EXHIBIT 150
PART 15

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

* * *

Document Name: ASTM F1951: Standard Specification for Determination of Accessibility of Surface Systems Under and Around Playground Equipment

CFR Section(s): 36 CFR 1191, App B, 1008.2.6.1

Standards Body: American Society for Testing and Materials

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1951 – 99

An American National Standard

Standard Specification for Determination of Accessibility of Surface Systems Under and Around Playground Equipment[1]

This standard is issued under the fixed designation F 1951; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

The need for systematic and consistent means of evaluating the capability of surface systems to provide access to playgrounds has been amplified by the passage of the Federal Americans with Disabilities Act. The goal of this specification is to establish uniform means to measure the characteristics of surface systems in order to provide the potential buyer with performance specifications to select materials for use as an accessible surface under and around playground equipment.

1. Scope

1.1 This specification establishes minimum characteristics for those factors that determine accessibility. This specification applies to all types of materials that can be used under and around playground equipment.

1.2 The material under and around playground equipment that meets this specification must also comply with Specification F 1292 if the surface is within the fall zone.

1.3 This specification does not imply that an injury cannot be incurred if the surface system complies with this specification.

1.4 The values stated in inch-pound units are to be regarded as standard. The SI units given in parentheses are for information only.

1.5 The following precautionary statement pertains only to the test method portions, Sections 6 and 7, of this specification: *This standard does not purport to address all of the safety concerns, if any, 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.*

NOTE 1—Specification F 1951 – 99 replaces ASTM PS 83, Provisional Standard Specification for Determination of Accessibility of Surface Systems Under and Around Playground Equipment.

2. Referenced Documents

2.1 *ASTM Standards:*

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[2]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[2]

F 1292 Specification for Impact Attenuation of Surface Systems Under and Around Playground Equipment[3]

F 1487 Consumer Safety Performance Specification for Playground Equipment for Public Use[3]

2.2 *U.S. Architectural and Transportation Barriers Compliance Board Document:*

Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities

2.3 *U.S. Consumer Product Safety Commission Document:*

Handbook for Public Playground Safety, 1991

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *camber, n*—the angular position in the vertical direction of the individual main wheel axis. Zero camber occurs when the wheel axis is parallel to the ground surface.

3.1.2 *loose fill system, n*—a surface system consisting of small independent, movable components; that is, sand, gravel, wood chip, etc.

3.1.3 *maneuverability, n*—the ability of a surfacing material to allow unencumbered traversing or locomotion of a person with or without prosthetic aids or wheelchair.

3.1.4 *toe, n*—the difference in separation distance between the front of the two main wheels and the rear of the two main

---

[1] This specification is under the jurisdiction of ASTM Committee F-8 on Sports Equipment and Facilities and is the direct responsibility of Subcommittee F08.63 on Playground Surfacing Systems.

Current edition approved Feb. 10, 1999. Published June 1999.

[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 15.07.

wheels of a wheelchair. Proper toe alignment occurs when the axle is perpendicular to the direction of rolling.

4. General Requirements

4.1 Playground surfaces represented as complying with this specification shall meet all applicable requirements specified herein. Anyone representing compliance with this specification shall keep such essential records as are necessary to document any claim that the requirements within this specification have been met.

4.2 For the surface within the fall zone of the surrounded playground equipment, the surface must meet U.S. Consumer Product Safety Commission minimum requirements of 200 *g*-max and 1000 HIC at its critical height when tested in accordance with Specification F 1292.

4.3 Accessibility specification certification compliance shall be conducted by an independent accredited testing laboratory.

5. Performance Requirement

5.1 *Maneuverability*—When tested in accordance with the test methods described in Sections 6 and 7 of this specification, a surface in place shall have average work per foot (work per meter) values for straight propulsion and for turning less than the average work per foot (work per meter) values for straight propulsion and for turning, respectively, on a hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14).

6. Wheelchair Work Measurement Method—Straight Propulsion

6.1 *Test Equipment and Setup*:

6.1.1 *Test Wheelchair*—A 16-in. (40.64-cm) width rehabilitation wheelchair with pneumatic rear tires, front wheels with pneumatic tires, and a total weight of 31 ± 4.4 lb (14 ± 2 kg) shall be used as the test wheelchair. The rear wheels shall be identical with 24 by 1.375-in. (61 by 3.5-cm) pneumatic tires and pushrim diameters of 20 in. (50.8 cm). The front wheels with pneumatic tires shall be identical with 8 by 1-in. (20.3 by 2.54-cm) wheels with pneumatic tires. One main rear wheel shall be capable of measuring the forces applied to the pushrim that are tangential to the pushrim and parallel to the direction of travel. The wheelchair shall be adjusted such that there is minimal toe and minimal camber. Tire pressures shall be set to the maximum pressure specified by the manufacturer ±2 psi.

6.1.2 *Test Wheelchair Rider*—A 165 +11, –4.4-lb (75 +5, –2 kg) test wheelchair rider shall propel the wheelchair during testing.

6.1.3 *Weight of Total System*—The total weight of the wheelchair-rider system, including any distance measurement or data acquisition equipment residing on the wheelchair, shall be a minimum of 187.2 lb (85 kg) and a maximum of 255 lb (116 kg).

6.1.4 *Weight Distribution*—The wheelchair rider shall be seated in the wheelchair such that 40± 2 % of the total weight is supported by the front casters and the rear wheels support the remaining 60 ± 2 % when measured in a static position with the wheelchair rider's hands placed on the rear wheel pushrims in the topmost position.

6.1.5 *Distance Measurement*—A method to measure the total distance that the wheelchair has been propelled must be present. This distance shall be 6.56 +0.66 / –0 ft (2.0 +0.20 / –0 m) from its starting, measured to an accuracy of ± 0.79 in. (2 cm).

6.1.6 *Wheel Angular Displacement Measurement (Optional)*—A method to measure the angular displacement of the pushrim force measuring wheel can be used. It shall have an accuracy of at least ± 0.5°.

6.1.7 *Data Acquisition*—A data acquisition system shall be used to record the forces applied to the pushrim and the end of the trial at a minimum frequency of 50 Hz.

6.2 *Test Specimen*:

6.2.1 An installed site of playground surfacing shall be used as the test specimen. The minimum test specimen size shall be 4 ft (1.22 m) wide by 8 ft (2.44 m) in length.

6.2.2 The surface shall be level and free of surface dirt, ice, or contaminants.

6.2.3 Testing shall be conducted when surface temperature, as measured by a temperature probe, is between 40 and 100°F (4 and 38°C).

6.3 *Test Procedure*:

6.3.1 Starting from a stationary position with the wheelchair casters in the trailing position, the test wheelchair rider shall propel the wheelchair across the test surface a distance of 6.56 +0.66 / –0 ft (2.0 +0.20 / –0 m) using four uniform pushes. The distance the wheelchair actually rolls shall be recorded to an accuracy of ± 0.79 in. (± 2 cm). The wheelchair rider shall contact the pushrims only during the trial and shall maintain the same posture assumed during weight distribution measurement. The wheelchair shall be propelled in a straight path. At least three of the wheelchair wheels shall be in contact with the test surface during the trial. Each trial shall be completed in 7.0 ±1.0 s.

6.3.2 Record the forces applied to the pushrim to an accuracy of ± 0.15 ft × lbf (± 0.2 N × m), at a minimum frequency of 50 Hz.

6.3.3 Consider the trial acceptable if it meets the following criteria:

6.3.3.1 Pushrim torque values below –3.69 ft × lbf (–5.0 N × m) (reverse torque) do not occur;

6.3.3.2 One or more wheels do not slip on the surface creating torque values above 7.38 ft × lbf (10 N × m) with no forward movement of the wheelchair;

6.3.3.3 The time to complete the 6.56-ft (2.0-m) distance is 7.0 ± 1.0 s;

6.3.3.4 The torque applied to the wheelchair pushrim is zero or decreasing at the end of the trial;

6.3.3.5 The four propulsion strokes cause the wheelchair to travel a total distance of 6.56 +0.66 / –0 ft (2.0 +0.20 / –0 m).

6.3.4 Repeat 6.3.1-6.3.3 until a total of five acceptable trials are recorded. Use a leveled surface for each trial. If testing cannot be completed successfully on the test surface, document the reasons.

6.3.5 Repeat 6.3.1-6.3.4 with the same test wheelchair rider on a hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14) and a cross slope of 0 ± 0.5 %.

6.4 *Calculation*:

6.4.1 Calculation of work per foot (work per meter):

6.4.1.1 For each trial, calculate the average torque by integrating the area under the torque-time curve and dividing by the time to complete the trial.

6.4.1.2 Calculate the total work required for each trial by multiplying the average torque value by the total wheel angular displacement. If the test wheelchair was instrumented with only one pushrim force measuring wheel, multiply this value by two.

6.4.1.3 For each trial, normalize the total work required to work per foot (work per meter) by dividing by the length of the trial.

6.4.2 Alternative method for calculating work per foot (work per meter):

6.4.2.1 For each trial, calculate the average work per foot (work per meter) by integrating the area under the torque-angular displacement curve or the torque-distance curve, and then dividing by the total angular displacement or length of the trial, respectively. If the test wheelchair was instrumented with only one pushrim force measuring wheel, multiply this value by two.

6.4.3 Discard the low and high work per foot (work per meter) values and average the remaining three trials to determine the average work per foot (work per meter) required to negotiate the test surface and the hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14).

6.5 *Report*—Report the following information:

6.5.1 A reference to this specification.

6.5.2 Complete identification of the test specimen including manufacturer, type, manufacturer's lot number, if appropriate, thickness, and any other pertinent information.

6.5.3 For loose fill systems, specify the procedures used to install the test specimen prior to testing, and the procedures used to level the test specimen prior to each test trial. Describe the method of compaction, if any.

6.5.4 Complete identification of the test wheelchair including name of manufacturer, model, identification number, and weight.

6.5.5 Weight of the test wheelchair rider, total weight and front-to-rear weight distribution of the wheelchair-rider system.

6.5.6 Testing conditions including atmospheric and surface temperatures and any other pertinent information.

6.5.7 Date of tests.

6.5.8 The name and address of the test institution.

6.5.9 Pushrim torque versus time graphs for each trial.

6.5.10 Work per foot (work per meter) values to the nearest 0.1 ft × lbf (0.1 N × m) and total trial times for all five trials on the test surface and on the hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14).

6.5.11 Average work per foot (work per meter) to the nearest 0.1 ft × lbf (0.1 N × m) for the test surface and for the hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14). If testing could not be successfully completed on the test surface, the report must state this, as well as the reasons why testing could not be performed according to the test procedure. If the wheelchair continued to roll and could not stop at the specified distance, the work per foot (work per meter) required to negotiate the test surface shall be considered less than on the hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14).

7. Wheelchair Work Measurement Method—Turning

7.1 *Test Equipment and Setup*:

7.1.1 *Test Wheelchair*—A 16-in. (40.64-cm) width rehabilitation wheelchair with pneumatic rear tires, front wheels with pneumatic tires, and a total weight of 31 ± 4.4 lb (14 ±2 kg) shall be used as the test wheelchair. The rear wheels shall be identical with 24 by 1.375-in. (61 by 3.5-cm) pneumatic tires and pushrim diameters of 20 in. (50.8 cm). The front wheels with pneumatic tires shall be identical with 8 by 1-in. (20.3 by 2.54-cm) wheels with pneumatic tires. One main rear wheel shall be capable of measuring the forces applied to the pushrim that are tangential to the pushrim and parallel to the direction of travel. The wheelchair shall be adjusted such that there is minimal toe and minimal camber. Tire pressures shall be set to the maximum pressure specified by the manufacturer ±2 psi.

7.1.2 *Test Wheelchair Rider*—A 165 +11, –4.4-lb (75 +5, –2 kg) test wheelchair rider shall propel the wheelchair during testing.

7.1.3 *Weight of Total System*—The total weight of the wheelchair-rider system, including any distance measurement or data acquisition equipment residing on the wheelchair, shall be a minimum of 187.2 lb (85 kg) and a maximum of 255 lb (116 kg).

7.1.4 *Weight Distribution*—The wheelchair rider shall be seated in the wheelchair such that 40± 2 % of the total weight is supported by the front casters and the rear wheels support the remaining 60 ± 2 % when measured in a static position with the wheelchair rider's hands placed on the rear wheel pushrims in the topmost position.

7.1.5 *Turn Guide Test Fixture*—A test-fixture shall be used to guide the wheelchair through the turning maneuver. The test fixture shall be constructed such that it guides the wheelchair through a 90° turn. The turn guide shall be 4.75 ± 0.4 in. (12 ± 1 cm) in height and have a radius of curvature of 12.00 ± 0.05 in. (30.5 ± 0.13 cm) (see Fig. 1). The outside of the 12.0-in. (30.5-cm) turn guide shall by lined with a 0.25 ± 0.02-in. (0.635 ± 0.05-cm) polyethylene strip to provide an antifriction surface; thus, the turn guide with polyethylene strip shall have an outside radius of 12.25 ± 0.07 in. (31.135 ± 0.18 cm). The rear wheel axle location of the test wheelchair shall be tethered to the center of curvature of the turn guide. The length of the tether shall be set such that when taut the lower portion of the wheelchair pushrim is 0.32 ± 0.08 in. (8 ± 2 mm) from the turn guide.

7.1.6 *Angle Measurement*—A method to measure the angle that the wheelchair has been turned must be present. This angle shall be 90 +10 / –0° from its starting position, measured to an accuracy of ± 2°.

7.1.7 *Wheel Angular Displacement Measurement (Optional)*—A method to measure the angular displacement of the pushrim force measuring wheel can be used. It shall have an accuracy of at least ± 0.5°.

7.1.8 *Data Acquisition*—A data acquisition system shall be used to record the forces applied to the pushrim and the end of the trial at a minimum frequency of 50 Hz.

7.2 *Test Specimen*:

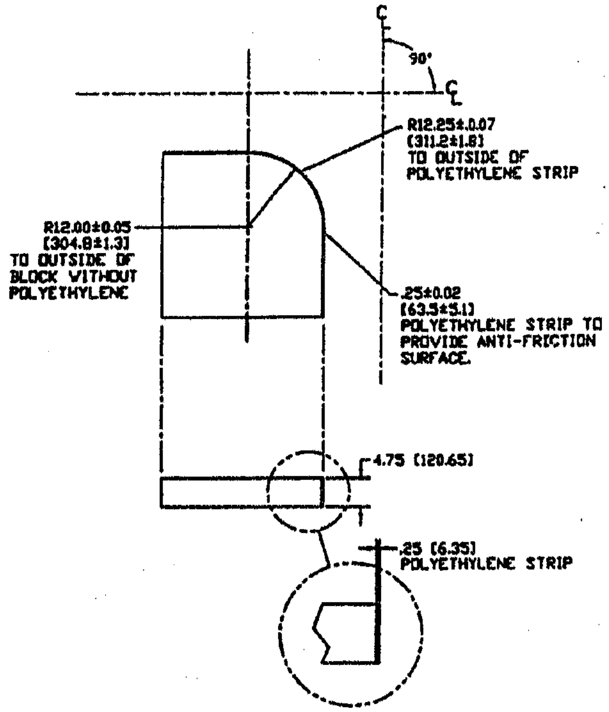


FIG. 1 Turn Guide Test Fixture

7.2.1 An installed site of playground surfacing shall be used as the test specimen. The minimum test specimen size shall be 4 ft (1.22 m) wide by 8 ft (2.44 m) in length.

7.2.2 The surface shall be level and free of surface dirt, ice, or contaminants.

7.2.3 Testing shall be conducted when surface temperature, as measured by a temperature probe, is between 40 and 100°F (4 and 38°C).

7.3 *Test Procedure*:

7.3.1 Starting from a stationary position with the wheelchair casters in the trailing position, the test wheelchair rider shall propel the wheelchair on the test surface around the turn guide using four uniform pushes until the wheelchair is oriented 90 +10 / –0° from its starting position. The angle the wheelchair actually turns shall be recorded to an accuracy of ± 2°. The wheelchair rider shall contact the pushrim of the wheel that is on the outside of the turn only during the trial and shall maintain the same posture assumed during weight distribution measurement. At least three of the wheelchair wheels shall be in contact with the test surface during the trial. Each trial shall be completed in 7.0 ± 1.0 s.

7.3.2 Record the forces applied to the pushrim to an accuracy of ± 0.15 ft × lbf (± 0.2 N × m), at a minimum frequency of 50 Hz.

7.3.3 Consider the trial acceptable if it meets the following criteria:

7.3.3.1 Pushrim torque values below –3.69 ft × lbf (–5.0 N × m) (reverse torque) do not occur;

7.3.3.2 The wheel on the outside of the turn does not slip on the surface creating torque values above 7.38 ft × lbf (10 N × m) with no forward movement of the wheelchair;

7.3.3.3 The time to complete the entire turn is 7.0 ± 1.0 s;

7.3.3.4 The torque applied to the wheelchair pushrim is zero or decreasing at the end of the turn;

7.3.3.5 The four propulsion strokes cause the wheelchair to be oriented 90 +10 / –0° from its starting position.

7.3.4 Repeat 7.3.1-7.3.3 until a total of five acceptable trials are recorded. Use a leveled surface for each trial. If testing cannot be successfully completed on the test surface, document the reasons.

7.3.5 Repeat 7.3.1-7.3.4 with the same test wheelchair rider on a hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14) and a cross slope of 0 ± 0.5 %. The wheelchair shall start the turn facing 45° from the uphill direction and be turned toward the uphill direction until it is facing 45° from the uphill direction in the opposite direction that the wheelchair started (see Fig. 2).

7.4 *Calculation*:

7.4.1 Calculation of work per foot (work per meter):

7.4.1.1 For each trial, calculate the average torque by integrating the area under the torque-time curve and dividing by the time to complete the trial.

7.4.1.2 Calculate the work per foot (work per meter) required for each trial by multiplying the average torque value by the estimated, total wheel angular displacement over the length of the test, and then dividing by the length of the test to normalize the work required.

7.4.2 Alternative method for calculating work per foot (work per meter):

7.4.2.1 For each trial, calculate the average work per foot (work per meter) by integrating the area under the torque-angular displacement curve or the torque-distance curve, and then dividing by the total angular displacement or length of the trial, respectively.

7.4.3 Discard the low and high work per foot (work per meter) values and average the remaining three trials to determine the average work per foot (work per meter) required to

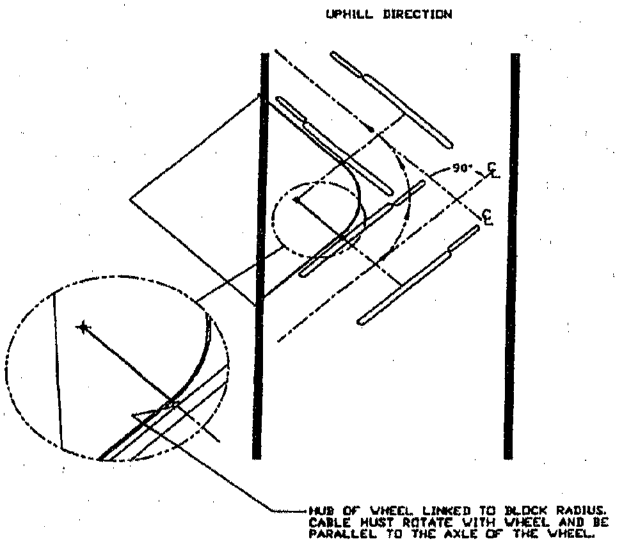


FIG. 2 Turning on Hard, Smooth Surface With Grade of 7.1 ± 0.2 % (1:14)

negotiate the test surface and the hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14).

7.5 *Report*—Report the following information:

7.5.1 A reference to this specification.

7.5.2 Complete identification of the test specimen including manufacturer, type, manufacturer's lot number, if appropriate, thickness, and any other pertinent information.

7.5.3 For loose fill systems, specify the procedures used to install the test specimen prior to testing, and the procedures used to level the test specimen prior to each test trial. Describe the method of compaction, if any.

7.5.4 Complete identification of the test wheelchair including name of manufacturer, model, identification number, and weight.

7.5.5 Weight of test wheelchair rider, total weight and front-to-rear weight distribution of the wheelchair-rider system.

7.5.6 Test conditions, including atmospheric and surface temperatures and any other pertinent information.

7.5.7 Date of tests.

7.5.8 The name and address of the test institution.

7.5.9 Pushrim torque versus time graphs for each trial.

7.5.10 Work per foot (work per meter) values to the nearest 0.1 ft × lbf (0.1 N × m) and total trial time for all five trials on the test surface and on the hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14).

7.5.11 Average work per foot (work per meter) to the nearest 0.1 ft × lbf (0.1 N × m) for the test surface and for the hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14). If testing could not be successfully completed on the test surface, the report must state this, as well as the reasons why testing could not be performed according to the test procedure. If the wheelchair continued to roll and could not stop at the specified distance, the work per foot (work per meter) required to negotiate the test surface shall be considered less than on the hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14).

8. Precision and Bias

8.1 *Potential Sources of Error or Deviations*:

8.1.1 Variations in weight distribution during wheelchair propulsion due to changes in test wheelchair rider positioning;

8.1.2 Variations in pneumatic tire pressure caused by temperature differences;

8.1.3 Variations in surface characteristics caused by changes in moisture and temperature; and

8.1.4 Variations in friction between the pushrim of the wheelchair and the polyethylene strip of the turn guide test fixture, brought about by subtle differences in the position of the chair with respect to the turn guide.

8.2 *Precision*—Preliminary results have been obtained through a preliminary test program (see Appendix X2); however, additional statistical analysis must be conducted.

8.3 *Bias*—These methods have no bias because surface accessibility is defined only in terms of these test methods.

9. Keywords

9.1 playground surface accessibility; playground surfacing; wheelchair maneuverability

APPENDIXES

(Nonmandatory Information)

X1. RATIONALE

X1.1 The need to have playground surfaces that are firm and stable and, if within the use zone, resilient, thereby enabling use by people with mobility impairments, has been acknowledged by the U.S. Architectural and Transportation Barriers Compliance Board. In addition, the Board understands that playground owners and operators, as well as manufacturers of playground surfacing, desire quantifiable measurement methods to determine the accessibility of playground surfacing systems. This specification has been developed to address this need for quantifiable measurement of accessibility for persons with mobility impairments that do or do not use assistive mobility devices, including but not limited to wheelchairs, crutches, and walkers. The test methods in this specification address access not only for children but also for adults who may traverse the surfacing to aid children who are playing.

X1.2 Testing was conducted to evaluate the firmness of playground surfaces using both wheelchair casters and standard crutch tips. The wheelchair maneuverability test procedures in this specification are more reliable and more stringent than currently available crutch tip penetration measurement methods. Testing showed that surfaces that failed the crutch tip penetration tests also failed the wheelchair maneuverability tests. A test procedure for crutch tip penetration does not presently provide any additional information.

X1.3 The type of adaptive equipment (for example, wheelchair, crutch, walker) used by a person with a mobility limitation will affect the work required to negotiate a surface. The wheelchair configuration will also affect the work required to maneuver across a surface. A wheelchair with smaller diameter or narrower width wheels will require more work to cross a surface than a wheelchair with larger diameter or wider width wheels. The wheelchair maneuverability test procedures are performed with a rehabilitation type wheelchair with main wheel and caster wheel sizes that are typically found on everyday wheelchairs that are most commonly used by persons with mobility limitations that use a wheelchair for all activities of daily life. Persons using a hospital-type wheelchair with narrow, solid tires are not generally using this type of wheelchair in outdoor environments.

X1.4 The weight of a person with a mobility limitation using adaptive equipment will affect the work required to traverse a surface and up a ramp. A heavier person will require more work and a lighter person will require less work on both a level surface and up a ramp. All wheelchair maneuverability testing is performed with a standardized 165-lb (75-kg) test mass commonly used for wheelchair testing. A 165-lb (75-kg) test wheelchair rider corresponds to a 50th percentile male adult. This weight provided the most repeatable results when testing on various surfaces and ramp angles.

X2. PRELIMINARY TEST PROGRAM

X2.1 *Preliminary Test Program*—A preliminary interlaboratory study of wheelchair work for straight propulsion and turning was conducted based upon Practice E 691 with six laboratories and six materials, with each laboratory obtaining two test results for each material. Examination of the results of this study raised several issues, which warrant further statistical analysis.

X2.1.1 *Repeatability and Reproducibility Conditions*—All six laboratories conducted testing at the same test site and with the same equipment over a period of three months. Testing was conducted outdoors under various environmental conditions. Each laboratory used a different test wheelchair rider. The data acquisition equipment was powered down between the two sets of trials on each material.

X2.1.2 *Test Result for This Study*—For purposes of this study, a work ratio was calculated by dividing the average work per foot (work per meter) for the test surface by the average work per foot (work per meter) for the hard, smooth surface with a grade of 7.1 ± 0.2 % (1:14):

$$\text{work ratio} = \frac{\text{average work per foot for test surface}}{\text{average work per foot for 7.1 \% ramp}} \qquad \text{(X2.1)}$$

X2.2 *Preliminary Estimate of Repeatability and Reproducibility*—On average, the typical standard deviation for the work ratios are as shown in Table X2.1. The terms repeatability standard deviation (within a laboratory) and reproducibility standard deviation (between laboratories) are used as specified in Practice E 177. See Tables X2.2 and X2.3 for more detail. The terms repeatability limit and reproducibility limit are used as specified in Practice E 177.

TABLE X2.1 Typical Standard Deviations for Work Ratios

Wheelchair Work Measurement Method—Work Ratios	Straight Propulsion	Turning
95 % repeatability standard deviation (within a laboratory)	0.0914	0.1148
95 % reproducibility standard deviation (between laboratories)	0.1942	0.1490

TABLE X2.2 Wheelchair Work Measurement Method—Straight Propulsion[A]

Material	Avg. Work Ratio	Repeatability Std Dev.	Reproducibility Std Dev.	Repeatability Limit	Reproducibility Limit
A	0.422	0.0268	0.0741	0.0750	0.2074
B	0.899	0.0320	0.0320	0.0896	0.0896
D	0.914	0.0299	0.0456	0.0836	0.1277
C	0.973	0.0440	0.1066	0.1231	0.2986
E	1.149	0.0310	0.0946	0.0867	0.2649
F	1.330	0.0324	0.0632	0.0907	0.1770

[A] A = accessible carpet.
B = inaccessible carpet.
C = 1:16 ramp.
D = cedar chips.
E = 1:12 ramp.
F = 1:10 ramp.

TABLE X2.3 Wheelchair Work Measurement Method—Turning[A]

Material	Avg. Work Ratio	Repeatability Std Dev.	Reproducibility Std Dev.	Repeatability Limit	Reproducibility Limit
A	0.505	0.0208	0.0254	0.0583	0.0712
B	0.774	0.0366	0.0527	0.1026	0.1475
D	0.882	0.0505	0.0610	0.1414	0.1708
C	0.977	0.0534	0.0607	0.1495	0.1699
E	1.113	0.0385	0.0385	0.1078	0.1078
F	1.290	0.0462	0.0809	0.1293	0.2266

[A] A = accessible carpet.
B = inaccessible carpet.
C = 1:16 ramp.
D = cedar chips.
E = 1:12 ramp.
F = 1:10 ramp.

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM F462: Slip-Resistant Bathing Facilities

CFR Section(s): 24 CFR 200, Subpart S

Standards Body: American Society for Testing and Materials

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 462 – 79 (Reapproved 1999)

Standard Consumer Safety Specification for Slip-Resistant Bathing Facilities[1]

This standard is issued under the fixed designation F 462; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This consumer safety specification addresses the bathtub and shower accidents that are due in whole or in part to the slipperiness of the bathing surface.

In response to the accident analysis and assignment of causes developed and identified for the U.S. Consumer Product Safety Commission by the Abt Associates, Inc., final report, "A Systematic Program to Reduce the Incidence and Severity of Bathtub and Shower Area Injuries," June 4, 1975,[2] this consumer safety specification provides a means to reduce accidents in bath and shower units caused directly or indirectly by the slipperiness of the bathing surface.[3]

It is not possible to cover, in this consumer safety specification, bath and shower units that are used in a manner for which they were never intended. Furthermore, children do not always act prudently, and the motions of the elderly and infirm are not always under complete control. These problems will be covered in a consumer-education-type publication, designed to describe the hazards of the bathing area, and suggestions concerning bather's conduct to reduce these hazards.

This consumer safety specification is written within the current state of the art of bath and shower technology.

1. Scope

1.1 This consumer safety specification covers the slip resistance of bathtubs and shower structures or combinations, used for bathing or showering, or both, herein referred to as bathing facilities.

1.2 This specification establishes definitions, methods of testing the slip resistance of bathing facilities, and the in-use performance requirements needed to minimize the accidents caused by slipperiness during any reasonable use.

1.3 This consumer safety specification is intended to describe a means to reduce accidents to persons, especially children and the aged, resulting from the use of bathing facilities.

1.4 The following safety hazards caveat pertains only to the test method portion, Section 8, of this specification. *This standard does not purport to address all of the safety concerns, if any, 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. Referenced Documents

2.1 *ASTM Standards:*

D 459 Terminology Relating to Soaps and Other Detergents[4]

D 799 Specification for Liquid Toilet Soap[4]

2.2 *Federal Specification:*[5]

PS-624g Soap, Toilet, Liquid and Paste

3. Terminology

3.1 *Definitions:*

3.1.1 *applique*—a material affixed to the bathing surface or sump of a bathtub or shower for the purpose of increasing its slip resistance.

3.1.2 *bathing*—the act of subjecting all, a substantial part, or a specified part of the body to the action of water in a bathing facility, with or without soap or bath oil, for purposes of health or cleansing.

---

[1] This specification is under the jurisdiction of ASTM Committee F15 on Consumer Products and is the direct responsibility of Subcommittee F15.03 on Safety Standards for Bathtub and Shower Structures.

Current edition approved March 29, 1979. Published May 1979.

[2] Available from the Consumer Product Safety Commission, Washington, DC 20207.

[3] "Performance Characteristics of Sanitary Plumbing Fixtures," available from the Consumer Product Safety Commission, Washington, DC 20207.

[4] *Annual Book of ASTM Standards*, Vol 15.04.

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

3.1.3 *bathing facility*—a bathtub, shower structure, or a combination of a bathtub and shower, designed to restrict or contain the flow of water, or both, usually for the bathing use of one adult or one child at a time.

3.1.4 *bathing surface*—the portion of the sump of a bathing facility on which, by either common usage or design, a bather might be expected to step, stand, sit, or come in contact with while bathing or showering.

3.1.5 *bath oil*—a functional (emollient) or nonfunctional (cosmetic) formulation in the form of a liquid (clear or opaque), oil or nonoil, spray, powder, or encapsulated liquid.

3.1.6 *coefficient of friction*—the ratio of the frictional force to the force, usually gravitational, acting perpendicular to the two surfaces in contact. This coefficient is a measure of the relative difficulty with which the surface of one material willslide over a surface adjoining itself, or of another material. The static or starting coefficient of friction is related to the force measured to begin movement of the surfaces relative to each other. The kinetic or sliding coefficient of friction is related to the force measured in sustaining this movement.

3.1.7 *dam*—a horizontal elevated surface that must be traversed to enter a tub or shower structure, or a combination of both. Relative terms are "rim" for tubs and combination tub/showers, and "threshold" for shower structures.

3.1.8 *friction*—the resisting force that arises when a surface of one substance slides, or tends to slide, against a surface adjoining itself or another substance. Between surfaces of solids in contact there may be two kinds of friction: (*1*) *static friction*—the resistance opposing the force required to start to move one surface on or over another; and (*2*) *dynamic friction*—the resistance opposing the force required to move one surface on or over another at a variable, fixed, or predetermined speed.

3.1.9 *retrofit*—a component used to replace similar worn or expended parts of a manufactured product; a component that is employed to modify a finished product in order to alter its functional character.

3.1.10 *soap*—the product formed by the saponification or neutralization of fats, oils, waxes, rosins, or their acids, with organic or inorganic bases.

3.1.11 *slip resistance*—the property of a bathing surface that acts in opposition to those forces and movements exerted by a bather under all conditions of bathing or showering that can result in uncontrolled sliding; it is directly proportional to the coefficient of friction.

3.1.12 *slipperiness*—the property of a surface that indicates the degree of which uncontrolled sliding (of portions of the body) may occur.

3.1.13 *smooth surface*—a surface that is not textured.

3.1.14 *sump*—the portion of a bathing facility intended for the collection of water, as limited by the height of the dam.

3.1.15 *textured surface*—a bathing surface that contains elevations or depressions, or both, or that incorporates a second material for the purpose of improving the slip resistance of the surface.

3.1.16 *water (pure)*— the liquid that consists of an oxide of hydrogen of the ratio one atom of oxygen to two atoms of hydrogen.

4. Compliance

4.1 No bathing facility shall either by label or other means indicate compliance with this specification unless it conforms to all requirements contained herein.

4.2 No product intended to be used as a slip-resistant retrofit item to a bathing facility shall either by label or other means indicate compliance with this specification unless it conforms to all requirements contained herein.

4.3 If a bathing facility is intended to be retrofitted, treated, etc., to provide slip resistance after installation, there must be an indication, by label or other means, that the unit will not be in compliance unless the surface is treated with the approved material(s) provided, in accordance with manufacturer's installation instructions.

5. Requirements

5.1 The slip-resistant requirements specified herein are designed to reduce the probability of falls due to slipping.

5.2 For any surface that is textured or treated with appliques, the pattern shall be such that a 1½ by 3-in. (38.1 by 76.2-mm) rectangular template placed anywhere on the bathing surface shall cover some textured or treated area.

5.3 The slip resistance of the bathing surface shall remain at or above the level required by this specification during the life of the manufacturer's guarantee, using cleaning methods recommended by the manufacturer.

NOTE 1—It is emphasized that this specification was written within the state of the art existing in early 1976. It is intended that a section dealing with durability will replace 5.3 at the time of the next revision of this specification.

5.4 Any nonintegral slip-resistant material applied to a sump or bathing surface shall be removable without harm to the bathing surface.

5.5 All slip-resistant surfaces shall withstand, without marked deterioration, the action of normal bathing soaps, bath oils, body oils, and dirt normally encountered in bathing and showering.

5.6 *Characteristics of the Slip-Resistant Surface*—This consumer safety specification provides for nine pairs of measurements (see 9.1.1) distributed over that portion of the bathing surface upon which measurements can be made as a basis for determining compliance. These measurements are assumed characteristic of the entire bathing surface. In order to make this assumption valid, the entire bathing surface is required to have the same characteristics as the region chosen for slip-resistance measurements. Conformance with this requirement is determined by visual inspection and consideration of the quality control methods applied to the manufacturing process.

6. Instructions for the Operation of the NIST-Brungraber Portable Slip-Resistance Tester

6.1 *Principles of Operation*:

6.1.1 The NIST-Brungraber portable slip-resistance tester[6] is designed to measure the static coefficient of friction between

---

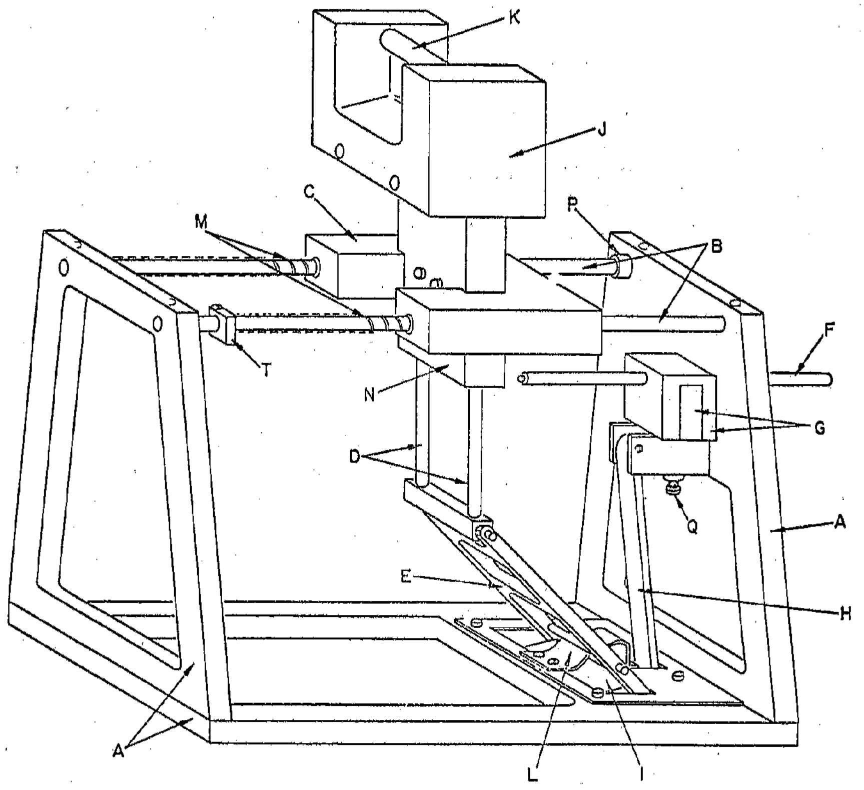
[6] "A New Portable Tester for the Evaluation of the Slip Resistance of Walking Surfaces," *NIST Technical Note 953*, National Institute of Standards and Technology, Washington, DC 20207.

a representative foot surface and a surface for walking or standing under true field conditions (see Fig. 1). It does this by applying a predetermined vertical force (the weight) through vertical shafts and an articulated shaft to the sensor shoe.

6.1.2 At the start of a test, the carriage is brought forward to a stop position such that the articulated shaft is not vertical but set at a slight angle towards the back of the tester. (This is accomplished by either introducing an initial position stop at the front of the carriage or by using the tester in an "uphill" mode on a surface inclined to an angle of at least 1°.) This established an unbalanced lateral force against the carriage. At the instant that the handle is released and the vertical load is applied, the carriage begins to move back along the travel bars, inducing an increasing lateral load on the shoe as the angle between the articulated shaft and the vertical shaft increases. The tangent of this angle at the moment that slip occurs is directly related to the static coefficient of friction. This angle is measured by the recording shaft, which is magnetized and drawn along by attachment of the attraction plate as the carriage moves backwards. When slip occurs, the sensor shoe hits the trigger so that the recorder clamp grips the recording shaft, retaining the shaft in the position assumed at the time of slip. The measurement of slip resistance is read opposite a notch in the indicator tube at the front of the recorder clamp from a linear-graduated scale imprinted along the length of the recorder shaft. This value can be directly translated to the static coefficient of friction by use of the calibration chart or table supplied with the tester.

6.1.3 The motion of the carriage is controlled by the springs. The retaining plate keeps the shoe in position while the tester is being lifted and moved to a new test location.

6.1.4 When evaluating surfaces with low values of coefficient of friction, such as soapy bathing surfaces, the initial position stop (a short section of plastic tubing that is on the front end of one of the travel rods) should be removed. This permits the tester to start in the position corresponding to a zero value of coefficient of friction and requires that the carriage be given a slight initial push immediately after the handle is released, unless the test is conducted "uphill" on a surface inclined to at least 1°. For best results and to reduce operator



A	Main frame	K	Handle
B	Travel bars	L	Retainer plate
C	Carriage	M	Control springs
D	Vertical shaft	N	Adjustable attraction screw for magnet
E	Articulated strut	O	Sensor facing clip (not shown)
F	Recording shaft with magnet	P	Initial position stop
G	Recorder clamp	Q	Trigger adjustment screw
H	Trigger	R	Adjustable trigger stop (not shown)
I	Sensor shoe	S	Indicator tube for recording shaft (not shown)
J	Weight	T	Adjustable collar

FIG. 1 NIST-Brungraber Tester

error as much as possible, tests on bathing surfaces should be conducted in the "uphill" mode whenever possible, since in this mode the tester is self-actuating.

6.1.5 Tests on soapy surfaces should never be conducted in the "downhill" position as this will cause a premature forward motion of the shoe and the tester will not function. Also, when conducting tests on soapy surfaces, the tester should be restrained from slipping by holding firmly with the hand that is not being used to operate it.

6.2 *Operation of the Tester*—For a detailed step-by-step procedure on the NIST-Brungraber Tester, refer to Annex A1.

6.3 *Calibration of Tester*:

6.3.1 The scale on the NIST-Brungraber Tester is graduated in tenths of an inch (or 2.5 mm). The value read from this scale can be used directly in comparing the relative slip resistance of materials, or the corresponding value of static coefficient of friction can be determined from a calibration chart or table supplied with the tester.

6.3.2 Calibration of the NIST-Brungraber Tester is effected by comparison with standard weights or standard springs that are applied in such a manner as to provide a precisely controlled, simulated friction force. Calibration with weights is done by installing a low-friction pulley at the rear of the tester, replacing the sensor shoe with a low-friction linear ball bearing,[7] and placing the tester on a carefully leveled sheet of plate glass. A string and bridle arrangement attached to the shoe, passing over the pulley and aligned horizontally, permits the simulation of a well-defined friction force by attaching standard weights to the string. The weight on the string (the drag force of the linear ball bearings is negligibly small, but has been determined and included) divided by the total of the weights on the articulated shaft, including the weight of the shaft, shoe, sensor, etc., is the simulated coefficient of friction. This is compared with readings from the tester for a series of different loads on the string. The results are presented in the form of a calibration chart or table. Calibration with standard springs is carried out in essentially the same manner, except that the well-defined friction force is established with a selection of calibrated springs that are stretched between the low-friction linear ball bearing shoe and the rear of the tester frame.

6.3.3 The two existing models of the NIST-Brungraber Tester have been calibrated repeatedly, in the horizontal position as well as tilted laterally as much as 4°. The results to date indicate that the calibration is essentially the same for both testers and is not affected by lateral tilts of up to 4°.

6.3.4 The testers have also been calibrated after being modified or adjusted to permit the evaluation of sloping surfaces. When testing surfaces that slope upwards in the direction of test, adjust the collars for the control springs to prevent excessive speed of travel of the tester carriage. For surfaces inclined up to as much as 4°, if the tester is adjusted as described to permit full travel of the carriage without an excessive jolt at the end of travel, satisfactory calibrations are obtained.

7. Test Specimens

7.1 *Description*—The test specimen shall consist of the bathing surface.

7.2 *Leveling*—Bathing facilities are normally tested in the installed condition. After leveling, the bathing surfaces will have the same slopes encountered under normal bathing conditions and test measurements taken on these slopes are more indicative of the slip situation existing during bathing.

7.3 *Marking for Slip-Resistance Measurements*:

7.3.1 *Determining the Measurement Area*— The measurement area is that portion of the bathing surface which can be measured by the 1½ by 3-in. (38.1 by 76.2-mm) sensor of the NIST-Brungraber Tester after the bathing facility has been leveled. Establish the measurement area experimentally by placing the tester at all possible locations around the perimeter of the bathing surface and marking the portions of the surface that can be reached by the sensor when the tester is used in the "uphill" mode. As an example of how the measurement area can be established, the following instructions apply to the standard 5-ft (1.5-m) tub.

7.3.1.1 Place the NIST-Brungraber Tester in the bathtub as close as possible to the drain end, with the sensor end towards the rear (uphill) and the side of the tester as close as possible to the far side of the tub. Note and mark the location of the sensor. Call this location Point 1.

7.3.1.2 Move the tester along the far wall and as close to the rear wall as possible. Note and mark the location of the sensor. Call this location Point 2.

7.3.1.3 In a similar manner, locate Points 3 and 4. Then connect Points 1, 2, 3, and 4. This establishes the measurement area. (See Fig. 2 for an illustration of a tub with testers in positions 1, 2, 3, and 4 and Fig. 3 for the measurement area and measurement zones.)

7.3.2 *Establishing the Measurement Zones*:

7.3.2.1 Divide the measurement area into nine approximately equal areas. These are measurement zones.

7.3.2.2 Suitably identify these zones using any convenient system that does not affect the slip resistance of the surface and number them as shown in Fig. 3.

