



Member of the FM Global Group

Approval Standard for Residential Automatic Sprinklers for Fire Protection

Class Number 2030

August 2009

Foreword

The FM Approvals certification mark is intended to verify that the products and services described will meet FM Approvals' stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of Approval Standards is to present the criteria for FM Approval of various types of products and services, as guidance for FM Approvals personnel, manufacturers, users and authorities having jurisdiction.

Products submitted for certification by FM Approvals shall demonstrate that they meet the intent of the Approval Standard, and that quality control in manufacturing shall ensure a consistently uniform and reliable product. Approval Standards strive to be performance-oriented. They are intended to facilitate technological development.

For examining equipment, materials and services, Approval Standards:

- a) must be useful to the ends of property conservation by preventing, limiting or not causing damage under the conditions stated by the Approval listing; and
- b) must be readily identifiable.

Continuance of Approval and listing depends on compliance with the Approval Agreement, satisfactory performance in the field, on successful re-examinations of equipment, materials, and services as appropriate, and on periodic follow-up audits of the manufacturing facility.

FM Approvals LLC reserves the right in its sole judgment to change or revise its standards, criteria, methods, or procedures.

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1. INTRODUCTION

1.1 Purpose

- 1.1.1 This standard states Approval criteria for automatic residential sprinklers for fire protection service.
- 1.1.2 Approval criteria may include, but are not limited to, performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a follow-up program.

1.2 Scope

- 1.2.1 This standard sets performance requirements for automatic residential sprinklers in class number 2030.
- 1.2.2 Other types of automatic residential sprinklers may be FM Approved if they meet the requirements and intent of this standard. Residential sprinklers of unusual design may be subjected to special tests to determine their suitability.
- 1.2.3 Approval Standards are intended to verify that the product described will meet stated conditions of performance, safety and quality useful to the ends of property conservation.

1.3 Basis for Requirements

- 1.3.1. The requirements of this standard are based on experience, research and testing, and/or the standards of other organizations. The advice of manufacturers, users, trade associations, jurisdictions and/or loss control specialists was also considered.
- 1.3.2. The requirements of this standard reflect tests and practices used to examine characteristics of automatic residential sprinklers for the purpose of obtaining Approval. Residential sprinklers having characteristics not anticipated by this standard may be FM Approved if performance equal, or superior, to that required by this standard is demonstrated, or if the intent of the standard is met. Alternatively, automatic residential sprinklers which meet all of the requirements identified in this standard may not be FM Approved if other conditions which adversely affect performance exist or if the intent of this standard is not met.

1.4 Basis for Approval

Approval is based upon satisfactory evaluation of the product and the manufacturer in the following major areas:

- 1.4.1 Examination and tests on production samples shall be performed to evaluate:
 - The suitability of the product;
 - The performance of the product as specified by the manufacturer and required by FM Approvals; and, as far as practical,
 - The durability and reliability of the product.
- 1.4.2 An examination of the manufacturing facility(ies) and audit of quality control procedures shall be made to evaluate the manufacturer's ability to consistently produce the product which was examined and tested, and the marking procedures used to identify the product. These examinations are repeated as part of FM Approvals' product follow-up program. (Refer to Section 5.2, Facility and Procedures Audit.)

1.5 Basis for Continued Approval

Continued Approval is based upon:

- Production or availability of the product as currently FM Approved;
- The continued use of acceptable quality assurance procedures;
- Satisfactory field experience;
- Compliance with terms stipulated in the Master Agreement;
- Satisfactory re-examination of production samples for continued conformity to requirements; and
- Satisfactory Facilities and Procedures Audits (F&PAs) conducted as part of FM Approval's product follow-up program.

Also, as a condition of retaining Approval, manufacturers may not change a product or service without prior authorization by FM Approvals.

1.6 Effective Date

The effective date of an Approval Standard mandates that all products tested for Approval after the effective date shall satisfy the requirements of that standard. Products FM Approved under a previous edition shall comply with the new version by the effective date or forfeit Approval.

The effective date of this standard is **August 31, 2010** for compliance with all requirements.

1.7 System of Units

Units of measurement used in this standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Appendix A lists the selected units and conversions to SI units for measures appearing in this standard. Conversion of U.S. customary units is in accordance with the American Society for Testing Materials (ASTM) SI10-2002, *"IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System."* Two units of measurement (liters and bar), outside of, but recognized by SI, are commonly used in international fire protection and are used in this standard.

1.8 Applicable Documents

The following standards, test methods, and practices are referenced in this standard or beneficial in understanding this standard:

ANSI/ASME B1.20.1-1983 (R2001), *Pipe Threads, General Purpose (Inch)*

ANSI/ASME B16.3-1998, *Malleable-Iron Threaded Fittings*

ANSI/ASME B16.4-1998, *Gray Iron Threaded Fittings*

ASTM SI10-2002, *IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System*

ASTM B117-2003, *Standard Practice for Operating Salt Spray (Fog) Apparatus*

ASTM E1-2003a, *Standard Specification for ASTM Liquid-in-Glass Thermometers*

ASTM E11-2004, *Standard Specification for Wire Cloth and Sieves for Testing Purposes*

ASTM G36-1994(2000), *Standard Practice for Evaluating Stress-Corrosion-Cracking Resistance of Metals and Alloys in a Boiling Magnesium Chloride Solution*

FM Global Property Loss Prevention Data Sheets

International Organization for Standardization, ISO 17025 - 2005, *General requirements for the competence of testing and calibration laboratories*

PPP-B640d (as amended) Class II Government Grade
Rail Classification Rule 41, Section 3
National Motor Freight Classification Rule 222
IATA & ATA shipment by air, both domestic and overseas

1.9 Definitions

For purposes of this standard, the following terms apply:

Accepted

This term refers to installations acceptable to the authority enforcing the applicable installation rules. When the authority is FM Global, such locations are termed “FM Global Accepted.” Acceptance is based upon an overall evaluation of the installation. Factors other than the use of FM Approved equipment impact upon the decision to accept, or not to accept. Acceptance is not a characteristic of a product. It is installation specific. A product accepted for one installation may not be acceptable elsewhere. (Contrast with FM Approved.)

Amplitude

The maximum displacement of sinusoidal motion from position of rest to one-half of the total displacement.

Assembly Load

The force which is applied to the sprinkler frame due to assembly of the operating parts plus the equivalent force resulting from the maximum rated inlet pressure.

Coated or Plated Sprinkler

A sprinkler which has a factory applied coating or plating for corrosion protection or decorative purposes.

Concealed Sprinkler

A sprinkler in which the entire body, including the operating mechanism, is above a concealing plate, the margin of which is nearly flush to the ceiling surface.

Conductivity (C-Factor)

A measure of the conductance between the sprinkler's heat responsive element and the other components of the sprinkler expressed in units of (ft/s)^{1/2} or (m/s)^{1/2}.

Corrosion Resistant

Materials having resistance to corrosion equal to or exceeding that of bronze alloy having a minimum copper content of 80 percent.

Decorative Sprinkler

A sprinkler which is factory-painted or coated to improve its aesthetics. The coating is not considered a corrosion-resistant barrier.

Design Area

The maximum area that a single residential sprinkler is intended to protect.

Design Load

See Element Design Load.

Discharge Coefficient (K-Factor)

The coefficient of discharge as expressed in the equation:

$$K = \frac{Q}{P^{1/2}}$$

Where Q is the flow in gallons per minute (gal/min) and P is the pressure in pounds per square inch (psi). Expressed in SI units: Q is the flow in liters per minute (L/min) and P is the pressure in bar.

Element Design Load

The load actually applied on the operating element (fusible element or bulb) at the maximum rated inlet pressure.

FM Approvals Certification Marks

The FM Approvals Certification Marks are detailed in Appendix C. Their use is mandatory on all units of FM Approved automatic residential sprinklers for fire protection service. These registered marks cannot be used except as authorized by FM Approvals via the granting of Approval to a specific product.

FM Approved

This term refers to products FM Approved by FM Approvals. Such products are listed in the Approval Guide, an online resource of FM Approvals. All products so listed have been successfully examined by FM Approvals, and their manufacturers have signed and returned a Master Agreement to FM Approvals. This form obligates the manufacturer to allow re-examination of the product and audit of facilities and procedures at FM Approvals' discretion. It further requires the manufacturer not to deviate from the FM Approved configuration of the product without review by and agreement of FM Approvals. Approval is manufacturing site and product specific.

Flush Sprinkler

A sprinkler in which essentially all of the body, with the exception of the heat responsive assembly, is mounted above the lower plane of the ceiling.

Fusible Element Sprinkler

A sprinkler that opens under the influence of heat by the melting of a component.

Glass Bulb Sprinkler

A sprinkler that opens under the influence of heat by bursting of a glass bulb due to pressure resulting from expansion of the enclosed fluid.

Hang-Up (Lodgement)

A malfunction in the operation of a sprinkler which, when operated under a typical system water pressure, experiences the lodging of an operating part (cap, gasket, lever, etc.) on or between the frame, deflector and/or compression screw, adversely affecting the water distribution for a period in excess of 10 seconds. A momentary hesitation of an operating part to clear itself from temporary contact with the frame, deflector and/or compression screw does not constitute a hang-up.

Heat Responsive Element

The component of a sprinkler assembly that, when subjected to the influence of heat, ruptures, bursts or otherwise functions, causing water to be discharged through the sprinkler orifice.

Leak Point

The pressure at which leakage of water in excess of one drop per minute occurs.

Maximum Service Pressure

The maximum rated working pressure of a sprinkler, typically 175 psi (12.1 bar).

Operating Temperature

The temperature, in degrees Fahrenheit (°F) or Celsius (°C), at which the heat responsive element of a sprinkler operates when subjected to a controlled rate-of-temperature-rise liquid bath.

Orientation, Best Case

When testing sprinklers for sensitivity in the FM Approvals plunge tunnel, the orientation of a sprinkler which results in the fastest operating time, or the lowest Response Time Index (RTI). Typically, this orientation is one in which the sprinkler waterway axis and the plane of the frame arms are both perpendicular to the air flow and, in the case of non-symmetric elements, the heat responsive element is upstream of the frame arms.

Orientation, Worst Case

For use in this standard, when testing sprinklers for sensitivity in the FM Approvals plunge tunnel, the worst case orientation is a given angular offset from the orientation which results in the slowest operating time, or the highest Response Time Index (RTI). The angular offset for residential (quick response rated) sprinklers is 25 degrees.

Orifice

The opening in a sprinkler body through which the water is discharged.

Pendent Sprinkler

A sprinkler designed such that the water exiting the orifice is directed downwards against the deflector.

Quick Response Sprinkler

A sprinkler having a Response Time Index (RTI) and Conductivity factor (C) combination which fall into the indicated area on the graph in Figure E-1. Generally, this is a sprinkler having an RTI equal to or less than $90 \text{ (ft}\cdot\text{s)}^{1/2}$ [$50 \text{ (m}\cdot\text{s)}^{1/2}$] and a C-factor equal to or less than $1.81 \text{ (ft/s)}^{1/2}$ [$1.0 \text{ (m/s)}^{1/2}$], when the sprinkler is tested in the best-case orientation.

Recessed Sprinkler

A sprinkler in which part or most of the body of the sprinkler, other than the part which connects to the piping, is mounted within a recessed housing with the plane of the orifice above the plane of the ceiling, or behind the plane of the wall on which the sprinkler is mounted.

Residential Sprinkler

A thermo-sensitive device designed to react at a predetermined temperature by automatically releasing a stream of water and distributing it in a specified pattern and quantity over a designated area. When properly installed in a wet pipe system and below horizontal smooth ceilings in accordance with internationally recognized installation standards, residential sprinklers are intended to aid in the control of open flame type residential fires, prevent flashover (i.e. transition to full involvement) in the room of fire origin resulting in improved tenability. Sprinkler spacing will be in accordance with the manufacturer's published guidelines and the product's listing.

Response Time Index (RTI)

A measure of sprinkler sensitivity expressed as $RTI = \tau (u)^{1/2}$ where τ is the time constant of the heat responsive element in units of seconds, and u is the gas velocity expressed in feet per second (or meters per second). The quantity τ relates the properties of the heat responsive element and the heated gas flow. RTI can be used in combination with the C-factor to predict the response of a sprinkler in fire environments defined in terms of gas temperature and velocity versus time. RTI is expressed in units of $(\text{ft}\cdot\text{s})^{1/2}$ or $(\text{m}\cdot\text{s})^{1/2}$.

Service Pressure

The working hydrostatic pressure of a sprinkler system.

Sidewall Sprinkler

A sprinkler intended for installation near a wall and ceiling interface and designed to discharge water outward and onto adjacent walls.

Single Sprinkler Flow Rate

The minimum water flow rate specified for operation of a single residential sprinkler.

Strutting

Partial fracture of a glass bulb or partial rupture of a fusible element which does not result in sprinkler operation.

Upright Sprinkler

A sprinkler designed such that the water exiting the orifice is directed upward against the deflector.

Weep Point

The pressure at which any visible leakage of water is detected.

1.10 References

1. Heskestad, G. and Smith, H. F. *Investigation of a New Sprinkler Sensitivity Approval Test: The Plunge Tunnel*, Factory Mutual Research Corporation, FMRC Serial Number 22485, December 1976.
2. Heskestad, G. and Smith, H. F., *Plunge Test for Determination of Sprinkler Sensitivity*, Factory Mutual Research Corporation, FMRC Job Identifier (J. I.) 3A1E2.RR, December 1980.
3. Heskestad, G. and Bill, R. G. Jr., *Conduction Heat Loss Effects on Thermal Response of Automatic Sprinklers*, Factory Mutual Research Corporation, J. I. 0N0J5.RU, and J. I. 0N1J6.RU, September 1987.
4. Heskestad, G. and Bill, R. G. Jr., *Plunge Test Procedures for Recessed, Flush and Concealed Sprinklers*, Factory Mutual Research Corporation, J. I.0Y0J1.RA, February 1995.
5. Khan, M. M., Chaffee, J. L., and Alpert, R. L., *Determination of Operating Temperatures of Glass Bulb Sprinklers Using a Thermal Liquid Bath*, Project Identifier 0003002215, August 2000.

2. GENERAL INFORMATION**2.1 Product Information**

- 2.1.1 A residential automatic sprinkler is a thermo-sensitive device designed to react at a predetermined temperature by releasing a stream of water and distributing it in a specified pattern and density over a designated area when installed on the appropriate sprinkler piping.
- 2.1.2 In order to meet the intent of this standard, sprinklers shall be examined on a model-by-model, type-by-type, manufacturer-by-manufacturer, and plant-by-plant basis. This is predicated on the basis that the manufacturing of sprinklers requires sufficient skill in its execution that identical designs, fabricated in identical materials by different manufacturers or, even by different plants of the same manufacturer, have been seen to perform differently in testing. Sample sprinklers, selected in conformance to this criterion, shall satisfy all of the requirements of this standard.

2.2 Approval Application Requirements

To apply for an Approval examination the manufacturer, or its authorized representative, shall submit a request to:

Hydraulics Group Manager
FM Approvals Hydraulics Laboratory
743A Reynolds Road
West Glocester, RI 02814 U.S.A.

The manufacturer shall provide the following preliminary information with any request for Approval consideration:

- A complete list of all models, types, sizes, and options for the control mode sprinklers being submitted for Approval consideration;
- A complete set of manufacturing drawings, general assembly drawings, materials list(s), assembly load calculations, anticipated marking format, brochures, sales literature, specification sheets, installation, operation and maintenance procedures, and;
- The number and location of facilities manufacturing the specified product.

All documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level. All foreign language documents shall be provided with English translation.

2.3 Requirements for Samples for Examination

Following generation and authorization of an Approval examination proposal, the manufacturer shall submit samples for examination and testing. Sample requirements are to be determined by FM Approvals following review of the preliminary information. Sample requirements may vary depending on design features, results of prior or similar testing, and results of the foregoing tests. It is the manufacturer's responsibility to submit samples representative of production. Any decision to use data generated utilizing prototypes is at the discretion of FM Approvals. The manufacturer shall provide any special test fixtures, such as those which may be required to evaluate the strength of heat responsive elements, requested by FM Approvals to evaluate the residential sprinklers.

3. GENERAL REQUIREMENTS

3.1 Review of Documentation

During the initial investigation and prior to physical testing, the manufacturer's specifications, technical data sheets, and design details shall be reviewed to assess the ease and practicality of installation and use. The product shall be capable of being used within the limits of the Approval investigation.

3.2 Physical or Structural Features

- 3.2.1 Stampings shall show no cracking or splitting and be free of burrs.
- 3.2.2 Deflectors of sprinklers shall be securely attached.
- 3.2.3 Sprinklers shall be designed and manufactured such that adjustment of the assembly load or replacement of operating parts shall not be possible without visible permanent damage to the device.
- 3.2.4 All connections shall be suitable for use with fittings having tapered pipe threads which conform to a national or internationally recognized standard. Sprinklers which are to be sold in the United States shall be threaded to suit fittings manufactured in accordance with ANSI/ASME B1.20.1, *Pipe Threads, General Purpose (Inch)*.
- 3.2.5 Residential sprinklers having water passageways with cross-sectional dimensions less than 3/8 in. (9.5 mm) may necessitate the use of individual or system strainers per appropriate installation standards. At the sole discretion of FM Approvals, sprinklers incorporating such passages shall require

a statement in various publications (i.e. manufacturer's literature, Approval Reports, Approval Guide, etc.) referring to the size of the openings and indicating their need for use with appropriate strainers.

- 3.2.6 A special wrench, facilitating installation, shall be available from the manufacturer and provided to FM Approvals for evaluation. If installation using a common wrench is permitted by the manufacturer, such wrench shall not easily damage the sprinkler. If a common wrench is to be used for installation, the possibility of wrench slippage exists with possible subsequent damage to the sprinkler and the possibility of hidden damage so as to render the sprinkler inoperative. For this reason, sprinklers permitted by the manufacturer to be installed with a common wrench shall meet the following requirement: the minimum length of the wrench flats shall be equal to the distance between the flats of the sprinkler.
- 3.2.7 All operating parts shall have ample clearance with near zero possibility of binding or wedging. An analysis of the design drawings may be conducted to evaluate the worst combination of tolerances in parts so as to assess the possibility of such malfunction.
- 3.2.8 Plated or coated residential sprinklers shall be subjected to additional evaluation and testing, beyond that specified in this standard, to verify the integrity of their mechanical and operational properties and marking clarity. Factory plating or coating of residential sprinklers shall not change the mechanical or operational properties of the sprinkler beyond acceptable limits stated in this standard.
- 3.2.9 Finishes such as plating, decorative painting, or coating shall not be applied to sprinklers by anyone other than the sprinkler manufacturer, or vendor, at the time of manufacture. Examination of residential sprinklers with such finishes or coatings is required. Such sprinklers shall meet all requirements of residential sprinklers.
- 3.2.10 Ornamental sprinklers such as concealed types may have factory-painted cover plates, if the painted plates have been tested as part of the sprinkler evaluation.
- 3.2.11 Inlet protrusion into the fitting shall not adversely affect the flow of water through the fitting.
- 3.2.12 Approval of residential automatic sprinklers is restricted to a maximum nominal operating temperature of 225°F (107°C).

3.3 Materials

All materials used in automatic residential sprinklers shall be suitable for the intended application. Residential sprinkler parts exposed to water shall be constructed of corrosion resistant materials. When unusual materials are used, special tests, beyond those specified in this standard, may be necessary to verify their suitability.

3.4 Markings

- 3.4.1 All sprinklers shall be marked in accordance with one of the two marking schemes described in Section 3.4.1.1 and 3.4.1.2. The manufacturer may use either one or both of the schemes and shall notify FM Approvals prior to making any marking changes on the sprinklers.

- 3.4.1.1 The following marking scheme is intended to meet the National Fire Protection Association (NFPA) marking requirements adopted in 1999 and effective January 1, 2001.

Sprinklers shall be permanently marked with a one- or two-character manufacturer symbol, followed by three or four numbers. This marking, or sprinkler identification number (SIN) shall uniquely identify the sprinkler based upon the following:

- Orifice size or shape
- Deflector type or orientation

- Pressure rating
- Thermal sensitivity (i.e. response classification)

The manufacturer shall be assigned the one- or two-character manufacturer symbol by contacting the International Fire Sprinkler Association (www.sprinklerworld.org).

The manufacturer shall not place this identification mark on any other product.

In addition to the SIN, the following shall be displayed on a non-operating part of the sprinkler:

- Nominal temperature rating (in °F or °C at a minimum);
- Year of manufacture (Note: sprinklers manufactured in the first 6 months or last 3 months of a calendar year may be marked with the previous or following year respectively, as the year of manufacture);
- The FM Approvals Certification Mark (see Appendix C).

Optionally, the following additional information may be displayed on a non-operating part of the sprinkler:

- Manufacturer's name or identifying symbol (logo);
- Model designation (see Section 3.4.2 below);
- Nominal K-factor (in English units: gal/min/(psi)^{1/2});
- The word "PENDENT", the word "UPRIGHT", or other designation to indicate type or orientation, as appropriate;

3.4.1.2 In lieu of the marking requirements of section 3.4.1.1, sprinklers shall be permanently marked on a non-operating component with the following:

- Manufacturer's name or identifying symbol (logo);
- Model designation (see Section 3.4.2 below);
- Nominal K-factor (in English units: gal/min/(psi)^{1/2});
- The word "PENDENT", the word "UPRIGHT", or other designation to indicate type or orientation, as appropriate;
- Nominal temperature rating (in °F or °C at a minimum);
- Year of manufacture (Note: sprinklers manufactured in the first 6 months or last 3 months of a calendar year may be marked with the previous or following year respectively, as the year of manufacture);
- The FM Approvals Certification Mark (see Appendix C).

3.4.2 Regardless of the marking scheme utilized, the sprinkler identification number (SIN), model designation, and/or type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the sprinkler as FM Approved. The manufacturer shall not place this identification mark on any other product.

