Member of the FM Global Group

Examination Standard for Water Mist Systems

Class Number 5560

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Foreword

This standard is intended to verify that the products and services described will meet stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of this standard is to present the criteria for examination of various types of products and services.

Examination in accordance with this standard shall demonstrate compliance and verify that quality control in manufacturing shall ensure a consistent and reliable product.

Table of Contents

1. INTRODUCTION

1.1 Purpose

1.1.1 This standard states testing and certification requirements for water mist systems for use as fire control and/or extinguishing systems.

1.1.2 Testing and certification 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 surveillance program.

1.2 Scope

1.2.1 This standard encompasses the design and performance requirements for water mist systems for use as fire control and/or extinguishing systems designed and installed per the manufacturers design and installation manual, requirements of applicable national or international standards and the requirements of the authority having jurisdiction. Certification is limited to use in the occupancies described Sections 1.2.3.1 through 1.2.3.15. Due to the current state of water mist system technology, a comprehensive absolute standard for the testing of water mist system components is not possible. Since each water mist system is unique in its operation and design, the component testing of the water mist 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, the certification agency will prepare a customized evaluation program for the specific water mist system. While customization of the component testing is necessary, the fire test protocols are generic and required for all water mist 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 water mist is an evolving technology water mist systems shall be certified 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 in enclosures with volumes not exceeding 2825 ft^3 (80 m^3), Appendix A. This application includes enclosures with machinery such as internal combustion engines (excluding engine test cells), 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 with volatilities less than or equal to heptane; enclosures with incidental use or storage of hydrocarbon ignitable liquids (also known as flammable liquids) of not more than two 55 gal (208 L) drums. All hazards included under the scope of this total compartment application shall be protected for a minimum of twice the longest time to extinguish the test fires, time to shut down process equipment, or 10 minutes, whichever is greater.

1.2.3.2 Protection of gas turbines in enclosures with volumes not exceeding 2825 ft^3 (80 m^3), Appendix B. Gas turbines included under the scope of this total compartment application shall be protected for a minimum of twice the longest time to extinguish the test fires, turbine rundown time (including the time that the turbine surfaces are above the auto-ignition temperature of the lubricating fluid), the time to shut down process equipment, or 10 minutes, whichever is greater.

1.2.3.3 Protection of machinery in enclosures with volumes not exceeding 9175 ft^3 (260 m^3), Appendix C. This application includes rooms with machinery such as internal combustion engines (excluding engine test cells), oil pumps, oil tanks, fuel filters, generators, transformer vaults, gear boxes, drive shafts, lubrication skids, diesel engine driven generators, and other similar machinery using fuel and/or lubrication fluids with volatilities less than or equal to heptane. All hazards included under the scope of this total compartment application shall be protected for a minimum of twice the longest time to extinguish the test fires, the time to shut down process equipment, or 10 minutes, whichever is greater.

1.2.3.4 Protection of gas turbines in enclosures with volumes not exceeding 9175 ft^3 (260 m^3), Appendix D. Gas turbines included under the scope of this total compartment application shall be protected for a minimum of twice the longest time to extinguish the test fires, turbine rundown time (including the time that the turbine surfaces are above the auto-ignition temperature of the lubricating fluid), the time to shut down process equipment, or 10 minutes, whichever is greater.

1.2.3.5 Protection of machinery in enclosures with volumes exceeding 9175 ft^3 (260 m^3), Appendix E. This application includes enclosures with machinery such as internal combustion engines (excluding engine test cells), 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 with volatility less than or equal to heptane; enclosures with incidental use or storage of hydrocarbon ignitable liquids (also known as flammable liquids) of not more than two 55 gal (208 L) drums. All hazards included under the scope of this total compartment application shall be protected for a minimum of twice the longest time to extinguish the test fires, the time to shut down process equipment, or 10 minutes, whichever is greater.

1.2.3.6 Protection of gas turbines in enclosures with volumes exceeding 9175 ft^3 (260 m^3), Appendix F. Gas turbines included under the scope of this total compartment application shall be protected for a minimum of twice the longest time to extinguish the test fires, the turbine rundown time (including the time that the turbine surfaces are above the auto-ignition temperature of the lubricating fluid), the time to shut down process equipment, or 10 minutes, whichever is greater. For primary protection consideration, see Section 1.9, Definitions, "Primary Protection".

1.2.3.7 Protection of Non-Storage Occupancies, Hazard Category 1 (HC-1), Appendix G. Protection of Non-Storage Occupancies, Hazard Category 2 (HC-2) and Non-Storage Occupancies, Hazard Category 3 (HC-3) are covered in Section 1.2.3.15. The occupancies are defined as Hazard Category 1 (HC-1). The applications are currently limited to ceiling heights of 8 ft (2.4 m) for restricted areas and 16 ft 5 in. (5 m) for unrestricted areas (refer to Section 1.9, Definitions, "Light Hazard Occupancy," for specific descriptions of restricted and unrestricted areas). The water supply shall be capable of supplying 60 minutes of water to the hydraulically most remote nine automatic nozzles or all automatic nozzles within a 1,500 ft^2 (140 m^2) demand area, whichever is greater, for systems Approved for the protection of unrestricted areas. For installations with less than 1500 ft^2 (140 m^2) in area, the water supply shall be capable of supplying 60 minutes of water to all nozzles in the protected area. For systems Approved for the protection of restricted areas, the water supply shall be capable of supplying 60 minutes of water to all automatic nozzles within the compartment.

1.2.3.8 Protection of wet benches and other similar processing equipment, Appendix H. This application includes tools which consist of ventilated and unventilated compartments, spin rinse dryers, alcohol vapor dryers, chemical and mechanical polishing tools, and step and repeat exposure systems. All hazards included under the scope of this local application shall be protected for a minimum of 2 minutes or twice the longest time to extinguish the worst case fire scenario, whichever is greater. Time delays are limited to 30 seconds, unless tested for a longer time duration.

1.2.3.9 Protection of local application occupancies, Appendix I. Water mist systems which successfully pass the fire scenarios described in Appendix I shall be limited to the protection of the following applications:

A. Ignitable liquid (also known as flammable liquid) pool fires where the liquid release can be confined to a diked area. The entire surface of the diked area shall be protected by the water mist system.
B. Ignitable liquid (also known as flammable liquid) channel fires in channels not exceeding the water mist system manufacturer's maximum specified width and with no limit to channel length.
C. Partially obstructed ignitable liquid (also known as flammable liquid) pool fires where the percentage of obstructed surface is limited to that tested.
D. Spray fires up to 6 MW fueled by ignitable liquid (also known as flammable liquid).
E. Spray and pool fire combinations where the release can be confined to a diked area.
F. Ignitable liquid (also known as flammable liquid) residues (ink and paper dust) on printing presses.

Applicants desiring to protect special hazard equipment with ignitable liquids (also known as flammable liquids) with volatilities less than or equal to that of heptane will need to conduct the fire scenarios described in Appendix I, substituting heptane for diesel as the test fuel where appropriate. All hazards shall be protected for a minimum of twice the longest time to extinguish the test fires, time to shut down process equipment, or 10 minutes, whichever is greater.

1.2.3.10 Protection of industrial oil cookers, Appendix J. Application of the water mist system is limited to the protection of the industrial oil cookers only, and does not include the protection of other equipment such as exhaust ducts, heaters, heat exchangers, and food processing areas, unless tested for these applications. Consideration of the application and use of nozzle protection caps to prevent or reduce the amount of nozzle contamination should be given and the use of such caps should be included in the fire test and nozzle performance test requirement programs. This local application does not include the protection of other equipment such as exhaust air ducts, heaters, heat exchangers, and food processing or food preparation areas.

Industrial oil cookers are typically non-insulated conveyorized fryers, or occasional batch kettles, used in food processing plants for chicken, fish, potato products (e.g., fries/chips), doughnuts and many other food products. These cookers are extremely different in size, configuration, and construction from standard kitchen or restaurant oil cookers or fryers and require a different type of extinguishment system.

Industrial oil cookers normally have large cooking surfaces, from 50 ft^2 (4.6 m^2) to several hundred square feet. They contain from several hundred gallons up to approximately 5000 gallons (18900 L) of cooking oil. Industrial oil cookers (except for some batch kettles) typically have moveable covers, or hoods, that may be hydraulically operated.

The hood is generally in a closed position during a normal operation period. However, the hood may be occasionally opened for routine maintenance. There are also exhaust stacks connected on top of the hood.

The most severe fire incident involving industrial oil cookers is a fire caused by overheating the cooking oil until it reaches its auto-ignition temperature (AIT). Installation of an interlocking system to prevent the oil from reaching its AIT is a normal practice in the industry. However, the AIT fire may still occur due to a system malfunction or simple human error. Thus, all the performance tests proposed in this document require extinguishment of an AIT fire. The AIT fire is particularly challenging because of its rapid spread of flame over the oil surface and its difficulty in extinguishment, as it requires flame extinction over the entire surface with simultaneous rapid cooling to prevent re-ignition.

Exhaust air fans should be interlocked to automatically shutdown upon fire detection or operation of the water mist system. Exhaust duct protection should be specified in the manufacturer's design, installation, operation and maintenance manual. (Note: Water spray protection for the ducts is required if operation of the duct system during water mist system discharge is necessary. Automatic sprinkler protection is recognized as an effective alternative to water spray.)

Commonly used cooking oils, their flash points, and AITs are listed in Table 1.2.3.10 as a reference only. Canola oil is considered a representative vegetable oil and may be used as the testing medium in the Appendix J fire tests. Canola oil has a nominal density equal to 7.8 lb/gal (0.93 kg/L) and nominal specific heat equal to 0.59 BTU/lb·°F (2.5 kJ/kg·°C). Alternative cooking oils may be used based on the manufacturer's intended applications for protection, and certification shall be limited to cooking oils with flash points and AITs less than or equal to the tested oil.

Table 1.2.3.10. Nominal Flash Points and Auto Ignition Temperatures (AIT) of Typical Commonly Used Cooking Oils

Cooking Oil	***Flash Point***		***Auto Ignition Temperature (AIT)***	
	°F	***(°C)***	***°F***	***(°C)***
Canola	641	(338)	686	(363)
Corn	647	(342)	684	(362)
Cotton Seed	633	(334)	690	(366)
Peanut	659	(348)	698	(370)
Soybean (Soya)	631	(333)	710	(377)
Sunflower	644	(340)	678	(359)
Palm	623	(328)	710	(377)

The agent supply shall be capable of supplying agent to all open nozzles at the maximum rated operating pressure for a minimum of twice the total time needed to extinguish the worst case fire scenario and subsequently cool the oil to a temperature below its flash point, as established by testing in accordance with Appendix J, or 10 minutes, whichever is greater.

1.2.3.11 Protection of continuous wood board presses, Appendix K. Application of the water mist system is limited to the protection of the continuous wood board press only, and does not include the protection of other equipment unless tested for other applications. All hazards included under the scope of this application shall be protected for a minimum of twice the longest time to extinguish the test fires or 30 minutes, whichever is greater.

1.2.3.12 Protection of ventilated bench-top chemical fume laboratory hoods or enclosures using ignitable liquids, Appendix L. A fire that initiates within a fume hood or enclosure can quickly spread, particularly where there is appreciable use of solvents and/or combustibles, and result in extensive damage to the laboratory and surrounding area. The installation of an integrated water mist system provides an enhanced fire protection strategy to the automatic sprinkler system that can maximize loss prevention and minimize business interruption.

1.2.3.13 Protection of data center processing equipment rooms/halls which include control rooms, process control rooms, diagnostic equipment, and critical systems and equipment associated with data centers, Appendix M and N. Forced ventilation is included in the evaluation to a maximum nominal upward velocity of 3.3 ft/s (1 m/s) through perforated floor openings and a maximum 4 ft/sec (1.2 m/s) horizontal airflow from server cabinets. Preaction systems are limited to single interlock configurations with a maximum 30 second water delivery time delay.

For above raised floor protection the water supply shall be capable of supplying 60 minutes of water to the hydraulically most remote nozzles. The design area of the water mist system shall be 6 nozzles or 1.5 times the number of operated nozzles during fire performance testing, whichever is greater. For below raised floor protection the water supply shall be capable of supplying 60 minutes of water to the hydraulically most remote nozzles. The design area of the water mist system shall be a minimum of 6 nozzles for an area of coverage design and a minimum of 4 nozzles for a local application design. For an installation including both above and below raised floor protection the design area of the water mist system shall be based on the most hydraulically demanding protection.

The systems are for the protection of data and power cables with a maximum Fire Propagating Index (FPI) of 26 in the metric unit when tested in accordance with FM Approvals Examination Standard Class 3972, Test Standard for Cable Fire Propagation. Alternative cables with a higher FPI may be used based on the manufacturer's intended applications for protection, and certification shall be limited to cables FPIs less than or equal to the tested cable. The systems are not intended to protect data processing equipment with packaging awaiting installation. Packaged equipment is to be located in storage and staging areas separate from data processing equipment rooms (i.e., where fire involving the storage will not expose critical equipment). Where storage and staging areas are not available, limit in-process packaged equipment in data processing equipment rooms to a temporary basis with regular removal of the packaging during the installation.

The systems are tested and listed to provide primary protection of the occupancy. The systems have been proven to extinguish fire involving cables but are not intended to provide equipment protection.

1.2.3.14 Protection of machinery in enclosures with volumes exceeding 9175 ft^3 (260 m^3) and protection of gas turbines in enclosures with volumes exceeding 9175 ft^3 (260 m^3), Appendix O. The ½-scale fire performance testing described in Appendix O can be conducted as an option to the full-scale fire performance testing described in Appendix E and/or Appendix F. Reference Section 1.2.3.5 and 1.2.3.6 for information on the applications under the scope of Appendix E and Appendix F.

1.2.3.15 Protection of Non-Storage Occupancies, Hazard Category 2 (HC-2) and Hazard Category 3 (HC-3), Appendix P. Protection of Non-Storage Occupancies, Hazard Category 1 (HC-1) are covered under Section 1.2.3.7. The occupancies are defined as Hazard Category 2 (HC-2) and Hazard Category 3 (HC-3). The water supply shall be capable of supplying 60 minutes of water to the hydraulically most remote nine automatic nozzles, or 1.5 times the number of operated nozzles during fire performance testing, whichever is greater. Water mist systems with certification for HC-3 are suitable for HC-3, HC-2, and HC-1. Water mist systems with certification for HC-2 are suitable for HC-2 and HC-1. Water mist systems with certification for HC-1 are only suitable for HC-1 (see Section 1.2.3.7).

1.2.3.16 Protection of other occupancies, Appendix Q. Manufacturers interested in pursuing water mist system fire protection of other occupancies or hazards are invited to request, in writing, a detailed description of the desired occupancy and proposed fire protection water mist system. Appropriate system component and fire test performance requirements may then be jointly developed. Suggested occupancies are as listed in Appendix P.

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 water mist systems for the purpose of obtaining certification. Water mist systems having characteristics not anticipated by this standard may be certified if performance equal, or superior, to that required by this standard is demonstrated.

1.4 Basis for Certification

Certification 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 for certification; and, as far as practical,

- The durability and reliability of the product.

1.4.2 An examination of the manufacturing facilities and audit of quality control procedures may be made to evaluate the manufacturer's ability to consistently produce the product, which is examined and tested, and the marking procedures used to identify the product. Subsequent surveillance may be required by the certification agency in accordance with the certification scheme to ensure ongoing compliance.

1.4.3 A review of the proposed water mist system "Design, Installation, Operation and Maintenance" manual.

1.5 Basis for Continued Certification

The basis for continual certification may include, but is not limited to, the following based upon the certification scheme and requirements of the certification agency:

- production or availability of the product as currently certified;
- the continued use of acceptable quality assurance procedures;
- satisfactory field experience;
- compliance with the terms stipulated by the certification;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory surveillance audits conducted as part of the certification agencies product surveillance program.

1.6 Effective Date

The effective date of this certification standard mandates that all products tested for certification after the effective date shall satisfy the requirements of this standard.

The effective date of this Standard is eighteen (18) months after the publication date of the standard for compliance with all requirements.

1.7 System of Units

Units of measurement used in this Standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Conversion of U.S. customary units is in accordance with ANSI/IEEE/ASTM SI 10. Two units (liter and bar), outside of but recognized by SI, are commonly used in international fire protection and are used in this Standard.

1.8 Normative References

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

ASME Publications

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

ASME *Boiler and Pressure Vessel Code*

ASTM Publications

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

ASTM A36, *Standard Specification for Carbon Structural Steel*

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

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

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

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

ASTM D1331, *Standard for Test Methods for Surface and Interfacial Tension of Solutions of Surface-Active Agents*, 2014

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

ASTM E8, *Standard Test Methods for Tension Testing of Metallic Materials*

ASTM E28-14, *Standard Test Methods for Softening Point of Resins Derived from Naval Stores by Ring-and-Ball Apparatus*

ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*

ASTM E290, *Standard Test Methods for Bend Testing of Material for Ductility*

ASTM E2058, *Standard Test Methods for Measurement of Synthetic Polymer Material Flammability Using a Fire Propagation Apparatus (FPA)*

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

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

ASTM SI 10, *American National Standard for Metric Practice*

Compressed Gas Association

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

CGA Pamphlet S-1.1, *Pressure Relief Standards Part 1 – Cylinders for Compressed Gases, Edition 12*

FM Approvals

1151 Boston-Providence Turnpike, P.O. Box 9102, Norwood, MA 02062 USA
http://www.fmapprovals.com

FM 1011/1012/1013, *Examination Standard for Deluge and Preaction Systems*

FM 1020, *Examination Standard for Water Control Valves*

FM 1311, *Examination Standard for Centrifugal Fire Pumps Split-Case Type (Axial or Radial)*

FM 1312, *Examination Standard for Fire Pumps (Vertical Shaft, Turbine Type)*

FM 1313, *Examination Standard for Positive Displacement Pumps (Rotary Gear Type)*

FM 1319, *Examination Standard for Centrifugal Fire Pumps (Horizontal, End Suction Type)*

FM 1321/1323, *Examination Standard for Controllers for Electric Motor and Diesel Engine Driven Fire Pumps*

FM 1951/1952/1953, *Examination Standard for Pipe Hanger Components for Automatic Sprinkler Systems*

FM 3010, *Examination Standard for Fire Alarm Signaling Systems*

FM 3111, *Examination Standard for Manual Pull Stations for Alarm Signaling*

FM 3210, *Examination Standard for Heat Detectors for Automatic Fire Alarm Signaling*

FM 3230, *Examination Standard for Smoke Actuated Detectors for Automatic Fire Alarm Signaling*

FM 3972, *Test Standard for Cable Fire Propagation*

FM 5130, *Examination Standard for Foam Extinguishing Systems*

FM 5560, *Examination Standard for Water Mist Systems*

FM 5580, *Examination Standard for Hybrid (Water and Inert Gas) Systems*

NFPA Publications

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

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam Systems*, 2016
NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, 2019
NFPA 72, *National Fire Alarm Code*, 2019
NFPA 750, *Standard on Water Mist Protection Systems*, 2019

U.S. Dept. of Transportation

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

Title 49, Code of Federal Regulations (CFR), *Hazardous Material Regulations of the Department of Transportation*

1.9 Terms and 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. Acceptance is based upon an overall evaluation of the installation. Factors other than the use of certified 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.

Additive

A liquid such as foam concentrates, emulsifiers, and hazardous vapor suppression liquids and foaming agents intended to be injected into the water stream.

Additive Proportioning

Additive proportioning is the method (such as premix, metered, or balanced pressure) used for the introduction of an additive or additive mixture at the recommended percent ratio into the water system.

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 Media, Water Mist

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 Water Mist Nozzle

A thermo-sensitive device designed to react at a predetermined temperature by automatically releasing water mist 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. A fusible element nozzle is a nozzle that opens under the influence of heat by the melting of a thermo-sensitive component. A glass bulb nozzle is a nozzle that opens under the influence of heat by bursting of a glass bulb through pressure resulting from expansion of the enclosed fluid.

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 $(ft/s)^{1/2}$ or $(m/s)^{1/2}$.

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 water mist system using open nozzles attached to a piping system that is connected to a water supply through a valve that is opened by means of a detection system installed in the same area as the mist nozzles. When the valve opens, 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 Water Mist System

A water mist 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 Water Mist 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 water mist, the number and types of nozzles, and the nozzle placement in a specific installation (Contrast with Pre-Engineered Water Mist Systems).

Fire Control

Limiting the size of a fire by distribution of water 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.

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.

Foam Concentrate Pump

A pump that is used to inject additives into the water stream.

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.

High Pressure System

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

Hybrid Fire Extinguishing System

A distribution system connected to a supply of media that is equipped with one or more nozzles capable of delivering the media. The extinguishing media in a hybrid fire extinguishing system is comprised of water and an inert gas, where both components are critical factors in fire control, suppression, or extinguishment. The gas is important to fire extinguishment, by oxygen dilution or displacement and increasing the heat capacity of the atmosphere supporting the flame, rather than only serving as an atomizing medium, as in a water mist system. The gases used in hybrid fire extinguishing systems may include helium, neon, argon, nitrogen, carbon dioxide, or blends of these gases. For the water component of the media, 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 fire extinguishing systems shall be evaluated in accordance with the *Certification Standard for Hybrid (Water and Inert Gas) Fire Extinguishing Systems* (Class 5580). An extinguishing system using compressed air as an atomizing medium shall be considered a twin fluid water mist system and be evaluated according to the *Certification Standard for Water Mist Systems* (Class 5560). Similarly, an extinguishing system using water and inert gas, where the inert gas has been determined to serve as an atomizing medium only and not directly affect fire extinguishment, as described above and verified in the *Certification Standard for Hybrid (Water and Inert Gas) Fire Extinguishing Systems* (Class 5580), shall be considered a twin fluid water mist system and be evaluated according to the *Certification Standard for Water Mist Systems* (Class 5560).

Ignitable liquid (also known as flammable liquid)

Any liquid or liquid mixture that will burn. A liquid will burn if it has a measurable fire point. Ignitable liquids include flammable liquids, combustible liquids, inflammable liquids, or any other term for a liquid that will burn.

Intermediate Pressure System

A water mist 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 water mist nozzles.

Local-Application Water Mist System

A water mist system arranged to discharge directly on, or around, an object or hazard, typically an ignitable liquid (also known as flammable or combustible liquid) hazard. Where a pool fire could occur, curbing or diking should be provided to prevent spread of fire beyond the hazard protected. Water mist protection of local applications is considered a special protection system.

Low Pressure System

A water mist 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 (excluding engine test cells), 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 ignitable liquids (also known as 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 water mist 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 water mist system pumps, the pressure required above liquid vapor pressure to fill each pumping chamber or cavity while open to the inlet chamber.