Determining the Measurement Area

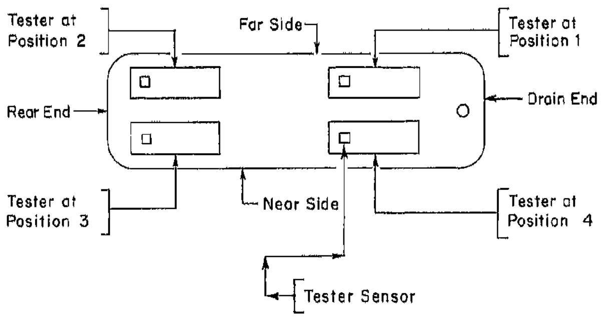
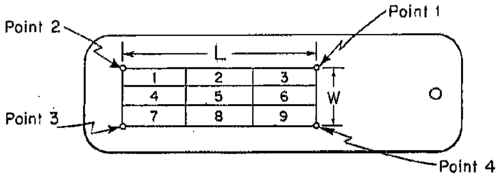


FIG. 2 Tub with Testers in Positions 1, 2, 3, and 4

---

[7] A unit available from Turnomat, Inc., Rochester, NY or equivalent, has been found satisfactory for this purpose.



Measurement Area = Area L x W
Measurement Zones = Areas Marked 1 through 9

FIG. 3 Measurement Area and Measurement Zones

8. Test Method

8.1 This method is designed to determine the slip resistance of a bathing surface by measuring its static coefficient of friction with an NIST-Brungraber Tester.

8.2 *Preparation for Testing*—Prepare the reference or bathing surface for testing as follows:

8.2.1 Thoroughly clean and rinse the surface with alcohol or other cleaning agents so that there is no residue left on the surface.

8.2.2 Support the tub or shower base so that the spatial orientation of the bathing surface will be as if the unit were properly installed in a bathroom.

8.2.3 Plug the drain and introduce sufficient liquid soap solution, as specified in 8.3, to cover all areas to be tested to a depth of at least ½ in. (12.7 mm) and not more than 1½ in. (38.1 mm).

8.2.4 Take static coefficient of friction readings at nine specified locations as described in 9.1.

8.2.5 If specimens cut from a bathing surface or float glass are to be tested, clean them in accordance with 8.2.1, and support them so that the surface to be tested is at an angle of at least 1° and not more than 3° from the horizontal.

8.3 *Soap Solution*:

8.3.1 The soap solution shall consist of one part of liquid soap complying with Fed. Spec. P-S-624g, or Specification D 799, mixed with four parts of distilled or deionized water. The liquid soap shall be made from 100 % coconut oil fatty acids, saponified with potassium hydroxide and brought to the correct pH value by the addition of acetic acid; 0.010 to 0.015 % of EDTA (ethylenediaminotetraacetic acid) shall be added as a chelating agent. Since the soap is 15 % active, the resulting solution is 3 % active.[8] Use the soap solution at normal room temperature, 70± 5°F (21.1 ± 2.8°C).

8.3.2 When not actually in use for testing, store the soap solution in a clean, closed container. If the soap solution displays any "curd" or other material floating in it, or deposited from it, discard it and replace with a fresh solution.

8.4 *Reference Surface*—To help maintain continuity within one user's tests and consistency among all users of this procedure, each user shall have a reference surface consisting of a 12 by 30 by ¼-in. (304.8 by 762 by 6.35-mm) thick piece of plate or float glass. Prepare the reference surface in accordance with 8.2.4 and verify the readings by taking six measurements as follows:

8.4.1 At the beginning and end of any series of tests.

8.4.2 Any time the soap solution is replaced by a fresh sample.

8.4.3 At the beginning and end of any day of tests, if a series extends for more than one day.

8.5 *Test Sensor*—The test sensor shall be made of medical grade silicone rubber.[9] Cast a 1½ by 3 in. (38.1 by 76.2 mm), having a thickness of 3/16 ± 1/16 in. (4.8 ± 1.6 mm), following the instructions supplied by the manufacturer. Attach the section, as cast, either directly to the shoe of the tester or to a detachable clip which in turn can be attached to the shoe of the tester by means of a suitable adhesive.[10] The sensor needs no special care, such as presoaking or storing in a soaked condition. It is only necessary that the sensor's test surface be kept clean and that it be inspected for mechanical damage from time to time. If the test surface evidences any mechanical damage, roughness, or missing areas, replace the sensor.

8.6 *Recording of Data*—Record and retain the following data to evidence compliance with this specification:

8.6.1 The 18 results of the NIST-Brungraber Tester,

8.6.2 Angle of inclination of the tester at each of the nine locations tested, both transverse and parallel to the direction of the test,

8.6.3 Temperature of the room in which the tests were conducted,

8.6.4 Temperature of the soap solution at the time the tests were conducted, and

8.6.5 Results of the NIST-Brungraber Tester on the reference surface.

9. Measurements and Interpretation of Results

9.1 *Number Required*:

9.1.1 *Measurements*—Eighteen measurements, two in each of the measurement zones, are required to establish the slip resistance of a bathing surface. The two measurements in each zone are taken without moving the NIST-Brungraber Tester.

9.1.2 *Compliance-Determining Measurements*—The lowest average static coefficient of friction in any of the nine measurement zones (average of the two readings) shall be the basis for determining compliance with this specification.

9.2 *Required Level of Performance*— The required level of performance for compliance with this specification shall be a static coefficient of friction no less than 0.04, as determined in 9.1.2.

---

[8] The Dermi-Klene Co., 306 Oak Place, Brea, CA 92621, will supply soap to these specifications in lots of at least three cases of 12 gal per case. To assure compliance with the above requirements, the order should identify the soap as 8520-00-228-0598-C.

[9] Silastic 382, available from Dow-Corning Corp., Midland, MI, or equivalent, has been found suitable for this purpose.

[10] Scotch-Weld Structural Adhesive made by 3M, St. Paul, MN, or silastic medical adhesive silicone Type A made by Dow Corning have been found to be satisfactory for this purpose.

ANNEX

(Mandatory Information)

A1. STEP-BY-STEP OPERATION OF THE NIST-BRUNGRABER SLIP-RESISTANCE TESTER

A1.1 Perform the following procedure:

A1.1.1 Carefully remove the tester from its case, inspecting it for any loose or damaged parts.

A1.1.2 Using a clean cloth or paper napkin, thoroughly wipe all parts of the main, horizontal travel bars that come in contact with the linear ball bushings in the carriage.

A1.1.3 Select a sensor clip having a suitable facing material and attach it to the bottom of the sensor shoe, making certain that the vertical extension in the clip extends up through the hole in the base plate and lies behind the trigger. Also be certain that the clip is pushed back with respect to the shoe as far as it will go, so that the vertical extension on the clip is thoroughly engaged in the single notch at the front of the shoe.

A1.1.4 Remove the recording shaft from the case and wipe it thoroughly with a clean cloth or paper napkin.

A1.1.5 Insert the magnetic end of the recording shaft through the indicator tube at the front of the tester, pushing the rod back until the magnet engages the head of the adjustable carbon steel bolt attached to the carriage. While inserting the shaft, be certain that the trigger-clutch assembly is thoroughly released by pushing the sensor shoe as far towards the rear of the tester as it will go. If the shaft fails to slide in easily, it may be necessary to back off the adjustment screw in the upper end of the trigger. This is done by first releasing the knurled locknut on it.

A1.1.6 Adjust the trigger mechanism by first putting the tester on a level surface, with the sensor shoe to the rear of its possible travel and with the carriage fully forward, with the initial stop (the short piece of flexible plastic tubing) removed. Then adjust the trigger so that the 0.05-in. (1.3-mm) thick spacer, supplied with the tester, can be easily placed between the trigger and the vertical extension on the front of the sensor clip. Set the trigger stop so that there is a 0.05-in. gap between the stop and the front of the trigger, with the trigger again at the front of its travel. At no time during these adjustments should the trigger be pushed hard enough to bend it. The 0.05-in. gap between the trigger and the stop permits some elastic bending of the trigger during the operation of the tester, but the trigger should be free of bending stress while being adjusted.

A1.1.7 With the carriage fully forward and the magnet on the recording shaft engaged with the attraction screw in the carriage, check the zero reading. If the zero line on the recording shaft does not lie opposite the notches in the indicator tube, bring them into alignment by releasing the thumb nut on the attraction screw in the carriage and adjusting it as needed. Before attempting to adjust the zero position of the recording shaft, first check the indicator tube to be sure it is tightly secured in front of the tester and is so positioned that the recording shaft may be easily read from the top of the tester.

A1.1.8 Check the free movement of the recording shaft by holding the sensor shoe in its rearward position and moving the carriage, by hand, throughout its travel. The recording shaft must travel freely, without breaking the magnetic attachment to the attraction screw in the carriage. If the shaft does not move freely, check the shaft for straightness. If the shaft has been bent, it may be possible to carefully straighten it; if not, it must be replaced. During this operation, the sensor shoe can be held in its rearward position either by hand or by temporarily adjusting the trigger stop such that all movement of the trigger is prevented.

A1.1.9 With the tester on a level surface and the sensor shoe again held in its rearward position, adjust the spring-control collar(s) so that the carriage will move freely throughout its entire travel, using the initial-position stop to initiate the travel. That is, the collar should be adjusted such that the carriage, while dragging the recording shaft, will just move to the end of its travel (the weight fully descended) without causing an excessive bump at the end of the travel.

A1.1.10 With the tester fully adjusted, the proper sensor in place, and the initial stop (the short piece of flexible plastic tubing) installed at the front of one of the main travel bars, conduct a test by picking up the tester by the handle, placing it on the area of the floor or bathing surface to be evaluated, and releasing the handle. Read the value of the resulting NIST-Brungraber number from the recording shaft at the index formed by the pair of notches in the indicator tube. Then convert the NIST-Brungraber number to an equivalent value of static coefficient of friction by means of the calibration chart or curve that is supplied with the tester. When picking up the tester, take care to see that the clutch is released, permitting free movement of the recording shaft before the recording shaft is forced forward to its initial position. This can most easily be done by inducing a slightly rearward force on the handle during the initial part of the picking-up operation. This assures that the sensor shoe is lifted free of the floor or bathing surface, thereby permitting it to return to its initial position, releasing the trigger and clutch, before the recording shaft is pushed by the carriage back to the initial position.

A1.1.11 By repeating the procedure in A1.1.10, additional readings can be taken at the same or newly selected spots on the walking or bathing surface. When taking repeat tests at the same identical spot, hold the tester in place with one hand, and operate it with the other. In this case, exercise special care to be sure to apply a rearward bias to the handle when first lifting it to assure that the recording shaft is free to be returned to its starting position.

A1.1.12 It should be noted that with the initial-position stop in place, readings of less than 0.5, which correspond to a static coefficient of friction of about 0.03, cannot be taken. However, such values of coefficient of friction are quite low and would represent an extremely hazardous condition for most walking or bathing surfaces. In fact, the operator of the tester would have to exercise great care to prevent self injury. In the event the presence of water or other contaminant on the surface makes it so slippery that the tester registers a value equal to the initial setting of the tester, indicating that the recording shaft did not travel at all, a repeat test should be performed with the initial-stop removed. In this case, the tester is not self-starting, and it will be necessary to impart a slight rearward push to the handle as soon as the sensor comes in contact with the floor or bathing surface. It is important that there be no delay between the contact of the sensor with the floor or bathing surface and the start of the carriage movement, since it is under those circumstances (the presence of water or other liquid contaminants) that a time delay will permit the squeezing-out of the contaminant, which may promote adhesion of the sensor to the floor or bathing surface and result in an unrealistically high indication of the slip resistance of the walking surface.

A1.2 When evaluating extremely slippery surfaces such as bathtubs or shower bases in the presence of soapy water, certain modifications must be made to the previous instructions for the operation of the NIST-Brungraber Tester, which are for dry, level floors.

A1.2.1 To promote free and complete drainage, most bathtub and shower base surfaces have a built-in slope towards the drain, of about 1½ to 2°. By taking advantage of this slope and operating the NIST-Brungraber Tester "uphill," it can be adjusted so that it is self-starting without the use of the initial-position stop. This permits the measurement of low values of coefficient of friction, less than 0.03, while still retaining the desirable self-starting feature that reduces operator error. Thus, wherever possible, bathtub and shower surfaces should be tested "uphill" at a 1 to 2° slope and the tester should be adjusted and calibrated for this mode of operation.

A1.2.2 Follow the instructions in A1.1.1-A1.1.8 for use of the tester on slippery surfaces. For adjustment of the spring control collar(s), the adjustment should be carried out with the tester inclined "uphill" at the approximate angle it is to be used and with the initial-position stop removed. For the actual operation of the tester, remove the initial-position stop and conduct the test in the "uphill" direction. If it is too difficult to incline the surface and it must be tested in the level position, satisfactory results can be obtained by carefully following the instructions in A1.1.12. However, the tester shall then be adjusted and calibrated for use on a level surface. When evaluating such surfaces as bathtubs or shower bases, particular care should be used to hold the tester in place with one hand while operating it with the other, since movement of the tester during the conduction of a test will result in a false reading.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name:	ASTM F478: Standard Specification for In-Service Care of Insulating Line Hose and Covers
CFR Section(s):	29 CFR 1910.137(b)(2)(ix)
Standards Body:	American Society for Testing and Materials

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 478 – 92 (Reapproved 1999)

Standard Specification for In-Service Care of Insulating Line Hose and Covers[1]

This standard is issued under the fixed designation F 478; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers the in-service care, inspection, testing, and use voltage of insulating line hose and covers for protection from electrical shock.

1.2 The following safety hazards caveat applies only to the test method portion, Section 7, of this specification: *This standard does not purport to address all of the safety problems, if any, 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.* Specific precautionary statements are given in Note 1.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1049 Specification for Rubber Insulating Covers[2]

D 1050 Specification for Rubber Insulating Line Hose[2]

D 2865 Practice for Calibration of Standards and Equipment for Electrical Insulating Materials Testing[3]

F 819 Definitions of Terms Relating to Electrical Protective Equipment for Workers[2]

2.2 *ANSI Standards:*

C 84.1 Voltage Ratings for Electric Power Systems and Equipment (60 Hz)[4]

2.3 *IEEE Standard:*

IEEE Standard 4, Techniques for High Voltage Testing[5]

3. Terminology

3.1 *breakdown*—the electrical discharge or arc occurring between the electrodes and through the equipment being tested.

3.2 *bulk storage*— the storage of hose or covers together with one or more layers piled neatly, but without the benefit of spacers, supports, or special protective containers.

3.3 *cover*—an electrically insulated enclosure designed to be installed temporarily on various types of irregularly shaped electrical equipment to protect personnel and equipment working in the close proximity.

3.4 *designated person*—an individual who is qualified by experience or training to perform an assigned task.

3.5 *distorted*—physically changed from the natural and original shape, caused by stress of any type.

3.6 *electrical testing facility*—a location with qualified personnel, testing equipment, and procedures for the inspection and electrical testing of electrical insulating protective equipment.

3.7 *electrode*—the energized or grounded conductor portion of electrical test equipment which is placed near or in contact with the material or equipment being tested.

3.8 *flashover*—the electrical discharge or arc occurring between electrodes and over or around, but not through, the equipment being tested.

3.9 *hose*—an electrical insulating tube with a longitudinal slit designed to be installed temporarily on energized electrical wires.

3.10 *ozone*—a very active form of oxygen that may be produced by corona, arcing, or ultraviolet rays.

3.11 *ozone cutting and checking*—cracks produced by ozone in a material under mechanical stress.

3.12 *retest*—the tests given after the initial acceptance test, usually performed at regular periodic intervals or as required because of physical inspection.

3.13 *voltage, maximum use*—the a-c voltage (rms) classification of the protective equipment that designates the maximum nominal design voltage of the energized system that may be safely worked. The nominal design voltage is equal to phase-to-phase voltage on multiphase circuits.

3.13.1 If there is no multiphase exposure in a system area, and the voltage exposure is limited to phase (polarity on d-c systems) to ground potential, the phase (polarity on d-c systems) to ground potential shall be considered to be the nominal design voltage.

---

[1] This specification is under the jurisdiction of ASTM Committee F-18 on Electrical Protective Equipment for Workers and is the direct responsibility of Subcommittee F18.25 on Insulating Cover-up Equipment.

Current edition approved Feb. 11, 1992. Published April 1992. Originally published as F 478 – 76. Last previous edition F 478 – 87.

[2] *Annual Book of ASTM Standards*, Vol 10.03.

[3] *Annual Book of ASTM Standards*, Vol 10.02.

[4] Available from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

[5] Available from Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08854-4150.

3.13.2 If electrical equipment and devices are insulated, or isolated, or both, such that the multiphase exposure on a grounded wye circuit is removed, then the nominal design voltage may be considered as the phase-to-ground voltage on that circuit.

3.14 *voltage, maximum retest*—voltage, either a-c rms or d-c average, that is equal to the proof test voltage for new protective equipment.

3.15 *voltage, nominal design*—a nominal value consistent with the latest revision of ANSI C84.1, assigned to the circuit or system for the purpose of conveniently designating its voltage class.

3.16 *voltage, retest*— voltage, either a-c rms or d-c average, that used protective equipment must be capable of withstanding for a specific test period without breakdown.

4. Significance and Use

4.1 Compliance with this specification should continue to provide personnel with insulating line hose and covers of known and acceptable quality after initial acceptance in accordance with Specifications D 1050 and D 1049. The standards herein are to be considered as minimum requirements.

4.2 A margin of safety shall be provided between the maximum use voltage and their class proof voltage in accordance with Specifications D 1050 and D 1049, as shown in Table 1.

4.3 The user of this type of protective equipment shall be knowledgeable of and instructed in the correct and safe inspection and use of this equipment.

5. Classification

5.1 Line hose covered in this specification are designed as Type I or Type II; Class 0, Class 1, Class 2, Class 3 or Class 4; Style A, Style B, Style C or Style D. Covers covered in this standard are designated as Type I or Type II; Class 0, Class 1, Class 2, Class 3 or Class 4; Style A, Style B, Style C, Style D or Style E.

5.1.1 *Type I*—High-grade *cis*-1,4-polyisoprene rubber compound of natural or synthetic origin, properly vulcanized.

5.1.2 *Type II*—Ozone resistant, made of any elastomer or combination of elastomeric compounds.

5.1.3 The class designations are based on the electrical properties in Specifications D 1050 and D 1049.

TABLE 1 Voltage Requirements Line Hose and Covers

Class Designation of Hose and Covers	A-C Use Voltage, rms, max[A]	A-C Retest Voltage, rms	D-C Retest Voltage, avg
0	1000	5000	20 000
1	7500	10 000	40 000
2	17 000	20 000	50 000
3	26 500	30 000	60 000
4	36 000	40 000	70 000

[A] The maximum use voltage is based on the following equations:

1. Maximum use voltage = 0.95 a-c and d-c retest voltage– 2 000, Classes 1, 2, 3, and 4.
2. Maximum use voltage = 0.95 a-c and d-c reset voltage – 30 500, Classes 1, 2, 3, and 4.
3. Maximum use voltage 1 0.95 a-c and d-c retest voltage – 18 000, Class 0.

5.1.4 The style designations are based on the designs and descriptions in Specifications D 1050 and D 1049.

6. Washing and Inspection

6.1 The recommended sequence of washing and inspection of contaminated insulating line hose and covers is as follows:

6.1.1 Washing,

6.1.2 Drying,

6.1.3 Inspection,

6.1.4 Marking, and

6.1.5 Packing for storage and shipment.

6.2 The hose and covers may be washed with a soap, mild non-bleaching detergent, or a cleaner recommended by the equipment manufacturer. After washing, the hose and covers shall be rinsed thoroughly with water.

6.2.1 The cleaning agent shall not degrade the insulating qualities of the line hose and covers.

6.2.2 A commercial tumble-type washing machine may be used, where practicable, but caution must be observed to eliminate any interior surfaces or edges that will cut, abrade, puncture, or pinch the hose or covers.

6.3 The hose and covers shall be air dried. The air temperature shall not be over 150°F (65.5°C). They may be suspended to allow drainage and air circulation or dried in a commercial tumble-type automatic dryer. In an automatic dryer, caution must be observed to eliminate any ozone-producing lamps and interior surfaces that will cut, abrade, puncture, or pinch the hose and covers.

6.4 Insulating line hose and covers shall be given a detailed inspection over the entire inner and outer surface for punctures, cuts, severe ozone cutting, or any other obvious condition that would adversely affect performance.

6.5 The hose and covers shall be marked in accordance with Section 12.

7. Electrical Tests

7.1 Where the inspection specified in Section 6 indicates that there may be reason to suspect the electrical integrity of a line hose or cover, an electrical test shall be performed before reissuing the line hose or cover for service.

7.2 Both a-c and d-c voltage retest methods are included in this section and either or both methods may be selected for electrical test.

NOTE 1—**Precaution**: In addition to other precautions, it is recommended that the test apparatus be designed to afford the operator full protection in the performance of duties. Reliable means of de-energizing and grounding the high-voltage circuit should be provided. It is particularly important to incorporate positive means of grounding the high-voltage section of d-c test apparatus due to the likely presence of high-voltage capacitance charges at the conclusion of the test.

7.3 Any electrical retest shall be performed at normal room temperatures and on clean hose or covers at an electrical testing facility.

7.4 *Electrodes*:

7.4.1 The entire area of each hose and cover shall be tested, as nearly as practicable, between electrodes that apply the electrical stress uniformly over the test area without producing damaging corona or mechanical strain in the hose or cover. The electrodes shall be of such dimensions and so placed as to avoid flashover at the edges.

7.4.2 For hose, the inside electrode shall be a metal mandrel of the size in Table 2. The outer electrode should be a close-fitting wet sponge or wet fabric blanket, metal foil, or a smooth metal form; extending to within ½ in. (13 mm) of the edge of the lip of the hose, and extending to a distance from the end of the hose as specified in Table 3. If the hose has a connector end, the form should extend to within ½ in. (13 mm) of the connector end. When Style C line hose is tested, the outer electrode may fit around the outside diameter of the hose, but not the extended lip (Note 2).

Note 2—These end clearances are intended to serve as a guide and under some conditions may have to be increased to prevent flashover.

7.4.3 For covers, the electrodes shall be one of those described in the following methods:

7.4.3.1 *Method 1 for Types I and II*—Water as inner and outer electrodes.

7.4.3.2 *Method 2 for Types I and II*—Wet sponge or wet felt inner electrode; and wet sponge, wet felt, or metal foil outer electrode.

7.4.3.3 *Method 3 for Type II*—Fixed form metal or metal foil inner or outer electrodes, or both.

Note 3—Method 3 electrodes shall not be used with Type I materials when testing with alternating current due to the possibility of corona cutting.

7.5 *A-C Test*:

7.5.1 *Voltage Supply and Regulation*—The voltage supply and control equipment should be of such size and design that, with the test specimens in the circuit, the crest factor (ratio of peak to mean effective) of the test voltage shall differ by not more than 5 % from that of a sinusoidal wave over the upper half of the range of the test voltage. The correct rms value of the sinusoidal voltage waveform applied to the hose or cover may be measured by one of the following methods:

7.5.1.1 A voltmeter used in conjunction with a calibrated instrument transformer connected directly across the high voltage circuit,

7.5.1.2 A calibrated electrostatic voltmeter connected directly across the high voltage circuit,

7.5.1.3 An a-c meter connected in series with appropriate high voltage type resistors directly across the high voltage circuit.

7.5.1.4 The accuracy of the voltage measuring circuit shall be ±2 % of full scale. To ensure the continued accuracy of the test voltage, as indicated by the test equipment voltmeter, the test equipment shall be calibrated at least annually in accordance with the latest revision of Practice D 2865 or IEEE Standard 4. The crest factor may be checked by the use of a peak reading voltmeter connected directly across the high-voltage circuit.

TABLE 2 Line Hose Test Mandrel Size

Hose Size, Inside Diameter, in. (mm)	Recommended Test Mandrel Size, Outside Diameter, in. (mm)
¼ (6.4)	3/16 (4.8)
⅝ (16)	9/16 (14.3)
1 (25)	15/16 (23.8)
1¼ (32)	1 3/16 (30)
1½ (38)	1¼ (31.8)
2 (51)	1¾ (44.4)
2½ (63.5)	2¼ (57.2)

TABLE 3 Flashover Clearances Between Electrodes[A]

Class Designation, Glove or Sleeve	A-C Retest		D-C Retest	
	in.	mm	in.	mm
0	3	76	3	76
1	3	76	4	102
2	5	127	6	152
3	7	178	8	203
4	10	254	12	305

[A] Flashover clearances are stated in terms of the shortest electrical air path between electrodes around the edge of the item being tested. In those cases where atmospheric conditions make the specified clearances impractical, the distance may be increased by the maximum of 2 in. (51 mm).

7.5.2 *A-C Retest*—Electrical retest of a hose or cover shall be in accordance with the requirements of Section 8.

Note 4—It is recommended that the retest voltage be applied initially at a low value and increased gradually at a constant rate-of-rise of approximately 1000 V/s a-c until the prescribed test voltage level is reached. Unless an electrical puncture has occurred already, the applied voltage should be reduced to at least half value at the end of the test period before opening the test circuit.

7.6 *D-C Test*:

7.6.1 *Voltage Supply and Regulation*:

7.6.1.1 The d-c test voltage can be obtained from a source capable of supplying a d-c voltage whose peak-to-peak a-c ripple component does not exceed 2 % of the average voltage value under no-load conditions.

7.6.1.2 The d-c test voltage shall be measured by a method that provides the average value of the voltage applied to the hose or cover. It is recommended that the voltage be measured by the use of a d-c meter connected in series with appropriate high-voltage type resistors across the high-voltage circuit; or by an electrostatic voltmeter of proper range. The accuracy of the voltage measuring circuit shall be within ±2 % of full scale. The test equipment shall be calibrated at least annually, in accordance with the latest revision of Practice D 2865 or the latest revision of IEEE Standard 4.

7.6.2 *D-C Retest*—Electrical retest of a hose or cover shall be in accordance with the requirements of Section 8.

Note 5—It is recommended the d-c retest voltage should be applied in the same manner as for a-c retest voltage, with the exception of a rate-of-rise of approximately 3000 V/s.

8. Rejection Criteria

8.1 Any hose or cover that fails to comply with the electrical retest requirements as indicated in this section shall be rejected.

8.2 Each hose or cover shall withstand the 60-Hz a-c retest voltage (rms value) or the d-c retest voltage (average value) specified in Table 1. The test voltage shall be applied continuously for not less than 1 min and not more than 3 min.

8.3 Any hose or cover that upon inspection is found to have punctures, deep cuts, severe corona or ozone cutting, contamination from injurious materials, or has lost its normal elasticity, shall be rejected.

8.4 Minor surface corona cutting or ozone checking need not be cause for rejection.

9. Precision and Bias

9.1 No statement is made about either the precision or the bias of the test methods in this specification for measuring the dielectric strength since the results merely state whether there is conformance to the criteria for success specified in the procedure.

10. Repairs

10.1 Hose and covers shall not be repaired. Hose may be used in shorter lengths if the defective portion is cut off.

11. Field Care, Inspection, and Storage

11.1 The field care and inspection of electrical insulating line hose and covers, performed by the individual, is an important requirement in providing protection from electrical shock. Defective or suspected defective line hose and covers shall not be used. They shall not be re-issued for use until they have been inspected and retested at an electrical testing facility, and meet the requirements of Section 8.

11.2 Before use and installation on energized conductors, devices, or equipment, line hose and covers shall be inspected visually for defects and at other times if there is cause to suspect any damage.

11.3 Line hose and covers shall be wiped clean of any oil, grease, or other damaging substances as soon as practicable. Line hose and covers whose surface becomes otherwise contaminated shall be set aside and cleaned in accordance with Section 6.

11.4 Loose bulk storage or packaging may be used for hose or covers in transit or in temporary holding operations provided such storage is limited to periods not in excess of 1 month, and there is not severe distortion.

11.5 Line hose and covers shall be stored without distortion and mechanical stress in a location as cool, dark, and dry as possible. They shall be stored or packaged in a suitable compartment or in containers such as boxes or bags. The area shall be as free as possible of ozone, chemicals, oils, solvents, damaging vapors and fumes, and away from electrical discharges and sunlight.

11.6 Line hose and covers shall not have any identifying adhesive tapes or labels applied to them by other than authorized personnel. Tape shall not be used to secure line hose and covers for shipment or storage.

11.7 Line hose and covers with any of the following defects shall not be used:

11.7.1 Holes other than factory produced openings on the top, sides, or lips of the line hose or covers, tears and punctures, serious cuts, and rope or wire burns that extend more than one third the depth of the thickness of the rubber.

11.7.2 Texture changes: swelling, softening, hardening, and becoming sticky or inelastic.

11.7.3 Other defects that damage the insulating properties.

11.8 Line hose and cover should be left in service on energized lines for minimum necessary periods of time as exposure may result in ozone checking, corona cutting, or excessive weathering.

12. Marking

12.1 If the hose and covers are not readily identifiable as to class, they shall be marked.

12.2 Hose or covers that have been rejected and are not suitable for electrical service shall be defaced, cut, or otherwise marked and identified to indicate that they are not to be used for electrical service.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

* * *

Document Name:

CFR Section(s):

Standards Body:

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 631 – 80 (Reapproved 1985)

Standard Method for Testing Full Scale Advancing Spill Removal Devices[1]

1. Scope

1.1 This standard provides a method for determining performance parameters of full-scale advancing oil spill removal devices in recovering floating oil when tested in a controlled test facility.

1.2 *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 whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 88 Test Method for Saybolt Viscosity[2]

D 341 Viscosity-Temperature Charts for Liquid Petroleum Products[3]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)[3]

D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[3]

D 2161 Method for Conversion of Kinematic Viscosity to Saybolt Universal Viscosity or to Saybolt Furol Viscosity[4]

D 2904 Practice for Interlaboratory Testing of a Textile Test Method that Produces Normally Distributed Data[5]

D 2905 Practice for Statements on Number of Specimens for Textiles[5]

D 2906 Practice for Statements on Precision and Bias for Textiles[5]

3. Summary of Method

3.1 The spill removal device may be tested in a wave/tow tank or other suitable facility with a controllable test environment. Controlled test variables include device velocity relative to the water velocity, oil properties and slick thickness, wave conditions, and pertinent device variables. It is essential that the device be operated in a steady-state condition during the sampling period when oil encounter rate, recovery rate, recovery efficiency, and device parameters are monitored, measured, and recorded.

4. Significance

4.1 This test method provides quantitative data in the form of oil recovery rates, throughput efficiencies, and oil recovery efficiencies under controlled test conditions. The data can be used for evaluating design characteristics of a particular advancing spill removal device or as a means of comparing two or more devices. Caution must be exercised whenever test data are used to predict performance in actual spill situations as the uncontrolled environmental conditions which affect performance in the field are rarely identical to conditions in the test tank. Other variables such as mechanical reliability, presence of debris, ease of repair, ease of deployment, required operator training, operator fatigue, seaworthiness, and transportability also affect performance in an actual spill but are not measured by this method. These variables should be considered along with the test data when making comparisons or evaluations of advancing spill removal devices.

5. Definitions

5.1 *oil recovery rate*—the volume of oil recovered by the device per unit of time.

5.2 *throughput efficiency*—the ratio, expressed as a percentage, of the volume of oil recovered to the volume of oil encountered.

5.3 *oil recovery efficiency*—the ratio, expressed as a percentage, of the volume of oil recovered to the volume of total fluids recovered.

5.4 *advancing oil spill removal device*—a device that removes spilled oil from the water surface when there is relative motion between the device and the water. The device may move through the surrounding fluid or it may be stationary and the surrounding fluid moved past the device.

5.5 *data collection period*—the period of time during a test run when the performance data is recorded.

5.6 *oil*—the fluid distributed on the water of the test facility and recovered by the spill removal device (see Section 8).

5.7 *oil encounter rate*—the volume of oil per unit time actively directed to the removal mechanism.

5.8 *oil slick thickness*—the average thickness of the oil slick encountered by the test device.

5.9 *full-scale equipment*—equipment of the size that is (or will be) available commercially.

6. Interferences

6.1 The table of results (see 13.1) shall address the possibility of test facility effects. For example, wall effects

---

[1] This method is under the jurisdiction of ASTM Committee F-20 on Spill Control Systems and is the direct responsibility of Subcommittee F20.12, on Removal.

Current edition approved Jan. 3, 1980. Published April 1980.

[2] *Annual Book of ASTM Standards*, Vol 04.04.

[3] *Annual Book of ASTM Standards*, Vol 05.01.

[4] *Annual Book of ASTM Standards*, Vol 05.02.

[5] *Annual Book of ASTM Standards*, Vol 07.01.

may interfere hydrodynamically with the device's performance.

7. Test Facilities

7.1 At least two types of test facilities, a wave/tow tank and a current tank, may be used to conduct the test outlined in this method.

7.1.1 *Wave/Tow Tank*—A wave/tow tank has a movable bridge or other mechanism for towing the test device through water for the length of the facility. A wave generator may be installed on one end, or on the side of the facility, or both.

7.1.2 *Current Tank*—A current tank is a water-filled tank equipped with a pump or other propulsion system for moving the water through a test section where the test device is mounted. A wave generator may be installed on this type of test facility.

7.1.3 Other facilities, such as private ponds or flumes, may also be used, provided the test parameters can be suitably controlled and environmental regulations adhered to.

7.2 Ancillary systems for facilities include, but are not limited to, a distribution system for accurately delivering oils to the water surface, skimming systems to assist in cleaning the facility between tests, and adequate tankage for storing the test oils.

8. Test Oils

8.1 Three standard test oils for use with this test method are defined in Appendix X1. These oils cover a wide range of properties and are designated with respect to viscosity and specific gravity as light, medium, and heavy. These oils must be Newtonian fluids and may be crude, refined, or simulant.

8.2 If it is desired to use an oil with properties that do not correspond to a standard test oil, a statement must be made in the table of results (see 13.1) that a standard test oil was not used. This statement must discuss the effect of the nonstandard oil on test data with respect to the probable results using the most similar standard test oil.

8.3 The viscosity of oil varies greatly with temperature. Frequently test oils must be distributed in the test facility at temperatures different from the water temperature. When this occurs, the oil generally will approach the surface water temperature.

8.4 If oils that originally meet the conditions stated in Appendix X1 are reused, their properties may change and should be evaluated prior to reuse.

9. Safety Precautions

9.1 Test operations shall conform to established safety requirements for both test facility operations and oil handling. Particular caution must be exercised when handling flammable or toxic test oils.

10. Test Device

10.1 The test device shall be deployed in accordance with facility operating characteristics. The device must be operated in accordance with the manufacturer's specified operating instructions with respect to mechanical operations and established maintenance routines. Modifications to the device for testing purposes shall follow the manufacturer's recommendations and shall be recorded with the test results.

11. Calibration and Standardization

11.1 At the outset of the test, the independent or control test parameters are selected. Typical test variables include:

Test oils	light, medium, and heavy
Test speed	upper and lower limits and speed increments selected as appropriate
Oil slick thickness	appropriate increments for the device being tested
Wave conditions	wave characteristics of significant height, average length, and period and pattern may be varied as appropriate

12. Procedure

12.1 Prior to the test, select the operating parameters, such as tow speed, wave conditions, test oil, and oil distribution rate. Then prepare the facility and spill removal device for the test run. Occasionally, it may be necessary to preload the device with oil to achieve steady-state operation within a reasonable period of time. Any preload must be carefully measured and discharged into the device. Measure or note immediately prior to each test the following parameters describing ambient conditions:

12.1.1 Air temperature,

12.1.2 Water temperature near the surface,

12.1.3 Wind speed,

12.1.4 Wind direction relative to the test device, and

12.1.5 General weather conditions, for example, rain, overcast, sunny, etc.

12.2 Start the wave generator (if necessary), oil distribution system, tow mechanism or water flow, and the spill removal device to begin a test run. Direct the discharge flow of recovered fluid from the device into a holding tank or back into the test tank out of the device's sweep path during the transient start-up period. After steady-state operation is achieved, monitor the discharge flow to obtain performance data. The discharge may be pumped through a flow meter to obtain a flow rate and sampled periodically to obtain the oil-to-fluid ratio. Alternatively, the discharge may be diverted into calibrated sample tanks from which the flow rate and oil-to-fluid ratio may be determined. In either case, the data collection period begins when sampling starts and ends when sampling stops. During the data collection period or immediately thereafter, measure and record the following parameters:

12.2.1 Oil distribution rate,

12.2.2 Fluid recovery rate (oil and water),

12.2.3 Tow speed or current speed,

12.2.4 Wave characteristics,

12.2.5 Length of the data collection period,

12.2.6 Oil encounter rate, and

12.2.7 Operating parameters of the spill recovery device such as belt speed, weir setting, pump speed, etc.

12.3 At the completion of the data collection period, divert the discharge of the spill removal device back into the holding tank or test tank. Stop the wave generator, tow mechanism or water flow, oil distribution, and spill removal device. Analyze samples of the discharge to determine oil-to-fluid ratio. Analyze samples of the recovered test oil to determine the following:

12.3.1 Specific gravity,

12.3.2 Viscosity,

12.3.3 Surface tension,

12.3.4 Interfacial tension with respect to test tank water, and

12.3.5 Water content.

12.4 Perform the analyses in 12.3 at the surface water temperature or in such a way that the values of these parameters at the surface water temperature can be determined from the analytical data.

13. Calculation or Interpretation of Results

13.1 Prepare a table of results for the test run containing the following entries:

13.1.1 Test identification number.

13.1.2 Date and time of day.

13.1.3 Average speed (tow speed or current speed) during data collection period.

NOTE—This rate is averaged over the data collection period.

13.1.4 Test oil type (light, medium, heavy, or non-standard).

13.1.5 Oil slick thickness.

13.1.6 For regular waves, include height, average period (or length), and whether head or following. For irregular waves, include significant height, significant frequency, spectral characteristics, and whether head or following.

13.1.7 Oil properties at test temperatures, including specific gravity, viscosity, surface tension, interfacial tension with tank water, and initial water content of oil.

13.1.8 Total volume of oil distributed during data collection period.

13.1.9 Total volume of oil encountered during data collection period.

13.1.10 Total volume of fluid (oil/water) recovered during data collection period.

13.1.11 Average oil distribution rate (see Note).

13.1.12 Average oil encounter rate (see Note).

13.1.13 Average fluid (oil/water) recovery rate (see Note).

13.1.14 Average oil recovery efficiency (see Note).

13.1.15 Average oil recovery rate (see Note).

13.1.16 Average throughput efficiency (see Note).

13.1.17 Ambient conditions, including air temperature, surface water temperature, wind speed, wind direction, and brief statement of weather conditions during test run.

13.1.18 Length of data collection period.

13.1.19 Volume of oil in device at beginning of data collection period.

13.1.20 Volume of oil in device at end of data collection period.

13.1.21 Operating parameters of the device such as belt speed, weir setting, pump speed, etc.

13.1.22 Brief discussion of interferences or limiting factors (see 6.1).

13.2 If any of the data required by 13.1 are not applicable to the device being tested, a statement must be included in the table of results describing the reasons for omitting the data.

14. Precision and Accuracy

14.1 Statistical measures of accuracy and precision may be determined that will indicate the reliability of test results as well as the degree of standardization in test procedures. Examples of procedures may be found in Appendix X2.

APPENDIXES

X1. STANDARD TEST OILS

X1.1 General

X1.1.1 The ranges of physical properties for standard test oils will be as outlined in X1.2 through X1.5.

X1.2 Viscosity

X1.2.1 *Light Oil*—3 to 10 cSt (mm^2/s) at 60°F (15.6°C).

X1.2.2 *Medium Oil*—100 to 300 cSt (mm^2/s) at 60°F (15.6°C).

X1.2.3 *Heavy Oil*—500 to 2000 cSt (mm^2/s) at 60°F (15.6°C).

X1.3 Specific Gravity

X1.3.1 *Light Oil*—0.83 to 0.88.

X1.3.2 *Medium Oil*—0.90 to 0.94.

X1.3.3 *Heavy Oil*—0.94 to 0.97.

X1.4 Surface Tension

X1.4.1 *All Oils*—24 to 34 dynes/cm (mN/m) with distilled water at 77°F (25°C).

X1.5 Interfacial Tension

X1.6 *All Oils*—26 to 32 dynes/cm (mN/m) with distilled water at 77°F (25°C).

X2. DETERMINATION OF PRECISION AND ACCURACY

X2.1 The following properties may be determined by the ASTM standards listed which are considered for use in this method for full scale advancing skimmers:

X2.1.1 *Viscosity*—Methods D 88 and D 445.

X2.1.2 *Specific Gravity*—Method D 1298.

X2.1.3 *Viscosity versus Temperature*—Standard D 341.

X2.1.4 *Viscosity Conversion*—Method D 2161.

X2.1.5 *Interlaboratory Testing*—Practice D 2904.

X2.1.6 *Number of Test Replicates*—Practice D 2905.

X2.1.7 *Precision and Accuracy*—Practice D 2906.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

* * *

Document Name: ASTM F631: Standard Guide for Collecting Skimmer Performance Data in Controlled Environments

CFR Section(s): 33 CFR 154 Appendix C

Standards Body: American Society for Testing and Materials

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 631 – 93

Standard Guide for Collecting Skimmer Performance Data in Controlled Environments[1]

This standard is issued under the fixed designation F 631; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This standard provides a guide for determining performance parameters of full-scale oil spill removal devices in recovering floating oil when tested in controlled environments.

1.2 This guide involves the use of specific test oils that may be considered hazardous materials after testing is completed. It is the responsibility of the user of this guide to procure and abide by the necessary permits for disposal of the used test oil.

1.3 *This standard does not purport to address all of the safety problems, if any, 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. Referenced Documents

2.1 *ASTM Standards:*

D 97 Test Method for Pour Point of Petroleum Oils[2]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)[2]

D 971 Test Method for Interfacial Tension of Oil Against Water by the Ring Method[2,3]

D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[2]

D 2983 Test Method for Low-Temperature Viscosity of Automotive Fluid Lubricants Measured by Brookfield Viscometer[4]

D 4007 Test Method for Water and Sediment in Crude Oil by the Centrifuge Method (Laboratory Procedure)[4]

F 625 Practice for Describing Environmental Conditions Relevant to Spill Control Systems for Use on Water[5]

F 808 Guide for Collecting Skimmer Performance Data in Uncontrolled Environments[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *advancing skimmer*—a device that removes spilled oil from the water surface when there is relative motion between the device and the water. The device may move through the surrounding fluid or it may be stationary and the surrounding fluid moved past the device.

3.1.2 *data collection period*—the period of time during a test run when the performance data are recorded.

3.1.3 *full-scale equipment*—equipment of the size that is (or will be) available commercially.

3.1.4 *oil*—the fluid distributed on the water of the test facility and recovered by the spill removal device (see Section 8).

3.1.5 *oil encounter rate*—the volume of oil per unit time actively directed to the removal mechanism (m^3/h).

3.1.6 *oil recovery efficiency*—the ratio, expressed as a percentage, of the volume of oil recovered to the volume of total fluids recovered.

3.1.7 *oil recovery rate*—the volume of oil recovered by the device per unit of time (m^3/h).

3.1.8 *oil slick thickness*—the average thickness of the oil slick encountered by the test device (mm).

3.1.9 *throughput efficiency*—the ratio, expressed as a percentage, of the volume of oil recovered to the volume of oil encountered.

4. Significance and Use

4.1 This guide provides quantitative data in the form of oil recovery rates, throughput efficiencies, and oil recovery efficiencies under controlled test conditions. The data can be used for evaluating design characteristics of a particular spill removal device or as a means of comparing two or more devices. Caution must be exercised whenever test data are used to predict performance in actual spill situations as the uncontrolled environmental conditions that affect performance in the field are rarely identical to conditions in the test tank. Other variables such as mechanical reliability, presence of debris, ease of repair, ease of deployment, required operator training, operator fatigue, seaworthiness, and transportability also affect performance in an actual spill but are not measured by this guide. These variables should be considered along with the test data when making comparisons or evaluations of spill removal devices.

5. Summary of Guide

5.1 The spill removal device may be tested in a wave/tow tank or other facility that is suitable for controlling the appropriate test parameters. Significant testing results can be obtained using simple test tanks or ponds, particularly when calm water and low velocity advancing tests are desired as an economical means to screen and compare devices. Controlled test variables include relative velocity, oil properties

---

[1] This guide is under the jurisdiction of ASTM Committee F-20 on Hazardous Substances and Oil Spill Response and is the direct responsibility of Subcommittee F20.12 on Removal.

Current edition approved July 15, 1993. Published September 1993. Originally published as F 631 – 80. Last previous edition F 631 – 80 (1985).

[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 10.03.

[4] *Annual Book of ASTM Standards*, Vol 05.02.

