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# **Approval Standard for Hybrid (Water and Inert Gas) Fire Extinguishing Systems**

**Class Number 5580**

**November 2009**

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# Foreword

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## 1. INTRODUCTION

### 1.1 Purpose

- 1.1.1 This standard states FM Approvals criteria for hybrid fire extinguishing systems for use as fire control and/or extinguishing systems.
- 1.1.2 FM Approvals criteria may include, but are not limited to, component, system and fire testing performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a follow-up program.

### 1.2 Scope

- 1.2.1 This standard encompasses the design and performance requirements for hybrid fire extinguishing systems for use as fire control and/or extinguishing systems designed and installed per FM Global Property Loss Prevention Data Sheets. Prior to any performance testing of the system and components, the system shall be evaluated in accordance with Section 4.34 to properly classify it as a hybrid extinguishing system.

Approval is limited to use in the occupancies described Sections 1.2.3.1 through 1.2.3.10. Due to the current state of this technology, a comprehensive absolute standard for the testing of hybrid system components is not possible. Since each hybrid system is unique in its operation and design, the component testing of the system shall be performed on a case-by-case basis. The component testing section is intended to be used as a guideline for the manufacturer as to the scope of the test program that can be expected. Upon request for a program, and appropriate system documentation, FM Approvals will prepare a customized evaluation program for the specific hybrid system. While customization of the component testing is necessary, the fire test protocols are generic and required for all hybrid fire extinguishing systems. The manufacturer's design calculations, stated performance requirements, as well as component functionality and reliability will be verified.

- 1.2.2 This standard is intended to verify that the product described will meet stated conditions of performance, safety and quality useful to the ends of property conservation.
- 1.2.3 Since hybrid fire extinguishing systems are an evolving technology, FM Approvals has determined that these systems shall be FM Approved for the protection of specific applications and specific protected area volumes. Extrapolation beyond the volumes which were tested is not permitted except where explicitly noted. The scope of this standard encompasses the following occupancy protection applications:
  - 1.2.3.1 Protection of machinery spaces with volumes not exceeding 2825 ft<sup>3</sup> (80 m<sup>3</sup>), Appendix B. This application includes enclosures with machinery such as internal combustion engines, oil pumps, oil tanks, fuel filters, generators, transformer vaults, gear boxes, drive shafts, lubrication skids, diesel engine driven generators, and other similar equipment using liquid hydrocarbon fuel and/or hydraulic, heat transfer, and lubrication fluids; enclosures with incidental use or storage of hydrocarbon flammable liquids of not more than two 55 gal (208 L) drums. All hazards included under the scope of this total flooding application shall be protected in accordance with Section 1.2.4.
  - 1.2.3.2 Protection of combustion turbines in enclosures with volumes not exceeding 2825 ft<sup>3</sup> (80 m<sup>3</sup>), Appendix C. Combustion turbines included under the scope of this total flooding application shall be protected in accordance with Section 1.2.4. Consultation with FM Global Property Loss Prevention Data Sheet Number 7-79, *Fire Protection for Combustion Turbine Installations*, is required for installation of these systems.
  - 1.2.3.3 Protection of machinery spaces with volumes not exceeding 9175 ft<sup>3</sup> (260 m<sup>3</sup>), Appendix D. This application includes enclosures with machinery such as internal combustion engines, oil pumps, oil tanks, fuel filters, generators, transformer vaults, gear boxes, drive shafts, lubrication skids, diesel engine driven generators, and other similar equipment using liquid hydrocarbon fuel and/or hydraulic, heat transfer, and lubrication fluids; enclosures with incidental use or storage of

- hydrocarbon flammable liquids of not more than two 55 gal (208 L) drums. All hazards included under the scope of this total flooding application shall be protected in accordance with Section 1.2.4.
- 1.2.3.4 Protection of combustion turbines in enclosures with volumes not exceeding 9175 ft<sup>3</sup> (260 m<sup>3</sup>), Appendix E. Combustion turbines included under the scope of this total flooding application shall be protected in accordance with Section 1.2.4. Consultation with FM Global Property Loss Prevention Data Sheet Number 7-79, *Fire Protection for Combustion Turbine Installations*, is required for installation of these systems.
  - 1.2.3.5 Protection of machinery spaces with volumes exceeding 9175 ft<sup>3</sup> (260 m<sup>3</sup>), Appendix F. This application includes enclosures with machinery such as internal combustion engines, oil pumps, oil tanks, fuel filters, generators, transformer vaults, gear boxes, drive shafts, lubrication skids, diesel engine driven generators, and other similar equipment using liquid hydrocarbon fuel and/or hydraulic, heat transfer, and lubrication fluids; enclosures with incidental use or storage of hydrocarbon flammable liquids of not more than two 55 gal (208 L) drums. All hazards included under the scope of this total flooding application shall be protected in accordance with Section 1.2.4.
  - 1.2.3.6 Protection of combustion turbines in enclosures with volumes exceeding 9175 ft<sup>3</sup> (260 m<sup>3</sup>), Appendix G. Combustion turbines included under the scope of this total flooding application shall be protected in accordance with Section 1.2.4. Consultation with FM Global Property Loss Prevention Data Sheet Number 7-79, *Fire Protection for Combustion Turbine Installations*, is required for installation of these systems.
  - 1.2.3.7 Protection of computer room sub floor occupancies, Appendix H. Typical occupancies within the scope of this application are defined in FM Global Property Loss Prevention Data Sheet Numbers 4-0, *Special Protection Systems*, and 5-32, *Electronic Data Processing Systems*. System installations shall be limited to computer room sub-floor areas and heights not exceeding that tested in Appendix H. Additionally, the equivalent opening area of the sub-floor shall not exceed that tested in Appendix H. The agent supply shall be capable of supplying agent to all nozzles at the maximum rated operating pressure for 10 minutes. This protocol only evaluates the fire extinguishment capabilities of the hybrid fire extinguishing system for de-energized electrical cables and equipment. An evaluation of the smoke cleansing capabilities is not made. Consultation with FM Global Property Loss Prevention Data Sheet Numbers 4-0, *Special Protection Systems*, and 5-32, *Electronic Data Processing Systems*, is required for installation of these systems.
  - 1.2.3.8 Protection of other occupancies, Appendix I. Manufacturers interested in pursuing hybrid fire extinguishing system fire protection of other occupancies are invited to request, in writing, a detailed description of the desired occupancy and proposed fire protection system. Appropriate system component and fire test performance requirements may then be jointly developed. The FM Global Property Loss Prevention Data Sheet Number 4-0, *Special Protection Systems*, should be consulted with for the basic installation parameters. Suggested occupancies are as listed in Appendix I.
- 1.2.4 Hybrid fire extinguishing systems shall provide the following levels of protection with regard to agent quantity and discharge duration.
- 1.2.4.1 For primary protection, agent supply shall be equivalent to that required for an automatic sprinkler protection system for the hazard protected.
  - 1.2.4.2 Special Protection Systems (see Section 1.9, definitions)
    - 1.2.4.2.1 If the longest extinguishment time for the fire scenarios required in Appendices B through H is less than five minutes, the required agent supply shall be 10 minutes or the time to shut down process equipment, whichever is greater. For turbine enclosures, the required agent supply shall be 10 minutes, the turbine rundown time (including the time that the turbine surfaces are above the auto-ignition temperature of the lubricating fluid), or the time to shut down process equipment, whichever is greater.

- 1.2.4.2.2 If the longest extinguishment time for the fire scenarios required in Appendices B through G is greater than five minutes, the required agent discharge duration shall be identical to that required in Section 1.2.4.2.1.

Additionally, the required cumulative agent discharge rate used during the fire testing in Appendices B through G shall be multiplied by a safety factor of 1.2. This may be achieved by a reduction of nozzle spacing, a reduction of protected enclosure area, or placement of additional nozzles. This safety factor shall not be accounted for by increasing the discharge rates of individual nozzles.

- 1.2.4.2.3 The longest extinguishment time for the fire scenarios required in Appendices B through G shall not exceed eight minutes. The longest extinguishment time for the fire scenarios required in Appendix H shall not exceed five minutes.
- 1.2.4.2.4 A summary of the design requirements for hybrid fire extinguishing systems serving as special protection systems is provided in Table 1.2.4.2.4.

Table 1.2.4.2.4 – *Hybrid Fire Extinguishing System Design Criteria*

<i>Extinguishment Time</i>	<i>Discharge Time</i>	<i>Agent Quantity Safety Factor</i>
0 to 5 minutes	10 minutes (minimum)	Not required
5 to 8 minutes	10 minutes (minimum)	20 percent
Greater than 8 minutes	Not permitted	

\* The fire extinguishing time for computer room sub-floor protection shall not exceed five minutes.

### 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 has also been considered.
- 1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of hybrid systems for the purpose of obtaining Approval. Hybrid systems having characteristics not anticipated by this standard may be FM Approved if performance equal, or superior, to that required by this standard is, in the sole opinion of FM Approvals, demonstrated, or if the intent of the standard is met. Alternatively, hybrid systems that meet all of the requirements identified in this standard may not be FM Approved if, in the sole opinion of FM Approvals, other conditions which adversely affect performance exist or if the intent of this standard is not met.

### 1.4 Basis for Approval

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

- 1.4.1 Examination and tests on production samples shall be performed to evaluate:
- The suitability of the product;
  - The performance of the product as specified by the manufacturer and required by FM Approvals; and, as far as practical,
  - The durability and reliability of the product.
- 1.4.2 An examination of the manufacturing facility(ies) and audit of quality control procedures. This examination shall be made to evaluate the manufacturer's ability to produce the product which was examined and tested, and the marking procedures used to identify the product. These examinations are repeated as part of FM Approval's Product Follow-Up Program.

1.4.3 A review of the proposed hybrid system “Design, Installation, Operation and Maintenance” manual.

## 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 Master Agreement;
- Satisfactory re-examination of production samples for continued conformity to requirements; and
- Satisfactory Facilities and Procedures Audits (F&PA’s) conducted as part of FM Approvals product follow-up program.

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

## 1.6 Effective Date

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

The effective date of this standard is **November 30, 2010** for compliance with all requirements.

## 1.7 System of Units

Units of measurement used in this 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 J lists the selected units and conversions to SI units for measures appearing in this standard. Conversion of U.S. customary units is in accordance with the American Society for Testing Materials (ASTM) SI 10 2002, "*American National Standard for Use of the International System of Units (SI): The Modern Metric System.*" Two units of measurement (liter and bar), outside of, but recognized by SI, are commonly used in international fire protection and are used in this standard.

## 1.8 Applicable Documents

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

### ANSI Publications

American National Standards Institute, Inc., 11 West 42nd Street, 13th floor, New York, NY 10036

ANSI B1.20.1, *Pipe Threads, General Purpose (Inch)*, 1992

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

ANSI B16.4, *Gray Iron Threaded Fittings*, 1998

ANSI B16.18, *Cast Copper Alloy Solder Joint Pressure Fittings*, 2001

ANSI B16.22, *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*, 2001

ANSI/ASME, *Boiler and Pressure Vessel Code*, 2001

ANSI/Hydraulic Institute (HI) Standard 3.1-3.6, *Rotary Pump Standards*, 1994

**ASME Publications**

American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016

ASME *Boiler and Pressure Vessel Code*, 2001

ASME B31.1, *Power Piping Code*, 1998

**ASTM Publications**

American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

ASTM A 269, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*, 2000

ASTM A 351/ASTM A 351M, *Standard Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex) for Pressure-Containing Parts*, 2000

ASTM A 403/ASTM A 403M, *Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings*, 2000

ASTM A 632, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service*, 1990

ASTM A 774/ASTM A 774M, *Standard Specification for As-Welded Wrought Austenitic Stainless Steel Fittings for General Corrosive Service at Low and Moderate Temperatures*, 2000

ASTM A 778, *Standard Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products*, 2000

ASTM A 789/ASTM A 789M, *Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service*, 1995

ASTM A 815/ASTM A 815M, *Standard Specification for Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings*, 1998

ASTM B 32, *Standard Specification for Solder Metal*, 2000

ASTM B 42, *Standard Specification for Seamless Copper Pipe, Standard Sizes*, 1998

ASTM B 75, *Standard Specification for Seamless Copper Tube*, 1999

ASTM B 88, *Standard Specification for Seamless Copper Water Tube*, 1999

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

ASTM B 251, *Standard Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube*, 1997

ASTM B 813, *Standard Specification for Liquid and Paste Fluxes for Soldering Applications of Copper and Copper-Alloy Tube*, 2000

ASTM D395-03 *Standard Test Methods for Rubber Property – Compression Set*, 2003

ASTM D412-06a *Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers-Tension*, 2006

ASTM D573-04, *Standard Test Method for Rubber – Deterioration in an Air Oven*, 2004

ASTM D1331-89, *Standard for Test Methods for Surface and Interfacial Tension of Solutions of Surface-Active Agents*, 2001

ASTM E-1, *Standard Specification for ASTM Liquid-in-Glass Thermometers*, 2003

ASTM E 8, *Standard Test Methods for Tension Testing of Metallic Materials*, 2008

ASTM E-11, *Standard Specification for Wire-Cloth and Sieves for Testing Purposes*, 2001

ASTM E-28, *Standard Test Methods for Softening Point of Resins Derived from Naval Stores by Ring-and-Ball Apparatus*, 1999

ASTM E84-08a, *Standard Test Method for Surface Burning Characteristics of Building Materials*, 2008

ASTM E 290, *Standard Test Methods for Bend Testing of Material for Ductility*, 2004

ASTM E 779, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*, 2003

ASTM E 799, *Standard Practice for Determining Data Criteria and Processing for Liquid Drop Size Analysis*, 2003

ASTM E-1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, 2004

ASTM E-2058, *Standard Test Methods for Measurement of Synthetic Polymer Material Flammability Using a Fire Propagation Apparatus (FPA)*, 2003

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

ASTM G155, *Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials*, 2004

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

#### **AWS Publications**

American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126

AWS A5.8, *Specification for Filler Metals for Brazing and Braze Welding*, 1992

AWS B2.1, *Specification for Welding Procedure and Performance Qualification*, 2000

AWS D10.9, *Specification for Qualification of Welding Procedures and Welders for Piping and Tubing*, 1980

#### **Bureau of Explosives (BOE)**

BOE Publications, PO Box 1020, Sewickley, PA 15143-1020

Tariff No. BOE-6000-G, *Hazardous Materials Regulations of the Department of Transportation by Air, Rail, Highway, Water, and Military Explosives by Water Including Specifications for Shipping Containers*, Latest Edition

#### **Compressed Gas Association**

Compressed Gas Association, 4221 Walney Road, 5th Floor, Chantilly VA 20151-2923

CGA Pamphlet S-1.1, *Safety Relief Devices Standards - Cylinders for Compressed Gases*

#### **FM Global**

FM Global, 75 Remittance Drive Suite #6182, Chicago, IL 60675-6182

Property Loss Prevention Data Sheets

#### **FM Approvals**

1151 Boston-Providence Turnpike, P.O. Box 9102, Norwood, MA 02062 USA

<http://www.fmapprovals.com>

FM Approvals' Approval Standards

*Quality Assurance Guidelines for Manufacturers of FM Approved and Specification Tested Products*, October 2003

#### **IMO Publications**

International Maritime Organization, 4 Albert Embankment, London, SE1 7SR, United Kingdom

IMO Assembly Resolution A.800 (19), November 1995

IMO Code for Application of Fire Test Procedures, 1998

IMO FP40/WP.9 Annex 3, *Report of the 40th Session of the Subcommittee on Fire Protection*, September 1997

IMO MSC/Circ. 668, *Alternative Arrangements for Halon Fire-Extinguishing Systems in Machinery Spaces and Pump Rooms*, December 1994

IMO MSC/Circ. 728, *Revised Test Method for Equivalent Water-Based Fire-Extinguishing Systems for Machinery Spaces of Category A and Cargo Pump-Rooms Contained in MSC/Circ. 668*, June 1996

IMO MSC/Circ. 913, *Guidelines for the Approval of Fixed Water-Based Local Application Fire-Fighting Systems for Use in Category A Machinery Spaces*, 1999

SOLAS Regulation 11-2/12.4.1, *International Convention for the Safety of Life at Sea (SOLAS)*, Consolidated Edition, 1992



**ISO Publications**

International Standards Organization, 1 rue de Varembe, Case Postale 56, CH-1211 Geneve 20, Switzerland

ISO 1219-1, *Fluid power systems and components - Graphic symbols and circuit diagrams - Part 1: Graphic symbols*, 1991

ISO 1219-2, *Fluid power systems and component s- Graphic symbols and circuit diagrams - Part 2: Circuit diagrams*, 1995

ISO 5660-1, *Reaction-to-fire tests -- Heat release, smoke production and mass loss rate -- Part 1: Heat release rate (cone calorimeter method)*, 2002

ISO 10380, *Pipework -- Corrugated metal hoses and hose assemblies*, 2003

ISO 17025, *General Requirements for the Competence of Testing and Calibration Laboratories*, 2005

ISO 9000, *Quality management systems – Fundamentals and Vocabulary*, 2005

**NFPA Publications**

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2005

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, 2007

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 2008

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 2008

NFPA 70, *National Electrical Code*, 2008

NFPA 72, *National Fire Alarm Code*, 2007

NFPA 170, *Standard for Fire Safety Symbols*, 2006

NFPA 750, *Standard on Water Mist Protection Systems*, 2006

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 2008

**U.S. Dept. of Transportation**

U.S. Government Printing Office, 732 N. Capitol Street, NW, Washington, DC 20401

Title 49, Code of Federal Regulations, Parts 171 to 190, Sections 178.36 and 178.37, specifications for DOT-3A, 3AA-1800, October 2003

**1.9 Definitions**

For purposes of this standard, the following terms apply:

***Accepted***

This term refers to installations acceptable to the authority having jurisdiction and 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 the equipment. Acceptance is not a characteristic of a product. It is installation specific. A product accepted for one installation may not be acceptable elsewhere. (Contrast with FM Approved).

***Amplitude***

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

***Assembly Load***

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

***Atomizing Medium***

Compressed air or other gases that produce water mist by mechanical mixing with water.

**Authority Having Jurisdiction**

The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.

**Automatic Nozzle**

A thermo-sensitive device designed to react at a predetermined temperature by automatically releasing hybrid media and distributing it in a specified pattern and quantity over a designated area that operate independently of other nozzles by means of a detection/activation device built into the nozzle.

**Coated or Plated Nozzle**

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

**Concealed Nozzle**

A nozzle in which the entire body, including the operating mechanism, is above a concealing plate.

**Conductivity Factor (C-Factor)**

A measure of the conductance between the nozzle's heat responsive element and the other components of the nozzle expressed in units of (ft/s)<sup>1/2</sup> or (m/s)<sup>1/2</sup>.

**Decorative Nozzle**

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

**Deluge System**

A hybrid fire extinguishing system using open nozzles attached to a piping system that is connected to water and gas supplies through a valve or valves that are opened by means of a detection system installed in the same area as the mist nozzles. When the valve(s) open, water flows into the piping system and discharges through all nozzles attached to the system.

**Discharge Coefficient (K-Factor)**

The coefficient of discharge as expressed in the equation:

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

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.

**Dry Pipe System**

A hybrid fire extinguishing system using automatic nozzles attached to a piping system containing air, nitrogen, or other inert gas under pressure, the release of which (as from an opening of an automatic nozzle) allows the water pressure to open a dry pipe valve. The water then flows into the piping system and discharges through any activated nozzles.

**Dump Valve**

An automatic valve installed on the discharge side of a positive displacement pump to relieve pressure prior to the pump driver reaching operating speed.

 **$Dv_f$** 

A drop diameter such that the cumulative volume, from zero diameter to this respective diameter, is the fraction,  $f$ , of the corresponding sum of the total distribution. For example,  $Dv_{0.50}$  is the volume median diameter; that is, 50 percent of the total volume of liquid is in drops of smaller diameter and 50 percent is in drops of larger diameter.

***Element Design Load***

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

***Enclosure***

A confined, or partially confined, volume.

***Engineered Systems***

Those systems that need individual calculation and design to determine the flow rates, nozzle pressures, pipe size, area, or volume protected by each nozzle, discharge density of the hybrid media, the number and types of nozzles, and the nozzle placement in a specific installation (Contrast with Pre-Engineered Systems).

***Fire Control***

Limiting the size of a fire by distribution of hybrid media so as to decrease the heat release rate and pre-wet adjacent combustibles, while controlling ceiling gas temperatures to avoid structural damage.

***Fire Extinguishment***

The complete suppression of a fire until there are no burning combustibles.

***Fire Pump Controller***

A group of devices that serve to govern, in some predetermined manner, the starting and stopping of the fire pump driver and to monitor and signal the status and condition of the fire pump unit.

***Fire Pump Unit***

An assembled unit consisting of a fire pump, driver, controller, and accessories.

***Fire Suppression***

The sharp reduction of the rate of heat release of a fire and the prevention of regrowth.

***Flammable Liquid***

A liquid that can produce flammable vapors that can be ignited and burn at some temperature.

***FM Approvals Certification Marks***

The FM Approvals certification marks are detailed in Appendix M. Their use is mandatory on all FM Approved systems. These registered marks cannot be used except as authorized by FM Approvals via the granting of Approval to a specific product. For hybrid systems, the FM Approvals certification mark shall be placed on the system placard and not on individual components unless those components have undergone a separate evaluation to the applicable standards.

***FM Approved***

This term refers to products FM Approved by FM Approvals. Such products are listed in the Approval Guide, a publication of FM Approvals, issued annually, or one of the supplements. 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 contract obligates the manufacturer to allow re-examination of the product and audit of facilities and procedures at FM Approvals' discretion. It further requires the manufacturer not to deviate from the as-FM Approved configuration of the product without review by and agreement of FM Approvals. Approval is product specific.

***Flush Nozzle***

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

***Fusible Element Nozzle***

A nozzle that opens under the influence of heat by the melting of a thermo-sensitive component.

***Gaseous Extinguishing System***

A distribution system connected to an agent supply that is equipped with one or more nozzles capable of delivering the agent, intended to control, suppress, or extinguish fires. The primary component of the agent supply is an inert gas, consisting of one or more of the gases helium, neon, argon, nitrogen, or carbon dioxide. Any water included in the agent supply is considered negligible as a factor in fire control, suppression, or extinguishment.

***Glass Bulb Nozzle***

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

***Hang-Up (Lodgment)***

A malfunction in the operation of a nozzle 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.

***Heat Responsive Element***

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

***High Pressure System***

A hybrid fire extinguishing system where the distribution system piping is exposed to pressures of 500 psi (34.5 bar) or greater.

***Hybrid Agent***

See Hybrid Media.

***Hybrid Fire Extinguishing System***

A distribution system connected to a supply of hybrid media that is equipped with one or more nozzles capable of delivering the media, intended to control, suppress, or extinguish fires.

***Hybrid Media***

An agent used for fire control, suppression, or extinguishment that is comprised of water and an inert gas, consisting of one or more of the gases helium, neon, argon, nitrogen, or carbon dioxide. Both components are critical factors in fire control, suppression, or extinguishment, as determined in Section 4.34. For the water component of the medium, the  $DV_{0.99}$ , for the flow weighted cumulative volumetric distribution of water droplets, is less than 1,000 microns at the minimum design operating pressure of the nozzle.

***Hybrid Nozzle***

A special purpose device containing one or more orifices designed to produce and deliver a mixture of water and inert gas meeting the definition of Hybrid Medium and/or meeting the specific requirements of an FM Approved hybrid fire extinguishing system test protocol. Nozzles can be designed to operate independently of other nozzles, as a group of nozzles, or a combination of the two.

***Intermediate Pressure System***

A hybrid fire extinguishing system where the distribution system piping is exposed to pressures greater than 175 psi (12.1 bar) but less than 500 psi (34.5 bar).

***Leak Point***

The leak point is the pressure at which leakage of water in excess of one drop per minute occurs from hybrid nozzles.

***Low Pressure System***

A hybrid fire extinguishing system where the distribution system piping is exposed to pressures of 175 psi (12.1 bar) or less.

***Machinery Space***

These areas include enclosures with machinery such as internal combustion engines, oil pumps, oil tanks, fuel filters, generators, transformer vaults, gear boxes, drive shafts, lubrication skids, diesel engine driven generators, and other similar equipment using liquid hydrocarbon fuel and/or hydraulic, heat transfer, and lubrication fluids; enclosures with incidental use or storage of hydrocarbon flammable liquids of not more than two 55 gal (208 L) drums.

***Maximum Nozzle Operating Pressure***

The maximum nozzle operating pressure is the highest pressure that the nozzle distribution system is designed for.

***Maximum System Operating Pressure***

The maximum system operating pressure is the highest pressure that any one system component is subject to. Typically, this would be the pressure available in cylinder storage at the maximum operating temperature or the pressure at the pump discharge.

***Maximum System Pressure***

The highest pressure available from the pressure source. Typically, this would be the pressure setting of the pressure relief device.

***Minimum Bend Radius***

The smallest radius (expressed in inches [mm]) that a flexible hose is safely allowed to bend, as specified by the manufacturer.

***Net Positive Inlet Pressure Available (NPIPA)***

For hybrid fire extinguishing system pumps, the total of the inlet and barometric pressure minus the vapor pressure of the liquid at the inlet temperature. This value must be equal to or greater than the net positive inlet pressure required (NPIPR) as established by the pump manufacturer for the speed, pressure and fluid characteristics which exist.

***Net Positive Inlet Pressure Required (NPIPR)***

For hybrid fire extinguishing system pumps, the pressure required above liquid vapor pressure to fill each pumping chamber or cavity while open to the inlet chamber.

***Nozzle***

See Hybrid Nozzle.

***Open Nozzles***

Nozzles that operate as an entire system or grouping of nozzles, containing open orifices. The agent flow to these nozzles is activated by an independent detection system.

***Operating Pressure***

The pressure at which a component functions under normal conditions.

***Operating Temperature***

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

***Orientation, Best Case***

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

***Orientation, Worst Case***

For use in this standard, when testing nozzles for sensitivity in the FM Approvals plunge tunnel, the worst case orientation is a given angular offset from the orientation which results in the slowest operating time, or the highest Response Time Index (RTI). For standard response nozzles this angular offset is 15 degrees. The angular offset for quick response nozzles is 25 degrees.

***Orifice***

An orifice is the opening in a nozzle body through which the hybrid medium is discharged.

***Pendent Nozzle***

A nozzle so designed that the water leaving the orifice(s) is directed downwards.

***Positive Displacement Pump***

A pump that is characterized by a method of producing flow by capturing a specific volume of fluid per pump revolution and reducing the fluid void by a mechanical means to displace the pumping fluid.

***Preaction System***

A hybrid fire extinguishing system using automatic nozzles attached to a piping system containing air that may, or may not, be under pressure, with a supplemental detection system installed in the same area as the mist nozzles. The actuation of the detection system opens a valve that allows agent to flow into the piping system and discharge through any activated nozzles.

***Pre-engineered Systems***

Those systems having predetermined flow rates, nozzle pressures, and water quantities regardless of the installation.

***Pressure Control Valve***

A pilot-operated pressure-reducing valve designed for the purpose of reducing the downstream water pressure to a specific value under both flowing (residual) and non-flowing (static) conditions.

***Pressure-Reducing Valve***

A valve designed for the purpose of reducing the downstream pressure under both flowing (residual) and non-flowing (static) conditions.

***Pressure-Regulating Device***

A device designed for the purpose of reducing, regulating, controlling, or restricting water or gas pressure. Examples include pressure-reducing valves, pressure control valves, and pressure-restricting devices.

***Primary Protection***

A fire extinguishing system is considered as a primary protection system when the system is installed for protection of the occupancy and building, such as a sprinkler system. When a fire extinguishing system is recommended as a means of primary protection, the agent supply shall be equivalent to an automatic sprinkler system for the same hazard, per the applicable FM Global Property Loss Prevention Data Sheets.

***Propellant***

A compressed gas that serves to push water out of storage vessels, through pipe networks, or through distribution components.

**Quick Response Nozzle**

A nozzle having a Response Time Index (RTI) and Conductivity factor (C) combination which fall into the indicated area on the graph in Figure 4.2.27.1. Generally, this is a nozzle 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 nozzle is tested in the best-case orientation. For recessed, flush and concealed nozzles, the criteria outlined in Sections 4.2.27 or 4.2.28 shall be met, as appropriate.

**Rated Working Pressure**

The maximum pressure at, or below, which all components shall operate trouble free.

**Recessed Nozzle**

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

**Relief Valve**

A device that allows the diversion of liquid or gas in order to limit excess pressure in a system.

**Response Time Index (RTI)**

A measure of nozzle sensitivity expressed as  $RTI = \tau(u)^{1/2}$  where  $\tau$  is the time constant of the heat responsive element in units of seconds, and  $u$  is the gas velocity expressed in feet per second (meters per second). The quantity  $\tau$  relates the properties of the heat responsive element and the heated gas flow. RTI can be used to predict the response of a nozzle 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  $\text{(m}\cdot\text{s)}^{1/2}$ .

**Sidewall Nozzle**

A nozzle intended for installation near a wall and ceiling interface and designed to discharge water outward from the wall.

**Special Protection System**

A fire extinguishing system that is installed for the protection of areas where hybrid systems and other limited agent supply systems, such as water mist, carbon dioxide, dry chemical, or clean agent systems would be acceptable methods of protection. The agent supply should be in accordance with Section 1.2.4.

**Standard Response Nozzle**

A nozzle having a Response Time Index (RTI) and C-factor combination which fall into the indicated area on the graph in Figure 4.2.27.1. Generally, this is a nozzle having an RTI between  $145 \text{ (ft}\cdot\text{s)}^{1/2}$  and  $635 \text{ (ft}\cdot\text{s)}^{1/2}$  [ $80 \text{ m}\cdot\text{s)}^{1/2}$  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 nozzle is tested in the best-case orientation. Recessed, flush and concealed nozzles shall meet the criteria outlined in Sections 4.2.27 or 4.2.28, as appropriate.

**Strutting**

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

**Total Flooding System**

A system designed to protect all hazards in an enclosure. An example of a total flooding system is the use of hybrid fire extinguishing systems for the total flooding protection of combustion turbines and associated equipment in these enclosures.

**Total Suction Head**

The pressure condition at the inlet of an operating pump when the suction pressure is above atmospheric. The total suction head is the algebraic sum of the gauge reading in psi (bar) at the pump suction nozzle, referred to the pump centerline, and the velocity head at the point of gauge attachment. Also called "positive suction pressure."

***Total Suction Lift***

The pressure condition at the inlet of an operating pump when suction pressure is below atmospheric. The total suction lift is the algebraic sum of the gauge reading in psi (bar) at the suction nozzle of the pump, referred to the pump centerline, and the velocity head at the point of gauge attachment.

***Twin Fluid Water Mist System***

A water mist system in which water and atomizing media are supplied to a water mist nozzle. These systems may use an independent piping system for each fluid or a single piping system. Twin fluid systems also include effervescent systems, in which compressed air or other gases is injected into the water line upstream the water mist nozzle.

***Unloader Valve***

A type of relief valve that is designed to relieve excess flow for high pressure pumps.

***Volatility***

A measure of the potential hazard of a fuel. Generally, lower flash points and lower boiling points will characterize fuels with higher volatilities. Other properties, such as fuel solubility in water, should also be considered.

***Water Mist***

A water spray for which the  $DV_{0.99}$ , for the flow weighted cumulative volumetric distribution of water droplets, is less than 1,000 microns at the minimum design operating pressure of the water mist nozzle.

***Water Mist Nozzle***

A special purpose device containing one or more orifices designed to produce and deliver an atomized water spray meeting the definition of Water Mist or meeting the specific requirements of an FM Approved water mist fire test protocol. Nozzles can be designed to operate independently of other nozzles, as a group of nozzles, or a combination of the two.

***Water Mist System***

A distribution system connected to a water supply that is equipped with one or more nozzles capable of delivering water mist, intended to control, suppress, or extinguish fires.

***Wet Pipe System***

A hybrid fire extinguishing system using automatic nozzles attached to a piping system containing water and connected to a water supply so that water discharges immediately from automatic nozzles operated by the heat from a fire.

***Working Pressure***

The maximum anticipated stationary (non-flowing) pressure applied to the system components exclusive of momentary spike or surge pressures.

***Weep Point***

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

***Zoned Application System***

A system designed to protect hazards in a predetermined portion of an enclosure.



## 1.10 References

1. Heskestad, G. and Smith, H. F., Investigation of a New Sprinkler Sensitivity Approval Test, Factory Mutual Research Corporation, December 1976.
2. Heskestad, G. and Smith, H. F., Plunge Test for Determination of Sprinkler Sensitivity, Factory Mutual Research Corporation, December 1980.
3. Heskestad, G. and Bill, R. G. Jr., Conduction Heat Loss Effects on Thermal Response of Automatic Sprinklers, Factory Mutual Research Corporation, September 1987.
4. Heskestad, G. and Bill, R. G. Jr., Plunge Test Procedures for Recessed, Flush and Concealed Sprinklers, Factory Mutual Research Corporation, February 1995.
5. Bill, R. G. Jr., and Hill, E. E., Extended Coverage Sprinklers in Light Hazard Occupancies. Factory Mutual Research Corporation, September 1993.
6. Khan, M. M., Chaffee, J. L., and Alpert, R. L., Determination of Operating Temperatures of Glass Bulb Sprinklers Using a Thermal Liquid Bath, August 2000.

## 2. GENERAL INFORMATION

### 2.1 Product Information

- 2.1.1 A hybrid system is a fire protection system using fine water sprays and inert gas. The combination of very small water droplets and inert gas allow the hybrid media to control or extinguish fires by cooling of the flame, fire plume, and fuel, oxygen displacement by water vapor, radiant heat attenuation, and inerting by the gaseous portion of the media.
- 2.1.2 In order to meet the intent of this standard, hybrid fire extinguishing systems shall be examined on a model-by-model, type-by-type and manufacturer-by-manufacturer, and plant-by-plant basis. This is predicated on the basis 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 systems, 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:

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

The manufacturer shall provide the following preliminary information with any request for Approval consideration. All documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level.

- 2.2.1 Any marketing literature showing the general specifications and functions of the system.
- 2.2.2 A complete list of all models, types, sizes, and system variations and options to be examined. This may be submitted in the form of a specification or drawing.
- 2.2.3 An instruction manual—listing all design, installation, operation, and maintenance instructions.

- 2.2.4 Quality control procedures detailing routine testing and final inspection procedures. These may include receiving inspection, in-process inspection, final inspection, and calibration of measuring and testing equipment procedures.
- 2.2.5 Procedures detailing the system acceptance testing once the hybrid fire extinguishing system is installed.
- 2.2.6 The following drawings should be provided:
- Electrical schematic(s)
  - Final assembly drawings and parts lists sufficient to detail primary components (all), operator controls, and their locations;
  - Complete set of mechanical drawings for all machined parts;
  - Complete part specifications (including manufacturer's model numbers, size, ratings, etc.) for all purchased parts;
  - Specification sheets for all parts/components;
  - Drawings showing all construction details, sheet metal gauge and paint finish;
  - Product label drawing(s) showing all required marking information. The label drawing shall show the proposed label location on the equipment and artwork showing the manufacturer's name, address, model and serial numbers, equipment ratings, warning markings, and the FM Approved Mark, (see Appendix M).
- 2.2.7 The number and location of manufacturing facilities.

Test programs will be scheduled only on receipt of all material listed above. All foreign language documents shall be provided with English translation.

### **2.3 Requirements for Samples for Examination**

Following generation and authorization of an Approval examination, the manufacturer shall prepare components for examination and testing. Sample requirements are to be determined by FM Approvals following review of the preliminary information. Sample requirements may vary depending on design features, results of prior testing, and results of the foregoing tests. It is the manufacturer's responsibility to submit samples representative of production. Any decision to use data generated utilizing prototype components or systems is at the sole discretion of FM Approvals.

### 3. GENERAL REQUIREMENTS

#### 3.1 Review of Documentation

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

#### 3.2 Physical or Structural Construction Features

3.2.1 To ensure the successful performance of the hybrid fire extinguishing system, and to minimize the chance of re-ignition of a fire, enclosures and/or hazards provided with FM Approved hybrid fire extinguishing systems shall be equipped with the following automatic interlocks and safeguards, as applicable:

- Automatic door closures,
- Electrical system shutdown,
- Fuel and lubrication (where practical) supply shutoff,
- Ventilation system shutdown (alternatively, the hybrid system shall be fire tested at the maximum ventilation rate specified in the system manufacturer's manual),
- Containment for flammable liquid releases, and
- Hybrid fire extinguishing system protection over the entire area of the containment or hazard.

These restrictions may be relaxed with additional testing and review and/or acceptance of documentary evidence, submitted by the manufacturer, substantiating the manufacturer's claims.

3.2.2 The manufacturer shall provide a diagram or schematic drawing of the system which indicates the minimum and maximum system operating pressures of each section, or sub-system, of the system.

3.2.3 The test program requirements shall be based on assembly and manufacturing drawings supplied by the manufacturer prior to the start of testing. Following the results of testing, if additional hardware is required, the test program will be revised.

3.2.4 For all components downstream of the pressurization system (pump, gas, and/or other method), the test pressures will be calculated using a base working pressure equal to the maximum system operating pressure of the pressurized system. For pump systems, this shall be zero flow or "shut off" pressure.

3.2.5 For all components downstream of any high pressure cylinders, the test pressures shall be calculated using a working pressure equal to the maximum system operating pressure and temperature of the cylinder.

3.2.6 Water tanks shall meet the requirements of FM Global Property Loss Prevention Data Sheet Number 3-2, *Water Tanks for Fire Protection*, or the ASME *Boiler and Pressure Vessel Code*, as applicable. (Hybrid systems for sale in countries other than the United States may meet the national requirements of the country where the system is to be installed. A complete review of additional pressure vessel codes is required prior to Approval.) Hybrid systems shall only use potable water sources. For wet bench applications, circulating de-ionized water shall be used.

3.2.7 Air, nitrogen, and other gas cylinder(s) shall meet the requirements of the ASME *Boiler and Pressure Vessel Code*, Section VII, or the requirements of U.S. Department of Transportation, Title 49, *Code of Federal Regulations*, Parts 171 to 180, or equivalent national codes for the country of use (reference Section 4.9).

3.2.8 Hydrostatic strength of components should be based on 150 percent of the maximum system operating pressure but not less than 700 psi (48.3 bar).

- 3.2.9 Functional operating pressure of components and systems should be based on a pressure of no less than 175 psi (12 bar). Leakage pressure testing should be based 120 percent of the maximum system pressure and temperature but not less than 500 psi (34.5 bar).
- 3.2.10 Generally, no plastic or elastomeric components are to be used (these parts may be used at the sole discretion of FM Approvals, contingent on additional testing). Suitability of materials along with certification of materials compatibility shall be submitted for review. Suitability of materials with the expected environmental atmospheres along with certification of material and environment compatibility shall be submitted for review.
- 3.2.11 The use of FM Approved fire detection devices is required for deluge systems. Fire detection devices and manual pull stations used in the system shall be FM Approved components.
- 3.2.12 Non-FM Approved electrical components, including automatic release devices, control panels, sequence boxes, and other applicable devices, will be included within the scope of the FM Approvals project examination.
- 3.2.13 Documented use of FM Approved components, if evaluated for the same system characteristics, may be sufficient reason to waive the tests described below for those components, based on the sole discretion of FM Approvals.
- 3.2.14 Placement of all system components, with the exception of the nozzles and piping, shall be in a location outside the protected area.
- 3.2.15 Galvanized piping is permitted for FM Approved hybrid fire extinguishing systems in accordance with FM Global Property Loss Prevention Data Sheet Number 4-0, *Special Protection Systems*, provided:
- The system is a low pressure system;
  - The galvanized piping is applied to the inert gas supply lines only;
  - A strainer is provided at the nozzle inlet; and
  - The smallest nozzle nominal orifice diameter is greater than or equal to 0.375 in (10 mm).
- 3.2.16 Controls
- 3.2.16.1 For normal operation, a system shall be either automatically controlled or operable from a manual control, easily accessible to the hazard, or both. If the normal manual means of actuation incorporates electric power, the source of that power shall be completely independent of any electric power source used for automatic operation. A power source used for both normal manual and automatic operation shall be provided with an independent backup, such as a battery. Systems without automatic nozzles shall be provided with an alternate means of fully mechanical manual emergency control, regardless of their normal means of operation. Fully mechanical manual emergency controls shall not require an electric power source, but may make use of the hybrid fire extinguishing system's working pressure to operate the release. These emergency controls shall be located at or near the device being controlled.
- 3.2.16.2 Control panels shall comply as a releasing control with NFPA Standard 72 and FM Approvals' *Fire Alarm Signaling Systems* (Class 3010) and the *Electrical Equipment for Measurement, Control and Laboratory Use* (Class 3810). Control panels need not be submitted as a part of a system. However, system design shall be such that the system is operable by a minimum of one FM Approved detection and release panel.

### 3.3 Components

A component of a hybrid fire extinguishing system product covered by this standard shall comply with the requirements for that component, and shall be used in accordance with its rated values and other limitations. For a component that contains features or characteristics that are not necessary in the application of the component in the hybrid fire extinguishing system, the component is not required to comply with the corresponding performance requirement(s) specified by this standard.

At a minimum, components required for the automatic starting and continued operation of the hybrid fire extinguishing system shall be designed or selected for maximum long term reliability. Hybrid fire extinguishing systems are to be of the constant water delivery type. Hybrid fire extinguishing systems with an extended pause in the extinguishing supply are not permitted. System design should take into account the possibility of component failure and the potential for that failure to impair the automatic or manual starting of the system. Such impairments shall be minimized through failsafe, redundant components, over-design, de-rating, or other means.

### 3.4 Markings

#### 3.4.1 Hybrid Fire Extinguishing System Marking

3.4.1.1 A permanently-marked, legible, corrosion-resistant nameplate shall be securely attached to the system in an easily visible location. The nameplate shall include the minimum following information:

- Manufacturer's name or trademark;
- Model identification;
- System ratings;
- Equipment operating ratings;
- Serial number or other traceable code markings;
- FM Approvals Certification Mark, (see Appendix M); and,
- Manufacturing location source code where necessary.

3.4.1.2 Each hybrid fire extinguishing system shall also have a similar corrosion-resistant data plate listing the instructions for manual emergency operation prominently displayed. These instructions shall be complete and easily understood, so that an individual with no prior knowledge of the system's operation shall be able to manually engage the system by following such instructions. Individual controls shall be clearly and unambiguously identified in these instructions and correspondingly labeled on the system.

3.4.1.3 Any other pertinent marking information required by the referenced standards or other national or international standards to which the system is manufactured shall be permanently marked on a suitable data plate.

3.4.1.4 The model or type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the product as FM Approved. The manufacturer shall not place this model or type identification on any other product unless covered by a separate agreement.

3.4.2 In instances where a system nameplate is not applicable, marking of the nozzle may be sufficient. In these cases, nozzles shall be marked in accordance with one of the two marking schemes described in Sections 3.4.2.1 and 3.4.2.2. The manufacturer may use either one or both of the schemes and shall notify FM Approvals prior to making any marking changes on the nozzles.

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

- Orifice size or shape
- Deflector type or orientation
- Pressure rating
- Thermal sensitivity (i.e. response classification)

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

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

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

- Nominal temperature rating (in °F or °C at a minimum);
- Year of manufacture (Note: nozzles manufactured in the first six months or last three months of a calendar year may be marked with the previous or following year respectively, as the year of manufacture)

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

- Manufacturer's name or identifying symbol (logo);
- Model designation (see Section 3.4.3 below);
- Nominal K-factor (in English units: gal/min/(psi)<sup>1/2</sup>);
- The word "PENDENT" (or the letter "P"), or other designation to indicate type or orientation, as appropriate;
- The FM Approvals Certification Mark **SHOULD NOT** be placed on the nozzle.

3.4.2.2 In lieu of the marking requirements of section 3.4.2.1, nozzles shall be permanently marked on a non-operating component with the following:

- Manufacturer's name or identifying symbol (logo);
- Model designation (see Section 3.4.2.3 below);
- Nominal K-factor (in English units: gal/min/(psi)<sup>1/2</sup>);
- The word "PENDENT" (or the letter "P"), the word "UPRIGHT" (or the letter "U"), or other designation to indicate type or orientation, as appropriate;
- Nominal temperature rating (in °F or °C at a minimum);
- Year of manufacture (Note: nozzles 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 nozzles shall be marked with the words "Quick Response" or the initials "QR";
- The FM Approvals Certification Mark **SHOULD NOT** be placed on the nozzle.

3.4.2.3 Regardless of the marking scheme used, the nozzle identification number, model designation, and/or type identification shall correspond with the manufacturer's catalog designation. The manufacturer shall not place this identification mark on any other product.

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

- 3.4.3 For fusible type nozzles, the operating temperature, or the temperature rating color code, as defined in Table 3.4.5, shall appear on a visible area of the fusible element or an associated operating component.
- 3.4.4 For fusible type nozzles, the year of manufacture shall appear on a visible area of the fusible element or an associated operating component. Nozzles 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.
- 3.4.5 All automatic nozzles, with the exception of glass bulb type nozzles, shall be color coded in accordance with Table 3.4.5. Paint of the correct color shall be applied to at least 50 percent of each frame arm surface. This application of paint shall be visible on the nozzle from all directions. The color identification for coated, plated and recessed nozzles may be a dot on the top of the deflector, the color of the coating material or colored frame area. This dot shall be visible from a distance of 3 feet (0.9 m).

Table 3.4.5 - Temperature Ratings, Classifications, and Color Codes

<b>Nominal Temperature<sup>1</sup> Rating Range</b>		<b>Maximum Ambient Temperature At Nozzle Level</b>		<b>Temperature Classification</b>	<b>Nozzle Frame Color Code</b>
<b>°F</b>	<b>(°C)</b>	<b>°F</b>	<b>(°C)</b>		
135 to 170	(57 to 77)	100	(38)	Ordinary	None or Black
175 to 225	(79 to 107)	150	(66)	Intermediate	White
250 to 300	(121 to 149)	225	(107)	High	Blue
325 to 375	(163 to 191)	300	(149)	Extra High	Red
400 to 475	(204 to 246)	375	(191)	Very Extra High	Green
500 to 575	(260 to 302)	475	(246)	Ultra High	Orange
650	(343)	625	(329)	Ultra High	Orange/Tag

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

Table 3.4.6 - Temperature Ratings and Bulb Color Codes

<b>Nominal Temperature Rating</b>		<b>Bulb Color Code</b>
<b>°F</b>	<b>(°C)</b>	
135	(57)	Orange
155	(68)	Red
175	(79)	Yellow
200, 225	(93, 107)	Green
250, 286	(121, 141)	Blue
325, 360	(162, 182)	Mauve
400 to 650	(204 to 343)	Black

- 3.4.7 Flush nozzles shall be color coded. Such color identification may be a dot suitably located and visible on the link, arms, or other component as appropriate. Such location shall be evaluated on a case-by-case basis.
- 3.4.8 For all concealed nozzles, the cover plate shall be marked with the words "Do Not Paint" in characters at least 1/8 in. (3.2 mm) in height.
- 3.4.9 Horizontal sidewall nozzles shall include the word "Top" on the deflector to indicate orientation.
- 3.4.10 Vertical sidewall nozzles shall bear an arrow indicating the direction of flow and the word "flow".
- 3.4.11 Factory plated nozzles shall be identified as such with a distinctive marking so as to distinguish the product from unauthorized field plating.

- 3.4.12 For factory decorative-painted (coated) nozzles, some portion of the nozzle shall remain unpainted and readily visible from a minimum of 1 foot (0.3 m). This would allow a means to determine if the nozzle were repainted in the field. Field painting is prohibited.
- 3.4.13 For bulb-type nozzles, the manufacturer shall place a distinctive mark on a non-operating part of the nozzle to denote the bulb manufacturer if more than one source is used in a given design.
- 3.4.14 All markings shall be permanent and visible from a distance of 3 feet (0.9 m). The markings shall remain visible through any factory-applied plating or decorative coating.

### **3.5 Manufacturer's Design, Installation and Operation Instructions**

Design, installation, operation and maintenance instructions shall be furnished by the manufacturer with every hybrid fire extinguishing system. These instructions shall be submitted to FM Approvals as a part of the examination of a system. The design manual shall describe in detail the scaling parameters used for the smaller room sizes and different configurations than those tested. Reference Section 4.32 for manual details.

### **3.6 Calibration**

All equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage of the equipment. A copy of the calibration certificate for each piece of test equipment is required for FM Approvals records, indicating that the calibration was performed against working standards whose calibration is certified as traceable to the National Institute of Standards and Technology (NIST) or to other acceptable reference standards and certified by 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.

### **3.7 Test Facilities**

If review of all required information indicates suitability for Approval, testing of sample hybrid fire extinguishing systems for specific occupancy protection will be scheduled. The range of component and fire tests to be conducted shall be specified by FM Approvals. The manufacturer shall provide facilities and all properly calibrated instrumentation required to perform the tests deemed necessary by FM Approvals if the testing cannot be conducted at an FM Approvals facility. If other standards are contemplated, they should be forwarded to FM Approvals for review and acceptance prior to the generation of the test program. The manufacturer shall also provide personnel to install and operate the hybrid system. For testing not conducted at an FM Approvals facility, a representative of FM Approvals shall witness all the tests and shall receive copies of the data and equipment calibration certificates. All the tests shall be conducted at normal ambient conditions as noted in the fire performance testing requirements in the Appendices.

### **3.8 Tolerances**

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



## 4. PERFORMANCE REQUIREMENTS

This standard is composed of two parts: component testing and fire testing. Due to the current state of hybrid fire extinguishing system technology, a comprehensive absolute standard for the testing of hybrid system components is not possible. Since each system is unique in its operation and design, the component testing of the hybrid fire extinguishing system shall be performed on a case-by-case basis. The component testing section is intended to be used as a guideline for the manufacturer as to what type of test program can be expected. Performance requirement testing may be conducted for an individual component, component assembly or as an entire system, as deemed necessary at the sole opinion of FM Approvals. Use of FM Approved equipment is strongly encouraged. Documented use of FM Approved components, if evaluated for the same system characteristics, may be sufficient reason to waive the tests described below for those components or sub-assemblies, based on the sole discretion of FM Approvals. Electrical components that require a hazardous location rating will be evaluated under the scope of the Approval examination, with evaluations and required testing performed by the FM Approvals Electrical Group. Upon request for a program, and appropriate system documentation, FM Approvals will prepare a customized evaluation program for the specific hybrid fire extinguishing system. While customization of the component testing is necessary, the fire test protocols are generic for all hybrid fire extinguishing systems. The manufacturer's design calculations, stated performance requirements, and component functionality and reliability will be verified.

### 4.1 General Examination and Performance Requirement Test Procedures

Tests described in Section 4.1 are cited throughout the component performance requirements. They are described here in detail, and only referenced in other sections. All testing is conducted at a normal ambient temperature of 70 °F ± 5 °F (21.1 °C ± 2.8 °C) unless otherwise specified.

#### 4.1.1 Examination

##### 4.1.1.1 Requirements

The hybrid fire extinguishing system shall conform to the manufacturer's drawings and specifications and to Approval requirements.

##### 4.1.1.2 Test/Verification

A hybrid fire extinguishing system, and all individual system components, representative of the manufacturer's final production equipment to be FM Approved shall be examined and compared to drawings and engineering specifications. It shall be verified that the sample system conforms to the physical and structural requirements described in Section 3, General Requirements.

#### 4.1.2 Valve Seat Leakage

##### 4.1.2.1 Requirements

All valves shall be leak tight when subjected to an upstream hydrostatic test pressure of 120 percent of the maximum system operating pressure.

##### 4.1.2.2 Test/Verification

With the outlet side open to atmosphere, the upstream side of each size valve shall be subjected to hydrostatic pressure of 120 percent of the maximum system operating pressure, to prove the sealing ability. The test pressures shall be maintained for five minutes, with no leakage allowed.

### 4.1.3 Hydrostatic Strength

#### 4.1.3.1 Requirements

Component bodies shall withstand 150 percent of the maximum system operating pressure, but not less than 700 psi (48.3 bar), without rupture, cracking or permanent distortion.

#### 4.1.3.2 Test/Verification

Component bodies of each size shall be subjected to a hydrostatic test pressure of 150 percent of the maximum system operating pressure, or 700 psi (48.3 bar), whichever is greater, for five minutes. No rupture, cracking or permanent distortion of the component body is allowed. After this test the component shall be fully operable. Reinforcement of gaskets is permitted, if necessary, during testing.

### 4.1.4 Operating Pressure

#### 4.1.4.1 Requirements

Operational components of each size shall be tested in an as received condition to determine their pressure operating characteristics and minimum operating pressure.

#### 4.1.4.2 Test/Verification

Components of each size shall be tested in an as received condition five times to determine the pressure operating characteristics and the recommended minimum operating pressure. It shall be determined that each component is capable of operating between 85 and 110 percent of the recommended operating pressure for the component. If there is an adjustment, the component will be tested at the minimum and maximum settings, as recommended by the manufacturer, to determine the operating characteristics. Results shall be included in the installation and operating instructions of the system.

### 4.1.5 Durability - Cycling

#### 4.1.5.1 Requirements

At the conclusion of a cycle operational test, excessive component wear or damage shall not occur. The number of cycle operations shall be 500 for instantaneous, single or limited component operations and 20,000 for continuous component operations.

#### 4.1.5.2 Tests/Verification

Prior to the start of the durability test, a sample component shall be hydrostatically pressurized to the maximum system operating pressure. The sample shall then be cycled 500 times if of the instantaneous or single operation type device or 20,000 times if of the continuous operation type device, depending on its normal expected operation, through its full open to close and close to open positions, or its full range of travel.

The pressure upstream of the test component in the closed position shall be equal to the maximum system operating pressure for the duration of this test. The pressure downstream of the test component shall alternate between atmospheric (0 psi, 0 bar) and maximum system operating pressure. During the test, the pressurization rate shall be five to ten cycles per minute. After this test, the component shall be fully operable. The component shall then be disassembled and moving parts shall be visibly examined for signs of excessive wear or damage. Post testing may include 4.1.2 (Valve Seat Leakage), 4.1.3 (Hydrostatic Strength) and 4.1.4 (Operating Pressure).

#### 4.1.6 Extreme Temperatures Operation

##### 4.1.6.1 Requirements

Following the completion of the minimum and maximum operational temperature exposure periods, a sample component shall be evaluated for proper operation with the inlet pressurized, if applicable, to the maximum system operating pressure. The component shall then be visually examined and, if deemed necessary, shall be subjected to any of the appropriate tests as detailed in this standard.

##### 4.1.6.2 Test/Verification

The component shall be conditioned in an environmental chamber set at 40 °F (4.4 °C) for a period of 24 hours. Immediately upon removal from the conditioning chamber the component shall be tested for proper function, with the inlet pressurized, if applicable, to the maximum system operating pressure. Post testing may include 4.1.2 (Valve Seat Leakage), 4.1.3 (Hydrostatic Strength) and 4.1.4 (Operating Pressure).

The same component that completed the low temperature exposure test shall be conditioned in an environmental chamber set at 130 °F (54.4 °C) for a period of 24 hours. Immediately upon removal from the conditioning chamber, the component shall be tested for proper function, with the inlet pressurized, if applicable, to the maximum system operating pressure. Post testing may include 4.1.2 (Valve Seat Leakage), 4.1.3 (Hydrostatic Strength) and 4.1.4 (Operating Pressure).

#### 4.1.7 Salt Spray Corrosion

##### 4.1.7.1 Requirements

In order to evaluate the resistance to corrosion of the component or component assembly, such as might be experienced by dissimilar materials in contact over long periods of time; the component shall withstand a timed exposure to a salt spray atmosphere. When tested as detailed in Section 4.1.7.2 (Salt Spray - Corrosion), visual evidence of severe deterioration or impending failure of any component shall constitute failure. Corrosion resistant material specifications shall be submitted for review.

##### 4.1.7.2 Test/Verification

One previously untested component, component assembly, or system shall be operated to confirm proper operation prior to exposure.

If necessary, the component 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 component. The component shall be supported in its intended installation position.

The sample component shall be exposed to salt spray (fog) as specified by ASTM B117, *Standard for Salt Spray (Fog) Testing*, with the exception of the salt solution. The salt solution shall consist of 20 percent (by weight) of common salt (sodium chloride) dissolved in deionized water with a pH between 6.5 and 7.2 and specific gravity from 1.126 and to 1.157.

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

Following the exposure to the salt fog, the sample 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 component shall be fully operable under rated operating pressure conditions. Post testing may include 4.1.2 (Valve Seat Leakage), 4.1.3 (Hydrostatic Strength) and 4.1.4 (Operating Pressure).

#### 4.1.8 Vibration Resistance

##### 4.1.8.1 Requirements

The component, or component assemblies, shall withstand vibration without leakage, joint separation, or excessive wear to the sealing components as a result of vibration resistance testing.

##### 4.1.8.2 Tests/Verification

Compliance shall be verified by testing one sample of each component type or size. The component shall be pressurized to the maximum system operating pressure during the entire test and shall be subjected to the vibration sequence of 4.1.8. The plane of vibration shall be vertical, both along its longitudinal and latitudinal axis. Post testing may include 4.1.2 (Valve Seat Leakage), 4.1.3 (Hydrostatic Strength) and 4.1.4 (Operating Pressure).

The component, or component assemblies, shall be attached to a mounting plate. The mounting plate shall be attached, by the method of the manufacturer's suggested installation procedure, to the table of a vibration machine so that the component or component assemblies are vibrated vertically. This test shall be conducted with the component, or component assemblies, pressurized. The component, or component assemblies, shall be subjected to the above vibration conditions and continuously monitored for 15 minutes for each condition (75 minutes total). If one or more resonant point(s) are detected, the component, or component assemblies shall be vibrated for the remainder of the test at such frequency or frequencies for a period of time proportionate to the number of resonant frequencies. If resonant point(s) are not detected, the component, or component assemblies, shall be subjected to each vibration condition for a period of 5 hours (25 hours total).

Table 4.1.8 - *Vibration Conditions*

<i>Total Displacement/Stroke inch</i>	<i>(mm)</i>	<i>Frequency Hz</i>	<i>Time Hours</i>
0.020	(0.51)	28	5
0.040	(1.04)	28	5
0.150	(3.81)	28	5
0.040	(1.04)	18 to 37 (variable)	5
0.070	(1.78)	18 to 37 (variable)	5

#### 4.1.9 Valve Locking/Supervision Ability

##### 4.1.9.1 Requirements

All manual hand operated valves, and mechanisms, shall be provided with a device such that it can be secured and/or locked and/or supervised in the intended installation position. Details of locking methods are presented in FM Global Property Loss Prevention Data Sheet Number 2-81, *Fire Protection System Inspection, Testing and Maintenance and Other Fire Loss Prevention Inspections*.

