



Member of the FM Global Group

Approval Standard for Quick Response Storage Sprinklers for Fire Protection

Class Number 2008

February 2018

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.

Table of Contents

1 INTRODUCTION	1
1.1 Purpose.....	1
1.2 Scope.....	1
1.3 Basis for Requirements	2
1.4 Basis for Approval	2
1.5 Basis for Continued Approval	2
1.6 Effective Date	2
1.7 System of Units.....	3
1.8 Normative References.....	3
1.9 Definitions	3
1.10 References.....	8
2 GENERAL INFORMATION.....	9
2.1 Product Information	9
2.2 Approval Application Requirements	9
2.3 Requirements for Samples for Examination	9
3 GENERAL REQUIREMENTS.....	10
3.1 Review of Documentation	10
3.2 Physical or Structural Features	10
3.3 Markings	11
3.4 Manufacturer's Installation and Operation Instructions	13
3.5 Calibration	13
4 PERFORMANCE REQUIREMENTS.....	14
4.1 Examination	14
4.2 Assembly Load/Frame Strength	14
4.3 Strength of Heat Responsive Element	15
4.4 Leakage.....	16
4.5 Hydrostatic Strength	16
4.6 30-Day Leakage.....	17
4.7 Water Hammer.....	17
4.8 Operating Temperature (Liquid Bath)	17
4.9 Air Bath.....	18
4.10 Hang-Up of Operating Parts	19
4.11 Strength of Deflector (Flow Endurance).....	20
4.12 Vacuum.....	20
4.13 High Ambient Temperature Exposure (90 Day Test).....	20
4.14 Thermal Shock (Glass Bulb Sprinklers Only)	21
4.15 Discharge Coefficient (K-Factor)	21
4.16 Moist Air.....	22
4.17 Corrosion - Salt Spray.....	23
4.18 Corrosion - Stress Cracking.....	23
4.19 Corrosion - Carbon Dioxide-Sulfur Dioxide	25
4.20 Corrosion - Hydrogen Sulfide.....	25
4.21 Vibration	26
4.22 Rough Use and Abuse.....	27
4.23 High Temperature Exposure	27
4.24 Freezing	28
4.25 Minimum Operating Pressure.....	28

4.26	Process Residue	28
4.27	Conductivity (C-Factor).....	29
4.28	Sensitivity - Response Time Index (RTI)	30
4.29	Distribution - K14.0 (K200) and K16.8 (K240) Pendent Quick Response Storage Sprinklers	31
4.30	Actual Delivered Density (ADD)	34
4.31	Thrust Measurement	38
4.32	Fire Tests - K14.0 (K200) Upright Quick Response Storage Sprinklers	39
4.33	Fire Tests - K16.8 (K240) Upright Quick Response Storage Sprinklers	40
4.34	Fire Tests - K22.4 (K320) and K25.2 (K360) Pendent Quick Response Storage Sprinklers	41
4.35	Fire Tests - K14.0 (K200) and K16.8 (K240) Dry Pendent Quick Response Storage Sprinklers	43
4.36	Additional Tests	45
5	OPERATIONS REQUIREMENTS	45
5.1	Demonstrated Quality Control Program	46
5.2	Surveillance Audit Program.....	46
5.3	Manufacturer's Responsibilities	47
5.4	Manufacturing and Production Tests	47
	APPENDIX A : UNITS OF MEASUREMENT	48
	APPENDIX B : TOLERANCES	50
	APPENDIX C : TOLERANCE LIMIT CALCULATIONS	51
	APPENDIX D : FIGURES.....	52
	APPENDIX E : SAMPLE LISTING.....	83

1 INTRODUCTION

1.1 Purpose

- 1.1.1 This standard states FM Approvals criteria for K14.0 (K200) and larger standard coverage quick response ceiling level storage 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 surveillance audit program.

1.2 Scope

- 1.2.1 This standard encompasses the design requirements, performance requirements, methods of test, and marking requirements for fusible element and glass bulb quick response ceiling level storage sprinklers (herein also referred to simply as “sprinklers”) in the following product categories and class numbers:

Table 1.2.1 Product Categories and Class Numbers

<i>Class Number</i>	<i>Sprinkler Product Category</i>
2008	K14.0 (K200)
2026	K25.2 (K360)
2027	K16.8 (K240)
2028	K22.4 (K320)

- 1.2.1.1 This standard includes design requirements, performance requirements, methods of test, and marking requirements for K14.0 and K16.8 dry pendent quick response storage sprinklers.
- 1.2.1.2 In-rack sprinklers, K11.2 (K160) storage sprinklers and extended coverage storage sprinklers are covered under Approval Standard FM2000.
- 1.2.2 These sprinklers are intended for use in certain occupancies, typically those containing storage or other occupancy hazards characterized by high heat-release rate fires. They are not recommended for use in occupancies where quick response sensitivity is not considered compatible with the occupancy hazard (e.g., low flash point ignitable liquids, oxidizing chemicals, etc.). Refer to the FM Global Property Loss Prevention Data Sheets for more specific information.
- 1.2.3 Other types of sprinklers may be FM Approved if they meet the requirements and intent of this standard. Sprinklers of unusual design may be subjected to special tests to determine their suitability.
- 1.2.4 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 quick response storage sprinklers for the purpose of obtaining Approval. 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, quick response storage 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 A first audit shall be conducted to evaluate the manufacturer's ability to consistently produce the product which was examined and tested as part of the Approval project. The audit shall review the facility and in-place quality control procedures used in the manufacturing of the product. Typically, areas of review are incoming inspection, work in progress, production testing, final quality control, marking, calibration of equipment, shipping procedures, and document and drawing control. These audits are repeated quarterly as part of FM Approvals' Surveillance Audit Program. (Refer to Section 5.2, Surveillance Audit Program.)

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 the terms stipulated in the Approval report;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory Surveillance Audits conducted as part of FM Approvals' Surveillance Audit 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 else forfeit Approval.

The effective date of this Standard is one year from date of issue 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 National Standards Institute (ANSI)/Institute of Electrical and Electronics Engineers (IEEE)/American Society for Testing and Materials (ASTM) SI 10, "American National Standard for Metric Practice."

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 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEEE/ASTM SI 10, American National Standard for Metric Practice

ANSI/ASME B1.20.1, *Pipe Threads, General Purpose, Inch*

ASTM B117-16, *Standard Practice for Operating Salt Spray (Fog) Apparatus*

ASTM E1, *Standard Specification for ASTM Liquid-In-Glass Thermometers*

ASTM G36-94(2013), *Standard Practice for Evaluating Stress-Corrosion-Cracking Resistance of Metals and Alloys in a Boiling Magnesium Chloride Solution*

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

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.)

Actual Delivered Density (ADD)

The rate at which the water is actually deposited from operating sprinklers onto the top horizontal surface of a burning storage array.

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.

Conductivity (C-Factor)

A measure of the conductance between the sprinkler's heat responsive element and the other components of the sprinkler, including the fitting, 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.

Design Load

See Element Design Load.

Discharge Coefficient (K-Factor)

The coefficient of discharge, K, 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. The discharge coefficient, therefore, has units of gal/min/(psi)^{1/2} or L/min/(bar)^{1/2}.

Dry-Type Sprinkler

A device consisting of a sprinkler permanently attached to an extension nipple which has a closure at the inlet end to prevent system water from entering the nipple until the sprinkler operates.

Element Design Load

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

Extended Coverage Sprinkler

A sprinkler with an intended area of coverage which exceeds the standard coverage area applicable to that type of sprinkler. Extended coverage Hazard Category 1-3 (HC-1 through HC-3) sprinklers are non-storage sprinklers that have an intended area of coverage between 225 and 400 sq ft (21 and 37 m²). Extended coverage storage sprinklers have an intended area of coverage between 100 and 196 sq ft (9 and 18 m²). The minimum and maximum allowable spacings for extended-coverage sprinklers can be found in the applicable occupancy-specific FM Global Data Sheet.

FM Approvals Certification Marks

Their use is mandatory on all FM Approved automatic sprinklers for fire protection. 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 agreement obligates the manufacturer to allow re-examination of the product and surveillance audits at the discretion of FM Approvals. It further requires the manufacturer not to deviate from the as -Approved configuration of the product without review by and agreement of FM Approvals. Approval is manufacturing site and product specific.

FM Global Standard Cartoned Expanded Plastic Commodity (Polystyrene Meat Trays)

A commodity product consisting of expanded polystyrene plastic food service trays (or meat trays) packaged in single-wall corrugated cartons. Each carton contains 200 plastic trays arranged in four stacks of 50 trays each. Typical trays weigh approximately 0.54 ounces (15 g) each, measure approximately 10.5 in. x 10.5 in. x 0.2 in thick. (27 cm x 27 cm x 0.5 cm) and consist of expanded foam plastic. Each carton measures 21 in. x 21 in. x 20 in. (53 cm x 53 cm x 51 cm) and weighs 8.9 lbs. (4.0 kg) when filled with the plastic trays. Each pallet load consists of eight cartons placed in a 2 x 2 x 2 array upon a 42 in. x 42 in. x 5 in. (107 cm x 107 cm x 13 cm) two-way, slatted deck hardwood pallet.

FM Global Standard Class 2 Commodity

A commodity product that consists of three double-wall corrugated paper cartons. The dimensions for the inner, middle, and outer box are 40.3 in. x 40.3 in. x 37.8 in. (1.02 m x 1.02 m x 0.96 m), 41.0 in. x 41.0 in. x 39.1 in. (1.04 m x 1.04 m x 0.99 m), and 41.8 in. x 41.8 in. x 41.5 in. (1.06 m x 1.06 m x 1.05 m), respectively. Inside the cartons is a five-sided sheet metal liner, representing a non-combustible content. The cartoned liner is supported on an ordinary, two-way, slatted deck, hardwood pallet, measuring 42 in. x 42 in. x 5 in. (1.07 m x 1.07 m x 13 cm). The total combustible weight of the commodity is approximately 127.4 lb (57.8 kg); the corrugated containerboard weighs approximately 78.0 lb (35.4 kg), and the pallet weighs approximately 49.4 lb (22.4 kg).

FM Global Standard Cartoned Unexpanded Plastic Commodity

A commodity product of cartoned Group A unexpanded plastic, consisting of rigid crystalline polystyrene jars (empty, 16 fl. oz. size) packaged in compartmented, single wall, corrugated cartons measuring 21 in. x 21 in. x 20 in. (53 cm x 53 cm x 51 cm). Jars are arranged in five layers, 25 per layer for a total of 125. Each pallet load consists of eight cartons, arranged in a 2x2x2 array upon a 42 in. x 42 in. x 5 in. (107 cm x 107 cm x 13 cm) two-way, slatted deck hardwood pallet.

FM Global Standard Igniter

A standard igniter is the ignition source used for all FM Approvals full scale fire tests (see Sections 4.32 - 4.35). A standard igniter consists of either 2 or 4 half-igniters, depending on the ignition location. When ignition is located at the intersection of the longitudinal and center transverse flue spaces of a double row rack (i.e., centered in the main array), 4 half igniters are used. When ignition is located within the center transverse flue space and positioned 2 ft (0.6 m) to one side of the longitudinal flue of a double row rack (i.e., offset within the main array), 2 half igniters are used. Each half-igniter consists of a 3 in. diameter by 3 in. long (76 mm x 76 mm) cylinder of rolled cellucotton, soaked with 4 fluid ounces (118 ml) of gasoline, then sealed in a polyethylene plastic bag. Igniters are prepared no more than 15 minutes prior to testing. They are positioned at the base of the bottom tier pallet loads, lit with a propane torch to signal the start of the test, and the fires are allowed to develop naturally.

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 (Lodgment)

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 60 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.

Hazard Category 1 (HC-1) (formerly Light Hazard Occupancy)

A non-storage occupancy in which the quantity and/or combustibility of contents is low and fires with relatively low rates of heat release are expected. See FM Global Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties* for examples of such occupancies.

Hazard Category 2 (HC-2) (formerly Ordinary Hazard Group 1 Occupancy)

A non-storage occupancy in which the quantity and/or combustibility of contents is moderate. See FM Global Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties* for examples of such occupancies.

Hazard Category 3 (HC-3) (formerly Ordinary Hazard Group 2 Occupancy)

A non-storage occupancy in which the quantity and/or combustibility of contents is high. See FM Global Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties* for examples of such occupancies.

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.

In-Rack Sprinkler

A sprinkler intended for use in racks or beneath open gratings, which is equipped with a shield mounted above the heat responsive element to protect it from water discharge from nearby sprinklers at higher elevations. In-rack sprinklers are also commonly known as rack storage or intermediate level sprinklers. The design of an in-rack sprinkler may consist of a standard spray (upright or pendent) sprinkler equipped with a shield.

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).

Non-Storage Sprinkler

A sprinkler that has been categorized by FM Global as acceptable for protecting non-storage-type occupancies and/or other occupancy hazards characterized by low to moderate heat-release rate fires as permitted in a FM Global occupancy-specific Property Loss Prevention Data Sheet. Generally, extended coverage sprinklers with nominal discharge coefficients less than $25.2 \text{ gal/min}/(\text{psi})^{1/2}$ ($360 \text{ L/min}/(\text{bar})^{1/2}$) and standard coverage sprinklers with nominal discharge coefficients less than $11.2 \text{ gal/min}/(\text{psi})^{1/2}$ ($160 \text{ L/min}/(\text{bar})^{1/2}$) are categorized as non-storage sprinklers. NOTE: Storage sprinklers may also be used to protect non-storage occupancies unless indicated otherwise in the occupancy-specific FM Global data sheet.

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 A

A plunge tunnel condition in which the sprinkler is situated such that the air flow is perpendicular to both the waterway axis and the plane of the frame arms and the heat responsive element is upstream of the frame arms (see Figure D-1). Orientation A is typically also the best case orientation.

Orientation B

A plunge tunnel condition in which the sprinkler is situated such that the air flow is perpendicular to both the waterway axis and the plane of the frame arms and the heat responsive element is downstream of the frame arms (see Figure D-1).

Orientation C (head on)

A plunge tunnel condition in which the sprinkler is situated such that the axis of the sprinkler inlet is parallel to the air flow and the deflector faces and is perpendicular to the air flow (see Figure D-1).

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 (see also “Orientation A”, above).

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 downward against the deflector.

Quick Response Sprinkler

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.

Quick Response Storage Sprinkler

A storage sprinkler having a Response Time Index (RTI) equal to or less than $90 \text{ (ft}\cdot\text{s)}^{1/2}$ [$50 \text{ (m}\cdot\text{s)}^{1/2}$] and a Conductivity (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. Quick response storage sprinklers have an RTI which meets quick response sensitivity requirements. K14.0 (K200) and larger standard coverage quick response ceiling level storage sprinklers, as covered under this standard, have an RTI of 35 to 65 $\text{(ft}\cdot\text{s)}^{1/2}$ [19 to 36 $\text{(m}\cdot\text{s)}^{1/2}$].

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 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.

Standard Response Sprinkler

A sprinkler having a Response Time Index (RTI) between 145 and 635 $\text{(ft}\cdot\text{s)}^{1/2}$ [80 and 350 $\text{(m}\cdot\text{s)}^{1/2}$] and a C-factor equal to or less than $3.62 \text{ (ft/s)}^{1/2}$ [$2.0 \text{ (m/s)}^{1/2}$], when the sprinkler is tested in the best case orientation.

Standard Spray Sprinkler

An upright or pendent non-storage sprinkler having a nominal discharge coefficient of 2.8, 5.6 or 8.0 gal/min/(psi)^{1/2} (40, 80 or 115 L/min/(bar)^{1/2}). An upright or pendent storage sprinkler having a nominal discharge coefficient of 11.2, 14.0, or 16.8 gal/min/(psi)^{1/2} (160, 200 or 240 L/min/(bar)^{1/2}). Extended coverage sprinklers are excluded from the standard spray sprinkler category.

Storage Sprinkler

A sprinkler that has been categorized by FM Global as acceptable for protecting storage-type occupancies and/or any other occupancy hazards characterized by high heat-release rate fires as permitted in an occupancy-specific FM Global Property Loss Prevention Data Sheet. Generally, extended coverage sprinklers with nominal discharge coefficients greater than or equal to 25.2 gal/min/(psi)^{1/2} (360 L/min/(bar)^{1/2}) and standard coverage sprinklers with nominal discharge coefficients greater than or equal to 11.2 gal/min/(psi)^{1/2} (160 L/min/(bar)^{1/2}) are categorized as storage sprinklers. In-rack sprinklers are also classified as storage sprinklers since they are used almost exclusively in storage racks.

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. Brown, W.R. and Chan, T and Hill, E.E. and Kung, H, Discharge Characteristics of ESFR Sprinklers for Protection of 30 Ft High Buildings, FM Global Research Corporation, J.I. 0W0J1.RA, April 1994.
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

A quick response storage sprinkler is a thermo-sensitive device designed to react at a predetermined temperature by releasing a stream of water and distributing it with a specified pattern and flow rate over a designated area when installed on the appropriate sprinkler piping.

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, should submit a request to information@fmaprovals.com.

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 products or services 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 manufacturing facilities.

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

2.3 Requirements for Samples for Examination

2.3.1 Following authorization of an Approval examination, the manufacturer shall submit samples for examination and testing based on the following:

- Sample requirements to be determined by FM Approvals following review of the preliminary information.
- Requirements for samples may vary depending on design features, results of prior or similar testing, and results of any foregoing tests.
- The manufacturer shall submit samples representative of production. Any decision to use data generated using 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 sprinklers.

3 GENERAL REQUIREMENTS

3.1 Review of Documentation

- 3.1.1 During the initial investigation and prior to physical testing, the manufacturer's specifications and details shall be reviewed to assess the ease and practicality of installation and use. The Approval investigation shall define the limits of the Approval.

3.2 Physical or Structural Features

- 3.2.1 All materials used in quick response storage sprinklers shall be suitable for the intended application. 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.
- 3.2.2 Stampings shall show no cracking or splitting and be free of burrs.
- 3.2.3 Deflectors of sprinklers shall be securely attached.
- 3.2.4 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.
- 3.2.5 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, *ANSI Standard for Pipe Threads*, per Table 3.2.5.

Table 3.2.5. Threaded Connections

<i>Nominal K-Factor gal/min/(psi)^{1/2}</i>	<i>U.S. Nominal Thread Size, in.</i>
14.0	3/4
16.8	3/4
22.4	1
25.2	1

- 3.2.6 Connections incorporating thread sizes larger than those stated in Section 3.2.5 are permitted for special purpose sprinklers such as dry and adjustable types.
- 3.2.7 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 Guides, etc.) referring to the size of the openings and indicating their need for use with appropriate strainers.
- 3.2.8 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.
- 3.2.9 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.

- 3.2.10 Plated or coated-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 sprinklers shall not change the mechanical or operational properties of the sprinkler beyond acceptable limits stated in this standard.
- 3.2.11 Finishes such as plating, 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 sprinklers with such finishes or coatings is required. Such sprinklers shall meet all requirements for their respective class(es) of sprinkler(s).
- 3.2.12 Inlet protrusion into the fitting shall not adversely affect the flow of water through the fitting.
- 3.2.13 An open (operated) sprinkler that is identical in design and construction to an FM Approved quick response storage sprinkler, less its operating components, is considered to be FM Approved.

3.3 Markings

- 3.3.1 All sprinklers shall be marked in accordance with one of the two marking schemes described in 3.3.1.1 and 3.3.1.2. 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.
- 3.3.1.1 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 (<http://www.firesprinkler.global>).

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 Marks.

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 3.3.2 below);
- Nominal K-factor per Table 4.15.1 (in English units: gal/min/(psi)^{1/2});
- The word "PENDENT" (or the letters "PEND"), the word "UPRIGHT" (or the letters "UPRT"), or other designation to indicate type or orientation, as appropriate;

- 3.3.1.2 In lieu of the marking requirements of Section 3.3.1.1, sprinklers shall be permanently marked on a non-operating component with the following:
- Manufacturer's name or identifying symbol (logo);
 - Model designation (see Section 3.3.2 below);
 - Nominal K-factor per Table 4.15.1 (in U.S. customary units: gal/min/(psi)^{1/2});
 - The word "PENDENT" (or the letters "PEND"), the word "UPRIGHT" (or the letters "UPRT"), 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);
 - Quick response sprinklers shall be marked with the words "Quick Response" or the initials "QR";
 - The FM Approvals Certification Marks.
- 3.3.2 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.
- 3.3.3 For fusible type sprinklers, the operating temperature, or the temperature rating color code, as defined in Table 3.3.5, shall appear on a visible area of the fusible element or an associated operating component.
- 3.3.4 If a manufacturer produces 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.
- 3.3.5 All sprinklers, with the exception of glass bulb type sprinklers, shall be color coded in accordance with Table 3.3.5. 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 or plated 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 3.3.5. 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>		
155 to 165	(68 to 74)	100	(38)	Ordinary	None or Black
200 to 220	(93 to 104)	150	(66)	Intermediate	White

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

- 3.3.6 Bulb type sprinklers shall comply with the bulb color designation shown in Table 3.3.6. The bulb fluid color shall be considered a suitable method of temperature identification in addition to permanent marking elsewhere on the sprinkler.

Table 3.3.6. Temperature Ratings and Bulb Color Codes

Nominal Temperature Rating		Bulb Color Code
°F	(°C)	
155 to 165	(68 to 74)	Red
200 to 220	(93 to 104)	Green

- 3.3.7 Factory plated sprinklers shall be identified as such with a distinctive marking so as to distinguish the product from unauthorized field plating.
- 3.3.8 For factory 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.
- 3.3.9 For bulb-type 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.
- 3.3.10 With the exception of wax-coated sprinklers, 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 coating.

3.4 Manufacturer's Installation and Operation Instructions

The manufacturer shall provide the user with adequate instructions for proper installation with each shipment. 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.

3.5 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 a 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.

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 Requirement

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

4.1.2 Test/Verification

A sample or samples 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 Requirement

The frame of a 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 Tests/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 a precision 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 to 5 seconds) to twice the sum of the force recorded in Section 4.2.2A, 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.
- C. Alternate Assembly Load Test Method for Sprinklers with a Belleville Washer Type Seal:

The following test method may be employed for determining the assembly load of sprinklers incorporating a Belleville washer type seal (i.e., coned-disc spring or cupped spring washer) as it has been determined to provide results equivalent to or more accurate than the method described in Section 4.2.2A.

Mount an assembled sprinkler into a solid fixture and mark the pipcap/seat, spring, and frame for orientation purposes. This enables the components to be reassembled in their original positions. Set a dial indicator on the bottom of the sprinkler, through the waterway, and in contact with the bottom of the pipcap/seat. Zero the indicator gage and operate the heat responsive element using

pliers or by another suitable mechanical means. Remove the compression screw from the sprinkler, if necessary, then align and re-assemble the operating components (spring and pipcap/seat) in the waterway. Set a hydraulic ram with a load cell (or other suitable means of load application and measurement) on top of the sprinkler and employ a suitable fixture such that load can be applied to the pipcap/seat. Apply a load to the pipcap/seat and compress the spring until the dial indicator returns to zero. Wait ten minutes, then record the reported load as the assembly load.

NOTE: If the alternate method is used to determine assembly load, a separate frame strength test must still be performed as described in Section 4.2.2B.

4.3 Strength of Heat Responsive Element

4.3.1 Requirement

- 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 4.3.2A2.
- 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 C.