3.4.3 For fusible type sprinklers, the operating temperature, or the temperature rating color code, as defined in Table 3.4.5, shall appear on a visible area of the fusible element or an associated operating component.

3.4.4 If a manufacturer produces residential sprinklers with the same model designation at more than one facility, each sprinkler shall bear a distinctive marking on a non-operating part to identify it as the product of a particular location.

3.4.5 All residential sprinklers, with the exception of glass bulb type sprinklers, shall be color coded in accordance with Table 3.4.5. Paint of the correct color shall be applied to at least 50 percent of each frame arm surface. This application of paint shall be visible on the sprinkler from all directions. The color identification for coated, plated and recessed sprinklers may be a dot on the top of the deflector,

the color of the coating material or colored frame area. This dot shall be visible from a distance of 3 feet (0.9 m).

Table 3.4.5 Temperature Ratings, Classifications, and Color Code

<i>Nominal Temperature¹ Rating Range</i>		<i>Maximum Ambient Temperature at Sprinkler Level</i>		<i>Temperature Classification</i>	<i>Sprinkler Frame Color Code</i>
<i>°F</i>	<i>(°C)</i>	<i>°F</i>	<i>(°C)</i>		
135 to 170	(57 to 77)	100	(38)	Ordinary	None or Black
175 to 225	(79 to 107)	150	(66)	Intermediate	White

Note: ¹ FM Approved sprinklers shall have a specific temperature rating within the range.

- 3.4.6 Bulb type sprinklers, including decorative factory-painted or coated sprinklers, shall comply with the bulb color designation shown in Table 3.4.6. The bulb fluid color shall be considered a suitable method of temperature identification in addition to permanent marking elsewhere on the sprinkler.

Table 3.4.6 Temperature Ratings and Bulb Color Codes

<i>Nominal Temperature Rating</i>		<i>Bulb Color Code</i>
<i>°F</i>	<i>(°C)</i>	
135	(57)	Orange
155	(68)	Red
175	(79)	Yellow
200, 225	(93, 107)	Green

- 3.4.7 Flush sprinklers shall be color coded. Such color identification may be a dot suitably located and visible on the link, arms, or other component as appropriate. Such location shall be evaluated on a case-by-case basis.
- 3.4.8 For all concealed sprinklers, the cover plate shall be marked with the words "Do Not Paint" in characters at least 1/8 in. (3.2 mm) in height.
- 3.4.9 Horizontal sidewall sprinklers shall include the word "Top" on the deflector to indicate orientation.
- 3.4.10 Vertical sidewall sprinklers shall bear an arrow indicating the direction of flow and the word "flow."
- 3.4.11 Factory plated sprinklers shall be identified as such with a distinctive marking so as to distinguish the product from unauthorized field plating.
- 3.4.12 For factory decorative-painted (coated) sprinklers, some portion of the sprinkler shall remain unpainted and readily visible from a minimum of 1 foot (0.3 m). This would allow a means to determine if the sprinkler were repainted in the field. Field painting is prohibited.
- 3.4.13 For bulb-type residential sprinklers, the manufacturer shall place a distinctive mark on a non-operating part of the sprinkler to denote the bulb manufacturer if more than one source is used in a given design.
- 3.4.14 All markings shall be permanent and visible from a distance of 3 feet (0.9 m). The markings shall remain visible through any factory-applied plating or decorative coating.

3.5 Manufacturer's Installation and Operation Instructions

The manufacturer shall provide the user with adequate instructions for proper installation with each shipment. Residential sprinklers shall be installed and maintained in accordance with applicable installation rules. Field modification, such as replacing a component on a sprinkler, plating, or painting, is prohibited.

3.6 Calibration

All equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage of the equipment. A copy of the calibration certificate for each piece of test equipment is required for FM Approvals records, indicating that the calibration was performed against working standards whose calibration is certified as traceable to the National Institute of Standards and Technology (NIST) or to other acceptable reference standards and certified by an ISO 17025 calibration laboratory. The test equipment must be clearly identified by label or sticker showing the last date of the calibration and the next due date. A copy of the service accreditation certificate as an ISO 17025, *General Requirements for the Competence of Testing and Calibration Laboratories*, calibration laboratory is required for FM Approvals records.

The calibration of recently purchased new equipment is also required. Documentation indicating either the date of purchase or date of shipment, equipment description, model and serial number is required for identification. The period from the time the equipment was put into service to the date of testing must be within an interval that does not require the equipment to be calibrated as determined on the basis of the parameters mentioned above.

3.7 Tolerances

Tolerances on units of measure shall be as described in Appendix B, unless otherwise specified.

4. PERFORMANCE REQUIREMENTS

Test Pressures

All test pressures are based on the maximum rated working pressure of 175 psi (12.1 bar). Other pressures will be considered at the sole discretion of FM Approvals.

4.1 Examination

4.1.1 Requirements

The residential sprinklers shall conform to the manufacturer's drawings and specifications and to FM Approvals requirements.

4.1.2 Test/Verification

A sample shall be examined and compared to drawings and specifications. It shall be verified that the sample conforms to the physical and structural requirements described in Section 3, General Requirements.

4.2 Assembly Load/Frame Strength

4.2.1 Requirements

The frame of a residential sprinkler shall be capable of withstanding twice the assembly load without sustaining permanent elongation or deformation in excess of 0.2 percent of the distance between the load bearing parts of the sprinkler.

4.2.2 Test/Verification

- A. Fifteen previously untested sprinklers shall be individually tested to determine the assembly load. With the threaded portion of the sprinkler restrained from movement, the heat responsive element of the test sample shall be removed and the negative axial deflection of the frame, resulting from the release of the assembly shall be recorded. Deflection measurements shall be made using an indicator capable of reading to an accuracy of 0.00001 in. (0.00025 mm). A force necessary to return the deflection of the frame to the original zero position shall then be applied and the value of the force recorded.
- B. Each of these sprinklers shall then be subjected momentarily (for 1 second to 5 seconds) to twice the sum of the force recorded in Section 4.2.2.A, plus the force applied to the sprinkler as a result of the maximum rated working pressure [typically 175 psi (12.1 bar)]. The amount of permanent set after the load application shall be determined. The percentage of permanent frame elongation shall be calculated using the minimum distance between the load bearing points, determined to the nearest 0.001 in. (0.03 mm), from the plane of the sprinkler orifice to the center of the compression bearing surface of the sprinkler.

4.3 Strength of Heat Responsive Element

4.3.1 Requirements

- A. A heat responsive element of the fusible type shall be (1) capable of sustaining a load 15 times its maximum design load for a period of 100 hours or (2) demonstrate the ability to sustain the maximum element design load when tested in accordance with Section 4.3.2.A.2.
- B. For a heat responsive element of the glass bulb type, the lower tolerance limit of bulb strength shall be greater than two times the upper tolerance limit of sprinkler assembly load based on calculations with a degree of confidence of 0.99 (99 percent). Calculations shall be based on the Normal or Gaussian Distribution except where another distribution can be shown to be more applicable due to manufacturing or design factors. The method for calculating the upper and lower tolerance limits is shown in Appendix D.

4.3.2 Tests/Verification

A. Heat Responsive Element of the Fusible Type

1. Fifteen samples shall be loaded with a weight representing the equivalent of 15 times the design load. All samples must remain undamaged after sustaining this load for a period of 100 hours.
2. Fusible type heat responsive elements which cannot pass the test described in 4.3.2.A.1 shall meet the following requirements. Sample fusible type heat-responsive elements shall be subjected to loads in excess of the design load which will produce failure both within and after 1000 hours. The test samples shall be maintained at an environmental temperature of $70^{\circ}\text{F} \pm 5^{\circ}\text{F}$ ($21^{\circ}\text{C} \pm 2.6^{\circ}\text{C}$). At least 15 samples shall be loaded to various degrees in order to establish a basis of time as a function of load. Failures which are not related to the solder bond shall be disregarded. A least square, full logarithmic regression curve shall be plotted

from which both the load to failure at 1 hour (L_o) and the load to failure at 1000 hours (L_m) shall be determined. The actual maximum design load (L_d) on the fusible element, as determined using the upper tolerance limit of assembly load from Section 4.2.2.A, shall be less than or equal to the value determined in the expression:

$$L_d = 1.02 \frac{L_m^2}{L_o}$$

Where:

- L_d = Maximum design load for the heat responsive element
- L_m = Load resulting in failure at 1000 hours
- L_o = Load resulting at failure in 1 hour

3. Where physical limitations of the fusible element prevent the application of the loads described in Section 4.3.1.A, alternate methods of determining the adequacy of the design shall be developed to ensure that such elements should not fail during the anticipated life span.

B. Heat Responsive Element of the Bulb Type

The results of the assembly load test, Section 4.2.2.A, shall form the basis for calculating the upper tolerance limit of the sprinkler assembly load. The lower tolerance limit for bulb strength shall be determined using the results obtained from subjecting a minimum of 25 sample bulbs to an increasing load until the bulbs fail. Each test shall be conducted with the bulb mounted in hardened steel inserts with seating surfaces having dimensions which conform to the actual mating components of the sprinkler. The inserts shall have a hardness within the range Rockwell C 38-50 (see Figure E-2). They shall be provided by the manufacturer each time the test is specified. The load shall be applied at a rate of compression not exceeding 0.05 in./min (1.27 mm/min). The results obtained from the two sets of data shall be utilized for the tolerance limit calculations as described in Appendix D, Tolerance Limit Calculations.

4.4 Leakage

4.4.1 Requirements

Residential sprinklers shall not weep or leak at, or below, 500 psi (34.5 bar) hydrostatic pressure and shall not leak at 30 psi (2.1 bar) pneumatic pressure.

4.4.2 Test/Verification

- A. Hydrostatic Leakage - Ten previously untested sprinklers shall be individually subjected to a slowly rising hydrostatic pressure. The pressure shall be increased from 0 psi to 500 psi (0 bar to 34.5 bar), at a rate not to exceed 300 psi (20.7 bar) per second, and maintained at 500 psi (34.5 bar) for 1 minute.
- B. Pneumatic Leakage - Four previously untested sprinklers shall be individually conditioned at $-20^{\circ}\text{F} \pm 10^{\circ}\text{F}$ ($-29^{\circ}\text{C} \pm 6^{\circ}\text{C}$) for 24 hours. Each sample shall be pneumatically pressurized to $30 \text{ psi} \pm 2 \text{ psi}$ ($2.1 \text{ bar} \pm 0.1 \text{ bar}$) and immersed in glycol liquid conditioned to $-20^{\circ}\text{F} \pm 10^{\circ}\text{F}$ ($-29^{\circ}\text{C} \pm 6^{\circ}\text{C}$), and observed for 5 minutes.

4.5 Hydrostatic Strength

4.5.1 Requirements

Residential sprinklers shall be capable of withstanding, without rupture, an internal hydrostatic pressure of up to 700 psi (48.3 bar) for a period of 1 minute.

4.5.2 Tests/Verification

If all samples comply with the requirements of Section 4.4.2.A, each sample shall be further subjected to a gradually increasing hydrostatic pressure to 700 psi (48.3 bar) at a rate not to exceed 300 psi (20.7 bar) per minute. The test pressure shall be maintained for 1 minute. If leakage at the orifice prevents testing at 700 psi (48.2 bar), the maximum attainable test pressure shall be maintained for 1 minute. Leakage at the orifice above a hydrostatic pressure of 500 psi (34.4 bar) shall be deemed acceptable.

4.6 30-Day Leakage

4.6.1 Requirements

Residential sprinklers shall not weep or leak when subjected to an internal hydrostatic pressure of 300 psi (20.7 bar) for a continuous period of 30 days. Following this test period, the samples shall not weep or leak at, or below, 500 psi (34.5 bar) when tested in accordance with Section 4.4.2.A (Hydrostatic Leakage). The samples shall also show no evidence of distortion or physical damage.

4.6.2 Tests/Verification

Five previously untested samples shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 500 psi (34.5 bar). The samples shall then be installed on a water-filled test apparatus which is to be maintained at ambient temperature and at a constant pressure of 300 psi (20.7 bar) for 30 days. The samples shall be examined weekly during the test period for evidence of leakage at the seal.

Following this test, the samples shall be subjected to the post-tests detailed above.

4.7 Water Hammer

4.7.1 Requirements

Residential sprinklers shall be capable of withstanding 100,000 applications of a pressure surge from approximately 50 psi to 500 psi (3.4 bar to 34.5 bar) without leakage, distortion, or physical damage. Following satisfactory completion of this test, the samples shall not weep or leak at, or below, 500 psi (34.5 bar) when tested in accordance with Section 4.4.2.A (Hydrostatic Leakage). The samples shall also show no evidence of distortion or physical damage.

4.7.2 Tests/Verification

Five previously untested samples shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 500 psi (34.5 bar). They shall then be installed on a water-filled manifold and subjected to changes in pressure from approximately 50 psi +0/-50 psi to 500 psi +0/-50 psi (3.4 bar +0/-3.4 bar to 34.5 bar +0/-3.4 bar) for 100,000 cycles +1,000/-0 cycles. The cycle period shall be between 1 second and 10 seconds. Observations shall be made for evidence of leakage at least twice a day during the test period.

Following this test, the samples shall be subjected to the post-tests detailed above.

4.8 Operating Temperature (Liquid Bath)

4.8.1 Requirements

All residential sprinklers and cover plates shall have an actual operating temperature within ± 3.5 percent of the marked nominal temperature rating, when immersed in a constant rate-of-temperature-rise liquid bath.

4.8.2 Tests/Verification

Ten previously untested sprinklers shall be immersed in a vessel containing a liquid as specified in Table 4.8.2.

Table 4.8.2 Liquid Bath Conditions

<i>Nominal Temperature Rating of Sprinkler</i>		<i>Bath Liquid</i>	<i>Maximum Rate of Temperature Rise</i>	
<i>°F</i>	<i>(°C)</i>		<i>°F/min</i>	<i>(°C/min)</i>
0 - 175	(0 - 79)	Water	0.8	(0.4)
176 - 225	(80 - 107)	Glycerin	0.5	(0.3)

The sprinklers shall be placed on a grate or rack suspended above the bottom of the vessel. The liquid level shall not exceed 1 in. (25.4 mm) above the top of the sprinkler, and whenever possible, shall not exceed 1.5 in. (38.1 mm) above the top of the temperature sensitive element. The vessel shall be provided with a source for heating the liquid, a means to agitate the liquid, and a device to measure the temperature of the liquid (see Figure E-3 for a typical test set-up). The liquid shall be agitated at a constant rate of 200 rpm \pm 10 rpm via a paddle measuring 4 in. (100 mm) long by 0.8 in. (20 mm) high. The device used to measure the temperature of the liquid shall be calibrated in accordance with the ASTM Standard E-1, *Standard Specification for ASTM Thermometers*, or the equivalent. It shall be immersed such that readings are taken at the same depth as the sprinkler temperature sensitive element.

The temperature of the bath shall be raised until the liquid is 20°F \pm 2°F (11.1°C \pm 1.1°C) below the nominal temperature rating of the sprinkler. The temperature rise shall then be controlled at a rate not exceeding that specified in Table 4.8.2 until operation of all sprinklers occurs. If one or more sprinklers fails to operate at, or below, the maximum temperature as stated in Section 4.8.1, the rate of rise shall continue to be controlled until all the sprinklers have operated, or until the bath reaches a temperature ten percent above the nominal temperature rating of the sprinklers, at which point the test shall be terminated. The temperature of the liquid bath at the time of operation shall be recorded for each sprinkler.

Partial fracture of a glass bulb or partial rupture of a fusible element which does not result in sprinkler operation, i.e., strutting, shall necessitate an additional sensitivity test (Air Bath Test, Section 4.9) in order to verify proper operation of the sprinkler in air.

4.9 Air Bath

4.9.1 Requirements

The heat responsive element of all sprinklers shall operate properly when the sprinklers are subjected to a constant rate-of-temperature-rise air bath.

4.9.2 Tests/Verification

Fifty previously untested sprinklers shall be placed on their threaded inlets in a programmable oven circulating air at ambient temperature. The temperature in the oven shall be steadily raised to $20^{\circ}\text{F} \pm 2^{\circ}\text{F}$ ($11^{\circ}\text{C} \pm 1.1^{\circ}\text{C}$) below the nominal temperature rating of the sprinklers over a 20 minute period. Once this temperature is reached, the oven shall be maintained at constant temperature for a period of 60 minutes \pm 5 minutes. The temperature shall then be raised at a constant rate of $1^{\circ}\text{F} \pm 0.5^{\circ}\text{F}$ ($0.5^{\circ}\text{C} \pm 0.3^{\circ}\text{C}$) per minute until the temperature reaches $40^{\circ}\text{F} \pm 5^{\circ}\text{F}$ ($22^{\circ}\text{C} \pm 2.8^{\circ}\text{C}$) above the nominal temperature rating of the sprinklers.

Partial fracture of a glass bulb or partial rupture of a fusible element, i.e., strutting, shall be deemed a failure.

4.10 Hang-Up of Operating Parts

4.10.1 Requirements

When tested as described below, not more than 1 percent of the samples shall exhibit a hang-up, or lodgment, of operating parts on the non-operating components (i.e. frame, compression screw, deflector, etc.) of the sprinkler.

Samples shall operate fully and completely, and shall exhibit no binding of internal components. Upon operation, the measured discharge coefficient (K-factor) of all samples shall comply with Section 4.15, Discharge Coefficient (K-Factor).

Any non-operation caused by binding of an operating element or improper fracturing of a glass bulb, shall be considered a hang-up. Momentary obstructions which clear in less than 10 seconds are not considered hang-ups. Pressures other than those shown in Table 4.10.2 may be tested at the sole discretion of FM Approvals.

4.10.2 Tests/Verification

Samples shall be selected in accordance with Table 4.10.2 and shall be individually installed in their intended installation position, on a pipe manifold as described in Figure E-4. Each sample shall be subjected to an inlet water pressure in accordance with Table 4.10.2, operated using a suitable open flame heat source, and observed for complete and proper functioning. A total of 100 sprinklers shall be tested.

The samples shall be tested with the pipe manifold configured for single-fed flow. At the discretion of FM Approvals, five samples shall be tested at each pressure with the pipe manifold configured for double-fed flow, and the remaining samples shall be tested with single-fed flow (see Figure E-4).

Upon activation of each sample, the discharge coefficient may be measured to verify proper and complete operation.

Table 4.10.2 Hang-Up Test Samples

<i>Pressure¹</i>		<i>Number of Samples</i>
<i>psi</i>	<i>(bar)</i>	
7	(0.5)	10
25	(1.7)	15
50	(3.4)	15
75	(5.2)	15
100	(6.9)	15
125	(8.6)	10
150	(10.3)	10
175	(12.1)	10

Note: ¹ A tolerance of ± 5 percent applies to all pressures specified in the table.

4.11 Strength of Deflector (Flow Endurance)

4.11.1 Requirements

The deflector, as well as other non-operating components of the sprinkler, and their methods of attachment, shall be designed and manufactured such that sprinkler operation and subsequent water flow does not cause damage to these parts or cause their disengagement from the sprinkler. Following test completion, there shall be no evidence of deflector distortion, damage, or impending separation from the frame on any of the sprinklers tested. The deflector and other non-operating components shall not be loosened.

4.11.2 Tests/Verification

Three previously untested sample sprinklers shall be individually installed in the test apparatus detailed in Figure E-4 in their intended orientation. Water shall be introduced to the inlet of each sprinkler at a pressure of $225 \text{ psi} \pm 10 \text{ psi}$ ($15.5 \text{ bar} \pm 0.7 \text{ bar}$). Each sprinkler shall then be operated using a suitable heat source and water flow shall be maintained at $225 \text{ psi} \pm 10 \text{ psi}$ ($15.5 \text{ bar} \pm 0.7 \text{ bar}$) for a period of 15 minutes.

4.12 Vacuum

4.12.1 Requirements

Residential sprinklers shall be designed such that when the inlet of an assembled sprinkler is subjected to a vacuum, as might be experienced during draining of a sprinkler system, the sprinkler shall not be damaged or leak when tested as described in Section 4.12.2. Following this test, each sample shall not weep or leak at a pressure of $5 \text{ psi} \pm 0.5 \text{ psi}$ ($0.3 \text{ bar} \pm 0.03 \text{ bar}$) when tested in accordance with Section 4.4.2.A (Hydrostatic Leakage). Additionally, each sample shall not weep or leak at any pressure at, or below, 500 psi (34.5 bar).

4.12.2 Test/Verification

Three previously untested sprinklers shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 500 psi (34.5 bar). The sprinklers shall then be subjected to a vacuum of 26 in. Hg (660 mm Hg) for a period of one minute.

Following this test, the samples shall be subjected to the post-tests detailed above.

4.13 High Ambient Temperature Exposure (90 Day Test)

4.13.1 Requirements

- A. Residential sprinklers shall be capable of withstanding an exposure to a high ambient temperature in accordance with Table 4.13.1.1 and Section 4.13.2 for a period of 90 days without evidence of weakness or failure. Following the exposure period, each sample shall not weep or leak at, or below, 500 psi (34.5 bar) when tested in accordance with Section 4.4.2.A (Hydrostatic Leakage). Subsequently, half of the sprinklers shall be tested for conformance to the requirements for sensitivity as described in Sections 4.28 [Sensitivity - Response Time Index (RTI)] and 4.29 [Sensitivity (Recessed, Flush, and Concealed Types)], as applicable. The remaining samples shall be tested for operating temperature as described in Section 4.8 [Operating Temperature (Liquid Bath)]. Exceptions are noted as described below.

