# UL 1709

## STANDARD FOR SAFETY

## Rapid Rise Fire Tests of Protection Materials for Structural Steel

UL Standard for Safety for Rapid Rise Fire Tests of Protection Materials for Structural Steel, UL 1709

Sixth Edition, Dated August 8, 2022

***Summary of Topics***

***This revision of ANSI/UL 1709 dated July 8, 2024 includes the following changes in requirements:***

> ***– Fire Test Procedures for Passive Fire Protection Systems for Critical Process Control Equipment (CPCE); Part 3, Section 18 – 24, and Annex C – Annex E***
>
> ***– Fire Resistance Rating Procedures for Hollow Section Column Tests with Reactive Materials; 8.5 – 8.7, 16.5A, Section A5***

Text that has been changed in any manner or impacted by ULSE's electronic publishing system is marked with a vertical line in the margin.

The requirements are substantially in accordance with Proposal(s) on this subject dated February 23, 2024 and May 17, 2024.

No Text on This Page

**AUGUST 8, 2022**
(Title Page Reprinted: July 8, 2024)

**ANSI/UL 1709-2024**



**UL 1709**

# Standard for Rapid Rise Fire Tests of Protection Materials for Structural Steel

First Edition – February, 1989
Second Edition – February, 1994
Third Edition – March, 2005
Fourth Edition – August, 2011
Fifth Edition – February, 2017

**Sixth Edition**

**August 8, 2022**

This ANSI/UL Standard for Safety consists of the Sixth Edition including revisions through July 8, 2024.

The most recent designation of ANSI/UL 1709 as an American National Standard (ANSI) occurred on July 8, 2024. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

Comments or proposals for revisions on any part of the Standard may be submitted to ULSE at any time. Proposals should be submitted via a Proposal Request in the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

No Text on This Page

## CONTENTS

# PART 1 – GENERAL REQUIREMENTS

## INTRODUCTION

### 1 Scope

1.1 This Standard describes a full-scale test method for measuring the thermal resistance of protective materials, systems, or constructions to rapid-temperature-rise fires.

1.2 Part 1 of this Standard describes the furnace calibration and furnace control requirements.

### 2 Units of Measurement

2.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

### 3 Referenced Publications

3.1 Any undated reference to a code or standard appearing in the requirements of this Standard shall be interpreted as referring to the latest edition of that code or standard.

3.2 The following publications are referenced in this Standard:

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

UL 263, *Fire Tests of Building Construction and Materials*

UL 2431, *Durability of Fire Resistive Coatings and Materials*

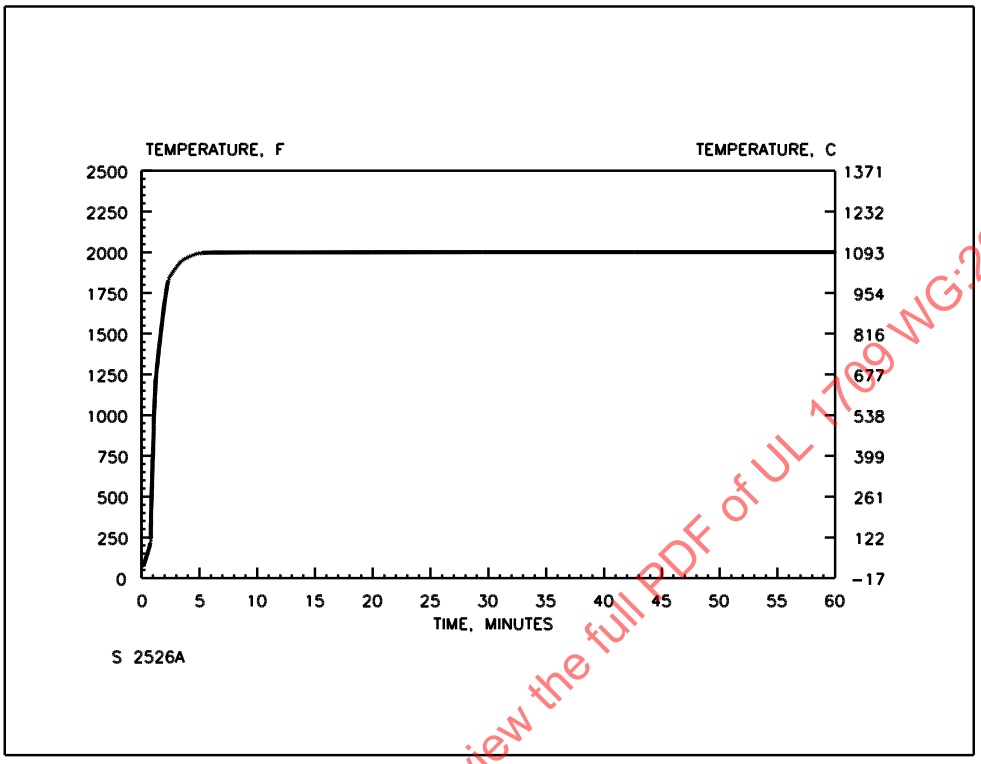
## FULL-SCALE TEST METHOD

### 4 Furnace Control

4.1 The fire environment within the furnace is to develop a total heat flux of 65,000 ±5000 Btu/h · $ft^2$ (204 ±16 kW/$m^2$) and an average temperature of 2000 ±100 °F (1093 ±56 °C) within 5 min from the start of the test. The fire environment is to be controlled by reproducing the furnace temperatures recorded during the furnace calibration method specified in the Furnace Calibration section of the relevant Part of this Standard. This temperature is to be maintained throughout the remainder of the fire test as shown in Figure 4.1.

**Figure 4.1**

**Time-Temperature Curve**




4.2 The furnace is to be controlled to maintain the area under the time-temperature curve to within 10 % of the corresponding area under the standard time-temperature curve shown in Figure 4.1 for fire tests of 60 min or less duration; to within 7.5 % for tests longer than 60 min but not longer than 120 min; and to within 5 % for tests exceeding 120 min in duration. The area under the time-temperature curve is to be obtained by averaging the results from the pyrometer or thermocouple readings.

4.3 A correction is to be applied for variation of the furnace exposure from the prescribed, where such variation will affect the test results, by multiplying the indicated time period by two-thirds of the value obtained by dividing the difference in area between the curve of average furnace temperature and the standard curve for the first three-fourths of the period by the area between the standard curve above a base line of 68 °F (20 °C) for the same part of the indicated period during the first part of the test. For fire exposure times longer than standard, the indicated rating period is to be increased by the amount of the correction and for fire exposure times less than standard, the indicated rating period is to be similarly decreased. The correction can be expressed by the following formula:

$$C = \frac{2I(A - A_S)}{3(A_S)}$$

In which:

*C* is the correction in the same units as *I*

*I* is the indicated fire-resistance period

*A* is the area under the curve of indicated average furnace temperature for the first three-fourths of the indicated period

$A_s$ is area under the standard furnace curve for the same part of the indicated period

4.4 The temperature fixed by the requirements of the Furnace Calibration section of the relevant Part of this Standard, is to be the average temperature obtained from the readings of eight thermocouples symmetrically disposed and distributed within the test furnace to show the temperature near all parts of the assembly or assemblies.

4.5 The thermocouples are to be fabricated by fusion-welding the twisted ends of 0.064 in (1.6 mm) diameter (No. 14 B & S gauge) chromel-alumel wires having a time constant of 2 min or less, and mounting the wires in porcelain insulators. The thermocouple assembly is to be inserted through a standard weight, nominal 1/2-in iron, steel or inconel pipe, and the end of the pipe from which the welded junction protrudes is to be open. The thermocouple junction is to protrude 1/2 in (12.7 mm) from the open end of the pipe.

4.6 The junction of the thermocouples is to be placed 4 in (102 mm) away from the exposed face of the test specimen and located at the 1/3 and 2/3 heights of the test specimen. The junction of the thermocouples is not to touch the specimen during the test, as a result of specimen deflection.

4.7 Each thermocouple within the furnace shall be read at intervals not exceeding 1 min during the first 30 min of the test and at intervals not exceeding 5 min during the remainder of the test.

## 5 Furnace Calibration

5.1 A furnace calibration record is to be maintained and the furnace is to be recalibrated after completion of any repair that could alter the heat generation, retention or flow characteristics of the furnace. The calibration shall be conducted at a frequency not to exceed 10 years.

5.2 The exposure of the furnace is to be measured with thermocouples and calorimeters as described by the relevant subsequent Part of this Standard.

5.3 The measured values of all thermocouples and calorimeters are to be recorded at intervals not exceeding 1 min.

5.4 The thermocouples used to measure the temperatures within the furnace are to be constructed as described in 4.5.

5.5 Calorimeters are to have a minimum range of 100,000 Btu/h · $ft^2$ (315 kW/$m^2$) and a 180° view angle

5.6 Combustion gas samples from within the furnace are to be obtained as described by the relevant subsequent Part of this Standard.