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 4.3.2A1 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 ± 5 °F (21 ± 2.6 °C). At least 15 samples shall be loaded to various degrees in order to establish a basis of time to failure as a function of load. Failures which are not related to the solder bond shall be disregarded. A least squares, 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 on the fusible element, as determined using the upper tolerance limit of assembly load from Section 4.2.2A, shall be less than or equal to the maximum permitted design load (L_d) determined in the expression:

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

Where:

L_d = Maximum permitted design load for the heat responsive element

L_m = Load resulting in failure at 1000 hours

L_o = Load resulting in failure in 1 hour

3. Where physical limitations of the fusible element prevent the application of the loads described in Section 4.2.2A, 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 4.2.2A, 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 D-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 C, Tolerance Limit Calculations.

4.4 Leakage

4.4.1 Requirement

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. Additionally, dry type sprinklers shall not weep or leak at the junction of the inlet and the extension nipple when that connection is subjected to external pneumatic pressures from 0 to 15 psi (0 to 1.0 bar).

4.4.2 Tests/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 to 500 psi (0 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 $-20 \pm 10^{\circ}\text{F}$ ($-29 \pm 6^{\circ}\text{C}$) for 24 hours. Each sample shall be pneumatically pressurized to 30 ± 2 psi (2.1 ± 0.1 bar) and immersed in glycol liquid conditioned to $-20 \pm 10^{\circ}\text{F}$ ($-29 \pm 6^{\circ}\text{C}$), and observed for 5 minutes.
- C. Pneumatic Leakage – Dry Sprinkler Inlet (Dry Sprinklers Only) - 5 previously untested sprinklers shall be individually installed on a test apparatus which isolates the junction of the inlet and extension nipple (see Figure D-3). Each sample shall be immersed in water, pneumatically pressurized to 15 ± 2 psi (1.0 ± 0.1 bar), and observed for 5 minutes for evidence of leakage.

4.5 Hydrostatic Strength

4.5.1 Requirement

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 4.4.2A, 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 second. 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 Requirement

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 4.4.2A (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 Requirement

Sprinklers shall be capable of withstanding 100,000 applications of a pressure surge from approximately 50 to 500 psi (3.4 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 4.4.2A (Hydrostatic Leakage). The samples shall also show no evidence of distortion or physical damage. Subsequently, the samples shall exhibit positive operation and release of all operating parts at the minimum operating pressure when tested in accordance with Section 4.25.2 (Minimum Operating Pressure).

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 +0/-50 to 500 +0/-50 psi (3.4 +0/-3.4 to 34.5 + 0/-3.4 bar) for 100,000 +1,000/-0 cycles. The cycle period shall be between 1 and 4 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 Requirement

Sprinklers 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

Nominal Temperature Rating of Sprinkler		Bath Liquid	Maximum Rate of Temperature Rise	
°F	(°C)		°F/min	(°C/min)
155 - 165	(68 - 74)	Water	0.8	(0.4)
200 - 220	(93 - 104)	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 heat responsive 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 D-4 for a typical test set-up). The liquid shall be agitated at a constant rate of 200 ± 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 E1, *Standard Specification for ASTM Liquid-In-Glass Thermometers*, or the equivalent. It shall be immersed such that readings are taken at the same depth as the sprinkler heat responsive element.

The temperature of the bath shall be raised until the liquid is $20 \pm 2^\circ\text{F}$ ($11.1 \pm 1.1^\circ\text{C}$) 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 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 Requirement

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

NOTE: the air bath test is required only if strutting is observed during a liquid bath test.

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 $20 \pm 2^\circ\text{F}$ ($11.1 \pm 1.1^\circ\text{C}$) 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 ± 5 minutes. The temperature shall then be raised at a constant rate of $1 \pm 0.5^\circ\text{F}$ ($0.5 \pm 0.3^\circ\text{C}$) per minute until the temperature reaches $40 \pm 5^\circ\text{F}$ ($22 \pm 2.8^\circ\text{C}$) 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 Requirement

When tested as described below, there shall be no 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 discharge coefficient (K-factor) of all samples may be measured and 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 D-5. 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 80 sprinklers shall be tested.

EXCEPTION: Dry sprinklers shall be tested at both the minimum and maximum lengths, and may require a total sample quantity of up to 200 sprinklers. The pipe manifold of Figure D-5 shall be modified by installing a plugged tee in place of the elbow and may be modified further to accommodate long samples of dry sprinklers.

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 D-5).

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)	10
50	(3.4)	10
75	(5.2)	10
100	(6.9)	10
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 Requirement

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 D-5 in their intended orientation. Water shall be introduced to the inlet of each sprinkler at a pressure of 225 ± 10 psi (15.5 ± 0.7 bar). Each sprinkler shall then be operated using a suitable heat source and water flow shall be adjusted to and maintained at 225 ± 10 psi (15.5 ± 0.7 bar) for a period of 15 minutes.

4.12 Vacuum

4.12.1 Requirement

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 4.12.2. Following this test, each sample shall not weep or leak at a pressure of 5 ± 0.5 psi (0.3 ± 0.03 bar) when tested in accordance with Section 4.4.2A (Hydrostatic Leakage). Additionally, each sample shall not weep or leak at a pressure at, or below, 500 psi (34.5 bar).

4.12.2 Tests/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 (0.88 bar) 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 Requirement

- A. Sprinklers shall be capable of withstanding an exposure to a high ambient temperature in accordance with Table 4.13.1 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 4.4.2A (Hydrostatic Leakage). Subsequently, half of the sprinklers shall be tested for conformance to the requirements for sensitivity as described in Section 4.28, [Sensitivity - Response Time Index (RTI)], in orientation A or B, whichever results in the slowest operating times. The remaining samples shall be tested for operating temperature as described in Section 4.8 [Operating Temperature (Liquid Bath)].

Table 4.13.1. 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>
155 to 165	(68 to 74)	100	(38)
200 to 220	(93 to 104)	150	(66)

Note: ¹Tolerance on Nominal Test Temperature at stabilized condition: $\pm 3^{\circ}\text{F}$ (1.7°C)

- B. For dry-type sprinklers, samples may be tested to verify clearing of the waterway when operated using a suitable heat source, in the prescribed orientation with the appropriate associated minimum inlet water pressure as stated in Section 4.25.2 (Minimum Operating Pressure).

4.13.2 Tests/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, air circulating constant-temperature oven and subjected to a high ambient temperature selected in accordance with Table 4.13.1 for a period of 90 ± 1 days.

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. Results from such samples may be used to terminate the test early.

4.14 Thermal Shock (Glass Bulb Sprinklers Only)

4.14.1 Requirement

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 Tests/Verification

Five previously untested samples shall be conditioned for 5 ± 1 minutes 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 to 30 seconds into a second liquid bath maintained at $50 \pm 5^{\circ}\text{F}$ ($10 \pm 2.8^{\circ}\text{C}$). 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 Requirement

The mean value of the discharge coefficient (K-factor) shall be consistent with Table 4.15.1 when sprinklers are tested as detailed in Section 4.15.2. For each sample and pressure direction, not more than one individual value shall fall outside of the stated range.

Table 4.15.1. K-Factor Ranges

Nominal Discharge Coefficient (gal/min/(psi) ^{1/2}) (L/min/(bar) ^{1/2})		Nominal Discharge Coefficient Range (gal/min/(psi) ^{1/2}) (L/min/(bar) ^{1/2})	
14.0	200	13.5 - 14.5	195-209
16.8	240	16.0 - 17.6	231-254
22.4	320	21.3 - 23.5	307 - 339
25.2	360	23.9 - 26.5	344-382

4.15.2 Tests/Verification

Four samples shall be individually tested using the test apparatus for determining K-factor shown in Figure D-6 at increasing and decreasing pressures over the complete operating range, 25 to 175 psi (1.7 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)].

For dry (fixed length) sprinklers, tests shall be conducted on a minimum of two of the longest and two of the shortest lengths, and may be conducted on one sample of an intermediate length.

For dry (adjustable type) sprinklers, tests shall be conducted on a minimum of two samples while adjusted to the longest and the shortest length, and may be conducted at one intermediate position.

4.16 Moist Air

4.16.1 Requirement

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 4.4.2A (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 4.25.2 (Minimum Operating Pressure).

4.16.2 Tests/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 \pm 2°F (95 \pm 1.1°C) for a period of 90 \pm 1 days. 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 Requirement

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, 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 Section 4.28 [Sensitivity - Response Time Index (RTI)], in orientation A or B, whichever results in the slowest operating times. At the 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 Tests/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.

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.

When sprinklers are intended to be classified as corrosion resistant, 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 Requirement

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 the minimum operating pressure when tested in accordance with Section 4.25.2 (Minimum Operating Pressure). The remaining samples 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.

4.18.2 Tests/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 $0.73 \pm 0.43 \text{ ft}^3$ ($0.02 \pm 0.01 \text{ m}^3$).

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, at least two previously untested sprinklers shall be degreased and then exposed to a boiling magnesium chloride solution for a period of 500 ± 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 44 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. The samples shall then be subjected to the post-exposure tests 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 Requirement

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 Section 4.28 [Sensitivity - Response Time Index (RTI)], in orientation A or B, whichever results in the slowest operating times. Should the deflector or other non-operating components, or their means of attachment 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.

4.19.2 Tests/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 exposed to a moist carbon dioxide-sulfur dioxide-air mixture for a period of 10 days.

When sprinklers are intended to be classified as corrosion resistant, the samples shall be exposed 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, each sprinkler shall be tested in its intended installation position.

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 Requirement

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 Section 4.28 [Sensitivity - Response Time Index (RTI)], in orientation A or B, whichever results in the slowest operating times. Should the deflector or other non-operating components, or their means of attachment 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.

4.20.2 Tests/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.

When sprinklers are intended to be classified as corrosion resistant, the samples shall be exposed 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, each sprinkler shall be tested in its intended installation position.

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 Requirement

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 4.4.2A (Hydrostatic Leakage). Subsequently, the sprinklers shall be tested for conformance to the requirements for sensitivity as described in Section 4.28 [Sensitivity - Response Time Index (RTI)], in orientation A or B, whichever results in the slowest operating times.

4.21.2 Tests/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

Total Displacement		Frequency Hz	Time Hours
in.	(mm)		
0.015	(0.38)	30 to 60 variable	25
0.050	(1.27)	10 to 30 variable	25

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 (30 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 25 hours (50 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 Requirement

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 4.4.2A (Hydrostatic Leakage). Subsequently, the samples shall be tested for conformance to the requirements for sensitivity as described in Section 4.28 [Sensitivity - Response Time Index (RTI)], in orientation A or B, whichever results in the slowest operating times. Complete operation of a sprinkler during the tumble test described in Section 4.22.2B is permitted.

This test is not required for dry sprinklers if they are packaged in such a fashion as to preclude damage during shipping. Additional testing shall be at the sole discretion of FM Approvals.

4.22.2 Tests/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 D-7). The weight shall be dropped from a height of 3.2 ft ± 2 in. (1.0 m ± 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 Requirement

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/ADD tests (Section 4.29 or 4.30) on exposed samples to validate compliance with these requirements.

4.23.2 Tests/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 Requirement

Following exposure to freezing temperatures, sprinklers shall either (a) operate, (b) leak subsequent to thawing when hydrostatically pressurized from 5 to 175 psi (0.35 to 12.1bar), 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 Section 4.28 [Sensitivity - Response Time Index (RTI)], in orientation A or B, whichever results in the slowest operating times.

4.24.2 Tests/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 of 1 in. nominal diameter Schedule 40 or 80 steel pipe 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 Requirement

Sprinklers shall be designed to produce positive operation and release of all operating parts at the 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.

For sprinklers designed such that moveable parts are not intended to be released or expelled, proper actuation of all components to permit full water discharge is required.

4.25.2 Tests/Verification

Ten previously untested sprinklers shall be individually installed on a pipe manifold in their intended orientation, if feasible, and subjected to an inlet water pressure of 5 psi (0.3 bar). Each sample shall be 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 Requirement

In order to evaluate the resistance of the assembly to years of service in dusty or corrosive environments, sprinklers shall withstand a timed exposure to a salt spray atmosphere.

4.26.2 Tests/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 Requirement

The conductivity (C-factor) shall not exceed $1.81 \text{ (ft/s)}^{1/2}$ [$1.0 \text{ (m/s)}^{1/2}$]. Dry sprinklers are not subject to these requirements.

4.27.2 Tests/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 either the "A" or "B" orientation, whichever results in the slowest operating times, as determined in Section 4.28 [Sensitivity-Response Time Index (RTI)].

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 0.1 oz. (3 ml) 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 $5 +0.5/-0 \text{ psi}$ [$0.3(+0.04/-0) \text{ bar}$]. 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

Sprinkler Nominal Operating Temperature ¹		Tunnel Gas Temperature	Tunnel Gas Velocity	Maximum Variation of Gas Temperature During Test From Selected Temperatures	
°F	(°C)	°F (°C)	ft/s (m/s)	°F	(°C)
135 - 170	(57 - 77)	190 - 765 (88 - 407)	0.7 - 10 (0.2 - 3.05)	± 11	(± 6)
170 - 225	(79 - 107)			± 16	(± 9)
250 - 300	(121 - 149)			± 45	(± 25)
325 - 375	(163 - 191)			± 45	(± 25)

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 is the C-factor at velocity u_H

C_L is the C-factor at velocity u_L

C is the average C-factor of the sprinkler

ΔT_g is the actual gas (air) temperature minus the mount temperature

ΔT_b is the mean liquid bath operating temperature minus the mount temperature

u_H is the actual gas velocity in the test section at which the sprinklers operated

u_L is the actual gas velocity in the test section at which the sprinklers failed to operate within 15 minutes

The 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 Requirement

Sprinklers shall meet the Response Time Index (RTI) limits of 35 to 65 (ft·s)^{1/2} [19 to 36 (m·s)^{1/2}] when tested in orientations A and B as described in Section 4.28.2. The RTI shall not exceed 250 (ft·s)^{1/2} [138 (m·s)^{1/2}] when tested in orientation C.

As an exception to the RTI limits in this section, one of the twelve RTI values may deviate from the specified limits by not more than 10 percent.

NOTE: The C-factor is not included in the RTI calculation for quick response storage sprinklers.

4.28.2 Tests/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 3 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.

- A. Twelve samples of each nominal temperature rating shall be tested. Four tests shall be conducted for each of the three orientations defined in Section 1.9 (Definitions) and detailed in Figure D-1. The RTI is calculated as described in Section 4.28.2F for each orientation, respectively.
- B. The plunge tests are conducted using the sprinkler mount detailed in Figure D-8. 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. An air supply is then attached at the air hose connection 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., mechanical 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

Sprinkler Nominal Temperature Rating		Temperature in Test Section		Average Gas (Air) Velocity of Test Section	
°F	(°C)	°F	(°C)	ft/s	(m/s)
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:

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

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)

NOTE: due to the speed at which they operate, the influence of conductivity on the response time of quick response storage sprinklers is deemed insignificant, therefore C-factor is disregarded in the RTI calculation.

4.29 Distribution - K14.0 (K200) and K16.8 (K240) Pendent Quick Response Storage Sprinklers

4.29.1 Requirement

- A. K14.0 (K200) pendent quick response storage sprinklers shall be capable of distributing water in such a manner as to meet or exceed the requirements specified in Table 4.29.1a. For each test condition with a minimum single non-flue pan requirement, not more than one individual non-flue

pan shall have a collection less than the minimum required. Dry pans (i.e., zero water collection) are not permitted.

- B. K16.8 (K240) pendent quick response storage sprinklers shall be capable of distributing water in such a manner as to meet or exceed the requirements specified in Table 4.29.1b. For each test condition with a minimum single non-flue pan requirement, not more than one individual non-flue pan shall have a collection less than the minimum required. Dry pans (i.e., zero water collection) are not permitted.
- C. There are no distribution requirements for quick response storage sprinklers other than the K14.0 (K200) and K16.8 (K240) pendent sprinklers.

NOTE: Distribution testing does not apply to dry type quick response storage sprinklers.

Table 4.29.1a. Distribution Requirements for K14.0 (K200) Pendent Quick Response Storage Sprinklers

Number of Sprinklers Over the Water Collection System	Sprinkler Spacing ft, (m)	Pipe Spacing ft, (m)	Ceiling Clearance to Water Collection Pans ft-in (m)	Pressure ^{1,2} psi, (bar)	Minimum 16-pan Average Density gal/min/ft ² (mm/min)	Minimum Flue Space (4 Pans) Average gal/min/ft ² (mm/min)	Minimum 20-pan Average Density gal/min/ft ² (mm/min)	Minimum Non-flue 10-pan Average Density ³ gal/min/ft ² (mm/min)	Minimum Single Non-flue-pan Density gal/min/ft ² (mm/min)
1	-	-	10 (3.04)	50 (3.4)	0.52 (21.22)	1.0 (40.80)	N/R	N/R	N/R
1	-	-	14-6 (4.42)	50 (3.4)	0.48 (19.58)	0.89 (36.31)	N/R	N/R	N/R
1	-	-	14-6 (4.42)	75 (5.2)	N/R	1.7 (69.36)	0.91 (37.13)	0.50 (20.40)	0.26 (10.61)
2	10 (3.04)	-	4-2 (1.27)	50 (3.4)	0.60 (24.48)	N/R	N/R	N/R	N/R
2	10 (3.04)	-	10 (3.04)	50 (3.4)	0.54 (22.03)	N/R	N/R	N/R	N/R
2	-	10 (3.04)	4-2 (1.27)	50 (3.4)	0.58 (23.66)	N/R	N/R	N/R	N/R
2	-	10 (3.04)	10 (3.04)	50 (3.4)	0.57 (23.26)	N/R	N/R	N/R	N/R
2	12 (3.66)	-	4-2 (1.27)	50 (3.4)	0.44 (17.95)	N/R	N/R	N/R	N/R
2	-	12 (3.66)	4-2 (1.27)	50 (3.4)	0.45 (18.36)	N/R	N/R	N/R	N/R
2	10 (3.04)	-	4-2 (1.27)	75 (5.2)	N/R	N/R	0.77 (31.42)	0.60 (24.48)	0.20 (8.16)
2	-	10 (3.04)	4-2 (1.27)	75 (5.2)	N/R	N/R	0.77 (31.42)	0.60 (24.48)	0.20 (8.16)
4	10 (3.04)	10 (3.04)	4-2 (1.27)	50 (3.4)	0.68 (27.74)	N/R	N/R	N/R	N/R
4	10 (3.04)	10 (3.04)	10 (3.04)	50 (3.4)	0.86 (35.09)	N/R	N/R	N/R	N/R
4	8 (2.44)	12 (3.6)	4-2 (1.27)	50 (3.4)	0.66 (26.93)	N/R	N/R	N/R	N/R
4	10 (3.04)	10 (3.04)	4-2 (1.27)	75 (5.2)	N/R	N/R	0.71 (28.97)	0.60 (24.48)	0.37 (15.10)

1. All 50 psi (3.4 bar) tests are performed on a system fed from both directions (double feed).
2. All 75 psi (5.2 bar) tests are performed on a system fed from one direction (single feed), except for the two sprinkler, single pipe tests which are performed on a double feed system.
3. Average of the ten non-flue-pans with the lowest water collection.

N/R = No requirement

(See Figures D-9 through D-14)

Table 4.29.1b. Distribution Requirements for K16.8 (K240) Pendent Quick Response Storage Sprinklers

Number of Sprinklers Over the Water Collection System	Sprinkler Spacing ft (m)	Pipe Spacing ft (m)	Ceiling Clearance to Water Collection Pans ft-in (m)	Pressure ^{1,2} psi (bar)	Minimum 16-pan Average Density gal/min/ft ² (mm/min)	Minimum Flue Space (4 Pans) Average gal/min/ft ² (mm/min)	Minimum 20-pan Average Density gal/min/ft ² (mm/min)	Minimum Non-flue 10-pan Average Density ³ gal/min/ft ² (mm/min)	Minimum Single Non-flue-pan Density gal/min/ft ² (mm/min)
1	-	-	10 (3.04)	35 (2.4)	0.52 (21.22)	1.0 (40.80)	N/R	N/R	N/R
1	-	-	14-6 (4.42)	35 (2.4)	0.48 (19.58)	0.89 (36.31)	N/R	N/R	N/R
1	-	-	14-6 (4.42)	50 (3.4)	N/R	1.7 (69.36)	0.91 (37.13)	0.50 (20.40)	0.26 (10.61)
2	10 (3.04)	-	4-2 (1.27)	35 (2.4)	0.60 (24.48)	N/R	N/R	N/R	N/R
2	10 (3.04)	-	10 (3.04)	35 (2.4)	0.54 (22.03)	N/R	N/R	N/R	N/R
2	-	10 (3.04)	4-2 (1.27)	35 (2.4)	0.58 (23.66)	N/R	N/R	N/R	N/R
2	-	10 (3.04)	10 (3.04)	35 (2.4)	0.57 (23.26)	N/R	N/R	N/R	N/R
2	12 (3.66)	-	4-2 (1.27)	35 (2.4)	0.44 (17.95)	N/R	N/R	N/R	N/R
2	-	12 (3.66)	4-2 (1.27)	35 (2.4)	0.45 (18.36)	N/R	N/R	N/R	N/R
2	10 (3.04)	-	4-2 (1.27)	50 (3.4)	N/R	N/R	0.77 (31.42)	0.60 (24.48)	0.20 (8.16)
2	-	10 (3.04)	4-2 (1.27)	50 (3.4)	N/R	N/R	0.77 (31.42)	0.60 (24.48)	0.20 (8.16)
4	10 (3.04)	10 (3.04)	4-2 (1.27)	35 (2.4)	0.68 (27.74)	N/R	N/R	N/R	N/R
4	10 (3.04)	10 (3.04)	10 (3.04)	35 (2.4)	0.86 (35.09)	N/R	N/R	N/R	N/R
4	8 (2.44)	12 (3.6)	4-2 (1.27)	35 (2.4)	0.66 (26.93)	N/R	N/R	N/R	N/R
4	10 (3.04)	10 (3.04)	4-2 (1.27)	50 (3.4)	N/R	N/R	0.71 (28.97)	0.60 (24.48)	0.37 (15.10)

1. All 35 psi (2.4 bar) tests are performed on a system fed from both directions (double feed).
2. All 50 psi (3.4 bar) tests are performed on a system fed from one direction (single feed), except for the two sprinkler, single pipe tests which are performed on a double feed system.
3. Average of the ten non-flue-pans with the lowest water collection.

N/R = No requirement

(See Figures D-9 through D-14)

4.29.2 Tests/Verification

At least one sample set shall be tested to the requirements of Table 4.29.1a for K14.0 (K200) pendent quick response storage sprinklers or Table 4.29.1b for K16.8 (K240) pendent quick response storage sprinklers. Prior to the test, all samples shall be operated using a suitable heat source to remove the heat responsive assembly. The sprinkler test area shall be designed as shown in Figures D-9 through D-13. The water collection areas shall be in accordance with the specifications in Figure D-14. The test apparatus shall be located in a room of sufficient volume so as to minimize the entrainment of additional water spray. No significant drafts or other air movement shall be allowed into, or out of, the test area.

The water collection system, Figure D-14, shall be covered until the required pressure has been obtained. At that time, the cover shall be quickly removed in such a manner as to not cause water collected on top of the cover to be deposited into the collection pans. The test shall be conducted for a period of 5 minutes, or until the water level in the fullest collection bucket reaches its maximum measurable level, whichever occurs first. At the conclusion of the test, the cover shall be immediately placed over the collection pans to prevent further water collection.

4.30 Actual Delivered Density (ADD)

4.30.1 Requirement

Quick response storage sprinklers shall meet the requirements stated in Tables 4.30.1b - 4.30.1g, as applicable, for the tests described in Section 4.30.2 when tested in the FM Approvals ADD/PWD apparatus.

For dry pendent quick response storage sprinklers and quick response storage sprinklers having nominal discharge coefficients equal to or greater than K22.4 (K320), ADD tests are used only to determine the ignition locations for full scale fire testing – minimum collection requirements are not specified. The least favorable ignition scenario will be identified by the lowest average density collected.

