

Manual of Petroleum Measurement Standards Chapter 19.3—Evaporative Loss Measurement

Part B—Air Concentration Test Method—Rim-Seal Loss Factors for Floating-Roof Tanks

FIRST EDITION, AUGUST 1997

REAFFIRMED, FEBRUARY 2023



American
Petroleum
Institute

SPECIAL NOTES

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed. The use of API publications is voluntary. In some cases, third parties or authorities having jurisdiction may choose to incorporate API standards by reference and may mandate compliance.

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

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

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

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

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

Copyright © 1997 American Petroleum Institute

FOREWORD

This standard provides rules for testing the rim seals of external, covered, and 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.”

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

Suggested revisions are invited and should be submitted to Measurement Coordination, American Petroleum Institute, 200 Massachusetts Avenue, NW, Washington, DC 20001.

CONTENTS

	Page
0 INTRODUCTION.....	1
1 SCOPE	1
2 NORMATIVE REFERENCES	1
2.1 API Normative Standards.....	1
2.2 ASTM Normative Standards.....	1
2.3 ASME Normative Standards.....	1
3 TERMINOLOGY	1
3.1 Definitions	1
3.2 Units of Measurement	3
3.3 Nomenclature	3
4 SUMMARY OF TEST METHOD.....	4
5 SIGNIFICANCE AND USE.....	4
6 LIMITATIONS TO TEST METHOD	4
6.1 Evaluation of Results	4
6.2 Low Loss Rates	4
7 TEST APPARATUS	4
7.1 Test Apparatus Schematic	4
7.2 Test Room	4
7.3 Test Chamber	4
7.4 Inlet Air Flow Control Section.....	8
7.5 Outlet Air Flow Control Section	8
7.6 Air Blower.....	8
7.7 Vibration Damping.....	8
7.8 Rim Seals	8
7.9 Test Liquid	8
7.10 Emptying and Filling	9
7.11 Spill Pan	9
8 TEST ITEM	9
8.1 Test Item Construction	9
8.2 Test Rim Seal Attachment.....	9
8.3 Test Rim Seal End Connections.....	9
8.4 Tall Rim Seals	9
9 PREPARATION OF APPARATUS.....	9
9.1 Test Item Placement	9
9.2 Test Room Air Temperature Control.....	9
9.3 Air Blower Startup	9
9.4 Steady-State Operation	9
10 INSTRUMENTATION AND CALIBRATION	9
10.1 Accuracy	9
10.2 Data Acquisition System.....	10

	Page
10.3 Temperature Measurement	10
10.4 Wind Speed Measurement	10
10.5 Concentration Measurement	10
10.6 Atmospheric Pressure Measurement.....	11
10.7 Static Pressure Measurement	11
10.8 Differential Pressure Measurement	11
11 TEST PROCEDURE.....	11
11.1 Rim-Seal Gaps	11
11.2 Levels of Wind Speed	12
11.3 Data to be Recorded	12
11.4 Duration of Test.....	13
12 CALCULATION OF TEST RESULTS	13
12.1 Calibration Corrections	13
12.2 Rim-Seal Loss Rate.....	13
12.3 Vapor Pressure Function	13
12.4 Rim-Seal Loss Factor.....	14
12.5 Uncertainty Analysis	14
13 REPORT OF TEST RESULTS	14
13.1 Report.....	14
13.2 Data Curves	14
13.3 Rim-Seal Loss Factor Graph.....	14
14 PRECISION AND BIAS	15
APPENDIX A—UNCERTAINTY ANALYSIS	17
APPENDIX B—WIND SPEED CALIBRATION	23
APPENDIX C—DETERMINATION OF LOSS FACTOR EQUATION.....	25
APPENDIX D—METRIC UNITS	27
APPENDIX E—BIBLIOGRAPHY	29

Figures

1 Plan View of the Air Concentration Test Facility.....	5
2 Elevation View of the Air Concentration Test Facility.....	6
3 Section View of the Air Concentration Test Facility	7
4 Typical Data Curve (Rim-Seal Loss Rate).....	15
5 Typical Rim-Seal Loss Factor Graph	16

Tables

1 Instrument Requirements	10
A-1 Summary of Example Uncertainty Analysis Results	19
C-1 Example Loss Factors	26
C-2 Example Loss Factor Equation Database.....	26
C-3 Example Loss Factor Equation Constants.....	26

Chapter 19.3—Evaporative Loss Measurement

PART B—AIR CONCENTRATION TEST METHOD—RIM-SEAL LOSS FACTORS FOR FLOATING-ROOF TANKS

0 Introduction

The purpose of this standard is to establish a uniform method for use in measuring evaporative rim-seal loss factors of rim seals used on external, covered, and internal floating-roof tanks. These rim-seal loss factors are to be determined in terms of loss rate, seal gap area, 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 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 external and internal floating-roof tanks. The test method involves passing a controlled flow rate of air through a test chamber that contains a test liquid and a test rim seal, and measuring the concentration of the test liquid vapor in the air streams entering and leaving the test chamber. 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 19.3, Part F, “Evaporative Loss Factor for Storage