[5] *Annual Book of ASTM Standards*, Vol 11.04.

and slick thickness, wave conditions, and pertinent device variables. It is essential that the device be operated in a steady-state condition during the sampling period when oil encounter rate, recovery rate, recovery efficiency, and device parameters are monitored, measured, and recorded.

6. Interferences

6.1 The table of results (see 13.1) shall address the possibility of test facility effects. For example, wall effects may interfere hydrodynamically with the device's performance.

6.2 Care should be taken that any containment means that is not inherent in the skimming device does not affect the oil distribution to the device.

7. Test Facilities

7.1 Several types of test facilities can be used to conduct the test outlined in this guide.

7.1.1 *Wave/Tow Tank*—A wave/tow tank has a movable bridge or other mechanism for towing the test device through water for the length of the facility. A wave generator may be installed on one end, or on the side of the facility, or both.

7.1.2 *Current Tank*—A current tank is a water-filled tank equipped with a pump or other propulsion system for moving the water through a test section where the test device is mounted. A wave generator may be installed on this type of test facility.

7.1.3 Other facilities, such as private ponds or flumes, may also be used, provided the test parameters can be suitably controlled.

7.2 Ancillary systems for facilities include, but are not limited to, a distribution system for accurately delivering oils to the water surface, skimming systems to assist in cleaning the facility between tests, and adequate tankage for storing the test oils.

8. Test Oils

8.1 Test oils for use with this guide should be selected to fall within the parameters specified in Appendix X1. These oils may be crude, refined, or simulated.

8.2 If test oils vary significantly from the recommended ranges, the test report shall discuss the implications of such deviations on the performance of the device.

8.3 The viscosity of oil varies greatly with temperature. Frequently test oils must be distributed in the test facility at temperatures different from the water temperature. When this occurs, the oil generally will approach the surface water temperature.

8.4 If oils that originally meet the conditions stated in Appendix X1 are reused, their properties may change and should be evaluated prior to reuse.

9. Safety Precautions

9.1 Test operations shall conform to established safety (and regulatory) requirements for both test facility operations and oil handling. Particular caution must be exercised when handling flammable or toxic test oils.

10. Test Device

10.1 The test device shall be deployed in accordance with facility operating characteristics. The device must be operated in accordance with the manufacturer's specified operating instructions with respect to mechanical operations and established maintenance routines. Modifications to the device, in any modification from commercial design, shall be recorded with the test results.

11. Test Variables

11.1 At the outset of the test, the independent or control test parameters are selected. The test evaluator should include a discussion of the procedures that were used to establish calibration and standardization. Data should be expressed with an indication of variability. Typical test variables include:

Test oils	as stated in Appendix XI
Test speed	upper and lower limits and speed increments selected as appropriate within ±0.1 m/s
Oil slick thickness	1, 5, and 25 mm and other thicknesses as appropriate
Wave conditions	wave characteristics of significant height, average length, and average significant period and pattern may be varied as appropriate to the design of the skimmer
Wave height	0 mm, 150 mm, and 450 mm
Debris	Use various materials to simulate various forms of natural debris that may hinder skimmer operation. Recommended materials include: polypropylene rope, ½ in. diameter, cut into lengths ranging from 4 in. to 2 ft; softwood lumber, nominal dimensions 2 by 2 in., lengths ranging from 4 in. to 2 ft; foam sponges, nominal size 4 to 12 in; broken ice, nominal size 1 to 4 in. diameter; seaweed, lengths up to 5 ft; plastic or aluminum disposable containers (such as soda cans); sorbent pads, booms, or sheets; or other suitable materials. Use adequate number of pieces to produce concentrations at the skimmer inlet area corresponding to 50 % surface coverage.

12. Procedure

12.1 Prior to the test, select the operating parameters, such as tow speed (as applicable), wave conditions, test oil, and oil distribution rate. Then prepare the facility and spill removal device for the test run. Occasionally, it may be necessary to preload the device with oil to achieve steady-state operation within a reasonable period of time. Any preload must be carefully measured and discharged into the device. Measure or note immediately prior to each test the following parameters describing ambient conditions:

12.1.1 Air temperature (°C),

12.1.2 Water temperature near the surface (°C),

12.1.3 Wind speed (m/s),

12.1.4 Wind direction relative to the test device, and

12.1.5 General weather conditions, for example, rain, overcast, sunny, etc.

12.2 Start the wave generator (if necessary), oil distribution system, tow mechanism or water flow (if necessary), and the spill removal device to begin a test run. Direct the discharge flow of recovered fluid from the device into a holding tank or back into the test tank out of the device's sweep path during the transient start-up period. After steady-state operation is achieved, monitor the discharge flow to obtain performance data. The discharge may be pumped through a flowmeter to obtain a flow rate and sampled periodically to obtain the oil-to-fluid ratio. Alternatively, the discharge may be diverted into calibrated sample tanks from which the flow rate and oil-to-fluid ratio may be determined. In either case, the data collection period begins when sampling starts and ends when sampling stops. During the data collection period or immediately thereafter, measure and record the following parameters:

12.2.1 Oil distribution rate (m^3/h),

12.2.2 Fluid recovery rate (oil and water) (m^3/h),

12.2.3 Tow speed or current speed (m/s),

12.2.4 Wave characteristics (see Practice F 625 for environmental descriptors and classifications),

12.2.5 Length of data collection period,

12.2.6 Oil encounter rate (m^3/h), and

12.2.7 Operating parameters of the spill recovery device such as belt speed (m/s), weir setting (mm below fluid level), pump speed (r/min), etc.

12.3 At the completion of the data collection period, divert the discharge of the spill removal device back into the holding tank or test tank. Stop the wave generator, tow mechanism or water flow, oil distribution, and spill removal device. Depending on the degree and variability of changes in the oil properties, the test evaluator will determine the required schedule of analysis to provide representative samples. Analyze representative samples of the discharge to determine oil-to-fluid ratio. Analyze representative samples of the recovered test oil to determine the following:

12.3.1 Density (g/mL),

12.3.2 Viscosity (mm^2/s),

12.3.3 Surface tension (mN/m),

12.3.4 Interfacial tension with respect to test tank water (mN/m), and

12.3.5 Water content (percent of total mixture).

12.4 Perform the analyses in 12.3 at the surface water temperature or in such a way that the values of these parameters at the surface water temperature can be determined from the analytical data.

13. Report

13.1 Prepare a schematic diagram of the layout for the test series.

13.2 Prepare a table of results for the test run containing the following entries:

13.2.1 Test identification number.

13.2.2 Date and time of day.

13.2.3 Average speed (tow speed or current speed, m/s) during data collection period.

NOTE—This rate is averaged over the data collection period.

13.2.4 Test oil type.

13.2.5 *Oil slick thickness*—Calculation of slick thickness should include a brief discussion of the method used for measuring variation in the thickness, especially for heavy oils.

13.2.6 For regular waves, include height, average period (or length), and whether head or following. For irregular waves, include significant height, significant frequency, spectral characteristics, and whether head or following. Primary and secondary (reflected) wave basin characteristics shall be described.

13.2.7 Oil properties at test temperatures, including density, viscosity, surface tension, interfacial tension with tank water, and initial water content of oil.

13.2.8 Recovered oil properties as performed in 12.3.

13.2.9 Total volume of oil distributed during data collection period.

13.2.10 Total volume of oil encountered during data collection period.

13.2.11 Total volume of fluid (oil/water) recovered during data collection period.

13.2.12 Average oil distribution rate (see Note).

13.2.13 Average oil encounter rate (see Note).

13.2.14 Average fluid (oil/water) recovery rate (see Note).

13.2.15 Average oil recovery efficiency (see Note).

13.2.16 Average oil recovery rate (see Note).

13.2.17 Average throughput efficiency (see Note).

13.2.18 Ambient conditions, including air temperature, surface water temperature, wind speed, wind direction, and brief statement of weather conditions during test run.

13.2.19 Length of data collection period.

13.2.20 Volume of oil in device at beginning of data collection period.

13.2.21 Volume of oil in device at end of data collection period.

13.2.22 Operating parameters of the device such as belt speed, weir setting, pump speed, etc.

13.2.23 For tests conducted in the presence of debris, report the following:

13.2.23.1 Size and type of debris forms used;

13.2.23.2 Approximate concentration, expressed as surface coverage (percent);

13.2.23.3 Mode of debris handling, or processing, or both;

13.2.23.4 Effectiveness of debris handling, or processing, or both; and

13.2.23.5 When comparing results, specify reasons for performance degradation (if any), differentiating between oil encounter degradation and that of the skimming mechanism.

13.2.24 Brief discussion of interferences or limiting factors (see 6.1).

13.3 If any of the data required by 13.2 are not applicable to the device being tested, a statement must be included in the table of results describing the reasons for omitting the data.

13.4 Report qualitative comments on device operating parameters such as mechanical reliability, ease of repair, ease of deployment, required operator training, operator fatigue, seaworthiness, and transportability.

14. Keywords

14.1 oil; oil recovery; skimmer

APPENDIX

(Nonmandatory Information)

X1. STANDARD TEST OILS

X1.1 Values in Table X1.1 refer to test fluid properties at test temperatures. Test methods for fluid properties are specified as follows: viscosity, Test Methods D 445 and D 2983 (report shear rate for viscosity measurement, should be in the range of 1 to 10 s^{-1}); density, Test Method D 1298; interfacial tension, Test Method D 971; pour point, Test Method D 97. For all test oils (with the exception of emulsions), maximum sediment and water (BSW) of 0.1 % (see Test Method D 4007).

X1.2 Of the five viscosity ranges, numbers I, II, and IV are especially recommended as being indicative, respectively, of lightly weathered, moderately weathered, and significantly weathered crude oils.

X1.3 The following lists examples of hydrocarbon oils that could be used to fall within the specified ranges. This list is intended for guidance only; it should be noted that viscosities of all oils will vary greatly with both temperature and the specific product. Selected oils may be crude, refined, or simulated. In the case of crudes and light refined products, it is acceptable and may be desirable to pre-weather the oil in order to produce a desired viscosity, increase the oil's flash point to a safe level, and produce a more stable test fluid.

TABLE X1.1 Candidate Test Oils

NOTE—Test oils should be selected to fall within these five categories.

	Viscosity, mm²/s	Density, g/mL	Oil-Air Interfacial Tension, mN/m	Oil-Water Interfacial Tension, mN/m	Pour Point, °C
I[A]	150 to 250	0.90 to 0.93	28 to 34	20 to 30	< −3
II[B]	1500 to 2500	0.92 to 0.95	30 to 40	20 to 30	< −3
III[C]	17 000 to 23 000	0.95 to 0.98	20 to 40	20 to 40	< 10
IV[D]	50 000 to 70 000	0.96 to 0.99	20 to 40	20 to 40	...
V[E]	130 000 to 170 000	0.96 to 0.99	20 to 40	20 to 40	...

[A] 1) Alaska North Slope crude oil, 10 to 15 % weathered by volume.
2) Fuel oil No. 4 (heavy); can be prepared by blending 40 % fuel oil No. 2 and 60 % fuel oil No. 6.

[B] Fuel oil No. 5; can be prepared by blending 20 to 25 % fuel oil No. 2 with 75 to 80 % fuel oil No. 6.

[C] Residual fuel oil (that is, fuel oil No. 6 prepared to above criteria).

[D] Residual fuel oil (that is, heavy cut of fuel oil No. 6).

[E] Emulsified crude oil, 50 to 80 % water content. The oil may be emulsified by blowing compressed air through water on which the oil is floating.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name:

CFR Section(s):

Standards Body:

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 682 – 82a (Reapproved 1998)

An American National Standard

Standard Specification for Wrought Carbon Steel Sleeve-Type Pipe Couplings[1]

This standard is issued under the fixed designation F 682; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers wrought carbon steel sleeve-type pipe couplings suitable for joining carbon steel pipes.

1.2 Type I couplings are intended for use on all schedules of pipe in which the pipe wall thickness does not exceed the wall thickness of standard weight pipe. Type II couplings are intended for use on all schedules of pipe in which the pipe wall thickness does not exceed the wall thickness of extra strong pipe.

1.3 This specification does not cover cast steel couplings.

NOTE 1—The values stated in inch-pound units are to be regarded as the standard.

NOTE 2—See Appendix X1 for rationale used to develop this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 53/A 53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless[2]

A 106 Specification for Seamless Carbon Steel Pipe for High-Temperature Service[2]

A 234/A234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service[2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[4]

2.2 *Manufacturer's Standardization Society of the Valve and Fittings Industry Standard:*

MSS SP-25 Standard Marking System for Valves, Fittings, Flanges and Unions[5]

2.3 *ASME Boiler and Pressure Vessel Code:*

Section VIII Unfired Pressure Vessels[6]

Section IX Welding Qualifications[6]

2.4 *Federal Regulations:*

Title 46, Code of Federal Regulations (CFR), Shipping, Parts 41 to 69[7]

2.5 *ANSI Standards:*

B16.5 Pipe Flanges and Flange Fittings[8]

3. Classification

3.1 Couplings are furnished in two types as follows:

3.1.1 *Type I*—Couplings (see 1.2).

3.1.2 *Type II*—Couplings (see 1.2).

NOTE 3—Type II couplings may be used in place of Type I couplings for all schedules of pipe in which the pipe wall thickness does not exceed the wall thickness of standard weight piping through 18 in. or Schedule 40 piping through 16 in.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity (number of couplings of each size and type),

4.1.2 Name of material (sleeve-type pipe couplings),

4.1.3 Size (nominal, see Table 1 and Table 2 and Fig. 1),

4.1.4 Type (see 3.1),

4.1.5 ASTM designation and date of issue.

5. Materials and Manufacture

5.1 *Materials*—The couplings shall be manufactured from material having a chemical composition conforming to the requirements of 7.1 and with the mechanical properties of Section 9.

5.2 *Manufacture*—The initial form of the raw material shall be at the discretion of the manufacturer except couplings shall not be machined from unformed plate. The material shall be such that the finished couplings conform to all of the specified requirements (see Appendix X2).

5.3 Couplings fabricated by welding shall be (*a*) made by welders, welding operators, and welding procedures qualified

---

[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

Current edition approved July 30, 1982. Published October 1982. Originally published as F 682 – 80. Last previous edition F 682 – 82.

[2] *Annual Book of ASTM Standards*, Vol 01.01.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 03.05.

[5] Available from Manufacturer's Standardization Society of the Valve and Fitting Industry, 1815 N. Fort Myer Dr., Arlington, Va 22209.

[6] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[7] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[8] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

TABLE 1 Dimensions for Type I Couplings (See Fig. 1)

Nominal Size, in.	Dimension A, Inside Diameter, in. (mm)[A]	Dimension B, Outside Diameter, in. (mm)[B]	Dimension C, Thickness, min, in. (mm)	Dimension D, Length, in. (mm)[C]
¼	0.589 (15.0)	0.875 (22.2)	0.143 (3.6)	1 (25)
⅜	0.724 (18.4)	0.992 (25.2)	0.134 (3.4)	1¼ (32)
½	0.889 (22.6)	1.201 (30.5)	0.156 (4.0)	1¼ (32)
¾	1.099 (27.9)	1.401 (35.6)	0.151 (3.8)	1½ (38)
1	1.364 (34.6)	1.710 (43.4)	0.173 (4.4)	1½ (38)
1¼	1.709 (43.4)	2.057 (52.2)	0.174 (4.4)	1½ (38)
1½	1.949 (49.5)	2.306 (58.6)	0.179 (4.5)	1½ (38)
2	2.424 (61.6)	2.807 (71.3)	0.192 (4.9)	1½ (38)
2½	2.924 (74.3)	3.444 (87.5)	0.260 (6.6)	1½ (38)
3	3.545 (90.0)	4.105 (104.3)	0.280 (7.1)	1½ (38)
3½	4.070 (103.4)	4.633 (117.7)	0.282 (7.2)	2 (51)
4	4.570 (116.1)	5.164 (131.2)	0.297 (7.5)	2 (51)
5	5.660 (143.8)	6.286 (159.7)	0.313 (8.0)	2 (51)
6	6.720 (170.7)	7.409 (188.2)	0.345 (8.8)	2 (51)
8	8.720 (221.5)	9.527 (242.0)	0.404 (10.3)	2½ (64)
10	10.880 (276.4)	11.875 (301.6)	0.498 (12.6)	2½ (64)
12	12.880 (327.2)	13.800 (350.5)	0.460 (11.7)	2½ (64)
14	14.140 (359.2)	15.050 (382.3)	0.455 (11.6)	2½ (64)
16	16.160 (410.5)	17.050 (433.1)	0.445 (11.3)	2½ (64)
18	18.180 (461.8)	19.050 (483.9)	0.435 (11.0)	2½ (64)

[A] Tolerances shall be (*1*) Sizes through 3 in. incl: +0.000, −0.010 in. (+0.000, −0.254 mm); (*2*) Sizes 3½through 10 in. incl: +0.030, −0.000 in. (+0.762, −0.000 mm); and (*3*) Sizes above 10 in.: +0.060, −0.000 in. (+1.524, −0.000 mm).

[B] Tolerances shall be (*1*) Sizes through 10 in. incl: +0.125, −0.000 in. (+3.175, −0.000 mm) and (*2*) Sizes above 10 in.: +1.000, −0.000 in. (+25.4, −0.000 mm).

[C] Tolerances for all sizes shall be +0.250, −0.000 in. (+6.4, −0.000 mm).

TABLE 2 Dimensions for Type II Couplings (See Fig. 1)

Nominal Size, in.	Dimension A, Inside Diameter, in. (mm)[A]	Dimension B, Outside Diameter, in. (mm)[B]	Dimension C, Thickness, min, in. (mm)	Dimension D, Length, in. (mm)[C]
¼	0.589 (15.0)	1.055 (26.8)	0.233 (5.9)	1 (25)
⅜	0.724 (18.4)	1.156 (29.4)	0.216 (5.5)	1¼ (32)
½	0.889 (22.6)	1.369 (34.8)	0.240 (6.1)	1¼ (32)
¾	1.099 (27.9)	1.557 (39.5)	0.229 (5.8)	1½ (38)
1	1.364 (34.6)	1.876 (47.7)†	0.256 (6.5)†	1½ (38)
1¼	1.709 (43.4)	2.221 (56.4)†	0.256 (6.5)†	1½ (38)
1½	1.949 (49.5)	2.469 (62.7)†	0.260 (6.6)†	1½ (38)
2	2.424 61.6)	2.986 (75.8)†	0.281 (7.1)†	1½ (38)
2½	2.924 (74.3)	3.648 (92.7)†	0.362 (9.2)†	1½ (38)
3	3.545 (90.0)	4.340 (110.2)†	0.398 (10.1)†	1½ (38)
3½	4.070 (103.4)	4.891 (124.2)†	0.411 (10.4)†	2 (51)
4	4.570 (116.1)	5.444 (138.3)	0.437 (11.1)	2 (51)
5	5.660 (143.8)	6.613 (168.0)	0.477 (12.1)	2 (51)
6	6.720 (170.7)	7.875 (200.0)	0.578 (14.7)	2 (51)
8	8.720 (221.5)	10.125 (257.2)	0.703 (17.8)	2½ (64)
10	10.880 (276.4)	12.150 (308.6)	0.635 (16.1)	2½ (64)
12	12.880 (327.2)	14.150 (359.4)	0.635 (16.1)	2½ (64)
14	14.140 (359.2)	15.400 (391.2)	0.630 (16.0)	2½ (64)
16	16.160 (410.5)	17.400 (442.0)	0.620 (15.7)	2½ (64)
18	18.180 (461.8)	19.400 (492.8)	0.610 (15.5)	2½ (64)

[A] Tolerances shall be (*1*) Sizes through 3 in. incl: +0.000, −0.010 in. (+0.000, −0.254 mm); (*2*) Sizes 3½through 10 in. incl: +0.030, −0.000 in. (+0.762, −0.000 mm); and (*3*) Sizes above 10 in.: +0.060, −0.000 in. (+1.524, −0.000 mm).

[B] Tolerances shall be (*1*) Sizes through 10 in. incl: +0.125, −0.000 in. (+3.175, −0.000 mm) and (*2*) Sizes above 10 in.: +1.000, −0.000 in. (+25.4, −0.000 mm).

[C] Tolerances for all sizes shall be +0.250, −0.000 in. (+6.4, −0.000 mm).

† Editorially corrected.

under the provisions of ASME Boiler and Pressure Vessel Code, Section IX; (*b*) heat treated in accordance with Section 6 of this specification; and (*c*) nondestructively tested as follows:

5.3.1 *Sizes 3-in. NPS and Below*—Radiographically examined throughout the entire length of each fabricated weld in accordance with Paragraph UW-51 of ASME Code, Section VIII.

5.3.2 *Sizes 3½-in. NPS Through 16-in. NPS*— No nondestructive tests required, and

5.3.3 *Sizes 18-in. NPS and Above*—Any method of nondestructive testing may be used provided the tests are conducted in accordance with the applicable parts of ASME Code, Section VIII.

6. Heat Treatment

6.1 *Couplings Made from Plate or Tubular Products*:

6.1.1 Couplings machined from tubular products need not be heat treated.

6.1.2 Hot-formed couplings upon which the final forming

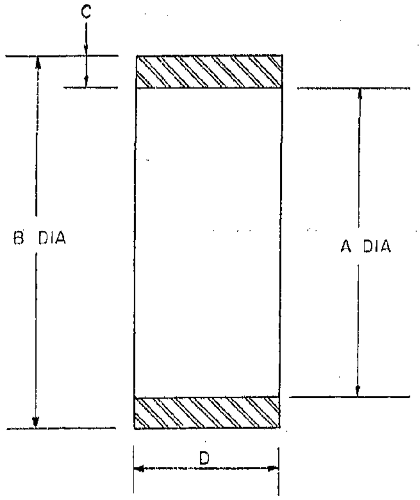


FIG. 1 Sleeve-Type Pipe Coupling

operation is completed at a temperature above 1150°F (621°C) and below 1800°F (982°C) need not be heat treated provided they are cooled in still air. If the manufacturer elects to heat treat such couplings it shall be by one of the procedures described in 6.3.

6.1.3 Hot-formed couplings finished at a temperature in excess of 1800°F (982°C) shall subsequently be annealed, normalized, or normalized and tempered.

6.1.4 Cold-formed couplings upon which the final forming operation is completed at a temperature below 1150°F (621°C) shall be normalized or shall be stress-relieved at 1100 to 1250°F (593 to 677°C) for 1 h/in. of thickness.

6.1.5 Couplings produced by fusion welding shall be postweld heat treated at 1100 to 1250°F (593 to 677°C), when the nominal wall thickness at the welded joint is ¾ in. or greater.

6.2 *Carbon Steel Couplings Made from Forgings*—Couplings made from forgings shall subsequently be annealed, normalized, or normalized and tempered.

6.3 *Heat Treatment Procedures*—Couplings after forming at an elevated temperature shall be cooled to a temperature below the critical range under suitable conditions to prevent injuries by too rapid cooling, but in no case more rapidly than the cooling rate in still air. Couplings that are to be heat treated shall be treated as follows:

6.3.1 *Full Annealing*—Couplings shall be uniformly reheated to a temperature above the transformation range and, after being held for a sufficient time at this temperature, cooled slowly to a temperature below the transformation range.

6.3.2 *Normalizing*—Couplings shall be uniformly reheated to a temperature above the transformation range and subsequently cooled in air at room temperature.

6.3.3 *Tempering and Postweld Heat Treatment*—Couplings shall be reheated to the prescribed temperature below the transformation range, held at temperature for not less than 1 h/in. of thickness at the thickest section, and cooled in the furnace or in still air.

7. Chemical Requirements

7.1 The couplings shall conform to the requirements as to chemical composition prescribed in Table 3.

7.2 Weld metal used in the construction of the couplings shall be mild steel analysis No. Al of Table QW-442, Section IX of the ASME Boiler and Pressure Vessel Code.

8. Product Analysis

8.1 Product analyses may be made by the purchaser from finished products representing each lot. The chemical composition thus determined shall conform to the requirements specified in Table 3.

8.2 In the event the couplings do not conform to the requirements specified in Table 3, referee analyses shall be made on additional couplings from the same lot in accordance with Practice E 59.

9. Mechanical Properties

9.1 The steel shall conform to the requirements as to tensile properties prescribed in Table 4.

9.2 The yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen under load shall be determined.

9.3 Tension tests shall be made on material representative of and in the same condition of heat treatment as the finished coupling.

9.3.1 Records of the tension tests shall be certification that the material of the coupling meets the requirements of this specification provided the heat treatments are the same. If the raw material was not tested, the coupling manufacturer shall perform the required test on material representative of the finished coupling.

9.4 The tests required by this specification shall conform to those described in the latest issue of Test Methods and Definitions A 370.

10. Dimensions and Permissible Variations

10.1 The dimensions and permissible variations for sleeve couplings to this specification are prescribed in Table 1 and Table 2.

11. Workmanship, Finish, and Appearance

11.1 Sleeve couplings shall have a workmanlike finish, free of scale and injurious defects. Ends shall be finished square and without burrs.

12. Hydrostatic Testing

12.1 Hydrostatic testing is not required by this specification.

12.2 All couplings shall be capable of withstanding, without failure, leakage, or impairment of serviceability, a test pressure equal to that prescribed in the specification for the pipe with which the fitting is recommended to be used.

13. Product Marking

13.1 Identification marks consisting of the manufacturer's

TABLE 3 Chemical Requirements

	Composition, max, %
Carbon	0.30
Manganese	1.20
Phosphorus	0.05
Sulfur	0.06

TABLE 4 Tension Requirements

Tensile strength, min, ksi (MPa)	60 (414)
Yield Point, min, ksi (MPa)	35 (241)
Elongation in 2 in. or 50.8 mm, min, %	23

symbol or name, the ASTM designation number, type, and size shall be legibly stamped on each fitting, and in such a position as not to injure the usefulness of the fitting. SP-25 may be followed except the word "steel" shall not be substituted for the ASTM designation.

13.2 Where couplings are manufactured by an activity for its own use, the marking requirements of 13.1 do not pertain.

14. Keywords

14.1 carbon steel sleeve-type pipe couplings; couplings; pipe couplings; Type I couplings; Type II couplings

APPENDIXES

(Nonmandatory Information)

X1. RATIONALE USED FOR DEVELOPMENT OF SPECIFICATION F 682

X1.1 This specification has been developed to provide two types of couplings. Type I is for use on all schedules of pipe in which the pipe wall thickness does not exceed the wall thickness of standard weight pipe. Type II is for use on all schedules of pipe in which the pipe wall thickness does not exceed the wall thickness of extra strong pipe. Note 3 provides an option that allows the use of Type II couplings in place of Type I couplings, if desired.

X1.2 The design criteria for the couplings is based on CFR Title 46, Subpart 56.70-15(d)3 and 4 as follows:

X1.2.1 For couplings through 3-in. IPS, the clearance between the system pipe outside diameter and the sleeve coupling inside diameter has been held to a maximum of 0.080 in. when considering tolerances to allow these couplings to be used in Class I piping through 3 in. when not subjected to full radiography as allowed by CFR Title 46. The inside diameter of the coupling is therefore equal to the minimum outside diameter of the pipe to be joined +0.080 in. with a tolerance of +0.000, −0.010 in. This provides for a maximum diametral clearance of 0.080 in.

NOTE X1.1—The minimum outside diameter of the pipe was determined by subtracting the largest minus tolerance from either Specification A 53/A 53M (ABS Grades 1, 2, and 3) or Specification A 106 (ABS Grades 4 and 5).

X1.2.2 The coupling inside diameter and tolerance in sizes 3½ in. and above for use in Class II piping has been taken from ANSI B16.5, Table 9, for slip-on flanges.

X1.2.3 The minimum length of the coupling has been set at 1 in. This satisfies the USCG requirement of 3⁄8-in. minimum depth of pipe insertion when used in Class I piping.

X1.2.4 To meet the USCG requirement that "the fillet weld shall have a throat dimension of not less than the nominal thickness of the pipe or tubing being joined," a coupling outside diameter of not less than the nominal outside diameter of the system pipe plus two times 1.4 T has been used. (T = nominal pipe thickness.)

X1.2.5 Hoop stress calculations have been performed to ensure that the strength of the coupling is equal to or greater than that of pipe being joined.

X1.3 A tolerance of +0.125, −0.000 in. was established for the outside diameter of couplings through 10 in. and a tolerance of +1.000, −0.000 in. for couplings 12 in. and larger. This allows the use of commercially available tubular products without machining the outside diameter and limits the maximum outside diameter thereby allowing designers to determine the hole size which would be required to pass a coupling through a penetration.

X1.4 Testing heat treatment requirements have been taken from Specification A 234/A 234M as discussed with USCG G-MMT-2⁄82.

X1.4.1 Radiography requirements have been taken from CFR Title 46, Subpart 56.95 as discussed with USCG G-MMT-2⁄82.

X1.5 Although marking is not specifically required by USCG, "marking" has been included in the specification to allow for material control and segregation of the couplings in industry.

X2. TUBULAR RAW STOCK MATERIAL SIZES FOR MANUFACTURE OF COUPLINGS

X2.1 Tubular products listed in Table X2.1 may be used for the manufacture of couplings without machining the coupling outside diameter. Other tubular sizes as well as other wrought materials (that is, forging, bars, billets, plate, and so forth, see 5.2) may also be used provided all the requirements of this specification are satisfied.

TABLE X2.1 Tubular Products Used for Couplings

Nominal Size, in.	Type I Couplings	Type II Couplings
¼	0.875 OD × 0.563 ID	1.062 OD × 0.563 ID
⅜	¾ in. IPS Sch 160	1.188 OD × 0.688 ID
½	1 in. IPS Sch 160	1.375 OD × 0.875 ID
¾	1.500 OD × 1.062 ID	1¼ in. IPS XX Strong
1¼	1.750 OD × 1.250 ID	1½ in. IPS Sch 160
1½	2.125 OD × 1.625 ID	2.250 OD × 1.688 ID
1	2 in. IPS Sch 80	2.500 OD × 1.937 ID
2½	2½ in. IPS Sch 80	3.000 OD × 2.375 ID
2	3 in. IPS Sch 80	3.750 OD × 2.875 ID
3½	4.125 OD × 3.500 ID	4.375 OD × 3.500 ID
3	4.750 OD × 4.000 ID	5.000 OD × 4.000 ID
4	5.250 OD × 4.500 ID	5 in. IPS Sch 120
5	6.375 OD × 5.375 ID	6 in. IPS Sch 120
6	7.500 OD × 6.500 ID	8.000 OD × 6.500 ID
8	9.625 OD × 8.625 ID	10.250 OD × 8.500 ID
10	12.000 OD × 10.750 ID	12 in. IPS Sch 120
12	14 in. IPS Sch 60	16 in. IPS Sch 160
14	16 in. IPS Sch 100	16 in. IPS Sch 80
16	18 in. IPS Sch 80	18 in. IPS Sch 80
18	20 in. IPS Sch 80	20 in. IPS Sch 80

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

◆

Document Name:

CFR Section(s):

Standards Body:

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 715 - 81 (Reapproved 1986)

Standard Methods of Testing Spill Control Barrier Membrane Materials[1]

1. Scope

1.1 These methods cover laboratory-conducted performance tests for spill control barrier membrane materials.

1.2 *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. Referenced Documents

2.1 *ASTM Standards:*

D 543 Test Method for Resistance of Plastics to Chemical Reagents[2]

D 751 Methods of Testing Coated Fabrics[3]

D 882 Test Methods for Tensile Properties of Thin Plastic Sheeting[2]

D 975 Specification for Diesel Fuel Oils[4]

D 1004 Test Method for Initial Tear Resistance of Plastic Film and Sheeting[2]

D 2261 Test Method for Tearing Strength of Woven Fabrics by the Tongue (Single Rip) Method (Constant-Rate-of-Extension Tensile Testing Machine)[5]

D 2262 Test Method for Tearing Strength of Woven Fabrics by the Tongue (Single Rip) Method (Constant-Rate-of-Traverse Tensile Testing Machine)[5]

2.2 *Federal Standard:*

Fed. Std. No. 191B Textile Test Methods[6]

2.3 *Military Specification:*

MIL-T-6396 C Tank, Fuel, Oil, Water-Alcohol, Coolant Fluid, Aircraft, Non-Self-Sealing, Removable, Internal[6]

3. Significance and Use

3.1 Membrane materials are subjected to these tests in order to provide data that reasonably relate to membrane response under the actual conditions of spill control barrier use.

3.2 Although these methods provide data on individual performance characteristics of membrane materials, all combinations of actual conditions of spill control barrier use are not simulated in this sequence of tests.

4. Base Line Tests

4.1 *Number of Specimens*—Subject seven specimens of spill control membrane materials to tests prescribed in 4.2 through 4.6. Perform all tests parallel and perpendicular to the axis of barrier when in use.

4.2 *Tensile Strength:*

4.2.1 *Supported Materials*—Fed. Std. No. 191B Method 5102 (cut strip), equivalent to Method D 751.

4.2.2 *Unsupported Materials*—Dumb Bell Sample, Method D 882, measured in pound-force per square inch.

4.3 *Tear Strength:*

4.3.1 *Supported Materials*—Fed Std No. 191B Method 5134 (tongue tear) equivalent to Methods D 2261 or D 2262. If standard sample does not achieve true tear or if fabric design requires roping to achieve high tear, sample size may be enlarged in order to achieve cord breakage, but all other procedures must be maintained. Such sample size change must be recorded in test results.

4.3.2 *Unsupported Materials*—Graves Method D 1004.

4.4 *Adhesion*—Fed Std. No. 191B Method 5970, after 5 days at 70°C in water, or Method D 751, after 5 days at 70°C in water.

4.5 *Puncture Resistance*—MIL-T-6396 C.

4.6 *Hydrostatic Resistance*—Fed. Std. No. 191B Method 5512 (Mullen Hydrostatic Test).

4.7 *Storage Life*—To be determined.

4.8 *Mildew*—Fed. Std. No. 191B Method 5762 (Mixed Cidal Spore Test).

5. Weather and Petroleum Sample Tests Related to Base Line Tests

5.1 *Specimen Preparation*—Subject samples of spill control barrier membrane material to the following preparations: weather resistance to be followed by resistance to petroleum products:

5.1.1 *Weather Resistance*—Fed. Std. No. 191B Method 5804, 500-h exposure.

5.1.2 *Resistance to Petroleum Products*—Method D 543, with 96-h exposure to No. 2 diesel stock as prescribed in Specification D 975, at ambient temperature.

5.2 *Weather and Petroleum Sample Test*—Perform each of the following tests within 1 h of the termination of the test in 5.1.2.

5.2.1 *Tensile Strength:*

5.2.1.1 *Supported Materials*—Same as base line test (4.2.1).

5.2.1.2 *Unsupported Materials*—Same as base line test (4.2.2).

5.2.2 *Tear Strength:*

---

[1] These methods are under the jurisdiction of ASTM Committee F-20 on Hazardous Substances and Oil Spill Response and are the direct responsibility of Subcommittee F20.11 on Control.

Current edition approval Feb. 27, 1981. Published July 1981.

[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 09.02.

[4] *Annual Book of ASTM Standards*, Vol 05.01.

[5] *Annual Book of ASTM Standards*, Vol 07.01.

[6] Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120.

5.2.2.1 *Supported Materials*—Same as base line test (4.3.1).

5.2.2.2 *Unsupported Materials*—Same as base line test (4.3.2).

5.2.3 *Adhesion*—Same as base line test (4.4). Samples shall be heat-sealed or cemented.

5.2.4 *Puncture Resistance*—Same as base line test (4.5).

5.2.5 *Hydrostatic Resistance*—Same as base line test (4.6).

5.3 *Interpretation of Results*—The results of each test in 5.2 shall be compared with the results of the same test in Section 4, and a percentage of change shall be noted.

6. Weather and Petroleum Sample Tests Followed by Hydrostatic Resistance, Related to Base Line Hydrostatic Test

6.1 *Specimen Preparation*—Use the three remaining samples from 5.1 for the tests in 6.2 and 6.3.

6.2 *Weather and Petroleum Sample Tests*—Perform each of the following tests within 1 h of the termination of the test in 5.1.2.

6.2.1 *Abrasion Resistance*—Fed. Std. No. 191B Method 5306 (Taber), using a H18 wheel and 1000-gf load, abraded 300 cycles.

6.2.2 *Low-Temperature Resistance*—Fed. Std. No. 191B Method 5874, at 2 h soak at −29°C with 2.5 kg mandrel roller weight.

6.2.3 *Flexibility*—To be determined.

6.3 *Hydrostatic Test*—Test for hydrostatic resistance in accordance with 4.6.

6.4 *Interpretation of Results*—The results of each test in 6.3 shall be compared with the results of 4.6, and a percentage of change shall be noted.

7. Precision and Bias

7.1 The precision and bias of test measurements are addressed in each individual test method cited in Sections 3, 4, and 5.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name:

CFR Section(s):

Standards Body:

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 715 – 95

Standard Test Methods for Coated Fabrics Used for Oil Spill Control and Storage[1]

This standard is issued under the fixed designation F 715; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover laboratory-conducted performance tests for coated fabrics used in spill control barriers or in temporary storage devices.

1.2 *This standard does not purport to address all of the safety concerns, if any, 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. Referenced Documents

2.1 *ASTM Standards:*

D 86 Test Method for Distillation of Petroleum Products[2]
D 93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester[2]
D 97 Test Method for Pour Point of Petroleum Products[2]
D 129 Test Method for Sulfur in Pretroleum Products (General Bomb Method)[2]
D 130 Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test[2]
D 287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)[2]
D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (And the Calculation of Dynamic Viscosity)[2]
D 482 Test Method for Ash from Petroleum Products[2]
D 524 Test Method for Ramsbottom Carbon Residue of Petroleum Products[2]
D 543 Test Method for Resistance of Plastics to Chemical Reagents[3]
D 613 Test Method for Cetane Number of Diesel Fuel Oil[4]
D 664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration[4]
D 751 Test Methods for Coated Fabrics[5]
D 975 Specification for Diesel Fuel Oils[2]
D 1149 Test Method for Rubber Deterioration—Surface Ozone Cracking in a Chamber[6]
D 1266 Test Method for Sulfur in Petroleum Products (Lamp Method)[2]
D 1298 Practice for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[2]
D 1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption[2]
D 1796 Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure)[2]
D 2425 Test Method for Hydrocarbon Types in Middle Distillates by Mass Spectrometry[2]
D 2500 Test Method for Cloud Point of Petroleum Oils[2]
D 2644 Tolerances for Yarns Spun on the Woolen System[7]
D 3117 Test Method for Wax Appearance Point of Distillate Fuels[8]
D 4157 Test Method for Abrasion Resistance of Textile Fabrics (Oscillatory Cylinder Method)[9]
G 26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials[10]

2.2 *Federal Standard:*

Fed. Std. No. 191A Textile Test Methods[11]

2.3 *Military Specification:*

MIL-T-6396 E Tank, Fuel, Oil, Water-Alcohol, Coolant Fluid, Non-Self-Sealing, Removable, Internal[11]

3. Significance and Use

3.1 Membrane materials are subjected to these tests in order to provide data that reasonably relate to membrane response under the actual conditions of spill control barrier or storage device use.

3.2 Although these test methods provide data on individual performance of membrane materials, all combinations of actual conditions of spill control barrier or storage device use are not simulated in this sequence of tests.

4. Base Line Tests

4.1 *Number of Specimens*—Subject specimens of spill control membrane materials to the tests prescribed in 4.2 through 4.11. Perform all tests in the direction of both the warp and fill of the fabric. The number of specimens to be tested are as specified in the procedures referenced in 4.2 through 4.11.

4.2 *Mass and Thickness*—Test Methods D 751.

4.3 *Tensile Strength and Elongation at Break*—Test

---

[1] These test methods are under the jurisdiction of ASTM Committee F-20 on Hazardous Substances and Oil Spill Response and are the direct responsibility of Subcommittee F20.11 on Control.

Current edition approval May 15, 1995. Published July 1995. Originally published as F 715 – 81. Last previous edition F 715 – 81 (1994)$^{\epsilon1}$.

[2] *Annual Book of ASTM Standards,* Vol 05.01.

[3] *Annual Book of ASTM Standards,* Vol 08.01.

[4] *Annual Book of ASTM Standards,* Vol 05.04.

[5] *Annual Book of ASTM Standards,* Vol 09.02.

[6] *Annual Book of ASTM Standards,* Vol 09.01.

[7] *Annual Book of ASTM Standards,* Vol 07.01.

[8] *Annual Book of ASTM Standards,* Vol 05.02.

[9] *Annual Book of ASTM Standards,* Vol 07.02.

[10] *Annual Book of ASTM Standards,* Vol 14.02.

[11] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 1 Detailed Requirements for Test Diesel Fuel Caterpillar 1G2/1H2

NOTE—Diesel fuels meeting the detailed requirements in Table 1 are available from Howell Hydrocarbons and Chemical Incorporated, 1201 South Sheldon Road, Channelview, TX 77530.

Property	ASTM Test Method	Requirement	
Flash point	D 93	140°F (60.0°C) min or legal	
Pour point	D 97	20°F (−7°C) max	
Cloud point	D 2500 or D 3117	Report	
Water and Sediment	D 1796	0.05 vol % max	
Ramsbottom carbon on 10 % residium	D 524	0.20 mass % max	
Ash	D 482	0.01 mass % max	
Distillation	D 86	IBP report 10 % report 50 % 500–530°F (260–277°C) 90 % 590–620°F (310–327°C) EP 650–690°F (343–366°C)	
Kinematic viscosity at 104°F (40.0°C)	D 445	2.0–4.0 cSt (2.0–4.0 mm^2/s)	
Total sulfur (must be natural)	D 2644 (Alt. D 129 or D 1266)	0.380–0.420 mass %	
Copper, corrosion (122°F, 50°C, 3 h)	D 130	No. 2 max	
Acid number (TAN-E)	D 664	0.15 mg KOH/g max	
Centane number	D 613	47.0–53.0	
Density	D 287 or D 1298	report	
API gravity	D 287 (Alt. D 1298)	33–35 API	
Cracked stocks		none	
Hydrocarbon types	D 1319	report	
Hydrocarbon types	D 2425	Component	mass %
		aliphatic paraffins	45.0–65.0
		monocycloparaffins, tetrocycloparaffins	report
		dicycloparaffins	0.0–15.0
		alkylbenzenes	5.0–10.0
		indans/tetralins, indenes	report
		napthalene	report
		napthalenes	5.0–15.0
		acenapthenes, acenapthylenes, tricyclic aromatics	report

Methods D 751 for Breaking Strength, Procedure A—Grab Test Method.

4.4 *Tear Strength*—Test Methods D 751 for Tearing Strength, Procedure B—Tongue Tear Method. If standard sample does not achieve true tear or if the fabric design requires roping to achieve high tear, sample size may be enlarged in order to achieve cord breakage, but all other procedures must be maintained. Such sample size change must be recorded in test results.

4.5 *Adhesion*—Test Methods D 751 after 5 days at 70°C in water.

4.6 *Puncture Resistance*—MIL-T-6396 E, procedure outlined in 4.6.17.

4.7 *Abrasion Resistance*—Test Method D 4157, abrade the specimen using a 2.72-kg (6-lb) dead weight load tension and a 2.72-kg (6-lb) dead weight load using extra coarse, 40 grit sandpaper as the abradant. Cycle continuously to exposure of threads.

4.8 *Seam Strength*—Test Methods D 751. Perform test with seam orientation as in device design.

4.9 *Seam Adhesion*—Repeat adhesion test (see 4.5) for specimens containing a seam.

4.10 *Blocking Resistance*—Test Methods D 751.

4.11 *Mildew*—Fed. Std. No. 191A, Method 5762 (Mixed Cidal Spore Test).

5. Weather and Petroleum Sample Tests Related to Base Line Tests

5.1 *Specimen Preparation*—Subject samples of spill control barrier or storage device membrane material to the following preparations: weather resistance to be followed by resistance to petroleum products:

5.1.1 *Weather Resistance*—Practice G 26, Test Method 2 (also referred to as Test Method B—Alternate Exposure to Light and Darkness and Intermittent Exposure to Water Spray), using deionized water and a 7000 watt xenon burner tube, 500-h exposure.

5.1.2 *Resistance to Petroleum Products*—Test Method D 543, with 96-h exposure to Diesel Fuel Grade No. 2, as prescribed in Specification D 975 and further meeting the specifications shown in Table 1 (Note). Conduct tests at ambient temperature.

