



Standard Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies¹

This standard is issued under the fixed designation E 1529; 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 performance of structural members and assemblies exposed to fire conditions resulting from large, free-burning (that is, outdoors), fluid-hydrocarbon-fueled pool fires is of concern in the design of hydrocarbon processing industry (HPI) facilities and other facilities subject to these types of fires. In recognition of this unique fire protection problem, it is generally required that critical structural members and assemblies be of fire-resistant construction.

Historically, such requirements have been based upon tests conducted in accordance with Test Methods E 119, the only available standardized test for fire resistant construction. However, the exposure specified in Test Methods E 119 does not adequately characterize large hydrocarbon pool fires. Test Methods E 119 is intended to be representative of building fires where the primary fuel is solid in nature, and where there are significant constraints on the movement of air to the fire, and the combustion products away from the fire (that is, through doors, windows). In contrast, neither condition is typical of large hydrocarbon pool fires (see Appendix X1 on Commentary).

One of the most distinguishing features of the pool fire is the rapid development of high temperatures and heat fluxes that can subject exposed structural members and assemblies to a thermal shock much greater than that associated with Test Methods E 119. As a result, it is important that fire resistance requirements for HPI assemblies of all types of materials be evaluated and specified in accordance with a standardized test that more closely approximates the anticipated fire conditions. Such a standard is found in the test methods herein.

1. Scope

1.1 The test methods described in this fire-test-response standard are used for determining the fire-test response of columns, girders, beams or similar structural members, and fire-containment walls, of either homogeneous or composite construction, that are employed in HPI or other facilities subject to large hydrocarbon pool fires.

1.2 It is the intent that tests conducted in accordance with these test methods will indicate whether structural members of assemblies, or fire-containment wall assemblies, will continue to perform their intended function during the period of fire exposure. These tests shall not be construed as having determined suitability for use after fire exposure.

1.3 These test methods prescribe a standard fire exposure for comparing the relative performance of different structural

and fire-containment wall assemblies under controlled laboratory conditions. The application of these test results to predict the performance of actual assemblies when exposed to large pool fires requires a careful engineering evaluation.

1.4 These test methods may be useful for testing other items such as piping, electrical circuits in conduit, floors or decks, and cable trays. Because failure criteria and test specimen descriptions are not provided in these test methods, testing these types of items will require appropriate specimen details and end-point or failure criteria.

1.5 *Limitations*—These test methods do not provide the following:

1.5.1 Full information on the performance of assemblies constructed with components or of dimensions other than those tested.

1.5.2 An evaluation of the degree to which the assembly contributes to the fire hazard through the generation of smoke, toxic gases, or other products of combustion.

1.5.3 Simulation of fire behavior of joints or connections between structural elements such as beam-to-column connections.

¹ These test methods are under the jurisdiction of ASTM Committee E05 on Fire Standards and are the direct responsibility of Subcommittee E05.11 on Construction Assemblies.

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1.5.4 Measurement of flame spread over the surface of the test assembly.

1.5.5 Procedures for measuring the test performance of other structural shapes (such as vessel skirts), equipment (such as electrical cables, motor-operated valves, etc.), or items subject to large hydrocarbon pool fires, other than those described in 1.1.

1.5.6 The erosive effect that the velocities or turbulence, or both, generated in large pool fires has on some fire protection materials.

1.5.7 Full information on the performance of assemblies at times less than 5 min because the rise time called out in Section 5 is longer than that of a *real* fire.

1.6 These test methods do not preclude the use of a *real* fire or any other method of evaluating the performance of structural members and assemblies in simulated fire conditions. Any test method that is demonstrated to comply with Section 5 is acceptable.

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

1.8 *This standard is used to measure and describe the response of materials, products, or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire hazard or fire risk assessment of the materials, products, or assemblies under actual fire conditions.*

1.9 *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.*

1.10 The text of this standard references notes and footnotes which provide explanatory information. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 ASTM Standards:

- B 117 Practice for Operating Salt Spray (Fog) Apparatus²
- D 822 Practice for Conducting Tests on Paint and Related Coatings and Materials Using Filtered Open-Flame Carbon-Arc Exposure Apparatus³
- E 119 Test Methods for Fire Tests of Building Construction and Materials⁴
- E 176 Terminology Relating to Fire Standards⁴
- E 511 Test Method for Measuring Heat Flux Using a Copper-Constantan Circular Foil, Heat-Flux Gage⁵

2.2 Code of Federal Regulations:

- 46 CFR 164.007 Structural Insulations⁶

² Annual Book of ASTM Standards, Vol 03.02.