##### 4.1.9.2 Tests/Verification

Submitted sample valves shall be examined for the provision of a secured and/or locking and/or supervision device, which will be tested during other applicable valve testing requirements for suitability.

#### 4.1.10 Friction Loss Determination

##### 4.1.10.1 Requirements

The construction of any valve shall be such that any obstruction to the passage of water through the valve body is minimal. With the ball or disc in the full open position, the loss in pressure through the valve shall not exceed 5 percent of the manufacturer's published values at the required maximum system pressure and flow requirements.

##### 4.1.10.2 Tests/Verification

Tests shall be conducted to verify that the friction loss through any valve does not exceed 5 percent of the manufacturer's published values at the maximum system pressure and flow requirements. A sample valve shall be installed between two test pipes of the same nominal diameter as the valve and equipped with piezometer rings. The pressure loss between the piezometer shall be measured for sufficient flow rates to determine the friction loss characteristics of the valve. This test may be waived at the sole discretion of FM Approvals if drawing and calculation reviews of the manufacturer's flow data are satisfactory.

#### 4.1.11 Seals and O-rings

##### 4.1.11.1 Requirements

- A. Parts shall have a tensile set of the material in the as-received condition of not more than 19 percent. Parts constructed with silicone rubber (rubber having poly-organosiloxane as its characteristic constituent) shall have a tensile strength of not less than 500 psi (34.5 bar) and at least 100 percent ultimate elongation. Parts constructed with material other than silicone rubber shall have a tensile strength of not less than 1500 psi (103.4 bar) and at least 200 percent ultimate elongation. Tensile strength, ultimate elongation, and tensile set shall be determined in accordance with ASTM D 412, *Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension*, Method A, with exceptions as stated in Section 4.1.11.2A.
- B. A compression set of the material in the as-received condition shall be not more than 15 percent, as determined in Section 4.1.11.2B.
- C. Seals formed using a rubber material or synthetic elastomer shall be subjected to an accelerated aging test, as described in Section 4.1.11.2C. Following the test the material shall have not less than 80 percent of the as-received tensile strength and 50 percent of the as-received ultimate elongation.

##### 4.1.11.2 Tests/Verification

For standard elastomers, the material manufacturer's certificates of compliance verifying the conformance to the performance requirements listed in Section 4.1.11.1 shall be considered acceptable. The test certificates shall demonstrate that the tests were conducted by an ISO 9000 certified facility, and that the test equipment was calibrated by an ISO 17025, *General Requirements for the Competence of Testing and Calibration Laboratories*, certified agency. Where such certifications are not available, tests of the elastomer shall be conducted, as follows:

- A. Tensile strength, ultimate elongation, and tensile set shall be determined in accordance with ASTM D 412, *Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension*, Method A, with the exception that, for tensile set determinations, the elongation shall be maintained for 3 minutes, and the tensile set shall be measured 3 minutes after release of the specimen. The elongation of a specimen for a tensile set determination shall be such that the 1 in. (25 mm) spacing of the benchmarks increases to 3 in. (76 mm). If a specimen breaks outside the benchmarks, or if either the measured tensile strength or ultimate elongation of the specimen is less than the required value, an additional specimen shall be tested, and those

results shall be considered final. Results of tests for specimens that break in the curved portion just outside the benchmarks shall be permitted to be accepted if the measured strength and elongation values are within the minimum requirements.

- B. Testing shall be conducted in accordance with ASTM D 395, *Standard Test Methods for Rubber Property - Compression Set*, Method B. Type I specimens of the material shall be prepared and then exposed for 22 hours at 70 °F ± 2 °F (21 °C ± 1 °C).
- C. Specimens shall be prepared in the same manner as for tensile strength and ultimate elongation tests, except that benchmarks spaced 1 in. (25 mm) apart shall be stamped on the specimens after the test exposure. Specimens shall be tested at 212 °F (100 °C) for 70 hours in accordance with ASTM D 573, *Standard Test Method for Rubber - Deterioration in an Air Oven*.

#### 4.1.12 Pipe Coupling Gaskets

##### 4.1.12.1 Requirements

One sample gasket of each material under examination shall be subjected to high temperature exposure and a different sample to low temperature exposure. Samples subjected to the temperature exposure tests shall be installed in their intended assemblies during exposure. Following the exposure periods, no leakage shall occur when the assembly is exposed to pneumatic pressure equal to 50 psi (3.5 bar). Additionally, the gasket, after removal from the assembly, shall not crack when squeezed from any two opposite points.

##### 4.1.12.2 Tests/Verifications

Certificates of compliance verifying the performance of the sealing compounds for use at the prescribed temperature and pressure ranges, as well as with the fluids used in the hybrid system, shall be considered acceptable. The test certificates shall demonstrate that any applicable tests were conducted by an ISO 9000 certified facility, and that the test equipment was calibrated by an ISO 17025, *General Requirements for the Competence of Testing and Calibration Laboratories*, certified agency. Where such certifications are not available, tests shall be conducted, as follows:

The high temperature exposure shall consist of 300 °F (149 °C) oven-air exposure for 45 days. After exposure, the assembly will be allowed to cool to ambient air temperature. It shall then be pneumatically pressurized to 50 psi (3.5 bar) and submerged in water. No leakage shall occur. The gasket, after removal from the assembly, shall be squeezed from two opposite points, and observed for evidence of cracking.

The low temperature exposure shall consist of -40 °F (-40 °C) air exposure for 4 days. After exposure, the assembly shall be submerged in -40 °F (-40 °C) antifreeze and pneumatically pressurized to 50 psi (3.5 bar).

No leakage shall occur. The assembly will then be allowed to warm to ambient temperature and disassembled. The gasket, after removal from the assembly, shall be squeezed from two opposite points, and observed for evidence of cracking.

## 4.2 Hybrid Fire Extinguishing System Nozzles

The nozzles used in the hybrid fire extinguishing system shall be representative of production nozzles and shall pass all of the applicable requirements specified in this section. In addition, nozzle performance will be visually examined during the fire tests. All nozzle test pressures are based on the maximum nozzle operating pressure, which shall be a minimum of 175 psi (12.1 bar). Samples of the nozzles used for fire testing shall be procured immediately following the fire tests and shall be retained by FM Approvals. These nozzles shall be compared to those supplied for component testing.

### 4.2.1 Assembly Load/Frame Strength (Automatic/Closed nozzles only)

#### 4.2.1.1 Requirements

The frame of a nozzle 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 nozzle.

#### 4.2.1.2 Test/Verification

- A. Fifteen previously untested nozzles shall be individually tested to determine the assembly load. With the threaded portion of the nozzle 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. 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 nozzles shall then be subjected momentarily (for 1 to 5 seconds) to twice the sum of the force recorded in Section 4.2.1.2 A plus the force applied to the nozzle as a result of the maximum nozzle operating pressure, but no less than 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 nozzle orifice to the center of the compression bearing surface of the nozzle.
- C. Where physical limitations of the nozzle prevent the application of the load as described above, alternate methods of determining the assembly load shall be developed.

### 4.2.2 Strength of Heat Responsive Element (Automatic/Closed nozzles only)

#### 4.2.2.1 Requirements

- A. A heat responsive element of the fusible type shall be (1) capable of sustaining a load 15 times its maximum design load for a period of 100 hours or (2) demonstrate the ability to sustain the maximum element design load when tested in accordance with Section 4.2.2.2.
- B. For a heat responsive element of the glass bulb type, the lower tolerance limit of bulb strength shall be greater than two times the upper tolerance limit of nozzle 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 L.

## 4.2.2.2 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 4.2.2.2.A.1 shall meet the following requirements. Sample fusible type heat-responsive elements shall be subjected to loads in excess of the design load which will produce failure both within and after 1000 hours. The test samples shall be maintained at an environmental temperature of  $70\text{ }^{\circ}\text{F} \pm 5\text{ }^{\circ}\text{F}$  ( $21\text{ }^{\circ}\text{C} \pm 2.6\text{ }^{\circ}\text{C}$ ). At least 15 samples shall be loaded to various degrees in order to establish a basis of time as a function of load. Failures which are not related to the solder bond shall be disregarded. A least square, full logarithmic regression curve shall be plotted from which both the load to failure at 1 hour ( $L_o$ ) and the load to failure at 1000 hours ( $L_m$ ) shall be determined. The actual maximum design load ( $L_d$ ) on the fusible element, as determined using the upper tolerance limit of assembly load from Section 4.2.2.1.A, shall be less than, or equal to, the value determined in the expression:

$$L_d = 1.02[(L_m)^2/L_o]$$

Where:

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

3. Where physical limitations of the fusible element prevent the application of the loads described in Section 4.3.2.A, alternate methods of determining the adequacy of the design shall be developed to ensure that such elements should not fail during the anticipated life span.

## B. Heat Responsive Element of the Bulb Type

The results of the assembly load test, Section 4.2.2.1.A, shall form the basis for calculating the upper tolerance limit of the nozzle 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 nozzle. The inserts shall have hardness within the range Rockwell C 38-50 (see Figure N-5). 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 used for the tolerance limit calculations as described in Appendix L, Tolerance Limit Calculations.

## 4.2.3 Leakage (Automatic/Closed nozzles only)

## 4.2.3.1 Requirements

Nozzles shall not weep or leak at, or below a test pressure equivalent to 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar) hydrostatic pressure and shall not leak at a pneumatic test pressure equivalent to 20 percent of the maximum nozzle operating pressure, but not less than 30 psi (2.1 bar).



#### 4.2.3.2 Test/Verification

- A. Hydrostatic Leakage - Ten previously untested nozzles shall be individually subjected to a slowly rising hydrostatic pressure. The pressure shall be increased from 0 to 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (0 to 34.5 bar), at a rate not to exceed 300 psi (20.7 bar) per minute, and maintained at 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar), for one minute.
- B. Pneumatic Leakage - Four previously untested nozzles shall be individually conditioned at  $-20\text{ }^{\circ}\text{F} \pm 10\text{ }^{\circ}\text{F}$  ( $-29\text{ }^{\circ}\text{C} \pm 6\text{ }^{\circ}\text{C}$ ) for 24 hours. Each sample shall be pneumatically pressurized to 20 percent of the maximum nozzle operating pressure, but not less than 30 psi (2.1 bar), immersed in glycol liquid conditioned to  $-20\text{ }^{\circ}\text{F}$  ( $-29\text{ }^{\circ}\text{C}$ ), and observed for five minutes for evidence of leakage.

#### 4.2.4 Hydrostatic Strength (Automatic/Closed nozzles only)

##### 4.2.4.1 Requirements

Nozzles shall be capable of withstanding, without rupture, an internal hydrostatic pressure of 150 percent of the maximum nozzle operating pressure, but not less than 700 psi (48.3 bar), for a period of one minute.

##### 4.2.4.2 Tests/Verification

If all samples comply with the requirements of Section 4.2.3.2.A, each sample shall be further subjected to a gradually increasing hydrostatic pressure to 150 percent of the maximum nozzle operating pressure, but not less than 700 psi (48.3 bar), at a rate not to exceed 300 psi (20.7 bar) per minute. The test pressure shall be maintained for one minute. If leakage at the orifice prevents testing at these pressures, the maximum attainable test pressure shall be maintained for one minute. Leakage at the orifice above a hydrostatic pressure of 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.4 bar), shall be deemed acceptable.

#### 4.2.5 30-Day Leakage (Automatic/Closed nozzles only)

##### 4.2.5.1 Requirements

Nozzles shall not weep or leak when subjected to an internal hydrostatic pressure of 110 percent of the maximum nozzle operating pressure, but not less than 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, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar), when tested in accordance with Section 4.2.3.2 (Hydrostatic Leakage). The samples shall also show no evidence of distortion or physical damage.

##### 4.2.5.2 Tests/Verification

Five previously untested nozzle samples shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 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 110 percent of the maximum nozzle operating pressure, but not less than 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.

#### 4.2.6 Water Hammer (Automatic/Closed nozzles only)

##### 4.2.6.1 Requirements

Nozzles shall be capable of withstanding 100,000 applications of a pressure surge from approximately 50 to 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (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, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar), when tested in accordance with Section 4.2.3.2A (Hydrostatic Leakage). The samples shall also show no evidence of distortion or physical damage.

##### 4.2.6.2 Tests/Verification

Five previously untested samples shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar). They shall then be installed on a water-filled manifold and subjected to changes in pressure from approximately 50 to 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar). The cycle period shall be between 1 and 10 seconds. Observations shall be made for evidence of leakage at least twice a day during the test period.

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

#### 4.2.7 Operating Temperature (Liquid Bath) (Automatic/Closed nozzles only)

##### 4.2.7.1 Requirements

All nozzles and cover plates having nominal temperature ratings less than 400 °F (204 °C) shall have an actual operating temperature within  $\pm 3.5$  percent of the marked nominal temperature rating, when immersed in a constant rate-of-temperature-rise liquid bath. Nozzles and cover plates with nominal temperature ratings of 400 °F (204 °C) or greater shall meet the requirements stated above, or shall have an actual operating temperature within 107 percent of the marked nominal temperature rating (i.e. -0 percent +7 percent).

##### 4.2.7.2 Tests/Verification

Ten previously untested nozzles shall be immersed in a vessel containing a liquid as specified in Table 4.2.7.2.

Table 4.2.7.2 - Liquid Bath Conditions

Nominal Temperature Rating of Nozzle		Bath Liquid	Maximum Rate of Temperature Rise	
°F	(°C)		°F/min	(°C/min)
0 – 175	(0 - 79)	Water	0.8	(0.4)
176 – 360	(80 - 182)	Glycerin	0.5	(0.3)
361 +	(183 +)	Vegetable Oil	0.5	(0.3)

The nozzles 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 nozzle, and whenever possible, shall not exceed 1 in. (25.4 mm) above the top of the temperature sensitive element. The vessel shall be provided with a source for heating the liquid, a means to agitate the liquid, and a device to measure the temperature of the liquid. The liquid shall be agitated at a constant rate of 200 rpm  $\pm$  10 rpm via a paddle measuring 4 in. (100 mm) long by 0.8 in. (20 mm) high. The device used to measure the temperature of the liquid shall be calibrated in accordance with the ASTM Standard E-1, *Standard Specification for ASTM Thermometers*, or the equivalent. It shall be immersed such that readings are taken at the same depth as the sprinkler temperature sensitive element.

The temperature of the bath shall be raised until the liquid is 20 °F (11.1 °C) below the nominal temperature rating of the nozzle. The temperature rise shall then be controlled at a rate not exceeding that specified in Table 4.2.7.2 until operation of all nozzles occurs. If one or more nozzles fail to operate at, or below, the maximum temperature as stated in Section 4.2.7.1, the rate of rise shall continue to be controlled until all the nozzles have operated, or until the bath reaches a temperature ten percent above the nominal temperature rating of the nozzles, at which point the test shall be terminated. The temperature of the liquid bath at the time of operation shall be recorded for each nozzle.

Partial fracture of a glass bulb or partial rupture of a fusible element which does not result in nozzle operation, i.e., strutting, shall necessitate an additional sensitivity test (Air Bath Test, Section 4.2.8) in order to verify proper operation of the nozzle in air.

#### **4.2.8 Air Bath (Automatic/Closed nozzles only)**

##### **4.2.8.1 Requirements**

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

##### **4.2.8.2 Tests/Verification**

Fifty previously untested nozzles 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 °F (11 °C) below the nominal temperature rating of the nozzles over a 20 minute period. Once this temperature is reached, the oven shall be maintained at constant temperature for a period of 60 minutes. The temperature shall then be raised at a constant rate of 1 °F ± 0.5 °F (0.5 °C ± 0.3 °C) per minute until the temperature reaches 40 °F (22 °C) above the nominal temperature rating of the nozzles.

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

#### **4.2.9 Hang-Up of Operating Parts (Automatic/Closed nozzles only)**

##### **4.2.9.1 Requirements**

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

Samples shall operate fully and completely, and shall exhibit no binding of internal components. Upon operation, the measured discharge coefficient (K-factor) of all samples shall comply with Section 4.2.14, 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 60 seconds are not considered hang-ups. Pressures other than those described in 4.2.9.2 may be tested at the sole discretion of FM Approvals.

## 4.2.9.2 Tests/Verification

Samples shall be individually installed in their intended installation position, on a pipe manifold as described in Figure N-1. Each sample shall be subjected to an inlet water pressure in accordance with Table 4.2.9.2, operated using a suitable open flame heat source, and observed for complete and proper functioning. A total of 100 nozzles shall be tested. Samples shall be tested at various percentages of the minimum pressure at nozzle operation, at the increments shown in Table 4.2.9.2.

Table 4.2.9.2 - Test Pressures

<i>Number of Samples</i>	<i>Percentage of System Pressure</i>
5	5
5	10
5	20
5	30
10	40
10	50
10	60
10	70
10	80
10	90
10	100
5	110
5	120

The samples shall be tested with the pipe manifold configured for single-fed flow. At the discretion of FM Approvals, five samples shall be tested at each pressure with the pipe manifold configured for double-fed flow, and the remaining samples shall be tested with single-fed flow (see Figure N-1).

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

**4.2.10 Strength of Deflector (Flow Endurance)**

## 4.2.10.1 Requirements

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

## 4.2.10.2 Tests/Verification

Three previously untested sample nozzles shall be individually installed in the test apparatus detailed in Figure N-1 in their intended orientation. Water and/or gas shall be introduced to the inlet of each nozzle at 130 percent of the maximum nozzle operating pressure, but not less than 225 psi (15.5 bar). Each nozzle shall then be operated using a suitable heat source and flow of agent shall be maintained at 130 percent of the maximum nozzle operating pressure, but not less than 225 psi (15.5 bar), for a period of 15 minutes.

**4.2.11 Vacuum (Automatic/Closed nozzles only)**

4.2.11.1 Requirements

Nozzles shall be designed such that when the inlet of an assembled nozzle is subjected to a vacuum, as might be experienced during draining of a hybrid system, the nozzle shall not be damaged or leak when tested as described in 4.2.11.2. Following this test, each sample shall not weep or leak at 3 percent of the maximum nozzle operating pressure, but not less than 5 psi (0.3 bar), when tested in accordance with Section 4.2.3.2A (Hydrostatic Leakage). Additionally, each sample shall not weep or leak at a pressure at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar).

4.2.11.2 Test/Verification

Three previously untested nozzles shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar). The nozzles shall then be subjected to a vacuum of 26 in. Hg (660 mm Hg) for a period of one minute.

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

**4.2.12 High Ambient Temperature Exposure (90 Day Test) (Automatic/Closed nozzles only)**

4.2.12.1 Requirements

A. Nozzles shall be capable of withstanding an exposure to a high ambient temperature in accordance with Table 4.2.12.1A and Section 4.2.12.2 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, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar), when tested in accordance with Section 4.2.3.2.A (Hydrostatic Leakage). Subsequently, half of the nozzles shall be tested for conformance to the requirements for sensitivity as described in Sections 4.2.27, 4.2.28, and 4.2.29, as applicable. The remaining samples shall be tested for operating temperature as described in Section 4.2.7 [Operating Temperature (Liquid Bath)]. Exceptions are noted as described below.

Table 4.2.12.1A - High Ambient Temperature Exposure Test Conditions

<i>Nozzle Nominal Temperature Rating</i>		<i>Nominal<sup>1</sup> Test Temperatures</i>	
<i>°F</i>	<i>(°C)</i>	<i>°F</i>	<i>(°C)</i>
135 - 170	(57 - 77)	100	(38)
175 - 225	(79 - 107)	150	(66)
250 - 300	(121 - 149)	225	(107)
325 - 375	(163 - 191)	300	(149)
400 - 475	(204 - 246)	365	(185)
500 - 575	(260 - 302)	465	(241)
650	(343)	Evaluated on a case-by-case basis	

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

B. High ambient temperature can affect platings and coatings such as decorative (painting) or corrosion resistant (wax, asphalt, etc.) which may ultimately impact the performance of nozzles. Following exposure of coated or plated nozzles, there shall be no evidence of shrinking, hardening, cracking, or flaking of the coating or plating. Following this test, each sample shall not weep or leak at or below, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar), when tested in accordance with Section 4.2.3.2.A (Hydrostatic Leakage). Subsequently, each sample shall operate satisfactorily when tested in accordance with Section 4.2.29 (Sensitivity-Air Oven).

- C. For nozzle coatings which contain volatiles, such as wax coatings, the softening point shall be at least 20 °F (11 °C) under the nominal temperature rating of the nozzles and not less than 20 °F (11 °C) above the maximum allowed installation temperature. Nozzles with coatings that do not meet this requirement shall be evaluated on a case-by-case basis. The permissible softening point temperatures are summarized in Table 4.2.12.1C

Table 4.2.12.1C - Permitted Softening Points of Volatile Nozzle Coatings

<b>Nozzle Nominal Temperature Rating</b> °F (°C)		<b>Minimum Softening Point Temperature</b> °F (°C)		<b>Maximum Softening Point Temperature</b> °F (°C)	
0 - 139	(0 - 59)	Evaluated on a case-by-case basis			
140 - 170	(60 - 77)	120	(49)	120 - 150	(49 - 65)
171 - 189	(78 - 87)	Not Permitted			
190 - 225	(88 - 107)	170	(77)	170 - 205	(77 - 96)
226 - 264	(108 - 129)	Not Permitted			
265 - 300	(130 - 149)	245	(118)	245 - 280	(118 - 138)
301 - 339	(150 - 170)	Not Permitted			
340 - 375	(171 - 191)	320	(160)	320 - 355	(160 - 179)
376+	(192+)	Evaluated on a case-by-case basis			

- D. Concealed-type nozzles incorporating a solder alloy or other temperature sensitive material to attach the cover plate shall not experience separation of the cover plate, while suspended, during the exposure. Following the test, the nozzle covers shall be tested for operating temperature as stated in Section 4.2.7 [Operating Temperature (Liquid Bath)].

#### 4.2.12.2 Test/Verification

- A. Ten previously untested nozzles shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar). The samples shall then be placed in an automatically controlled, circulating constant-temperature oven and subjected to a high ambient temperature selected in accordance with Table 4.2.12.1A for a period of 90 days.
- B. For coatings which contain volatiles, such as wax coatings, a sample of the coating shall be placed in an open container and subjected to the maximum allowed installation temperature of the nozzle as stated in Table 4.2.12.1A for a period of 90 days. Prior to and following the 90-day test, the softening point of these coating samples shall be determined using ASTM E-28, *Test Method for Softening Point by Ring and Ball Apparatus*, or its equivalent, as determined by FM Approvals.

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

**4.2.13 Thermal Shock (Glass bulb nozzles only)**

## 4.2.13.1 Requirements

Nozzles 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 nozzle during the cycling portion of this test shall be deemed unacceptable. Following the sequence detailed in Section 4.2.13.2, each sample shall meet the operating temperature requirements specified in Section 4.2.7 [Operating Temperature (Liquid Bath)].

## 4.2.13.2 Test/Verification

Five previously untested samples shall be conditioned for five 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 4.2.7.2.

The nozzles shall then be removed and immediately submerged for a period of 15 to 30 seconds into a second liquid bath maintained at 50 °F ± 5 °F (10 °C ± 2.8 °C). This sequence of heating and plunging into the cold liquid bath shall be repeated three times on each sample. Following this test, the samples shall be subjected to the post-tests detailed above.

**4.2.14 Discharge Coefficient, K-Factor**

## 4.2.14.1 Requirements

The mean value of the discharge coefficient (K-factor) for each fire test and production nozzle shall be within ± 5 percent of the values obtained from four production samples when tested as detailed in Section 4.2.14.2. This mean value shall be within ± 5 percent of the manufacturer's published discharge coefficient. Additionally, not more than one value shall fall outside of the stated range.

## 4.2.14.2 Test/Verification

Four fire test and production samples shall be tested using the test apparatus for determining Kfactor shown in Figure N-2 at increasing and decreasing pressures from 15 psi (1.03 bar) below the minimum nozzle operating pressure to the maximum nozzle operating pressure, in 10 percent pressure 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:

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

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

Since a precise discharge coefficient is difficult to determine for a hybrid nozzle, the discharge coefficient of the nozzle may be measured under one or more of the following conditions, as applicable:

- Maximum gas pressure, water pressure varied as described above.
- Minimum gas pressure, water pressure varied as described above.
- Gas pressure varied as described above, maximum water pressure.
- Gas pressure varied as described above, minimum water pressure.
- Gas measurements and/or water measurements performed independently (gas pressure varied, then test repeated with the water pressure varied as described above)

#### 4.2.15 Moist Air (Any nozzle with moving parts)

##### 4.2.15.1 Requirements

Nozzles 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, 100 percent of the maximum nozzle operating pressure, but not less than 175 psi (12.1 bar), when tested in accordance with Section 4.2.3.2.A (Hydrostatic Leakage). Subsequently, the samples shall exhibit positive operation and release of all operating parts at the minimum nozzle operating pressure as stated in the manufacturer's installation instructions when tested in accordance with Section 4.2.24.2 (Minimum Operating Pressure).

##### 4.2.15.2 Test/Verification

Five previously untested nozzles shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar). They shall then be exposed to an atmosphere having a relative humidity of 98 percent  $\pm$  2 percent and a temperature of 203 °F  $\pm$  2 °F (95 °F  $\pm$  1.1 °C) for a period of 90 days. If the exposure temperature nears or exceeds the nominal temperature rating of the nozzle, the heat responsive element shall be specially fabricated for this test. The nozzles shall be installed on a pipe manifold which contains water in approximately 50 percent of its volume. The entire manifold, along with the nozzles, 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.

#### 4.2.16 Corrosion - Salt Spray

##### 4.2.16.1 Requirements

In order to evaluate the resistance to corrosion of the assembly, such as might be experienced by dissimilar materials in contact over long periods of time; nozzles shall withstand a timed exposure to a salt spray atmosphere. When tested as detailed in Section 4.2.16.2, visual evidence of severe deterioration or impending failure of any component shall constitute failure.

- A. For automatic/closed nozzles: Following exposure, all of the samples shall be subjected to a hydrostatic pressure of 100 percent of the maximum nozzle operating pressure, but not less than 175 psi (12.1 bar) for one minute without leakage. Subsequently, the nozzles shall be tested for conformance to the requirements for sensitivity as described in Sections 4.2.27 (Sensitivity - RTI), 4.2.28 (Sensitivity - R, F & C Types) and 4.2.29 (Sensitivity - Air Oven) as applicable. At the discretion of FM Approvals, half of the samples may be tested for operating temperature as described in Section 4.2.7 [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 tested for compliance with the requirements in Section 4.2.10 [Strength of Deflector (Flow Endurance)].
- B. For open nozzles: One sample shall be tested in accordance with Section 4.2.14 (Discharge Coefficient). The discharge coefficient shall be within  $\pm$  5 percent of the mean value when new. Should the deflector or other non-operating components, or their attachment method, exhibit questionable corrosive attack, at least one sample shall be tested for compliance with the requirements in Section 4.2.10 [Strength of Deflector (Flow Endurance)].



#### 4.2.16.2 Test/Verification

Eight previously untested samples shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar).

Each nozzle 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 to the interior of the nozzle. Each nozzle shall be supported in its intended installation position.

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

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

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

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

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

### 4.2.17 Corrosion - Stress Cracking

#### 4.2.17.1 Requirements

Nozzles 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.

- A. For automatic/closed nozzles: After exposure, the nozzles shall not weep or leak at, or below, 100 percent of the maximum nozzle operating pressure, but not less than 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 4.2.24. The remaining samples shall be subjected to a water flow at a pressure of 100 percent of the maximum nozzle operating pressure, but not less than 175 psi (12.1 bar), for a period of one minute. Following the completion of this test, the deflector shall not show evidence of fracture, distortion, or impending separation from the frame.
- B. For open nozzles: One sample shall be tested in accordance with Section 4.2.14 (Discharge Coefficient). The discharge coefficient shall be within  $\pm 5$  percent of the mean value when new. The remaining samples shall be subjected to a water flow at a pressure of 100 percent of the maximum nozzle operating pressure, but not less than 175 psi (12.1 bar), for a period of one minute. Following the completion of this test, the deflector shall not show evidence of fracture, distortion, or impending separation from the frame.

## 4.2.17.2 Test/Verification

## A. Copper Based Parts (Ammonia Test)

In order to determine the susceptibility of copper based nozzle parts to stress corrosion cracking, four previously untested nozzles shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar). They 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 to the interior of the nozzle. 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. 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 nozzles. 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  $0.73 \pm 0.34 \text{ ft}^3$  ( $0.02 \pm 0.01 \text{ m}^3$ ).

Aqueous ammonia having a density of  $58.7 \text{ lb/ft}^3 \pm 0.6 \text{ lb/ft}^3$  ( $0.94 \text{ g/cm}^3 \pm 0.01 \text{ g/cm}^3$ ) 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  $0.075 \text{ gal/ft}^3$  ( $10 \text{ L/m}^3$ ) 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 chamber shall be conditioned to a temperature of  $93 \text{ }^\circ\text{F} \pm 4 \text{ }^\circ\text{F}$  ( $34 \text{ }^\circ\text{C} \pm 2 \text{ }^\circ\text{C}$ ) 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, nozzles 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 based nozzle parts to stress corrosion cracking, four previously untested nozzles shall be degreased and then exposed to a boiling magnesium chloride solution for a period of 500 hours as described below, and in accordance with ASTM G36, *Standard Practice for Evaluating Stress-Corrosion-Cracking Resistance of Metals and Alloys in a Boiling Magnesium Chloride Solution*. Special fixtures or elevated temperature operating elements may be employed to simulate assembly loading on parts, where appropriate.

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

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

C. Parts Manufactured from Other Materials

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

#### 4.2.18 Corrosion - Carbon Dioxide-Sulfur Dioxide

##### 4.2.18.1 Requirements

Nozzles 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.

- A. For automatic/closed nozzles: Following the visual examination, the samples shall not weep or leak at, or below, 100 percent of the maximum nozzle operating pressure, but not less than 175 psi (12.1 bar), when hydrostatically tested for one minute. Subsequently, half of the samples shall be tested for compliance with Section 4.2.7 [Operating Temperature (Liquid Bath)], and half of the samples shall be tested for conformance to the requirements for sensitivity as described in Sections 4.2.27 (Sensitivity - RTI), 4.2.28 (Sensitivity - R, F & C Types) and 4.2.29 (Sensitivity - Air Oven) as applicable. Should the deflector or other non-operating components, or their attachment exhibit questionable corrosive attack, at least one sample shall be tested in accordance with the requirements in Section 4.2.10 [Strength of Deflector (Flow Endurance)].
- B. For open nozzles: One sample shall be tested in accordance with Section 4.2.14 (Discharge Coefficient). The discharge coefficient shall be within  $\pm 5$  percent of the mean value when new. Should the deflector or other non-operating components, or their attachment exhibit questionable corrosive attack, at least one sample shall be tested in accordance with the requirements in Section 4.2.10 [Strength of Deflector (Flow Endurance)].

##### 4.2.18.2 Test/Verification

Four previously untested nozzles shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 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.

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

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

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

There shall be provisions in the test chamber to prevent droplets of condensation from falling from the top of the enclosure directly onto the nozzles. 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 0.5 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.

#### **4.2.19 Corrosion - Hydrogen Sulfide**

##### **4.2.19.1 Requirements**

Nozzles 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.

- A. For automatic/closed nozzles: Following the visual examination, the samples shall not weep or leak at, or below, 100 percent of the maximum nozzle operating pressure, but not less than 175 psi (12.1 bar), when hydrostatically tested for one minute. Subsequently, half of the samples shall be tested for compliance with Section 4.2.7 [Operating Temperature (Liquid Bath)], and half of the samples shall be tested for conformance to the requirements for sensitivity as described in Sections 4.2.27 (Sensitivity - RTI), 4.2.28 (Sensitivity - R, F & C Types) and 4.2.29 (Sensitivity - Air Oven) as applicable. Should the deflector or other non-operating components, or their attachment exhibit questionable corrosive attack, at least one sample shall be tested in accordance with the requirements in Section 4.2.10 [Strength of Deflector (Flow Endurance)].
- B. For open nozzles: One sample shall be tested in accordance with Section 4.2.14 (Discharge Coefficient). The discharge coefficient shall be within  $\pm 5$  percent of the mean value when new. Should the deflector or other non-operating components, or their attachment exhibit questionable corrosive attack, at least one sample shall be tested in accordance with the requirements in Section 4.2.10 [Strength of Deflector (Flow Endurance)].

##### **4.2.19.2 Test/Verification**

Four previously untested nozzles shall be hydrostatically tested to confirm that they do not weep or leak at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar). They shall then be exposed to a moist hydrogen sulfide-air mixture for a period of 10 days.

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

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

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

There shall be provisions in the test chamber to prevent droplets of condensation from falling from the top of the enclosure directly onto the nozzles. 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 0.5 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

#### 4.2.20 Vibration

##### 4.2.20.1 Requirements

Nozzles shall be capable of withstanding the effects of vibration without deterioration of their performance characteristics.

- A. For automatic/closed nozzles: Following the vibration test detailed in Section 4.20.2, the nozzles shall not weep or leak at, or below, 100 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar), when tested in accordance with Section 4.2.3.2.A (Hydrostatic Leakage). Subsequently, the nozzles shall be tested for conformance to the requirements for sensitivity as described in Sections 4.2.27 (Sensitivity - RTI), 4.2.28 (Sensitivity - R, F & C Types) and 4.2.29 (Sensitivity - Air Oven) as applicable.
- B. For open nozzles: One sample shall be tested in accordance with Section 4.2.14 (Discharge Coefficient). The discharge coefficient shall be within  $\pm 5$  percent of the mean value when new. Should the deflector or other non-operating components, or their attachment method, show evidence of physical damage, at least one sample shall be tested for compliance with the requirements in Section 4.2.10 [Strength of Deflector (Flow Endurance)].

##### 4.2.20.2 Test/Verification

Four previously untested nozzles shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar). The samples shall then be subjected to the vibration conditions stated in Table 4.2.20.2.

Table 4.2.20.2 - *Vibration Conditions*

<i>Total Displacement in. (mm)</i>	<i>Frequency Hz</i>	<i>Time Hours</i>
0.02 (0.51)	28	5
0.04 (1.02)	28	5
0.15 (3.81)	28	5
0.04 (1.02)	8 to 37 variable	5
0.07 (1.78)	8 to 37 variable	5

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

The nozzles shall be attached to a rigid mounting plate and the plate bolted to the table of a vibration machine so that the nozzles are vibrated vertically. This test shall be conducted with the nozzles unpressurized. The nozzles may be pressurized for this test at the sole discretion of FM Approvals.

The nozzles shall be subjected to the above vibration conditions and continuously monitored for 15 minutes at each condition (75 minutes total). If one or more resonant point(s) is detected, the nozzles 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 nozzles shall be subjected to each vibration condition for a period of 5 hours (25 hours total).

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

#### 4.2.21 Rough Use and Abuse

##### 4.2.21.1 Requirements

Nozzles 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 nozzle shall reveal no permanent distortion, cracks, breaks, or other evidence of impending failure.

- A. For automatic/closed nozzles: Each nozzle shall not weep or leak at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar), when tested in accordance with Section 4.2.3.2.A (Hydrostatic Leakage). Subsequently, the samples shall be tested for conformance to the requirements for sensitivity as described in Sections 4.2.27 (Sensitivity - RTI), 4.2.28 (Sensitivity - R, F & C Types) and 4.2.29 (Sensitivity - Air Oven) as applicable. Complete operation of a nozzle during the tumble test described in Section 4.21.2.B is permitted. Additional testing shall be at the sole discretion of FM Approvals.
- B. For open nozzles: One sample shall be tested in accordance with Section 4.2.14 (Discharge Coefficient). The discharge coefficient shall be within  $\pm 5$  percent of the mean value when new. Should the deflector or other non-operating components, or their attachment method, show evidence of physical damage, at least one sample shall be tested for compliance with the requirements in Section 4.2.10 [Strength of Deflector (Flow Endurance)].

##### 4.2.21.2 Test/Verification

- A. Drop Test - Five previously untested nozzles shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar). Each nozzle shall then be tested by dropping a weight equal to that of the nozzle onto the deflector end of the nozzle along the axial centerline of the nozzle (see Figure N-3). The weight shall be dropped from a height of 3.2 ft (1.0 m) above the deflector. The weight shall be prevented from impacting the test sample more than once.
- B. Tumble Test - Five previously untested nozzles shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar). Each nozzle shall then be individually subjected to a tumbling test for three minutes. Nozzles provided with shipping caps, which are intended for removal only after completion of the nozzle 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 nozzle and five wood blocks. The blocks shall be 1.5 in. (40 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.

#### 4.2.22 High Temperature Exposure

##### 4.2.22.1 Requirements

Nozzles, 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 4.2.14) and/or Nozzle Discharge Characteristics (Section 4.2.30) tests on exposed samples to validate compliance with these requirements.

##### 4.2.22.2 Test/Verification

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

#### 4.2.23 Freezing (Automatic/Closed nozzles only)

##### 4.2.23.1 Requirements

Following exposure to freezing temperatures, nozzles shall either (a) operate, (b) leak subsequent to thawing when hydrostatically pressurized from 3 percent of the maximum nozzle operating pressure to the maximum nozzle operating pressure, or (c) sustain no damage. For (c), nozzles shall not weep or leak at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar), and one of the nozzles shall be subsequently tested for conformance to the requirements for sensitivity as described in Sections 4.2.27 (Sensitivity - RTI), 4.2.28 (Sensitivity - R, F & C Types) and 4.2.29 (Sensitivity - Air Oven) as applicable. The remaining sample shall be tested for compliance with Section 4.2.7 (Operating Temperature - Liquid Bath).

##### 4.2.23.2 Test/Verification

Two previously untested nozzles shall be hydrostatically tested to confirm that there are no weep or leak points at, or below, 120 percent of the maximum nozzle operating pressure, but not less than 500 psi (34.5 bar). Each nozzle shall be attached to one end of a 10 in. (254 mm) minimum length of 1 in. nominal diameter Schedule 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  $-20\text{ }^{\circ}\text{F} \pm 10\text{ }^{\circ}\text{F}$  ( $-30\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ ) for a period of 24 hours, or until operation occurs.

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

#### 4.2.24 Minimum Operating Pressure (Any nozzle with moving parts)

##### 4.2.24.1 Requirements

Automatic nozzles shall be designed to maintain closure of their water seal for an extended period of time without leakage and to produce positive operation and release of all operating parts at 5 percent of the minimum nozzle operating pressure. Following operation of the heat responsive element, all parts which are intended to prohibit the discharge or leakage of the hybrid media shall clear the exit of the waterway within 5 seconds.

For nozzles where parts may not be released or expelled, proper actuation of all components to permit full discharge of the hybrid media is required.

#### 4.2.24.2 Test/Verification

Ten previously untested nozzles shall be subjected to an inlet water and/or gas pressure at 5 percent of the minimum nozzle operating pressure, and operated using a suitable heat source. If a sample does not operate fully as described above, the pressure shall be slowly increased to determine the actual minimum nozzle operating pressure.

### 4.2.25 Process Residue

#### 4.2.25.1 Requirements

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

#### 4.2.25.2 Test/Verification

Verification of Section 4.2.25.1 shall be made in conjunction with Section 4.2.16 (Corrosion-Salt-Spray). Additional process residue tests may be conducted at the sole discretion of FM Approvals. For open nozzles, one sample shall be tested in accordance with Section 4.2.14 (Discharge Coefficient). The discharge coefficient shall be within  $\pm 5$  percent of the mean value when new.

### 4.2.26 Conductivity (C-Factor) (Automatic/Closed nozzles only)

#### 4.2.26.1 Requirements

The conductivity (C-factor) shall not exceed  $1.81 \text{ (ft/s)}^{1/2}$  [ $1.0 \text{ (m/s)}^{1/2}$ ] for quick response type nozzles. Standard response nozzles shall have a C-factor not exceeding  $3.62 \text{ (ft/s)}^{1/2}$  [ $2.0 \text{ (m/s)}^{1/2}$ ]. Coated, flush, recessed and concealed nozzles are not subject to these requirements.

#### 4.2.26.2 Test/Verification

The C-factor shall be determined using the prolonged plunge test method. The prolonged plunge test is an iterative process to determine the C-factor and may require up to twenty nozzle samples. A new nozzle 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 nozzles of each nominal temperature rating in the "best case" orientation as determined in the Sensitivity Test (Section 4.2.27).

Prior to testing, each nozzle shall have 1 to 1.5 wraps of PTFE sealant tape applied to the nozzle threads. Nozzles shall be allowed to reach ambient temperature for a period of not less than 30 minutes.

A minimum of 0.0007 gal (0.025 L) of water, conditioned to ambient temperature, shall be introduced into the nozzle inlet and mounting fixture prior to testing. All nozzles are to be tested with the inlet end of each sample connected to a source of pressure at 5 psi + 0.5/-0.0 psi (0.3 bar + 0.04/- 0.0 bar). All tests shall be conducted with the geometric center of the heat responsive element located at least 1.5 in. (38 mm) from the interior horizontal surfaces of the test section, and with the centerline of the waterway perpendicular to the airflow in the test chamber.

A timer accurate to  $\pm 0.01$  seconds with suitable measuring devices to sense the time between when the nozzle is plunged into the tunnel and when it operates shall be used to obtain the response time.

The mount temperature shall be maintained at  $68 \text{ }^\circ\text{F} \pm 2 \text{ }^\circ\text{F}$  ( $20 \text{ }^\circ\text{C} \pm 1 \text{ }^\circ\text{C}$ ) for the duration of each test. The mount temperature shall be recorded at the beginning of the test and at the time of nozzle 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 4.2.26.2.



To determine the C-factor, each nozzle 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 nozzle location shall be maintained within  $\pm 0.2$  ft/s ( $\pm 0.07$  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 4.2.26.2. If the nozzle does not operate at the highest velocity in the range, a higher temperature shall be used and the same procedure repeated.

Table 4.2.26.2 - Range of Test Conditions for C-factor

Nozzle Nominal Operating Temperature <sup>1</sup>		Tunnel Gas Temperature °F (°C)	Tunnel Gas Velocity ft/s (m/s)	Maximum Variation of Gas Temperature During Test From Selected Temperatures	
°F	(°C)			°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)

Note: <sup>1</sup>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 nozzle is determined by computing the average of the C-factors calculated at the two velocities ( $u_H$  and  $u_L$ ) using the following equations:

$$C_H = (\Delta T_g / \Delta T_b - 1) u_H^{1/2} \quad C_L = (\Delta T_g / \Delta T_b - 1) u_L^{1/2}$$

Where:  $C_H$  - C-factor at velocity  $u_H$

$C_L$  - C-factor at velocity  $u_L$

$C$  - Average C-factor of the nozzle

$\Delta T_g$  - Actual gas (air) temperature minus the mount temperature

$\Delta T_b$  - Mean liquid bath operating temperature minus the mount temperature

$u_H$  - Actual gas velocity in the test section at which the nozzles operated

$u_L$  - Actual gas velocity in the test section at which the nozzles failed to operate within 15 minutes

The nozzle 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.

#### 4.2.27 Sensitivity - Response Time Index (RTI) (Automatic/Closed nozzles only)

##### 4.2.27.1 Requirements

The terms “Best Case Orientation” and “Worst Case Orientation” as defined in Section 1.9 (Definitions) apply to this section:

- A. All new standard response nozzles, with the exception of coated, flush, recessed, and concealed types, shall meet the following requirements:

The Response Time Index (RTI) shall fall within the limits detailed in Figure 4.2.27.1 when the nozzle is tested in the best case orientation as described in Section 4.2.27.2.

The RTI shall be less than or equal to  $1090 \text{ (ft}\cdot\text{s)}^{1/2}$  [ $600 \text{ (m}\cdot\text{s)}^{1/2}$ ], or 250 percent of the measured RTI in the best case orientation, whichever is less, when the nozzle is tested in the worst case orientation as described in Section 4.2.27.2.

- B. All new quick response nozzles, with the exception of coated, flush, recessed, and concealed types, shall have an RTI not exceeding  $90 \text{ (ft}\cdot\text{s)}^{1/2}$  [ $50 \text{ (m}\cdot\text{s)}^{1/2}$ ] when tested in the best case orientation.
- C. Recessed, flush and concealed nozzles shall comply with the requirements of the Sensitivity Test for recessed, flush and concealed nozzles (Section 4.2.28).
- D. In the case of nozzles for which testing in accordance with Section 4.2.27.2 is not practical (such as wax coated), the sensitivity requirement shall be that the time for operation in a controlled rate-of-temperature-rise air oven not exceed the limits shown in Table 4.2.28.1.2 or Table 4.2.28.1.3, as appropriate, when tested in accordance with the Air Oven Sensitivity Test (Section 4.2.29).
- E. As an exception to the RTI limits in this section, one of the ten RTI values may deviate from the specified limits by not more than 10 percent.

##### 4.2.27.2 Test/Verification

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

- A. Ten samples shall be tested in the best case orientation, as described in Section 4.2.27.1. If, at the judgment of FM Approvals, compliance with the requirements for worst-case RTI (See Section 4.2.27.1A.1) is in question, a sufficient number of tests may be conducted in various nozzle orientations relative to air flow, such that the worse-case orientation is determined. Subsequently, five samples shall be tested in the worst case orientation, and five samples shall be tested in the best case orientation.
- B. The plunge tests are conducted using the nozzle mount detailed in Figure N-4. Each nozzle shall have one to one-and-a-half wrap(s) of sealant tape applied to the nozzle threads and shall be threaded into the mount at connection "A" (See Figure N-4). An air supply is then attached at connection "B" (See Figure N-4) and shall be pressurized to 5 psi + 0.5/-0 psi (0.3 bar + 0.04/-0 bar).

- C. A tunnel with gas velocity and temperature conditions at the test section established in accordance with Table 4.2.27.2 shall be used 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 nozzle and nozzle 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  $\pm 0.01$  seconds with suitable controlling devices, e.g., mercury switch for plunge (start), pressure switch for operation (stop), shall be used to accurately measure the time to operate.

Figure 4.2.27.1 RTI and C-Factor Limits for Best Case Orientation

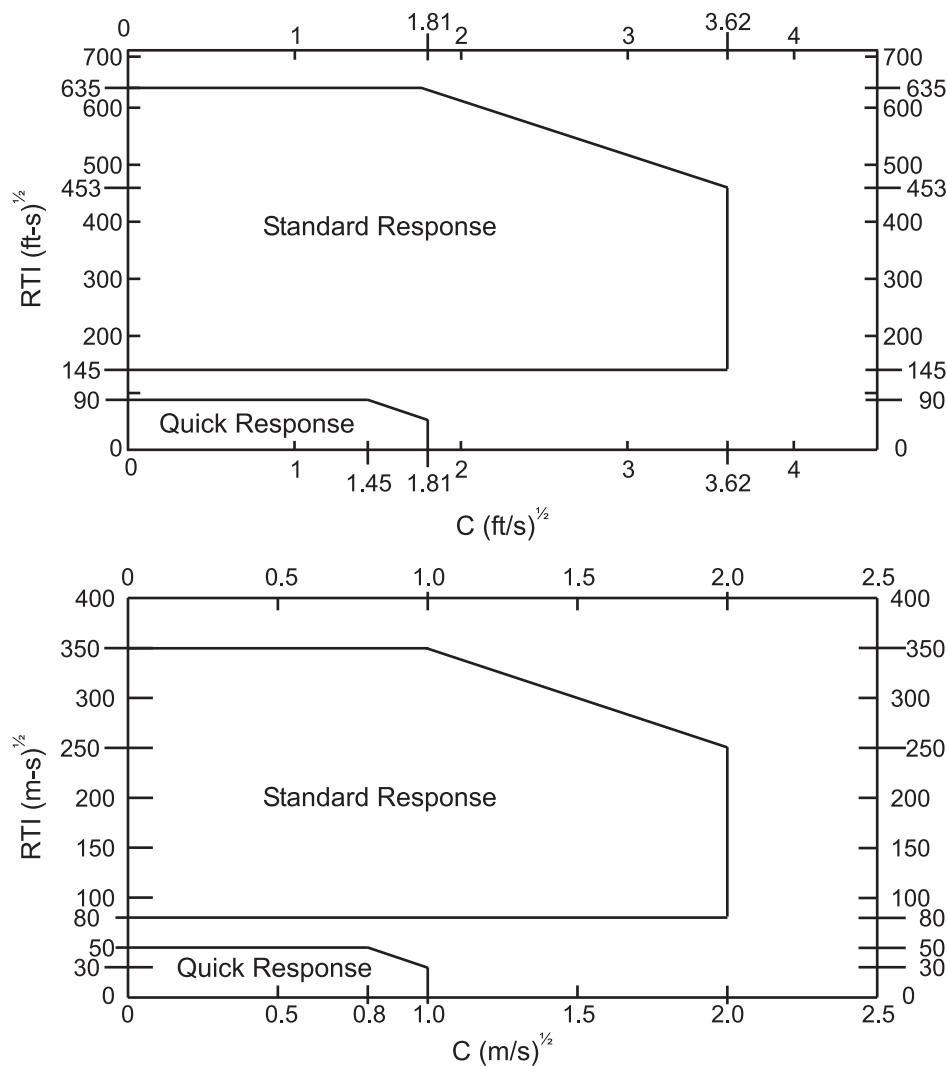


Table 4.2.27.2 - Plunge Test Conditions

Nozzle Nominal Temperature Rating °F (°C)		Temperature in Test Section °F (°C)		Average Gas (Air) Velocity of Test Section 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)		
250 - 300	(121 - 149)	765 ± 45	(407 ± 25)		
325 - 375	(163 - 191)	765 ± 45	(407 ± 25)		

- F. In all cases, the RTI shall meet the requirements as stated in Section 4.2.27.1 when calculated as follows:

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

- Where:  $t_r$  - response time of the nozzle, in seconds  
 $u$  - actual air velocity in the test section of the tunnel (from Table 4.2.27.2), in ft/s (m/s)  
 $\Delta T_b$  - mean operating temperature of the nozzle, as determined in Section 4.8 [Operating Temperature (Liquid Bath)] minus the ambient temperature, in °F (°C)  
 $\Delta T_g$  - actual gas (air) temperature minus the ambient temperature, in °F (°C)  
 $C$  - C-factor as determined in Section 4.2.26 [Conductivity (C-Factor)], in (ft/s)<sup>1/2</sup> [(m/s)<sup>1/2</sup>]

#### 4.2.28 Sensitivity (Recessed, Flush, and Concealed Types) (Automatic/Closed nozzles only)

##### 4.2.28.1 Requirements

Standard and quick response recessed, flush and concealed nozzles shall operate within the maximum response times as calculated in Section 4.2.28.2.A when tested as detailed in Section 4.2.28.2.B, in the least protrusive position possible.

Standard and quick response recessed, flush and concealed nozzles which have been subjected to tests that require post-exposure sensitivity testing shall be tested at plunge tunnel conditions corresponding to a gas temperature of 387 °F (197 °C) and a velocity of 8.53 (ft/s)<sup>1/2</sup> [2.6 (m/s)<sup>1/2</sup>].

4.2.28.2 Test/Verification

- A. The maximum response time shall be calculated using the combinations of RTI and C-factor shown in Table 4.2.28.2.1 and the plunge tunnel conditions detailed in Table 4.2.28.2.2 for the respective response category.

Table 4.2.28.2.1 - RTI and C-Factor Combinations

Response Category	RTI		C-Factor	
	(ft·s) <sup>1/2</sup>	[(m·s) <sup>1/2</sup> ]	(ft/s) <sup>1/2</sup>	[(m/s) <sup>1/2</sup> ]
Standard	635	[350]	1.8	[1.0]
	455	[250]	3.6	[2.0]
Quick	90	[50]	1.4	[0.8]
	55	[30]	1.8	[1.0]

Table 4.2.28.2.2 - Tunnel Conditions

Response Category	Plunge Tunnel Gas Temperature		Plunge Tunnel Velocity		Applied Vacuum mm Hg
	°F	(°C)	ft/sec	(m/s)	
Standard	262	(128)	3.28	(1.0)	0.007
			8.53	(2.6)	0.007
			11.48	(3.5)	0.007
	387	(197)	3.28	(1.0)	0.010
			8.53	(2.6)	0.010
			11.48	(3.5)	0.010
	555	(291)	3.28	(1.0)	0.013
			8.53	(2.6)	0.013
			11.48	(3.5)	0.013
Quick	262	(128)	3.28	(1.0)	0.007
			8.53	(2.6)	0.007
			11.48	(3.5)	0.007
	387	(197)	3.28	(1.0)	0.010
			8.53	(2.6)	0.010
			11.48	(3.5)	0.010

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

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

- Where:  $t_{max}$  - maximum allowed response time of nozzle, in seconds
- $RTI$  - Response Time Index from Table 4.2.28.2.1, in (ft·s)<sup>1/2</sup> [(m·s)<sup>1/2</sup>]
- $\Delta T_b$  - upper temperature limit of the nozzle (1.035 x nominal temperature rating) minus the ambient temperature, in °F (°C)
- $C$  - C- factor from Table 4.2.28.2.1, in (ft/s)<sup>1/2</sup> [(m/s)<sup>1/2</sup>]
- $u$  - actual gas (air) velocity in the test section of the tunnel from Table 4.2.28.2.2, in ft/s (m/s)
- $\Delta T_g$  - actual gas (air) temperature in the test section (see Table 4.2.28.2.2) minus the ambient temperature, in °F (°C)

- B. Compliance with the requirements for maximum operating time shall be determined by operating nozzle samples in the FM Approvals plunge tunnel, using the modified plunge tunnel test plate described in Figure N-4.

The nozzles shall be tested in the best case orientation.

A vacuum in accordance with Table 4.2.28.2.2 shall be applied to and maintained in the upper enclosure of the modified plunge tunnel test plate (Figure N-4). The test shall be repeated three times at each condition to ensure accuracy and product repeatability.

#### 4.2.29 Sensitivity (Air Oven) (Automatic/Closed nozzles only)

##### 4.2.29.1 Requirements

New, uncoated nozzles, which cannot be tested in the plunge tunnel, shall operate within a time limit not exceeding the maximum permitted in Table 4.2.29.1.1 for the respective nominal temperature rating. New nozzles having corrosion resistant coatings (decorative, wax, etc.), which cannot be tested in the plunge tunnel, shall operate within a time limit not exceeding the maximum permitted in Table 4.2.29.1.2 for the respective nominal temperature rating.

Nozzles having corrosion resistant coatings (decorative, wax, etc.), which cannot be tested in the plunge tunnel, and have been subjected to environmental testing, shall operate within the limits stated in Table 4.2.29.1.3.

Table 4.2.29.1.1 - Air Oven Nozzle Sensitivity for New, Uncoated Nozzles Utilizing the Time vs. Temperature Data per Table 4.2.29.2

Nozzle Nominal Temperature Rating °F (°C)		Maximum Operating Temperature °F (°C)		Maximum Operating Time Min:sec
135 - 170	(57 - 76)	525	(274)	1:15
175 - 225	(79 - 107)	550	(288)	1:45
250 - 300	(121 - 149)	575	(302)	3:00
325 - 375	(163 - 191)	605	(319)	5:00
400 - 475	(204 - 246)	640	(338)	7:30
500 - 575	(260 - 302)	735	(391)	15:00

Table 4.2.29.1.2 - Air Oven Nozzle Sensitivity for New Nozzles Having Corrosion Resistant Coating Utilizing the Time vs. Temperature Data per Table 4.2.29.2

Nozzle Nominal Temperature Rating °F (°C)		Maximum Operating Temperature °F (°C)		Maximum Operating Time Min:sec
135 - 170	(57 - 76)	527	(275)	1:34
175 - 225	(79 - 107)	559	(293)	2:11
250 - 300	(121 - 149)	586	(308)	3:45
325 - 375	(163 - 191)	622	(328)	6:15
400 - 475	(204 - 246)	664	(351)	9:22
500 - 575	(260 - 302)	786	(419)	18:45

Table 4.2.29.1.3 - Air Oven Nozzle Sensitivity for Aged or Elevated Temperature Exposed Nozzles Having Corrosion Resistant Coating Utilizing the Time vs. Temperature Data per Table 4.2.29.2

Nozzle Nominal Temperature Rating °F (°C)		Maximum Operating Temperature °F (°C)		Maximum Operating Time min:sec
135 - 170	(57 - 76)	555	(291)	2:00
175 - 225	(79 - 107)	575	(302)	3:00
250 - 300	(121 - 149)	605	(319)	5:00
325 - 375	(163 - 191)	645	(341)	8:00
400 - 475	(204 - 246)	670	(355)	10:00
500 (260) and Over		to be evaluated on a case-by-case basis		

#### 4.2.29.2 Test/Verification

Ten previously untested nozzles of each nominal temperature rating shall be individually operated in an air oven with the inlet of the nozzle pressurized to the minimum operating pressure as determined in Section 4.2.24, (Minimum Operating Pressure). The rate-of-temperature-rise within the oven shall be controlled in accordance with Table 4.2.29.2.

Table 4.2.29.2 - Time vs. Temperature Points for air Oven Nozzle Sensitivity Test

Time min:sec	Temperature °F (°C)	Time min:sec	Temperature °F (°C)	Time min:sec	Temperature °F (°C)
0:15	275 (135)	6:00	620 (325)	16:00	750 (400)
0:30	410 (210)	7:00	630 (330)	17:00	765 (405)
0:45	475 (245)	8:00	645 (340)	18:00	778 (415)
1:00	505 (265)	9:00	660 (350)	19:00	790 (420)
1:15	525 (275)	10:00	670 (355)	20:00	805 (430)
1:30	540 (280)	11:00	685 (365)	22:00	830 (445)
2:00	555 (290)	12:00	695 (370)	24:00	855 (455)
3:00	575 (300)	13:00	710 (375)	26:00	880 (470)
4:00	590 (310)	14:00	725 (385)	28:00	905 (485)
5:00	605 (320)	15:00	735 (390)	30:00	930 (500)

#### 4.2.30 Nozzle Discharge Characteristics

##### 4.2.30.1 Requirements

One nozzle, less the operating mechanism, if any, of each model/type and K-factor shall be tested for discharge characteristics at the minimum and maximum nozzle operating pressures.

##### 4.2.30.2 Test/Verification

One nozzle, less the operating mechanism, if any, of each model/type and K-factor, at the minimum and maximum nozzle operating pressures, shall be tested utilizing a PDPA (Phase-Doppler-Particle Analyzer) instrument for:

- A. Local drop size distributions in a spray cross-section;
- B. Local water flux distribution in the same spray cross-section; and
- C. The gross drop size distribution derived from the above two local measurements.