Table 4.13.1.1 High Ambient Temperature Exposure Test Conditions

<i>Sprinkler Nominal Temperature Rating</i>		<i>Nominal¹ Test Temperatures</i>	
<i>°F</i>	<i>(°C)</i>	<i>°F</i>	<i>(°C)</i>
135 - 170	(57 - 77)	100	(38)
175 - 225	(79 - 107)	150	(66)

Note: ¹Tolerance on Nominal Test Temperature at stabilized condition: ± 3°F (1.7°C)

- B. High ambient temperature can affect platings and coatings which may ultimately impact the performance of residential sprinklers. Following exposure of coated or plated sprinklers, there shall be no evidence of shrinking, hardening, cracking, or flaking of the coating or plating. Following this test, each sample shall not weep or leak at or below, 500 psi (34.5 bar) when tested in accordance with Section 4.4.2.A (Hydrostatic Leakage). Subsequently, each sample shall operate satisfactorily when tested in accordance with Sections 4.28 [Sensitivity - Response Time Index (RTI)] and 4.29 [Sensitivity (Recessed, Flush, and Concealed Types)], as applicable.
- C. Concealed-type residential sprinklers incorporating a solder alloy or other temperature sensitive material to attach the cover plate shall not experience separation of the cover plate, while suspended, during the exposure. Following the test, the sprinkler covers shall be tested for operating temperature as stated in Section 4.8 [Operating Temperature (Liquid Bath)].

4.13.2 Test/Verification

Ten previously untested sprinklers shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 500 psi (34.5 bar). The samples shall then be placed in an automatically controlled, circulating constant-temperature oven and subjected to a high ambient temperature selected in accordance with Table 4.13.1.1 for a period of 90 days ± 1 day.

Following these tests, the samples shall be subjected to the post-tests detailed above. Manufacturers may submit additional samples for evaluation prior to completion of the required test period. Such samples are for reference only.

4.14 Thermal Shock (Glass Bulb Sprinklers Only)

4.14.1 Requirements

Residential sprinklers having frangible glass bulbs shall operate within their nominal operating temperature range after being exposed to a series of rapid temperature changes (i.e. thermal shocks). Operation of a sprinkler during the cycling portion of this test shall be deemed unacceptable. Following the sequence detailed in Section 4.14.2, each sample shall meet the operating temperature requirements specified in Section 4.8 [Operating Temperature (Liquid Bath)].

4.14.2 Test/Verification

Five previously untested samples shall be conditioned for 5 minutes \pm 1 minute in a liquid bath maintained at a temperature of seven percent below their nominal rating. The bath liquid shall be selected in accordance with Table 4.8.2.

The sprinklers shall then be removed and immediately submerged for a period of 15 seconds to 30 seconds into a second liquid bath maintained at 50°F \pm 5°F (10°C \pm 2.8°C). This sequence of heating and plunging into the cold liquid bath shall be repeated three times on each sample.

Following this test, the samples shall be subjected to the post-tests detailed above.

4.15 Discharge Coefficient (K-Factor)

4.15.1 Requirements

The mean value of the discharge coefficient (K-factor) of a residential sprinkler shall be within \pm 5 percent of the nominal K-factor, as specified by the manufacturer, when tested as detailed in Section 4.15.2. Additionally, not more than one individual reading measured while increasing pressure and one individual reading measured while decreasing pressure shall fall outside of this range.

4.15.2 Test/Verification

Four samples shall be individually tested using the test apparatus for determining K-factor shown in Figure E-5 at increasing and decreasing pressures over the complete operating range, 25 psi to 175 psi (1.7 bar to 12.1 bar) in 10 psi (0.7 bar) increments. With the deflector and a portion of the frame removed, if necessary, to facilitate testing, each sample shall be inserted into the test fixture and torqued to a rotation one-half turn (180 degrees) beyond "hand tight" using an appropriate wrench.

The K-factor shall be determined using the expression:

$$K = \frac{Q}{P^{1/2}}$$

where Q = flow rate [gal/min (L/min)] and P = pressure [psi (bar)].

4.16 Moist Air

4.16.1 Requirements

Residential sprinklers shall withstand an exposure to high temperature and humidity for a continuous period of 90 days. Following the exposure, samples shall not weep or leak at, or below, 175 psi (12.1 bar) when tested in accordance with Section 4.4.2.A (Hydrostatic Leakage). Subsequently, the samples shall exhibit positive operation and release of all operating parts at a pressure of 5 psi (0.3 bar) when tested in accordance with Section 4.25 (Minimum Operating Pressure).

4.16.2 Test/Verification

Five previously untested sprinklers shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 500 psi (34.5 bar). They shall then be exposed to an atmosphere having a relative humidity of 98 percent \pm 2 percent and a temperature of 203°F \pm 2°F (95°C \pm 1.1°C) for a period of 90 days \pm 1 day. If the exposure temperature nears or exceeds the nominal temperature rating of the sprinkler, the heat responsive element shall be specially fabricated to prevent operation during this test. The sprinklers shall be installed on a pipe manifold which contains water in approximately 50 percent of its volume. The entire manifold, along with the sprinklers, shall be placed in the high temperature and humidity enclosure for the duration of the test.

Following this test, the samples shall be subjected to the post-tests detailed above.

4.17 Corrosion - Salt Spray

4.17.1 Requirements

In order to evaluate the resistance to corrosion of the assembly, such as might be experienced by dissimilar materials in contact over long periods of time; residential sprinklers shall withstand a timed exposure to a salt spray atmosphere.

When tested as detailed in Section 4.17.2, visual evidence of severe deterioration or impending failure of any component shall constitute failure. Following exposure, all of the samples shall be subjected to a hydrostatic pressure of 175 psi (12.1 bar) for one minute without leakage. Subsequently, the sprinklers shall be tested for conformance to the requirements for sensitivity as described in Sections 4.28 [Sensitivity - Response Time Index (RTI)] and 4.29 [Sensitivity (Recessed, Flush, and Concealed Types)], as applicable. At the sole discretion of FM Approvals, some or all of the samples may be tested for operating temperature as described in Section 4.8 [Operating Temperature (Liquid Bath)]. Should the deflector or other non-operating components, or their attachment method, exhibit questionable corrosive attack, at least one sample shall be subjected to water flow at a pressure of 175 psi (12.1 bar) for a period of one minute. Upon completion of this test, the deflector shall not show evidence of fracture, distortion or impending separation from the frame.

4.17.2 Test/Verification

Eight previously untested samples shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 500 psi (34.5 bar).

Each sprinkler inlet shall be filled with deionized water and sealed with a non-reactive material (e.g., plastic cap) so as to prevent the introduction of salt fog into the waterway of the sprinkler. When feasible, each sprinkler shall be supported in its intended installation position.

Cover plates, common to the design of concealed sprinklers, shall be tested separately and shall be oriented such that salt fog residue cannot pool on the plate.

The samples shall be exposed to salt spray (fog) as specified by ASTM B117, Standard for Salt Spray (Fog) Testing. The salt solution shall consist of 20 percent by weight of common salt (sodium chloride) dissolved in deionized water.

The samples shall be exposed for a period of 10 days.

For residential sprinklers having a corrosion resistant coating, the samples shall be exposed for a period of 30 days.

Following exposure to the salt fog, the samples shall be removed from the test chamber and permitted to air dry for a two- to four-day drying period. Following this drying period, the samples shall be subjected to the post-exposure tests detailed above.

4.18 Corrosion - Stress Cracking

4.18.1 Requirements

Residential sprinklers shall be resistant to stress corrosion cracking, as determined through the process described below. Following exposure, the samples shall not show evidence of cracking, delamination, or degradation.

After exposure, the sprinklers shall not weep or leak at, or below, 175 psi (12.1 bar) when hydrostatically tested for one minute. Subsequently, half of the samples shall exhibit positive operation and release of all operating parts at a pressure of 5 psi (0.3 bar) when tested in accordance with Section 4.25 (Minimum Operating Pressure). The remaining samples shall be subjected to water flow at a pressure of 175 psi (12.1 bar) for a period of one minute. Upon completion of this test, the deflector shall not show evidence of fracture, distortion or impending separation from the frame.

4.18.2 Test/Verification

A. Copper Based Parts (Ammonia Test)

In order to determine the susceptibility of copper based sprinkler parts to stress corrosion cracking, four previously untested sprinklers shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 500 psi (34.5 bar). The samples shall then be subjected to a moist ammonia environment for a period of 10 days.

The inlet end of each sample shall be filled with deionized water and sealed with a non-reactive material (e.g., plastic cap) so as to prevent the introduction of the ammonia atmosphere into the waterway of the sprinkler. The samples to be tested shall be free from any non-permanent protective coating and, if necessary, shall be degreased. If a permanent coating is an inherent part of the design, such coating shall be subjected to tests as deemed necessary by FM Approvals to evaluate its protective integrity. When feasible, the samples shall be tested in their intended orientation.

There shall be provisions in the test chamber to prevent droplets of condensation from falling from the top of the enclosure directly onto the sprinklers. Such shield or other means shall be constructed of glass or other non-reactive materials.

The samples shall be exposed to the moist ammonia-air mixture maintained in a glass chamber with a volume of $0.73 \text{ ft}^3 \pm 0.43 \text{ ft}^3$ ($0.02 \text{ m}^3 \pm 0.01 \text{ m}^3$).

Aqueous ammonia having a density of $58.7 \pm 0.6 \text{ lb/ft}^3$ ($0.94 \pm 0.01 \text{ g/cm}^3$) shall be maintained in the bottom of the chamber, approximately 1.5 in. (40 mm) below the bottom of the samples. A volume of aqueous ammonia equal to $0.075 \pm 0.006 \text{ gal/ft}^3$ ($10 \pm 0.86 \text{ L/m}^3$) of the test chamber volume shall result in approximately the following atmospheric concentrations: 35 percent

ammonia, 5 percent water vapor, and 60 percent air. Prior to beginning the exposure, the test chamber shall be conditioned to a temperature of $93 \pm 4^\circ\text{F}$ ($34 \pm 2^\circ\text{C}$) for a period of not less than one hour, and shall be maintained as such throughout the exposure period. The moist ammonia-air mixture shall be maintained at essentially atmospheric pressure. Provision shall be made for venting the chamber, such as by the use of a capillary tube, to avoid buildup of pressure.

Upon removal, sprinklers shall be rinsed in potable water and air dried. Following a two- to four-day drying period, visual examination of the samples shall be made. The samples shall then be subjected to the post-exposure tests detailed above.

B. Austenitic, Ferritic, and Duplex Stainless Steel Parts (Boiling Magnesium Chloride Test)

In order to determine the susceptibility of stainless steel sprinkler parts to stress corrosion cracking, four previously untested sprinklers shall be degreased and then exposed to a boiling magnesium chloride solution for a period of 500 hours \pm 12 hours as described below, and in accordance with ASTM G36, *Standard Practice for Evaluating Stress-Corrosion-Cracking Resistance of Metals and Alloys in a Boiling Magnesium Chloride Solution*. Special fixtures or elevated temperature operating elements may be employed to simulate assembly loading on parts, where appropriate.

Samples are to be placed in a flask fitted with a wet condenser. The flask shall be filled approximately one-half full with a nominal 42 percent by weight magnesium chloride solution, placed on a thermostatically-controlled electrically-heated mantle, and maintained at a boiling temperature of $302^\circ\text{F} \pm 4^\circ\text{F}$ ($150^\circ\text{C} \pm 2^\circ\text{C}$).

Following exposure, the samples shall be removed and rinsed in potable water. Following a two- to four-day drying period, visual examination of the samples shall be made. Samples which show evidence of cracking, delamination, degradation, or evidence of separation of permanently attached parts shall then be subjected to the post-exposure tests as detailed above.

C. Parts Manufactured from Other Materials

Parts manufactured from other materials shall withstand comparable tests based upon the type of material employed at the sole discretion of FM Approvals.

4.19 Corrosion - Carbon Dioxide-Sulfur Dioxide

4.19.1 Requirements

Residential sprinklers shall be resistant to corrosion resulting from exposures to a moist carbon dioxide-sulfur dioxide-air mixture. Following the exposure period, the samples shall be examined for deterioration or impending failure of any component. Such condition is unacceptable and constitutes failure. Following the visual examination, the samples shall not weep or leak at, or below, 175 psi (12.1 bar) when hydrostatically tested for one minute. Subsequently, half of the samples shall be tested for compliance with Section 4.8 [Operating Temperature (Liquid Bath)], and half of the samples shall be tested for conformance to the requirements for sensitivity as described in Sections 4.28 [Sensitivity - Response Time Index (RTI)] and 4.29 [Sensitivity (Recessed, Flush, and Concealed Types)], as applicable. Should the deflector or other non-operating components, or their attachment method, exhibit questionable corrosive attack, at least one sample shall be subjected to a water flow at a pressure of 175 psi (12.1 bar) for a period of one minute. Upon completion of this test, the deflector shall not show evidence of fracture, distortion or impending separation from the frame.

4.19.2 Test/Verification

Four previously untested sprinklers shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 500 psi (34.5 bar). They shall then be exposed to a moist carbon dioxide-sulfur dioxide-air mixture for a period of 10 days.

For residential sprinklers having corrosion-resistant coatings, eight previously untested samples shall be exposed to this test for a period of 30 days.

The inlet end of each sample shall be filled with deionized water and sealed with a non-reactive material (e.g., plastic cap) so as to prevent the introduction of the gas mixture into the waterway of the sprinkler. When feasible, the sprinklers shall be tested in their intended installation position.

Cover plates, common to the design of concealed sprinklers, shall be tested separately and shall be oriented such that residue cannot pool on the plate.

There shall be provisions in the test chamber to prevent droplets of condensation from falling from the top of the enclosure directly onto the sprinklers. Such shield or other means shall be constructed of glass or other non-reactive materials.

The samples shall be tested in a chamber having provisions for gas inlet and outlet. Sulfur dioxide and carbon dioxide are to be supplied to the test chamber from commercial cylinders. An amount of sulfur dioxide equivalent to one percent of the volume of the test chamber, and an equal volume of carbon dioxide shall be introduced into the chamber each day after the chamber has been purged. Approximately 0.53 gallons (2.0 liters) of deionized water shall be maintained in the bottom of the chamber.

Following the exposure, the samples shall be removed from the test chamber and permitted to air dry for a two- to four-day drying period. Following this drying period, the samples shall be subjected to the post-exposure tests detailed above.

4.20 Corrosion - Hydrogen Sulfide

4.20.1 Requirements

Residential sprinklers shall be resistant to corrosion resulting from exposures to a moist hydrogen sulfide-air mixture. Following the exposure period, the samples shall be examined for deterioration or impending failure of any component. Such condition is unacceptable and constitutes failure. Following the visual examination, the samples shall not weep or leak at, or below, 175 psi (12.1 bar) when hydrostatically tested for one minute. Subsequently, half of the samples shall be tested for compliance with Section 4.8 [Operating Temperature (Liquid Bath)], and half of the samples shall be tested for conformance to the requirements for sensitivity as described in Sections 4.28 [Sensitivity - Response Time Index (RTI)] and 4.29 [Sensitivity (Recessed, Flush, and Concealed Types)], as applicable. Should the deflector or other non-operating components, or their attachment method, exhibit questionable corrosive attack, at least one sample shall be subjected to a water flow at a pressure of 175 psi (12.1 bar) for a period of one minute. Upon completion of this test, the deflector shall not show evidence of fracture, distortion or impending separation from the frame.

4.20.2 Test/Verification

Four previously untested sprinklers shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 500 psi (34.5 bar). They shall then be exposed to a moist hydrogen sulfide-air mixture for a period of 10 days.

For residential sprinklers having corrosion-resistant coatings, eight previously untested samples shall be exposed to this test for a period of 30 days.

The inlet end of each sample shall be filled with deionized water and sealed with a non-reactive material (e.g., plastic cap) so as to prevent the introduction of the gas mixture into the waterway of the sprinkler. When feasible, the sprinklers shall be tested in their intended installation position.

Cover plates, common to the design of concealed sprinklers, shall be tested separately and shall be oriented such that residue cannot pool on the plate.

There shall be provisions in the test chamber to prevent droplets of condensation from falling from the top of the enclosure directly onto the sprinklers. Such shield or other means shall be constructed of glass or other non-reactive materials.

The samples shall be tested in a chamber having provisions for gas inlet and outlet. Hydrogen sulfide is to be supplied to the test chamber from a commercial cylinder. An amount of hydrogen sulfide equivalent to one percent of the volume of the test chamber shall be introduced into the chamber each day after the chamber has been purged. Approximately 0.53 gallons (2.0 liters) of deionized water shall be maintained in the bottom of the chamber.

Following the exposure, the samples shall be removed from the test chamber and permitted to air dry for a two- to four-day drying period. Following this drying period, the samples shall be subjected to the post-exposure tests detailed above.

4.21 Vibration

4.21.1 Requirements

Residential sprinklers shall be capable of withstanding the effects of vibration without deterioration of their performance characteristics. Following the vibration test detailed in Section 4.21.2, the sprinklers shall not weep or leak at, or below, 500 psi (34.5 bar) when tested in accordance with Section 4.4.2.A (Hydrostatic Leakage). Subsequently, the sprinklers shall be tested for conformance to the requirements for sensitivity as described in Sections 4.28 [Sensitivity - Response Time Index (RTI)] and 4.29 [Sensitivity (Recessed, Flush, and Concealed Types)], as applicable.

4.21.2 Test/Verification

Four previously untested sprinklers shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 500 psi (34.5 bar). The samples shall then be subjected to the vibration conditions stated in Table 4.21.2.

Table 4.21.2 Vibration Conditions

<i>Total Displacement in. (mm)</i>	<i>Frequency Hz</i>	<i>Time Hours</i>
0.020 (0.51)	28	5
0.040 (1.02)	28	5
0.150 (3.81)	28	5
0.040 (1.02)	8 to 37 variable	5
0.070 (1.78)	8 to 37 variable	5

For the variable frequency conditions, the frequency shall be varied with a cycle period of 25 ± 5 seconds.

The sprinklers shall be attached to a rigid mounting plate and the plate bolted to the table of a vibration machine so that the sprinklers are vibrated vertically. This test shall be conducted with the

sprinklers unpressurized. The sprinklers may be pressurized for this test at the sole discretion of FM Approvals.

The sprinklers shall be subjected to the above vibration conditions and continuously monitored for 15 minutes at each condition (75 minutes total). If one or more resonant point(s) is detected, the sprinklers shall be vibrated for the remainder of the test at such frequency(ies) for a period of time proportionate to the number of resonant frequencies. Otherwise the sprinklers shall be subjected to each vibration condition for a period of 5 hours (25 hours total).

Following this test, the samples shall be subjected to the post-tests detailed above.

4.22 Rough Use and Abuse

4.22.1 Requirements

Residential sprinklers shall have adequate strength to withstand impacts associated with handling, shipment, and installation without deterioration of performance or reliability. Following the tests detailed below, a visual examination of each sprinkler shall reveal no permanent distortion, cracks, breaks, or other evidence of impending failure. Also, each sprinkler shall not weep or leak at, or below, 500 psi (34.5 bar) when tested in accordance with Section 4.4.2.A (Hydrostatic Leakage). Subsequently, the samples shall be tested for conformance to the requirements for sensitivity as described in Sections 4.28 [Sensitivity - Response Time Index (RTI)] and 4.29 [Sensitivity (Recessed, Flush, and Concealed Types)], as applicable. Complete operation of a sprinkler during the tumble test described in Section 4.22.2.B is permitted. Additional testing shall be at the sole discretion of FM Approvals.

4.22.2 Test/Verification

- A. Drop Test - Five previously untested sprinklers shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 500 psi (34.5 bar). Each sprinkler shall then be tested by dropping a weight equal to that of the sprinkler, ± 0.011 lb (± 5 g), onto the deflector end of the sprinkler along the axial centerline of the waterway (see Figure E-6). The weight shall be dropped from a height of 3.2 ft ± 2 in. (1.0 ± 50 mm) above the deflector. The weight shall be prevented from impacting the test sample more than once.
- B. Tumble Test - Five previously untested sprinklers shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 500 psi (34.5 bar). Each sprinkler shall then be individually subjected to a tumbling test for three minutes. Sprinklers provided with shipping caps, which are intended for removal only after completion of the sprinkler installation, shall be tested with the caps in place. Each sample shall be placed in a vinyl lined right hexagonal prism shaped drum designed to provide a tumbling action. The drum shall have a length along the axis of rotation of 10 in. (255 mm). The internal distance between two opposite and parallel sides of the drum shall be 12 in. (305 mm). For each test, the drum shall contain one sprinkler and five wood blocks. The blocks shall be 1.5 ± 0.12 in. (40 ± 3 mm) cubes made of hardwood (i.e. oak, maple, etc). The drum shall be rotated at one revolution per second about its longitudinal axis.

Following these tests, the samples shall be subjected to the post-tests detailed above.

4.23 High Temperature Exposure

4.23.1 Requirements

Residential sprinklers, less operating mechanisms, shall not show significant deformation, blistering, or fracture following exposure to an elevated temperature as detailed below. FM Approvals may conduct Discharge Coefficient (K-Factor) (Section 4.15) and/or Distribution (Section 4.30) tests on exposed samples to validate compliance with these requirements.

4.23.2 Test/Verification

One previously untested, but open, sprinkler, supported on its threaded inlet, shall be heated in an oven or furnace having a temperature of $1470 \pm 20^{\circ}\text{F}$ ($800 \pm 11^{\circ}\text{C}$) for a period of 15 minutes. Following this exposure, the sprinkler shall be removed with tongs, preferably by holding the threaded inlet portion, and promptly submerged in a water bath with a temperature of $60 \pm 10^{\circ}\text{F}$ ($15 \pm 6^{\circ}\text{C}$).

4.24 Freezing

4.24.1 Requirements

Following exposure to freezing temperatures, residential sprinklers shall either (a) operate, (b) leak subsequent to thawing when hydrostatically pressurized from 5 psi to 175 psi (0.3 bar to 12.1 bar), or (c) sustain no damage. For (c), sprinklers shall not weep or leak at, or below, 500 psi (34.5 bar) and subsequently, the sprinklers shall be tested for conformance to the requirements for sensitivity as described in Sections 4.28 [Sensitivity - Response Time Index (RTI)] and 4.29 [Sensitivity (Recessed, Flush, and Concealed Types)], as applicable.

