid shall be normal-hexane (n-hexane) or isohexane, technical grade or better. During a test, the temperature of the test liquid shall not be permitted to exceed its normal boiling-point temperature. Samples of the test liquid shall be taken both before and after the test period and tested to determine the Reid vapor pressure of the mixture in accordance with ASTM D323.

The required quantity of test liquid may be reduced by floating it on top of water. The depth of the test liquid layer shall be sufficient to ensure that it completely covers the surface of the water for the duration of the test. The depth of the test liquid layer must also be sufficient to ensure that the change in vapor pressure of the test liquid as a result of evaporation of lighter hydrocarbon components does not cause the test liquid vapor pressure to decrease by more than 5 percent during the test.

Test rim seals that normally extend into the liquid product on a storage tank shall be mounted in the test assembly in a manner that permits free flow of the test liquid to all rim space areas below the test rim seal. For example, when testing a mechanical-shoe primary seal, the layer of test liquid that is floating on water must extend below the bottom of the shoe.

7.3.4 Emptying and Filling

All penetrations of or attachments to the test assembly, including those for emptying and filling, must be leak-tight. A method of indicating the liquid level in the test assembly must be provided to control initial filling and for monitoring purposes during a test. The preferred method of indicating the liquid level is by means of a sight tube or window, but other methods that do not result in any loss of test liquid product or its vapors may also be used.

7.4 DATA ACQUISITION ROOM

The data acquisition room is to be large enough to house the data acquisition system and personnel required for the test method. The data acquisition room shall be constructed and controlled such that the air temperature in the room is capable of being maintained within ±5°F of a selected room temperature for the duration of the test period.

7.4.1 Insulation

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

7.4.2 Air Temperature Control System

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

7.4.3 Circulation Fan

The data acquisition room shall be equipped with a fan that circulates the air within the room so as to reduce air temperature variations within the room.

8 Test Item

8.1 TEST ITEM CONSTRUCTION

The test items to be tested according to this test method are rim seals for internal floating-roof tanks. Items to be tested shall be full-scale samples of the rim seals. These shall be constructed according to the manufacturer's standard practice and shall include all features typical to actual use.

8.2 TEST RIM SEAL ATTACHMENT

The rim seal to be tested shall be attached to the test assembly in a manner similar to its attachment to a floating-roof rim in practice. Test rim seals that normally extend into the liquid product on a floating roof shall be mounted in a similar manner on the test assembly.

8.3 TEST RIM SEAL END CONNECTIONS

The ends of the test rim seal shall be sealed to the end plates of the test assembly. A suitable sealant or caulk may be used for this purpose.

9 Preparation of Apparatus

9.1 TEST ASSEMBLY PLACEMENT

Install the test rim seal on the test assembly, as described in 7.3.2 and 8.2. Suspend the test assembly from the load cells. Fill the test assembly with test liquid to the proper level, as described in 7.3.4. Insert rim-seal gap spacers between the test rim seal and the shell plate to create the required rim-seal gap area, as described in 11.1.

9.2 TEST ROOM AIR TEMPERATURE CONTROL

Start the test room air temperature control system and adjust the test room temperature to the required level.

9.3 DATA ACQUISITION ROOM AIR TEMPERATURE CONTROL

Start the data acquisition room air temperature control system and adjust the data acquisition room air temperature to the required level.

9.4 STEADY STATE OPERATION

Start the data acquisition system and record the test assembly weight loss over a period of time until a steady rate of weight loss versus time is achieved. Following this initial start-up period during which the evaporation rate stabilizes, the subsequent test data recorded by the data acquisition system, as described in 11.3, shall constitute the record of test data that is to be used in calculating the evaporative loss factor.

10 Instrumentation and Calibration

10.1 ACCURACY

Each parameter to be measured requires a sensor, an indicator, and a method of recording the data. The specifications that follow describe the required instruments, the methods to be employed in the measurement process, and the accuracy requirements. Calibration procedures are specified to minimize systematic error, or bias, in the instruments. The instrument requirements are summarized in Table 2.

Procedures are also specified for certain steps of the measurement process which have been identified as likely potential sources of random error, so as to limit the imprecision associated with these steps. One such step is the method of indicating observed values and recording them. The process of receiving signals from the sensors, determining the values corresponding to the signals, and recording the results may be collectively referred to as data acquisition. Data acquisition is to be accomplished with a programmable electronic data acquisition system so that the frequency and precision of observations can be controlled within specified tolerances.

The demonstrated accuracy of the sensors shall be based on the readings indicated by the data acquisition system, thereby providing verification of the indicator as well as the sensor. Calibration standards shall be traceable to national measurement reference standards maintained by NIST.

10.2 DATA ACQUISITION SYSTEM

The data acquisition system shall be capable of recording all of the data transmitted by the sensors. The data acquisition system shall include a chronometer that indicates time in intervals not greater than one second with a demonstrated accuracy of ±0.1 percent. The data acquisition system shall be capable of being programmed to record individual sensor readings at a specified frequency. The data acquisition system shall have the capability to record sensor readings multiple times within a specified time period, and then determine the mean and the standard deviation of these values. The data acquisition system should be capable of real-time display of the observed values, so that any out-of-specification conditions can be detected and corrected as soon as possible. The software of the system shall be verified by using the data acquisition system as the indicator when calibrating the sensors.

10.3 WEIGHT MEASUREMENT

The weight of the test assembly shall be sensed with high-precision load cells, and the signals indicating the load cell weight measurements shall be transmitted to the data acquisition system. The load cells shall be capable of sensing weight changes of ±0.01 percent of the weight of the test assembly. Rim seals that exhibit relatively low rates of evaporative loss may require the use of load cells that are capable of sensing even smaller weight changes, or the length of a test period