The measurements of (A) and (B) will provide the spatial variations in terms of drop size distribution and mist flux; and the gross distribution gives the overall distribution of the drops discharged from the nozzle at a discharging pressure. The formula for this evaluation shall be:

$$R_j = \frac{\sum (R_{j,i} \cdot A_i \cdot V_i''')}{\sum (A_i \cdot V_i''')}$$

Where:  $R_j$  - gross volume fraction for drop sizes equal to and less than  $d_j$  at a given elevation below the nozzle tip  
 $R_{i,j}$  - cumulative volume fraction for drop sizes equal to and less than drop size  $d_j$  at location  $i$  in a horizontal spray section  
 $V_i'''$  - water flux per unit area at location  $i$  in a horizontal spray section  
 $A_i$  - local area centered at location  $i$  at which  $R_{i,j}$  and  $V_i'''$  are measured

#### 4.2.31 Impingement (Automatic/Closed Nozzles only)

##### 4.2.31.1 Requirements

Nozzles shall not wet adjacent nozzles installed at the same level, in any direction, at the manufacturer's installation instructions minimum nozzle spacing. When tested, there shall be no direct impingement or dripping of agent from the adjacent nozzle or target.

##### 4.2.31.2 Test/Verification

Distribution tests shall be conducted at pressures of 30, 60, 85 and 100 percent of the maximum nozzle operating pressure using an open (operated) sample nozzle installed on a pipe manifold mounted below a suspended ceiling. An assembled target nozzle shall be installed on the same pipe manifold at the minimum specified distance from the discharging nozzle. A second target nozzle, or other target having the same width and height as the maximum plan area of the nozzle, shall be placed at the same height and at the same distance from the discharging nozzle, along the line perpendicular to the pipe manifold. In the case of recessed, flush or concealed type nozzles, tests shall be conducted with the nozzles installed in the ceiling as intended, in the most protrusive position possible.

#### 4.2.32 Protective Caps

##### 4.2.32.1 Requirements

For automatic/closed or open type nozzles provided with protective caps that remain in place after installation, proper actuation of all components for prompt operation and permitting full agent discharge is required for any performance requirement tested nozzles, as determined by need, and as detailed in any of the 4.2.1 to 4.2.31 performance requirements with post testing as required.

##### 4.2.32.2 Test/Verification

Verification of Section 4.2.24.1 shall be determined and conducted at the sole discretion of FM Approvals as detailed in any of the 4.2.1 to 4.2.31 performance requirements with post testing as required.



### 4.3 Automatic Releases

The automatic release should be evaluated and tested for functionality and compatibility with electrical specifications of the actuating device and control panel of the hybrid fire extinguishing system. The Approval examination shall be in accordance with the *Approval Standard for Automatic Releases* (Class 1930). Manufacturers are strongly encouraged to use FM Approved automatic releases.

### 4.4 Ball Valve (Manual and Pneumatic Actuation)

#### 4.4.1 Ball or Disc Strength

##### 4.4.1.1 Requirements

The valve ball, disc or other sealing mechanism shall withstand exposure to a hydrostatic pressure of 150 percent of the maximum system operating pressure or 700 psi (48.2 bar), whichever is greater. During, and at the conclusion of the test, no fracture, permanent distortion, or functional impairment shall occur. After this test the valve shall be fully operable and shall comply with the leakage requirements in Section 4.1.2 (Seat Leakage).

##### 4.4.1.2 Tests/Verification

A sample valve of each size shall be closed. With one side open to atmosphere, the other side shall be hydrostatically pressurized to 150 percent of the maximum system operating pressure, or 700 psi (48.2 bar), whichever is greater. The test pressure shall be held for five minutes. For this strength test, special provisions may be made to prevent leakage past the seat. This test shall be repeated for both directions of flow.

#### 4.4.2 Stem Seal

##### 4.4.2.1 Requirement

Stem seals shall not leak when subjected to a hydrostatic pressure equal to the maximum system operating pressure.

##### 4.4.2.2 Tests/Verification

A sample valve of each size with the ball, disc or other sealing mechanism in a partially open position shall be subjected to its maximum system operating pressure for five minutes with no visible stem leakage. Cycling of the ball, disc or other sealing mechanism a minimum of 12 times during this time span shall not cause leakage past the stem seal.

#### 4.4.3 Operating Force Test

##### 4.4.3.1 Requirements

The force to open the valve shall be measured. An internal hydrostatic pressure of 90 psi (6.2 bar), or 50 percent of the maximum system operating pressure, whichever is greater, shall be applied to the valve for various time periods. The force required to open the valve at the end of each time period shall not exceed 50 lb force (222 N) applied to the outermost end of the valve handle. No damage to any internal components of the valve shall result.

##### 4.4.3.2 Tests/Verification

Sample valves shall be subjected to 90 psi (6.2 bar), or 50 percent of the maximum system operating pressure, whichever is greater, for consecutive periods of one week, two weeks, and one month. Initially, and at the end of each specified period, the force to open the valve shall be measured.

#### 4.4.4 Stability Test - Disc Type Valves Only

##### 4.4.4.1 Requirement

With all the valve parts loosened to a point approaching body and/or stem leakage, a sample valve shall be subjected to flow at a velocity of 50 ft/s (15 m/s) for fifteen minutes. The valve shall remain in the fully open position.

##### 4.4.4.2 Tests/Verification

Tests shall be conducted to show that the disc type valve remains open as required above.

#### 4.4.5 Additional Performance Tests (as applicable)

##### 4.4.5.1 Requirements

General Performance Requirements: 4.1.1.1 (Examination), 4.1.2.1 (Valve Seat Leakage), 4.1.3.1 (Hydrostatic Strength), 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray – Corrosion), 4.1.9.1 (Valve Locking/Supervision Ability), and 4.1.10.1 (Friction Loss Determination)

##### 4.4.5.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.1.2 (Examination), 4.1.2.2 (Valve Seat Leakage), 4.1.3.2 (Hydrostatic Strength), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray – Corrosion), 4.1.9.2 (Valve Locking/Supervision Ability), and 4.1.10.2 (Friction Loss Determination). For pneumatically actuated valves, the requirements of 4.1.6.1 (Extreme Temperatures Operation) and 4.1.7.1 (Salt Spray - Corrosion) shall be tested under pneumatic operation. After the completion of the tests for 4.1.6.1 (Extreme Temperatures Operation), the valve shall be re-pressurized to the maximum system operating pressure for five minutes and shall comply with the requirements in Section 4.1.2.1 (Valve Seat Leakage) and Section 4.4.2.1 (Stem Seal). The valve shall then be disassembled and moving parts shall be visibly examined for signs of excessive wear or damage.

#### 4.5 Check and Shuttle Valves

##### 4.5.1 Clapper - Poppet Strength

##### 4.5.1.1 Requirements

The valve clapper - poppet shall withstand exposure to a hydrostatic pressure of two times the maximum system operating pressure. During, and at the conclusion of the test, no fracture, permanent distortion, or functional impairment shall occur. After this test, the valve shall be fully operable and shall comply with the leakage requirements in Section 4.1.2.1 (Valve Seat Leakage).

##### 4.5.1.2 Tests/Verification

A hydrostatic pressure of two times the maximum system operating pressure shall be applied to the outlet side of the valve with the inlet of the valve open to atmosphere. The test pressure shall be held for five minutes. During, and at the conclusion of the test, no fracture, permanent distortion or functional impairment shall occur. Full compliance with Sections 4.1.1.2 (Examination) and 4.1.2.1 (Valve Seat Leakage) is required after the clapper - poppet strength test.

#### 4.5.2 Additional Performance Tests (as applicable)

##### 4.5.2.1 Requirements

General Performance Requirements: 4.1.1.1 (Examination), 4.1.2.1 (Valve Seat Leakage), 4.1.3.1 (Hydrostatic Strength), 4.1.4.1 (Operating Pressure), 4.1.5.1 (Durability - Cycling), 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray – Corrosion), 4.1.10.1 (Friction Loss Determination) and 4.1.11.1 (Seals & O-rings).

##### 4.5.2.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.1.2 (Examination), 4.1.2.2 (Valve Seat Leakage), 4.1.3.3 (Hydrostatic Strength), 4.1.4.2 (Operating Pressure), 4.1.5.2 (Durability - Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion), 4.1.10.2 (Friction Loss Determination) and 4.1.11.2 (Seals & O-rings).

#### 4.6 Connection Block Assembly – Cylinder Manifold

##### 4.6.1 Performance Tests (as applicable)

##### 4.6.1.1 Requirements

General Performance Requirements: 4.1.1.1 (Examination), 4.1.3.1 (Hydrostatic Strength) 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray - Corrosion), 4.1.8.1 (Vibration Resistance) (if more than one part) and 4.1.12.1 (Pipe Coupling Gaskets).

##### 4.6.1.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.1.2 (Examination), 4.1.3.2 (Hydrostatic Strength), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion), 4.1.8.2 (Vibration Resistance) and 4.1.12.2 (Pipe Coupling Gaskets).

#### 4.7 Control Panel

The control panel shall be evaluated and tested for functionality and compatibility with electrical specifications of the electrically operated equipment associated with the hybrid system, including the actuating solenoid, fire detection automatic releases, etc.. The Approval examination shall be in accordance with the *Approval Standard for Controllers for Electric Motor Driven and Diesel Engine Driven Fire Pumps* (Class 1321/1323), and/or the *Approval Standard for Electrical Equipment for Measurement, Control and Laboratory Use* (Class 3810), and/or FM Approvals' *Fire Alarm Signaling Systems* (Class 3010), and the local protective signaling systems requirements in NFPA 72, *National Fire Alarm Code*. Manufacturers are strongly encouraged to use FM Approved control panels.

#### 4.8 Cylinder Burst Discs - Sealing Membrane – Rupture Disc Assemblies

##### 4.8.1 Pressure Operation

##### 4.8.1.1 Requirement

The cylinder burst and/or rupture disc and/or sealing membrane shall be pressurized until failure and/or operation. The pressure at failure or operation shall be within -10, +0 percent of the manufacturer's published rating.

#### 4.8.1.2 Test/Verification

A minimum of ten cylinder burst and/or rupture discs or sealing membranes shall be pressurized until operation or failure to determine the allowable pressure range and requirements. Results shall be recorded for operational data files and manual information.

### 4.8.2 Pressure Relief Calculations

#### 4.8.2.1 Requirement

The construction and size of the burst disc and dispersion device shall, at a minimum, be appropriate for the anticipated pressure of the extinguishing agent/medium at the maximum allowable pressure vessel transportation, storage, and/or installation temperature.

#### 4.8.2.2 Test/Verification

Appropriate documentation and calculations shall be submitted to verify that the construction and size of the burst disc complies with the flow capacity requirements specified by the formula in CGA Pamphlet S-1.1, *Safety Relief Devices Standards - Cylinders for Compressed Gases*, or equivalent national code for country of use.

## 4.9 Cylinder, Gas Storage

### 4.9.1 Construction Design

#### 4.9.1.1 Requirements

Gas storage cylinders should be fabricated, tested, approved, equipped and provided with labeling in accordance with recognized, international standards, such as the current specifications of the ASME *Boiler and Pressure Vessel Code*, Section VII, or the requirements of U.S. Department of Transportation, Title 49, *Code of Federal Regulations*, Parts 171 to 180, or equivalent national codes for the country of use. The design working pressure shall be in accordance with the pressure at the manufacturer's maximum specified transportation, storage, and/or installation temperature.

#### 4.9.1.2 Test/Verification

All documentation concerning the fabrication and testing of the cylinders shall be provided to FM Approvals for initial evaluation of the following:

- Verification that the pressure vessel standard is adequate for the system storage pressure, and appropriate for the jurisdiction in which the equipment will be used. If the standard does not meet this requirement, there may be additional minimum criteria established by FM Approvals.
- Verification that the design is in accordance with the standard. Typical verification includes a review of certification to manufacture to the standard, minimum wall thickness calculations, authorized materials, material tests, and general chemical analysis tests.
- Verification that the manufacturer is capable of producing cylinders in accordance with the design. Typical verification would include volumetric expansion and hydrostatic pressure tests.

#### 4.9.2 One Year Leakage Loss Test

##### 4.9.2.1 Requirement

A minimum of three sample cylinder and valve assemblies of each size and pressure rating shall be monitored for pressurized weight loss. The cylinder weight loss during the one year test period shall not exceed the mass change equivalent to a 0.50 percent decrease in the normal storage pressure, based on the minimum cylinder size used with each specific discharge valve size.

##### 4.9.2.2 Test/Verification

Each sample cylinder and valve shall be pressurized to the system's specified working pressure. Test sample assemblies shall incorporate all components subjected to the normal working pressure, including operating devices. The cylinder and valve assembly shall be stored at 70 °F ± 5 °F (21 °C ± 2.6 °C) and weighed at 0, 1, 3, 6 and 12 months, and the projected weight loss over a one year period shall be extrapolated. The test shall be suspended if the calculated leakage at any time exceeds the allowable quantity. The duration of this test may be reduced at the sole discretion of FM Approvals.

#### 4.9.3 Extreme Low Temperature Test

##### 4.9.3.1 Requirement

A minimum of three sample cylinder and valve assemblies of each size and pressure rating shall be subjected to the minimum system operation temperature for 30 days. At the conclusion of the temperature exposure, the cylinder weight loss shall not exceed the mass change equivalent to a 0.042 percent decrease in the normal storage pressure, based on the minimum cylinder size used with each specific discharge valve size.

##### 4.9.3.2 Test/Verification

Each sample cylinder and valve shall be pressurized to the system's specified working pressure. Test sample assemblies shall incorporate all components subjected to the normal working pressure, including operating devices. The cylinder and valve assembly shall be weighed prior to the exposure period, and shall be conditioned in a conditioning chamber set at 40 °F (4.4 °C) for a period of 30 days. Following removal from the conditioning chamber, the pressurized cylinder shall be weighed, and compared to the initial sample weight, to determine if loss of agent has occurred. One sample cylinder and valve assembly of each size and pressure rating shall then be successfully discharged, and subsequently examined and tested per Section 4.1, as applicable.

#### 4.9.4 Extreme High Temperature Test

##### 4.9.4.1 Requirement

A minimum of three sample cylinder and valve assemblies of each size and pressure rating shall be subjected to the maximum system operation temperature for 30 days. At the conclusion of the temperature exposure, the cylinder weight loss shall not exceed the mass change equivalent to a 0.042 percent decrease in the normal storage pressure, based on the minimum cylinder size used with each specific discharge valve size.

##### 4.9.4.2 Test/Verification

Each sample cylinder and valve shall be pressurized to the system's specified working pressure. Test sample assemblies shall incorporate all components subjected to the normal working pressure, including operating devices. The cylinder and valve assembly shall be weighed prior to the exposure period, and shall be conditioned in a conditioning chamber set at 130 °F (54.4 °C) for a period of 30 days. Following removal from the conditioning chamber, the pressurized cylinder shall be

weighed, and compared to the initial sample weight, to determine if loss of agent has occurred. One sample cylinder and valve assembly of each size and pressure rating shall then be successfully discharged, and subsequently examined and tested per Section 4.1, as applicable.

#### 4.9.5 Hydrostatic Integrity

##### 4.9.5.1 Requirements

Gas storage cylinders shall be hydrostatically tested without failure at a pressure equal to 1.5 times the rated pressure of the cylinder burst disc, or in accordance with the applicable published standard, whichever pressure is higher. Allowable standards shall be those acceptable to the authority having jurisdiction, based on the intended market for the system. Approval shall be limited to installations within jurisdictions accepting the standard to which the cylinders have been manufactured. No cracking, fracture, or failure to retain the test pressure shall be allowed.

##### 4.9.5.2 Tests/Verification

Each sample shall be subjected to the required test pressure, using water as the pressurizing medium. For the last 20 percent of the required pressure, the rate of pressure increase shall be no more than 10 percent per minute. The required test pressure shall be held for a minimum of one minute, or in accordance with the applicable published standard, whichever is longer.

Cylinder designs consisting of the same diameter, wall thickness, and material of construction, but with differing heights, may be evaluated by testing of selected representative samples rather than samples of all cylinder heights.

Deviation in samples from the calculated minimum wall thickness may be accommodated by increasing the test pressure in proportion to the wall thickness. This may be used for up to a maximum difference of 20 percent. Alternate validation methods, such as finite element analysis, may be accepted at the discretion of FM Approvals for hydrostatic strength.

#### 4.9.6 Permanent Volumetric Expansion

##### 4.9.6.1 Requirements

Permanent volumetric expansion testing is required under some pressure vessel standards. If required by the standard to which the cylinder is designed, such tests shall be conducted in accordance with that standard. If the cylinder manufacturer is required by the authority having jurisdiction to be under recognized third party surveillance, permanent volumetric expansion testing may not require witnessing by FM Approvals. Certifications of tests witnessed by the recognized third party shall be submitted for review by FM Approvals for compliance with this requirement. Acceptable third parties shall include those granted reciprocity for boiler and pressure vessel inspection to the ASME *Boiler and Pressure Vessel Code*.

When subjected to the proof test pressure, the permanent volumetric expansion of a gas storage cylinder shall not exceed 10 percent of the total expansion. The proof test pressure shall be as specified in the ASME *Boiler and Pressure Vessel Code*, Section VII, or the U.S. Department of Transportation, Title 49, *Code of Federal Regulations*, Parts 171 to 180, or the equivalent national codes for the country of use.

#### 4.9.6.2 Requirements

Each sample shall be subjected to the required test pressure, using water as the pressurizing medium. For the last 20 percent of the required pressure, the rate of pressure increase shall be no more than 10 percent per minute. The required test pressure shall be maintained for a minimum of one minute, or in accordance with the applicable published standard, whichever is longer. The total expansion of the cylinder shall be measured. The applied pressure shall then be removed from the sample, and the permanent expansion shall be measured.

Cylinder designs consisting of the same diameter, wall thickness, and material of construction, but with differing heights, may be evaluated by testing selected representative samples rather than samples of all cylinder heights.

### 4.9.7 Additional Performance Tests (as applicable)

#### 4.9.7.1 Requirements

General Performance Requirements: 4.1.1.1 (Examination) and 4.1.7.1 (Salt Spray – Corrosion).

#### 4.9.7.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.1.2 (Examination) and 4.1.7.2 (Salt Spray – Corrosion).

## 4.10 Cylinder Valve Assembly

### 4.10.1 Performance Tests (as applicable)

#### 4.10.3.1 Requirements

General Performance Requirements: 4.1.1.1 (Examination), 4.1.2.1 (Valve Seat Leakage), 4.1.3.1 (Hydrostatic Strength), 4.1.4.1 (Operating Pressure), 4.1.5.1 (Durability - Cycling), 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray - Corrosion), 4.1.8.1 (Vibration Resistance), 4.1.11.1 (Seals & O-rings), 4.8.1.1 (Pressure Operation), 4.8.2.1 (Pressure Relief Calculations), 4.9.2 (One Year Leakage Loss), 4.9.3 (Extreme Low Temperature), 4.9.4 (Extreme High Temperature), 4.26.1.1 (Equipment Assembly Ratings), and 4.26.2.1 (Dielectric Strength).

#### 4.10.3.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.1.2 (Examination), 4.1.2.2 (Valve Seat Leakage), 4.1.3.2 (Hydrostatic Strength), 4.1.4.2 (Operating Pressure), 4.1.5.2 (Durability - Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion), 4.1.8.2 (Vibration Resistance), 4.1.11.2 (Seals & O-rings), 4.8.1.2 (Pressure Operation), 4.8.2.2 (Pressure Relief Calculations), 4.9.2 (One Year Leakage Loss), 4.9.3 (Extreme Low Temperature), 4.9.4 (Extreme High Temperature), 4.26.1.2 (Equipment Assembly Ratings), and 4.26.2.2 (Dielectric Strength).

### 4.11 Detection Devices (Fire & Smoke)

Detection devices should be evaluated and tested for functionality and compatibility with electrical specifications of the electrically operated equipment associated with the hybrid system, including the actuating solenoid, fire detection automatic releases, etc. The Approval examination shall be in accordance with the *Approval Standard for Thermostats - Spot Type* (Class 3210), *Approval Standard for Fixed Temperature Thermostats* (Class 3211), *Approval Standard for Combination Fixed Temperature & Rate of Rise Thermostats* (Class 3213), and *Approval Standard for Smoke Detectors* (Class 3230/3250). Manufacturers are strongly encouraged to use FM Approved detection devices.

#### 4.12 Drain/Fill Valve (as applicable)

##### 4.12.1 Performance Tests

General Performance Requirements: 4.1.1.1 (Examination), 4.1.2.1 (Valve Seat Leakage), 4.1.3.1 (Hydrostatic Strength) 4.1.5.1 (Durability - Cycling), 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray - Corrosion), 4.1.8.1 (Vibration Resistance), 4.1.10.1 (Friction Loss Determination) and 4.1.11.1 (Seals & O-rings).

##### 4.12.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.1.2 (Examination), 4.1.2.2 (Valve Seat Leakage), 4.1.3.2 (Hydrostatic Strength), 4.1.5.2 (Durability - Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion), 4.1.8.2 (Vibration Resistance), 4.1.10.2 (Friction Loss Determination) and 4.1.11.2 (Seals & O-rings).

#### 4.13 Fittings and Piping (Including Couplings and Tubing)

All fittings and couplings, and piping and tubing, in low, intermediate, and high pressure systems shall be in accordance with FM Global Property Loss Prevention Data Sheet Numbers 2-8N, *Installation of Sprinkler Systems*, and 4-0, *Special Protection Systems*. Information regarding the fittings and coupling, and piping and tubing used in the hybrid system shall be submitted to FM Approvals. With consideration given to the pressure ratings of the system, these materials will be examined and evaluated for conformance to the materials, hydrostatic strength, and corrosion resistance required by the data sheets referenced above. Galvanized piping shall not be used in the water lines in FM Approved hybrid systems. Manufacturers are strongly encouraged to use FM Approved equipment.

##### 4.13.1 Joining Methods

###### 4.13.1.1 Requirement

All piping and rigid tubing shall be joined by welding, compression or threaded fittings, grooved end couplings, or plain end fittings. All allowable joining methods shall be listed by the manufacturer.

###### 4.13.1.2 Test/Verification

Documentation detailing all allowable joining methods shall be submitted by the manufacturer and reviewed to determine necessary examination and testing.

##### 4.13.2 Additional Performance Tests (as applicable)

###### 4.13.2.1 Requirements

General Performance Requirements: 4.1.3.1 (Hydrostatic Strength), 4.1.5.1 (Durability - Cycling), 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray - Corrosion), 4.1.8.1 (Vibration Resistance), and 4.1.11.1 (Seals & O-rings).

###### 4.13.2.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.3.2 (Hydrostatic Strength), 4.1.5.2 (Durability - Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion), 4.1.8.2 (Vibration Resistance), and 4.1.11.2 (Seals & O-rings).



#### 4.14 Flow Switches (Pressure Actuated)

##### 4.14.1 Actuation Point Accuracy and Repeatability

###### 4.14.1.1 Requirements

- A. Accuracy: The actuation point shall be within the manufacturer's specification for accuracy or within  $\pm 5$  percent of full scale value for adjustable types;  $\pm 5$  percent of set value for factory pre-set types, whichever is less.

Note: The scale markings for some adjustable switches may only be approximate, serving only as a starting point for adjustment upon installation. Therefore, the accuracy requirement does not apply.

- B. Repeatability: The actuation point shall repeat within the manufacturer's specification or within  $\pm 1$  percent of the set value, whichever is less.
- C. Reset: Reset, automatic or manual, shall not occur until the input is above (low limit) or below (high limit) the actuation value.

###### 4.14.1.2 Test/Verification

An input signal shall be applied, slowly, until the switch actuates. The input shall be applied as an increasing signal for a high limit switch, and as a decreasing signal for a low limit switch. This test shall be repeated a minimum of five times. Adjustable type switches shall be tested at 25, 50, and 75 percent of scale.

- A. Accuracy is the deviation from the set value, expressed as a percent of full scale value.
- B. Repeatability (non-repeatability) is the difference between the highest and the lowest input value needed to cause actuation, expressed as a percentage of the set value.
- C. As part of this test, it shall be verified that reset does not occur until the input is inside the limit.

##### 4.14.2 Dielectric Strength

###### 4.14.2.1 Requirement

Electrical components shall be capable of withstanding an applied voltage between all terminals provided for external connections and ground. There shall be no arcing or breakdown, and components shall continue to function properly subsequent to this test.

###### 4.14.2.2 Test/Verification

A test voltage of 1000 V, AC, plus twice the rated operating voltage, shall be applied between electrical terminals and ground for a period of one minute.

Exception: For operating voltages of 54 V or less the test voltage shall be 500 V, AC

##### 4.14.3 Additional Performance Tests (as applicable)

###### 4.14.3.1 Requirements

General Performance Requirements: 4.1.1.1 (Examination), 4.1.3.1 (Hydrostatic Strength) 4.1.4.1 (Operating Pressure), 4.1.5.1 (Durability - Cycling), 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray - Corrosion), 4.1.8.1 (Vibration Resistance) and 4.1.10.1 (Friction Loss Determination).

#### 4.14.3.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.1.2 (Examination), 4.1.3.2 (Hydrostatic Strength), 4.1.4.2 (Operating Pressure), 4.1.5.2 (Durability - Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion), 4.1.8.2 (Vibration Resistance) and 4.1.10.2 (Friction Loss Determination). Following tests 4.1.5.2 (Durability - Cycling), 4.1.6.2 (Extreme Temperatures Operation) and 4.1.8.2 (Vibration Resistance), a post test 4.1.4.2 (Operating Pressure) should be conducted.

### 4.15 High Pressure Flexible Distribution Hose

#### 4.15.1 Fatigue Test

##### 4.15.1.1 Requirements

Flexible hose with threaded end fittings shall be subjected to 20,000 cycles of repeated flexing at a rate of 5 to 30 cycles/min, in a direction parallel with the axis of the end fittings, while pressured to their rated working pressure. There shall be no deterioration of the flexible hose or its performance characteristics. Following the cycling test, the flexible hose with threaded end fittings shall comply with the hydrostatic test requirements in Section 4.1.3 (Hydrostatic Strength).

##### 4.15.1.2 Test/Verification

The fatigue test shall be conducted in accordance with Section 8.3 of ISO Standard 10380:2003, *Pipework - Corrugated metal hoses and hose assemblies*. A minimum of two samples of flexible hose with fittings, of the longest size submitted for Approval, shall be subjected to 20,000 cycles of repeated flexing at a rate of 5 to 30 cycles/min in a direction parallel with the axis of the end fittings while pressurized to their rated working pressure, as shown in Figure N-6. The sample hose shall be mounted in a U shape, with the end fittings at a horizontal distance from each other of twice the minimum dynamic bend radius of the hose, as defined by the manufacturer's literature. One end of the sample shall be held in a fixed position and the other end shall be flexed in the vertical plane a distance of four times the nominal diameter of the nozzle fittings above and below the position of the fixed end, for a total vertical movement of eight times the nominal diameter. After completion of 20,000 cycles, if deemed necessary by visual inspection, deterioration of the performance characteristics shall be evaluated via the test detailed in Section 4.1.10 (Friction Loss Determination). The samples shall then be subjected to the hydrostatic post-test, as detailed in Section 4.1.3 (Hydrostatic Strength).

#### 4.15.2 Vacuum Test

##### 4.15.2.1 Requirements

Flexible hose with threaded end fittings shall withstand a vacuum of 26 in. Hg (654 mm Hg) without collapse, leakage or deterioration of the flexible hose performance characteristics. Following the vacuum test detailed in Section 4.15.2, there shall be no deterioration of the performance characteristics, and the flexible hose with threaded end fittings shall not leak or fail when tested in accordance with Section 4.1.3 (Hydrostatic Strength).

#### 4.15.2.2 Tests/Verification

One previously untested sample shall be subjected to a vacuum of 26 in. Hg (654 mm Hg) for a period of 5 minutes, during which time there shall be no collapse or leakage. After completion of the vacuum test, if deemed necessary by visual inspection, deterioration of the performance characteristics shall be evaluated via the test detailed in Section 4.1.10 (Friction Loss Determination). The sample shall then be subjected to the hydrostatic post-test as detailed in Section 4.1.3 (Hydrostatic Strength).

### 4.15.3 Seal Integrity Test

#### 4.15.3.1 Requirements

Flexible hose with threaded end fittings that incorporate a sealing mechanism, such as o-rings or gaskets, shall withstand an exposure to temperatures of 40 °F (4.4 °C) and 130 °F (54.4 °C), or to the manufacturer's specifications, without cracking, leaking, permanent deformation, or deterioration of the performance characteristics of the seal.

#### 4.15.3.2 Test/Verification

One sample of the flexible hose with threaded end fittings and sealing mechanism, for each sealing mechanism material under examination, shall be subjected to the following tests:

- A. The hose shall be hydrostatically tested to confirm that there is no leakage at 1.5 times the maximum system operating pressure or 700 psi (48.3 bar), whichever is greater.
- B. The hose shall be drained and subjected to a high temperature oven-air exposure of 130 °F (54.4 °C), or to the manufacturer's specifications, for 45 days. After exposure, the hose shall be allowed to cool to ambient air temperature. It shall then be pneumatically pressurized to 50 psi (34.5 bar), submerged in water, and observed for evidence of leakage.
- C. The sealing mechanism, after removal from the hose, shall not crack when squeezed together from any two diametrically opposite points.
- D. A second hose sample shall be hydrostatically tested to confirm that there is no leakage at four times the rated working pressure.
- E. The hose shall be drained and subjected to a low temperature exposure of 40 °F (4.4 °C), or to the manufacturer's specifications, for four days. Immediately after exposure, the hose shall be submerged in antifreeze at 40 °F (4.4 °C), or to the manufacturer's specifications, shall be pneumatically pressurized to 50 psi (3.5 bar), and observed for evidence of leakage. The depressurized hose shall then be allowed to warm to ambient temperature and disassembled. The sealing mechanism, after removal from the hose, shall not crack when squeezed together from any two diametrically opposite points.

### 4.15.4 High Pressure Flow Test

#### 4.15.4.1 Requirement

Flexible hose with threaded end fittings shall withstand the effects of a high pressure flow. Following the high pressure flow test detailed in Section 4.15.4.2, there shall be no deterioration of the hose, its fittings or its attachment.

#### 4.15.4.2 Tests/Verification

A flexible hose with threaded end fittings shall be installed in its normal operating configuration, including fitting the hose to any applicable components such as a hybrid nozzle. The hybrid fire extinguishing system shall be operated. A minimum of seven tests shall be conducted with pressures ranging from the minimum to the maximum system operating pressures in approximate evenly spaced pressure increments.

### 4.15.5 Additional Performance Tests (as applicable)

#### 4.15.5.1 Requirements

General Performance Requirements: 4.1.3.1 (Hydrostatic Strength), (The hose shall be bent 90 degrees with the threaded end fitting restrained and the hose unrestrained on a flat surface.), 4.1.7.1 (Salt Spray - Corrosion) and 4.1.8.1 (Vibration Resistance) (An attached section, depending on intended installation application, shall be secured to a vibration table with the end fitting in a vertical plane and the hose bent in a 90° angle at its minimum bend radius, as defined by the manufacturer's literature. The other end of the flexible nozzle hose with threaded end fittings shall be securely fixed in a horizontal plane.), and 4.1.10.1 (Friction Loss Determination).

#### 4.15.5.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.3.2 (Hydrostatic Strength) (There shall be no deterioration of the flexible hose performance characteristics.), 4.1.7.2 (Salt Spray – Corrosion) and 4.1.8.2 (Vibration Resistance) (The test sample shall be filled with water and pressurized to 90 psi (6.2 bar) while being subjected to the vibration conditions in Table 4.1.8. After completion of the vibration test, if deemed necessary by visual inspection, deterioration of the performance characteristics shall be evaluated via the test detailed in Section 4.1.10 (Friction Loss Determination). The samples shall then be subjected to the hydrostatic post-test as detailed in Section 4.3.1 (Hydrostatic Strength), and 4.1.10.2 (Friction Loss Determination).

## 4.16 Level Switch (Water)

### 4.16.1 Equipment Assembly Rating (Voltage Variation)

#### 4.16.1.1 Requirement

The level switch shall operate properly over a primary source voltage range of 85 to 110 percent of the rated voltage while at the maximum and minimum specified installation temperatures. There shall be no change in operating characteristics, or failure to respond to level limit alarms and trip points. These test requirements are in accordance with the *Approval Standard for Water Level Limit Controls for Boilers* (Class 7710).

#### 4.16.1.2 Test/Verification

A sample switch shall be conditioned to the minimum specified installation temperature for 16 hours. While still at that temperature, the sample shall be mounted in the position of normal use and shall be subjected to a source voltage range from 85 to 110 percent of the rated voltage.

The sample shall then be conditioned to the maximum specified installation temperature for 16 hours. While still at that temperature, the sample shall be mounted in the position of normal use and shall be subjected to a source voltage range from 85 to 110 percent of the rated voltage.

#### 4.16.2 Dielectric Strength

##### 4.16.2.1 Requirement

Electrical components shall be capable of withstanding an applied voltage between all terminals provided for external connections and ground. There shall be no arcing or breakdown, and components shall continue to function properly subsequent to this test.

##### 4.16.2.2 Test/Verification

A test voltage of 1000 V, AC, plus twice the rated operating voltage, shall be applied between electrical terminals and ground for a period of one minute.

Exception: For operating voltages of 54 V or less the test voltage shall be 500 V, AC.

#### 4.16.3 Additional Performance Tests (as applicable)

##### 4.16.3.1 Requirements

General Performance Requirements: 4.1.3.1 (Hydrostatic Strength) 4.1.4.1 (Operating Pressure), 4.1.5.1 (Durability - Cycling), 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray - Corrosion) and 4.1.8.1 (Vibration Resistance).

##### 4.16.3.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.3.2 (Hydrostatic Strength), 4.1.4.2 (Operating Pressure) (Vary the water level at maximum pressure as a functionality check.) 4.1.5.2 (Durability - Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion) and 4.1.8.2 (Vibration Resistance). After 4.1.5.1 (Durability - Cycling) and 4.1.6.1 (Extreme Temperatures Operation), the switch shall function as intended. In no case shall the electromechanical relay contacts fuse in the closed position.

#### 4.17 Manual Pull Station/Manual Release

Manual pull stations shall be evaluated and tested for functionality and compatibility with electrical specifications of the electrically operated equipment associated with the hybrid fire extinguishing system, including the actuating solenoid, fire detection automatic releases, etc. The Approval examination shall be in accordance with the *Approval Standard for Manual Fire Alarm Boxes* (Class 3111). Manufacturers are strongly encouraged to use FM Approved detection devices.

This standard provides information regarding the typical tests that are required by FM Approvals. FM Approvals reserves the right to modify this outline as required to suit the specific tests needs of a given piece of equipment. Performance requirement testing may include Enclosures, Normal Operation, Voltage Variation, Environmental Conditioning, Vibration, Dielectric, Cycles of Operation, Radio Frequency Interference, Surge Line Transient Tests, and Marking Requirements.

##### 4.17.1 Manual Release Specifications

###### 4.17.1.1 Requirement

Manual release devices shall operate properly with applied forces no greater than 40 lb (178 N), linear movement no more than 14 in. (36 cm), torque no greater than 40 lbf·ft (54 N·m), nor rotational movement of over 270 degrees when configured with the most adverse arrangement allowed by the manufacturer's installation instructions. Components shall exhibit strength equal to or greater than 1.5 times the required operating force.

#### 4.17.1.2 Test/Verification

A minimum of one sample of each device shall be tested. Properly calibrated force gauges, torque meters, and measuring tapes shall be used to measure operational requirements. Tests shall be conducted under the most adverse condition with respect to normal system pressure, if applicable. Devices using flexible mechanical cable actuation shall be tested with the most adverse cable routing (maximum length of cables, number of changes of direction, etc.). No impairment of operation shall be allowed.

After measurement of the required actuating force or torque, 1.5 times that value shall be applied to the device. No failure or impairment of subsequent operation shall result.

### 4.18 Mounting Cylinder Bracket

#### 4.18.1 High Pressure Discharge Test

##### 4.18.1.1 Requirements

A hybrid fire extinguishing system unit, including its discharge valve, brackets, manifold check valves, selector valves, and discharge piping, shall withstand without permanent distortion, rupture, or other malfunction that would render the device inoperable.

##### 4.18.1.2 Test/Verification

A high pressure discharge test shall be conducted on the mounting cylinder bracket assembly with discharge hose. The hybrid system unit is to be filled with extinguishing agent and pressurized to a pressure corresponding to the pressure of the system unit at the maximum storage temperature. The hybrid system unit is to be connected to the minimum amount of piping and largest nozzle flow rate intended for the system. The hybrid system unit is then to be installed and discharged. After discharge, the hybrid system unit is to be visually examined for distortion or damage. Distortion and damage shall be confirmed by conducting testing in accordance with Section 4.1.2 (Valve Seat Leakage) and subsequently disassembling the components. This test is to be either repeated or configured for all possible hybrid system unit operating positions of the selector/control valves.

#### 4.18.2 Catastrophic Failure Test

##### 4.18.2.1 Requirements

Brackets or clamps used for securing cylinders shall ensure that components are not damaged in the event of a catastrophic pressurized gas release. At the end of the discharge, the cylinder shall be firmly attached to the bracket and mounting surface.

##### 4.18.2.2 Test/Verification

The cylinder mounting bracket shall be installed per the manufacturer's instructions. A cylinder, pressurized to a pressure corresponding to the pressure of the cylinder at the maximum storage temperature, shall be mounted in the bracket. A 1 ft. (0.3 m) length of pipe shall be attached to the cylinder valve. An electrically activated solenoid valve shall be remotely opened and the gas discharged.

## 4.19 Pneumatic Actuator

### 4.19.1 Pressure Requirement Activation Test

#### 4.19.1.1 Requirement

One sample actuator of each type and size shall be subjected to a pressure requirement activation test. The time and pressure to operate the valve with the pneumatic actuator will be recorded and the pressure requirement verified to the specifications of the actuator.

#### 4.19.1.2 Test/Verification

The actuator shall be tested for the pressure required to fully operate the actuator while the device to which the actuator is attached is pressurized to 100 percent of the maximum system operating pressure.

### 4.19.2 Additional Performance Tests (as applicable)

#### 4.19.2.1 Requirements

General Performance Requirements: 4.1.3.1 (Hydrostatic Strength), 4.1.5.1 (Durability - Cycling), 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray - Corrosion), 4.1.8.1 (Vibration Resistance), and 4.1.11.1 (Seals & O-rings).

#### 4.19.2.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.3.2 (Hydrostatic Strength), 4.1.5.2 (Durability - Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion), 4.1.8.2 (Vibration Resistance), and 4.1.11.2 (Seals & O-rings). After 4.1.5.2 (Durability - Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion) and 4.1.8.2 (Vibration Resistance), the actuator shall function as intended.

## 4.20 Pressure Gauges

### 4.20.1 General

Properly calibrated and appropriately selected instrumentation, such as a dead weight tester or a gauge comparator, shall be used for testing, and shall be operated in conformity with their manufacturer's instructions. Generally, a minimum of one unused gauge should be used for each test described herein. Exact sample size and allocation will be determined at the sole discretion of FM Approvals.

### 4.20.2 Durability

#### 4.20.2.1 Requirements

Appearance and ruggedness of the gauge shall be suitable for its intended application. The gauges will be examined for conformity to the manufacturer's drawings and specifications as well as for general acceptability.

#### 4.20.2.2 Test/Verification

Gauges shall exhibit reasonable quality and proper fabrication. They shall be regular and uniform in appearance and free from blemishes. Gauges shall be free from sharp edges and burrs. Cases shall be of sufficiently rugged construction to withstand reasonable handling without damage. "Reasonable handling" shall specifically include hand threading of a gauge into a pipe fitting preparatory to final tightening with a wrench.

### 4.20.3 Readability

#### 4.20.3.1 Requirements

Gauges shall be correctly readable to within one minor scale calibration increment in uniform lighting conditions of 50 lm/ft<sup>2</sup> (538 lux) by an observer whose vision has been corrected to 20/20 and who is stationed 6 ft (1.83 m) from the gauge. Appropriate markings to identify operable range, as applicable, shall be provided with appropriate color indications (i.e., green for “normal” and red for “re-charging”).

#### 4.20.3.2 Test/Verification

Readings during tests shall be taken to eliminate parallax error. A minimum of five observations shall be made, spanning the entire scale range of the gauge.

### 4.20.4 Accuracy

#### 4.20.4.1 Requirements

Gauge accuracy shall be checked against a properly calibrated dead weight tester, or a gauge comparator, at a minimum of five points spanning the full range of the scale.

#### 4.20.4.2 Test/Verification

Readings shall be within plus or minus two percent of the full scale of the actual pressure over the center third of the scale and within plus or minus three percent over the remaining two-thirds, after gentle tapping of the gauge to eliminate frictional effects.

### 4.20.5 Hysteresis

#### 4.20.5.1 Requirements

The required accuracy level per Section 4.20.4 shall be verified in both increasing and decreasing pressure readings.

#### 4.20.5.2 Test/Verification

The five points checked during the accuracy test shall be checked in both ascending and descending order in succession, to evaluate hysteresis error.

### 4.20.6 Overpressure

#### 4.20.6.1 Requirements

The gauge accuracy shall remain within the limits specified in 4.20.4 after it has been overpressurized.

#### 4.20.6.2 Test/Verification

A pressure equal to 150 percent of the full scale range of the gauge shall be applied to the gauge by hydrostatic means for a period of five seconds. The accuracy test shall then be rerun. If the manufacturer specifies that the gauge is suitable for a higher level of overpressure, this test shall be conducted using that level.



#### **4.20.7 Hydrostatic Strength**

##### 4.20.7.1 Requirements

The gauge shall be subjected to a hydrostatic pressure equal to 150 percent of the full scale range, 150 percent of the rated pressure of the gas storage cylinder burst disc (if applicable), or 700 psi (48.3 bar), whichever is greater, for a period of five minutes without rupture. The gauge shall then be pressurized to failure. No broken or ruptured part shall be thrown with such violence as to constitute a hazard to personnel. Generally, no debris shall be thrown outside of a 6 ft (1.8 m) cylindrical volume centered on the vertical centerline of the gauge.

##### 4.20.7.2 Test/Verification

The gauge shall be subjected to a hydrostatic pressure equal to 150 percent of the full scale range, 150 percent of the rated pressure of the gas storage cylinder burst disc (if applicable), or 700 psi (48.3 bar), whichever is greater, for a period of five minutes. The pressure shall then be increased until failure occurs. Failure shall be defined as inability to contain pressure.

#### **4.20.8 Vibration**

##### 4.20.8.1 Requirements

The gauge accuracy shall remain within the limits specified in 4.20.4 after completion of the vibration sequence.

##### 4.20.8.2 Test/Verification

The gauge shall be connected to a manifold and pressurized to approximately 50 percent of its full scale range with air as the pressurizing medium. The gauge and manifold assembly shall be mounted on a vibration test machine and subjected to vibration along the vertical centerline of the gauge. The vibration sequence shall be as described in 4.1.8 (Vibration Resistance).

#### **4.20.9 Wear**

##### 4.20.9.1 Requirements

The gauge accuracy shall remain within the limits specified in 4.20.4 after completion of 20,000 pressure cycles.

##### 4.20.9.2 Test/Verification

The gauge shall be operated 20,000 times between zero and approximately half its maximum scale range by hydrostatic means, at a frequency of approximately 1 hertz.

#### **4.20.10 Salt Spray Corrosion**

##### 4.20.10.1 Requirements

After the Salt Spray Corrosion exposure per Section 4.1.7.1, the gauge shall operate freely and reliably. Exposures to other atmospheres may be required to further evaluate the corrosion resistance of certain materials.

#### 4.20.10.2 Test/Verification

The gauge shall have its inlet sealed and be subjected to the test outlined in 4.1.7.2 (Salt Spray Corrosion). Following the exposure period, the gauge shall be permitted to dry in room atmosphere for two to four days in an upright position. The gauge shall then be disassembled and examined for evidence of stress corrosion cracking of its parts. If no stress corrosion cracking is evident, the gauge should be cleaned as necessary, reassembled, and operated.

### 4.20.11 Moisture

#### 4.20.11.1 Requirements

The gauge accuracy shall remain within the limits specified in 4.20.4 after exposure to moisture.

#### 4.20.11.2 Test/Verification

The gauge shall be mounted in its normal position and approximately one gallon (3.8 L) of tap water shall be poured over the gauge twice per day for 10 days. Each pour shall last approximately 20 seconds. The gauge shall then be allowed to dry in the same position, in ambient conditions, for five days.

## 4.21 Pressure Control Devices - Automatic - Dump - Reducing - Reducing Station - Regulating - Relief - Restricting - Safety - Unloader Valves

### 4.21.1 Diaphragm Strength

#### 4.21.1.1 Requirements

Any diaphragm supplied shall withstand a strength test without tear, rupture, or other failure.

#### 4.21.1.2 Test/Verification

Diaphragms in either the pressure relief valve or the associated devices shall be subjected to a hydrostatic pressure of two times the maximum system operating pressure or 350 psi (24 bar), whichever is greater, for five minutes. During, and at the conclusion of, this test, there shall be no evidence of leakage or functional impairment.

### 4.21.2 Disc/Plug Assembly, or Equivalent Component Strength

#### 4.21.2.1 Requirements

The valve disc/plug assembly or equivalent component shall withstand strength testing without fracture, permanent distortion, or functional impairment.

#### 4.21.2.2 Tests/Verification

With the inlet open to atmosphere, a hydrostatic pressure of two times the maximum system operating pressure shall be applied to the outlet of the pressure relief valve. This pressure shall be maintained for five minutes. During and at the conclusion of this test, no leakage, fracture, permanent distortion, or functional impairment shall occur.

### 4.21.3 Operating Pressure

#### 4.21.3.1 Requirements

Operational components of each size shall be tested in an as received condition to determine their pressure operating characteristics and minimum operating pressure. After the valve has been pressurized to the rated set pressure, and the opening pressure has been verified, it shall reseat itself leak tight at no less than 90 percent of the operating pressure. The pressure at which the plug/disc opens shall be within  $\pm 5$  percent of the valve set pressure.

#### 4.21.3.2 Test/Verification

The pressure at which the seat/disc opens shall be measured and recorded. The inlet pressure shall then be increased to at least 102 percent of the recorded operating pressure to ensure a clear opening. The pressure shall be reduced slowly until the valve reseats and seals. The reseating pressure shall be measured and recorded. This test shall be repeated three times, with all three readings being satisfactory.

### 4.21.4 Durability - Cycling

#### 4.21.4.1 Requirements

At the conclusion of the cycle operational test, the spring of a pressure control device shall show no signs of fatigue failure, and the test valve shall meet the requirements of Sections 4.1.1.1 (Examination) and 4.1.2.1 (Valve Seat Leakage).

#### 4.21.4.2 Tests/Verification

The sample shall be subjected to fluctuating pressure, from zero to the maximum system operating pressure, in the direction to exercise the spring, at a rate of no more than 10 cycles per minute for a total of 20,000 cycles. Following this test, the component shall be visually examined for signs of excessive wear or damage. Post testing shall include Sections 4.1.1 (Examination) and 4.1.2.2 (Valve Seat Leakage).

### 4.21.5 Additional Performance Tests (as applicable)

#### 4.21.5.1 Requirements

General Performance Requirements: 4.1.1.1 (Examination), 4.1.2.1 (Valve Seat Leakage) 4.1.3.1 (Hydrostatic Strength), 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray - Corrosion), 4.1.8.1 (Vibration Resistance), 4.1.9.1 (Valve Locking/Supervision Ability), 4.1.10.1 (Friction Loss Determination), and 4.1.11.1 (Seals & O-rings).

#### 4.21.5.2 Tests/Verifications

General Performance Tests/Verification Procedures: 4.1.1.2 (Examination), 4.1.2.2 (Valve Seat Leakage), 4.1.3.2 (Hydrostatic Strength), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion), 4.1.8.2 (Vibration Resistance), 4.1.9.2 (Valve Locking/Supervision Ability), 4.1.10.2 (Friction Loss Determination) and 4.1.11.2 (Seals & O-rings).

## 4.22 Pressure Switches

### 4.22.1 Dielectric Strength

#### 4.22.1.1 Requirement

Electrical components shall be capable of withstanding an applied voltage between all terminals provided for external connections and ground. There shall be no arcing or breakdown, and components shall continue to function properly subsequent to this test.

#### 4.22.1.2 Test/Verification

A test voltage of 1000 V, AC, plus twice the rated operating voltage, shall be applied between electrical terminals and ground for a period of one minute.

Exception: For operating voltages of 54 V or less the test voltage shall be 500 V, AC.

### 4.22.2 Additional Performance Requirements (as applicable)

#### 4.22.2.1 Requirements

General Performance Requirements: 4.1.3.1 (Hydrostatic Strength) 4.1.4.1 (Operating Pressure), 4.1.5.1 (Durability - Cycling), 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray - Corrosion), and 4.1.8.1 (Vibration Resistance).

#### 4.22.2.2 Tests/Verifications

General Performance Tests/Verification Procedures: 4.1.3.2 (Hydrostatic Strength), 4.1.4.2 (Operating Pressure), 4.1.5.2 (Durability - Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion) and 4.1.8.2 (Vibration Resistance). After 4.1.5.2 (Durability - Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion) and 4.1.8.2 (Vibration Resistance), the pressure switch shall function as intended.

## 4.23 Sequence (Cycle) Box (Fire Alarm Signaling System)

Detection devices should be evaluated and tested for functionality and compatibility with electrical specifications of the electrically operated equipment associated with the hybrid fire extinguishing system, including the actuating solenoid, fire detection automatic releases, fire alarm signaling system, etc. The Approval examination shall be in accordance with the *Approval Standard for Fire Alarm Signaling Systems* (3010). Manufacturers are strongly encouraged to use FM Approved detection devices.

This standard provides information regarding the typical tests that are required by FM Approvals. FM Approvals reserves the right to modify this outline as required to suit the specific tests needs of a given piece of equipment. Performance requirement testing may include: Enclosures, Normal Operation, Power Supply/Electrical Supervision, Circuit Supervision (IDC), Smoke Detector Compatibility, Circuit Supervision (NAC), Circuit Supervision (SLC), SLC Device Compatibility, Voltage Variations, Environmental Conditioning, Battery Charge/Discharge, Vibration, Dielectric/Shock, Equipment Load Rating, Battery Circuit Reverse Polarization, Protective Grounding, Protection From Fire, RFI Immunity, Surge Line Transient Tests and Marking Requirements.

Optional special system features and/or applications that may need to be examined and evaluated include: Release Circuits for Automatic Extinguishing Release Applications and Pre-Action and Deluge Release Applications, Cross Zoning, Confirmation/Verification, Pre-signal, Positive Alarm Sequence, Drift Compensation, Guards Tour, Emergency Voice/Alarm Communications Service, Sound Pressure Level Tests, Auxiliary Service, Central Supervising Station Systems, Remote Supervisory Station Systems and Proprietary Supervisory Station Systems.

The *Approval Standard for Fire Alarm Signaling Systems* (3010) performance requirements are largely based on NFPA 72, *National Fire Alarm Code*, and other applicable FM Standards. References to the appropriate NFPA standard and paragraph describing the specific requirement pertaining to a fire alarm signaling system may be included.

Testing may be waived at the sole discretion of FM Approvals if original test data from other international testing laboratories is submitted and considered satisfactory.

## 4.24 Sight Glass

### 4.24.1 Hydrostatic Pressure Test

#### 4.24.1.1 Requirement

The sight glass shall withstand a hydrostatic pressure equivalent to 150 percent of the water storage tank system pressure or 700 psi (48.3 bar), whichever is greater, without rupture, cracking or permanent distortion.

#### 4.24.1.2 Test/Verification

A sample liquid sight glass shall be subjected to a hydrostatic pressure equivalent to 150 percent of the water storage tank system pressure or 700 psi (48.3 bar), whichever is greater, for a duration of five minutes.

### 4.24.2 Impact Test

#### 4.24.2.1 Requirement

A liquid sight glass shall withstand, without cracking or damage, the impact test outlined in 4.24.2.2.

#### 4.24.2.2 Test/Verification

The sample shall be conditioned to the minimum usage temperature specified by the manufacturer for a period of 16 hours. The sample shall then be subjected to an impact energy of 2.0 ft-lbf (2.7 joules) resulting from a test mass of 4 lbm (1.8 kg) falling vertically from a height of 6 in. (150 mm). The test mass shall be a steel hemisphere of 1 in. (20 mm) diameter. The liquid sight glass shall be positioned on a concrete surface to simulate rigid installation and the test weight directed to impact any surface of the equipment that may be affected. It is unnecessary to subject any one location to more than one impact. Subsequent to the impact, the liquid sight glass shall be examined for cracks or damage and subjected to a leakage test at the maximum working pressure.

## 4.25 Solenoid Valves

### 4.25.1 Equipment Assembly Ratings (Voltage Variation)

#### 4.25.1.1 Requirement

A sample solenoid valve of each voltage rating shall operate properly over a primary source voltage range of 85 to 110 percent of the rated voltage while at the maximum and minimum specified installation temperatures. There shall be no change in operating characteristics, or failure to respond to limit alarms and trip points.

#### 4.25.1.2 Test/Verification

A sample solenoid valve shall be conditioned to the minimum specified installation temperature for 16 hours. While still at that temperature, the sample shall be mounted in the position of normal use, and shall be subjected to a source voltage range from 85 to 110 percent of the rated voltage with the associated pressure for the minimum temperature applied to the valve seat. Activation voltage and current shall be documented.

The sample shall then be conditioned to the maximum specified installation temperature for 16 hours. While still at that temperature, the sample shall be mounted in the position of normal use and shall be subjected to a source voltage range from 85 to 110 percent of the rated voltage with the associated pressure for the maximum temperature applied to the valve seat. Activation voltage and current shall be documented.

### 4.25.2 Dielectric Strength

#### 4.25.2.1 Requirement

Electrical components shall be capable of withstanding an applied voltage between all terminals provided for external connections and ground. There shall be no arcing or breakdown, and components shall continue to function properly subsequent to this test.

#### 4.25.2.2 Test/Verification

A test voltage of 1000 V, AC, plus twice the rated operating voltage, shall be applied between electrical terminals and ground.

Exception: For operating voltages of 54 V or less the test voltage shall be 500 V, AC.

### 4.25.3 Additional Performance Tests (as applicable)

#### 4.25.3.1 Requirements

General Performance Requirements: 4.1.1.1 (Examination), 4.1.2.1 (Valve Seat Leakage) 4.1.3.1 (Hydrostatic Strength), 4.1.4.1 (Operating Pressure), 4.1.5.1 (Durability - Cycling), 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray - Corrosion), 4.1.8.1 (Vibration Resistance), 4.1.9.1 (Valve Locking/Supervision Ability), 4.1.10.1 (Friction Loss Determination), and 4.1.11.1 (Seals & O-rings).

#### 4.25.3.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.1.2 (Examination), 4.1.2.2 (Valve Seat Leakage) 4.1.3.2 (Hydrostatic Strength), 4.1.4.2 (Operating Pressure), 4.1.5.2 (Durability - Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion), 4.1.8.2 (Vibration Resistance), 4.1.9.2 (Valve Locking/Supervision Ability), 4.1.10.2 (Friction Loss Determination), and 4.1.11.2 (Seals & O-rings).

## 4.26 Suction Filters/Strainers

### 4.26.1 Hydrostatic Pressure Test

#### 4.26.1.1 Requirement

The corrosion resistant strainer body shall be able to withstand a hydrostatic pressure equivalent to 150 percent of the maximum system operating pressure, but not less than 700 psi (48.3 bar), without rupture, cracking or permanent distortion. The strainer perforations shall be able to withstand a hydrostatic pressure equivalent to 120 percent of the maximum system operating pressure, but not less than 500 psi (34.5 bar), without deformation of the filter.

#### 4.26.1.2 Test/Verification

A sample corrosion resistant strainer body shall be subjected to a hydrostatic test pressure of 150 percent of the maximum system operating pressure, but not less than 700 psi (48.3 bar), for a duration of five minutes. Subsequently, the strainer perforations shall be plugged and the strainer inlet side shall be subjected to a hydrostatic test pressure equal to 120 percent of the maximum system operating pressure, but not less than 500 psi (34.5 bar), for a duration of five minutes.

### 4.26.2 Filter Rating or Strainer Mesh Opening

#### 4.26.2.1 Requirement

The maximum filter rating or strainer mesh openings shall be 80 percent of the minimum nozzle waterway dimension and shall be sized to include the friction loss for the required supply flow and duration, accounting for the condition of the water and similar local circumstances.

#### 4.26.2.2 Test/Verification

A sample filter or strainer shall be subjected to an optical examination for size determination, and shall be subjected to testing per Section 4.1.10 (Friction Loss Determination).

### 4.26.3 Additional Performance Tests (as applicable)

#### 4.26.3.1 Requirements

General Performance Requirements: 4.1.1.1 (Examination) and 4.1.7.1 (Salt Spray - Corrosion).

#### 4.26.3.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.1.2 (Examination) and 4.1.7.2 (Salt Spray - Corrosion).

## 4.27 Hybrid Fire Extinguishing System Pumps

### 4.27.1 Documentation Requirements

Engineering drawings and calculations shall be submitted for review to show:

- Pump body design strength.
- Pump body bolt strength.
- Bearing life calculations.
- Shaft strength calculations.
- Hybrid system fire pump installation plan.

The pump package should be arranged and configured in accordance with the following:

- FM Global Property Loss Prevention Data Sheet Number 3-7N, *Stationary Pumps for Fire Protection*.
- FM Global Property Loss Prevention Data Sheet Number 4-0, *Special Protection Systems*.
- NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, Chapter 8, Section 8.3.
- NFPA 750, *Standard on Water Mist Fire Protection Systems*, Chapter 5, Section 5.9.

Reference Figure 4.27, “Typical System Pump Piping and Fittings.” No automatic fire pump shut-off features are permitted in the fire pump installation design. A strainer or filter shall be included prior to the system pump.

#### 4.27.2 Hydraulic Pump Performance

##### 4.27.2.1 Requirements

The pump shall develop its specified total head when delivering its rated capacity at the rated speed and the most extreme positive and negative inlet pressure conditions (maximum flooded suction and maximum suction lift) specified by the manufacturer.

The maximum power required shall be determined.

##### 4.27.2.2 Test/Verification

A minimum of one sample pump of each type and rated capacity shall be tested. The pump shall be operated at various flow rates and speeds, if applicable, to generate total head, power, and efficiency curves. A minimum of five flow readings shall be taken to generate the curves. Test fluid temperature shall be continuously monitored. The suction and discharge pressures, power required, and speed shall be measured. All test speeds must be within  $\pm 4$  percent of the rated speed. Test data shall be corrected to rated speed, by means of affinity relationships, in order to develop characteristic curves.