³ Annual Book of ASTM Standards, Vol 06.01.

⁴ Annual Book of ASTM Standards, Vol 04.07.

⁵ Annual Book of ASTM Standards, Vol 15.03.

⁶ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

3. Terminology

3.1 *Definitions*—Refer to Terminology E 176 for definitions of terms used in these test methods.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *total cold wall heat flux*—the heat flux that would be transferred to an object whose temperature is 70°F (21°C).

4. Summary of Test Methods

4.1 A standard fire exposure of controlled extent and severity is specified. The test setup will provide an average total cold wall heat flux on all exposed surfaces of the test specimen of 50 000 Btu/ft²·h ± 2500 Btu/ft²·h (158 kW/m² ± 8 kW/m²). The heat flux shall be attained within the first 5 min of test exposure and maintained for the duration of the test. The temperature of the environment that generates the heat flux of procedures in 6.2 shall be at least 1500°F (815°C) after the first 3 min of the test and shall be between 1850°F (1010°C) and 2150°F (1180°C) at all times after the first 5 min of the test. Performance is defined as the time period during which structural members or assemblies will continue to perform their intended function when subjected to fire exposure. The results are reported in terms of time increments such as ½ h, ¾h, 1 h, 1½h, etc.

4.1.1 These test methods are cited as the “Standard Large Hydrocarbon Pool Fire Tests.”

5. Significance and Use

5.1 These test methods are intended to provide a basis for evaluating the time period during which a beam, girder, column, or similar structural assembly, or a nonbearing wall, will continue to perform its intended function when subjected to a controlled, standardized fire exposure.

5.1.1 In particular, the selected standard exposure condition simulates the condition of total continuous engulfment of a member or assembly in the luminous flame (fire plume) area of a large free-burning-fluid-hydrocarbon pool fire. The standard fire exposure is basically defined in terms of the total flux incident on the test specimen together with appropriate temperature conditions.

5.1.2 It is recognized that the thermodynamic properties of free-burning, hydrocarbon fluid pool fires have not been completely characterized and are variable depending on the size of the fire, the fuel, environmental factors (such as wind conditions), the physical relationship of the structural member to the exposing fire, and other factors. As a result, the exposure specified in these test methods is not necessarily representative of all the conditions that exist in large hydrocarbon pool fires. The specified standard exposure is based upon the best available information and testing technology. It provides a basis for comparing the relative performance of different assemblies under controlled conditions.

5.1.3 Any variation to construction or conditions (that is, size, method of assembly, and materials) from that of the tested assembly is capable of substantially changing the performance characteristics of the assembly.

5.2 Separate procedures are specified for testing column specimens with and without an applied superimposed load.

5.2.1 The procedures for testing loaded columns stipulate that the load shall be applied axially. The applied load is to be

the maximum load condition allowed under nationally recognized structural design criteria unless limited design criteria are specified and a corresponding reduced load applied.

5.2.2 The procedure for testing unloaded column specimens includes temperature limits for steel columns. These limits are intended to define the temperature above which a steel column with an axially applied design allowable load would fail structurally. The procedure for unloaded specimens also provides for the testing of other than steel columns provided that appropriate acceptance criteria have been established.

5.3 Separate procedures are also specified for testing beam assemblies with and without an applied superimposed load.

5.3.1 The procedure for testing loaded specimens stipulates that the beam shall be simply supported and may or may not be restrained against longitudinal thermal expansion, depending on the intended use. The applied load is intended to be the allowable design load permitted for the beam as determined in accordance with accepted engineering practice.

5.3.2 The procedure for testing unloaded beams includes temperature limits for steel. These limits are to define the temperature above which a simply supported, unrestrained beam would fail structurally if subjected to the allowable design load. The procedure for unloaded specimens also provides for the testing of other than steel and reinforced concrete beams provided that appropriate acceptance criteria have been established.