4.24.2 Test/Verification

Two previously untested sprinklers shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 500 psi (34.5 bar). Each sprinkler shall be attached to one end of a 10 in. (254 mm) minimum length Schedule 40 or 80 steel pipe of 1 in. nominal diameter using an appropriate fitting. Each assembly shall then be filled to capacity with water and sealed. The samples shall then be exposed to a temperature of $-20^{\circ}\text{F} \pm 10^{\circ}\text{F}$ ($-30^{\circ}\text{C} \pm 5^{\circ}\text{C}$) for a period of 24 hours, or until operation occurs.

Following this test, the samples shall be subjected to the post-tests detailed above.

4.25 Minimum Operating Pressure

4.25.1 Requirements

A residential sprinkler shall be designed to produce positive operation and release of all operating parts at a minimum operating pressure of 5 psi (0.3 bar). Following operation of the heat responsive element, all parts which are intended to prohibit the discharge or leakage of water shall clear the exit of the waterway within 5 seconds.

4.25.2 Test/Verification

Ten previously untested sprinklers shall be subjected to an inlet water pressure of 5 psi (0.3 bar) and operated using a suitable heat source. If a sample does not operate fully as described above, the pressure shall be slowly increased to determine the actual minimum operating pressure.

4.26 Process Residue

4.26.1 Requirements

To simulate years of service in dusty or corrosive environments, the ability of lightly coated or corroded residential sprinklers to operate shall be verified.

4.26.2 Test/Verification

Verification of Section 4.26.1 shall be made in conjunction with Section 4.17 (Corrosion - Salt Spray). Additional process residue tests may be conducted at the sole discretion of FM Approvals.

4.27 Conductivity (C-Factor)

4.27.1 Requirements

The conductivity (C-factor) shall not exceed $1.81 \text{ (ft/s)}^{1/2}$ [$1.0 \text{ (m/s)}^{1/2}$] for residential sprinklers. Coated, flush, recessed and concealed sprinklers are not subject to these requirements.

4.27.2 Test/Verification

The C-factor shall be determined using the prolonged plunge test method. The prolonged plunge test is an iterative process to determine the C-factor and may require up to twenty sprinkler samples. A new sprinkler sample shall be used for each test even if the sample does not operate during the test.

Determination of the C-factor shall be performed with sprinklers of each nominal temperature rating in the "best case" orientation as determined in the Sensitivity - Response Time Index (RTI) (Section 4.28).

Prior to testing, each sprinkler shall have one to three wraps of PTFE sealant tape applied to the threads. Sprinklers shall be allowed to reach ambient temperature for a period of not less than 30 minutes.

A minimum of 0.0007 gal (0.025 L) of water, conditioned to ambient temperature, shall be introduced into the sprinkler inlet and mounting fixture prior to testing. All sprinklers are to be tested with the inlet end of each sample connected to a source of pressure at $5 +0.5/-0$ psi ($0.3 +0.04/-0$ bar). All tests shall be conducted with the geometric center of the heat responsive element located at least 1.5 in. (38 mm) from the interior horizontal surfaces of the test section and with the centerline of the waterway perpendicular to the airflow in the test chamber.

A timer accurate to ± 0.01 seconds with suitable measuring devices to sense the time between when the sprinkler is plunged into the tunnel and when it operates shall be utilized to obtain the response time.

The mount temperature shall be maintained at $68 \pm 2^\circ\text{F}$ ($20 \pm 1^\circ\text{C}$) for the duration of each test. The mount temperature shall be recorded at the beginning of the test and at the time of sprinkler operation. If a sample does not operate, the mount temperature shall be recorded after 15 minutes has elapsed. Testing shall start with a tunnel gas temperature from the range detailed in Table 4.27.2.

To determine the C-factor, each sprinkler shall be immersed in the test stream at a selected gas velocity and air temperature for a maximum of 15 minutes. The average gas velocity in the tunnel test section at the sprinkler location shall be maintained within $\pm 0.2 \text{ ft/s}$ (0.07 m/s) of the selected velocity. Velocities are to be chosen such that actuation is bracketed between two successive test velocities. That is, two velocities shall be established such that, at the lower velocity (u_L), actuation does not occur in the 15 minute test interval. At the next higher velocity (u_H), actuation shall occur within the 15 minute time limit. To establish u_L and u_H , the velocity shall be raised by 10 percent

increments within the range detailed in Table 4.27.2. If the sprinkler does not operate at the highest velocity in the range, a higher temperature shall be used and the same procedure repeated.

Table 4.27.2 Range of Test Conditions for C-factor

<i>Sprinkler Nominal Operating Temperature¹</i>		<i>Tunnel Gas Temperature</i>	<i>Tunnel Gas Velocity</i>	<i>Maximum Variation of Gas Temperature During Test From Selected Temperatures</i>	
<i>°F</i>	<i>(°C)</i>	<i>°F (°C)</i>	<i>ft/s (m/s)</i>	<i>°F</i>	<i>(°C)</i>
135 - 170	(57 - 77)	190 - 765	0.7 - 10	± 11	(± 6)
170 - 225	(79 - 107)	(88 - 407)	(0.2 - 3.05)	± 16	(± 9)

Note: ¹ For temperature ratings between those shown, a linear interpolation shall be used to determine the maximum variation from selected temperature.

Test velocity selection shall insure that:

$$(u_H/u_L)^{1/2} \leq 1.1$$

The C-factor of the sprinkler is determined by computing the average of the C-factors calculated at the two velocities (u_H and u_L) using the following equations:

$$C_H = (\Delta T_g / \Delta T_b - 1) u_H^{1/2} \qquad C_L = (\Delta T_g / \Delta T_b - 1) u_L^{1/2} \qquad C = \frac{C_L + C_H}{2}$$

Where:

- C_H = C-factor at velocity u_H
- C_L = C-factor at velocity u_L
- C = average C-factor of the sprinkler
- ΔT_g = actual gas (air) temperature minus the mount temperature
- ΔT_b = mean liquid bath operating temperature minus the mount temperature
- u_H = actual gas velocity in the test section at which the sprinklers operated
- u_L = actual gas velocity in the test section at which the sprinklers failed to operate within 15 minutes

The sprinkler C-factor is determined by repeating the bracketing procedure. The C-factor values from at least two non-operations shall be averaged. The C-factor values from at least two operations shall be averaged. The final C-factor value is the calculated numerical average of these two values.

4.28 Sensitivity - Response Time Index (RTI)

4.28.1 Requirements

The following definitions apply to this Section:

Orientation, Best Case – The orientation of a sprinkler which results in the fastest operating time, or the lowest Response Time Index (RTI). Typically, this orientation is one in which the sprinkler waterway axis and the plane of the frame arms are both perpendicular to the air flow and, in the case of non-symmetric elements, the heat responsive element is upstream of the frame arms.

Orientation, Worst Case – For use in this standard, the worst case orientation is a given angular offset from the orientation which results in the slowest operating time, or the highest Response Time Index (RTI). The angular offset for residential sprinklers is 25 degrees.

- A. All new residential sprinklers, with the exception of flush, recessed, and concealed types, shall have an RTI not exceeding 90 (ft·s)^{1/2} [50 (m·s)^{1/2}] when tested in the best case orientation.
- B. The worst case RTI for residential sprinklers shall not exceed two times the RTI in the best case orientation.

- C. Recessed, flush and concealed residential sprinklers shall comply with the requirements of the Sensitivity (Recessed, Flush, and Concealed Types) (Section 4.29).
- D. As an exception to the RTI limits in this section, one of the ten RTI values may deviate from the specified limits by not more than 10 percent.

4.28.2 Test/Verification

Compliance with the requirements for RTI shall be determined by operating sprinkler samples in the FM Approvals plunge tunnel, as described below. The FM Approvals plunge tunnel is further described in documents 1 through 4 as referenced in Section 1.10. All tests shall be conducted with the geometric center of the heat responsive element located at least 1.5 in. (38 mm) from the interior horizontal surfaces of the test section, and with the waterway centerline perpendicular to the air flow through the test chamber.

- A. Ten samples shall be tested in the best case orientation, as described in Section 4.28.1. If, in the judgment of FM Approvals, compliance with the requirements for worst-case RTI (See Section 4.28.1.B) is in question, a sufficient number of tests may be conducted in various sprinkler orientations relative to air flow, such that the worse-case orientation is determined. Subsequently, five samples shall be tested in the worst case orientation, and five samples shall be tested in the best case orientation.
- B. The plunge tests are conducted using the sprinkler mount detailed in Figure E-7. Each sprinkler shall have one to three wrap(s) of PTFE sealant tape applied to the sprinkler threads and shall be threaded into the mount at the sprinkler mounting connection, or connection "A" (See Figure E-7). An air supply is then attached at the air hose connection, or connection "B" (See Figure E-7), and shall be pressurized to 5 (+0.5/-0) psi [0.3 (+0.04/-0) bar].
- C. A tunnel with gas velocity and temperature conditions at the test section established in accordance with Table 4.28.2 shall be utilized to conduct the sensitivity test. To minimize radiation exchange between the sensing element and the boundaries confining the flow, the test section of the apparatus shall be constructed of appropriate materials with an uninsulated metal test duct. Tunnel conditions shall be stabilized for a minimum of 30 minutes prior to testing.
- D. Each sprinkler and sprinkler mount shall be allowed to reach ambient temperature for a period of not less than 30 minutes prior to testing.
- E. A timer accurate to ± 0.01 seconds, with suitable controlling devices [e.g., mercury switch for plunge (start), pressure switch for operation (stop)], shall be utilized to accurately measure the time to operate.

Table 4.28.2 Plunge Test Conditions

<i>Sprinkler Nominal Temperature Rating</i>		<i>Temperature in Test Section</i>		<i>Average Gas (Air) Velocity of Test Section</i>	
<i>°F</i>	<i>(°C)</i>	<i>°F</i>	<i>(°C)</i>	<i>ft/s</i>	<i>(m/s)</i>
135 - 171	(57 - 77)	387 ± 11	(197 ± 6)	8.4 ± 0.2	(2.56 ± 0.07)
174 - 225	(79 - 107)	555 ± 16	(291 ± 9)		

F. In all cases, the RTI shall meet the requirements as stated in Section 4.28.1 when calculated as follows:

$$RTI = \left(\frac{-t_r u^{1/2}}{\ln \left[1 - \frac{\Delta T_b (1 + C/u^{1/2})}{\Delta T_g} \right]} \right) \cdot [1 + C/u^{1/2}]$$

Where:

- t_r = response time of the sprinkler, in seconds
- u = actual air velocity in the test section of the tunnel (from Table 4.28.2), in ft/s (m/s)
- ΔT_b = mean operating temperature of the sprinkler, as determined in Section 4.8 [Operating Temperature (Liquid Bath)] minus the ambient temperature, in °F (°C)
- ΔT_g = actual gas (air) temperature minus the ambient temperature, in °F (°C)
- C = C-factor as determined in Section 4.27 [Conductivity (C-Factor)], in (ft/s)^{1/2} [(m/s)^{1/2}]

4.29 Sensitivity (Recessed, Flush, and Concealed Types)

4.29.1 Requirements

Recessed, flush and concealed residential sprinklers shall operate within the maximum response times as calculated in Section 4.29.2.A when tested as detailed in Section 4.29.2.B, in the least protrusive position possible.

Recessed, flush and concealed residential sprinklers which have been subjected to tests that require post-exposure sensitivity testing shall be tested at plunge tunnel conditions corresponding to a gas temperature of 387°F (197°C) and a velocity of 8.4 ft/s (2.56 m/s).

4.29.2 Test/Verification

A. The maximum response time shall be calculated using the combinations of RTI and C-factor shown in Table 4.29.1 and the plunge tunnel conditions detailed in Table 4.29.2 for the respective response category.

Table 4.29.1 RTI and C-Factor Combinations

<i>RTI</i>		<i>C-Factor</i>		<i>Offset Angle</i> (degrees)
(ft-s) ^{1/2}	[(m-s) ^{1/2}]	(ft/s) ^{1/2}	[(m/s) ^{1/2}]	
90	[50]	1.4	[0.8]	0
55	[30]	1.8	[1.0]	0
225	[125]	3.6	[2.0]	25

Table 4.29.2 Tunnel Conditions

<i>Response Category</i>	<i>Plunge Tunnel Gas Temperature</i>		<i>Plunge Tunnel Gas Velocity</i>		<i>Applied Vacuum</i> mm Hg
	°F	(°C)	ft/sec	(m/s)	
Quick	275	(135)	8.4	(2.56)	0.007
			11.5	(3.5)	0.007
	387	(197)	8.4	(2.56)	0.010
			11.5	(3.5)	0.010

The maximum permitted sprinkler operating times can be calculated using the following equation:

$$t_{\max} = \frac{-RTI \cdot \ln\left[1 - \frac{\Delta T_b (1 + C/u^{1/2})}{\Delta T_g}\right]}{u^{1/2} \cdot (1 + C/u^{1/2})}$$

Where:

- t_{\max} = maximum allowed response time of sprinkler, seconds
- RTI = Response Time Index from Table 4.29.1, (ft·s)^{1/2} [(m·s)^{1/2}]
- ΔT_b = upper temperature limit of the sprinkler (1.035 x nominal temperature rating) minus an average ambient temperature, °F (°C)
- C = C- factor from Table 4.29.1, (ft/s)^{1/2} [(m/s)^{1/2}]
- u = actual gas (air) velocity in the test section of the tunnel from Table 4.29.2, ft/s (m/s)
- ΔT_g = actual gas (air) temperature, corrected for radiation effects on the temperature sensing device, in the test section (see Table 4.29.2) minus the ambient temperature, °F (°C)

NOTE: the ambient temperature is considered to be 68°F (20°C) for calculation purposes.

- B. Compliance with the requirements for maximum operating time shall be determined by operating sprinkler samples in the FM Approvals plunge tunnel, using the modified plunge tunnel test plate described in Figure E-8.

The sprinklers shall be tested in both the best case orientation and the worst case orientation as if the sprinkler was a pendent sprinkler. For the worst case orientation, the angular offset shall be 25 degrees (see Table 4.29.1).

A vacuum in accordance with Table 4.29.2 shall be applied to and maintained in the upper enclosure of the modified plunge tunnel test plate (Figure E-8). The test shall be repeated three times at each condition to ensure accuracy and product repeatability.

4.30 Distribution

4.30.1 Requirements

A. Horizontal Surface (Floor)

When installed in accordance with the installation instructions and tested as detailed in Section 4.30.2.A.1, residential sprinklers shall be capable of distributing water over a horizontal surface such that the water collected in any 1 ft² (0.09 m²) collection pan within the design area shall be at least 0.02 gal/min/ft² (0.8 mm/min). The following exceptions apply:

1. Upright and pendent sprinklers - in each quadrant of the design area, the water collected in not more than four 1 ft² (0.09 m²) collection pans shall be at least 0.015 gal/min/ft² (0.6 mm/min).
2. Sidewall sprinklers - in each half (split along the sprinkler centerline) of the design area, the water collected in not more than eight 1 ft² (0.09 m²) collection pans shall be at least 0.015 gal/min/ft² (0.6 mm/min).

Sprinklers with factory painted or decorative finishes, such as plating, shall comply with the same performance criteria as those without such finishes.

B. Vertical Surface (Walls)

When installed in accordance with the installation instructions and tested as detailed in Section 4.30.2.B.2, residential sprinklers shall be capable of distributing water over a vertical surface as follows:

1. Walls within the design area shall be fully wetted to within 28 in. (711 mm) of the ceiling with the sprinkler discharging water at the specified design flow rate.
2. For square design areas, each wall within the design area shall be wetted with at least 5 percent of the total sprinkler discharge.
3. For rectangular coverage areas, the walls within the design area shall be wetted with at least 20 percent of the total sprinkler discharge. Each wall within the design area shall be wetted with an amount of water proportional to its length, in accordance with the following formula:

$$WW = 20\%(D/P)$$

Where:

- WW = required amount of water collected on a wall, in percent
 D = wall length, in feet
 P = total perimeter of coverage area, in feet

4.30.2 Test/Verification

A. Horizontal Surface (Floor)

Tests shall be conducted on an individual sprinkler using design flow rates and design areas specified in the manufacturer's installation instructions. If the manufacturer is seeking Approval at a discharge density less than 0.1 gal/min/ft² (4.1 mm/min), additional testing shall be conducted at a discharge density of 0.1 gal/min/ft² (4.1 mm/min) in order to determine the worst case discharge density for the purpose of fire testing.¹ Prior to distribution testing, the sprinkler shall be operated, using a suitable heat source, to remove the heat responsive assembly. The sprinkler deflector shall be located in its intended position as specified in the installation instructions. Each test shall be conducted for a period of 20 minutes.

1. Upright and pendent sprinklers - An open upright, pendent, recessed pendent, flush pendent, or concealed pendent residential sprinkler shall be installed in its intended position in a reducing pipe fitting having a nominal 1 in. (25 mm) inlet and an outlet the same size as the sprinkler inlet, and shall be supplied with water through nominal 1 in. piping.

Whenever possible, sprinklers shall be installed with the frame arms parallel to the branch line pipe. Sprinklers having designs which do not incorporate frame arms shall be oriented at the sole discretion of FM Approvals.

Upright residential sprinklers shall be installed directly into a reducing tee and located below a suspended ceiling. Unless deemed otherwise by FM Approvals, pendent residential sprinklers, including recessed, flush, and concealed types, shall be installed in a smooth, flat suspended ceiling and supplied with water from a branch line located above the ceiling.

¹ FM Global Loss Prevention Data Sheets 2-8N and 3-26 specify 0.1 gal/min/ft² (4.1 mm/min) as the minimum discharge density for residential sprinklers for the protection of light hazard occupancies. If requested, a product may receive FM Approval for discharge densities lower than 0.1 gal/min/ft² (4.1 mm/min) if all requirements of this Standard are met to the satisfaction of FM Approvals. In such a case, both the requested discharge density and 0.1 gal/min/ft² (4.1 mm/min) will be tested to determine which provides lower test results. The density producing the lower results will be used for Fire (Residential Enclosure) (Section 4.31).

For pendent, recessed pendent, flush pendent and concealed pendent residential sprinklers, the length of the nipple leading to the sprinkler fitting shall not be less than 10 in. (250 mm). In cases where adjustment of the distance between the deflector and the ceiling is possible, (e.g., recessed type), distribution tests shall be conducted at both extremes of deflector position.

Collector pans measuring 1 ft² (0.09 m²) shall be placed on the floor in one quadrant of the design area with the tops of the pans located 8 ft (2.4 m) below the ceiling (See Figure E-9). Water shall be collected for the test period and measured to verify compliance with the requirements in Section 4.30.1.A.1. The distribution test shall then be repeated with the sprinkler rotated 90 degrees about its vertical axis. If visual observation indicates a non-symmetrical distribution pattern, water shall be collected in the entire design area.

2. Sidewall sprinklers - An open horizontal sidewall, recessed horizontal sidewall, flush horizontal sidewall or concealed horizontal sidewall residential sprinkler shall be installed in its intended position in a reducing pipe fitting having a nominal 1 in. (25 mm) inlet and an outlet the same size as the sprinkler inlet, and shall be supplied with water through nominal 1 in. piping.

The sprinkler shall be installed under a smooth, flat ceiling which extends at least over the water collection pans. Unless deemed otherwise by FM Approvals, the sprinkler shall be mounted in a smooth, flat wall and supplied with water from a branch line located behind the wall.

The length of the nipple leading to the sprinkler fitting shall not be less than 10 in. (250 mm). In cases where adjustment of the distance between the deflector and the mounting wall is possible, (e.g., recessed type), distribution tests shall be conducted at both extremes of deflector position.

Collector pans measuring 1 ft² (0.09 m²) shall be placed on the floor in one half of the design area with the tops of the pans located 6 ft, 10 in. (2.08 m) below the ceiling (See Figure E-10). Water shall be collected for the test period and measured to verify compliance with the requirements in Section 4.30.2.A.2. If visual observation indicates a non-symmetrical distribution pattern, water shall be collected in the entire design area.

B. Vertical Surface (Walls)

Tests shall be conducted on an individual sprinkler using design flow rates and design areas specified in the installation instructions. If the manufacturer is seeking Approval at a discharge density less than 0.1 gal/min/ft² (4.1 mm/min), additional testing shall be conducted at a discharge density of 0.1 gal/min/ft² (4.1 mm/min) in order to determine the worst case discharge density for the purpose of fire testing.¹ Prior to distribution testing, the sprinkler shall be operated, using a suitable heat source, to remove the heat responsive assembly. The sprinkler deflector shall be located in its intended position as specified in the installation instructions. Each test shall be conducted for a period of 10 minutes.

An open residential sprinkler shall be installed in its intended position in a reducing pipe fitting having a nominal 1 in. (25 mm) inlet and an outlet the same size as the sprinkler inlet, and shall be supplied with water through nominal 1 in. piping.

¹ FM Global Loss Prevention Data Sheets 2-8N and 3-26 specify 0.1 gal/min/ft² (4.1 mm/min) as the minimum discharge density for residential sprinklers for the protection of light hazard occupancies. If requested, a product may receive FM Approval for discharge densities lower than 0.1 gal/min/ft² (4.1 mm/min) if all requirements of this Standard are met to the satisfaction of FM Approvals. In such a case, both the requested discharge density and 0.1 gal/min/ft² (4.1 mm/min) will be tested to determine which provides lower test results. The density producing the lower results will be used for Fire (Residential Enclosure) (Section 4.31).

Whenever possible, upright, pendent, recessed pendent, flush pendent, or concealed pendent sprinklers shall be installed with the frame arms parallel to the branch line pipe. Sprinklers having designs which do not incorporate frame arms shall be oriented at the sole discretion of FM Approvals.