Nonstorage Occupancy Hazard Category 1 (HC-1) [formerly Light Hazard Occupancy]

An occupancy where the quantity and/or combustibility of contents is low and fires with relatively low rates of heat release are expected. Light Hazard Occupancies may include occupancies having conditions similar to: apartments, churches, clubs, eaves and overhangs (if combustible construction with no combustibles beneath), educational facilities, hospitals, institutional facilities, libraries (except large stack rooms), museums, nursing or convalescent homes, offices, data processing areas without open storage of information media, residential facilities, restaurant seating areas, theaters and auditoriums (excluding stages and prosceniums), and unused attics.

Nonstorage Occupancy Hazard Category 1 (HC-1), Restricted Certification [formerly Light Hazard Occupancy]

Water mist systems that are certified for use in restricted areas must be installed in enclosed spaces with areas not exceeding that tested in Appendix G, Section I.4.2 and ceiling heights not exceeding 8 ft. (2.4 m). The occupancy consists of combustible or noncombustible materials that are not maintained in a storage arrangement.

Nonstorage Occupancy Hazard Category 1 (HC-1), Unrestricted Certification [formerly Light Hazard Occupancy]

Water mist systems that are certified for use in unrestricted areas may be installed in open spaces of unlimited area and ceiling heights not exceeding 16 ft. 5 in. (5 m). These systems may also be installed in enclosed spaces, as described in Section 1.9, Definitions, "Nonstorage Occupancy Hazard Category 1 (HC-1), Restricted Certification [formerly Light Hazard Occupancy]." The occupancy consists of combustible or noncombustible materials that are not maintained in a storage arrangement.

Nonstorage Occupancy Hazard Category 2 (HC-2)

An occupancy with areas of moderate continuous combustible loading with combustibles in process, or operations of moderate hazard due to limited quantities of plastics or ignitable liquids. Examples include manufacturing, such as machine shops, woodworking, and electronic assembly, as well as retail, theatres, and food production.

Nonstorage Occupancy Hazard Category 3 (HC-3)

An occupancy with areas generally continuous heavier combustible loading with limited quantities of ignitable liquids and/or heavier amounts of plastics. Examples include plastic manufacturing, vehicle manufacturing and assembly, and printing plants.

Nozzle

See Water Mist Nozzle.

Open Water Mist Nozzles

Nozzles that operate as an entire system or grouping of nozzles, containing open orifices. The water 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 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 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 water is discharged.

Pendent Nozzle

A nozzle so designed that the water leaving the orifice 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 Water Mist System

A water mist 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 water to flow into the piping system and discharge through any activated nozzles.

Pre-engineered Water Mist 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 water 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 pressure. Examples include pressure-reducing valves, pressure control valves, and pressure-restricting devices.

Primary Protection

A water mist system is considered as a primary protection system when the water mist system is installed for protection of the occupancy and building, such as a sprinkler system. An example of a water mist system serving as a means of primary protection is an installation for the protection of non-storage occupancies, where the water mist system is designed for the protection of the occupancy and building. The agent supply should be equivalent to an automatic sprinkler system for the same hazard.

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 $(ft\cdot s)^{1/2}$ [50 $(m\cdot s)^{1/2}$] and a C-factor equal to or less than 1.81 $(ft/s)^{1/2}$ [1.0 $(m/s)^{1/2}$], when the nozzle is tested in the best-case orientation. For recessed, flush and concealed nozzles, the criteria outlined in Sections 4.2.27 (Sensitivity - RTI) or 4.2.28 (Sensitivity - R, F & C Types) 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 = ⍰$(u)^{1/2}$ where ⍰ 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 ⍰ 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 $(ft \cdot s)^{1/2}$ or $(m \cdot s)^{1/2}$.

Sidewall Nozzle

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

Single Fluid System

A water mist system using only water to supply each nozzle.

Special Protection System

A fire extinguishing system that is installed for the protection of areas where water mist and other limited agent supply systems, such as carbon dioxide, dry chemical, or clean agent systems would be acceptable methods of protection. The agent supply should be adequate for a minimum of:

a. twice the time to extinguish a worst case test fire in an accepted fire test scenario; or,
b. the total time to shutdown process equipment including the time it takes for surface temperatures to drop below the auto-ignition temperature of the fluid, or;
c. 10 minutes, whichever is greater.

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 and 635 $(ft \cdot s)^{1/2}$ [80 and 350 $(m \cdot s)^{1/2}$] and a C-factor equal to or less than 3.62 $(ft/s)^{1/2}$ [2.0 $(m/s)^{1/2}$], 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 (Sensitivity - RTI) or 4.2.28 (Sensitivity - R, F & C Types), as appropriate.

Strutting

Partial fracture of a glass bulb or partial rupture of a fusible element which does no result in operation of the automatic nozzle.

Total Compartment System

A system designed to protect all hazards in an enclosure. An example of a total compartment system is the use of water mist systems for the total compartment protection of gas 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 System

A water mist system in which water and atomizing media are supplied to the 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 and/or meeting the specific requirements of a 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 Water Mist System

A water mist 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 static (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.

2. GENERAL INFORMATION

2.1 Product Information

2.1.1 A water mist system is a fire protection system using fine water sprays (i.e. water mist). The very small water droplets allow the water mist to control or extinguish fires by cooling of the flame, fire plume, and fuel, oxygen displacement by water vapor, and radiant heat attenuation.

2.1.2 In order to meet the intent of this standard, water mist 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 water mist systems, selected in conformance to this criterion, shall satisfy all of the requirements of this standard.

2.2 Certification Application Requirements

The manufacturer shall provide the following preliminary information with any request for certification 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 water mist 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, and warning markings

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

2.3.1 Following generation and authorization of a certification examination, the manufacturer shall prepare components for examination and testing based on the following:

- Sample requirements are to be determined by the certification agency following review of the preliminary information.

2.3.2 Sample requirements may vary depending on design features, results of prior testing, and results of the foregoing tests.

2.3.3 The manufacturer shall submit samples representative of production. Any decision to use data generated utilizing prototype components or systems is at the discretion of the certification agency.

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 certification investigation.

3.2 Physical or Structural Construction Features

3.2.1 To ensure the successful performance of the water mist system, and to minimize the chance of re-ignition of a fire, enclosures and/or hazards provided with certified water mist 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 water mist system shall be fire tested at the maximum ventilation rate specified in the system manufacturer's manual),
- Containment for ignitable liquid (also known as flammable liquid) releases, and
- Water mist 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 water mist 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 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 Water (or extinguishing fluid) tanks shall meet the requirements of the ASME *Boiler and Pressure Vessel Code*, as applicable. (Water mist 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 certification.) Water mist systems shall only use potable water sources. For wet bench applications, circulating de-ionized water shall be used.

3.2.6 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).

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

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 the certification agency, 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 (such as wet benches) along with certification of material and environment compatibility shall be submitted for review.

3.2.11 The use of certified fire detection devices is required for deluge water mist systems. Fire detection devices and manual pull stations used in the system shall be certified components.

3.2.12 Non-certified electrical components, including automatic release devices, control panels, sequence boxes, and other applicable devices, will be included within the scope of the certification project examination.

3.2.13 Documented use of certified 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 the certification agency.

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 not permitted for use in water mist systems certified according to this standard.

3.2.16 Applications/hazards where clogging from grease vapors, moisture, or other foreign matter can enter the piping and/or plug the nozzle orifice, protective nozzle caps are to be provided. In lieu of protective nozzle caps, an alternative method is allowed which identifies the specifications/procedure to prevent clogging in the Design, Installation, Operation, and Maintenance Manual.

3.2.17 Atmospheric water storage tanks are to be constructed from corrosion resistant materials, similar or equivalent to:

- Stainless steel – 304L or 316 grades
- High-density cross-linked polyethylene

3.3 Components

A component of a water mist 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 water mist 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 or cycled operation of the water mist system shall be designed or selected for maximum long term reliability. Water mist systems may be of the constant or cycled water delivery type. Cycled operation systems shall have a minimum water discharge period equal to 50 percent of one complete cycle, such that the time period during which the system is off is less than or equal to the water discharge period. This time period that the system is not discharging shall not exceed one minute. Water mist systems with an extended pause in the extinguishing supply, beyond that described above, are not permitted. Water mist 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 Water Mist 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;
- Certification Marks and,
- Manufacturing location source code where necessary.

3.4.1.2 Each deluge 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 certification agency's mark of conformity.

3.4.1.5 The certification agency's mark of conformity shall be displayed visibly and permanently on the product and/or packaging as appropriate and in accordance with the requirements of the certification agency. The manufacturer shall exercise control of this mark as specified by the certification agency and the certification scheme.

3.4.2 In instances where a system nameplate is not applicable, such as single fluid, low pressure systems not requiring a special delivery system such as gas and water storage cylinder(s), 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.

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

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).

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)$^{1/2}$);
- The word "PENDENT" (or the letter "P"), or other designation to indicate type or orientation, as appropriate;
- The 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)$^{1/2}$);
- 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 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 ft (0.9 m).

Table 3.4.5 Temperature Ratings, Classifications, and Color Codes

Nominal Temperature[1] Rating Range °F	(°C)	***Maximum Ambient Temperature At Nozzle Level*** °F	(°C)	***Temperature Classification***	***Nozzle Frame Color Code***
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 Glass 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

Nominal Temperature Rating °F	(°C)	***Bulb Color Code***
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 glass 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 ft (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 water mist system. These instructions shall be submitted to the certification agency 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 4.35 for manual details.

3.6 Calibration

3.6.1 Each piece of equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage. A copy of the calibration certificate for each piece of test equipment is required. The certificate shall indicate that the calibration was performed against working standards whose calibration is certified and traceable to an acceptable reference standard and certified by an ISO/IEC 17025 accredited calibration laboratory. The test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date. A copy of the service provider's accreditation certificate as an ISO/IEC 17025 accredited calibration laboratory should be available.

3.6.2 When the inspection equipment and/or environment is not suitable for labels or stickers, other methods such as etching of control numbers on the measuring device are allowed, provided documentation is maintained on the calibration status of thus equipment.

3.7 Test Facilities

If review of all required information indicates suitability for certification, testing of sample water mist systems for specific occupancy protection will be scheduled. The range of component and fire tests to be conducted shall be specified by the certification agency. The manufacturer shall provide facilities and all properly calibrated instrumentation required to perform the tests deemed necessary by the certification agency. If other standards are contemplated, they should be forwarded to the certification agency for review and acceptance prior to the generation of the test program. The manufacturer shall also provide personnel to install and operate the water mist system. A representative of the certification agency 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 measurements shall be as described in Appendix S, unless otherwise specified.

4. PERFORMANCE REQUIREMENTS

This standard is composed of two parts: component testing and fire testing. Due to the current state of water mist system technology, a comprehensive absolute standard for the testing of water mist components is not possible. Since each water mist system is unique in its operation and design, the component testing of the water mist 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 the certification agency. Use of certified equipment is strongly encouraged. Documented use of certified 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 the certification agency. Electrical components that require a hazardous location rating will be evaluated under the scope of the certification examination. Upon request for a program, and appropriate system documentation, The certification agency will prepare a customized evaluation program for the specific water mist system. While customization of the component testing is necessary, the fire test protocols are generic for all water mist 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 water mist system shall conform to the manufacturer's drawings and specifications and to certification requirements.

4.1.1.2 Test/Verification

A water mist system, and all individual system components, representative of the manufacturer's final production equipment to be certified 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 then 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 water mist 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, *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 Table 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

Total Displacement/Stroke		***Frequency***	***Time***
inch	***(mm)***	***Hz***	***Hours***
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.

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 the certification agency 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 D412, *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 elostomer shall be conducted, as follows:

A. Tensile strength, ultimate elongation, and tensile set shall be determined in accordance with ASTM D412, *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 D395, *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 D573, *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 water mist 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 Water Mist Nozzles

The nozzles used in the water mist fire protection 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 the certification agency. 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 it's 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 T.

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°F ± 5°F (21°C ± 2.6°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 4.2.2.2.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 U-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 T, 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°F ± 10°F (-29°C ± 6°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°F (-29°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 ± 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 ± 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 E1, *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°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 Section 4.2.9.2 may be tested at the sole discretion of the certification agency.

4.2.9.2 Tests/Verification

Samples shall be individually installed in their intended installation position, on a pipe manifold as described in Figure U-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. Ten samples shall be tested at 5 percent of the minimum pressure at nozzle operation to 120 percent of the system operating pressure, at increments shown in Table 4.2.9.2.

Table 4.2.9.2. Test Pressures

Number of Samples	***Percentage of System Pressure***
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 the certification agency, 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 U-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 U-1 in their intended orientation. Water 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 water flow 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 water mist 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 (Sensitivity - RTI), 4.2.28 (Sensitivity - R, F & C Types) and 4.2.29 (Sensitivity - Air Oven), 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

Nozzle Nominal Temperature Rating °F	(°C)	*Nominal[1] Test Temperatures* °F	(°C)
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	

1. 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

Nozzle Nominal Temperature Rating		***Minimum Softening Point Temperature***		***Maximum Softening Point Temperature***	
°F	***(°C)***	***°F***	***(°C)***	***°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 E28, *Test Method for Softening Point by Ring and Ball Apparatus*, or its equivalent, as determined by the certification agency.

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.

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

A. Four production samples and a representative quantity of fire test samples (representative quantity to be selected at the discretion of the certification agency) shall be tested using the test apparatus for determining K-factor shown in Figure U-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)].

B. For twin fluid systems, a precise discharge coefficient cannot be determined. In this case, 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 in 4.2.14.2A
   - Minimum gas pressure, water pressure varied as in 4.2.14.2A
   - Gas pressure varied as in 4.2.14.2A, maximum water pressure
   - Gas pressure varied as in 4.2.14.2A, minimum water pressure
   - Gas measurements and water measurements performed independently (gas pressure varied as in 4.2.14.2A; water pressure varied as in 4.2.14.2A)

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 ± 2 percent and a temperature of 203°F ± 2°F (95°C ± 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 the certification agency, 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 ± 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 into the waterway 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 (Minimum Operating Pressure). 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 ± 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 into the waterway 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 the certification agency 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 ± 0.34 ft^3 (0.02 ± 0.01 m^3).

Aqueous ammonia having a density of 58.7 ± 0.6 lb/ft^3 (0.94 ± 0.01 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 gal/ft^3 (10 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°F ± 4°F (34°C ± 2°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°F ± 4°F (150°C ± 2°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 the certification agency.

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 ± 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 into the waterway 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 0.53 gallons (2.0 liters) of deionized water shall be maintained in the bottom of the chamber.

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

4.2.19 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 ± 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 into the waterway 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 0.53 gallons (2.0 liters) of deionized water shall be maintained in the bottom of the chamber.

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

4.2.20 Vibration

4.2.20.1 Requirements

Nozzles or nozzles with protective caps (reference 4.2.32) 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 or open nozzles with protective caps: One sample shall be tested in accordance with Section 4.2.14 (Discharge Coefficient). The discharge coefficient shall be within ± 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)]. Protective caps shall remain in place following the vibration exposure.

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). Open nozzles that employ protective caps shall be tested with caps attached. The samples shall then be subjected to the vibration conditions stated in Table 4.2.20.2.

Table 4.2.20.2 Vibration Conditions

Total Displacement ***in.***	***(mm)***	***Frequency Hz***	***Time Hours***
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 ± 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 discretion of the certification agency.

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 discretion of the certification agency.

B. For open nozzles: One sample shall be tested in accordance with Section 4.2.14 (Discharge Coefficient). The discharge coefficient shall be within ± 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 waterway (see Figure U-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. The certification agency may conduct Discharge Coefficient (K-Factor) (Section 4.2.14) and/or Water Mist 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°F ± 20°F (800°C ± 11°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°F ± 10°F (15°C ± 6°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°F ± 10°F (-30°C ± 5°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 water shall clear the exit of the waterway within 5 seconds. Open nozzles that employ protective caps shall be tested to ensure they operate as intended to allow full discharge from nozzles.

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

4.2.24.2 Test/Verification

Ten previously untested nozzles shall be subjected to an inlet water 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 the certification agency. For open nozzles, one sample shall be tested in accordance with Section 4.2.14 (Discharge Coefficient). The discharge coefficient shall be within ± 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 $(ft/s)^{1/2}$ [1.0 $(m/s)^{1/2}$] for quick response type nozzles. Standard response nozzles shall have a C-factor not exceeding 3.62 $(ft/s)^{1/2}$ [2.0 $(m/s)^{1/2}$]. 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 + 0.5/-0.0 psi (0.3 + 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 ± 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°F ± 2°F (20°C ± 1°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 ± 0.2 ft/s (± 0.07 m/s) of the selected velocity. Velocities are to be chosen such that actuation is bracketed between two successive test velocities. That is, two velocities shall be established such that, at the lower velocity (u_L), actuation does not occur in the 15 minute test interval. At the next higher velocity (u_H), actuation shall occur within the 15 minute time limit. To establish u_L and u_H, the velocity shall be raised by 10 percent increments within the range detailed in Table 4.2.26.2. 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[1] ***°F***	***(°C)***	***Tunnel Gas Temperature °F (°C)***	***Tunnel Gas Velocity ft/s (m/s)***	***Maximum Variation of Gas Temperature During Test From Selected Temperatures °F***	***(°C)***
135 - 170	(57 - 77)	190 - 765 (88 - 407)	0.7 - 10 (0.2 - 3.05)	± 11	(± 6)
170 - 225	(79 - 107)			± 16	(± 9)
250 - 300	(121 - 149)			± 45	(± 25)
325 - 375	(163 - 191)			± 45	(± 25)

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

Test velocity selection shall insure that:

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

The C-factor of the 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:

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

Where:
- C_H - is the C-factor at velocity u_H
- C_L - is the C-factor at velocity u_L
- C - is the average C-factor of the nozzle
- ΔT_g - is the actual gas (air) temperature minus the mount temperature
- ΔT_b - is the mean liquid bath operating temperature minus the mount temperature
- u_H - is the actual gas velocity in the test section at which the nozzles operated
- u_L - is the 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 $(ft{\cdot}s)^{1/2}$ [600 $(m{\cdot}s)^{1/2}$], 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 $(ft{\cdot}s)^{1/2}$ [50 $(m{\cdot}s)^{1/2}$] 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 plunge tunnel, as described below. 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 the certification agency, 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 U-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 U-4). An air supply is then attached at connection "B" (See Figure U-4) and shall be pressurized to 5 (+0.5/-0) psi [0.3 (+0.04/-0) bar].

C. A tunnel with gas velocity and temperature conditions at the test section established in accordance with Table 4.2.27.2 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 ± 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

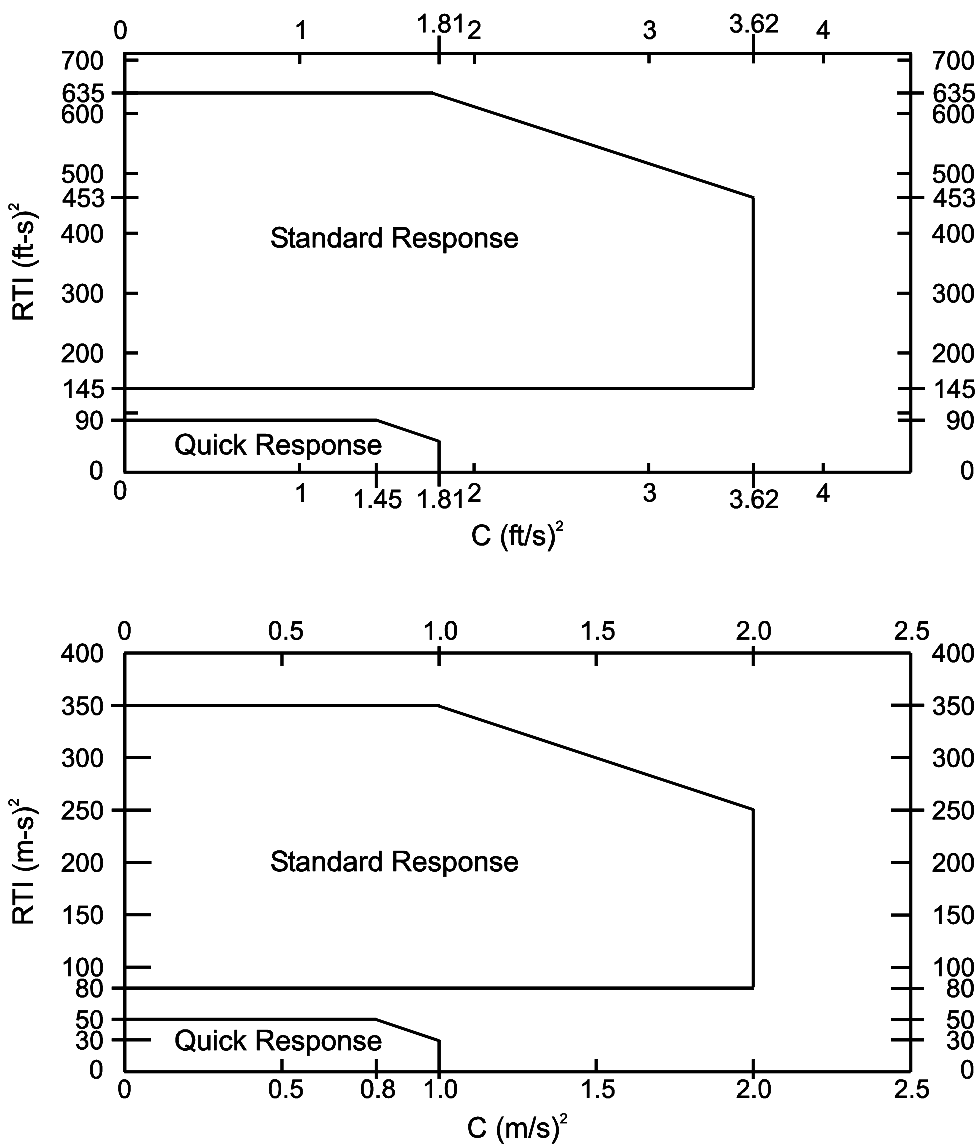


Table 4.2.27.2 Plunge Test Conditions

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:

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

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)

ΔT_b - mean operating temperature of the nozzle, as determined in Section 4.7 [Operating Temperature (Liquid Bath)] minus the ambient temperature, in °F (°C)

ΔT_g - actual gas (air) temperature minus the ambient temperature, in °F (°C)

C - C-factor as determined in Section 4.2.26 [Conductivity (C-Factor)], in $(ft/s)^{1/2}$ $[(m/s)^{1/2}]$

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.

Recessed, flush, and concealed extended coverage light hazard nozzles shall meet the requirements of quick response nozzles of the same type.

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 $(ft/s)^{1/2}$ [2.6 $(m/s)^{1/2}$].