5.3.3 It is recognized that beam assemblies that are tested without load will not deflect to the same extent as an identical assembly tested with load. As a result, tests conducted in accordance with the unloaded beam procedure are not intended to reflect the effects of crack formation, dislodgement of applied fire protection materials, and other factors that are influenced by the deflection of the assembly.

5.4 A separate procedure is specified for testing the fire-containment capability of a wall/bulkhead/partition, etc. Acceptance criteria include temperature rise of nonfire exposed surface, plus the ability of the wall to prohibit passage of flames or hot gases, or both.

5.5 In most cases, the structural assemblies that will be evaluated in accordance with these test methods will be located outdoors and subjected to varying weather conditions that are capable of adversely affecting the fire endurance of the assembly. A program of accelerated weathering followed by fire exposure is described to simulate such exposure.

CONTROL OF FIRE TEST

6. Fire Test Exposure Conditions

6.1 Expose the test specimen to heat flux and temperature conditions representative of total continuous engulfment in the luminous flame regime of a large free-burning fluid-hydrocarbon-fueled pool fire. See Appendix X1 for the rationale for selection of this condition. Essential conditions are specified in 6.2 and 6.3. Use calibration assemblies to demonstrate that the required heat flux and temperature levels are generated in the test facility.

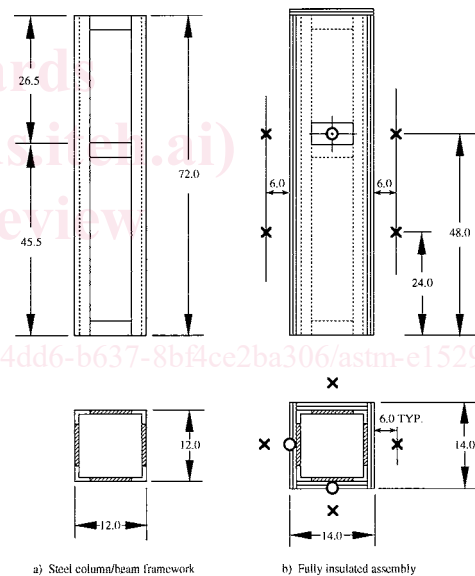
6.2 The test setup will provide an average total cold wall heat flux (6.2.1) on all exposed surfaces of the test specimen of 50 000 Btu/ft²·h ± 2500 Btu/ft²·h (158 kW/m² ± 8 kW/m²).

Adjust the flow of fuel and air, or vary other parameters, or both, within the individual test facility as necessary to achieve the specified setup. Attain the cold wall heat flux of 50 000 Btu/ft²·h within the first 5 min of test exposure; maintain it for the duration of the test. (See 7.1 through 7.3 for measurement and control details.)

6.2.1 In all cases in these test methods, the heat flux values cited are total cold wall heat fluxes.

6.3 The temperature of the environment that generates the heat flux specified in 6.2 shall be at least 1500°F (815°C) after the first 3 min of the test and shall be between 1850°F (1010°C) and 2150°F (1180°C) at all times after the first 5 min of the test. (See 9.1-9.4 for measurement and control details.)

6.4 Continue the fire-endurance test until the specified conditions of acceptance are exceeded or until the specimen has withstood the fire exposure for a period equal to that for which classification is being sought. Continue the test beyond the time at which the specified conditions of acceptance are exceeded when the purpose in doing so is to obtain additional performance data.



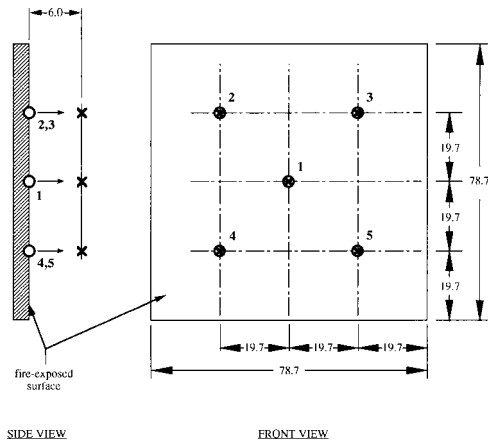
- NOTE 1—O represents total heat flux sensor; X a gas temperature sensor.
- NOTE 2—Heat flux measurements are required on two faces of the column.
- NOTE 3—Temperature measurements are required on all faces.
- NOTE 4—All dimensions are in inches.

