Standard Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies[1]

This standard is issued under the fixed designation E1529; 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 E119, the only available standardized test for fire resistant construction. However, the exposure specified in Test Methods E119 does not adequately characterize large hydrocarbon pool fires. Test Methods E119 is used for representation of building fires where the primary fuel is solid in nature, and in which 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 E119. 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 is more representative of 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 provide for quantitative heat flux measurements during both the control calibration and the actual test. These heat flux measurements are being made to support the development of design fires and the use of fire safety engineering models to predict thermal exposure and material performance in a wide range of fire scenarios.

1.5 These test methods are useful for testing other items such as piping, electrical circuits in conduit, floors or decks, and cable trays. Testing of these types of items requires development of appropriate specimen details and end-point or failure criteria. Such failure criteria and test specimen descriptions are not provided in these test methods.

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

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

[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 Fire Resistance.

Current edition approved Nov. 1, 2016. Published December 2016. Originally approved in 1993. Last previous edition approved in 2014 as E1529 – 14a. DOI: 10.1520/E1529-16.

*A Summary of Changes section appears at the end of this standard

1.6.2 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.

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

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

1.6.5 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.

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

1.6.7 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.

1.7 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.

1.8 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.9 *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.*

1.10 *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.*

1.11 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:*[2]

B117 Practice for Operating Salt Spray (Fog) Apparatus

D822 Practice for Filtered Open-Flame Carbon-Arc Exposures of Paint and Related Coatings

E119 Test Methods for Fire Tests of Building Construction and Materials

E176 Terminology of Fire Standards

E457 Test Method for Measuring Heat-Transfer Rate Using a Thermal Capacitance (Slug) Calorimeter

E459 Test Method for Measuring Heat Transfer Rate Using a Thin-Skin Calorimeter

E511 Test Method for Measuring Heat Flux Using a Copper-Constantan Circular Foil, Heat-Flux Transducer

E814 Test Method for Fire Tests of Penetration Firestop Systems

E2683 Test Method for Measuring Heat Flux Using Flush-Mounted Insert Temperature-Gradient Gages

2.2 *Code of Federal Regulations:*[3]

46 CFR 164.007 Structural Insulations

2.3 *IMO Documents:*[4]

IMO A754

2.4 *ISO Standard:*[5]

ISO 834-1 Fire Resistance Tests – Elements of Building Construction – Part 1: General Requirements

2.5 *ISO/IEC Standards:*[6]

17011 Conformity assessment—General Requirements for accreditation bodies accrediting conformity assessment bodies

17025 General requirements for the competence of testing and calibration laboratories

3. Terminology

3.1 *Definitions*—Refer to Terminology E176 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/ft ^{2}·h ± 2500 Btu/ft^2·h (158 kW/m^2 ± 8 kW/m^2). 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, ¾ h, 1 h, 1½ h, etc.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

[4] Available from the International Maritime Organization (IMO), Environmental Standards Division (CG-5224), U.S. Coast Guard Headquarters, 2100 Second Street SW, Washington, DC 20593; http://www.uscg.mil/environmental_standards/

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[6] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

4.1.1 These test methods require quantitative measurements of thermal exposure during both furnace calibration and actual testing.

4.1.2 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. Quantitative measurements of the thermal exposure (total heat flux) are required during both furnace calibration and actual testing.

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 steel column specimens includes temperature limits. These limits are intended to define the temperature above which a steel column with an axially applied design allowable load would fail structurally.

5.2.3 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. Application of restraint against longitudinal thermal expansion depends on the intended use, as specified by the customer. 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.

5.6 These test methods provide for quantitative heat flux measurements to support the development of design fires and the use of fire safety engineering models to predict thermal exposure and material performance in a wide range of fire scenarios.

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, which describes measurements in intermediate to large scale pool fires with calorimeters of different sizes and shapes, for the rationale used in the selection of the temperatures and heat flux specifications. 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 After the first 5 min, 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/ft^2·h ± 2500 Btu/ft^2·h (158 kW/m^2 ± 8 kW/m^2). 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/ft^2·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.)