Tanks Certification Program,” First Edition, March 1997

Manual of Petroleum Measurement Standards, Chapter 19.3, Part G, “Certified Loss Factor Testing Laboratory Registration,” First Edition, March 1997

2.2 ASTM NORMATIVE STANDARDS

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*

2.3 ASME NORMATIVE STANDARDS

ASME²

MFC-3M *Measurement of Fluid Flow in Pipes Using Orifice, Nozzle and Venturi*

3 Terminology

3.1 DEFINITIONS

3.1.1 ACT facility: The entire facility used in the Air Concentration Test (ACT) method. The ACT facility includes the test chamber, the sensors and data acquisition system, the air blower, the air inlet and outlet ducts, and the test liquid storage.

3.1.2 air concentration test method: The test method used to establish evaporative rim-seal loss factors for rim seals used on external, covered, and internal floating-roof tanks that involves passing a controlled flow rate of air through a test chamber that contains a test liquid and a test rim seal, and measuring the concentration of the test liquid vapor in the air streams entering and leaving the test chamber.

3.1.3 covered floating roof: A floating roof that results from covering an external floating roof with a fixed roof at the top of the tank shell. This effectively converts the external floating roof to an internal floating roof, while retaining the external-type of floating-roof design. These floating roofs are typically designed in accordance with Appendix C

¹ASTM International, 100 Bar Harbor Drive, West Conshohocken, Pennsylvania 19428.

²American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.

of the American Petroleum Institute Standard 650, *Welded Steel Tanks for Oil Storage*.

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

3.1.5 deck: That part of a floating roof that 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, that accommodate some functional or operational feature of the tank.

3.1.6 deck fitting: The device that 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.

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

3.1.8 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.

3.1.9 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 the American Petroleum Institute Standard 650, *Welded Steel Tanks for Oil Storage*.

3.1.10 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 the American Petroleum Institute Standard 650, *Welded Steel Tanks for Oil Storage*.

3.1.11 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.

3.1.12 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.

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

3.1.14 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.

3.1.15 rim seal: A flexible device that spans 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.

3.1.16 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.

3.1.17 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.

3.1.18 test chamber: The portion of the ACT facility that contains the test rim seal and the test liquid.

3.1.19 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 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 D, 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 Velocity

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

3.2.4 Pressure

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

3.2.5 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 certain coefficients (which are dimensionless) in order 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 K_c , 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 [7] and 2519 [11], and in API *Manual of Petroleum Measurement Standards*, Chapter 19.2 [12].

Note: The numbers in parentheses indicate a reference in the Appendix E, Bibliography.

3.3 NOMENCLATURE

Symbol	Description	Units
A_g	Rim-seal gap area	ft ²
A_p	Constant in the vapor pressure equation	dimensionless
B_p	Constant in the vapor pressure equation	°R
C_i	Concentration of hydrocarbon vapor in the test chamber inlet air	ppmv
C_o	Concentration of hydrocarbon vapor in the test chamber outlet air	ppmv
D	Tank diameter	ft
D_v	Density of hydrocarbon vapor in the test chamber outlet air	lb/ft ³
F_g	Rim-seal gap area factor	ft 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 chamber	ft
L_r	Rim-seal loss rate	lb/yr
L_s	Length of the test rim seal	ft
M_v	Molecular weight of test liquid vapor	lb/lb-mole
P	Vapor pressure of the test liquid	psia
P_a	Atmospheric pressure	psia
P_d	Static pressure in the outlet duct at the air flow rate sensor	psia
P^*	Vapor pressure function	dimensionless
Q_a	Volumetric flow rate of the outlet air at actual conditions	acfm
R	Universal gas constant (10.73)	ft ³ psia/lb-mole °R
T_d	Temperature of the air in the outlet duct at the air flow rate sensor	°R or °F
T_l	Stock liquid temperature	°R or °F
V	Wind speed	mph



4 Summary of Test Method

The test method described in this standard uses a mass balance procedure to measure a rate of evaporative loss. A test chamber is fitted with a test rim seal. Spacers are placed between the test rim seal and the simulated tank shell of the test chamber 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. A prescribed level of air flow rate through the test chamber is set. The concentration of the test liquid vapors in the air is measured at the test chamber inlet and outlet. A mass balance is then used to determine the loss rate of the volatile hydrocarbon test liquid vapor through the rim seal. 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 external, covered, and 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 *Manual of Petroleum Measurement Standards*, Chapter 19.3, Part G, “Certified Loss Factor Testing Laboratory Registration.” The values determined by this method are to be evaluated in accordance with the API *Manual of Petroleum Measurement Standards*, Chapter 19.3, Part F, “Evaporative Loss Factor for Storage Tanks Certification Program” in order 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 *Manual of Petroleum Measurement Standards*, Chapter 19.3, Part F, “Evaporative Loss Factor for Storage Tanks Certification Program.”