Table 4.30.1a can be used as a reference guide to find the applicable set of tables for a specific sprinkler.

Table 4.30.1a. Applicable Tables for ADD Measurements

<i>Nominal Discharge Coefficient (gal/min/(psi)^{1/2})</i>	<i>Style</i>	<i>Applicable Table</i>
K14.0 (K200)	Upright	4.30.1b
K14.0 (K200)	Pendent	4.30.1c
K16.8 (K240)	Upright	4.30.1d
K16.8 (K240)	Pendent	4.30.1e
K22.4 (K320), K25.2 (K360)	Pendent	4.30.1f
K14.0 (K200), K16.8 (K240)	Dry Pendent	4.30.1g

Table 4.30.1b. ADD Requirements for K14.0 (K200) Upright Quick Response Storage Sprinklers

Number of Sprinklers Centered Over the ADD Apparatus	Sprinkler Spacing ft (m)	Pipe Spacing ft (m)	Ceiling Clearance to Water Collection Pans ft (m)	Freeburn Convective Heat Release kBTU/min (MW)	Pressure psi (bar)	Direction of Feed Flow	Minimum 20 Pan Average Density gal/min/ft ² (mm/min)
1	-	-	10	28	50	Double	0.35
	-	-	(3)	(0.5)	(3.4)		(14.3)
1	-	-	10	28	75	Double	0.52
	-	-	(3)	(0.5)	(5.2)		(21.2)
2	10	-	5	114	50	Double	0.55
	(3)	-	(2)	(2)	(3.4)		(22.4)
2	10	-	5	114	75	Double	0.69
	(3)	-	(2)	(2)	(5.2)		(28.2)
2	-	10	5	114	50	Double	0.55
	-	(3)	(2)	(2)	(3.4)		(22.4)
2	-	10	5	114	75	Double	0.69
	-	(3)	(2)	(2)	(5.2)		(28.2)
4	10	10	5	142	50	Double	0.60
	(3)	(3)	(2)	(2.5)	(3.4)		(24.5)
4	10	10	5	142	75	Double	0.68
	(3)	(3)	(2)	(2.5)	(5.2)		(27.7)

Table 4.30.1c. ADD Requirements for K14.0 (K200) Pendent Quick Response Storage Sprinklers

Number of Sprinklers Centered Over the ADD Apparatus	Sprinkler Spacing ft (m)	Pipe Spacing ft (m)	Ceiling Clearance to Water Collection Pans ft (m)	Freeburn Convective Heat Release kBTU/min (MW)	Pressure psi (bar)	Direction of Feed Flow	Minimum 20 Pan Average Density gal/min/ft ² (mm/min)
1	-	-	15	75	50	Double	0.46
	-	-	(4.6)	(1.3)	(3.4)		(18.8)
1	-	-	15	150	50	Double	0.24
	-	-	(4.6)	(2.6)	(3.4)		(9.8)
2	12	-	4	150	50	Single	0.29
	(3.7)	-	(1.2)	(2.6)	(3.4)		(11.8)
2	-	12	4	150	50	Double	0.29
	-	(3.7)	(1.2)	(2.6)	(3.4)		(11.8)
4	8	12	4	150	50	Double	0.63
	(2.4)	(3.7)	(1.2)	(2.6)	(3.4)		(25.7)

Table 4.30.1d. ADD Requirements for K16.8 (K240) Upright Quick Response Storage Sprinklers

Number of Sprinklers Centered Over the ADD Apparatus	Sprinkler Spacing ft (m)	Pipe Spacing ft (m)	Ceiling Clearance to Water Collection Pans ft (m)	Freeburn Convective Heat Release kBTU/min (MW)	Pressure psi (bar)	Direction of Feed Flow	Minimum 20 Pan Average Density gal/min/ft ² (mm/min)
1	-	-	10	28	35	Double	0.55
	-	-	(3)	(0.5)	(2.4)		(22.4)
1	-	-	10	28	50	Double	0.65
	-	-	(3)	(0.5)	(3.4)		(26.5)
2	10	-	5	114	35	Double	0.55
	(3)	-	(2)	(2)	(2.4)		(22.4)
2	10	-	5	114	50	Double	0.69
	(3)	-	(2)	(2)	(3.4)		(28.2)
2	-	10	5	114	35	Double	0.55
	-	(3)	(2)	(2)	(2.4)		(22.4)
2	-	10	5	114	50	Double	0.69
	-	(3)	(2)	(2)	(3.4)		(28.2)
4	10	10	5	142	35	Double	0.70
	(3)	(3)	(2)	(2.5)	(2.4)		(28.6)
4	10	10	5	142	50	Double	0.90
	(3)	(3)	(2)	(2.5)	(3.4)		(36.7)

Table 4.30.1e. ADD Requirements for K16.8 (K240) Pendent Quick Response Storage Sprinklers

Number of Sprinklers Centered Over the ADD Apparatus	Sprinkler Spacing ft (m)	Pipe Spacing ft (m)	Ceiling Clearance to Water Collection Pans ft (m)	Freeburn Convective Heat Release kBTU/min (MW)	Pressure psi (bar)	Direction of Feed Flow	Minimum 20 Pan Average Density gal/min/ft ² (mm/min)
1	-	-	15	75	35	Double	0.34
	-	-	(4.6)	(1.3)	(2.4)		(13.9)
1	-	-	15	150	35	Double	0.27
	-	-	(4.6)	(2.6)	(2.4)		(11.0)
2	12	-	4	150	35	Single	0.27
	(3.7)	-	(1.2)	(2.6)	(2.4)		(11.0)
2	-	12	4	150	35	Double	0.39
	-	(3.7)	(1.2)	(2.6)	(2.4)		(15.9)
4	8	12	4	150	35	Double	0.63
	(2.4)	(3.7)	(1.2)	(2.6)	(2.4)		(25.7)

Table 4.30.1f. ADD Test Conditions for K22.4 (K320) and K25.2 (K360) Pendent Quick Response Storage Sprinklers

Sprinkler Nominal Discharge Coefficient (gal/min/(psi) ^{1/2})	Number of Sprinklers Centered Over the ADD Apparatus	Sprinkler Spacing ft (m)	Pipe Spacing ft (m)	Ceiling Clearance to Water Collection Pans ft (m)	Freeburn Convective Heat Release kBTU/min (MW)	Pressure psi (bar)	Direction of Feed Flow	Minimum 20 Pan Average Density gal/min/ft ² (mm/min)
22.4	2	12	-	6	150	20	Double	N/R
		(3.7)	-	(1.8)	(2.6)	(1.4)		
	4	12	8	6	170	20	Double	N/R
		(3.7)	(2.4)	(1.8)	(3.0)	(1.4)		
25.2	2	12	-	6	150	15	Double	N/R
		(3.7)	-	(1.8)	(2.6)	(1.0)		
	4	12	8	6	170	15	Double	N/R
		(3.7)	(2.4)	(1.8)	(3.0)	(1.0)		

N/R = No requirement

Table 4.30.1g. ADD Test Conditions for K14.0 (K200) and K16.8 (K240) Dry Pendent Quick Response Storage Sprinklers

Sprinkler Nominal Discharge Coefficient (gal/min/(psi) ^{1/2})	Number of Sprinklers Centered Over the ADD Apparatus	Sprinkler Spacing ft (m)	Pipe Spacing ft (m)	Ceiling Clearance to Water Collection Pans ft (m)	Freeburn Convective Heat Release kBTU/min (MW)	Pressure psi (bar)	Direction of Feed Flow	Minimum 20 Pan Average Density gal/min/ft ² (mm/min)
14.0	2	12	-	6	150	50	Double	N/R
		(3.7)	-	(1.8)	(2.6)	(3.4)		
	4	12	8	6	150	50	Double	N/R
		(3.7)	(2.4)	(1.8)	(2.6)	(3.4)		
16.8	2	12	-	6	150	35	Double	N/R
		(3.7)	-	(1.8)	(2.6)	(2.4)		
	4	12	8	6	150	35	Double	N/R
		(3.7)	(2.4)	(1.8)	(2.6)	(2.4)		

N/R = No requirement

4.30.2 Tests/Verification

Actual Delivered Density (ADD) measurements shall be taken using the test apparatus shown in Figures D-15 and D-16. The ADD apparatus shall consist of two major components: a fire source and a simulated commodity. The fire source shall consist of a number of spray nozzles equally spaced on the circumference of a circle. Heptane shall be used as the fuel for the fire. Approximately 6 in. (152 mm) below the fire source shall be an array of collection pans representing a simulated commodity.

The array shall approximate the geometry and size of a single tier rack-storage commodity of two pallet loads deep by two pallet loads wide, with a 6 in. (15.2 cm) flue space between each pallet. Sixteen square water collection pans, representing the top surface of the commodity within the ignition area, shall collect water that would normally reach the commodity's top surface. Four additional pans, representing the flue spaces between pallet loads of commodity, shall collect water that would normally be delivered to the flue spaces.

A flat horizontal ceiling with minimum dimensions of 36.5 x 33.5 ft (11.13 x 10.21 m) shall be suspended above the apparatus. The test apparatus shall be located in a room of sufficient volume to minimize the entrainment of additional water spray.

Open quick response storage sprinklers having a nominal K-factor of $16.8 \text{ gal/min}/(\text{psi})^{1/2}$ or less shall be connected to nominal 2 in. sprinkler pipes under the suspended ceiling via 2 in. x 2 in. x 3/4 in. nominal threaded tees, threadolet fittings with bushings, or a suitable alternative.

Open quick response storage sprinklers having a nominal K-factor greater than $16.8 \text{ gal/min}/(\text{psi})^{1/2}$ shall be connected to nominal 2.5 in. sprinkler pipes under the suspended ceiling via 2.5 in. x 2.5 in. x 1 in. nominal threaded tees, threadolet fittings with bushings, or a suitable alternative.

EXCEPTION: dry type quick response storage sprinklers may be connected to nominal 2.5 in. or larger sprinkler pipes, depending upon the size of the threaded connection used in the design.

Pendent sprinklers shall be installed with the sprinkler piping center line located 9 in. (23 cm) below the ceiling. Upright sprinklers shall be installed with sprinkler piping center line located 12 in. (30 cm) below the ceiling.

EXCEPTION: dry type quick response storage sprinklers may be installed at other elevations as permitted by their design. Where ADD tests are used only to determine the ignition locations for full scale fire testing, the sprinklers may be installed at the maximum permitted distance below the ceiling, as used in the fire tests.

The frame arms of each sprinkler shall be aligned parallel with the sprinkler pipe. The pipes shall be fed with water flowing from either a single direction, or both directions (double), as specified in the appropriate Table (4.30.1b-g) above.

Prior to each measurement, the heptane spray shall be ignited and stabilized at a flow rate corresponding to the required heat release. Once the fuel flow rate has been stabilized, water shall be discharged from the sprinklers. Water collected by all pans is to be channeled to the collectors of the apparatus. Water shall be collected until one or more collection buckets are filled, or for a minimum of 10 minutes, whichever occurs first, for each test detailed in Section 4.30.1.

For all tests, measurements shall be recorded for up to five different sets of samples.

4.31 Thrust Measurement

4.31.1 Requirement

K14.0 (K200) and K16.8 (K240) pendent quick response storage sprinklers shall meet the minimum thrust force requirements shown in Table 4.31.1 when tested in accordance with Section 4.31.2. Three replications of each test condition shall be conducted. There are no thrust force requirements for quick response storage sprinklers other than K14.0 (K200) and K16.8 (K240) pendent types.

NOTE: Thrust testing does not apply to dry type quick response storage sprinklers.

Table 4.31.1. Thrust Measurements

Sprinkler Nominal K- Factor	Pressure		Direction of Feed Flow	Ceiling Clearance to Thrust Plate		Minimum Required Thrust	
	psi	(bar)		ft	(m)	lb/ft ²	(mbar)
14.0 (200)	50	(3.4)	Double	4	(1.2)	1.5	(0.71)
	50	(3.4)	Double	7	(2.1)	0.94	(0.44)
	75	(5.1)	Single ¹	7	(2.1)	2.1 ¹	(0.99) ¹
16.8 (240)	35	(2.4)	Double	4	(1.2)	1.5	(0.71)
	35	(2.4)	Double	7	(2.1)	0.94	(0.44)
	50	(3.4)	Single ¹	7	(2.1)	2.1 ¹	(0.99) ¹

1. For the single direction flow condition, the maximum thrust may not occur at a point centered directly beneath the sprinkler.

4.31.2 Tests/Verification

Three open sprinklers shall be individually installed as shown in Figure D-17. The center core thrust over a nominal 13.5 in. (345 mm) diameter plate shall be measured while discharging water at the pressures shown in Table 4.31.1.

4.32 Fire Tests - K14.0 (K200) Upright Quick Response Storage Sprinklers

4.32.1 Requirement

K14.0 (K200) upright quick response storage sprinklers shall perform satisfactorily in full-scale fire test scenarios as detailed in Section 4.32.2 within the limits stated in Table 4.32.1.

There are no fire test requirements for K14.0 (K200) pendent quick response storage sprinklers.

Table 4.32.1. K14.0 (K200) Upright Quick Response Storage Sprinkler Fire Test Limits

Test	A	B	C	D	E
Peak/Maximum One Minute Average Steel Temperature °F (°C)	1200/1000 (649/538)	1200/1000 (649/538)	1200/1000 (649/538)	1200/1000 (649/538)	1200/1000 (649/538)
Aisle Jump/Fire Spread	See below*	See below*	See below*	See below*	See below*
Maximum Number of Sprinklers to Operate**	12	8	12	8	8

* Fire spread must be confined to the length of the main array. Fire spread to the ends of the main array or to a target array is not permitted.

** Sprinklers installed along the perimeter of the ceiling are not permitted to operate.

4.32.2 Tests/Verification

The tests detailed in Table 4.32.2 shall be conducted in an indoor fire test facility with an adjustable ceiling measuring 80 ft x 80 ft (24.4 m x 24.4 m). Sprinklers having a nominal temperature rating of 160°F (70°C) shall be installed on nominal 2 in. diameter Schedule 40 sprinkler pipes. In order to simulate the effect of large pipe sizes on the sprinkler distribution pattern, the outside diameter of the pipe(s) in the area over ignition shall be equal to that of a nominal 2.5 in. diameter Schedule 40 sprinkler pipe. The pipes shall be oriented perpendicular to the length of the test array and positioned such that the sprinklers are centered about the geometric center of the ceiling. Ignition shall be accomplished using an FM Global standard igniter and shall take place at the bottom of the first tier of the test array, located at the geometric center of the double row-rack as described in the appropriate figure listed in Table 4.32.2. Temperatures shall be monitored by thermocouples located at the ceiling. Two-way, 42 in. x 42 in. x 5 in. slatted hardwood pallets placed in metal storage racks shall support the commodity. Target arrays shall be

located adjacent to the test array, separated by an aisle space 4 ft (1.2 m) wide. The commodity type, storage arrangement and height of the target arrays shall be selected to correspond to the test array. Commodity moisture content shall be 6 percent \pm 2 percent (dry basis).

Table 4.32.2. K14.0 (K200) Upright Quick Response Storage Sprinkler Test Scenarios

<i>Test</i>	<i>A*</i>	<i>B</i>	<i>C**</i>	<i>D</i>	<i>E</i>
Storage Type	Double-Row Rack (Figure D-18)	Double-Row Rack (Figure D-19)	Double-Row Rack (Figure D-20)	Double-Row Rack (Figure D-21)	Double-Row Rack (Figure D-22)
Fuel (FM Global Standard Commodity)	Cartoned Expanded Plastic	Cartoned Expanded Plastic	Cartoned Unexpanded Plastic	Cartoned Unexpanded Plastic	Cartoned Unexpanded Plastic
Nominal Array Height, ft (m)	19 (5.8)	24 (7.3)	24 (7.3)	24 (7.3)	29 (8.8)
Nominal Ceiling Height, ft (m)	30 (9.1)	30 (9.1)	30 (9.1)	35 (10.7)	35 (10.7)
Nominal Clearance-to-ceiling ft (m)	11 (3.4)	6 (1.8)	6 (1.8)	11 (3.4)	6 (1.8)
Ignition	Below 1 sprinkler	Between 2 sprinklers	Between 2 sprinklers	Below 1 sprinkler	Between 2 sprinklers
Sprinkler Spacing ft x ft (m x m)	10 x 10 (3.0 x 3.0)	10 x 10 (3.0 x 3.0)	10 x 10 (3.0 x 3.0)	10 x 10 (3.0 x 3.0)	10 x 10 (3.0 x 3.0)
Deflector to Ceiling, in. (mm)	7 (180)	7 (180)	7 (180)	7 (180)	7 (180)
Water Pressure, psi (bar)	50 (3.4)	50 (3.4)	50 (3.4)	75 (5.2)	75 (5.2)
Test Duration (min)	30	30	30	30	30

* This test shall include a bar joist obstruction consisting of 4 inch web, centered directly above the ignition location, oriented along the longitudinal flue of the main array

** One of the two sprinklers shall be rendered inoperative to simulate a plugged sprinkler condition.

4.33 Fire Tests - K16.8 (K240) Upright Quick Response Storage Sprinklers

4.33.1 Requirement

K16.8 (K240) upright quick response storage sprinklers shall perform satisfactorily in full-scale fire test scenarios as detailed in Section 4.33.2 within the limits stated in Table 4.33.1.

There are no fire test requirements for K16.8 (K240) pendent quick response storage sprinklers.

Table 4.33.1. K16.8 (K240) Upright Quick Response Storage Sprinkler Fire Test Limits

<i>Test</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>
Peak/Maximum One Minute Average Steel Temperature °F (°C)	1200/1000 (649/538)	1200/1000 (649/538)	1200/1000 (649/538)	1200/1000 (649/538)	1200/1000 (649/538)
Aisle Jump/Fire Spread	See below*	See below*	See below*	See below*	See below*
Maximum Number of Sprinklers to Operate**	12	8	12	8	8

* Fire spread must be confined to the length of the main array. Fire spread to the ends of the main array or to a target array is not permitted.

** Sprinklers installed along the perimeter of the ceiling are not permitted to operate.

4.33.2 Tests/Verification

The tests detailed in Table 4.33.2 shall be conducted in an indoor fire test facility with an adjustable ceiling measuring 80 ft x 80 ft (24.4 m x 24.4 m). Sprinklers having a nominal temperature rating of 160°F (70°C) shall be installed at the spacing indicated in Table 4.33.2, on

nominal 2 in. diameter Schedule 40 sprinkler pipes. In order to simulate the effect of large pipe sizes on the sprinkler distribution pattern, the outside diameter of the pipe(s) in the area over ignition shall be equal to that of a nominal 2.5 in. diameter Schedule 40 sprinkler pipe. The pipes shall be oriented perpendicular to the length of the test array and positioned such that the sprinklers are centered about the geometric center of the ceiling. Ignition shall be accomplished using an FM Global standard igniter and shall take place at the bottom of the first tier of the test array, located at the geometric center of the double row-rack as described in the appropriate figure listed in Table 4.33.2. Temperatures shall be monitored by thermocouples located at the ceiling. Two-way, 42 in. x 42 in. x 5 in, slatted hardwood pallets placed in metal storage racks shall support the commodity. Target arrays shall be located adjacent to the test array, separated by an aisle space 4 ft (1.2 m) wide. The commodity type, storage arrangement and height of the target array shall be selected to correspond to the test array. Commodity moisture content shall be 6 percent \pm 2 percent (dry basis).

Table 4.33.2. K16.8 (K240) Upright Quick Response Storage Sprinkler Test Scenarios

<i>Test</i>	<i>A*</i>	<i>B</i>	<i>C**</i>	<i>D</i>	<i>E</i>
Storage Type	Double-Row Rack (Figure D-23)	Double-Row Rack (Figure D-24)	Double-Row Rack (Figure D-25)	Double-Row Rack (Figure D-26)	Double-Row Rack (Figure D-27)
Fuel (FM Global Standard Commodity)	Cartoned Expanded Plastic	Cartoned Expanded Plastic	Cartoned Unexpanded Plastic	Cartoned Unexpanded Plastic	Cartoned Unexpanded Plastic
Nominal Array Height ft (m)	19 (5.8)	24 (7.3)	24 (7.3)	24 (7.3)	29 (8.8)
Nominal Ceiling Height, ft (m)	30 (9.1)	30 (9.1)	30 (9.1)	35 (10.7)	35 (10.7)
Nominal Clearance-to-ceiling ft (m)	11 (3.4)	6 (1.8)	6 (1.8)	11 (3.4)	6 (1.8)
Ignition	Below 1 sprinkler	Between 2 sprinklers	Between 2 sprinklers	Below 1 sprinkler	Between 2 sprinklers
Sprinkler Spacing ft x ft (m x m)	10 x 10 (3.0 x 3.0)	10 x 10 (3.0 x 3.0)	10 x 10 (3.0 x 3.0)	10 x 10 (3.0 x 3.0)	10 x 10 (3.0 x 3.0)
Deflector to Ceiling, in. (mm)	7 (180)	7 (180)	7 (180)	7 (180)	7 (180)
Water Pressure, psi (bar)	35 (2.4)	35 (2.4)	35 (2.4)	50 (3.4)	50 (3.4)
Test Duration (min)	30	30	30	30	30

* This test shall include a bar joist obstruction consisting of 4 inch web, centered directly above the ignition location, oriented along the longitudinal flue of the main array

** One of the two sprinklers shall be rendered inoperative to simulate a plugged sprinkler condition

4.34 Fire Tests - K22.4 (K320) and K25.2 (K360) Pendent Quick Response Storage Sprinklers

4.34.1 Requirement

K22.4 (K320) and K25.2 (K360) pendent quick response storage sprinklers shall perform satisfactorily in full-scale fire test scenarios as detailed in Section 4.34.2 within the limits stated in Tables 4.34.1.

NOTE: Extended coverage storage sprinklers are covered under Approval Standard FM2000.

Table 4.34.1. K22.4 (K320) and K25.2 (K360) Pendent Quick Response Storage Sprinkler Fire Test Limits

<i>Test</i>	<i>A</i>	<i>B</i>	<i>C</i>
Peak/Maximum One Minute Average Steel Temperature °F (°C)	1200/1000 (649/538)	1200/1000 (649/538)	1200/1000 (649/538)
Aisle Jump/Fire Spread	See below*	See below*	See below*
Maximum Number of Sprinklers to Operate**	8	8	8

* Fire spread must not extend beyond the last transverse flue to either side of ignition and must not burn through the back side of either target array.

** Sprinklers installed along the perimeter of the ceiling are not permitted to operate.

4.34.2 Tests/Verification

The tests detailed in Table 4.34.2 shall be conducted in an indoor fire test facility with an adjustable ceiling measuring 80 ft x 80 ft (24.4 m x 24.4 m). Sprinklers having a nominal temperature rating of 160°F (70°C) shall be installed at the spacing indicated in Table 4.34.2, on nominal 2.5 in. diameter Schedule 40 sprinkler pipes. The pipes shall be oriented perpendicular to the length of the test array and positioned such that the sprinklers are centered about the geometric center of the ceiling. Ignition shall be accomplished using an FM Global standard igniter and shall take place in the center transverse flue space at the bottom of the first tier of the main rack, offset 2 ft (0.6 m) from the geometric center of the rack. Ignition location for test A shall be selected based on the lowest Actual Delivered Density (ADD) results at the corresponding conditions. Temperatures shall be monitored by thermocouples located at the ceiling. Two-way, 42 in. x 42 in. x 5 in, slatted hardwood pallets placed in metal storage racks shall support the commodity. Target arrays shall be located adjacent to the test array, separated by an aisle space 4 ft (1.2 m) wide. The commodity type, storage arrangement and height of the target array shall be selected to correspond to the test array. Commodity moisture content shall be 6 percent \pm 2 percent (dry basis).