Upright residential sprinklers shall be installed directly into a reducing tee and located below a suspended ceiling. Unless deemed otherwise by FM Approvals, pendent residential sprinklers, including recessed, flush, and concealed types, shall be installed in a smooth, flat suspended ceiling and supplied with water from a branch line located above the ceiling. Horizontal sidewall residential sprinklers, including recessed, flush, and concealed types, shall be mounted in a smooth, flat wall and supplied with water from a branch line located behind the wall.

For pendent and horizontal sidewall sprinklers, including recessed, flush and concealed types, the length of the nipple leading to the sprinkler fitting shall not be less than 10 in. (250 mm). In cases where adjustment of the distance between the deflector and the ceiling or wall is possible, (e.g., recessed type), distribution tests shall be conducted at both extremes of deflector position.

Walls shall be erected to represent the length and width of the design area (See Figure E-11). The walls shall be constructed of nonporous materials or covered with a layer of nonporous material (e.g. plastic sheeting) so that water impinging on the walls is not absorbed.

Collector pans measuring 1 ft² (0.09 m²) shall be placed on the floor against the walls along the length and width of the design area. The tops of the pans shall be located 6 ft, 10 in. (2.08 m) below the ceiling (See Figure E-11) and shall be shielded to within 2 in. (51 mm) of the wall to prevent sprinkler discharge from directly entering the pans. Provisions shall be made to ensure that water impinging on the walls is channeled into the pans and prevented from running between the pans and the wall.

Water shall be collected for the test period and measured, and walls shall be visually inspected for wetting to verify compliance with the requirements in Section 4.30.2.B. At the sole discretion of FM Approvals, a permeable paper covering may be applied to the walls to facilitate visual verification of wetting.

For upright, pendent, recessed pendent, flush pendent, and concealed pendent sprinklers, the distribution test shall then be repeated with the sprinkler rotated 90 degrees about its vertical axis. If visual observation indicates a non-symmetrical distribution pattern, additional tests may be required at the sole discretion of FM Approvals.

4.31 Fire (Residential Enclosure)

4.31.1 Requirements

When installed in accordance with the installation instructions and fire tested as described in Section 4.31.2, residential sprinklers shall be capable of maintaining control within the following limits:

- A. At the two thermocouple locations 3 in. (76 mm) below the ceiling, as illustrated in Figures E-12 to E-14, the temperature shall not exceed 600°F (316°C).
- B. The temperature at the thermocouple location 5.25 ft (1.6 m) above the floor, as illustrated in Figures E-12 to E-14, shall not exceed 200°F (93°C).
- C. The temperature at the location described in Section 4.31.2.B. shall not exceed 130°F (54°C) for a continuous period of more than 2 minutes.
- D. At the location illustrated in Figures E-12 to E-14, the temperature of the ceiling material 1/4 in. (6.4 mm) above the finished ceiling surface shall not exceed 500°F (260°C).

- E. During the test period, not more than two sprinklers shall operate, and the sprinkler farthest from the fuel source shall not operate.

See Figure E-12 (upright and pendent sprinklers, including flush, recessed, and concealed pendent sprinklers) or Figures E-13 and E-14 (sidewall sprinklers, including flush, recessed, and concealed sidewall sprinklers) for temperature measuring locations.

4.31.2 Test/Verification

Residential sprinklers shall be subjected to the tests specified in this Section using design flow rates and design areas specified in the manufacturer's installation instructions. If the manufacturer is seeking Approval at a discharge density less than 0.1 gal/min/ft² (4.1 mm/min) and the results of distribution tests at the lower density surpass the results measured at 0.1 gal/min/ft² (4.1 mm/min),¹ the fire test may be repeated a discharge density of 0.1 gal/min/ft² (4.1 mm/min).¹ The decision to conduct this test is at the sole discretion of FM Approvals. If multiple temperature ratings are submitted, tests shall be conducted on samples of each nominal temperature rating (see exception later in this Section).

A. Test Enclosure

Upright and pendent sprinklers, including flush, recessed, and concealed pendent sprinklers, shall be subjected to the fire test arrangement illustrated in Figure E-12. The test enclosure width shall be equal to the rated sprinkler coverage width. The test enclosure length shall be equal to twice the rated coverage length. The test enclosure shall have a nominal 8 ft (2.4 m) high ceiling.

Sidewall sprinklers, including flush, recessed, and concealed sidewall sprinklers, shall be subjected to both fire test arrangements illustrated in Figures E-13 and E-14. The test enclosure width shall be equal to the rated sprinkler coverage length. The test enclosure length shall be equal to 1-1/2 times the rated sprinkler coverage width plus 9 ft (2.7 m). The test enclosure shall have a nominal 8 ft (2.4 m) high ceiling.

The test enclosure ceiling shall be covered with acoustical panels or gypsum board attached to furring strips. Acoustical panels shall be used in the 4 ft x 4 ft (1.2 m x 1.2 m) area directly over the fire source and shall measure 2 ft x 4 ft (0.6 m x 1.2 m). The panels shall be 5/8 in. (15.9 mm) thick, have a density of 13.5 lb/ft³ ± 1.5 lb/ft³ (216 kg/m³ ± 24 kg/m³). For each fire test, new acoustical panels shall be installed in the 4 ft x 4 ft (1.2 m x 1.2 m) area directly over the fire source.

The test enclosure shall have two door openings located on opposite walls. Each opening shall be 7 ft 4 in. (2.2 m) high, resulting in an 8 in. (200 mm) lintel above the doorway. The width and position of each opening shall be as specified in Figures E-12 to E-14.

B. Fuel Package

Sheets of Douglas fir three-ply paneling measuring 4 ft x 8 ft (1.2 m x 2.4 m) shall cover two of the test enclosure walls at a common corner. The paneling shall be 1/4 in. (6 mm) thick with each ply constructed of Douglas fir, and shall conform to the requirements specified in Table 4.31.1. The paneling shall be conditioned at 70°F ± 5 °F (21 °C ± 2.8 °C) and 50 percent ± 10 percent relative humidity for at least 72 hours prior to test. One sheet shall be attached to each wall at the common corner (see Figure E-15). The sheets shall be attached to 0.5 in. (12.7 mm) thick wood furring strips using only enough noncombustible fasteners to ensure the sheets do not sag, bow or otherwise separate from the furring strips.

¹ FM Global Loss Prevention Data Sheets 2-8N and 3-26 specify 0.1 gal/min/ft² (4.1 mm/min) as the minimum discharge density for residential sprinklers for the protection of light hazard occupancies. If requested, a product may receive FM Approval for discharge densities lower than 0.1 gal/min/ft² (4.1 mm/min) if all requirements of this Standard are met to the satisfaction of FM Approvals. In such a case, both the requested discharge density and 0.1 gal/min/ft² (4.1 mm/min) will be tested to determine which provides lower test results. The density producing the lower results will be used for Fire (Residential Enclosure) (Section 4.31).

Table 4.31.1 - Required Burning Characteristics of Douglas Fir Three-Ply Paneling

<i>Property</i>	<i>Test Method</i>	<i>Requirement</i>
Critical Heat Flux	Standard Test Methods for Measurement of Synthetic Polymer Material Flammability Using A Fire Propagation Apparatus (FPA) - ASTM E 2058 - 02a with imposed radiant heat fluxes between 10 and 60 kW/m ²	11 ± 2.2 kW/m ²
Thermal Response Parameter		220 ± 50 kW-s ^{1/2} /m ²
Chemical Heat of Combustion	Standard Test Methods for Measurement of Synthetic Polymer Material Flammability Using A Fire Propagation Apparatus (FPA) - ASTM E 2058 - 02a with an imposed heat flux of 50 kW/m ²	11 ± 1 kJ/g
Peak Heat Release Rate		450 ± 45 kW/m ²

The fire source shall consist of a wood crib and simulated furniture. See Figure E-12 (upright and pendent sprinklers, including flush, recessed, and concealed pendent sprinklers) or Figures E-13 and E-14 (sidewall sprinklers, including flush, recessed, and concealed sidewall sprinklers) for placement of the fire source in the test enclosure.

The wood crib shall be dimensioned approximately 12 in. x 12 in. x 6 in. high (300 mm x 300 mm x 150 mm) and shall consist of four layers of lumber (see Figure E-15). Each layer shall consist of four 12 in. (300 mm) long pieces of 2 in. x 2 in. trade size [approximately 1-1/2 in. x 1-1/2 in. (38 mm x 38 mm) actual size] kiln-dried spruce or fir lumber. The lumber in each layer shall be placed at right angles to the adjacent layers. Individual wood members in each layer shall be evenly spaced along the 12 in. length and stapled to adjacent layers. The crib weight shall be 5.5 lb to 7 lb (2.5 kg to 3.2 kg).

After assembly, the wood crib shall be conditioned at a temperature of 220°F ± 10°F (104°C ± 5°C) for 24 to 72 hours. Following the conditioning period, the crib shall be placed in a plastic bag and stored at room temperature for at least 4 hours prior to testing.

The wood crib shall be placed on top of a nominal 12 in. x 12 in. x 4 in. high (300 mm x 300 mm x 100 mm), 12 gauge [0.10 in. (2.5 mm) thick] steel pan (see Figure E-15) located on the floor in a corner of the test enclosure. The wood crib shall be centered on the pan and positioned 2 in. (51 mm) from each wall (see Figure E-15).

The simulated furniture shall be made up of foam cushions attached to a plywood backing and supported by a steel frame. The cushions shall consist of two pieces of uncovered pure polypropylene oxide polyol, polyether foam having a density of 1.70 lb/ft³ to 1.90 lb/ft³ (27.2 kg/m³ to 30.4 kg/m³) and measuring 34 in. wide x 30 in. high x 3 in. thick (860 mm wide x 60 mm high x 76 mm thick). Five samples of the polyether foam shall be tested for burning characteristics and the average properties shall conform to the requirements specified in Table 4.31.2.

Each foam cushion shall be fixed to a 35 in. x 31 in. (890 mm x 790 mm), nominal 1/2 in. (12.7 mm) thick plywood backing using an aerosol urethane foam adhesive. Location of the foam on the plywood shall result in a 0.5 in. (13 mm) gap between the sides of the cushion and the sides of the backing, and a 1 in. (25 mm) gap between the bottom of the cushion and the bottom of the backing as illustrated in Figure E-15.

The foam cushion and plywood backing assembly shall be conditioned at 70°F ± 5°F (21°C ± 2.8°C) and 50 percent ± 10 percent relative humidity for at least 24 hours prior to testing. Before each test, the foam and plywood backing assembly shall be placed in a steel support frame that holds the assembly in the vertical position.

Table 4.31.2 - Required Burning Characteristics of Polyether Foam

<i>Property</i>	<i>Test Method</i>	<i>Requirement</i>
Chemical Heat of Combustion	Standard Test Methods for Measurement of Synthetic Polymer Material Flammability Using a Fire Propagation Apparatus (FPA), ASTM E 2058-02a, at 30 kW/m ²	22 kJ/g ± 3 kJ/g
Peak Heat Release Rate (HRR)		230 kW/m ² ± 50 kW/m ²

The simulated furniture, wood crib, and steel pan shall be placed on a piece of cement board sheathing or equivalent noncombustible sheathing material measuring 4 ft x 4 ft x 1/4 in. thick (1.2 m x 1.2 m x 6 mm thick) as illustrated in Figure E-15. For each test, a new or dry sheathing shall be used.

C. Sprinklers

Three new residential sprinklers shall be installed in the test enclosure for each fire test. Two sprinklers shall be installed at the rated spacing dimensions specified in the manufacturer's installation instructions. The third sprinkler (or monitoring sprinkler) shall be installed near the doorway furthest from the fire. The heat responsive element and temperature rating of all three sprinklers shall be identical.

EXCEPTION: If requested by the manufacturer, and at the sole discretion of FM Approvals, tests may be conducted with the first two sprinklers having the highest nominal temperature rating and the monitoring sprinkler having a lower nominal temperature rating. Such test conditions are intended to enable fire testing of two nominal temperature ratings at once.

For upright and pendent sprinklers, including flush, recessed, and concealed pendent sprinklers, the monitoring sprinkler shall be installed in the pendent position such that the center of the heat responsive element is 2 in. (51 mm) below the ceiling.

For sidewall sprinklers, including flush, recessed, and concealed sidewall sprinklers, the monitoring sprinkler shall be installed in the most protrusive position possible such that the center of the heat responsive element is 4 in. (102 mm) below the ceiling.

The two residential sprinklers nearest the fire source (the operating sprinklers) shall be installed in reducing pipe fittings having a 1 in. (25 mm) inlet and an outlet the same size as the sprinkler inlet and shall be supplied with water through 1 in. (25 mm) piping. The length of the nipple leading to the sprinkler fitting shall not be less than 10 in. (250 mm). See Figures E-9 and E-10 (which illustrate the water delivery piping for Distribution testing, but is the same arrangement for Fire testing).

For upright and pendent sprinklers, the two operating sprinklers shall be installed with their deflectors located 3 in. (76 mm) below the ceiling, or as otherwise specified in the installation instructions. Recessed, flush and concealed sprinklers shall be installed in their intended location, in the least protrusive position possible in accordance with the installation instructions.

Upright and pendent sprinklers, including flush, recessed, and concealed pendent sprinklers, shall be tested with the operating sprinklers orientated such that the frame arms or deflector pins are parallel to the short wall of the test enclosure. The test shall then be repeated with the operating sprinklers rotated 90 degrees about their vertical axes.

Recessed, flush or concealed sprinklers having vented escutcheons shall be installed and tested in both a manner that does not inhibit airflow through the escutcheons (unblocked) and in a manner that inhibits airflow through the escutcheons (blocked). The blocked condition shall be achieved by placing a 36 in. x 15-1/2 in. x 8 in. thick (910 mm x 390 mm x 200 mm thick) section of R-25 fiberglass insulation over the portion of the sprinkler which is located above the ceiling or behind the wall. The insulation shall be installed in a simulated wood joist channel measuring 36 in. x 16 in. x 10 in. (910 mm x 400 mm x 250 mm). A length of trade size 2 in. by 4 in. [approximately 1-1/2 in. x 3-1/2 in. (38 mm x 89 mm) actual size] lumber shall be secured to the inside of each channel end over ends of the insulation to help retain the insulation.

For sidewall sprinklers, the test shall be conducted with the two operating sprinklers installed such that their deflectors are located 4 in. (100 mm) below the ceiling. The test shall be repeated with the two operating sprinklers installed such that their deflectors are located at the maximum permitted distance below the ceiling as specified in the manufacturer's installation instructions.

D. Test Conditions and Instrumentation

Using a bypass line, water flow shall be preset to the minimum design flow rate specified in the manufacturer's installation instructions for the design area being tested.

Prior to each test, the room shall be dried and all water from previous testing shall be removed. There shall be no visible water on the floor, ceiling, or walls. The air in the test enclosure shall be conditioned to an ambient temperature of 80°F ± 5°F (27°C ± 3°C) as measured at the thermocouple located 3 in. (76 mm) below the ceiling (see Figures E-12 to E-14).

No. 20 AWG (0.52 mm) chromel-alumel thermocouples or the equivalent shall be used to monitor the temperatures at each thermocouple location. Temperatures shall be continuously recorded during the test period. To prevent water impingement from affecting thermocouple measurements, thermocouples subject to water spray shall be protected with a shield which is large enough to cover the thermocouple ends. The shield shall be noncombustible, water impermeable material formed into an umbrella shape and attached to the wire above each thermocouple end.

E. Conducting the Test

Two 6 in. x 2 in. x 1-1/4 in. (150 mm x 50 mm x 30 mm) bricks shall be placed on the cement board sheathing against the foam cushions, ends flush with the edge of the foam. Two cotton wicks, approximately 6 in. (6.4 mm) long and 1/4 in. (6.4 mm) in diameter, shall be soaked in commercial grade heptane and placed on the bricks, ends flush with the edge of the bricks and foam (see Figure E-15).

16 fl. oz. (0.47 L) of water and eight fl. oz. (0.24 L) of commercial grade heptane shall be placed in the steel pan which supports the wood crib.

The heptane in the pan shall be ignited using a suitable open flame heat source. Immediately following ignition of heptane in the pan, the heptane soaked cotton wicks shall be ignited.

The fire test shall be conducted for a period of 30 minutes after the ignition of the wood crib.

EXCEPTION: If, after 10 minutes, all the combustibles have been extinguished, or if only the wood crib is sustaining combustion, the test shall be terminated.

Throughout the test, water flow to the operating sprinklers shall be maintained at the minimum design flow rate specified in the manufacturer's installation instructions for the design area being tested.

When the manufacturer's installation instructions specify sprinkler design areas in excess of 12 ft x 12 ft (3.7 m x 3.7 m), the sprinklers shall be tested to the requirements in this section in an enclosure sized to correspond to a 12 ft x 12 ft (3.7 m x 3.7 m) design area (see Figures E-12 to E-14 and Section 4.31.2 A), at the same minimum design flow rate as the next larger design area, or a lesser flow rate, as specified in the manufacturer's installation instructions.

4.32 Additional Tests

Additional tests, including supplementary full scale fire tests, may be required, depending on design features, results of any tests, material application, or to verify the integrity and reliability of the sprinkler, at the sole discretion of FM Approvals.

Unexplainable failures shall not be permitted. A re-test shall only be permitted at the sole discretion of FM Approvals and with adequate technical justification of the conditions and reasons for failure, otherwise, a design change shall be required.

5. OPERATIONS REQUIREMENTS

A quality control program is required to assure that subsequent residential sprinklers produced by the manufacturer at an authorized location shall present the same quality and reliability as the specific residential sprinklers examined. Design quality, conformance to design, and performance are the areas of primary concern. Design quality is determined during the Approval examination and tests, and is covered in the Approval Report. Conformance to design is verified by control of quality and is covered in the Facilities and Procedures Audit (F&PA). Quality of performance is determined by field performances and by periodic re-examination and testing.

5.1 Demonstrated Quality Control Program

5.1.1 The manufacturer shall demonstrate a quality assurance program which specifies controls for at least the following areas:

- Existence of corporate quality control guidelines;
- Incoming quality assurance, including testing;
- In-process quality assurance, including testing;
- Final inspection and tests;
- Equipment calibration;
- Drawing and change control;
- Packaging and shipping;
- Handling and disposition of non-conformance materials.
- in order to assure adequate traceability of materials and products, the manufacturer shall maintain records of all quality control tests performed, for a minimum period of two years from the date of manufacture.

5.1.2 Documentation/Manual

There shall exist an authoritative collection of procedures and policies. Such documentation shall provide an accurate description of the quality management system while serving as a permanent reference for implementation and maintenance of that system. The system shall require that sufficient records are maintained to demonstrate the required quality and verify operation of the quality system.

5.1.3 Drawing and Change Control

The manufacturer shall establish a system of product configuration control that shall allow no unauthorized changes to the product. Changes to critical documents, identified in the Approval Report, shall be reported to, and authorized by, FM Approvals prior to implementation for production. The manufacturer shall assign an appropriate person or group to be responsible for reporting proposed changes to FM Approved or Listed products to FM Approvals before implementation. The manufacturer shall notify FM Approvals of changes in the product or of persons responsible for keeping FM Approvals advised by means of FM Approvals Form 797, Approved Product/ Specification-Tested Revision Report or Address/ Main Contact Change Report. Records of all revisions to all FM Approved products shall be maintained.

5.2 Facilities and Procedures Audit (F&PA)

5.2.1 An audit of the manufacturing facility is part of the Approval investigation to verify implementation of the quality control program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to insure a consistently uniform and reliable product. Initial inspections of facilities already producing similar products may be waived at the discretion of FM Approvals.

5.2.2 Unannounced follow-up inspections shall be conducted at least annually by FM Approvals, or its designate, to determine continued compliance. More frequent audits may be required by FM Approvals.

5.2.3 The client shall manufacture the product or service only at the location(s) audited by FM Approvals and as specified in the Approval Report. Manufacture of products bearing the FM Approvals Certification Mark is not permitted at any other locations without prior written authorization by FM Approvals.

5.3 Manufacturer's Responsibilities

The manufacturer shall notify FM Approvals of changes in product construction, design, components, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation of such changes.

5.4 Manufacturing and Production Tests

For each of the following requirements, records of testing shall be maintained for a minimum of two years.

5.4.1 Test Requirement No. 1 - Hydrostatic Pressure

The manufacturer shall pressure test 100 percent of production to a hydrostatic pressure, or equivalent, of 500 psi (34.5 bar) for 2 seconds.

5.4.2 Test Requirement No. 2 - Operating Temperature

The manufacturer shall perform periodic tests for operating temperature of glass bulbs and fusible elements.

5.4.3 Test Requirement No. 3 - Element Strength

The manufacturer shall perform periodic tests for operating element strength.

5.4.4 Test Requirement No. 4 - Glass Bulb Integrity

The manufacturer shall test 100 percent of the glass bulb sprinklers to ensure that the glass bulb has not been damaged during assembly.