The performance of the pump shall also be verified at the maximum flooded suction and suction lift specified in the manufacturer’s design, installation, operation, and maintenance manual. At each of these conditions, there shall be no inability to maintain specified net head or speed, loosening or distortion of any part(s), overheating, or cavitation as evidenced by an increase in noise or excessive fluid temperature.

In determining pump capacity requirements and testing the hydraulic pump performance, consideration shall be given to the maximum number of operating nozzles for the hydraulically most remote installation design allowed by the manufacturer’s installation instructions, including required hose stream demands, and to the installation requirements of FM Global Property Loss Prevention Data Sheet Number 4-0, *Special Protection Systems*. Each nozzle type, if different K-factors are used, shall be considered.

Tests, correction calculations to rated speeds, and net positive inlet pressure requirements (NPIPR) determination shall be conducted in conformance to ANSI/HI Standard 3.6, American National Standard for Rotary Pump Tests. Alternatively, another national or internationally recognized standard appropriate to the specified pump design and intended market for the pump may be used at the sole discretion of FM Approvals.

Additional information regarding testing of various types of pumps is located in the following documents:

- *Approval Standard for Centrifugal Fire Pumps Split-Case Type (Axial or Radial)* (Class 1311).
- *Approval Standard for Centrifugal Fire Pumps (Vertical Shaft Turbine Type)* (Class 1312).
- *Approval Standard for Positive Displacement Fire Pumps (Rotary Gear Type)* (Class 1313).
- *Approval Standard for Centrifugal Fire Pumps (Horizontal End Suction Type)* (Class 1319).



### 4.27.3 Endurance Test

#### 4.27.3.1 Requirements

The pump shall be capable of continuous operation for 24 hours under the conditions stated in Section 4.27.3.2, without excessive vibration, loosening of parts, visible distortion of the baseplate, excessive generation of heat in the bearings or interfaces between moving and stationary parts, or rubbing of the rotor or of other moving parts.

#### 4.27.3.2 Tests/Verification

A sample pump shall be operated continuously for 24 hours at maximum speed and maximum capacity. No loosening, distortion, overheating, or degradation of performance shall be allowed. Following the test, the pump shall be disassembled and examined for signs of rubbing. A method of ensuring that the pump runs continuously for 24 hours must be provided. All test speeds must be within  $\pm 4$  percent of the rated speed.

### 4.27.4 Flange and Gasket Tightness

#### 4.27.4.1 Requirement

No leakage, except at the shaft packing, shall be observed when the pump casing and cover is hydrostatically tested at the required pressure for five minutes.

#### 4.27.4.2 Test/Verification

A sample pump casing and cover of each model and material shall be hydrostatically tested to a pressure greater than or equal to the sum of the maximum rated differential pressure of the pump plus the maximum allowable suction pressure specified by the pump manufacturer ( $P_{\max} + P_{\max. \text{Suction}}$ ). The maximum rated differential pressure,  $P_{\max}$ , is the highest relief valve setting specified for Approval. The test pressure shall be maintained for five minutes. In no case shall the maximum allowable suction pressure,  $P_{\max. \text{Suction}}$ , be less than 75 psi (5.2 bar), or the leakage test be conducted at a pressure less than 250 psi (17.3 bar). Casing bolts normally provided with the pump shall be used for this test.

### 4.27.5 Hydrostatic Strength

#### 4.27.5.1 Requirements

No rupture, cracking, or permanent distortion of any part of the pump shall be observed when the pump is hydrostatically tested at the required pressure for five minutes.

#### 4.27.5.2 Tests/Verification

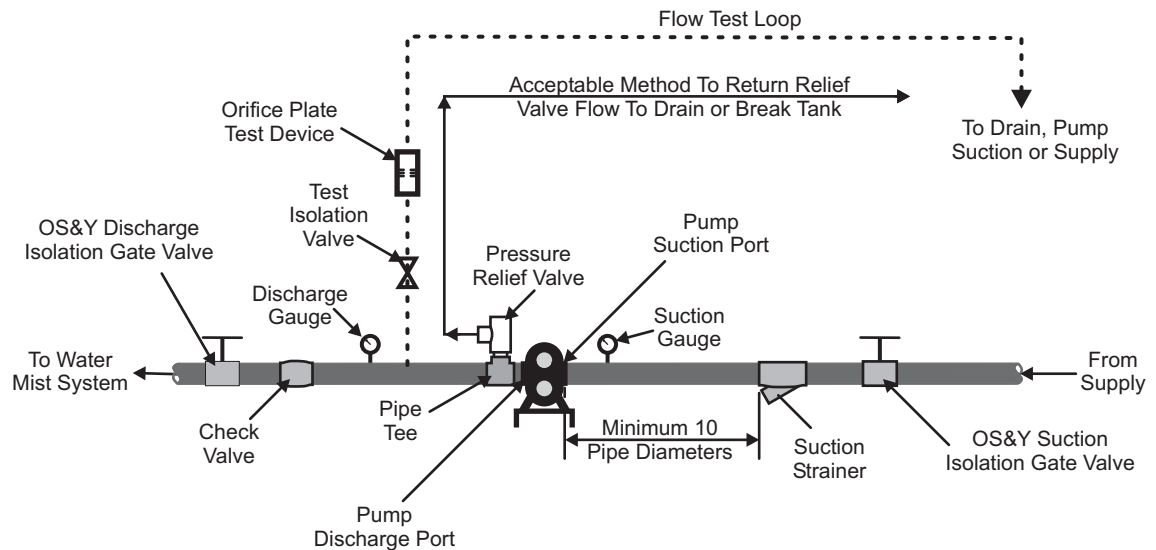
A sample casing of each model and material shall be hydrostatically tested to a pressure greater than or equal to twice the sum of the maximum rated pressure differential of the pump plus a maximum allowable suction pressure specified by the pump manufacturer,  $2 \times (P_{\max} + P_{\max. \text{Suction}})$ . The maximum rated differential pressure,  $P_{\max}$ , is the highest relief valve setting specified for Approval. The test pressure shall be maintained for five minutes. In no case shall the maximum allowable suction pressure,  $P_{\max. \text{Suction}}$ , be less than 75 psi (5.2 bar), or the test be conducted at a pressure less than 400 psi (27.6 bar). Casing bolts normally provided with the pump shall be used for this test.

#### 4.27.6 Pressure Relief Valves

Pressure relief valves shall comply with the requirements outlined in the following documents:

- FM Global Property Loss Prevention Data Sheet Number 3-7N, *Stationary Pumps for Fire Protection*.
- FM Global Property Loss Prevention Data Sheet Number 4-0, *Special Protection Systems*.
- NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, Chapter 8, Section 8.3.
- *FM Approval Standard for Hybrid (Water and Inert Gas) Fire Extinguishing Systems (Class 5580)*, Section 4.21 (Pressure Control Devices - Automatic - Dump - Reducing - Reducing Station - Regulating - Relief - Restricting - Safety - Unloader Valves).

Figure 4.27. Typical Hybrid Fire Extinguishing System Pump Piping and Fittings



### 4.28 Water Storage Tanks

#### 4.28.1 Documentation Review

##### 4.28.1.1 Requirements

Documentation shall be submitted prior to testing to verify that the manufacturer of the water tank is authorized to fabricate a pressure vessel meeting the requirements of the ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1, or equivalent. The requirements of FM Global Property Loss Prevention Data Sheet Number 3-2, *Water Tanks for Fire Protection*, shall also be verified.

##### 4.28.1.2 Test/Verification

Documentation shall be reviewed to verify that the manufacturer of the pressure vessel is performing the inspection and tests that apply to the water storage tank, as described in Part UG-90 and Subsections B and C of the ASME *Boiler and Pressure Vessel Code*, Section VIII, Division 1, or equivalent.

The storage cylinders should be fabricated, tested, approved, and provided with labeling in accordance with recognized, international standards, such as the current specifications of the ASME *Boiler and Pressure Vessel Code*, Section VIII, or the requirements of U.S. Dept. of Transportation, Title 49, *Code of Federal Regulations*, Parts 171 to 190, Sections 178.36 and 178.37, specifications for DOT-3A, 3AA-1800, or higher, seamless steel cylinders, or equivalent national codes for the country of use. The design working pressure shall be in accordance with the manufacturer's listing.

If the system is to be installed outside the United States, the pressure vessel shall comply with the regulations of the country in which it is to be installed.

#### **4.28.2 Additional Performance Tests (as applicable)**

##### **4.28.2.1 Requirements**

Should documentation be insufficient, the following General Performance Requirements may be required: 4.1.3.1 (Hydrostatic Strength), 4.1.6.1 (Extreme Temperatures Operation) 4.1.7.1 (Salt Spray - Corrosion), 4.1.8.1 (Vibration Resistance), 4.1.11.1 (Seals & O-rings), 4.9.2.1 (One Year Leakage Loss Test), 4.9.3.1 (Extreme Low Temperature Test), and 4.9.4.1 (Extreme High Temperature Test).

##### **4.28.2.2 Tests/Verifications**

General Performance Requirement Test Procedures: 4.1.3.2 (Hydrostatic Strength), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion), 4.1.8.2 (Vibration Resistance), 4.1.11.2 (Seals & O-rings), 4.9.2.2 (One Year Leakage Loss Test), 4.9.3.2 (Extreme Low Temperature Test), and 4.9.4.2 (Extreme High Temperature Test).

#### **4.29 Water Valves (Control)**

##### **4.29.1 Performance Tests (as applicable)**

##### **4.29.1.1 Requirements**

General Performance Requirements: 4.1.1.1 (Examination), 4.1.2.1 (Valve Seat Leakage), 4.1.3.1 (Hydrostatic Strength) 4.1.4.1 (Operating Pressure), 4.1.5.1 (Durability - Cycling), 4.1.6.1 (Extreme Temperatures Operation), 4.1.8.1 (Vibration Resistance), 4.1.9.1 (Valve Locking/Supervision Ability) and 4.1.10.1 (Friction Loss Determination).

##### **4.29.1.2 Tests/Verifications**

General Performance Requirement Test Procedures: 4.1.1.2 (Examination), 4.1.2.2 (Valve Seat Leakage), 4.1.3.2 (Hydrostatic Strength), 4.1.4.2 (Operating Pressure), 4.1.5.2 (Durability - Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.8.2 (Vibration Resistance), 4.1.9.2 (Valve Locking/Supervision Ability) and 4.1.10.2 (Friction Loss Determination).

#### **4.30 Pipe Hangers and Hydraulic Tube Clamping Components**

Distribution piping support hangers and components should be FM Approved. Hydraulic tube clamping and components and other water or gas agent piping attachments should be evaluated and tested for functionality and compatibility with manufacturer's distribution system. The examination shall be in accordance with the *Approval Standard for Pipe Hanger Components* (Class 1951, 1952 and 1953).

### 4.31 Hydraulic Calculations Method

#### 4.31.1 Calculation Method

Hydraulic calculations for twin fluid systems may be conducted as follows:

1. Determine the water pressure required at the most remote nozzle using nozzle specifications supplied by the manufacturer. Determine the flow rates and pressure at each nozzle location.
2. Determine the water pressure and flow rates at each nozzle from information provided by the nozzle manufacturer.
3. Calculate the pneumatic piping system independently to verify that the pipe sizes are adequate to provide the required pressure and flow at each nozzle and that the system is sized to provide the flow rate and pressure needed.

The Hazen-Williams calculation method for hydraulic calculations may be used for the piping in low pressure hybrid systems containing a single fluid (i.e., water). For copper and stainless steel piping or tubing, Hazen-Williams C values of 150 may be used.

The Darcy-Weisbach calculation method for hydraulic calculations shall be used for the piping in intermediate and high pressure systems containing a single fluid (i.e., water), and for the piping in low pressure systems that cannot be calculated using the Hazen-Williams method.

#### 4.31.2 Computer Program

The hydraulic computer calculation program and design manual shall be submitted to conduct sample calculations to verify its accuracy. The extinguishing systems used in the test program and hand calculations will be reviewed for verification of the design criteria.

#### 4.31.3 Verification of Flow

Representative hybrid systems may be subject to verification of flow calculation tests. These tests will be conducted to verify the accuracy of the hydraulic calculations to the actual event. The following parameters should be verified for accuracy:

- Minimum and maximum discharge time
- Types of tee splits to be used
- Minimum pipeline flow rates
- Maximum and minimum pipe diameter increase
- Variance of pipe volume to each nozzle
- Maximum and minimum pipe diameter decrease
- Maximum variance in nozzle pressure

#### 4.32 Design, Installation, Operation and Maintenance Manual

Design, installation, operation, and maintenance instruction manual(s) shall be submitted for review. An English version of this manual should be submitted to FM Approvals.

The review by FM Approvals and FM Global Engineering Standards shall verify compliance to the requirements outlined by FM Global Property Loss Prevention Data Sheet Number 4-0, *Special Protection Systems*. The manual(s) should also reflect those requirements that are applicable to hybrid fire extinguishing systems, as outlined in the following sections.

- The manual(s) shall provide a description and operating details of all equipment associated with the fire protection system by part and/or model number.
- The mode of fire protection (control, suppression, or extinguishment) afforded by the system shall be indicated.
- The manual(s) shall specify the size, schedule, supporting method, and material for all piping, tubing, and fittings, as well as allowable shapes.
- The installation instructions shall be clear and concise and specify all limitations and restrictions. Diagrams of typical system installations shall be included for typical hazards.
- Any variations of the system shall be discussed in detail, including the limitations and restrictions of each system. The manual(s) shall clearly identify which configurations are FM Approved by FM Approvals.
- The manual(s) shall specify all nozzle(s) performance criteria including, but not limited to, maximum ceiling heights, spacing and arrangement, flow rates, area of coverage, spray angle, and specified density.
- If applicable, the manual(s) shall also describe the design requirements with regard to the hybrid media safety factor, as described in Section 1.2.4 and Appendix A. This should include the method(s) employed to achieve the additional hybrid media supply, including reduced nozzle spacing, reduced protected enclosure area, and/or additional nozzle placement requirements. This safety factor shall not be accounted for by increasing the discharge rates of individual nozzles.
- The manual(s) shall clearly identify all requirements for detection and actuation.
- The manual(s) shall state if the fire protection systems can be interconnected. If the systems can be interconnected, the manual(s) shall clearly indicate how the system interconnections are accomplished.
- The manual(s) shall state the ambient operating temperature range of the fire protection system. If the nozzles and delivery system have different temperature ranges, these shall be specifically noted.
- The minimum and maximum operating pressures of the system and its sub-systems shall be clearly specified at ambient 70 °F (21 °C) conditions, and at the minimum and maximum operating temperatures.
- The manual(s) shall specify the required acceptance and commissioning procedures, as described in Section 4.33.
- The manual(s) shall specify the required inspection and maintenance for the system. In addition, the manual(s) shall specify the frequency and method of the inspections and maintenance.
- The manual(s) shall contain detailed instructions for restoring the complete system to full operation after a complete or partial discharge. In addition, the manual(s) shall specify the estimated time to return the system to operation.
- The manual(s) shall identify either a date or revision to the manual, as well as a designation number, and shall be provided with a means by which the user can readily identify if the manual(s) are of the current revision. These items are to be identified on each page of the manual.
- The manual(s) shall identify the manufacturer or private labeler, address, contact and service information.
- If there are references to other manuals, these publications should be included or summarized so that information needed for proper installation is available.
- The manual(s) shall address design considerations, including structural strength and integrity, and enclosure leakage and venting, to account for pressure effects within the protected enclosure resulting from system discharge.
- The manual(s) shall address life safety considerations to account for potentially low oxygen concentrations within the protected enclosure resulting from system discharge.

### 4.33 System Acceptance and Commissioning Documentation

- 4.33.1 All hybrid fire extinguishing systems shall successfully meet all system acceptance and commissioning procedures and should be documented with copies to the system owner and manufacturer (at a minimum).
- 4.33.2 All acceptance and commissioning procedures shall be reviewed by FM Approvals. Changes requested by FM Approvals may be mandatory prior to the granting of Approval.
- 4.33.3 Acceptance and commissioning testing should include the following, at a minimum, and shall be documented in the manufacturer's design, installation, operation, and maintenance manual(s):
  - 4.33.3.1 Acceptance procedures shall be in accordance with FM Global Property Loss Prevention Data Sheet Number 4-0, *Special Protection Systems*, or the equivalent national code of the country of use.
  - 4.33.3.2 An appropriate Authority Having Jurisdiction representative should be given advance notice of such testing and be present for commissioning of the system.
  - 4.33.3.3 A trained manufacturer's representative should be present to properly test and reset the system following the acceptance test.
  - 4.33.3.4 FM Global recommends a full discharge test to verify nozzle layout, and discharge pattern. Flow tests also are intended to determine whether obstructions would interfere with the operation of the system and whether smaller piping and nozzle orifices flow free and clear and are not subject to clogging by foreign matter in the water. The use of a test connection will not allow for verification of these critical system performance criteria.
  - 4.33.3.5 During the discharge test, replace one of the nozzles with a pressure gauge or transducer and record or observe readings to verify proper discharge pressure, consistent with the design calculations.
  - 4.33.3.6 Operate the maximum number of nozzles or systems (when multiple systems are installed) that are expected to operate at the same time.
  - 4.33.3.7 Test all operating parts of the system to verify their proper function. In addition to direct system operating components, this shall include the operation of dampers, ventilation shutoffs, fuel shutoffs, door closures, and other electrical supplies to the protected area.
  - 4.33.3.8 Information regarding the status of the equipment in the protected enclosure during the discharge test shall be provided. If machinery is shut down for the purposes of the discharge test, independent tests shall be conducted to verify the proper operation of machine shutdowns following system operation.
  - 4.33.3.9 Inspect, clean, and replace filters and strainers if necessary.
  - 4.33.3.10 Information regarding personnel safety during the discharge test shall be provided by the manufacturer. This should include, at a minimum, safety precautions related to high pressure water discharge, inhalation of atomized contaminants, low oxygen concentration, and noise concerns. The potential for low oxygen concentrations should be evaluated with straight discharge tests (no fire) during the hybrid fire extinguishing system fire tests per Section 4.34.
  - 4.33.3.11 The use of personal protective equipment (PPE), including eye and hearing protection, protective clothing, respirators, and other PPE, should be required, as applicable. In the event that personnel cannot witness the discharge as a result of safety concerns, consideration should be given to the use of video cameras to verify the discharge.
  - 4.33.3.12 Documentation and/or calculations verifying that the integrity of the enclosure is sufficient to withstand the discharge of the hybrid fire extinguishing system for the conditions in the hazard. If the integrity of the structure cannot be verified, proper venting shall be provided and documented.

- 4.33.3.13 The manufacturer, or assigned representative, shall provide a copy of the acceptance and commissioning test results. Documentation shall identify the individual who conducted the tests, and shall be left on site with the owner of the hybrid fire extinguishing system, at a minimum.

#### **4.34 Hybrid Fire Extinguishing System Classification Tests**

Prior to any performance testing of the system and components, the system shall be evaluated in accordance with Appendix A to properly classify it as a hybrid extinguishing system.

#### **4.35 Fire Tests**

Hybrid fire extinguishing systems for a particular application shall successfully meet all fire test performance requirements for that application, as described in the Appendices B through H.

#### **4.36 Additional Tests**

Additional tests, including performance tests of any accessories or 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 controller, 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 with adequate technical justification of the conditions and reasons for failure.

## **5. OPERATIONS REQUIREMENTS**

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

### **5.1 Demonstrated Quality Control Program**

#### **5.1.1 Quality Assurance Program**

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; (if applicable)
- Final inspection and tests;
- Equipment calibration;
- Drawings, operating manuals, and specific test procedures change control;
- Product labeling;
- Packaging and shipping;
- Handling and disposition of non-conformance materials.

### 5.1.2 Documentation/Manual

There shall be an authoritative collection of quality 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 should require that sufficient records are maintained to demonstrate achievement of the required quality and verify operation of the quality system.

Reference: FM Approvals, *Quality Assurance Guidelines for Manufacturer's of FM Approved and Specification Tested Products*, October 2003.

### 5.1.3 Records

To assure adequate traceability of materials and products, the manufacturer shall maintain a record of all quality assurance tests performed and shall maintain this record for a minimum period of two years from the date of manufacture.

### 5.1.4 Drawing, Specification, and Document and Change Control

The manufacturer shall establish a system of product configuration control that shall not allow unauthorized changes to the product. Revisions to critical documents, identified in the Approval Report, must 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 revisions to FM Approvals before implementation. The manufacturer shall notify FM Approvals of changes in the product or of persons responsible for keeping FM Approvals advised by means of FM Approvals Form 797, Approved Product/Specification-Tested Revision Report or Address/Main Contact Change Report. Records of all revisions to all FM Approved products shall be maintained. In situations involving significant modifications to an FM Approved product, the notification shall be in the form of a formal request for an Approval examination. Records of all revisions to all FM Approved products shall be maintained. Forms 797 are provided to the manufacturer by FM Approvals.

In summary, when a manufacturer revises a drawing, specification, or document which is listed in the controlled document list of the Approval Report, the manufacturer's representative must submit a Form 797 to FM Approvals by mail or electronically. The following information must be included: the revised drawing which clearly specifies the change and reason for the change; the product model and size affected; the original FM Approvals Project ID(s); and the appropriate FM Approvals representative, who should be one of the two signatories of the original Approval Report.

5.1.4.1 The table below has been included as a guide to manufacturers of what is considered to be a significant change to FM Approvals. As mentioned above, modifications that fit this category shall be documented by means of a letter stating the change, and requesting a quotation for an Approval examination.



<i>Modification</i>	<i>Description/Example</i>
Increase of Pressure Rating	The system was originally Approved for 175 psi (12.1 bar), and now is to be evaluated to 300 psi (20.8 bar).
Addition of Product Sizes	The system was originally Approved for 1 – 4 inch NPS, and now Approval of 6 and 8 inch NPS is desired.
Addition of a New or Alternate Component	The system was originally Approved without a pressure switch, and a pressure switch will now be added to the system.
Addition or Relocation of the Manufacturing Location	The product was originally Approved in location A, and now is desired to be made in locations A and B, or only in location B.
Change in Manufacturing Process	Change of a pressure containing component from machined bar stock to a sand casting.
Changes to Critical Design, Dimensions, Materials, Hydraulic and Electrical Components.	<ul style="list-style-type: none"> <li>• Pressure containing component wall thickness.</li> <li>• Modifications to a component's shape and/or material.</li> <li>• Dimension changes to hybrid nozzles.</li> </ul>
Change in the supplier of a purchased part.	The system originally included a valve manufactured by Company A, and will now include a similar valve manufactured by Company B.

5.1.4.2 The table below has been included as a guide to manufacturers of modifications that are commonly submitted on FM Approvals Form 797.

<i>Modification</i>	<i>Description/Example</i>
Change in Company Contact Information	Name, Title, Phone Number, Fax Number, Email Address, Company Office Address, Company Name
Updating of Drawings	The Form 797 is used to notify FM Approvals in the event of minor dimensional changes to non-critical features, minor changes in notes, location of title block, re-creation of the same drawing on CAD, etc.
Changes in Markings	Describe what changes are to be made and include a drawing of the proposed marking.
Changes in Materials	Where new material is either superior, or comparable to the material used in the original Approval
Updating of Documentation	Creation of new, or revisions to, sales literature, Design, Installation, Operation, and Maintenance Manual, , Quality Manual, etc.

5.1.4.3 For instances where the modification is difficult to categorize, manufacturers are encouraged to contact FM Approvals to discuss the nature of the change, and inquire about how to send the information to FM Approvals. The examples shown in Sections 5.1.4.1 and 5.1.4.2 are based on common examples of modifications as they relate to the manufacture of hybrid fire extinguishing systems.

5.1.4.4 FM Approvals, at its sole discretion, shall determine when additional testing is necessary to validate proposed changes.

## 5.2 Facilities and Procedures Audit (F&PA)

- 5.2.1 An audit of the manufacturing facility is part of the Approval investigation to verify implementation of the quality assurance program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to insure a consistently uniform and reliable product. Initial inspections of facilities already producing similar Approved products may be waived at the discretion of FM Approvals.
- 5.2.2 Unannounced follow-up inspections shall be conducted at least annually by FM Approvals, or its designate, to determine continued compliance. More frequent audits may be required by FM Approvals. Satisfactory field experience is the final test of Approval. Unsatisfactory field experience because of FM Approved equipment malfunction may necessitate withdrawal of Approval. Satisfactory field experience often is determined by the adequacy of the final layout and installation in the FM Global insured location.
- 5.2.3 FM Approved products or services shall be produced or provided at, or from, the location(s) audited by FM Approvals, as specified in the Approval Report. Manufacture of products bearing the FM Approvals Certification Mark is not permitted at any other locations without prior written authorization by FM Approvals.

## 5.3 Installation Inspections

Field installation inspections may be conducted to review an installation. The inspections are conducted to assess ease of application, and conformance to written specifications. When more than one application technique is used, one or all may be inspected at the sole discretion of FM Approvals.

## 5.4 Manufacturer's Responsibilities

- 5.4.1 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.
- 5.4.2 Where all or part of the quality control has been subcontracted, the manufacturer shall, at a minimum, conduct sufficient oversight audits to verify the continued application of the required controls.
- 5.4.3 The manufacturer shall provide complete instructions for the recharge and usage of systems. The instructions shall provide specific quality assurance procedures on the use of calibrated equipment, such as scales, pressure gauges, and other necessary critical equipment, in the recharging a system.
- 5.4.4 The manufacturer shall identify and provide instructions on those components and equipment of the hybrid fire extinguishing system to be verified for proper operation as part of the acceptance test.
- 5.4.5 The manufacturer, or assigned representative, shall identify a documented system acceptance check and operational test in accordance with FM Global Property Loss Prevention Data Sheet Number 4-0, *Special Protection Systems*.

## 5.5 Manufacturing and Production Tests

### 5.5.1 Test Requirement No. 1 - System Operation

The manufacturer shall performance test 100 percent of production hybrid fire extinguishing systems in accordance with the requirements of the *Approval Standard for Hybrid (Water and Inert Gas) Fire Extinguishing Systems* (Class 5580), and the appropriate national or international standard(s) used during manufacturing.

### 5.5.2 Test Requirement No. 2 – Nozzles (Automatic/Closed nozzles only)

5.5.2.1 Seat Leakage - The manufacturer shall pressure test 100 percent of production to a hydrostatic pressure of 120 percent of the maximum system operating pressure, but not less than 500 psi (34.5 bar), for 2 seconds.

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

5.5.2.3 Operating Element Strength - The manufacturer shall perform periodic tests for operating element strength.

5.5.2.4 Production Testing - The manufacturer shall test 100 percent of the glass bulb nozzles to ensure that the glass bulb has not been damaged during assembly.

### 5.5.3 Test Requirement No. 3 - Equipment Seat Leakage

The manufacturer shall test 100 percent of production system equipment, as applicable, for seat leakage at the maximum system operating pressure for a minimum of 15 seconds with no leakage allowed.

### 5.5.4 Test Requirement No. 4 - Equipment Hydrostatic Strength

The manufacturer shall test 100 percent of production system equipment, as applicable, to twice the maximum system operating pressure. The pressure shall be held for a minimum of 30 seconds with no evidence of body leakage or distortion. Following the body leakage test, all applicable equipment shall be operated with no evidence of sticking or binding.

### 5.5.5 Test Requirement No. 5 - Pump Driver Performance Test

The manufacturer shall performance test 100 percent of production pump drivers in accordance with the requirements of the national or international standard(s) used during manufacturing. The national or international standard(s) may permit an alternate method of evaluating power. The de-rated power and factory speed setting are to be applied to the pump driver nameplate at this time, along with an appropriate serial number.

### 5.5.6 Test Requirement No. 6 - Pump Performance Test

The manufacturer shall performance test 100 percent of production hybrid system pumps, recording flow, total head, speed and power consumed at a minimum of six points spanning from shut off to beyond 1.2 times rated flow. Speeds shall be within 4 percent of the listed speed. In order to develop the characteristic curve, test data shall be corrected to rated speed by means of the affinity relationships. This curve shall be supplied with the pump.

### 5.5.7 Test Requirement No. 7 - Cylinder/Storage Container Leakage Test

The manufacturer shall leak test all filled agent storage containers prior to release for shipment.

## FIRE PERFORMANCE TESTING REQUIREMENTS

### APPENDIX A through H

#### General Instrumentation and Test Equipment Requirements

- A. The hybrid fire extinguishing system, operating without manual intervention, shall successfully complete all described performance fire tests for their specific applications.
- B. The tests should be conducted for the specified length of time or until the fire is extinguished, as required by the applicable Fire Performance Testing Appendix.
- C. The test laboratory should be of adequate size with natural or minimal ventilation so as to not interfere with the fire testing within the enclosure or about the mockup or test fuel package. Additionally, the size of the test laboratory should not impact extinguishment of any test fires (i.e., depletion of oxygen due to an inadequately sized test laboratory).
- D. For all fire tests, the ceiling, floor, and walls should be as dry as possible, with only ambient moisture content allowed. The relative humidity in the test enclosure should not significantly differ from that of the ambient relative humidity.
- E. The test enclosures or laboratory shall be at an ambient temperature of  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ) prior to the start of the test. The enclosure or hall shall be at as uniform an ambient temperature as reasonably possible. Localized hot or cold spots are not permitted. All non-fire induced drafts shall be eliminated.
- F. The minimum operating nozzle pressure (as specified by the manufacturer) shall be used for all tests, unless otherwise noted. System operating pressures shall be repeatable to within  $\pm 5$  percent. If the system pressures cannot be controlled within the specified tolerance, fire tests should be conducted at the minimum and maximum pressure by using external means to control the system pressure.
- G. The maximum nozzle ceiling height and spacing (as specified by the manufacturer) shall be used for all tests. This includes utilizing the maximum ceiling spacing of the nozzles from the walls.
- H. The ceiling nozzle arrangement shall have uniform spacing. The ceiling nozzle spacing from the wall shall be uniform, preferably one half of the main spacing.
- I. System components, component locations, operating conditions and test enclosure details shall remain unaltered throughout all of the fire tests for a given application. All fire tests should be conducted using the specifications from the manufacturer's design manual in regard to nozzle placement, spray flux, and spray duration. Additionally, for the protection of combustion turbine enclosures, the discharge should be such that excessive turbine shell distortion is avoided, as determined by the spray cooling tests described in Appendices C, E, and G.
- J. In conjunction with the performance fire tests, each hybrid fire extinguishing system should be subjected to a straight discharge test with no fire to evaluate the resulting oxygen concentration. This evaluation should be conducted using the maximum extinguishing agent flow and pressure. The discharge duration for the test shall be the maximum required for the system and occupancy to be protected. Oxygen measurements should be recorded at a location(s) within the test enclosure to be selected by FM Approvals. This information shall be used to evaluate personnel safety, and should be accounted for in the manufacturer's design, installation, operation, and maintenance manual (see Sections 4.32 and 4.33).

#### Required Recorded Observations during Testing

- A. The start of ignition procedure.
- B. The start of test fuel (ignition).
- C. The time when the extinguishing system is activated with hybrid media discharging from the nozzles.

- D. The time when the fire(s) is extinguished, suppressed or controlled. Visual registration of the fire extinguishment by means of a thermal imaging camera is strongly recommended.
- E. The time when the extinguishing system is shut off.
- F. The time of re-ignition (if any).
- G. The time of when the fuel is shut off, if applicable (i.e. for spray fires).
- H. The time when the test is finished.
- I. The following measurements should be recorded to within a  $\pm 5$  percent tolerance level at intervals not exceeding one second using a computerized data acquisition system. Measurements should begin and end at least one minute prior to ignition and after extinguishment of the test fire(s).
- Extinguishing agent flow and pressure, measured continuously on the high pressure side of the pump, cylinder, or equivalent equipment.
  - Extinguishing agent pressure at the two most remote nozzles.
  - Gas consumption, measured by means of a pressure or weighing cell on which the gas storage cylinder is placed during the tests.
- J. Additional test information, as required by the applicable Fire Performance Testing Appendix.
- K. Registration should be by means of a written laboratory test and computer log.

**Required Recorded Observations after Testing**

- A. Record any percent damage to system components, mockup or test enclosure.
- B. Record the amount (percentage) of fuel consumed (including target arrays).
- C. The level of fuel still remaining in the pools or trays to make sure that no limitation of fuel occurred during the test. Re-ignition of the pool after extinguishment is a suitable alternative to verify the existence of fuel.

## APPENDIX A: Hybrid Fire Extinguishing System Classification

### A.1 General Testing Requirements

A hybrid fire extinguishing system is a twin fluid system in which the gas is a critical component to fire extinguishment rather than only serving as an atomizing medium, as in a water mist system. A water mist system employs small water droplets to control or extinguish fires by cooling of the flame, fire plume, and fuel, displacement of oxygen by water vapor, and radiant heat attenuation. The gas in a hybrid system is equally significant to fire extinguishment, by oxygen dilution or displacement and increasing the heat capacity of the atmosphere supporting the flame. The gases used in hybrid fire extinguishing systems may include helium, neon, argon, nitrogen, carbon dioxide, or blends of these gases. The use of hybrid fire extinguishing systems is currently only permitted in the applications described in the *Approval Standard for Hybrid (Water and Gas) Fire Extinguishing Systems* (Class 5580), Appendices B through H. Other applications may be explored and verified in the future.

The test protocol calls for a series of tests to determine the nature of the fire extinguishing system. The system will be evaluated to determine if it is gaseous in nature, if it is a twin fluid water mist system, or if both the gas and water are critical to fire extinguishment. In the case of the latter, the system will be classified as a hybrid extinguishing system.

### A.2 Test Enclosures (see Figure A-1)

In addition to the appropriate test enclosures described in the applicable fire performance test appendix in the *Approval Standard for Hybrid (Water and Gas) Fire Extinguishing Systems* (Class 5580), the following test enclosure shall be constructed for the purposes of analyzing the nature of the system in accordance with Section A.5.

The test enclosure area shall have main dimensions of 24.0 ft by 24.0 ft by 16.1 ft high (7.3 m by 7.3 m by 4.9 m high). The enclosure should be constructed of wood or metal frame with an inner lining of minimum 0.5 in. (13 mm) gypsum or 0.03 in. (0.7 mm) galvanized steel. To minimize leakages, all joints and gaps shall be sealed. At 9 ft (2.7 m) from one of the enclosure corners, in one of the walls parallel to the machinery equipment mockup, a 2.7 ft by 6.7 ft high (0.8 m by 2.0 m high) personnel door should be installed with a locking mechanism. A 4.0 ft by 8.0 ft high (1.2 m by 2.4 m high) removable panel should also be installed for test enclosure access (The personnel door may be constructed within this panel). A minimum of two hinged ceiling hatches measuring approximately 3 ft by 6 ft (0.9 m by 1.8 m) should be installed in opposite diagonal corners for heat and smoke release at the conclusion of the fire test. The floor should be noncombustible and any floor drainage or vent openings should be sealed during testing. A small louvered vent may be provided to allow the intake of air, to prevent excessive suctioning of the walls and ceiling and maintain structural integrity of the fire test enclosure.

### A.3 Machinery Equipment Mockup

The machinery mockup is a horizontal flat steel table and steel baffles to provide shielded spaces for fires (see Figure A-1). The specific details and thermal mass of the obstructions are not simulated.

The mockup unit should be centered along one of the 24.0 ft (7.3 m) walls of the enclosure, such that the mockup is parallel to the wall with the personnel door. FM Approvals reserves the right to alter the placement of the mockup unit with respect to the aspect ratio of the enclosure.

A horizontal 22 gauge (0.85 mm thick) galvanized steel sheet metal table measuring 3.3 ft by 24 ft (1.0 m by 7.3 m) is placed at 3.3 ft (1 m) elevation on steel legs. This is located in the center of the room or at a location within the test cell to be selected by FM Approvals after the nozzles are installed (as per manufacturer's design criteria). This allows the fire to be placed in an area considered the most challenging to the specific system being tested. The bottom of a cylindrical piece of equipment is simulated with 22 gauge (0.85 mm thick) galvanized steel sheet metal directed upward at an angle of 45 degrees on either side of the horizontal steel sheet metal table surface. These side pieces also extend longitudinally the entire length of the enclosure, rising to a height of 4.9 ft (1.5 m) above the horizontal steel sheet metal surface. The total width of the mockup is 6.6 ft (2.0 m). If multiple sections of steel sheet metal are used, there should be a minimal gap between the various sections to permit water run-off. It is recommended to either butt up or simply attach the table and sheet metal extension surfaces with screw fasteners.

The space below the table is partially shielded from the agent discharge using 3.3 ft high by 1.6 ft wide (1 m by 0.5 m) sheet metal baffles. The side baffles should be of 22 gauge (0.85 mm thick) galvanized steel sheet metal construction and removable. They may be installed on support legs and kept in place by being pinched between the underside of the steel table and 45 degree angle extensions and the floor for ease of removal. Placement of additional baffles or obstructions may be needed to prevent the direct impact of hybrid media on the pool or spray test fires, at the sole discretion of FM Approvals.

#### A.4 Instrumentation and Test Equipment Requirements

In addition to the instrumentation and test requirements described previously under “General Instrumentation and Test Equipment Requirements,” the following measurements should be recorded to within a  $\pm 5$  percent tolerance level at intervals not exceeding one second using a computerized data acquisition system. Measurements should begin and end at least one minute prior to ignition and after extinguishment of the test fire(s).

- A. Fuel pressure and flow at the outlet of fuel pump (fuel flow and pressure should be measured prior to each test series).
- B. Fuel temperature within the fuel storage container. All fuels shall be at an ambient temperature of  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ).
- C. Test enclosure temperatures measured in the center portion of the room at the 1/3, 2/3 and ceiling heights. The enclosure and mockup shall initially be at an ambient temperature  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ) for all tests.
- D. Temperature of air into the spray fires, measured approximately 20 in. (50 cm) horizontally behind fuel spray nozzle with bare bead thermocouples welded from 28 gauge chromel-alumel wire.
- E. Spray fire temperatures with a thermocouple located approximately 10 in. (25 cm) ahead of flame stabilizer at the cone radius.
- F. Extinguishment should be registered by thermocouples located in front of the spray fires as previously described. The fire can be considered to be extinguished when temperature registration drops below  $212\text{ }^{\circ}\text{F}$  ( $100\text{ }^{\circ}\text{C}$ ) and does not increase. Registration by means of thermal imaging equipment, in addition to the thermocouples, is strongly encouraged.
- G. Oxygen, carbon monoxide and carbon dioxide concentrations, measured approximately 20 in. (50 cm) horizontally behind the fuel spray nozzle, at the same level above the floor, and away from any open door or ventilation source.
- H. Oxygen concentration measured in the corner of the test enclosure, away from the test fire and the personnel door.
- I. For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

<i>Fire Size</i>	<i>1 MW Heptane Spray</i>	<i>2 MW Heptane Spray</i>
Spray Nozzle	Monarch F-80, 24.00	Monarch F-80, 50.00
Fuel Type	Heptane	Heptane
Nominal Oil Pressure	125 psi (8.6 bar)	125 psi (8.6 bar)
Nominal Fuel Flow	31 gph (117 liters/hour)	62 gph (235 liters/hour)
Fuel Temperature	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )

<i>Fire Size</i>	<i>1 MW Diesel Spray</i>	<i>2 MW Diesel Spray</i>
Spray Nozzle	Monarch F-80, 24.00	Monarch F-80, 50.00
Fuel Type	Diesel	Diesel
Nominal Oil Pressure	125 psi (8.6 bar)	125 psi (8.6 bar)
Nominal Fuel Flow	28 gph (106 liters/hour)	56 gph (212 liters/hour)
Fuel Temperature	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )

NOTE: The free burn characteristics of the fires employed in the fire tests have been calibrated under the FM Global Research Fire Products Collector. Alternative spray nozzles than those listed above may be used if the free burn characteristics are verified by FM Approvals.

- J. The fixture stand for the spray fire arrangements should be constructed of a metal, self standing secure arrangement with the oil burner nozzle mounted within and centered at the closed end of a metal cylindrical flame stabilizer can measuring 5.9 in. diameter by 3.0 in. long (150 mm by 75 mm) with a thickness of 0.010 in. (0.25mm).

## A.5 System Classification

The system shall successfully complete the performance fire tests described in this section. During the fire tests, all systems shall operate without manual intervention.

### A.5.1 Fire Tests

#### A.5.1.1 Shielded 1 MW Spray Fire (Gas and Water)

Criterion:	The fire is to be extinguished.
Fuel:	Systems used in applications containing hazards with volatilities less than or equal to light diesel shall be tested with diesel fuel. Systems used in applications containing hazards with volatilities less than or equal to heptane shall be tested with heptane.
Type:	Horizontal spray
Spray Nozzle:	1 MW spray nozzle
Fire Location:	The test fire shall be located below the table at a position determined to be the most challenging based on the system discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the wall without the access door.
Fire Preburn Time:	15 seconds
Test Procedure:	The spray fire shall be ignited in the enclosure with the personnel access door closed. The system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### A.5.1.2 Shielded 2 MW Spray Fire, System Performance under Limited Natural Ventilation (Gas and Water)

Criterion:	The fire is to be extinguished.
Fuel:	Systems used in applications containing hazards with volatilities less than or equal to light diesel shall be tested with diesel fuel. Systems used in applications containing hazards with volatilities less than or equal to heptane shall be tested with heptane.
Type:	Horizontal spray
Spray Nozzle:	2 MW spray nozzle
Fire Location:	The test fire shall be located below the table at a position determined to be the most challenging based on the system discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the wall without the access door.
Fire Preburn Time:	15 seconds



Test Procedure: A shielded 2 MW spray fire shall be ignited in the enclosure with the personnel access door open. The system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### **A.5.1.3 Shielded 2 MW Spray Fire, System Performance under Limited Natural Ventilation (Gas Only)**

Test Procedure: The system water supply shall be disconnected such that only the gas will discharge during system operation. Test A.5.1.2 shall be repeated using the system gas only. If this is not possible due to the nature of the system, this test may be omitted.

### **A.5.2 System Classification**

#### **A.5.2.1 Analysis of Gas Influence**

It is strongly recommended to conduct the gas only test described in Section A.5.1.3 as a means of preliminary screening of the system.

If the test fire is not extinguished by the system gas only, the system is not a gaseous system. Rather, the system is classified as either a twin fluid water mist system or a hybrid system, and differentiation between these two system types shall be achieved based on the analysis described in Section A.5.2.2.

If the test fire is extinguished by the system gas only, the system is not a twin fluid water mist system. Rather, the system is classified as either a gaseous extinguishing system or a hybrid system, and differentiation between these two system types shall be achieved based on the analysis described in Section A.5.2.2.

If it is not possible to run the gas only test due to the nature of the system, further evaluation of the system is required, as described in Section A.5.2.2.

#### **A.5.2.2 Analysis of Combined Water and Gas Influence**

##### **A.5.2.2.1 Oxygen Concentration**

The dry-based oxygen concentration at fire extinguishment during the tests described in Sections A.5.1.1 and A.5.1.2 shall be examined. The oxygen concentration at fire extinguishment serves as the basis for system classification, as follows. Both oxygen measurement locations described in Section A.4 shall be examined, and the measurements should be similar. If discrepancies between the two measurements exist, the measurement located away from the test fire and personnel door shall be used.

1. The system is a gaseous extinguishing system if the oxygen concentration at fire extinction is less than 12.5 percent. (Additionally, the test fire described in Section A.5.1.3 will have been extinguished using the system gas only.)
2. The system is a hybrid extinguishing system if the oxygen concentration at fire extinction is between 12.5 percent and 16 percent.
3. The system is a twin fluid water mist system if the oxygen concentration at fire extinction is greater than 16 percent. (Additionally, the test fire described in Section A.5.1.3 will not have been extinguished using the system gas only.)

#### A.5.2.2.2 Gas Temperature

The enclosure gas temperature is difficult to measure with a sufficient degree of reliability. As such, the dry-based oxygen concentration presented in Section A.5.2.2.1 is a more suitable parameter to differentiate a hybrid extinguishing system from gaseous systems and twin fluid water mist systems. However, the gas temperature may be used as a secondary parameter in classifying the system. These measurements should only be used when the oxygen concentration alone is insufficient to distinctly characterize the system.

Due to the use of small water droplets, a water mist system will have a significant cooling effect on the ambient conditions in a fire scenario. Specifically, water mist should cause an immediate decrease in temperature in an enclosure. If an immediate reduction in temperature does not occur, the temperature rise between system activation and fire extinction will be less than that for a gaseous or hybrid system. These other system types will not demonstrate equivalent levels of cooling.

The thermocouple temperatures recorded in the tests described in Sections A.5.1.1 and A.5.1.2 may be analyzed. If the test data shows a decrease in thermocouple temperature immediately following system discharge, and the thermocouple temperature at fire extinguishment is less than that at system activation, the system should generally be classified as a water mist system. If required, system evaluation based on enclosure temperature measurements shall be conducted at the discretion of FM Approvals.

#### A.5.2.3 Gaseous Extinguishing System Classification

For a system using water and gas that has been classified as a gaseous system, the system should be examined in accordance with the *Approval Standard for Clean Agent Fire Extinguishing Systems* (Class 5600) and FM Global Property Loss Prevention Data Sheet Number 4-9, *Clean Agent Fire Extinguishing Systems*.

#### A.5.2.4 Twin Fluid Water Mist System Classification

For a system using water and gas that has been classified as a twin fluid water mist system, the system should be examined according to the *Approval Standard for Water Mist Systems* (Class 5560) and FM Global Property Loss Prevention Data Sheet Number 4-2, *Water Mist Systems*.

#### A.5.2.5 Hybrid Extinguishing System Classification

For a system using water and gas that has been classified as a hybrid extinguishing system, the system should be examined in accordance with the *Approval Standard for Hybrid (Water and Inert Gas) Fire Extinguishing Systems* (Class 5580), including the requirements listed in Section A.6.

## A.6 Hybrid System Requirements

### A.6.1 Fire Performance Tests

The applicable fire tests for listing in the designated occupancy prescribed in Appendices B through H shall be conducted in full.

### A.6.2 Hybrid System Design and Installation Requirements

#### A.6.2.1 Primary Protection System

For primary protection, agent supply shall be equivalent to that required for an automatic sprinkler protection system for the hazard protected.

#### A.6.2.2 Special Protection System (see Section 1.9, definitions)

If the longest extinguishment time for the fire scenarios required in Section A.6.1, for Appendices B through G, is greater than five minutes, the required agent supply shall be 10 minutes or the time to shut down process equipment, whichever is greater. For turbine enclosures, the required agent supply shall be 10 minutes, the turbine rundown time (including the time that the turbine surfaces are above the auto-ignition temperature of the lubricating fluid), or the time to shut down process equipment, whichever is greater. Additionally, where the extinguishment time for the longest fire scenario is greater than five minutes, the required cumulative agent discharge rate used during the fire testing shall be multiplied by a safety factor of 1.2. This may be achieved by a reduction of nozzle spacing, a reduction of protected enclosure area, or placement of additional nozzles. This safety factor shall not be accounted for by increasing the discharge rates of individual nozzles.

The longest extinguishment time for the fire scenarios required in Section A.6.1 shall not exceed eight minutes, unless otherwise specified in the applicable Appendix.

A summary of these requirements is provided in Table A.6.2.2.

Table A.6.2.2 - Hybrid Fire Extinguishing System Design Criteria

<i>Extinguishment Time</i>	<i>Discharge Time</i>	<i>Agent Quantity Safety Factor</i>
0 to 5 minutes	10 minutes (minimum)	Not required
5 to 8 minutes	10 minutes (minimum)	20 percent
Greater than 8 minutes	Not permitted	

\* The fire extinguishing time for computer room sub-floor protection shall not exceed five minutes.

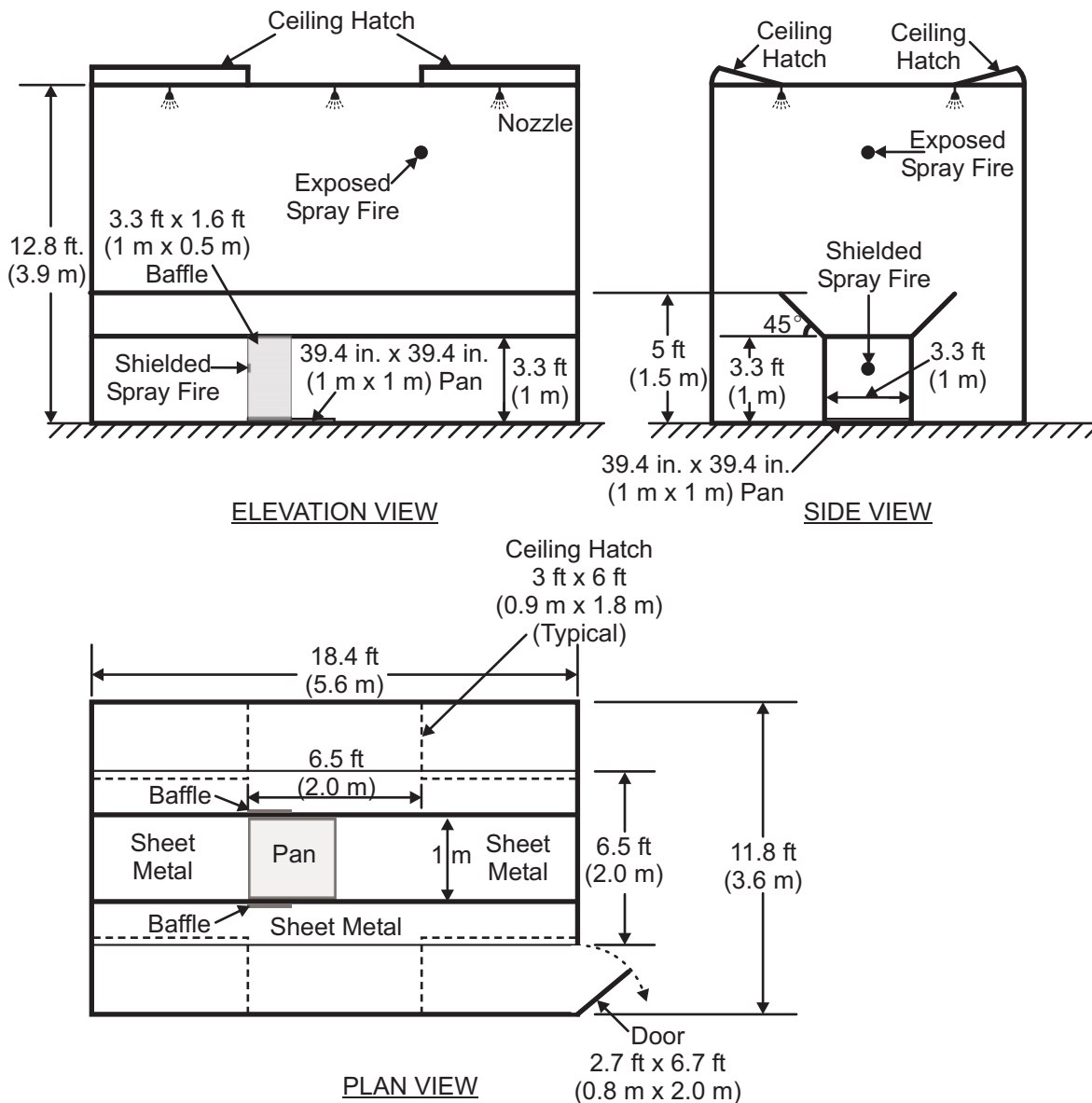


Figure A-1. Test Enclosure and Machinery Mockup Steel Plate

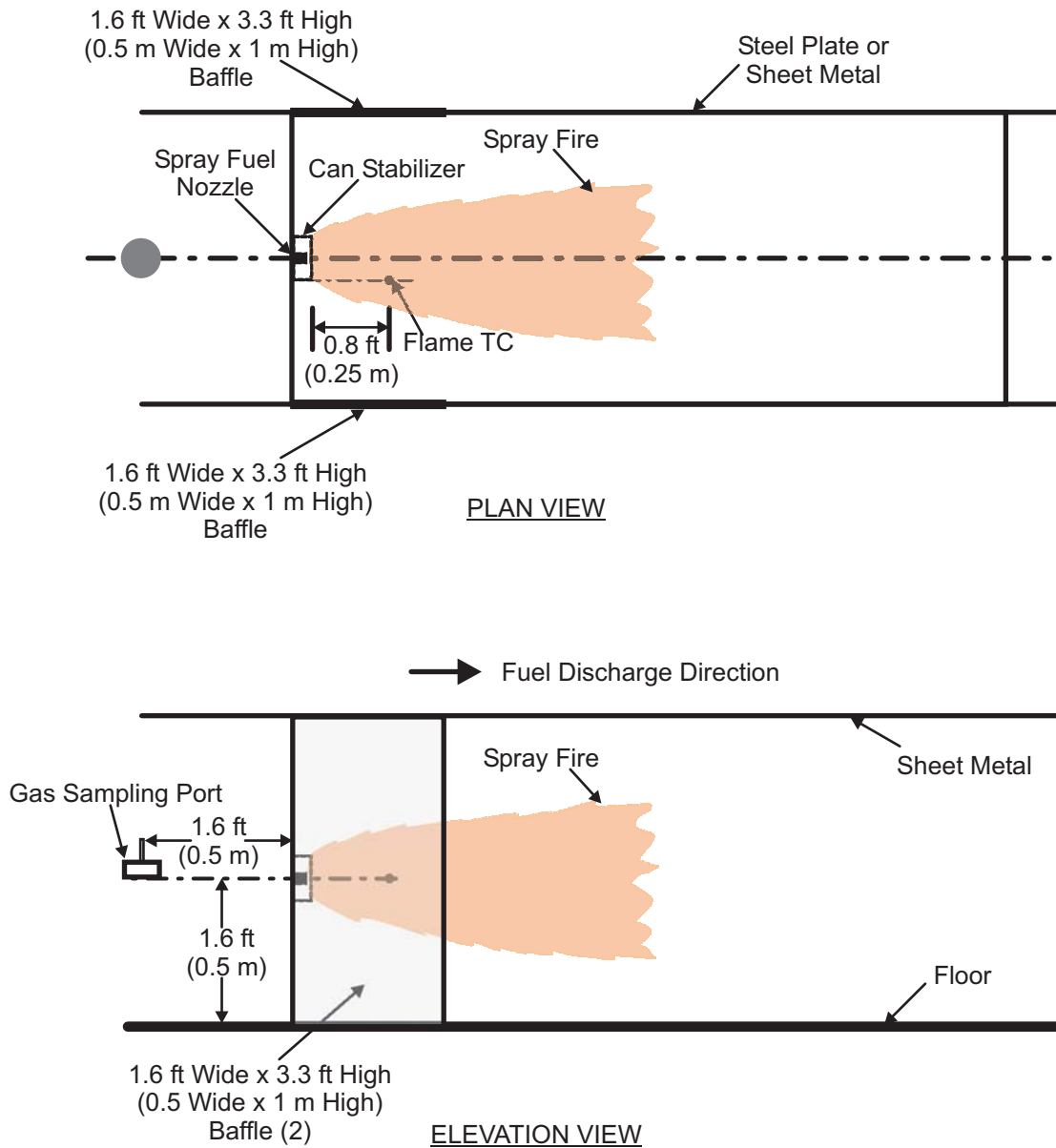


Figure A-2. Fire Source Configuration and Instrumentation for Shielded Spray Fire Testing

## APPENDIX B: Fire Tests for Hybrid Fire Extinguishing Systems for the Protection of Machinery Spaces with Volumes not Exceeding 2825 ft<sup>3</sup> (80 m<sup>3</sup>)

### B.1 Test Enclosure (see Figure B-1)

The test enclosure area shall have main dimensions of 18.4 ft by 11.8 ft by 12.8 ft high (5.6 m by 3.6 m by 3.9 m high). The enclosure should be constructed of wood or metal frame with an inner lining of minimum 0.5 in. (13 mm) gypsum or 0.03 in. (0.7 mm) galvanized steel. To minimize leakages, all joints and gaps shall be sealed. In one of the shorter walls, at the junction of a longer wall, a 2.7 ft by 6.7 ft high (0.8 m by 2.0 m high) personnel door should be installed with a locking mechanism. A minimum of two hinged ceiling hatches measuring approximately 3 ft by 6 ft (0.9 m by 1.8 m) should be installed in opposite diagonal corners for heat and smoke release at the conclusion of the fire test. The floor should be noncombustible and any floor drainage or vent openings should be sealed during testing. A small louvered vent may be provided to allow the intake of air, to prevent excessive suctioning of the walls and ceiling and maintain structural integrity of the fire test enclosure.

### B.2 Machinery Equipment Mockup

The machinery mockup is a horizontal flat steel table and steel baffles to provide shielded spaces for fires (see Figure B-1). The specific details and thermal mass of the obstructions are not simulated.

The mockup unit shall be centered along the longer wall dimension in the test enclosure. FM Approvals reserves the right to alter the placement of the mockup unit with respect to the aspect ratio of the enclosure.

A horizontal 22 gauge (0.85 mm thick) galvanized steel sheet metal table measuring 3.3 ft. by 18.4 ft (1.0 m by 5.6 m) is placed at a 3.3 ft (1 m) elevation on steel legs. This is located in the center of the room or at a location within the test cell to be selected by FM Approvals after the nozzles are installed (as per the manufacturer's design criteria). This allows the fire to be placed in an area considered the most challenging to the specific system being tested. The bottom of a cylindrical piece of equipment is simulated with 22 gauge (0.85 mm thick) galvanized sheet metal directed upward at an angle of 45 degrees on either side of the horizontal steel sheet metal table surface. These side pieces also extended longitudinally the entire length of the enclosure, rising to a height of 4.9 ft (1.5 m) above the horizontal steel sheet metal surface. The total width of the mockup is 6.6 ft (2.0 m). If multiple sections of steel sheet metal are used, there should be a minimal gap between the various sections to permit water run-off. It is recommended to either butt up or simply attach the sheet metal surfaces with screw fasteners.

The space below the table is partially shielded from hybrid media using 3.3 ft high by 1.6 ft wide (1 m by 0.5 m) sheet metal baffles located at the end of the table, away from the enclosure personnel door. The side baffles should be of 22 gauge (0.85 mm thick) galvanized sheet metal construction and removable. They may be installed on support legs and kept in place by being pinched between the underside of the steel table and 45 degree angle extensions and the floor for ease of removal. Placement of additional baffles or obstructions may be needed to prevent the direct impact of mist on the pool or spray test fires, at the sole discretion of FM Approvals.

### B.3 Instrumentation and Test Equipment Requirements

In addition to the instrumentation and test requirements described previously under "General Instrumentation and Test Equipment Requirements," the following measurements should be recorded to within a  $\pm 5$  percent tolerance level at intervals not exceeding one second using a computerized data acquisition system. Measurements should begin and end at least one minute prior to ignition and after extinguishment of the test fire(s).