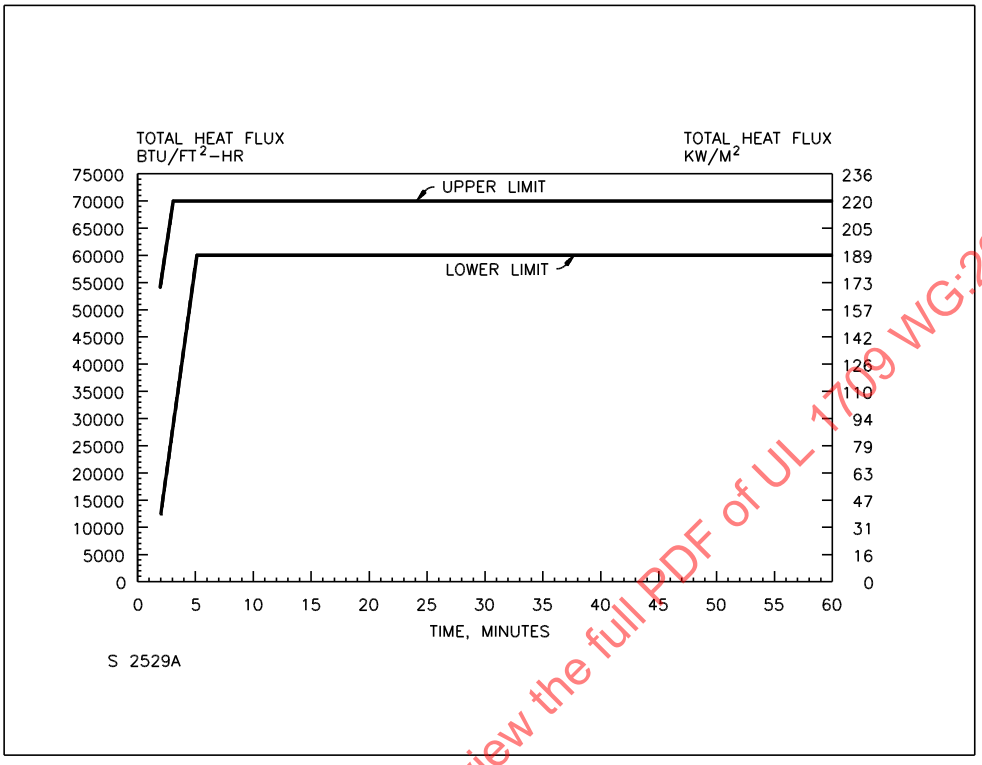
5.7 The combustion gas samples are to be obtained continuously by use of a vacuum pump and the oxygen content measured by an oxygen analyzer.

5.8 The fire environment during the calibration test is to comply with the requirements of 4.1. The length of the calibration test is to be 60 min.

5.9 Individual total heat flux measurements are to lie within the limits shown in Figure 5.1.

**Figure 5.1**

**Time-total Heat Flux Curve**




5.10 The average furnace temperature is to be determined by averaging the temperatures recorded by the furnace control thermocouples . The average shall be 2000 ±100 °F (1093 ±56 °C) and individual temperatures are to be 2000 ±200 °F (1093 ±111 °C) 5 min after the start of the test and until the end of the test.

## 6 Test Specimen

6.1 The size of the test specimen shall be representative of the design, materials, and workmanship for which classification is desired.

6.2 All thermocouples for the purpose of recording specimen temperature are to be fabricated from minimum 0.032 in (0.8 mm) diameter (No. 20 B & S gauge) chromel-alumel, inconel sheathed wires or equivalent having a time constant of 2 s or less.

# PART 2 – STRUCTURAL STEEL

## INTRODUCTION

## 7 General

7.1 Unless specifically stated otherwise, the requirements in Part 1 of this Standard are applicable.

7.2 Part 2 of this Standard covers additional procedures for use in conjunction with Part 1 of this Standard, intended to evaluate the thermal resistance of protective material applied to structural members and the ability of the protective material to withstand the fire exposure.

7.3 Part 2 of this Standard describes the minimum testing requirements for classification, the limits of applicability of test results and acceptable methodology to determine the classification achieved.

7.4 The test method includes a supplementary test method for beams, intended to evaluate the ability of protective materials to perform when subject to significant deflections, for use in conjunction with the full-scale exposure test and applicable for beams and other sections subject to bending. Information published in accordance with this test method may also include product design tables for beams and sections subject to bending derived from the supplementary test method and accompanying methodology.

7.5 Information published in accordance with this test method may also include product design tables for alternate limiting temperatures derived from a multi-temperature analysis. Such tables are provided to aid in conditions where a performance-based-design approach is implemented.

## 8 Glossary

8.1 For the purpose of the requirements in Part 2 of this Standard, the following definitions apply.

8.2 CONFIGURATION OF SECTION – The type of section, defined by reference to its shape and structural use. For example: open column, open beam, hollow column, hollow beam.

8.3 HOLLOW SECTION – A tube or pipe or similar shape that has a cross-section containing enclosed space.

8.4 OPEN SECTION – A wide flange or similar shape section that has a cross-section containing no enclosed space.

8.5 PASSIVE (Non-reactive) MATERIALS – Materials which do not change their physical form when exposed to high temperatures. Examples are gypsum board and Spray-Applied Fire Resistive Materials (SFRM), which passively insulate when exposed to high temperatures.

8.6 REACTIVE MATERIALS – Materials which undergo a chemical reaction and change their physical form when exposed to high temperatures. An example is Intumescent Fire-Resistive Materials (IFRM), which react, expand and insulate when exposed to high temperatures.

8.7 SECTION FACTOR – A ratio, such as W/D and A/P, that provides a means for sizing structural members for purposes of fire protection. The section factor is related to the slenderness or massiveness of the structural member and is indicative of the amount of heat energy that can enter the structural member and the rate at which it will heat up.

## 9 Terms of Abbreviation

9.1 For the purpose of the requirements in Part 2 of this Standard, the following terms of abbreviation are used.

*D* or *DFT* thickness of fire protection material (in)

$D_{min}$ minimum thickness of fire protective coating (in)

$D_{max}$ maximum thickness of fire protection coating (in)

$D_{mid}$ an intermediate thickness of fire protection coating lying within the mid third between $D_{min}$ and $D_{max}$ (in)

*t* the period or duration of classification (minutes)

*T* the temperature (°F or °C) used as the criteria in an engineering assessment (engineering analysis or study) intended to provide supplementary information to the classification

*W/D* where *W* is the weight of the open steel section per lineal foot and *D* is the perimeter of protection material at the interface between the open steel section and the protection material

*A/P* where *A* is the cross-sectional area of the hollow section and *P* is the perimeter of protection material at the interface between the hollow steel section and the protection material

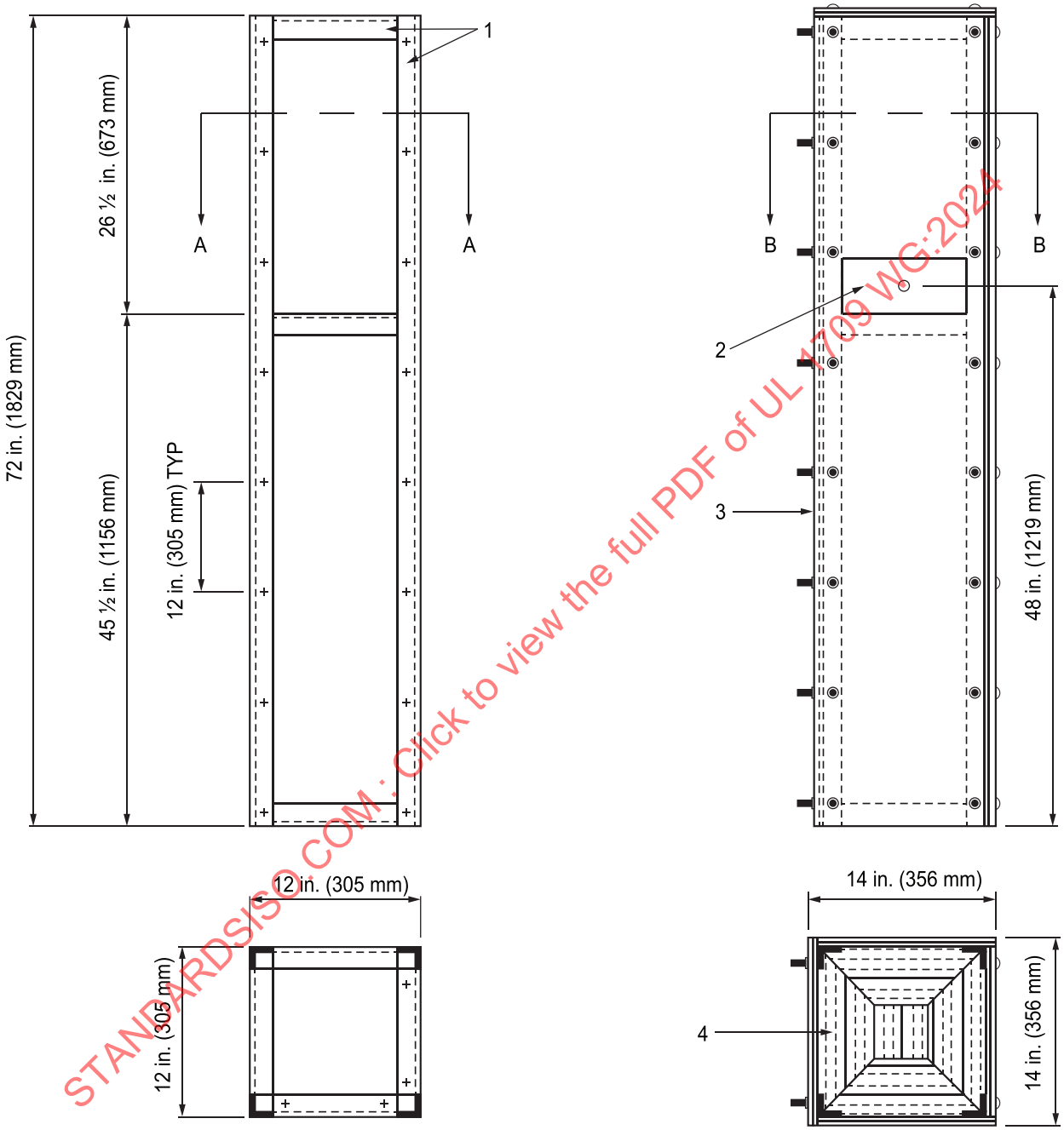
## FULL-SCALE TEST METHOD

### 10 Furnace Calibration

10.1 The exposure of the furnace is to be measured with thermocouples and calorimeters mounted within a nominal 14 by 14 in by 6 ft high (357 by 357 by 1829 mm) vertical calibration column centered within the furnace chamber. The calibration column is to be fabricated from noncombustible materials, constructed and instrumented as shown in Figure 10.1 and Figure 10.2.