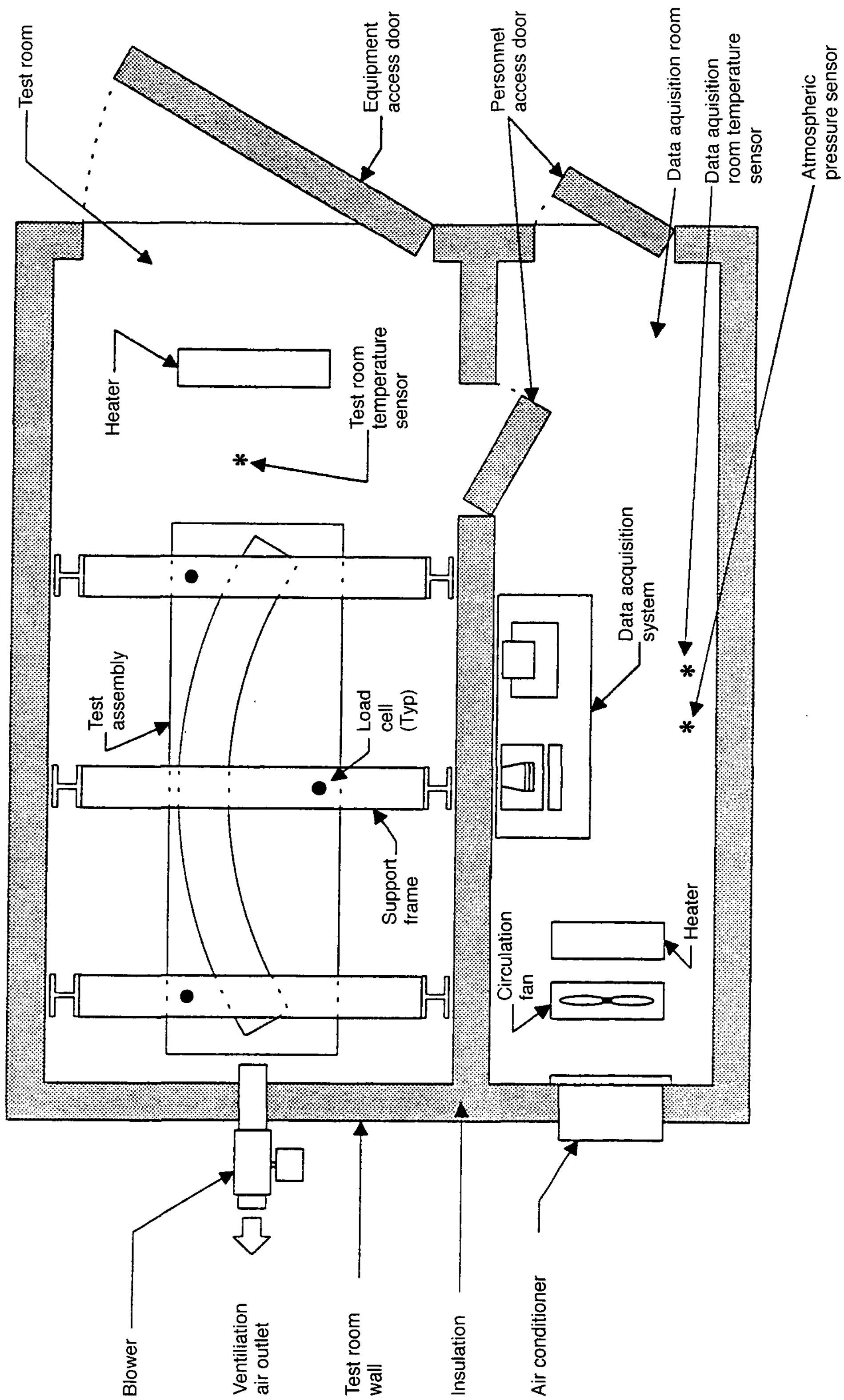


Figure 1—Plan View of a Typical Weight Loss Test Facility

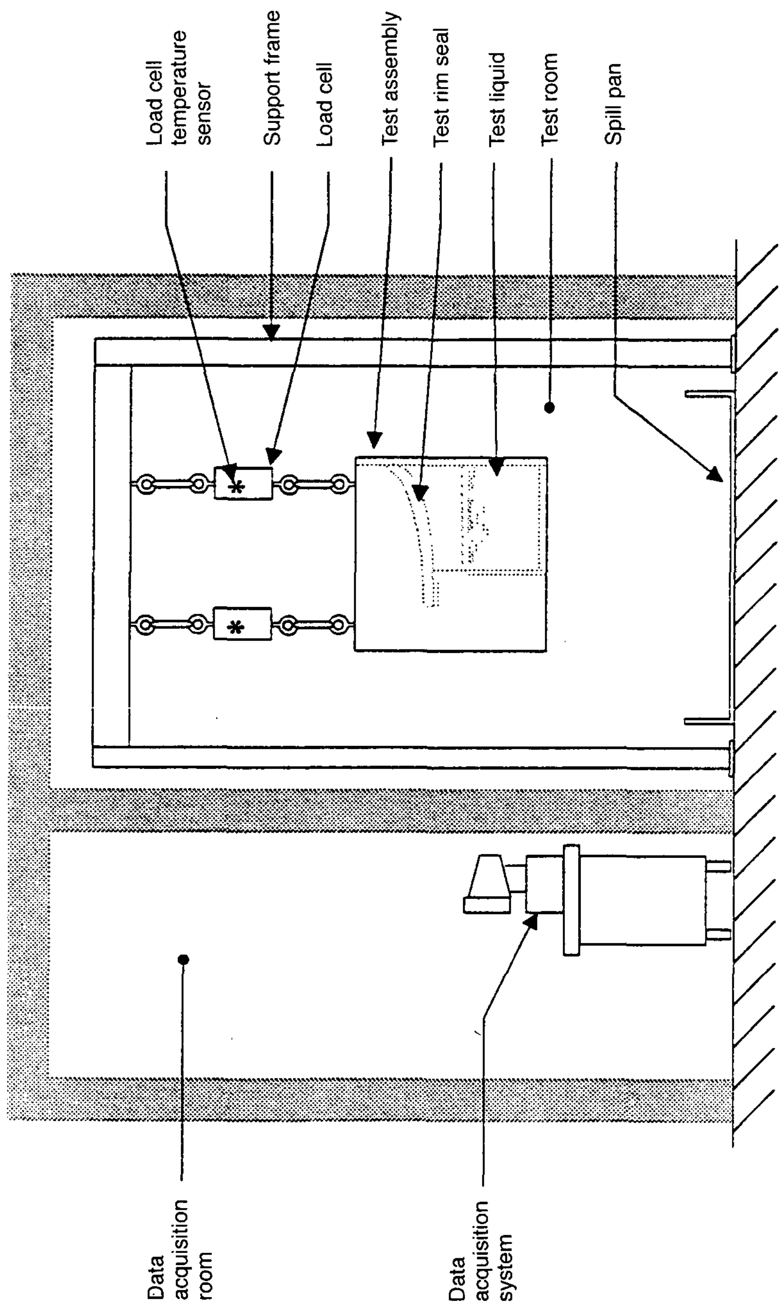


Figure 2—Elevation View of a Typical Weight Loss Test Facility

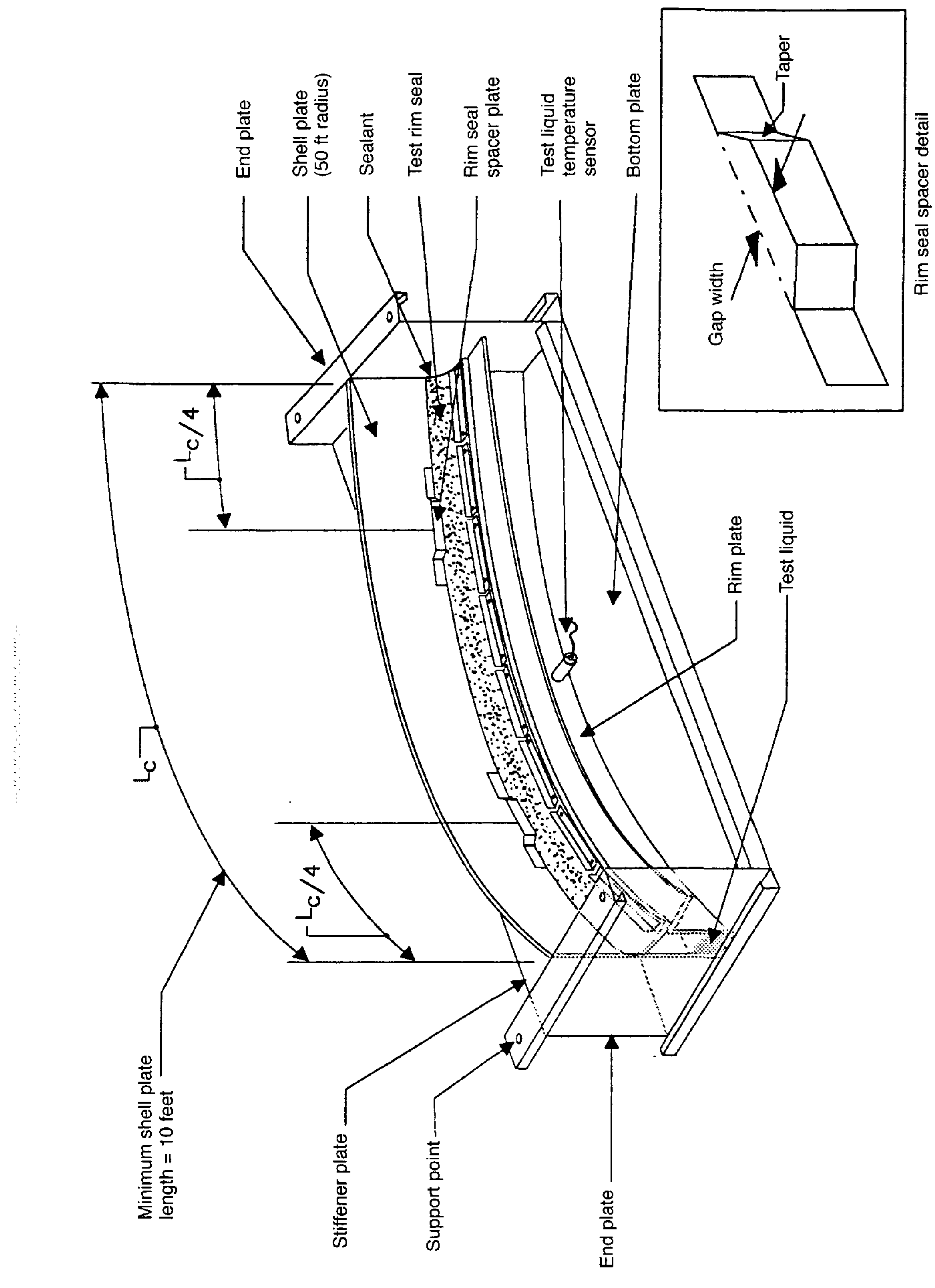


Figure 3—Test Assembly

may need to be extended to permit adequate measurement of the weight change.

10.3.1 Load Cell Locations

The load cells shall be located in the test room and attached to the support frame, as shown in Figures 1 and 2.

10.3.2 Load Cell Bias

Two separate procedures shall be undertaken to investigate the bias of the load cells. First, the load cells shall be calibrated. Second, the variation over time in the observed value for a weight of known mass shall also be determined.