5.2 *Weather and Petroleum Sample Tests*—Perform each of the following tests within 1 h of the termination of the test in 5.1.2.

5.2.1 *Tensile Strength*—Same as base line test (4.3).

5.2.2 *Tear Strength*—Same as base line test (4.4).

5.2.3 *Adhesion*—Same as base line test (4.5).

5.2.4 *Puncture Resistance*—Same as base line test (4.6).

5.2.5 *Abrasion Resistance*—Same as base line test (4.7).

5.2.6 *Seam Strength*—Same as base line test (4.8).

5.2.7 *Seam Adhesion*—Same as base line test (4.9).

5.2.8 *Blocking Resistance*—Same as base line test (4.10).

5.2.9 *Low Temperature Resistance*—Fed. Std. No. 191A, Method 5874, 2-h soak at −29°C with a 2.5-kg mandrel roller weight. Visually examine specimen and report signs of cracking or flaking. Do not perform hydrostatic resistance test.

5.2.10 *Ozone Resistance*—Test Method D 1149.

6. Precision and Bias

6.1 The precision and bias of test measurements are addressed in each individual test method cited in Sections 3, 4, and 5.

7. Keywords

7.1 barrier; coated fabrics; membrane materials; membranes; oil spill; spill control; storage devices; temporary storage devices

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

* * *

Document Name: ASTM F722: Standard Specification for Welded Joints for Shipboard Piping Systems

CFR Section(s): 33 CFR 155.140

Standards Body: American Society for Testing and Materials

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 722 – 82 (Reapproved 1998)

An American National Standard

Standard Specification for Welded Joints for Shipboard Piping Systems[1]

This standard is issued under the fixed designation F 722; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers typical details of welded joints commonly used in shipboard piping systems. These joints and other joints may be used provided the welding procedures used have been qualified in accordance with the applicable regulatory rules and regulations.

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *Federal Standards:*

Code of Federal Regulations Title 46, Shipping, Parats 30 to 40[2]

Code of Federal Regulations Title 46, Shipping, Parts 41 to 69[2]

Code of Federal Regulations Title 46, Shipping, Parts 140 to 149[2]

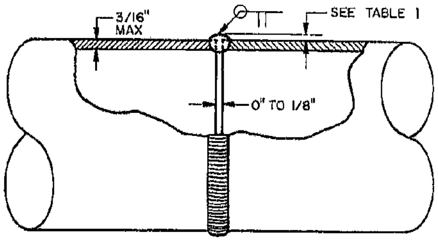
Rules for Building and Classing Steel Vessels[3]

3. Application, Service, Limitations, and List of Weld Joint Details

3.1 Details of welded joints, including application, service, and limitation notes, are provided in the appropriate figures, as follows:

3.1.1 *Butt-Welded Joints for Pipes, Valves, Fittings, and Flanges*:

Fig. 1 Butt Joint, Square
Fig. 2 Butt Joint, V-Grooved
Fig. 3 Butt Joint, V-Grooved, Welded Both Sides
Fig. 4 Butt Joint, Double V-Grooved, Welded Both Sides
Fig. 5 Butt Joint, Compound Bevel V-Grooved, Welded Both Sides
Fig. 6 Butt Joint, V-Grooved, Miter Type
Fig. 7 Butt Joint, V-Grooved, Welded with Bevel End-Type Backing Ring

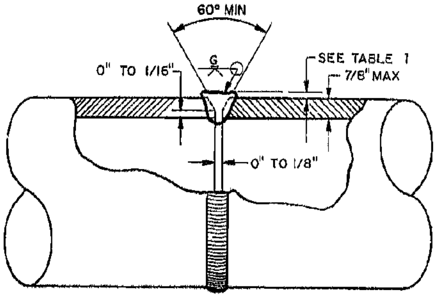


⅛ in. = 3 mm
3/16 in. = 5 mm

Application—Class II piping
Systems or Service—For services such as gravity drains (including plumbing), vents, and overflows.
Remarks—1. Root of weld need not be ground.

FIG. 1 Butt Joint, Square

Fig. 8 Butt Joint, Compound Bevel V-Grooved, Welded with Bevel End-Type Backing Ring
Fig. 9 Butt Joint, V-Grooved Welded with Bevel End Lug-Type Backing Ring
Fig. 10 Butt Joint, V-Grooved, Welded with Square End-Type Backing Ring
Fig. 11 Butt Joint, V-Grooved, Welded with Consumable Insert Ring



1/16 in. = 2 mm
⅛ in. = 3 mm
⅞ in. = 22 mm

Application—Class II piping
System or Service—All provided root of weld is visually inspected where possible to ensure complete weld penetration.
Remarks—1. For services such as vents, overflows, and gravity drains (including plumbing) the root of the weld need not be ground.

FIG. 2 Butt Joint, V-Grooved

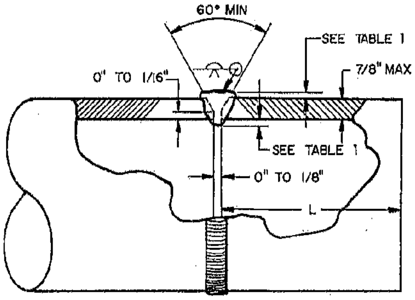
---

[1] This specification is under the jurisdiction of ASTM Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

Current edition approved July 30, 1982. Published August 1982. Originally published as F 722 – 81. Last previous edition F 722 – 81.

[2] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

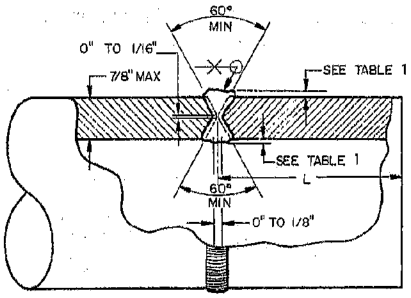
[3] Available from American Bureau of Shipping, 2 World Trade Center, 106th Floor, New York, NY 10048.



1/16 in. = 2 mm
1/8 in. = 3 mm
7/8 in. = 22 mm

Application—Class I and II piping above 2-in. NPS
System or Service—All
Remarks—1. Internal weld shall be made first and ground, chipped, or cleaned by some other means to assure sound welds.
2. The "L" dimension should be held to a minimum to facilitate welding and inspection on the inside surface of the pipe.

FIG. 3 Butt, Joint, V-Grooved, Welded Both Sides



1/16 in. = 2 mm
1/8 in. = 3 mm
7/8 in. = 22 mm

Application—Class I and II piping above 2-in. NPS
System or Service—All
Remarks—1. Internal weld shall be made first and ground, chipped, or cleaned by some other means to assure sound welds.
2. The "L" dimension should be held to a minimum to facilitate welding and inspection on the inside surface of the pipe.

FIG. 4 Butt Joint, Double V-Grooved, Welded Both Sides

Fig. 12 Butt Joint, Compound Bevel V-Grooved, Welded with Consumable Insert Ring

Fig. 13 Butt Joint, U-Grooved, Welded with Consumable Insert Ring

Fig. 14 Butt Joint, V-Grooved, Welded with Consumable Insert Ring

Fig. 15 Butt Joint, Socket Weld to Socket Weld Valve, Fitting or Flange Welded on Pipe Nipple

Fig. 16 Butt Joint, Transition between Unequal Inside and Outside Diameter Components

3.1.2 *Fillet Welded Joints for Valves, Fittings, and Flanges*:

Fig. 17 Fillet Welded Sleeve-Type Pipe Coupling

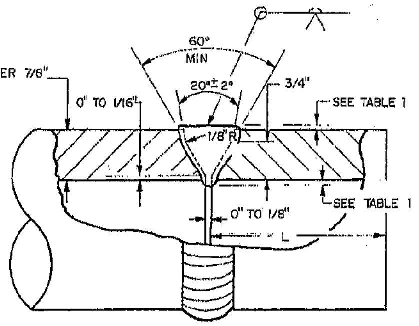
Fig. 18 Fillet Welded Socket Weld Fitting or Valve

Fig. 19 Fillet Welded Socket Weld-Flange

Fig. 20 Double Fillet Welded Slip-On Flange (Forged)

Fig. 21 Double Fillet Welded Slip-On Flange (Plate Type)

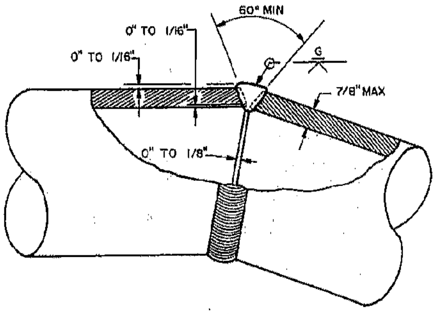
Fig. 22 Fillet Welded Slip-On Flange (Plate Type), Single Bevel



in.	1/16	1/8	3/4	7/8
mm	2	3	19	22

Application—Class I and II piping above 2-in. NPS
Systems or Service—All
Remarks—1. Internal weld shall be made first and ground, chipped, or cleaned by some other means to assure sound welds.
2. The "L" dimension should be held to a minimum to facilitate welding and inspection on the inside surface of the pipe.

FIG. 5 Butt Joint, Compound Bevel V-Grooved, Welded Both Sides



1/16 in. = 2 mm
1/8 in. = 3 mm
7/8 in. = 22 mm

Application—Class II piping where use will not cause objectionable pressure drop or turbulence.
System or Service—All provided root of weld is visually inspected where possible to ensure complete weld penetration.
Remarks—1. For services such as vents, overflows, and gravity drains (including plumbing), the root of the weld need not be ground.
2. Miter segments shall be designed in accordance with ANSI B31.1, paragraph 104.33, and 46 CFR 56.07-10(f).

FIG. 6 Butt Joint, V-Grooved, Miter Type

3.1.3 *Fabricated Joints*:

Fig. 23 Fillet Welded Internal Root Connection

Fig. 24 Fillet Welded External Root Connection

Fig. 25 Fillet Reinforced External Root Connection Single Bevel

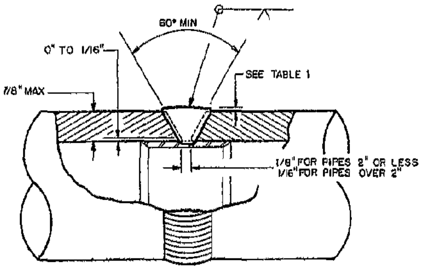
Fig. 26 Fillet Reinforced External Root Connection, Single Bevel, Welded Both Sides

Fig. 27 Fillet Reinforced External Root Connection, Single Bevel, Welded with Square End Backing Ring

Fig. 28 Fillet Reinforced Internal Root Connection, Single Bevel, Welded with Square End Backing Ring

3.1.4 *Outlet and Boss Connections*:

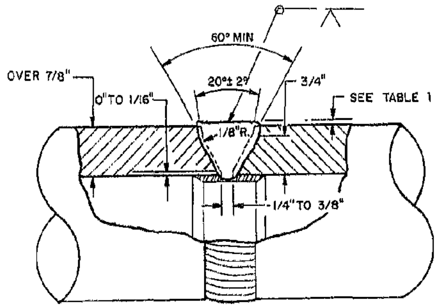
Fig. 29 Fillet Reinforced Boss Connection Without Pilot, Single Bevel



in.	1/16	1/8	3/16	7/8
mm	2	3	5	22

Application—Class I and II piping
System or Service—All, except as noted in remarks
Remarks—1. Backing ring may be tack-welded in place to facilitate fabrication.
2. When used in the following services, backing rings shall be removed.
(A) Lube oil service discharge piping from the lube oil pumps to the reduction gears, HP and LP turbines, and lube oil gravity tank.
(B) Superheated steam outlet piping from the main boilers to the HP and LP turbines and turbo generators and desuperheated steam from the main boilers to turbine driven main feed pumps.
(C) Central hydraulic systems.

FIG. 7 Butt Joint, V-Grooved, Welded with Bevel End-Type Backing Ring



in.	1/16	1/8	1/4	3/8	3/4	7/8
mm	2	3	6	10	19	22

Application—Class I and II piping
System or Service—All, except as noted in remarks
Remarks—1. Backing ring may be tack-welded in place to facilitate fabrication.
2. When used in the following services, backing rings shall be removed.
(A) Lube oil service discharge piping from the lube oil pumps to the reduction gears, HP and LP turbines, and lube oil gravity tank.
(B) Superheated steam outlet piping from the main boilers to the HP and LP turbines and turbo generators and desuperheated steam from the main boilers to turbine driven main feed pumps.
(C) Central hydraulic systems.

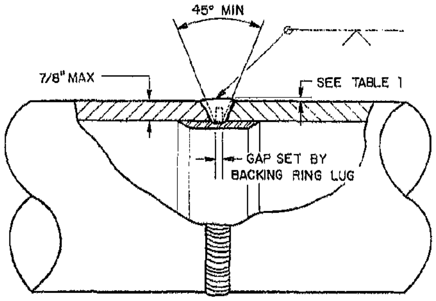
FIG. 8 Butt Joint, Compound Bevel V-Grooved, Welded with Bevel End-Type Backing Ring

Fig. 30 Fillet Reinforced Boss Connection with Pilot, Single Bevel

Fig. 31 Fillet Reinforced Boss Connection (Couplet) with Integral Backing Ring

Fig. 32 Fillet Reinforced External Root Connection, Single Bevel with Integrally Reinforced Outlet

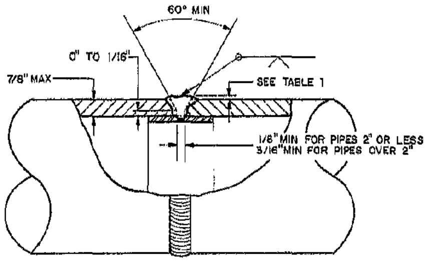
Fig. 33 Fillet Reinforced External Root Connection Welded Both Sides, Single Bevel with Integrally Reinforced Outlet



7/8 in. = 22 mm

Application—Class I and II piping
Systems or Service—All, except as noted in remarks
Remarks—1. Backing ring may be tack-welded in place to facilitate fabrication
2. When used in the following services, backing rings shall be removed.
(A) Lube oil service discharge piping from the lube oil pumps to the reduction gears, HP and LP turbines, and lube oil gravity tank.
(B) Superheated steam outlet piping from the main boilers to the HP and LP turbines and turbo generators and desuperheated steam from the main boilers to turbine driven main feed pumps.
(C) Central hydraulic systems.

FIG. 9 Butt Joint, V-Grooved Welded with Bevel End Lug-Type Backing Ring



in.	1/16	1/8	3/16	7/8
mm	2	3	5	22

Application—Class I and II piping
Systems or Service—All
Remarks—1. After welding, backing ring shall be machined flush with inside diameter of pipe or fitting.

FIG. 10 Butt Joint, V-Grooved, Welded with Square End-Type Backing Ring

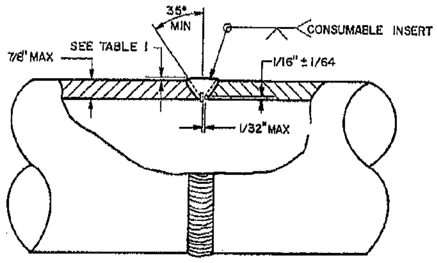
4. Piping Classifications and Butt Weld Reinforcements

4.1 Piping classifications in accordance with Subpart 56.04 of USCG Regulations apply to this specification. For definitions of ABS Group I and II Pipe Connections, see ABS Rules, Section 30, Paragraph 30.13.

4.2 Maximum thickness of butt weld reinforcements in accordance with Subpart 56.70, Table 56.70-15, of USCG Regulations are listed in Table 1.

5. Keywords

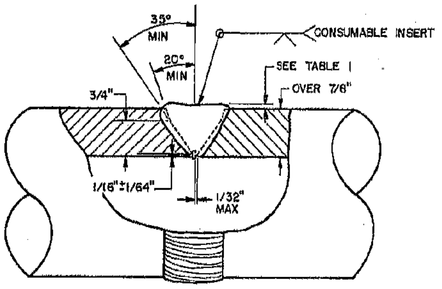
5.1 backing ring pipe welds; boss connections; flange welds; miter joint weld; pipe welds; root connections; sleeve pipe welds; socket welds; welded joints



in.	1/64	1/32	1/16	7/8
mm	0.4	1	2	22

Application—Class I and II piping
System or Service—All
Remarks—1. Internal misalignment of pipes shall not exceed 1/16 in. (2 mm).
2. Consumable insert ring shall be centered before welding.

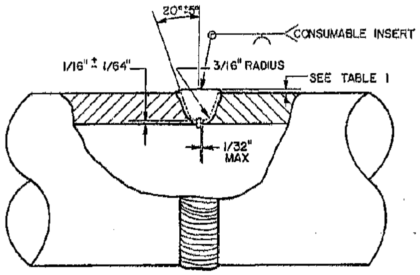
FIG. 11 Butt Joint, V-Grooved, Welded with Consumable Insert Ring



in.	1/64	1/32	1/16	3/4	7/8
mm	0.4	1	2	19	22

Application—Class I and II piping
System or Service—All
Remarks—1. Internal misalignment of pipes shall not exceed 1/16 in. (2 mm).
2. Consumable insert ring shall be centered before welding.

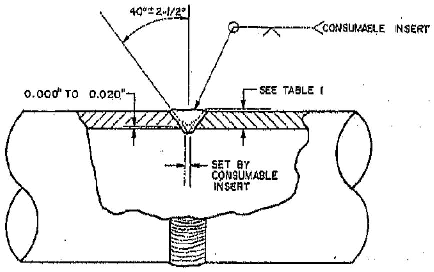
FIG. 12 Butt Joint, Compound Bevel V-Grooved, Welded with Consumable Insert Ring



in.	1/64	1/32	1/16	3/16
mm	0.4	1	2	5

Application—Class I and II Piping
System or Service—All
Remarks—1. Internal misalignment of pipes shall not exceed 1/16 in. (2 mm).
2. Consumable insert ring shall be centered before welding.

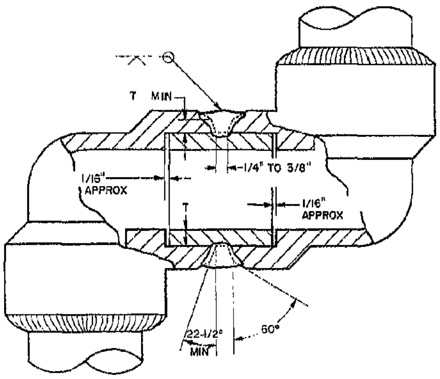
FIG. 13 Butt Joint, U-Grooved, Welded with Consumable Insert Ring



0.020 in. = 0.51 mm.

Application—Class I and II piping
System or Service—All
Remarks—1. Internal misalignment of pipes shall not exceed 1/32 in. (1 mm).
2. Consumable insert ring shall be centered before welding.

FIG. 14 Butt Joint, V-Grooved, Welded with Consumable Insert Ring



1⁄16 in. = 2 mm
1⁄4 in. = 6 mm
3⁄8 in. = 10 mm

Application—Fittings: See Fig. 18. Flanges: See Fig. 19.

System or Service—See Fig. 18 and Fig. 19.

Remarks—1. Size of weld shall be equal to or greater than "T."

2. For Class I piping, depth of insertion of the pipe nipple into the fitting shall not be less than 3⁄8 in. (10 mm).

3. Weld to be deposited in a minimum of two passes unless specifically approved otherwise in a special procedure qualification.

FIG. 15 Butt Joint, Socket Weld to Socket Weld Valve, Fitting or Flange Welded on Pipe Nipple

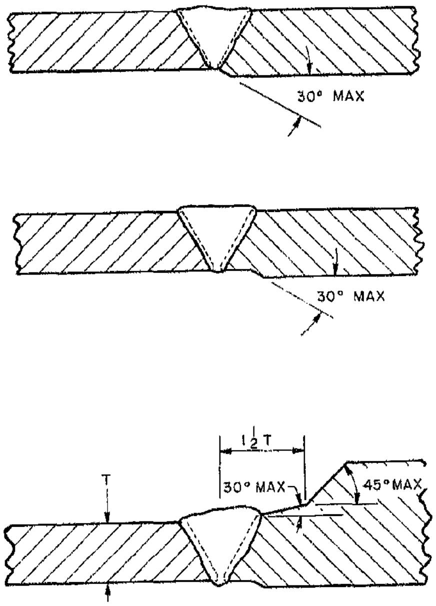
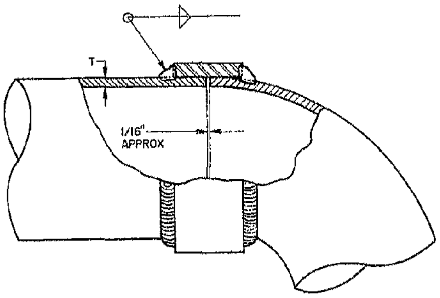


FIG. 16 Butt Joint, Transition Between Unequal Inside and Outside Diameter Components



1⁄16 in. = 2 mm

Application—Class I piping 3-in. NPS max where not subject to full radiography by 46 CFR Table 56.95-10. Class II piping all sizes.

Systems or Service—All

Remarks—1. Size of weld shall be 1.4 T min but not less than 1⁄8 in. (3 mm).

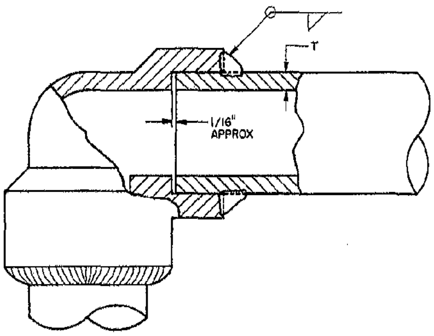
2. For Class I piping, depth of insertion of pipe, tube, or fitting in sleeve shall not be less than 3⁄8 in. (10 mm).

3. Weld to be deposited in a minimum of two passes unless specifically approved otherwise in a special procedure qualification.

4. For Class I piping, the inside diameter of the sleeve shall not exceed the outside diameter of the pipe, tube, or fitting by more than 0.080 in. (2.03 mm).

5. Couplings may be used with flat or beveled end pipes and fitting.

FIG. 17 Fillet Welded Sleeve-Type Pipe Coupling



1⁄16 in. = 2 mm

Application—Class I piping 3-in. NPS max where not subject to full radiography by 46 CFR Table 56.95-10. Class II piping all sizes.

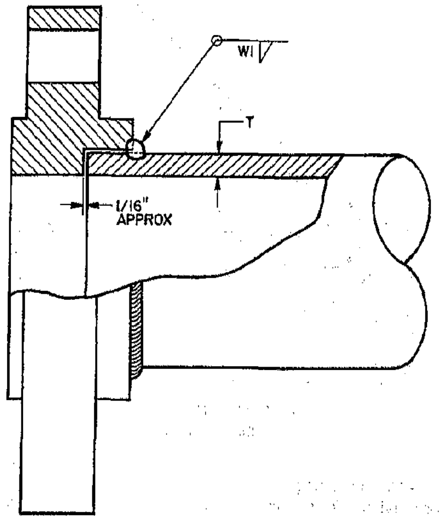
System or Service—All, except socket welds shall not be used where severe erosion or crevice corrosion is expected to occur.

Remarks—1. Size of weld shall be 1¼ T min but not less than 1⁄8 in. (3 mm).

2. For Class I piping, depth of insertion of pipe or tube into the fitting shall not be less than 3⁄8 in. (10 mm).

3. Weld to be deposited in a minimum of two passes unless specifically approved otherwise in a special procedure qualification.

FIG. 18 Fillet Welded Socket Weld Fitting or Valve



1⁄16 in. = 2 mm.

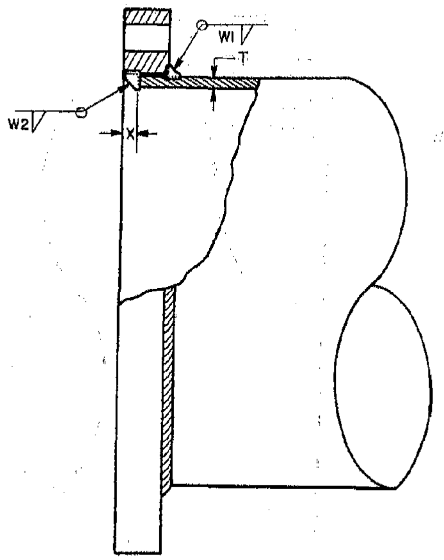
Application—Class I piping 3-in. NPS max for 600# and lower classes and 2½-in. NPS for 900 and 1500# classes. 3-in. size not permitted where subject to full radiography by 46 CFR Table 56.95-10. Class II piping all sizes.

System or Service—All, except socket welds shall not be used where severe erosion or crevice corrosion is expected to occur

Remarks—1. Size of Weld W1 shall be 1.4 T min. for Class II piping, size of weld may be limited to 17⁄32 in. (13 mm) max.

2. Weld to be deposited in a minimum of two passes unless specifically approved otherwise in a special procedure qualification.

FIG. 19 Fillet Welded Socket Weld Flange



Application—Class II piping not exceeding 150 psi (1034 kPa) or 450°F (232°C)

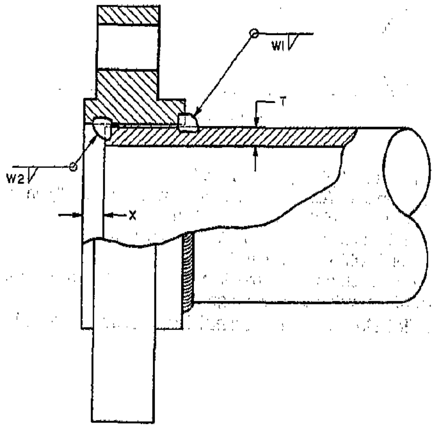
System or Service—All

Remarks—1. Size of Weld 8a W1 shall be 1.4 "T" min but may be limited to 17⁄32 in. (13 mm).

2. Size of Weld W2 shall be equal to "T" or ¼ in. (6 mm), whichever is smaller.

3. Distance X shall be T plus 1⁄16in. (2 mm) min but may be limited to ⅜in. (10 mm).

FIG. 21 Double Fillet Welded Slip-on Flange (Plate Type)



Application—Class I and II piping not to exceed the service pressure temperature ratings for the 300# and lower classes. Slip-on flanges shall not be used on Class I piping where subject to full radiography by 46 CFR Table 56.95-10.

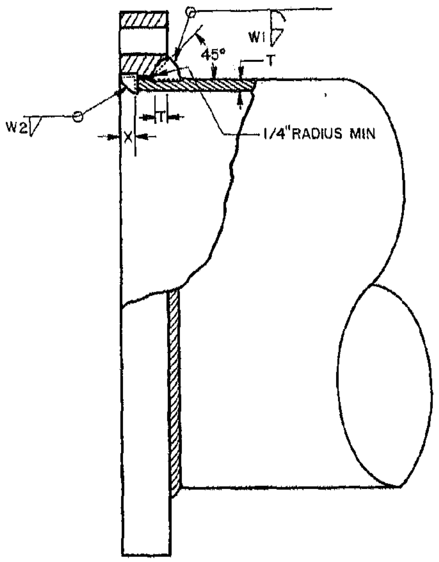
System or Service—All

Remarks—1. Size of Weld W1 shall be 1.4 T min. for Class II piping, size of weld may be limited to 17⁄32 in. (13 mm) max.

2. Size of Weld W2 shall be equal to "T" or ¼ in. (6 mm), whichever is smaller.

3. Dimension X shall be equal to T plus 1⁄16 in. (2 mm) min. for Class II piping, Dimension X may be limited to ⅜in. (10 mm).

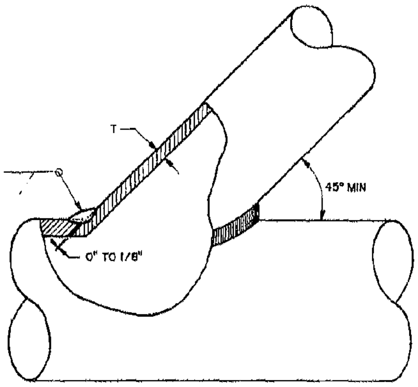
FIG. 20 Double Fillet Welded Slip-on Flange (Forged)



¼ in. = 6 mm

Application—Class II piping not exceeding 150 psi (1034 kPa) or 650°F (343°C)
System or Service—All
Remarks—1. Size of Weld W1 shall be 1.4 "T" min but may be limited to 17⁄32 in. (13 mm).
2. Size of Weld W2 shall be equal to "T" or ¼ in. (6 mm), whichever is smaller.
3. Distance X shall be "T" plus 1⁄16 in. (2 mm) min but may be limited to ⅜ in. (10 mm).

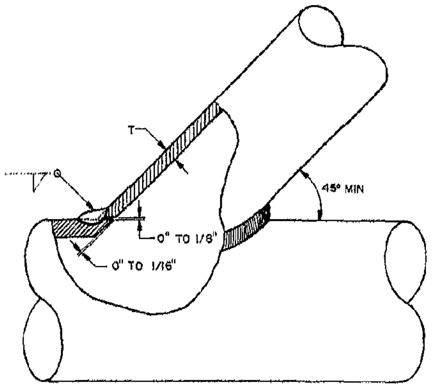
FIG. 22 Fillet Welded Slip-on Flange (Plate-Type) Single Bevel



⅛ in. = 3 mm

Application—Class II piping
System or Service—For services such as vents, overflows, and gravity drains (including plumbing).
Remarks—1. Size of weld shall be T min.

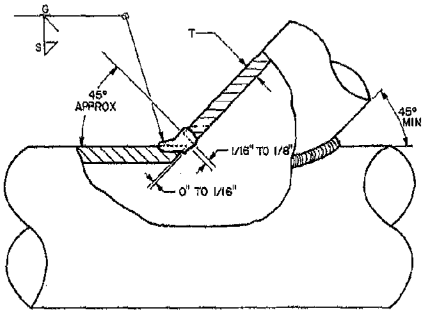
FIG. 23 Fillet Welded Internal Root Connection



1⁄16 in. = 2 mm
⅛ in. = 3 mm

Application—Class II piping.
System or Service—For services such as vents, overflows, and gravity drains (including plumbing).
Remarks—1. Size of weld shall be T min.

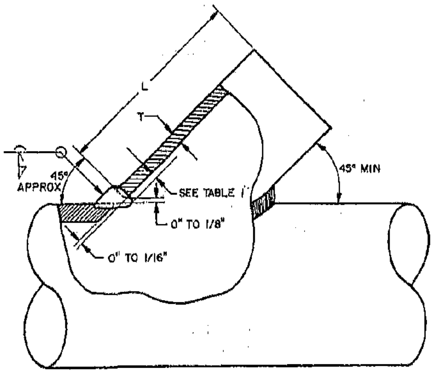
FIG. 24 Fillet Welded External Root Connection



1⁄16 in. = 2 mm
⅛ in. = 3 mm

Application—Class II piping above 2-in. NPS.
System or Service—All, provided root of weld is visually inspected where possible to ensure complete weld penetration.
Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 0.7 T or ¼ in. (6 mm), whichever is smaller.
2. For services such as vents, overflows, and gravity drains (including plumbing), the root of the weld need not be ground.

FIG. 25 Fillet Reinforced External Root Connection Single Bevel



1/16 in. = 2 mm
1/8 in. = 3 mm

Application—Class I and II piping above 2-in. NPS

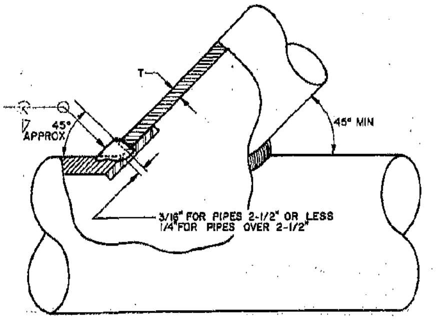
System or Service—All.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 0.7 T or 1/4 in. (6 mm), whichever is smaller.

2. Internal weld shall be made first and ground, chipped, or cleaned by some other means to assure sound welds.

3. The "L" dimension should be held to a minimum to facilitate welding and inspection on the inside surface of the pipe.

FIG. 26 Fillet Reinforced External Root Connection, Single Bevel, Welded Both Sides



3/16 in. = 5 mm
1/4 in. = 6 mm

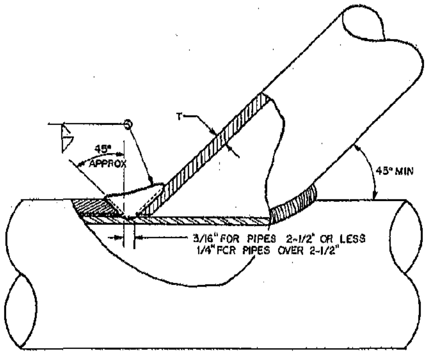
Application—Class I and II piping.

System or Service—All.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 0.7 T or 1/4 in. (6 mm), whichever is smaller.

2. After welding, backing ring shall be machined flush with inside diameter of pipe.

FIG. 27 Fillet Reinforced External Root Conn, Single Bevel, Welded with Square End Backing Ring



3/16 in. = 5 mm
1/4 in. = 6 mm

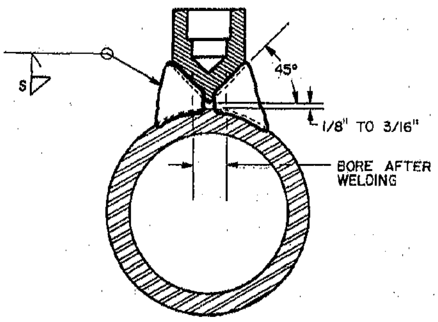
Application—Class I and II piping.

System or Service—All.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 0.7 T or 1/4 in. (6 mm), whichever is smaller.

2. After welding, backing ring shall be machined flush with inside diameter of pipe.

FIG. 28 Fillet Reinforced Internal Root Conn, Single Bevel, Welded With Square End Backing Ring



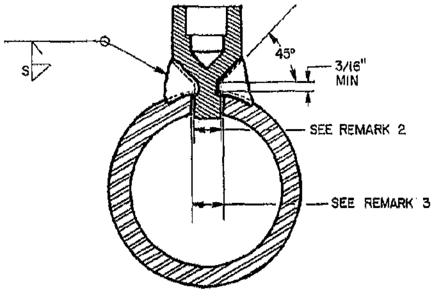
1/8 in. = 3 mm
3/16 in. = 5 mm

Application—Class I and II piping.

System or Service—All.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of 1/4 in. (6 mm).

FIG. 29 Fillet Reinforced Boss Conn Without Pilot, Single Bevel



3⁄16 in. = 5 mm

Application—Class I and II piping.

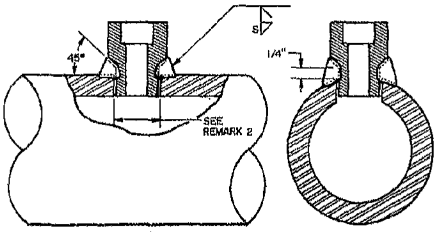
System or Service—All.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of ¼ in. (6 mm).

2. Pilot hole shall be 1⁄32 in. (1 mm) larger than pilot diameter.

3. Final bore after welding shall be a minimum of ⅛ in. (3 mm) larger than pilot diameter.

FIG. 30 Fillet Reinforced Boss Conn with Pilot, Single Bevel



¼ in. = 6 mm

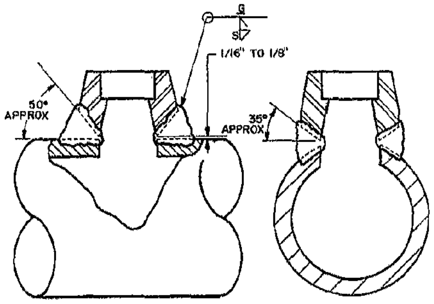
Application—Class I and II piping 2-in. NPS max.

System or Service—All, provided pressure does not exceed 1025 psi (7067 kPa) max or temperature does not exceed 750°F (399°C) max.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of ¼ in. (6 mm).

2. Pilot hole diameter shall be equal to backing ring OD plus 1⁄32 in. (1 mm).

FIG. 31 Fillet Reinforced Boss Conn (Couplet) with Integral Backing Ring



1⁄16 in. = 2 mm
⅛ in. = 3 mm

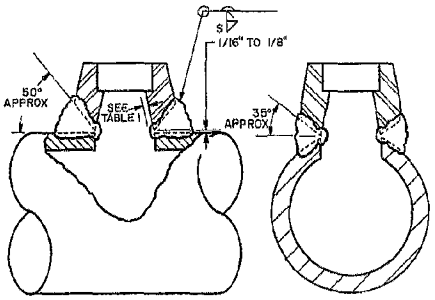
Application—Class II piping.

System or Service—All, provided root of weld is visually inspected where possible to ensure complete weld penetration.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of ¼ in. (6 mm).

2. For services such as vents, overflows, and gravity drains (including plumbing), the root of the weld need not be ground.

FIG. 32 Fillet Reinforced External Root Conn, Single Bevel with Integrally Reinforced Outlet



Application—Class I and II piping.

System or Service—All.

Remarks—1. Reinforcing fillet S shall have a minimum throat dimension of ¼ in. (6 mm).

2. Internal weld shall be made first and ground, chipped, or cleaned by some other means to assure sound welds.

FIG. 33 Fillet Reinforced External Root Conn Welded Both Sides, Single Bevel with Integrally Reinforced Outlet

TABLE 1 Maximum Butt Weld Reinforcement, in. (mm)

NOTE 1—For double-welded butt joints, this limitation on reinforcement given above applies separately to both inside and outside surfaces of the joint.

NOTE 2—For single-welded butt joints, the reinforcement limits given above apply to the outside surface of the joint only.

NOTE 3— The thickness of weld reinforcement is based on the thickness of the thinner of the materials being joined.

NOTE 4—The weld reinforcement thicknesses must be determined for the higher of the abutting surfaces involved.

NOTE 5—For boiler external piping, use the column titled "above 750°F" for weld reinforcement thicknesses.

NOTE 6—See 4.2.

Nominal Wall Thickness of Pipe or Tube, in.	Maximum Operating Temperature of Piping System, °F (°C)				
	0 to 350 (−18 to 177)	to	350 to 750 (177 to 399)	to	Above 750 (399)
Up to 1/8	3/16 (5)		3/32 (2)		1/16 (2)
Over 1/8 to 3/16	3/16 (5)		1/8 (3)		1/16 (2)
Over 3/16 to 1/2	3/16 (5)		5/32 (4)		1/16 (2)
Over 1/2 to 1	3/16 (5)		3/16 (5)		3/32 (2)
Over 1 to 2	1/4 (6)		1/4 (6)		1/8 (3)
Over 2	greater of 1/4 (6) or 1/8 the width of the weld		greater of 1/4 (6) or 1/8 the width of the weld		5/32 (4)

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

CERTIFICATE

By Authority Of

THE UNITED STATES OF AMERICA

Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM F808: Guide for Collecting Skimmer Performance Data in Uncontrolled Environments

CFR Section(s): 33 CFR 154, Appendix C, 6.3.1

Standards Body: American Society for Testing and Materials

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 808 – 83 (1988)$^{\epsilon 1}$

Standard Guide for Collecting Skimmer Performance Data in Uncontrolled Environments[1]

This standard is issued under the fixed designation F 808; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

$^{\epsilon 1}$NOTE—Sections 3 and 4 were renumbered editorially in April 1988.

1. Scope

1.1 This guide describes methods for collecting data to measure the performance of skimmers in removing (recovering) oil slicks in uncontrolled environments (that is, other than in a controlled test facility).

2. Referenced Documents

2.1 *ASTM Standards:*

D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[2]

D 1331 Test Methods for Surface and Interfacial Tension of Solutions of Surface-Active Agents[3]

D 1746 Test Method for Transparency of Plastic Sheeting[4]

D 1796 Test Method for Determination of Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure)[5]

D 2983 Test Method for Low-Temperature Viscosity of Automotive Fluid Lubricants Measured by Brookfield Viscometer[6]

3. Definitions

3.1 *data collection period*—that period of time during which performance data are recorded.

3.2 *oil recovery efficiency*—the ratio of the oil recovery rate (water-free oil) to the oil slick recovery rate (in percent).

NOTE 1—The data from this calculation may not be indicative of performance of the skimmer if the floating oil is contaminated (for example with water, as in a mousse or emulsion, or with debris or ice easily ingested by the skimmer).

3.3 *oil recovery rate*—the volume of water-free oil removed from the water surface by the skimmer, per unit time.

3.4 *oil slick*—the oily fluid encountered by the skimmer. (Most real oil slicks are actually composed of various proportions of pure oil, water-in-oil (W/O) emulsionn, and oil-in-water (O/W) emulsions. Therefore, efficiencies and other performance criteria must be differentiated between those based on the oil slick itself, and those based on only the water-free oil contained within the oil slick.)

3.5 *oil slick encounter rate*—that volume of oil slick per unit time actively directed to the skimmer.

3.6 *oil slick recovery efficiency*—the ratio of the oil slick recovery rate to the total volumetric rate of fluids recovered (in percent).

3.7 *oil slick recovery rate*—the volume of oil slick removed from the water surface by the skimmer, per unit time.

3.8 *oil slick thickness*—the thickness of the oil slick encountered by the skimmer.

3.9 *skimmer*—a device that removes oil slicks or free oil from the water surface. The device may move through the surrounding fluid or it may be relatively stationary.

3.10 *storage efficiency*—the ratio of the oil slick recovery rate to the mean volumetric rate of oil and emulsion (excluding free water) delivered to storage. Most oil skimmers have at least a tendency to further emulsify the recovered oil and water through the action of pumping, belt squeezing, or other processing techniques. If the resulting emulsion is fairly stable, excessive storage capacity in the on-board or external tanks may be required to accommodate the increased volume of oily waste. A measure of the emulsification tendency of a skimmer can be expressed as the Storage Efficiency as defined herein. For example, if a skimmer picked up 80 gal/min of oil and stable emulsion plus 20 gal/min of underlying water (oil slick recovery efficiency of 80 %) but transferred 90 gal/min of oil and stable emulsion to storage plus 10 gal/min of free water (which is subsequently pumped back overboard), the storage efficiency would be (80/90 gal per min) × 100 = 89 %. As the storage efficiency would depend to some extent on the amount of settling time allowed, and on the height and area of the liquid column in the settling vessel, any measurement of the storage efficiency must specify these parameters. Thus, a skimmer with a poor oil slick recovery efficiency (picks up considerable water), but with a good storage efficiency (does not emulsify the water picked up), may present no more storage capacity problems than a skimmer with a good oil slick recovery efficiency, if the free water can be discharged back overboard.

3.11 *throughput efficiency*—the ratio of the oil recovery rate (water-free oil) to the total volumetric rate of water-free oil encountered by the skimmer (in percent).

4. Significance and Use

4.1 The data provided by the methods described herein

---

[1] This guideline is under the jurisdiction of ASTM Committee F-20 on Hazardous Substances and Oil Spill Response and is the direct responsibility of Subcommittee F20.12 on Removal.

Current edition approved April 6, 1983. Published July 1983.

[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 15.04.

[4] *Annual Book of ASTM Standards*, Vol 08.02.

[5] *Annual Book of ASTM Standards*, Vol 05.01.

[6] *Annual Book of ASTM Standards*, Vol 05.02.

can enable performance measurements to be made of the type obtained in a controlled test facility. However, the quality and accuracy of the data will depend on the type of environment in which the data are taken, and the type of instruments available. Such data will, therefore, be unlikely to compare in accuracy and reproducibility to similar data obtained in a controlled test facility.

4.2 The data will be significant if all of them are taken at approximately the same time and in the immediate vicinity of the skimmer. All data should be recorded as a function of time for later correlation with other events.

4.3 The situations in which this guide applies include both accidental and planned spills in natural waterways where equipment is to be evaluated under field conditions.

4.4 The guidelines provided will enable personnel at oil spills to determine the effectiveness of skimmers under field conditions as well as to gage the quantity of material recovered. Such information could also be useful in improving future skimmer designs.

4.5 Each datum can usually be obtained by more than one method, and the method used will depend on the degree of preparedness of the equipment user, the time available to take the measurement, and the general conditions under which the skimmer is used. The methods suggested for obtaining data are listed in order of preference. The method actually used to obtain the data should be described.

ENVIRONMENTAL CONDITIONS

5. General

5.1 Environmental conditions existing at the time of testing in the vicinity of the skimmer are important for both manufacturers and users in assessing the capabilities of the equipment. The following sections consider measurement techniques for important environmental conditions.