APPENDIX A: Units of Measurement

AREA:	in ² - "square inches" (mm ² - "square millimeters") mm ² = in ² x 6.4516 x 10 ² ft ² - "square feet" (m ² - "square meters") m ² = ft ² x 0.09292
CONDUCTIVITY (C-FACTOR):	(ft/s) ^{1/2} - "square root of feet per second" ([m/s] ^{1/2} - "square root of meters per second") (m/s) ^{1/2} = (ft/s) ^{1/2} x 0.552
DISCHARGE COEFFICIENT (K-FACTOR):	gal/min/(psi) ^{1/2} - "gallons per minute per square root of pounds per square inch" (L/min/(bar) ^{1/2} - "liters per minute per square root of bar") L/min/(bar) ^{1/2} = gal/min/(psi) ^{1/2} x 14.414
ENERGY:	BTU - "British thermal units" (J - "joules") J = BTU x 1.0551 x 10 ³
FLOW:	gal/min - "gallon per minute" (L/min - "liters per minute") L/min = gal/min x 3.7854
FORCE:	lb - "pounds" (N - "newtons") N = lb x 4.4482
FREQUENCY:	Hz - "hertz" (also the SI unit)
HEAT RELEASE RATE:	BTU/min - "British thermal units per minute" (kW - "kilowatts") kW = BTU/min x 0.0176 BTU/min - "British thermal units per minute" (MW - "megawatts") MW = BTU/min x 0.0000176 kBTU/min = BTU/min x 1000 MW = kBTU/min x 0.0176
LENGTH:	in. - "inches" (mm - "millimeters") mm = in. x 25.4 ft - "feet" (m - "meters") m = ft x 0.3048
LIQUID VOLUME:	gal - "gallons" (L - "liters") L = gal x 3.7854 gal - "gallons" (fl. oz. - "fluid ounces") fl. oz. = gal x 0.0078125
MASS:	lb - "pounds" (kg - "kilograms") kg = lb x 0.454
PRESSURE:	psi - "pounds per square inch" (bar - "bar") bar = psi x 0.06895 psi - "pounds per square inch" (kPa - "kilopascals") kPa = psi x 6.895 bar - "bar" (kPa - "kilopascals") kPa = bar x 100 psi - "pounds per square inch" (inHg - "inches of mercury") inHg = psi x 2.0358 bar - "bar" (inHg - "inches of mercury") inHg = bar x 29.53

RESPONSE TIME INDEX (RTI):	$(\text{ft}\cdot\text{s})^{1/2}$ - "square root of foot seconds" [$(\text{m}\cdot\text{s})^{1/2}$ - "square root of meter seconds"] $(\text{m}\cdot\text{s})^{1/2} = (\text{ft}\cdot\text{s})^{1/2} \times 0.552$
TEMPERATURE:	$^{\circ}\text{F}$ - "degrees Fahrenheit" ($^{\circ}\text{C}$ - "degrees Celsius") $^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times 0.556$
TORQUE (MOMENT):	$\text{lb}\cdot\text{ft}$ - "pound-feet" ($\text{N}\cdot\text{m}$ - "newton-meters") $\text{N}\cdot\text{m} = \text{lb}\cdot\text{ft} \times 1.356$
VOLUME PER UNIT AREA:	$\text{gal}/\text{min}/\text{ft}^2$ - "gallons per minute per square feet" (mm/min - "millimeters per minute") $\text{mm}/\text{min} = 40.75 \times \text{gal}/\text{min}/\text{ft}^2$

APPENDIX B: Tolerances

Unless otherwise stated, the following tolerances shall apply:

Angle	$\pm 2^\circ$
Frequency (Hz)	± 5 percent of value
Length	± 2 percent of value
Volume	± 5 percent of value
Rotation	± 1 RPM
Pressure	± 3 percent of value
Temperature	± 5 percent of value
Time	+ 5/-0 seconds
	+ 0.1/-0 minutes
	+ 0.1/-0 hours
	+ 0.25/-0 days

Unless stated otherwise, all tests shall be carried out at a room (ambient) temperature of $68 \pm 9^\circ\text{F}$ ($20 \pm 5^\circ\text{C}$).

APPENDIX C: FM Approvals Certification Marks

FM Approvals certifications marks are to be used only in conjunction with products or services that have been FM Approved by FM Approvals and in adherence with usage guidelines.



FM APPROVED mark:

Authorized by FM Approvals as a certification mark for any product that has been FM Approved. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.



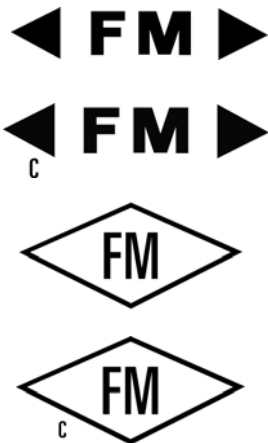
FM APPROVED mark with "C" only:

Authorized by FM Approvals as a certification mark for any product that has been evaluated by FM Approvals in accordance with Canadian codes and standards. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.



FM APPROVED mark with "C" and "US":

Authorized by FM Approvals as a certification mark for any product that has been evaluated by FM Approvals in accordance with US and Canadian codes and standards. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.



Cast-On FM APPROVALS marks:

Where reproduction of the FM APPROVED mark described above is impossible because of production restrictions, use these modified versions of the FM APPROVED mark. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable.

Downloadable art and other FM Approvals resources are available by visiting our Web site at www.fmapprovals.com

FM Approvals Certification Marks

Usage Guidelines

- All FM Approvals certification marks are the sole property of FM Approvals LLC (“FM Approvals”) and are registered or the subject of applications for registration in the United States and many other countries. They are for use only according to these guidelines.
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- No FM Approvals certification mark or aspect thereof may be incorporated as part of a business name, Internet domain name, or brand name/trademark for products/product lines. This includes both design aspects (the FM Approvals “diamond,” etc.) and word aspects (“FM,” “Approved,” etc.). The use of any FM Approvals certification mark as a trademark is strictly prohibited.
- The Approval Standard number or class number may not be incorporated as part of a business name, Internet domain name, or brand name/trademark for products/product lines. For example, a company may not say “ABC Company’s 4100 Fire Door is FM Approved”; the proper terminology is, “ABC Company’s Fire Door is FM Approved per Approval Standard 4100.”
- FM Approvals certification marks, except for the FM Approvals Quality System Registration mark, may not be used on business stationery/cards/signage because this could mischaracterize the relationship with FM Approvals. Additionally, these items should not reference any FM Approvals certification mark.
- Products or services may not be marketed under any mark or name similar to “FM Global,” “FM Approvals” or any of the FM Approvals certification marks. Further, products or services may not be marketed to imply a relationship beyond the scope of any Approval made by FM Approvals.
- When an FM Approvals certification mark is used in advertising material or on product packaging, all material must reflect the specific circumstances under which the product was FM Approved. The material must clearly differentiate between products that are FM Approved and those that are not, and may not, in any way, imply a more substantial relationship with FM Approvals.
- A company may not reference the intent to submit a product for Approval or the expectation that a company will have a certain product FM Approved in the future. For example, a company may not state, “Approval by FM Approvals pending” or “Approval by FM Approvals applied for.”
- FM Approvals certification marks should not be preceded or followed by a qualifier that indicates a degree of certification or acceptability. For example, “exceeds,” “first” or “only” may not be used to qualify any FM Approvals certification mark.
- Only original artwork issued by FM Approvals should be used. The FM Approvals certification marks should not be altered in any way other than to resize the artwork proportionately. Unacceptable uses of the marks include, but are not limited to, adding/deleting wording or artwork, reducing the artwork to an illegible size, animation or distortion.
- The text of the FM Approvals certification marks may not be translated into any language other than English.
- FM Approvals certification marks must appear in a size and location that is readily identifiable, but less prominent than the name of the owner of the certification or the manufacturer/seller/distributor of the certified products.

APPENDIX D: Tolerance Limit Calculations

Utilizing the data obtained as described in Sections 4.2.2 and 4.3.2(B), the mean and standard deviation for the assembly load and the bulb strength shall be calculated using the following equation:

$$\sigma_{n-1} = \left(\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1} \right)^2$$

Where:

- σ_{n-1} = standard deviation
- \bar{x} = sample mean
- x_i = individual values of each sample tested
- n = number of samples tested

Based upon the number of sprinklers or bulbs tested (n), a value, γ , shall be selected from Table D1 where the degree of confidence is 0.99 and the proportion of samples is 0.99.

Table D1. γ Factors for One-Sided Tolerance Limits For Normal Distributions (99 Percent of Samples)

n	γ	n	γ	n	γ
10	5.075	17	4.038	24	3.638
11	4.828	18	3.961	25	3.601
12	4.633	19	3.893	30	3.446
13	4.472	20	3.832	35	3.334
14	4.336	21	3.776	40	3.250
15	4.224	22	3.727	45	3.181
16	4.124	23	3.680	50	3.124

Tolerance limits shall then be calculated as follows:

$$LTL = \bar{x}_B - \gamma_B \sigma_{(n-1)B}$$

$$ULTL = \bar{x}_S + \gamma_S \sigma_{(n-1)B}$$

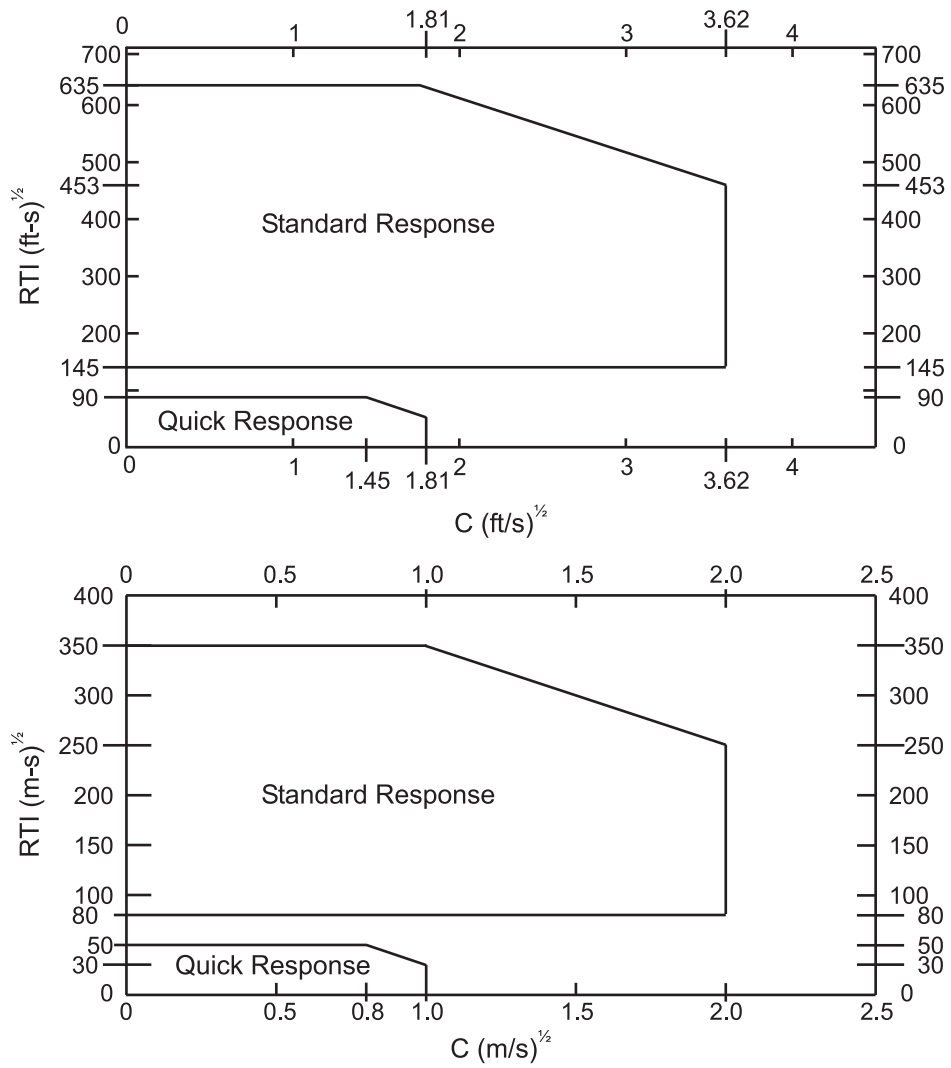
Where:

- LTL = lower tolerance limits for bulb strength
- UTL = upper tolerance limit for sprinkler assembly load
- \bar{x}_B = mean bulb strength
- γ_B = bulb strength factor (γ) from Table D1
- $\sigma_{(n-1)B}$ = sample unbiased standard deviation for the bulb
- \bar{x}_S = mean assembly load
- $\sigma_{(n-1)S}$ = sample unbiased standard deviation for the assembly load
- γ_S = assembly load factor (γ) from Table D1

Compliance with the requirement shall be confirmed if $LTL > 2 \times UTL$.

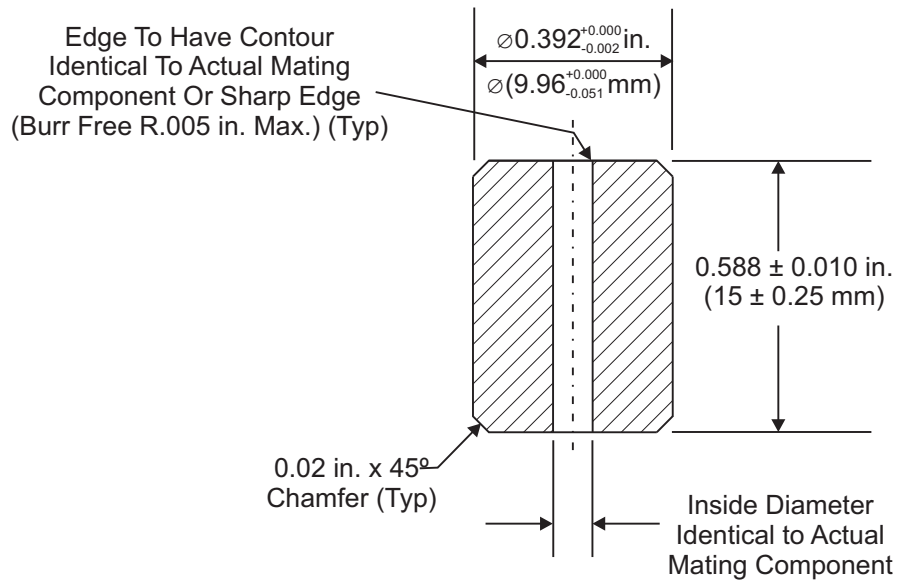
Outliers may be discarded from the sample base utilizing appropriate statistical techniques at the discretion of FM Approvals.

APPENDIX E: Figures

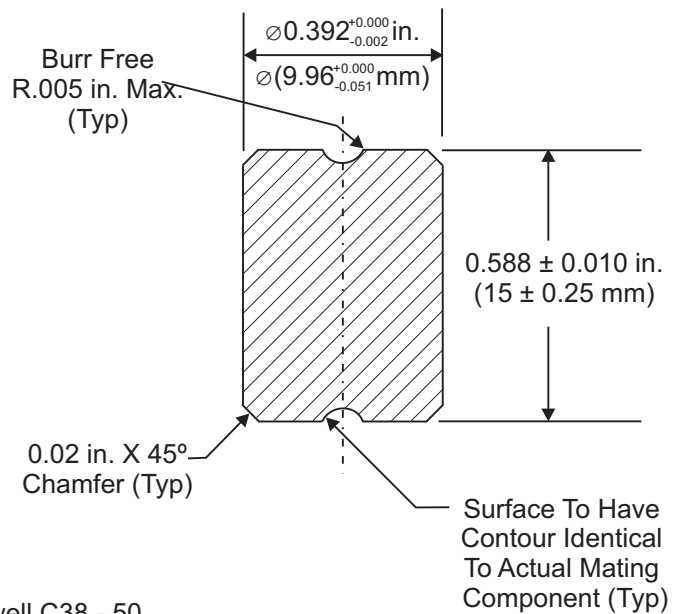


E-1: RTI and C-Factor Limits for Best Case Orientation

For Designs with Line Contact:



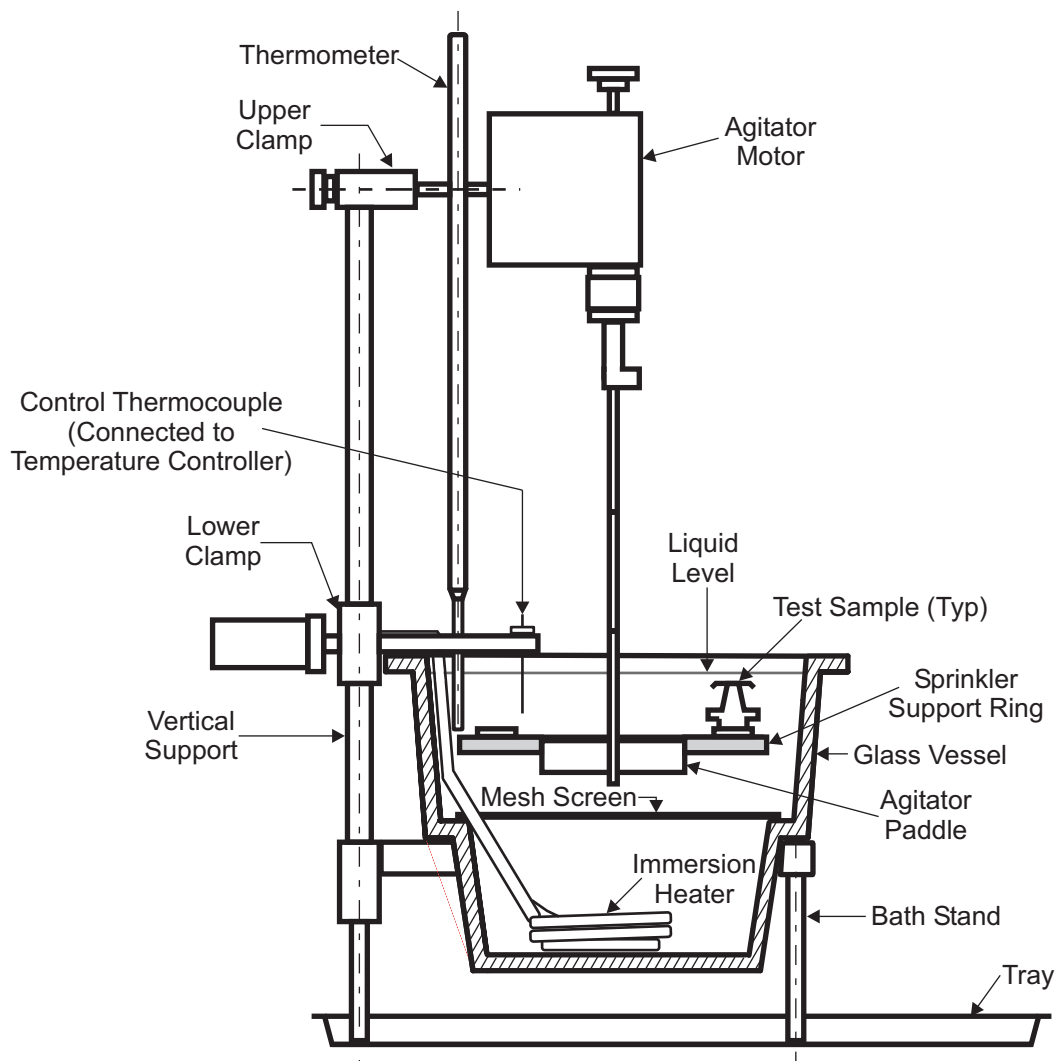
Or: For Designs with Surface Contact:



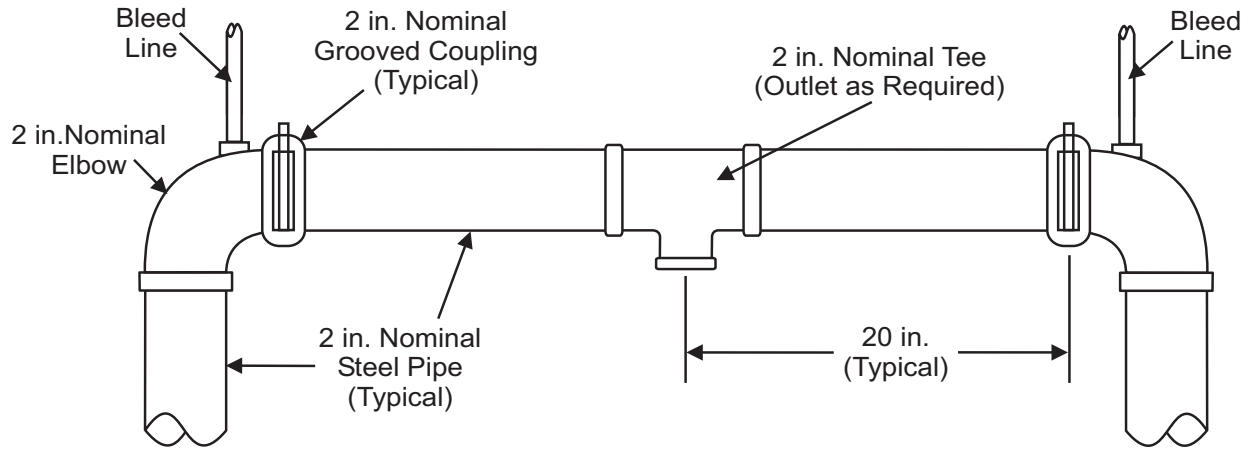
REQUIRED:

- * Material - Hardened Steel, Rockwell C38 - 50
- * Markings - Manufacturer, Bulb Size, Seat Diameter

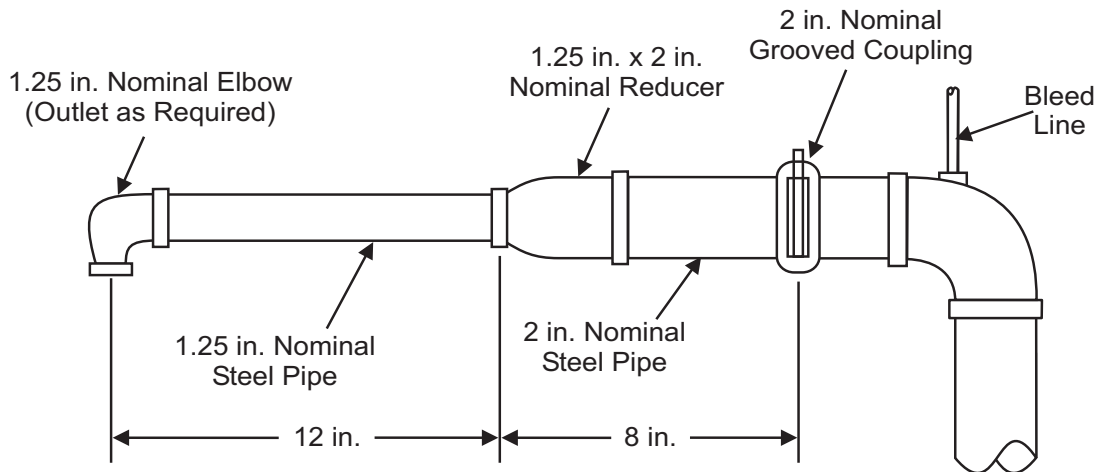
E-2: Bulb Crush Inserts for Strength of Element Test