10.3.2.1 Load Cell Calibration

A load cell shall be calibrated through its range of usage by measuring weights of known mass. The weights shall have certified accuracies of ±0.1 percent.

10.3.2.2 Dead Weight Effects

A load cell shall be calibrated through its range of expected temperature variation by measuring a single weight of known mass for a period of 200 hours. The mass of the weight shall be within the range of usage for the test. The weight shall have a certified accuracy of ±0.1 percent.

10.3.2.2.1 Temperature Variation Effects

The observed values for the weight of the known mass at varying load cell temperatures shall be applied to the method presented in Appendix A to develop a correlation equation for the effect of temperature variation of the load cell.

10.3.2.2.2 Drift Effects

The rate at which the observed value for the weight of the known mass varies over time shall be determined.

10.3.2.2.3 Signal-to-Noise Ratio

If insufficient signal-to-noise ratio of the load cells is observed, electronic-signal conditioning equipment may be installed. If used, the procedures for load cell calibration, dead weight effects, temperature variation effects, and drift effects must be performed with the electronic-signal conditioning equipment installed.

10.3.3 Averaging Weight Readings

Since the testing conditions, as well as the power supply to the electronic instruments, are not in a strictly steady state, the weight indicated on any instrument may fluctuate with time. An individual reading shall therefore be taken as the average of at least 30 observations made during a period not greater than 5 minutes.

10.4 TEMPERATURE MEASUREMENT

Temperatures shall be sensed with thermocouples, and the signal transmitted to the data acquisition system. The temperature measuring system shall be capable of sensing temperature changes of ±0.2°F with a demonstrated accuracy of ±0.5°F.

10.4.1 Thermocouple Locations

Thermocouples shall be located so as to measure the bulk temperature of the test liquid, the temperature of the air in the test room, the temperature of the air in the data acquisition room, and the temperature of each load cell.

10.4.1.1 Test Liquid Temperature

A thermocouple shall be located within 3 inches below the test liquid surface in the test assembly to measure the bulk temperature of the test liquid, as shown in Figure 3.

10.4.1.2 Test Room Temperature

A thermocouple shall be located near the test assembly to measure the air temperature in the test room, as shown in Figure 1.

10.4.1.3 Load Cell Temperature

A thermocouple shall be located on each load cell to measure the temperature of the load cell, as shown in Figure 2.

10.4.1.4 Data Acquisition Room Temperature

A thermocouple shall be located near the data acquisition system to measure the air temperature in the data acquisition room, as shown in Figure 1.

10.4.2 Thermocouple Calibration

Each thermocouple shall be calibrated in accordance with ASTM E220 using the temperature measurement system. All thermocouple calibrations shall be based on the temperature - electromotive force tables in ASTM E230. The observed values shall not vary from the true values by more than ±0.5° F.

10.5 VOLTAGE MEASUREMENT

Voltage shall be measured with an electrical meter in the data acquisition system. The voltage supplied to the load cells shall be maintained within ±1 percent of the voltage used to calibrate the load cells.

10.6 ATMOSPHERIC PRESSURE MEASUREMENT

Atmospheric pressure shall be sensed with a pressure sensor, and the signal transmitted to the data acquisition system. The atmospheric pressure sensor shall be capable of sensing atmospheric pressure changes of ±0.01 psia with a demonstrated accuracy of ±0.05 psia.

10.6.1 Atmospheric Pressure Sensor Location

The atmospheric pressure sensor shall be located near the data acquisition system to measure the atmospheric pressure in the data acquisition room, as shown in Figure 1.

10.6.2 Atmospheric Pressure Sensor Calibration

The atmospheric pressure sensor shall be calibrated for at least two levels of pressure using the atmospheric pressure measurement system. The observed values shall not vary from the true values by more than ±0.05 psia.

11 Test Procedure

11.1 RIM-SEAL GAPS

Insert the rim-seal gap spacers with the specified rim-seal gap area between the test rim seal and the shell plate of the test assembly.

A rim-seal gap is defined as any space, or opening, between the tank shell and the rim seal that provides an unobstructed path from the top of the seal to the stored product liquid surface or to a position beneath the rim seal for inserting a 0.125-inch diameter probe.

11.1.1 Rim-Seal Gap Area Factor

The rim-seal gap area, A_g, is the total cumulative area of the rim-seal gaps. The rim-seal gap area factor, F_g, is the total cumulative area of rim-seal gaps, A_g, divided by the tank diameter, D. The units of the rim-seal gap area factor are in^2 gap area/ft tank diameter, or in^2/ft. The rim-seal gap area per unit length of rim seal can be determined from $F_g/3.142$ and has units of in.^{2} gap area/ft. rim seal.

11.1.2 Rim-Seal Gap Spacers

To create a specified rim-seal gap area, gap spacers may be inserted between the rim seal and the inside surface of the tank shell. Gap spacers may consist of spacer bars or spacer plates. When spacer bars are used, they must not create a blockage to circumferential air flow at the location of the spacer bar. When spacer plates are used, they should have sides that taper from the widest gap width back to the tank shell.

Gap spacers used in the primary seal should not create a gap width that exceeds 1.5 inches. Gap spacers used in the secondary seal should not create a gap width that exceeds 0.5 inch. If larger gap areas are required for testing, the circumferential length at which the rim seal is intentionally gapped should be extended.

11.1.3 Rim-Seal Gap Spacer Locations

When rim-seal gap spacers are used to create a specified rim-seal gap area factor, F_g, two equally sized rim-seal gap spacers shall be used, each located from the ends of the test

Table 2—Instrument Requirements

Variable to be Measured	Instrument Type	Maximum Tolerable Error	Maximum Calibration Interval
Weight of the test assembly	Load Cell	±0.1%	3 months
Atmospheric pressure in the data acquisition test room	Pressure Sensor	±0.05 psia	6 months
Time of the observation	Clock of the DAS	±0.1%	6 months
Temperature of the air in the test room	Thermocouple	±0.5°F	6 months
Average bulk temperature of the test liquid	Thermocouple	±0.5°F	6 months
Temperature of the air in the data acquisition room	Thermocouple	±0.5°F	6 months
Temperature of the load cell	Thermocouple	±0.5°F	6 months
Voltage delivered by the power supply	Voltmeter of the DAS	±0.1%	6 months

assembly at positions that are one-quarter of the length of the test assembly shell plate, L_c, as shown in Figure 3.

11.1.4 Rim-Seal Gap Area Factor Test Conditions

Tests shall be conducted at the specified values of the rim-seal gap area factor, F_g. The rim-seal gap area factor shall be assigned a value of zero when no rim-seal gap spacers are inserted and when the only gaps present are those that result from the fit of the rim seal to the inside surface of the test assembly shell plate.

Example:

As an example of determining the rim-seal gap area, A_g, that is to be used on the test assembly for a specified rim-seal gap area factor, F_g, assume that the length of the test assembly shell plate, L_c, is 10 feet, as shown in Figure 3. If the specified rim-seal gap area factor, F_g, is 1.0 in.^{2} gap area/ft tank dia., then the required rim-seal gap area per unit length of rim seal is F_g/3.142 = (1.0 in^2 gap area/ft tank dia.)/(3.142) = 0.3183 in.^{2} gap area/ft. rim seal. For the 10 foot length of rim seal on the test assembly, the total rim-seal gap area, A_g, is (10 ft.)(0.3183 in^2 gap area/ft rim seal) = 3.183 in^2 gap area. Since two equally-sized rim-seal gap spacers are required to be installed on the test assembly, each gap spacer is required to have an area of 1.592 in^2. This gap area could be produced, for example, by a gap spacer that is 0.5 inches wide and about 3.183 inches long. The exact circumferential length of the gap spacer depends upon the shape of the taper at each end of the gap spacer.

11.2 DATA TO BE RECORDED

11.2.1 Test Rim Seal

A description of the test rim seal shall be recorded, including the name of the manufacturer and any model name or number. Dimensions of the test rim seal shall be recorded on a drawing, and a drawing shall be made of the end sealing arrangement. Photographs shall also be taken to document the test rim seal, its installation procedure, and its final arrangement on the test assembly.

11.2.2 Instruments

Names, model numbers, serial numbers, scale ranges, and calibration data shall be recorded for all instruments used in the test.

11.2.3 Test Data

Test data for each determination shall be recorded. All test data shall be recorded electronically by the data acquisition system to a storage device from which it may be downloaded to a printer. All recorded data shall include the time of the observed reading. Each of the following test data shall be recorded during each measurement reading period.