6. Wave Height

6.1 *Instrumented Buoy*—Instrumented buoys, although relatively sophisticated, generally provide the most accurate wave data, and are therefore preferred over other wave height measurement methods.

6.1.1 *Free-Floating Buoy*—One type of instrumented buoy that contains accelerometers and electronics to convert vertical motions of the buoy into recordable signals. Signals can be recorded as a function of time within the buoy, or transmitted to a boat or ship by means of cable or radio. Some buoys can be towed at skimmer speed to collect data in the immediate vicinity of the skimmer. The results generally require analysis of the recorded data at a later time to obtain accurate statistical data on wave heights and periods. Both swell waves and wind-driven waves are measured.

6.1.2 *Spar Buoy*—Another type of instrumented buoy that remains relatively stationary with respect to the waves and swell, and uses pressure, acoustic, or other types of wave-height sensors. These buoys are generally not towed, but signal processing characteristics are similar to other instrumented buoys.

6.2 *Simple Spar Buoy*—A simple free-floating spar boy (not instrumented) constructed of a long buoyant pole with a weight at one end, and painted with stripes at measured intervals, can be used for estimates of wave heights. The buoy should be made long in comparison to the expected wind-driven wave height so that it remains relatively stationary vertically. By observing the heights of a series of waves against the painted stripes, statistical information on wave heights can be determined. Swell waves will not be observed unless the buoy is extremely long, but in general, swell waves are not significant to a skimmer's performance unless the skimmer is incorporated into a relatively large vessel.

6.3 *Visual Estimate*—Experienced observers may be able to estimate a characteristic wave height that experience has shown to be approximately the average of the highest one-third of the waves ("significant" wave height). Long swell heights are usually estimated separately. The use of a background, such as a dock, offshore structure, large ship, or other relatively stable reference point may help an observer to judge the wave heights more accurately.

7. Wave Length, Period, and Direction

7.1 *Wave Recording*—The data from devices such as described in 6.1 can be obtained to compute wave periods and statistical wave lengths. The use of statistical wave data provides more accurate information than the other methods listed below. It is best interpreted by trained individuals. Wave direction cannot be determined with a single-wave recording instrument.

7.2 *Visual Estimate*—Experienced observers may be able to estimate a characteristic wave length and period, that is related to the "significant" wave described in 6.3. A visual background such as a large ship, jetty, or similar structure in the immediate vicinity of the skimmer, would be helpful in improving the estimate. Wave propagation direction can be estimated with the aid of a compass, and will generally be in the approximate direction toward which the wind is blowing.

8. Skimmer Forward Velocity (Towed or Self-Propelled)

8.1 *Chip Log*—A wood chip or similar floating object is dropped overboard and the time for the chip to traverse a known distance along the hull is measured. This distance divided by the time interval gives a good estimate of the skimmer speed relative to the surface at that particular moment. Several measurements should be taken during the data collection period to obtain an average skimmer speed. As long as the chip log is not affected by the presence of the ship's hull (turbulence, boundary layer effects, wake, etc.), it will give a good estimate of velocity on the surface where the oil is present.

8.2 *Current Meter*—Various types of current meters are available that can provide an accurate measure of forward velocity in the 0 to 3-m/s range common to most skimmers. The meter can be fixed to, or towed by the skimmer, or the skimmer-towing vessel. The meter output can be recorded as a function of time throughout the data collection period. The velocity measured will be relative to the water surface as opposed to the land or the bottom, and therefore will automatically take into account natural currents in the waterway. Note, however, that current speed on the surface (as measured by a chip log) may be different than the current a short distance below the surface, where a current meter typically would be positioned.

8.3 *Towing Vessel Speedometer*—The speedometer on the towing vessel, or on a vessel moving at the same speed as the skimmer, can give a reliable velocity estimate if the speedometer is properly calibrated for low speeds, and is properly maintained; if not, inaccuracy can be high. Other ship speed estimates, such as screw rpm correlations are generally less reliable.

9. Skimmer Motion Relative to Waves

9.1 *Wave Probe*—Various types of wave-measuring instruments (capacitance probes, acoustic devices, resistance probes, pressure sensors) can be attached to larger skimmers near the point where relative motion is critical, such as near a weir lip, oil intake point, etc. The output can be recorded continuously during the data collection period, and statistical relative motion information can be calculated at a later time. Oil coating of the sensor can be a problem with some devices. In general, the relative vertical motions are the most significant to skimmer performance, whether generated by pitching or heaving; therefore, instrumenting for separate measurements of pitch and heave would not normally be necessary. The use of measuring instruments, if they are properly calibrated and not subjected to oil coating or fouling, can provide the most accurate and complete record of skimmer motions.

9.2 *Visual or Photographic Estimates*—Relative motion data can be obtained by observing the water level changes *at the point of interest* on the skimmer. It may be helpful to paint or affix a measurement scale (grid, yardstick, etc.). A movie record will facilitate future analysis. (A clock in the field of view would be helpful.) The direction of the skimmer relative to the average wave propagation direction can be estimated visually with the aid of a compass.

10. Skimmer Velocity Relative to the Oil Slick

10.1 For unconfined slicks this is the same as the skimmer forward velocity, as determined in Section 8. Where substantial holdup has occurred immediately in front of the skimmer (boom systems and skimmer with herding arms) the slick may be moving at nearly the same speed as the skimmer, relative to the water. For use in encounter rate calculations in accordance with Section 9.2, where the slick thickness immediately in front of the skimmer is used, the slick-to-skimmer relative velocity immediately in front of the skimmer is needed, and is determined as follows:

10.2 *Chip Log or Current Stick*—The distance that the floating object moves relative to the skimmer, divided by the observed time interval will yield the desired velocity. A current stick must not be deep enough to be influenced by the water under the slick, nor be tall enough to be influenced by the wind. This approach is most feasible with manned skimmers where the observer can get close to the object.

11. Wind Speed and Direction

11.1 *Anemometer*—This can give wind speed and, in some models, direction, which can be recorded continuously. Various types are available and most larger vessels have these instruments on board. Although shipboard anemometers can provide more accurate data than the other methods described below, they are generally not as accurate as weather station instruments.

11.2 *Hand-Held Wind Speed Meter*—An inexpensive, hand-held meter is available that uses a rotameter principle to give instantaneous wind-speed readings. It is sensitive to wind direction and moisture contamination but can be useful in estimating average wind speeds. Average wind direction must be estimated by observation, with the aid of a compass.

11.3 *Visual Estimate*—Experienced observers can often estimate average wind velocities using the Beaufort criteria for Sea State. However, because the Beaufort wind velocity-Sea State correlation is a function of the duration and length of travel of the wind over the water (fetch), the wind speed estimate is relatively subjective. Average wind direction is estimated as in 11.2.

12. Surface Water Temperature

12.1 *Thermometer*—An accurate thermometer placed in the water, or in a freshly drawn water sample, will give good results.

13. Air Temperature

13.1 *Thermometer*—Hand-held thermometer, or outside-mounted ship's thermometer.

14. General Weather Description

14.1 A general weather description should include approximate degree and type of cloud cover, degree and type of precipitation (rain, snow, hail, fog), visibility, extent of whitecap formation on waves, general weather condition (fair, stormy, etc.). The description should cover the entire duration of the data collection period.

15. Current Speed and Direction (Relative to Bottom)

15.1 Speed can be determined by various types of current meters, with or without direction indication. Chips or current sticks, measured relative to a fixed object (buoy, platform, pile, etc.) are also useful.

OIL SLICK CONDITIONS

16. General

16.1 Data on the oil slick will be among the least precise data that can be collected, due to the difficulty in conducting representative sampling. All sampling should be performed in the vicinity of the skimmer.

16.2 At most spills, data on the oil slick properties will not be available until some time after the samples have been taken, because of the analysis procedures required. Therefore, a thorough sampling program is necessary.

17. Required Critical Data

17.1 *Oil Type and Source*—This information can usually be obtained from the spiller or government agencies tasked with identifying the oil. Several 1-L samples of the oil slick may be useful for identification purposes later if the type and source information is not available from others. A suitable preservative will be necessary.

17.2 *Oil Viscosity at Skimming Temperature:*

17.2.1 *Viscometer*—A Brookfield viscometer, a similar laboratory-type viscometer, or other suitable devices can be used with oil slick samples collected from the vicinity of the skimmer if fluid is non-newtonian. The samples should be tightly sealed to prevent evaporation, and free water should be excluded. Samples should be tested at skimming temperature (see 17.5), or at least at two or three other temperatures so that an estimate of viscosity at the skimmer can be made (excessive heating must be avoided, however, as emulsion properties may change). Samples should be tested as soon as possible in their original state to minimize property changes due to emulsion settling, photodegradation, etc. (see Test Method D 2983). A laboratory viscometer will give the most controlled, accurate, and reproducible viscosity measurement and therefore is the preferred method. However, if a delay in measurement is anticipated, one of the other following methods may be preferred for expediency.

17.2.2 *Falling Ball*—A rapid and expedient method of estimating viscosity is to drop a sphere through a thick layer of oil, and record the length of time for the ball to traverse the layer.

17.2.2.1 The following equation can be used to determine viscosity:

$$u = 13\ 830\ d^2\ (S_{\text{ball}} - S_{\text{oil}}))/(U)$$

where:

u = viscosity in centipoise,
d = ball diameter in inches,
S = specific gravity (relative to fresh water), and
U = ball falling velocity, inches per second (thickness of oil layer traversed/time to traverse).

This equation is accurate if the Reynolds number (Re) is one or less, that is,

$$\text{Re} = (645\ d\ U\ S_{\text{oil}})/(u)$$

17.2.2.2 If, after conducting a test and determining a viscosity, one checks and finds that *Re* is greater than one, another ball of smaller diameter or lower specific gravity, or both, should be used. Different specific gravities result from different ball materials (for example, copper BB, $S = 8.91$; steel ball bearing, $S = 7.87$; glass or marble ball, $S = 2.4$ to 2.8). A new ball diameter, *d*new, should be selected such that:

$$d_{\text{new}} - d_{\text{old}} \times [Re_{\text{old}}\ S_{\text{ball}} - S_{\text{oil new}}]/[(S_{\text{ball}} - S_{\text{oil}})_{\text{old}}]$$

17.2.2.3 If the next try with the new ball still gives a Reynolds number greater than one, the above process can be repeated.

17.2.2.4 The container used to hold the oil should have the following features:

(*a*) Diameter should be greater than 20 times the ball diameter to keep error to less than 10 %;

(*b*) Oil thickness should be sufficient to permit a falling time of at least 3 s (to minimize stop watch errors), and preferably more; and

(*c*) Container should give some indication of when traversing of the oil layer is completed (a glass bottom; glass walls with a water layer below the oil so that the ball can be observed leaving the oil layer; a metal bottom that will provide a sound when the ball touches it; a glass container with marks on the side for translucent oils; etc.).

17.2.2.5 In addition, the ball should be released at the oil surface (not above it), as this method depends upon the ball reaching a steady-state (terminal) velocity quickly. At least three measurements should be averaged to obtain a mean sample viscosity. Calibrating the apparatus with a fluid of known viscosity (similar to the sample) will give a better idea of the errors, and can be used to develop a correction factor for the data. The oil temperature should be recorded. (Note that laboratory-quality falling-ball viscometer are available commercially, as is an inexpensive field-type version for translucent oils of up to 400 cp viscosity.)

17.2.3 *Eye Dropper*—another simple and rapid expedient for estimating viscosity is to allow the oil to flow by gravity through an eye dropper or similar device and measure the time of flow. The tubes should be precalibrated with fluids of known viscosity, or else data can be taken at the scene and then the tubes calibrated later. Water, diesel fuel, and motor oils are common fluids that could be used for on-scene calibration. With viscous oils or emulsions, larger diameter tubes may be necessary to minimize flow time. As an alternative, an Ostwald viscometer or suitable cup viscometer can be used. This type uses the same principle as the tube, but they are carefully made (of glass) for various viscosity ranges, and can be purchased already calibrated. Temperature compensation is difficult, and a fresh sample at a known temperature should be tested. At least three tests should be made and the results (time intervals) averaged to obtain a mean value. All free water should be excluded.

17.3 *Oil/Water Content of Oil Slick:* This is determined from periodic grab samples of the oil slick (free water excluded). Each sample may be allowed to settle in a transparent, cylindrical vessel until separation of oil, W/O emulsion, and O/W emulsion phases have occurred. Then, the volume of each phase can be measured and analyzed for oil and water content using the extraction technique described in Test Method D 1746. With this technique, a motor-driven or hand-crank centrifuge is usually required to assist the separation, although in many cases a sufficiently accurate measurement can be obtained (within 2 to 3 %) without a centrifuge. One hundred millilitre samples should be sufficient. (Alternatively, the original sample can be mixed thoroughly and a composite sample analyzed for oil and water content by Test Method D 1796.) If gravity settling indicates that no emulsion is present, use of the extraction technique will be unnecessary. The fraction of oil in the slick is computed by summing the oil quantities in each phase and dividing by the total sample volume.

17.4 *Slick Thickness* (for example, at entrance to skimmer or free slick—location must be identified):

17.4.1 *Thickness Multiplying Samplers:*

17.4.1.1 Two versions of this type of device have been used. The "cookie cutter" is an inverted funnel or cone attached to a clear acrylic graduated cylinder with an air valve at the top. The device is manually pushed through the surface slick and the collected oil thickness is multiplied by the area ratio of the conic section as the sample is pushed into the cylinder. The air valve is then closed so that the oil layer thickness (in the cylinder) can be read off by raising the cylinder above the slick surface. Between measurements, the insides have to be swabbed with kerosene. This system is most easily used from a Zodiac-type boat (to place the operator nearer the surface). Two sizes would be useful: (*1*) a ten-to-one funnel for slicks 5 to 50 mm thick; and (*2*) a one-to-one funnel for slicks 50 to 500 mm thick. About one sample per minute can be read. Error is estimated to be about 10 %, neglecting sample variability due to real thickness variance.

17.4.1.2 A second variation is a rectangular floating "box", open on one side, so that when it is floated on the water surface the inside will flood part way with a small, representative area of the slick and underlying water. The box is constructed so that when the open end is closed off and it is quickly lifted out of the water and turned on its end (open side up), the slick will be compressed into a much smaller horizontal area, similar to the "cookie cutter" principle, therefore multiplying the actual thickness by the ratio of the original to "new" slick surface areas. Because the box can be constructed of clear plastic, a calibrated scale can be imprinted on the side for direct reading. With a 5:1 multiplying ratio, a slick thickness of 0.5 mm or greater can be determined. Operational problems are similar to the "cookie cutter" concept. These methods are generally preferred over the other methods below because of their simplicity, accuracy, speed of operation (instant results), and general applicability.

17.4.2 *Oleophilic Sorbent Blanket*—Oil slicks on the order of 0.2 to 2.0 mm thick can be monitored by oleophilic sorbent blankets, which have a preferential affinity for oil in the presence of water. Typical blankets made of 80 pores per inch (ppi), fully-reticulated polyurethane foam; thickness of ¼-in.; and platform areas between 1 to 16 square feet have been used successfully in previous full-scale oil spill trials. The blankets are simply cast on "representative" portions of the slick, allowed to remain on the surface for a fixed time period (about 20 s), and then recovered. Water and oil are extracted by means of a mechanical wringer, and stored for later assay in pre-labeled containers (or the whole blanket can be stored in a plastic Ziplock bag). The system is compact, lightweight, portable, can be used with any conventional small workboat, and is not affected by adverse weather conditions. No particular training is required for system use, although it is imperative that the sampling boat be professionally helmed and that other vessels not cut through the slick ahead of the sampling boat. Sampling frequency is limited to about one per minute. The method is somewhat viscosity sensitive, although for viscous oils a larger pore size (40, 20, or even 10 ppi) might be used to advantage.

17.4.3 *Electronic Devices:*

17.4.3.1 A wide variety of electronic instrumentation has been used to measure slick thickness in the laboratory and the field, including the following:

(*a*) Conductivity probes,

(*b*) Capacitative probes,

(*c*) Inductive probes,

(*d*) Acoustic thickness gauges,

(*e*) Acoustic interface sensors, and

(*f*) Viscosity sensors.

17.4.3.2 All of these techniques have proven less than satisfactory. They share several or all of the following deficiencies:

(*a*) Inability to measure very thin slicks accurately, particularly in waves,

(*b*) Problems with coating of sensors with oil,

(*c*) Difficulty in resolving the frequently ill-defined oil slick/water interface, and

(*d*) Poor at-sea reliability.

17.4.3.3 Potential advantages of electronic systems are as follows:

(*a*) Continuous readings possible,

(*b*) Remote readout possible,

(*c*) Data could be recorded automatically, and

(*d*) Personnel need not be in the vicinity of the instrument.

17.4.4 *Measuring Sticks*—Two variations of this approach have been used. Such methods are suitable for only thick slicks, such as the pool of oil collected by an oil boom.

17.4.4.1 *Thieving Paste*—This is a paste-like material that is spread onto a measuring stick, and is used to detect the presence of water in the bottom of fuel tanks. It is useful only where transparent oils (light oils, gasoline) are encountered, and where wave action is not severe. The coated measuring stick is thrust down into the oil, and the depth of penetration is noted on the stick. When the stick is withdrawn, the paste will have changed color where it was in contact with water. The difference between the penetration depth and the color change is the slick thickness. A small boat is necessary to perform this check. Oil-in-water emulsions may not be detected.

17.4.4.2 *Floating Measuring Stick*—This is a measuring stick that extends below the oil-water interface, and is floated vertically in the oil slick with the aid of a stable buoyant float. The measurement must be taken from below the interface by a diver. By marking the stick with distinctive markings, the slick thickness can be read by the diver some distance from the stick. A series of these sticks, separated from each other by lengths of line, can be used to measure a slick thickness profile. Such devices are relatively independent of wave conditions.

17.5 *Slick Temperature:*

17.5.1 *Direct Measurement*—Dip an accurate thermometer into the oil slick or into a freshly drawn sample from the vicinity of the skimmer.

17.5.2 *Indirect Measurement*—In most cases, if the slick is thin and has been on the water for some time, the water temperature (Section 12) will suffice for an estimate of the oil temperature.

17.6 *Measurement of Oil Slick Width*—A measurement of the oil slick width is necessary for calculating the oil slick encounter rate (see Section 24). To permit this calculation, the slick width should be measured at the same point that the slick thickness (17.4) and velocity relative to the skimmer (Section 10) are measured. This may be in the free slick, or in the thickened region in front of the skimmer if a containment boom is being utilized. The width must be measured perpendicular to the surface velocity direction.

17.6.1 *Observations*—Aerial photographs of the slick and skimmer together (for reference) provide perhaps the best means of estimating the width. However, good contrast is needed to distinguish areas where no slick exists. As slicks can be thin, patchy and irregular, both the slick thickness and width measurements may be subject to considerable error. Other methods, such as infrared photography, and direct observe estimates, can be helpful in corroborating the measurements obtained through aerial photography. For small spills, direct observe estimates alone may suffice.

17.6.2. *Distance Line*—When containment booms are used, a rope of known length may be stretched across the mouth of the boom and attached to the tow points. The length of the rope will be the required slick width measurement if slick thickness and velocity data are also measured at the rope. Problems with this technique are that the rope may interfere with traffic, and the slick may be quite discontinuous at this point.

17.7 *Debris Description*—An estimate of the quantity and type of debris (as a function of time) encountered by the skimmer should be made. Debris includes seaweed, dead fish, sorbents, twigs, tree limbs, leaves, garbage, etc.

17.8 *Oil Slick Specific Gravity*—This can be measured using an appropriate hydrometer (Test Method 1298) in the field or in the laboratory. The temperature should be noted. (See 17.2.1 for sampling considerations.)

18. Recommended Additional Data

18.1 These quantities may be difficult to quantify accurately, especially where emulsions and thin slicks are involved.

18.2 *Oil Slick Surface Tension*—This is best performed in the laboratory (Test Methods D 1331) using a sample of freshly recovered oil slick (see 17.2.1 for sampling considerations). The test temperature should be noted, and results at the skimmer ambient temperature should be obtained, if possible. Results are subject to error if emulsions are present.

18.3 *Oil/Water Interfacial Tension*—This is best performed in the laboratory (Test Methods D 1331) using samples of freshly recovered oil slick and pure water, taken separately from the vicinity of the skimmer. Alternatively, a composite oil-water sample can be used, although the presence of an emulsion at the interface can result in unreliable measurements. For comparison with other data, oil (or water-in-oil emulsion) and distilled water should be used in addition to other measurements. The test temperature should be noted, and results at the skimmer ambient temperature should be obtained, if possible.

18.4 *General Description of Slick Continuity*—Items for consideration are as follows:

18.4.1 Dimensions and shape of oil patches or windows;

18.4.2 The presence of sheen, black oil, or other color characteristics of the slick encountered by the skimmer, as a function of time;

18.4.3 Frequency of encounter of slicks (time in slick, time between slicks);

18.4.4 Presence and frequency of tar balls, rafts, emulsion patches, debris; and

18.4.5 any other observations (odors, etc.)

18.5 *Slick Boundary Conditions*

18.5.1 Items for consideration include the presence of boundaries such as pilings, beaches (including characteristics such as rocks, rip-rap, slope, etc.); docks and piers; ships and other vessels; and containment barriers.

18.5.2 The absence of any boundaries should also be noted as well as the number of sides restricted (compass bearings and chart locations may be appropriate).

18.5.3 Other obstructions such as the spacing of pilings, etc., that affect the ability of the skimmer to maneuver should be noted.

18.5.4 Vertical restrictions can also be important, as in the case of low piers or shallow water.

18.5.5 Items such as marsh grass (or marshes themselves), floating debris, and sorbent can also be considered as slick boundaries.

18.6 *Photographs*—Color photographs of the slick should be taken, if possible. Aerial photographs and other imagery methods (infrared, etc.) are also useful in describing slick geometry and characteristics. The effects of sea state and wind can also be revealed by photographs.

RECOVERED FLUID CONDITIONS

19. Required Critical Data

19.1 *Recovery Rate of Total Fluid as a Function of Time*—This should be measured with a calibrated flow meter suitable for the fluid being recovered. Selection of a proper flow meter is difficult, however. Typical instruments are generally subject to variances in physical properties (such as viscosity, density, conductivity, etc.), particularly when recovering combined oil, water, and emulsion fluids which can vary from moment to moment in composition. A positive displacement type meter is perhaps the best, but these too may present problems in size and weight, continuous readout capability, and pressure drop. A more cumbersome alternative to a positive displacement meter is to measure the time to collect a known volume of the pumped fluid in a separate container, and then calculate an average flow rate. If pumping is periodic (as from a sump), a short-term mean pumping rate should be computed for use in steady-state rate calculations.

19.2 *Total Amount of Fluid Collected*—This should be determined from the dimensions of the volume of fluid collected in the receiver(s). Less desirably, a collection rate versus time curve (from 19.1) can be integrated to obtain an estimated volume collected. Recovered water pumped back overboard from storage should be determined also.

19.3 *Amount of Debris Recovered*—This should include a breakdown by type, if feasible, and the frequency or rate of collection.

19.4 *Oil/Water Content of Recovered Fluid:*

19.4.1 *Determined From Periodic Samples of the Recovery Pump Output*—These samples should be collected from the line leading to the storage tanks (on-board or external). Each sample should be allowed to settle in a transparent container of constant diameter for a period of time (the time period should be recorded; approximately 10 min may be sufficient for the bulk of the settling to occur). The volumes of pure oil, W/O emulsion, O/W emulsion, and pure water phases should be recorded. Samples of each oil-containing phase should then be extracted (Test Method D 1796) for determination of the oil and water content. One hundred millilitre samples will usually be sufficient. (Alternatively, the entire sample in the settling container can be re-mixed and a single sample taken to determine the total amount of oil and water by Test Method D 1796.)

19.4.2 *Determined From the Total Volume of Recovered Fluid Collected*—In this case, the entire tank contents are treated as the "settling container" in 19.4.1, and the procedure described therein is followed. The alternative approach of re-emulsifying the entire tank contents for extracting a single composite sample will be virtually impossible, however. **CAUTION:** This approach is valid only if no free water is separated from the tank contents and pumped overboard before the contents are analyzed (that is, if the tanks do not include a separator function). Also, location of interfaces between phases in skimmer tanks may be very difficult and subject to considerable inaccuracy. If the tanks are large compared to the recovery rate, analysis of the tank contents probably will not represent steady-state skimming performance.

20. Recommended Data

20.1 *Viscosity of Recovered Fluid*—See 17.2 for methods. Separate phases in the settled samples are best measured separately. Actual conditions, including technique used and temperature, should be stated.

20.2 *Specific Gravity of Recovered Fluid*—See 17.8 for method. The same consideration of settled samples described in 20.1 should be applied.

20.3 *Interfacial and Surface Tensions of Recovered Fluid*—See Sections 18.2 and 18.3 for methods.

SKIMMER CONTROL SETTINGS

21. General

21.1 A recording of skimmer performance variables is intended to provide documentation on the way the skimmer was operated. Preferably, each skimmer would be operated at maximum efficiency all the time; however, this is unreasonable to expect. A description of the factors influencing the skimmer operating conditions is therefore recommended.

22. Critical Data

22.1 All data should be recorded as a function of time in order to relate it to oil collection data. The ability to obtain some of these data will depend on installed instrumentation existing on the skimmer.

22.2 Critical data to be taken include the following as appropriate:

22.2.1 Pump rate.

22.2.2 Engine speed.

22.2.3 Speed of oil slick pickup device (sorbent belt, disk, etc.).

22.2.4 Weir depth.

22.2.5 Hydraulic fluid flow rate and pressure.

22.2.6 Pneumatic flow rate and pressure.

22.2.7 Electrical current and voltage.

22.2.8 Door openings, gill door settings, ramps, etc.

22.2.9 Other controllable parameters that affect skimmer performance (boom hookup, hoses, tanks, etc.). Provide sketches as appropriate.

22.2.10 Description of performance-limiting skimmer problems (mechanical, electrical, etc.) encountered during testing.

22.2.11 Significant noncontrollable factors (tank volumes, separator functioning, location of sample points, etc.).

CALCULATION

23. General

23.1 Throughput efficiency and recovery rate are the two most commonly calculated results of skimming tests in controlled environments. For uncontrolled environments, where conditions may be rapidly changing, these efficiencies should be calculated at several times during operations. The appropriate time upon which to base an efficiency calculation is when all of the input data were obtained during a quasi-steady state operating period.

24. Oil Slick Encounter Rate (OSER)

$$\text{OSER} = \text{oil slick thickness (17.4)} \times \text{oil slick width (17.6)} \times \text{skimmer velocity relative to the oil slick (Section 11)}$$

25. Oil Encounter Rate (OER)

$$\text{OER} = \frac{\begin{array}{c}\text{oil slick encounter rate (Section 24)}\\ \times\ \text{sum of oil volumes in oil, W/O}\\ \text{emulsion and O/W emulsion}\\ \text{phases in oil slick sample (17.3)}\end{array}}{\text{total volume of oil slick sample (17.3)}}$$

26. Oil Recovery Rate (ORR)

$$\text{ORR} = \frac{\begin{array}{c}\text{sum of oil content in oil, W/O emulsion and O/W}\\ \text{emulsion phases in recovered fluid sample (19.4.1)}\end{array}}{\begin{array}{c}\text{total volume of recovered fluid sample (19.4.1)}\\ \times\ \text{mean pumping rate of total fluid to storage (19.1)}\end{array}}$$

27. Oil Slick Recovery Rate (OSRR)

$$\text{OSRR} = \frac{\text{total volume of oil slick sample (17.3)}}{\begin{array}{c}\text{sum of oil volumes in oil, W/O emulsion,}\\ \text{and O/W emulsion phases in slick oil sample (17.3)}\\ \times\ \text{oil recovery rate (Section 26)}\end{array}}$$

28. Oil Slick Throughput Efficiency (OSTE)

$$\text{OSTE} = \frac{\text{oil slick recovery rate (Section 27)}}{\text{oil slick encounter rate (Section 23)}} \times 100\ \%$$

29. Throughput Efficiency (TE)

$$\text{TE} = \frac{\text{oil recovery rate (Section 26)}}{\text{oil encounter rate (Section 25)}} \times 100\ \%$$

NOTE 2—This value should be the same as 8.6

30. Oil Slick Recovery Efficiency (OSRE)

$$\text{OSRE} = \frac{\text{oil slick recovery rate (Section 27)}}{\text{total fluid recovery rate (19.1)}} \times 100\ \%$$

31. Recovery Efficiency (RE)

$$\text{RE} = \frac{\text{oil recovery rate (Section 26)}}{\text{total fluid recovery rate (19.1)}} \times 100\ \%$$

32. Storage Efficiency (SE)

$$\text{SE (10 min)} = \frac{\text{oil slick recovery rate (Section 27)}}{\begin{array}{c}\text{mean pumping rate of total fluid to storage}\\ \times\ \text{fraction of free water in settling}\\ \text{container after 10 min settling (9.4.1)}\end{array}} \times 100\ \%$$

NOTE 3—Storage efficiencies based on any convenient settling time basis may be computed.

GEOGRAPHICAL DESCRIPTION OF OPERATIONS AREA

33. Report

33.1 The report should include data, calculations, photography, and other observations.

33.2 Nautical charts or maps of the slick region should be provided. These should be marked to show the position and velocity direction of the skimmer, current, wind, and oil slick at the times that the data were collected. The point of origin of the slick should also be indicated.

34. Data Sheets

34.1 A data sheet format is given in Table 1. This includes all of the data discussed above, and can be used as a checklist to ensure that significant data are obtained.

TABLE 1 Data Sheet for Skimmer Testing in Uncontrolled Environments

Conditions	Time Recorded	Method/ Equipment Used
Environmental Conditions:		
Wave height (Section 6)		
Wave length and direction (Section 7)		
Skimmer forward velocity (relative to the water) (Section 8)		
Skimmer velocity (relative to the oil slick (Section 10)		
Skimmer motion relative to waves (Section 9)		
Wind speed (Section 11)		
Wind direction (Section 11)		
Surface water temperature (Section 12)		
Air temperature (Section 13)		
Current speed and direction (relative to the bottom) (Section 15)		
General weather description (14.1)		
Oil Slick Conditions (Where applicable):		
Oil type and source (17.1)		
Oil viscosity at skimming temperature (17.2)		
Oil/water content of oil slick (17.3)		
Slick thickness (at entrance to skimmer (17.4)		
Slick thickness (free slick) (17.4)		
Slick temperature (17.5)		
Oil slick surface tension (18.2)		
Oil/water interfacial tension (18.3)		
Oil slick specific gravity (17.8)		
Oil slick width (17.6)		
Debris description (17.7)		
General description of slick continuity (18.4)		
Slick boundary conditions (18.5)		
Recovered Fluid Conditions:		
Recovery rate (19.1)		
Total amount collected (19.2)		
Oil/water content (19.4)		
Viscosity (20.1)		
Specific gravity (20.2)		
Debris amount (19.3)		
Skimmer Control Settings (As Applicable):		
Pump rate		
Engine speed		
Speed of oil slick pickup device		
Weir depth		
Hydraulic fluid flow rate/pressure		
Pneumatic flow rate/pressure		
Electrical current/voltage		
Door openings, etc.		
Other controllable parameters		
Description of performance limiting variables		
Significant non-controllable variables		
Calculated Results:		
Oil slick encounter rate		
Oil encounter rate		
Oil recovery rate		
Oil slick recovery rate		
Oil slick throughput efficiency		
Throughput efficiency		
Oil slick recovery efficiency		
Recovery efficiency 4.2		
Storage efficiency		
Geographical Description of Operations Area: Listcharts prepared, and attach		
Photographs, Describe and attach		

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

* * *

Document Name: ASTM G151: Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources

CFR Section(s): 49 CFR 571.106 S12.7(b)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: G 151 – 97

Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources[1]

This standard is issued under the fixed designation G 151; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice provides general procedures to be used when exposing nonmetallic materials in accelerated test devices that use laboratory light sources. Detailed information regarding procedures to be used for specific devices are found in standards describing the particular device being used. For example, detailed information covering exposures in devices that use carbon-arc, xenon-arc, and fluorescent UV light sources are found in Practices G 23, G 26, and G 53, respectively.

NOTE 1—New performance based standards describing exposures in carbon-arc, xenon-arc, and fluorescent UV exposures are being developed by Subcommittee G 03.03.

1.2 This practice also describes general performance requirements for devices used for exposing nonmetallic materials to laboratory light sources. This information is intended primarily for producers of laboratory accelerated exposure devices.

NOTE 2—Certification of conformance to the performance requirements for new exposure devices generally is the responsibility of the manufacturer.

1.3 This practice provides information on the use and interpretation of data from accelerated exposure tests. Specific information about methods for determining the property of a nonmetallic material before and after exposure are found in standards describing the method used to measure each property. Information regarding the reporting of results from exposure testing of plastic materials is described in Practice D 5870.

NOTE 3—The Committee G-3 is developing standard guides for application of statistics to exposure test results and for addressing variability in exposure testing of nonmetallic materials.

NOTE 4—This standard is technically equivalent to ISO DIS 4892, Part 1.

1.4 *This standard does not purport to address all of the safety concerns, if any, 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. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D 3924 Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquer and Related Materials[3]

D 5870 Practice for Calculating Property Retention Index of Plastics[3]

E 41 Terminology Relating to Conditioning[4]

E 171 Specification for Standard Atmospheres for Conditioning and Testing Flexible Barrier Materials[5]

E 585 Specification for Base-Metal Thermocouple Materials[6]

E 644 Test Methods for Testing Industrial Resistance Thermometers[6]

E 772 Terminology Relating to Solar Energy Conversion[7]

E 839 Test Methods for Sheathed Thermocouples and Sheathed Thermocouple Material[6]

G 7 Practice for Atmospheric Environmental Exposure Testing of Nonmetallic Materials[4]

G 23 Practice for Operating Light Exposure Apparatus (Carbon-Arc) Type With and Without Water for Exposure of Nonmetallic Materials[4]

G 24 Practice for Conducting Exposures to Daylight Filtered Through Glass[4]

G 26 Practice for Operating Light-Exposure Apparatus (Xenon-Arc) Type With and Without Water for Exposure of Nonmetallic Materials[4]

G 53 Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV Condensation Type) for Exposure of Nonmetallic Materials[4]

G 113 Terminology Relating to Natural and Artificial Weathering Tests for Nonmetallic Materials[4]

G 130 Method for Calibration of Narrow- and Broad-Band Ultraviolet Radiometers Using a Spectroradiometer[4]

G 147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests[4]

---

[1] This practice is under the jurisdiction of ASTM Committee G-3 on Weathering and Durability and is the direct responsibility of Subcommittee G03.03 on Simulated and Controlled Exposure Tests.

Current edition approved July 10, 1997. Published May 1998.

[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 06.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 15.09.

[6] *Annual Book of ASTM Standards*, Vol 14.03.

[7] *Annual Book of ASTM Standards*, Vol 12.02.

2.2 *ISO Standards:*

ISO 4892, Part 1 Plastics: Exposure to laboratory Light Sources–General Guidance[8]

ISO 9370 Plastics: Instrumental Determination of Radiant Exposure in Weathering Tests–General Guidance and Basic Test Method[8]

2.3 *CIE Documents:*

CIE Publication Number 85: 1989, Technical Report–Solar Spectral Irradiance[9]

3. Terminology

3.1 *Definitions*—The definitions given in Terminologies E 41, E 772, and G 113 are applicable to this practice.

4. Significance and Use

4.1 *Significance*:

4.1.1 When conducting exposures in devices that use laboratory light sources, it is important to consider how well the accelerated test conditions will reproduce property changes and failure modes associated with end-use environments for the materials being tested. In addition, it is essential to consider the effects of variability in both the accelerated test and outdoor exposures when setting up exposure experiments and when interpreting the results from accelerated exposure tests.

4.1.2 No laboratory exposure test can be specified as a total simulation of actual use conditions in outdoor environments. Results obtained from these laboratory accelerated exposures can be considered as representative of actual use exposures only when the degree of rank correlation has been established for the specific materials being tested and when the type of degradation is the same. The relative durability of materials in actual use conditions can be very different in different locations because of differences in UV radiation, time of wetness, relative humidity, temperature, pollutants, and other factors. Therefore, even if results from a specific exposure test conducted according to this practice are found to be useful for comparing the relative durability of materials exposed in a particular exterior environment, it cannot be assumed that they will be useful for determining relative durability of the same materials for a different environment.

4.1.3 Even though it is very tempting, calculation of an *acceleration factor* relating x h or megajoules of radiant exposure in a laboratory accelerated test to y months or years of exterior exposure is not recommended. These acceleration factors are not valid for several reasons.

4.1.3.1 Acceleration factors are material dependent and can be significantly different for each material and for different formulations of the same material.

4.1.3.2 Variability in the rate of degradation in both actual use and laboratory accelerated exposure test can have a significant effect on the calculated acceleration factor.

4.1.3.3 Acceleration factors calculated based on the ratio of irradiance between a laboratory light source and daylight, even when identical bandpasses are used, do not take into consideration the effects of temperature, moisture, and differences in spectral power distribution between the laboratory light source and daylight.

NOTE 5—If use of an acceleration factor is desired in spite of the warnings given in this practice, such acceleration factors for a particular material are only valid if they are based on data from a sufficient number of separate exterior and laboratory accelerated exposures so that results used to relate times to failure in each exposure can be analyzed using statistical methods. An example of a statistical analysis using multiple laboratory and exterior exposures to calculate an acceleration factor is described by J.A. Simms (1).[10]

4.1.4 There are a number of factors that may decrease the degree of correlation between accelerated tests using laboratory light sources and exterior exposures. More specific information on how each factor may alter stability ranking of materials is given in Appendix X1.

4.1.4.1 Differences in the spectral distribution between the laboratory light source and sunlight.

4.1.4.2 Light intensities higher than those experienced in actual use conditions.

4.1.4.3 Test conditions where specimens are exposed continuously to light when actual use conditions provide alternate periods of light and dark.

4.1.4.4 Specimen temperatures higher than those in actual conditions.

4.1.4.5 Exposure conditions that produce unrealistic temperature differences between light and dark colored specimens.

4.1.4.6 Exposure conditions, which produce very frequent cycling between high and low specimen temperatures, or which produce unrealistic thermal shock.

4.1.4.7 Unrealistically high or low levels of moisture.

4.1.4.8 Absence of biological agents or pollutants.

4.2 Use of accelerated tests with laboratory light sources.

4.2.1 Results from accelerated exposure tests conducted according to this standard are best used to compare the relative performance of materials. A common application is conducting a test to establish that the level of quality of different batches does not vary from a control material with known performance. Comparisons between materials are made best when the materials are tested at the same time in the same exposure device. Results can be expressed by comparing the exposure time or radiant exposure necessary to reduce the level of a characteristic property to some specified level.

4.2.1.1 It is strongly recommended that at least one control material be exposed with each test for the purpose of comparing the performance of the test materials to that of the control. Ideally, the control material should be of similar composition and construction and be chosen so that its failure modes are the same as that of the material being tested. It is preferable to use two controls, one with relatively good durability and one with relatively poor durability.

4.2.1.2 Sufficient replicates of each control material and each test material being evaluated are necessary in order to allow statistical evaluation of results. Unless otherwise specified, use a minimum of three replicates for all test and control

---

[8] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[9] CIE

[10] The boldface numbers in parentheses refer to the list of references at the end of this standard.

materials. When material properties are measured using destructive tests, a separate set of specimens is needed for each exposure period.

4.2.2 In some applications, reference materials are used to establish consistency of the operating conditions in an exposure test. Reference materials, for example, blue wool test fabric, also may be used for the purpose of timing exposures.

4.2.2.1 In some cases, a reference material is exposed at the same time as a test material and the exposure is conducted until there is a defined change in property of the reference material. The test material then is evaluated. In some cases the results for the test material are compared to those for the reference material. These are inappropriate uses of reference materials when they are not sensitive to exposure stresses, which produce failure in the test material, or when the reference material is very sensitive to an exposure stress that has very little effect on the test material.

NOTE 6—Definitions for control and reference material that are appropriate to weathering tests are found in Terminology G 113.

NOTE 7—Subcommittee G03.01 is developing a standard practice for selecting and characterizing weathering reference materials used to establish consistency of operating conditions in a laboratory accelerated test.

4.3 Results from accelerated exposure tests only should be used to establish a pass/fail approval of materials after a specific time of exposure to a prescribed set of conditions when the variability in the exposure and property measurement procedure has been quantified so that statistically significant pass/fail judgments can be made.

5. Requirements for Laboratory Exposure Devices

5.1 *Light Source*:

5.1.1 The exposure device shall provide for placement of specimens and any designated sensing devices in positions which provide uniform irradiance by the light source.

NOTE 8—In some devices, several individual light sources are used simultaneously. In these devices, the term *light source* refers to the combination of individual light sources being used.

5.1.2 Manufacturers of exposure devices shall assure that the irradiance at any location in the area used for specimen exposures is at least 70 % of the maximum irradiance measured in this area. Procedures for measuring irradiance uniformity are found in Annex A1.

NOTE 9—During use, the irradiance uniformity in exposure devices can be affected by several factors, such as deposits, which can develop on the optical system and chamber walls. Irradiance uniformity also can be affected by the type and number of specimens being exposed. The irradiance uniformity as assured by the manufacturer is valid for new equipment and well defined measuring conditions.

5.1.3 Periodic repositioning of the specimens during exposure is not necessary if the irradiance at positions farthest from the center of the specimen area is at least 90 % of that measured at the center of the exposure area.

5.1.4 If irradiance at positions farthest from the center of the exposure area is between 70 and 90 % of that measured at the center, one of the following three techniques shall be used to used for specimen placement.

5.1.4.1 Periodically reposition specimens during the exposure period to ensure that each receives an equal amount of radiant exposure. The repositioning schedule shall be agreed upon by all interested parties.

5.1.4.2 Place specimens only in the exposure area where irradiance is at least 90 % of the maximum irradiance.

5.1.4.3 Randomly position replicate specimens within the exposure area that meets the irradiance uniformity requirements defined in 5.1.4

5.1.5 Replace lamps and filters according to the schedule recommended by the device manufacturer. Follow the apparatus manufacturer's instructions for lamp and filter replacement and for pre-aging of lamps or filters, or both.

5.1.6 CIE Publication No. 85-1989 provides data on solar spectral irradiance for typical atmospheric conditions, which can be used as a basis for comparing laboratory light sources with daylight. For example, global solar irradiance in the 300 to 2450 nm band is given as 1090 W/m^2 for relative air mass 1, with 1.42 cm precipitable water, and 0.34 cm of ozone (measured at a pressure of 1 atmosphere and temperature of 0°C). Table 1 shows a broad band condensed spectral irradiance for global solar radiation at this atmospheric condition in the UV, visible and infrared portions of the spectrum. This represents the maximum global solar irradiance that would be experienced by materials exposed on a horizontal surface at the equator near noon on a clear day at the spring or autumn equinox.

5.1.6.1 Direct radiation from xenon burners, open flame carbon arcs, and some fluorescent lamps contains considerable amounts of short wavelength ultraviolet radiation not present in daylight. With proper selection of filters for these light sources, much of the short wavelength light can be eliminated. Even when filters are used, however, a small, but significant, amount of this short wavelength (less than 300 nm) radiation often is present in the spectral distribution of the filtered light source. Fluorescent UV lamps can be selected to have a spectral output corresponding to a particular ultraviolet region of sunlight. The xenon arc, when appropriately filtered, produces radiation with a spectral power distribution that is a good simulation of average sunlight throughout the UV and visible region.

5.1.7 A radiometer, which complies with the requirements outlined in ISO 9370 may be used to measure irradiance, E, or the spectral irradiance, E, and the radiant exposure, H, or the spectral radiant exposure, H, on the specimen surface.

5.1.7.1 If used, the radiometer shall be mounted so that it receives the same irradiance as the specimen surface. If it is not positioned within the specimen plane, it shall be calibrated for irradiance at the specimen distance.