E-3: Operating Temperature (Liquid Bath) Typical Test Setup



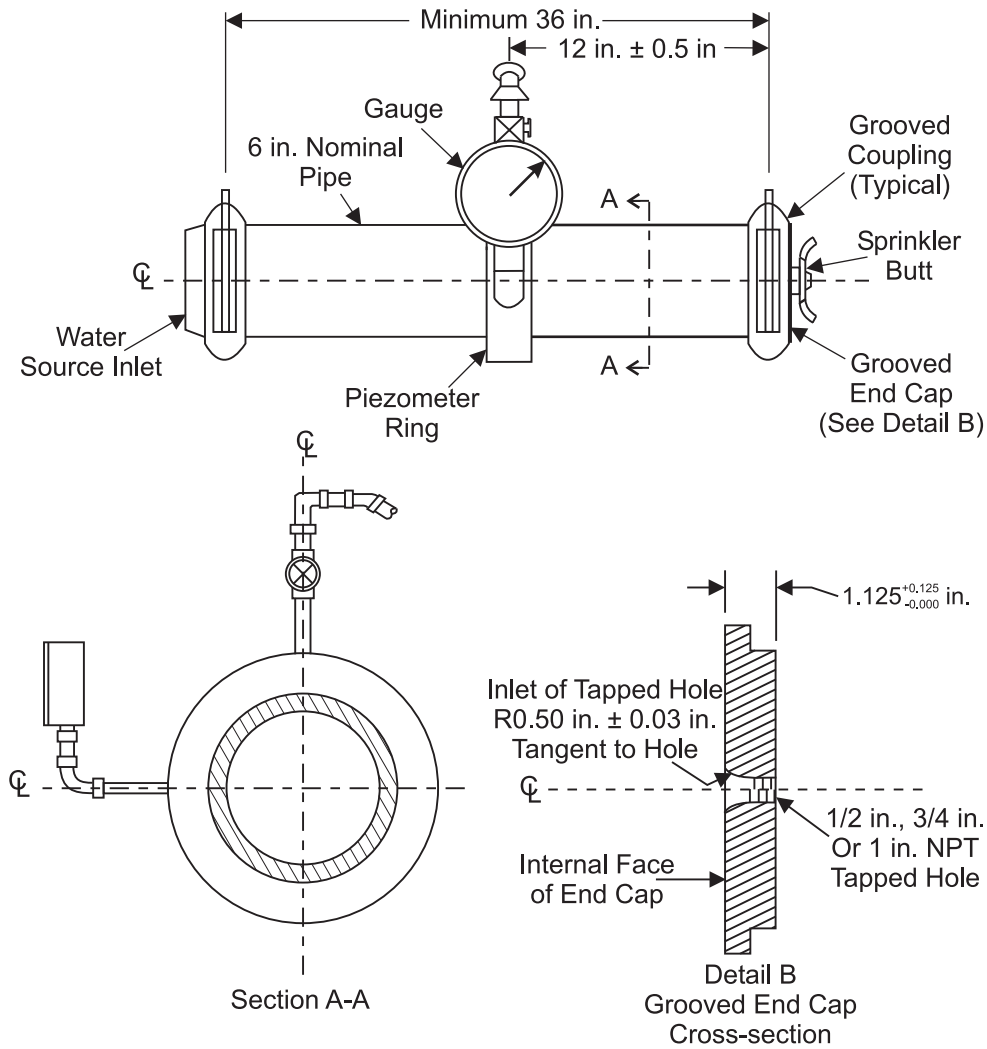
Test Apparatus for Double-Fed Flow



Test Apparatus for Single-Fed Flow

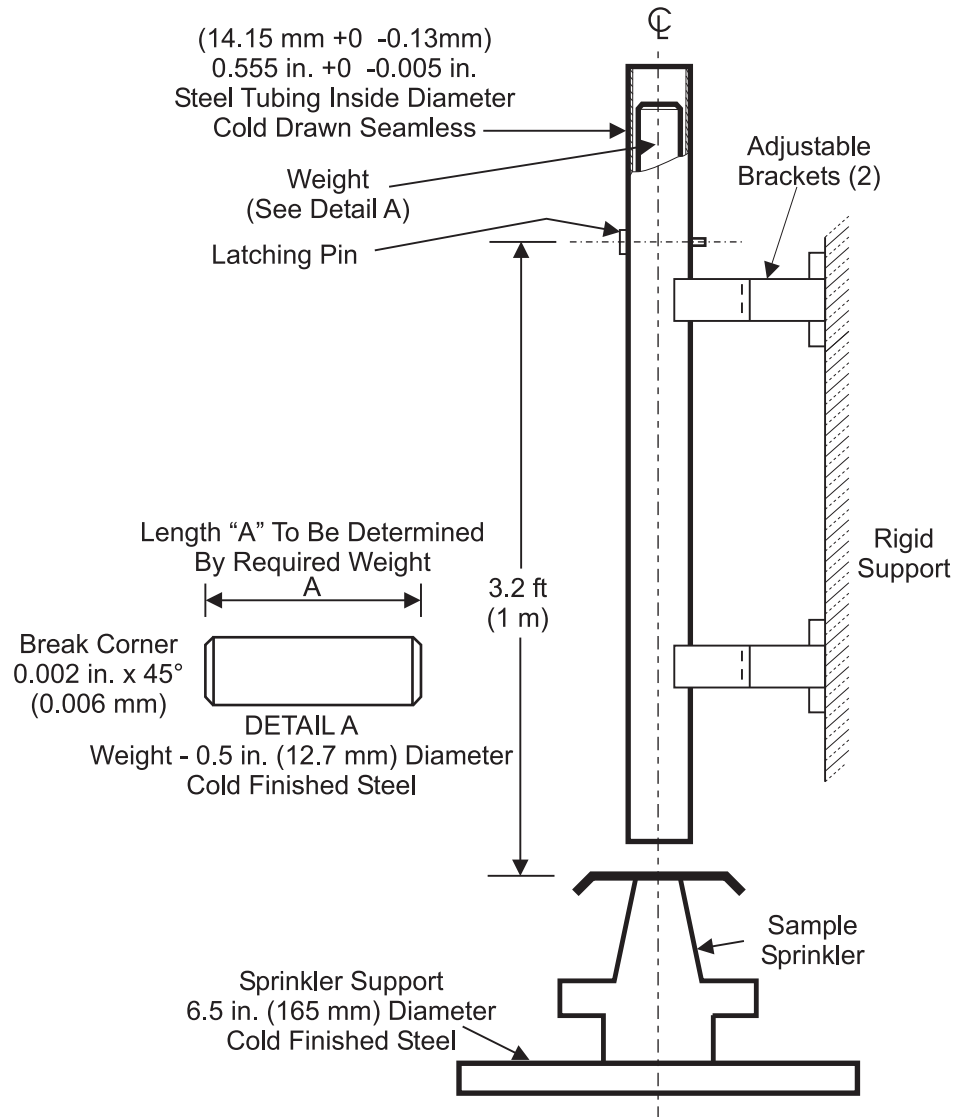
Note: All dimensions are nominal size.

E-4: Test Apparatus for Hang-up of Operating Parts (Lodgement) Test

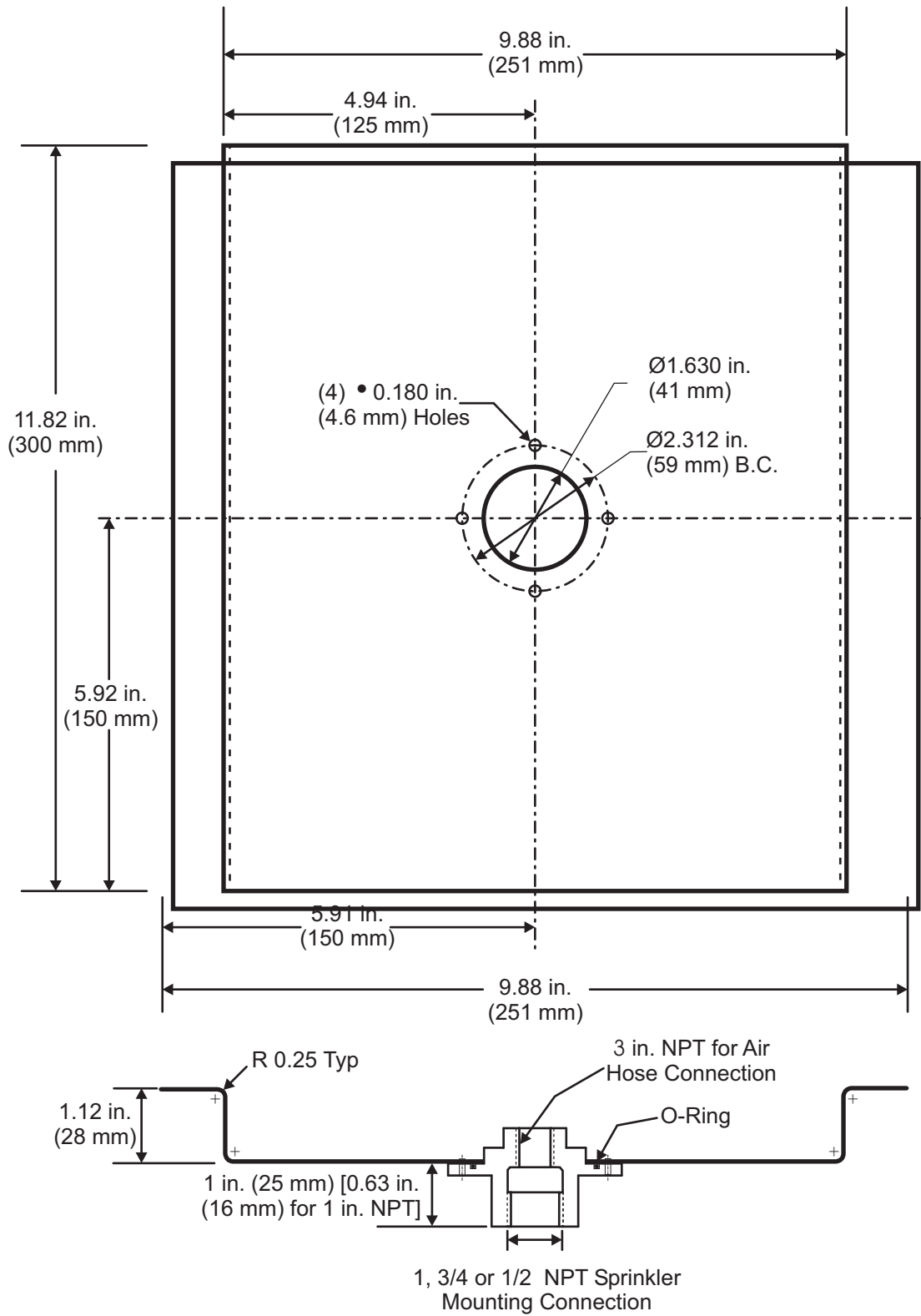


Note: All dimensions are nominal size unless otherwise indicated.
Radius on Inlet may be truncated on internal face.

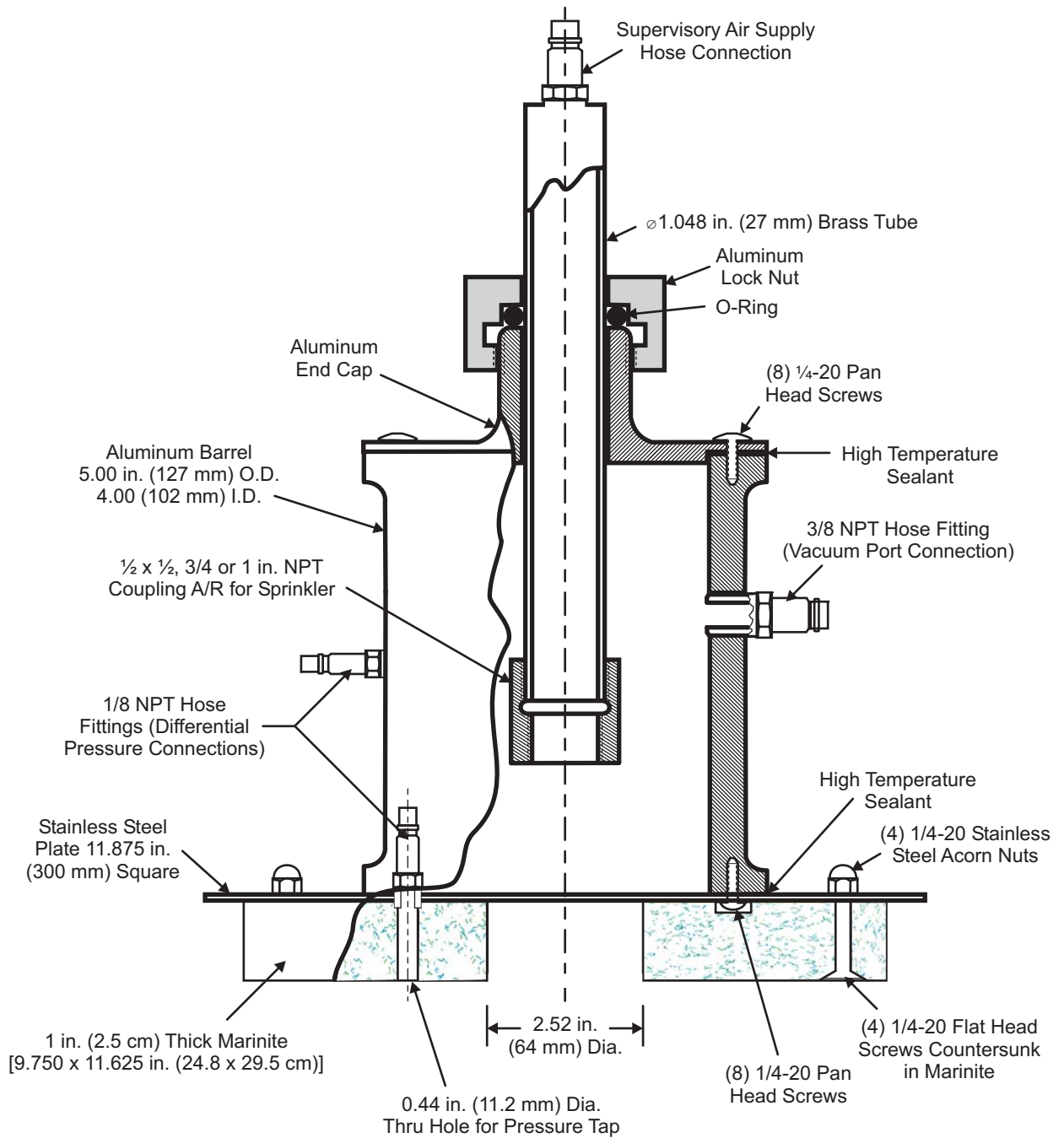
E-5: Test Apparatus for Measuring Nominal Discharge Coefficient (K-Factor)



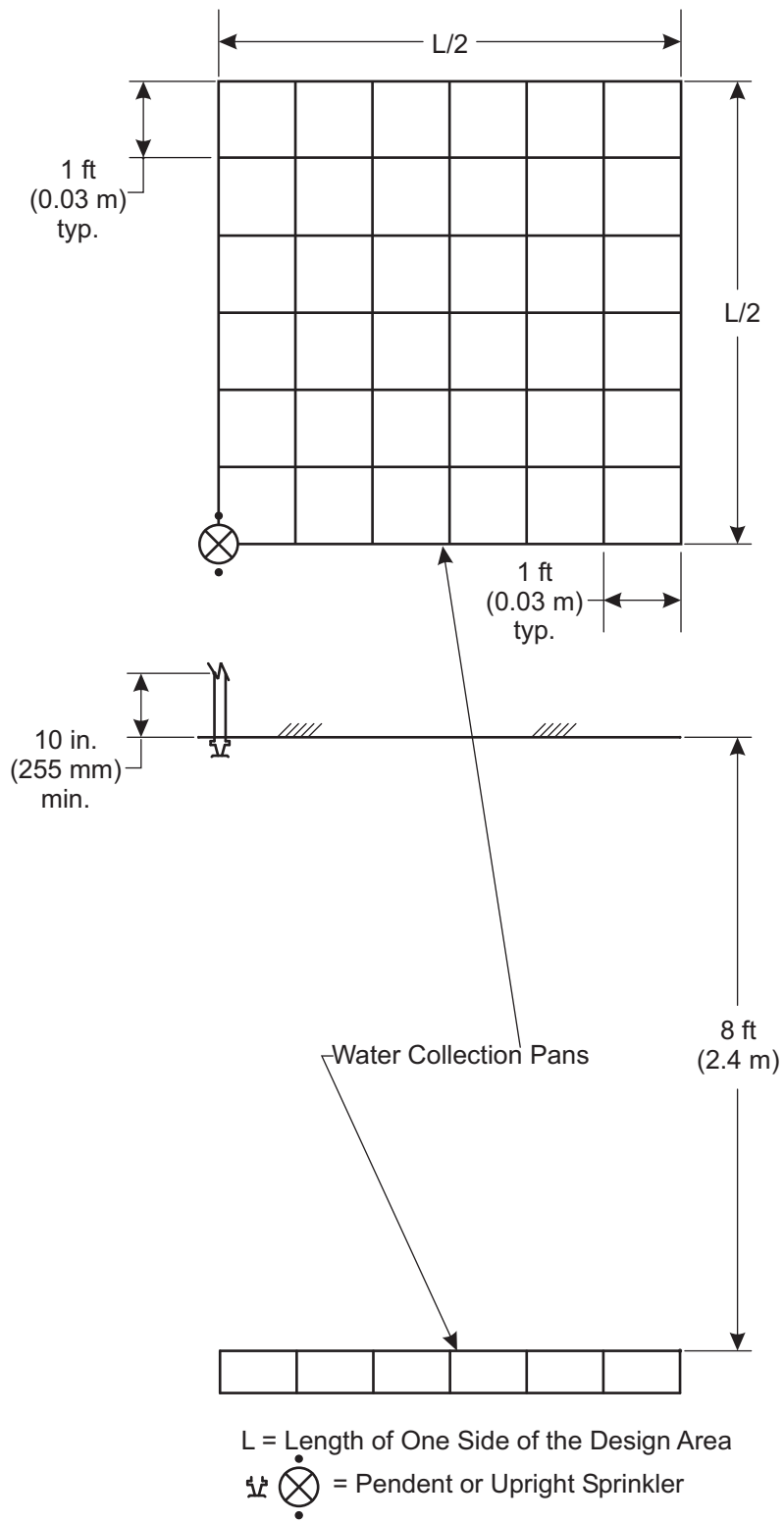
E-6: Rough use and Abuse (Drop Impact) Test Apparatus



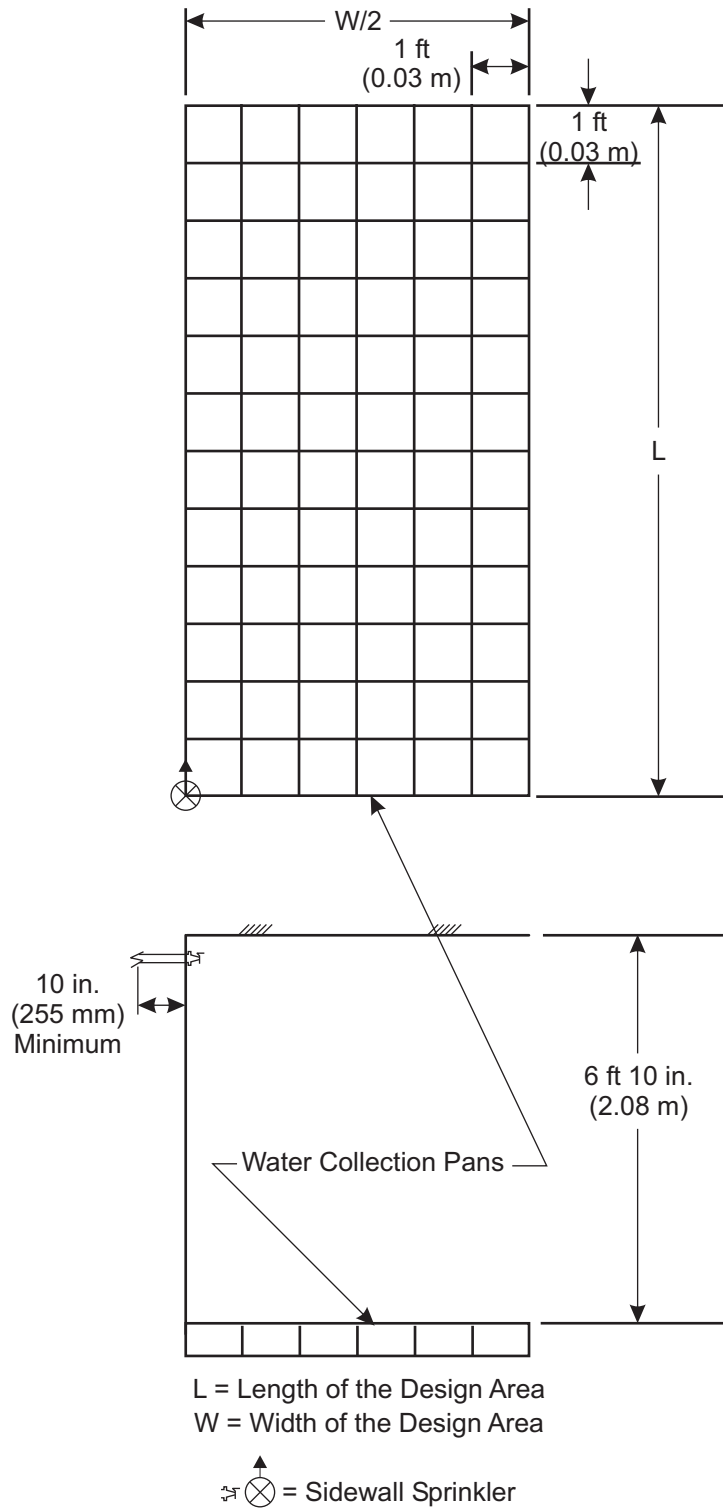
E-7: Plunge Tunnel Test Plate (For Sensitivity - RTI Test)