**Figure 10.1**

**Calibration Column I**




su2293

**KEY**

1 2" x 2" x 3/16" (51 x 51 x 4.8 mm) steel angles welded to form framework

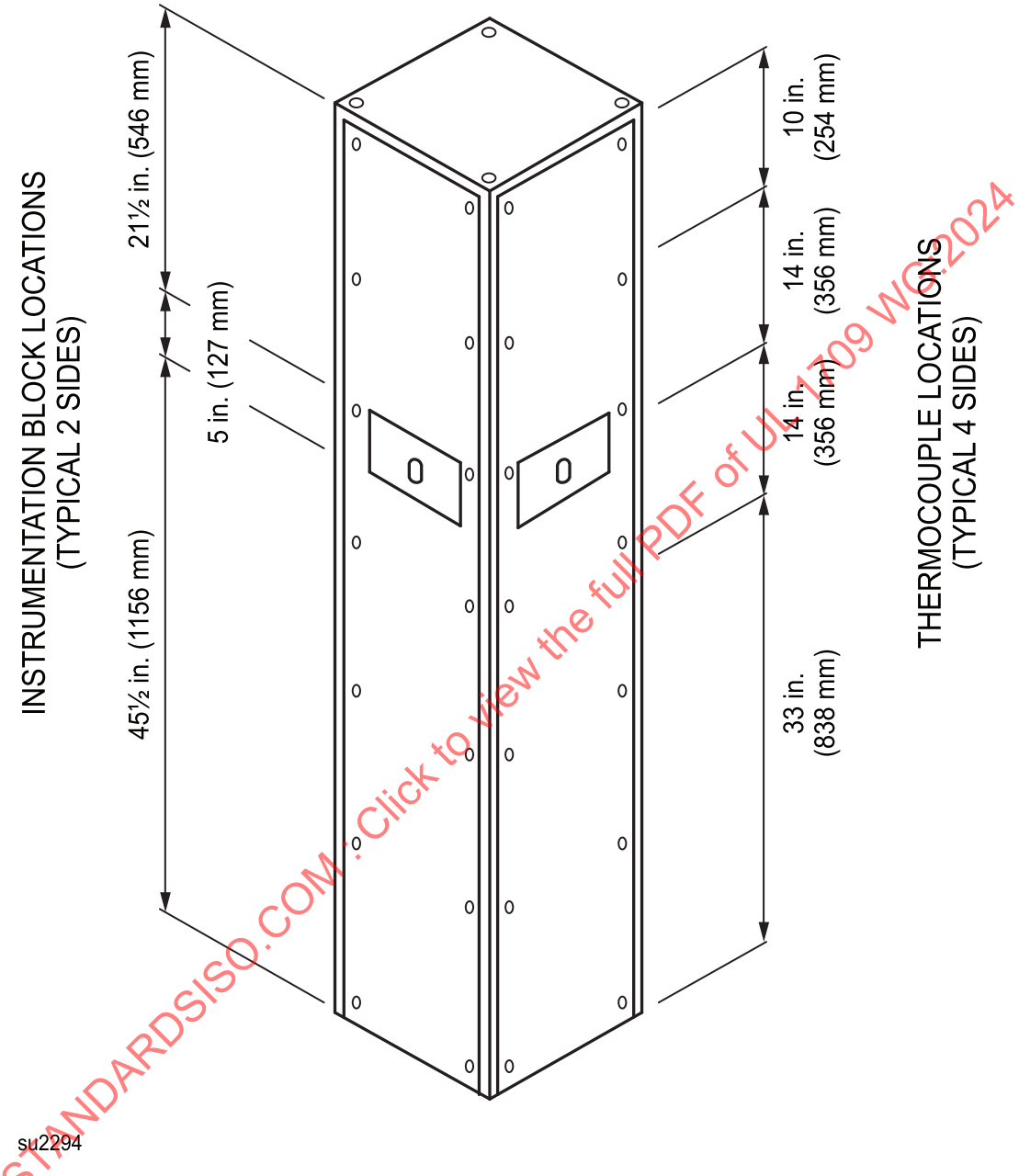
2 Instrumentation block (2 required)

3 Two layers of nom. 1.2" (13 mm) Marinite or equivalent inorganic insulation boards installed on four sides and top of calibration column, secured to framework with No. 1/4 – 20 steel bolts with nuts and 1-1/4 (32 mm) diameter steel washers

4 Entire cavity of calibration column filled with nom. 6 lb/ft$^3$ (3484 kg/m$^3$) density mineral wool batts

**Figure 10.2**

**Calibration Column II**



10.2 The temperature of the furnace is to be measured by eight thermocouples, each located 4 in (102 mm) from the exposed face of the calibration column and at the 1/3 and 2/3 heights.

10.3 The measured values of all thermocouples and calorimeters are to be recorded at intervals not exceeding 1 min.

10.4 The thermocouples used to measure the temperatures on the face of the calibration column are to be No. 28 gauge, Type K inconel sheathed thermocouples having a time constant of 0.5 s or less. The thermocouple junction is to be located 1/4 in (6.3 mm) from the face of the calibration column.

10.5 The thermocouples used to measure the temperatures within the furnace are to be constructed as described in Section 4, Furnace Control, in Part 1 of this Standard.

10.6 The calorimeters are to have a minimum range of 100,000 Btu/h · $ft^2$ (315 kW/$m^2$) and a 180° view angle.

10.7 Combustion gas samples from within the furnace are to be obtained from a probe of stainless steel tubing having an outer diameter not less than 3/16 in (4.7 mm) and a wall thickness not less than 1/32 in (0.8 mm). The probe tip is to be positioned vertically at the mid-height of the calibration column and horizontally located 4 in (102 mm) from the face of the calibration column.

10.8 The combustion gas samples are to be obtained continuously by use of a vacuum pump and the oxygen content measured by an oxygen analyzer.

10.9 The individual total heat flux measurements and average furnace temperature during the calibration test is to comply with conditions given in Part 1 of this Standard. The length of the calibration test is to be 60 min.

10.10 A record of the temperatures measured near the face of the column and the oxygen content are to be retained on file for a period of 10 years.

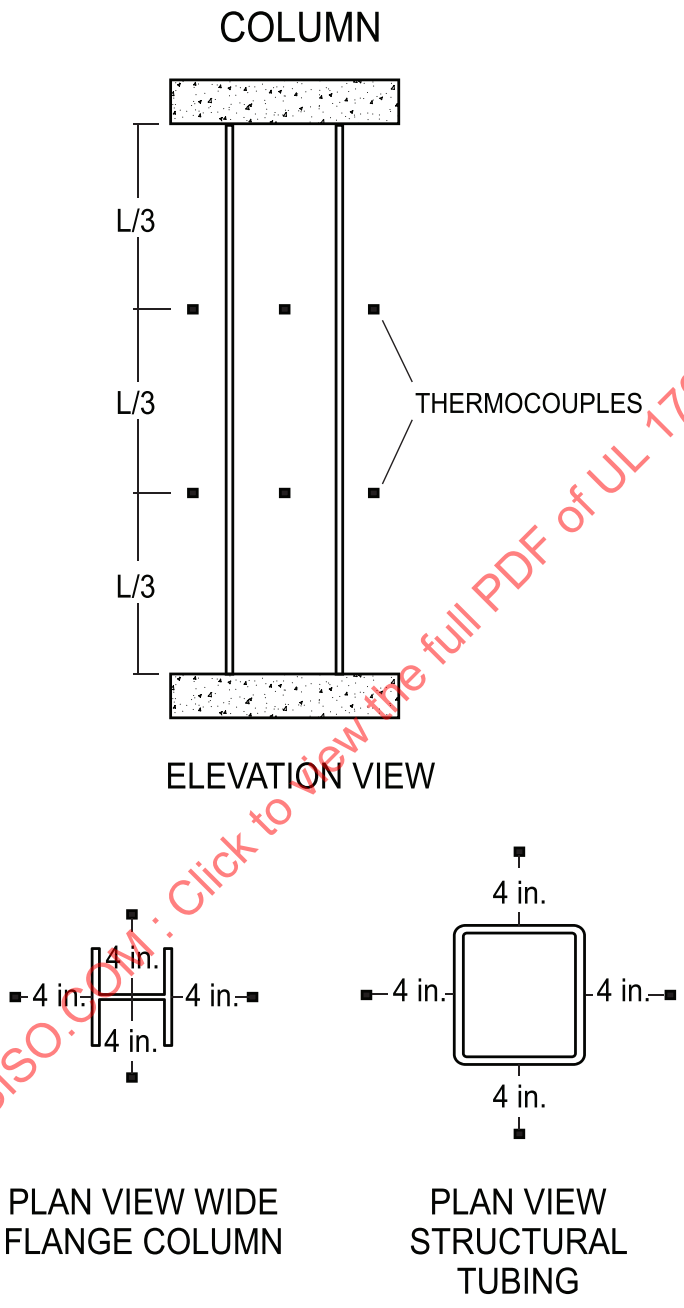
## 11 Furnace Control

11.1 Tests shall be conducted in accordance with Part 1 of this Standard.

11.2 The average furnace temperature is to be determined by averaging the temperatures recorded by the eight thermocouples placed 4 in (102 mm) from the column as shown in Figure 11.1. The average shall be 2000 ±100 °F (1093 ±56 °C) and individual temperatures are to be 2000 ±200 °F (1093 ±111 °C) 5 min after the start of the test and until the end of the test.