11.2.3.1 Weight, Temperature, and Time

The weight of the test assembly, the temperature of the test liquid, the temperature of the air in the test room, the temperature of the air in the data acquisition room, the temperature of the load cells, and the time of the readings shall be observed simultaneously. The sequence of readings shall be controlled by the data acquisition system. Each reading shall be the arithmetic mean of 30 observations made within a period of no more than 5 minutes. Readings shall be recorded at intervals of 1 hour or less.

11.2.3.2 Voltage and Time

The voltage delivered by the power supply to the load cells and the time of the readings shall be observed simultaneously. Readings shall be recorded at intervals of 1 hour or less.

11.2.3.3 Atmospheric Pressure and Time

The atmospheric pressure in the data acquisition room and the time of the readings shall be observed simultaneously. Readings shall be recorded at intervals of 1 hour or less.

11.2.3.4 Test Liquid Vapor Pressure and Time

The Reid vapor pressure and the time of sampling shall be recorded. Samples of the test liquid shall be taken both before and after the test period and tested to determine the Reid vapor pressure of the mixture in accordance with ASTM D323. The vapor pressure during the test period shall be determined from an interpolated vapor pressure based on the Reid vapor pressure of the samples obtained before and after the test period.

11.2.4 Log Book

An operator's log book shall be maintained to document any general observations, as well as the sequence and timing of the tests performed. In addition, the log book shall contain recorded data concerning the test rim-seal gap area and test assembly liquid level.

11.3 DURATION OF TEST

Rim seals that exhibit a high rate of loss experience a correspondingly high rate of evaporation at the surface of the test liquid. The initial loss rate observed for these rim seals may be unstable due to the evaporative cooling effect on the temperature of the test liquid at its surface. To test for stable conditions, trial observations shall be make until steady readings are obtained. Observations shall then be recorded for a period of not less than 24 hours after obtaining steady readings. Rim seals that exhibit a low rate of loss may require a longer period to establish their loss rate.

An indication of appropriate test duration may be obtained by performing the uncertainty analysis described in Appendix

B while the test is in progress and observing the change in the calculated uncertainty over time.

12 Calculation of Test Results

12.1 CALIBRATION CORRECTIONS

Calibration corrections shall be applied to individual readings before performing calculations. These corrections could be applied by the data acquisition system to the individual readings during the course of the test.

12.2 RIM-SEAL LOSS RATE

The rim-seal loss rate, L, of the test rim seal shall be obtained from measurements of weight, time, temperature, and atmospheric pressure. Individual readings of the weight of the test assembly are determined as the arithmetic mean of a series of observations (see 11.2.3.1). The standard deviation of each reading shall be calculated. The total weight of the test assembly is the sum of the weight readings indicated by the individual load cells.

The loss rate and its variance, along with the uncertainty based on a 95 percent confidence interval, shall be determined from a correlation of the measurements of the weight of the test assembly and time to the effect of temperature variation during the test period, as described in Appendix A.

12.3 VAPOR PRESSURE FUNCTION

The vapor pressure function, P^*, as described in API Publications 2517 and 2519, and in API *MPMS*, Chapter 19.2, shall be determined from the mean of the measurements of test liquid temperature, T, °F, and the mean of the measurements of atmospheric pressure, P_a, recorded during the test period, using Equations 1, 2, and 3.

$$(T, °R) = (T, °F) + 459.67 \quad (1)$$

$$P = exp\left[A_P - \frac{B_P}{(T, °R)}\right] \quad (2)$$

$$P^* = \frac{(P/P_a)}{[1 + [1 - (P/P_a)]^{0.5}]^2} \quad (3)$$

where

P_a = mean atmospheric pressure in the test room during the test period (psia),

A_p = 13.824 (dimensionless) for n-hexane, and

B_p = 6,907.2 (° R) for n-hexane.

The value of the vapor pressure constants, A_p and B_p, for isohexane depend on the actual test liquid composition.

12.4 RIM-SEAL LOSS FACTOR

The rim-seal loss factor, K_r, for each test shall be calculated from the rim-seal loss rate, L, and the vapor pressure function, P^*, using Equations 4 and 5.

$$L_r = (L, \text{lb/hr})(24 \text{ hr/day})(365.25 \text{ day/yr}) \quad (4)$$

$$K_r = \frac{(3.1416)L_r}{(L_s P^* M_v K_c)} \quad (5)$$

where

L_r = rim-seal loss rate (lb/yr),

L_s = length of the test rim seal (ft),

M_v = molecular weight of the test liquid vapor (lb/lb-mole);
= 86.18 (lb/lb-mole) for n-hexane, and

K_c = product factor of the test liquid (dimensionless);
= 1.0 (dimensionless) for n-hexane and isohexane.

12.5 UNCERTAINTY ANALYSIS

Determine the uncertainty in the calculated rim-seal loss factor, K_r, by using the procedure described in Appendix B, Uncertainty Analysis.

13 Report Of Test Results

13.1 REPORT

The report of a laboratory test to determine the rim-seal loss factor of a test rim seal shall include:

a. Name and location of the laboratory.
b. Description and drawings of the test apparatus.
c. Name and location of the test rim seal manufacturer.
d. Reid vapor pressure of the test liquid, as required in 7.3.3.
e. Description and drawings of the test rim seal, as required in 11.2.1.
f. Description of the method of joining and sealing the ends of the test rim seal to the end plates of the test assembly, as required in 7.3.2.
g. Description and calibration data for the instruments, as required in 11.2.2.
h. Test data, as required in 11.2.3.
i. Results of calculations, as outlined in Section 12.
j. Results of the uncertainty analysis, as outlined in Appendix B.

13.2 LOSS RATE CURVE

Each reading of weight loss and time shall be recorded on a loss rate curve. The values shown on the curve shall be the arithmetic mean of the observations, as described in 11.2.3.1, after the weight loss values have been corrected for variations in temperature, as required in 12.2 and described in Appendix A. A typical loss rate curve is shown in Figure 4.

An accompanying table shall list the date, and time, and corrected weight for each reading, as well as the standard deviation of the weight measurements. The temperatures of the test liquid, the air in the test room, the air in the data acquisition room, and the load cells shall be shown for each reading. The atmospheric pressure in the data acquisition room shall also be listed for each reading.

13.2.1 Coordinates

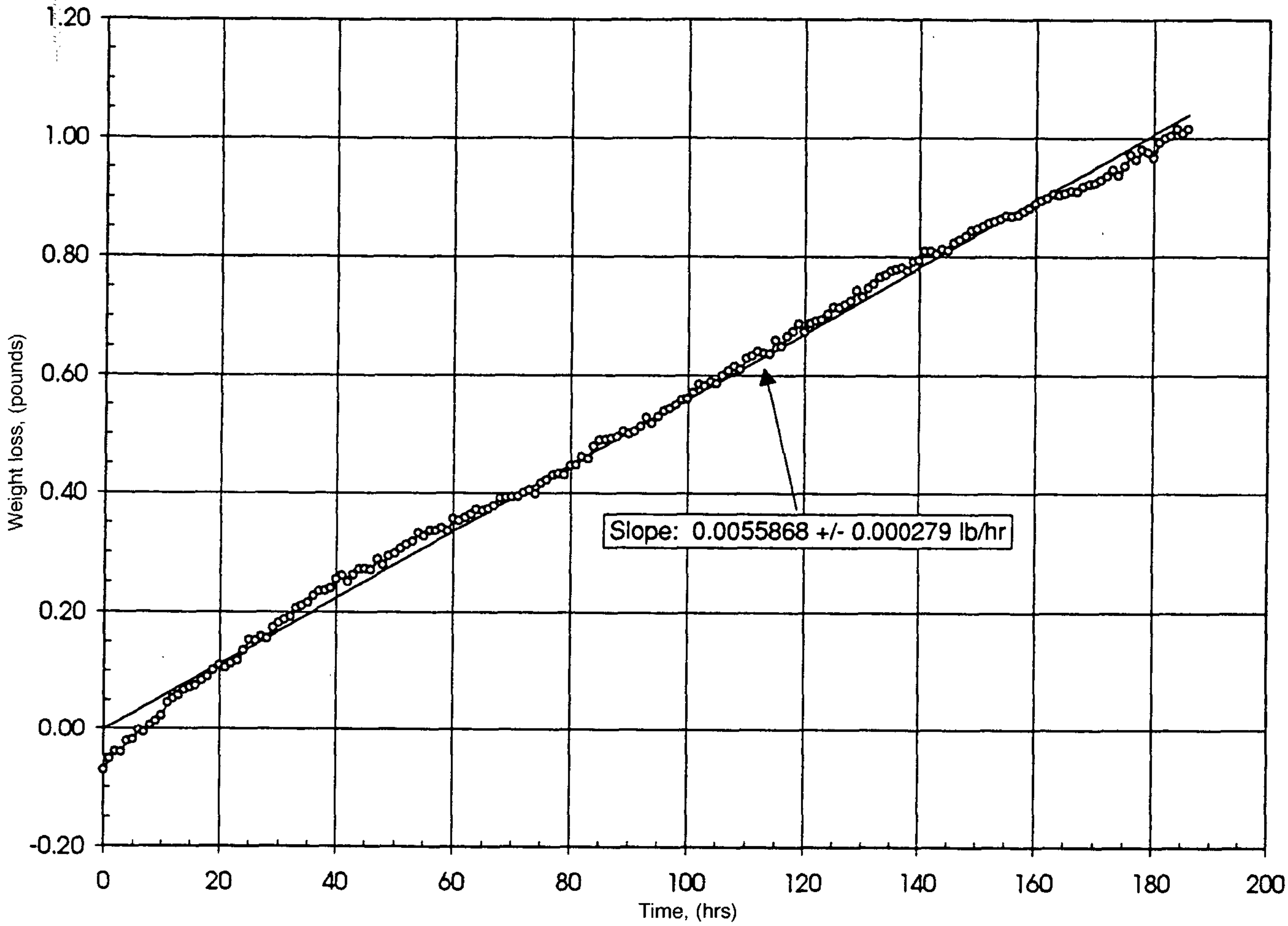
The loss rate curves shall be drawn with time as the abscissa and weight loss as the ordinate.