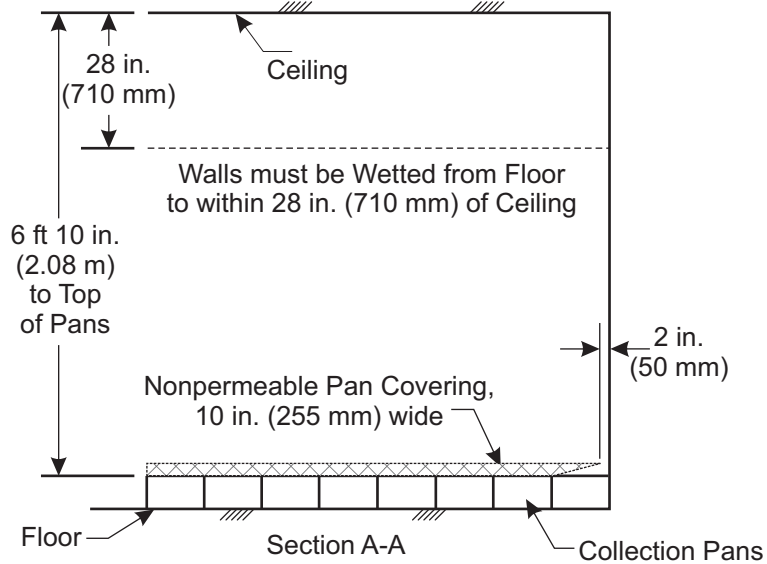
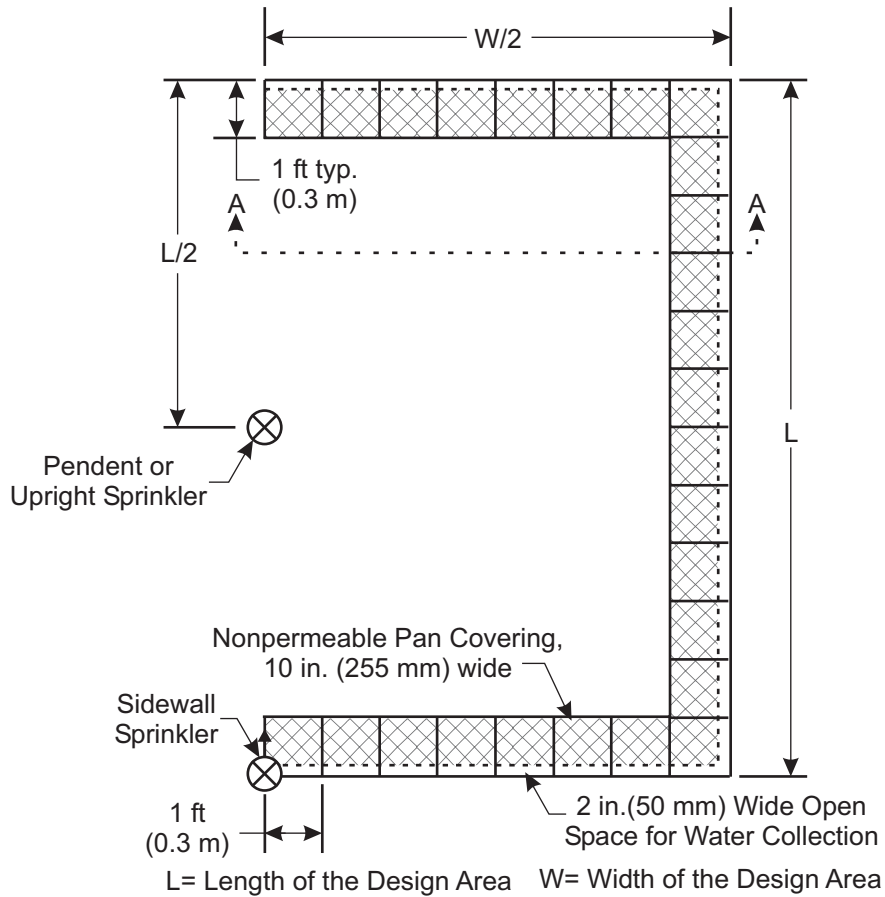
E-8: Modified Plunge Tunnel Test Plate (For Sensitivity Test - Recessed, Flush and Concealed Sprinklers)



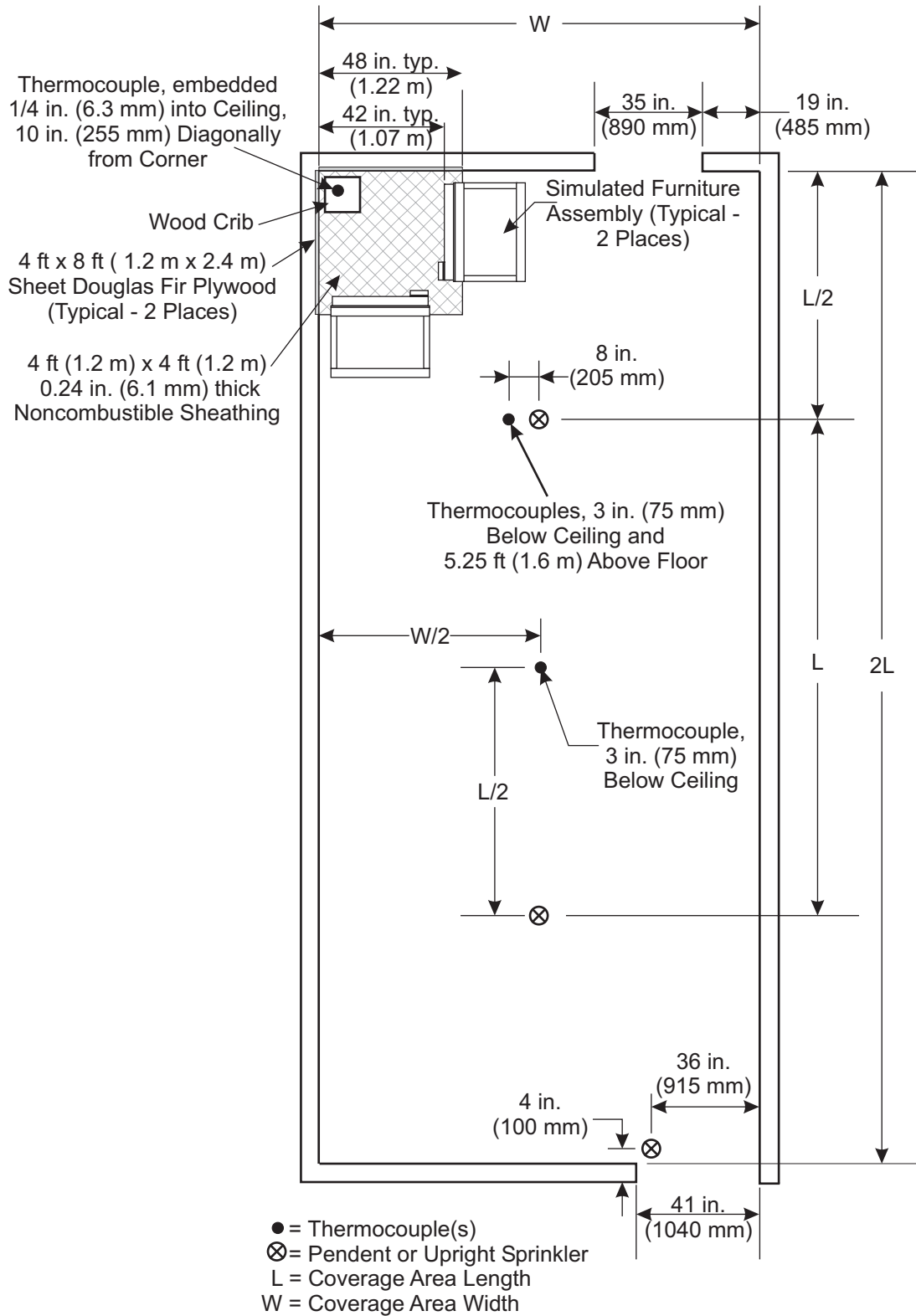
E-9: Pendent and Upright Distribution Configuration



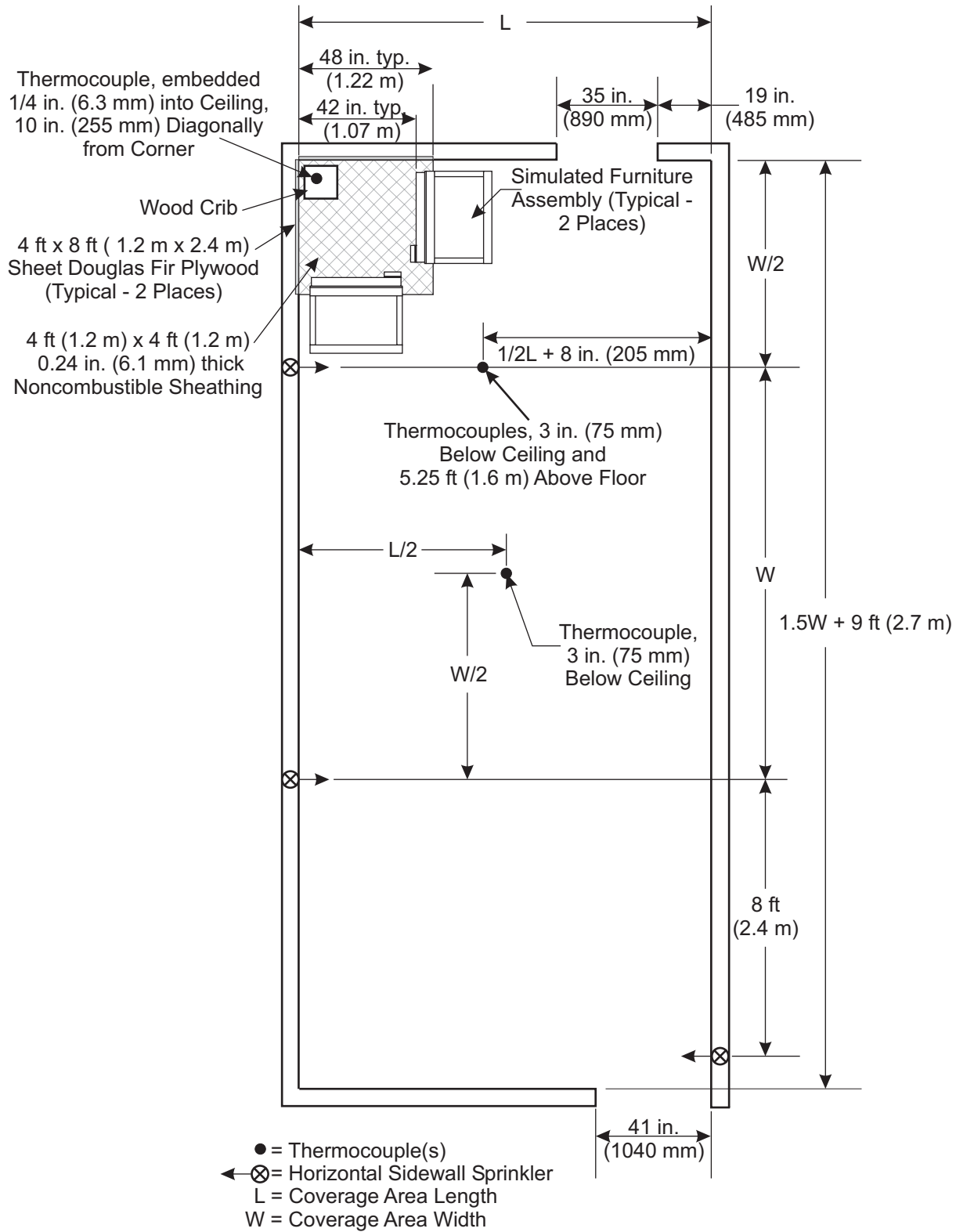
E-10: Horizontal Sidewall Distribution Configuration



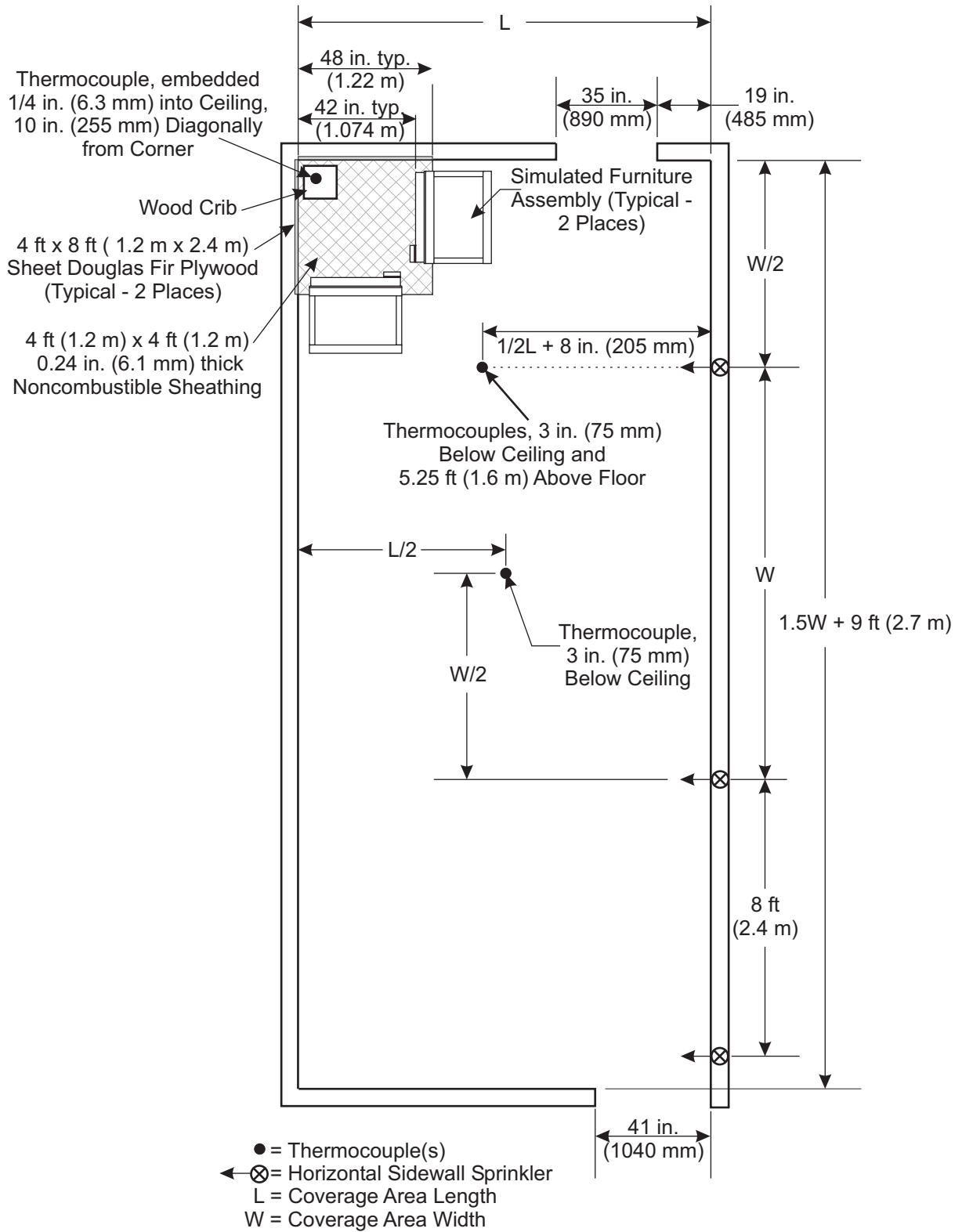
E-11: Wall Wetting and Wall Collection



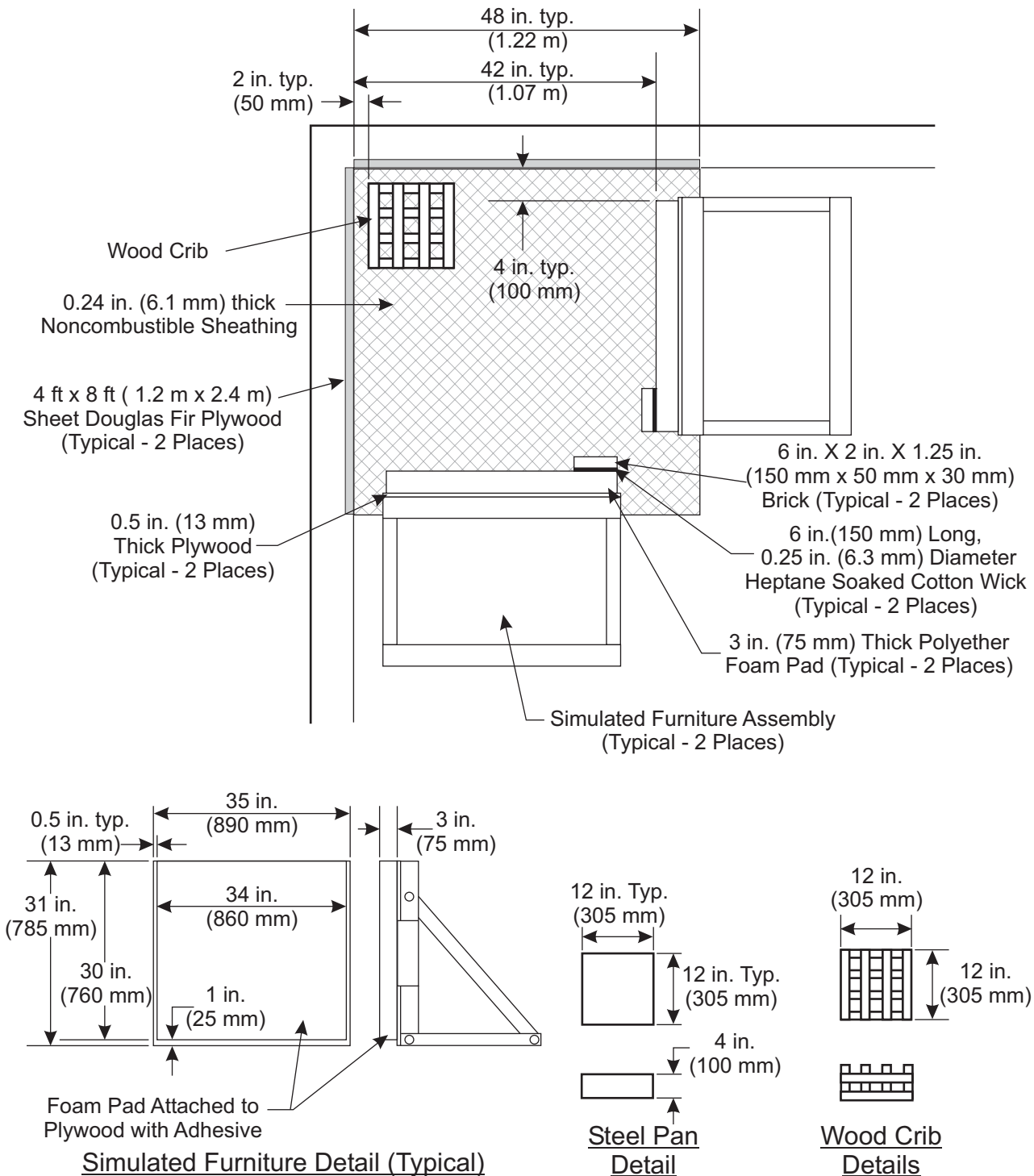
E-12: Residential Fire Test Enclosure – Pendent and Upright Configuration



E-13: Residential Fire Test Enclosure – Horizontal Sidewall Configuration (Near Wall)



E-14: Residential Fire Test Enclosure – Horizontal Sidewall Configuration (Far Wall)



E-15: Residential Fire Test – Fuel Package Detail

APPENDIX F: Sample Listing

Mfg. Name
Mfg. Address

<i>Product</i>	<i>Primary Class of Work</i>	<i>Listing Country</i>	<i>K</i>	<i>Type</i>	<i>Response</i>	<i>Element</i>	<i>NPT (in.)</i>	<i>Finishes</i>	<i>Temp. Ratings °F</i>	<i>Temp. Ratings °C</i>
XYZ	2030-AS, Residential	United States of America	5.0	Pendent	QR	3 mm	1/2	Brass, Chrome, Polyester	155, 175	68, 79
XYZ	2030-AS, Residential	United States of America	5.0	Recessed Pendent	QR	3 mm	1/2	Brass, Chrome, Polyester	155, 175	68, 79

XYZ

Residential Sprinkler Minimum Flow Requirements

<i>Company</i>	<i>Model</i>	<i>Max. Coverage Area, ft x ft (m x m)</i>	<i>Min. Flow Rate, gpm (L/min)</i>
Mfg. Name	XYZ	12 x 12 (3.7 x 3.7)	22 (83.3)
		14 x 14 (4.3 x 4.3)	22 (83.3)
		16 x 16 (4.9 x 4.9)	24 (90.8)
		18 x 18 (5.5 x 5.5)	33 (125)



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