**Figure 11.1**

**Furnace Control Thermocouple Location – Column**



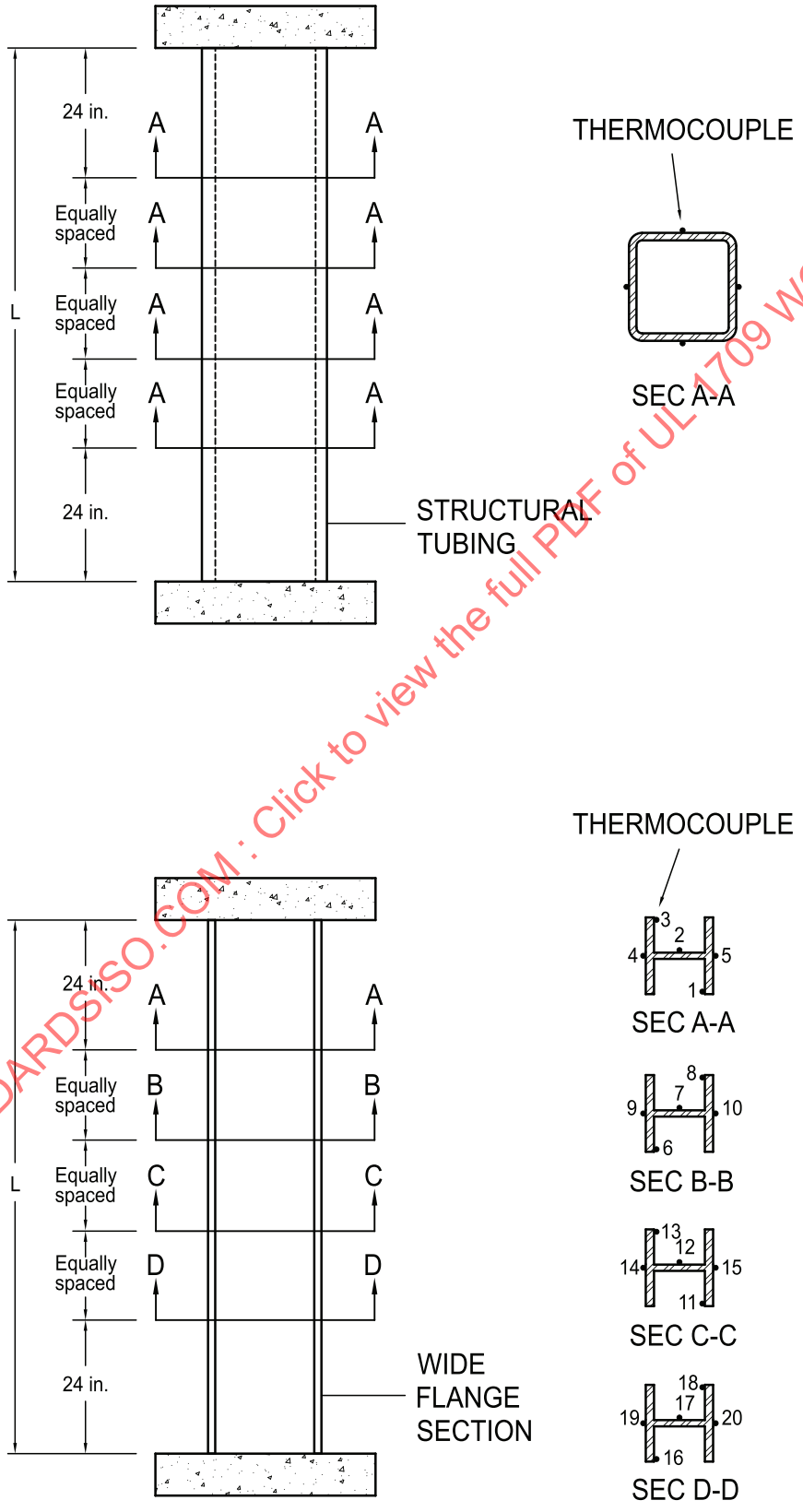
## 12 Test Specimen

12.1 The size of the steel section used in the test specimen shall be representative of the design, materials, and workmanship for which classification is desired. In cases where classification is required across a range of steel sizes and shapes the procedures in Annex A shall be followed, indicating the number of specimens required to be tested. Open sections (e.g. wide flange columns) and hollow sections (e.g. pipes, tubes) shall be considered separately for classification.

12.2 The protection material shall be applied to the steel specimen in accordance with acceptable field practice. The length of protected open or hollow steel column exposed to flame (L in Figure 12.1) shall be at least 8 ft (2.44 m). Steel columns are to be supported vertically during application of protection material and during fire exposure.

**Figure 12.1**

**Thermocouple Location Columns**




su2292

12.3 The temperature of the open steel column is to be measured by no fewer than five thermocouples located at each of four levels (minimum of 20 thermocouples). The upper and lower levels are to be 2 ft (610 mm) from the ends of the steel column, and the other two intermediate levels are to be equally spaced between the upper and lower levels. The thermocouples at each level are to be placed to measure significant temperatures of the component elements of the steel column. Figure 12.1 shows required locations of thermocouples on wide flange and tubular steel columns.

12.4 The temperature of the hollow steel column is to be measured by no fewer than four thermocouples located at each of four levels (minimum of 16 thermocouples). The upper and lower levels are to be 2 ft (610 mm) from the ends of the steel column, and the other two intermediate levels are to be equally spaced between the upper and lower levels. The thermocouples at each level are to be placed to measure significant temperatures of the component elements of the steel column. Figure 12.1 shows required locations of thermocouples on tubular steel columns.

12.5 The applied protection material is to be restrained against longitudinal thermal expansion greater than that of the steel column by attaching rigid steel plates or reinforced concrete to the ends of the steel column prior to application of the protection material. The plates or concrete are to be sized to provide direct bearing over the entire transverse area of the protection material.

12.6 The ends of the test sample, including the means for restraint, are to have sufficient thermal insulation to prevent significant direct heat transfer through to the ends of the steel section from the furnace.

12.7 Prior to test, the test specimen is to be conditioned such that the dampest portion of the test specimen has achieved a moisture content corresponding to drying to equilibrium with air in the range of 50 to 75 % relative humidity at 73 ±5 °F (22.8 ±2.8 °C). If the protection product requires a different moisture content to perform as intended, such moisture content may be allowed provided the moisture content and justification of acceptance are documented in the report, and the moisture content is included in the classification.

12.8 Moisture content equilibrium with air shall be determined to have been reached when successive weekly weighings of a representative specimen, prepared at the same time as the test specimen, indicate that the representative specimen has stopped losing weight.

## 13 Performance Criteria

13.1 The transmission of heat through the protection material during the period of fire exposure for which classification is desired shall not raise the average temperature at any of the four levels of the steel column above 1000 °F (538 °C) and no thermocouple shall indicate a temperature greater than 1200 °F (649 °C).

## 14 Report

14.1 The following shall be included in the test report:

a) Full details of the test specimens including surface preparation, anti-corrosive treatment or coating systems, any fixing methods and application methods appropriate to the protection material;

b) A generic description and accurate details of the fire protection system and any reinforcement, sealer coats, or retention methods present;

c) Description of the conditioning of the test specimens and their installation within the test furnace;

d) The measured dimensions of the fire protection system together;

e) If relevant, the load utilization along with the calculation method and standard used in the derivation of this value;

f) Individual furnace temperature measurements and the average of all individual furnace temperature measurements, taken as specified in Section 11, Furnace Control.

g) If relevant, measured longitudinal deformations, rates of deformation and the times at which they occur;

h) Observations made and times at which they occur; and

i) Individual temperature measurements and the average temperature of each measuring station.

## 15 Environmental Performance

15.1 Products evaluated for fire endurance under the requirements of this Part of the Standard shall also comply with the applicable performance requirements in UL 2431 for Material Classification Category I-A: Outdoor, Heavy Industrial.

## 16 Applicability of Results and Classification

16.1 An individual classification of an open or hollow column may be obtained by the tests described within this document and based upon the performance criteria specified in Section 13. The fire endurance classification is applicable to the type of construction representative of the design that the test is intended to examine.

16.2 Classification is applicable only to steel columns and only in the configuration (either open sections such as wide flange columns or hollow sections such as tubes and pipes) of the steel tested.

16.3 Supplementary product design tables for the same configuration of steel tested as a column can be generated for beams by following the procedure in Annex B, on the basis of the supplementary test procedure in Section 17, Additional Procedures for Beams.

16.4 Classification of multiple steel column sections, covering a range of *W/D* or *A/P* values, and durations may be accomplished by following the procedures outlined in Annex A, Sections A1, A2 and A3.

16.5 Classification is applicable to steel columns exposed on 4 sides, or less than all four sides. When the steel column is exposed on less than all four sides, the sides that are not exposed (and that cannot be coated by fire protection material) must be in direct contact with material of substantial heat sink such as concrete.

16.5A Ratings for hollow sections, covering both tubular and pipe sections, may be accomplished by following the procedures outlined in Annex A, Section A5.

16.6 Classification may be extended to sections of identical configuration with a value of *W/D* or *A/P* greater than that tested. The fire protection thickness *D* for the maximum *W/D* or *A/P* classified at the same duration shall be applied in these cases. Classification may not be extended to sections with a value of *W/D* or *A/P* lower than that tested.