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*** $(ft\cdot s)^{1/2}$	***RTI*** $[(m\cdot s)^{1/2}]$	***C-Factor*** $(ft/s)^{1/2}$	***C-Factor*** $[(m/s)^{1/2}]$
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*** ***°F***	***(°C)***	***Plunge Tunnel Velocity*** ***ft/sec***	***(m/s)***	***Applied Vacuum mm Hg***
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:

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

Where:

- t_{max} - maximum allowed response time of nozzle, in seconds
- RTI - Response Time Index from Table 4.2.28.2.1, in $(ft\cdot s)^{1/2}$ $[(m\cdot s)^{1/2}]$
- ΔT_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 $(ft/s)^{1/2}$ $[(m/s)^{1/2}]$
- u - actual gas (air) velocity in the test section of the tunnel from Table 4.2.28.2.2, in ft/s (m/s)
- ΔT_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 plunge tunnel, using the modified plunge tunnel test plate described in Figure U-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 U-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		***Maximum Operating Temperature***		***Maximum Operating Time***
°F	***(°C)***	***°F***	***(°C)***	***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		***Maximum Operating Temperature***		***Maximum Operating Time***
°F	***(°C)***	***°F***	***(°C)***	***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 by 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 Water Mist Discharge Characteristics (To Be Conducted at the Discretion of the certification agency)

4.2.30.1 Requirements

One nozzle, less the operating mechanism, if any, of each model/type and K-factor shall be tested for water mist 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:

$$R_k = \frac{\sum \left(R_{j,i} \times A_i \times V_i'' \right)}{\sum \left(A_i \times V_i'' \right)}$$

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 water from the adjacent nozzle or target.

4.2.31.2 Test/Verification

Water 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 water 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.

At a minimum the following tests shall be performed with protective caps:

- 4.2.16 - Corrosion - Salt Spray
- 4.2.20 - Vibration
- 4.2.21 - Rough Use and Abuse
- 4.2.24 – Minimum Operating Pressure

4.2.32.2 Test/Verification

Verification of Section 4.2.32.1 shall be determined and conducted at the sole discretion of the certification agency 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 water mist system. Manufacturers are strongly encouraged to use certified 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 bars), 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 500 psi (34.5 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 water mist system, including the actuating solenoid, fire detection automatic releases, etc. The certification examination shall be in accordance with the *Examination Standard for Controllers for Electric Motor Driven and Diesel Engine Driven Fire Pumps* (Class 1321/1323) and/or the *Examination Standard for 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 certified 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 the certification agency 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 the certification agency.
- 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 the certification agency.

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. Certification 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 the certification agency 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 the certification agency. Certifications of tests witnessed by the recognized third party shall be submitted for review by the certification agency 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)

4.10.1.1 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 (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), 4.28.1.1 (Equipment Assembly Ratings), and 4.28.2.1 (Dielectric Strength).

4.10.1.2 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 (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), 4.28.1.2 (Equipment Assembly Ratings), and 4.28.2.2 (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 water mist system, including the actuating solenoid, fire detection automatic releases, etc. The examination shall be in accordance with the *Examination Standard for Heat Detectors for Automatic Fire Alarm Signaling* (Class 3210) and *Examination Standard for Smoke Actuated Detectors for Automatic Fire Alarm Signaling* (Class 3230). Manufacturers are strongly encouraged to use certified 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)

Information regarding the fittings and couplings, and piping and tubing used in the water mist system shall be submitted to the certification agency. 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 water mist systems. Manufacturers are strongly encouraged to use certified 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, tools, and equipment 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 - 500 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 - 500 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 ± 5 percent of full-scale value for adjustable types; ± 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 ± 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).

4.15 Foam Equipment (Foam, Injector, Proportioner, Pumps, Valves, etc.)

4.15.1 General

4.15.1.1 At a minimum, a water mist system using a foam concentrate must include a foam concentrate, a proportioning and mixing device, and a discharge device. Mixing and proportioning devices can include proportioners, eductors, and pre-mix tanks, or any other device which can be demonstrated to meter the proper ratio of concentrate to water over the full range of flows to be included in the system's certification. Examination Standard, Class 5130, *Foam Extinguishing Systems* details requirements that may be referenced for testing of foam equipment to be used in a water mist system.

4.15.1.2 Discharge water mist nozzles of each type and size shall demonstrate that they can produce foam of the same quality as that used in the fire extinguishing tests over their full range of flows.

4.15.1.3 Certification of a foam concentrate as a water mist system component is granted only for use in certified water mist foam extinguishing systems which have been performance tested specifically with that concentrate. Certification of systems using certified concentrates are granted separately, subsequent to certification of the concentrate as a component for use in water mist foam extinguishing systems. Component certified concentrates need only be listed separately from the systems with which they are certified if the concentrate and system manufacturer are different corporate entities, or at the concentrate manufacturer's request.

4.15.1.4 Foam concentrates shall only be certified at the mixture strength(s) at which they are fire tested.

4.15.1.5 Similarly, mechanical components for foam systems may only be component certified for use in certified systems with which they have been performance tested.

4.15.1.6 Systems shall only be listed for use with concentrates and at mixture strength(s) with which they were fire tested.

4.15.1.7 General Foam Performance and Quality Tests

A. The water mist foam system, operating without manual intervention, shall successfully complete all Appendix specific performance fire tests with the designated foam concentrate and percentage during a fixed time period or to extinguishment.

B. NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam Systems*.

C. The manufacturer of a system to be certified must have effective control over the configuration and manufacture of the components and the formulation of the concentrate to be included to ensure that all systems produced under the certification will offer the same performance as that originally tested.

4.15.1.8 The system submitted for certification shall demonstrate the ability to produce foam of essentially the same quality as that used in the fire suppression tests and at the limits of its range of flows, concentrate storage temperatures, and other operating parameters, as verified in Section 4.15.2 through 4.15.4. Performance, Foam Quality and Fire Testing shall be conducted at each mixture strength to be certified.

4.15.2 Film Forming Test

4.15.2.1 Requirement

A film forming foam liquid concentrate shall have a spreading coefficient greater than zero when tested as described in Section 4.15.2.2.

4.15.2.2 Test/Verification

4.15.2.2.1 The surface tension of the foam solution and the interfacial tension of the foam solution and cyclohexane shall be determined using a tensiometer as described in ASTM D1331, *Standard for Test Methods for Surface and Interfacial Tension of Solutions of Surface-Active Agents*.

4.15.2.2.2 The surface tension of the foam solution shall be determined on samples of the foam liquid concentrate mixed with both distilled water and synthetic sea water in the concentration recommended by the manufacturer. The determinations shall be conducted with the samples conditioned at 70°F ± 5°F (21°C ± 3°C).

4.15.2.2.3 The interfacial tension of the foam solution and cyclohexane shall be determined as described in Sections 4.15.2.2.1 and 4.15.2.2.2 except that after immersion of the tensiometer ring in the foam solution, a layer of reagent grade (not less than 99 percent) cyclohexane should be carefully added on top of the foam solution. Contact between the tensiometer ring and the cyclohexane should be avoided. After waiting five minutes, the interfacial tension shall be determined.

4.15.2.2.4 The spreading coefficient of the foam liquid concentrate should be calculated as follows:

$$SC = S_c - S_f - S_{cf}$$

Where:

SC = Spreading coefficient, dynes/cm

S_c = Surface tension of cyc1ohexane, dynes/cm

S_f = Surface tension of foam solution, dynes/cm

S_{cf} = Interfacial tension of the foam solution and cyclohexane, dynes/cm

4.15.3 Foam Quality Tests

4.15.3.1 Requirements

Foam produced using the specific combination(s), as specified by the manufacturer, of foam liquid concentrate, mixture strength, fresh water, and full-scale equipment, shall have the following acceptable quality limits when compared to the quality produced in the fire extinguishing tests:

Table 4.15.3.1 Quality Equivalency Limits

Parameter	***Minimum Below Fire Extinguishment Foam***	***Maximum Above Fire Extinguishment Foam***	***Remarks***
Expansion Ratio	-10 percent, or -1 expansion ratio unit, whichever is greater	+20 percent, or +2 expansion ratio units, whichever is greater	A ratio of 3:1 denotes three expansion ratio units, 5:1 denotes five expansion ratio units, etc.
25 Percent Drain Time	-10 percent, or -1 minute, whichever is greater	+20 percent, or +2 minutes, whichever is greater	25 percent drain time also shall not be less than 30 seconds

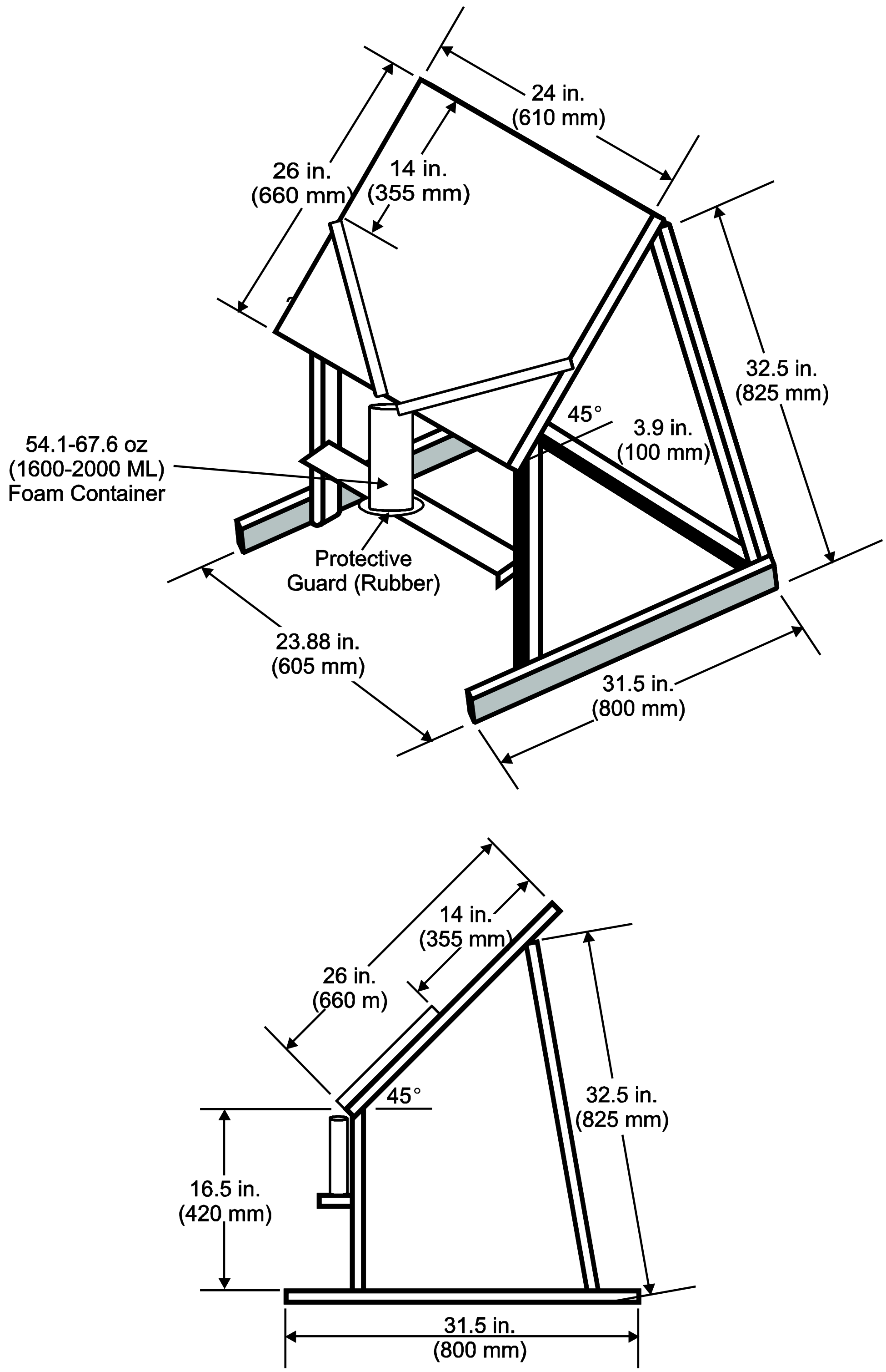
4.15.3.2 Tests/Verification

4.15.3.2.1 To determine compliance with the requirements of Section 4.15.3.1, a sample of the foam shall be obtained by directing foam discharging from generating equipment onto a foam slider. A typical "slider" consists of a sheet of smooth metal, plastic, or wood held on a frame at an angle of 45 degrees to the floor. Foam reaching the "slider" surface should be guided into a foam sample container placed at the bottom of the sheet. To prevent foam agitation in the container, excessive overflowing of foam solution should be avoided.

4.15.3.2.2 The foam shall be discharged at the following pressures:

a. Minimum inlet pressure.
b. Normal inlet pressure, and
c. Maximum inlet pressure.

Figure 4.15.3.2.1 Typical Foam Slider



4.15.3.2.3 The foam containers used with the foam slider shall be graduated cylinders of 54.1 to 67.6 oz (1600 to 2000 ml) capacity. The containers shall be weighed prior to the test to the nearest gram and the tare weight shall be recorded. The specific size of the containers used is not critical, as long as the volume is accurately measured and the graduations are a maximum of 0.1 times the liquid volume for 25 percent drainage.

4.15.3.2.4 The foam discharge shall be stabilized at the desired concentration and flow rate. The foam shall be running freely down the slider, presenting a uniform, steady-state appearance, at the time of sample collection.

4.15.3.2.5 The containers shall be filled with foam from the sample collector. Timers shall be started at the completion of filling.

4.15.3.2.6 Observations of the liquid level at the bottom of the containers shall be recorded at 15 second intervals. Data recording shall continue for a minimum of 30 seconds after the liquid quantity exceeds 1/10 of the graduated cylinder's volume, or all foam has been liquefied, whichever occurs first. Data recording intervals may be increased to 30 seconds if the 25 percent drainage times exceed 5 minutes.

4.15.3.2.7 The foam container external surfaces shall be thoroughly wiped off and each container reweighed. Net weights shall be calculated for each container by subtracting its tare weight from the final weight.

4.15.3.2.8 Each container shall be thoroughly rinsed out with water and refilled with foam solution, at the same concentration used to generate the foam samples. The refilled containers shall be reweighed and the net weights of the solution shall then be calculated by subtracting the tare weights. Alternatively, the weight of foam solution may be calculated from the specific gravity of the solution and the container volume, if the solution specific gravity has been determined to a level of accuracy acceptable to the certification agency.

4.15.3.2.9 The expansion ratio shall be calculated by dividing the total of the net weights of the unexpanded solution from both containers (Section 4.15.3.2.8) by the total of the net weights of the expanded foam samples from each (Section 4.15.3.2.7).

4.15.3.2.10 Twenty-five percent drainage time shall be determined by fitting the best line to the time versus collection data for each container and calculating the time for drainage of 25 percent of the container volume. This process shall be automated using an electronic spreadsheet program such as Microsoft Excel. The data for the time of collection (in seconds) shall be plotted as a function of the volume of solution collected (in grams) using the spreadsheet software. The spreadsheet shall also be used to fit the best line to the data and obtain the equation of that line, as well as its R2 correlation coefficient. If the correlation coefficient is 0.95, or higher, then the equation for that line shall be used to calculate the time to collect liquid solution equivalent to 0.25 of the graduate cylinder's foam weight. This shall be termed the "25 percent drainage time" for the sample. If the correlation coefficient is less than 0.95, the test shall be repeated until data is obtained that generates a curve fit of acceptable accuracy. The value for the two containers shall be averaged and recorded. This shall determine the 25 percent drainage time to be used for future comparisons.

4.15.4 Verification of Liquid-Concentrate Concentration

4.15.4.1 Requirements

A conductivity meter or other equivalent instrument shall be used to verify the percentage of foam liquid concentrate dissolved in the foam samples used in the expansion test and 25 percent drain time test in Section 4.15.3.

4.15.4.2 Test/Verification

Concentration determinations shall be based on weight or volume measurements of the water and concentrate when premixed foam solutions are used. The instrument reading obtained should be corrected, as necessary, for temperature. The foam solution concentration may then be determined using a calibration chart. To prepare a calibration chart, instrument readings should be made for solutions of known percentage liquid concentrates bracketing the percentage of interest, and the results plotted as a graph of known percentage versus instrument reading.

4.15.5 Additional Foam Equipment Component Performance Tests (As Applicable)

4.15.5.1 Requirements

Any individual components, such as proportioner, foam injection pump, foam storage tank, etc., may also be further examined or tested to investigate any safety or reliability concerns arising from their materials, configuration, application, or operation.

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 - 500 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). Additionally, the requirements in the *Examination Standard for Foam Extinguishing Systems* (Class 5130) may apply.

4.15.5.2 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), 4.1.4.2 (Operating Pressure), 4.1.5.2 (Durability - 500 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). Additionally, the tests in the *Examination Standard for Foam Extinguishing Systems* (Class 5130) may be conducted, as applicable.

4.16 High Pressure Flexible Distribution Hose

4.16.1 Fatigue Test

4.16.1.1 Requirements

Flexible hose with threaded end fittings intended for distribution pipe/tubing to nozzle connection 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. Flexible hose with threaded end fittings intended for gas cylinder to manifold connection shall be subject to 3,000 cycles of repeated flexing at a rate of 5 to 30 cycles/min, in a direction parallel with the axis of the end fittings. 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).

4.16.1.2 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 certification, shall be subjected to the required number of cycles (in Section 4.16.1.1) 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 U-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, r, 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 the required 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).

4.16.2 Vacuum Test (Not Required for Systems with Open Nozzles)

4.16.2.1 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 4.16.2.2, 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).

4.16.2.2 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).

4.16.3 Seal Integrity Test

4.16.3.1 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.

4.16.3.2 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.

4.16.4 High Pressure Flow Test

4.16.4.1 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 4.16.4.2, there shall be no deterioration of the water mist hose, its fittings or its attachment.

4.16.4.2 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 water mist nozzle. The water mist 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.

4.16.5 Additional Performance Tests (As Applicable)

4.16.5.1 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 degree 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).

4.16.5.2 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).

4.17 Level Switch (Water)

4.17.1 Equipment Assembly Rating (Voltage Variation)

4.17.1.1 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.

4.17.1.2 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.

4.17.2 Dielectric Strength

4.17.2.1 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.

4.17.2.2 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.

4.17.3 Additional Performance Tests (As Applicable)

4.17.3.1 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).

4.17.3.2 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.

4.18 Manual Pull Station/ Manual Release/ Emergency Mechanical 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 water mist system, including the actuating solenoid, fire detection automatic releases, etc. The examination shall be in accordance with the *Examination Standard for Manual Pull Stations for Alarm Signaling* (Class 3111). Manufacturers are strongly encouraged to use certified detection devices. Emergency mechanical manual releases shall be evaluated and tested for functionality for use with the water mist system.

4.18.1 Manual Release Specifications

4.18.1.1 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.

4.18.1.2 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.

4.19 Mounting Cylinder Bracket

4.19.1 High Pressure Discharge Test

4.19.1.1 Requirements

A water mist 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.

4.19.1.2 Test/Verification

A high pressure discharge test shall be conducted on the mounting cylinder bracket assembly with discharge hose. The water mist 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 water mist system unit is to be connected to the minimum amount of piping and largest nozzle flow rate intended for the system. The water mist system unit is then to be installed and discharged. After discharge, the water mist 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 water mist system unit operating positions of the selector/control valves.

4.20 Pneumatic Actuated Plastic Valves

(Note: Plastic valves are only permitted in wet water mist systems for the protection of wet benches and other similar processing equipment.)

4.20.1 Quick Burst Test

4.20.1.1 Requirement

A plastic valve of each model and size shall be subjected to a quick burst pressure requirement test. The valve shall not have permanent distortion, rupture, or other malfunction that would render the device inoperable.

4.20.1.2 Test/Verification

Component bodies of each size shall be subjected to a hydrostatic test pressure of 150 percent of the maximum system operating pressure. The internal pressure shall be raised from 0 to the required pressure in not less than 60 and not more than 70 seconds.

4.20.2 Threaded Connection Torque Test

4.20.2.1 Requirement

A plastic valve of each model and size shall be subjected to a threaded connection torque test. The torque value to failure shall be greater than the manufacturer's recommended torque.

4.20.2.2 Test/Verification

A plastic fitting shall be threaded into the valve per the manufacturer's instructions. The torque will be determined to fail the threads of either the fitting or the valve. The fitting threads are the preferred threads to fail first.

4.20.3 Water Immersion Test

4.20.3.1 Requirements

A plastic valve of each model and size shall be subjected to a water immersion test. The valve shall continue to cycle with minimal change (+0, -10 percent) in the required inlet air pressure for the pneumatic actuator. Weight change at each interval shall not exceed 2 percent of the initial weight. Following the exposure periods, no leakage or deformation is allowed.

4.20.3.2 Test/Verification

Notes: Valve shall be closed when immersed.
Valve and actuator shall be immersed.

- The valve and actuator assembly shall be weighed and immersed in a water bath maintained at 130°F (54.4°C).
- The assembly shall be weighed after 2 hours in a water bath maintained at 130°F (54.4°C).
- The assembly shall be weighed after an additional 22 hours in a water bath maintained at 130°F (54.4°C).
- The assembly shall be weighed after an additional 24 hours in a water bath maintained at 130°F (54.4°C).
- The assembly shall be weighed after an additional 24 hours in a water bath maintained at 130°F (54.4°C).
- The assembly shall be weighed after an additional 24 hours in a water bath maintained at 130°F

(54.4°C).

- The assembly shall be weighed after an additional 72 hours in a water bath maintained at 130°F (54.4°C).

The valve shall be cycled from full close to full open to full close, with the inlet unpressurized, [0 psi (0 bar)], 100 times using the minimum inlet air pressure for the pneumatic actuator. The valve shall continue to cycle with minimal change (+0, -10 percent) in the required inlet air pressure for the pneumatic actuator.

The test described in Section 4.1.2 (Valve Seat Leakage) shall be conducted with inlet hydrostatically pressurized to the maximum system operating pressure for five minutes.

4.20.4 Ultraviolet Light and Water Test

4.20.4.1 Requirements

A plastic valve of each model and size shall be exposed to ultraviolet light and water for 720 hours in accordance with Table X3.1, Cycle 1, of ASTM G155, *Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials*. At the conclusion of the test, there shall be no cracking or crazing of the valve and the valve shall comply with the requirements in Section 4.1.3 (Hydrostatic Strength). There shall be minimal change (+0, -10 percent) in the required inlet air pressure for the pneumatic actuator.

4.20.4.2 Tests/Verification

A sample valve shall be exposed to ultraviolet light and water for 720 hours. The valve shall be inspected for cracking and crazing after 360 hours. If no cracking or crazing is apparent, the exposure shall continue for the full 720 hours.

During each operating cycle, each sample shall be exposed to light and water spray for 18 minutes and to only light for 102 minutes (total 120 minutes). The air temperature within the apparatus during operations shall be 145°F ± ~9°F (63°C ± ~5°C). Following exposure, the valve shall be visually examined, and full compliance with Section 4.1.3 (Hydrostatic Strength) is required. Additionally, the pneumatic actuator operating characteristics shall be verified.