If test B is successfully completed with only a single sprinkler operating, test C may be omitted at the sole discretion of FM Approvals.

Table 4.34.2. K22.4 (K320) and K25.2 (K360) Pendent Quick Response Storage Sprinkler Test Scenarios

<i>Test</i>	<i>A</i>	<i>B</i>	<i>C</i>
Storage Type	Double-Row Rack (Figure D-28)	Double-Row Rack (Figure D-29)	Double-Row Rack (Figure D-29)
Fuel (FM Global Standard Commodity)	Cartoned Unexpanded Plastic	Cartoned Unexpanded Plastic	Cartoned Unexpanded Plastic
Nominal Array Height ft (m)	24 (7.3)	19 (5.8)	19 (5.8)
Nominal Ceiling Height, ft (m)	30 (9.1)	30 (9.1)	30 (9.1)
Nominal Clearance-to-ceiling ft (m)	6 (1.8)	11 (3.4)	11 (3.4)
Ignition	Between 2 or 4 sprinklers*	Below 1 sprinkler	Below 1 sprinkler
Sprinkler Spacing** ft x ft (m x m)	8 x 12 (2.4 x 3.7)	8 x 8 (2.4 x 2.4)	10 x 10 (3.0 x 3.0)
Heat Responsive Element to Ceiling, in. (mm)	17 (430)	17 (430)	17 (430)
Water Pressure for K=22.4, psi (bar)	20 (1.4)	20 (1.4)	20 (1.4)
Water Pressure for K=25.2, psi (bar)	15 (1.0)	15 (1.0)	15 (1.0)
Test Duration (min)	30	30	30

* The ignition location for test A is based on worst-case scenario determined by ADD testing.

** Sprinkler spacing = Distance between adjacent pipes x Distance between sprinklers on the same pipe.

4.35 Fire Tests - K14.0 (K200) and K16.8 (K240) Dry Pendent Quick Response Storage Sprinklers

4.35.1 Requirement

K14.0 (K200) and K16.8 (K240) dry pendent quick response storage sprinklers shall perform satisfactorily in full-scale fire test scenarios as detailed in Section 0 within the limits stated in Table 4.35.1.

Table 4.35.1. K14.0 (K200) and K16.8 (K240) Dry Pendent Quick Response Storage Sprinkler Fire Test Limits

<i>Test</i>	<i>A</i>	<i>B</i>	<i>C</i>
Peak/Maximum One Minute Average Steel Temperature °F (°C)	1200/1000 (649/538)	1200/1000 (649/538)	1200/1000 (649/538)
Aisle Jump/Fire Spread	See below*	See below*	See below*
Maximum Number of Sprinklers to Operate**	8	8	8

* Fire spread must not extend beyond the last transverse flue to either side of ignition and must not burn through the back side of either target array.

** Sprinklers installed along the perimeter of the ceiling are not permitted to operate.

4.35.2 Tests/Verification

The tests detailed in Table 0a or 0b shall be conducted in an indoor fire test facility with an adjustable ceiling measuring 80 ft x 80 ft (24.4 m x 24.4 m). Sprinklers having a nominal temperature rating of 160°F (70°C) shall be installed at the spacing indicated in Table 0a or b, on nominal 2 in. diameter Schedule 40 sprinkler pipes. The pipes shall be oriented perpendicular to

the length of the test array and positioned such that the sprinklers are centered about the geometric center of the ceiling. Ignition shall be accomplished using an FM Global standard igniter and shall take place in the center transverse flue space at the bottom of the first tier of the main rack, offset 2 ft (0.6 m) from the geometric center of the rack. Ignition location for test A shall be selected based on the lowest Actual Delivered Density (ADD) results at the corresponding conditions. Temperatures shall be monitored by thermocouples located at the ceiling. Two-way, 42 in. x 42 in. x 5 in, slatted hardwood pallets placed in metal storage racks shall support the commodity. Target arrays shall be located adjacent to the test array, separated by an aisle space 4 ft (1.2 m) wide. The commodity type, storage arrangement and height of the target array shall be selected to correspond to the test array. Commodity moisture content shall be 6 percent \pm 2 percent (dry basis).

If test B is successfully completed with only a single sprinkler operating, test C may be omitted at the sole discretion of FM Approvals.

Table 0a. K14.0 (K200) Dry Pendent Quick Response Storage Sprinkler Test Scenarios

Test	A	B	C
Storage Type	Double-Row Rack (Figure D-30)	Double-Row Rack (Figure D-31)	Double-Row Rack (Figure D-31)
Fuel (FM Global Standard Commodity)	Cartoned Unexpanded Plastic	Cartoned Unexpanded Plastic	Cartoned Unexpanded Plastic
Nominal Array Height ft (m)	24 (7.3)	19 (5.8)	19 (5.8)
Nominal Ceiling Height, ft (m)	30 (9.1)	30 (9.1)	30 (9.1)
Nominal Clearance-to-ceiling ft (m)	6 (1.8)	11 (3.4)	11 (3.4)
Ignition	Between 2 or 4 sprinklers*	Below 1 sprinkler	Below 1 sprinkler
Sprinkler Spacing** ft x ft (m x m)	10 x 10 (3.0 x 3.0)	8 x 10 (2.4 x 3.0)	10 x 10 (3.0 x 3.0)
Heat Responsive Element to Ceiling, Pendent Sprinklers, in. (mm)	13 (330)	13 (330)	13 (330)
Water Pressure, psi (bar)	50 (3.4)	50 (3.4)	50 (3.4)
Test Duration (min)	30	30	30

* The ignition location for test A is based on worst-case scenario determined by ADD testing.

** Sprinkler spacing = Distance between adjacent pipes x Distance between sprinklers on the same pipe.

Table 0b. K16.8 (K240) Dry Pendent Quick Response Storage Sprinkler Test Scenarios

<i>Test</i>	<i>A</i>	<i>B</i>	<i>C</i>
Storage Type	Double-Row Rack (Figure D-30)	Double-Row Rack (Figure D-31)	Double-Row Rack (Figure D-31)
Fuel (FM Global Standard Commodity)	Cartoned Unexpanded Plastic	Cartoned Unexpanded Plastic	Cartoned Unexpanded Plastic
Nominal Array Height ft (m)	24 (7.3)	19 (5.8)	19 (5.8)
Nominal Ceiling Height, ft (m)	30 (9.1)	30 (9.1)	30 (9.1)
Nominal Clearance-to-ceiling ft (m)	6 (1.8)	11 (3.4)	11 (3.4)
Ignition	Between 2 or 4 sprinklers*	Below 1 sprinkler	Below 1 sprinkler
Sprinkler Spacing** ft x ft (m x m)	10 x 10 (3.0 x 3.0)	8 x 10 (2.4 x 3.0)	10 x 10 (3.0 x 3.0)
Heat Responsive Element to Ceiling, Pendent Sprinklers, in. (mm)	13 (330)	13 (330)	13 (330)
Water Pressure, psi (bar)	35 (2.4)	35 (2.4)	35 (2.4)
Test Duration (min)	30	30	30

* The ignition location for test A is based on worst-case scenario determined by ADD testing.

** Sprinkler spacing = Distance between adjacent pipes x Distance between sprinklers on the same pipe.

4.36 Additional Tests

Additional tests, including 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 acceptable 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 sprinklers produced by the manufacturer at an authorized location shall present the same quality and reliability as the specific sprinklers examined. Design quality, conformance to design, and performance are the areas of primary concern.

- Design quality is determined during the examination and tests, and is documented in the Approval Report.
- Continued conformance to this Standard is verified by the Surveillance Audit Program.
- 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 assurance 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; and
 - handling and disposition of non-conformance materials.
- 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 Records
- To assure adequate traceability of materials and products, the manufacturer shall maintain a record of all quality assurance tests performed, for a minimum period of two years from the date of manufacture.
- 5.1.4 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. In situations involving significant changes to an Approved product, the notification shall be in the form of a formal request for an Approval examination. For modifications of a more common nature, the manufacturer shall provide notification to FM Approvals by means of FM Approvals Form 619, *FM Approved Product/Specification-Tested Revision Request Form*. Records of all revisions to all FM Approved products shall be maintained.

5.2 Surveillance Audit Program

- 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 uniform product consistent with that which was tested and FM Approved. Initial inspections of facilities already producing similar products may be waived at the discretion of FM Approvals.
- 5.2.2 Surveillance audits shall be conducted periodically, but at least annually, by FM Approvals or its representatives, or more frequently depending on jurisdictional requirements. At issue of this standard the Occupational and Safety Health Administration (OSHA) of the United States Department of Labor requires audits of manufacturing sites producing products for use in hazardous locations during each quarter the product is manufactured.
- 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.

- 5.2.4 In the event that all or part of the quality inspection is subcontracted, the manufacturer shall provide FM Approvals with documentation outlining the nature of the inspection, frequency, test details, and pass/fail criteria that was provided to the subcontracted company, and documentation that they have received and implemented these procedures.

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") $\text{mm}^2 = \text{in}^2 \times 6.4516 \times 10^2$ ft^2 - "square feet" (m^2 - "square meters") $\text{m}^2 = \text{ft}^2 \times 0.09292$
CONDUCTIVITY (C-FACTOR):	$(\text{ft/s})^{1/2}$ - "square root of feet per second" $([\text{m/s}]^{1/2})$ - "square root of meters per second" $(\text{m/s})^{1/2} = (\text{ft/s})^{1/2} \times 0.552$
DISCHARGE COEFFICIENT (K-FACTOR):	$\text{gal}/\text{min}/(\text{psi})^{1/2}$ - "gallons per minute per square root of pounds per square inch" $(\text{L}/\text{min}/(\text{bar})^{1/2})$ - "liters per minute per square root of bar" $\text{L}/\text{min}/(\text{bar})^{1/2} = \text{gal}/\text{min}/(\text{psi})^{1/2} \times 14.414$
ENERGY:	BTU - "British thermal units" (J - "joules") $\text{J} = \text{BTU} \times 1.0551 \times 10^3$
FLOW:	gal/min - "gallon per minute" (L/min - "liters per minute") $\text{L}/\text{min} = \text{gal}/\text{min} \times 3.7854$
FORCE:	lb - "pounds" (N - "newtons") $\text{N} = \text{lb} \times 4.4482$
FREQUENCY:	Hz - "hertz" (also the SI unit)
HEAT RELEASE RATE:	BTU/min - "British thermal units per minute" (kW - "kilowatts") $\text{kW} = \text{BTU}/\text{min} \times 0.0176$ BTU/min - "British thermal units per minute" (MW - "megawatts") $\text{MW} = \text{BTU}/\text{min} \times 0.0000176$ $\text{kBTU}/\text{min} = \text{BTU}/\text{min} \times 1000$ $\text{MW} = \text{kBTU}/\text{min} \times 0.0176$
LENGTH:	in. - "inches" (mm - "millimeters") $\text{mm} = \text{in.} \times 25.4$ ft - "feet" (m - "meters") $\text{m} = \text{ft} \times 0.3048$
LIQUID VOLUME:	gal - "gallons" (L - "liters") $\text{L} = \text{gal} \times 3.7854$ oz. - "ounces" (ml - "milliliters") $\text{ml} = \text{oz.} \times 29.6$
MASS:	lb - "pounds" (kg - "kilograms") $\text{kg} = \text{lb} \times 0.454$

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 mbar = bar x 0.001 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):	lb·ft - "pound-feet" (N·m - "newton-meters") N·m = lb·ft x 1.356
VOLUME PER UNIT AREA:	gal/min/ft ² - "gallons per minute per square feet" (mm/min - "millimeters per minute") mm/min = 40.75 x gal/min/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 should be carried out at a room (ambient) temperature of $68 \pm 12^\circ\text{F}$ ($20 \pm 6.7^\circ\text{C}$).

APPENDIX C: TOLERANCE LIMIT CALCULATIONS

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

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

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)

<i>n</i>	γ	<i>n</i>	γ	<i>n</i>	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:

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

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

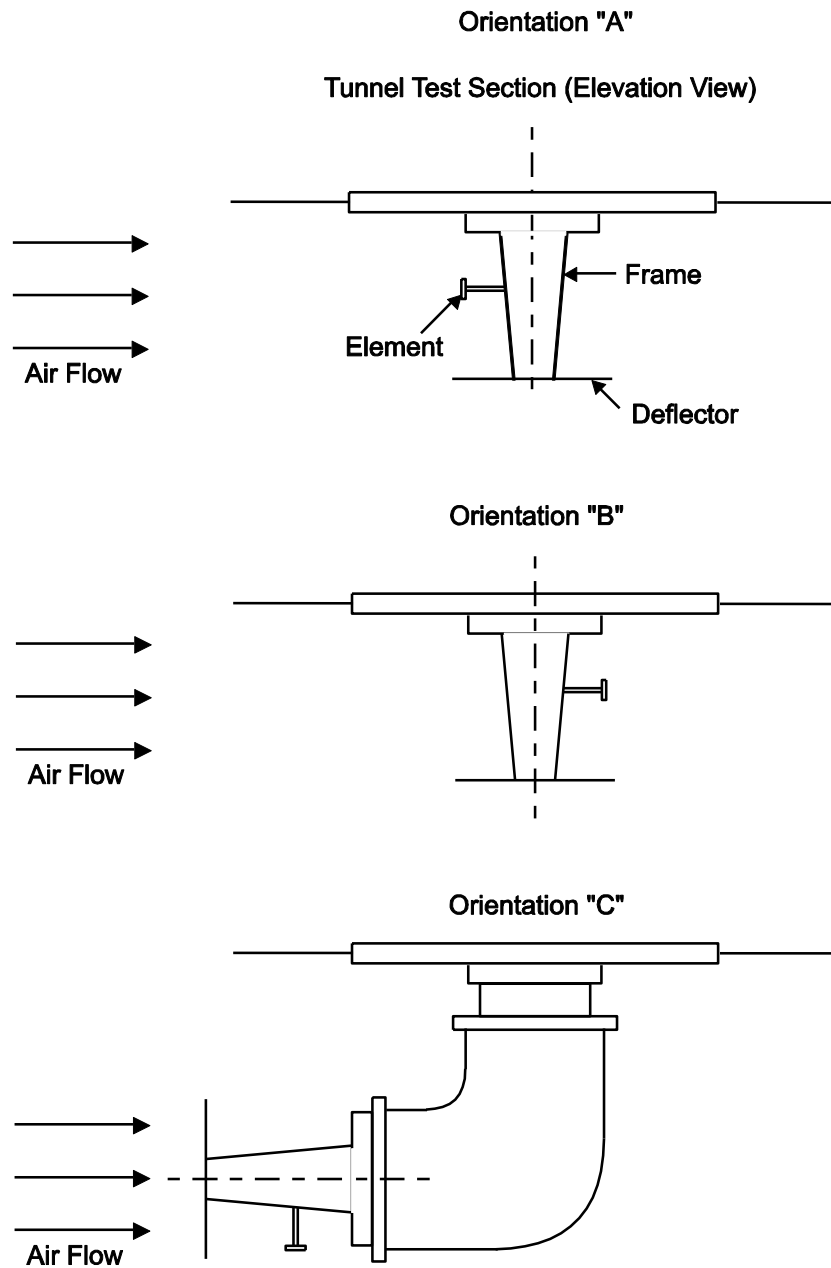
Where:

- 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.

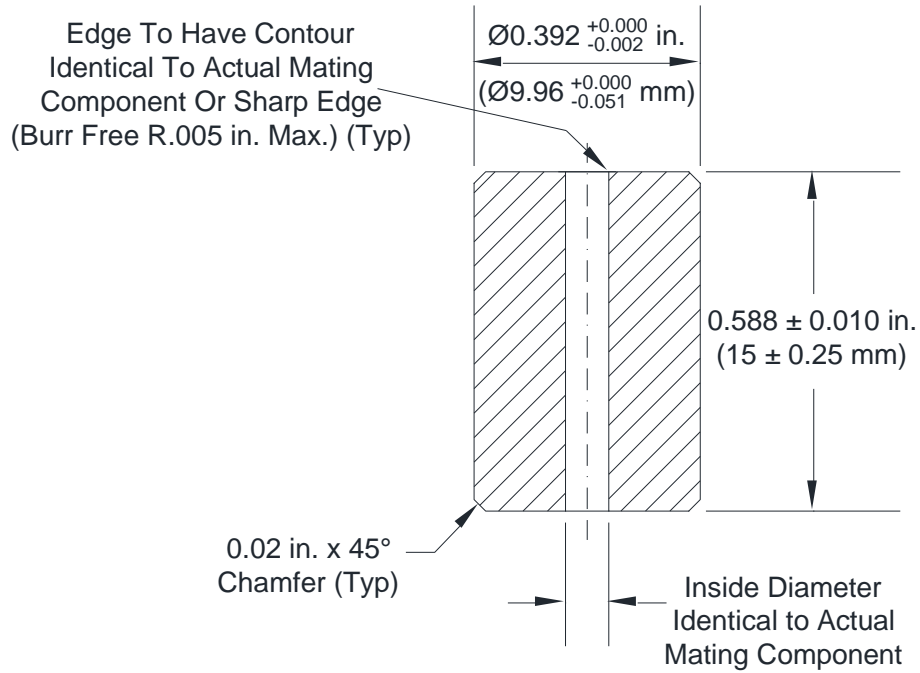
APPENDIX D: FIGURES



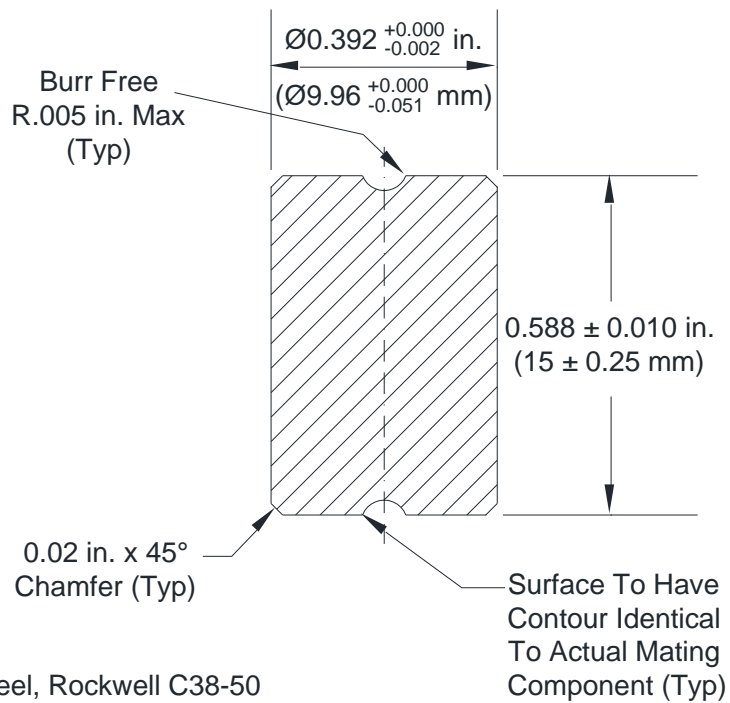
Note: In the case where the sprinkler has a symmetrical heat responsive element and frame, position "A" would be the same as position "B". Testing in both positions is not required.

D-1: Orientations A, B, C (For Sensitivity - RTI Test)

For Designs with Line Contact:



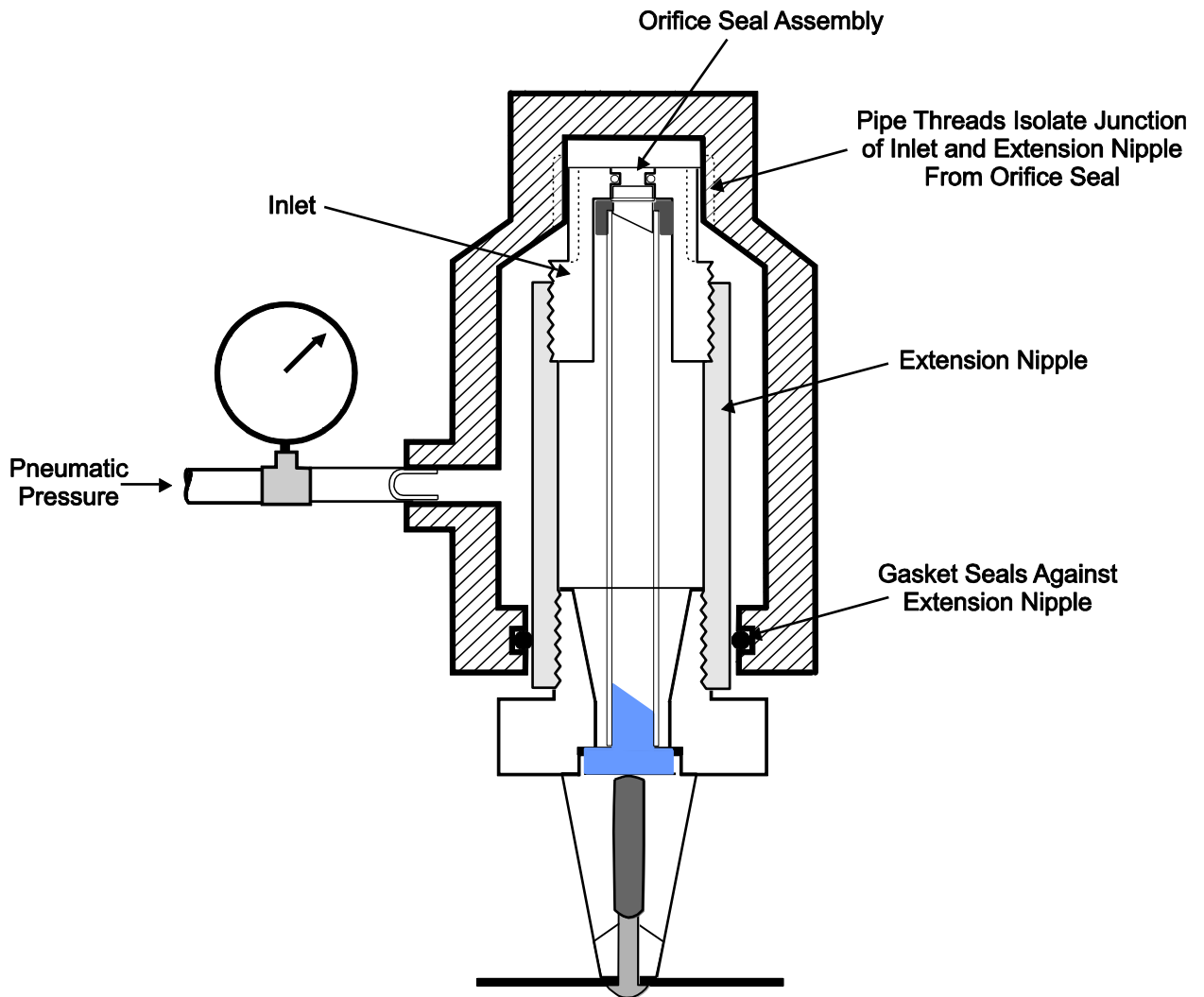
Or: For Designs with Surface Contact:



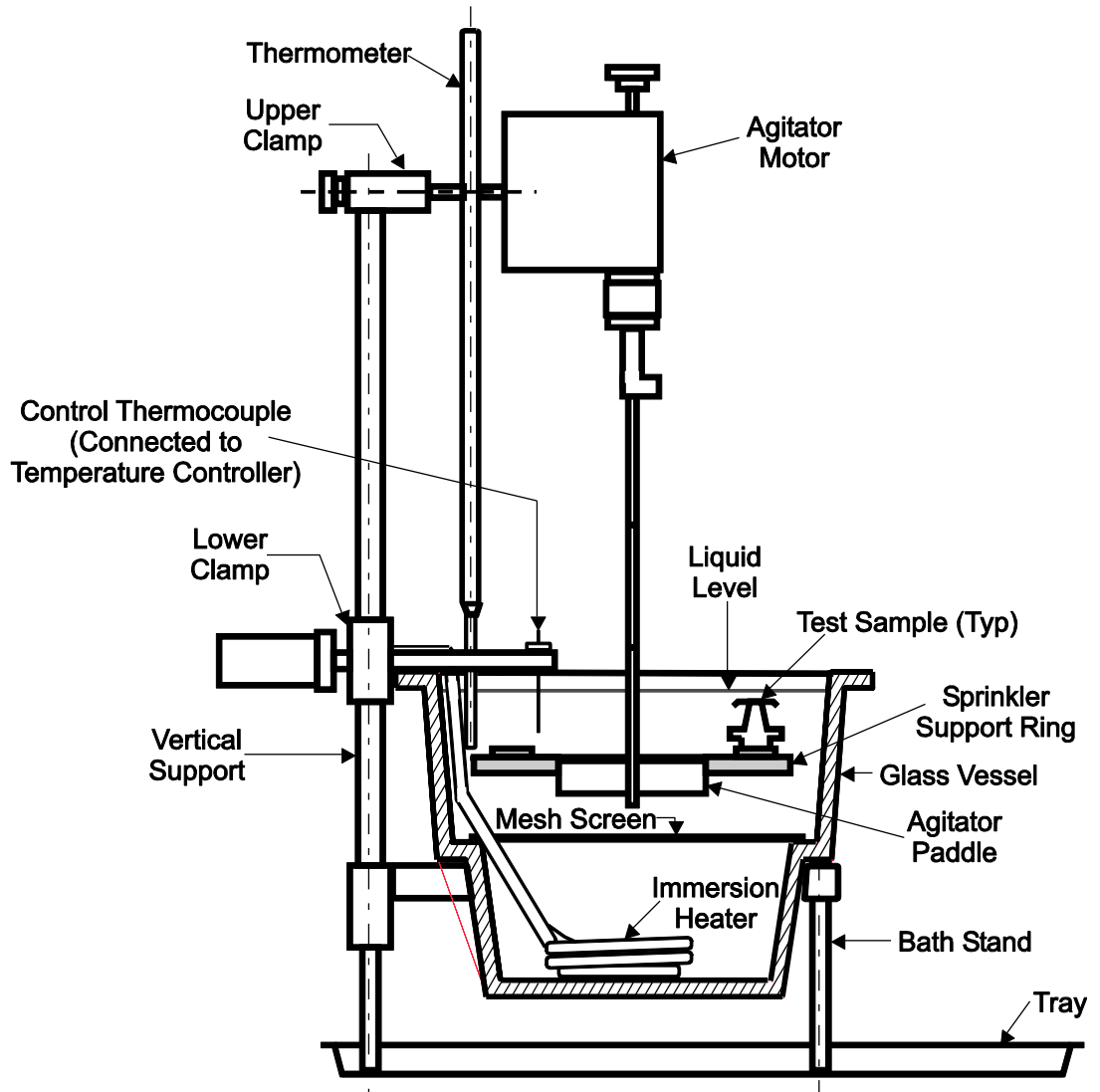
REQUIRED:

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

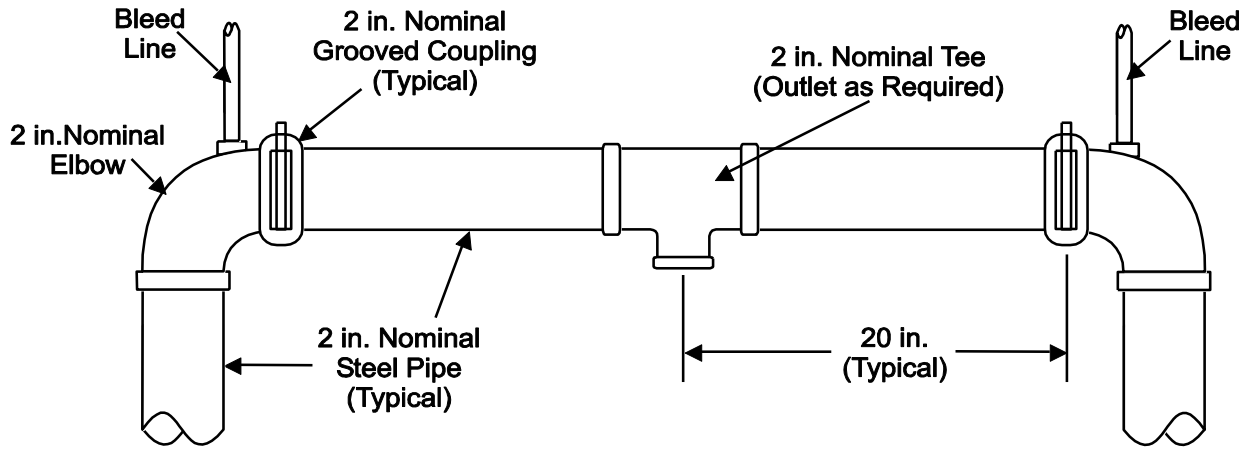
D-2: Bulb Crush Inserts for Strength of Element Test



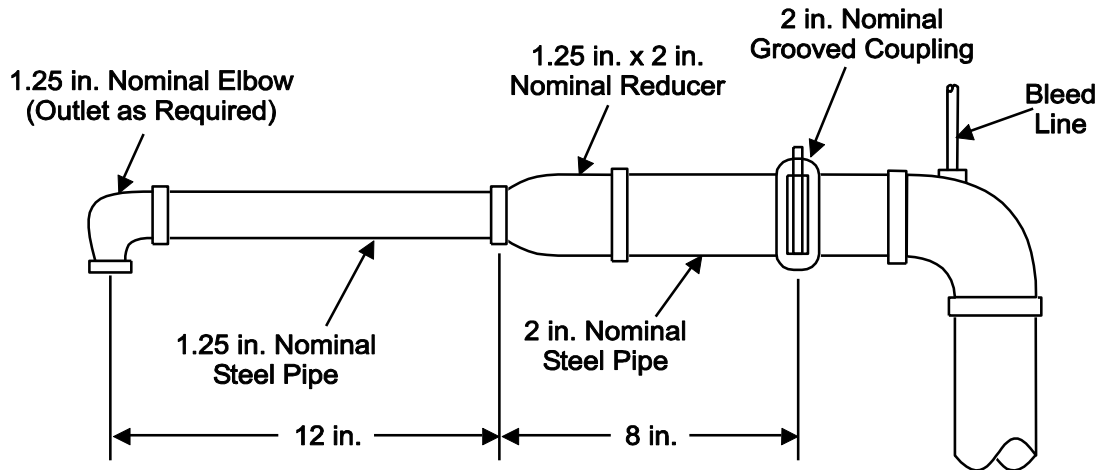
D-3: Pneumatic Leakage - Dry Sprinkler Inlet Test (Dry Sprinklers Only)



D-4: Operating Temperature (Liquid Bath) Typical Test Setup



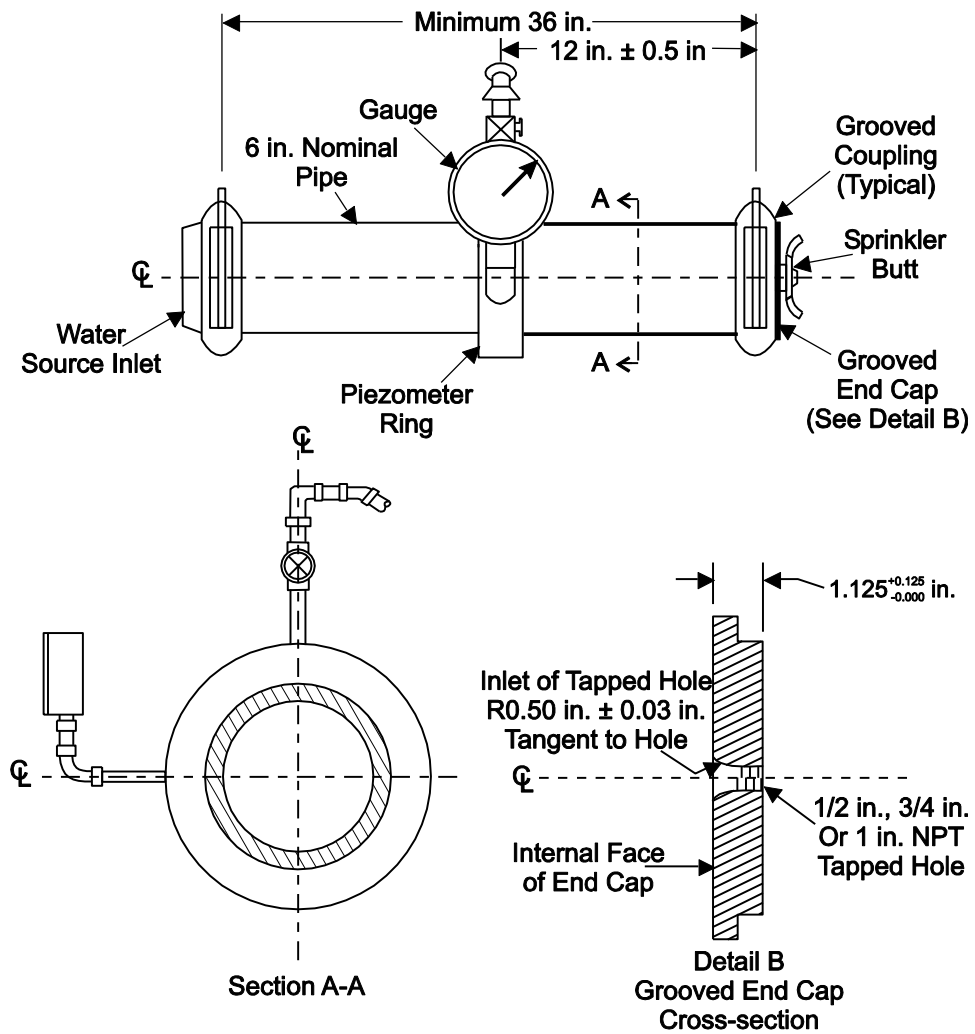
Test Apparatus for Double-Fed Flow



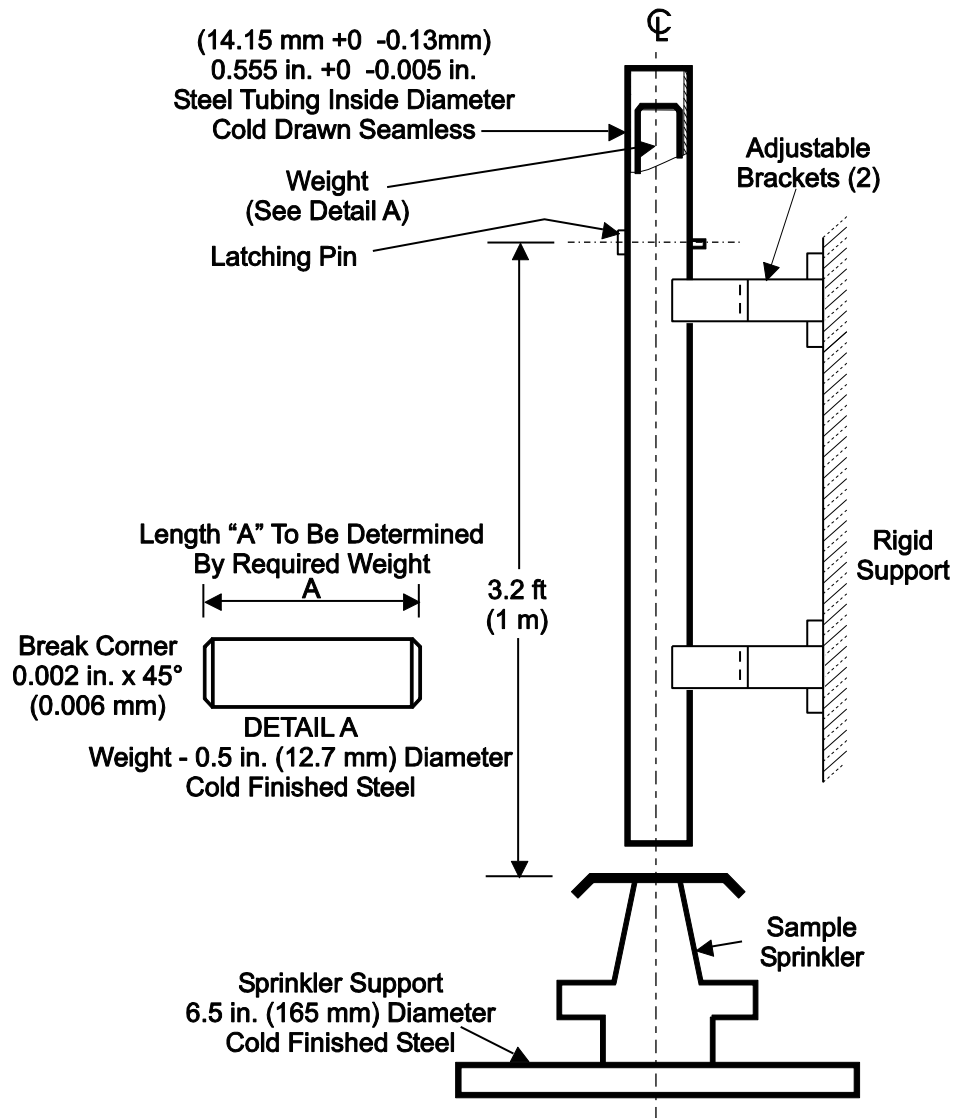
Test Apparatus for Single-Fed Flow

Note: All dimensions are nominal size.

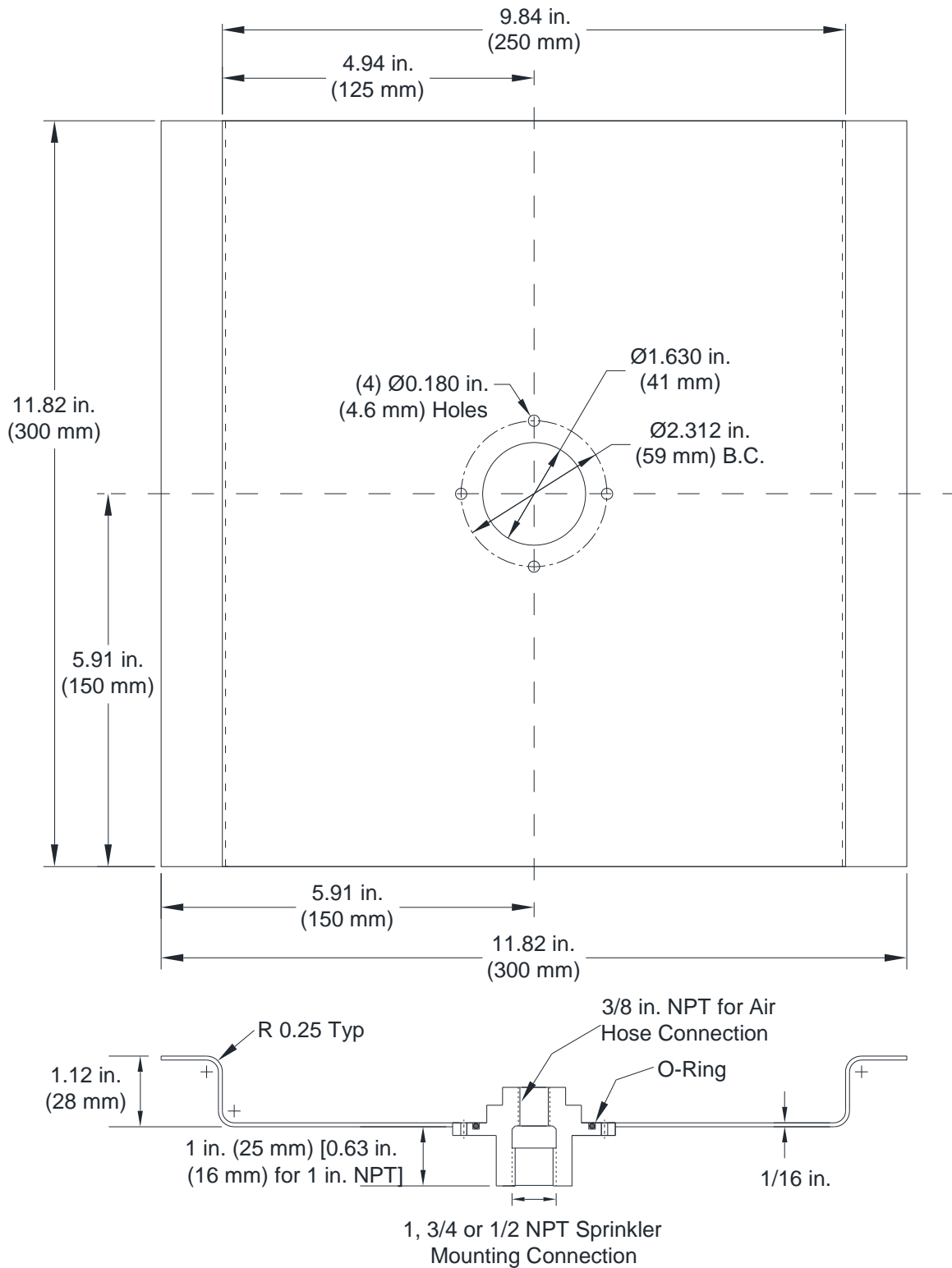
D-5: Test Apparatus for Hang-up of Operating Parts Test



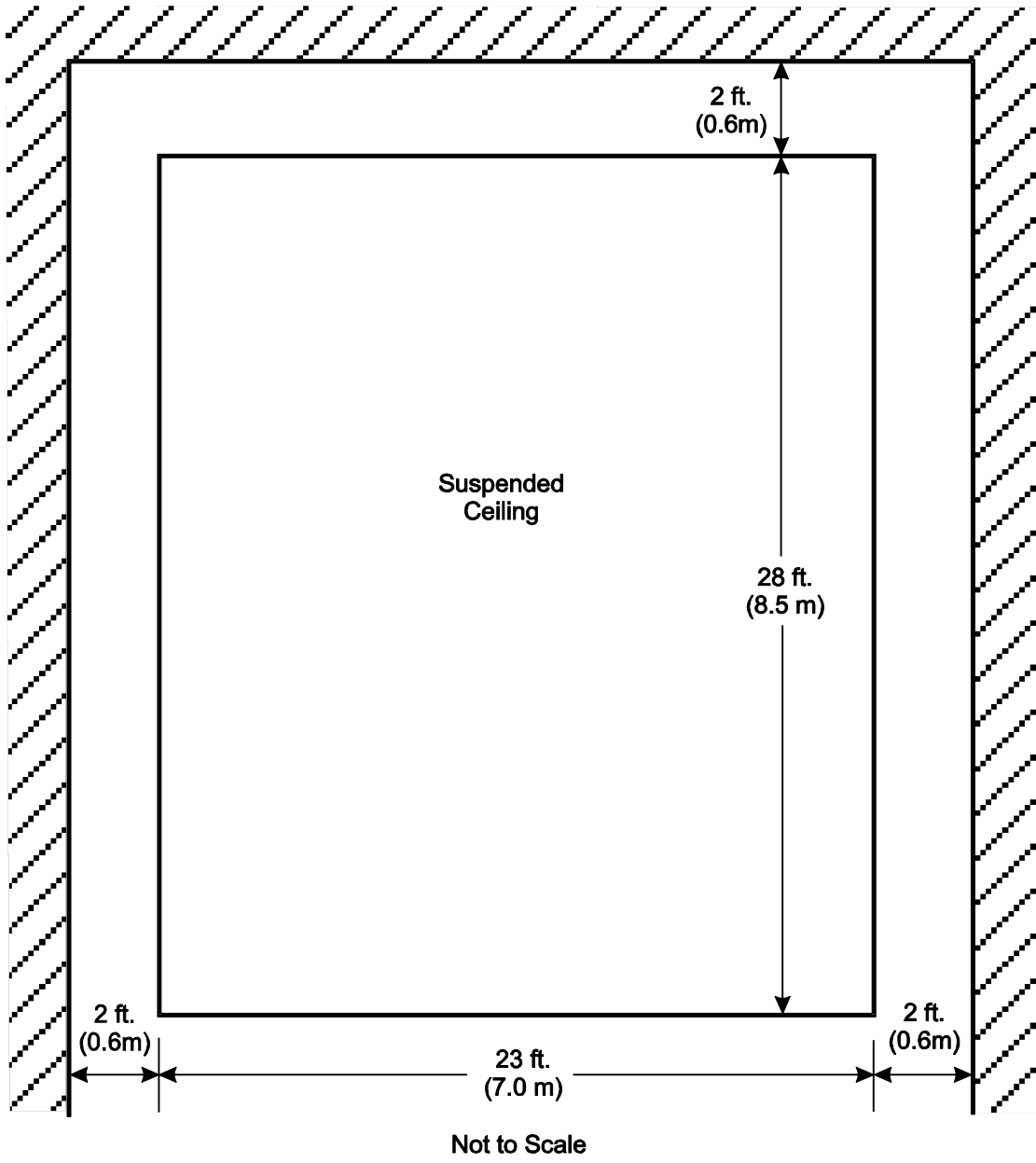
D-6: Test Apparatus for Measuring Nominal Discharge Coefficient (K-Factor)



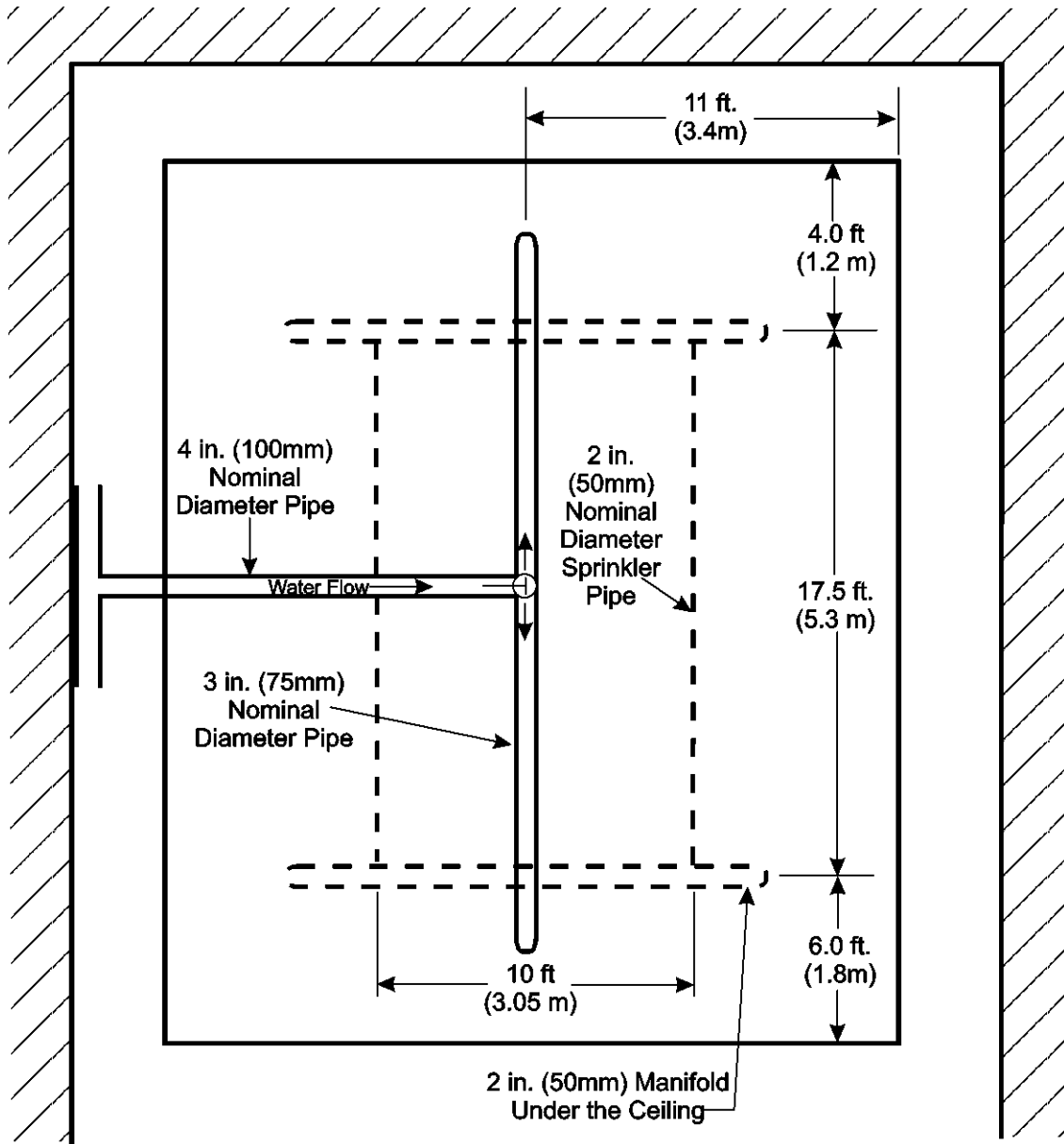
D-7: Rough use and Abuse (Drop Impact) Test Apparatus