5.1.7.2 The radiometer shall be calibrated in the emission region of the light source used. Calibration of narrow or

TABLE 1 Spectral Global Irradiance (condensed from Table 4 of CIE Publication No. 85–1989)

Wavelength (nm)	Irradiance (Wm^{-2})	Percent Total (300-2450 nm)	Percent of UV and Visible (300-800 nm)
300-320	4.1	0.4	0.6
320-360	28.5	2.6	4.2
360-400	42.0	3.9	6.2
300-400	74.6	6.8	11.0
400-800	604.2	55.4	89.0
300-800	678.8	62.2	100.0
800-2450	411.6	37.8	...
300-2450	1090.4	100.0	...

broad-band ultraviolet radiometers with a spectroradiometer shall be conducted according to Method G 130. Calibration shall be checked according to the radiation measuring instrument manufacturer's instructions. A full calibration of the radiometer shall be conducted at least once/year. More frequent calibrations are recommended.

5.1.7.3 When measured, the irradiance in the wavelength range agreed upon by all interested parties shall be reported. Some apparatus provide for measuring irradiance in a specific wavelength range for example, 300–400 or 300–800 nm, or in a narrow bandpass centered around a single wavelength, for example, 340 nm.

5.2 *Temperature*:

5.2.1 The surface temperature of exposed materials depends primarily on the amount of radiation absorbed, the emissivity of the specimen, the thermal conduction within the specimen, and the heat transmission between specimen and air or specimen holder. Since it is not practical to monitor the surface temperature of individual test specimens, a specified black-panel sensor is used to measure and control temperature within the test chamber. It is strongly recommended that the black panel temperature sensor be mounted on a support within the specimen exposure area so that it receives the same radiation and cooling conditions as a flat test panel surface using the same support. The black panel also may be located at a fixed distance position different from the test specimens and calibrated for temperature in the specimen exposure area. This is not recommended, however, because black panels mounted at a fixed position away from the specimens may not indicate temperatures representative of the test specimens, even if they are calibrated to record temperature at positions within the specimen exposure area, due to differences in light intensity and movement of air.

5.2.2 Exposure devices shall use either an uninsulated black panel or an insulated black panel as black panel sensor. Requirements for each type are found in Annex A2.

5.2.3 The temperature indicated by the uninsulated black-panel or insulated thermometer depends on the irradiance of the laboratory light source and the temperature and speed of air moving in the test chamber. Uninsulated black-panel temperatures generally correspond to those for dark coatings on metal panels. Insulated black panel thermometer temperatures generally correspond to those for the exposed surface of dark samples with poor thermal conductivity. At conditions used in typical exposure tests, the temperature indicated by an insulated black panel thermometer will be 3-12°C higher than an uninsulated black panel thermometer. The response time for temperature changes is slightly slower for insulated black panel thermometers compared to uninsulated black panel thermometers.

5.2.3.1 At low irradiance, the difference between the temperature indicated by an uninsulated black panel or insulated black panel and the real specimen may be small. When light sources that emit very little infrared radiation are used, there generally will be very small difference in temperatures indicated by the two types of black panels or between light and dark colored specimens.

5.2.4 In order to evaluate the range of surface temperatures of the exposed specimens, the use of an uninsulated white panel or insulated white standard thermometer is recommended, in addition to the uninsulated black panel or insulated black panel thermometer. In some cases, temperature of either the uninsulated or insulated white panel thermometer may be used to specify exposure conditions. The uninsulated or insulated white panel shall be constructed in the same way as the corresponding uninsulated or insulated black panel thermometer, except for use of a white coating with a good resistance to aging. The reflectance of the white coating between 300 and 1000 nm shall be at least 90 % and at least 60 % between 1000 and 2500 nm.

5.2.5 Exposure devices which control temperature of a black or white temperature sensor shall be able to maintain temperature within± 3°C of the desired temperature. Manufacturers of exposure devices shall assure that the temperature of a black or white panel temperature sensor placed anywhere within the specimen exposure area shall be within ± 5 % of the desired centigrade temperature.

5.2.6 The test report shall indicate whether an insulated or uninsulated black or white panel was used. If either type of black or white panel thermometer is not positioned in the specimen exposure area, the exact position used shall be described in the test report.

NOTE 10—There can be differences in temperature indicated by a single type of black panel thermometer, depending on the specific design of the device supplied by different manufacturers. Work is being conducted within Subcommittee 6 ISO TC/61 to characterize the differences between the different types of temperature sensing devices and between temperature sensing devices of the same type.

5.2.7 If chamber air temperature is measured, the temperature sensing element shall be shielded from the light source and water spray. Exposure devices, which control temperature of chamber air shall be able to maintain temperature of chamber air within ± 3°C of the desired temperature.

5.2.8 Calibrate thermocouples according to instructions provided by the device manufacturer. If no instructions are provided by the device manufacture, sheathed thermocouples shall be calibrated according to Method E 839, and resistance thermometers used as the sensing element for black or white panel thermometers shall be calibrated according to Method E 644. Unless otherwise specified, devices used to measure temperature shall be calibrated at least annually. Wherever possible, calibrations should be traceable to a nationally recognized standards agency.

5.3 *Humidity and Wetting*:

5.3.1 The presence of moisture may have a significant effect on exposure tests. Any apparatus operated according to this standard, which attempts to simulate the effects of moisture, shall have means for providing moisture to specimens using one or more of the following methods: humidification of chamber air, formation of condensation, water spray, or immersion. The type and rate of material degradation can be affected significantly by the method used to provide moisture stress.

5.3.2 The purity of the water used for specimen wetting is very important. Without proper treatment to remove cations, anions, organics, and particularly silica, exposed specimens will develop spots or stains that do not occur in exterior exposures. It is strongly recommended that water used for specimen wetting contain maximum of 1 ppm solids and a maximum of 0.2 ppm silica. Distillation, or a combination of deionization and reverse osmosis can effectively produce water with the desired purity. If the water used for specimen wetting is above 1 ppm solids, the solids and silica levels must be reported. Recirculation of water used for specimen wetting is not recommended and must not be done unless the recirculated water meets the purity requirements listed above.

5.3.3 If specimens are found to have deposits or stains after exposure, the water purity must be checked to determine if it meets the purity requirements described in 5.3.2. On some occasions, exposed specimens can be contaminated by deposits from bacteria than can grow in the purified water used for specimen wetting. If bacterial contamination is detected, the entire system used for specimen wetting shall be flushed with a chlorinating solution, such as sodium hypochlorite and thoroughly rinsed prior to resuming exposures.

5.3.4 Although it does not always correlate with silica content, it is recommended that the conductivity of the water used for specimen wetting be monitored continuously and that exposures be stopped whenever the conductivity is above 5 µS/cm.

5.3.5 All components of the specimen wetting unit shall be fabricated from stainless steel, plastic, or other material that does not contaminate the water. If plastic materials are used, they shall not leach low molecular weight UV absorbing components into the water.

5.3.6 In devices where humidity within the test chamber is controlled, sensors used to determine humidity shall be placed within the test chamber air flow and shielded from direct radiation and water spray. When humidity is controlled, the measured relative humidity shall be within ± 5 % of the desired humidity.

5.3.6.1 Calibrate the sensors used to determine humidity according to the device manufacturer's instructions.

5.3.7 Any device intended to introduce wetting of specimens, for example, by spray or immersion, shall have means to program intervals with and without wetting.

NOTE 11—There is currently no generally accepted method for characterizing the uniformity or consistency of specimen wetting.

5.4 *Other Apparatus Requirements*—Although various apparatus designs are used in practice, each apparatus shall include the following:

5.4.1 Any device intended to provide light and dark cycles shall have means to program intervals with or without light. The time of each light and dark cycle shall be controlled to within ± 10 % of the shortest cycle time used. It is preferable to use cycle timers that are accurate and reproducible as possible. Optionally, means to provide a record of the length of light and dark cycles may be provided.

5.4.2 To fulfill the requirements of particular test procedures, the apparatus also may need to provide means to register or record the following operational parameters.

5.4.2.1 Line voltage;

5.4.2.2 Lamp voltage and where appropriate, lamp wattage;

5.4.2.3 Lamp current;

5.4.2.4 Temperature of uninsulated or insulated black or white panel thermometer;

5.4.2.5 Test chamber air temperature;

5.4.2.6 Test chamber relative humidity,

5.4.2.7 Water spray cycles;

5.4.2.8 Irradiance or radiant exposure, or both, over a specified spectral region; and,

5.4.2.9 Duration of exposure (radiation time and total, if different).

5.4.3 Follow the recommendations of the device manufacturer regarding calibration of devices used to record each operational parameter.

6. Test Specimens

6.1 *Form and Preparation:*

6.1.1 The dimensions of the test specimens normally are those specified in the appropriate test method for the property or properties to be measured after exposure. When the behavior of a specific type of article is to be determined, the article itself should be exposed whenever possible.

6.1.2 For some tests, specimens to be exposed may be cut from a larger sheet or part that is formed by extrusion, injection molding, or other process. The exact shape and dimensions of the specimens to be exposed will be determined by the specific test procedure used for measurement of the property of interest. The procedures used to machine or cut individual test specimens from a larger sheet or part may affect the results of the property measurement and the apparent durability. Therefore, the method used for specimen preparation shall be agreed upon by the interested parties and should be related closely to the method normally used to process the material in typical application.

6.1.3 Unless otherwise specified or required, do not cut individual test specimens for property measurement from larger specimens that have been exposed. The effects any cutting or machining operation may have on the properties of individual test specimens usually are much larger when the test specimens are cut from a large piece after exposure. This is especially true for materials that embrittle on exposure.

6.1.3.1 When test specimens are cut from an exposed sheet or larger part, they should be taken from an area that is at least 20 mm from the fixture holding the material or from the exposed specimen edges. In no circumstances shall any material from the exposed face be removed during the test specimen preparation.

6.1.4 When comparing materials in an exposure test, use test specimens that are similar in dimensions and exposed area.

6.2 *Number of Test Specimens:*

6.2.1 The number of test specimens for each test condition or exposure period shall be that specified in the appropriate test method for the property or properties to be measured after exposure.

6.2.2 Unless otherwise specified or required, use at least three replicate specimens where properties are measured using nondestructive tests and six replicate specimens where properties are measured using destructive tests.

6.2.3 When destructive tests are used to determine the properties being measured, the total number of test specimens required will be determined by the number of exposure periods used and whether unexposed file specimens are tested at the same time as exposed specimens.

6.2.4 Control materials with known durability should be included with each exposure test. It is recommended that control materials known to have relatively poor and good durability be used. Control materials are used for the purpose of comparing the performance of the test materials to the controls. Before laboratory to laboratory comparisons are made it is necessary to establish agreed upon control materials. The number of specimens of the control material should be the same as that used for test materials.

6.3 *Storage and Conditioning*:

6.3.1 Conditioning and handling of test, control, reference, and file specimens shall be according to Practice G 147.

6.3.2 If test specimens are cut or machined from larger pieces, they should be conditioned after machining according to Practice D 618, or Specifications D 3924, E 171. In some circumstances, it may be necessary to precondition the sheets prior to cutting or machining to facilitate specimen preparation. The properties of some materials are very sensitive to moisture content and the duration of conditioning may need to be longer than those specified in these standards, particularly where specimens have been exposed to climatic extremes.

6.3.3 Some materials will change color during storage in the dark, particularly after weathering. It is essential that color measurement or visual comparison be carried out as soon as possible after exposure once the exposed surface has dried.

7. Exposure Conditions and Procedure

7.1 Do not touch the surface of exposed specimens or optical components with bare skin because oils that are deposited may act as UV absorbers or contain contaminants which accelerate degradation.

7.2 Specific conditions and procedures for the exposure test depend upon on the type of device used and the material being tested. For carbon-arc, xenon-arc, and fluorescent UV exposures, these can be found in Practices G 23, G 26, and G 53 and in other standards which reference these practices.

7.2.1 Select material properties that exhibit a significant change during the exposure period in order to provide weathering performance discrimination among a series of materials.

7.2.2 Periodic evaluation of test and control materials is recommended to determine the variation in magnitude and direction of property change as a function of exposure time or radiant exposure.

7.2.2.1 The time or radiant exposure necessary to produce a defined change in a material property can be used to evaluate or rank the stability of materials. This method is preferred over evaluating materials after an arbitrary exposure time or radiant exposure.

7.3 Follow the procedures described in the appropriate standard for measuring properties on test specimens before and after exposure.

7.4 If nondestructive tests are used to measure properties of the materials being tested, properties of test specimens shall be measured before beginning the exposure. The same property then is measured on the test specimens after each exposure period. Care should be taken to make the property measurement after each exposure period in the same position on the test specimen.

NOTE 12—To monitor the response of the instrument used to measure the desired property, one can measure a calibration standard each time the test instrument is used.

7.5 If destructive tests are used to measure properties of the materials being tested, separate sets of test specimens will be needed for each exposure period. The property is measured on each set of exposed specimens. The value of the property after exposure may be compared to the property measured on an unexposed set of specimens measured prior to beginning the exposure. Alternatively, the property can be measured on a separate set of unexposed file specimens at the same time as the property of exposed specimens is measured. The results for the unexposed file specimens and from the exposed specimens can then be compared.

NOTE 13—Procedures and formulas for calculating the change in material property of test materials and reference materials after exposure can be found in Practice D 5870.

8. Test Report

8.1 The test report shall contain the following information;

8.1.1 Specimen description;

8.1.2 A full description of the specimens and their origin;

8.1.3 Compound details, cure time, and temperature where appropriate; and

8.1.4 Complete description of the method used for preparation of test specimens.

NOTE 14—If exposure tests are conducted by a contracting agency, specimens usually are identified by code number. In such cases, it is the responsibility of the originating laboratory to provide the complete specimen description when reporting results of the exposure test.

8.2 *Description of Exposure Test*—Description of the exposure device and light source including:

8.2.1 Type of device and light source;

8.2.2 Description of the filters used;

8.2.3 If required, mean and tolerance for irradiance at the specimen surface, including the bandpass in which the radiation was measured; and,

8.2.4 If required, mean and tolerance for wattage used for laboratory light source.

8.3 Type of black or white panel, or both thermometer used—Exact position of the black or white panel thermometer if it was not located in the test specimen exposure area.

8.4 If required, type of instrument used to measure humidity.

8.5 Complete description of exposure cycle used, including the following information for each light and dark period used:

8.5.1 Mean and tolerance limits for temperature recorded by the black panel thermometer;

8.5.2 Mean and tolerance limits for relative humidity of air passing over test specimens;

8.5.3 Time of water spray period and the conditions of water used for specimen spray, if used, including total solids and silica content if total solids is greater than 1 ppm;

8.5.4 Time of each light and dark period;

8.5.5 Mean and tolerance for white panel temperature, if applicable; and

8.5.6 Mean and tolerance for chamber air temperature, if applicable.

8.6 Description of method used to mount specimens in exposure frame, including a description of any material used as backing for test specimens.

8.7 Procedure for test specimen repositioning, if used.

8.8 Description of the radiometers used for measuring light dosage, if used.

8.9 *Test Results:*

8.9.1 Complete description of the test procedure used for measurement of any properties reported;

8.9.2 Results from property measurement on test specimens;

8.9.3 Results from property measurement on control specimens;

8.9.4 Results from property measurement on unexposed file specimens, if determined; and,

8.9.5 Exposure period (either time in hours, or radiant energy in Jm^2 and the bandpass in which it was measured).

8.10 The date of the test.

9. Precision and Bias

9.1 Precision and bias information can be found in relevant standards describing the specific type of exposure device.

10. Keywords

10.1 accelerated; durability; exposure; light; temperature; weathering; ultraviolet; UV-radiation

ANNEXES

(Mandatory Information)

A1. PROCEDURES FOR MEASURING IRRADIANCE UNIFORMITY IN SPECIMEN EXPOSURE AREA

A1.1 In devices that use a drum to hold specimens and rotate them around a light source, measure irradiance at a position in the specimen drum that is closest to the light source (position *A*) in Fig. A1.1 and at two positions within the specimen drum that are farthest from the light source (position *B*) in Fig. A1.1. The relationship between the irradiance at position *B* relative to the irradiance at position *A* shall be as follows:

$$B \geq 0.7\,A \qquad \text{(A1.1)}$$

A1.2 In devices where specimens are positioned in a flat plane in front of a light source, measure irradiance at a position in the specimen plane that is closest to the light source (position *X* in Fig. A1.2) and in two opposite corners of the plane where test specimens are placed (position *Y* in Fig. A1.2). The relationship between the irradiance at position *Y* relative to the irradiance at position *X* shall be as follows:

$$Y \geq 0.7\,X \qquad \text{(A1.2)}$$

A1.3 If device design indicates that the maximum irradiance may not be at the center of the exposure area, the actual maximum irradiance shall be used for *A* or *X* in Eq A1.1 and Eq A1.2. Additional measurements of irradiance at other positions within the exposure area may also be made. In all cases, however, the irradiance measured at these positions shall be at least 70 % of the maximum irradiance.

A1.4 As an alternate to irradiance measurements, uniformity of irradiance may be determined by use of reference materials. The change in characteristic property of the reference material shall be known function preferably linear, of radiant exposure. Do not use reference materials, which show an induction time with little change in property as a function of radiant exposure. Fig. A1.3 is a typical plot of measured property as a function of radiant exposure for reference materials. Prior to using a reference material to determine uniformity of irradiance, repeatability of the property change for specimens of the reference material exposed at the same position must be determined. When reference materials are used, all specimens shall be from the same lot. Expose reference material specimens at the center of the exposure area and at positions farthest from the center. All specimens shall be exposed at the same time. Expose the reference specimens until there is a measurable change in the characteristic property being monitored. The change in measured property of the reference material at positions farthest from the center shall be at least 70 % of the change measured on the specimen exposed at the center.

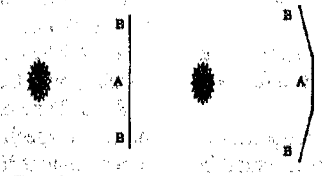


FIG. A1.1 Measurement of Irradiance in Devices Using a Rotating Specimen Drum

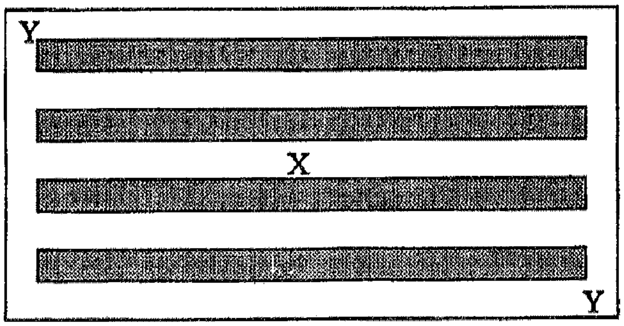
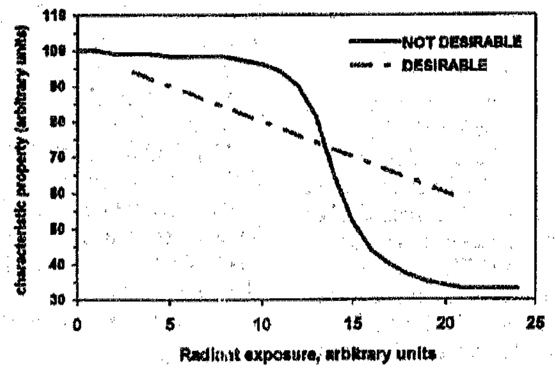


FIG. A1.2 Measuring Irradiance Uniformity in Device With a Flat Specimen Plane (Shaded Areas Indicate Light Sources)



NOTE 1—Typical plot of measured property for a reference material with a linear change with radiant exposure and a material that shows an induction period before measurable property change. Reference materials showing a linear change in property as a function of radiant exposure are desirable for use in characterizing irradiance uniformity.

FIG. A1.3 Typical Plot of Measured Property for Reference Materials

NOTE A1.1—Actual measurements of irradiance are preferred over use of reference materials because differences in property change between reference material specimens exposed at the extremes of the exposure and those exposed at the center may be affected significantly by differences in temperature or moisture conditions, or both, as well as differences in irradiance.

A2. REQUIREMENTS FOR UNINSULATED AND INSULATED BLACK PANEL THERMOMETERS

A2.1 Uninsulated black-panel thermometers consist of a plane (flat) metal plate that is resistant to corrosion. The surface of this plate that faces the light source shall be coated with a black layer which has good resistance to aging. The coated black plate shall absorb at least 90-95 % of all incident flux to 2500 nm. A thermal sensitive element shall be firmly attached to the center of the exposed surface. This thermal sensitive element can be a black-coated stem-type bimetallic dial sensor or a resistance sensor. The backside of the metal panel shall be open to the atmosphere within the exposure chamber.

A2.2 Insulated black panel thermometers consist of a plane (flat) stainless steel plate with a thickness of about 0.5 mm. The minimum dimensions for the stainless steel plate are 70 mm by 40 mm (2). The surface of this plate facing the light source shall be coated with a black layer which has good resistance to aging. The coated black plate shall absorb at least 90-95 % of all incident flux to 2500 nm. A platinum resistance sensor shall be attached in good thermal contact to the center of the plate on the side opposite the radiation source. This side of the metal plate shall be attached to 5 mm thick base plate made of unfilled polyvinylidene fluoride (PVDF). A small space sufficient to hold the platinum resistance sensor shall be machined in the PVDF base plate. The distance between the sensor and this recess in the PVDF plate is about 1 mm. The length and the width of the PVDF plate must be sufficient so that no metallic thermal contact exists between the black coated metal plate and the mounting holder into which it is fitted. The metallic mounts of the insulated black panel holder shall be at least 4 mm from the edges of the metal plate. Black standard thermometers which differ in construction are permitted, as long as the temperature of the alternate construction is within ± 1.0°C of the specified construction at all steady state temperature and irradiance settings the exposure device is capable of attaining. In addition, the time needed for an alternate black standard thermometer construction to reach steady state must be within 10 % of the time needed for the specified black standard thermometer to reach steady state.

NOTE A2.1—Insulated black panel thermometers are referred to as black standard thermometers in ISO 4892.

APPENDIX

(Nonmandatory Information)

X1. FACTORS THAT DECREASE DEGREE OF CORRELATION BETWEEN ACCELERATED TESTS USING LABORATORY LIGHT SOURCES AND ACTUAL USE EXPOSURES

X1.1 Differences in the spectral distribution or intensity between the laboratory light source and sunlight.

X1.1.1 Shorter than normal wavelength exposures are often used to obtain faster failure rates in laboratory accelerated exposure tests. For outdoor exposures, the cut-on for short wavelength UV radiation is generally considered to be about 300 nm. Exposures to UV radiation of wavelengths less than 300 nm, may produce degradation reactions, which do not occur when the material is used outdoors. If a laboratory light source used in an accelerated test contains UV radiation of wavelengths shorter than that found in the actual use condition, the mechanism of degradation and stability ranking of materials can be dramatically different in the accelerated test.

X1.1.2 It may not be necessary to simulate daylight over the entire spectrum, if radiation in a specific region is known to produce the type of degradation of interest in the materials being tested and does not alter stability ranking of materials. Laboratory light sources, which have a very strong emission in a narrow band relative to the rest of the ultraviolet or visible spectrum, however, may cause a particular reaction to be favored relative to others which may be very important (3). This type of light source also may not produce changes caused in exposures to daylight. Exposures to light sources, which only produce ultraviolet radiation may not produce color fade caused by visible radiation, and may cause polymer yellowing that is more pronounced than that produced in exposures to daylight.

X1.2 *Light Intensities Higher Than Those Experienced in Actual Use Conditions*—Light intensities higher than those experienced in actual use conditions typically are used in exposures to laboratory light sources in order to accelerate degradation. There are several reasons why the use of abnormally high irradiance can change the mechanism of material degradation relative to the conditions found in actual use environment. Some materials are more sensitive to changes in light intensity than others, so the use of abnormally high irradiance can alter the stability ranking of materials.

X1.2.1 In exterior exposures, polymers in an excited state caused by absorption of a high energy photon typically will decay to ground state before absorbing another high energy photon. In exposures to laboratory light sources with abnormally high light flux, however, the rate of photon absorption is so high that the material will often absorb a high energy photon when it is still in an excited state (4).

X1.2.2 Free radicals are formed in materials exposed to ultraviolet light. Reactions leading to degradation occur when the free radicals interact with the material. Free radicals also can recombine with other free radicals in reactions that do not lead to degradation. The high concentration of free radicals formed under high irradiance conditions results in a greater percentage of recombination due to the close proximity of the free radicals, particularly in polymers exposed at temperatures below their T_g (5).

X1.2.3 Oxygen diffusion can sometimes become rate limiting in polymer oxidation processes where abnormally high irradiance, or abnormally high specimen temperatures, are used for test acceleration (6). This can produce differences in the mechanism for degradation reactions and may cause an abnormal ratio of surface to bulk oxidation, which could result in unnatural color shifts or physical property changes.

X1.3 *Continuous Exposure to Light from a Laboratory Light Source Without Any Dark Periods*—Continuous exposure to light from laboratory light sources often is used in order to achieve accelerated degradation relative to actual use conditions. Continuous exposure to light, however, may eliminate critical dark reactions that occur in outdoor exposures or indoor use conditions where there are regular periods without light.

X1.4 *Specimen Temperatures That Are Abnormally High Relative to Actual Use Conditions*—Temperatures higher than those experienced in actual use conditions often are used to obtain faster degradation in laboratory accelerated tests. Some polymers are much more susceptible to degradation from thermal effects than others. For materials that are subject to the same rate, and type of photodegradation, exposures at abnormally high temperatures may make a temperature sensitive material appear to be less durable compared to a less temperature sensitive material. In addition, exposures at temperatures above the glass transition temperature of polymers can alter dramatically the mechanism of degradation and stability ranking compared to exposures conducted at a temperature below the glass transition temperature. The black panel temperature used in a laboratory accelerated test should be maintained in a reasonable range, which usually is no higher than the maximum observed for the black panel in actual use conditions.

X1.5 *Exposure Conditions That Produce Unrealistically Large Temperature Differences Between Light and Dark Colored Specimens*—Some laboratory light sources produce large amounts of infrared radiation. In order to prevent overheating of specimens, the infrared radiation can be reduced using infrared absorbing or reflecting filters, or by passing large amounts of air through the specimen chamber to cool specimens. If measures to control the amount of infrared radiation reaching specimens being exposed are not sufficient, the temperature differences between light and dark colored specimens of the same material can be larger than would be seen in natural exposure. Some laboratory light sources produce very little or no infrared radiation. When these types of laboratory light sources are used, the difference between dark and light colored specimens may be less than that found in outdoor exposures.

X1.6 *Temperature Cycling Conditions That are Different from Those Found in Actual Use Conditions*—Abnormally high temperature cycling frequencies can produce mechanically-induced cracking or other degradation not seen in outdoor exposures. Exposure devices, which spray specimens with water when the light source is on, can produce an abnormally rapid change in temperature that also may produce cracking not produced in outdoor exposures.

X1.7 *Unrealistically High or Low Levels of Moisture*—Moisture is very important for producing degradation of many polymers. If the amount of moisture, or the way in which specimens are exposed to the effects of moisture in a laboratory accelerated test differs from the actual use environment, the mechanism and rate of degradation may be much different. This can have a significant effect on the stability ranking of materials.

X1.8 *Absence of Biological Agents or Pollutants*—Materials that are exposed in warm, wet locations often are subject to significant growth of biological agents, such as fungi, bacteria, and algae. Pollutants present in many exterior environments have a significant affect on the mechanism and rate of degradation for some plastics. If these effects are not included in a laboratory accelerated exposure test, the mechanism and stability ranking of materials may be significantly different than that found in exterior exposures.

References

(1) Simms, J.A. "Journal of Coatings Technology," ASTM, Vol 50, 1987, pp. 45-53.

(2) Boxhammer, J., Kockott, D., Trubiroha, P., "Black Standard Thermometer," Materialprüfung, Vol 35, 1993, p. 5.

(3) Searle, N.D.," Effect of Light Source Emissions on Durability Testing," *Symposium Accelerated and Outdoor Durability Testing of Organic Materials, ASTM STP 1202*, ASTM, 1993, p.

(4) Schnabel, W., "Polymer Degradation, Principles and Practical Applications," pp. 95–100, Macmillan Publishing Co., Inc., New York, NY 1981.

(5) Grassie, N., Scott, G., "Polymer Degradation and Stabilization," pp. 75–76, Cambridge University Press, New York, NY 1985.

(6) Clough, R.I., Gillen, K.T., "Physical Techniques for Profiling Heterogeneous Polymer Degradation," Polymer Stabilization and Degradation, ACS Symposium Series 280, Peter Klemchuk, Editor, American Chemical Society, Washington, D.C., 1985.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

* * *

Document Name:

CFR Section(s):

Standards Body:

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: G 154 – 00a

Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials[1]

This standard is issued under the fixed designation G 154; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the basic principles and operating procedures for using fluorescent UV light, and water apparatus intended to reproduce the weathering effects that occur when materials are exposed to sunlight (either direct or through window glass) and moisture as rain or dew in actual usage. This practice is limited to the procedures for obtaining, measuring, and controlling conditions of exposure. A number of exposure procedures are listed in an appendix; however, this practice does not specify the exposure conditions best suited for the material to be tested.

NOTE 1—Practice G 151 describes performance criteria for all exposure devices that use laboratory light sources. This practice replaces Practice G 53, which describes very specific designs for devices used for fluorescent UV exposures. The apparatus described in Practice G 53 is covered by this practice.

1.2 Test specimens are exposed to fluorescent UV light under controlled environmental conditions. Different types of fluorescent UV light sources are described.

1.3 Specimen preparation and evaluation of the results are covered in ASTM methods or specifications for specific materials. General guidance is given in Practice G 151 and ISO 4892-1. More specific information about methods for determining the change in properties after exposure and reporting these results is described in ISO 4582.

1.4 The values stated in SI units are to be regarded as the standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, 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.*

1.6 This standard is technically similar to ISO 4892-3 and ISO DIS 11507.

2. Referenced Documents

2.1 *ASTM Standards:*

D 3980 Practice for Interlaboratory Testing of Paint and Related Materials[2]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[3]

G 53 Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials[4]

G 113 Terminology Relating to Natural and Artificial Weathering Tests for Nonmetallic Materials[4]

G 151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices That Use Laboratory Light Sources[4]

2.2 *CIE Standard:*

CIE-Publ. No. 85: Recommendations for the Integrated Irradiance and the Spectral Distribution of Simulated Solar Radiation for Testing Purposes[5]

2.3 *ISO Standards:*

ISO 4582, Plastics—Determination of the Changes of Colour and Variations in Properties After Exposure to Daylight Under Glass, Natural Weathering or Artificial Light[6]

ISO 4892-1, Plastics—Methods of Exposure to Laboratory Light Sources, Part 1, Guidance[6]

ISO 4892-3, Plastics—Methods of Exposure to Laboratory Light Sources, Part 3, Fluorescent UV lamps[6]

ISO DIS 11507, Paint and Varnishes—Exposure of Coatings to Artificial Weathering in Apparatus—Exposure to Fluorescent Ultraviolet and Condensation Apparatus[6]

3. Terminology

3.1 *Definitions*—The definitions given in Terminology G 113 are applicable to this practice.

---

[1] This practice is under the jurisdiction of ASTM Committee G3 on Weathering and Durability and is the direct responsibility of Subcommittee G03.03 on Simulated and Controlled Exposure Tests.

Current edition approved June 10, 2000. Published September 2000. Originally published as G 154 – 97. Last previous edition G 154 – 00.

[2] Discontinued 1998. See *1998 Annual Book of ASTM Standards*, Vol 06.01.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 14.04.

[5] Available from Secretary, U.S. National Committee, CIE, National Institute of Standards and Technology (NIST), Gaithersburg, MD 20899.

[6] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

3.2 *Definitions of Terms Specific to This Standard*—As used in this practice, the term *sunlight* is identical to the terms *daylight* and *solar irradiance, global* as they are defined in Terminology G 113.

4. Summary of Practice

4.1 Specimens are exposed to repetitive cycles of light and moisture under controlled environmental conditions.

4.1.1 Moisture is usually produced by condensation of water vapor onto the test specimen or by spraying the specimens with demineralized/deionized water.

4.2 The exposure condition may be varied by selection of:

4.2.1 The fluorescent lamp,

4.2.2 The lamp's irradiance level,

4.2.3 The type of moisture exposure,

4.2.4 The timing of the light and moisture exposure,

4.2.5 The temperature of light exposure, and

4.2.6 The temperature of moisture exposure, and

4.2.7 The timing of a light/dark cycle.

4.3 Comparison of results obtained from specimens exposed in same model of apparatus should not be made unless reproducibility has been established among devices for the material to be tested.

4.4 Comparison of results obtained from specimens exposed in different models of apparatus should not be made unless correlation has been established among devices for the material to be tested.

5. Significance and Use

5.1 The use of this apparatus is intended to induce property changes associated with the end use conditions, including the effects of the UV portion of sunlight, moisture, and heat. These exposures may include a means to introduce moisture to the test specimen. Exposures are not intended to simulate the deterioration caused by localized weather phenomena, such as atmospheric pollution, biological attack, and saltwater exposure. Alternatively, the exposure may simulate the effects of sunlight through window glass. Typically, these exposures would include moisture in the form of condensing humidity.

NOTE 2—**Caution:** Refer to Practice G 151 for full cautionary guidance applicable to all laboratory weathering devices.

5.2 Variation in results may be expected when operating conditions are varied within the accepted limits of this practice. Therefore, no reference shall be made to results from the use of this practice unless accompanied by a report detailing the specific operating conditions in conformance with the Section 10.

5.2.1 It is recommended that a similar material of known performance (a control) be exposed simultaneously with the test specimen to provide a standard for comparative purposes. It is recommended that at least three replicates of each material evaluated be exposed in each test to allow for statistical evaluation of results.

6. Apparatus

6.1 *Laboratory Light Source*—The light source shall be fluorescent UV lamps. A variety of fluorescent UV lamps can be used for this procedure. Differences in lamp intensity or spectrum may cause significant differences in test results. A detailed description of the type(s) of lamp(s) used should be stated in detail in the test report. The particular testing application determines which lamp should be used. See Appendix X1 for lamp application guidelines.

NOTE 3—Do not mix different types of lamps. Mixing different types of lamps in a fluorescent UV light apparatus may produce major inconsistencies in the light falling on the samples, unless the apparatus has been specifically designed to ensure a uniform spectral distribution.

NOTE 4—Many fluorescent lamps age significantly with extended use. Follow the apparatus manufacturer's instructions on the procedure necessary to maintain desired irradiance (1,2).

6.1.1 Actual irradiance levels at the test specimen surface may vary due to the type or manufacturer of the lamp used, or both, the age of the lamps, the distance to the lamp array, and the air temperature within the chamber and the ambient laboratory temperature. Consequently, the use of a radiometer to monitor and control the radiant energy is recommended.

6.1.2 Several factors can affect the spectral power distribution of fluorescent UV lamps:

6.1.2.1 Aging of the glass used in some types of lamps can result in changes in transmission. Aging of glass can result in a significant reduction in the short wavelength UV emission of some lamp types,

6.1.2.2 Accumulation of dirt or other residue on lamps can affect irradiance,

6.1.2.3 Thickness of glass used for lamp tube can have large effects on the amount of short wavelength UV radiation transmitted, and

6.1.2.4 Uniformity and durability of phosphor coating.

6.1.3 *Spectral Irradiance*:

NOTE 5—Fluorescent UVA lamps are available with a choice of spectral power distributions that vary significantly. The more common may be identified as UVA-340 and UVA-351. These numbers represent the characteristic nominal wavelength (in nm) of peak emission for each of these lamp types. The actual peak emissions are at 343 and 350 nm, respectively.

6.1.3.1 *Spectral Irradiance of UVA-340 Lamps for Daylight UV*—The spectral power distribution of UVA-340 fluorescent lamps shall comply with the requirements specified in Table 1.

NOTE 6—The main application for UVA-340 lamps is for simulation of the short and middle UV wavelength region of daylight.

6.1.3.2 *Spectral Irradiance of UVA-351 Lamps for Daylight UV Behind Window Glass*—The spectral power distribution of UVA-351 lamp for Daylight UV behind Window Glass shall comply with the requirements specified in Table 2.

NOTE 7—The main application for UVA-351 lamps is for simulation of the short and middle UV wavelength region of daylight which has been filtered through window glass (3).

6.1.3.3 *Spectral Irradiance of UVB-313 Lamps*—The spectral power distribution of UVB-313 fluorescent lamps shall comply with the requirements specified in Table 2.

NOTE 8—Fluorescent UVB lamps have the spectral distribution of radiation peaking near the 313-nm mercury line. They emit significant amounts of radiation below 300 nm, the nominal cut on wavelength of global solar radiation, that may result in aging processes not occurring outdoors. Use of this lamp is not recommended for sunlight simulation. See Table 3.

TABLE 1 Relative Spectral Power Distribution Specification for UVA-340 Lamps for Daylight UV

Bandpass, nm	Fluorescent UVA-340 Lamp[A]	Sunlight[B]
Ultraviolet Wavelength Region Irradiance as a percentage of total irradiance from 260 to 400 nm		
260–270	0.0 %	0
271–280	0.0 %	0
281–290	0.0 %	0
291–300	< 0.2 %	0
301–320	6.2–6.6 %	5.6 %
321–340	27.1–30.7 %	18.5 %
341–360	34.2–35.4 %	21.7 %
361–380	19.5–23.7 %	26.6 %
381–400	6.6–7.8 %	27.6 %
Ultraviolet and Visible Wavelength Region Irradiance as a percentage of total irradiance from 300 to 800 nm[C]		
300–400	87.3 %[D]	11 %[E]
401–700	12.7 %[D]	72 %[E]

[A] UVA-340 data—The ranges given are based on spectral power distribution measurements made for lamps of different ages and operating at different levels of controlled irradiance. The ranges given are based on three sigma limits from the averages of this data.

[B] Sunlight data—The sunlight data is for global irradiance on a horizontal surface with a air mass of 1.2, column ozone 0.294 atm cm, 30 % relative humidity, altitude 2100 m (atmopsheric pressure of 787.8 mb), and an aerosol represented by an optical thickness of 0.81 at 300 nm and 0.62 at 400 nm.

[C] Data from 701 to 800 nm is not shown.

[D] UVA-340 data—Because the primary emission of fluorescent UV lamps is concentrated in the 300- to 400-nm bandpass, there are limited data available for visible light emissions of fluorescent UV lamps. Therefore, the data in this table are based on very few measurements and are representative only.

[E] Sunlight data—The sunlight data is from Table 4 of CIE Publication Number 85, global solar irradiance on a horizontal surface with an air mass of 1.0, column ozone of 0.34 atm cm, 1.42-cm precipitable water vapor, and an aerosol represented by an optical thickness of 0.1 at 500 nm.

TABLE 2 Relative Spectral Power Distribution Specification for UVA-351 Lamps for Daylight UV Behind Window Glass

Bandpass, nm	Fluorescent UVA-351 Lamp[A]	Estimated Window Glass Filtered Sunlight[B]
Ultraviolet Wavelength Region Irradiance as a percentage of total irradiance from 260 to 400 nm		
260–270	0.0 %	0 %
271–280	0.0 %	0 %
281–290	0.0 %	0 %
290–300	< 0.1 %	0 %
301–320	0.9–3.3 %	0.1–1.5 %
321–340	18.3–22.7 %	9.4–14.8 %
341–360	42.7–44.5 %	23.2–23.5 %
361–380	24.8–28.2 %	29.6–32.5 %
381–400	5.8–7.6 %	30.9 –34.5 %
Ultraviolet and Visible Wavelength Region Irradiance as a percentage of total irradiance from 300 to 800 nm[C]		
300–400	90.1 %[D]	9.0–11.1 %[E]
401–700	9.9 %[D]	71.3–73.1 %[E]

[A] UVA-351 data—The ranges given are based on spectral power distribution measurements made for lamps of different ages and operating at different levels of controlled irradiance. The ranges given are based on three sigma limits from the averages of this data.

[B] Sunlight data—The sunlight data is for global irradiance on a horizontal surface with an air mass of 1.2, column ozone 0.294 atm cm, 30 % relative humidity, altitude 2100 m (atmospheric pressure of 787.8 mb), and an aerosol represented by an optical thickness of 0.081 at 300 nm and 0.62 at 400 nm. The range is determined by multiplying solar irradiance by the upper and lower limits for transmission of single strength window glass samples used for studies conducted by ASTM Subcommittee G03.02.

[C] Data from 701 to 800 nm is not shown.

[D] UVA-351 data—Because the primary emission of fluorescent UV lamps is concentrated in the 300- to 400-nm bandpass, there are limited data available for visible light emissions of fluorescent UV lamps. Therefore, the data in this table are based on very few measurements and are representative only.

[E] Sunlight data—The sunlight data is from Table 4 of CIE Publication Number 85, global solar irradiance on a horizontal surface with an air mass of 1.0, column ozone of 0.34 atm cm, 1.42-cm precipitable water vapor, and an aerosol represented by an optical thickness of 0.1 at 500 nm. The range is determined by multiplying solar irradiance by the upper and lower limits for transmission of single strength window glass samples used for studies conducted by ASTM Subcommittee G03.02.

6.2 *Test Chamber*—The design of the test chamber may vary, but it should be constructed from corrosion resistant material and, in addition to the radiant source, may provide for means of controlling temperature and relative humidity. When required, provision shall be made for the spraying of water on the test specimen for the formation of condensate on the exposed face of the specimen or for the immersion of the test specimen in water.

6.2.1 The radiant source(s) shall be located with respect to the specimens such that the uniformity of irradiance at the specimen face complies with the requirements in Practice G 151.

6.2.2 Lamp replacement, lamp rotation, and specimen repositioning may be required to obtain uniform exposure of all specimens to UV radiation and temperature. Follow manufacturer's recommendation for lamp replacement and rotation.

6.3 *Instrument Calibration*—To ensure standardization and accuracy, the instruments associated with the exposure apparatus (for example, timers, thermometers, wet bulb sensors, dry bulb sensors, humidity sensors, UV sensors, and radiometers) require periodic calibration to ensure repeatability of test results. Whenever possible, calibration should be traceable to national or international standards. Calibration schedule and procedure should be in accordance with manufacturer's instructions.

6.4 *Radiometer*—The use of a radiometer to monitor and control the amount of radiant energy received at the sample is recommended. If a radiometer is used, it shall comply with the requirements in Practice G 151.

6.5 *Thermometer*—Either insulated or un-insulated black or white panel thermometers may be used. The un-insulated thermometers may be made of either steel or aluminum. Thermometers shall conform to the descriptions found in Practice G 151.

6.5.1 The thermometer shall be mounted on the specimen rack so that its surface is in the same relative position and subjected to the same influences as the test specimens.

6.5.2 Some specifications may require chamber air temperature control. Positioning and calibration of chamber air temperature sensors shall be in accordance with the descriptions found in Practice G 151.

NOTE 9—Typically, these devices control by black panel temperature only.

6.6 *Moisture*—The test specimens may be exposed to moisture in the form of water spray, condensation, or high humidity.

6.6.1 *Water Spray*—The test chamber may be equipped with a means to introduce intermittent water spray onto the test specimens under specified conditions. The spray shall be uniformly distributed over the samples. The spray system shall

TABLE 3 Relative Spectral Power Distribution Specification for UVB-313 Lamps

Bandpass, nm	Fluorescent UVB-313 Lamp[A,B]	Sunlight[C]
Ultraviolet Wavelength Region[A] Irradiance as a percentage of total irradiance from 260 to 400 nm		
260–270	< 0.1 %	0
271–280	0.1–0.7 %	0
281–290	3.2–4.4 %	0
291–300	10.7–13.7 %	0
301–320	38.0–44.6 %	5.6 %
321–340	25.5–30.9 %	18.5 %
341–360	7.7–10.7 %	21.7 %
361–380	2.5–5.5 %	26.6 %
381–400	0.0–1.5 %	27.6 %
Ultraviolet and Visible Wavelength Region Irradiance as a percentage of total irradiance from 300 to 800 nm[D]		
300–400	88.5 %[E]	11 %[F]
401–700	11.5 %[E]	72 %[F]

[A] UVB-313 data—Some UVB lamps have measurable emittance at the 254-nm mercury line. This may affect test results for some materials.

[B] UVB-313 data—The ranges given are based on spectral power distribution measurements made for lamps of a different ages and operating at different levels of controlled irradiance. The ranges given are based on three sigma limits from the averages of this data. Lamps that meet this specification are available from different manufacturers. These lamps may have significantly different irradiance levels (that is, total light output), but still have the same relative spectral power distribution.