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.

If it is determined that the loss rate of the test rim seal is less than the detection limit of the instrumentation, the report of test results shall state the de minimus value for the rim-seal loss factor that is based on the instrumentation detection limit.

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 external, covered, or internal 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. 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 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 room.

7.2.2 Air Temperature Control System

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

7.2.3 Circulation Fan

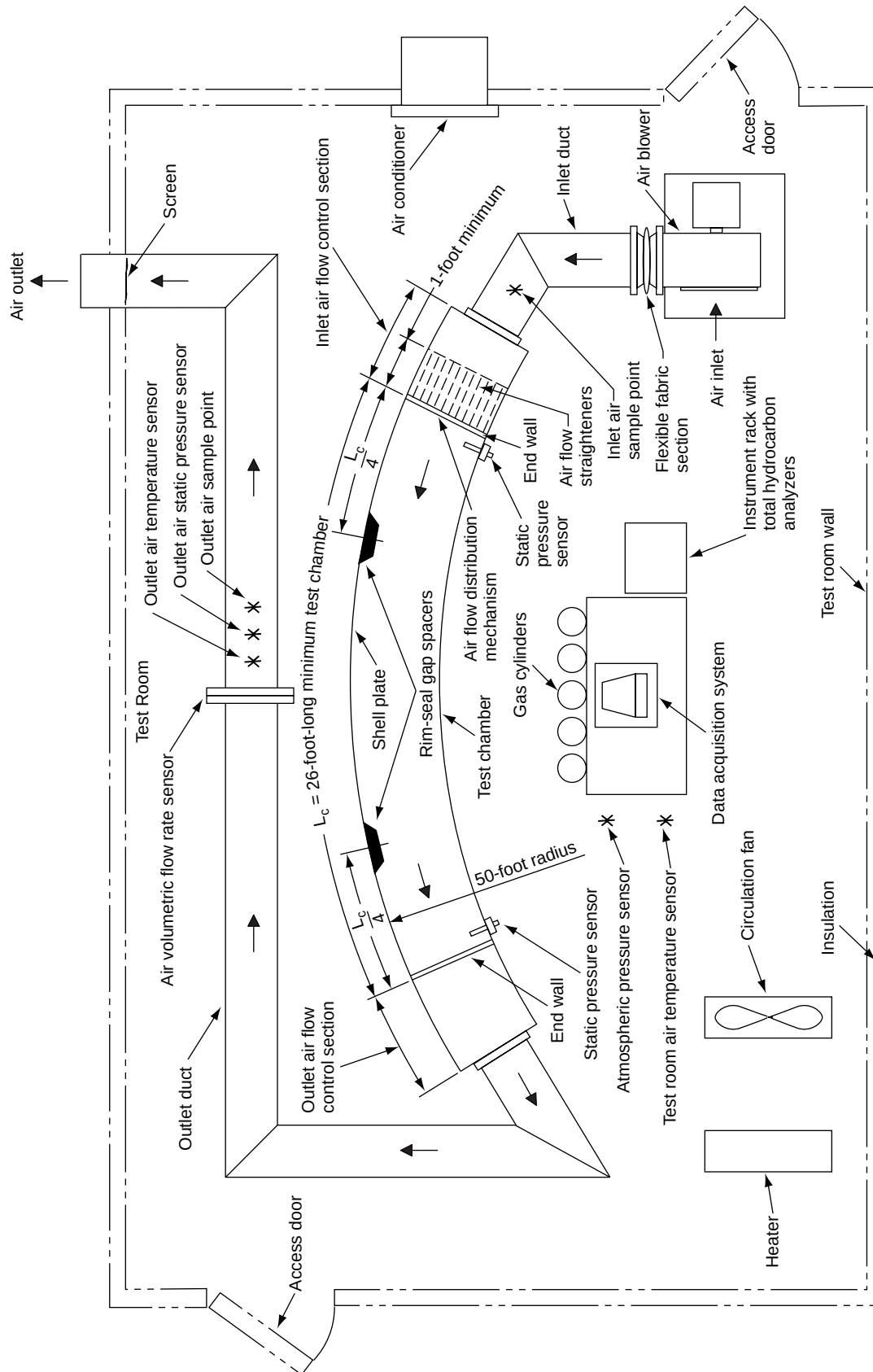
The test room shall be equipped with a fan that circulates the air within the test room to reduce air temperature variations in the test room.