13.2.2 Display

The loss rate curve shall show the individual readings and the first or second order polynomial curve of the correlation equation fit to the data in accordance with Appendix A. The slope of the temperature-corrected loss rate curve shall be expressed as a change in weight over time, along with the uncertainty based on a 95-percent confidence interval, in units of pounds per hour. Each loss rate curve shall list the test rim seal description, the rim-seal gap area, and the names of the rim-seal manufacturer and the laboratory.

14 Precision and Bias

The uncertainty in a measured evaporative loss factor indicates the probable or possible difference between the measured value and the true value. This uncertainty is obtained by using the procedure described in Appendix B, which uses the uncertainties in the individual measurements that include the effects of random error (imprecision) and systematic error (bias).



Test Rim-Seal Description:	Wiper Primary Seal
Rim-Seal Gap Area:	0 inch^2/foot diameter
Rim-Seal Manufacturer:	Seals-R-Us
Test Laboratory:	Tests-R-Us

Figure 4—Typical Loss Rate Curve

APPENDIX A—LOSS RATE DETERMINATION

A.1 General

Appendix A describes a method for determining the loss rate from the test data of a rim-seal loss factor test. The method includes correcting the test assembly weight readings for variations in the temperature of the load cell or data acquisition system.

The temperature of the air in the test room is to be maintained within ±5° F of a selected temperature, as listed in Section 7.2. Variations in the temperature of the test room can cause variations in the temperature of the load cells. Although the test room temperature variations may be small, they can cause variations in the weight readings, especially for rim seals that have low evaporative loss rates.

The method of weight loss temperature correction described in this Appendix A is written primarily around correcting the weight loss readings for variations in the load cell temperature. These same methods can also be applied to correct the weight loss readings for variations in the data acquisition system temperature or test liquid temperature, if necessary.

A.2 Nomenclature

The nomenclature used in Appendix A is listed in Table A-1.

Note: See Section 3 for definitions of unit abbreviations.

A.3 Weight Loss Temperature Correction

Deadweight tests performed on load cells have shown that the weight indication has a linear response to the load cell temperature as this temperature is varied around an average value. Based on these observations, the measured weight loss readings, W_{mi}, may be corrected to the average load cell temperature, T_a, using Equation A-1:

$$W_{ci} = W_{mi} - d(T_{mi} - T_a) \quad \text{(A-1)}$$

where

$$T_a = \frac{1}{n}\sum_{i=1}^{n}(T_{mi}) \quad \text{(A-2)}$$

The temperature correction coefficient, d, in Equation A-1 may be determined from a deadweight test on the load cell during which the load cell temperature is varied.

A.4 Weight Loss Correlation

The temperature-corrected weight loss versus time test data for evaporative loss rate tests on rim seals that have a large loss rate may be correlated with the second order polynomial of Equation A-3:

$$W = a + bt + ct^2 \quad \text{(A-3)}$$

The weight loss versus time test data from rim seals with a large loss rate may have a decreasing loss rate with time as the test liquid evaporates and the level of the test liquid decreases with time. In these cases, only the initial loss rate indicated by the coefficient b in Equation A-3 is representa-

Table A-1—Nomenclature for Appendix A

SYMBOL	DESCRIPTION	UNITS
a	Coefficient in the weight loss correlation	lb
b	Coefficient in the weight loss correlation	lb/hr
c	Coefficient in the weight loss correlation	lb/hr^2
d	Coefficient in the weight loss correlation	lb/°F
n	Number of weight loss measurements in a test	dimensionless
SSE	Sum of squares due to error (defined by Equation A-7)	lb
t	Time	hr
t_{mi}	Time of data point i, (i=1,2,...,n)	hr
T	Load cell temperature	°F
T_a	Average load cell temperature during a test	°F
T_{mi}	Measured load cell temperature during a test at time t_{mi}, (i=1,2,...,n)	°F
W	Weight loss of the test assembly	lb
W_{ai}	Correlated weight loss at time t_{mi}, (i = 1, 2, ..., n)	lb
W_{ci}	Corrected weight loss at time t_{mi}, (i = 1, 2, ..., n)	lb
W_i	Calculated weight loss at time t_{mi}, (i = 1, 2, ..., n)	lb
W_{mi}	Measured weight loss at time t_{mi}, (i = 1, 2, ..., n)	lb

tive of the rim-seal loss rate for use in determining the rim-seal loss factor.

The temperature-corrected weight loss versus time test data for evaporative loss rate tests on rim seals that have a low loss rate may be correlated with the first order polynomial of Equation A-4:

$$W = a + bt \quad \text{(A-4)}$$

In these cases, the coefficient b in Equation A-4 is the rim-seal loss rate that is to be used in determining the rim-seal loss factor.

A.5 Alternate Method of Weight Loss Temperature Correction

An alternate method of determining the temperature correction coefficient, d, is from a regression of the evaporative loss factor test data. In this case, the coefficients a, b, and c in Equation A-3 are determined at the same time as the temperature correction coefficient, d, using the regression method described below.

Consider the data set for a particular test which consists of paired values of the variables W_{mi}, T_{mi}, and t_{mi} for $i=1,2,3,...,n$, where the subscript m designates a measured value. One should determine the values of the coefficients a, b, c, and d so that Equation A-5 best fits the entire set of test data for a particular test:

$$W = a + bt + ct^2 + d(T - T_a) \quad \text{(A-5)}$$

For a specific time, t_{mi}, the measured weight loss is W_{mi}, and the measured load cell temperature is T_{mi}. Equation A-6 would predict a weight loss of W_i:

$$W_i = a + bt_{mi} + ct_{mi}^2 + d(T_{mi} - T_a) \quad \text{(A-6)}$$

where the average load cell temperature, T_a, is determined from Equation A-2.

The difference between the measured weight loss, W_{mi}, and the predicted weight loss, W_i, from Equation A-6 is due to the inability of the weight loss correlation to exactly predict the measured weight loss. The sum of squares due to error, SSE, is defined by Equation A-7:

$$SSE = \sum_{i=1}^{n} (W_i - W_{mi})^2 \quad \text{(A-7)}$$

To determine the best values for the coefficients a, b, c, and d, the following four conditions are imposed:

$$\frac{\partial SSE}{\partial a} = 0 \quad \text{(A-8)}$$

$$\frac{\partial SSE}{\partial b} = 0 \quad \text{(A-9)}$$

$$\frac{\partial SSE}{\partial c} = 0 \quad \text{(A-10)}$$

$$\frac{\partial SSE}{\partial d} = 0 \quad \text{(A-11)}$$

Substituting Equation A-5 into Equations A-8, A-9, A-10, and A-11, and using Equation A-6, the above four conditions generate four linear algebraic equations with four unknowns, a, b, c, and d. These four simultaneous linear algebraic equations can then be solved to yield four expressions for determining the coefficients a, b, c, and d.

A.6 Weight Loss Plots

For each evaporative loss factor test, it is useful to prepare plots of weight loss versus time.