D-8: Plunge Tunnel Test Plate (For Sensitivity - RTI Test)



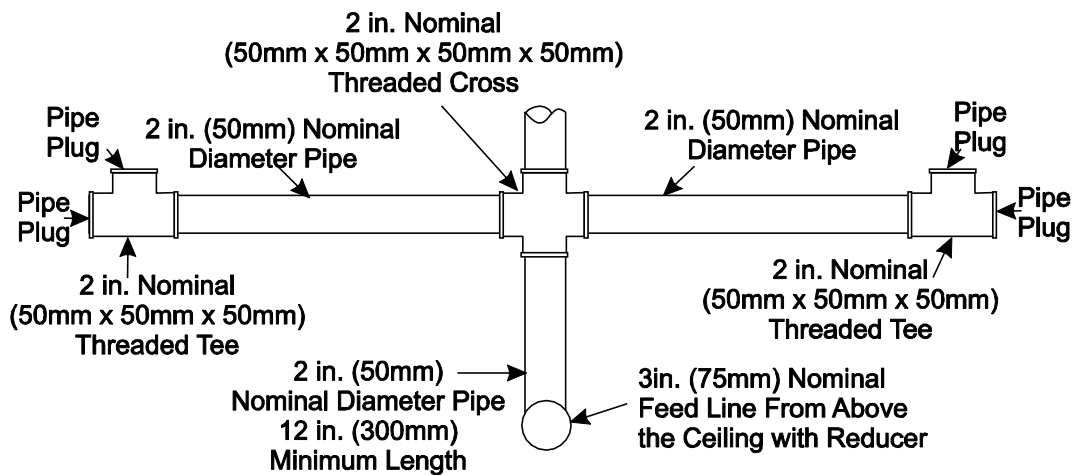
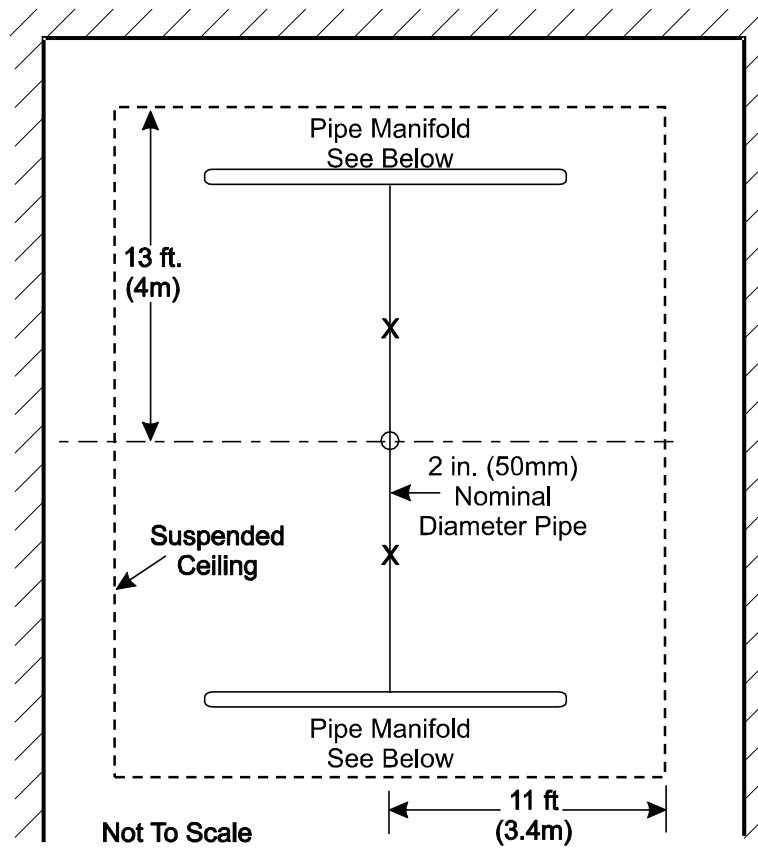
D-9: Water Distribution Collection Apparatus Minimum Enclosure Dimensions



Not to Scale

- - - - Indicates piping located below the ceiling

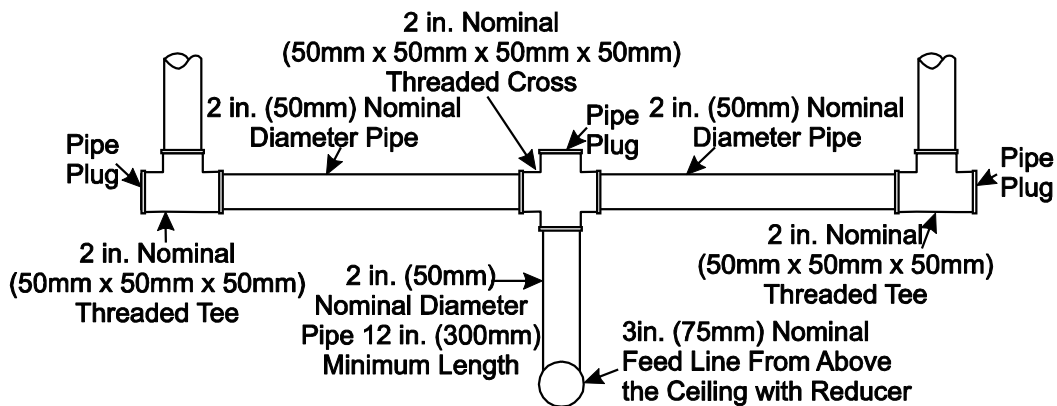
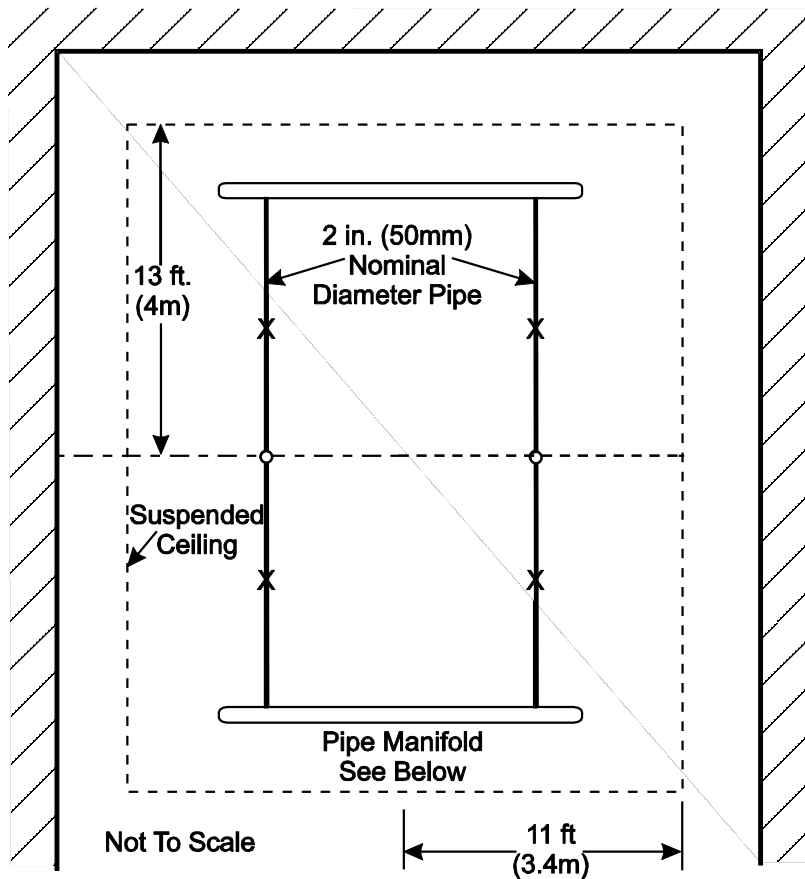
D-10: Water Distribution Collection Apparatus Overhead Piping Configuration



Note:

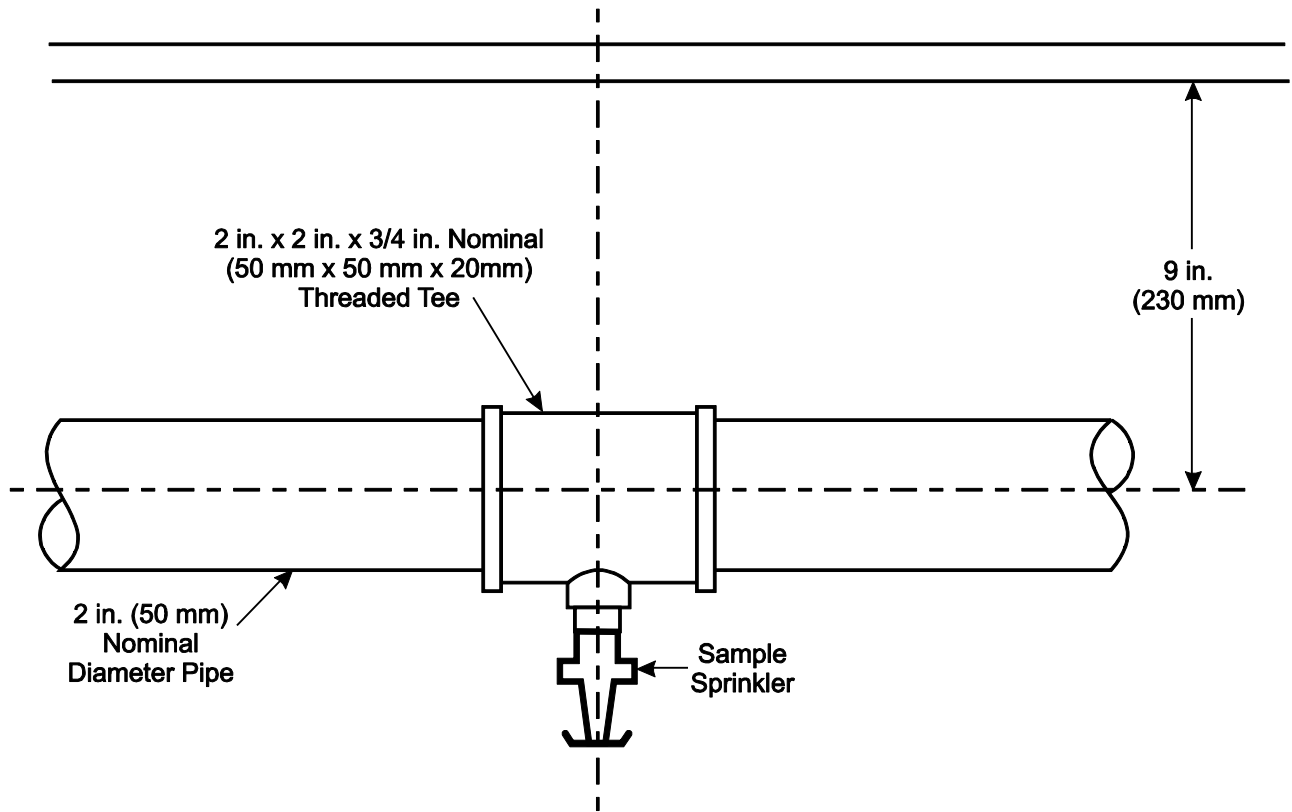
- o - Site for single sprinkler
- x - Sites for two sprinklers on the same branch line

D-11: Water Distribution Collection Apparatus Single Sprinkler Piping Configuration

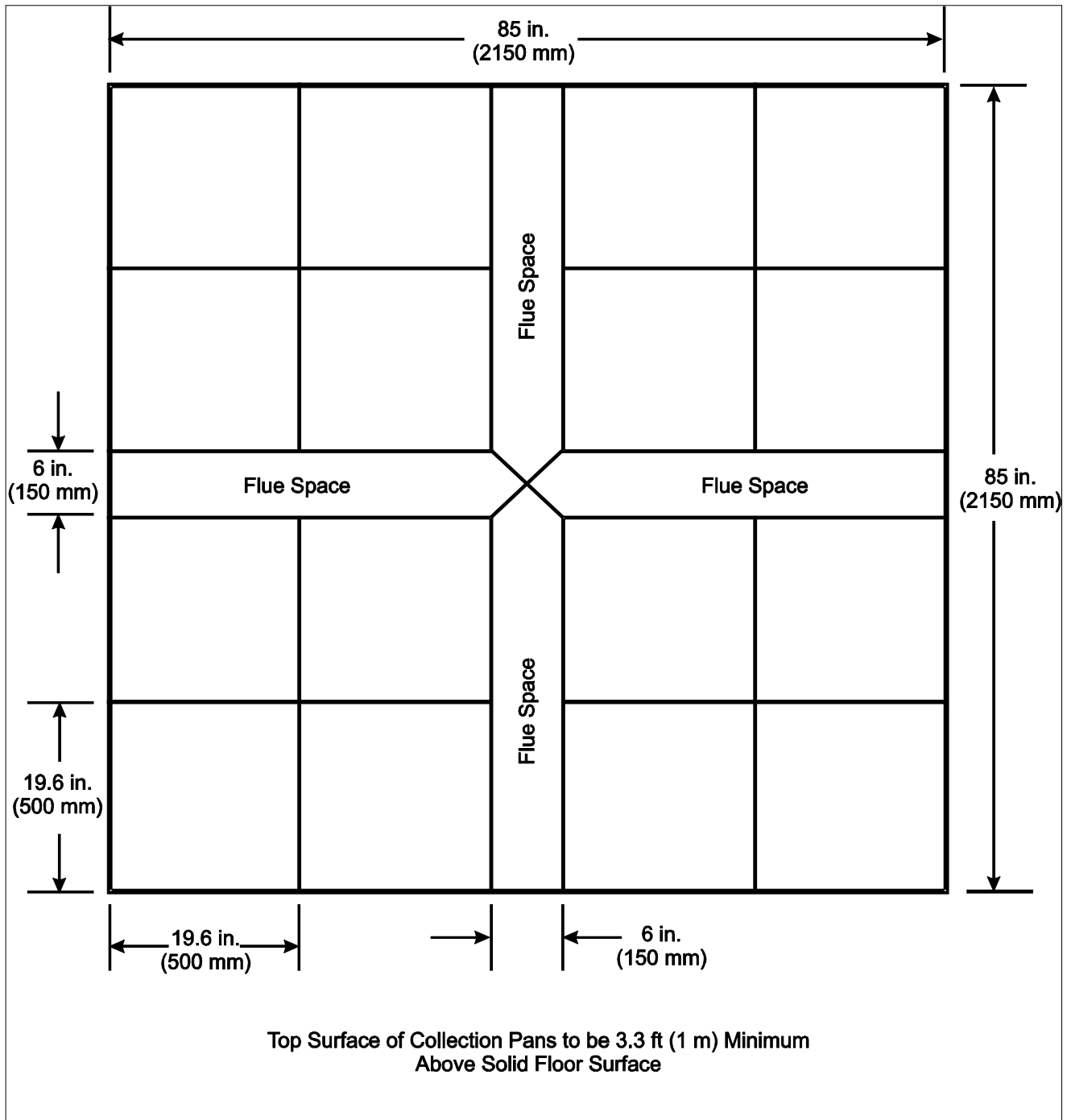


Note:
 o - Sites for two sprinklers on different branch lines
 x - Sites for four sprinkler test

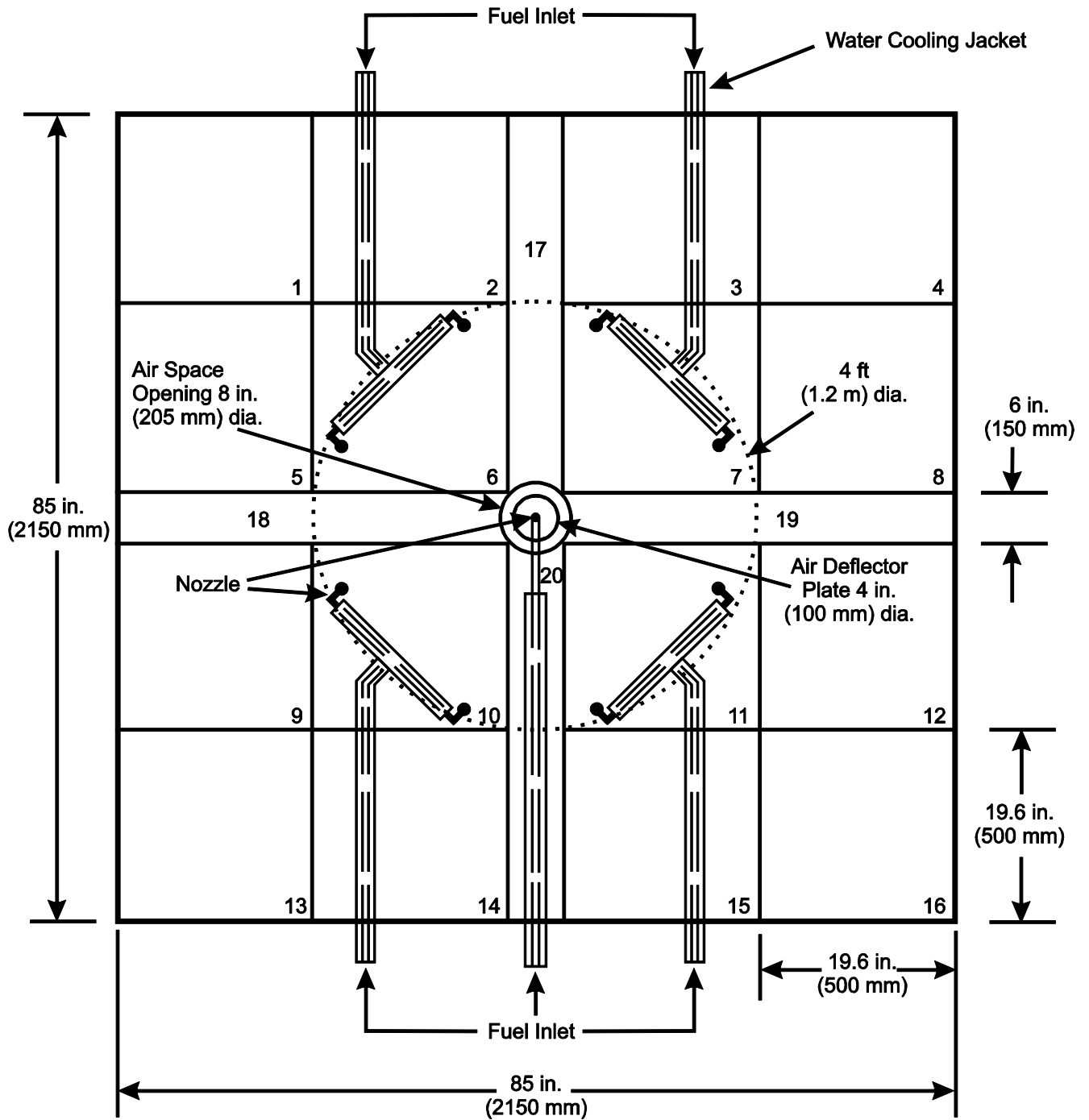
D-12: Water Distribution Collection Apparatus Multiple Sprinkler Piping Configuration



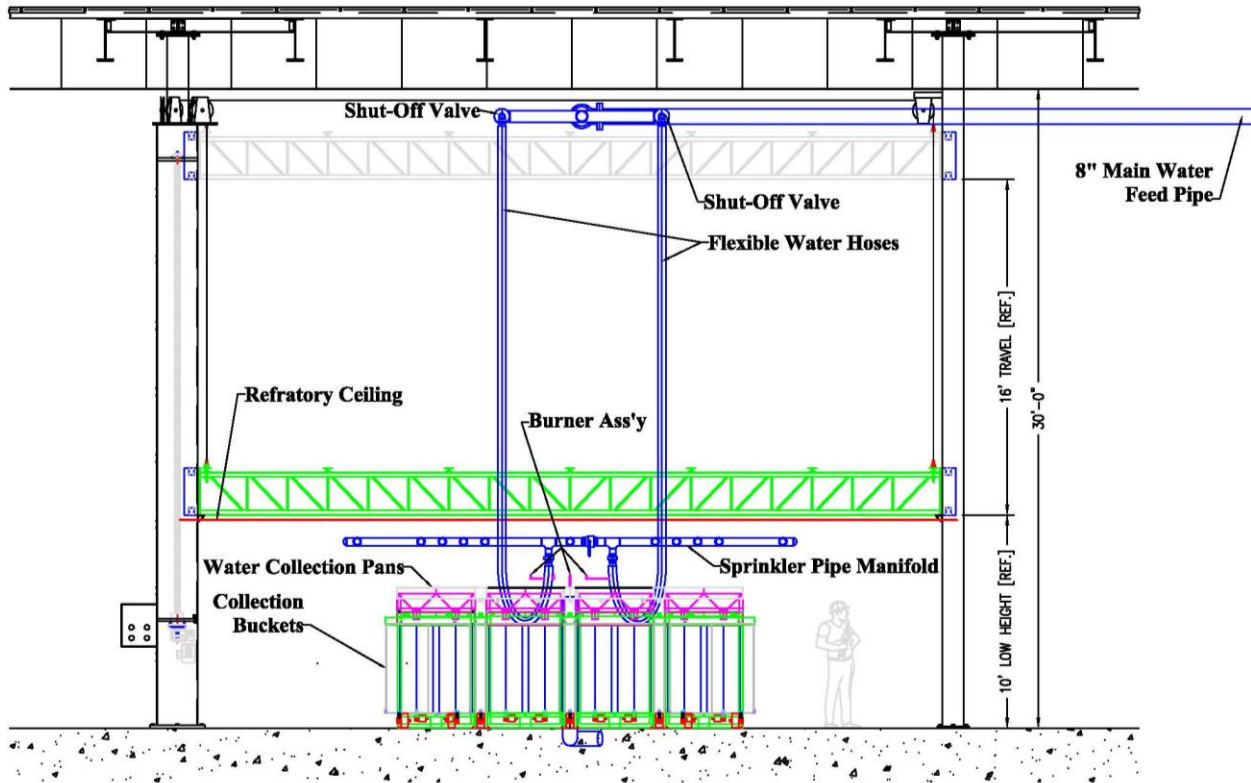
D-13: Water Distribution Collection Apparatus Piping Detail