7.2.4 Test Chamber Air

The air that is directed through the test chamber 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 test chamber shall be maintained within $\pm 10^{\circ}\text{F}$ of the temperature of the air in the test room.

7.3 TEST CHAMBER

The test chamber shall be a curved length of duct through which air may be directed by means of a blower, as illustrated in Figure 1. The curvature of the test chamber shall be based on the shell curvature of a 100-foot-diameter storage tank. The test chamber shall have a generally rectangular cross section so as to readily accommodate openings. There shall be openings in the sides of the test chamber to allow access to the test rim seal for inspection and modification and also to allow for viewing the test rim seal while the test is in progress. The top of the test chamber shall be removable to



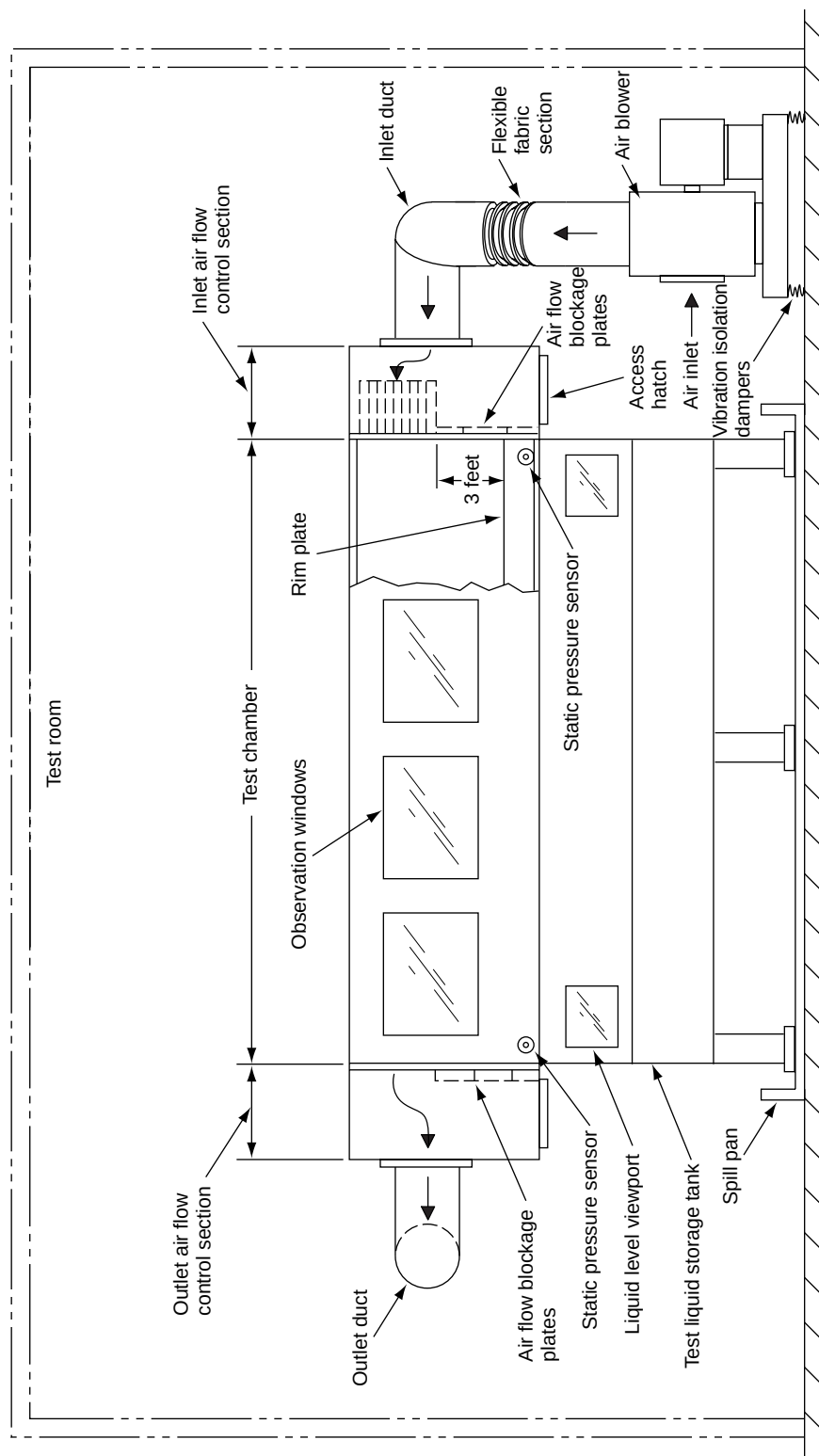


Figure 2—Elevation View of the Air Concentration Test Facility