FIG. 1 Calibration Assembly for Beams and Columns

7. Heat Flux Measurements

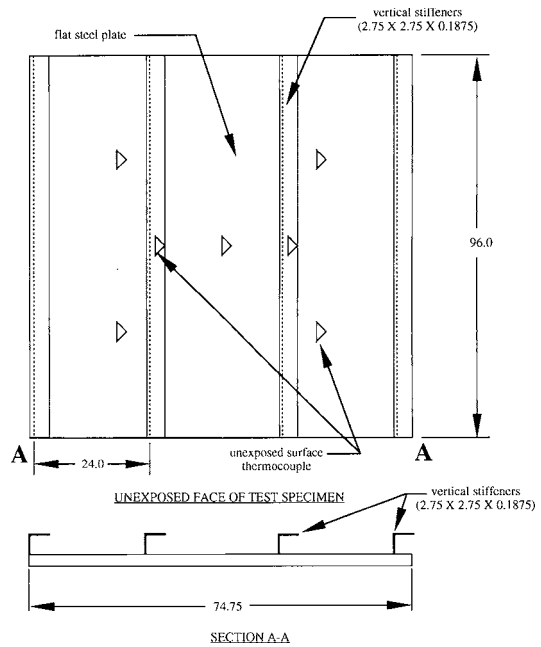
7.1 Measure the total heat flux as specified in 6.2 using a circular foil heat flux gage (often called a Gardon gage after the developer) as specified in Annex A1.

7.1.1 For columns or beams, the heat flux measurements will be made with a calibration assembly mounted in the appropriate orientation. The calibration assembly is to be



NOTE 1—O denotes site of heat flux measurement, X a gas temperature sensor.
 NOTE 2—Arrow denotes viewing direction of heat flux sensor.
 NOTE 3—All dimensions are in inches.

FIG. 2 Calibration Assembly for Fire-Containment Walls



NOTE 1—The overall dimensions shown are minimum. Increase as necessary to fit supporting frame into the wall of test furnace.
 NOTE 2—Except for steel plate thickness and thermocouple instrumentation, this specimen is intended to be identical to the steel bulkhead specified in IMO Resolution A.517(13). If IMO acceptance is desired, a second set of thermocouples may be required.

FIG. 3 Design of Steel Fire-Containment Wall Test Specimen

fabricated from noncombustible materials. The dimensions and instrumentation are shown in Fig. 1.⁷

7.1.2 For fire-containment walls, the heat flux measurements will be made with a calibration assembly with a minimum of 5 points as shown in Fig. 2.

7.1.3 All measurements made within 1 min (that is, recorded time ± 30 s) shall be considered as having been made at the same time.

7.2 At all times after the first 5 min of the test, the total heat flux shall be:

7.2.1 At any one point, between 37 500 and 62 500 Btu/ft²·h (118 to 197 kW/m²) (that is, 50 000 Btu/ft²·h ± 25 %).

7.2.2 For the average of the total number of measurement sites, between 47 500 and 52 500 Btu/ft²·h (50 000 Btu/ft²·h ± 5 %) (158 kW/m² ± 8 kW/m²).

8. Furnace Pressure Measurement

8.1 When testing any assembly that forms part of the wall of a test furnace (for example, walls, ceilings, floors, bulkheads, decks, doors, etc.), the furnace pressure shall be measured. The procedure is adapted from the differential pressure section of Test Method E 814.

8.2 Measure the gage pressure at three points 0.78 in. (20 mm) from the surface and located as follows:

8.2.1 *Vertical Surfaces*, at the center and quarter points on the vertical center line.

8.2.2 *Horizontal Surfaces*, at the center and quarter points on the longitudinal center line.