[C] Sunlight data—The sunlight data in for global irradiance on a horizontal surface with a air mass of 1.2, column ozone 0.294 atm cm, 30 % relative humidity, altitude 2100 m (atmospheric pressure of 787.8 mb), and an aerosol represented by an optical thickness of 0.081 to 300 nm and 0.62 at 400 nm.

[D] Data from 701 to 800 nm is not shown.

[E] UVB-313 data—Because the primary emission of fluorescent UV lamps is concentrated in the 300- to 400-nm bandpass, there is limited data available for visible light emissions of fluorescent UV lamps. Therefore, the data in this table are based on very low measurements and are representative only.

[F] Sunlight data—The sunlight data is from Table 4 of CIE Publication Number 85, global solar irradiance on a horizontal surface with an air mass of 1.0, column ozone of 0.34 atm cm, 1.42-cm precipitable water vapor, and an aerosol represented by an optical thickness of 0.1 at 500 nm.

be made from corrosion resistant materials that do not contaminate the water used.

6.6.1.1 *Spray Water Quality*—Spray water shall have a conductivity below 5 µS/cm, contain less than 1-ppm solids, and leave no observable stains or deposits on the specimens. Very low levels of silica in spray water can cause significant deposits on the surface of test specimens. Care should be taken to keep silica levels below 0.1 ppm. In addition to distillation, a combination of deionization and reverse osmosis can effectively produce water of the required quality. The pH of the water used should be reported. See Practice G 151 for detailed water quality instructions.

6.6.2 *Condensation*—The test chamber may be equipped with a means to cause condensation to form on the exposed face of the test specimen. Typically, water vapor shall be generated by heating water and filling the chamber with hot vapor, which then is made to condense on the test specimens.

6.6.3 *Relative Humidity*—The test chamber may be equipped with a means to measure and control the relative humidity. Such instruments shall be shielded from the lamp radiation.

6.7 *Specimen Holders*—Holders for test specimens shall be made from corrosion resistant materials that will not affect the test results. Corrosion resistant alloys of aluminium or stainless steel have been found acceptable. Brass, steel, or copper shall not be used in the vicinity of the test specimens.

6.8 *Apparatus to Assess Changes in Properties*—The necessary apparatus required by ASTM or ISO relating to the determination of the properties chosen for monitoring shall be used (see also ISO 4582).

7. Test Specimen

7.1 Refer to Practice G 151.

8. Test Conditions

8.1 Any exposure conditions may be used as long as the exact conditions are detailed in the report. Appendix X2 shows some representative exposure conditions. These are not necessarily preferred and no recommendation is implied. These conditions are provided for reference only.

9. Procedure

9.1 Identify each test specimen by suitable indelible marking, but not on areas used in testing.

9.2 Determine which property of the test specimens will be evaluated. Prior to exposing the specimens, quantify the appropriate properties in accordance with recognized ASTM or international standards. If required (for example, destructive testing), use unexposed file specimens to quantify the property. See ISO 4582 for detailed guidance.

9.3 *Mounting of Test Specimens*—Attach the specimens to the specimen holders in the equipment in such a manner that the specimens are not subject to any applied stress. To assure uniform exposure conditions, fill all of the spaces, using blank panels of corrosion resistant material if necessary.

NOTE 10—Evaluation of color and appearance changes of exposed materials shall be made based on comparisons to unexposed specimens of the same material which have been stored in the dark. Masking or shielding the face of test specimens with an opaque cover for the purpose of showing the effects of exposure on one panel is not recommended. Misleading results may be obtained by this method, since the masked portion of the specimen is still exposed to temperature and humidity that in many cases will affect results.

9.4 *Exposure to Test Conditions*—Program the selected test conditions to operate continuously throughout the required number of repetitive cycles. Maintain these conditions throughout the exposure. Interruptions to service the apparatus and to inspect specimens shall be minimized.

9.5 *Specimen Repositioning*—Periodic repositioning of the specimens during exposure is not necessary if the irradiance at the positions farthest from the center of the specimen area is at least 90 % of that measured at the center of the exposure area. Irradiance uniformity shall be determined in accordance with Practice G 151.

9.5.1 If irradiance at positions farther from the center of the exposure area is between 70 and 90 % of that measured at the center, one of the following three techniques shall be used for specimen placement.

9.5.1.1 Periodically reposition specimens during the exposure period to ensure that each receives an equal amount of radiant exposure. The repositioning schedule shall be agreed upon by all interested parties.

9.5.1.2 Place specimens only in the exposure area where the irradiance is at least 90 % of the maximum irradiance.

9.5.1.3 To compensate for test variability randomly position replicate specimens within the exposure area which meets the irradiance uniformity requirements as defined in 9.5.1.

9.6 *Inspection*—If it is necessary to remove a test specimen for periodic inspection, take care not to handle or disturb the test surface. After inspection, the test specimen shall be returned to the test chamber with its test surface in the same orientation as previously tested.

9.7 *Apparatus Maintenance*—The test apparatus requires periodic maintenance to maintain uniform exposure conditions. Perform required maintenance and calibration in accordance with manufacturer's instructions.

9.8 Expose the test specimens for the specified period of exposure. See Practice G 151 for further guidance.

9.9 At the end of the exposure, quantify the appropriate properties in accordance with recognized ASTM or international standards and report the results in conformance with Practice G 151.

NOTE 11—Periods of exposure and evaluation of test results are addressed in Practice G 151.

10. Report

10.1 The test report shall conform to Practice G 151.

11. Precision and Bias

11.1 *Precision:*

11.1.1 The repeatability and reproducibility of results obtained in exposures conducted according to this practice will vary with the materials being tested, the material property being measured, and the specific test conditions and cycles that are used. In round-robin studies conducted by Subcommittee G03.03, the 60° gloss values of replicate PVC tape specimens exposed in different laboratories using identical test devices and exposure cycles showed significant variability **(3)**. The variability shown in these round-robin studies restricts the use of "absolute specifications" such as requiring a specific property level after a specific exposure period **(4,5)**.

11.1.2 If a standard or specification for general use requires a definite property level after a specific time or radiant exposure in an exposure test conducted according to this practice, the specified property level shall be based on results obtained in a round-robin that takes into consideration the variability due to the exposure and the test method used to measure the property of interest. The round-robin shall be conducted according to Practice E 691 or Practice D 3980 and shall include a statistically representative sample of all laboratories or organizations that would normally conduct the exposure and property measurement.

11.1.3 If a standard or specification for use between two or three parties requires a definite property level after a specific time or radiant exposure in an exposure test conducted according to this practice, the specified property level shall be based on statistical analysis of results from at least two separate, independent exposures in each laboratory. The design of the experiment used to determine the specification shall take into consideration the variability due to the exposure and the test method used to measure the property of interest.

11.1.4 The round-robin studies cited in 11.1.1 demonstrated that the gloss values for a series of materials could be ranked with a high level of reproducibility between laboratories. When reproducibility in results from an exposure test conducted according to this practice have not been established through round-robin testing, performance requirements for materials shall be specified in terms of comparison (ranked) to a control material. The control specimens shall be exposed simultaneously with the test specimen(s) in the same device. The specific control material used shall be agreed upon by the concerned parties. Expose replicates of the test specimen and the control specimen so that statistically significant performance differences can be determined.

11.2 *Bias*—Bias can not be determined because no acceptable standard weathering reference materials are available.

12. Keywords

12.1 accelerated; accelerated weathering; durability; exposure; fluorescent UV lamps; laboratory weathering; light; lightfastness; non-metallic materials; temperature; ultraviolet; weathering

APPENDIXES

(Nonmandatory Information)

X1. APPLICATION GUIDELINES FOR TYPICAL FLUORESCENT UV LAMPS

X1.1 *General*

X1.1.1 A variety of fluorescent UV lamps may be used in this practice. The lamps shown in this section are representative of their type. Other lamps, or combinations of lamps, may be used. The particular application determines which lamp should be used. The lamps discussed in this Appendix differ in the total amount of UV energy emitted and their wavelength spectrum. Differences in lamp energy or spectrum may cause significant differences in test results. A detailed description of the type(s) of lamp(s) used shall be stated in detail in the test report.

X1.1.2 All spectral power distributions (SPDs) shown in this section are representative only and are not meant to be used to calculate or estimate total radiant exposure for tests in fluorescent UV devices. Actual irradiance levels at the test specimen surface will vary due to the type and/or manufacturer of the lamp used, the age of the lamps, the distance to the lamp array, and the air temperature within the chamber.

NOTE X1.1—All SPDs in this appendix were measured using a spectroradiometer with a double grating monochromator (1-nm band pass) with a quartz cosine receptor. The fluorescent UV SPDs were measured at the sample plane in the center of the allowed sample area. SPDs for sunlight were measured in Phoenix, AZ at solar noon at the summer solstice with a clear sky, with the spectroradiometer on an equatorial follow-the-sum mount.

X1.2 Simulations of Direct Solar UV Radiation Exposures

X1.2.1 *UVA-340 Lamps*—For simulations of direct solar UV radiation the UVA-340 lamp is recommended. Because UVA-340 lamps typically have little or no UV output below 300 nm (that is considered the "cut-on" wavelength for terrestrial sunlight), they usually do not degrade materials as rapidly as UVB lamps, but they may allow enhanced correlation with actual outdoor weathering. Tests using UVA-340 lamps have been found useful for comparing different nonmetallic materials such as polymers, textiles, and UV stabilizers. Fig. X1.1 illustrates the SPD of the UVA-340 lamp compared to noon, summer sunlight.

X1.2.2 *UVB-313 Lamps*—The UVB region (280 to 315 nm) includes the shortest wavelengths found in sunlight at the earth's surface and is responsible for considerable polymer damage. There are two commonly available types of UVB-313 lamps that meet the requirements of this document. These are known commercially as the UVB-313 and the FS-40. These lamps emit different amounts of total energy, but both peak at 313 nm and produce the same UV wavelengths in the same relative proportions. In tests using the same cycles and temperatures, shorter times to failure are typically observed when the lamp with higher UV irradiance is used. Furthermore, tests using the same cycles and temperatures with these two lamps may exhibit differences in ranking of materials due to difference in the proportion of UV to moisture and temperature.

NOTE X1.2—The Fig. X1.2 illustrates the difference between the lamps.

X1.2.2.1 All UVB-313 lamps emit UV below the normal sunlight cut-on. This short wavelength UV can produce rapid polymer degradation and often causes degradation by mechanisms that do not occur when materials are exposed to sunlight. This may lead to anomalous results. Fig. X1.2 shows the spectral power distribution (SPD) of typical UVB-313 lamps compared to the SPD of noon, summer sunlight.

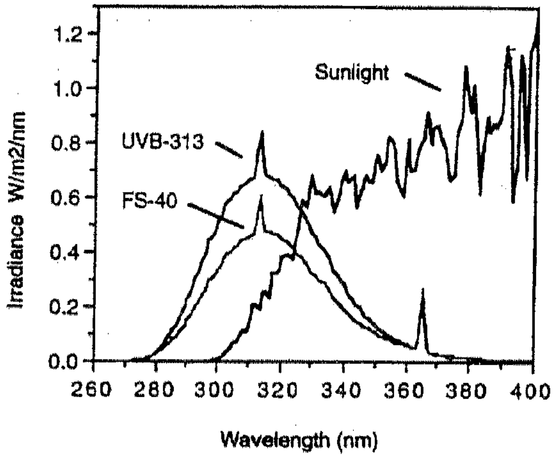


FIG. X1.2 Spectral Power Distributions of UVB Lamps and Sunlight

X1.3 Simulations of Exposures to Solar UV Radiation Through Window Glass

X1.3.1 *Filtering Effect of Glass*

Glass of any type acts as a filter on the sunlight spectrum (see Fig. X1.3). Ordinary glass is essentially transparent to light above about 370 nm. However, the filtering effect becomes more pronounced with decreasing wavelength. The shorter, more damaging UVB wavelengths are the most greatly affected. Window glass filters out most of the wavelengths below about 310 nm. For purposes of illustration, only one type of window glass is used in the accompanying graphs. Note that glass transmission characteristics will vary due to manufacturer, production lot, thickness, or other factors.

X1.3.2 *UVA-351 Lamps*

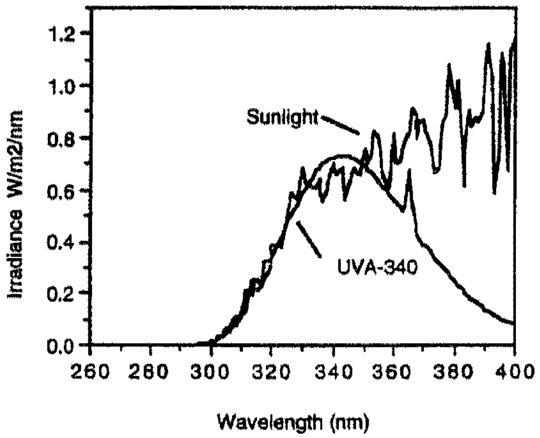


FIG. X1.1 Spectral Power Distributions of UVA-340 Lamp and Sunlight

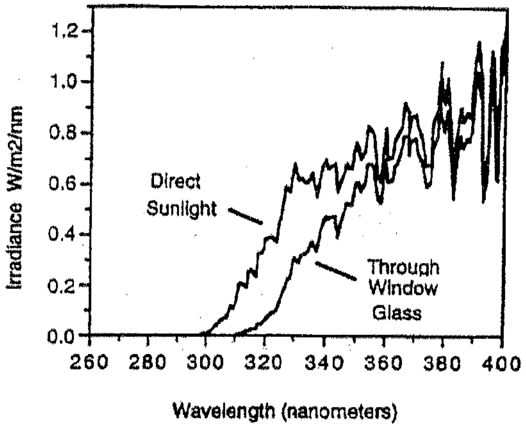


FIG. X1.3 Direct Sunlight and Sunlight Through Window Glass

For simulations of sunlight through window glass, UVA-351 lamps are recommended. The UVA-351 is used for these applications because the low end cut-on of this lamp is similar to that of direct sunlight which has been filtered through window glass (Fig. X1.4).

NOTE X1.3—UVB-313 lamps are not recommended for simulations of sunlight through window glass. Most of the emission of UVB-313 lamps is in the short wavelength UV that is filtered very efficiently by glass. Because of this, very little energy from this short wavelength region will reach materials in "behind glass" applications. This is because window glass filters out about 80 % of the energy from UVB-313 lamps, as shown in Fig. X1.5. As a result of filtering out these short wavelengths, its total effective energy is very limited. Further, because there is little longer wavelength energy, the glass-filtered UVB-313 is actually less severe than a UVA Lamp.

X1.4 Simulations of Exposures Where Glass or Transparent Plastic Forms Part of the Test Specimen

X1.4.1 *UVA-340 Lamps*

In some instances (for example, window sealants), glass or transparent plastic is part of the test specimen itself and normally acts as a filter to the light source. In these special cases, the use of UVA-340 lamps is recommended since the glass or plastic will filter the spectrum of the lamp in the same way that it would filter sunlight. Fig. X1.6 compares the spectral power distribution of sunlight filtered through window glass to the spectral power distribution of the UVA-340 lamp, both unfiltered and filtered through window glass.

NOTE X1.4—UBV-313 lamps are lamps not recommended for exposures where glass or transparent plastic forms part of the test specimen. See Note X1.3.

NOTE X1.5—UVA-351 lamps are not recommended for exposures where glass or transparent plastic forms part of the test specimen. This is because the UVA-351 has a special power distribution in the short wave UV region that is similar to sunlight that has already been filtered by window glass. As shown in Fig. X1.7, using this lamp through window glass or other transparent material further filters out the short wavelength UV and results in a spectrum that is deficient in the short wavelength UV.

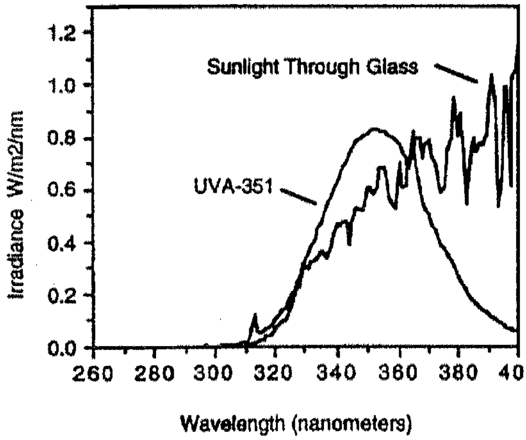


FIG. X1.4 Spectral Power Distributions of UVA-351 Lamp and Sunlight Through Window Glass

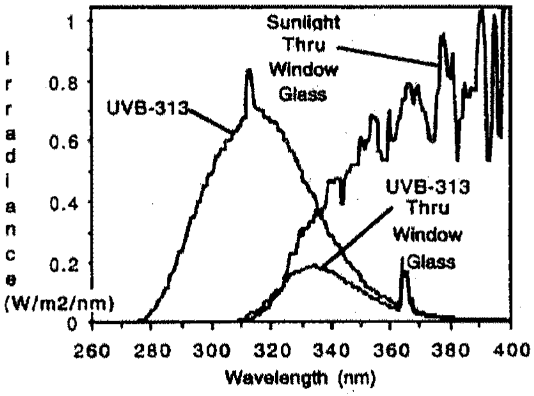


FIG. X1.5 Spectral Power Distributions of Unfiltered UVB-313 Lamp, UVB-313 Through Window Glass, and Sunlight Through Window Glass

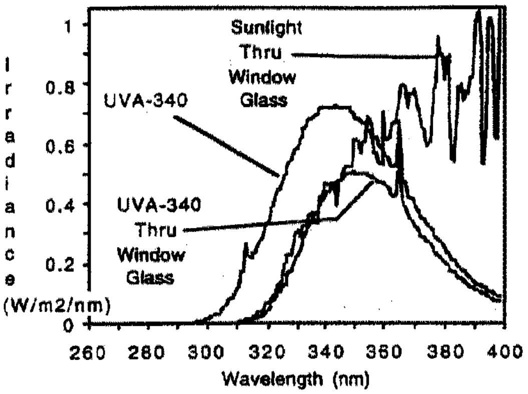


FIG. X1.6 Spectral Power Distributions of Unfiltered UVA-340 Lamp, UVA-340 Through Window Glass, and Sunlight Through Window Glass

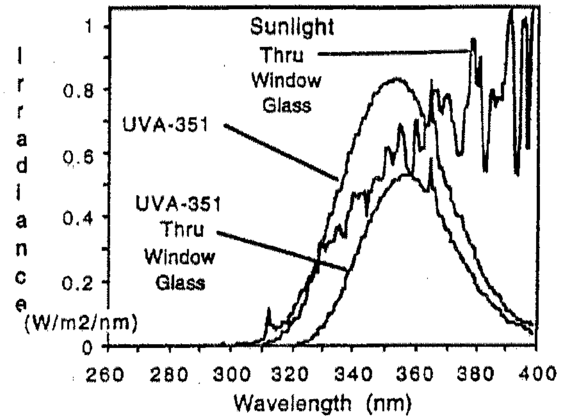


FIG. X1.7 Spectral Power Distributions of Unfiltered UVA-351 Lamp, UVA-351 Through Window Glass, and Sunlight Through Window Glass

X2. EXPOSURE CONDITIONS

X2.1 Any exposure conditions may be used, as long as the exact conditions are detailed in the report. Following are some representative exposure conditions. These are not necessarily preferred and no recommendation is implied. These conditions are provided for reference only (See Table X2.1).

NOTE X2.1—Cycle 1 is a commonly used exposure cycle for coatings and plastics. Cycle 2 has been widely used for coatings. Cycles 3 and 4 have been used for exterior automotive materials. Cycle 5 has been used for roofing materials. Cycle 6 has been used for high irradiance exposures of coatings and plastics. Cycle 7 has been used for thermal shock and for erosion testing of coatings for wood.

NOTE X2.2—When selecting programs of UV exposure followed by condensation, allow at least 2 h per interval to assure attainment of equilibrium.

NOTE X2.3—Surface temperature of specimens is an essential test quantity. Generally, degradation processes accelerate with increasing temperature. The specimen temperature permissible for the accelerated test depends on the material to be tested and on the aging criterion under consideration.

NOTE X2.4—Irradiance data shown is typical. Frequently, the irradiance is not controlled in this type of exposure device.

NOTE X2.5—The light output of fluorescent lamps is affected by the temperature of the air which surrounds the lamps. Consequently, in testers without feed-back-loop control of irradiance, the lamp output will decrease with increasing chamber temperature.

NOTE X2.6—Laboratory ambient temperature may have an effect on the light output of devices without feed-back-loop control of irradiance. Some fluorescent UV devices use laboratory ambient air to cool the lamps and thereby compensate for the drop in light output at higher exposure temperatures (see Note X2.5).

TABLE X2.1 Common Exposure Conditions

Cycle	Lamp	Typical Irradiance	Approximate Wavelength	Exposure Cycle
1	UVA-340	0.77 W/m²/nm	340 nm	8 h UV at 60 (± 3) °C Black Panel Temperature; 4 h Condensation at 50 (± 3) °C Black Panel Temperature
2	UVB-313	0.63 W/m²/nm	310 nm	4 h UV at 60 (± 3) °C Black Panel Temperature; 4 h Condensation at 50 (± 3) °C Black Panel Temperature
3	UVB-313	0.44 W/m²/nm	310 nm	8 h UV at 70 (± 3) °C Black Panel Temperature; 4 h Condensation at 50 (± 3) °C Black Panel Temperature
4	UVA-340	1.35 W/m²/nm	340 nm	8 h UV at 70 (± 3) °C Black Panel Temperature; 4 h Condensation at 50 (± 3) °C Black Panel Temperature
5	UVB-313	0.65 W/m²/nm	310 nm	20 h UV at 80 (± 3) °C Black Panel Temperature; 4 h Condensation at 50 (± 3) °C Black Panel Temperature
6	UVA-340	1.35 W/m²/nm	340 nm	8 h UV at 60 (± 3) °C Black Panel Temperature; 4 h Condensation at 50 (± 3) °C Black Panel Temperature.
7	UVA-340	1.35 W/m²/nm	340 nm	8 h UV at 60 (± 3) °C Black Panel Temperature; 0.25 h water spray (no light), temperature not controlled; 3.75 h condensation at 50 (± 3) °C Black Panel Temperature
8	UVB-313	28 W/m²	270 to 700 nm	8 h UV at 70 (± 3) °C Black Panel Temperature; 4 h Condensation at 50 (± 3) °C Black Panel Temperature

X2.2 For the most consistent results, it is recommended that apparatus without feed-back-loop control of irradiance be operated in an environment in which the ambient temperature is maintained between 18 and 27°C. Apparatus operated in ambient temperatures above or below this range may produce irradiances different from devices operated in the recommended manner.

NOTE X2.7—Fluorescent UV lamps emit relatively little infrared radiation when compared to xenon arc and carbon arc sources. In fluorescent UV apparatus, the primary heating of the specimen surface is by convection from heated air passing across the panel. Therefore, there is a minimal difference between the temperature of an insulated or uninsulated black or white panel thermometer, specimen surface, air in the test chamber, or different colored samples (3).

REFERENCES

(1) Mullen, P. A., Kinmonth, R. A., and Searle, N. D., "Spectral Energy Distributions and Aging Characteristics of Fluorescent Sun Lamps and Black Lights," *Journal of Testing and Evaluation*, Vol 3(1), 15–20, 1975.

(2) Fedor, G. R., and Brennan, P. J., "Irradiance Control in Fluorescent UV Exposure Testors," *Accelerated and Outdoor Durability Testing of Organic Materials, ASTM STP 1202*, American Society for Testing and Materials, 1993.

(3) Ketola, W., Robbins, J. S., "UV Transmission of Single Strength Window Glass," *Accelerated and Outdoor Durability Testing of Organic Materials. ASTM STP 1202*. Warren D. Ketola and Douglas Grossman, Editors, American Society for Testing and Materials, 1993.

(4) Fischer, R. M., "Results of Round-Robin Studies of Light- and Water-Exposure Standard Practices," *Accelerated and Outdoor Durability Testing of Organic Materials, ASTM STP 1202*. Warren K. Ketola and Douglas Grossman, Editors, American Society for Testing and Materials, 1993.

(5) Fischer, R. M., and Ketola, W. D., "Surface Temperatures of Materials in Exterior Exposures and Artificial Accelerated Tests," *Accelerated and Outdoor Durability Testing of Organic Materials, ASTM STP 1202*. Warren K. Ketola and Douglas Grossman, Editors, American Society for Testing and Materials, 1993.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM G21: Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi

CFR Section(s): 7 CFR 1755.910(d)(5)(iv)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: G 21 – 90

Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi[1]

This standard is issued under the fixed designation G 21; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This practice covers determination of the effect of fungi on the properties of synthetic polymeric materials in the form of molded and fabricated articles, tubes, rods, sheets, and film materials. Changes in optical, mechanical, and electrical properties may be determined by the applicable ASTM methods.

1.2 The values stated in SI units are to be regarded as the standard.

2. Referenced Document

2.1 *ASTM Standard:*

D 618 Methods of Conditioning Plastics and Electrical Insulating Materials for Testing[2]

3. Summary of Practice

3.1 The procedure described herein consists of (*1*) selection of suitable specimens for determination of pertinent properties, (*2*) inoculation of the specimens with suitable organisms, (*3*) exposure of inoculated specimens under conditions favorable to growth, (*4*) examination and rating for visual growth, and (*5*) removal of the specimens and observations or testing, either before cleaning or after cleaning and reconditioning.

NOTE 1—Since the procedure involves handling and working with fungi, it is recommended that personnel trained in microbiology perform the portion of the procedure involving handling of organisms and inoculated specimens.

4. Significance and Use

4.1 The resin portion of these materials is usually fungus-resistant in that it does not serve as a carbon source for the growth of fungi. It is generally the other components, such as plasticizers, cellulosics, lubricants, stabilizers, and colorants, that are responsible for fungus attack on plastic materials. It is important to establish the resistance to microbial attack under conditions favorable for such attack, namely, a temperature of 2 to 38°C (35 to 100°F) and a relative humidity of 60 to 100 %.

4.2 The effects to be expected are as follows:

4.2.1 Surface attack, discoloration, loss of transmission (optical).

4.2.2 Removal of susceptible plasticizers, modifiers, and lubricants, resulting in increased modulus (stiffness), changes in weight, dimensions, and other physical properties, and deterioration of electrical properties such as insulation resistance, dielectric constant, power factor, and dielectric strength.

4.3 Often the changes in electrical properties are due principally to surface growth and its associated moisture and to pH changes caused by excreted metabolic products. Other effects include preferential growths caused by nonuniform dispersion of plasticizers, lubricants, and other processing additives. Attack on these materials often leaves ionized conducting paths. Pronounced physical changes are observed on products in film form or as coatings, where the ratio of surface to volume is high, and where nutrient materials such as plasticizers and lubricants continue to diffuse to the surface as they are utilized by the organisms.

4.4 Since attack by organisms involves a large element of chance due to local accelerations and inhibitions, the order of reproducibility may be rather low. To assure that estimates of behavior are not too optimistic, the greatest observed degree of deterioration should be reported.

4.5 Conditioning of the specimens, such as exposure to leaching, weathering, heat treatment, etc., may have significant effects on the resistance to fungi. Determination of these effects is not covered in this practice.

5. Apparatus

5.1 *Glassware*—Glass vessels are suitable for holding specimens when laid flat. Depending on the size of the specimens, the following are suggested:

5.1.1 For specimens up to 75 mm (3 in.) in diameter, 150-mm (6-in.) covered Petri dishes.

5.1.2 For 75 mm (3 in.) and larger specimens, such as tensile and stiffness strips, large Petri dishes, trays of borosilicate glass, or baking dishes up to 400 by 500 mm (16 by 20 in.) in size, covered with squares of window glass.

5.2 *Incubator*—Incubating equipment for all test methods shall maintain a temperature of 28 to 30°C (82.4 to 86°C) and a relative humidity not less than 85 %. Automatic recording of wet- and dry-bulb temperature is recommended.

6. Reagents and Materials

6.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended

---

[1] This practice is under the jurisdiction of ASTM Committee G-3 on Durability of Nonmetallic Materials and is the direct responsibility of Subcommittee G03.04 on Biological Deterioration.

Current edition approved Oct. 26, 1990. Published December 1990. Originally published as D 1924 – 61. Last previous edition D 1924 – 63. Redesignated G 21 in 1970 (Reapproved 1990).

[2] *Annual Book of ASTM Standards*, Vol 08.01.

that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specification are available.[3] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

6.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean distilled water or water of equal purity.

6.3 *Nutrient-Salts Agar*[4]—Prepare this medium by dissolving in 1 L of water the designated amounts of the following reagents:

Potassium dihydrogen orthophosphate (KH_2PO_4)	0.7 g
Magnesium sulfate ($MgSO_4 \cdot 7H_2O$)	0.7 g
Ammonium nitrate (NH_4NO_3)	1.0 g
Sodium chloride (NaCl)	0.005 g
Ferrous sulfate ($FeSO_4 \cdot 7H_2O$)	0.002 g
Zinc sulfate ($ZnSO_4 \cdot 7H_2O$)	0.002 g
Manganous sulfate ($MnSO_4 \cdot H_2O$)	0.001 g
Agar	15.0 g
Potassium monohydrogen orthophosphate (K_2HPO_4)	0.7 g

Sterilize the test medium by autoclaving at 121°C (250°F) for 20 min. Adjust the pH of the medium by the addition of 0.01 *N* NaOH solution so that after sterilization the pH is between 6.0 and 6.5. Prepare sufficient medium for the required tests.

6.4 *Mixed Fungus Spore Suspension*:

NOTE 2—Since a number of other organisms may be of specific interest for certain final assemblies or components, such other pure cultures of organisms may be used if agreed upon by the purchaser and the manufacturer of the plastic. Reference (1) illustrates such a choice.

6.4.1 Use the following test fungi in preparing the cultures:

Fungi	ATCC No.[A]	MYCO No.[B]
Aspergillus niger	9642	386
Penicillium pinophilum[C]	11797	391
Chaetomium globosum	6205	459
Gliocladium virens	9645	365
Aureobasidium pullulans	15233	279c

[A] American Type Culture Collection, 12301 Parklawn Drive, Rockville, MD 20852.

[B] Mycological Services, Box 1056, Crawfordsville, IN 47933.

[C] Historically known as funiculosm.

Maintain cultures of these fungi separately on an appropriate medium such as potato dextrose agar. The stock cultures may be kept for not more than 4 months at approximately 3 to 10°C (37 to 50°F). Use subcultures incubated at 28 to 30°C (82 to 86°F) for 7 to 20 days in preparing the spore suspension.

6.4.2 Prepare a spore suspension of each of the five fungi by pouring into one subculture of each fungus a sterile 10-mL portion of water or of a sterile solution containing 0.05 g/L of a nontoxic wetting agent such as sodium dioctyl sulfosuccinate. Use a sterile platinum or nichrome inoculating wire to scrape gently the surface growth from the culture of the test organism.

6.4.3 Pour the spore charge into a sterile 125-mL glass-stoppered Erlenmeyer flask containing 45 mL of sterile water and 10 to 15 solid glass beads, 5 mm in diameter. Shake the flask vigorously to liberate the spores from the fruiting bodies and to break the spore clumps.

6.4.4 Filter the shaken suspension through a thin layer of sterile glass wool in a glass funnel into a sterile flask in order to remove mycelial fragments.

6.4.5 Centrifuge the filtered spore suspension aseptically, and discard the supernatant liquid. Resuspend the residue in 50 mL of sterile water and centrifuge.

6.4.6 Wash the spores obtained from each of the fungi in this manner three times. Dilute the final washed residue with sterile nutrient-salts solution (Note 3) in such a manner that the resultant spore suspension shall contain 1 000 000 ± 200 000 spores/mL as determined with a counting chamber.

6.4.7 Repeat this operation for each organism used in the test and blend equal volumes of the resultant spore suspension to obtain the final mixed spore suspension.

NOTE 3—Nutrient salts solution is identical with the composition for nutrient salts agar given in 6.3 except that the agar is omitted.

6.4.8 The spore suspension may be prepared fresh each day or may be held in the refrigerator at 3 to 10°C (37 to 50°F) for not more than 4 days.

7. Viability Control

7.1 With each daily group of tests place each of three pieces of sterilized filter paper, 25 mm (1 in.) square, on hardened nutrient-salts agar in separate Petri dishes. Inoculate these with the spore suspension by spraying the suspension from a sterilized atomizer[5] so that the entire surface is moistened with the spore suspension. Incubate these at 28 to 30°C (82 to 86°F) at a relative humidity not less than 85 % and examine them after 14 days' incubation. There shall be copious growth on all three of the filter paper control specimens. Absence of such growth requires repetition of the test.

8. Test Specimens

8.1 The simplest specimen may be a 50 by 50-mm (2 by 2-in.) piece, a 50-mm (2-in.) diameter piece, or a piece (rod or tubing) at least 76 mm (3 in.) long cut from the material to be tested. Completely fabricated parts or sections cut from fabricated parts may be used as test specimens. On such specimens, observation of effect is limited to appearance, density of growth, optical reflection or transmission, or manual evaluation of change in physical properties such as stiffness.

8.2 Film-forming materials such as coatings may be tested in the form of films at least 50 by 25 mm (2 by 1 in.) in size. Such films may be prepared by casting on glass and stripping after cure, or by impregnating (completely covering) filter paper or ignited glass fabric.

8.3 For visual evaluation, three specimens shall be inoculated. If the specimen is different on two sides, three specimens of each, face up and face down, shall be tested.

---

[3] "Reagent Chemicals, American Chemical Society Specifications," Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Reagent Chemicals and Standards," by Joseph Rosin, D. Van Nostrand Co., Inc., New York, NY, and the "United States Pharmacopeia."

[4] Agar and nutrient-salts agar are obtainable from biological laboratory supply sources.

[5] DeVilbiss No. 163 atomizer or equivalent has been found satisfactory for this purpose.

NOTE 4—In devising a test program intended to reveal quantitative changes occurring during and after fungal attack, an adequate number of specimens should be evaluated to establish a valid value for the original property. If five replicate specimens are required to establish a tensile strength of a film material, the same number of specimens shall be removed and tested for each exposure period. It is to be expected that values of physical properties at various stages of fungal attack will be variable; the values indicating the greatest degradation are the most significant (see 4.4). The *ASTM Manual on Presentation of Data and Control Chart Analysis STP 15D,* may be used as a guide.

9. Procedure

9.1 *Inoculation*—Pour sufficient nutrient-salts agar into suitable sterile dishes (see 5.1) to provide a solidified agar layer from 3 to 6 mm (⅛ to ¼ in.) in depth. After the agar is solidified, place the specimens on the surface of the agar. Inoculate the surface, including the surface of the test specimens, with the composite spore suspension by spraying the suspension from a sterilized atomizer[5] with 110 kPa (16 psi) of air pressure so that the entire surface is moistened with the spore suspension.

9.2 *Incubation*—Cover the inoculated test specimens and incubate at 28 to 30°C (82 to 86°F) and not less than 85 % relative humidity for a minimum of 21 days, recording the growth each week.

NOTE 5—Covered dishes containing nutrient agar are considered to have the desired humidity. Covers on large dishes may be sealed with masking tape.

9.3 *Observation for Visible Effects*—If the test is for visible effects only, remove the three specimens from the incubator and judge them as follows:

Observed Growth on Specimens	Rating
None	0
Traces of growth (less than 10 %)	1
Light growth (10 to 30 %)	2
Medium growth (30 to 60 %)	3
Heavy growth (60 % to complete coverage)	4

NOTE 6—Traces of growth may be defined as scattered, sparse fungus growth such as might develop from (*1*) a mass of spores in the original inoculum, or (*2*) extraneous contamination such as fingermarks, insect feces, etc. Continous cobwebby growth extending over the entire specimen, even though not obscuring the specimen, should be rated as 2.

NOTE 7—Considerable physical change in plastics may occur without much visual growth, hence some measure of change in physical property selected from those cited in the Appendix is recommended.

9.4 *Effect on Physical, Optical, or Electrical Properties*—Wash the specimens free of growth, immerse in an aqueous solution of mercuric chloride (1+1000) for 5 min, rinse in tap water, air dry overnight at room temperature, and recondition at the standard laboratory conditions defined in Methods D 618, 23 ± 1°C (73 ± 2°F) and 50 ± 2 % relative humidity, and test according to the respective methods used on control specimens (see the Appendix).

NOTE 8—For certain electrical tests, such as insulation resistance and arc resistance, specimens may be tested in the unwashed, humidified condition. Test values will be affected by surface growth and its associated moisture.

10. Report

10.1 The report shall include the following:

10.1.1 Organisms or organism used,

10.1.2 Time of incubation (if progressive),

10.1.3 Visual rating of fungus growth according to 9.3, and

10.1.4 Tabulation of progressive change in physical, optical, or electrical property against time of incubation. Give the number of observations, the mean, and the maximum observed change.

REFERENCES

(1) Bagdon, V. J., Military Specification Mil-P-43018(CE), "Plastic Sheets: Polyethylene Terephthalate, Drafting, Coated," June 13, 1961.

(2) Baskin, A. D., and Kaplan, A. M., "Mildew Resistance of Vinyl-Coated Fabrics," *Applied Microbiology,* APMBA, Vol 4, No. 6, November 1956.

(3) Berk, S., "Effect of Fungus Growth on Plasticized Polyvinyl Chloride Films," *ASTM Bulletin,* ASTBA, No. 168, September 1950, p. 53 (TP 181).

(4) Berk, S., Ebert, H., and Teitell, L., "Utilization of Plasticizers and Related Organic Compounds by Fungi," *Industrial and Engineering Chemistry,* IECHA, Vol 49, No. 7, July 1957, pp. 1115–1124.

(5) Brown, A. E., "Problem of Fungal Growth on Synthetic Resins, Plastics, and Plasticizers," *Modern Plastics,* MOPLA, Vol 23, 1946, p. 189.

(6) Ross, S. H., "Biocides for a Strippable Vinyl Plastic Barrier Material," Report PB-151-119, U. S. Department of Commerce, Office of Technical Services.

APPENDIX

(Nonmandatory Information)

X1. TEST METHODS FOR EVALUATION OF EFFECT OF FUNGI ON SYNTHETIC POLYMERIC MATERIALS

X1.1 For evaluation of the effect of fungi on mechanical, optical, and electrical properties, the following ASTM and other test methods are recommended.

Property	Methods
Tensile strength	D 638, D 882, D 1708[A]
Stiffness	D 747[A] TAPPI Test Method T 451-M-45 Fed. Std. No 191, Method 5204 (Clark Stiffness Test) Fed. Std. No 191, Method 5206 (Cantilever Bend Method)
Hardness	D 785[A]
Optical transmission	E 308[A]
Haze	D 1003[A]
Water vapor transmission	E 96[A]
Dielectric strength	D 149[A]
Dielectric constant-power factor	D 150[A]
Insulation resistance	D 257[A]
Arc resistance	D 495[A]

[A] These designations refer to the following ASTM methods:

D 149, Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies[2]
D 150, Test Methods for A-C Loss Characteristics and Dielectric Constant (Permittivity) of Solid Electrical Insulating Materials[2]
D 257, Test Methods for D-C Resistance or Conductance of Insulating Materials[2]
D 495, Test Method for High-Voltage, Low-Current, Arc Resistance of Solid Electrical Insulating Materials[2]
D 638, Test Method for Tensile Properties of Plastics[2]
D 747, Test Method for Stiffness of Plastics by Means of a Cantilever Beam[2]
D 785, Test Method for Rockwell Hardness of Plastics and Electrical Insulating Materials[2]
D 1003, Test Method for Haze and Luminous Transmittance of Transparent Plastics[2]
D 1708, Test Method for Tensile Properties of Plastics by Use of Microtensile Specimens[6]
E 96, Test Methods for Water Vapor Transmission of Materials in Sheet Form[7]
E 308, Rec. Practice for Spectrophotometry and Description of Color in CIE 1931 System[8]

---

[6] *Annual Book of ASTM Standards*, Vol 08.02.

[7] *Annual Book of ASTM Standards*, Vols 08.03 and 15.09.

[8] *Annual Book of ASTM Standards*, Vol 06.01.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

PUBLIC SAFETY

Public Access to ASTM E681

Standard Test Method for Concentration Limits of Flammability of Chemicals (Vapors and Gases)

The 1985 edition of ASTM E681 is incorporated by reference into law at by PHMSA at 49 CFR 173.115. The standard "may be used to determine guidelines for the safe handling of volatile chemicals ... particularly in assessing ventilation requirements for the handling of gases and vapors." The American Society for Testing and Materials (ASTM) makes available the 2009 edition of the standard for $46.00 and also has the 1998, 2001, and 2004 versions available for sale.

The 1985 version that is incorporated by reference is not available for purchase at any outlet. The standard as an individual document is not available in any public library in the United States. Two libraries in Australia have the 1985 edition of Section 14 of the ASTM Annual Book of Standards which may contain this document. In the United States, access is limited to a few elite universities that have subscribed to the ASTM annual service or by a personal visit to the PHMSA or Office of the Federal Register reading room. Public.Resource.Org was able to find this standard and several others by purchasing over 70 random volumes of ASTM standards that we found on the Amazon.Com used book marketplace, and then carefully compared the tables of contents to the registry of standards incorporated by reference looking for matches.

ASTM standards are particularly problematic for incorporation by reference. PHMSA incorporates 74 unique standards in their section of the CFR. In some cases, multiple incompatible (and currently obsolete) versions of standards are incorporated. For example, PHMSA incorporates both the 1990 and 2000 versions of ASTM A516 in different sections of the CFR. ASTM has continued to revise this standard, issuing new editions in 2001, 2003, 2004, 2005, 2006, and 2010.

ASTM has lobbied aggressively against public access to standards incorporated by reference. When the Department of Homeland Security wanted to make standards for emergency responders available, they were only able to do so under limited conditions and after paying a fee to ASTM.

We understand that standards bodies need money to function. However, with a $58 million revenue stream, million-dollar CEO salaries, and an important leadership role in the U.S. engineering community, ASTM could do much more. Access to the law is a cardinal principle of the American system of government and only a small portion of the ASTM standards base has ben incorporated into law. ASTM could do much more to meet their obligations to the American public while still meeting their financial goals.

Public Safety Analysis:
Carl Malamud, Public.Resource.Org
July 9, 2012

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

* * *

Document Name: ASTM E681: Standard Test Method for Concentration Limits of Flammability of Chemicals

CFR Section(s): 49 CFR 173.115(a)(2)

Standards Body: American Society for Testing and Materials

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: E 681 – 85

Standard Test Method for Concentration Limits of Flammability of Chemicals[1]

This standard is issued under the fixed designation E 681; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the lower and upper concentration limits of flammability of chemicals having sufficient vapor pressure to form flammable mixtures in air at one atmosphere pressure at the test temperature. This method may be used to determine these limits in the presence of inert dilution gases. No oxidant stronger than air should be used.

NOTE 1—The lower flammability limit and upper flammability limit are also referred to as the lower explosive limit (LEL) and upper explosive limit (UEL) respectively.

1.2 This test method is limited to an initial pressure of 101 kPa (1 atm) or less with a practical lower pressure limit of approximately 13.3 kPa (100 mm Hg). The maximum practical operating temperature of this equipment is approximately 150°C (302°F).

1.3 This test method is one of several being developed by Committee E-27 for determining the flammability of chemicals.

1.4 *This standard should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use.*

1.5 *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 whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific precaution statements are given in Section 7.

2. Summary of Method

2.1 A uniform mixture of a gas or vapor with air is ignited in a closed vessel and the upward and outward propagation of the flame away from the ignition source is noted by visual observation. The concentration of the flammable component is varied between trials until the composition which will just sustain propagation of the flame is determined.

3. Definitions

3.1 *lower limit of flammability or lower flammable limit* (LFL)—the minimum concentration of a combustible substance that is capable of propagating a flame through a homogeneous mixture of the combustible and a gaseous oxidizer under the specified conditions of test.

3.2 *upper limit of flammability or upper flammable limit* (UFL)—the maximum concentration of a combustible substance that is capable of propagating a flame through a homogeneous mixture of the combustible and a gaseous oxidizer under the specified conditions of test.

3.3 *propagation of flame*—as used in *this method*, the upward and outward movement of the flame front from the ignition source to the vessel walls, which is determined by visual observation.