4.20.5 Air-Oven Aging Test

4.20.5.1 Requirements

A plastic valve of each model and size shall be subjected to air-oven aging tests at 158°F (70°C). There shall be no cracking or crazing as a result of this test, and the valve shall comply with the requirements in Section 4.1.3 (Hydrostatic Strength). There shall be minimal change (+0, -10 percent) in the required inlet air pressure for the pneumatic actuator.

4.20.5.2 Test/Verification

A sample plastic valve shall be subjected to air-oven aging tests for 180 days at 158°F (70°C), and then allowed to cool at least 24 hours in air at 74°F (23°C) and 50 percent relative humidity. The sample plastic valves shall then be visually examined, and full compliance with Section 4.1.3 (Hydrostatic Strength) is required. Additionally, the pneumatic actuator operating characteristics shall be verified.

4.20.6 Additional Performance Tests (As Applicable)

4.20.6.1 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) and 4.1.10.1 (Friction Loss Determination). In addition, documentation of the compatibility and suitability of the plastic construction materials used to various corrosive atmospheres should be included in the manufacturer’s installation and operating instructions.

4.20.6.2 Tests/Verifications

General Performance Requirements: 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) and 4.1.10.2 (Friction Loss Determination). For 4.1.5.2 (Durability - Cycling), the valve should be operated and tested separately under no pressure and at 150 percent of the maximum system operating pressure. 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.

4.21 Pneumatic Actuator

4.21.1 Pressure Requirement Activation Test

4.21.1.1 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.

4.21.1.2 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.

4.21.2 Additional Performance Tests (As Applicable)

4.21.2.1 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).

4.21.2.2 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.

4.22 Pressure Gauges

4.22.1 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 the certification agency.

4.22.2 Durability

4.22.2.1 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.

4.22.2.2 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.

4.22.3 Readability

4.22.3.1 Requirements

Gauges shall be correctly readable to within one minor scale calibration increment in uniform lighting conditions of 50 lm/ft^2 (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").

4.22.3.2 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.

4.22.4 Accuracy

4.22.4.1 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.

4.22.4.2 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.

4.22.5 Hysteresis

4.23.5.1 Requirements

The required accuracy level per Section 4.22.4 shall be verified in both increasing and decreasing pressure readings.

4.23.5.2 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.

4.22.6 Overpressure

4.22.6.1 Requirements

The gauge accuracy shall remain within the limits specified in Section 4.22.4 (Accuracy) after it has been overpressurized.

4.22.6.2 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.

4.22.7 Hydrostatic Strength

4.22.7.1 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.

4.22.7.2 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.

4.22.8 Vibration

4.22.8.1 Requirements

The gauge accuracy shall remain within the limits specified in Section 4.22.4 (Accuracy) after completion of the vibration sequence.

4.22.8.2 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 Section 4.1.8 (Vibration Resistance).

4.22.9 Wear

4.22.9.1 Requirements

The gauge accuracy shall remain within the limits specified in Section 4.22.4 (Accuracy) after completion of 20,000 pressure cycles.

4.22.9.2 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.

4.22.10 Salt Spray Corrosion

4.22.10.1 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.

4.22.10.2 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.

4.22.11 Moisture

4.22.11.1 Requirements

The gauge accuracy shall remain within the limits specified in Section 4.22.4 (Accuracy) after exposure to moisture.

4.22.11.2 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.

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

4.23.1 Diaphragm Strength

4.23.1.1 Requirements

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

4.23.1.2 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.

4.23.2 Disc Assembly, or Equivalent Component/Disc Strength

4.23.2.1 Requirements

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

4.23.2.2 Tests/Verification

With the inlet open to atmosphere, a hydrostatic pressure of two times the maximum system operating 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.

4.23.3 Operating Pressure

4.23.3.1 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 ± 5 percent of the valve set pressure.

4.23.3.2 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.

4.23.4 Durability - Cycling

4.23.4.1 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).

4.23.4.2 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).

4.23.5 Additional Performance Tests (As Applicable)

4.23.5.1 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).

4.23.5.2 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).

4.24 Pressure Switches

4.24.1 Dielectric Strength

4.24.1.1 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.

4.24.1.2 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.

4.24.2 Additional Performance Requirements (As Applicable)

4.24.2.1 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).

4.24.2.2 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.

4.25 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 water mist system, including the actuating solenoid, fire detection automatic releases, fire alarm signaling system, etc. The certification examination shall be in accordance with the *Examination Standard for Fire Alarm Signaling System*s (3010). Manufacturers are strongly encouraged to use certified detection devices.

This standard provides information regarding the typical tests that are required. The certification agency 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 *Examination Standard for Fire Alarm Signaling Systems* (3010) performance requirements are largely based on NFPA 72, *National Fire Alarm Code*, and other applicable FM Approvals Examination 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 the certification agency if original test data from other international testing laboratories is submitted and considered satisfactory.

4.26 Sight Glass

4.26.1 Hydrostatic Pressure Test

4.26.1.1 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.

4.26.1.2 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.

4.26.2 Impact Test

4.26.2.1 Requirement

A liquid sight glass shall withstand, without cracking or damage, the impact test outlined in 4.27.2.2.

4.26.2.2 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.

4.27 Solenoid Valves

4.27.1 Equipment Assembly Ratings (Voltage Variation)

4.27.1.1 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.

4.27.1.2 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.

4.27.2 Dielectric Strength

4.27.2.1 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.

4.27.2.2 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.

4.27.3 Additional Performance Tests (As Applicable)

4.27.3.1 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).

4.27.3.2 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).

4.28 Suction Filters/Strainers

4.28.1 Hydrostatic Pressure Test

4.28.1.1 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 then 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 then 500 psi (34.5 bar), without deformation of the filter.

4.28.1.2 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 then 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 then 500 psi (34.5 bar), for a duration of five minutes.

4.28.2 Filter Rating or Strainer Mesh Opening

4.28.2.1 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. Additionally, the minimum total open area of the filter/strainer mesh shall be 100 percent of the smallest pipe or tube connected to the strainer/filter.

4.28.2.2 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).

4.28.3 Additional Performance Tests (As Applicable)

4.28.3.1 Requirements

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

4.28.3.2 Tests/Verifications

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

4.29 Water Mist System Pumps

4.29.1 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.
- Water mist system fire pump installation plan.

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

- NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, Chapter 8.
- NFPA 750, *Standard on Water Mist Fire Protection Systems*, Chapter 6, Section 6.9.

Reference Figure 4.29, "Typical Water Mist System Pump Piping and Fittings." No automatic fire pump shut-off features are permitted in the fire pump installation design.

4.29.2 Hydraulic Pump Performance

4.29.2.1 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.

4.29.2.2 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 ± 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. 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 the certification agency.

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

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

4.29.3 Endurance Test

4.29.3.1 Requirements

The pump shall be capable of continuous operation for 24 hours under the conditions stated in Section 4.29.3.2, 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.

4.29.3.2 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 ± 4 percent of the rated speed.

4.29.4 Flange and Gasket Tightness

4.29.4.1 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.

4.29.4.2 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} + $P_{max.\ Suction}$). The maximum rated differential pressure, P_{max}, is the highest relief valve setting specified for certification. The test pressure shall be maintained for five minutes. In no case shall the maximum allowable suction pressure, $P_{max.\ Suction}$, 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.

4.29.5 Hydrostatic Strength

4.29.5.1 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.

4.29.5.2 Tests/Verification

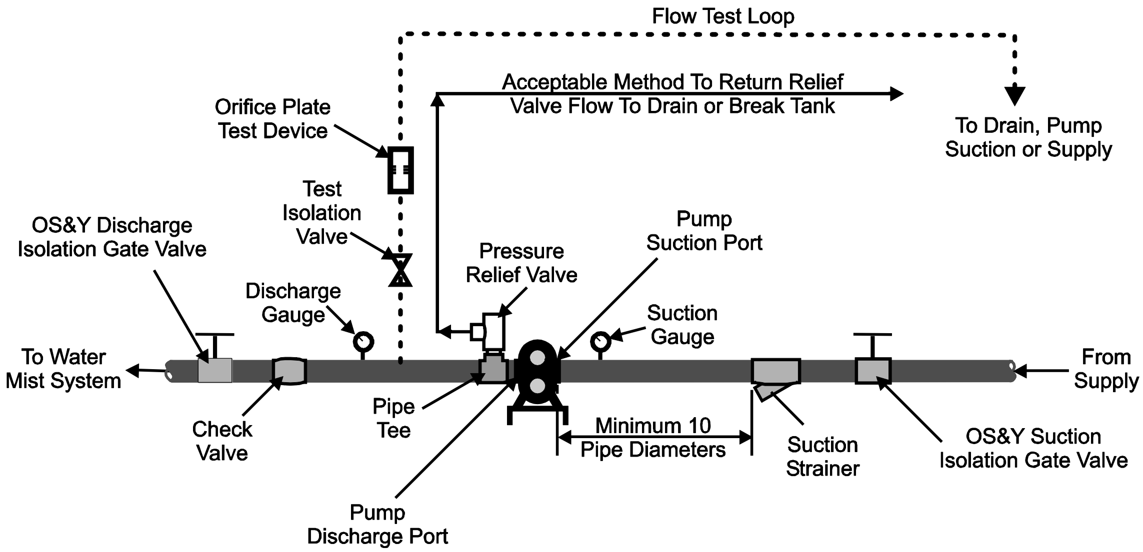
A sample casing of each model and material shall be hydrostatically tested to a pressure greater than or equal to twice the sum of the maximum rated pressure differential of the pump plus a maximum allowable suction pressure specified by the pump manufacturer, 2 x (P_{max} + $P_{max.\ Suction}$). The maximum rated differential pressure, P_{max}, is the highest relief valve setting specified for certification. The test pressure shall be maintained for five minutes. In no case shall the maximum allowable suction pressure, $P_{max.\ Suction}$, 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.

4.29.6 Pressure Relief Valves

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

- NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, Chapter 8
- NFPA 750, *Standard on Water Mist Protection Systems*, Chapter 6, Section 6.9
- *Examination Standard for Water Mist Systems* (Class 5560), Section 4.23 (Pressure Control Devices - Automatic - Dump - Reducing - Reducing Station - Regulating - Relief - Restricting - Safety - Unloader Valves).

Figure 4.29 Typical Water Mist System Pump Piping and Fittings



4.30 Water Storage Tanks

4.30.1 Documentation Review

4.30.1.1 Requirements

A. 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.

B. Documentation shall be submitted detailing materials of construction of atmospheric water storage tanks. The atmospheric water storage tanks shall also be specified in the Design, Installation, Operation, and Maintenance manual.

4.30.1.2 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.

4.30.2 Additional Performance Tests (As Applicable)

4.30.2.1 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).

4.30.2.2 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).

4.31 Water Valves (Control)

4.31.1 Performance Tests (As Applicable)

4.31.1.1 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 - 20,000 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).

4.31.1.2 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 - 20,000 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).

4.32 Preaction Valve Assembly

Performance, operational and design requirements for preaction valve assemblies are included in Examination Standard Class 1020, *Automatic Water Control Valves*, and Examination Standard Class 1011/1012/1013, *Deluge and Preaction Sprinkler Systems*. Preaction valves for use in water mist systems shall meet the requirements in these standards, as applicable, based on the design of the water mist system. A suitable test program will be determined based on reference to these Examination Standards and the minimum performance requirements in Section 4.32.1. Additionally, the method in which the water delivery delay from the preaction valve to the nozzles of the water mist system is calculated will require review and potential discharge testing for verification of the calculation method at the discretion of the certification organization.

4.32.1 Performance Tests

4.32.1.1 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), 4.1.9.1 (Valve Locking/Supervision Ability) and 4.1.10.1 (Friction Loss Determination).

4.32.1.2 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), 4.1.9.2 (Valve Locking/Supervision Ability) and 4.1.10.2 (Friction Loss Determination).

4.33 Pipe Hangers and Hydraulic Tube Clamping Components

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

4.34 Hydraulic Calculations Method

4.34.1 Calculation Method

The Hazen-Williams calculation method for hydraulic calculations may be used for low pressure systems with no additives.

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 intermediate and high pressure, single fluid, single phase systems, and for low pressure systems that cannot be calculated using the Hazen-Williams method (see Chapter 11 of NFPA 750, *Standard on Water Mist Protection Systems*).

For preaction systems the calculation method and/or empirical validation of the water delivery delay time is required to be submitted.

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.

4.34.2 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.

4.34.3 Verification of Flow

Representative water mist fire 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. Water mist systems utilizing fixed storage arrangements, i.e. pressurized gas containers and water containers, may also be subject to verification of flow testing to validate the flow characteristics of the systems. The following parameters, as applicable, 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

4.35 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 the certification agency.

The review by the certification agency shall verify compliance to the requirements of the certification agency, NFPA 750, *Standard on Water Mist Protection Systems*, Chapter 15 (System Inspection, Testing, and Maintenance), and the authority having jurisdiction. The manual(s) should also reflect those requirements that are applicable to water mist 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 manual(s) shall specify all critical system valves and identify the proper positioning of the valves.
- 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 certified.
- 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.
- The manual(s) shall include guidance on nozzle obstructions in accordance with NFPA 750, *Standard on Water Mist Protection Systems*, Section A.8.2.5.
- 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 a test connection configuration for those systems listed to protect Non-Storage Occupancies, Hazard Category 1 (HC-1), Hazard Category 2 (HC-2), and Hazard Category 3 (HC-3), as well as Data Processing Equipment Rooms/Halls, and any other application that does not permit the discharge of the water mist system.
- The manual(s) shall specify the required acceptance and commissioning procedures, as described in Section 4.36, this includes a sample test form for Acceptance Testing.
- 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.

4.36 System Acceptance and Commissioning Documentation

4.36.1 All water mist 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).

4.36.2 All acceptance and commissioning procedures shall be reviewed by the certification agency. Changes requested by the certification agency may be mandatory prior to the granting of certification.

4.36.3 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):

4.36.3.1 Acceptance procedures shall be in accordance with NFPA 750, *Standard on Water Mist Fire Protection Systems,* Chapter 14, or the equivalent national code of the country of use.

4.36.3.2 An appropriate Authority Having Jurisdiction representative should be given advance notice of such testing and be present for commissioning of the system.

4.36.3.3 A trained manufacturer's representative should be present to properly test and reset the system following the acceptance test.

4.36.3.4 A full discharge test to verify nozzle layout and discharge pattern is recommended. 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.

4.36.3.5 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.

4.36.3.6 Operate the maximum number of nozzles or systems (when multiple systems are installed) that are expected to operate at the same time.

4.36.3.7 Use a test connection configuration for those systems listed to protect Non-Storage Occupancies, Hazard Category 1 (HC-1), Hazard Category 2 (HC-2), and Hazard Category 3 (HC-3), as well as Data Processing Equipment Rooms/Halls, and any other application that does not permit the discharge of the water mist system.

4.36.3.8 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.

4.36.3.9 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.

4.36.3.10 Inspect, clean, and replace filters and strainers if necessary.

4.36.3.11 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 water mist system fire tests per Section 4.37.

4.36.3.12 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.

4.37 Fire Tests

Water mist systems for a particular application shall successfully meet all fire test performance requirements for that application, as described in the Appendices A through O.

4.38 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 the certification agency.

Unexplainable failures shall not be permitted. A re-test shall only be acceptable at the sole discretion of the certification agency with adequate technical justification of the conditions and reasons for failure.

5. OPERATIONS REQUIREMENTS

5.1 Demonstrated Quality Control Program

5.1.1 A quality assurance program is required to assure that subsequent products produced by the manufacturer shall present the same quality and reliability as the specific products examined. Design quality, conformance to design, and performance are the areas of primary concern.

- Design quality is determined during the examination and tests and may be documented in the certification report.
- Continued conformance to this standard is verified by the certifiers surveillance program.
- Quality of performance is determined by field performance and by periodic re-examination and testing.

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

- existence of corporate quality assurance guidelines;
- incoming quality assurance, including testing;
- in-process quality assurance, including testing;
- final inspection and tests;
- equipment calibration;
- drawing and change control;
- packaging and shipping; and
- handling and disposition of non-conforming materials.

5.1.3 Documentation/Manual

There should be an authoritative collection of procedures/policies. It should 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.

5.1.4 Records

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

5.1.5 Drawing and Change Control

- The manufacturer shall establish a system of product configuration control that shall allow no unauthorized changes to the product. Changes to critical documents, identified in the certification report, may be required to be reported to, and authorized by the certification agency prior to implementation for production.
- Records of all revisions to all certified products shall be maintained.

5.2 Surveillance Audit Program

5.2.1 An audit of the manufacturing facility may be part of the certification agencies surveillance requirements 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 ensure a uniform product consistent with that which was tested and certified.

5.2.2 Certified products or services shall be produced or provided at, or provided from, location(s) disclosed as part of the certification examination. Manufacture of products bearing a certification mark is not permitted at any other location prior to disclosure to the certification agency.

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 the certification agency.

5.4 Manufacturer's Responsibilities

5.4.1 The manufacturer shall notify the certification agency 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, or assigned representative, shall perform a documented system acceptance check and operational test in accordance with NFPA 750, *Standard on Water Mist Protection Systems*, Chapter 14. A copy of the results should be left on site and with the owner of the water mist system, at a minimum.

5.5 Manufacturing and Production Tests

5.5.1 Test Requirement No. 1 - System Operation

The manufacturer shall performance test 100 percent of production water mist systems in accordance with the requirements of the *Examination Standard for Water Mist Systems* (Class 5560), 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 150 percent of the maximum system operating pressure, but not less than a pressure of 700 psi (48.3 bar). 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 water mist 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.

6. Bibliography

ISO/IEC 17025: 2017, *General Requirements for the Competence of Testing and Calibration Laboratories*
ISO 9000, *Quality Management Principles*

FIRE PERFORMANCE TESTING REQUIREMENTS

APPENDIX A through O

General Instrumentation and Test Equipment Requirements

A. The water mist 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). Based on the size of the test laboratory relative to the size of the fire test enclosure the certification agency may require oxygen concentration to be monitored outside the fire test enclosure to validate this requirement.

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°F ± 18°F (20°C ± 10°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 ± 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. Doorway screening water mist nozzles are permitted. However, the arrangement and discharge from the doorway water mist nozzles must not enhance the heat release rate or increase the fire intensity of any fire test arrangement. Additionally, the discharge from these doorway nozzles must be of the water mist distribution type and are not permitted to discharge directly into the enclosure. These nozzles, if used, shall be specified in the design and installation manual. Doorway screening nozzles are not permitted to be used in lieu of automatic door closing devices. Certification is based on all doorways to be closed upon system actuation. Additional fire testing to prove the effect of door nozzles on enhancing the heat release rate or increase in the fire intensity may be conducted at the sole discretion of the certification agency.

J. Appendices A through F include fire tests to evaluate water mist in a total compartment application. One aspect of the testing in these appendices is the evaluation of the system performance under limited natural ventilation. Upon successful completion of these tests, the water mist system will have demonstrated the ability to overcome incidental openings such as unsealed cable penetrations, an open doorway, etc. However, this aspect of the fire testing serves as a safety factor to ensure successful system performance in the event of such fault conditions. Certification is based on all enclosure penetrations being sealed, all openings being closed, and all ventilation being shut down in the event of system actuation.

K. 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. Sprays may be continuous or intermittent in time. In the case of intermittent, or cycled, sprays, the time period during which the system is not discharging shall not be greater than 50 percent of one complete on/off cycle. Additionally, for the protection of gas turbine enclosures, the cycling parameters should be such that excessive turbine shell distortion is avoided, as determined by the spray cooling tests described in Appendices B, D, and F. The system off period shall not exceed one minute.

L. In conjunction with the performance fire tests, all twin fluid water mist systems should be subjected to a straight discharge test with no fire to evaluate the resulting discharge and 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 the certification agency. 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 4.35 and 4.36).

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 water mist 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 ± 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.
- If applicable, consumption of foam concentrate, measure by means of a weighing cell on which the foam tank is placed during the tests.
- If applicable, 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 the water mist extinguishment is a suitable alternative to verify the existence of fuel.

APPENDIX A: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF MACHINERY IN ENCLOSURES WITH VOLUMES NOT EXCEEDING 2825 FT^3 (80 M^3)

A.1 TEST ENCLOSURE (SEE FIGURE A-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.

A.2 MACHINERY EQUIPMENT MOCKUP

The machinery mockup is simulated with 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 shall be centered along the longer wall dimension in the test enclosure. The certification agency reserves the right to alter the placement of the mockup unit with respect to the aspect ratio of the enclosure.

Horizontal 22 gauge (0.85 mm thick) galvanized steel sheet metal table shall be placed at an elevation of 3.3 ft (1 m) on steel legs, so that the mockup extends longitudinally the entire length of the enclosure (see Figure A-1). This is located in the center of the room or at a location within the test cell to be selected by the certification agency 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 water mist 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 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 the certification agency.

A.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 ± 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 ± 18 °F (20 °C ± 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 °F ± 18 °F (20 °C ± 10 °C).

D. Test enclosure temperatures measured in the center portion of the room at the 1/3, 2/3 and ceiling heights with 20 gauge Type K thermocouples. The enclosure and mockup shall initially be at an ambient temperature 68 °F ± 18 °F (20 °C ± 10 °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 °F (100 °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. Due to the size of the test fires relative to the volume of the enclosure, consideration to the oxygen concentration is critical to verify that the test fires have not been self extinguished. Oxygen should generally be no less than 16 percent during the entire period of each test.

J. For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

Fire Size	***1 MW Diesel Spray***	***2 MW Diesel Spray***
Spray Nozzle	Monarch F-80, 24.00, PLP	Monarch F-80, 50.00, PLP
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 the certification agency.

Fire Size	***1 MW Heptane Spray***	***2 MW Heptane Spray***
Spray Nozzle	Monarch F-80, 24.00, PLP	Monarch F-80, 50.00, PLP
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 °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 the certification agency.

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.

A.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 water mist system shall successfully complete all eight 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 water mist 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.

A.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 water mist 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 water mist 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.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 water mist 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 water mist 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.4.3 Shielded 10.8 ft^2 (1 m^2) Diesel Pool Fire

Criterion: The fire is to be extinguished.

Fuel: Diesel
Type: 10.8 ft^2 (1.0 m^2) 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 water mist 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 mist 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. The system discharge should be shut off 45 seconds after extinguishment.

A.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 water mist 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 water mist 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 water mist 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.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 water mist 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 water mist 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.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 water mist 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 water mist 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.4.7 Shielded 10.8 ft^2 (1 m^2) Heptane Pool Fire

Criterion:	The fire is to be extinguished.

Fuel:	Heptane
Type:	10.8 ft^2 (1.0 m^2) 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 water mist 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 mist 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. The system discharge should be shut off 45 seconds after extinguishment.