8.3 The pressure measuring probe tips shall be as shown in Fig. 3 of Test Method E 814; this design is shown in Fig. 4 of

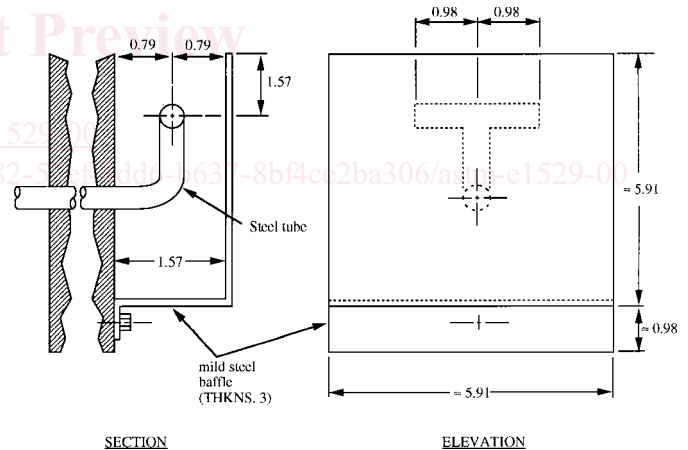


FIG. 4 Static Pressure-Measuring Device Dimensions in Millimetres

Test Method E 814. The probe tips are to be manufactured from stainless steel or other suitable material.

8.4 Measure the pressure by means of a manometer or equivalent transducer. The manometer or transducer shall be capable of reading 0.01 in. H₂O (2.5 Pa) increments with a measurement precision of 0.005 in. H₂O (12.5 Pa).

9. Gas Temperature Measurement

9.1 Measure the temperature of the gases adjacent to and impinging on the calibration or test specimens, as specified in

⁷ The calibration assembly design shown in Fig. 1 is similar to one developed by Underwriters Laboratories for their test method UL 1709 and is used with permission. This test method does not require the use of an exact duplicate of the Underwriters calibration assembly.

6.3, using factory manufactured 0.25-in. outside diameter (OD), inconel-sheathed, Type K, chromel-alumel thermocouples. The time constant, in air, of the thermocouple assemblies shall be less than 60 s. Use standard calibration thermocouples with an accuracy of $\pm 0.75\%$. A minimum length of 20 diameters (125 mm) of the sheathed junction end of the thermocouple shall be mounted parallel to the surface of the test specimen.

9.2 Obtain the gas temperature from the readings of not less than five thermocouples for a nonbearing wall specimen, and not less than eight thermocouples for a column or beam specimen. The thermocouples shall be symmetrically disposed and distributed to show the temperatures of the environment near all parts of the specimen.

9.2.1 For columns and beams, the thermocouple junction shall be placed 6 in. (152 mm) away from the exposed faces of the specimen at the beginning of the test, and during the test shall not touch the specimen as a result of specimen growth or deflection.

9.2.2 In the case of fire-containment walls, the thermocouple junctions shall be placed 6 in. (152 mm) away from the exposed face of the specimen at the beginning of the test, and shall not touch the specimen during the test as a result of specimen growth or deflection.

9.3 Measure the gas temperature at least once every 3 min at each required measurement site. Data shall be recorded within ± 30 s of the 3 min intervals to satisfy the minimum requirement.

9.4 At all times after the first 5 min of the test, the average gas temperature shall be between 1850°F (1010°C) and 2150°F (1180°C)

10. Test Facility Design

10.1 These test methods specify the environment to which a specimen shall be exposed, but does not specify test facility design. This approach was taken for several reasons:

10.1.1 It is consistent with the approach of Test Methods E 119,

10.1.2 It is important not to inhibit the creativity of experimenters in achieving the specified test environment, and

10.1.3 It is not desired to eliminate any existing facilities (or modification of them) or to eliminate the use of an actual fire *a priori*.

11. Calibration and Control of Furnace Type Test Facilities

11.1 If the test facility is of the furnace type, use the measurement and control procedures described in 11.2-11.6.

11.2 Calibration runs shall meet the following configurational and procedural criteria:

11.2.1 During all calibration runs, an instrumented calibration specimen shall be in place during the entire test. The calibration specimen shall be fabricated of noncombustible materials and shall be as follows:

11.2.1.1 For columns and beams, the box shape of Fig. 1, or its equivalent, oriented in the same position and inclination (for example, vertical or horizontal) as the subsequent materials test specimen would be.