A.6.1 MEASURED AND CALCULATED WEIGHT LOSS PLOTS

Figure A-1 is an example plot of measured weight loss, W_{mi}, and calculated weight loss, W_i, versus time. The plot of measured weight loss, W_{mi}, displays the recorded data of actual weight loss, W_{mi}, measurements. The plot of calculated weight loss, W_i, displays the first or second order weight loss correlation, Equation A-6, at the actual measured load cell temperature, T_{mi}.

$$W_i = a + bt_{mi} + ct_{mi}^2 + d(T_{mi} - T_a) \quad \text{(A-6)}$$

By comparing the plot of measured weight loss, W_{mi}, with the plot of calculated weight loss, W_i, one can visually see how well the weight loss correlation, Equation A-6, fits the measured test data.

A.6.2 CORRECTED AND CORRELATED WEIGHT LOSS PLOTS

Figure A-2 is an example plot of temperature-corrected weight loss, W_{ci}, and correlated weight loss, W_{ai}, versus time. The plot of temperature corrected weight loss, W_{ci}, displays the measured weight loss after it has been corrected to the average load cell temperature, T_a, using Equation A-1:

$$W_{ci} = W_{mi} - d(T_{mi} - T_a) \quad \text{(A-1)}$$

The plot of correlated weight loss, W_{ai}, displays the first or second order weight loss correlation at the average load cell temperature, T_a, using Equation A-12:

$$W_{ai} = a + bt_{mi} + ct_{mi}^2 \quad \text{(A-12)}$$

By comparing the plot of temperature-corrected weight loss, W_{ci}, with the plot of correlated weight loss, W_{ai}, one can visually see how well the weight loss correlation, Equation A-12, fits the temperature-corrected weight loss test data.

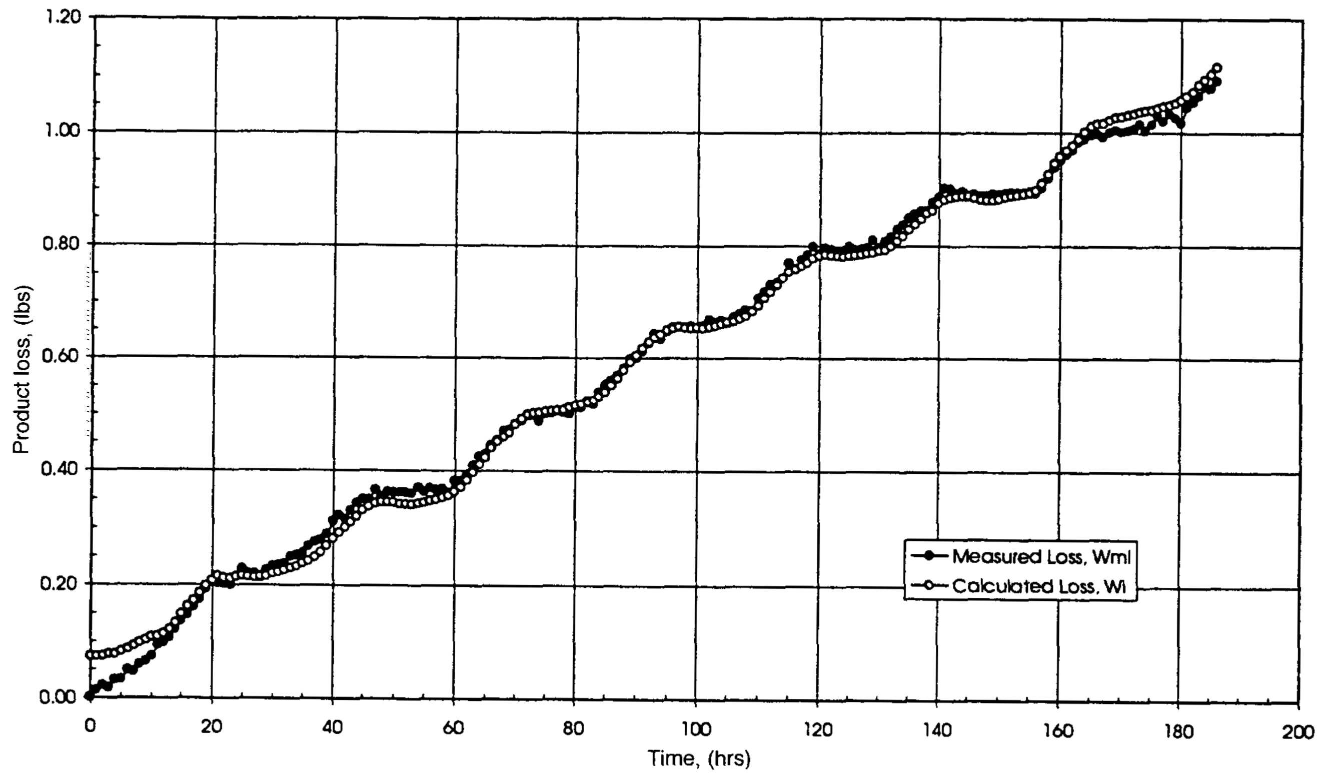


Figure A-1—Measured and Calculated Weight Loss Versus Time

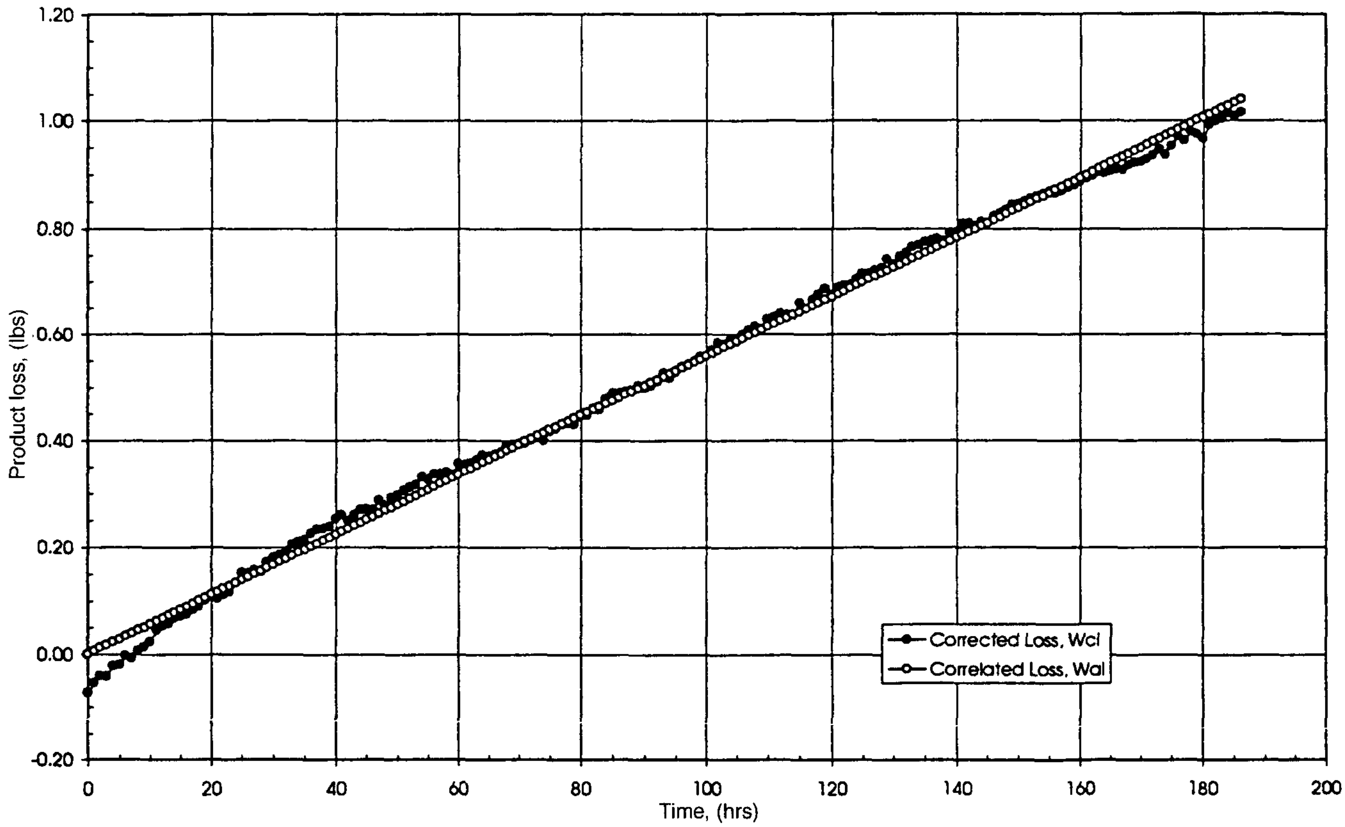


Figure A-2—Corrected and Correlated Weight Loss Versus Time

APPENDIX B—UNCERTAINTY ANALYSIS

B.1 General

Loss factor determinations are always subject to some level of uncertainty as a result of uncertainties in the measured variables. These individual uncertainties include both a systematic component, which is expressed as bias, and a random component, which is expressed as imprecision.