## 17 Supplementary Test Method for Beams

### 17.1 Furnace control

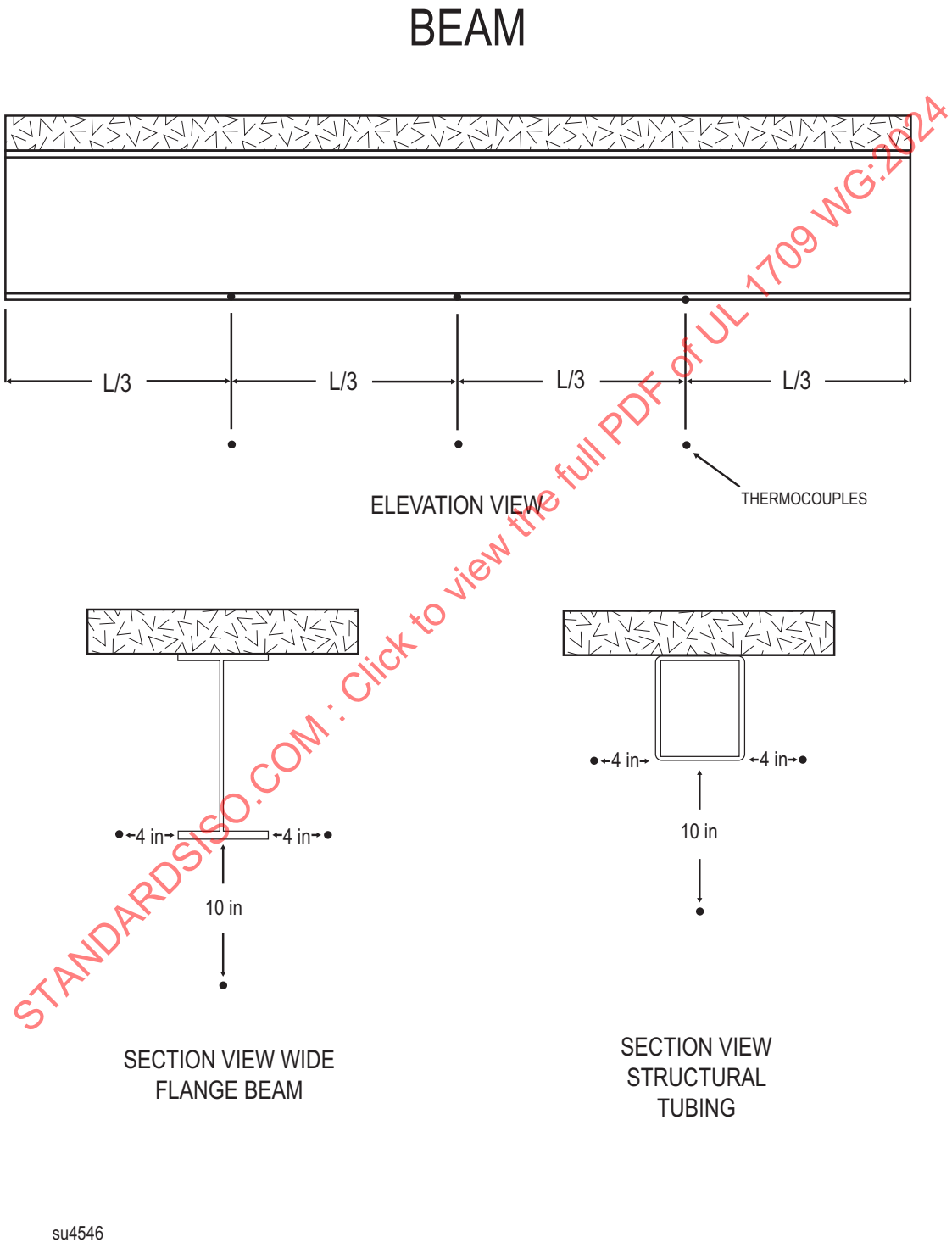
17.1.1 The supplementary test method results are used to generate supplementary product design tables for beams, and is not used to directly generate column classification. Comparative testing between a loaded and non-loaded beam is performed to establish the effect of deflection on the performance of the protection system, and to calculate a correction factor, which is applied as per Annex B.

17.1.2 The supplementary test method is not subject to calibration requirements as per the full-scale column exposure test. It is subject to furnace control requirements as specified in 17.1.3 and 4.2, 4.3 and 4.7 in Part 1 of this Standard.

17.1.3 The average furnace temperature is to be determined by averaging the temperatures recorded by the nine thermocouples placed 4 in (102 mm) away from the exposed face of the specimen at the beginning of the test, or 10 in (254 mm) away from the underside, as shown in Figure 17.1. The thermocouples shall not touch the specimen during the test as a result of specimen deflection. The average temperature shall be 2000 ±100 °F (1093 ±56 °C) and individual temperatures are to be 2000 ±200 °F (1093 ±111 °C) 5 min after the start of the test and until the end of the test.

**Figure 17.1**

**Furnace Control Thermocouple Location – Beam**



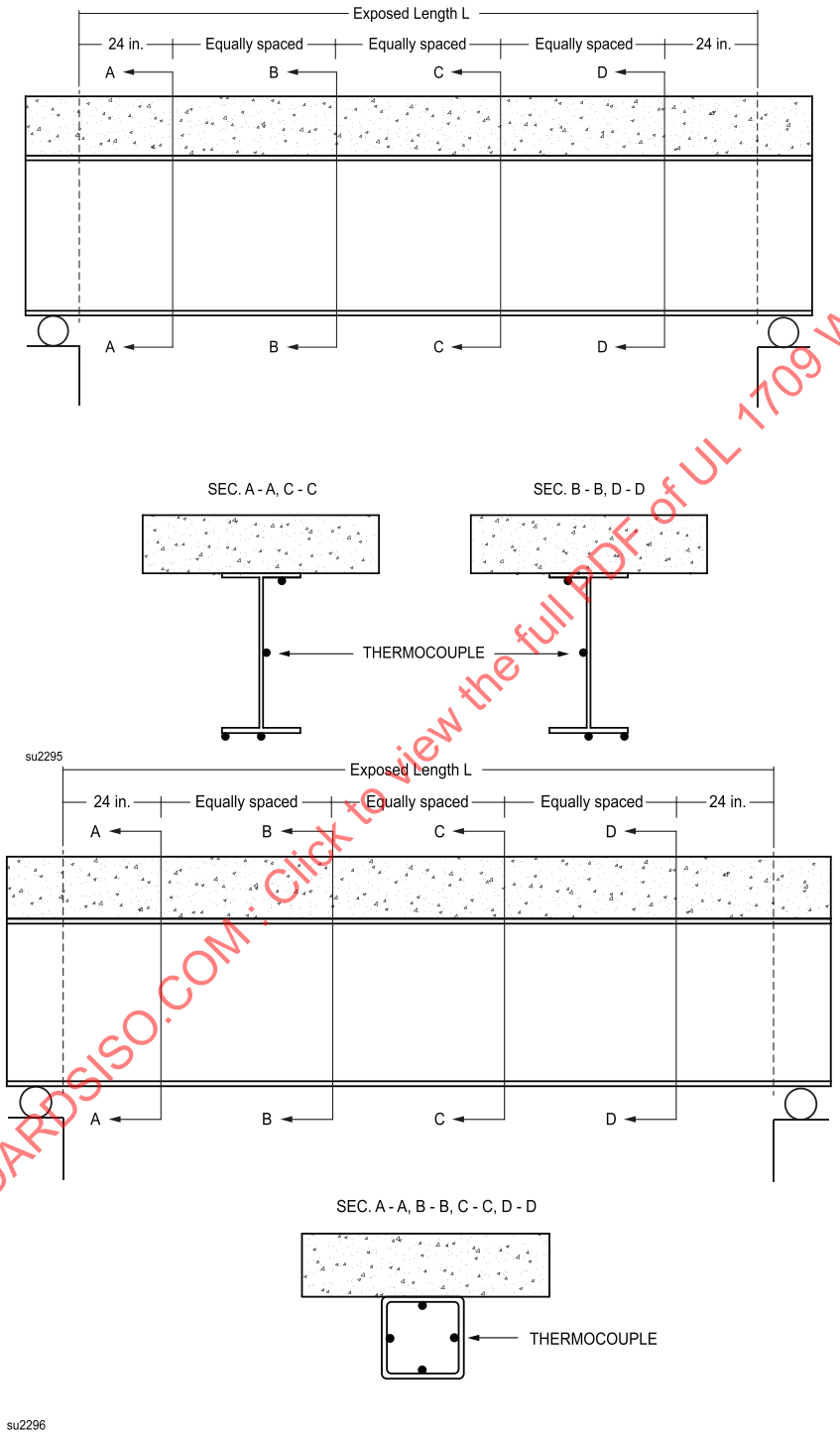
### 17.2 Test specimen

17.2.1 The protection material shall be applied to the steel beam specimen in accordance with acceptable field practice.

17.2.2 The length of the loaded open or hollow steel beams exposed to flame (L in Figure 17.2) shall be at least 12 ft (3.66 m).

**Figure 17.2**

**Thermocouple Location Beams**




17.2.3 An unloaded reference section shall be tested at the same time, positioned parallel with the loaded section.

17.2.4 The length of the unloaded reference section exposed to flame shall be at either 4 ft (1.22 m) or 12 ft (3.66 m).

17.2.5 The temperature of the loaded steel beam is to be measured by no fewer than four thermocouples located at each of four stations (minimum of 16 thermocouples). The end stations are to be 2 ft (610 mm) from the ends of the steel beam, and the two intermediate stations are to be equally spaced between the end stations. The thermocouples at each level are to be placed to measure significant temperatures of the component elements of the steel beam. Figure 17.2 shows required locations of the thermocouples on wide flange and tubular steel beams.

17.2.6 The temperature of the unloaded steel beam is to be measured by the same thermocouple arrangement as described in 17.2.5 in the case of 12 ft (3.66 m) beams, or no fewer than four thermocouples centrally located at one station in accordance with Figure 17.2 Sec A-A for 4 ft (1.22 m) beams.

17.2.7 All thermocouples for the purpose of recording specimen temperature are to be fabricated from minimum 0.032 in (0.8 mm) diameter (No. 20 B & S gauge) chromel-alumel, inconel sheathed wires or equivalent having a time constant of 2 s or less.