11.2.1.2 For fire-containment wall specimens, the calibration specimen shall consist of 25 mm of ceramic insulating board⁸ facing the fire. The board shall be suitably supported in a frame, and if necessary, its backface (that is, nonfire-exposed surface) shall be insulated with inorganic blanket insulation such that the temperature of the backface of the entire (composite) specimen does not exceed the criteria of 19.6.2.

11.2.2 Instrument the calibration specimen to make measurements that are specified as follows:

11.2.2.1 *Total Heat Flux*—See 7.1 through 7.2.

11.2.2.2 *Gas Temperature*—See 9.1-9.3.

11.2.3 The time duration of the calibration run shall be:

11.2.3.1 At least as long as the longest subsequent materials test for which it shall apply, or

11.2.3.2 Until the test facility has reached a steady condition such that the average cold wall heat flux and the average gas temperature are within $\pm 5\%$ of the specified values over a continuous period of 15 min.

11.3 A successful calibration run shall meet the following criteria:

11.3.1 *For Total Heat Flux*—See 6.2 and Section 7.

11.3.2 *For Gas Temperature*—See 6.3 and Section 9a.

11.4 A furnace type facility shall be considered calibrated after an initial test that meets the requirements of 11.2 and 11.3.

11.5 After the initial calibration, recalibrate the test facility if any repair or modification is made to the heat generation, heat retention, flow or other characteristics of the furnace that is capable of affecting the initial calibration. Between calibrations, record any repairs, modifications, or maintenance made to the facility.

11.6 Once the test facility has been successfully calibrated, materials for testing shall be subjected to a fire environment simulated by reproducing the time-temperature curves recorded during the furnace calibration.

11.6.1 The accuracy of the furnace control shall be such that the area under the time-temperature curve of the average of the gas temperature measurements of 9.1-9.3 is within 10 % of the corresponding curve developed in the furnace calibration for tests of $\frac{1}{2}$ h or less duration, within 7.5 % for those over $\frac{1}{2}$ h and not more than 1 h, and within 5 % for tests exceeding 1 h in duration.

TEST CONFIGURATIONS

12. Test Specimen

12.1 The test specimen shall be representative of the construction for which classification is desired as to materials, workmanship, and details such as the dimensions of various components. Build the test specimen under conditions representative of those encountered in actual construction to the extent possible. Determine the physical properties of the materials and components used in the construction of the test specimen where possible.

⁸ Marinite XL, a registered trademark of Johns-Manville Co., Manville Corp., Product Information Center, P.O. Box 5108, Denver, CO 80217, has been found suitable for this purpose. It has the following thermal properties: density of 46 lb/ft³ (737 kg/m³), thermal conductivity (at 350°F (177°C)) of 0.89 Btu.in./h-ft² · °F (0.13 W/m²·K), and specific heat (at 200°F (93°C)) of 0.28 Btu/lb. °F (117 J/kg·K).

12.2 For fire-protected steel columns and beams, both the weight (w) and heated perimeter (d) of the steel member significantly influence fire endurance as determined in accordance with these test methods. Consideration of the w/d ratio is paramount when designing a test program in order to directly compare the performance of different fire protection materials applied to structural steel beams and columns. It is desirable to conduct tests on a common size member, such as a W10 by 49 (W250 by 73) column to accommodate ease of making relative comparisons of thermal performance.

12.3 For fire containment steel wall specimens, the thickness of the steel plate will influence fire endurance as determined by these test methods. When designing the test program, however, in order to directly compare the performance of different fire protection materials applied to steel wall specimens, tests shall be performed using a standard steel wall thickness of 0.18 ± 0.02 -in. (4.5 ± 0.5 -mm). The 0.18 ± 0.02 -in. thick specimen is specified by IMO Resolution A.517 (13) and as such, has had a large number of tests conducted on it.

13. Conditioning

13.1 Protect the test specimen during and after fabrication to ensure the quality of its condition at the time of test. The specimen shall not be tested until after its strength has at least attained its design strength.