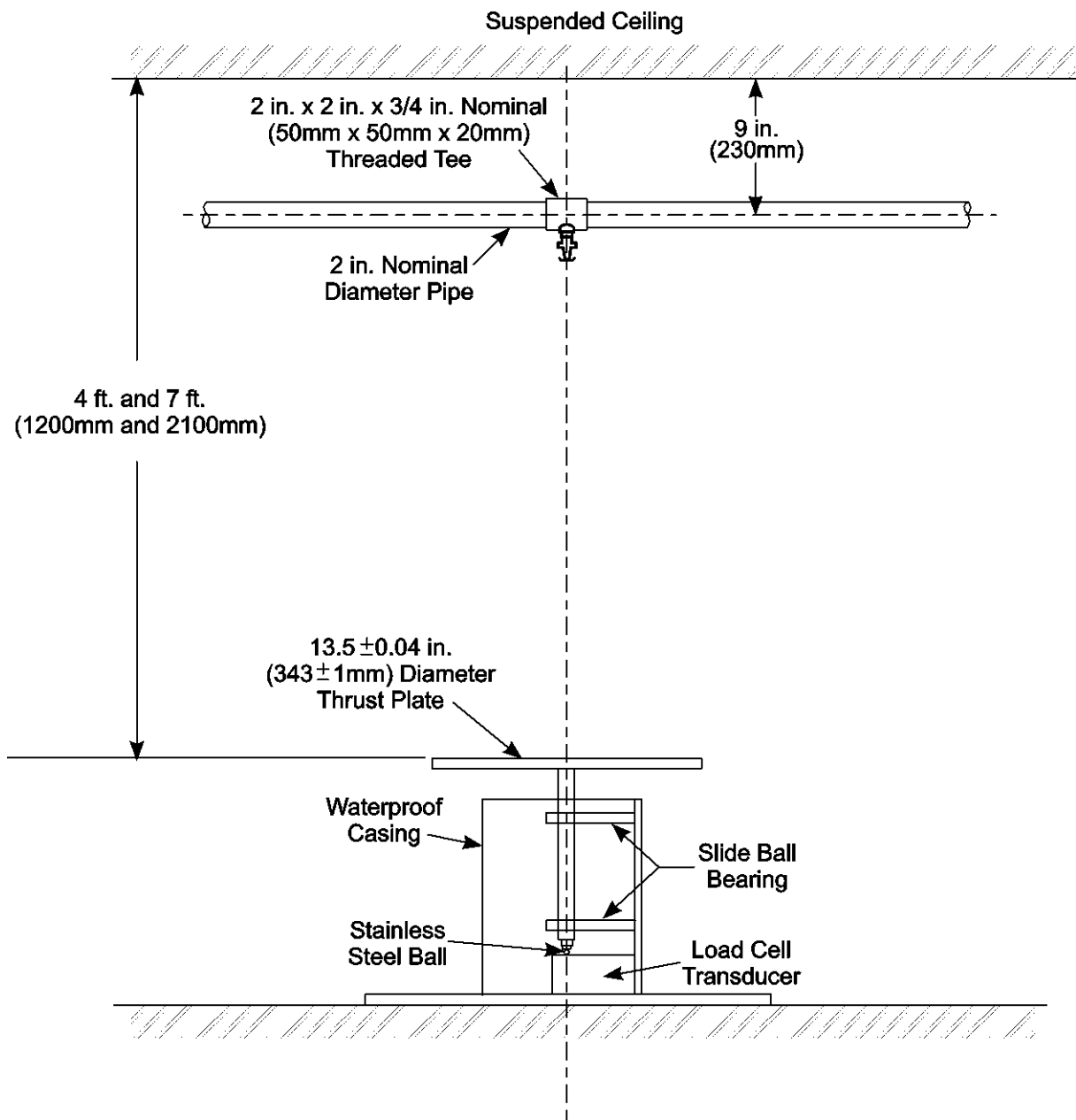
D-14: Water Distribution Collection Apparatus Collection Pan Assembly



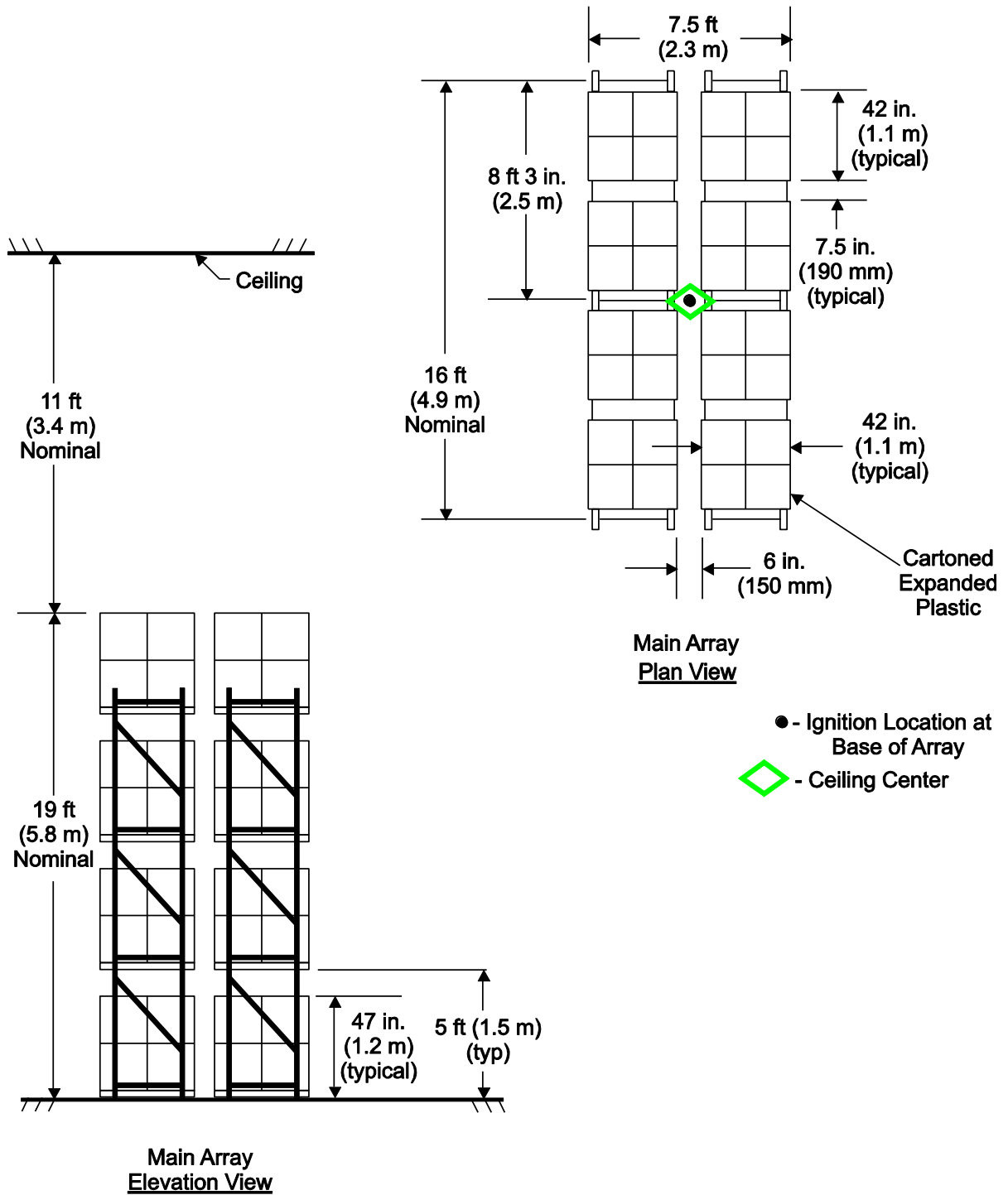
D-15: Actual Delivered Density (ADD) Apparatus



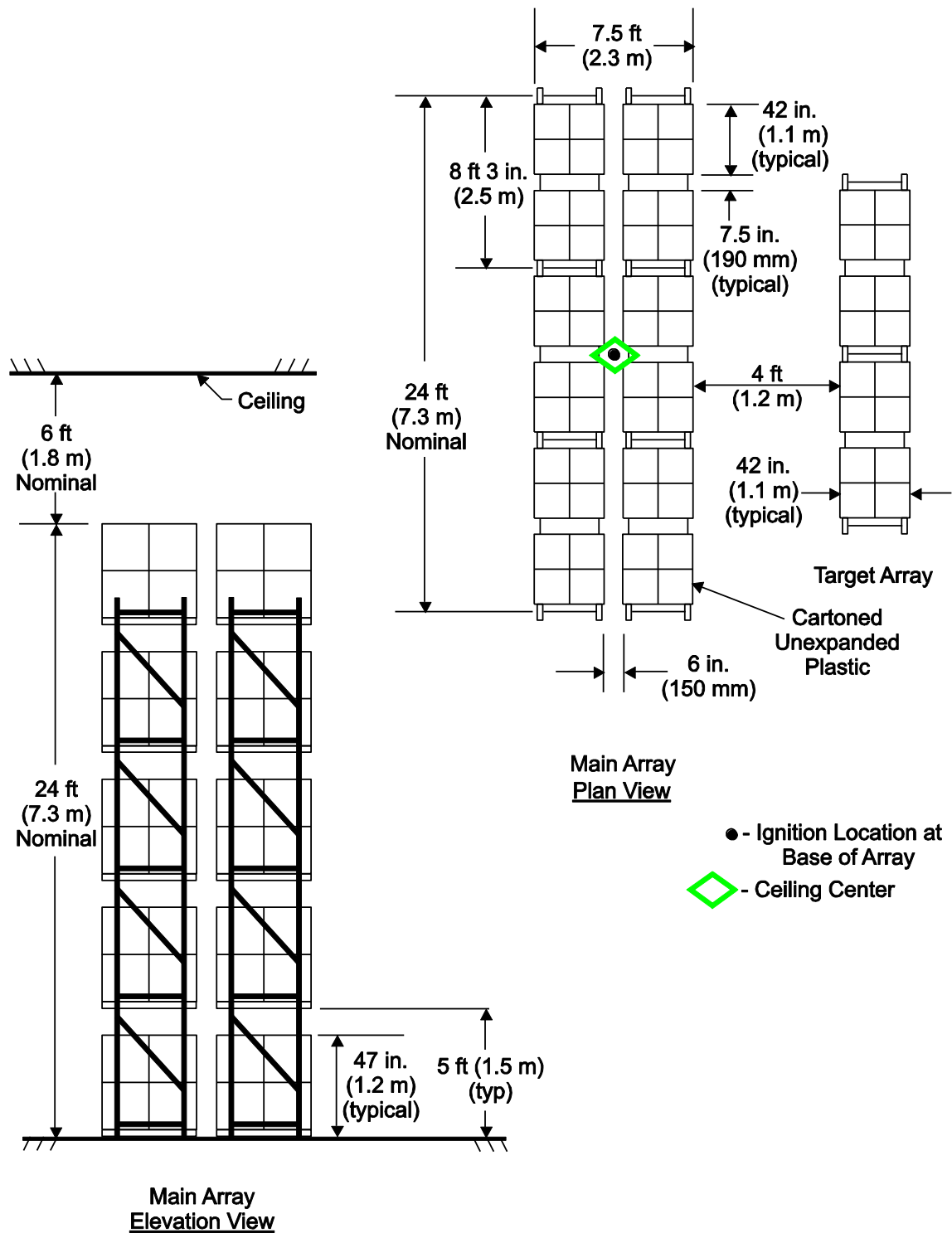
D-16: Actual Delivered Density (ADD) Apparatus – Elevation View



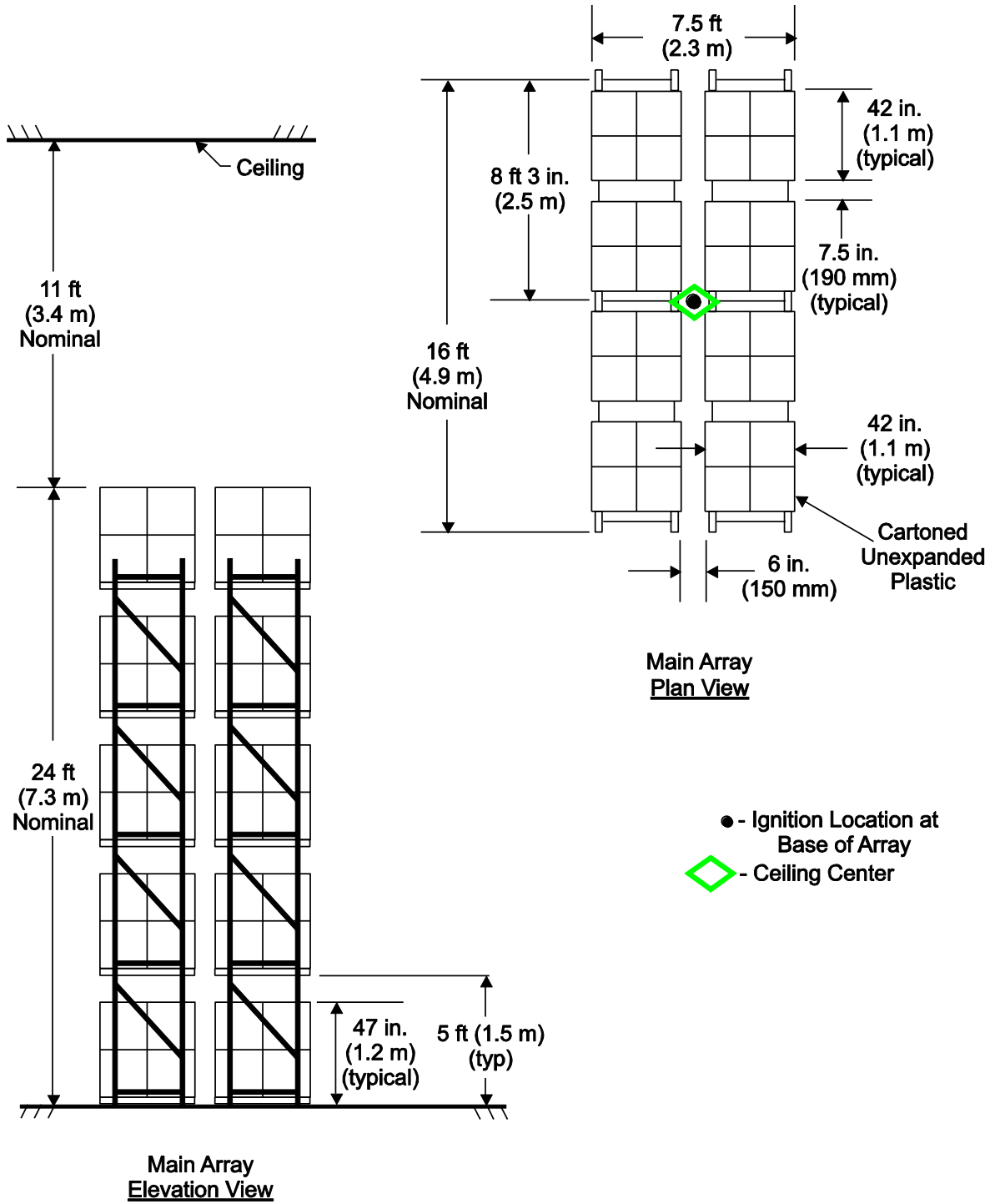
D-17: Thrust Measurement Test Apparatus



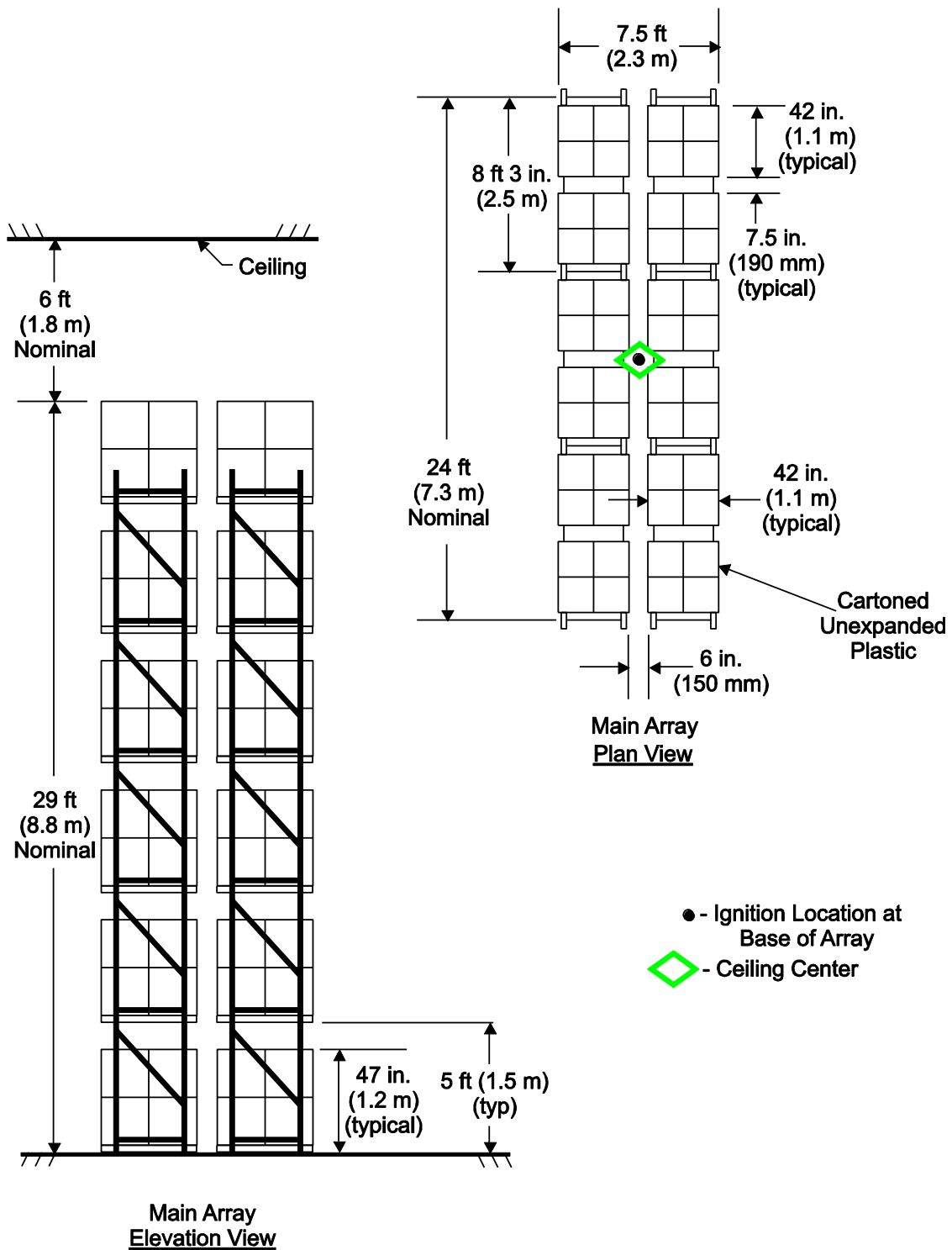
D-18: Full Scale Fire Test Array for K14.0 (K200) Upright, Test A



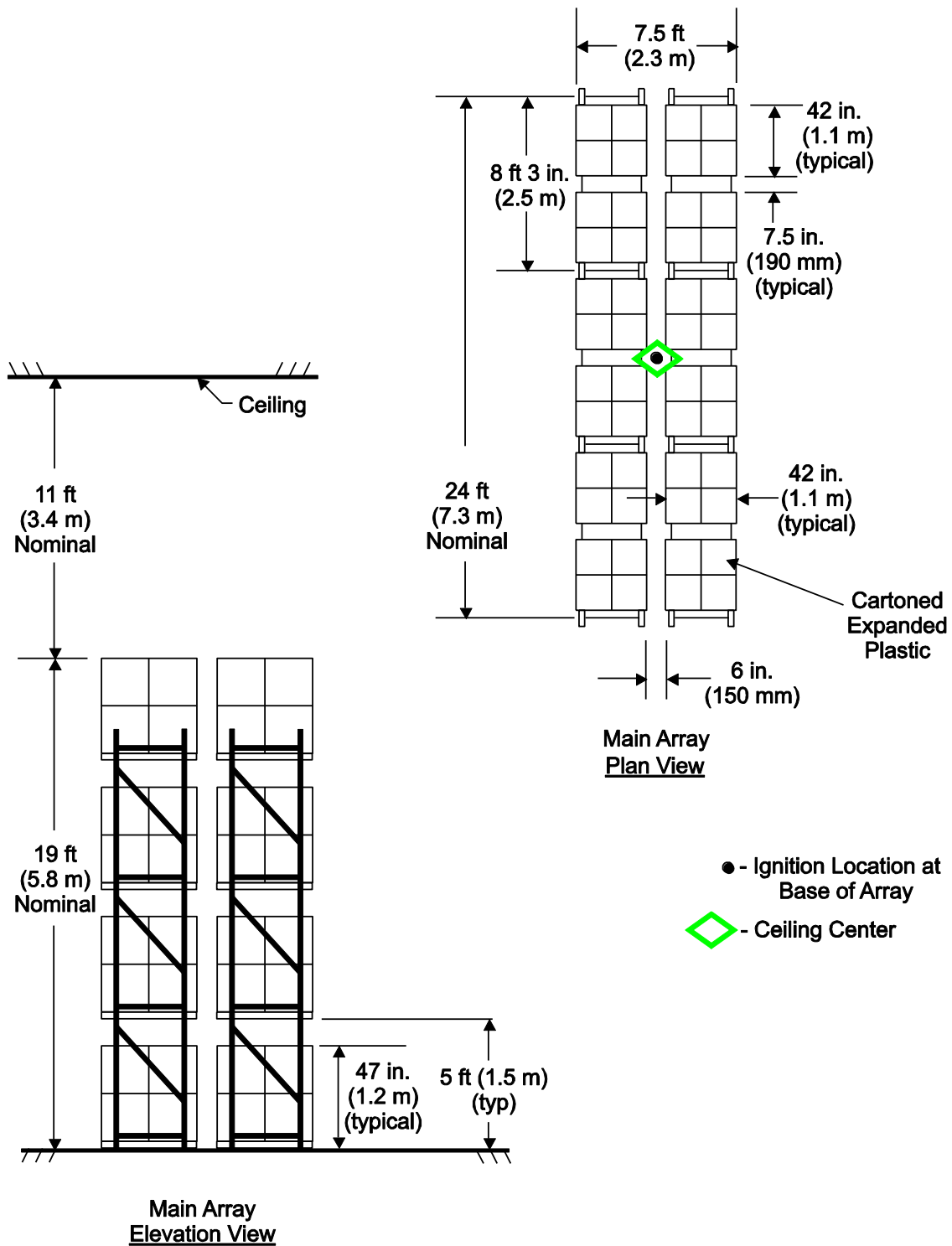
D-20: Full Scale Fire Test Array for K14.0 (K200) Upright, Test C