A.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 water mist 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 water mist 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 water mist 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.4.9 Additional Fire Tests

Based on the results of Fire Tests A.4.1 through A.4.8, additional fire testing may be required to ensure that the water mist system being evaluated meets the intent of this section of the standard. This testing will be performed at the sole discretion of the certification agency.

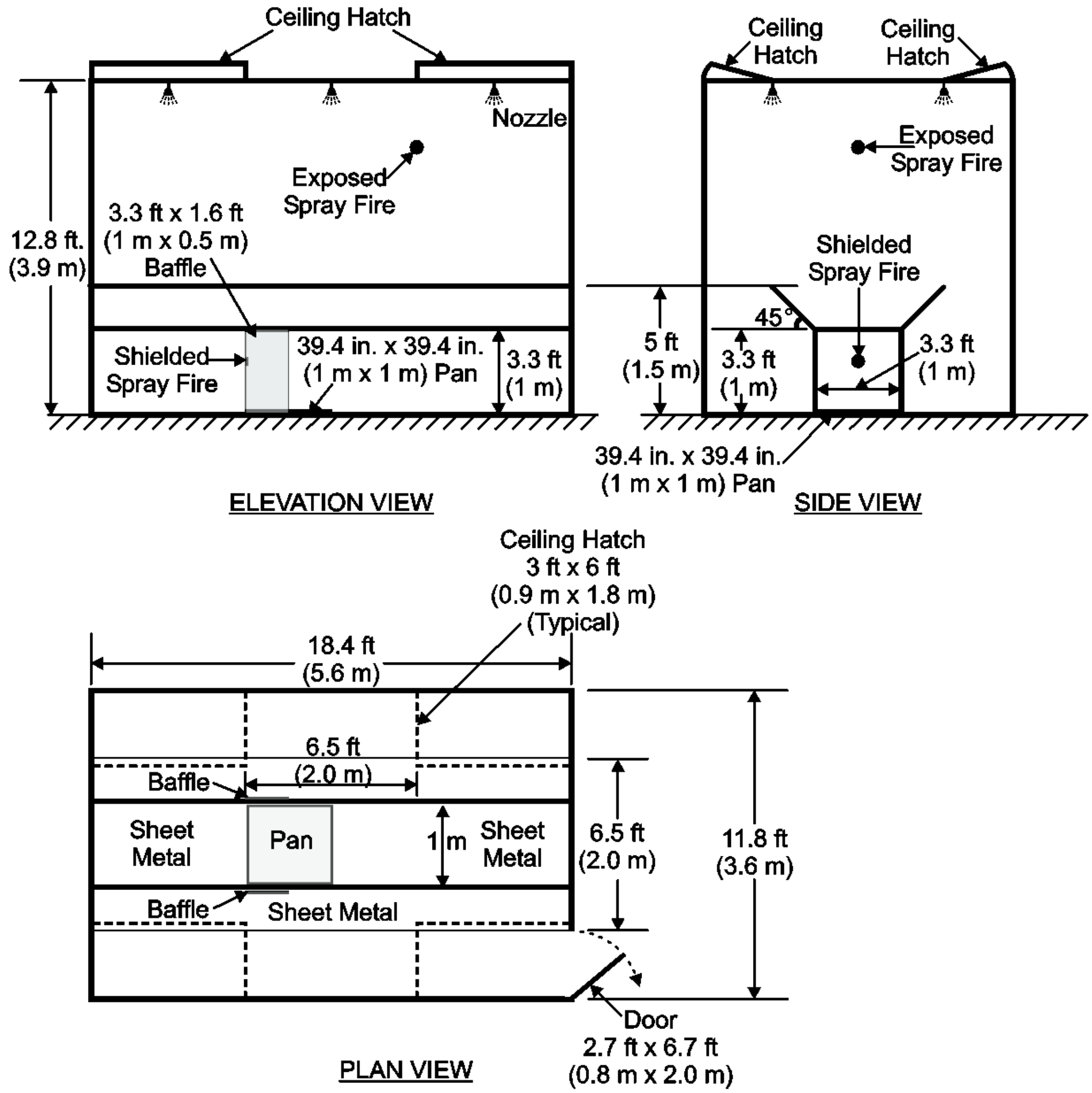


Figure A-1. Test Enclosure and Machinery Mockup Steel Table

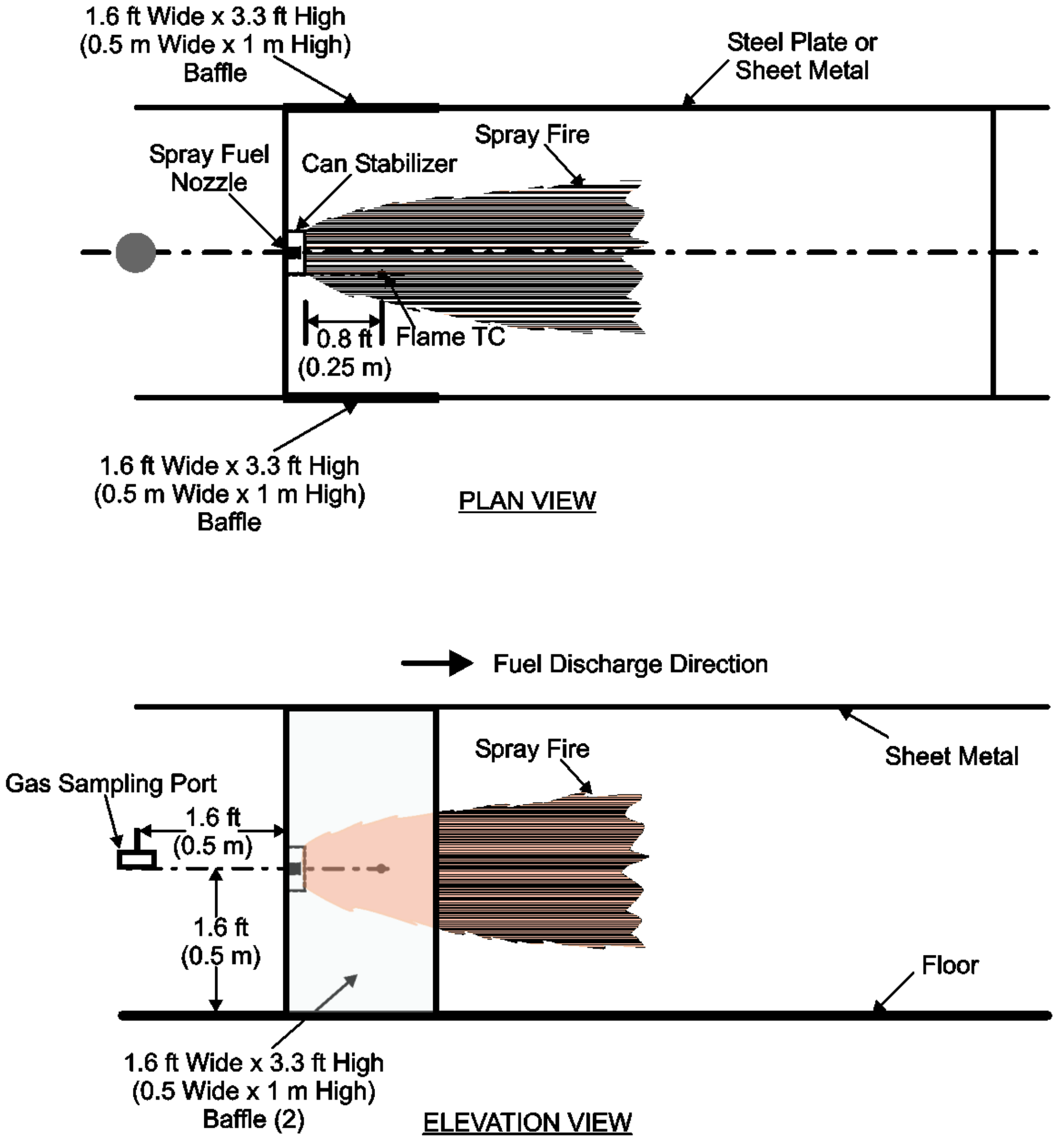


Figure A-2. Fire Source Configuration and Instrumentation for Shielded Spray Fire Testing

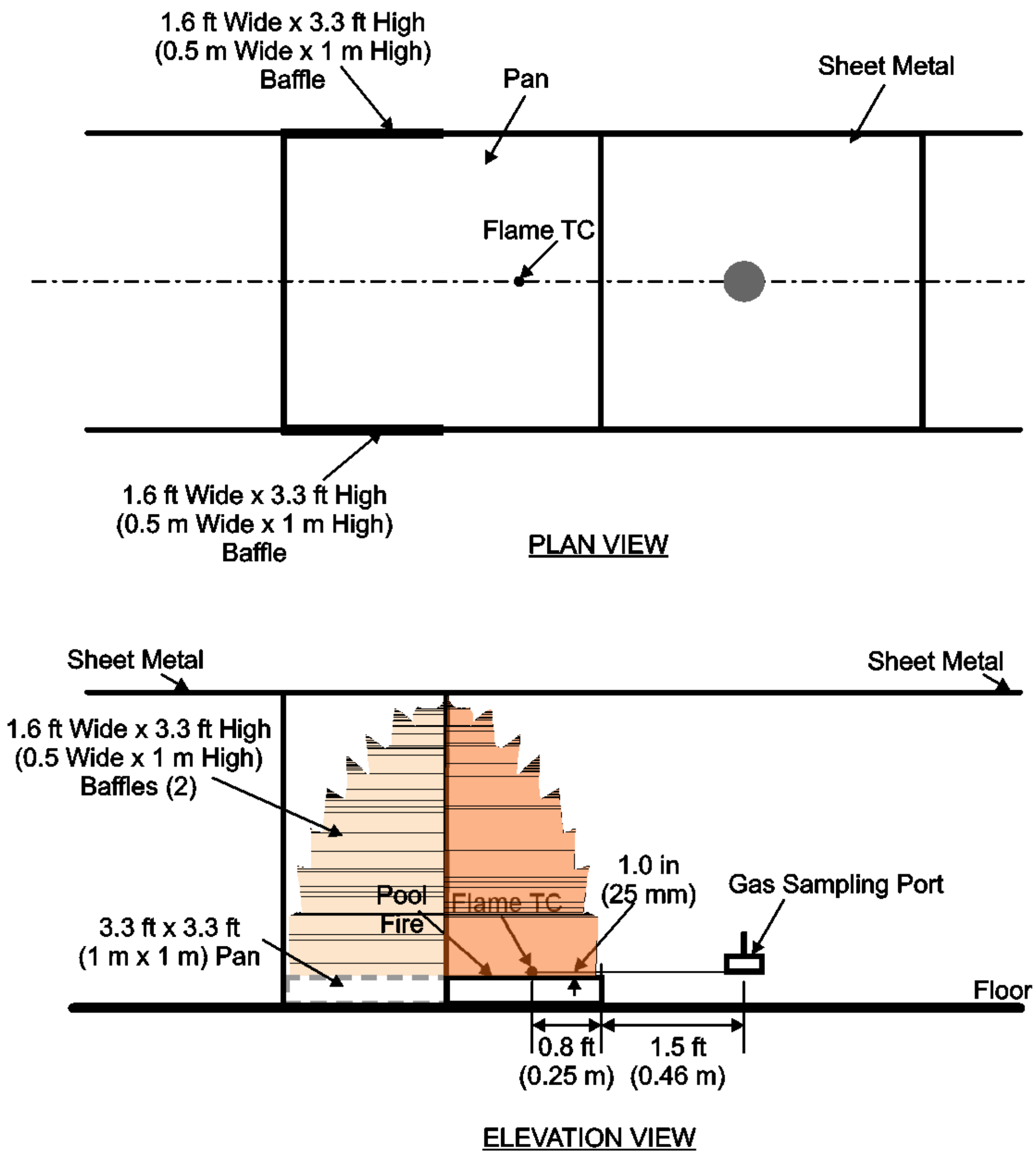


Figure A-3. Fire Source Configuration and Instrumentation for Shielded Pool Fire Testing

APPENDIX B: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF GAS TURBINES IN ENCLOSURES WITH VOLUMES NOT EXCEEDING 2825 FT^3 (80 M^3)

B.1 TEST ENCLOSURE (SEE FIGURE B-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.

B.2 GAS TURBINE MOCKUP

The gas turbine casing mockup is simulated with a horizontal flat steel plate 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 gas turbine mockup unit shall be centered along the longer wall dimension in the test enclosure. The certification agency 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 the certification agency 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 gas turbine mockup extends longitudinally the entire length of the enclosure (see Figure B-1).

To determine the cooling rate of the gas turbine steel plate mockup, caused by the discharge of the water mist 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 B-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 water mist 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 the certification agency.

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 ± 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 ± 18 °F (20 °C ± 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 °F ± 18 °F (20 °C ± 10 °C).

D. Test enclosure temperatures measured in the center portion of the room at the 1/3, 2/3 and ceiling heights with 20 gauge Type K thermocouples. The enclosure and mockup shall initially be at an ambient temperature 68 °F ± 18 °F (20 °C ± 10 °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 °F (100 °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. Due to the size of the test fires relative to the volume of the enclosure, consideration to the oxygen concentration is critical to verify that the test fires have not been self extinguished. Oxygen should generally be no less than 16 percent during the entire period of each test.

J. For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

Fire Size	***1 MW Diesel Spray***	***2 MW Diesel Spray***
Spray Nozzle	Monarch F-80, 24.00, PLP	Monarch F-80, 50.00, PLP
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 the certification agency.

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. (0.3 m) wide by 12 in. (0.3 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^3 (96 to 128 kg/m^3). 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.

B.4 FIRE TESTS

Intermediate pendent or upright nozzles that are not at ceiling level, or wall mounted nozzles, are permitted for the protection of gas turbines.

The water mist 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 water mist system shall successfully complete the first four (B.4.1 through B.4.4) fire performance tests and the Spray Cooling (heat transfer) test (B.4.5). An additional option for gas turbine applications is the protection of insulated turbines. Two additional fires tests, B.4.6 and B.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 water mist 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 water mist 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 water mist 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 water mist 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 water mist 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^2 (1 m^2) Diesel Pool Fire

Criterion: The fire is to be extinguished.

Fuel: Diesel
Type: 10.8 ft^2 (1.0 m^2) 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 water mist 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 mist 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. The system discharge should be shut off 45 seconds after extinguishment.

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 water mist 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 water mist 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 water mist 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 Spray Cooling (No Fire)

Criteria: The heat flux resulting from a water mist system discharge shall not adversely affect the turbine. Such assessment is to be made in accordance with methodology developed by the certification agency to measure the damage potential of water mist systems. This test, combined with heat transfer calculations, will determine the extent of the cooling of the turbine casing during the operation of the water mist system. Calculations should be based on the manufacturer's maximum recommended turbine size (diameter) to be installed within the enclosure and/or water mist 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 water mist 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 B-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 the certification agency 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 water mist 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.

B.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 water mist 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^2 (0.1 m^2) 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 water mist 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.

B.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^2 (1.0 m^2) 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 water mist 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^2 (1.0 m^2) 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 water mist system should be activated 30 seconds after the insulation mat fire is fully developed over the entire area of the mat.

B.4.8 Additional Fire Tests

Based on the results of Fire Tests B.4.1 through B.4.7, additional fire testing may be required to ensure that the water mist system being evaluated meets the intent of this section of the standard. This testing will be performed at the sole discretion of the certification agency.

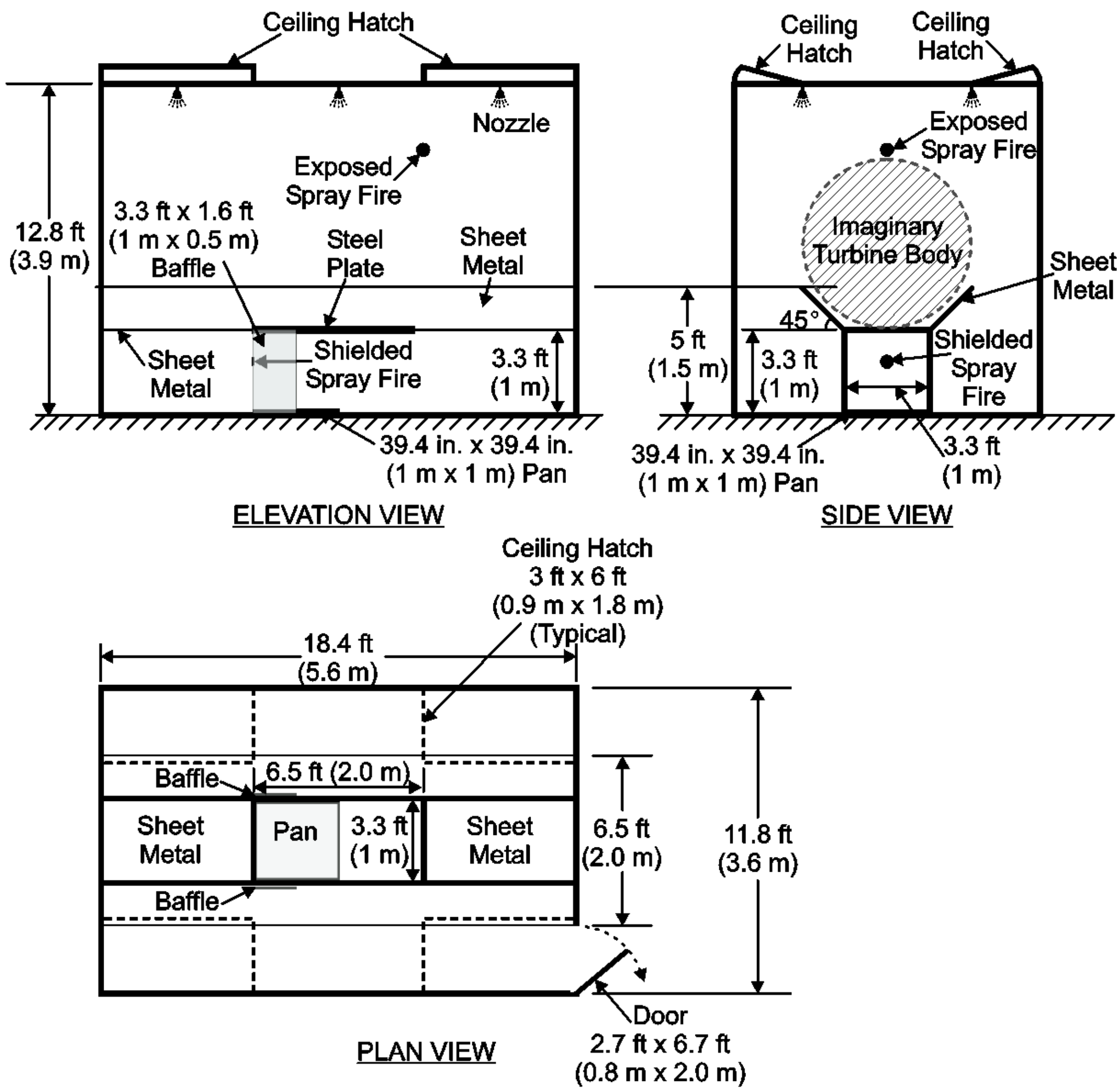


Figure B-1. Test Enclosure and Gas Turbine Simulator Steel Plate

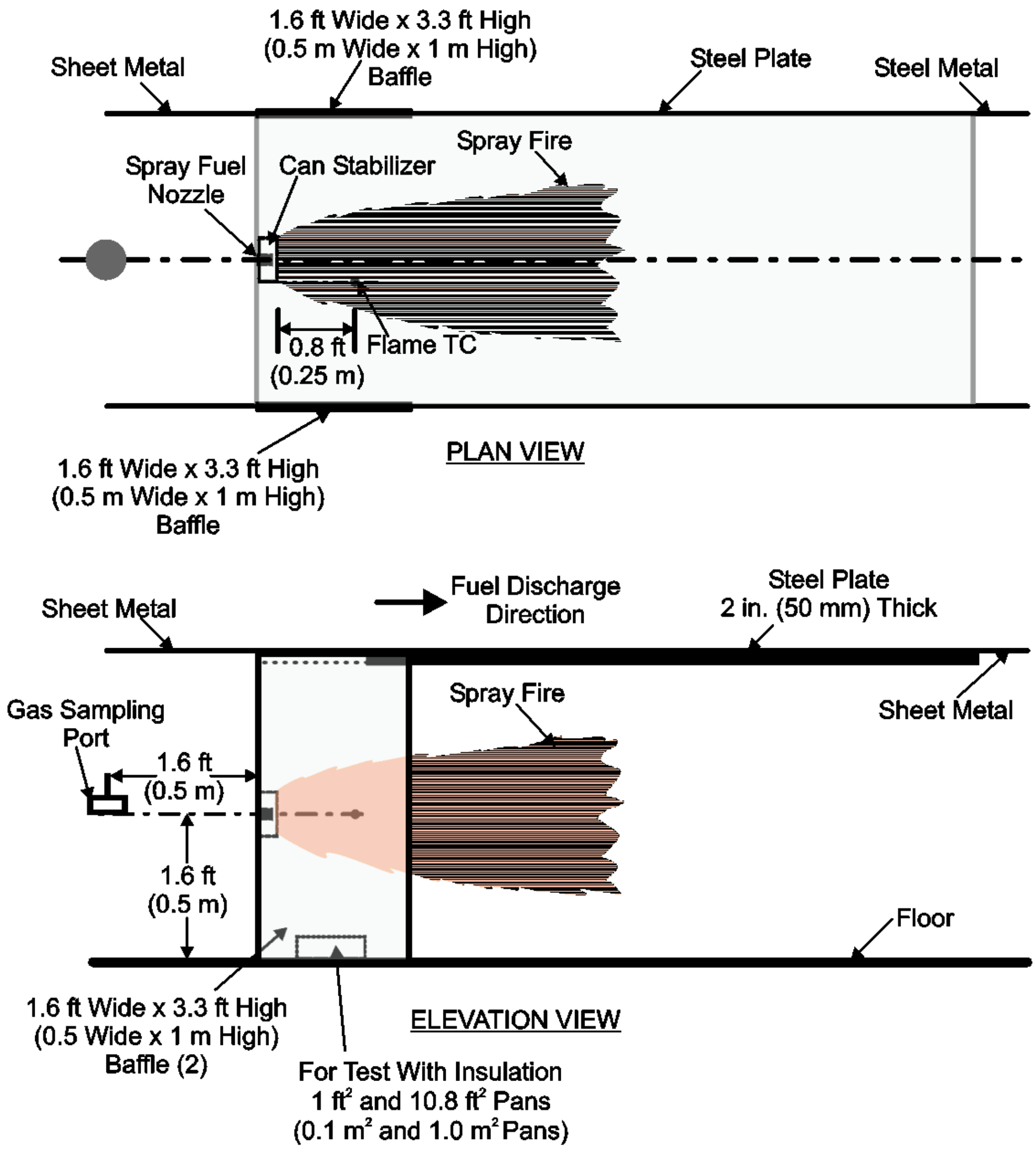


Figure B-2. Fire Source Configuration and Instrumentation for Shielded Spray Fire Testing