13.2 If the test specimen contains moisture, solvents, plasticizers, curing compounds, or similar agents, condition the specimen prior to the test with the objective of providing a condition within the specimen which is representative of the intended end-use environment of the assembly. When accelerated drying techniques are used to achieve this objective, avoid drying procedures that will alter the structural or fire endurance characteristics of the test specimen from those produced as a result of air drying under ambient atmospheric conditions. Record the temperature and humidity of the test specimen at the time of the fire test. (See 13.4.)

13.3 For some assemblies, it is difficult or impossible to achieve the objective of 13.2 even after an excessively lengthy period of time. In the event that specimens, air dried in a heated building, fail to meet this objective after a 12-month conditioning period or in the event that the nature of the assembly is such that it is evident that drying of the specimen interior is prevented due to hermetic sealing, the requirements of 13.2 are waived. In such cases, test the specimen after its strength has at least attained its design strength. Record the temperature and humidity of the test specimen at the time of the fire test. (See 13.4.)

13.4 If the specimen contains moisture or solvents, measure the actual content of such agents within 72 h prior to the test. Obtain this information by weight determinations, moisture meters, or any other appropriate techniques deemed suitable by the testing laboratory. If the condition of the tested specimen is capable of significantly changing within 72 h preceding the test, the actual content of moisture, solvents, and similar agents shall be made within 24 h prior to the test.

14. Accelerated Weathering and Aging Tests

14.1 Test procedures are specified in 14.2-14.9 that represent a recommended minimum test program for evaluating the weatherability for fire protection materials and assemblies using accelerated weathering and aging tests. These tests are applicable for fire protection materials for structural steel. These tests may also be applicable to other materials and assemblies. This is left to those interested parties involved to determine. Further, because it is recognized that accelerated aging/weathering testing is an art and not a science, preconditioning tests prior to aging/weather exposure (for example, tensile stressing of brittle materials), additional exposure environments may be required for some fire protection materials for structural steel, and for other materials and assemblies, if the parties involved have a particular concern about a particular material or an assembly in a particular environmental exposure.

NOTE 1—By defining a specific test program for protection materials for structural steel, it is not to be construed that the fire protection properties of these materials are especially vulnerable to weathering effects. Rather, it is a reflection of the state of the art that such a test program exists for these materials.

14.2 For evaluation of a protective material, apply the material to 2-ft long, 6 by 6 in. steel tubes with a $\frac{3}{16}$ -in. wall thickness. Provide each end of each steel tube with steel caps covered with the protection material being investigated.

14.3 Locate four Type K thermocouples having a time constant not greater than 2 s on each steel tube. The thermocouples shall measure the temperature at the center of each face of the steel tube.

14.4 The protective material thickness shall be sufficient to provide an endurance time of approximately 70 ± 29 min in accordance with 16.5.

14.5 Prepare a minimum of seven samples. Expose at least six samples to the environments and use at least one sample as a control for comparison purposes. Expose a sample to only one environment before it is subjected to the fire endurance test.

14.6 The accelerated weathering or aging environments shall consist of:

14.6.1 *Accelerated Aging*—A circulating air oven maintained at $160 \pm 5^\circ\text{F}$ ($71 \pm 3^\circ\text{C}$) and the air circulated at a rate to change the air volume in the oven each 8 h. The exposure time shall be at least 6480 h (270 days).

14.6.2 *Accelerated Weathering Exposure*—A weatherometer in accordance with Practice D 822. The exposure time shall be at least 720 h (30 days).

14.6.2.1 Samples are mounted on a rotating drum within the weatherometer. Operation of the weatherometer requires samples to be balanced and the sample weight not exceed the limits of the equipment.

14.6.3 *Wet/Freeze/Thaw Exposure*—Twelve cycles of simulated rainfall at 0.7 in. (17.8 mm) per day for 72 h, followed by an immediate exposure to $-40 \pm 5^\circ\text{F}$ ($-40 \pm 3^\circ\text{C}$) for 24 h, and then an immediate exposure to $+140 \pm 5^\circ\text{F}$ ($+60 \pm 3^\circ\text{C}$) for 72 h.