4. Significance and Use

4.1 The lower and upper limits of flammability of gases and vapors define the range of flammable concentrations in air.

4.2 Limits of flammability may be used to determine guidelines for the safe handling of volatile chemicals. They are used particularly in assessing ventilation requirements for the handling of gases and vapors.

NOTE 2—The break point between nonflammability and flammability occurs over a narrow concentration range at the lower flammable limit but is less distinct at the upper limit.

5. Interferences

5.1 This method is not applicable to certain readily oxidized chemicals. If significant oxidation takes place when the vapors are mixed with air, unreliable results are obtained. Flow systems designed to minimize hold-up time may be required for such materials.

5.2 Measured flammable limits are influenced by flame-quenching effects of the test vessel walls. The test vessel employed in this method is of sufficient size to eliminate the effects of flame quenching for most materials. However, there may be quenching effects, particularly on tests run at subambient pressures. For certain amines, halogenated materials, etc., which have large ignition-quenching distances, tests should be conducted in larger diameter vessels.

6. Apparatus

6.1 Figure 1 is a schematic diagram of the apparatus; details and dimensions are presented in Annex A1. The apparatus consists of a glass test vessel (*1*), an insulated chamber (*2*) equipped with a source of controlled-temperature air (*3*), an ignition device with an appropriate power supply (*4*), a magnetic stirrer (*5*), and a cover (*6*)

---

[1] This test method is under the jurisdiction of ASTM Committee E-27 on Hazard Potential of Chemicals and is the direct responsibility of Subcommittee E27.04 on Flammability and Ignitability of Liquid Chemicals.

Current edition approved Nov. 14, 1985. Published December 1985. Originally published as E 681 – 79. Last previous edition E 681 – 79$^{\epsilon 1}$.

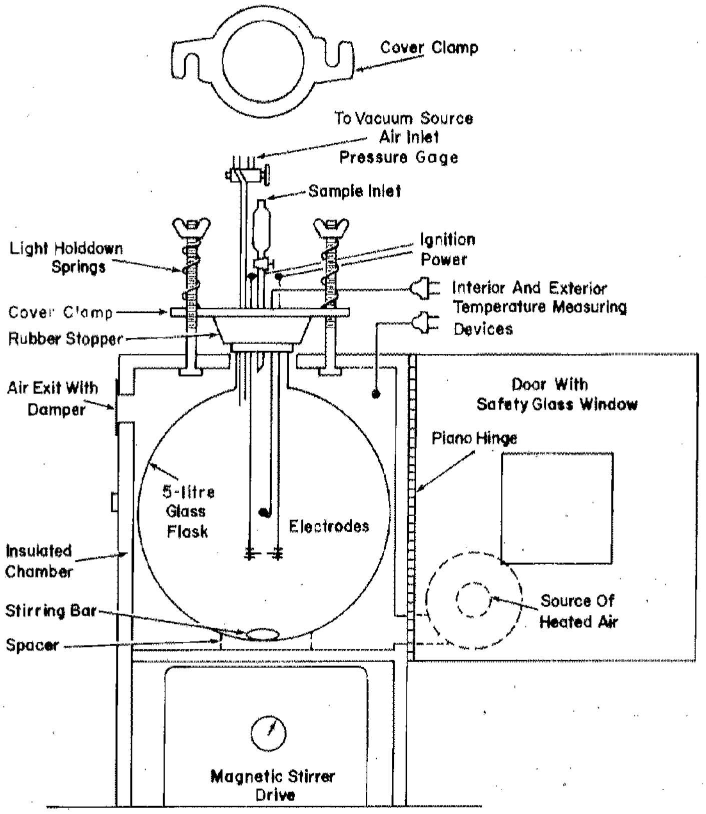


FIG. 1 Schematic Diagram of Test Apparatus

equipped with the necessary operating connections and components.

7. Safety Precautions

7.1 Tests should not be conducted in this apparatus with oxidizers stronger than air since explosive violence increases as oxidizer strength increases. Do not use oxygen, nitrous oxide, nitrogen dioxide, chlorine, etc., in this glass apparatus.

7.2 Adequate shielding must be provided to prevent injury in the event of equipment rupture, due to both implosions and explosions. A metal enclosure such as that recommended in A1.2 is one method suitable for this purpose.

7.2.1 Implosion of the test vessel at high vacuum levels is possible and, therefore, all evacuations must be made with the required shielding to protect against flying fragments.

7.2.2 Energetic explosions may be produced if tests are made at concentrations within the flammable range, between the LFL and UFL. The glass test vessel, equipped with a lightly held or loose cover, vents most explosions adequately. Nevertheless, shielding is required to protect against any probability of test vessel rupture. Methods for estimating initial test concentrations, discussed in Annexes A2, A3, and A4 may be employed to ensure that initial trials are conducted at concentrations less than the LFL or greater than the UFL.

7.2.3 In rare instances, particularly with upper limit tests, self-ignition may be encountered when air is rapidly introduced into the partially evacuated test vessel containing vaporized sample. Valves permitting remote operation, changes in sample and air introduction sequences, simple shields, and other techniques may be employed to ensure safe operations.

7.2.4 The test area should be equipped with electrical interlocks to prevent activation of the ignition source unless adequate shielding is in place.

7.3 Tests should not be conducted on thermally unstable materials which might undergo explosive decomposition reactions.

7.4 Tests should be conducted in a fume hood or other ventilated area to prevent personnel exposure to toxic chemicals or combustion products.

7.5 Precautions must be taken to ensure that the high-voltage spark ignition source does not contact temperature or pressure-measuring devices or other conductive paths which could create an electrical hazard to personnel or instrumentation outside the shielded area. Careful attention to electrical insulation integrity can reduce the possibility of hazard. Disconnects for all instrumentation lines will provide positive protection.

8. Equipment Calibration

8.1 Accurate determination of the flask volume is necessary for the calculation of flammable limits when sample measurement is on a weight or volume basis.

8.1.1 Determine the total volume of the flask as follows: Weigh a clean, dry flask with all components installed. Fill the flask with distilled water. Reinsert the cover, allowing the excess water to overflow, dry the outside of the flask, and reweigh. Record the difference in grams as the net volume of the flask in cubic centimetres. (Slight errors associated with water density differences are beyond the accuracy of this method.)

8.2 Calibrate pressure-, temperature-, and liquid-measuring devices against adequate standards.

9. Procedure

9.1 Assemble the equipment, as in Fig. 1, within an appropriate fume hood or other ventilated area and secure the door of the metal enclosure. The test vessel and all components should be clean and dry. Evacuate the system and flush with air to ensure removal of residual volatile materials that may be present as a result of cleaning or prior tests. As many as three evacuation/flush cycles may be required to ensure complete removal of combustion products between tests.

9.2 Adjust the flask to the desired test temperature. This temperature must be above the vapor condensation temperature of the mixture being tested.

9.2.1 It may be necessary to heat or insulate cover components and feed lines separately to prevent vapor condensation.

9.3 Record the actual barometric pressure at the test location.

9.4 Double check to make certain all safety precautions have been taken.

9.5 *Procedure for Sample Introduction as a Liquid:*

9.5.1 Evacuate the flask to a pressure of 1.33 to 6.65 kPa (10 to 50 mm Hg).

9.5.2 Place the desired liquid volume in a hypodermic syringe of appropriate size. Liquid volumes for initial trials may be estimated by methods given in Annex A2. Transfer the liquid to the inlet separatory funnel (see 9.5.4.1).

9.5.3 Turn on the stirrer at a minimum speed of 400 rpm.

9.5.4 Open the inlet stopcock. Allow the sample to be drawn into the flask. Close the stopcock when all the liquid has entered. Place a cover on the inlet separatory funnel.

9.5.4.1 A serum-bottle septum may be used in place of the separatory funnel. In this case, inject the sample directly into the flask by piercing the septum with the hypodermic needle. It will be necessary to make a volume correction if a significant volume of liquid is drawn from the needle or uncalibrated portion of the syringe.

9.5.5 When sample vaporization is complete, remove the separatory funnel cover and open the stopcock, permitting air to enter the test vessel slowly through the separatory funnel (see 7.2.3). Entering air sweeps traces of residual sample into the flask.

9.5.6 Release the cover hold-down devices and close the hood door.

9.5.7 Continue stirring for at least 5 min to obtain complete mixing and attainment of thermal equilibrium. Final trials should be made at longer mixing times to ensure optimal mixing conditions are achieved.

9.5.8 Turn off the stirrer.

9.5.9 Record the test temperature, *T*.

9.5.10 Disconnect instrumentation lines as required.

9.5.11 Darken the viewing area. Activate the ignition source. Observe for ignition and flame propagation away from the ignition source. Record as flammable any mixture producing a flame front that spreads from the ignition source and reaches the vessel walls.

NOTE 3—Mixtures having a composition just outside the flammable range exhibit a small cap of flame above the arc position; in some cases a vertical streak of flame may propagate to the vessel cover. (Absence of a cap flame may be an indication of insufficient ignition energy.) The onset of spherical, upward, and partial outward flame propagation signifies a limit or near-limit mixture. It is suggested that detailed observations of flame behavior be recorded on all trials. Include such notes as flame cap, no flame cap, upward and outward propagation, downward propagation, etc. These observations can serve as a guide to narrowing the region of uncertainty between go and no-go trials.

9.5.12 Vary sample size as required to find the minimum sample size, L_1, that gives flame propagation and the maximum sample size, L_2, below L_1, that does not give flame propagation. (The difference between L_1 and L_2 is a measure of the variability of the procedure for the material being studied.)

9.5.13 If numerous trials are required for a given series of tests, it may be necessary to remove the vessel for cleaning periodically, particularly for upper limit studies.

9.5.14 Final trials shall be made in a clean vessel.

NOTE 4—Ignition failures and inconsistent performance are occasionally encountered when highly conductive or very high ignition energy materials are tested using a spark ignition source. Limits for these materials should be determined using a fuse wire ignition source. Fuse wire ignition should also be used to confirm reduced pressure limit values arrived at on the basis of spark ignition source trials.

9.5.15 Record the values of the sample volumes L_1 and L_2. If partial propagation occurs over a range of sample sizes greater than 10 % of the sample size, the range should be specified in the report, for example, LFL = 5.4 ± 0.6 %).

9.5.16 Commence upper limit tests at a concentration greater than U_1, as defined in 9.5.17. Sample sizes for initial trials may be determined by methods given in Annex A3.

9.5.17 Record the values for the greatest sample quantity, U_1, that will propagate a flame and the least quantity, U_2, above U_1 that will not propagate a flame.

9.6 *Procedure for Sample Introduction as a Vapor:*

9.6.1 Sample concentration can be measured for gases and readily vaporized liquids on the basis of vapor pressure. In this instance, equip the vessel with a pressure transducer capable of reading to the nearest 0.0667 kPa (0.5 mm Hg). The system must also be capable of maintaining a vacuum of 0.0667 kPa or less.

9.6.2 Evacuate vessel and sample lines to a pressure of 0.0667 kPa (0.5 mm Hg or less).

9.6.3 Introduce the sample as a vapor through an appropriate inlet valve until the desired pressure is achieved. Introduce air as in 9.5.5, raising the pressure to atmospheric.

9.6.4 Carry out steps 9.5.6 through 9.5.17 as needed.

9.7 *Procedure for Sample Introduction as a Solid:*

9.7.1 Chemicals having melting points above room temperature but which totally melt and vaporize or totally sublime at the test conditions may be added to the test vessel as solids.

9.7.2 Bring the test vessel to atmospheric pressure (prior evacuation must be employed, as in 9.1, to ensure cleanliness).

9.7.3 Place the desired sample weight in the flask by raising the cover and inserting the sample.

9.7.4 Carry out steps 9.5.6 through 9.5.17 as needed.

NOTE 5—A small portion of the sample may be lost from the test vessel as the sample vaporizes and warms up to the test temperature. Losses are minimized by delaying the start of stirring until vaporization is complete. Maximum theoretical sample loss, which is small, may be readily calculated.

10. Calculations

10.1 Calculate the sample quantity, L or U, as follows:

$$L = \tfrac{1}{2}(L_1 + L_2) \tag{1}$$

$$U = \tfrac{1}{2}(U_1 + U_2) \tag{2}$$

where:

L = sample quantity used to calculate the lower flammable limit by Eq 3, and

U = sample quantity used to calculate the upper flammable limit by Eq 3.

For L_1 and L_2, see 9.5.12 . For U_1 and U_2, see 9.5.17.

10.2 Calculate the lower (LFL) and upper (UFL) flammable limits from the sample quantities. Ideal vapor phase behavior is assumed. (See Appendix X5.2 for a sample calculation and X5.1 for development of Eq 3.)

10.2.1 *Liquid Samples* (ideal vapor phase behavior is assumed):

$$\mathrm{LFL} = \frac{(L_v)(d)(T)}{(\mathrm{MW})(P)} \times \frac{(22.4)(P_o)(100)}{(V)(T_o)} \tag{3}$$

where:

LFL = lower flammable limit in mole or volume %,

L_v = L = sample volume from Eq 1, cm^3,

d = sample density, g/cm^3,

T = test temperature, K,

MW = sample molecular weight, g, and

P = test pressure, absolute, kPa (mm Hg).

10.2.1.1 The second term is a constant for a given test apparatus where: P_o = standard pressure (760 mm Hg), V = vessel volume (litres), and T_o = standard temperature (273 K). (Any set of consistent units may be used for these calculations.)

10.2.1.2 Calculate upper flammable limits by replacing LFL with UFL and L_v with U_v in Eq 3.

10.2.2 *Vapor Samples* (ideal vapor phase behavior is assumed):

$$\mathrm{LFL} = (L_p/P) \times 100 \tag{4}$$

where:

L_p = L = sample partial pressure (mm Hg) from Eq 1.

10.2.2.1 Calculate upper limits by replacing LFL with UFL and L_v with U_v.

10.2.3 *Solid Samples* (ideal vapor phase behavior is assumed):

10.2.3.1 Calculate lower flammable limits by using Eq 3 with the terms (L_v) (d) replaced by L_w where: $L_w = L$ = sample weight (g) from Eq 1.

10.2.3.2 Calculate upper flammable limits by replacing LFL with UFL and L_w with U_w.

10.3 *Complex Liquids, Solids, and Mixtures*—Flammability limits of some materials cannot be calculated in terms of mole or volume percent (Eq 3) since the molecular weight of the vapors is not known. This occurs in the case of unknown materials, multicomponent mixtures and materials exhibiting nonideal vapor phase behavior. It is more meaningful to express these limits in terms of weight of combustible per unit volume of mixture (mg/litre).

NOTE 5—Such limits are often given in the literature[2] as weight of combustible per litre of air at standard conditions (0°C and 760 mm Hg). These limits may be calculated from the following expression or by a similar expression for UFL:

$$\mathrm{LFL,\ mg/litre} = \frac{\mathrm{LFL(volume\ \%)}}{[100 - \mathrm{LFL(volume\ \%)}]\left[\dfrac{22.414(\mathrm{litre})}{\mathrm{MW\ (mg)}}\right]}$$

10.3.1 Calculate lower flammable limits of mixed vapors and materials exhibiting nonideal vapor phase behavior as follows:

$$\mathrm{LFL}_w = \frac{L_w}{V} \quad \text{or} \quad \frac{L_v(d)}{V} \times 100 \tag{5}$$

where: LFL_w = lower flammable limit, in milligrams per litre.

10.3.2 Calculate upper flammable limits using Eq 5 replacing LFL_w with UFL_w, L_w with U_w, and L_v with U_v.

11. Report

11.1 Report flammability limits, LFL and UFL, calculated in accordance with Eqs 3, 4 or 5, along with the test temperature, test pressure, and ignition source (spark or fuse wire) used.

11.2 Report the limits initially in accordance with the units of measurement used in the determinations, that is, on a volumetric basis (mole or volume percent) for gases or vapor samples and on a gravimetric basis (milligrams per litre) for liquid or solid samples.

11.3 By substitution in Eq 3, calculated limits may then also be given for the gases or vapors on a gravimetric basis and for the liquids or solids on a volumetric basis, provided molecular weights of the combustibles are known. The report shall note if nonideal vapor phase behavior is suspected or known to occur.

11.4 Report the test variability if it exceeds 10 % of the sample size (see 9.5.1.5).

12. Precision and Bias

12.1 The precision and bias of this method have not yet been established.

12.2 The minimum precision of the method shall be ±0.5 % for limits of 10 volume %. Test data available at present are inadequate to establish any measure of repeatability or reproducibility.

ANNEXES

(Mandatory Information)

A1. DIMENSIONS AND SPECIFICATIONS OF APPARATUS (Fig. 1)

A1.1 *Test Vessel*—The test vessel shall be a borosilicate glass boiling flask, short-ring neck, 5000-cm^3 capacity, approximately 222 mm (8¾ in.) in diameter and 305 mm (12 in.) in height.

A1.2 *Insulated Chamber*—The dimensions shall be as follows:

Inside: 279 by 279 by 305 mm (11 by 11 by 12 in.) high
Height: 483 mm (19 in.). Adjust to accommodate stirrer unit.
Rear panel: ≥200 by 200-mm vent area
Top hole: 70.0-mm (2¾-in.) diameter
Air inlet hole: to fit air supply unit
Air exit hole: to accommodate a simple slide damper

A1.2.1 *Materials*—Sheet metal of at least 16 gage covered with insulation. Generally a portion of the metal bottom must be partially removed and replaced with nonmagnetic material to permit operation of the magnetic stirrer. The rear panel should be equipped with a vent (≥ 200 by 200 mm) providing explosion relief at low over-pressures, ≤6.9 kPa (1 psi). A lightly held panel of insulating board may be used.

A1.2.2 *Door*, hinged and latched, fitted with a 102 to 127-mm (4- to 5-in.) square safe viewing window made of polycarbonate and at least 12.7-mm (½-in.) thickness or equivalent.

A1.2.3 *Bolts*, top-fitted with two ¼–20 bolts on 127-mm (5-in.) centers to secure test vessel cover.

A1.2.4 *Spacer*—A cylindrical spacer constructed of perforated metal and sized to position the top of the neck of the test vessel just above the top of the test chamber permits air circulation and facilitates insertion and removal of the test vessel.

NOTE A1.1—If heavy construction is employed for the front, top, and side walls of the chamber and in the front of the base area, and if the rear and bottom panels of the chamber are of lightweight materials, explosion venting will be to the rear, away from the operator, in the event of vessel rupture.

A1.2.5 *Alternatives*—Other thermostated chambers or ovens and heating means may be employed if they permit temperature control and proper test manipulation and observation with adequate safety.

A1.3 *Heater*—Heated air is supplied from a blower, at the rate of approximately 0.38 m^3/min (13.5 ft^3/min), feeding air through a variable electric heater of approximately 2400 W. Commercial blowers, heaters, and manual or automatic controls and combinations thereof are available.

A1.4 *Ignition Device:*

A1.4.1 *Electrode Rods*, 3.175 to 4.76-mm (⅛ to 3/16-in.) diameter stainless steel, 317.5 mm (12½ in.) long. The upper ends are threaded for connection to a high-voltage source and the lower ends are threaded for attachment of spark gap points, or fuse wire, or both. Electrode rods are threaded for attachment of spark gap points, or fuse wire, or both. Electrode rods are spaced at least 32 mm (1¼ in.) apart. Other materials of construction may be used as needed.

A1.4.2 *Spark Gap*, having 6.4-mm (¼-in.) electrode spacing. Gap electrode extensions may be fabricated of platinum or tungsten wire held in wire connector lugs.

A1.4.3 *Fuse Wire*—19-mm (¾-in.) loop of 40-gage copper wire attached to threaded electrode rods in place of spark gaps.

A1.4.4 *Power*, approximately 30 mA at 15 kV, supplied by the secondary of a 120-V, 60-Hz luminous tube transformer, or by an equivalent device. Power for the fuse wire is 120 V, 60 Hz.

A1.4.5 *Timer*, to limit spark duration to 0.2 to 0.4 s. Commercial interval timers are available.

A1.5 *Stirring Devices:*

A1.5.1 *Stirring Bar*, 63.5-mm (2½-in.) egg-shaped, plastic-coated, magnet bar.

A1.5.2 *Drive*—Laboratory magnetic stirrer capable of functioning through the bottom of the test chamber and vessel.

A1.6 *Test Vessel Cover*—The cover can be constructed of a No. 14 rubber stopper with necessary holes for electrodes, sample inlet device, air inlet and evacuation connection and temperature-measuring device (see Fig. 1). *It is important to note* that the stopper rests on top and not inside the neck of the flask in order to facilitate venting.

NOTE A1.2—It is possible to operate at temperatures greater than 150°C (302°F) and to obtain more positive vacuum sealing through the use of specially constructed metal covers. High temperature O-ring seals for the flask top and inlet separatory funnel, and ceramic feedthroughs for the spark ignition source may be employed.

A1.7 *Cover Retainer* (Fig. 1)—This device held in place with wing nuts, light springs, and ¼–20 bolts can improve vacuum tightness of the test vessel when used to clamp down on the vessel cover.

A1.8 *Temperature Measurement:*

A1.8.1 Thermocouple, thermistor, resistance thermometer or other device may be used. High response speed is not required but is desirable in order to sense the heating effects associated with air introduction (7.2.3).

NOTE A1.3—Certain bare wire thermocouples may cause catalytic oxidation of test vapors, as evidenced by a persistent high-temperature excursion of the thermocouple junction. If this occurs, other thermocouple materials should be employed.

A1.8.2 A temperature-measuring device outside the test vessel but in the heating chamber or inlet air stream can aid in controlling test temperature.

A1.9 *Pressure Measurement*—Any pressure-measuring system accurate to 0.067 kPa (0.5 mm Hg) in the range from 0.067 to 101.3 kPa (0.5 to 760 mm Hg) and capable of being operated at temperatures greater than the condensation temperature of the materials under test is adequate for this unit. Active volume outside the test vessel itself should be held to a minimum since all components must be above the condensation temperature of the materials being tested. Electrical heating tapes may be employed for heating components to the desired temperature.

A2. ESTIMATION OF LOWER FLAMMABLE LIMITS FOR THE PURPOSE OF SELECTING SAMPLE SIZE FOR INITIAL TESTS

A2.1 It is the responsibility of the operator to ensure that adequate safety measures are employed in selecting sample sizes and in running the flammability limit tests. These guidelines are intended to assist the operator in planning the sequence of testing to avoid mixture compositions that may cause test vessel failure.

A2.2 To avoid energetic reactions, it is important that lower limit tests commence at a concentration below the lower flammable limit. Estimated lower flammable limits may be used in conjunction with Eq 3 to calculate a starting sample size.

A2.2.1 Several methods of estimating lower flammable limits are listed below. The accuracy of these methods varies, with some being relatively precise for certain classes of chemicals. Experience with these methods will improve the ability to make a reasonable evaluation as to the precision of the estimate with various types of material.

A2.3 Lower flammable limits of most organic chemicals are in the range from 40 to 60 mg/litre,[2] (see Note 5). For most materials, a sample size equivalent to 35 mg/litre may be used for initial tests. However, reactive fuels such as hydrogen and diborane have lower limits considerably below 30 mg/litre. As has been emphasized, lower limit tests should be conducted with extreme caution and upper limit tests should not be conducted in this apparatus on such materials (see 7.2).

A2.4 Lower flammable limits may be estimated from closed-cup flash point and vapor pressure data. The following approximate relationship may be employed:

$$\frac{P_f}{P_o} \times 100 = \mathrm{LFL_e} \qquad \text{(A1.1)}$$

where:

$\mathrm{LFL_e}$ = estimated lower flammable limit, volume %,
P_f = vapor pressure of combustible at the closed-cup flash point, mm Hg,
P_o = standard atmospheric pressure = 760 mm Hg.

A2.4.1 The validity of the flash point and vapor pressure data must be established in order to ensure a reasonable estimate of the lower flammable limit.

A2.4.2 The closed-cup flash point may not represent the lowest temperature at which a material evolves flammable vapor. Therefore, a safety factor must be employed when using this method.

A2.5 Lower flammable limits may be estimated as a function of the stoichiometric composition;[2,3] that composition where complete combustion to CO_2 and H_2O and conversion of the halogens, X, to HX consumes all the oxygen in the system.

A2.5.1 The stoichiometric composition may be calculated making use of balanced chemical equations for the combustion reaction.

A2.5.2 For combustion in air, this calculation reduces to the following equation:

$$C_s = \frac{100}{1 + 4.773\left[n + q + \dfrac{(m - k - 2p)}{4}\right]} \qquad \text{(A1.2)}$$

where:

C_s = stoichiometric composition of the combustible in air or mol %,
n = number of carbon atoms in the molecule,
m = number of hydrogen atoms in the molecule,
p = number of oxygen atoms in the molecule,
q = number of nitrogen atoms in the molecule, and
k = number of halogen atoms in the molecule.

A2.5.3 For saturated compounds containing only carbon, hydrogen, and oxygen, the lower flammable limit equals approximately 0.54 times the stoichiometric composition.[2,3]

$$\mathrm{LFL_e} = 0.54\, C_s \qquad \text{(A1.3)}$$

A2.5.4 For saturated compounds other than those containing carbon, hydrogen, and oxygen, lower flammable limits are generally greater than 0.54 times the stoichiometric composition.[2] Since data are limited and values vary, it is recommended that the factor 0.54 be used in calculating lower flammable limits from calculated stoichiometric composition for all saturated, nonreactive hydrocarbons.

A2.6 Lower flammable limits may also be estimated on the basis of correlations of known lower flammable limits of materials which are members of the same homologous series.

A2.7 Lower flammable limits of known mixtures may be estimated from known lower flammable limits of the mixture components using Le Chatelier's law. Details of these calculations can be found in *Bulletin 627*[2] and other references.

A3. ESTIMATION OF UPPER FLAMMABLE LIMITS FOR THE PURPOSE OF SELECTING SAMPLE SIZE FOR INITIAL TESTS

A3.1 Upper limits cannot be predicted as precisely as lower limits. Therefore, wide safety factors should be employed when using estimated upper limits to establish sample sizes for initial flammable limit tests (see Section 7).

A3.2 For saturated compounds containing only carbon, hydrogen, oxygen, and halogens, the upper flammable limit is generally greater than 3.5 times the stoichiometric composition.[3]

$$\mathrm{UFL_e} \geq 3.5\, C_s \qquad \text{(A1.4)}$$

where: $\mathrm{UFL_e}$ = estimated upper flammable limit.

NOTE A3.1—Equation A1.4 is not valid, and upper limits exceed 3.5

---

[2] Zabetakis, M. G., "Flammability Characteristics of Combustible Gases and Vapors," *Bulletin 627*, U.S. Bureau of Mines, XMBUA, 1965.

[3] Hilado, C. J., "A Method for Estimating Limits of Flammability," *Journal of Fire and Flammability*, Vol 6, April 1965, p. 130.

times stoichiometric for certain unsaturated compounds, organic oxides, ethers, amines, and other reactive materials. It is suggested (see Section 7) that, with the exception of amines, upper limits not be conducted on such materials in this apparatus.

A3.2.1 The upper flammable limit estimated with Eq A1.4 may be used with Eq 3 to estimate a starting sample size for tests.

A4. CORRELATION OF KNOWN UPPER AND LOWER FLAMMABLE LIMITS WITH STOICHIOMETRIC COMPOSITION

A4.1 Details on a correlation of known upper and lower flammable limits with stoichiometric composition are described by Hilado.[3] These details may permit more exact estimation of lower and upper flammable limits than is proposed in A2 and A3. However, to quote from the reference, "These estimates must be very cautiously applied because there are many chemicals with unusual flammability characteristics. Estimated values are not a substitute for experimental data."

APPENDIX

(Nonmandatory Information)

X1. CALCULATION OF FLAMMABLE LIMITS FROM TEST DATA

X1.1 Basis of Eq 3

$$\mathrm{LFL} = \frac{\text{moles of combustible in test vessel}}{\text{total moles of gas in test vessel}} \times 100 \qquad \text{(X1)}$$

$$= \frac{(L_v)(d)}{\mathrm{MW}} \times \frac{1}{\dfrac{V}{22.4} \times \dfrac{P}{(P_o)} \times \dfrac{(T_o)}{T}} \times 100 \qquad \text{(X2)}$$

where:

LFL = lower flammable limit, mol or volume %,

L_v = L = liquid sample volume, cm^3, from Eq 1,

d = sample density, g/cm^3,

MW = sample molecular weight,

V = test vessel volume, litres,

22.4 = standard molar volume, litres,

P = test pressure, mm Hg,

T = test temperature, K,

P_o = standard pressure = 1 atm (760 mm Hg),

T_o = standard temperature = 273 K,

$$\mathrm{LFL} = \frac{(L_v)(d)(T)}{(\mathrm{MW})(P)} \times k \qquad \text{(X3)}$$

$$k = \frac{(22.4)(P_o)(100)}{(V)(T_o)} \qquad \text{(X4)}$$

X1.2 Sample Calculation

X1.2.1 Tests conducted in a 5100-cm^3 vessel at 24°C and 750 mm Hg with a liquid sample having a density of 0.775 g/cm^3 and a molecular weight of 84.16 produced the first flame propagation at 270 µl and no flame propagation at 260 µl.

L_v = ½ (L_1 + L_2) = ½(0.270 + 0.260) = 0.265 cm^3

d = 0.775 g/cm^3

MW = 84.16

V = 5.1 litres

P = 750 mm Hg

T = 24°C = 297 K

X1.2.2 Using Eq X4:

$$k = \frac{(22.4)(760)(100)}{(5.1)(273)} = 1222.7$$

This value will remain unchanged for all tests conducted in a system of 5.1-litre total volume.

X1.2.3 Using Eq 3 (see Section 10 on Eq X3):

$$\mathrm{LFL} = \frac{(0.265)(0.775)(297)}{(84.16)(750)} \times 1222.7 = 1.18$$

where the lower flammable limit (LFL) = 1.18 volume % at 750 mm Hg pressure and 24°C.

CERTIFICATE

By Authority Of

THE UNITED STATES OF AMERICA

Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

* * *

Document Name: ASTM F1271: Standard Specification for Spill Valves for Use in Marine Tank Liquid Overpressure Protection Applications

CFR Section(s): 46 CFR 39.20-9(c)(1)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:

THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: F 1271 – 90 (Reapproved 1995)$^{\epsilon 1}$

An American National Standard

Standard Specification for Spill Valves for Use in Marine Tank Liquid Overpressure Protections Applications[1]

This standard is issued under the fixed designation F 1271; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

$^{\epsilon 1}$ NOTE—Section 13 was added editorially in December 1995.

1. Scope

1.1 This specification provides the minimum requirements for design, construction, performance, and testing of devices to prevent marine tank liquid overpressurization (hereafter called spill valves).

1.2 The spill valves provided in accordance with this specification will satisfy Regulation II-2/59.1.6 of the 1981 and 1983 Amendments to the International Convention for the Safety of Life at Sea, 1974 (SOLAS), which states: "Provision shall be made to guard against liquid rising in the venting system to a height which would exceed the design head of the cargo tank. This shall be accomplished by high level alarms or overflow control systems or other equivalent means, together with gaging devices and cargo tank filling procedures."

1.3 The spill valves are not intended for the venting of vapors or the relief of vapor overpressurization or underpressurization of marine tanks.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The following precautionary caveat pertains only to the test methods portion, Section 8, of this specification: *This standard does not purport to address all of the safety concerns, if any, 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. Referenced Documents

2.1 *ASTM Standards:*

B 117 Test Method of Salt Spray (Fog) Testing[2]

F 722 Specification for Welded Joints for Shipboard Piping Systems[3]

2.2 *ANSI Standards:*[4]

B2.1 Pipe Threads

B16.1 Cast Iron Pipe Flanges and Flanged Fittings

B16.3 Malleable Iron Threaded Fittings

B16.4 Cast Iron Threaded Fittings

B16.5 Steel Pipe Flanges and Flanged Fittings

B16.11 Forged Steel Fittings, Socket-Welding and Threaded

B16.15 Cast Bronze Threaded Fittings

B16.24 Bronze Pipe Flanges and Flanged Fittings

B31.1 Power Piping

2.3 *Other Documents:*

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Pressure Vessels; Section IX, Welding and Brazing Qualifications[5]

Safety for Life at Sea Convention, Regulation II-2/59.1.6, Amendments 1981 and 1983[4]

46 CFR 153 Ships Carrying Bulk Liquid, Liquified Gas, or Compressed Gas Hazardous Materials[6]

3. Terminology

3.1 *Definition:*

3.1.1 *spill valve*—an independent device that automatically prevents liquid overpressurization of a tank by relieving liquid at a predetermined pressure set higher than the pressure reached in the tank when the tank vapor relieving device operates at its maximum design venting rate (based on a volumetric vapor volume 1.25 times the maximum design loading rate).

4. Ordering Information

4.1 Orders for spill valves in accordance with this specification shall include the following information, as applicable:

4.1.1 Nominal pipe size and end connections,

4.1.2 Product(s) in tank being protected by the spill valve,

4.1.3 Inspection and tests other than specified by this specification,

4.1.4 Required relieving pressure at maximum tank loading flow rate,

4.1.5 Set (opening) pressure,

4.1.6 Maximum tank design loading flow rate,

4.1.7 Inlet pressure drop resulting from the maximum tank design loading flow rate,

4.1.8 Back pressure of the spill valve discharge lines resulting from maximum tank design loading flow rate,

---

[1] This specification is under the jurisdiction of ASTM Committee F-25 on Shipbuilding and is the direct responsibility of Subcommittee F25.13 on Piping Systems.

Current edition approved Nov. 30, 1990. Published August 1991. Originally published as F 1271 – 89. Last previous edition F 1271 – 89.

[2] *Annual Book of ASTM Standards*, Vol 03.02.

[3] *Annual Book of ASTM Standards*, Vol 01.07.

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[5] Available from the American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[6] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

4.1.9 Purchaser's inspection requirements (see 9.1),

4.1.10 Installation inclinations in excess of 2½° (see 6.6),

4.1.11 Purchaser's specifications for preventing the valve from leaking due to cargo sloshing, and

4.1.12 Additional requirements or testing as contracted by the manufacturer and the purchaser.

5. Materials

5.1 Materials of construction shall be suitable for the service intended and resistant to the attack by the liquid carried in the tank being protected (see 4.1.2). Table I of 46 CFR 153 specifies materials that may not be used in components that contact liquid or vapor of each hazardous liquid cargo.

5.2 Housings of spill valves, and all other parts or bolting, or both, used for pressure retention, shall be constructed of materials having a solidus melting point of greater than 1700°F (927°C) and be listed in ANSI B31.1 or Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, except as noted in 5.5.

5.3 Corrosion-resistant materials shall be used for the following:

5.3.1 Housings, disks, spindles, and seats of valves.

5.3.2 Springs that actuate disks of valves. Springs plated with corrosion-resistant material are not acceptable.

5.4 Nonmetallic materials shall not be permitted except for gaskets, seals, bushings in way of moving parts, and valve diaphragms.

5.5 Bolting materials shall be at least equal to those listed in Table 1 of ANSI B16.5. Bolts, screws, and fasteners in contact with interior liquid shall be compatible with the liquid (see 4.1.2).

6. Other Requirements

6.1 Pressure-retaining housings shall be designed to withstand a hydrostatic pressure of at least 125 lb/in.^{2} (8.78 kg/cm^2) without rupturing or showing permanent distortion.

6.2 Housing shall have suitable pipe connections for the removal, maintenance, and testing of the spill valve.

6.2.1 Threaded or flanged pipe end connections shall comply with the applicable B 16 ANSI standards listed in 2.2 or as agreed upon by the manufacturer and the purchaser (see 4.1.12). Welded joints shall comply with Specification F 722.

6.3 The design of spill valves shall allow for ease of inspection and removal of internal elements for replacement, cleaning, or repair without removal of the spill valve.

6.4 All flat joints of the housing shall be machined true and shall provide for a joint having adequate metal-to-metal contact.

6.5 Where welded construction is used, welded joint design details, welding, and nondestructive testing shall be in accordance with Section VIII, Division 1 of the ASME Code and Specification F 722. Welders and weld procedures shall be qualified in accordance with Section IX of the ASME Code.

6.6 The spill valve shall be fully operable at static inclinations up to 2½° unless otherwise specified by the ordering information in Section 4.

6.7 Spill valves shall allow for efficient drainage of moisture without impairing their proper operation.

6.7.1 Where the design does not permit complete drainage of condensate through its connection to the tank, the housing shall be fitted with a plugged drain opening on the side of the atmospheric outlet of not less than nominal pipe size ½ in. (12 mm).

6.8 Housing, elements, and seal gasket materials shall be capable of withstanding the highest pressure and temperature to which the spill valve may be exposed under normal conditions.

6.9 Spill valves shall be vapor tight at pressures below the rated liquid relieving pressure.

6.10 Fastenings essential to the operation of the spill valve shall be protected against loosening.

6.11 Spill valves shall be designed and constructed to minimize the effect of fouling under normal conditions.

6.12 The spill valve shall not be provided with a means of positive closure. In installations where cargo sloshing is expected, the spill valve installation must be designed to preclude premature opening of the valve due to cargo sloshing. Also, the installation shall be designed so that it complies with applicable loadline and subdivision requirements.

6.13 Spill valves shall be capable of operating in freezing conditions.

6.14 Each of the free areas through the valve seat and through the valve discharge at maximum lift shall not be less than the cross-sectional area of the valve inlet connection.

6.15 Means shall be provided to check that any valve opens freely and does not remain lodged in the open position.

6.16 *Valve Disks:*

6.16.1 Valve disks shall be guided by a ribbed cage or other suitable means to prevent binding and ensure proper seating. Where valve stems are guided by bushings suitably designed to prevent binding and to ensure proper seating, the valves need not be fitted with ribbed cages.

6.16.2 Valve disks shall close tight against the valve seat by metal to metal contact; however, resilient seating seals may be provided if the design is such that the disk closes tight against the seat in case the seals are destroyed or in case they carry away.

6.16.3 Valve disks may be solid or hollow. The pressure at which the valve disks open fully at maximum flow rating shall not exceed 120 % of the set (opening) pressure.

6.17 Valves may be actuated by nonmetallic diaphragms.

6.17.1 Nonmetallic diaphragms are not allowed where failure results in unrestricted flow of flammable or toxic tank vapors to the atmosphere or in an increase in the pressure at which the valve normally releases.

6.18 Relief pressure adjusting mechanisms shall be permanently secured by lockwire, locknuts, or other suitable means.

6.18.1 Hollow portions of the valve used to vary the relieving pressure by adding or removing weight shall be watertight.

6.1.19 Spill valves shall not permit entrance of water when exposed to boarding seas.

7. Workmanship, Finish, and Appearance

7.1 Spill valves shall be of first class workmanship and free from imperfections that may affect their intended purpose.

7.2 Each finished spill valve shall be visually and dimensionally checked to ensure that the spill valve corresponds to this specification, is certified in accordance with Section 10, and is marked in accordance with Section 11.

8. Test Methods

8.1 *Prototype Tests:*

8.1.1 A prototype of the largest and smallest spill valve of each design, based on valve inlet connection size, shall be tested as specified in 8.1.5, 8.1.6, and 8.1.8 through 8.1.10. Additionally, all models shall be tested as specified in 8.1.7.

8.1.2 The spill valve shall have the dimensions of and most unfavorable clearances expected in production units.

8.1.3 Tests shall be conducted by a laboratory capable of performing the tests.

8.1.4 A test report shall be prepared by the laboratory that shall include:

8.1.4.1 Detailed drawings of the spill valve,

8.1.4.2 Types of tests conducted and results obtained,

8.1.4.3 Specific advice on approved attachments,

8.1.4.4 Types of liquid for which the spill valve is approved,

8.1.4.5 Drawings of the test rig,

8.1.4.6 The pressures at which the spill valve opens and closes and the efflux flow rate at various inlet pressures,

8.1.4.7 Records of all markings found on the prototype spill valve, and

8.1.4.8 A traceable report number.

8.1.5 *Corrosion Test*—A corrosion test shall be conducted in accordance with Test Method B 117. The valve shall be subjected to the test for a period of 240 h and allowed to dry for 48 h. There shall be no corrosion deposits that cannot be washed off.

8.1.6 *Hydrostatic Test*—A hydrostatic pressure test shall be conducted to show compliance with 6.1. The test shall be made with water or other liquid having a maximum viscosity of 40 SSU at 125°F (52°C) with a maximum pressure test temperature of 125°F (52°C). The minimum duration of the test shall be 1 min.

8.1.7 *Performance Tests*—Performance characteristics, including flow rates under various positive pressures, operating sensitivity, flow resistance, and velocity, shall be demonstrated by appropriate tests with a representative fluid.

8.1.8 *Freeze Test*—Simulate water sloshing on deck by spraying a prototype spill valve completely with water from all sides and below using a fully pressurized fire hose. Allow 3 min to drain off. Immediately immerse it in a freeze chamber prechilled to 20°F (−7°C). Hold it in a chamber for 2 h at this temperature. Immediately test the valve as in 8.1.7 to determine opening pressure while frozen. The unit passes the test if it opens within 10 % of its previously measured set (opening) pressure.

8.1.9 *Vapor Tightness Test*—Compliance with 6.9 shall be demonstrated by testing the spill valve with compressed air at 90 % of the spill valve set (opening) pressure. The test apparatus shall have a total volume of air (in cubic feet) equal to 5 × D, where D is the seat diameter of the spill valve, in inches (test volume may vary by ±10 %). The valve design shall be deemed satisfactory if the air leakage rate is such that the pressure drop is not more than 2 % in 2 h.

8.1.10 *Seaworthiness Test*—In a simulated installation, immerse the spill valve such that the seal is under 2 ft of water, minimum. Spray it for 10 min with a 2½-in. fire hose with a fully open ⅞-in. diameter nozzle at a pitot pressure of 80 psig measured at the open nozzle. Spray all parts of the valve, both immersed and non-immersed, from all angles. The hose nozzle shall not be located further than 10 ft from the spill valve during the course of this test. The valve design is sufficient if leakage through the housing or past the disk, or both, is no more than 1 oz.

8.1.11 After completion of all tests the device shall be disassembled and examined and no part of the device shall be damaged or show permanent deformation.

8.2 *Production Tests:*

8.2.1 Each finished spill valve is to be tested by a hydrostatic test conducted at 1½ times the rated relieving pressure of the spill valve, with the device secured closed. The test shall be made with water or other liquid having a maximum viscosity of 40 SSU at 125°F (52°C) with a maximum pressure test temperature of 125°F (52°C). The minimum duration of the test shall be 1 min. The purpose of this test is to detect leaks and structural imperfections. No visible leakage is permitted.

8.2.2 Before being shipped, each unit shall be tested as necessary to verify that it will function at its set (opening) pressure and that the disk moves freely and fully.

9. Inspection

9.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with this specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All examinations and inspections shall be made at the place of manufacture, unless otherwise agreed upon.

10. Certification

10.1 Manufacturer's certification that a spill valve has been constructed in accordance with this specification shall be provided in an instruction manual. The manual shall include the following:

10.1.1 Installation instructions, including size of the inlet and outlet, approved location for installation, and maximum or minimum length of pipe, if any, between the spill valve and the atmosphere,

10.1.2 Operating instructions,

10.1.3 Maintenance requirements,

10.1.3.1 Instructions on how to determine when spill valve cleaning is required and the method of cleaning,

10.1.4 Copy of prototype test report (see 8.1), and

10.1.5 Product(s) that the valve is designed for or restricted to, or both.

11. Product Marking

11.1 Each spill valve shall be permanently marked indicating the following:

11.1.1 Manufacturer's name or trademark,

11.1.2 Style, type, model, or other manufacturer's designation for the spill valve,

11.1.3 Direction of flow through the spill valve,

11.1.4 Maximum rated flow,
11.1.5 ASTM designation of this specification,
11.1.6 Relief pressure setting at full flow rating,
11.1.7 Set (opening) pressure, and
11.1.8 Indication of proper orientation of valve, if critical.

12. Quality Assurance

12.1 Spill valves shall be designed, manufactured, and tested in a manner that ensures they meet the characteristics of the prototype tested in accordance with this specification.

12.2 The spill valve manufacturer shall maintain the quality of the spill valves that are designed, tested, and marked in accordance with this specification. At no time shall a spill valve be sold with this specification designation that does not meet the requirements herein.

13. Keywords

13.1 marine technology; overflow control systems; overpressurization; overpressure protection; ships; spill valves