- A. Fuel pressure and flow at the outlet of fuel pump (fuel flow and pressure should be measured prior to each test series).
- B. Fuel temperature within the fuel storage container. All fuels shall be at an ambient temperature of  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ).

- C. Temperature of fuel in pools with thermocouple located in the approximate center of the initial fuel layer. All fuels shall initially be at an ambient temperature of  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ).
- D. Test enclosure temperatures measured in the center portion of the room at the 1/3, 2/3 and ceiling heights. The enclosure and mockup shall initially be at an ambient temperature  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ) for all tests.
- E. Temperature of air into the spray fires, measured approximately 20 in. (50 cm) horizontally behind fuel spray nozzle with bare bead thermocouples welded from 28 gauge chromel-alumel wire.
- F. Pool fire temperatures with a thermocouple located approximately 1 in. (2.5 cm) above the initial pool surface and 10 in. (25 cm) within the pool rim.
- G. Spray fire temperatures with a thermocouple located approximately 10 in. (25 cm) ahead of flame stabilizer at the cone radius.
- H. Extinguishment should be registered by thermocouples located above the pools and in front of the spray fires as previously described. The fire can be considered to be extinguished when temperature registration drops below  $212\text{ }^{\circ}\text{F}$  ( $100\text{ }^{\circ}\text{C}$ ) and does not increase. Registration by means of thermal imaging equipment, in addition to the thermocouples, is strongly encouraged.
- I. Oxygen, carbon monoxide and carbon dioxide concentrations, measured approximately 20 in. (50 cm) horizontally behind fuel spray nozzle or away from the pool, at the same level above the floor, and away from any open door or ventilation source.
- J. For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

<i>Fire Size</i>	<i>1 MW Diesel Spray</i>	<i>2 MW Diesel Spray</i>
Spray Nozzle	Monarch F-80, 24.00	Monarch F-80, 50.00
Fuel Type	Light diesel	Light diesel
Nominal Oil Pressure	125 psi (8.6 bar)	125 psi (8.6 bar)
Nominal Fuel Flow	28 gph (106 liters/hour)	56 gph (212 liters/hour)
Fuel Temperature	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )

NOTE: The free burn characteristics of the fires employed in the fire tests have been calibrated under the FM Global Research Fire Products Collector. Alternative spray nozzles than those listed above may be used if the free burn characteristics are verified by FM Approvals.

<i>Fire Size</i>	<i>1 MW Heptane Spray</i>	<i>2 MW Heptane Spray</i>
Spray Nozzle	Monarch F-80, 24.00	Monarch F-80, 50.00
Fuel Type	Heptane	Heptane
Nominal Oil Pressure	125 psi (8.6 bar)	125 psi (8.6 bar)
Nominal Fuel Flow	31 gph (117 liters/hour)	62 gph (235 liters/hour)
Fuel Temperature	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )

NOTE: The free burn characteristics of the fires employed in the fire tests have been calibrated under the FM Global Research Fire Products Collector. Alternative spray nozzles than those listed above may be used if the free burn characteristics are verified by FM Approvals.

- K. The fixture stand for the spray fire arrangements should be constructed of a metal, self standing secure arrangement with the oil burner nozzle mounted within and centered at the closed end of a metal cylindrical flame stabilizer can measuring 5.9 in. diameter by 3.0 in. long (150 mm by 75 mm) with a thickness of 0.010 in. (0.25mm).

L. General pool or tray specifications:

Pans or trays shall be 39.4 in. (1 m) wide by 39.4 in. (1 m) long, of steel construction, 0.068 in. (1.73 mm) thickness by 3.9 in. (10 cm) high, with no lip. A water base of 2.1 in. (5 cm) in height with a fuel load of at least 0.8 in. (2 cm) above should be used. Freeboard should be 1.2 in. (3 cm). Freeboard may be greater than 1.2 in. (3 cm) high, if a constant freeboard height is used for all application fire tests. Pan surfaces should be smooth and edges should be free of imperfections.

#### B.4 Fire Tests

Intermediate pendent or upright nozzles that are not at ceiling level, or wall mounted nozzles, are not permitted for the machinery spaces.

The hybrid fire extinguishing system shall successfully complete all four performance fire tests described in this section. During the fire tests, all systems shall operate without manual intervention.

Agent supply needed for the extinguishment time for the longest fire scenario will be reported and considered as one of the requirements when a hybrid extinguishing system is used as a special protection system (see Section 1.9, Definitions). For primary protection, agent supply shall be equivalent to that required for an automatic sprinkler protection system for the hazard protected.

##### B.4.1 Unshielded 1 MW Diesel Spray Fire

Criterion:	The fire is to be extinguished.
Fuel:	Diesel
Type:	Horizontal spray
Spray Nozzle:	1 MW spray nozzle
Fire Location:	The test fire shall be located above the table at a position determined to be the most challenging based on the hybrid media discharge. The fuel nozzle should be located at least 1.0 ft to 5.5 ft (30.5 cm to 167.6 cm) above the centerline of the table, with the spray fire aimed towards the center of the shorter wall with the access door.
Fire Preburn Time:	15 seconds
Test Procedure:	The spray fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

##### B.4.2 Shielded 1 MW Diesel Spray Fire

Criterion:	The fire is to be extinguished.
Fuel:	Diesel
Type:	Horizontal spray
Spray Nozzle:	1 MW spray nozzle
Fire Location:	The test fire shall be located below the table at a position determined to be the most challenging based on the hybrid media discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the shorter wall with the access door.
Fire Preburn Time:	15 seconds



Test Procedure: The spray fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### **B.4.3 Shielded 10.8 ft<sup>2</sup> (1 m<sup>2</sup>) Diesel Pool Fire**

Criterion: The fire is to be extinguished.

Fuel: Diesel

Type: 10.8 ft<sup>2</sup> (1.0 m<sup>2</sup>) pool fire

Fire Location: The test fire shall be centered below the steel table and located between the baffles, with the baffles located at a position determined to be the most challenging based on the hybrid media discharge

Fire Preburn Time: 30 seconds

Test Procedure: The pool fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. Following extinguishment, the fuel left in the pool or tray should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

#### **B.4.4 Shielded 2 MW Diesel Spray Fire, System Performance under Limited Natural Ventilation**

Criterion: The fire is to be extinguished.

Fuel: Diesel

Type: Horizontal spray

Spray Nozzle: 2 MW spray nozzle

Fire Location: The test fire shall be located below the table at a position determined to be the most challenging based on the hybrid media discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the shorter wall with the access door.

Fire Preburn Time: 15 seconds

Test Procedure: This test is conducted to determine the capability of the hybrid system to perform acceptably in a ventilated enclosure during system actuation. A shielded 2 MW diesel spray fire shall be ignited in the enclosure with the personnel access door open. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### **B.4.5 Unshielded 1 MW Heptane Spray Fire**

Criterion: The fire is to be extinguished.

Fuel: Heptane

Type: Horizontal spray

Spray Nozzle: 1 MW spray nozzle

Fire Location: The test fire shall be located above the table at a position determined to be the most challenging based on the hybrid media discharge. The fuel nozzle should be located at least 1.0 ft. to 5.5 ft (30.5 cm to 167.6 cm) above the centerline of the table, with the spray fire aimed towards the center of the shorter wall with the access door.

Fire Preburn Time: 15 seconds

Test Procedure: The spray fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### **B.4.6 Shielded 1 MW Heptane Spray Fire**

Criterion: The fire is to be extinguished.

Fuel: Heptane

Type: Horizontal spray

Spray Nozzle: 1 MW spray nozzle

Fire Location: The test fire shall be located below the table at a position determined to be the most challenging based on the hybrid media discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the shorter wall with the access door.

Fire Preburn Time: 15 seconds

Test Procedure: The spray fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### **B.4.7 Shielded 10.8 ft<sup>2</sup> (1 m<sup>2</sup>) Heptane Pool Fire**

Criterion: The fire is to be extinguished.

Fuel: Heptane

Type: 10.8 ft<sup>2</sup> (1.0 m<sup>2</sup>) pool fire

Fire Location: The test fire shall be centered below the steel table and located between the baffles, with the baffles located at a position determined to be the most challenging based on the hybrid media discharge.

Fire Preburn Time: 30 seconds

Test Procedure: The pool fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. Following extinguishment, the fuel left in the pool or tray should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

#### **B.4.8 Shielded 2 MW Heptane Spray Fire, System Performance Under Limited Natural Ventilation**

Criterion: The fire is to be extinguished.

Fuel: Heptane

Type: Horizontal spray

Spray Nozzle: 2 MW spray nozzle

Fire Location: The test fire shall be located below the table at a position determined to be the most challenging based on the hybrid media discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the shorter wall with the access door.

Fire Preburn Time: 15 seconds

Test Procedure: This test is conducted to determine the capability of the hybrid system to perform acceptably in a ventilated enclosure during system actuation. A shielded 2 MW diesel spray fire shall be ignited in the enclosure with the personnel access door open. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### **B.4.9 Additional Fire Tests**

Based on the results of Fire Tests B.4.1 through B.4.8, additional fire testing may be required to ensure that the hybrid fire extinguishing system being evaluated meets the intent of this section of the standard. This testing will be performed at the sole discretion of FM Approvals.

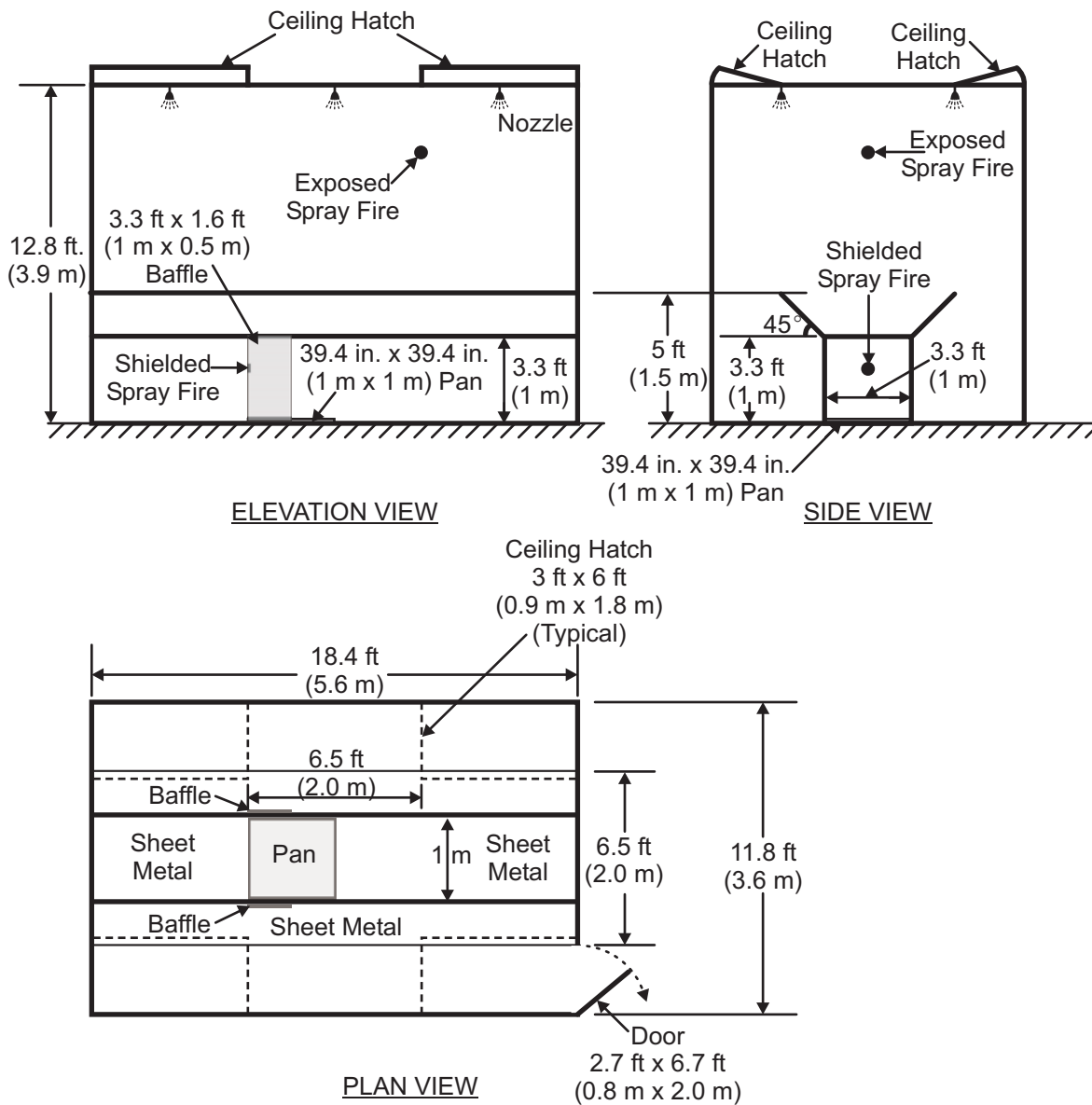


Figure B-1. Test Enclosure and Machinery Mockup Steel Table

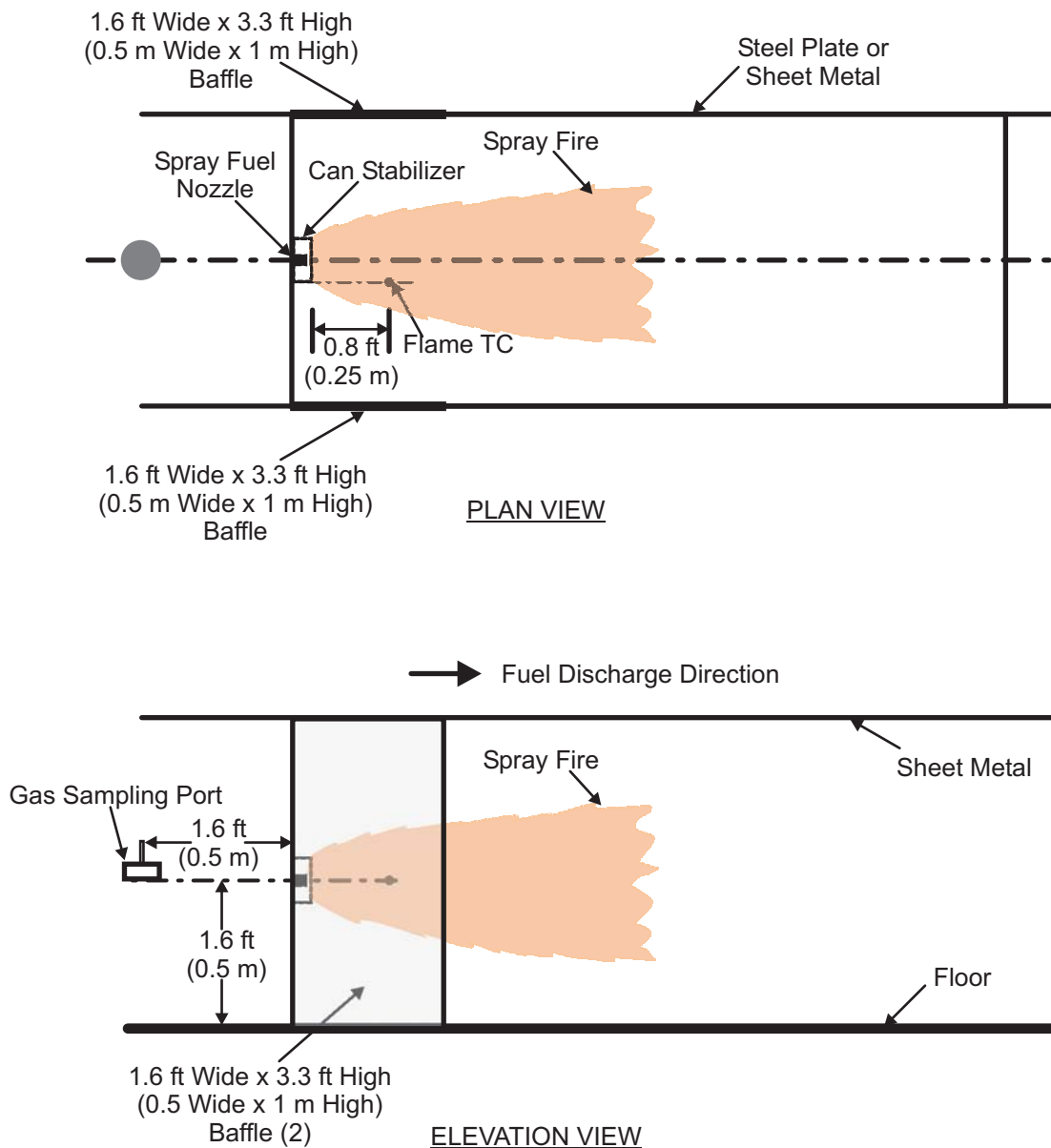


Figure B-2. Fire Source Configuration and Instrumentation for Shielded Spray Fire Testing

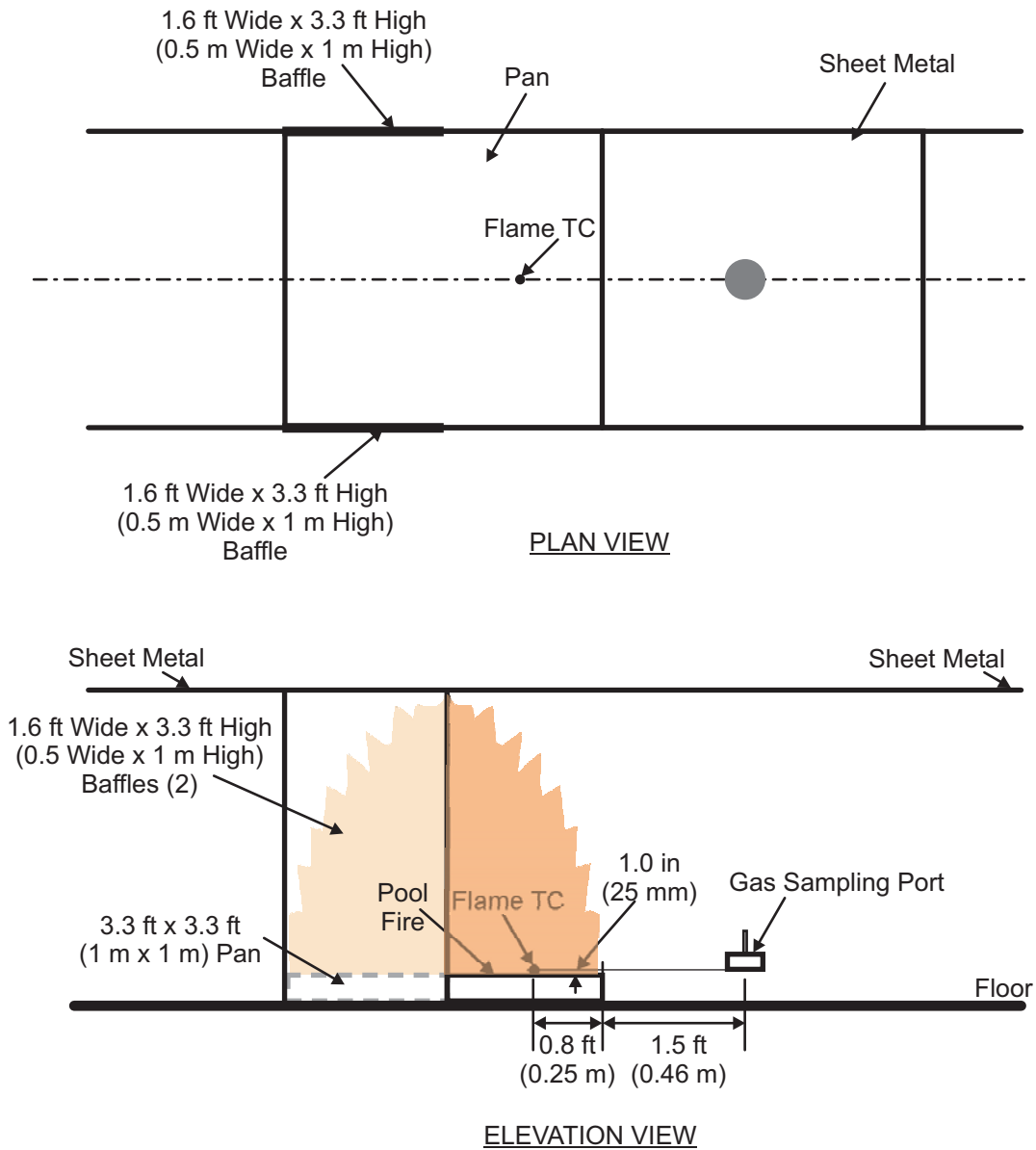


Figure B-3. Fire Source Configuration and Instrumentation for Shielded Pool Fire Testing

## APPENDIX C: Fire Tests for Hybrid Fire Extinguishing Systems for the Protection of Combustion Turbines with Volumes not Exceeding 2825 ft<sup>3</sup> (80 m<sup>3</sup>)

### C.1 Test Enclosure (see Figure C-1)

The test enclosure area has main dimensions of 18.4 ft by 11.8 ft by 12.8 ft high (5.6 m by 3.6 m by 3.9 m high). The enclosure should be constructed of wood or metal frame with an inner lining of minimum 0.5 in. (13 mm) gypsum or 0.03 in. (0.7 mm) galvanized steel. To minimize leakages, all joints and gaps shall be sealed. In one of the shorter walls, at the junction of a longer wall, a 2.7 ft by 6.7 ft high (0.8 m by 2.0 m high) personnel door should be installed with a locking mechanism. A minimum of two hinged ceiling hatches measuring approximately 3 ft by 6 ft (0.9 m by 1.8 m) should be installed in opposite diagonal corners for heat and smoke release at the conclusion of the fire test. The floor should be noncombustible and any floor drainage or vent openings should be sealed during testing. A small louvered vent may be provided to allow the intake of air, to prevent excessive suctioning of the walls and ceiling and maintain structural integrity of the fire test enclosure.

### C.2 Combustion Turbine Mockup

The combustion turbine casing mockup is simulated with a horizontal flat steel plate and steel baffles to provide shielded spaces for fires (see Figure C-1). The specific details and thermal mass of the obstructions are not simulated.

The combustion turbine mockup unit shall be centered along the longer wall dimension in the test enclosure. FM Approvals reserves the right to alter the placement of the mockup unit with respect to the aspect ratio of the enclosure.

A horizontal ASTM A36 hot rolled steel plate, 3.3 ft by 6.5 ft by 2 in. thick (1.0 m wide by 2.0 m long by 5 cm thick), is placed at 3.3 ft (1 m) elevation on steel legs at the four corners of the plate. This is located in the center of the room or at a location within the test cell to be selected by FM Approvals after the nozzles are installed (as per manufacturer's design criteria). This allows the fire to be placed in an area considered the most challenging to the specific system being tested. In lieu of actual turbine casing material, which is typically ductile iron, the test plate is constructed of hot rolled ASTM A36 steel. The center of the plate is instrumented across its thickness with thermocouples placed at various depths, as described below.

Horizontal 22 gauge (0.85 mm thick) galvanized steel sheet metal shall be placed at an elevation of 3.3 ft (1 m) on steel legs, on both sides of the ASTM A36 steel table, so that the combustion turbine mockup extends longitudinally the entire length of the enclosure (see Figure C-1).

To determine the cooling rate of the combustion turbine steel plate mockup, caused by the discharge of the hybrid system, three thermocouples should each be embedded near the center of the plate at approximately 0.5 in., 1.0 in. and 1.50 in. (12 mm, 25 mm and 38 mm) below the plate's top surface. The three inconel-sheathed thermocouples should be embedded in the plate by removing cylindrical plugs from the plate. The thermocouples should be inserted to allow the thermocouple wire to follow a horizontal path of sixteen thermocouple diameters in length, thus reducing errors due to the vertical temperature gradient in the plate. A heat conductive and electrically insulating sealant should be applied, and the steel cylindrical plugs should be replaced and welded to the plate around the top periphery of the plugs. This can be accomplished by using a 1.0 in. (25 mm) diameter miller tool, installing the thermocouples, and then refilling the hole with welded 1.0 in. (25 mm) round bar stock (see Figure C-5).

The underside curvature of the turbine is simulated with 22 gauge (0.85 mm thick) galvanized sheet metal directed upward at an angle of 45 degrees on either side of the steel plate and horizontal sheet metal extension surface. These side pieces also extend longitudinally the entire length of the enclosure, rising to a height of 4.9 ft (1.5 m) above the horizontal sheet metal and steel plate surfaces. The total width of the mockup is 6.6 ft (2.0 m). There should be a minimal gap between the various steel table and sheet metal surfaces to permit water run-off. For ease of conducting the spray cooling test, it is recommended to either butt up or simply attach the table and sheet metal extension surfaces with screw fasteners.

The space below the plate is partially shielded from hybrid media using 3.3 ft high by 1.6 ft wide (1 m by 0.5 m) sheet metal baffles located at the end of the plate, away from the enclosure personnel door. The side baffles should be of 22 gauge (0.85 mm thick) galvanized sheet metal construction and removable. They may be installed on support legs and kept in place by being pinched between the underside of the steel plate table and the 45 degree angle extensions and the floor for ease of removal. Placement of additional baffles or obstructions may be needed to prevent the direct impact of mist on the pool or spray test fires, at the sole discretion of FM Approvals.

### C.3 Instrumentation and Test Equipment Requirements

In addition to the instrumentation and test requirements described previously under “General Instrumentation and Test Equipment Requirements,” the following measurements should be recorded to within a  $\pm 5$  percent tolerance level at intervals not exceeding one second using a computerized data acquisition system. Measurements should begin and end at least one minute prior to ignition and after extinguishment of the test fire(s).

- A. Fuel pressure and flow at the outlet of fuel pump (fuel flow and pressure should be measured prior to each test series).
- B. Fuel temperature within the fuel storage container. All fuels shall be at an ambient temperature of  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ).
- C. Temperature of fuel in pools with thermocouple located in the approximate center of the initial fuel layer. All fuels shall initially be at an ambient temperature of  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ).
- D. Test enclosure temperatures measured in the center portion of the room at the 1/3, 2/3 and ceiling heights. The enclosure and mockup shall initially be at an ambient temperature  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ) for all tests.
- E. Temperature of air into the spray fires, measured approximately 20 in. (50 cm) horizontally behind fuel spray nozzle with bare bead thermocouples welded from 28 gauge chromel-alumel wire.
- F. Pool fire temperatures with a thermocouple located approximately 1 in. (2.5 cm) above the initial pool surface and 10 in. (25 cm) within the pool rim.
- G. Spray fire temperatures with a thermocouple located approximately 10 in. (25 cm) ahead of flame stabilizer at the cone radius.
- H. Extinguishment should be registered by thermocouples located above the pools and in front of the spray fires as previously described. The fire can be considered to be extinguished when temperature registration drops below  $212\text{ }^{\circ}\text{F}$  ( $100\text{ }^{\circ}\text{C}$ ) and does not increase. Registration by means of thermal imaging equipment, in addition to the thermocouples, is strongly encouraged.
- I. Oxygen, carbon monoxide and carbon dioxide concentrations, measured approximately 20 in. (50 cm) horizontally behind fuel spray nozzle or away from the pool, at the same level above the floor, and away from any open door or ventilation source.
- J. For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

<i>Fire Size</i>	<i>1 MW Diesel Spray</i>	<i>2 MW Diesel Spray</i>
Spray Nozzle	Monarch F-80, 24.00	Monarch F-80, 50.00
Fuel Type	Light diesel	Light diesel
Nominal Oil Pressure	125 psi (8.6 bar)	125 psi (8.6 bar)
Nominal Fuel Flow	28 gph (106 liters/hour)	56 gph (212 liters/hour)
Fuel Temperature	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )

NOTE: The free burn characteristics of the fires employed in the fire tests have been calibrated under the FM Global Research Fire Products Collector. Alternative spray nozzles than those listed above may be used if the free burn characteristics are verified by FM Approvals.



K. The fixture stand for the spray fire arrangements should be constructed of a metal, self standing secure arrangement with the oil burner nozzle mounted within and centered at the closed end of a metal cylindrical flame stabilizer can measuring 5.9 in. diameter by 3.0 in. long (150 mm by 75 mm) with a thickness of 0.010 in. (0.25mm).

L. General pool or tray specifications:

Pans or trays shall be of steel construction, 0.068 in. (1.73 mm) thickness by 3.9 in. (10 cm) high, with no lip. The two required pans shall be 39.4 in. (1 m) wide by 39.4 in. (1 m) long and 12 in. (0.1 m) wide by 12 in. (0.1 m) long. A water base of 2.1 in. (5 cm) in height with a fuel load of at least 0.8 in. (2 cm) above should be used. Freeboard should be 1.2 in. (3 cm). Freeboard may be greater than 1.2 in. (3 cm) high, if a constant freeboard height is used for all application fire tests. Pan surfaces should be smooth and edges should be free of imperfections.

M. Insulation mat specifications (optional):

The optional insulation mats shall be cut to the same dimensions as the pan or tray, and placed in a dry pan. The insulation mats should be constructed of mineral wool, be 2 in. (51 mm) in thickness, and contain a density of 6 to 8 lb/ft<sup>3</sup> (96 to 128 kg/m<sup>3</sup>). The fuel shall then be poured on top of the mat for soaking and absorption. The insulation mat should be fully saturated so that finger depression creates an instant small pool.

#### C.4 Fire Tests

Intermediate pendent or upright nozzles that are not at ceiling level, or wall mounted nozzles, are permitted for the protection of combustion turbines.

The hybrid fire extinguishing system shall prevent, and not cause, any damage to the critical turbine components. The damage to the turbine could be caused by direct fire impingement on the hot turbine casing, or by rapid cooling of the turbine casing, resulting in excessive deformation.

The hybrid fire extinguishing system shall successfully complete the first four (C.4.1 through C.4.4) fire performance tests and the Spray Cooling (heat transfer) test (C.4.5). An additional option for combustion turbine applications is the protection of insulated turbines. Two additional fires tests, C.4.6 and C.4.7, involving insulation mats of mineral wool composition, are required for this application extension. During the fire tests, all systems shall operate without manual intervention.

Agent supply needed for the extinguishment time for the longest fire scenario will be reported and considered as one of the requirements when a hybrid extinguishing system is used as a special protection system (see Section 1.9, Definitions). For primary protection, agent supply shall be equivalent to that required for an automatic sprinkler protection system for the hazard protected.

##### C.4.1 Unshielded 1 MW Diesel Spray Fire

Criterion:	The fire is to be extinguished.
Fuel:	Diesel
Type:	Horizontal spray
Spray Nozzle:	1 MW spray nozzle
Fire Location:	The test fire shall be located above the table at a position determined to be the most challenging based on the hybrid media discharge. The fuel nozzle should be located at least 1.0 ft. to 5.5 ft (30.5 cm to 167.6 cm) above the centerline of the table, with the spray fire aimed towards the center of the shorter wall with the access door.
Fire Preburn Time:	15 seconds

Test Procedure: The spray fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### C.4.2 Shielded 1 MW Diesel Spray Fire

Criterion: The fire is to be extinguished.

Fuel: Diesel

Type: Horizontal spray

Spray Nozzle: 1 MW spray nozzle

Fire Location: The test fire shall be located below the table at a position determined to be the most challenging based on the hybrid media discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the shorter wall with the access door.

Fire Preburn Time: 15 seconds

Test Procedure: The spray fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### C.4.3 Shielded 10.8 ft<sup>2</sup> (1 m<sup>2</sup>) Diesel Pool Fire

Criterion: The fire is to be extinguished.

Fuel: Diesel

Type: 10.8 ft<sup>2</sup> (1.0 m<sup>2</sup>) pool fire

Fire Location: The test fire shall be centered below the steel table and located between the baffles, with the baffles located at a position determined to be the most challenging based on the hybrid media discharge.

Fire Preburn Time: 30 seconds

Test Procedure: The pool fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. Following extinguishment, the fuel left in the pool or tray should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

#### C.4.4 Shielded 2 MW Diesel Spray Fire, System Performance under Limited Natural Ventilation

Criterion: The fire is to be extinguished.

Fuel: Diesel

Type: Horizontal spray

Spray Nozzle: 2 MW spray nozzle

Fire Location: The test fire shall be located below the table at a position determined to be the most challenging based on the hybrid media discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the shorter wall with the access door.

Fire Preburn Time: 15 seconds

**Test Procedure:** This test is conducted to determine the capability of the hybrid system to perform acceptably in a ventilated enclosure during system actuation. A shielded 2 MW diesel spray fire shall be ignited in the enclosure with the personnel access door open. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### **C.4.5 Spray Cooling (No Fire)**

**Criteria:** The heat flux resulting from a hybrid fire extinguishing system discharge shall not adversely affect the turbine. Such assessment is to be made in accordance with methodology developed by FM Approvals to measure the damage potential of hybrid systems. This test, combined with FM Global Research proprietary heat transfer calculations, will determine the extent of the cooling of the turbine casing during the operation of the hybrid system. Calculations should be based on the manufacturer's maximum recommended turbine size (diameter) to be installed within the enclosure and/or hybrid nozzle location(s) in the enclosure with respect to the turbine.

**Test Procedure:** The heat flux is affected by the stand-off distance of the hybrid nozzles. Therefore, the test shall be conducted at the minimum nozzle stand-off distance specified in the manufacturer's design manual. The nozzle(s) should be installed at a location(s) above the steel table, based on this specified distance. The design manual may also specify no direct spray impingement of the turbine casing.

A heptane spray fire should be used to heat the steel plate. The spray fire should be located underneath the test table with the fuel spray nozzle aimed at the table at a 30 degree grazing angle, with the flames centered and impinging on the steel table mid point (see Figure C-4). To avoid excess heating of the test enclosure, the ceiling hatches and access door may be left open during the heating of the plate. Additionally, it is recommended to use the 1 MW spray nozzle to heat the plate. An alternative heating system, such as propane burners spaced evenly below the entire steel plate, may be used if it provides uniform heating of the plate and is discussed with FM Approvals prior to testing.

When all three steel plate thermocouples are above 572 °F (300 °C), the spray fire should be shut off, and the steel plate shall be allowed to cool. When the last of three thermocouple readings drops to 572 °F (300 °C), the hybrid system should be activated and the temperature history of the plate shall be recorded for a total of 15 minutes. Uniform heating of the steel plate is critical. Heating, and the subsequent cooling, shall be such that the three thermocouples provide consistent readings at the time of system activation. If excessive variation [greater than 18 °F (10 °C)] exists between the three thermocouples, the heating system should be modified and the plate heated again.

The spray cooling data should be recorded in Microsoft Excel format. This data will be analyzed to determine the effective spray cooling heat flux for the particular test configuration. The heat flux is known to be affected by the drop size, impingement velocity, mass flux, surface composition and texture. However, the effects of these individual variables will not be investigated.

**C.4.6 Saturated Insulation Mat and Spray Fire (Optional Test)**

Criteria:	Both the spray and insulation mat fires are to be extinguished.
Fuel:	Diesel fuel and insulation mat
Type:	Horizontal spray and diesel fuel saturated insulation mat fires
Spray Nozzle:	1 MW spray nozzle
Fire Locations:	The insulation mat fire shall be centered below the steel table and located between the baffles, with the baffles located at a position determined to be the most challenging based on the hybrid media discharge. The insulation mat shall be positioned under the spray fire. The spray fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the shorter wall with the access door.
Fire Preburn Time:	30 seconds
Test Procedure:	A 2 in. (51 mm) thick insulation mat of mineral wool composition shall be cut to the same dimensions as the 1 ft <sup>2</sup> (0.1 m <sup>2</sup> ) pan and placed in the dry pan. The insulation mat shall then be saturated with diesel fuel, such that a liquid fuel pool occurs when slightly depressing the mat. The insulation mat fire shall be ignited in the enclosure with the personnel access door closed. The spray fire should be ignited 15 seconds after the insulation mat fire is fully developed over the entire area of the mat. The hybrid fire extinguishing system should then be activated 15 seconds after ignition of the spray fire (30 seconds after the insulation mat fire is fully developed). The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

**C.4.7 Large Saturated Insulation Mat (Optional Test)**

Criterion:	The insulation mat fire is to be controlled (only flamlets at the surface of the mat).
Fuel:	Diesel fuel and insulation mat
Type:	10.8 ft <sup>2</sup> (1.0 m <sup>2</sup> ) diesel fuel saturated insulation mat fire
Fire Location:	The test fire shall be centered below the steel table and located between the baffles, with the baffles located at a position determined to be the most challenging based on the hybrid media discharge.
Fire Preburn Time:	30 seconds
Test Procedure:	A 2 in. (51 mm) thick insulation mat of mineral wool composition shall be cut to the same dimensions as the 10.8 ft <sup>2</sup> (1.0 m <sup>2</sup> ) pan and placed in the dry pan. The insulation mat shall then be saturated with diesel fuel, such that a liquid fuel pool occurs when slightly depressing the mat. The insulation mat fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated 30 seconds after the insulation mat fire is fully developed over the entire area of the mat.

**C.4.8 Additional Fire Tests**

Based on the results of Fire Tests C.4.1 through C.4.7, additional fire testing may be required to ensure that the hybrid fire extinguishing system being evaluated meets the intent of this section of the standard. This testing will be performed at the sole discretion of FM Approvals.

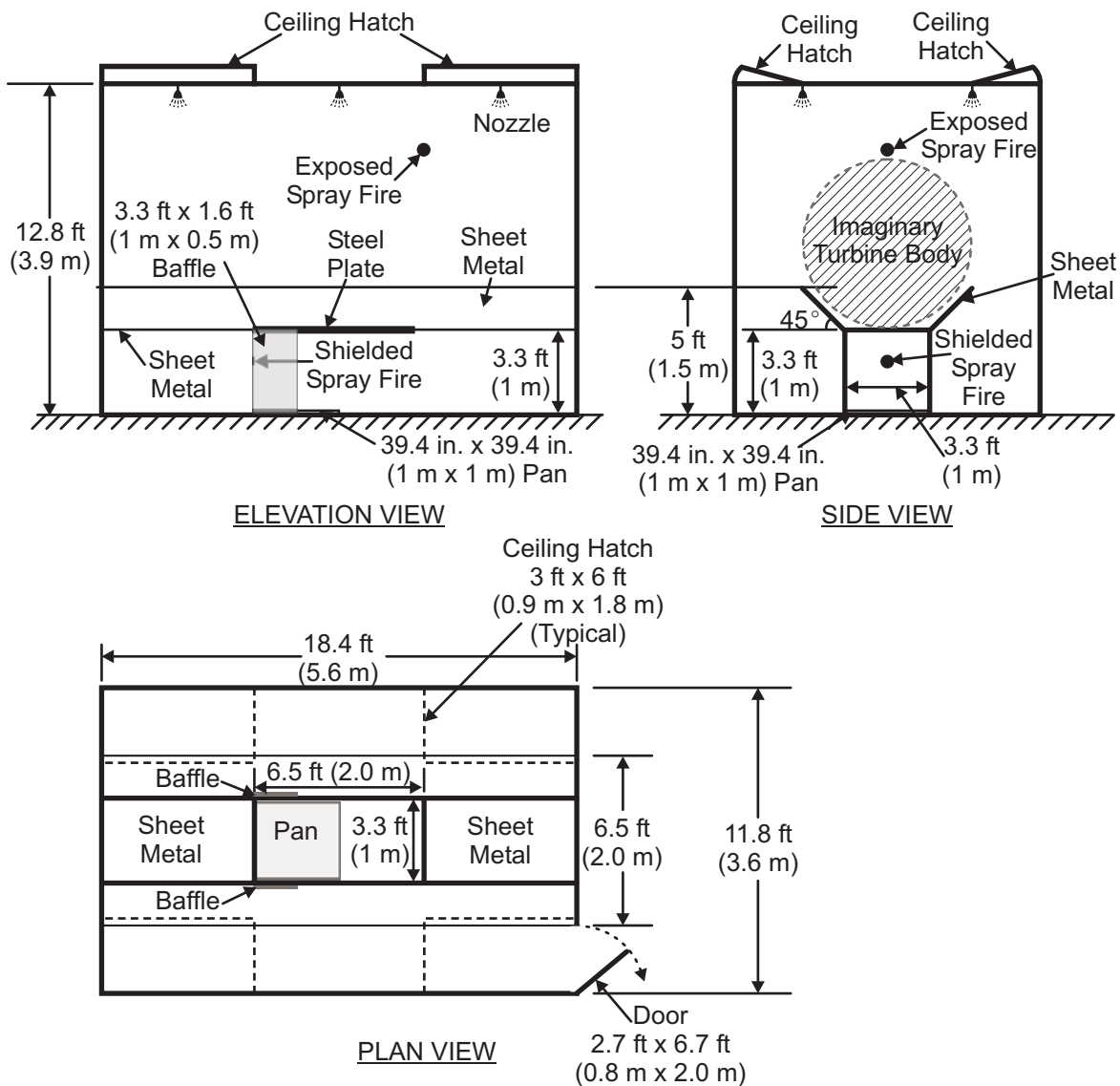


Figure C-1. Test Enclosure and Combustion Turbine Simulator Steel Plate

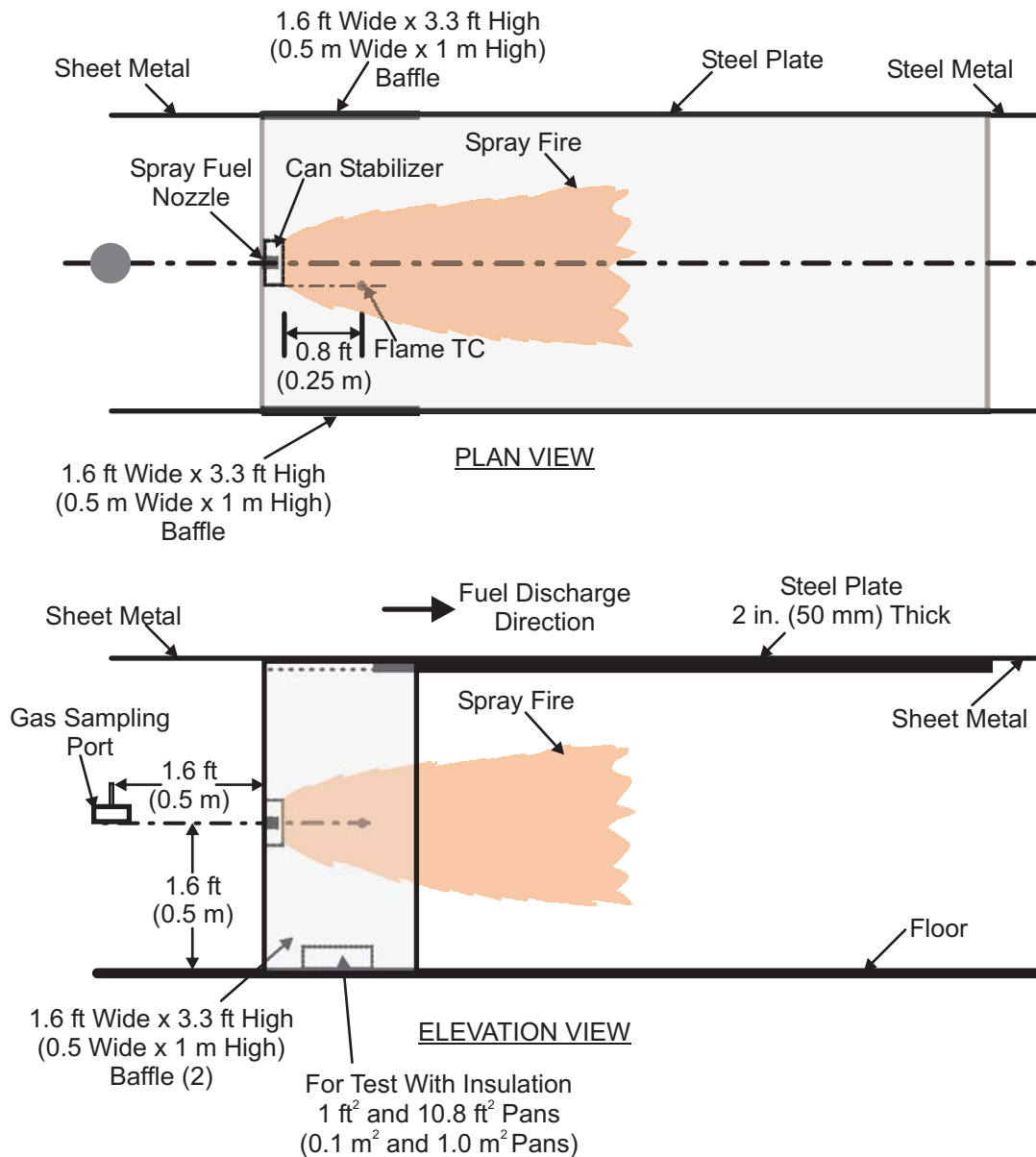


Figure C-2. Fire Source Configuration and Instrumentation for Shielded Spray Fire Testing

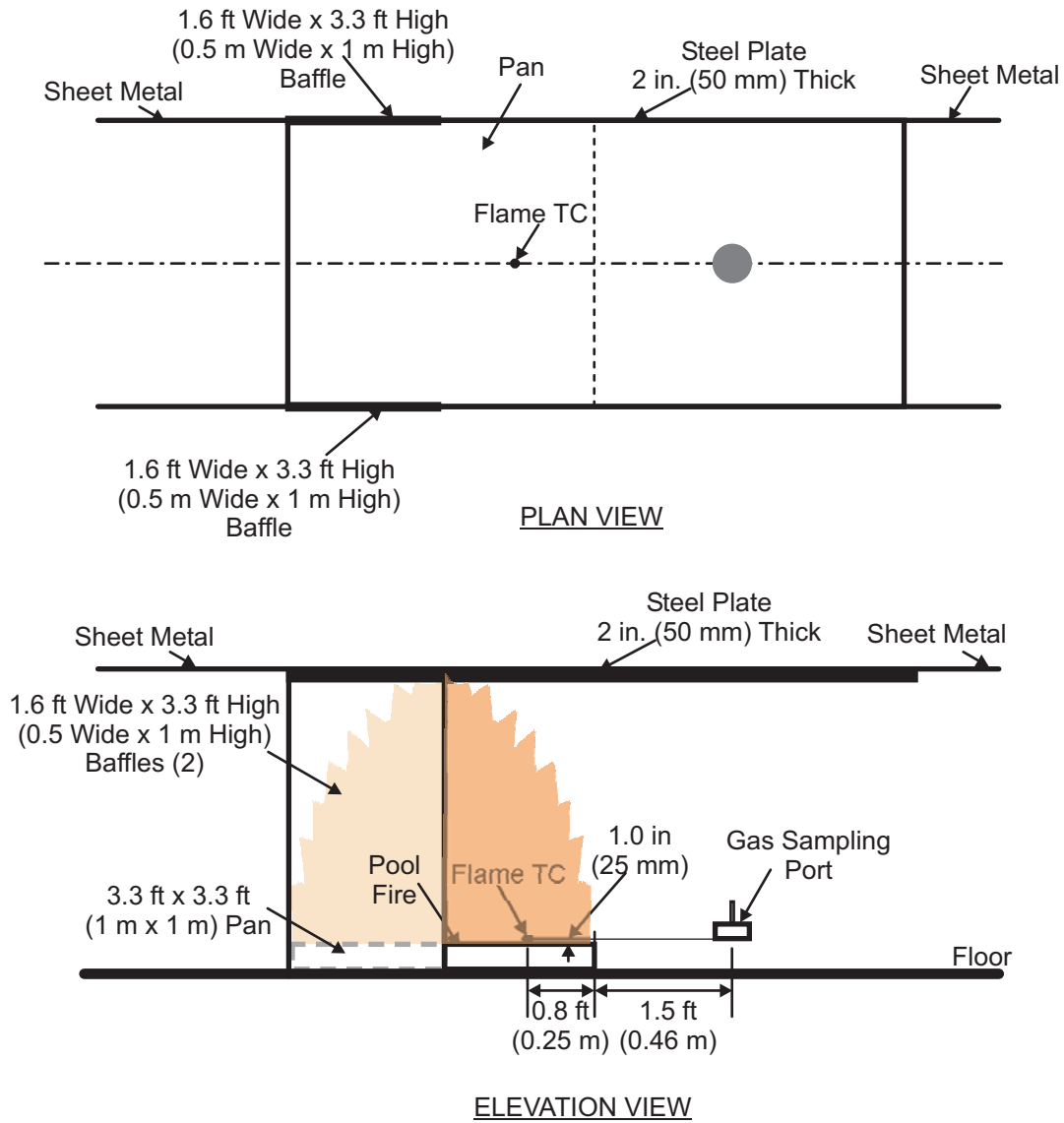


Figure C-3. Fire Source Configuration and Instrumentation for Shielded Pool Fire Testing

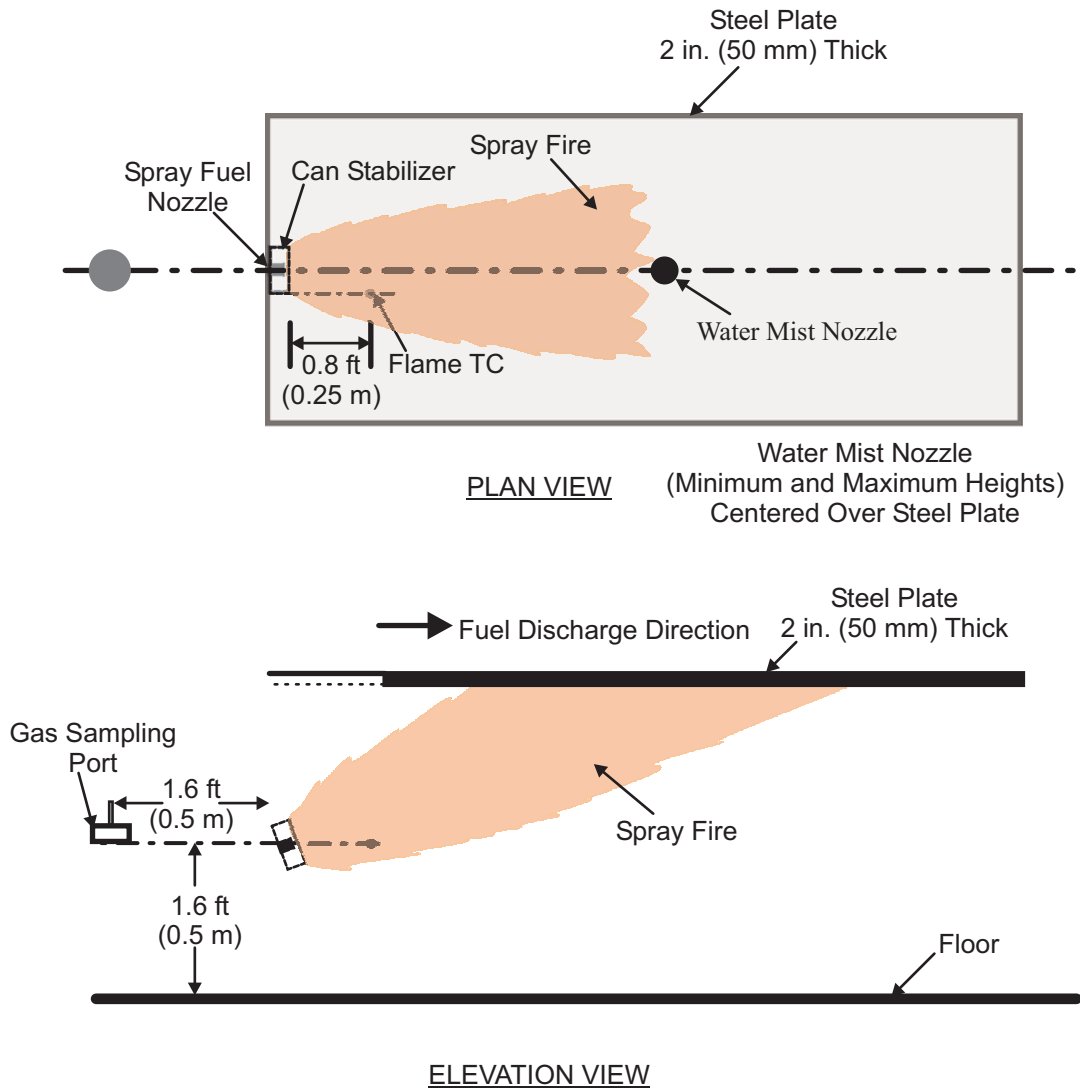


Figure C-4. Fire Source Configuration for Spray Cooling (No Fire) Testing



## **APPENDIX D: Fire Tests for Hybrid Fire Extinguishing Systems for the Protection of Machinery Spaces with Volumes not Exceeding 9175 ft<sup>3</sup> (260 m<sup>3</sup>)**

### **D.1 Test Enclosure (see Figure D-1)**

The test enclosure area shall have main dimensions of 24.0 ft by 24.0 ft by 16.1 ft high (7.3 m by 7.3 m by 4.9 m high). The enclosure should be constructed of wood or metal frame with an inner lining of minimum 0.5 in. (13 mm) gypsum or 0.03 in. (0.7 mm) galvanized steel. To minimize leakages, all joints and gaps shall be sealed. At 9 ft (2.7 m) from one of the enclosure corners, in one of the walls parallel to the machinery equipment mockup, a 2.7 ft by 6.7 ft high (0.8 m by 2.0 m high) personnel door should be installed with a locking mechanism. A 4.0 ft by 8.0 ft high (1.2 m by 2.4 m high) removable panel should also be installed in one of the walls to allow for test enclosure access (The personnel door may be constructed within this panel). A minimum of two hinged ceiling hatches measuring approximately 3 ft by 6 ft (0.9 m by 1.8 m) should be installed in opposite diagonal corners for heat and smoke release at the conclusion of the fire test. The floor should be noncombustible and any floor drainage or vent openings should be sealed during testing. A small louvered vent may be provided to allow the intake of air, to prevent excessive suctioning of the walls and ceiling and maintain structural integrity of the fire test enclosure.

### **D.2 Machinery Equipment Mockup**

The machinery mockup is a horizontal flat steel table and steel baffles to provide shielded spaces for fires (see Figure D-1). The specific details and thermal mass of the obstructions are not simulated.

The mockup unit should be centered along one of the 24.0 ft (7.3 m) walls of the enclosure, such that the mockup is parallel to the wall with the personnel door. FM Approvals reserves the right to alter the placement of the mockup unit with respect to the aspect ratio of the enclosure.

A horizontal 22 gauge (0.85 mm thick) galvanized steel sheet metal table measuring 3.3 ft by 24 ft (1.0 m by 7.3 m) is placed at 3.3 ft (1 m) elevation on steel legs. This is located in the center of the room or at a location within the test cell to be selected by FM Approvals after the nozzles are installed (as per manufacturer's design criteria). This allows the fire to be placed in an area considered the most challenging to the specific system being tested. The bottom of a cylindrical piece of equipment is simulated with 22 gauge (0.85 mm thick) galvanized steel sheet metal directed upward at an angle of 45 degrees on either side of the horizontal steel sheet metal table surface. These side pieces also extend longitudinally the entire length of the enclosure, rising to a height of 4.9 ft (1.5 m) above the horizontal steel sheet metal surface. The total width of the mockup is 6.6 ft (2.0 m). If multiple sections of steel sheet metal are used, there should be a minimal gap between the various sections to permit water run-off. It is recommended to either butt up or simply attach the table and sheet metal extension surfaces with screw fasteners.

The space below the table is partially shielded from hybrid media using 3.3 ft high by 1.6 ft wide (1 m by 0.5 m) sheet metal baffles. The side baffles should be of 22 gauge (0.85 mm thick) galvanized steel sheet metal construction and removable. They may be installed on support legs and kept in place by being pinched between the underside of the steel table and 45 degree angle extensions and the floor for ease of removal. Placement of additional baffles or obstructions may be needed to prevent the direct impact of mist on the pool or spray test fires, at the sole discretion of FM Approvals.

### **D.3 Instrumentation and Test Equipment Requirements**

In addition to the instrumentation and test requirements described previously under "General Instrumentation and Test Equipment Requirements," the following measurements should be recorded to within a  $\pm 5$  percent tolerance level at intervals not exceeding one second using a computerized data acquisition system. Measurements should begin and end at least one minute prior to ignition and after extinguishment of the test fire(s).

- A. Fuel pressure and flow at the outlet of fuel pump (fuel flow and pressure should be measured prior to each test series).
- B. Fuel temperature within the fuel storage container. All fuels shall be at an ambient temperature of  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ).
- C. Temperature of fuel in pools with thermocouple located in the approximate center of the initial fuel layer. All fuels shall initially be at an ambient temperature of  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ).
- D. Test enclosure temperatures measured in the center portion of the room at the 1/3, 2/3 and ceiling heights. The enclosure and mockup shall initially be at an ambient temperature  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ) for all tests.
- E. Temperature of air into the spray fires, measured approximately 20 in. (50 cm) horizontally behind fuel spray nozzle with bare bead thermocouples welded from 28 gauge chromel-alumel wire.
- F. Pool fire temperatures with a thermocouple located approximately 1 in. (2.5 cm) above the initial pool surface and 10 in. (25 cm) within the pool rim.
- G. Spray fire temperatures with a thermocouple located approximately 10 in. (25 cm) ahead of flame stabilizer at the cone radius.
- H. Extinguishment should be registered by thermocouples located above the pools and in front of the spray fires as previously described. The fire can be considered to be extinguished when temperature registration drops below  $212\text{ }^{\circ}\text{F}$  ( $100\text{ }^{\circ}\text{C}$ ) and does not increase. Registration by means of thermal imaging equipment, in addition to the thermocouples, is strongly encouraged.
- I. Oxygen, carbon monoxide and carbon dioxide concentrations, measured approximately 20 in. (50 cm) horizontally behind fuel spray nozzle or away from the pool, at the same level above the floor, and away from any open door or ventilation source.
- J. For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

<i>Fire Size</i>	<i>1 MW Diesel Spray</i>	<i>2 MW Diesel Spray</i>
Spray Nozzle	Monarch F-80, 24.00	Monarch F-80, 50.00
Fuel Type	Diesel	Diesel
Nominal Oil Pressure	125 psi (8.6 bar)	125 psi (8.6 bar)
Nominal Fuel Flow	28 gph (106 liters/hour)	56 gph (212 liters/hour)
Fuel Temperature	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )

NOTE: The free burn characteristics of the fires employed in the fire tests have been calibrated under the FM Global Research Fire Products Collector. Alternative spray nozzles than those listed above may be used if the free burn characteristics are verified by FM Approvals.