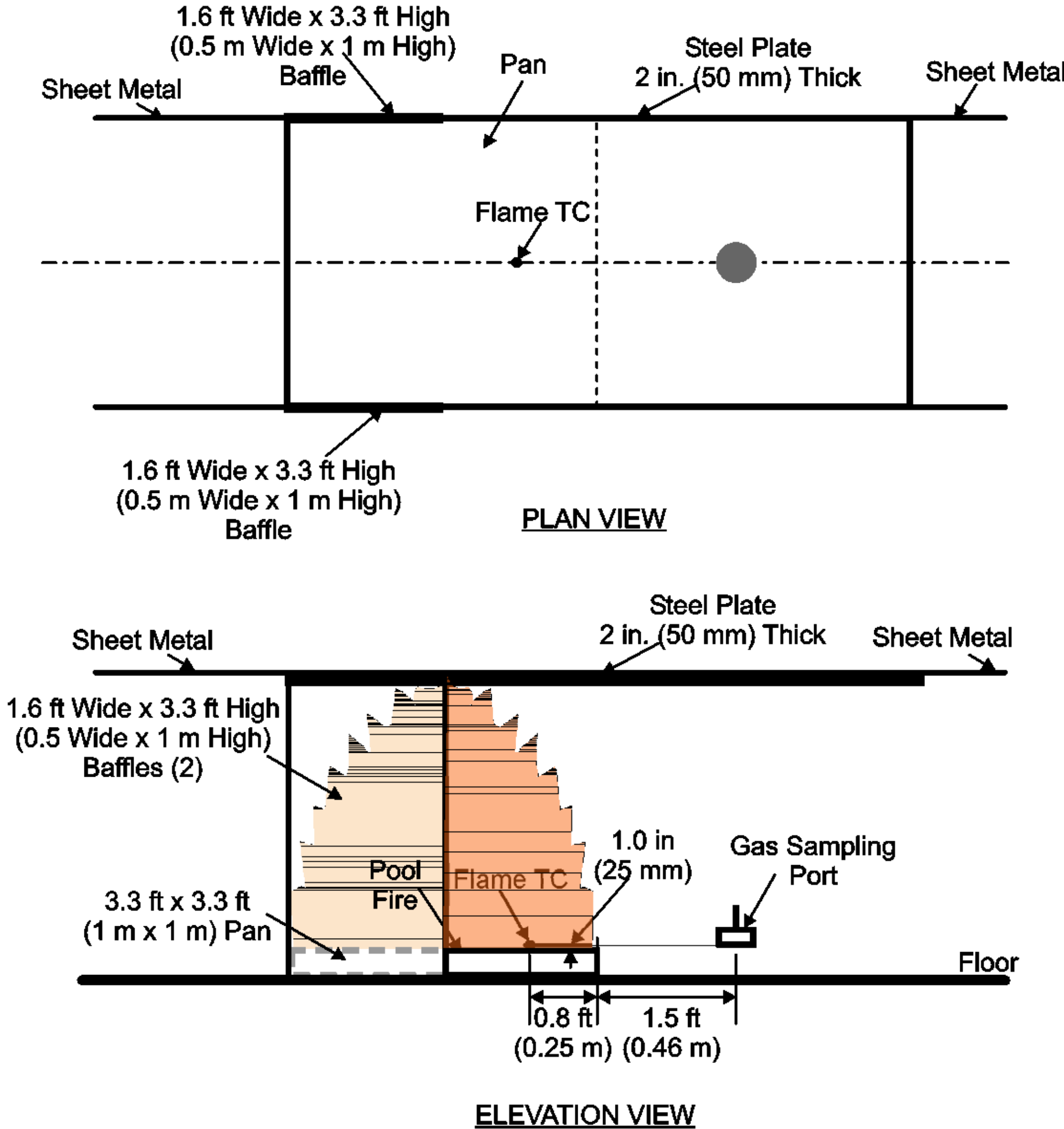


Figure B-3. Fire Source Configuration and Instrumentation for Shielded Pool Fire Testing

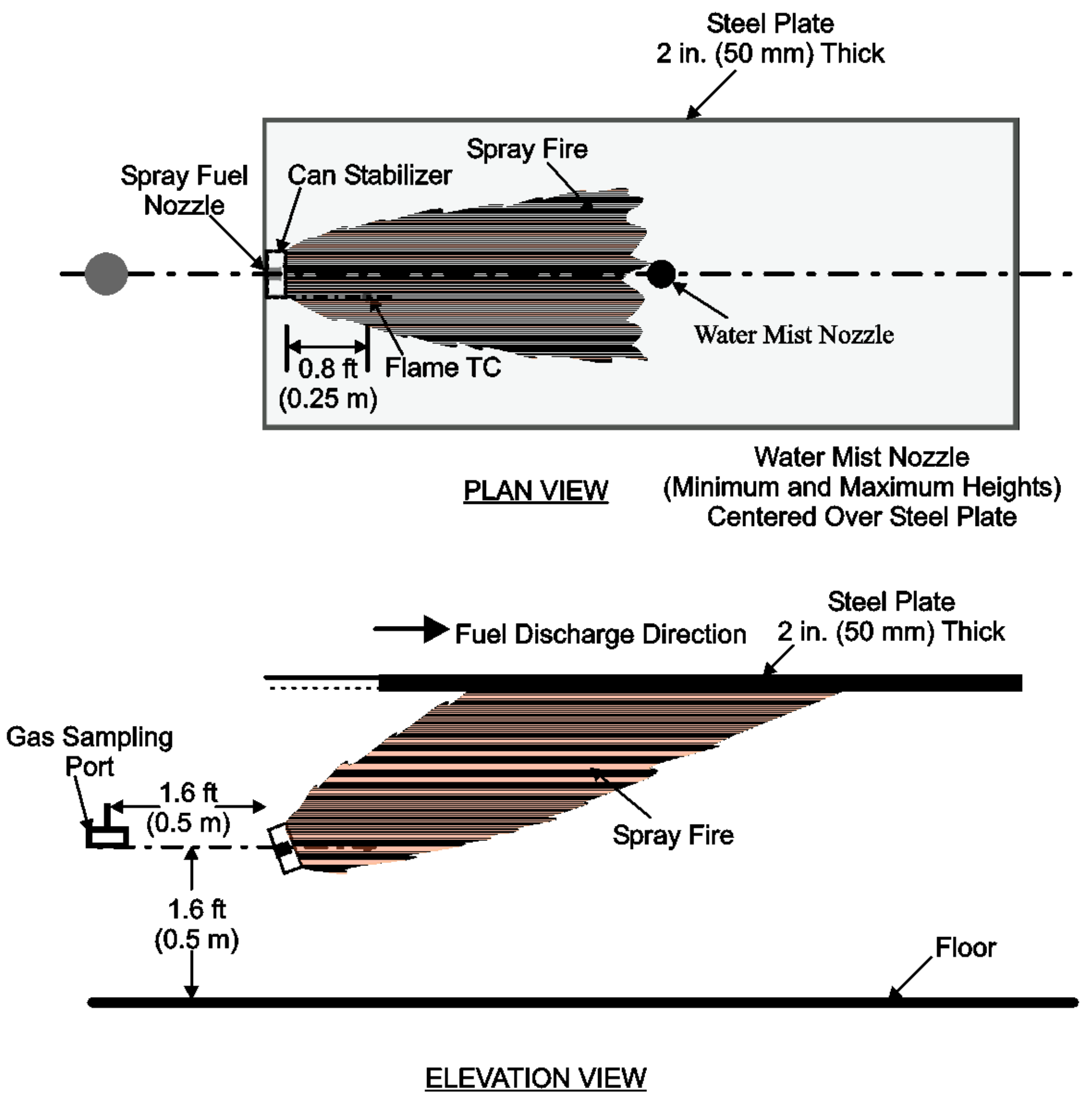


Figure B-4. Fire Source Configuration for Spray Cooling (No Fire) Testing

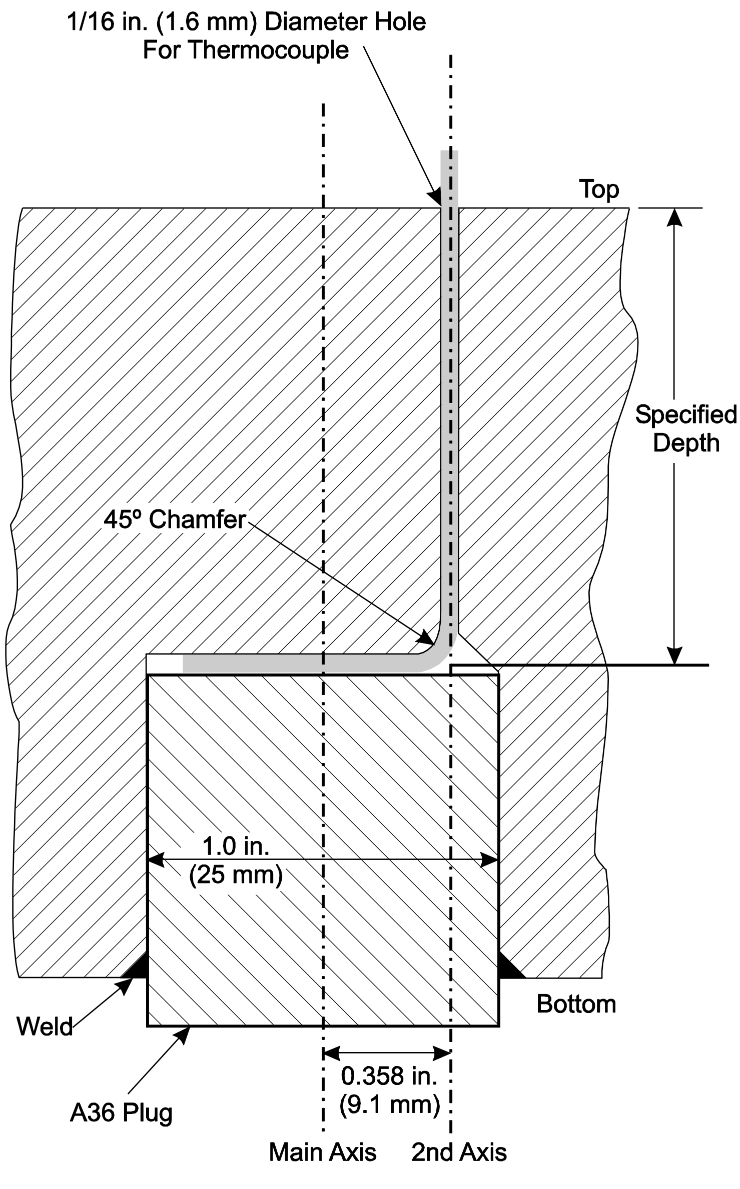


Figure B-5. Detail of Embedded Thermocouple for Spray Cooling Test

APPENDIX C: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF MACHINERY IN ENCLOSURES WITH VOLUMES NOT EXCEEDING 9175 FT^3 (260 M^3)

C.1 TEST ENCLOSURE (SEE FIGURE C-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.

C.2 MACHINERY EQUIPMENT MOCKUP

The machinery mockup is simulated with a horizontal flat steel table 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 mockup unit should be centered along the longer wall dimension in the test enclosure. The certification agency reserves the right to alter the placement of the mockup unit with respect to the aspect ratio of the enclosure.

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 mockup extends longitudinally the entire length of the enclosure (see Figure C-1). This is located in the center of the room or at a location within the test cell to be selected by the certification agency 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 water mist 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 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 the certification agency.

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 ± 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 ± 18 °F (20 °C ± 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 °F ± 18 °F (20 °C ± 10 °C).

D. Test enclosure temperatures measured in the center portion of the room at the 1/3, 2/3 and ceiling heights with 20 gauge Type K thermocouples. The enclosure and mockup shall initially be at an ambient temperature 68 °F ± 18 °F (20 °C ± 10 °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 °F (100 °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. Due to the size of the test fires relative to the volume of the enclosure, consideration to the oxygen concentration is critical to verify that the test fires have not been self extinguished. Oxygen should generally be no less than 16 percent during the entire period of each test.

J. For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

Fire Size	***1 MW Diesel Spray***	***2 MW Diesel Spray***
Spray Nozzle	Monarch F-80, 24.00, PLP	Monarch F-80, 50.00, PLP
Fuel Type	Diesel	Diesel
Nominal Oil Pressure	125 psi (8.6 bar)	125 psi (8.6 bar)
Nominal Fuel Flow	28 gal/hr (106 L/hr)	56 gal/hr (212 L/hr)
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 the certification agency.

Fire Size	***1 MW Heptane Spray***	***2 MW Heptane Spray***
Spray Nozzle	Monarch F-80, 24.00, PLP	Monarch F-80, 50.00, PLP
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 °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 the certification agency.

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.

C.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 water mist system shall successfully complete all ten 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 water mist 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 water mist 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 water mist 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 water mist 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 water mist 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^2 (1 m^2) Diesel Pool Fire

Criterion: The fire is to be extinguished.

Fuel:	Diesel
Type:	10.8 ft^2 (1.0 m^2) 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 water mist 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 mist 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. The system discharge should be shut off 45 seconds after extinguishment.

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 water mist 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 water mist 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 water mist 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 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 water mist 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 water mist 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^3 (130 m^3). 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^3 (130 m^3) 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.

C.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 water mist 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 water mist 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.4.7 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 water mist 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 water mist 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.4.8 Shielded 10.8 ft^2 (1 m^2) Heptane Pool Fire

Criterion:	The fire is to be extinguished.
Fuel:	Heptane
Type:	10.8 ft^2 (1.0 m^2) 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 water mist 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 mist 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. The system discharge should be shut off 45 seconds after extinguishment.

C.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 water mist 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 water mist 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 water mist 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.4.10 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 water mist 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 water mist 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^3 (130 m^3). 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^3 (130 m^3) 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.

C.4.11 Additional Fire Tests

Based on the results of Fire Tests C.4.1 through C.4.10, additional fire testing may be required to ensure that the water mist system being evaluated meets the intent of this section of the standard. This testing will be performed at the sole discretion of the certification agency.

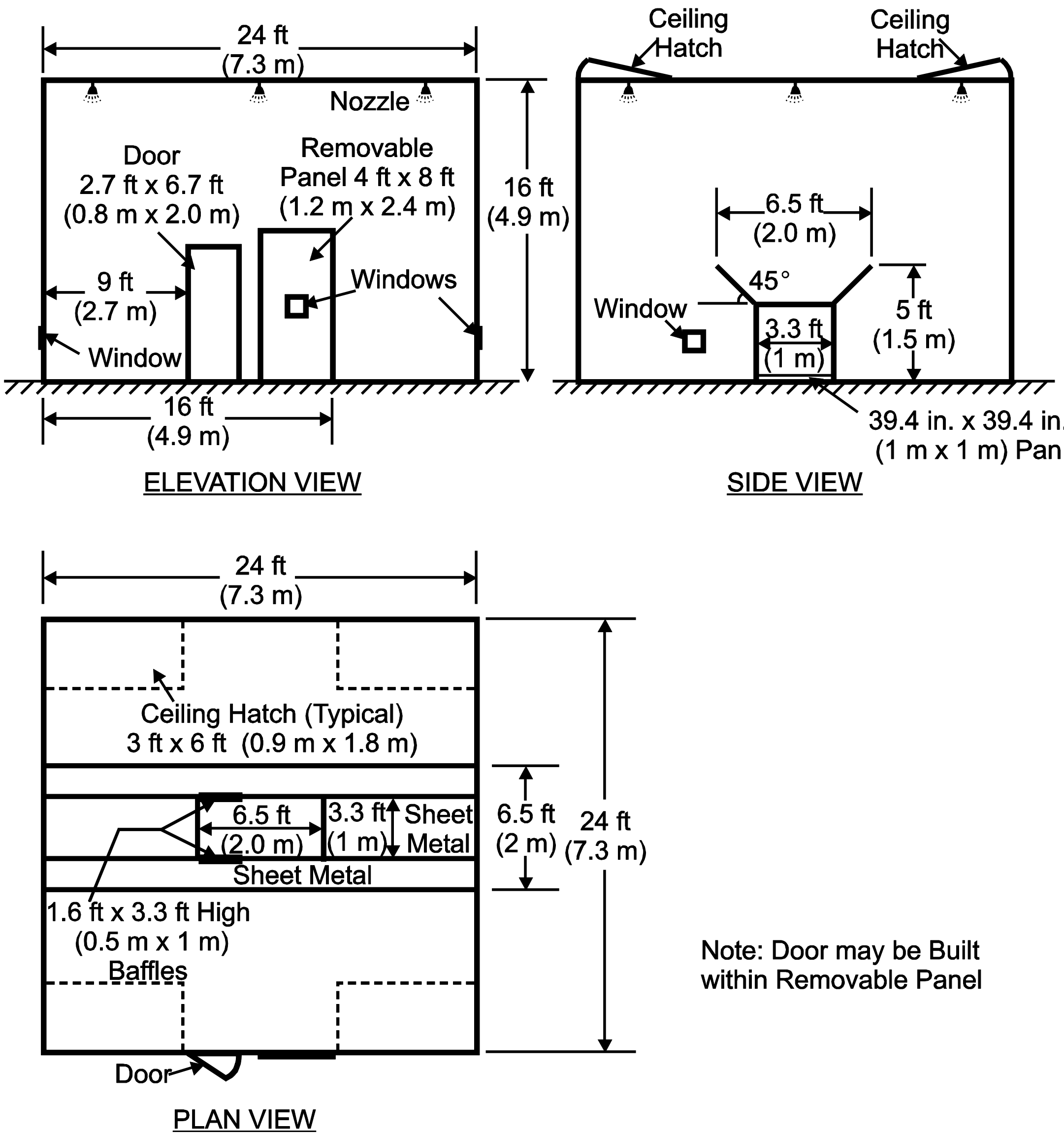


Figure C-1. Test Enclosure and Machinery Mockup Steel Plate

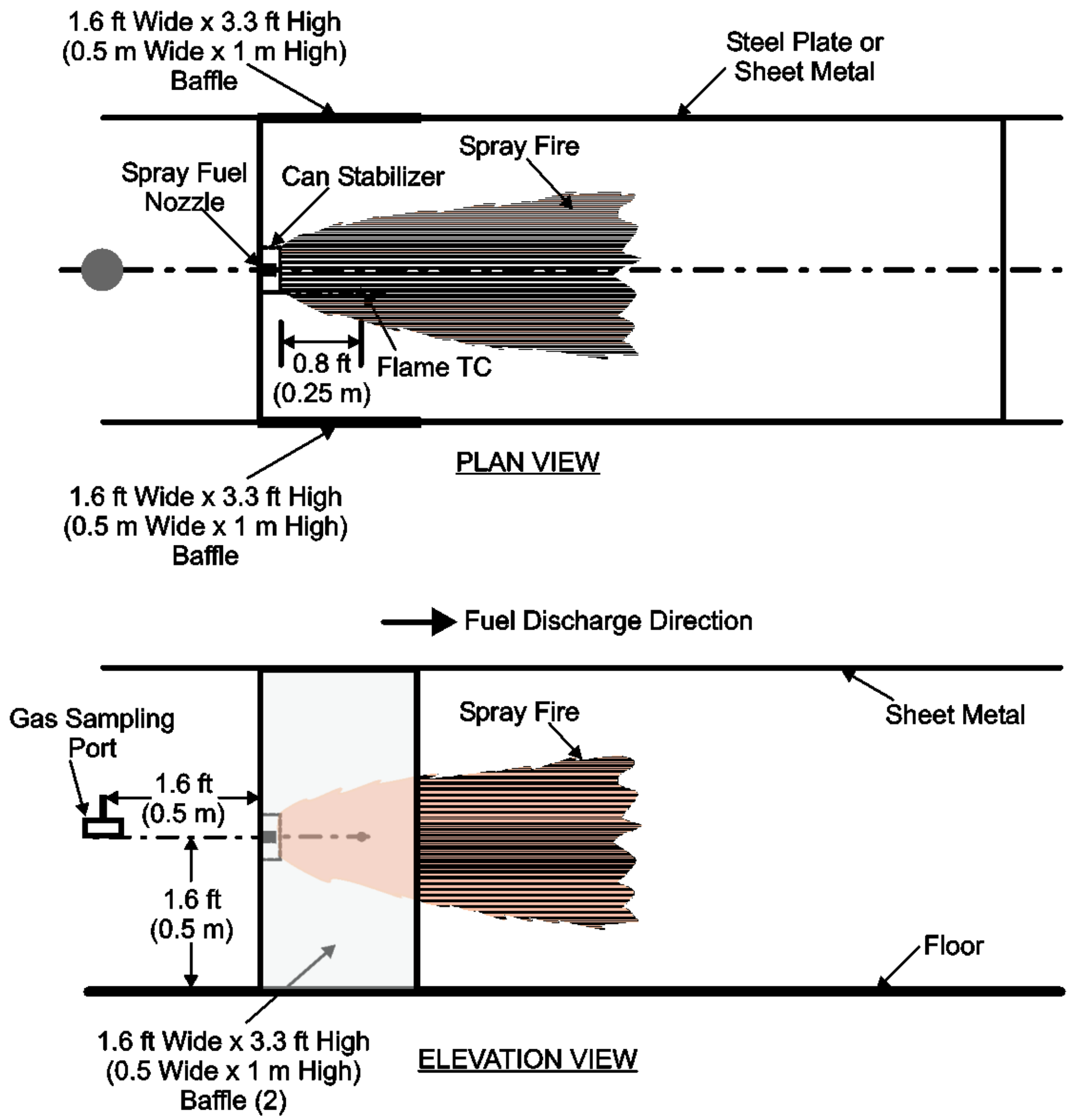


Figure C-2. Fire Source Configuration and Instrumentation for Shielded Spray Fire Testing

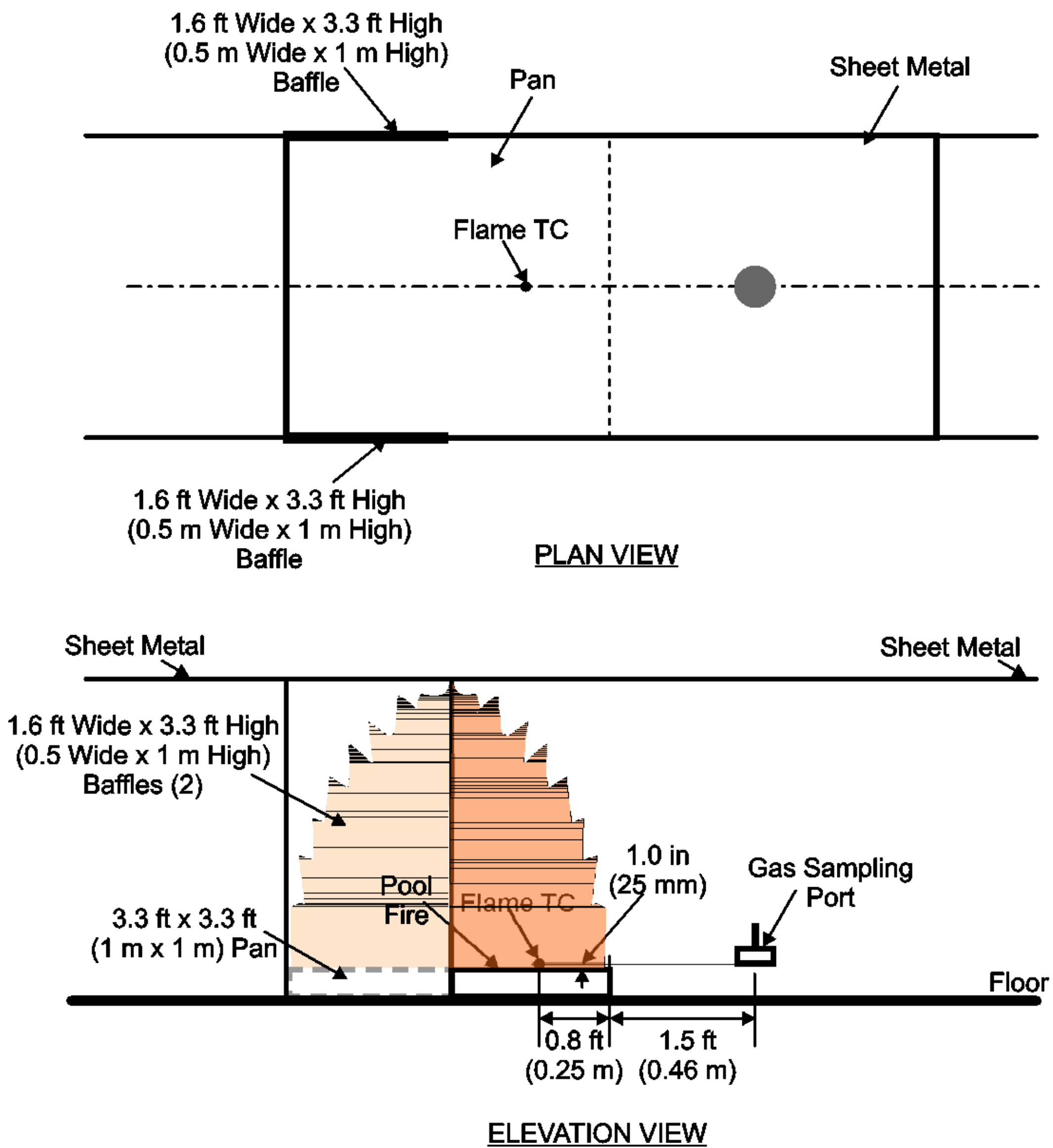


Figure C-3. Fire Source Configuration and Instrumentation for Shielded Pool Fire Testing

APPENDIX D: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF GAS TURBINES IN ENCLOSURES WITH VOLUMES NOT EXCEEDING 9175 FT^3 (260 M^3)

D.1 TEST ENCLOSURE (SEE FIGURE D-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.