17.2.8 Concrete toppings for the loaded beam shall be made of normal weight concrete with a nominal density of 140 – 150 pcf (2240 – 2400 kg/m$^3$). The concrete slab shall be sized, fixed to the steel beam in a non-composite manner, and any gaps sealed, in a manner appropriate to laboratory practice. No insulation material is permitted between the concrete and the steel beam.

### 17.3 Performance criteria

17.3.1 Loaded beam tests shall be loaded prior to commencing the test. This load is to be the maximum load condition allowed under nationally recognized structural design criteria. This load shall be maintained until both of the following limits are exceeded:

a) A maximum total deflection of:

$$(L^2) / (400\,d)$$

b) And after the deflection limit has been exceeded, a maximum rate of deflection per minute as determined over one-minute intervals of:

$$(L^2) / (9000\,d)$$

Where:

$L$ = the clear span of the beam

$d$ = the distance between the extreme fiber of the beam in the compression zone and the extreme fiber of the beam in the tensile zone

17.3.2 With reference to 17.3.1, the units of deflection, $L$ and $d$ must be expressed in the same units such as inches or millimeters.

17.3.3 On exceeding both of the limits in 17.3.1, the load shall be removed or reduced.

17.3.4 Following reduction of the load, the test may still be continued if agreed with the sponsor for the purposes of calculating correction factors as per Annex B. The beam shall remain at a minimum deflection of ($L^2$) / (400 $d$) for the remainder of the test duration.

17.3.5 The duration (*t*) at which the assessed temperature (*T*) is reached shall be defined as the duration at which the average temperature at any of the beam stations equals *T*, or the duration at which any thermocouple equals 1.2*T*, whichever is reached first.

## PART 3 – FIRE TEST PROCEDURES FOR PASSIVE FIRE PROTECTION SYSTEMS FOR CRITICAL PROCESS CONTROL EQUIPMENT

### INTRODUCTION

### 18 General

18.1 Unless specifically stated otherwise, the requirements in Part 1 of this Standard are applicable.

18.2 Part 3 of this Standard specifies an additional test procedure for use in conjunction with Part 1 of this Standard, intended for determining the fire resistance of critical process control equipment (CPCE), with a passive fire protection (PFP) system installed, when exposed to hydrocarbon-pool type fire conditions.

18.3 Part 3 of this Standard is applicable to critical process control equipment intended for non-marine applications but suitable for offshore fixed and mobile installations.

18.4 The test data obtained, when used in conjunction with applicable fire test standards, permit subsequent classification of the CPCE elements based on the duration of their performance against specified criteria.

18.5 Part 3 of this Standard makes provision for two types of fire test: functional tests, which test the operation of the item during fire exposure, and non-functional tests, which characterize the temperature response of the item. If the failure criteria of the CPCE item is known, non-functional tests are appropriate. In the absence of known failure criteria, or when item response is not predictable, then functional tests should be undertaken.

### 19 Glossary

19.1 For the purpose of the requirements in Part 3 of this Standard, the following definitions apply

19.2 CRITICAL PROCESS CONTROL EQUIPMENT (CPCE) – Industrial equipment that performs a safety-critical function by actively changing a hydrocarbon processing routine. This can include valves, actuators, sensors, control panels, transducers, junction boxes, etc.

19.3 OPERABILITY – The ability of an item of process control equipment to perform its required function, either a change in state (opening or closing) or activating a change in state.

19.4 PASSIVE FIRE PROTECTION (PFP) SYSTEM or ASSEMBLY – An entire passive fire protection system, including insulation, mesh reinforcement, weather sealing fabric, and any joining or other retention system such as a frame.

19.5 SECTION FACTOR – A number representing the ratio of an object's surface area exposed to fire to thermal mass. It is approximately proportional to the rate of heating of an object.

## 20 Test Method

### 20.1 General

20.1.1 The furnace control shall be carried out in accordance with Part 1, Section 4, Furnace Control of this Standard, including the requirement to perform a calibration column as per Section 5, Furnace Calibration of this Standard.

20.1.2 Prior to starting the test, confirm that all thermocouples are functional. Note and record the initial condition of the test specimen.

20.1.3 At the time of the test, the initial average internal temperature and surface temperature of the specimen shall be from 50 °F to 95 °F (10 °C to 35 °C) and shall be within 10 °F (5 °C) of the initial furnace temperature.

### 20.2 General behavior

20.2.1 Observations shall be made of the general behavior of the specimen(s) during the course of the test and notes concerning the phenomena such as cracking, melting or softening of the materials, spalling or charring, etc., of materials of construction of the test specimen shall be made.

20.2.2 The success or failure of each operation cycle shall be noted for functional tests.

20.2.3 Photographs of the test specimen shall be taken as soon as is practicable after the fire has been extinguished. These shall be included in the test report.

### 20.3 Thermocouples

20.3.1 The type and number of thermocouples for operating the furnace shall meet the requirements of 4.4 and 4.5 of this Standard.

20.3.2 The temperature of steel specimens shall be measured by type-k thermocouples in accordance with 6.2 of this Standard.

20.3.3 When this thermocouple type is inappropriate, for example on non-steel surfaces, the temperature shall be measured by disc thermocouples of the type described in ISO 834-1 or by exposed wire thermocouples of the type described in 3.3.1 by UL 263.

20.3.4 Air temperatures in voids shall be measured by exposed wire thermocouples.

NOTE: Additional information on surface preparation for thermocouple installation is in Annex D.

## 21 Test Specimens

### 21.1 General

21.1.1 Multiple types of test specimens are permissible, as categorized within Table 21.1. Each test specimen shall be identified as belonging to a category as stated below and shall comply with the requirements in the relevant clauses, as stated in the table.

**Table 21.1**
**Categories of Test Specimen**

| Category of test specimen | Description | Test type applicability |
|---|---|---|
| Functional specimen | An item of CPCE, operated during the fire test at a regular interval | Functional (see note) |
| Non-functional specimen | An item of CPCE, inoperative during the fire test | Non-functional |
| Characteristic specimen | A dummy specimen of equivalent size and section factor to an item of CPCE | Non-functional |
| NOTE: Functional tests can also be used to generate temperature data as per non-functional tests. | | |

21.1.2 Mounted protective systems shall be installed ensuring at least one joint type is present.

21.1.3 Corner joints, butt joints and overlap joints shall be considered as separate joint types and tested individually.

21.1.4 The type, design and orientation of joints and fittings used to secure the protection system shall be representative of the joint and fittings representative of actual field installations in accordance with the manufacturer's instructions.

21.1.5 Where the product has more than one type of installation, each installation type shall be tested separately.

NOTE 1: Additional information on joint and installation type is given in Annex E.

NOTE 2: Multiple joint types are allowed in a single test, subject to approval of the authority having jurisdiction.

21.1.6 Penetrations of the PFP system, such as ducts, control cables, drain plugs, ventilation grilles, etc., or integrated features critical to the fire-resistance of the CPCE, such as doors, control panels, etc., shall be included in the testing and shall be representative of the actual features for which classification is sought.

21.1.7 Penetrations of the PFP system for the use of instrumentation not present in practice (e.g. thermocouples) shall be designed and insulated so as to prevent heat transfer at a level above the surrounding PFP system. The cross-sectional area of additional insulation shall be no greater than the minimum required, and the penetrations shall not be located in the vicinity of critical (temperature sensitive) areas.

21.1.8 Air gaps present shall be measured and recorded on the test report, and form part of the overall system.

21.1.9 Functional specimens and non-functional specimens may consist of connected items of CPCE tested in combination, for example a valve and actuator. These shall represent a single test specimen, however, the instrumentation requirements described in 21.2.4 and 21.3.2 shall apply individually to all items for which insulation is evaluated.

## 21.2 Construction

21.2.1 Functional and non-functional test specimens shall be representative of the actual item (or connected items) of CPCE as intended in actual field installation, including the PFP system, its method of application, retention method, frame, joint design, and any penetrations present.

21.2.2 Functional specimens with a mechanical action shall have a suitable limit switch capable of confirming the correct operation of the item. The limit switch shall be connected to visual indicators at the control station to confirm the state of the item throughout the test.

21.2.3 A characteristic specimen is one that allows the PFP system to be fabricated and installed onto it in a manner representative of that on a specific CPCE item, without the use of the specific item. Characteristic specimens shall be fabricated from steel and shall have a section factor equal to or higher than the specific CPCE item they are representative of.

NOTE: Only certain types of CPCE are compatible with characteristic specimens, for example items predominantly made of steel.

21.2.4 Characteristic specimens shall consist of boxes and pipe sections, or a combination of the two, to match the scope of classification desired. Characteristic specimens shall be fully closed, permitting no gas entry or exit during test, and shall contain only air during fire tests.

21.2.5 The PFP system design, including the retention method, frame, joint design, application method, density, and any penetrations present, shall be representative of that installed on the actual item.

21.2.6 Fluid-carrying CPCE items (functional and non-functional test specimens) or specimens representative of fluid-carrying items (characteristic test specimens) tested in isolation or in combination with other protected items of CPCE shall be tested in the dry state. No benefit may be taken for the thermal mass of any liquid typically present.

21.2.7 Fluid-carrying CPCE items (functional and non-functional test specimens) or specimens representative of fluid-carrying items (characteristic test specimens) installed directly into pipelines shall either terminate at the flanges of the CPCE item or be attached to flanged sections of pipeline that extend 12 inches (300 mm) beyond the extents of the PFP system.

21.2.8 Specimens without attachment to a pipe section shall provide for continuation of the PFP system over the flanged areas of the CPCE item.

21.2.9 Specimens with attachment to a pipe section shall provide for an additional 12 inches (300 mm) of protection along the pipe section, representative of the actual design for minimizing secondary conduction.