<i>Fire Size</i>	<i>1 MW Heptane Spray</i>	<i>2 MW Heptane Spray</i>
Spray Nozzle	Monarch F-80, 24.00	Monarch F-80, 50.00
Fuel Type	Heptane	Heptane
Nominal Oil Pressure	125 psi (8.6 bar)	125 psi (8.6 bar)
Nominal Fuel Flow	31 gph (117 liters/hour)	62 gph (235 liters/hour)
Fuel Temperature	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )

NOTE: The free burn characteristics of the fires employed in the fire tests have been calibrated under the FM Global Research Fire Products Collector. Alternative spray nozzles than those listed above may be used if the free burn characteristics are verified by FM Approvals.

- K. The fixture stand for the spray fire arrangements should be constructed of a metal, self standing secure arrangement with the oil burner nozzle mounted within and centered at the closed end of a metal cylindrical flame stabilizer can measuring 5.9 in. diameter by 3.0 in. long (150 mm by 75 mm) with a thickness of 0.010 in. (0.25mm).

L. General pool or tray specifications:

Pans or trays shall be 39.4 in. (1 m) wide by 39.4 in. (1 m) long, of steel construction, 0.068 in. (1.73 mm) thickness by 3.9 in. (10 cm) high, with no lip. A water base of 2.1 in. (5 cm) in height with a fuel load of at least 0.8 in. (2 cm) above should be used. Freeboard should be 1.2 in. (3 cm). Freeboard may be greater than 1.2 in. (3 cm) high, if a constant freeboard height is used for all application fire tests. Pan surfaces should be smooth and edges should be free of imperfections.

#### D.4 Fire Tests

Intermediate pendent or upright nozzles that are not at ceiling level, or wall mounted nozzles, are not permitted for the machinery spaces.

The hybrid fire extinguishing system shall successfully complete all five performance fire tests described in this section. During the fire tests, all systems shall operate without manual intervention.

Agent supply needed for the extinguishment time for the longest fire scenario will be reported and considered as one of the requirements when a hybrid extinguishing system is used as a special protection system (see Section 1.9, definitions). For primary protection, agent supply shall be equivalent to that required for an automatic sprinkler protection system for the hazard protected.

##### D.4.1 Unshielded 1 MW Diesel Spray Fire

Criterion:	The fire is to be extinguished.
Fuel:	Diesel
Type:	Horizontal spray
Spray Nozzle:	1 MW spray nozzle
Fire Location:	The test fire shall be located above the table at a position determined to be the most challenging based on the hybrid media discharge. The fuel nozzle should be located at least 1.0 ft. to 5.5 ft (30.5 cm to 167.6 cm) above the centerline of the table, with the spray fire aimed towards the center of the wall without the access door.
Fire Preburn Time:	15 seconds
Test Procedure:	The spray fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

##### D.4.2 Shielded 1 MW Diesel Spray Fire

Criterion:	The fire is to be extinguished.
Fuel:	Diesel
Type:	Horizontal spray
Spray Nozzle:	1 MW spray nozzle
Fire Location:	The test fire shall be located below the table at a position determined to be the most challenging based on the hybrid media discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the wall without the access door.
Fire Preburn Time:	15 seconds

Test Procedure: The spray fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### **D.4.3 Shielded 10.8 ft<sup>2</sup> (1 m<sup>2</sup>) Diesel Pool Fire**

Criterion: The fire is to be extinguished.

Fuel: Diesel

Type: 10.8 ft<sup>2</sup> (1.0 m<sup>2</sup>) pool fire

Fire Location: The test fire shall be centered below the steel table and located between the baffles, with the baffles located at a position determined to be the most challenging based on the hybrid media discharge.

Fire Preburn Time: 30 seconds

Test Procedure: The pool fire shall be ignited in the enclosure with the personnel access door closed. The water hybrid fire extinguishing system should be activated subsequent to the required preburn time. Following extinguishment, the fuel left in the pool or tray should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

#### **D.4.4 Shielded 2 MW Diesel Spray Fire, System Performance under Limited Natural Ventilation**

Criterion: The fire is to be extinguished.

Fuel: Diesel

Type: Horizontal spray

Spray Nozzle: 2 MW spray nozzle

Fire Location: The test fire shall be located below the table at a position determined to be the most challenging based on the hybrid media discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the wall without the access door.

Fire Preburn Time: 15 seconds

Test Procedure: This test is conducted to determine the capability of the hybrid system to perform acceptably in a ventilated enclosure during system actuation. A shielded 2 MW diesel spray fire shall be ignited in the enclosure with the personnel access door open. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### **D.4.5 Shielded 2 MW Diesel Spray Fire, System Performance at Smaller Enclosure Volumes**

Criterion: The fire is to be extinguished.

Fuel: Diesel

Type: Horizontal spray

Spray Nozzle: 2 MW spray nozzle

Fire Location: The test fire shall be located below the table at a position determined to be the most challenging based on the hybrid media discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the wall without the access door.

Fire Preburn Time: 15 seconds

Test Procedure: This test is conducted to determine the capability of the hybrid system to perform acceptably in smaller volumes. A shielded 2 MW spray fire shall be ignited, with the personnel access door open, in an enclosure with a volume of 4590 ft<sup>3</sup> (130 m<sup>3</sup>). The smaller volume should be created by erecting a wall within the enclosure, or relocating one of the walls, perpendicular to the turbine mockup. If necessary, the personnel door may be relocated to accommodate the modified enclosure. Only the nozzles within the 4590 ft<sup>3</sup> (130 m<sup>3</sup>) volume are to be activated, subsequent to the required fire preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### D.4.6 Unshielded 1 MW Heptane Spray Fire

Criterion: The fire is to be extinguished.

Fuel: Heptane

Type: Horizontal spray

Spray Nozzle: 1 MW spray nozzle

Fire Location: The test fire shall be located above the table at a position to be determined to be the most challenging based on the hybrid media discharge. The fuel nozzle should be located at least 1.0 ft. to 5.5 ft (30.5 cm to 167.6 cm) above the centerline of the table, with the spray fire aimed towards the center of the wall without the access door.

Fire Preburn Time: 15 seconds

Test Procedure: The spray fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### D.4.7 Shielded 1 MW Heptane Spray Fire

Criterion: The fire is to be extinguished.

Fuel: Heptane

Type: Horizontal spray

Spray Nozzle: 1 MW spray nozzle

Fire Location: The test fire shall be located below the table at a position determined to be the most challenging based on the hybrid media discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the wall without the access door.

Fire Preburn Time: 15 seconds

Test Procedure: The spray fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### D.4.8 Shielded 10.8 ft<sup>2</sup> (1 m<sup>2</sup>) Heptane Pool Fire

Criterion: The fire is to be extinguished.

Fuel: Heptane

Type: 10.8 ft<sup>2</sup> (1.0 m<sup>2</sup>) pool fire

Fire Location: The test fire shall be centered below the steel plate and located between the baffles, with the baffles located at a position determined to be the most challenging based on the hybrid media discharge.

Fire Preburn Time: 30 seconds  
 Test Procedure: The pool fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. Following extinguishment, the fuel left in the pool or tray should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

#### **D.4.9 Shielded 2 MW Heptane Spray Fire, System Performance under Limited Natural Ventilation**

Criterion: The fire is to be extinguished.  
 Fuel: Heptane  
 Type: Horizontal spray  
 Spray Nozzle: 2 MW spray nozzle  
 Fire Location: The test fire shall be located below the table at a position determined to be the most challenging based on the hybrid media discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the wall without the access door.  
 Fire Preburn Time: 15 seconds  
 Test Procedure: This test is conducted to determine the capability of the hybrid system to perform acceptably in a ventilated enclosure during system actuation. A shielded 2 MW heptane spray fire shall be ignited in the enclosure with the personnel access door open. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### **D.4.10 Shielded 2 MW Heptane Spray Fire, System Performance at Smaller Enclosure Volumes**

Criterion: The fire is to be extinguished.  
 Fuel: Heptane  
 Type: Horizontal spray  
 Spray Nozzle: 2 MW spray nozzle  
 Fire Location: The test fire shall be located below the table at a position determined to be the most challenging based on the hybrid media discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the wall without the access door.  
 Fire Preburn Time: 15 seconds  
 Test Procedure: This test is conducted to determine the capability of the hybrid system to perform acceptably in smaller volumes. A shielded 2 MW spray fire shall be ignited, with the personnel access door open, in an enclosure with a volume of 4590 ft<sup>3</sup> (130 m<sup>3</sup>). The smaller volume should be created by erecting a wall within the enclosure, or relocating one of the walls, perpendicular to the turbine mockup. If necessary, the personnel door may be relocated to accommodate the modified enclosure. Only the nozzles within the 4590 ft<sup>3</sup> (130 m<sup>3</sup>) volume are to be activated, subsequent to the required fire preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### **D.4.11 Additional Fire Tests**

Based on the results of Fire Tests D.4.1 through D.4.10, additional fire testing may be required to ensure that the hybrid fire extinguishing system being evaluated meets the intent of this section of the standard. This testing will be performed at the sole discretion of FM Approvals.

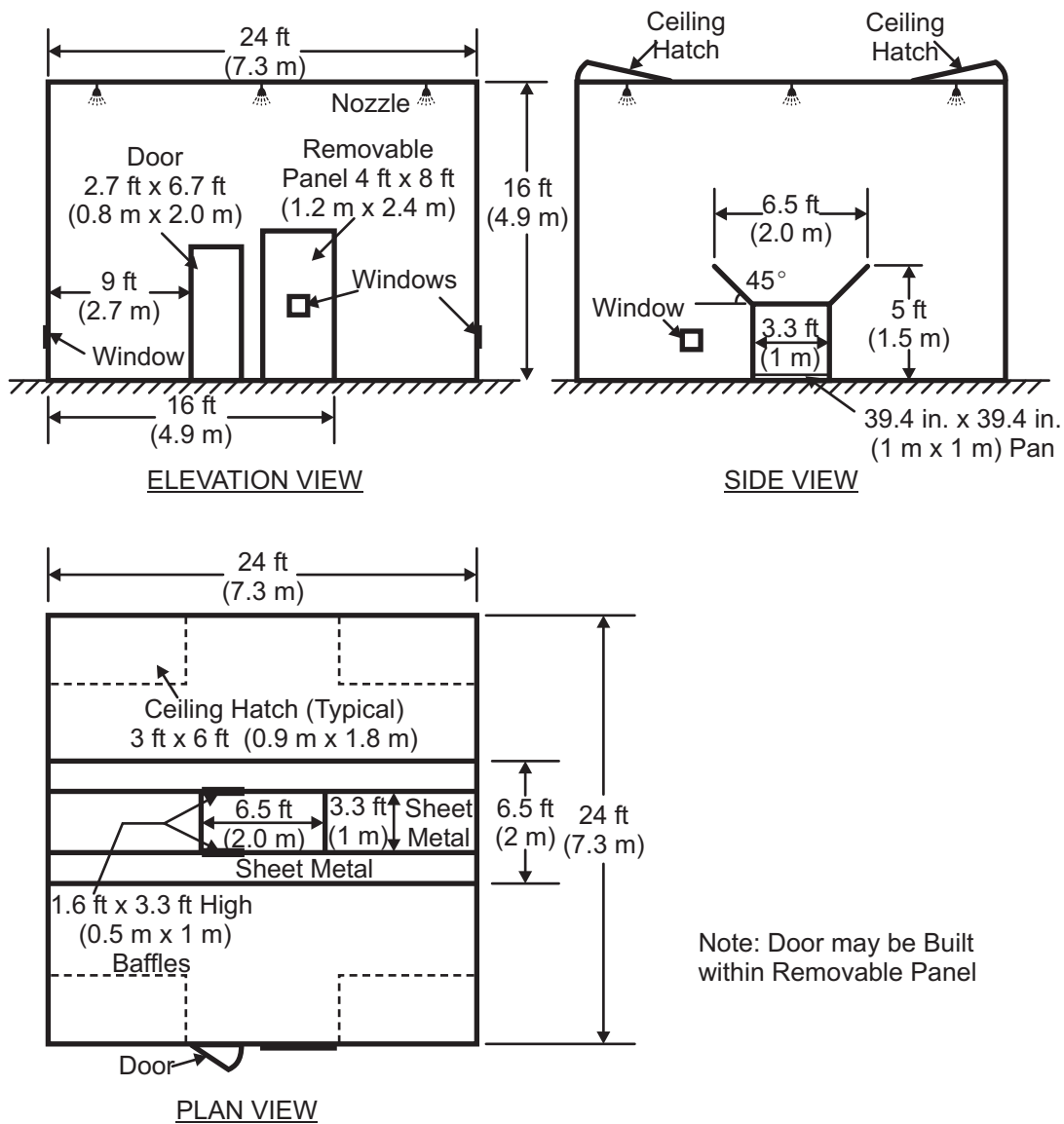


Figure D-1. Test Enclosure and Machinery Mockup Steel Plate

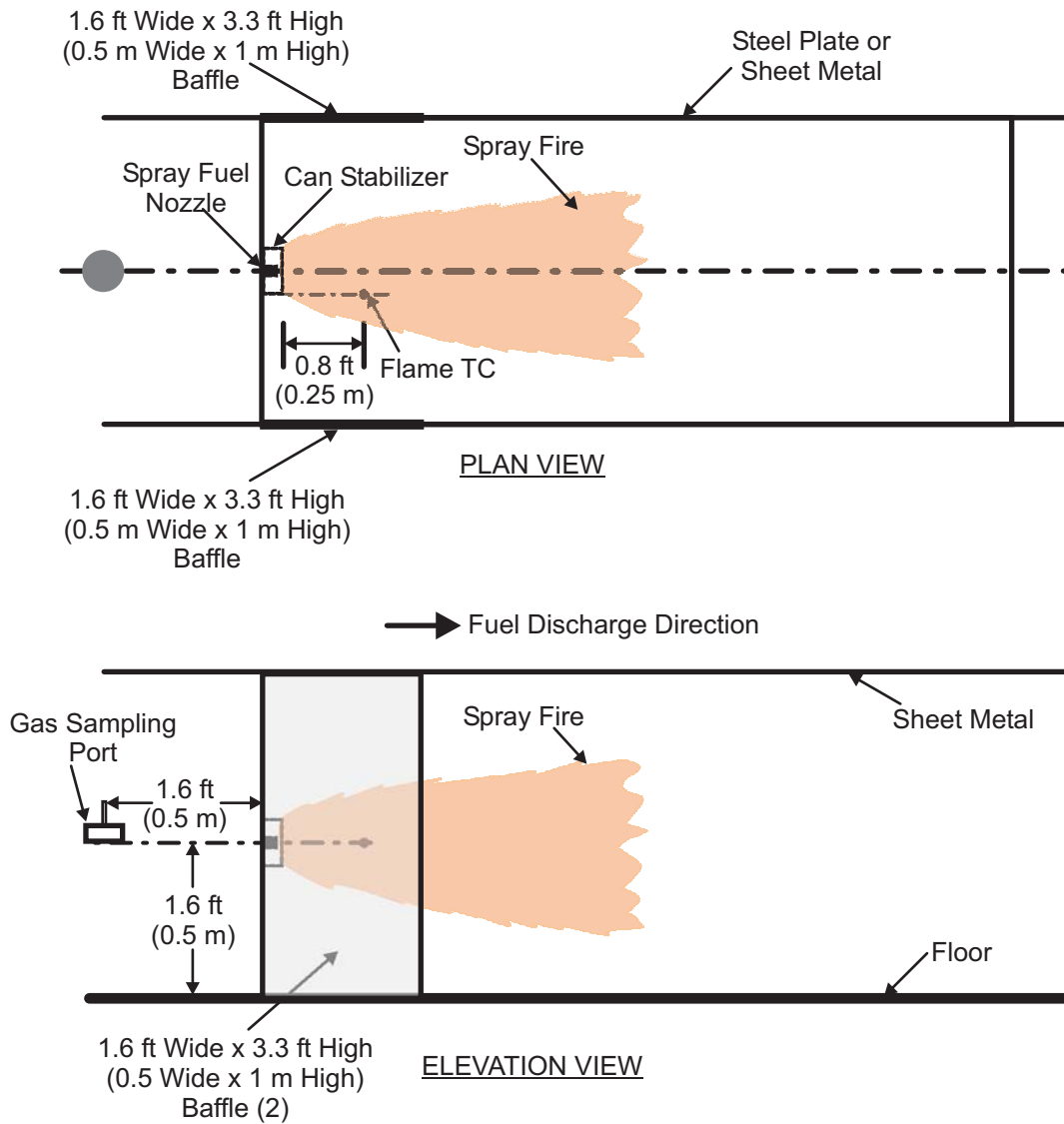


Figure D-2. Fire Source Configuration and Instrumentation for Shielded Spray Fire Testing



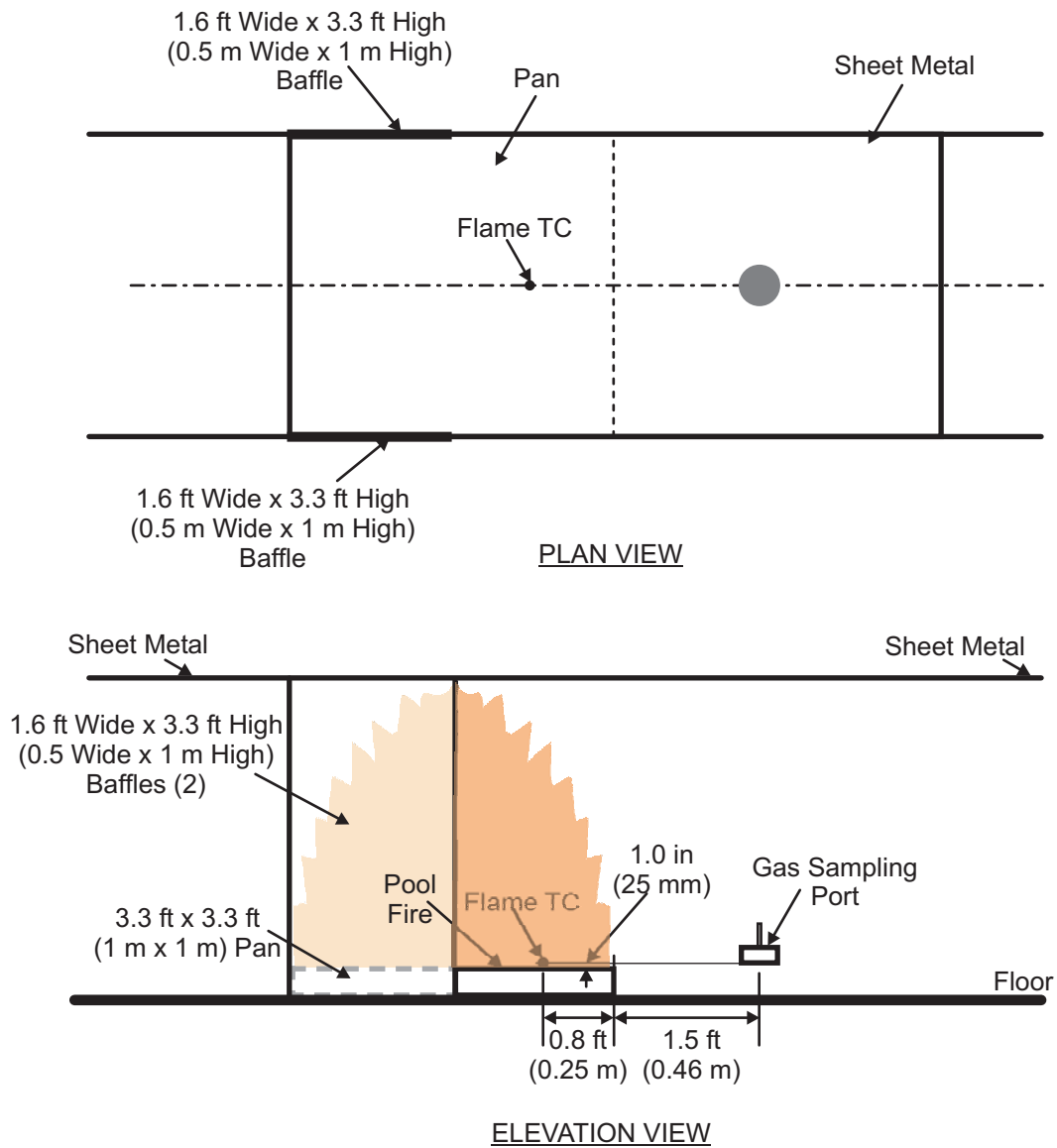


Figure D-3. Fire Source Configuration and Instrumentation for Shielded Pool Fire Testing

## APPENDIX E: Fire Tests for Hybrid Fire Extinguishing Systems for the Protection of Combustion Turbines with Volumes not Exceeding 9175 ft<sup>3</sup> (260 m<sup>3</sup>)

### E.1 Test Enclosure (see Figure E-1)

The test enclosure area has main dimensions of 24.0 ft by 24.0 ft by 16.1 ft high (7.3 m by 7.3 m by 4.9 m high). The enclosure should be constructed of wood or metal frame with an inner lining of minimum 0.5 in. (13 mm) gypsum or 0.03 in. (0.7 mm) galvanized steel. To minimize leakages, all joints and gaps shall be sealed. At 9 ft (2.74 m) from one of the enclosure corners, in one of the walls parallel to the machinery equipment mockup, a 2.7 ft by 6.7 ft high (0.8 m by 2.0 m high) personnel door should be installed with a locking mechanism. A 4.0 ft by 8.0 ft high (1.2 m by 2.4 m high) removable panel should also be installed for test enclosure access (The personnel door may be constructed within this panel). A minimum of two hinged ceiling hatches measuring approximately 3 ft by 6 ft (0.9 m by 1.8 m) should be installed in opposite diagonal corners for heat and smoke release at the conclusion of the fire test. The floor should be noncombustible and any floor drainage or vent openings should be sealed during testing. A small louvered vent may be provided to allow the intake of air, to prevent excessive suctioning of the walls and ceiling and maintain structural integrity of the fire test enclosure.

### E.2 Combustion Turbine Mockup

The combustion turbine casing mockup is simulated with a horizontal flat steel plate and steel baffles to provide shielded spaces for fires (see Figure E-1). The specific details and thermal mass of the obstructions are not simulated.

The combustion turbine mockup unit should be centered along the longer wall dimension in the test enclosure. FM Approvals reserves the right to alter the placement of the mockup unit with respect to the aspect ratio of the enclosure.

A horizontal ASTM A 36 hot rolled steel plate, 3.3 ft by 6.5 ft by 2 in. thick (1.0 m wide by 2.0 m long by 5 cm thick), is placed at 3.3 ft (1 m) elevation on steel legs at the four corners of the plate. This is located in the center of the room or at a location within the test cell to be selected by FM Approvals after the nozzles are installed (as per manufacturer's design criteria). This allows the fire to be placed in an area considered the most challenging to the specific system being tested. In lieu of actual turbine casing material, which is typically ductile iron, the test plate is constructed of hot rolled ASTM A36 steel. The center of the plate is instrumented across its thickness with thermocouples placed at various depths, as described below.

Horizontal 22 gauge (0.85 mm thick) galvanized steel sheet metal shall be placed at an elevation of 3.3 ft (1 m) on steel legs, on both sides of the ASTM A36 steel table, so that the combustion turbine mockup extends longitudinally the entire length of the enclosure (see Figure E-1).

To determine the cooling rate of the combustion turbine steel plate mockup, caused by the discharge of the hybrid fire extinguishing system, three thermocouples should each be embedded near the center of the plate at approximately, 0.5 in., 1.0 in, and 1.50 in. (12 mm, 25 mm, and 38 mm) below the plate's top surface. The three inconel-sheathed thermocouples should be embedded in the plate by removing cylindrical plugs from the plate.

The thermocouples should be inserted to allow the thermocouple wire to follow a horizontal path of sixteen thermocouple diameters in length, thus reducing errors due to the vertical temperature gradient in the plate. A heat conductive and electrically insulating sealant should be applied, and the steel cylindrical plugs should be replaced and welded to the plate around the top periphery of the plugs. This can be accomplished by using a 1.0 in. (25 mm) diameter miller tool, installing the thermocouples, and then refilling the hole with welded 1.0 in. (25 mm) round bar stock (see Figure E-5).

The underside curvature of the turbine is simulated with 22 gauge (0.85 mm thick) galvanized sheet metal directed upward at an angle of 45 degrees on either side of the steel plate and horizontal sheet metal extension surface. These side pieces also extend longitudinally the entire length of the enclosure, rising to a height of 4.9 ft (1.5 m) above the horizontal sheet metal and steel plate surfaces. The total width of the mockup is 6.6 ft (2.0 m). There should be a minimal gap between the various steel table and sheet metal surfaces to permit water run-off. For ease of conducting the

spray cooling test, it is recommended to either butt up or simply attach the table and sheet metal extension surfaces with screw fasteners.

The space below the plate is partially shielded from hybrid media using 3.3 ft high by 1.6 ft wide (1 m by 0.5 m) sheet metal baffles. The side baffles should be of 22 gauge (0.85 mm thick) galvanized sheet metal construction and removable. They may be installed on support legs and kept in place by being pinched between the underside of the steel plate table and the 45 degree angle extensions and the floor for ease of removal. Placement of additional baffles or obstructions may be needed to prevent the direct impact of mist on the pool or spray test fires, at the sole discretion of FM Approvals.

### E.3 Instrumentation and Test Equipment Requirements

In addition to the instrumentation and test requirements described previously under “General Instrumentation and Test Equipment Requirements,” the following measurements should be recorded to within a  $\pm 5$  percent tolerance level at intervals not exceeding one second using a computerized data acquisition system. Measurements should begin and end at least one minute prior to ignition and after extinguishment of the test fire(s).

- A. Fuel pressure and flow at the outlet of fuel pump (fuel flow and pressure should be measured prior to each test series).
- B. Fuel temperature within the fuel storage container. All fuels shall be at an ambient temperature of  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ).
- C. Temperature of fuel in pools with thermocouple located in the approximate center of the initial fuel layer. All fuels shall initially be at an ambient temperature of  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ).
- D. Test enclosure temperatures measured in the center portion of the room at the 1/3, 2/3 and ceiling heights. The enclosure and mockup shall initially be at an ambient temperature  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ) for all tests.
- E. Temperature of air into the spray fires, measured approximately 20 in. (50 cm) horizontally behind fuel spray nozzle with bare bead thermocouples welded from 28 gauge chromel-alumel wire.
- F. Pool fire temperatures with a thermocouple located approximately 1 in. (2.5 cm) above the initial pool surface and 10 in. (25 cm) within the pool rim.
- G. Spray fire temperatures with a thermocouple located approximately 10 in. (25 cm) ahead of flame stabilizer at the cone radius.
- H. Extinguishment should be registered by thermocouples located above the pools and in front of the spray fires as previously described. The fire can be considered to be extinguished when temperature registration drops below  $212\text{ }^{\circ}\text{F}$  ( $100\text{ }^{\circ}\text{C}$ ) and does not increase. Registration by means of thermal imaging equipment, in addition to the thermocouples, is strongly encouraged.
- I. Oxygen, carbon monoxide and carbon dioxide concentrations, measured approximately 20 in. (50 cm) horizontally behind fuel spray nozzle or away from the pool, at the same level above the floor, and away from any open door or ventilation source.

- J. For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

<i>Fire Size</i>	<i>1 MW Diesel Spray</i>	<i>2 MW Diesel Spray</i>
Spray Nozzle	Monarch F-80, 24.00	Monarch F-80, 50.00
Fuel Type	Light diesel	Light diesel
Nominal Oil Pressure	125 psi (8.6 bar)	125 psi (8.6 bar)
Nominal Fuel Flow	28 gph (106 liters/hour)	56 gph (212 liters/hour)
Fuel Temperature	68 °F ± 18 °F (20 °C ± 10 °C)	68 °F ± 18 °F (20 °C ± 10 °C)

NOTE: The free burn characteristics of the fires employed in the fire tests have been calibrated under the FM Global Research Fire Products Collector. Alternative spray nozzles than those listed above may be used if the free burn characteristics are verified by FM Approvals.

- K. The fixture stand for the spray fire arrangements should be constructed of a metal, self standing secure arrangement with the oil burner nozzle mounted within and centered at the closed end of a metal cylindrical flame stabilizer can measuring 5.9 in. diameter by 3.0 in. long (150 mm by 75 mm) with a thickness of 0.010 in. (0.25mm).
- L. General pool or tray specifications:

Pans or trays shall be of steel construction, 0.068 in. (1.73 mm) thickness by 3.9 in. (10 cm) high, with no lip. The two required pans shall be 39.4 in. (1 m) wide by 39.4 in. (1 m) long and 12 in. (0.1 m) wide by 12 in. (0.1 m) long. A water base of 2.1 in. (5 cm) in height with a fuel load of at least 0.8 in. (2 cm) above should be used. Freeboard should be 1.2 in. (3 cm). Freeboard may be greater than 1.2 in. (3 cm) high, if a constant freeboard height is used for all application fire tests. Pan surfaces should be smooth and edges should be free of imperfections.

- M. Insulation mat specifications (optional):

The optional insulation mats shall be cut to the same dimensions as the pan or tray, and placed in a dry pan. The insulation mats should be constructed of mineral wool, be 2 in. (51 mm) in thickness, and contain a density of 6 to 8 lb/ft<sup>3</sup> (96 to 128 kg/m<sup>3</sup>). The fuel shall then be poured on top of the mat for soaking and absorption. The insulation mat should be fully saturated so that finger depression creates an instant small pool.

#### E.4 Fire Tests

Intermediate pendent or upright nozzles that are not at ceiling level, or wall mounted nozzles, are permitted for the protection of combustion turbines.

The hybrid fire extinguishing system shall prevent, and not cause, any damage to the critical turbine components. The damage to the turbine could be caused by direct fire impingement on the hot turbine casing, or by rapid cooling of the turbine casing, resulting in excessive deformation.

The hybrid fire extinguishing system shall successfully complete the first five (E.4.1 through E.4.5) fire performance tests and the Spray Cooling (heat transfer) test (E.4.6). An additional option for combustion turbine applications is the protection of insulated turbines. Two additional fires tests (E.4.7 and E.4.8), involving insulation mats of mineral wool composition, are required for this application extension. During the fire tests, all systems shall operate without manual intervention.

Agent supply needed for the extinguishment time for the longest fire scenario will be reported and considered as one of the requirements when a hybrid extinguishing system is used as a special protection system (see Section 1.9, Definitions). For primary protection, agent supply shall be equivalent to that required for an automatic sprinkler protection system for the hazard protected.

**E.4.1 Unshielded 1 MW Diesel Spray Fire**

Criterion:	The fire is to be extinguished.
Fuel:	Diesel
Type:	Horizontal spray
Spray Nozzle:	1 MW spray nozzle
Fire Location:	The test fire shall be located above the table at a position determined to be the most challenging based on the hybrid media discharge. The fuel nozzle should be located at least 1.0 ft. to 5.5 ft (30.5 cm to 167.6 cm) above the centerline of the table, with the spray fire aimed towards the center of the wall without the access door.
Fire Preburn Time:	15 seconds
Test Procedure:	The spray fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

**E.4.2 Shielded 1 MW Diesel Spray Fire**

Criterion:	The fire is to be extinguished.
Fuel:	Diesel
Type:	Horizontal spray
Spray Nozzle:	1 MW spray nozzle
Fire Location:	The test fire shall be located below the table at a position determined to be the most challenging based on the hybrid media discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the wall without the access door.
Fire Preburn Time:	15 seconds
Test Procedure:	The spray fire shall be ignited in the enclosure with the personnel access door closed. The hybrid system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

**E.4.3 Shielded 10.8 ft<sup>2</sup> (1 m<sup>2</sup>) Diesel Pool Fire**

Criterion:	The fire is to be extinguished.
Fuel:	Diesel
Type:	10.8 ft <sup>2</sup> (1.0 m <sup>2</sup> ) pool fire
Fire Location:	The pool test fire shall be centered below the steel plate and located between the baffles, with the baffles located at a position determined to be the most challenging based on the hybrid media discharge.
Fire Preburn Time:	30 seconds
Test Procedure:	The pool fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. Following extinguishment, the fuel left in the pool or tray should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

**E.4.4 Shielded 2 MW Diesel Spray Fire, System Performance Under Limited Natural Ventilation**

Criterion:	The fire is to be extinguished.
Fuel:	Diesel
Type:	Horizontal spray
Spray Nozzle:	2 MW spray nozzle
Fire Location:	The test fire shall be located below the table at a position determined to be the most challenging based on the system discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the wall without the access door.
Fire Preburn Time:	15 seconds
Test Procedure:	This test is conducted to determine the capability of the hybrid system to perform acceptably in a ventilated enclosure during system actuation. A shielded 2 MW diesel spray fire shall be ignited in the enclosure with the personnel access door open. The hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

**E.4.5 Shielded 2 MW Diesel Spray Fire, System Performance at Smaller Enclosure Volumes**

Criterion:	The fire is to be extinguished.
Fuel:	Diesel
Type:	Horizontal spray
Spray Nozzle:	2 MW spray nozzle
Fire Location:	The test fire shall be located below the table at a position determined to be the most challenging based on the system discharge. The test fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the wall without the access door.
Fire Preburn Time:	15 seconds
Test Procedure:	This test is conducted to determine the capability of the hybrid system to perform acceptably in smaller volumes. A shielded 2 MW spray fire shall be ignited, with the personnel access door open, in an enclosure with a volume of 4590 ft <sup>3</sup> (130 m <sup>3</sup> ). The smaller volume should be created by erecting a wall within the enclosure, or relocating one of the walls, perpendicular to the turbine mockup. If necessary, the personnel door may be relocated to accommodate the modified enclosure. Only the nozzles within the 4590 ft <sup>3</sup> (130 m <sup>3</sup> ) volume are to be activated, subsequent to the required fire preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

**E.4.6 Spray Cooling (No Fire)**

Criteria:	The heat flux resulting from a hybrid fire extinguishing system discharge shall not adversely affect the turbine. Such assessment is to be made in accordance with methodology developed by FM Approvals to measure the damage potential of fire extinguishing systems. This test, combined with FM Global Research proprietary heat transfer calculations, will determine the extent of the cooling of the turbine casing during the operation of the hybrid system. Calculations should be based on the manufacturer's recommended turbine size (diameter) to be installed within the enclosure and/or hybrid nozzle location(s) in the enclosure with respect to the turbine.
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**Test Procedure:** The heat flux is affected by the stand-off distance of the hybrid nozzles. Therefore, the test shall be conducted at the minimum nozzle stand-off distance specified in the manufacturer's design manual. The nozzle(s) should be installed at a location(s) above the steel table, based on this specified distance. The design manual may also specify no direct spray impingement of the turbine casing.

A heptane spray fire should be used to heat the steel plate. The spray fire should be located underneath the test table with the fuel spray nozzle aimed at the table at a 30 degree grazing angle, with the flames centered and impinging on the steel table mid point (see Figure E-4). To avoid excess heating of the test enclosure, the ceiling hatches and access door may be left open during the heating of the plate. Additionally, it is recommended to use the 1 MW spray nozzle to heat the plate. An alternative heating system, such as propane burners spaced evenly below the entire steel plate, may be used if it provides uniform heating of the plate and is discussed with FM Approvals prior to testing.

When all three steel plate thermocouples are above 572°F (300°C), the spray fire should be shut off, and the steel plate allowed to cool. When the last of three thermocouple readings drops to 572°F (300°C), then the hybrid system should be activated and the temperature history of the plate shall be recorded for a total of 15 minutes. Uniform heating of the steel plate is critical. Heating, and the subsequent cooling, shall be such that the three thermocouples provide consistent readings at the time of system activation. If excessive variation [greater than 18 °F (10 °C)] exists between the three thermocouples, the heating system should be modified and the plate heated again.

The spray cooling data should be recorded in Microsoft Excel format. This data will be analyzed to determine the effective spray cooling heat flux for the particular test configuration. The heat flux is known to be affected by the drop size, impingement velocity, mass flux, surface composition and texture. However, the effects of these individual variables will not be investigated.

#### **E.4.7 Saturated Insulation Mat and Spray Fire (Optional Test)**

**Criteria:** Both the spray and insulation mat fires are to be extinguished.

**Fuel:** Diesel fuel and insulation mat

**Type:** Horizontal spray and diesel fuel saturated insulation mat fires

**Spray Nozzle:** 1 MW spray nozzle

**Fire Locations:** The insulation mat fire shall be centered below the steel table and located between the baffles, with the baffles located at a position determined to be the most challenging based on the hybrid media discharge. The insulation mat shall be positioned under the spray fire. The spray fire shall be located 20 in. (50 cm) above the floor, centered between the baffles underneath the test table, with the fuel spray nozzle aimed horizontally. The spray fire should be directed towards the center of the wall without the access door.

**Fire Preburn Time:** 30 seconds

**Test Procedure:** A 2 in. (51 mm) thick insulation mat of mineral wool composition shall be cut to the same dimensions as the 1 ft<sup>2</sup> (0.1 m<sup>2</sup>) pan and placed in the dry pan. The insulation mat shall then be saturated with diesel fuel, such that a liquid fuel pool occurs when slightly depressing the mat. The insulation mat fire shall be ignited in the enclosure with the personnel access door closed. The spray fire should be ignited 15 seconds after the insulation mat fire is fully developed over the entire area of the mat. The hybrid fire extinguishing system should then be activated 15 seconds after ignition of the spray fire (30 seconds after the insulation mat fire is fully developed). The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

**E.4.8 Large Saturated Insulation Mat (Optional Test)**

Criterion:	The insulation mat fire is to be controlled (only flamlets at the surface of the mat).
Fuel:	Diesel fuel and insulation mat
Type:	10.8 ft <sup>2</sup> (1.0 m <sup>2</sup> ) diesel fuel saturated insulation mat fire
Fire Location:	The test fire shall be centered below the steel table and located between the baffles, with the baffles located at a position determined to be the most challenging based on the hybrid media discharge.
Fire Preburn Time:	30 seconds
Test Procedure:	A 2 in. (51 mm) thick insulation mat of mineral wool composition shall be cut to the same dimensions as the 10.8 ft <sup>2</sup> (1.0 m <sup>2</sup> ) pan and placed in the dry pan. The insulation mat shall then be saturated with diesel fuel, such that a liquid fuel pool occurs when slightly depressing the mat. The insulation mat fire shall be ignited in the enclosure with the personnel access door closed. The hybrid fire extinguishing system should be activated 30 seconds after the insulation mat fire is fully developed over the entire area of the mat.

**E.4.9 Additional Fire Tests**

Based on the results of Fire Tests E.4.1 through E.4.8, additional fire testing may be required to ensure that the hybrid fire extinguishing system being evaluated meets the intent of this section of the standard. This testing will be performed at the sole discretion of FM Approvals.



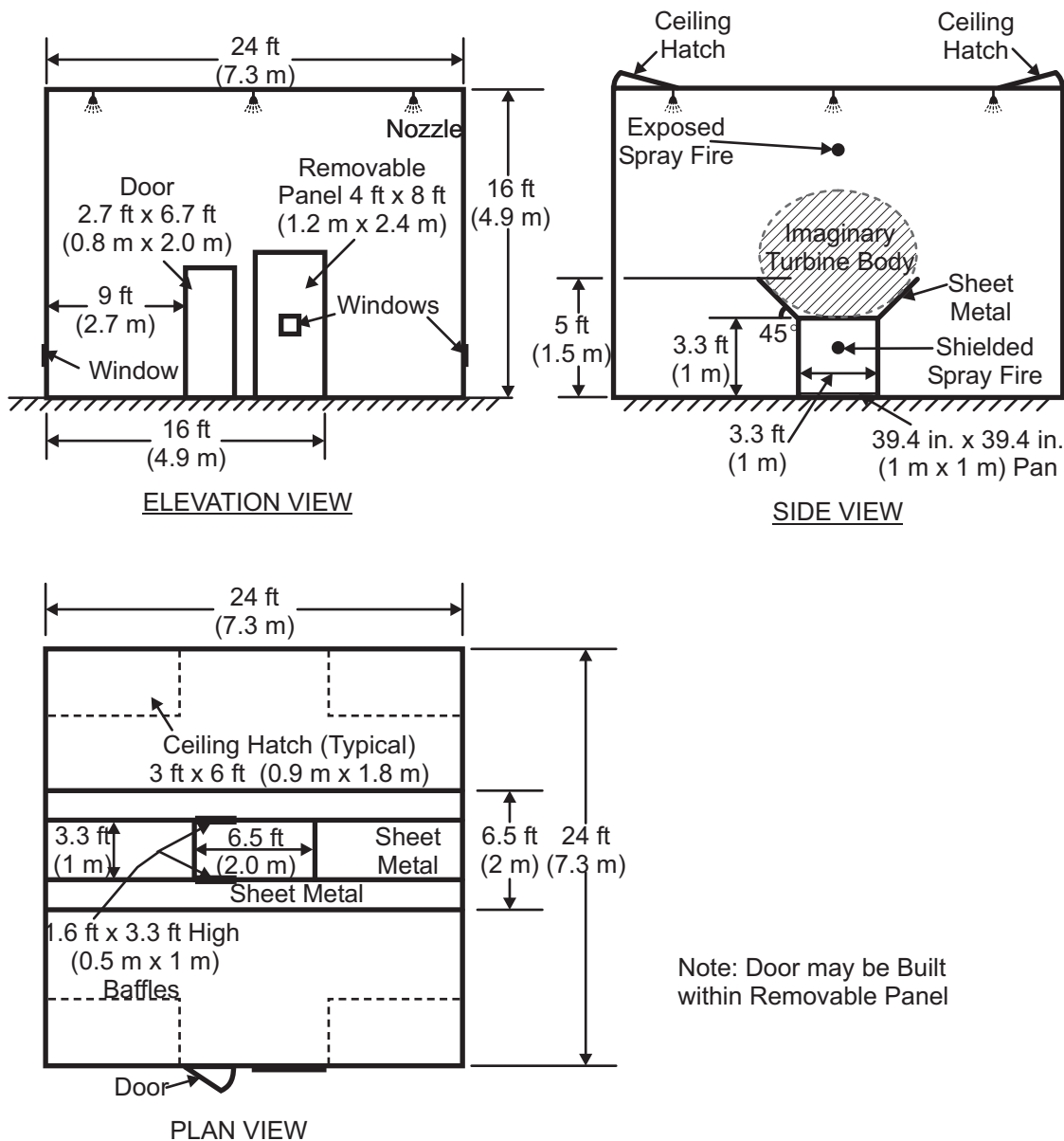


Figure E-1. Test Enclosure and Combustion Turbine Simulator Steel Plate

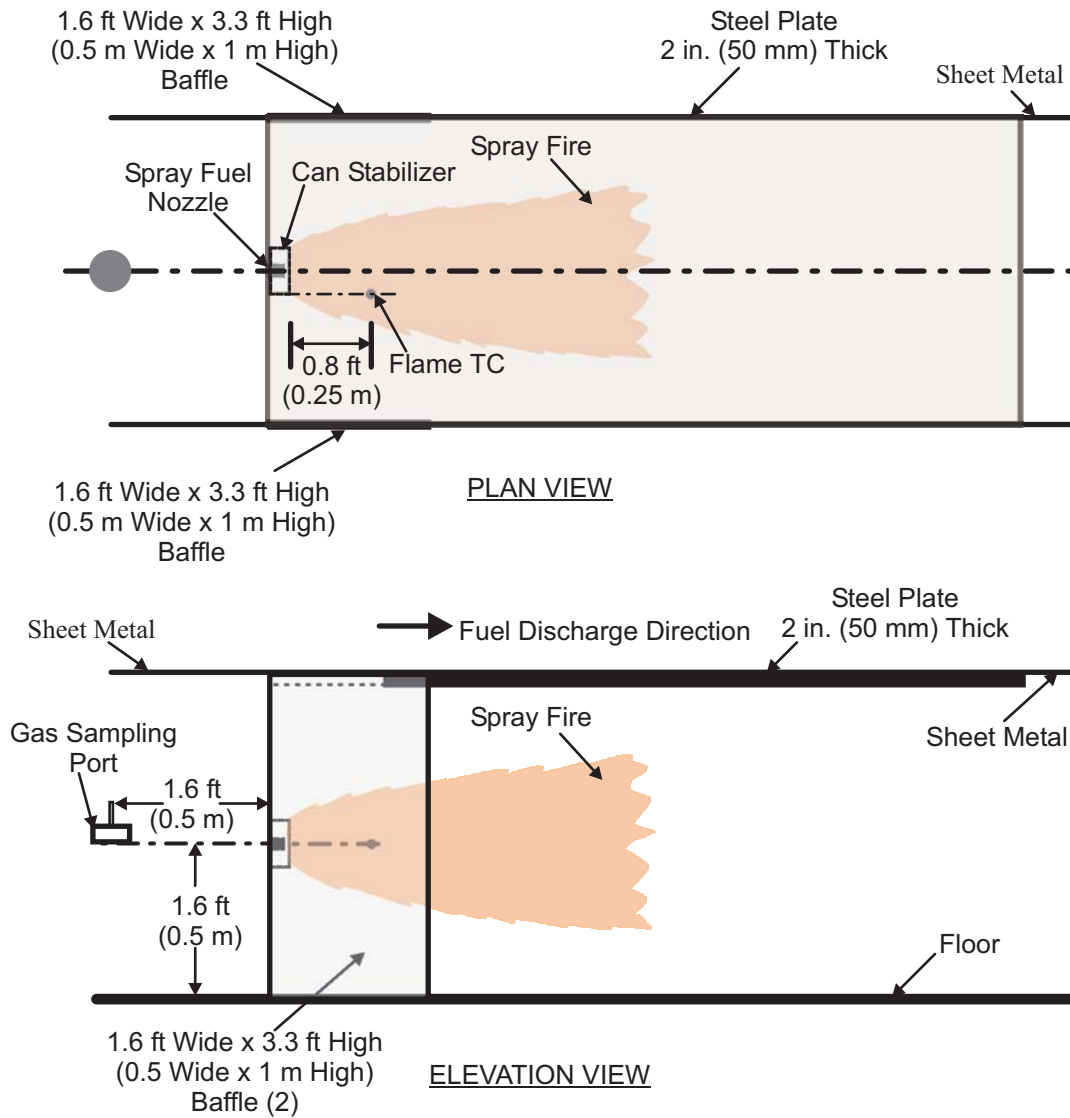


Figure E-2. Fire Source Configuration and Instrumentation for Shielded Spray Fire Testing

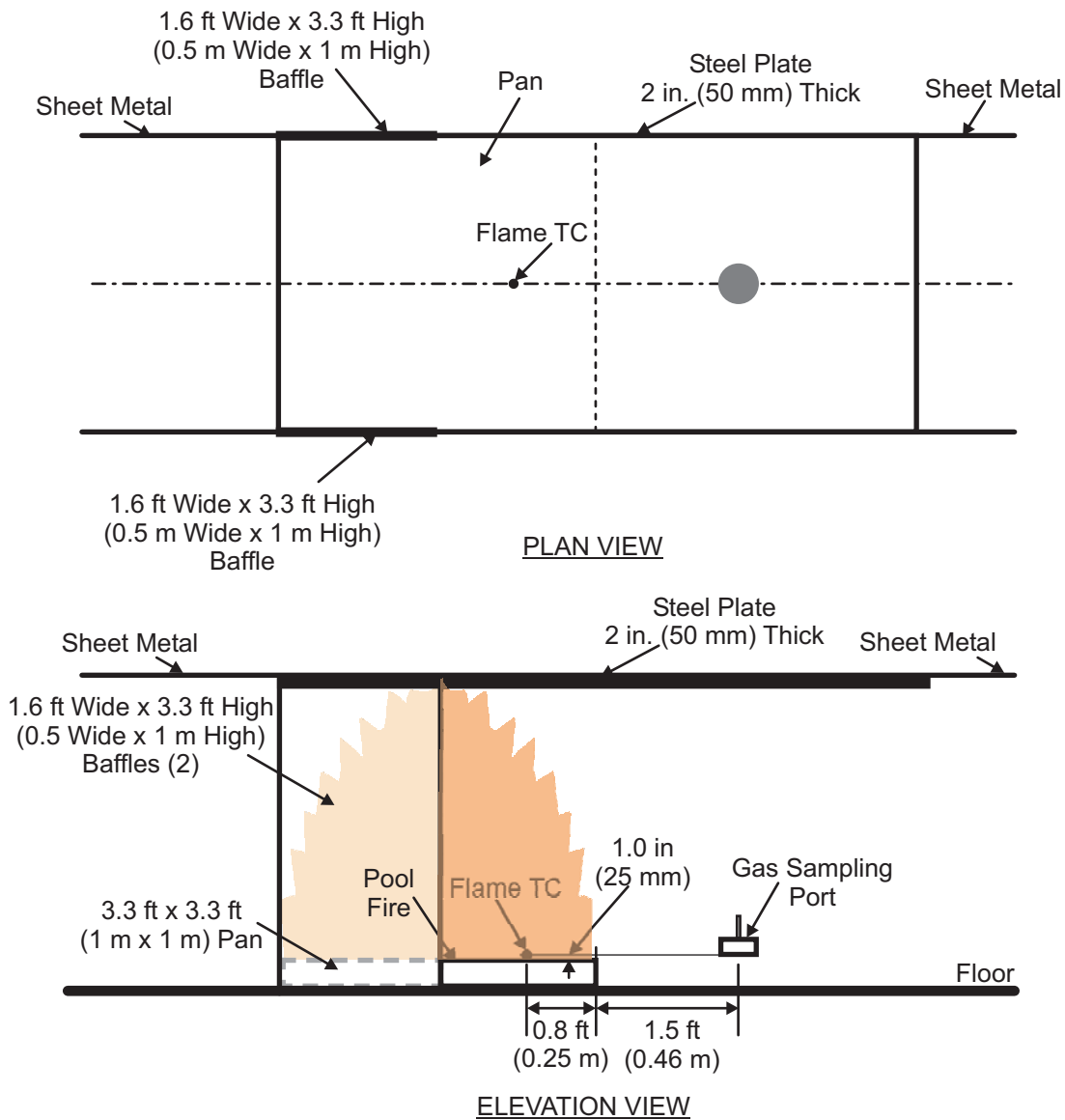


Figure E-3. Fire Source Configuration and Instrumentation for Shielded Pool Fire Testing

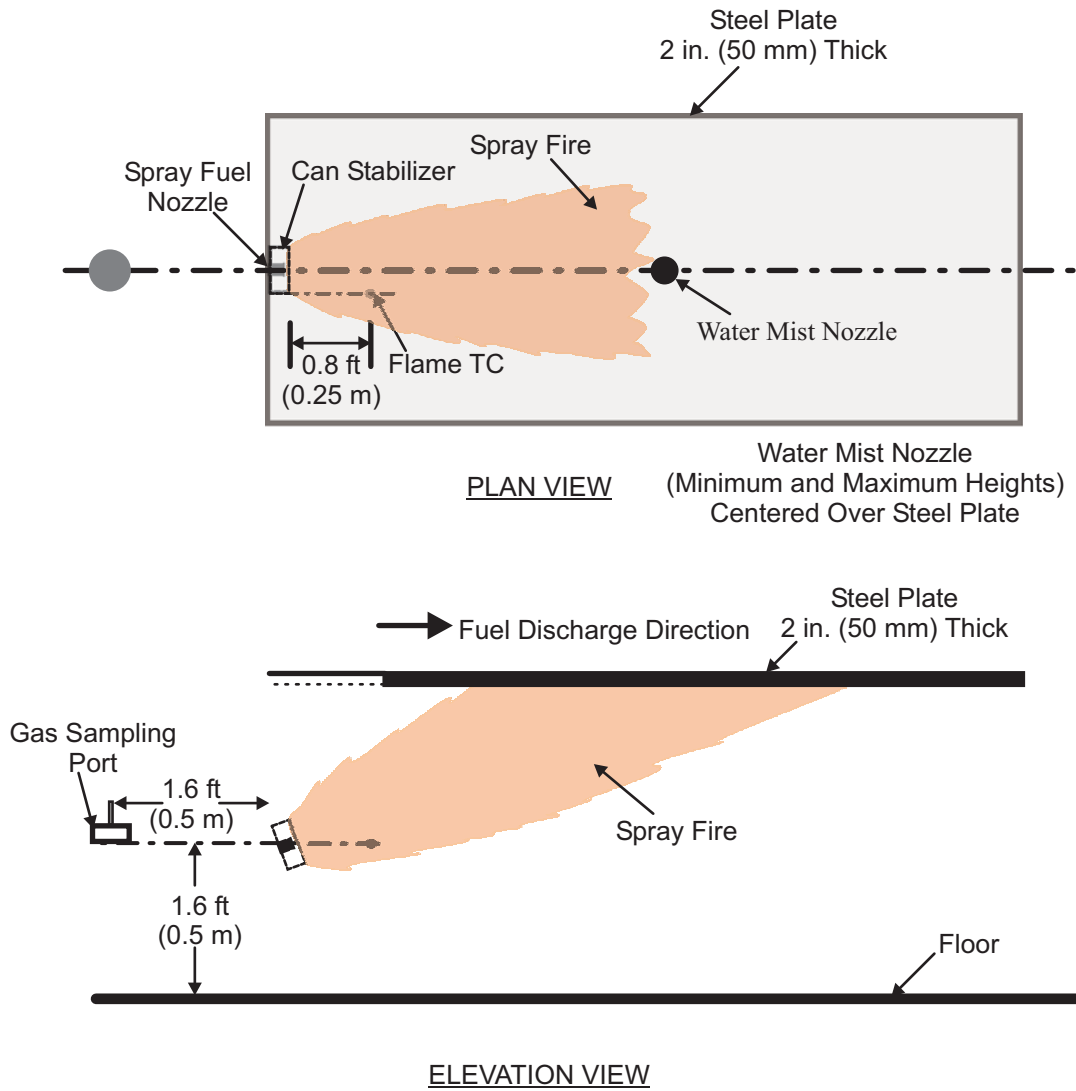


Figure E-4. Fire Source Configuration for Spray Cooling (No Fire) Testing

## APPENDIX F: Fire Tests for Hybrid Fire Extinguishing Systems for the Protection of Machinery Spaces with Volumes Exceeding 9175 ft<sup>3</sup> (260 m<sup>3</sup>)

### F.1 Test Enclosure (see Figure F-1)

The maximum enclosure area (as specified by the manufacturer) shall be tested. Enclosures should have equal length sides, although rectangular areas will be considered. FM Approvals may restrict the scope of the Approval to a limited range of aspect ratios depending on the outcome of the fire tests conducted in non-symmetric enclosures. Ceiling heights shall be restricted to either 16.4 ft (5 m) or 24.6 ft (7.5 m). The enclosure should be constructed of wood or metal frame with an inner lining of minimum 0.5 in. (13 mm) gypsum or 0.03 in. (0.7 mm) galvanized steel. To minimize leakages, all joints and gaps shall be sealed. An opening measuring 6.5 ft by 6.5 ft (2 m by 2 m) and 1.6 ft (0.5 m) above the floor level shall be installed in the center of one wall, as shown in Figure F-1. A minimum of two hinged ceiling hatches measuring approximately 3 ft by 6 ft (0.9 m by 1.8 m) should be installed in opposite diagonal corners for heat and smoke release at the conclusion of the fire test. The floor should be noncombustible and any floor drainage or vent openings should be sealed during testing. A small louvered vent may be provided to allow the intake of air, to prevent excessive suctioning of the walls and ceiling and maintain structural integrity of the fire test enclosure.

The machinery mockup unit should be centered in the test enclosure. In the case of rectangular enclosures, FM Approvals reserves the right to alter the placement of the machinery mockup unit based on the aspect ratio of the enclosure.

At the sole discretion of FM Approvals, additional fire tests in smaller enclosures may be performed to validate the manufacturer's scaling parameters.

### F.2 Machinery Mockup Unit (see Figures F-2 and F-3)

The machinery mockup unit measures 9 ft 10 in. (3 m) long by 3 ft 3 in. (1 m) wide by 9 ft 10 in. (3 m) high. It is fabricated from sheet steel with a nominal thickness of 0.2 in. (5 mm). A tray with a depth of 4 in. (100 mm) is formed at the top of the mockup unit. Two 12 in. (30.5 cm) diameter pipes, 9 ft 10 in. (3 m) in length, are attached to the unit to simulate obstructions. A 2 ft 3 in. (0.7 m) wide solid shelf is also connected to the unit, which provides a barrier to allow shielded fire tests to be conducted. Placement of additional baffles or obstructions may be needed to prevent the direct impact of mist on the pool or spray test fires, at the sole discretion of FM Approvals.

A 7.9 in. (200 mm) by 2 in. (50 mm) notch is cut into the side of the top tray opposite the solid shelf for the purposes of the flowing fire test (see Figure F-3).

The mockup unit shall be surrounded by a steel floor plate system, 19.7 ft (6 m) long by 13.1 ft (4.0 m) wide by 2.4 ft (0.75 m) high. A 43.1 ft<sup>2</sup> by 10 in. high (4 m<sup>2</sup> by 25.4 cm high) square pan should be located underneath the floor plate system.

### F.3 Instrumentation and Test Equipment Requirements

In addition to the instrumentation and test requirements described previously under "General Instrumentation and Test Equipment Requirements," the following measurements should be recorded to within a  $\pm 5$  percent tolerance level at intervals not exceeding one second using a computerized data acquisition system. Measurements should begin and end at least one minute prior to ignition and after extinguishment of the test fire(s).

- A. Fuel pressure and flow at the outlet of fuel pump (fuel flow and pressure should be measured prior to each test series).
- B. Fuel temperature within the fuel storage container. All fuels shall be at an ambient temperature of 68 °F  $\pm$  18 °F (20 °C  $\pm$  10 °C).