Appendix B describes a calculation method that shall be used to determine the uncertainty in the rim-seal loss factor, K_r, that results from the effects of the individual measurement uncertainties. The results of these calculations shall be included in the report of test results.

B.2 Definitions

The following definitions are used in Appendix B:

X = measured quantity.

U_x = absolute uncertainty in X.

E_x = per unit uncertainty in X.

From these definitions it follows that:

$$E_x = U_x/X \tag{B-1}$$

The per unit uncertainty, E_x, used in this standard shall be based on a 95-percent confidence interval, which implies that out of a large number of measurements having a normal statistical distribution, 95 percent may be expected to be within the limits specified, with 2.5 percent above the top limit and 2.5 percent below the bottom limit.

The results of measurements shall be reported as shown in Equation B-2:

$$X \pm U_x \tag{B-2}$$

B.3 Nomenclature

The nomenclature used in Appendix B consists of the nomenclature previously listed in Section 3.3, as well as that listed in Table B-1.

Table B-1—Nomenclature for Appendix B

Symbol	Description	Units
F	Defined by Equation B-7	dimensionless
R_p	Ratio of vapor pressure to atmospheric pressure	dimensionless
	Per Unit Uncertainty of:	
E_{A_p}	Constant in the vapor pressure equation	dimensionless
E_{B_p}	Constant in the vapor pressure equation	dimensionless
E_{K_c}	Product factor	dimensionless
E_{K_r}	Rim-seal loss factor	dimensionless
E_L	Rim-seal loss rate	dimensionless
E_{L_s}	Length of rim seal	dimensionless
E_{M_v}	Molecular weight of stock vapor	dimensionless
E_P	Vapor pressure of the stock	dimensionless
E_{P*}	Vapor pressure function	dimensionless
E_{P_a}	Atmospheric pressure	dimensionless
E_{R_p}	Ratio of vapor pressure to atmospheric pressure	dimensionless
E_T	Stock liquid temperature	dimensionless
	Absolute Uncertainty of:	
U_{A_p}	Constant in the vapor pressure equation	dimensionless

Table B-1—Nomenclature for Appendix B

Symbol	Description	Units
U_{B_p}	Constant in the vapor pressure equation	°R
U_{K_c}	Product factor	dimensionless
U_{K_r}	Rim-seal loss factor	lb-mole/ft yr
U_L	Rim-seal loss rate	lb/hr
U_{L_s}	Length of rim seal	ft
U_{M_v}	Molecular weight of stock vapor	lb/lb-mole
U_P	Vapor pressure of the stock	psia
U_{P*}	Vapor pressure function	dimensionless
U_{P_a}	Atmospheric pressure	psia
U_{R_p}	Ratio of vapor pressure to atmospheric pressure	dimensionless
U_T	Stock liquid temperature	°F or °R

Note: See Section 3 for definitions of unit abbreviations.

B.4 Uncertainty Formulas

This section presents the formulas that should be used to calculate the uncertainties.

B.4.1 UNCERTAINTY IN THE VAPOR PRESSURE

The per unit uncertainty in the vapor pressure, E_P, may be calculated from Equation B-3:

$$E_p = \left[A_p^2 E_{A_p}^2 + (B_p/T)^2(E_{B_p}^2 + E_T^2)\right]^{0.5} \qquad \text{(B-3)}$$

The per unit uncertainties of the constants in the vapor pressure equation, E_{A_p} and E_{B_p}, depend upon the purity of the test liquid.

A sample of the test liquid shall be tested to determine the Reid vapor pressure of the mixture, in accordance with ASTM D323. That vapor pressure determination shall also include a value for the per unit uncertainty in the vapor pressure, E_P.

The temperature of the test liquid, T, may vary during the course of a test. The stock vapor pressure, P, used in the loss factor determination is based on the mean of the measurements of the test liquid temperature recorded during the test period. The per unit uncertainty in the mean test liquid temperature shall include any known bias errors in the calibration of the temperature measurement instrumentation, as well as random errors resulting from variations in the temperature of the test liquid during the test period.

B.4.2 UNCERTAINTY IN THE VAPOR PRESSURE FUNCTION

In determining the per unit uncertainty of the vapor pressure function, P^*, it is convenient to define the parameter R_P as the ratio of the stock vapor pressure, P, to atmospheric pressure, P_a, as shown in Equation B-4:

$$R_p = P/P_a \qquad \text{(B-4)}$$

The per unit uncertainty in R_p may be calculated from Equation B-5:

$$E_{R_p} = [E_P^2 + E_{P_a}^2]^{0.5} \qquad \text{(B-5)}$$

The atmospheric pressure, P_a, may vary during the course of a test. The atmospheric pressure used in the loss factor determination is based on the mean of the measurements of atmospheric pressure recorded during the test period. The per unit uncertainty in the mean atmospheric pressure shall include any known bias errors in the calibration of the atmospheric pressure measurement instrumentation, as well as random errors resulting from variations in the atmospheric pressure during the test period. It should be noted, however, that the per unit uncertainty in the mean atmospheric pressure, E_{P_a}, is typically small in comparison to the per unit uncertainty in the mean stock vapor pressure, E_P.

The per unit uncertainty of the vapor pressure function, E_{P*}, may be calculated from Equation B-6:

$$E_{P*} = F E_{R_p} \qquad \text{(B-6)}$$

where

$$F = \left[\frac{1+(1-R_p)^{0.5}}{1+(1-R_p)^{0.5}-R_p}\right] \quad \text{(B-7)}$$

B.4.3 UNCERTAINTY IN THE RIM-SEAL LOSS FACTOR

The per unit uncertainty in the rim-seal loss factor, E_{Kr}, may be calculated from Equation B-8:

$$E_{K_r} = \left[E_L^2 + E_{L_s}^2 + E_{P*}^2 + E_{M_v}^2 + E_{K_c}^2\right]^{0.5} \quad \text{(B-8)}$$

The per unit uncertainty in the rim-seal loss rate shall include any known bias errors in the calibration of the weight measurement instrumentation, as well as random errors resulting from variations in the temperature-corrected weight readings that affect the weight loss versus time slope determination described in Appendix A, Loss Rate Determination.

A sample of the test liquid shall be tested to determine the stock vapor molecular weight. That vapor molecular weight determination shall also include a value for the per unit uncertainty in the stock vapor molecular weight, E_{M_v}.

A method for determining the per unit uncertainty in the product factor, E_{K_c}, is not known at this time, and a value of 0 may be assumed.

B.5 Example Uncertainty Analysis

This section presents an example uncertainty analysis for a rim-seal loss factor test. Table B-1 summarizes the results of the uncertainty analysis.

B.5.1 UNCERTAINTY IN THE VAPOR PRESSURE

Calculate P:

A_P = 13.790 (dimensionless; from the test data)

B_P = 6,527.0° R (from the test data)

T = 546.19° R (from the test data).

From Equation 2:

$P = exp\,[A_p - (B_p/T)]$

$= \exp\,[(13.790) - (6{,}527.0/546.19)]$

$=$ 6.2962 psia.

Calculate E_P:

E_{A_p} = $1.0000\text{x}10^{-3}$ (from the test data)

E_{B_p} = $1.0000\text{x}10^{-3}$ (from the test data)

E_T = $5.4926\text{x}10^{-3}$ (from the test data).

From Equation B-3:

$$E_p = \left[A_p^2 E_{A_p}^2 + (B_p/T)^2(E_{B_p}^2 + E_T^2)\right]^{0.5}$$

$= (13.790)^2(1.0000\text{x}10^{-3})^2 + (6{,}527.0/546.19)^2((1.0000\text{x}10^{-3})^2 + (5.4926\text{x}10^{-3})^2)]^{0.5}$

$= 6.8126\text{x}10^{-2}$

Calculate U_P:

$U_P = E_P P$

$= (6.8126\text{x}10^{-2})(6.2962)$

$=$ 0.42894 psia

B.5.2 UNCERTAINTY IN THE RATIO OF VAPOR PRESSURE TO ATMOSPHERIC PRESSURE

Calculate R_p:

P = 6.2962 psia (from Section B.5.1)

P_a = 14.696 psia (from the test data).

From Equation B-4:

$R_p = P/P_a$

$= (6.2962)/(14.696)$

$= 0.42843$

Calculate E_{R_p}:

E_P = $6.8126\text{x}10^{-2}$ (from Section B.5.1)

E_{P_a} = $3.0000\text{x}10^{-2}$ (from the test data).