21.2.10 The ends of the pipe system shall be protected with an insulation material intended to match the approximate intended performance of the PFP system.

## 21.3 Instrumentation

### 21.3.1 Instrumentation of functional specimens for operability

21.3.1.1 Thermocouples are optional if evaluating only for operability. Use of thermocouples is recommended to provide additional information on the performance of the item of CPCE, however the data is not used to determine acceptability.

### 21.3.2 Instrumentation of functional and non-functional specimens for insulation

21.3.2.1 The test specimen shall be provided with a minimum of six thermocouples.

21.3.2.2 A minimum of four thermocouples shall be positioned on the body of the test specimen, one in each location of importance. For example, the gear case, the terminal cover, the electronics cover, the top of the specimen, the area of control cable connection etc.

NOTE: The number and variety of CPCE items available to test, in isolation or in combination, make it impossible to prescribe thermocouple positions for all types of items. If the locations of importance are unknown the equipment manufacturer shall be consulted to identify locations vulnerable to heat input or critical to the operation of the item.

21.3.2.3 Functional test specimens with critical components that may be temperature sensitive (such as actuators) shall also have a minimum of three thermocouples positioned within the body of the test specimen, one in each location of importance, for example: gear-workings, motors, items that generate heat, thermal cut-outs, etc.

21.3.2.4 Test specimens with cylindrical sections shall have a minimum of 2 additional thermocouples on the cylinder, one on the top and one on the end.

21.3.2.5 Test specimens with mounted PFP systems and air gaps shall have a minimum of two additional thermocouples at positions of contact between the frame and the body of the test specimen.

21.3.2.6 Test specimens with air gaps may have additional thermocouples on the inside surface of the PFP for the purpose of obtaining additional information to inform modelling, however these thermocouples shall not be included in the temperature rise calculation.

21.3.2.7 A minimum of two thermocouples shall be placed on the body of the test specimen underneath the location of each joint.

21.3.2.8 If the requirements of 21.3.2.2 – 21.3.2.7 total less than six thermocouples, additional thermocouples shall be placed in locations determined by the test laboratory. Additional thermocouples may be installed at the discretion of the test laboratory, test sponsor or authority having jurisdiction at locations that represent a vulnerable or critical location on the CPCE item.

**21.3.3 Instrumentation for characteristic test specimens**

21.3.3.1 A minimum of six thermocouples shall be positioned on the body of the test specimen, including at the top, bottom and sides.

21.3.3.2 Test specimens with cylindrical sections shall have a minimum of two thermocouples on the cylinder, one on the top and one on the end.

21.3.3.3 Test specimens with mounted PFP systems and air gaps shall have a minimum of two additional thermocouples at positions of contact between the frame and the body of the test specimen.

21.3.3.4 Test specimens with air gaps may have additional thermocouples on the inside surface of the PFP for the purpose of obtaining additional information to inform modelling, however these thermocouples shall not be included in the temperature rise calculation.

21.3.3.5 A minimum of two thermocouples shall be placed on the body of the test specimen underneath the location of each joint.

21.3.3.6 If the requirements in 21.3.3.2 – 21.3.3.5 total less than six thermocouples, additional thermocouples shall be placed in locations determined by the test laboratory. Additional thermocouples may be installed at the discretion of the test laboratory or authority having jurisdiction at locations that represent a vulnerable or critical location on the CPCE item.

**21.4 Furnace mounting**

21.4.1 The test specimen shall be mounted on supports a minimum of 20 inches (0.5 m) above the furnace floor, in a manner designed to maximize the surface area of the specimen exposed to fire.

Supports may either support the PFP system directly, or they may penetrate the PFP system and support the CPCE item directly.

21.4.2 When the supports penetrate the PFP system they shall be constructed of steel and designed to minimize secondary conduction either into or out of the CPCE item.

NOTE: Minimization of secondary conduction to/from supports may be achieved by designing supports to have an equivalent W/D (section factor) to the CPCE item and insulating the supports with an insulation system intended to have equivalent performance to that of the primary PFP material.

### 21.5 Operation of functional specimens

21.5.1 Electrical, hydraulic, or pneumatic connection(s) external to the PFP system required to operate the CPCE item during the test shall be designed by the test laboratory, in conjunction with guidance from the component suppliers, to operate for the required duration of the test.

NOTE: This procedure is a test of the PFP system used to protect a CPCE item or assembly to ensure its correct function. Fire performance of ancillary equipment such as hydraulic lines and electrical cables external to the PFP are outside the scope of this method, and it is permissible to use additional insulation to ensure function of connection lines/cables throughout the duration of the test.

21.5.2 Operation of the CPCE items shall be performed at an interval not exceeding 300 seconds, measured between the start of each operation.

### 21.6 Conditioning

21.6.1 The test specimen shall be protected against adverse environmental conditions until the time of the test.

### 21.7 Design

21.7.1 Prior to the test, all necessary information for each of the materials used in the construction of the test specimen shall be submitted to the laboratory by the test sponsor.

### 21.8 Description

21.8.1 The test sponsor shall provide full construction details of the test specimen in the form of drawings (including a detailed schedule of components) and method of assembly, to confirm agreement between the actual specimen and the drawings and specifications prior to the test.

21.8.2 The drawings shall include dimensions and details of the thicknesses of insulation used, the method of securing or applying the insulation system and details of the components used for this purpose, details of joints, detail of fittings, connections, air gaps and all other details.

### 21.9 Examination of the test specimen

21.9.1 The test specimen shall be verified with the drawings and method of assembly provided.

21.9.2 Any area of discrepancy shall be resolved prior to commencement of the test.

21.9.3 Occasionally, it may not be possible to verify the conformity of all aspects of the specimen construction prior to the test and adequate evidence may not be available after the test. When it is necessary to rely on information provided then this shall be clearly stated in the test report.

21.9.4 The design of the test specimen and the construction details shall be accurately recorded in the test report.

21.9.5 Photographs of the test specimen shall be taken before the test.

## 22 Passive Fire Protection Systems

### 22.1 General

22.1.1 The surface of the test specimen shall be prepared, and the fire protection system applied, in a manner representative of practice.

22.1.2 The protection material shall be installed or applied to protect the entirety of the test specimen. Thickness should be measured at various locations and locations with different thicknesses of installed material should be noted.

### 22.2 Test report

22.2.1 The test report shall include the following information as a minimum. A clear distinction shall be made between the data provided by the sponsor and the data determined by the test:

a) Reference that the test was carried out in accordance with this document;

b) Any deviations from the test method;

c) Name and address of the testing laboratory;

d) Date and identification number of the report;

e) Name and address of the sponsor;

f) Name and/or identification of the product tested;

g) Name of the manufacturer of the test specimen and of the products and components used in the construction;

h) The category of the test specimen as described in Table 21.1, e.g. functional specimen, etc.;

i) Constructional details of the test specimen, clearly distinguishing between the CPCE and PFP, including description and drawing and principal details of components, with product names and model numbers (if applicable) stated for all components and constituent materials. The description and the drawings which are included in the test report shall, as far as practicable, be based on information derived from a survey of the test specimen. When full and detailed drawings are not included in the report, then the applicant's drawing(s) of the test specimen shall be authenticated by the laboratory and at least one copy of the authenticated drawing(s) shall be retained by the laboratory; in the case reference to the applicant's drawing(s) shall be given in the report together with a statement indicating the method of endorsing the drawing.;

j) Photographs of the test specimen;

k) All properties of materials used that have a bearing on the fire performance of the test specimen together with the means of application or installation, measurements of thickness, density and, where applicable, the moisture and/or organic content of the insulation material(s) as determined by the test laboratory;

l) Date of the test specimen arrival;

m) Details of specimen conditioning prior to test;

n) Date of test;

o) Test results:

1) Information concerning the location of all thermocouples fixed to the specimen, together with tabulated data obtained from each thermocouple during the test. Additionally, a graphical depiction of the data obtained may be included. A drawing shall be included which clearly illustrates the positions of the various thermocouples and identifies them relative to the temperature-time data;

2) The temperature rise of individual thermocouples reported at an appropriate time interval;

3) The operability of the specimen, if applicable, at the recorded time interval;

4) The classification attained by the test specimen, in terms of the duration achieved for a given performance criteria (refer to Section 23, Performance Criteria).

## 23 Performance Criteria

### 23.1 Operability

23.1.1 The successful completion of an operation cycle, or the continuity of signal if applicable, determines the continued operability of a functional test specimen. A cycle shall not be considered a demonstration of performance if failure of operation occurs during the cycle.

### 23.2 Specimen temperature

23.2.1 The time temperature profile at each measurement position on the body of the test specimen shall be used to determine the maximum temperature rise across the specimen during the test.

23.2.2 The position and time of any significant increase in the rate of temperature rise, if any, shall be recorded as it is indicative of possible failure of the coating/system/assembly at that point.

23.2.3 The localized maximum temperature rise shall be reported in conjunction with the nearest fire protection material thickness for coatings type systems.

### 23.3 Integrity of systems and assemblies

23.3.1 The penetration of flames or hot gases through any cracks, holes or breaches in joints shall be considered when assessing the integrity of a system.

23.3.2 Particularly for flexible systems (e.g., fiber-based materials), the condition of the method of fixing (straps, etc.) is also important.

23.3.3 The amount of penetration and condition of the method of fixing may be evaluated in terms of:

a) Evidence of passage of flames through the system with the fixing system ineffective;

b) Evidence of passage of hot gases/smoke through the system with the fixing system effective; and

c) No passage of hot gases through the system and with the fixing system effective.

23.3.4 If the temperature criterion is met, then a specimen meeting criterion 23.3.3(c) clearly provides a wider safety margin than a specimen meeting criterion 23.3.3(a). A statement of the criterion that is most appropriate shall be included in the report.