D.2 GAS TURBINE MOCKUP

The gas turbine casing mockup is simulated with a horizontal flat steel plate 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 gas turbine mockup unit should be centered along the longer wall dimension in the test enclosure. The certification agency 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 the certification agency 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 gas turbine mockup extends longitudinally the entire length of the enclosure (see Figure D-1).

To determine the cooling rate of the gas turbine steel plate mockup, caused by the discharge of the water mist 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 D-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 water mist 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 the certification agency.

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 ± 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 ± 18 °F (20 °C ± 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 °F ± 18 °F (20 °C ± 10 °C).

D. Test enclosure temperatures measured in the center portion of the room at the 1/3, 2/3 and ceiling heights with 20 gauge Type K thermocouples. The enclosure and mockup shall initially be at an ambient temperature 68 °F ± 18 °F (20 °C ± 10 °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 °F (100 °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. Due to the size of the test fires relative to the volume of the enclosure, consideration to the oxygen concentration is critical to verify that the test fires have not been self extinguished. Oxygen should generally be no less than 16 percent during the entire period of each test.

J. For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

Fire Size	***1 MW Diesel Spray***	***2 MW Diesel Spray***
Spray Nozzle	Monarch F-80, 24.00, PLP	Monarch F-80, 50.00, PLP
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 the certification agency.

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. (0.3 m) wide by 12 in. (0.3 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^3 (96 to 128 kg/m^3). 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.

D.4 FIRE TESTS

Intermediate pendent or upright nozzles that are not at ceiling level, or wall mounted nozzles, are permitted for the protection of gas turbines.

The water mist 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 water mist system shall successfully complete the first five (D.4.1 through D.4.5) fire performance tests and the Spray Cooling (heat transfer) test (D.4.6). An additional option for gas turbine applications is the protection of insulated turbines. Two additional fires tests (D.4.7 and D.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 water mist 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 water mist 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 water mist 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 water mist 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 water mist 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^2 (1 m^2) Diesel Pool Fire

Criterion:	The fire is to be extinguished.
Fuel:	Diesel
Type:	10.8 ft^2 (1.0 m^2) 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 water mist 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 mist 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. The system discharge should be shut off 45 seconds after extinguishment.

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 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 water mist 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 water mist 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 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 water mist 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^3 (130 m^3). 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^3 (130 m^3) 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 Spray Cooling (No Fire)

Criteria:	The heat flux resulting from a water mist system discharge shall not adversely affect the turbine. Such assessment is to be made in accordance with methodology developed by the certification agency to measure the damage potential of fire extinguishing systems. This test, combined with heat transfer calculations, will determine the extent of the cooling of the turbine casing during the operation of the water mist system. Calculations should be based on the manufacturer's recommended turbine size (diameter) to be installed within the enclosure and/or water mist 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 water mist 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 D-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 the certification agency 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 water mist 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.

D.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 water mist 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^2 (0.1 m^2) 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 water mist 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.

D.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^2 (1.0 m^2) 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 water mist 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^2 (1.0 m^2) 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 water mist system should be activated 30 seconds after the insulation mat fire is fully developed over the entire area of the mat.

D.4.9 Additional Fire Tests

Based on the results of Fire Tests D.4.1 through D.4.8, additional fire testing may be required to ensure that the water mist system being evaluated meets the intent of this section of the standard. This testing will be performed at the sole discretion of the certification agency.

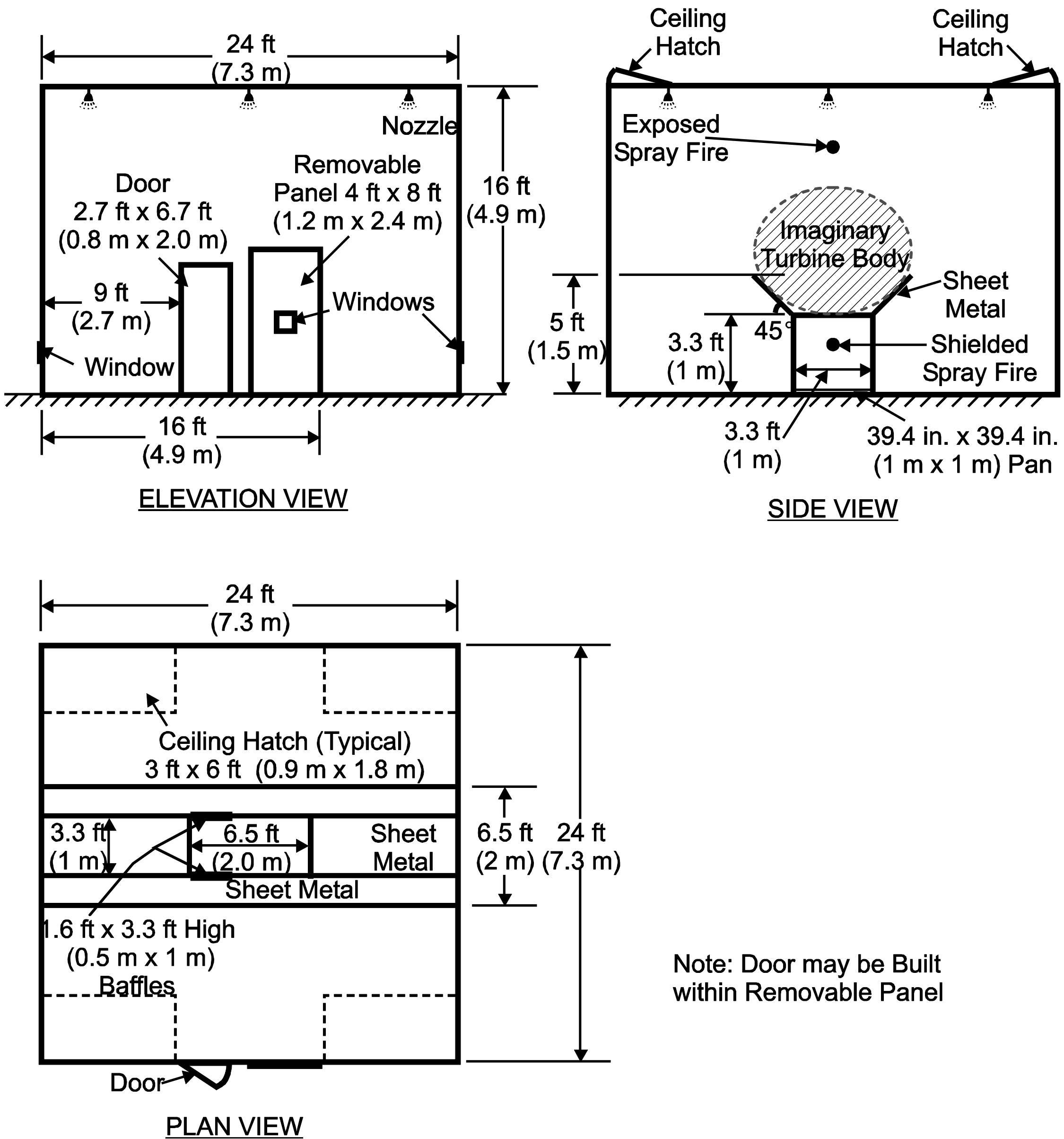


Figure D-1. Test Enclosure and Gas Turbine Simulator Steel Plate

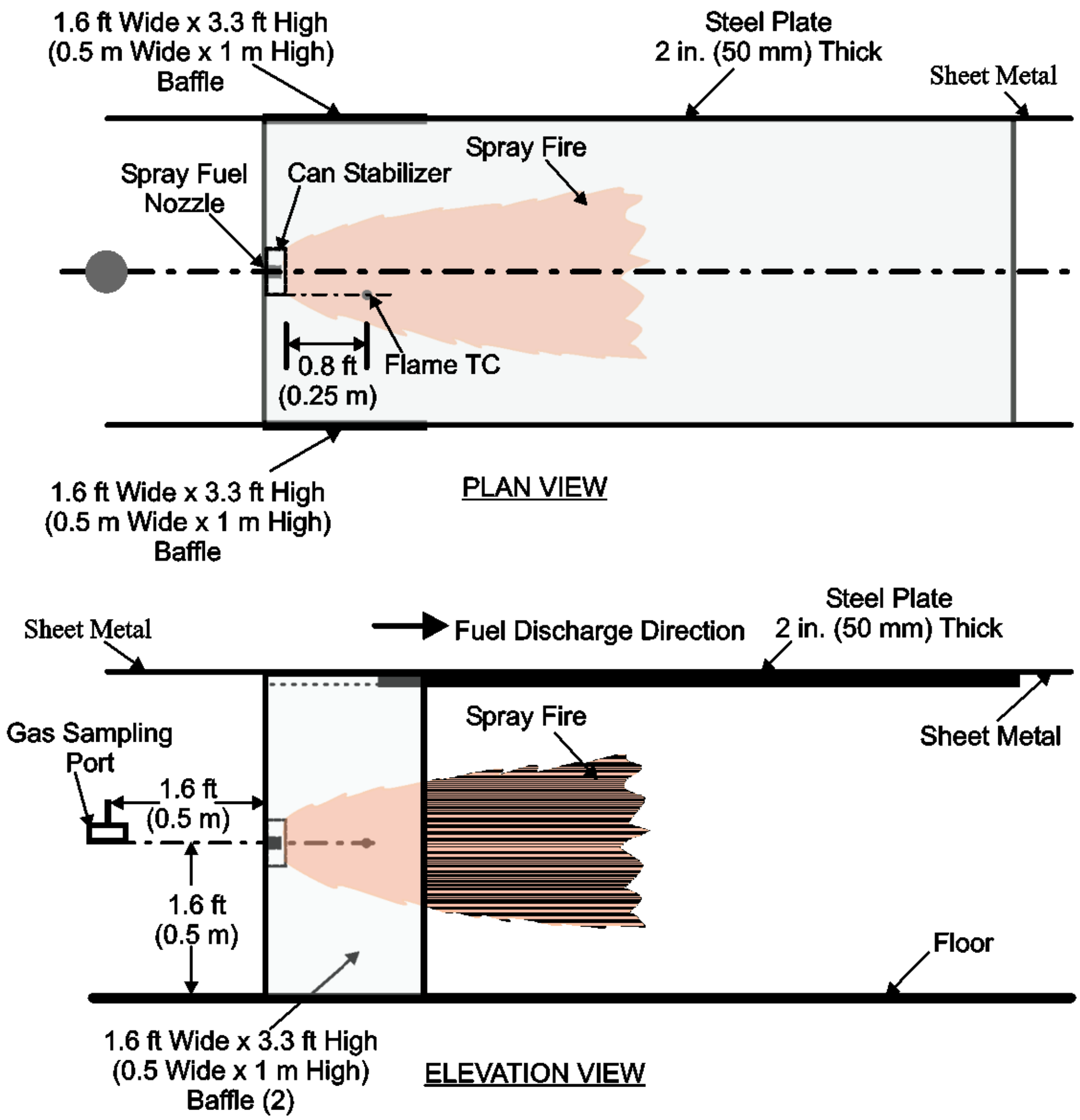


Figure D-2. Fire Source Configuration and Instrumentation for Shielded Spray Fire Testing

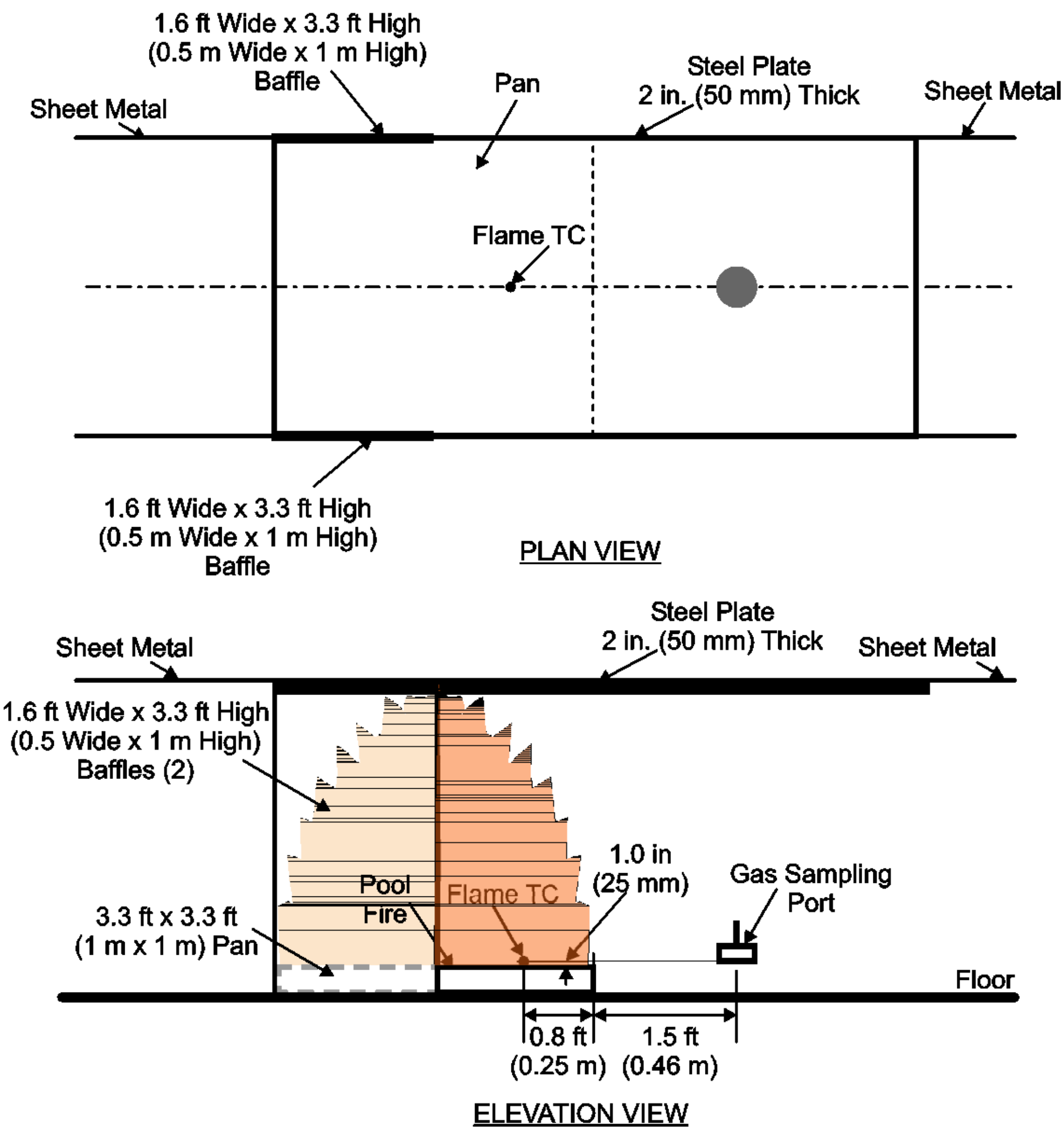


Figure D-3. Fire Source Configuration and Instrumentation for Shielded Pool Fire Testing

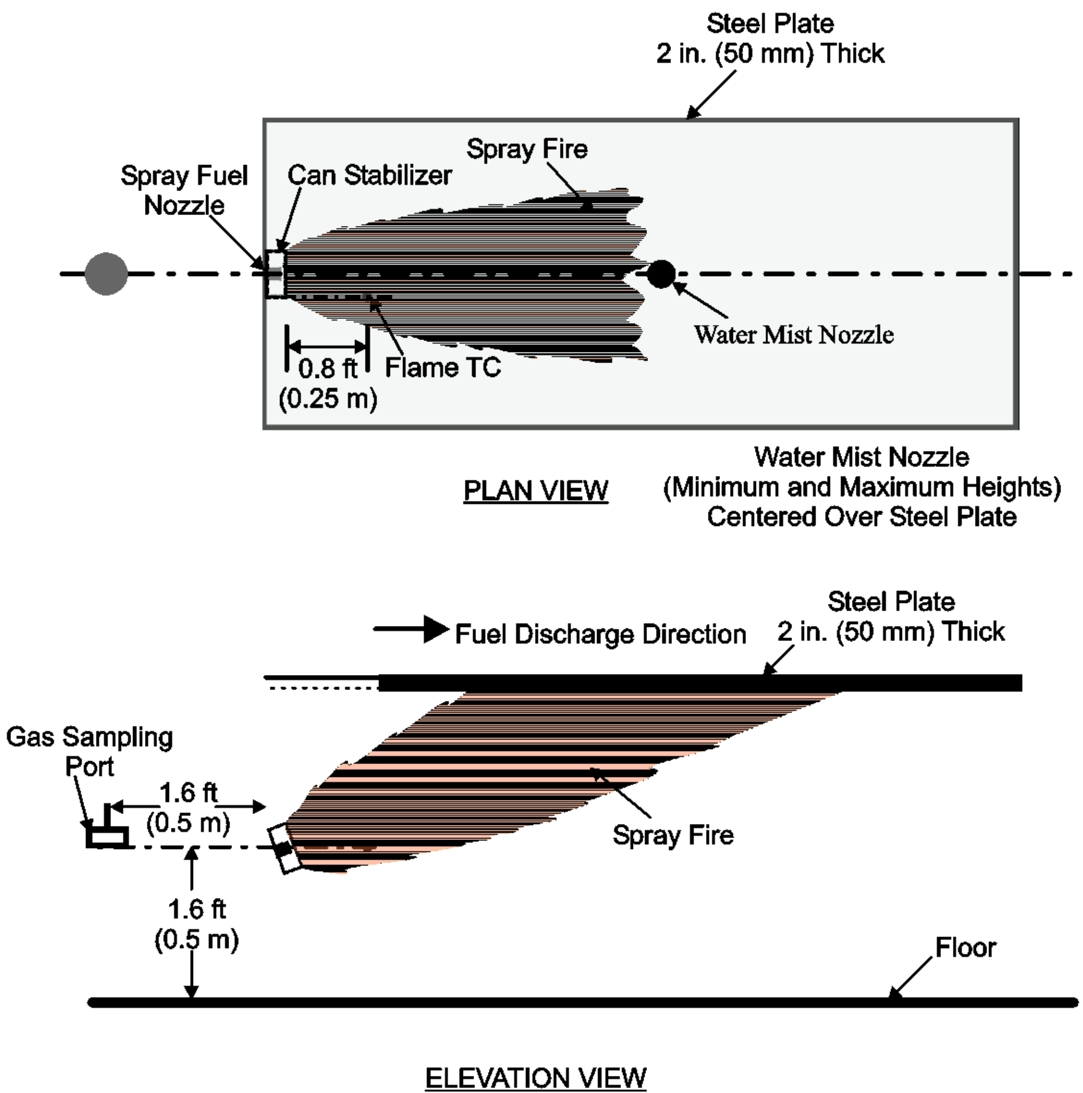


Figure D-4. Fire Source Configuration for Spray Cooling (No Fire) Testing

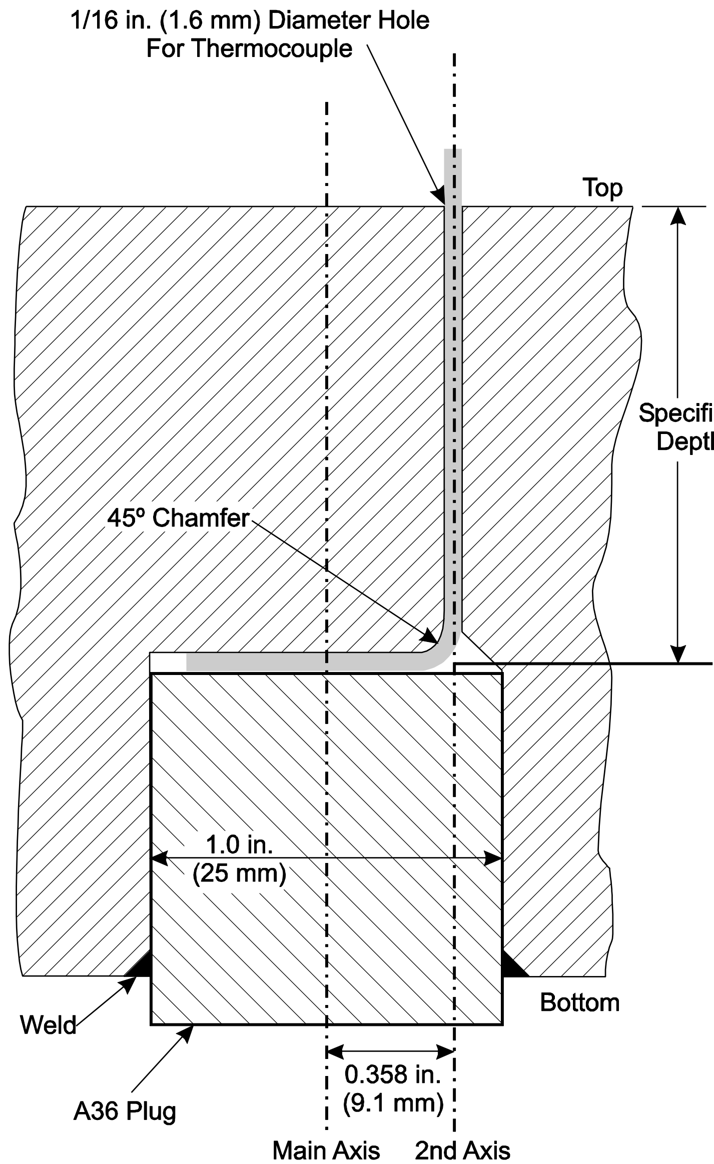


Figure D-5. Detail of Embedded Thermocouple for Spray Cooling Test

APPENDIX E: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF MACHINERY IN ENCLOSURES WITH VOLUMES EXCEEDING 9175 FT^3 (260 M^3)

E.1 TEST ENCLOSURE (SEE FIGURE E-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. The certification agency may restrict the scope of the certification to a limited range of aspect ratios depending on the outcome of the fire tests conducted in non-symmetric enclosures. The maximum enclosure height (as specified by the manufacturer) shall be tested. Enclosure heights shall be in 1 ft (0.3 m) increments. 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, the certification agency 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 the certification agency, additional fire tests in smaller enclosures may be performed to validate the manufacturer's scaling parameters.