From Equation B-5:

$$E_{R_p} = \left[E_P^2 + E_{P_a}^2\right]^{0.5}$$

$$= \left[(6.8126 \times 10^{-2})^2 + (3.0000 \times 10^{-2})^2\right]^{0.5}$$

$= 7.4439\text{x}10^{-2}$

Calculate U_{R_p}:

$U_{R_p} = E_{R_p} R_p$

$= (7.4439\text{x}10^{-2})(0.42843)$

$= 3.1892\text{x}10^{-2}$

B.5.3 UNCERTAINTY IN THE VAPOR PRESSURE FUNCTION

Calculate P^*:

R_p = 0.42843 (from Section B.5.2).

From Equation 3:

$$P^* = R_p/[1 + (1 - R_p)^{0.5}]^2$$

$$= (0.42843)/[1 + (1 - 0.42843)^{0.5}]^2$$

$$= 0.13894$$

Calculate E_{P^*}:

E_{R_p} = 7.4439x10^{-2} (from Section B.5.2).

From Equation B-7:

$$F = \left[\frac{1 + (1 - R_p)^{0.5}}{1 + (1 - R_p)^{0.5} - R_p}\right]$$

$$= \left[\frac{1 + (1 - 0.42843)^{0.5}}{1 + (1 - 0.42843)^{0.5} - (0.42843)}\right]$$

$$= 1.3227$$

From Equation B-6:

$$E_{P^*} = F E_{R_p}$$

$$= (1.3227)(7.4439 \times 10^{-2})$$

$$= 9.8461 \times 10^{-2}$$

Calculate U_{P^*}:

$$U_{P^*} = E_{P^*} P^*$$

$$= (9.8461 \times 10^{-2})(0.13894)$$

$$= 1.3680 \times 10^{-2}$$

B.5.4 UNCERTAINTY IN THE RIM-SEAL LOSS FACTOR

Calculate K_r:

L = 0.0055868 lb/hr (from the test data)

P^* = 0.13894 (from Section B.5.3)

M_v = 85.970 lb/lb-mole (from the test data)

L_s = 12.150 ft (from the test data)

K_c = 1.0000 (from the test data).

From Equations 4 and 5:

$$K_r = [(3.1416)(24)(365.25)L]/(L_s P^* M_v K_c)$$

$$= [(3.1416)(24)(365.25)(0.0055868)]/[(12.150)(0.13894)(85.970)(1.0000)]$$

$$= 1.0602 \text{ lb-mole/ft yr}$$

Calculate E_{K_r}:

E_L = 5.0000x10^{-2} (from the test data)

E_{P^*} = 9.8461x10^{-2} (from Section B.5.3)

E_{M_v} = 1.0000x10^{-3} (from the test data)

E_{L_s} = 3.4294x10^{-3} (from the test data)

E_{K_c} = 0 (from the test data).

From Equation B-8:

$$E_{K_r} = \left[E_L^2 + E_{L_s}^2 + E_{P^*}^2 + E_{M_v}^2 + E_{K_c}^2\right]^{0.5}$$

$$E_{K_r} = [(5.0000 \times 10^{-2})^2 + (3.4294 \times 10^{-3})^2 + (9.8461 \times 10^{-2})^2 + (1.0000 \times 10^{-3})^2 + (0)^2]^{0.5}$$

Calculate U_{K_r}:

$$U_{K_r} = E_{K_r} K_r$$

$$= (0.11049)(1.0602)$$

$$= 0.11713 \text{ lb-mole/ft yr}$$

Summary:

The rim-seal loss factor, K_r, that resulted from the test data of this example can be stated as follows:

$$K_r = 1.0602 \pm 0.1171 \text{ lb-mole/ft yr.}$$

Table B-2—Summary of Example Uncertainty Analysis Results

Description	Symbol	Units	Value
Given Test Data:			
Rim-seal loss rate	L	lb/hr	0.0055868
	U_L	lb/hr	2.7934x10^{-4}
	E_L	dimensionless	5.0000x10^{-2}
Stock liquid temperature	T	°F	86.520
	T	°R	546.19
	U_T	°R	3.0000
	E_T	dimensionless	5.4926x10^{-3}
Vapor pressure constant	A_p	dimensionless	13.790
	U_{A_p}	dimensionless	1.3790x10^{-2}
	E_{A_p}	dimensionless	1.0000x10^{-3}
Vapor pressure constant	A_p	°R	6,527.0
	U_{B_p}	°R	6.5270
	E_{B_p}	dimensionless	1.0000x10^{-3}
Atmospheric pressure	P_a	psia	14.696
	U_{P_a}	psia	0.44088
	E_{P_a}	dimensionless	3.0000x10^{-2}
Vapor molecular weight	M_v	lb/lb-mole	85.970
	U_{M_v}	lb/lb-mole	8.5970x10^{-2}
	E_{M_v}	dimensionless	1.0000x10^{-3}
Rim-seal length	L_s	feet	12.150
	U_{L_s}	feet	4.1667x10^{-2}
	E_{L_s}	dimensionless	3.4294x10^{-3}
Product factor	K_c	dimensionless	1.0000
	U_{K_c}	dimensionless	0
	E_{K_c}	dimensionless	0
Calculated Test Results:			
Vapor pressure	P	psia	6.2962
	U_P	psia	0.42894
	E_P	dimensionless	6.8126x10^{-2}
Ratio of vapor pressure to atmospheric pressure	R_P	dimensionless	0.42843

Table B-2—Summary of Example Uncertainty Analysis Results

Description	Symbol	Units	Value
Ratio of vapor pressure to atmospheric pressure	U_{R_p}	dimensionless	3.1892×10^{-2}
	E_{R_p}	dimensionless	7.4439×10^{-2}
Vapor pressure function	P^*	dimensionless	0.13894
	U_{P^*}	dimensionless	1.3680×10^{-2}
	E_{P^*}	dimensionless	9.8461×10^{-2}
Rim-seal loss factor	K_r	lb-mole/ft yr	1.0602
	U_{K_r}	lb-mole/ft yr	0.11713
	E_{K_r}	dimensionless	0.11049

APPENDIX C—METRIC UNITS

C.1 General

To convert the inch-pound units employed in the text to the equivalent SI units of the International System of Units, the guidelines of the API *Manual of Petroleum Measurement Standards*, Chapter 15 shall be followed. The unit of length is either the kilometer, designated km, or the meter, designated m. The unit of mass is the kilogram, designated kg. The unit of time is either the hour, designated hr, or the year, designated yr. The unit of temperature is the degree Celsius, designated °C, or the kelvin, designated K. The unit of electromotive force is the volt, designated V.

C.2 Pressure

The unit of pressure is the kilopascal, designated kPa.

C.3 Loss Factors

The text employs the pound-mole per year, designated lb-mole/yr, as the unit of loss rate. The loss rate is determined as the product of the tank diameter, D, in units of feet, times the dimensionless coefficients P^* and K_c, times the loss factor, K_r, in units of lb-mole per foot year, designated lb-mole/ft yr, as described in API *MPMS*, Chapter 19.2.

The equivalent SI unit for the loss rate is kilogram-mole per year, designated kmol/yr. The equivalent SI unit for the loss factor is kilogram-mole per meter year, designated kmol/m yr. As with the inch-pound units, the loss factor in kmole/m yr must be multiplied by the tank diameter, D, in units of meters and by the dimensionless coefficients P^* and K_c to obtain a loss rate in kmol/yr.

APPENDIX D—BIBLIOGRAPHY

Following is a list of related references not cited in the text.

API

Manual of Petroleum Measurement Standards (MPMS),
Chapter 19.2, "Evaporative Loss From Floating-Roof Tanks"
Chapter 19.3, Part B, "Air Concentration Test Method, Rim-Seal Loss Factors for Floating-Roof Tanks"

Std 650 *Welded Steel Tanks for Oil Storage*

Std 653 *Tank Inspection, Repair, Alternation, and Reconstruction*

Publ 2517D *Documentation File for API Publication 2517—Evaporative Loss from External Floating-Roof Tanks*

Publ 2518 *Evaporative Loss from Fixed-Roof Tanks*

Chicago Bridge & Iron Technical Services Company, *Loss Factor Measurements of Internal Floating Roof Rim Seals*, prepared for the API, Committee on Evaporation Loss Measurement

ASTM[2]

E 456-92 *Terminology Relating to Quality and Statistics*

E 1187-90 *Terminology Relating to Laboratory Accreditation*

E 1267-88 *Guide for ASTM Standard Specification Quality Statements*

E 1488-92 *Guide for Statistical Procedures to Use in Developing and Applying ASTM Test Methods*

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	H1903F	**MPMS 19.3 Pt. F, *Evaporative Loss Factor for Storage Tanks Certification Program***		**$40.00**	
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