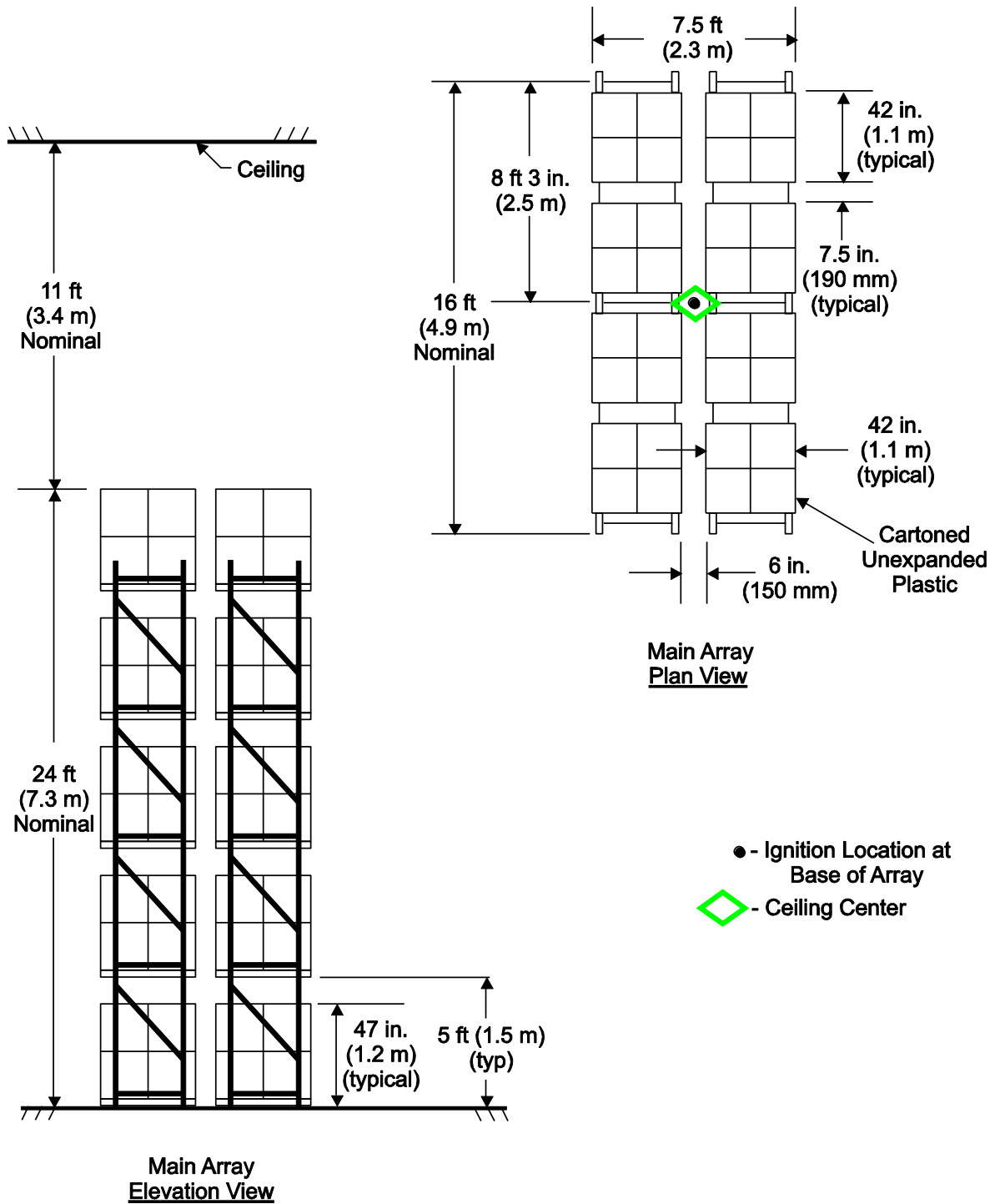
D-21: Full Scale Fire Test Array for K14.0 (K200) Upright, Test D



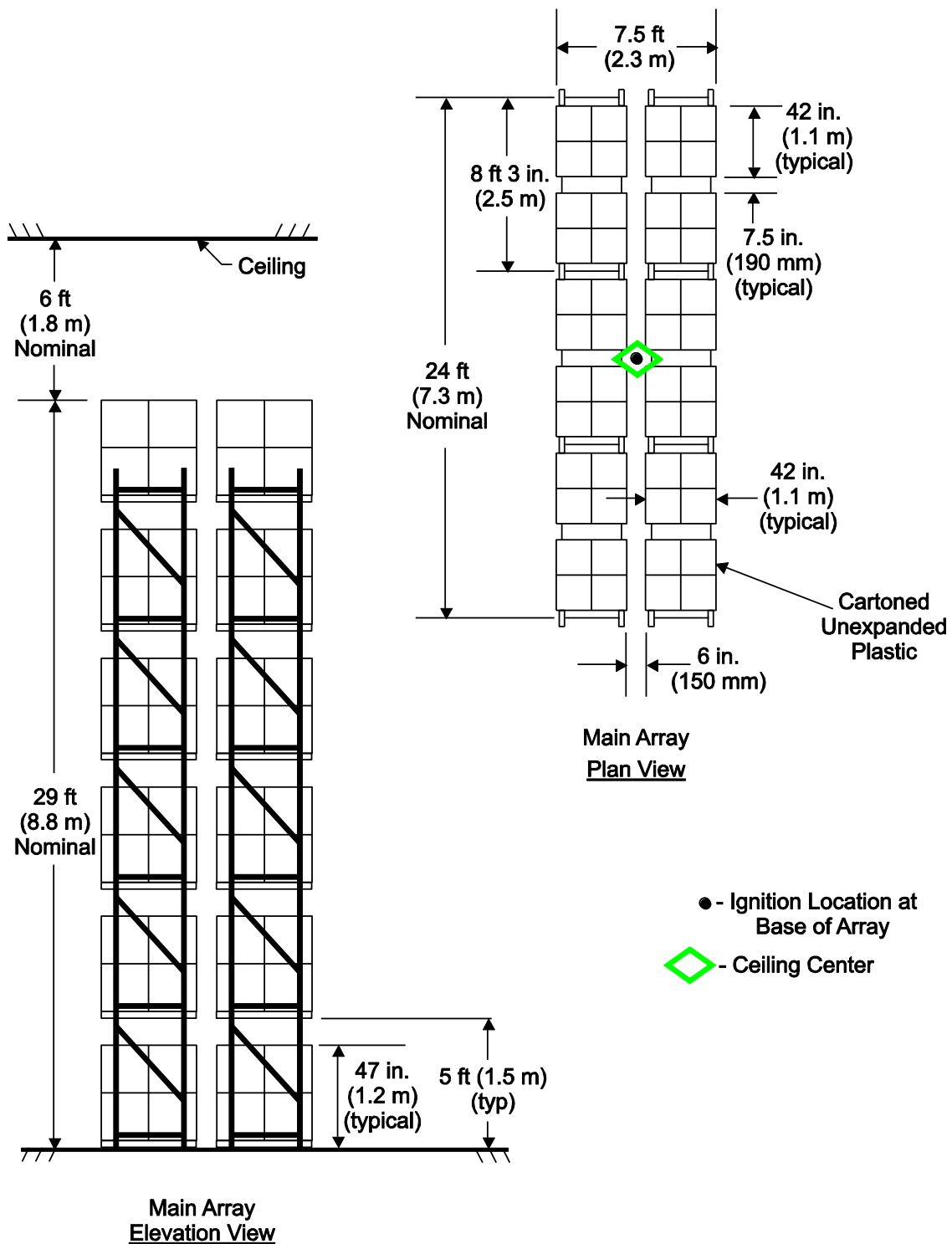
D-22: Full Scale Fire Test Array for K14.0 (K200) Upright, Test E



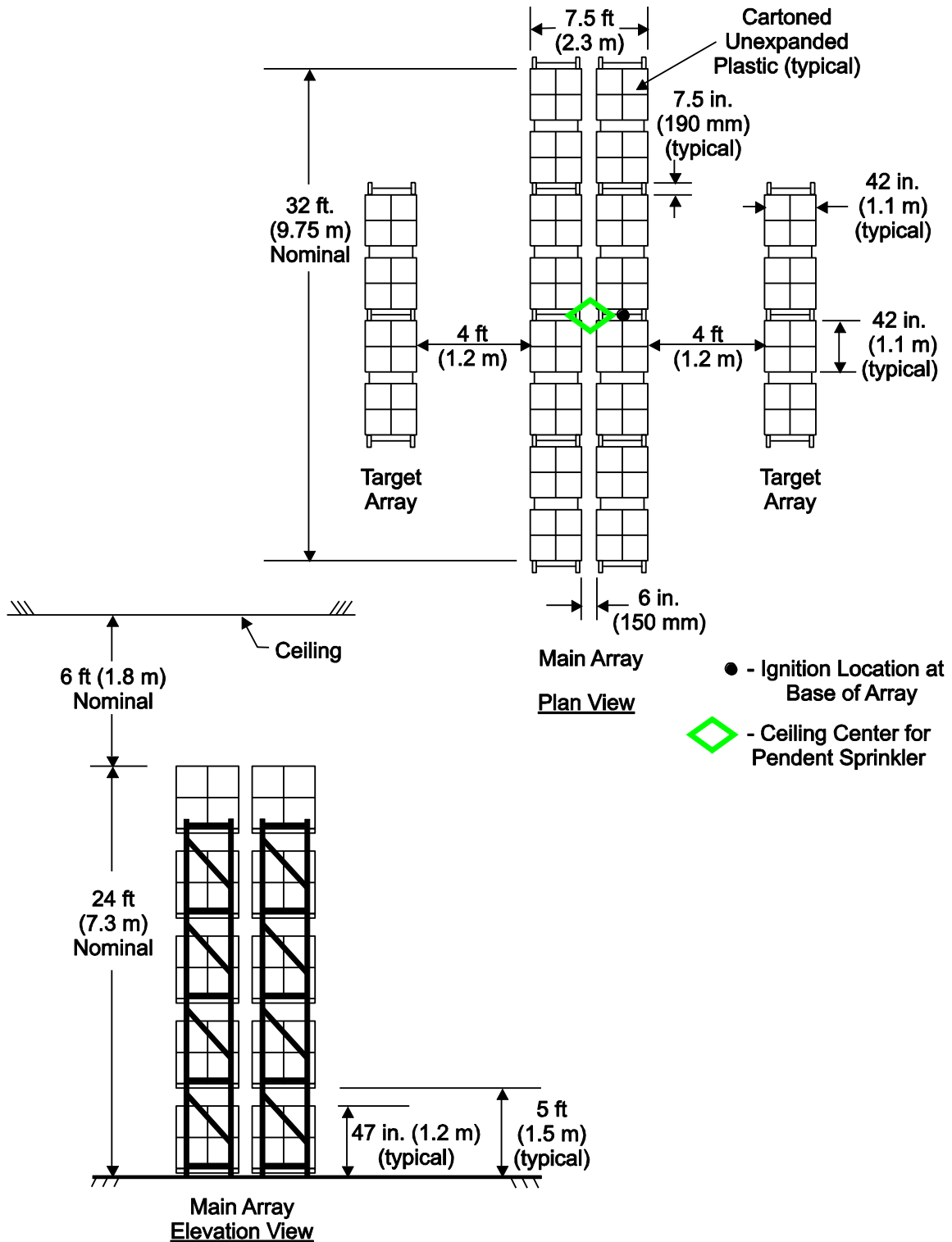
D-23: Full Scale Fire Test Array for K16.8 (K240) Upright, Test A



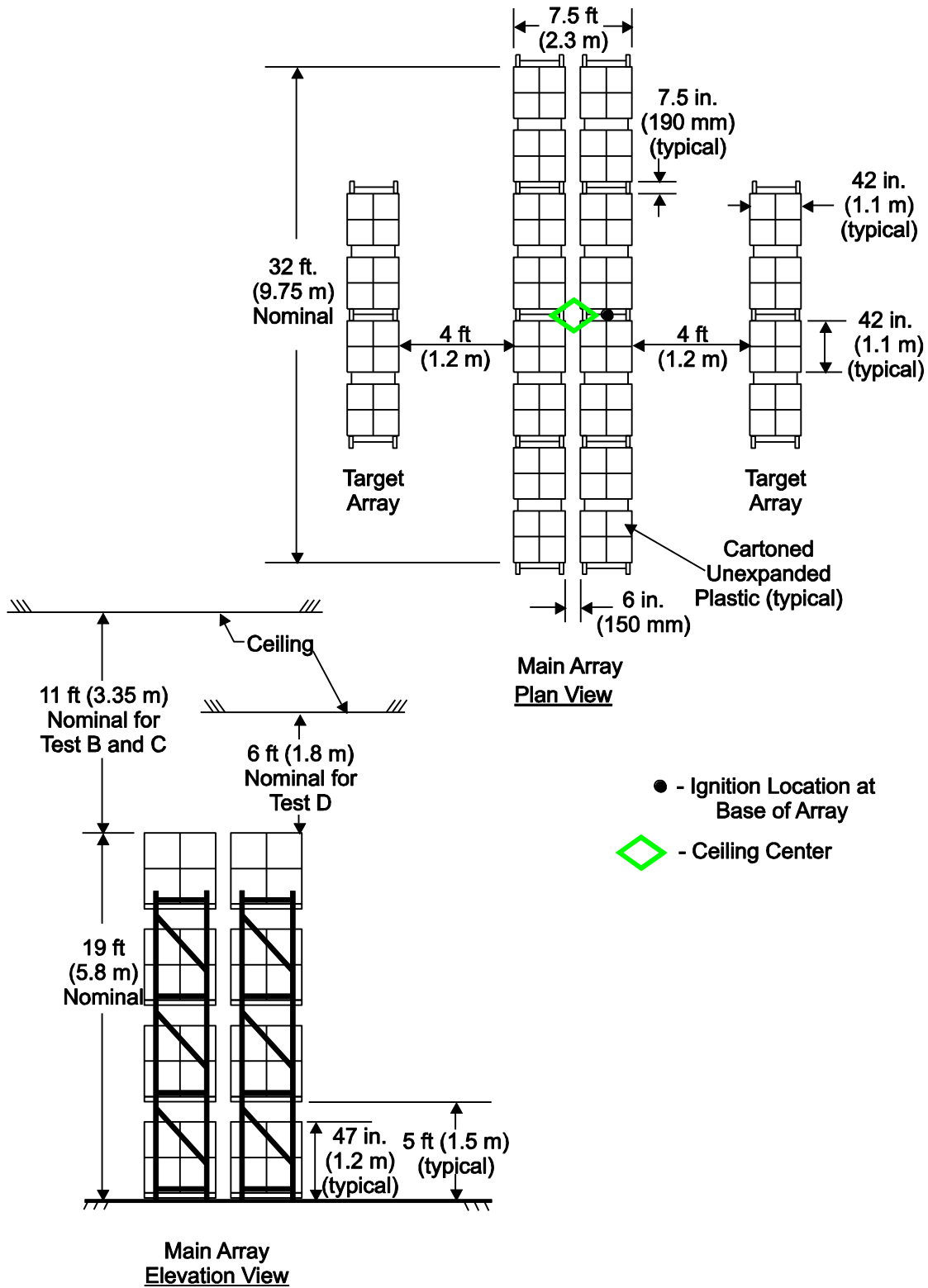
D-26: Full Scale Fire Test Array for K16.8 (K240) Upright, Test D



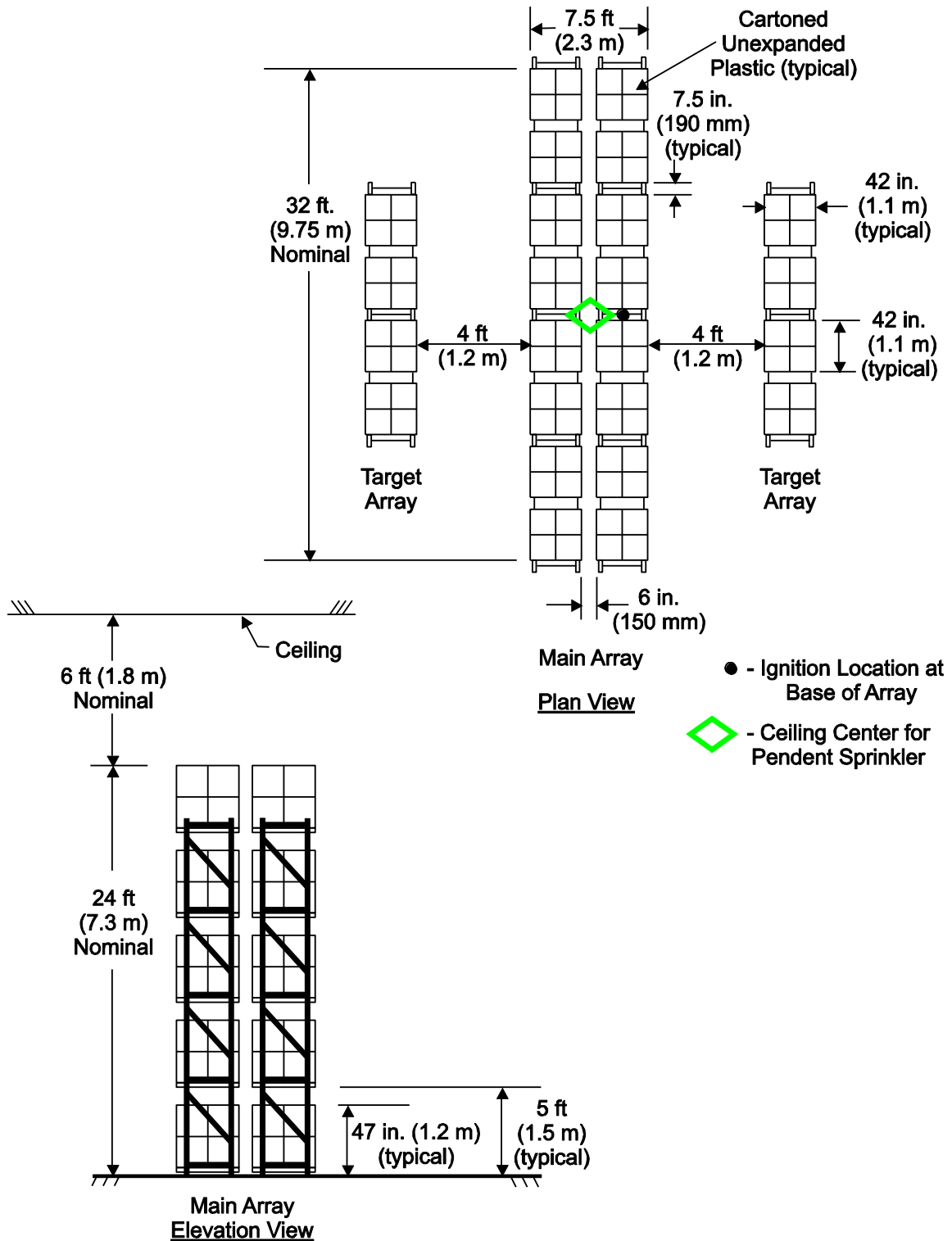
D-27: Full Scale Fire Test Array for K16.8 (K240) Upright, Test E



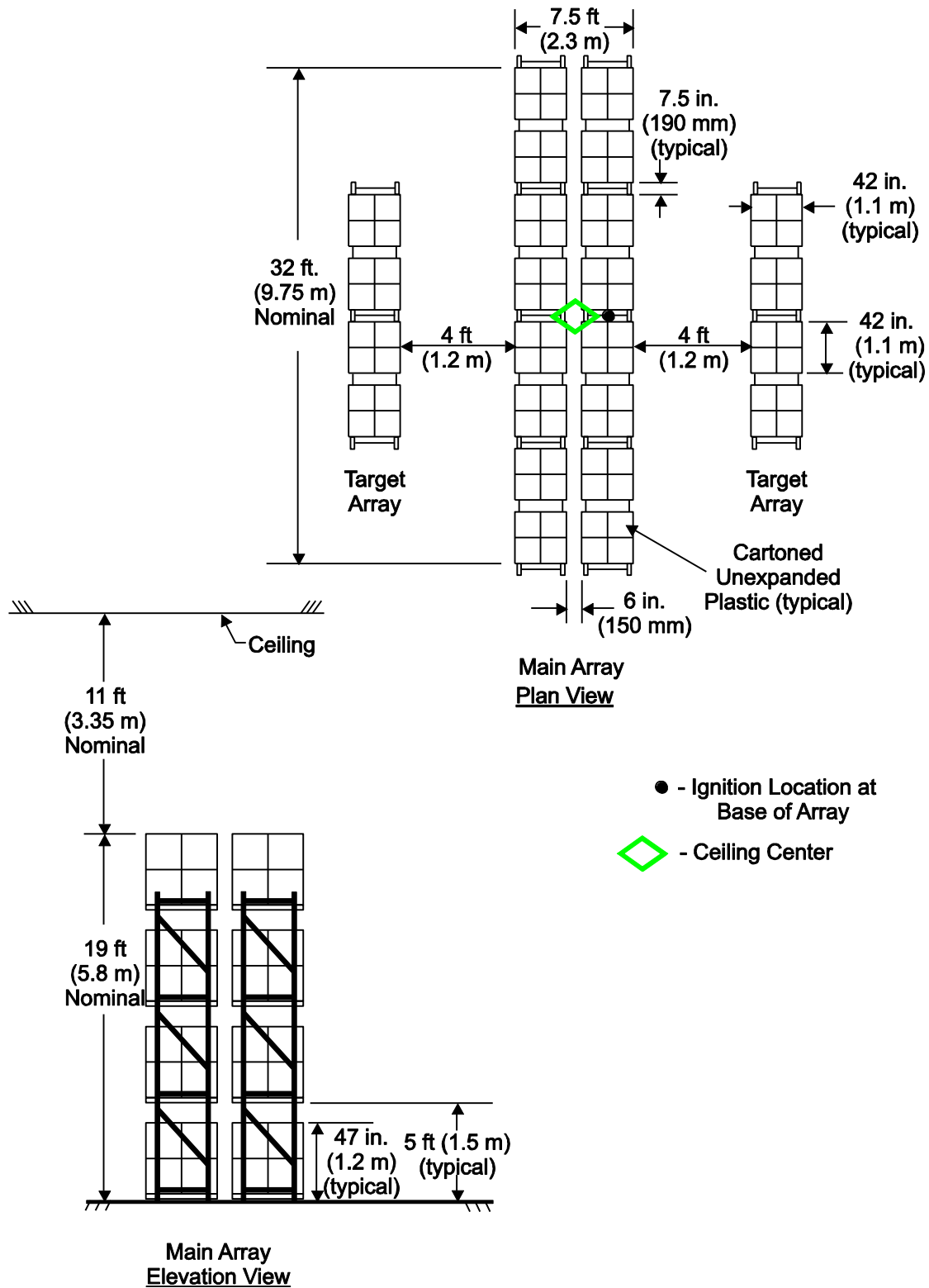
D-28: Full Scale Fire Test Array for K22.4 (K320) and K25.2 (K360) Pendent, Test A



D-29: Full Scale Fire Test Array for K22.4 (K320) and K25.2 (K360) Pendant, Test B and C



D-30: Full Scale Fire Test Array for K14.0 (K200) and K16.8 (K240) Dry Pendent, Test A



D-31: Full Scale Fire Test Array for K14.0 (K200) and K16.8 (K240) Dry Pendant, Test B and C

APPENDIX E: SAMPLE LISTING

Storage Sprinklers

K14.0 (K200) Pendent (Class 2008)

<i>Company</i>	<i>Model</i>	<i>K</i>	<i>Type</i>	<i>Response</i>	<i>Element</i>	<i>NPT (in.)</i>	<i>Finishes</i>	<i>Temp Ratings °F (°C)</i>
ABC	ABC2	14.0	Pendent	FR	Fusible	3/4	Brass	165°, 214°F (74°, 101°C)
PQR	PQR56	14.0	Pendent	FR	2.5 mm	3/4	Brass	155°, 200°F (68°, 93°C)
WXY	P	14.0	Pendent	FR	Fusible	3/4	Brass	165°, 212°F (74°, 100°C)
XYZ	XZ4456	14.0	Pendent	FR	2.5 mm	3/4	Brass	155°, 200°F (68°, 93°C)