NOTE: The reported information is intended to assist specifiers in drawing awareness that products which meet a particular temperature rating (e.g. "X" degrees C for "Y" minutes) may do so comfortably or may be on the verge of failure when they meet a desired rating.

## 24 Factors Affecting the Validity of the Test

### 24.1 Interruption of the test

24.1.1 It is likely that in some tests a control or instrumentation failure will result in an interruption. Restarting the test shall not be permitted.

NOTE: In the event of unintentional interruption occurring within the first 2 minutes of the test (e.g., failure to light all burners), the test may be restarted, commencing at a time of 0.

### 24.2 Failure of thermocouples

24.2.1 Up to one thermocouple may fail prior to a test after application or fitting of the protection material and the specimen shall be allowed.

24.2.2 During fire testing, a maximum of two thermocouples may fail (including any thermocouples that failed prior to the test) and the specimen shall still be considered valid for the purpose of obtaining temperature rise data.

NOTE: If one of the two failing thermocouples is over a critical area, and no other information is available (i.e. visual observation, temperature reading from a nearby thermocouple, etc.), further consideration may need to be given to the validity of the test.

24.2.3 Failure of thermocouples shall not prevent functional specimens from being tested for operability.

### 24.3 Failure of functional specimen control system

24.3.1 Failure of the control system of functional specimens preventing operation shall not prevent functional specimens from being tested for the purpose of obtaining temperature rise data.

# ANNEX A (Normative) – CLASSIFICATION PROCEDURES

## A1 Multi-Section Classification

A1.1 Where classification is required over a range of *W/D* for one duration then a minimum of 3 sections shall be tested if $D_{max} \leq 3.0\ D_{min}$, or 4 sections if $D_{max} > 3.0\ D_{min}$. This shall include $D_{min}$, $D_{max}$ and one or two varying intermediate thicknesses.

A1.2 All elements tested shall achieve within 10 % of the required classification time (*t*) for the temperature (*T*), and at least 50 % shall achieve a time greater than *t*. When *T* is other than as required in Section 13, the assessment shall be for the purpose of supplementary information to the classification.

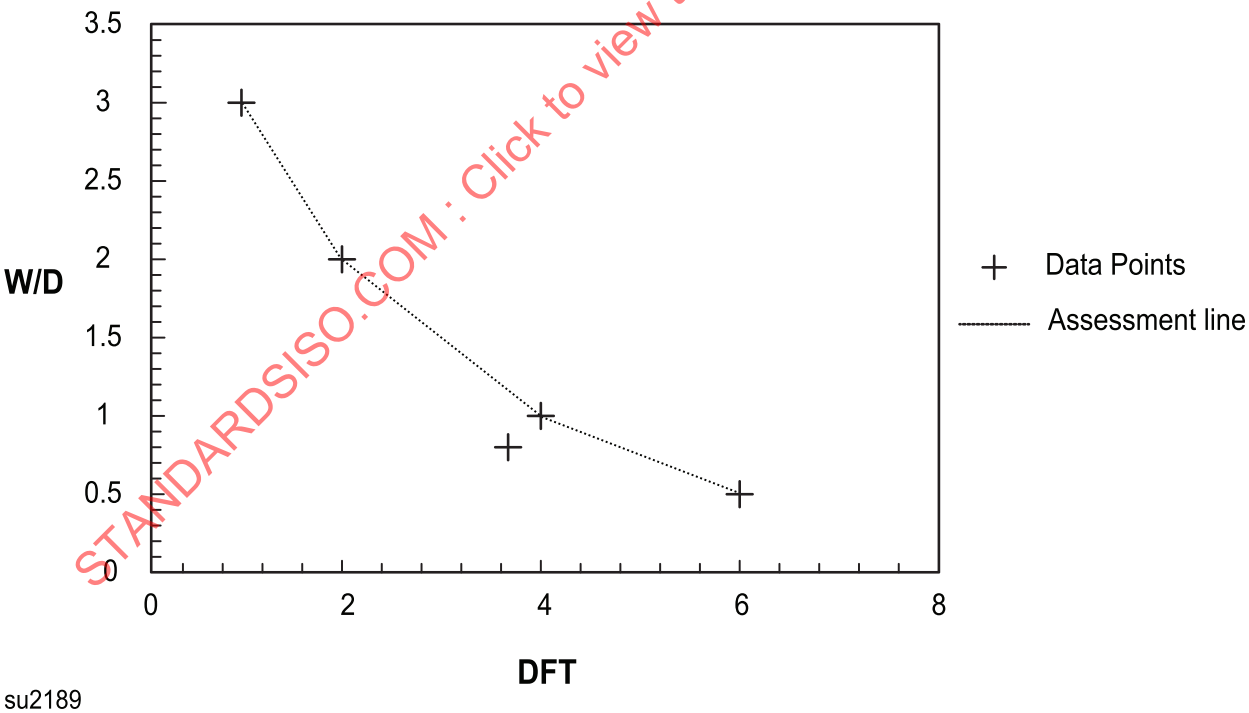
A1.3 All elements shall have the *DFT* for assessment corrected based on the performance compared to the required classification time (*t*) using the following equation:

$$D_{corrected} = D * (t / t_{actual})$$

A1.4 The data shall be plotted on a graph of *W/D* (y axis) against *D* (x axis) and interpolated through simple point to point line construction. Where there are two points of the same *W/D* the most conservative point shall be used. As *W/D* decreases the *DFT* shall increase. Points which do not meet this requirement shall be omitted (e.g. the data point at *W/D* of 0.8 in Figure A1.1).

**Figure A1.1**

**Example Assessment for Multi-Section Classification**




su2189

A1.5 The classification shall be applicable within the range of the maximum and minimum *D* and *W/D* or *A/P* tested.

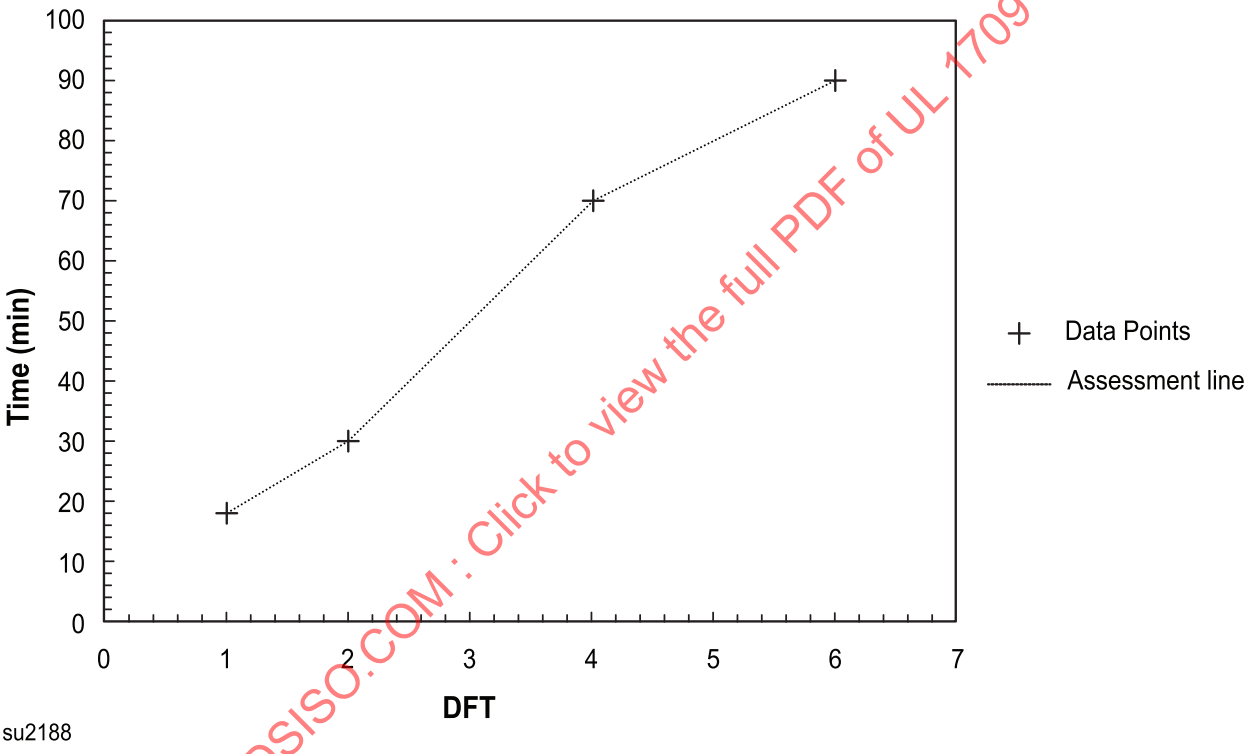
## A2 Multi-Duration Classification

A2.1 Where classification is required at one *W/D* or *A/P* for a range of durations then a minimum of 3 sections shall be tested if $D_{max} \leq 3.0\ D_{min}$, or 4 sections if $D_{max} > 3.0\ D_{min}$. This shall include $D_{min}$, $D_{max}$ and one or two varying intermediate thicknesses.

A2.2 The data shall be plotted on a graph of *t* (y axis) against *D* (x axis) and interpolated through simple point to point line construction. Where there are two points of the same *DFT* the most conservative point shall be used. As time increases the *DFT* shall increase. Points which do not meet this requirement shall be omitted. See Figure A2.1.

**Figure A2.1**

**Example Assessment for Multi-Duration, Single-Element Classification**






A2.3 The classification shall be applicable between the maximum and minimum duration and *D* tested.

## A3 Multi-Duration, Multi-Section Classification

A3.1 Where classification is required over a range of *W/D* or *A/P* and for a range of durations then a minimum of 7 sections shall be tested. These shall include as a minimum the sections described in Table A3.1. The individual thickness measurements of the fire protection material within each *D* band shall fall within 10 % of the average for that band.