- C. Temperature of fuel in pools with thermocouple located in the approximate center of the initial fuel layer. All fuels shall initially be at an ambient temperature of  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ).
- D. Test enclosure temperatures measured in the center portion of the room at the 1/3, 2/3 and ceiling heights. The enclosure shall initially be at an ambient temperature  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ) for all tests.
- E. Mockup temperatures, with thermocouples placed on the surface of center of the 12 in. (30 cm) diameter pipe located on top of the machinery mockup unit, and at the center of the vertical side face of the mockup (see Figure F-3). The mockup shall initially be at an ambient temperature  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ) for all tests. The thermocouple locations should be adjusted as necessary to avoid direct flame impingement.
- F. Temperature of air into the spray fires, measured approximately 20 in. (50 cm) horizontally behind fuel spray nozzle with bare bead thermocouples welded from 28 gauge chromel-alumel wire.
- G. Pool fire temperatures with a thermocouple located approximately 1 in. (2.5 cm) above the initial pool surface and 10 in. (25 cm) within the pool rim.
- H. Spray fire temperatures with a thermocouple located approximately 10 in. (25 cm) ahead of flame stabilizer at the cone radius.
- I. In the wood crib fire a total of four thermocouples should be installed as follows: approximately 4 in. (102 mm) above and centered over the wood crib surface, at the center of the wood crib and approximately 2 in. (50 mm) above the liquid fuel surface, 4 in. (100 mm) from the pool tray rim and 2 approximately 2 in. (50 mm) above the liquid fuel surface, and 4 in. (100 mm) from the pool tray rim and within the liquid fuel, approximately 0.4 in. (10 mm) above the base water layer surface.
- J. Extinguishment should be registered by thermocouples located above the pools and in front of the spray fires as previously described. The fire can be considered to be extinguished when temperature registration drops below  $212\text{ }^{\circ}\text{F}$  ( $100\text{ }^{\circ}\text{C}$ ) and does not increase. Registration by means of thermal imaging equipment, in addition to the thermocouples, is strongly encouraged.
- K. Oxygen, carbon monoxide and carbon dioxide concentrations, measured approximately 20 in. (50 cm) horizontally behind fuel spray nozzle or away from the pool, at the same level above the floor, and away from any open door or ventilation source.
- L. For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

<i>Fire Type</i>	<i>Low Pressure</i>	<i>Low Pressure – Low Flow</i>	<i>High Pressure</i>
Spray Nozzle	Lechler 460.728	Lechler 460.406	Spraying Systems TG 0.7
Fuel Type	Light diesel	Light diesel	Light diesel
Nominal Oil Pressure	120 psi (8.2 bar)	125 psi (8.6 bar)	2200 psi (150 bar)
Heat Release Rate	$5.8 \pm 0.6$ MW	$1.1 \pm 0.1$ MW	$1.8 \pm 0.2$ MW
Nominal Fuel Flow	$0.35 \pm 0.02$ lb/s ( $0.16 \pm 0.01$ kg/s)	$0.07 \pm 0.01$ lb/s ( $0.03 \pm 0.005$ kg/s)	$0.11 \pm 0.004$ lb/s ( $0.05 \pm 0.002$ kg/s)
Fuel Temperature	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )	$68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$ ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ )

NOTE: The free burn characteristics of the fires employed in the fire tests have been calibrated under the FM Global Research Fire Products Collector. Alternative spray nozzles than those listed above may be used if the free burn characteristics are verified by FM Approvals.

- K. The fixture stand for the spray fire arrangements should be constructed of a metal, self standing secure arrangement with the oil burner nozzle mounted within and centered at the closed end of a metal cylindrical flame stabilizer can measuring 5.9 in. diameter by 3.0 in. long (150 mm by 75 mm) with a thickness of 0.010 in. (0.25mm).

L. General pool or tray specifications:

Pans or trays shall be of steel construction, 0.068 in. (1.73 mm) thickness by 3.9 in. (10 cm) high, with no lip. The two required pans shall be 39.4 in. (1 m) wide by 39.4 in. (1 m) long and 12 in. (0.1 m) wide by 12 in. (0.1 m) long. A water base of 2.1 in. (5 cm) in height with a fuel load of at least 0.8 in. (2 cm) above should be used. Freeboard should be 1.2 in. (3 cm). Freeboard may be greater than 1.2 in. (3 cm) high, if a constant freeboard height is used for all application fire tests. Pan surfaces should be smooth and edges should be free of imperfections.

The pan or tray used for the circular heptane pool fire (Test F.4.8) shall be 5.25 ft (1.6 m) in diameter, of steel construction, 0.068 in. (1.73 mm) thickness by 7.2 in. (18.3 cm) high, with no lip. A fuel load of at least 0.8 in. (2 cm) should be used with an appropriate water base so that the fuel level is 6 in. (15.2 cm) above the base of the pan. Freeboard should be at least 1.2 in. (3 cm). Pan surfaces should be smooth and edges should be free of imperfections.

#### F.4 Fire Tests

Intermediate pendent or upright nozzles that are not at ceiling level, or wall mounted nozzles, are not permitted for the machinery spaces.

The hybrid fire extinguishing system shall successfully complete all eight performance fire tests. During the fire tests, all systems shall operate without manual intervention.

Agent supply needed for the extinguishment time for the longest fire scenario will be reported and considered as one of the requirements when a hybrid extinguishing system is used as a special protection system (see Section 1.9, Definitions). For primary protection, agent supply shall be equivalent to that required for an automatic sprinkler protection system for the hazard protected.

##### F.4.1 Low Pressure, Exposed, Diesel Spray Fire

Criterion:	Extinguishment of the spray fire
Fuel:	Diesel
Type:	Horizontal spray
Spray Nozzle:	Low pressure nozzle
Fire Location:	The test fire shall be located on top of the machinery mockup unit, at the edge of the shorter side of the top tray and 14 in. (355 mm) from the edge of the longer side of the top tray (see Figure F-2). The spray fire should be positioned to spray along the length of the mockup's top tray, away from the test enclosure opening.
Fire Preburn Time:	15 seconds
Test Procedure:	The spray fire shall be ignited, and the hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

##### F.4.2 Low Pressure, Angled, Diesel Spray Fire

Criterion:	Extinguishment of the spray fire
Fuel:	Diesel
Type:	Angled spray
Spray Nozzle:	Low pressure nozzle
Fire Location:	A 0.5 in. (13 mm) diameter rod shall be placed vertically on top of the machinery mockup unit, at the centerline of the longer side of top tray and 14 in. (355 mm) from the edge of this longer side. The test fire shall be located on top of the machinery mockup

unit, 3 ft 3 in. (1 m) away from the rod and 14 in. (355 mm) from the edge of the longer side of the top tray (see Figures F-3 and F-4). The spray fire should be positioned to spray along the length of the mockup's top tray, away from the test enclosure opening. The spray fire should be at a 45 degree angle relative to the top plane of the machinery mockup unit, such that the spray strikes the vertical rod.

Fire Preburn Time: 15 seconds

Test Procedure: The spray fire shall be ignited, and the hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### **F.4.3 Low Pressure, Concealed, Diesel Spray Fire**

Criterion: Extinguishment of the spray fire

Fuel: Diesel

Type: Horizontal spray

Spray Nozzle: Low pressure nozzle

Fire Location: The test fire shall be located under the shelf with the nozzle 4 in. (10cm) from the end of the machinery mockup unit, under the centerline of the 12 in. (30 cm) diameter pipe, and 5.25 ft (1.6 m) above the floor plate (See Figures F-2 and F-3). The spray fire should be positioned to spray along the length of the pipe, away from the test enclosure opening.

Fire Preburn Time: 15 seconds

Test Procedure: The spray fire shall be ignited, and the hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### **F.4.4 High Pressure, Exposed, Diesel Spray**

Criterion: Extinguishment of the spray fire

Fuel: Diesel

Type: Horizontal spray

Spray Nozzle: High pressure nozzle

Fire Location: The test fire shall be located on top of the machinery mockup unit, at the edge of the shorter side of the top tray and 14 in. (355 mm) from the edge of the longer side of the top tray (see Figure F-2). The spray fire should be positioned to spray along the length of the mockup's top tray, away from the test enclosure opening.

Fire Preburn Time: 15 seconds

Test Procedure: The spray fire shall be ignited, and the hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### **F.4.5 Low Pressure-Low Flow, Concealed, Diesel Spray and Pool Fires**

Criterion: Extinguishment of the spray fire and suppression of the pool fire

Fuel: Diesel

Type: Horizontal spray and 1 ft<sup>2</sup> (0.1 m<sup>2</sup>) pool fire

Spray Nozzle: Low pressure-low flow nozzle



Fire Location:	The spray fire shall be located under the shelf with the nozzle 4 in. (10 cm) from the end of the machinery mockup unit, under the centerline of the 12 in. (30 cm) diameter pipe, and 5.25 ft (1.6 m) above the floor plate (see Figures F-2 and F-3). The spray fire should be positioned to spray along the length of the pipe, away from the test enclosure opening. The pool fire shall be located in line with the spray fire; 4 ft 7 in. (1.4 m) from the end of the machinery mockup unit (see Figure F-2).
Fire Preburn Time:	120 seconds
Test Procedure:	The pool fire shall be ignited. The spray fire should be ignited 105 seconds after ignition of the pool fire. The hybrid fire extinguishing system should then be activated 15 seconds after ignition of the spray fire (120 seconds after the pool fire is ignited). The fuel spray should be shut off 15 seconds after spray fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off. Additionally, the fuel left in the pool or tray should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

#### F.4.6 Concealed, Heptane Pool Fire

Criterion:	Suppression of the pool fire
Fuel:	Heptane
Type:	10.8 ft <sup>2</sup> (1 m <sup>2</sup> ) pool fire
Fire Size:	2.4 MW (nominal)
Fire Location:	The test fire shall be centered under the shelf, on top of the floor plates (see Figure F-2).
Fire Preburn Time:	15 seconds
Test Procedure:	The pool fire shall be ignited, and the hybrid fire extinguishing system should be activated subsequent to the required preburn time. Following extinguishment, the fuel left in the pool or tray should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

#### F.4.7 Flowing Fire

Criterion:	Extinguishment of the fire
Fuel:	Heptane
Type:	Flowing
Fuel Flow Rate:	0.55 lb/s (0.25 kg/s) (nominal)
Fire Size:	28 MW (nominal)
Fire Location:	A fuel pipe shall be positioned above the top tray of the machinery mockup unit such that fuel is flowing into the top tray at the rate listed above. A fuel spray nozzle shall not be used during this test. As the tray fills with fuel, the fuel will eventually flow from the notch in the top of the machinery mockup unit and down the side of the machinery mockup unit.
Fire Preburn Time:	15 seconds
Test Procedure:	Ignition should occur as the mockup top tray just begins to overflow with fuel and pour down the vertical side of the mockup. The hybrid fire extinguishing system should be activated subsequent to the required preburn time.

**F.4.8 Wood Crib and Heptane Pool Fire**

Criteria:	Extinguishment of the crib fire and extinguishment of the pool fire
Fuel:	Wood crib and heptane
Type:	Pool fire with crib
Fire Size:	7.5 MW (nominal)
Wood Crib:	The wood crib is to weigh 11.9 to 13 lb (5.4 to 5.9 kg) and is to be dimensioned approximately 12 in. by 12 in. by 12 in. (305 mm by 305 mm by 305 mm). The crib is to consist of eight alternate layers of four trade size 1.5 in. by 1.5 in. (38.1 mm by 38.1 mm) kiln-dried spruce or fir lumber 12 in. (305 mm) long. The alternate layers of the lumber are placed at right angles to the adjacent layers. The individual wood members in each layer are to be evenly spaced along the length of the previous layer of wood members and stapled. After the wood crib is assembled, it is to be conditioned at a temperature of 120°F ± 9°F (49°C ± 5°C) for not less than 16 hours. Following the conditioning, the moisture content of the crib is to be measured with a probe type moisture meter. The moisture content of the crib should not exceed 5 percent prior to the fire test.
Fire Location:	The test fire shall be centered along the length of the machinery mockup unit and adjacent to the floor plates (see Figure F-1). The crib should be placed in the center of the 21.5 ft <sup>2</sup> (2 m <sup>2</sup> ) pool with the fuel level up to one-half its height. The pan is located 2.5 ft (0.75 m) off the floor.
Fire Preburn Time:	30 seconds
Test Procedure:	The pool fire shall be ignited, and the hybrid fire extinguishing system should be activated subsequent to the required preburn time. Following extinguishment, the fuel left in the pool or tray should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

**F.4.9 Additional Fire Tests**

Based on the results of Fire Tests F.4.1 through F.4.8, additional fire testing may be required to ensure that the hybrid fire extinguishing system being evaluated meets the intent of this section of the standard. This testing will be performed at the sole discretion of FM Approvals.

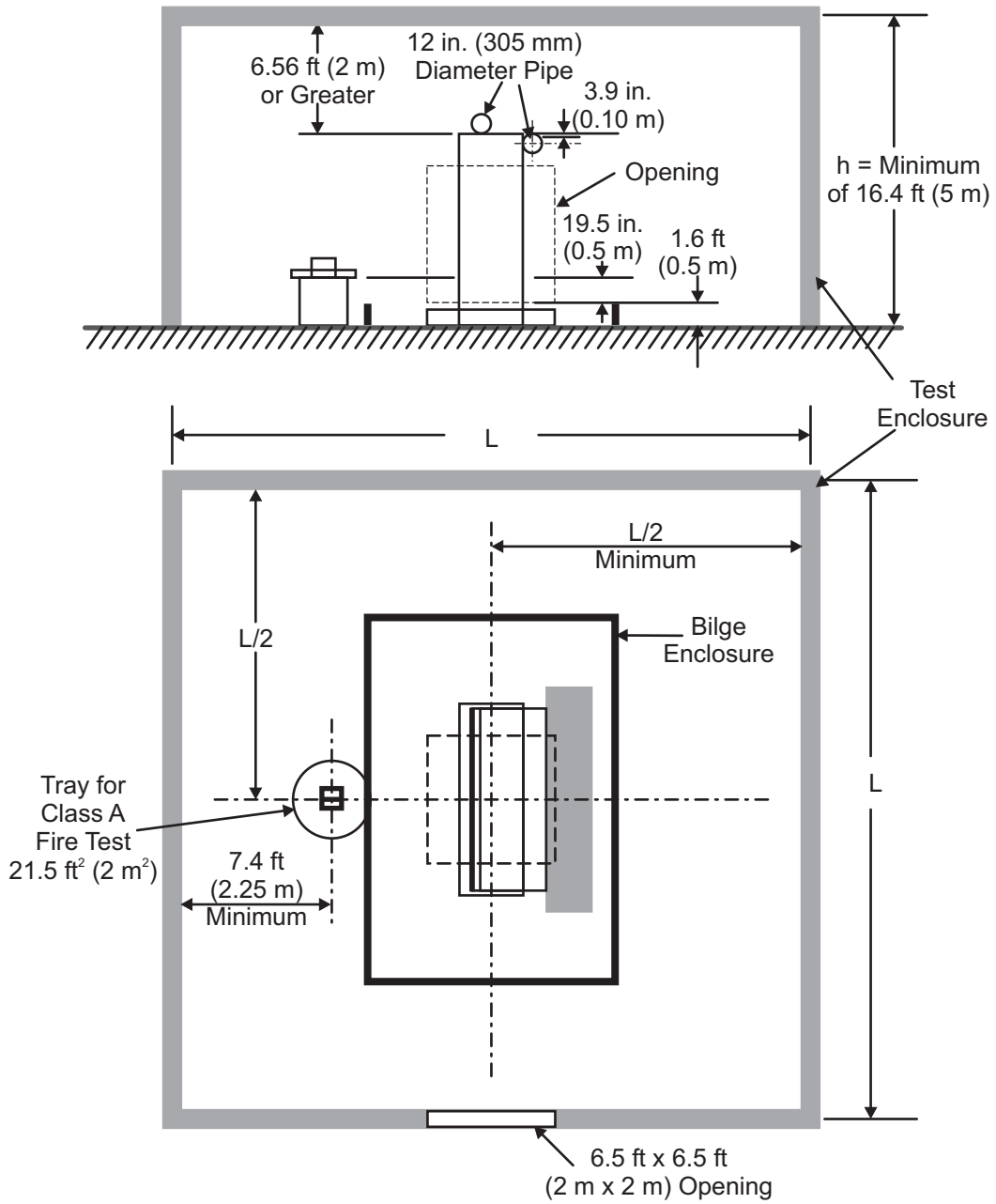


Figure F-1. Test Enclosure

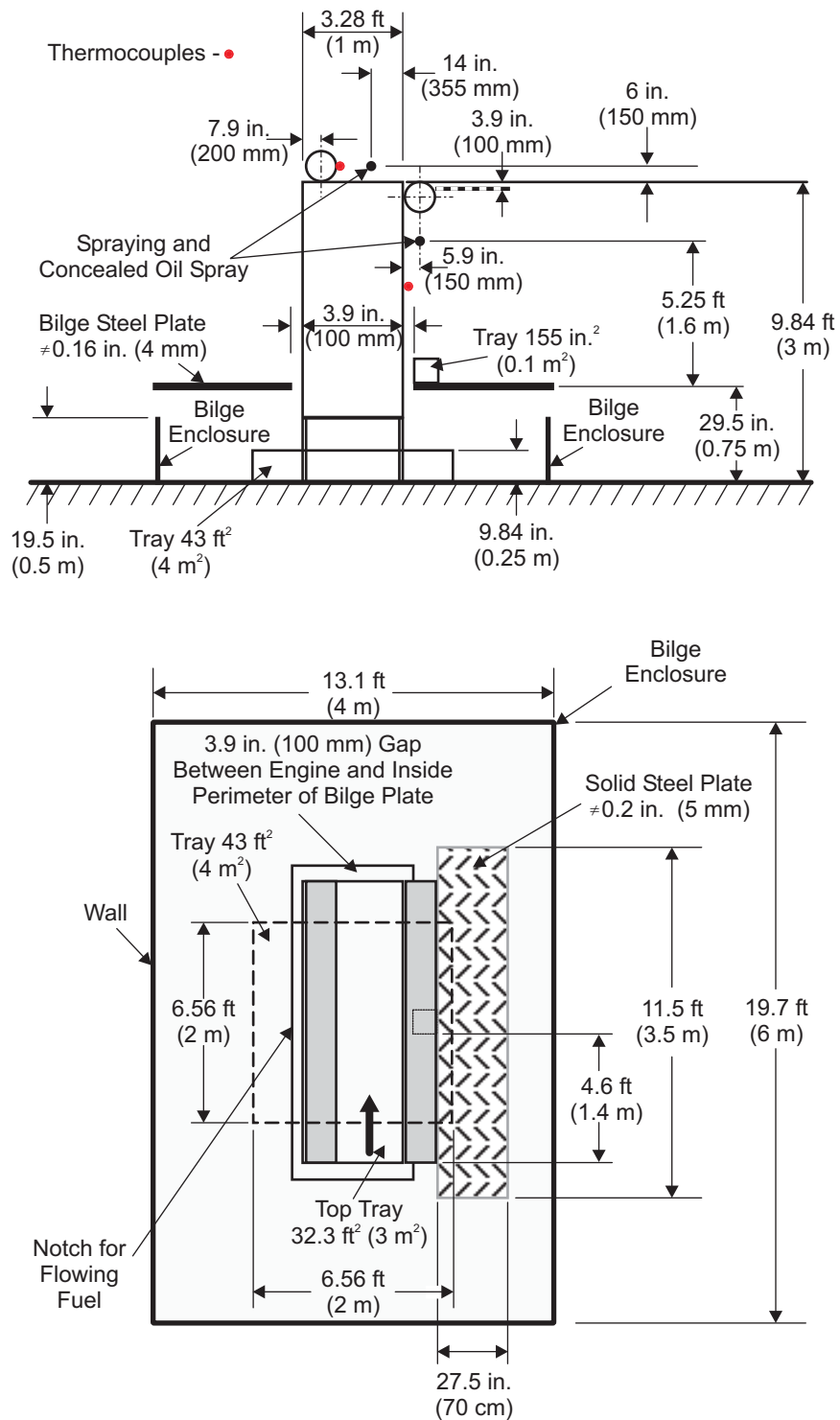


Figure F-2. Machinery Mockup Unit

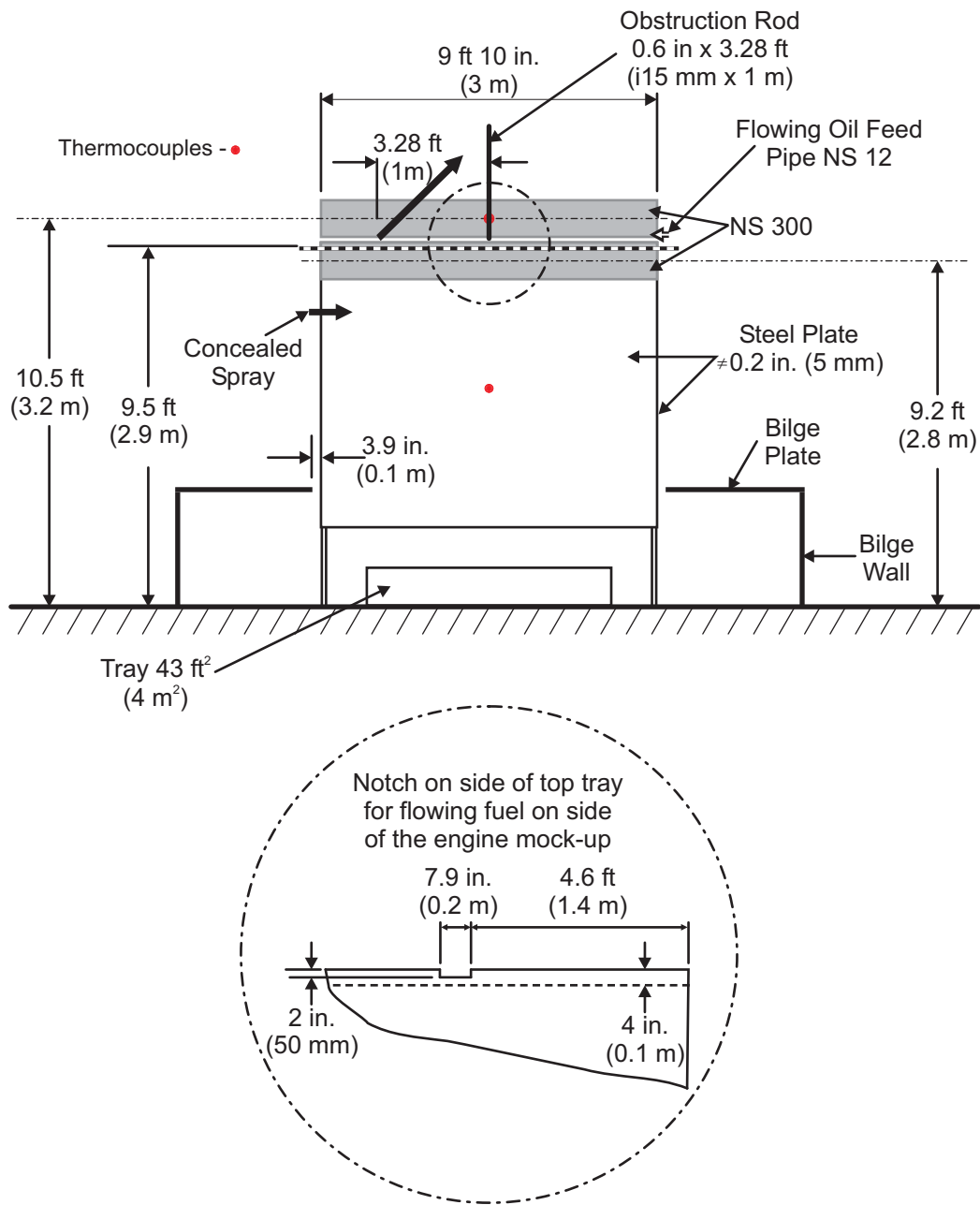


Figure F-3. Machinery Mockup Unit (continued)

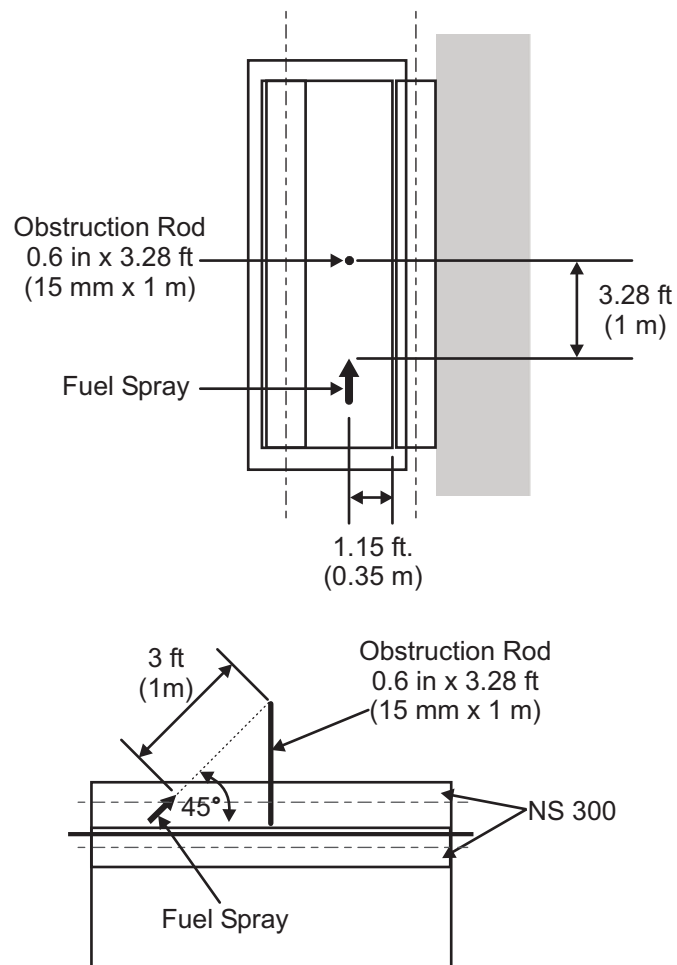


Figure F-4. Fire Test F.3.2, Position of Fuel Spray Nozzle and Obstruction Rod

## APPENDIX G: Fire Tests for Hybrid Fire Extinguishing Systems for the Protection of Combustion Turbines with Volumes Exceeding 9175 ft<sup>3</sup> (260 m<sup>3</sup>)

### G.1 Test Enclosure (see Figure G-1)

The maximum enclosure area (as specified by the manufacturer) shall be tested. Enclosures should have equal length sides, although rectangular areas will be considered. FM Approvals may restrict the scope of the Approval to a limited range of aspect ratios depending on the outcome of the fire tests conducted in non-symmetric enclosures. Ceiling heights shall be restricted to either 16.4 ft (5 m) or 24.6 ft (7.5 m). The enclosure should be constructed of wood or metal frame with an inner lining of minimum 0.5 in. (13 mm) gypsum or 0.03 in. (0.7 mm) galvanized steel. To minimize leakages, all joints and gaps shall be sealed. An opening measuring 6.5 ft by 6.5 ft (2 m by 2 m) and 1.6 ft (0.5 m) above the floor level shall be installed in the center of one wall, as shown in Figure G-1. A minimum of two hinged ceiling hatches measuring approximately 3 ft by 6 ft (0.9 m by 1.8 m) should be installed in opposite diagonal corners for heat and smoke release at the conclusion of the fire test. The floor should be noncombustible and any floor drainage or vent openings should be sealed during testing. A small louvered vent may be provided to allow the intake of air, to prevent excessive suctioning of the walls and ceiling and maintain structural integrity of the fire test enclosure.

The combustion turbine and engine mockup unit should be centered in the test enclosure. In the case of rectangular enclosures, FM Approvals reserves the right to alter the placement of the mockup unit based on the aspect ratio of the enclosure.

At the sole discretion of FM Approvals, additional fire tests in smaller enclosures may be performed to validate the manufacturer's scaling parameters.

### G.2 Combustion Turbine and Engine Mockup Unit (see Figures G-2 and G-3)

The mockup unit measures 9 ft 10 in. (3 m) long by 3 ft 3 in. (1 m) wide by 9 ft 10 in. (3 m) high. It is fabricated from sheet steel with a nominal thickness of 0.2 in. (5 mm). A tray with a depth of 4 in. (100 mm) is formed at the top of the mockup unit. Two 12 in. (30.5 cm) nominal diameter pipes, 9 ft 10 in. (3 m) in length, are attached to the unit to simulate obstructions. A 2 ft 3 in. (0.7 m) wide solid shelf is also connected to the unit, which provides a barrier to allow shielded fire tests to be conducted. Placement of additional baffles or obstructions may be needed to prevent the direct impact of mist on the pool or spray test fires, at the sole discretion of FM Approvals.

A 7.9 in. (200 mm) by 2 in. (50 mm) notch is cut into the side of the top tray opposite the solid shelf for the purposes of the flowing fire test (see Figure G-3).

The mockup unit is surrounded by a steel floor plate system, 19.7 ft (6 m) long by 13.1 ft (4.0 m) wide by 2.4 ft (0.75 m) high. A 43.1 ft<sup>2</sup> by 10 in. high (4 m<sup>2</sup> by 25.4 cm high) square pan should be located underneath. The floor plate system.

### G.3 Combustion Turbine Spray Cooling Mockup Unit (see Figures G-5 and G-6)

The combustion turbine casing mockup is simulated with a horizontal flat steel plate (see Figure G-5). The specific details and thermal mass of the obstructions are not simulated.

A horizontal ASTM A36 hot rolled steel plate 3.3 ft by 6.5 ft by 2 in. thick (1.0 m wide by 2.0 m long by 5 cm thick) is placed at 3.3 ft (1 m) elevation on steel legs at the four corners of the plate. This is located as described above or at a location within the test cell to be selected by FM Approvals after the nozzles are installed (as per manufacturer's design criteria). In lieu of actual turbine casing material, which is typically ductile iron, the test plate is constructed of hot rolled ASTM A36 steel. The center of the plate is instrumented across its thickness with thermocouples placed at various depths, as described below.

To determine the cooling rate of the combustion turbine steel plate mockup, caused by the discharge of the hybrid fire extinguishing system, three thermocouples should each be embedded near the center of the plate at approximately 0.5 in., 1.0 in., and 1.50 in. (12 mm, 25 mm, and 38 mm) below the plate's top surface. The three inconel-sheathed thermocouples should be embedded in the plate by removing cylindrical plugs from the plate.

The thermocouples should be inserted to allow the thermocouple wire to follow a horizontal path of sixteen thermocouple diameters in length, thus reducing errors due to the vertical temperature gradient in the plate. A heat conductive and electrically insulating sealant should be applied, and the steel cylindrical plugs should be replaced and welded to the plate around the top periphery of the plugs. This can be accomplished by using a 1.0 in. (25 mm) diameter miller tool, installing the thermocouples, and then refilling the hole welded 1.0 in. (25 mm) round bar stock (see Figure G-6).

#### G.4 Instrumentation and Test Equipment Requirements

In addition to the instrumentation and test requirements described previously under "General Instrumentation and Test Equipment Requirements," the following measurements should be recorded to within a  $\pm 5$  percent tolerance level at intervals not exceeding one second using a computerized data acquisition system. Measurements should begin and end at least one minute prior to ignition and after extinguishment of the test fire(s).

- A. Fuel pressure and flow at the outlet of fuel pump (fuel flow and pressure should be measured prior to each test series).
- B. Fuel temperature within the fuel storage container. All fuels shall be at an ambient temperature of  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ).
- C. Temperature of fuel in pools with thermocouple located in the approximate center of the initial fuel layer. All fuels shall initially be at an ambient temperature of  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ).
- D. Test enclosure temperatures measured in the center portion of the room at the 1/3, 2/3 and ceiling heights. The enclosure shall initially be at an ambient temperature  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ) for all tests.
- E. Mockup temperatures, with thermocouples placed on the surface of center of the 12 in. (30 cm) diameter pipe located on top of the machinery mockup unit, and at the center of the vertical side face of the mockup (see Figure G-3). The mockup shall initially be at an ambient temperature  $68\text{ }^{\circ}\text{F} \pm 18\text{ }^{\circ}\text{F}$  ( $20\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$ ) for all tests. The thermocouple locations should be adjusted as necessary to avoid direct flame impingement.
- F. Temperature of air into the spray fires, measured approximately 20 in. (50 cm) horizontally behind fuel spray nozzle with bare bead thermocouples welded from 28 gauge chromel-alumel wire.
- G. Pool fire temperatures with a thermocouple located approximately 1 in. (2.5 cm) above the initial pool surface and 10 in. (25 cm) within the pool rim.
- H. Spray fire temperatures with a thermocouple located approximately 10 in. (25 cm) ahead of flame stabilizer at the cone radius.
- I. In the wood crib fire a total of four thermocouples should be installed as follows: approximately 4 in. (102 mm) above and centered over the wood crib surface, at the center of the wood crib and approximately 2 in. (50 mm) above the liquid fuel surface, 4 in. (100 mm) from the pool tray rim and approximately 2 in. (50 mm) above the liquid fuel surface, and 4 in. (100 mm) from the pool tray rim and within the liquid fuel, approximately 0.4 in. (10 mm) above the base water layer surface.
- J. Extinguishment should be registered by thermocouples located above the pools and in front of the spray fires as previously described. The fire can be considered to be extinguished when temperature registration drops below  $212\text{ }^{\circ}\text{F}$  ( $100\text{ }^{\circ}\text{C}$ ) and does not increase. Registration by means of thermal imaging equipment, in addition to the thermocouples, is strongly encouraged.



- K. Oxygen, carbon monoxide and carbon dioxide concentrations, measured approximately 20 in. (50 cm) horizontally behind fuel spray nozzle or away from the pool, at the same level above the floor, and away from any open door or ventilation source.
- L. For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

<i>Fire Type</i>	<i>Low Pressure</i>	<i>Low Pressure – Low Flow</i>	<i>High Pressure</i>
Spray Nozzle	Lechler 460.728	Lechler 460.406	Spraying Systems TG 0.7
Fuel Type	Light diesel	Light diesel	Light diesel
Nominal Oil Pressure	120 psi (8.2 bar)	125 psi (8.6 bar)	2200 psi (150 bar)
Heat Release Rate	5.8 ± 0.6 MW	1.1 ± 0.1 MW	1.8 ± 0.2 MW
Nominal Fuel Flow	0.35 ± 0.02 lb/s (0.16 ± 0.01 kg/s)	0.07 ± 0.01 lb/s (0.03 ± 0.005 kg/s)	0.11 ± 0.004 lb/s (0.05 ± 0.002 kg/s)
Fuel Temperature	68 °F ± 18 °F (20 °C ± 10 °C)	68 °F ± 18 °F (20 °C ± 10 °C)	68 °F ± 18 °F (20 °C ± 10 °C)

NOTE: The free burn characteristics of the fires employed in the fire tests have been calibrated under the FM Global Research Fire Products Collector. Alternative spray nozzles than those listed above may be used if the free burn characteristics are verified by FM Approvals.

- M. The fixture stand for the spray fire arrangements should be constructed of a metal, self standing secure arrangement with the oil burner nozzle mounted within and centered at the closed end of a metal cylindrical flame stabilizer can measuring 5.9 in. diameter by 3.0 in. long (150 mm by 75 mm) with a thickness of 0.010 in. (0.25mm).
- N. General pool or tray specifications:

Pans or trays shall be of steel construction, 0.068 in. (1.73 mm) thickness by 3.9 in. (10 cm) high, with no lip. The two required pans shall be 39.4 in. (1 m) wide by 39.4 in. (1 m) long and 12 in. (0.1 m) wide by 12 in. (0.1 m) long. A water base of 2.1 in. (5 cm) in height with a fuel load of at least 0.8 in. (2 cm) above should be used. Freeboard should be 1.2 in. (3 cm). Freeboard may be greater than 1.2 in. (3 cm) high, if a constant freeboard height is used for all application fire tests. Pan surfaces should be smooth and edges should be free of imperfections.

The pan or tray used for the circular heptane pool fire (Test I.5.8) shall be 5.25 ft (1.6 m) in diameter, of steel construction, 0.068 in. (1.73 mm) thickness by 7.2 in. (18.3 cm) high, with no lip. A fuel load of at least 0.8 in. (2 cm) should be used with an appropriate water base so that the fuel level is 6 in. (15.2 cm) above the base of the pan. Freeboard should be at least 1.2 in. (3 cm). Pan surfaces should be smooth and edges should be free of imperfections.

- O. Insulation mat specifications (optional):

The optional insulation mats shall be cut to the same dimensions as the pan or tray, and placed in a dry pan. The insulation mats should be constructed of mineral wool, be 2 in. (51 mm) in thickness, and contain a density of 6 to 8 lb/ft<sup>3</sup> (96 to 128 kg/m<sup>3</sup>). The fuel shall then be poured on top of the mat for soaking and absorption. The insulation mat should be fully saturated so that finger depression creates an instant small pool.

## G.5 Fire Tests

Intermediate pendent or upright nozzles that are not at ceiling level, or wall mounted nozzles, are permitted for the protection of combustion turbines.

The hybrid fire extinguishing system shall prevent, and not cause, any damage to the critical turbine components. The damage to the turbine could be caused by direct fire impingement on the hot turbine casing, or by rapid cooling of the turbine casing, resulting in excessive deformation.

The hybrid system shall successfully complete the first eight (G.5.1 through G.5.8) fire performance tests and the Spray Cooling (heat transfer) test (G.5.11). An additional option for combustion turbine applications is the protection of insulated turbines. Two additional fire tests (G.5.9 and G.5.10), involving insulation mats of mineral wool composition, are required for this application extension. During the fire tests, all systems shall operate without manual intervention.

Agent supply needed for the extinguishment time for the longest fire scenario will be reported and considered as one of the requirements when a hybrid extinguishing system is used as a special protection system (see Section 1.9, Definitions). For primary protection, agent supply shall be equivalent to that required for an automatic sprinkler protection system for the hazard protected.

#### **G.5.1 Low Pressure, Exposed, Diesel Spray Fire**

Criterion:	Extinguishment of the spray fire
Fuel:	Diesel
Type:	Horizontal spray
Spray Nozzle:	Low pressure nozzle
Fire Location:	The test fire shall be located on top of the mockup unit, at the edge of the shorter side of the top tray and 14 in. (355 mm) from the edge of the longer side of the top tray (see Figure G-2). The spray fire should be positioned to spray along the length of the mockup's top tray, away from the test enclosure opening.
Fire Preburn Time:	15 seconds
Test Procedure:	The spray fire shall be ignited, and the hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### **G.5.2 Low Pressure, Angled, Diesel Spray Fire**

Criterion:	Extinguishment of the spray fire
Fuel:	Diesel
Type:	Angled spray
Spray Nozzle:	Low pressure nozzle
Fire Location:	A 0.5 in. (13 mm) diameter rod shall be placed vertically on top of the mockup unit, at the centerline of the longer side of top tray and 14 in. (355 mm) from the edge of this longer side. The test fire shall be located on top of the mockup unit, 3 ft 3 in. (1 m) away from the rod and 14 in. (355 mm) from the edge of the longer side of the top tray (see Figures G-3 and G-4). The spray fire should be positioned to spray along the length of the mockup's top tray, away from the test enclosure opening. The spray fire should be at a 45 degree angle relative to the top plane of the machinery mockup unit, such that the spray strikes the vertical rod.
Fire Preburn Time:	15 seconds
Test Procedure:	The spray fire shall be ignited, and the hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

**G.5.3 Low Pressure, Concealed, Diesel Spray Fire**

Criterion:	Extinguishment of the spray fire
Fuel:	Diesel
Type:	Horizontal spray
Spray Nozzle:	Low pressure nozzle
Fire Location:	The test fire shall be located under the shelf with the nozzle 4 in. (10 cm) from the end of the mockup unit, under the centerline of the 12 in. (30 cm) diameter pipe, and 5.25 ft (1.6 m) above the floor plate (See Figures G-2 and G-3). The spray fire should be positioned to spray along the length of the pipe, away from the test enclosure opening.
Fire Preburn Time:	15 seconds
Test Procedure:	The spray fire shall be ignited, and the hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

**G.5.4 High Pressure, Exposed, Diesel Spray**

Criterion:	Extinguishment of the spray fire
Fuel:	Diesel
Type:	Horizontal spray
Spray Nozzle:	High pressure nozzle
Fire Location:	The test fire shall be located on top of the mockup unit, at the edge of the shorter side of the top tray and 14 in. (355 mm) from the edge of the longer side of the top tray (see Figure G-2). The spray fire should be positioned to spray along the length of the mockup's top tray, away from the test enclosure opening.
Fire Preburn Time:	15 seconds
Test Procedure:	The spray fire shall be ignited, and the hybrid fire extinguishing system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

**G.5.5 Low Pressure-Low Flow, Concealed, Diesel Spray and Pool Fires**

Criterion:	Extinguishment of the spray fire and suppression of the pool fire
Fuel:	Diesel
Type:	Horizontal spray and 1 ft <sup>2</sup> (0.1 m <sup>2</sup> ) pool fire
Spray Nozzle:	Low pressure-low flow nozzle
Fire Location:	The spray fire shall be located under the shelf with the nozzle 4 in. (10 cm) from the end of the mockup unit, under the centerline of the 12 in. (30 cm) diameter pipe, and 5.25 ft (1.6 m) above the floor plate (see Figures G-2 and G-3). The spray fire should be positioned to spray along the length of the pipe, away from the test enclosure opening. The pool fire shall be located in line with the spray fire, 4 ft 7 in. (1.4 m) from the end of the mockup unit (see Figure G-2).
Fire Preburn Time:	120 seconds

Test Procedure: The pool fire shall be ignited. The spray fire should be ignited 105 seconds after ignition of the pool fire. The hybrid fire extinguishing system should then be activated 15 seconds after ignition of the spray fire (120 seconds after the pool fire is ignited). The fuel spray should be shut off 15 seconds after spray fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off. Additionally, the fuel left in the pool or tray should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

#### G.5.6 Concealed, Heptane Pool Fire

Criterion: Suppression of the pool fire

Fuel: Heptane

Type: 10.8 ft<sup>2</sup> (1 m<sup>2</sup>) pool fire

Fire Size: 2.4 MW (nominal)

Fire Location: The test fire shall be centered under the shelf, on top of the floor plates (see Figure G-2).

Fire Preburn Time: 15 seconds

Test Procedure: The pool fire shall be ignited, and the hybrid fire extinguishing system should be activated subsequent to the required preburn time. Following extinguishment, the fuel left in the pool or tray should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

#### G.5.7 Flowing Fire

Criterion: Extinguishment of the fire

Fuel: Heptane

Type: Flowing

Fuel Flow Rate: 0.55 lb/s (0.25 kg/s) (nominal)

Fire Size: 28 MW (nominal)

Fire Location: A fuel pipe shall be positioned above the top tray of the mockup unit such that fuel is flowing into the top tray at the rate listed above. A fuel spray nozzle shall not be used during this test. As the tray fills with fuel, the fuel will eventually flow from the notch in the top of the machinery mockup unit and down the side of the mockup unit.

Fire Preburn Time: 15 seconds

Test Procedure: Ignition should occur as the mockup top tray just begins to overflow with fuel and pour down the vertical side of the mockup. The hybrid fire extinguishing system should be activated subsequent to the required preburn time.

#### G.5.8 Wood Crib and Heptane Pool Fire

Criteria: Extinguishment of the crib fire and extinguishment of the pool fire

Fuel: Wood crib and heptane

Type: Pool fire with crib

Fire Size: 7.5 MW (nominal)

Wood Crib: The wood crib is to weigh 11.9 lb to 13 lb (5.4 kg to 5.9 kg) and is to be dimensioned approximately 12 in. by 12 in. by 12 in. (305 by 305 by 305 mm). The crib is to consist of eight alternate layers of four trade size 1.5 by 1.5 in. (38.1 by 38.1 mm) kiln-dried spruce or fir lumber 12 in. (305 mm) long. The alternate layers of the lumber are placed at right angles to the adjacent layers. The individual wood members in each layer are to be evenly spaced along the length of the previous layer of wood members and stapled. After the wood crib is assembled, it is to be conditioned at a temperature of 120°F ± 9°F

(49°C ± 5°C) for not less than 16 hours. Following the conditioning, the moisture content of the crib is to be measured with a probe type moisture meter. The moisture content of the crib should not exceed 5 percent prior to the fire test.

- Fire Location: The test fire shall be centered along the length of the mockup unit and adjacent to the floor plates (see Figure G-1). The crib should be placed in the center of the 21.5 ft<sup>2</sup> (2 m<sup>2</sup>) pool with the fuel level up to one-half its height. The pan is located 2.5 ft (0.75 m) off the floor.
- Fire Preburn Time: 30 seconds
- Test Procedure: The pool fire shall be ignited, and the hybrid fire extinguishing system should be activated subsequent to the required preburn time. Following extinguishment, the fuel left in the pool or tray should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

#### G.5.9 Saturated Insulation Mat and Spray Fire (Optional Test)

- Criteria: Extinguishment of the spray fire and suppression of the insulation mat fire
- Fuel: Diesel fuel and insulation mat
- Type: Horizontal spray and diesel fuel saturated insulation mat fires
- Spray Nozzle: Low pressure-low flow nozzle
- Fire Location: The spray fire shall be located under the shelf with the nozzle 4 in. (10 cm) from the end of the mockup unit, under the centerline of the 12 in. (30 cm) diameter pipe, and 5.25 ft (1.6 m) above the floor plate (see Figures G-2 and G-3). The spray fire should be positioned to spray along the length of the pipe, away from the test enclosure opening. The insulation mat fire shall be located in line with the spray fire, 4 ft 7 in. (1.4 m) from the end of the mockup unit (see Figure G-2).
- Fire Preburn Time: 120 seconds
- Test Procedure: A 2 in. (51 mm) thick insulation mat of mineral wool composition shall be cut to the same dimensions as the 1 ft<sup>2</sup> (0.1 m<sup>2</sup>) pan and placed in the dry pan. The insulation mat shall then be saturated with diesel fuel, such that a liquid fuel pool occurs when slightly depressing the mat. The insulation mat fire shall be ignited. The spray fire should be ignited 105 seconds after the insulation mat fire is fully developed over the entire area of the mat. The hybrid fire extinguishing system should then be activated 15 seconds after ignition of the spray fire (120 seconds after the insulation mat fire is fully developed). The fuel spray should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel spray is shut off.

#### G.5.10 Saturated Insulation Mat Fire (Optional Test)

- Criteria: Suppression (only flamlets on surface of the insulation mat) of the insulation mat fire
- Fuel: Diesel fuel and insulation mat
- Type: 10.8 ft<sup>2</sup> (1 m<sup>2</sup>) diesel fuel saturated insulation mat fire
- Fire Location: The test fire shall be centered under the shelf, on top of the floor plates (see Figure G-2).
- Fire Preburn Time: 120 seconds
- Test Procedure: A 2 in. (51 mm) thick insulation mat of mineral wool composition shall be cut to the same dimensions as the 10.8 ft<sup>2</sup> (1 m<sup>2</sup>) pan and placed in the dry pan. The insulation mat shall then be saturated with diesel fuel, such that a liquid fuel pool occurs when slightly depressing the mat. The insulation mat fire shall be ignited. The hybrid fire extinguishing system should be activated 120 seconds after the insulation mat fire is fully developed over the entire area of the mat.

### G.5.11 Spray Cooling (No Fire)

**Criteria:** The heat flux resulting from a hybrid fire extinguishing system discharge shall not adversely affect the turbine. Such assessment is to be made in accordance with methodology developed by FM Approvals to assess the damage potential of hybrid systems. This test, combined with the FM Global Research proprietary heat transfer calculations, will determine the extent of the cooling of the turbine casing during the operation of the hybrid system. Calculations should be based on the manufacturer's recommended turbine size (diameter) to be installed within the enclosure and/or hybrid nozzle location(s) in the enclosure with respect to the turbine.

**Test Procedure:** The heat flux is affected by the stand-off distance of the hybrid nozzles. Therefore, the test shall be conducted at the minimum nozzle stand-off distance specified in the manufacturer's design manual. The nozzle(s) should be installed at a location(s) above the steel table, based on this specified distance. The design manual may also specify no direct spray impingement of the turbine casing.

A heptane spray fire should be used to heat the steel plate. The spray fire should be located underneath the test table with the fuel spray nozzle aimed at the table at a 30 degree grazing angle with the flames centered and impinging on the steel table mid point (see Figure G-5). To avoid excess heating of the test enclosure, the ceiling hatches may be left open during the heating of the plate. Additionally, it is recommended to use the low pressure-low flow nozzle to heat the plate. An alternative heating system, such as propane burners spaced evenly below the entire steel plate, may be used if it provides uniform heating of the plate and is discussed with FM Approvals prior to testing.

When all three steel plate thermocouples are above 572°F (300°C), the spray fire should be shut off, and the steel plate allowed to cool. When the last of three thermocouple readings drops to 572 °F (300 °C), then the hybrid system should be activated and the temperature history of the plate shall be recorded for a total of 15 minutes. Uniform heating of the steel plate is critical. Heating, and the subsequent cooling, shall be such that the three thermocouples provide consistent readings at the time of system activation. If excessive variation [greater than 18 °F (10 °C)] exists between the three thermocouples, the heating system should be modified and the plate heated again.

The spray cooling test data should be recorded in Microsoft Excel format. The data will be analyzed to determine the effective spray cooling heat flux for the particular test configuration. The heat flux is known to be affected by the drop size, impingement velocity, mass flux, surface composition and texture. However, the effects of these individual variables will not be investigated.

### G.5.12 Additional Fire Tests

Based on the results of Fire Tests G.5.1 through G.5.11, additional fire testing may be required to ensure that the hybrid fire extinguishing system being evaluated meets the intent of this section of the standard. This testing will be performed at the sole discretion of FM Approvals.

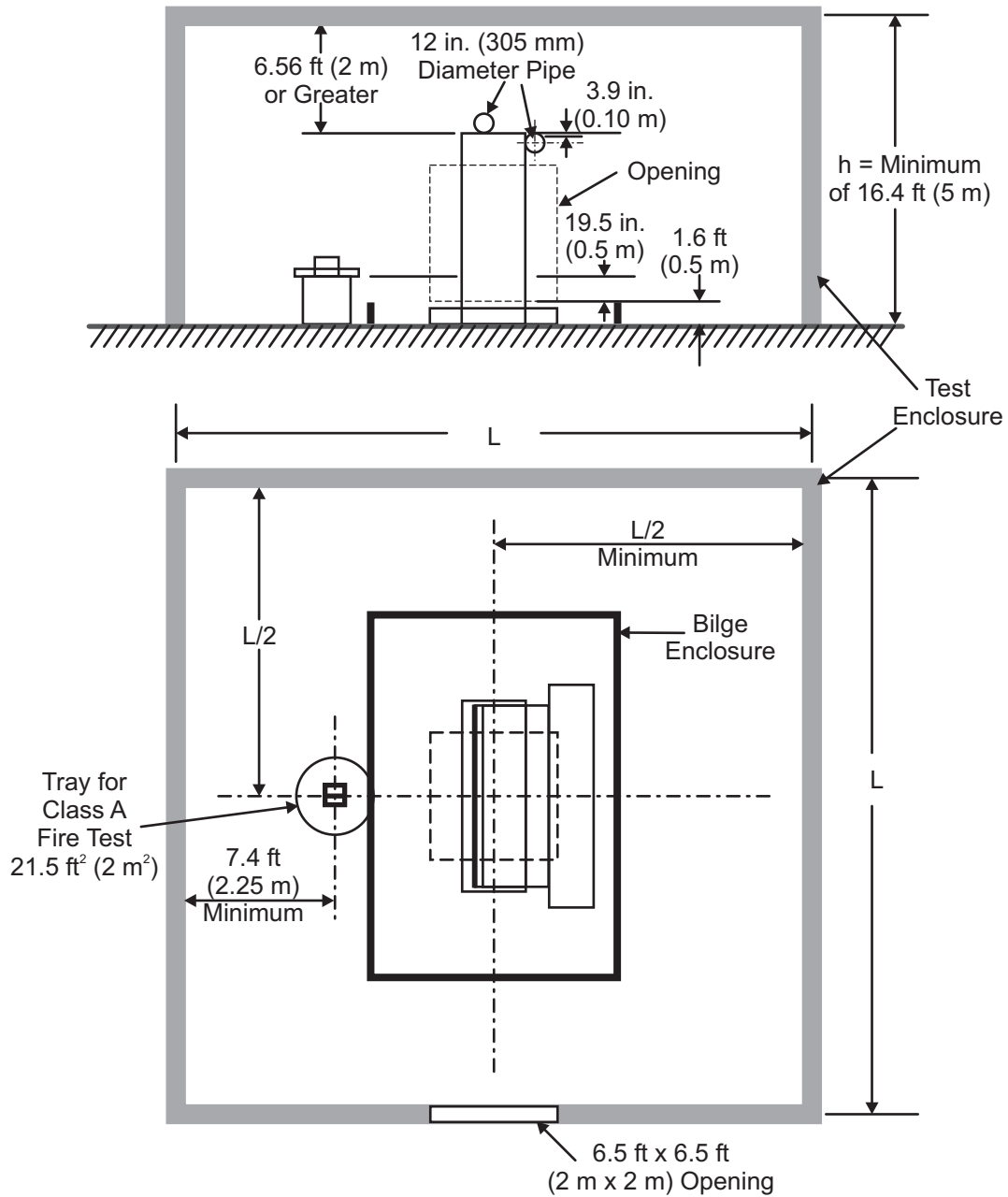


Figure G-1. Machinery and Combustion Turbine Test Enclosure

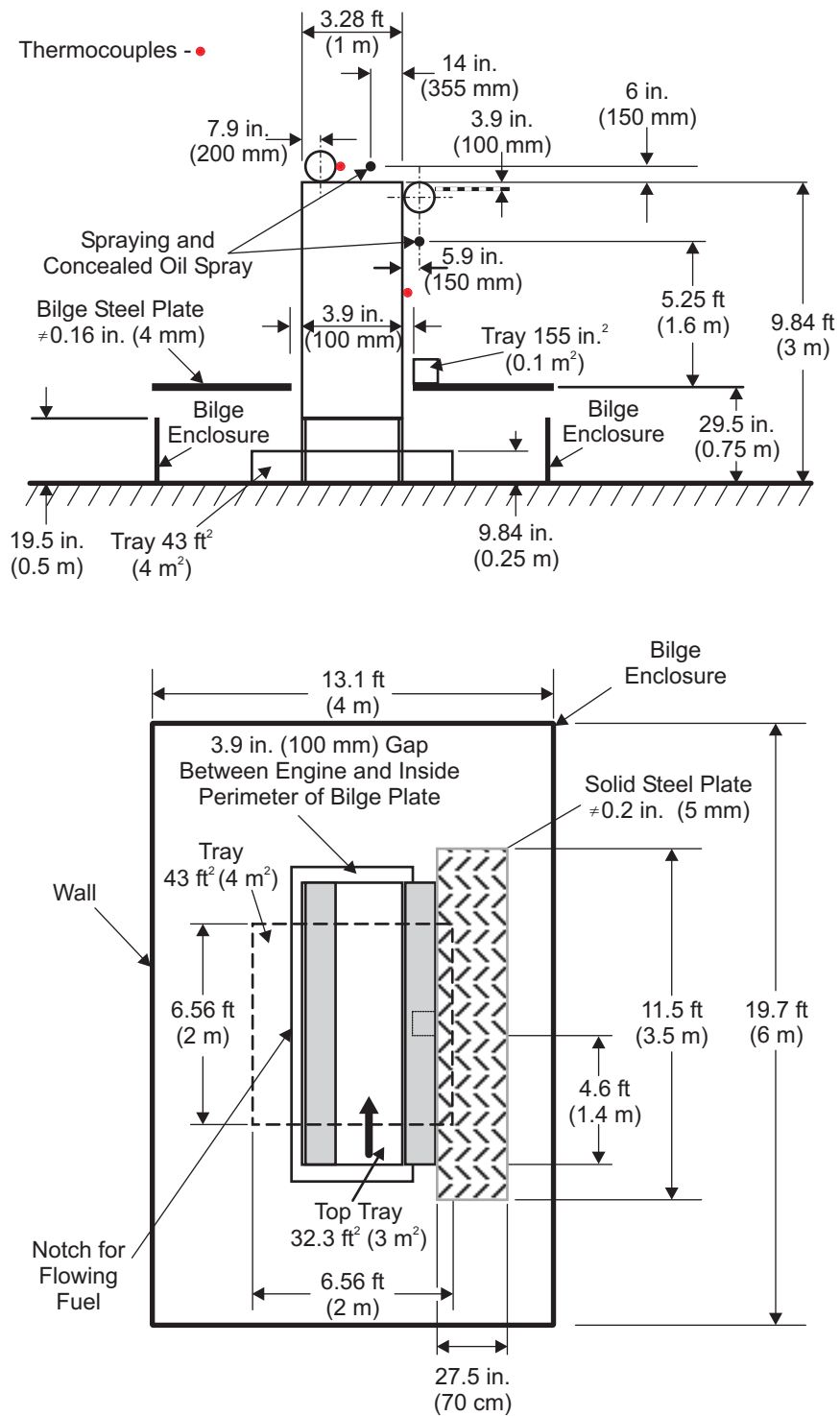


Figure G-2. Machinery and Combustion Turbine Mockup Unit



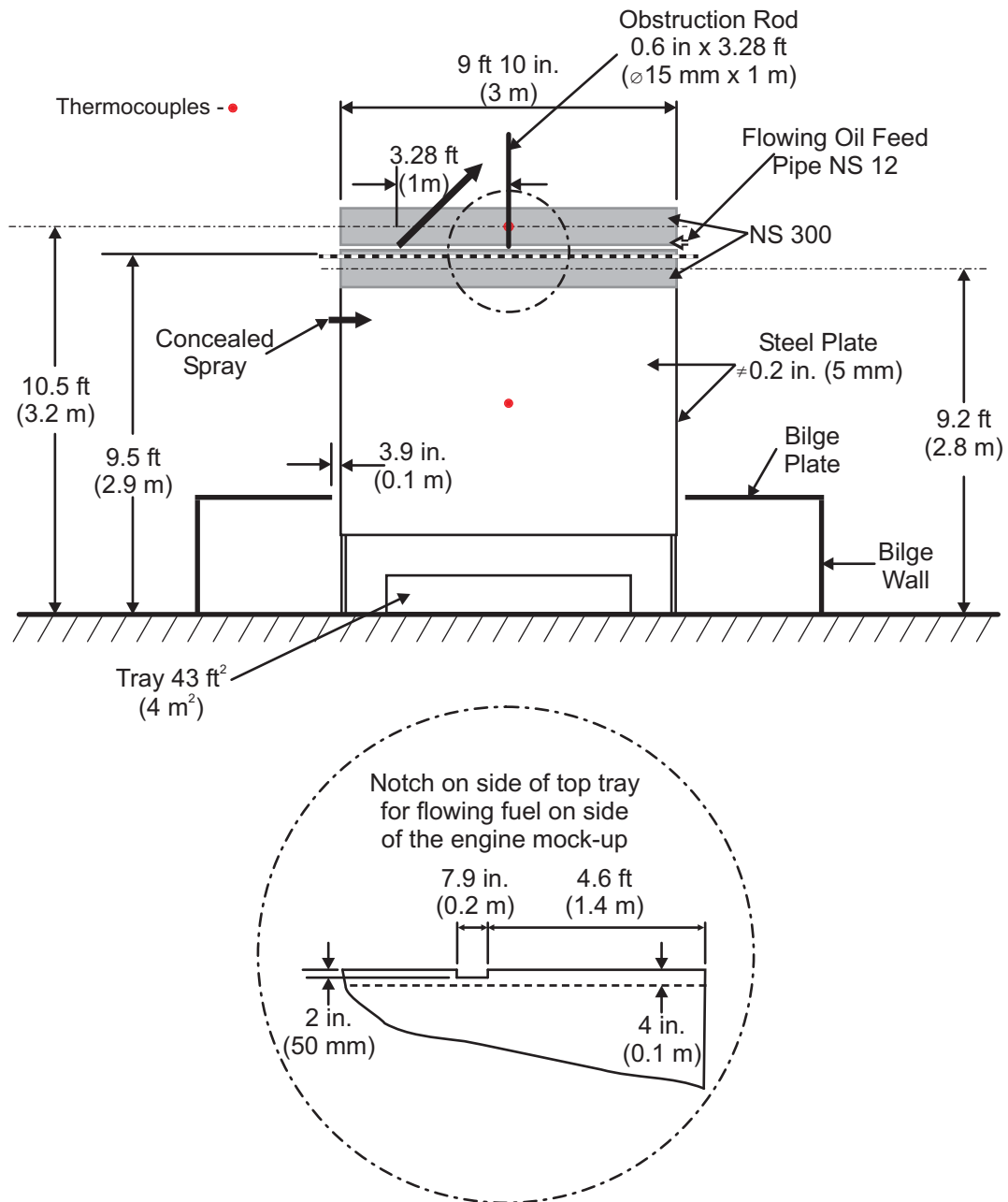


Figure G-3. Machinery and Combustion Turbine Mockup Unit (continued)

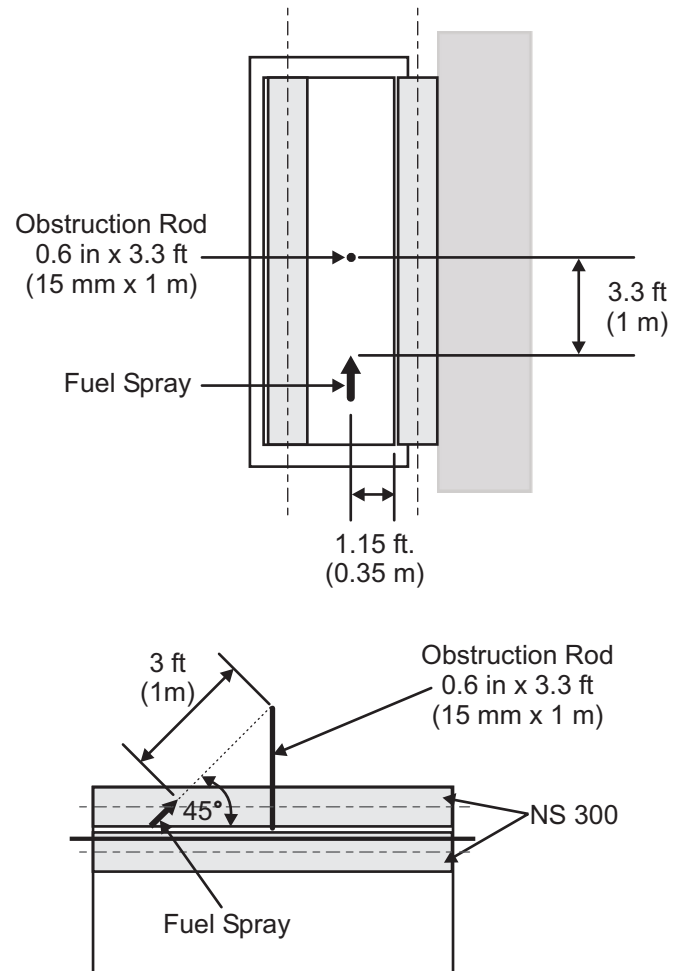


Figure G-4. Fire Test G.3.2, Position of Fuel Spray Nozzle and Obstruction Rod

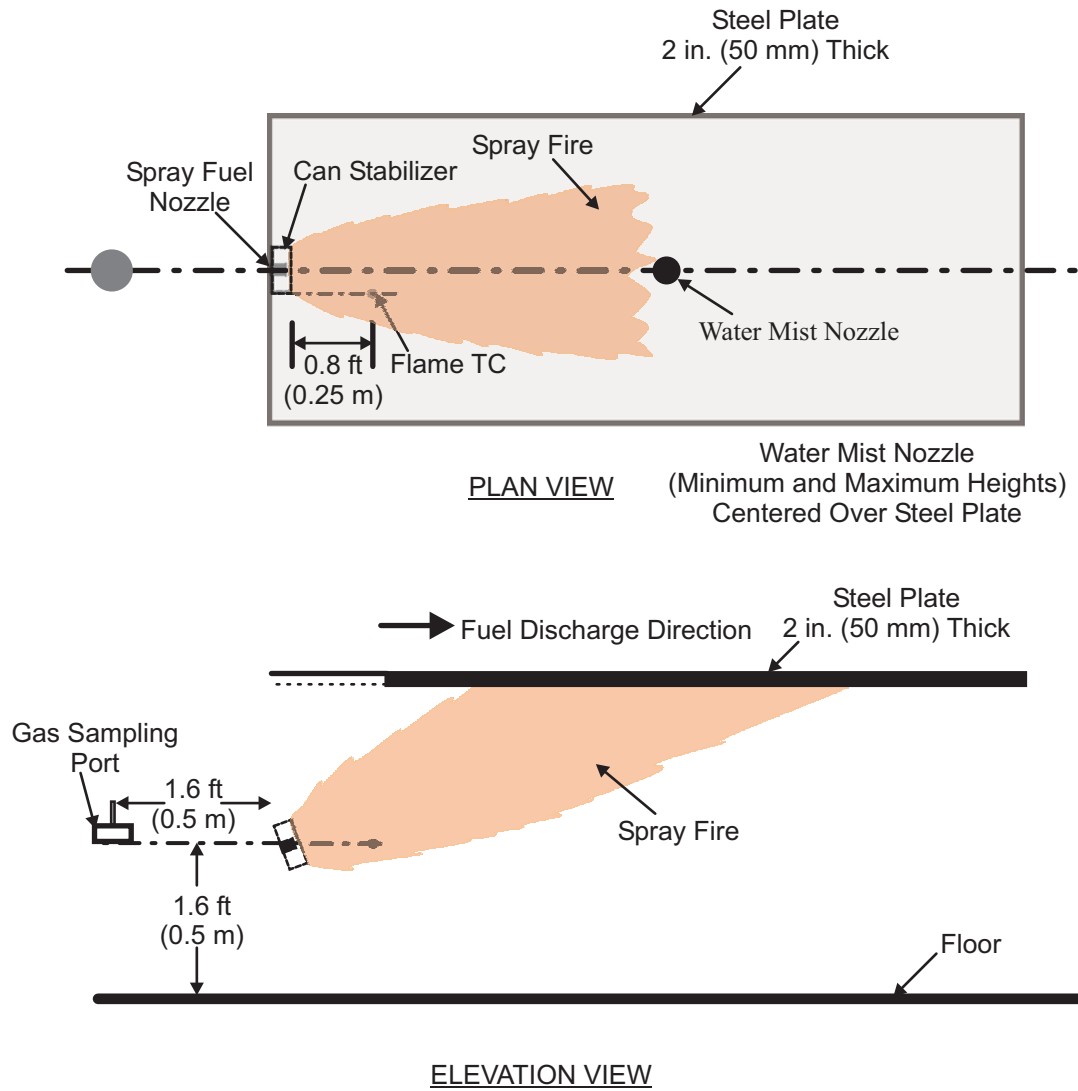


Figure G-5. Fire Source Configuration for Spray Cooling (No Fire) Testing

## APPENDIX H: Fire Tests for Hybrid Fire Extinguishing Systems for the Protection of Computer Room Sub Floors

### H.1 General Testing Requirements

The following criteria shall be met:

- A. Systems shall be operated with the restrictions imposed by the size of a sub-floor test room and an equivalent opening space of the floor area tested.
- B. The water supply and inert gas supply shall be capable of supplying 10 minutes of extinguishing agent to all nozzles in the determined design area.
- C. The manufacturer's design manual shall describe in detail the scaling parameters used for different room configurations.
- D. The maximum nozzle spacing shall be used for all tests. This includes using the maximum spacing of the nozzles from the walls.
- E. The minimum operating nozzle pressure (as specified by the manufacturer) shall be used for all tests. The pressure shall be established and maintained by means of a by-pass flow line.
- F. The hybrid fire extinguishing system, operating without manual intervention, shall successfully complete all fire tests for Approval. System components, component locations, and operating conditions shall remain unaltered throughout all of the fire tests.
- G. The test protocol calls for three sets of tests: telltale fire tests, a cable fire test and a test verifying the degree of moisture build-up inside a computer cabinet caused by the hybrid fire extinguishing system discharge.

### H.2 Instrumentation and Test Equipment Requirements

In addition to the instrumentation and test requirements described previously under "General Instrumentation and Test Equipment Requirements," the following measurements should be recorded to within a  $\pm 5$  percent tolerance level at intervals not exceeding one second using a computerized data acquisition system. Measurements should begin and end at least one minute prior to ignition and after extinguishment of the test fire(s).

- A. Temperature of fuel in the telltale cups, with the thermocouple located in the approximate center of the initial fuel layer. All fuels shall initially be at an ambient temperature of  $68^{\circ}\text{F} \pm 18^{\circ}\text{F}$  ( $20^{\circ}\text{C} \pm 10^{\circ}\text{C}$ ).
- B. Temperature of the cable fire, with two thermocouples located along the length of the cable bundle, 9 in. (23 cm) from the center of the fuel package in each direction. Both thermocouples shall be stainless steel sheathed, exposed junction type K thermocouples, 0.6 in. (16 mm) in diameter.
- C. Flame temperature of the telltale fires, measured by stainless steel sheathed, exposed junction type K thermocouples, 0.6 in. (16 mm) in diameter.
- D. Temperature in the enclosure, measured by Type K thermocouples (Gage 24).
- E. If applicable, gas temperature shall be measured using stainless steel sheathed, exposed junction type K thermocouples, 0.6 in. (16 mm) in diameter.
- F. Test equipment associated with conducting a door fan test in accordance with ASTM E 779, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*, including a door fan, pressure gauges, and any other applicable equipment.

- G. Oxygen concentration shall be measured in at least one location in the sub-floor. The elevation(s) and location(s) of the gas intake(s) in the sub-floor shall be determined by FM Approvals based on the maximum enclosure size and depth recommended by the manufacturer. The oxygen concentration shall be measured in at least two locations in the upper-floor structure. The elevations and locations of the gas intakes in the upper-floor structure shall be at, at a minimum, the following two locations:
- Centered in the upper-floor structure at 9 in. (0.24 m) above the floor tiles
  - Centered in the upper-floor structure at 7 ft. 3 in. (2.2 m) above the floor tiles

The operating range of all the analyzers is to be 0 to 25 percent by volume.

- H. Carbon monoxide and carbon dioxide shall be measured in at least one location. The elevation(s) and location(s) of the gas intake(s) shall be determined based on the maximum enclosure size and depth recommended by the manufacturer.
- I. Extinguishment should be determined by visual observation. Registration by means of thermal imaging equipment is strongly encouraged.

### H.3 Test Enclosure

A sub-floor test enclosure shall be constructed. The enclosure shall be rectangular, and the internal dimensions of the enclosure shall be the maximum enclosure size sought for Approval. The sub-floor enclosure shall be provided with viewing ports allowing a clear sightline to each fire.

The top of the enclosure shall be covered with 24 in. by 24 in. (0.61 m by 0.61 m) steel floor tiles. In order to simulate surface openings in normal computer room operation, some of the tiles shall be replaced with pegboards during the fire tests. Each pegboard shall have 0.24 in. (6 mm) diameter holes spaced with 1 in. (2.5 cm) between the centers of adjacent holes. These holes represent 28.27 in.<sup>2</sup> (182.4 cm<sup>2</sup>) open area, or 4.9 percent of the total area of one floor tile.

A sufficient number of floor tiles should be replaced with pegboards to provide the maximum floor opening area specified by the manufacturer. The total equivalent open area of the enclosure resulting from the replacement of floor tiles with pegboards shall be determined by a door fan test in accordance with ASTM E 779, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*. A fan shall be placed on the ceiling of the sub-floor test enclosure, facing down toward the enclosure. The fan shall be turned on and adjusted to produce a predetermined pressure differential in the enclosure (0.050 in. water column is generally used). It shall be assumed that the air flows through an equivalent open area, allowing this open area to be calculated as follows:

$$A = \frac{Q}{C_d \sqrt{2gl}}$$

where  $Q$  is the air flow rate in units of cfm (m<sup>3</sup>/min),  $C_d$  is the discharge coefficient (0.61),  $g$  is gravitational acceleration [32.2 ft/s<sup>2</sup> (9.8 m/s<sup>2</sup>)], and  $l$  is the length of air column equivalent to the pressure differential in units of ft (m). The minimum permissible combined floor opening area shall be 1 percent of the sub-floor enclosure area.

An upper-floor structure shall be built on top of the sub-floor test enclosure having the same length and width dimensions of the sub-floor. The height of the upper-floor structure shall be 8 ft (2.4 m). The enclosure should be constructed of wood or metal frame with an inner lining of minimum 0.5 in. (13 mm) gypsum or 0.03 in. (0.7 mm) galvanized steel. To minimize leakages, all joints and gaps shall be sealed.

## H.4 Fire Tests Configurations

### H.4.1 Telltale Fire Test – Singular Module

Criteria:	The fire is to be extinguished within 5 minutes of system operation.
Fuel:	Heptane
Type:	The telltale fire test shall include heptane cup fires. The cups shall be fabricated out of schedule 40 steel pipe, with an inside diameter of 3 in. (76 mm), and height of 5 in. (127 mm). The bottom of each can shall be welded onto 0.25 in. (6.4 mm) thick steel plate, approximately 4 in. (100 mm) square. The cups shall be filled with heptane to provide a freeboard equal to 2 in. (51 mm).
Fire Location:	<p>A baffle shall be erected in the center of the sub-floor (see Figure H-4) and extend the full height of the enclosure. The baffle width shall be 20 percent of the width of the walls to which it is parallel. The baffle should be placed such that a telltale fire placed behind the baffle is obstructed from possible direct impingement of gas/water mist discharge. If this is not possible due to the configuration of the water mist system nozzles, a second baffle should be constructed, resulting in an obstruction on either side of the telltale fire. If the enclosure is not square, separate tests shall be conducted with appropriate width baffles parallel to both the long and short walls.</p> <p>Seven telltale fires shall be located on the floor of the enclosure in the following locations, to verify that an extinguishing concentration can be achieved throughout the sub-floor: within 2 in. (50 mm) of each wall at each corner of the enclosure, at the center of the enclosure in the same plane as the baffle(s), and in the center of the enclosure and obstructed by the baffle(s) as described previously.</p>
Fire Preburn Time:	120 seconds
Test Procedure:	Each heptane can shall be ignited, and the required preburn time shall begin following ignition of the last can. The viewing ports shall remain open during the preburn to ensure that combustion gas buildup does not enhance extinguishment. They shall be closed 15 seconds prior to the initiation of discharge. Subsequent to the required preburn time, the hybrid fire extinguishing system should be activated. Following extinguishment, the fuel left in the pool or tray should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

### H.4.2 Cable Fire Test

Criteria:	The fire is to be extinguished within 5 minutes of system operation.
Fuel:	<p>The cable fire fuel load consists of twenty-five PVC jacketed communication cables. Each of the twenty-five cables shall include the following specifications:</p> <ol style="list-style-type: none"> <li>A. 30.5 in. (77.5 cm) in length</li> <li>B. Consist of six PVC jacketed bundles. <ul style="list-style-type: none"> <li>• Five bundles shall contain four pairs of AWG 24 solid copper conductors</li> <li>• One bundle shall contain five pairs of AWG 24 solid copper conductors.</li> <li>• All conductors shall be insulated with polyethylene (PE).</li> </ul> </li> <li>C. The nominal exterior diameter of the cable shall be 0.62 in. (15.75 mm). The cable shall be a riser and general purpose cable (except plenum). Samples of the cable shall be tested for burning characteristics using the FM Global Research Flammability Apparatus. For each property listed in Table H.4.2, three cables shall be placed in a 4 in. (102 mm) diameter aluminum dish. The sample surface area shall be 7 in.<sup>2</sup> (0.0045 m<sup>2</sup>). The properties shall conform to the minimum requirements specified in Table H.4.2.</li> </ol>

Table H.4.2 – Required Burning Characteristics of Cable

<i>Property</i>	<i>Test Method</i>	<i>Requirement</i>
Critical Heat Flux	<i>Standard Test Methods for Measurement of Synthetic Polymer Material Flammability Using A Fire Propagation Apparatus (FPA) -</i>	15 kW/m <sup>2</sup>
Thermal Response Parameter	ASTM E 2058 - 02a with imposed radiant heat fluxes between 10 and 60 kW/m <sup>2</sup>	180 kW-s <sup>1/2</sup> /m <sup>2</sup>
Chemical Heat of Combustion	<i>Standard Test Methods for Measurement of Synthetic Polymer Material Flammability Using A Fire Propagation Apparatus (FPA) -</i>	14 kJ/g
Peak Heat Release Rate	ASTM E 2058 - 02a with an imposed heat flux of 50 kW/m <sup>2</sup>	30 kW

**Fire Location:** The twenty-five cables shall be tied to four tubular heaters. Each tubular heater shall generate 925 W at 265 V, resulting in a total heat release rate from the heaters of approximately 3.7 kW. The cable fuel load shall be mounted on a simulated cable tray and placed on top of a 0.5 in. (1.3 cm) thick marine board sheet. This assembly shall be located in the center of the sub-floor enclosure. A picture of the fuel package is provided in Figure H-2.

The cable fire shall be obstructed from possible direct impingement of gas/water discharge by erecting two identical baffles on each side of the fuel load, parallel to the cable bundle. Each plywood baffle should be 3.3 ft (1 m) long and 18 in. (46 cm) high. A video camera shall be placed 15 in. (38 cm) away from the end of the cable bundle, providing a partial blockage of flow on a third side of the fuel package side (Figures H-3 and H-5).

**Fire Preburn Time:** 120 seconds after the tabular heater power has been turned off.

**Test Procedure:** The cable bundle shall be energized using the four tabular heaters. Five minutes after the appearance of flame on the video camera, the power should be turned off. The fuel package shall be allowed to free burn for two minutes after the power has been turned off. Subsequent to the required preburn time, the hybrid fire extinguishing system should be activated. Following extinguishment, the fuel left in the pool or tray should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

### H.4.3 Moisture Concentration Test

This test shall be conducted to verify the moisture concentration inside a computer cabinet in the upper-floor structure due to hybrid media discharge in the sub-floor.

**Criteria:** Following system discharge, the color of the two anhydrous calcium sulfate samples within the cabinet shall be identical to the two anhydrous calcium sulfate reference samples located on top of the cabinet and outside of the enclosure. No condensation shall be detected on the surface of either mirror.

**Test Procedure:** A mockup of a computer cabinet, similar to an IBM Application System 400, shall be placed on the floor of the upper-floor structure, in a location to be determined by FM Approvals. The cabinet shall have a 5 in. by 23.25 in. (12.7 cm by 59 cm) opening on the bottom to simulate cable passage from the sub-floor. A sufficient quantity of floor tiles shall be removed to accommodate the cabinet, and a skirt shall be attached to cabinet's rear door to direct the flow from this sub-floor opening into the cabinet.

Anhydrous calcium sulfate (97 percent CASO<sub>4</sub>, 3 percent CoCl<sub>2</sub>) shall be placed in four Pyrex Petri dishes to provide an indication of the degree of moisture content within the

enclosure following water mist system discharge. As an example, Drierite is a commercially available drying agent composed of calcium sulfate. Indicating Drierite, containing cobalt chloride, is normally blue in color and changes to pink upon absorption of moisture. The Pyrex Petri dishes shall be 4 in. (100 mm) in diameter by 0.6 in (15 mm) deep, and shall be placed at the following locations:

- Two dishes shall be located inside the cabinet at elevations of 2 ft (0.6 m) and 3.3 ft (1 m) above the floor of the upper-floor structure.
- One dish shall be placed outside, and on top of, the cabinet.
- One dish shall be placed outside of the test room.
- The two dishes placed outside the cabinet serve as references, representing the humidity of the surrounding environments.

In addition, two mirrors shall be placed inside the cabinet at elevations of 2 ft (0.6 m) and 3.3 ft (1 m) above the floor of the upper-floor structure.

The hybrid fire extinguishing system shall be discharged for the duration of the required agent supply, based on the results of tests H.4.1 and H.4.2 and the manufacturer's requirements. Following the discharge period, the mirrors and Petri dishes shall be examined for indications of excessive moisture penetration inside the computer cabinet.

#### H.4.4 Telltale Fire Test – Two Modules

(Note: This test is only applicable if the manufacturer desires to potentially extrapolate beyond the enclosure size tested in fire tests H.4.1 through H.4.3)

The sub-floor test enclosure shall be expanded such that the area of the enclosure is two times that which was used in fire tests H.4.1 through H.4.3. For example, if the original dimensions of the sub-floor are X by Y by H, the expanded enclosure shall have dimensions of 2X by Y by H or X by 2Y by H. The top of the expanded section of the enclosure should replicate the original sub-floor, including an equivalent number of floor tiles replaced by pegboards. A door fan test, as described in Section H.3, shall be conducted to verify the total equivalent open area is two times the area in fire tests H.4.1 through H.4.3, with an allowable variation of  $\pm 5$  percent. The minimum permissible combined floor opening area is 1 percent of the sub-floor enclosure area.

An additional hybrid fire extinguishing system shall be installed in the expanded section of the enclosure, identical to the configuration used in fire tests H.4.1 through H.4.3. The two modules shall be mirror images of each other.

Criteria:	The fire is to be extinguished within 5 minutes of system operation.
Fuel:	Heptane
Type:	The telltale fire test shall include heptane cup fires. The cups shall be fabricated out of schedule 40 steel pipe, with an inside diameter of 3 in. (76 mm), and height of 5 in. (127 mm). The bottom of each can shall be welded onto 0.25 in. (6.4 mm) thick steel plate, approximately 4 in. (100 mm) square. The cups shall be filled with heptane to provide a freeboard equal to 2 in. (51 mm).
Fire Location:	At least five telltale fires shall be located on the floor of the enclosure in areas to be determined by FM Approvals. The fires shall be located between the two water mist system modules to verify system performance in this intermediate location.
Fire Preburn Time:	120 seconds
Test Procedure:	Each heptane can shall be ignited, and the required preburn time shall begin following ignition of the last can. The viewing ports shall remain open during the preburn to ensure that combustion gas buildup does not enhance extinguishment. They shall be closed 15 seconds prior to the initiation of discharge. Subsequent to the required preburn time, the hybrid fire extinguishing system should be activated. Following extinguishment, the



fuel left in the pool or tray should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

#### **H.5 Extrapolation of Test Data**

Should a need arise to apply a hybrid fire extinguishing system to the protection of a computer sub floor area that is larger than tested, test data may be used to extrapolate to the larger areas on a case-by-case basis by FM Approvals. Such extrapolation shall be clearly defined by the manufacturer and shall become a part of the manufacturer's design, installation, operation, and maintenance manual and the Approval Guide Listing.

Systems shall be judged suitable for extrapolation beyond the enclosure size tested if all of the following criteria are met:

- A. The number of nozzles per unit area is unchanged for the fire tests.
- B. The nozzle discharge per unit area is unchanged for the fire tests.
- C. The difference in extinguishment times between tests and the extinguishment times are not indicating an increasing time trend.

Extrapolation beyond the height tested is not permitted.



Figure H-1. A Typical Heptane Cup used for Telltale Fire Tests



Figure H-2. Cable Fire Fuel Load



Figure H-3. Cable Fire

The cable fire fuel load is placed in the center of the enclosure. The left and right sides are blocked by baffles (1 m long, 0.46 m high); the top side in the photograph is partially blocked by video camera installation.

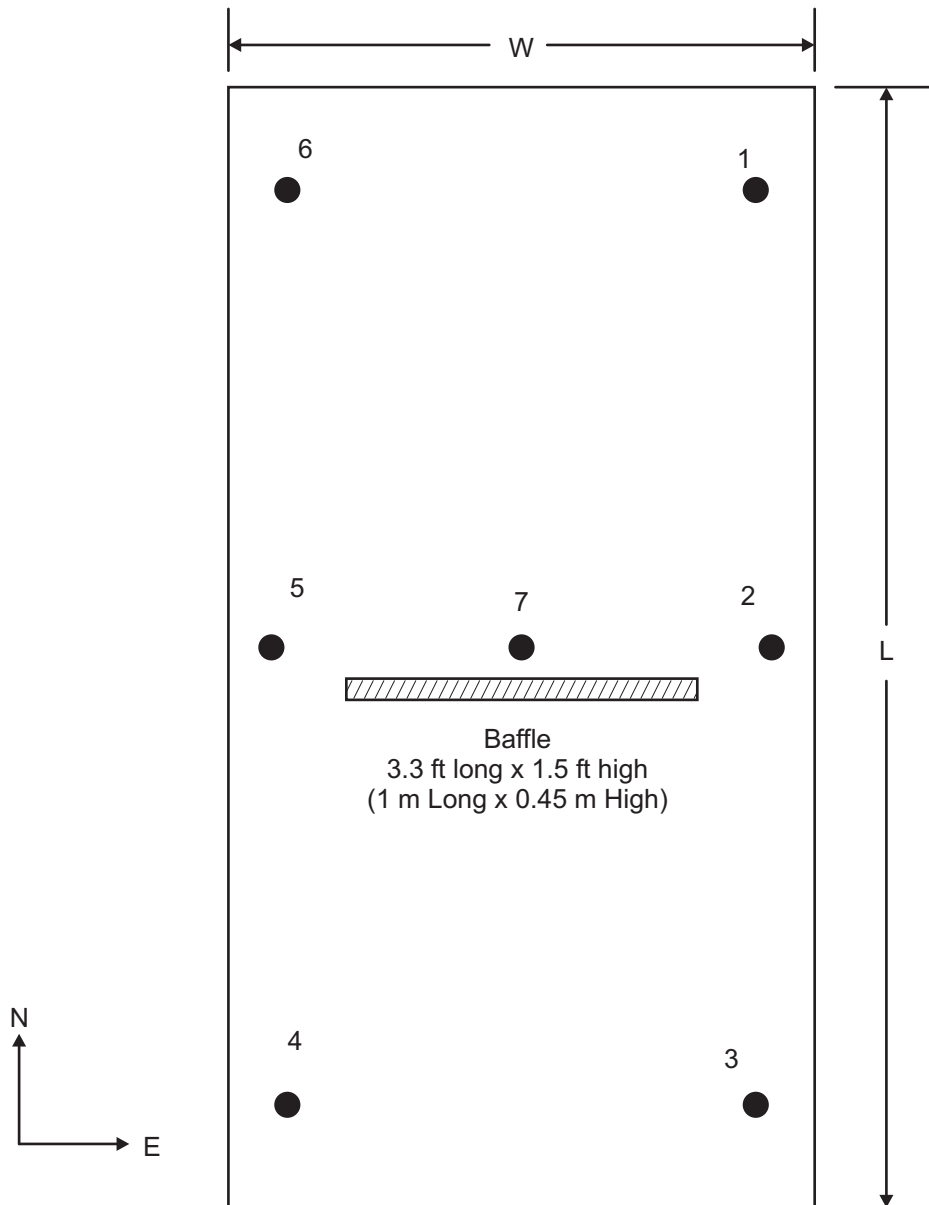


Figure H-4. Telltale Fire Locations

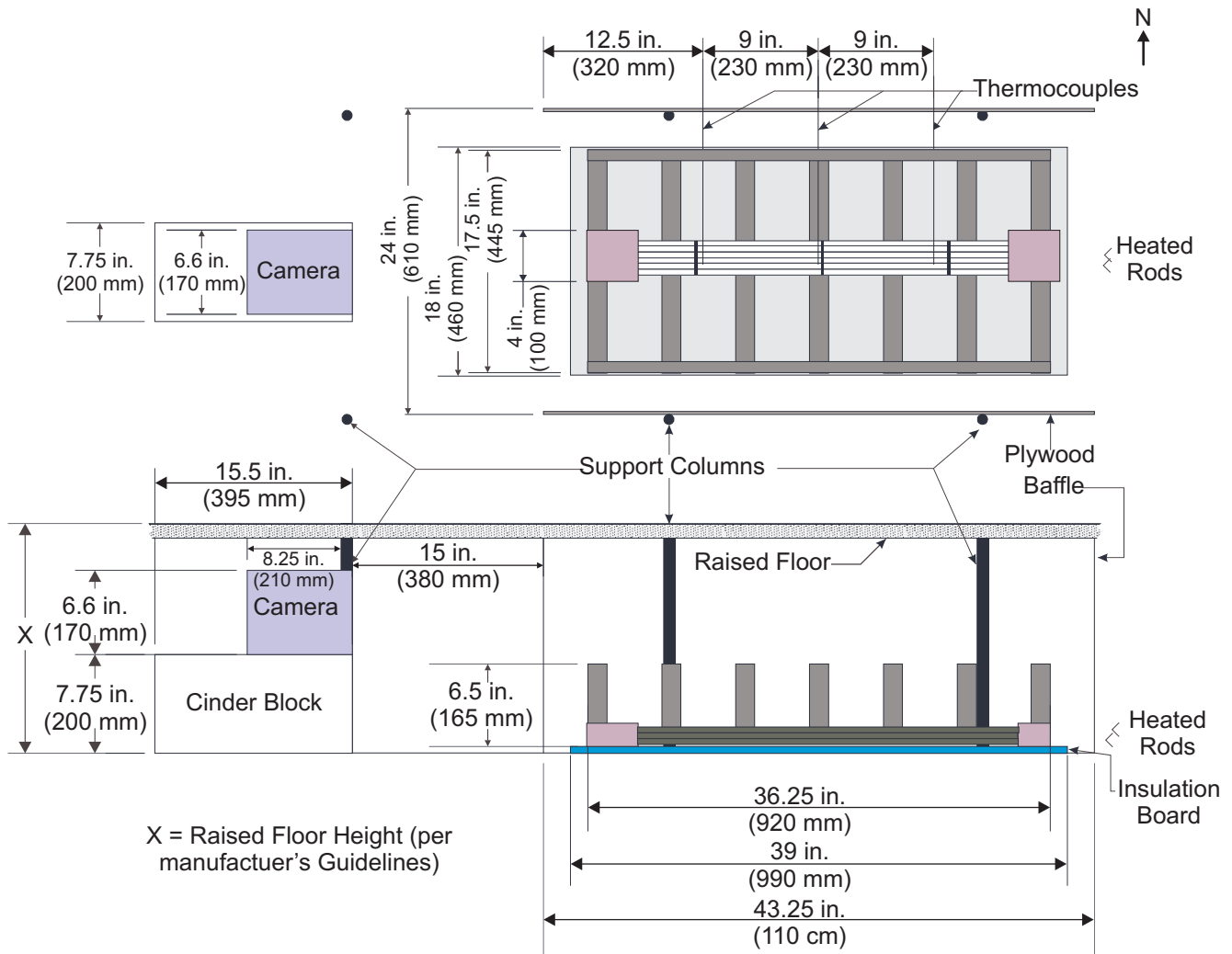


Figure H-5. Schematic Cable Fire Fuel

## **APPENDIX I: Other Occupancies which FM Global has an Interest in Protecting with Hybrid Fire Extinguishing Systems**

- Chemical fume hoods
- Electronic and telecommunication equipment areas
- Flammable liquid spray operations
- Flammable liquid storage in metal drums in storage rooms.
- Occupancies protected by special protection systems listed in FM Global Property Loss Prevention Data Sheet Number 4-0, *Special Protection Systems*, Appendix C, Section C.4.

### **I.1 General Testing Requirements**

FM Approvals and FM Global Research personnel and FM Global Property Loss Prevention Data Sheet Numbers 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*, and 4-0, *Special Protection Systems*, should be consulted with for occupancy determination and basic installation parameters.

## APPENDIX J: Units of Measurement

<b>AREA:</b>	in <sup>2</sup> - “square inches”; (mm <sup>2</sup> - “square millimeters”) ft <sup>2</sup> - “square feet”; (m <sup>2</sup> - square meters”) mm <sup>2</sup> = in <sup>2</sup> x 645.16 m <sup>2</sup> = ft <sup>2</sup> x 0.0929
<b>C-FACTOR:</b>	(ft/s) <sup>1/2</sup> - “square root of feet per second”; ([m/s] <sup>1/2</sup> - “square root of meters per second”) (m/s) <sup>1/2</sup> = (ft/s) <sup>1/2</sup> x 0.552
<b>DENSITY:</b>	lb/gal - “pounds per gallon”; (kg/L - “kilograms per liter”) kg/L = lb/gal x 0.1198
<b>ENERGY:</b>	Btu - “British thermal units”; (J - “joules”) J = Btu x 1055.056
<b>FLOW:</b>	gal/min - “gallon per minute”; (L/min - “liters per minute”) L/min = gal/min x 3.7854
<b>FORCE:</b>	lbf - “pounds-force”; (N - “newtons”) N = lb x 4.4482
<b>HEAT RELEASE RATE:</b>	Btu/min - “British thermal units per minute”; (kW - “kilowatts”) kW = Btu/min x 0.0176
<b>K-FACTOR:</b>	gal/min/(psi) <sup>1/2</sup> - “gallons per minute per square root of pounds per square inch”; (L/min/(bar) <sup>1/2</sup> - “cubic decimeters per minute per square root of bars”) (L/min/(bar) <sup>1/2</sup> = gal/min/(psi) <sup>1/2</sup> x 1.442
<b>LENGTH:</b>	in. - “inches”; (mm - “millimeters”) mm = in. x 25.4 ft - “feet”; (m - “meters”) m = ft x 0.3048
<b>MASS:</b>	Lb - “pounds”; (kg - “kilograms”) kg = lb x 0.454
<b>PRESSURE:</b>	psi - “pounds per square inch”; (bar - “bars”) bar = psi x 0.06895 psf - “pounds per square foot”; (bar - “bars”) bar = psf x 0.00479
<b>RTI:</b>	(ft·s) <sup>1/2</sup> - “square root of foot seconds”; ([m·s] <sup>1/2</sup> - “square root of meter seconds”) (m·s) <sup>1/2</sup> = (ft·s) <sup>1/2</sup> x 0.552
<b>SPECIFIC HEAT:</b>	BTU/lb·°F - “British thermal units per pound degrees Fahrenheit”; (kJ/kg·°K) - “kilojoule per kilogram degree Kelvin” kJ/kg·°K = BTU/lb·°F x 4.184
<b>TEMPERATURE:</b>	°F - “degrees Fahrenheit”; (°C - “degrees Celsius”) °C = (°F - 32) x 0.556
<b>TORQUE/MOMENT:</b>	lbf·ft - “pound-force foot”; (N·m - “newton meters”) N·m = lbf·ft x 1.356



**APPENDIX J: Units of Measurement (Continued)**

**VACUUM:** inHg - “inches of mercury”; psi - “pounds per square inch”; (bar - “bars”)

psi = inHg  $\times$  0.4912

bar = inHg  $\times$  0.0339

**VOLUME:** gal - “gallons”; (L - “liters”)

L = gal  $\times$  3.7854

**VOLUME PER UNIT AREA:** gal/min/ft<sup>2</sup> - “gallons per minute per square feet”

(mm/min - “millimeters per minute”)

mm/min = gal/min/ft<sup>2</sup>  $\times$  40.75

## APPENDIX K: Tolerances

Unless otherwise stated, the following tolerances shall apply:

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

Unless stated otherwise, all tests shall be carried out at a room (ambient) temperature of  $68^\circ\text{F} \pm 18^\circ\text{F}$  ( $20^\circ\text{C} \pm 10^\circ\text{C}$ ).

## APPENDIX L: Tolerance Limit Calculations

Utilizing the data obtained as described in Sections 4.2.1 and 4.2.2, 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:  $\sigma_{n-1}$  = standard deviation  
 $\bar{x}$  = sample mean  
 $x_i$  = individual values of each sample tested  
 $n$  = number of samples tested

Based upon the number of nozzles or bulbs tested ( $n$ ), a value,  $\gamma$ , shall be selected from Table L1 where the degree of confidence is 0.99 and the proportion of samples is 0.99.

Table L1 -  $\gamma$  Factors for One-Sided Tolerance Limits for Normal Distributions (99 Percent of Samples)

$n$	$\gamma$	$n$	$\gamma$	$n$	$\gamma$
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 nozzle assembly load  
 $\bar{x}_B$  = mean bulb strength  
 $\gamma_B$  = bulb strength factor ( $\gamma$ ) from Table L1  
 $\sigma_{(n-1)B}$  = 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  
 $\gamma_S$  = assembly load factor ( $\gamma$ ) from Table L1

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

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

## APPENDIX M: FM Approvals Certification Marks

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



### FM APPROVED mark:

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



### FM APPROVED mark with "C" only:

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



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

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



### Cast-On FM APPROVALS marks:

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

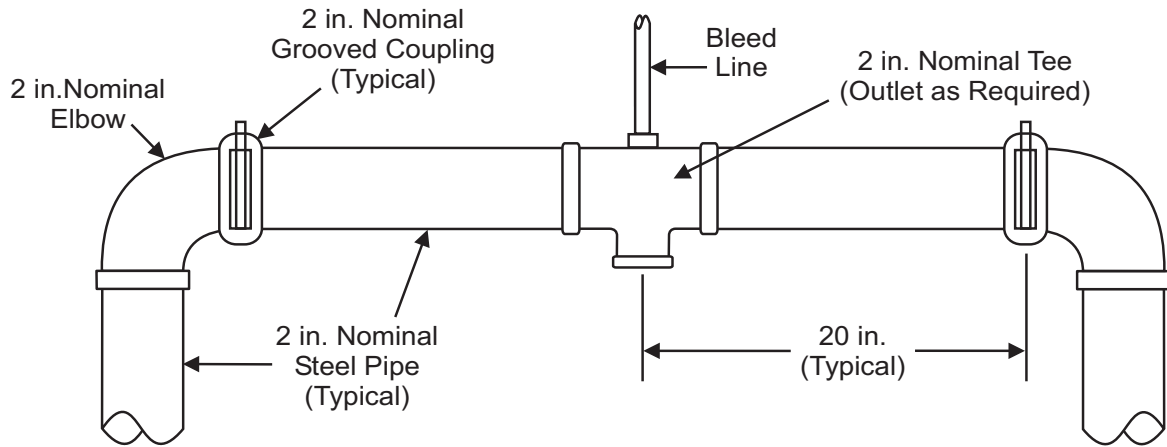
Downloadable art and other FM Approvals resources are available by visiting our Web site at [www.fmapprovals.com](http://www.fmapprovals.com)

## FM Approvals Certification Marks

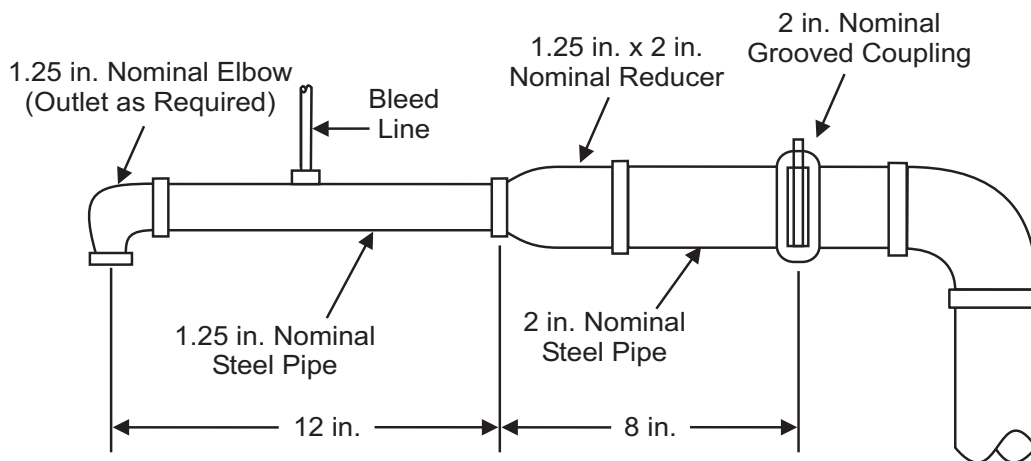
### Usage Guidelines

- All FM Approvals certification marks are the sole property of FM Approvals LLC (“FM Approvals”) and are registered or the subject of applications for registration in the United States and many other countries. They are for use only according to these guidelines.
- FM Approvals certification marks may be used only on FM Approved products and related product packaging, in advertising material, catalogs and news releases. Use of FM Approvals certification marks on such material is not a substitute for use of the complete FM Approvals certification mark on FM Approved products and/or product packaging.
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- The Approval Standard number or class number may not be incorporated as part of a business name, Internet domain name, or brand name/trademark for products/product lines. For example, a company may not say “ABC Company’s 4100 Fire Door is FM Approved”; the proper terminology is, “ABC Company’s Fire Door is FM Approved per Approval Standard 4100.”
- FM Approvals certification marks, except for the FM Approvals Quality System Registration mark, may not be used on business stationery/cards/signage because this could mischaracterize the relationship with FM Approvals. Additionally, these items should not reference any FM Approvals certification mark.
- Products or services may not be marketed under any mark or name similar to “FM Global,” “FM Approvals” or any of the FM Approvals certification marks. Further, products or services may not be marketed to imply a relationship beyond the scope of any Approval made by FM Approvals.
- When an FM Approvals certification mark is used in advertising material or on product packaging, all material must reflect the specific circumstances under which the product was FM Approved. The material must clearly differentiate between products that are FM Approved and those that are not, and may not, in any way, imply a more substantial relationship with FM Approvals.
- A company may not reference the intent to submit a product for Approval or the expectation that a company will have a certain product FM Approved in the future. For example, a company may not state, “Approval by FM Approvals pending” or “Approval by FM Approvals applied for.”
- FM Approvals certification marks should not be preceded or followed by a qualifier that indicates a degree of certification or acceptability. For example, “exceeds,” “first” or “only” may not be used to qualify any FM Approvals certification mark.
- Only original artwork issued by FM Approvals should be used. The FM Approvals certification marks should not be altered in any way other than to resize the artwork proportionately. Unacceptable uses of the marks include, but are not limited to, adding/deleting wording or artwork, reducing the artwork to an illegible size, animation or distortion.
- The text of the FM Approvals certification marks may not be translated into any language other than English.
- FM Approvals certification marks must appear in a size and location that is readily identifiable, but less prominent than the name of the owner of the certification or the manufacturer/seller/distributor of the certified products.

APPENDIX N: Figures N-1 through N-6



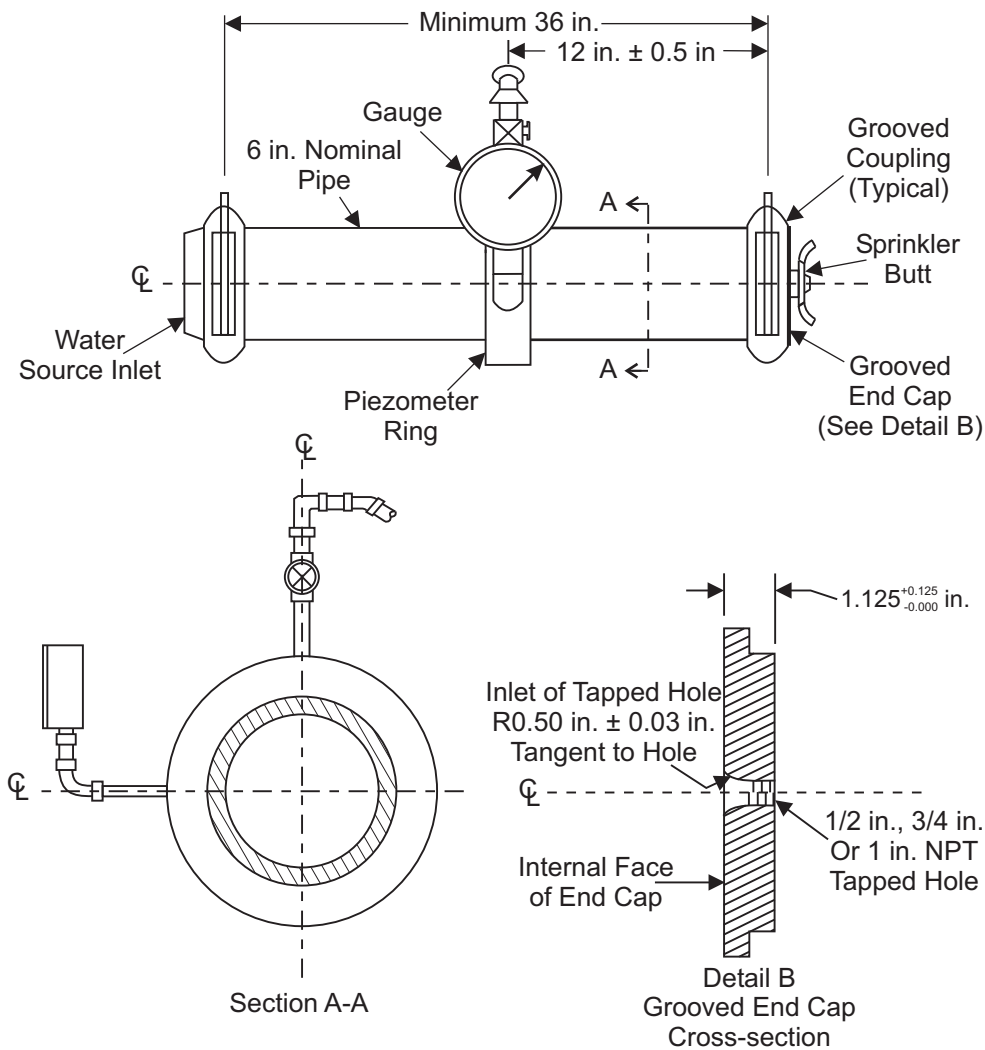
Test Apparatus for Double-Fed Flow



Test Apparatus for Single-Fed Flow

Note: All dimensions are nominal size.

Figure N-1. Hang-Up of Operating Parts



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

Figure N-2. Test Apparatus for Measuring Nominal K-Factors < 8.0 gal/min/psi (11.54 L/min/bar)

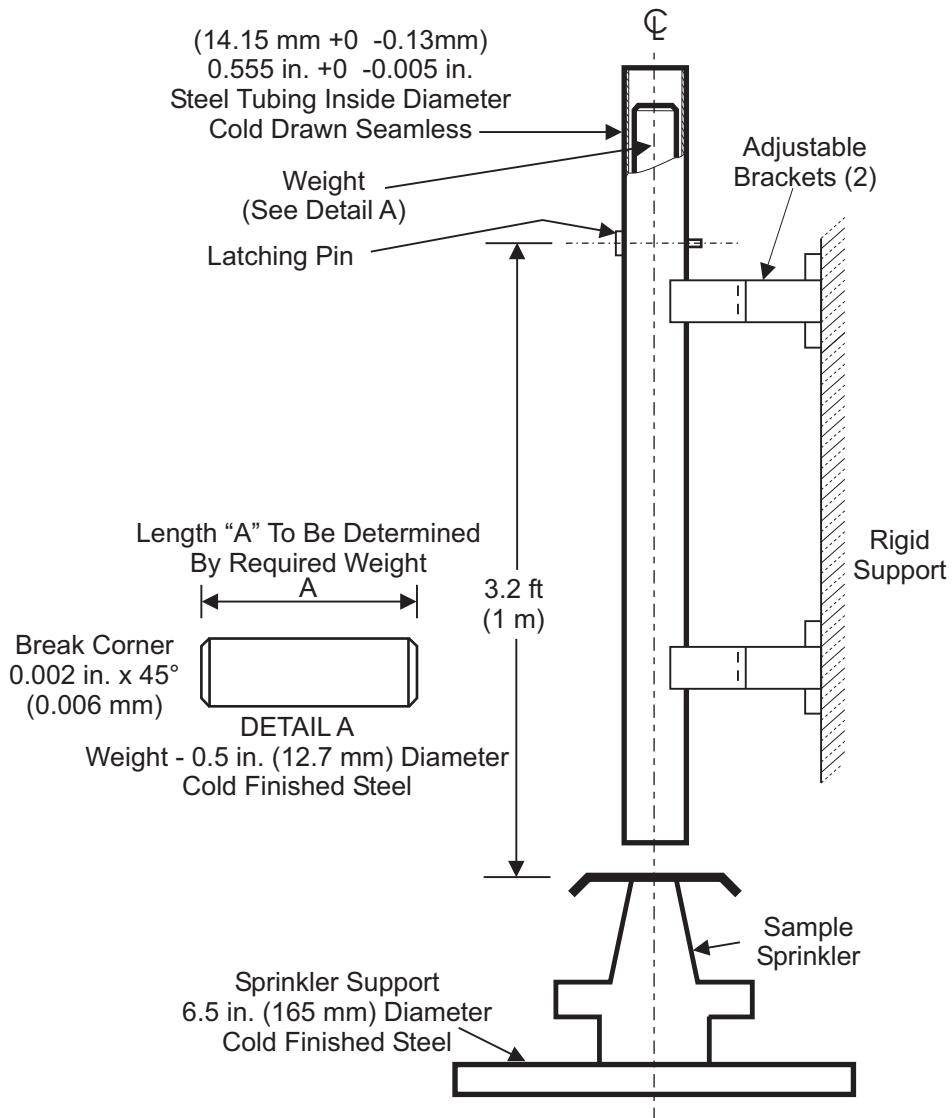
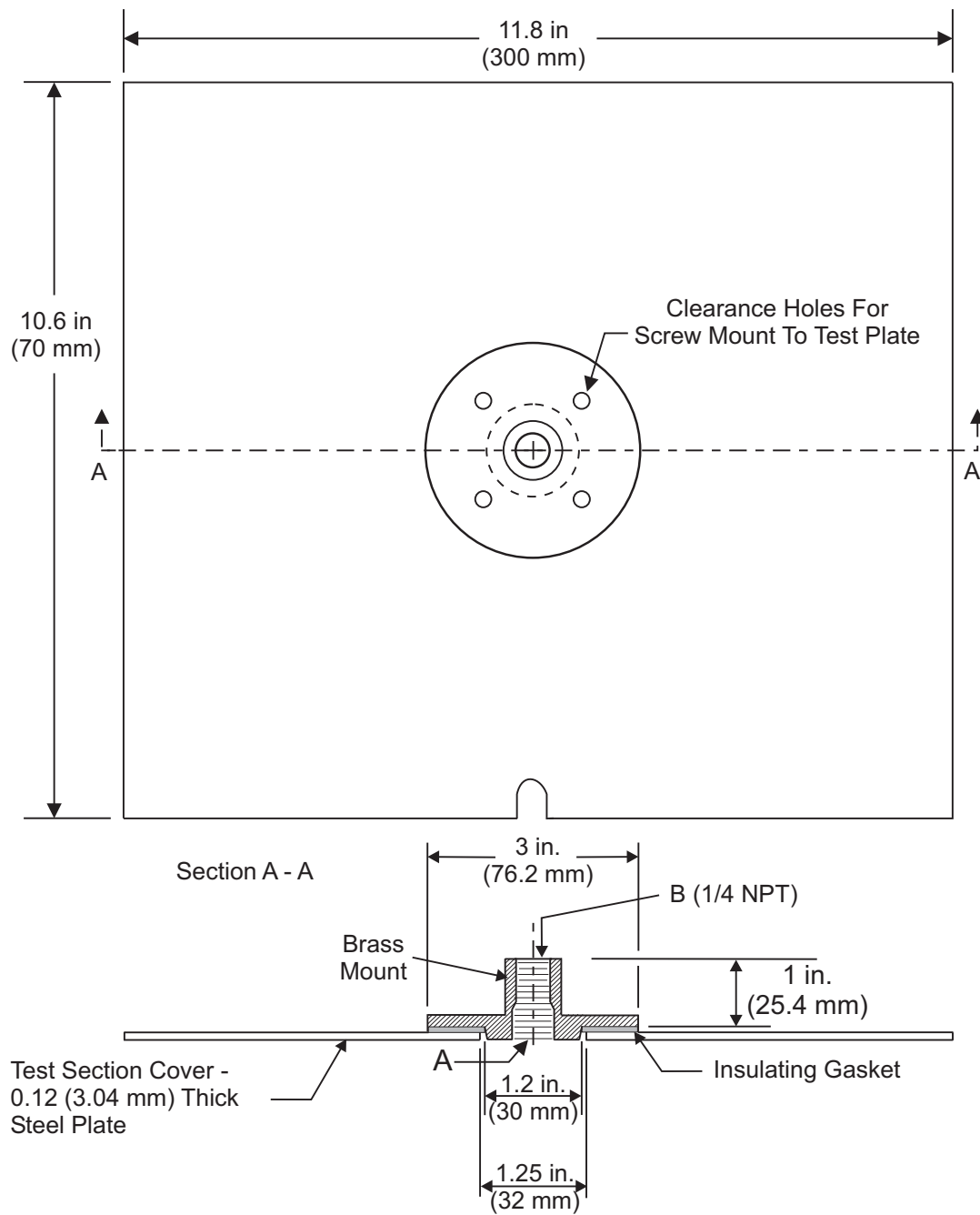


Figure N-3. Impact Test Apparatus

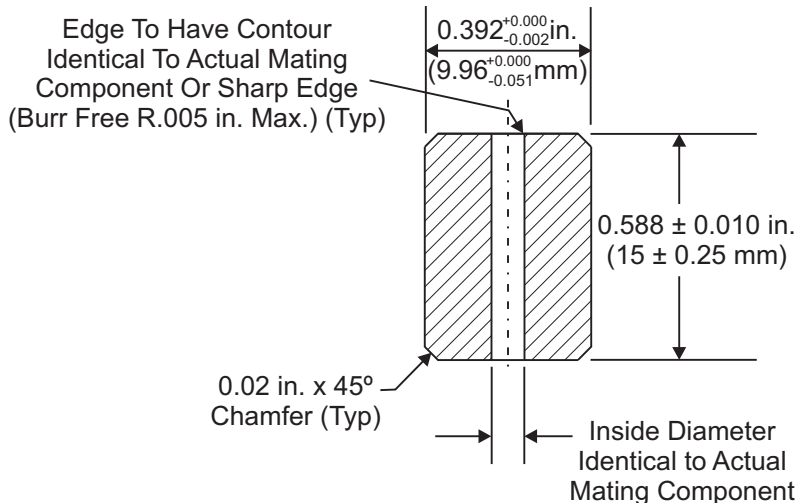




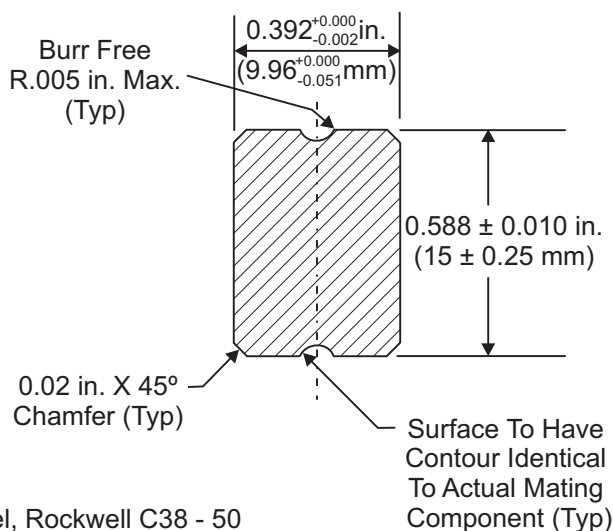
- A. Connection for mounting sprinkler, or nationally recognized thread.
- B. Connection for mounting hose, or nationally recognized thread.

Figure N-4. Plunge Tunnel Test Plate (For Sensitivity - RTI Test)

**For Designs with Line Contact:**



**Or: For Designs with Surface Contact:**



**REQUIRED:**

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

Figure N-5. Bulb Crush Inserts For Strength of Element Test

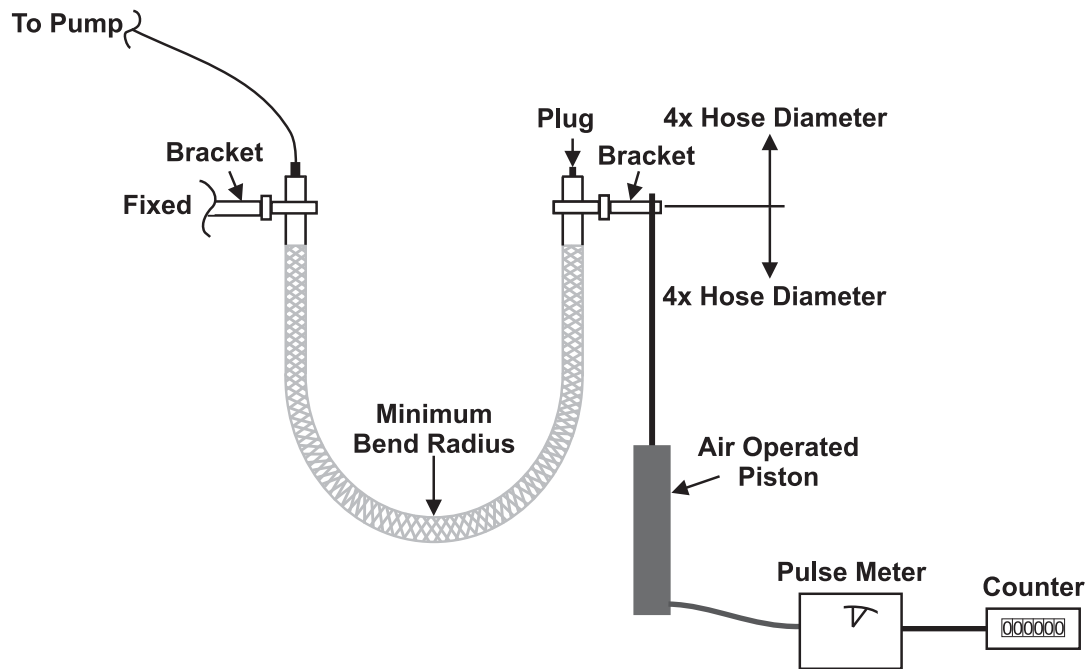


Figure N-6. Test Apparatus for Fatigue Test

## APPENDIX O: Sample Approval Guide Listing

Approval Guide listings for hybrid fire extinguishing systems shall include:

- Manufacturer's designation for system.
- Water and/or inert gas information.
- Pertinent discharge parameters.
- Nozzle operating pressure and/or flow rate.
- Hazard protection volume, area, and/or height limitations.
- Other relevant information related to the hazard to be protected.
- Minimum and maximum installation temperatures.
- Design, installation, operation, and maintenance manual identification by title, part number, issue date, and revision level.
- Design software title, part number, and version level (engineered systems, only).
- Any limitations to the Approval or exceptions to the listed manuals, software, or other documents.
- Installation provisions.



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