E.2 MACHINERY MOCKUP UNIT (SEE FIGURES E-2 AND E-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 the certification agency.

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 E-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^2 by 10 in. high (4 m^2 by 25.4 cm high) square pan should be located underneath the floor plate system.

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 ± 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 ± 18 °F (20 °C ± 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 °F ± 18 °F (20 °C ± 10 °C).

D. Test enclosure temperatures measured in the center portion of the room at the 1/3, 2/3 and ceiling heights with 20 gauge Type K thermocouples. The enclosure shall initially be at an ambient temperature 68 °F ± 18 °F (20 °C ± 10 °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 °F ± 18 °F (20 °C ± 10 °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 °F (100 °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. Due to the size of the test fires relative to the volume of the enclosure, consideration to the oxygen concentration is critical to verify that the test fires have not been self extinguished. Oxygen should generally be no less than 16 percent during the entire period of each test.

L. For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

Fire Type	***Low Pressure***	***Low Pressure – Low Flow***	***High Pressure***
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 the certification agency.

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. (0.3 m) wide by 12 in. (0.3 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.

E.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 water mist 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 water mist 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 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 E-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 water mist 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 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 0.6 in. (15 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 E-3 and E-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 water mist 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 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 E-2 and E-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 water mist 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.4.4 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 E-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 water mist 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 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^2 (0.1 m^2) 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 E-2 and E-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 water mist 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.

E.4.6 Concealed, Heptane Pool Fire

Criterion:	Suppression of the pool fire

Fuel:	Heptane
Type:	10.8 ft^2 (1 m^2) 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 E-2).
Fire Preburn Time:	15 seconds
Test Procedure:	The pool fire shall be ignited, and the water mist system should be activated subsequent to the required preburn time. The system discharge should be shut off 45 seconds after extinguishment. 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.4.7 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 water mist system should be activated subsequent to the required preburn time. The fuel flow should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel flow is shut off.

E.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 E-1). The crib should be placed in the center of the 21.5 ft^2 (2 m^2) 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 water mist system should be activated subsequent to the required preburn time. The system discharge should be shut off 45 seconds after extinguishment. 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.4.9 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 water mist system being evaluated meets the intent of this section of the standard. This testing will be performed at the sole discretion of the certification agency.

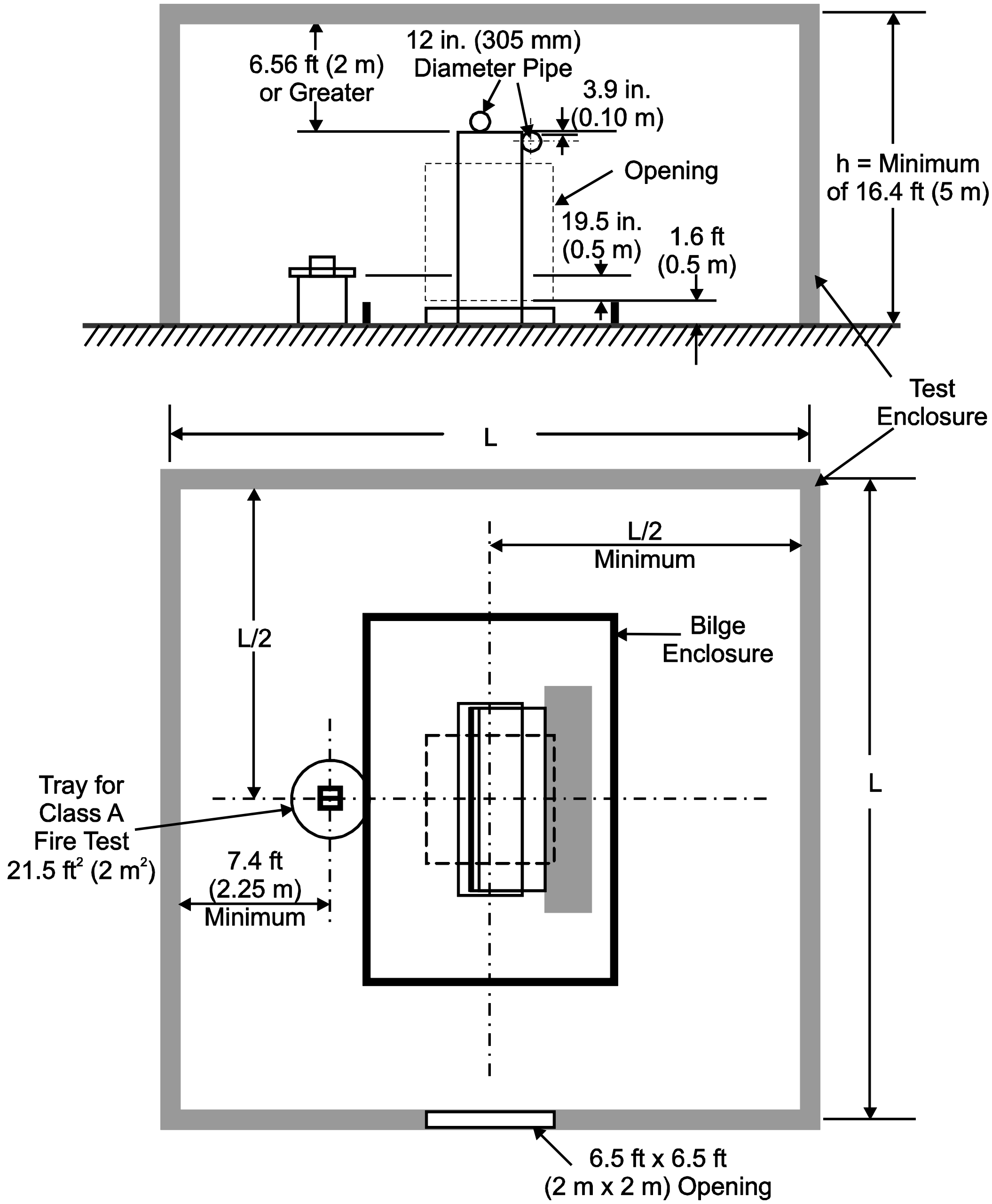


Figure E-1. Test Enclosure

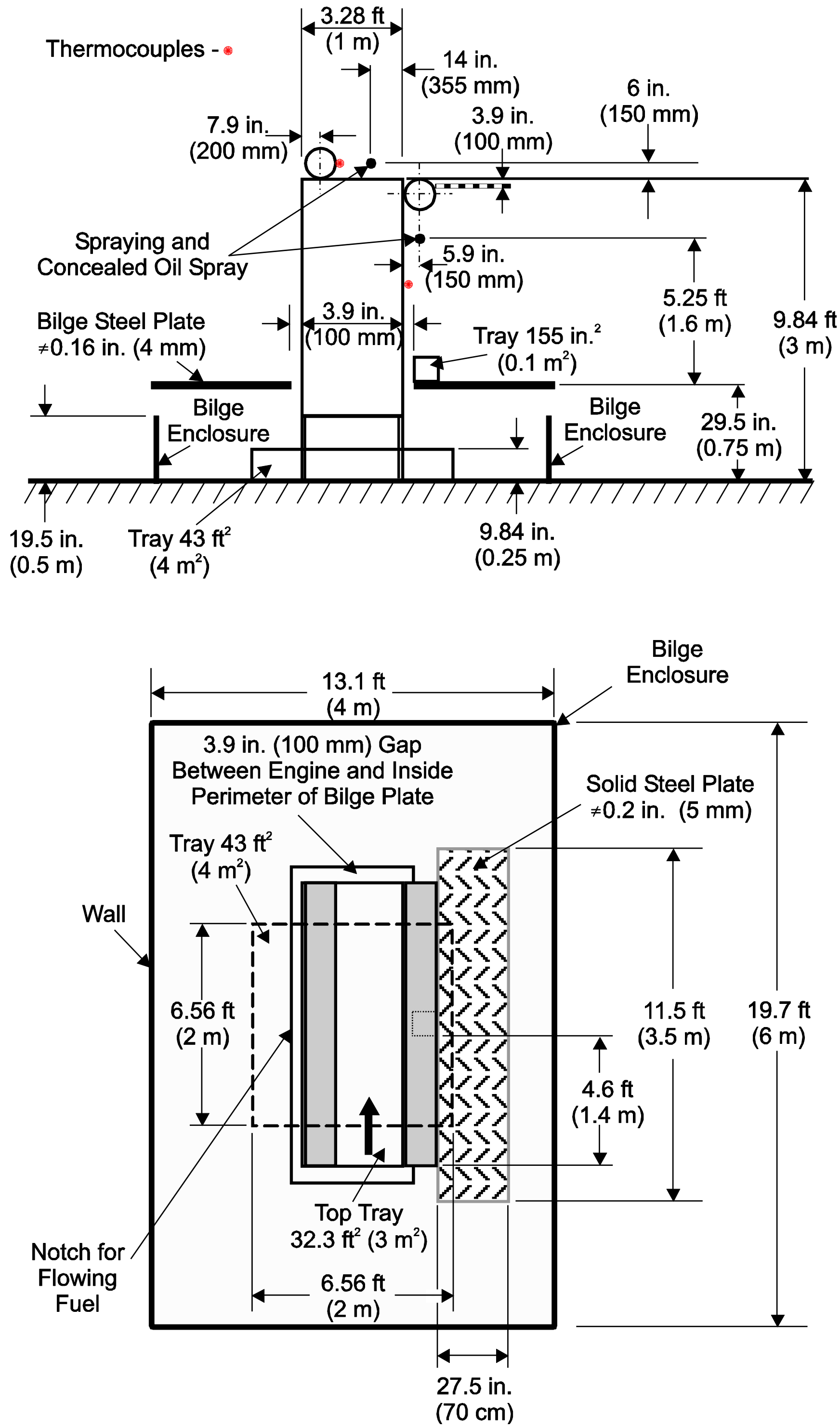


Figure E-2. Machinery Mockup Unit

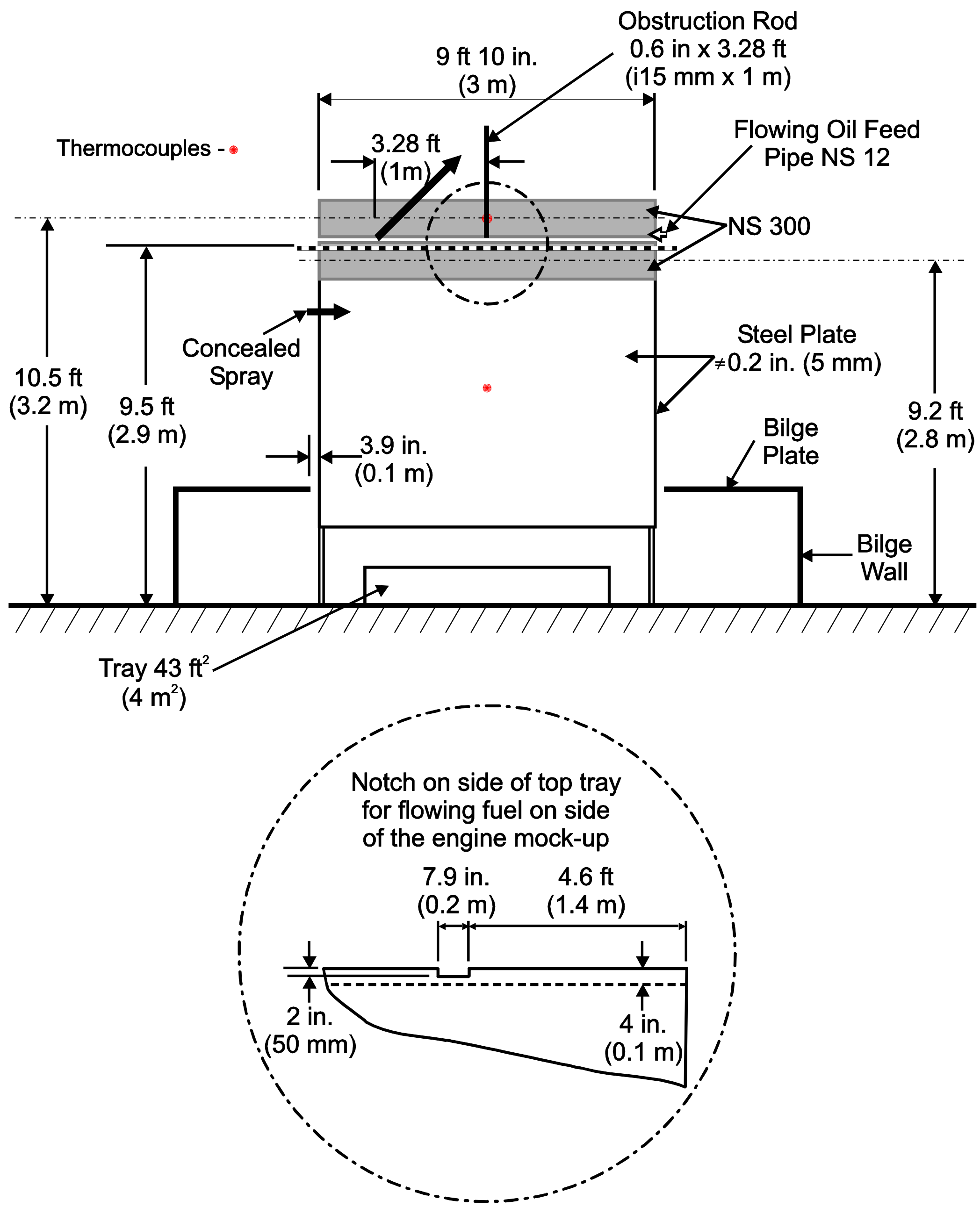


Figure E-3. Machinery Mockup Unit (Continued)

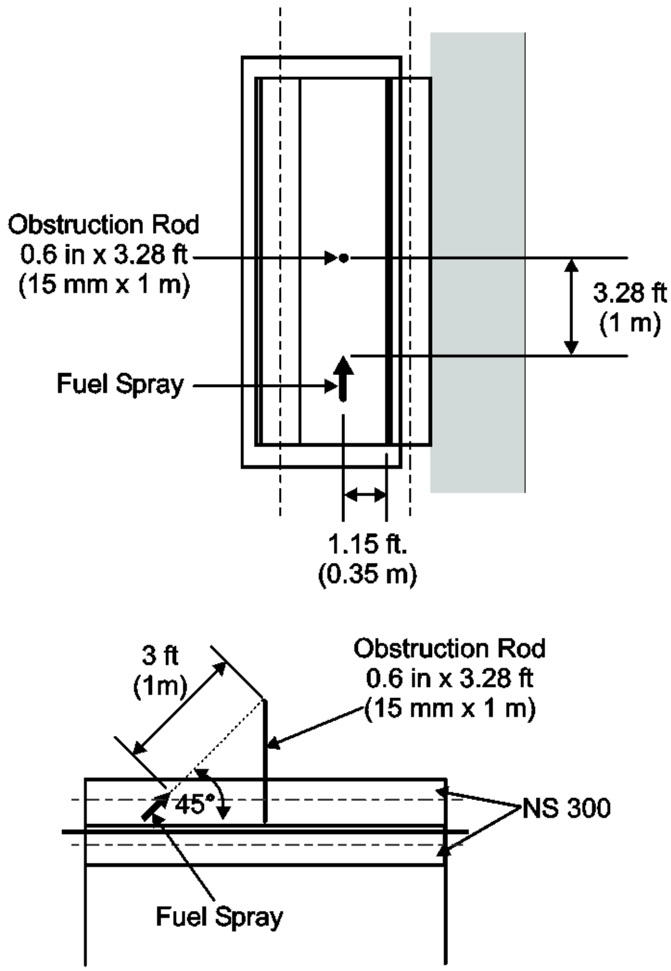


Figure E-4. Fire Test E.5.2, Position of Fuel Spray Nozzle and Obstruction Rod

APPENDIX F: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF GAS TURBINES IN ENCLOSURES WITH VOLUMES EXCEEDING 9175 FT^3 (260 M^3)

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. The certification agency may restrict the scope of the certification to a limited range of aspect ratios depending on the outcome of the fire tests conducted in non-symmetric enclosures. The maximum enclosure height (as specified by the manufacturer) shall be tested. Enclosure heights shall be in 1 ft (0.3 m) increments. 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 gas turbine and engine mockup unit should be centered in the test enclosure. In the case of rectangular enclosures, the certification agency reserves the right to alter the placement of the mockup unit based on the aspect ratio of the enclosure.

At the sole discretion of the certification agency, additional fire tests in smaller enclosures may be performed to validate the manufacturer's scaling parameters.

F.2 GAS TURBINE AND ENGINE MOCKUP UNIT (SEE FIGURES F-2 AND F-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 the certification agency.

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 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^2 by 10 in. high (4 m^2 by 25.4 cm high) square pan should be located underneath the floor plate system.

F.3 GAS TURBINE SPRAY COOLING MOCKUP UNIT (SEE FIGURE F-5)

The gas turbine casing mockup is simulated with a horizontal flat steel plate (see Figure F-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 the certification agency 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 gas turbine steel plate mockup, caused by the discharge of the water mist 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 F-6).

F.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 ± 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 ± 18 °F (20 °C ± 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 °F ± 18 °F (20 °C ± 10 °C).

D Test enclosure temperatures measured in the center portion of the room at the 1/3, 2/3 and ceiling heights with 20 gauge Type K thermocouples. The enclosure shall initially be at an ambient temperature 68 °F ± 18 °F (20 °C ± 10 °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 °F ± 18 °F (20 °C ± 10 °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 °F (100 °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. Due to the size of the test fires relative to the volume of the enclosure, consideration to the oxygen concentration is critical to verify that the test fires have not been self extinguished. Oxygen should generally be no less than 16 percent during the entire period of each test.

L For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

Fire Type	***Low Pressure***	***Low Pressure – Low Flow***	***High Pressure***
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 the certification agency.

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. (0.3 m) wide by 12 in. (0.3 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^3 (96 to 128 kg/m^3). 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.

F.5 FIRE TESTS

Intermediate pendent or upright nozzles that are not at ceiling level, or wall mounted nozzles, are permitted for the protection of gas turbines.

The water mist 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 water mist system shall successfully complete the first eight (F.5.1 through F.5.8) fire performance tests and the Spray Cooling (heat transfer) test (F.5.9). An additional option for gas turbine applications is the protection of insulated turbines. Two additional fire tests (F.5.10 and F.5.11), 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 water mist 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.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 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 water mist 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.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 0.6 in. (15 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 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 water mist 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.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 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 water mist 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.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 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 water mist 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.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^2 (0.1 m^2) 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 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 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 water mist 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.5.6 Concealed, Heptane Pool Fire

Criterion:	Suppression of the pool fire
Fuel:	Heptane
Type:	10.8 ft^2 (1 m^2) 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 water mist system should be activated subsequent to the required preburn time. The system discharge should be shut off 45 seconds after extinguishment. 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.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 water mist system should be activated subsequent to the required preburn time. The fuel flow should be shut off 15 seconds after the fire extinguishment. The system discharge should be shut off 45 seconds after the fuel flow is shut off.

F.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 F-1). The crib should be placed in the center of the 21.5 ft^2 (2 m^2) 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 water mist system should be activated subsequent to the required preburn time. The system discharge should be shut off 45 seconds after extinguishment. 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.5.9 Spray Cooling (No Fire)

Criteria: The heat flux resulting from a water mist system discharge shall not adversely affect the turbine. Such assessment is to be made in accordance with methodology developed by the certification agency to assess the damage potential of water mist systems. This test, combined with the heat transfer calculations, will determine the extent of the cooling of the turbine casing during the operation of the water mist system. Calculations should be based on the manufacturer's recommended turbine size (diameter) to be installed within the enclosure and/or water mist 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 water mist 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 F-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 the certification agency 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 water mist 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.

F.5.10 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 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 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 F-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^2 (0.1 m^2) 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 water mist 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.

F.5.11 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^2 (1 m^2) 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 F-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^2 (1 m^2) 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 water mist system should be activated 120 seconds after the insulation mat fire is fully developed over the entire area of the mat.

F.5.12 Additional Fire Tests

Based on the results of Fire Tests F.5.1 through F.5.11, additional fire testing may be required to ensure that the water mist system being evaluated meets the intent of this section of the standard. This testing will be performed at the sole discretion of the certification agency.

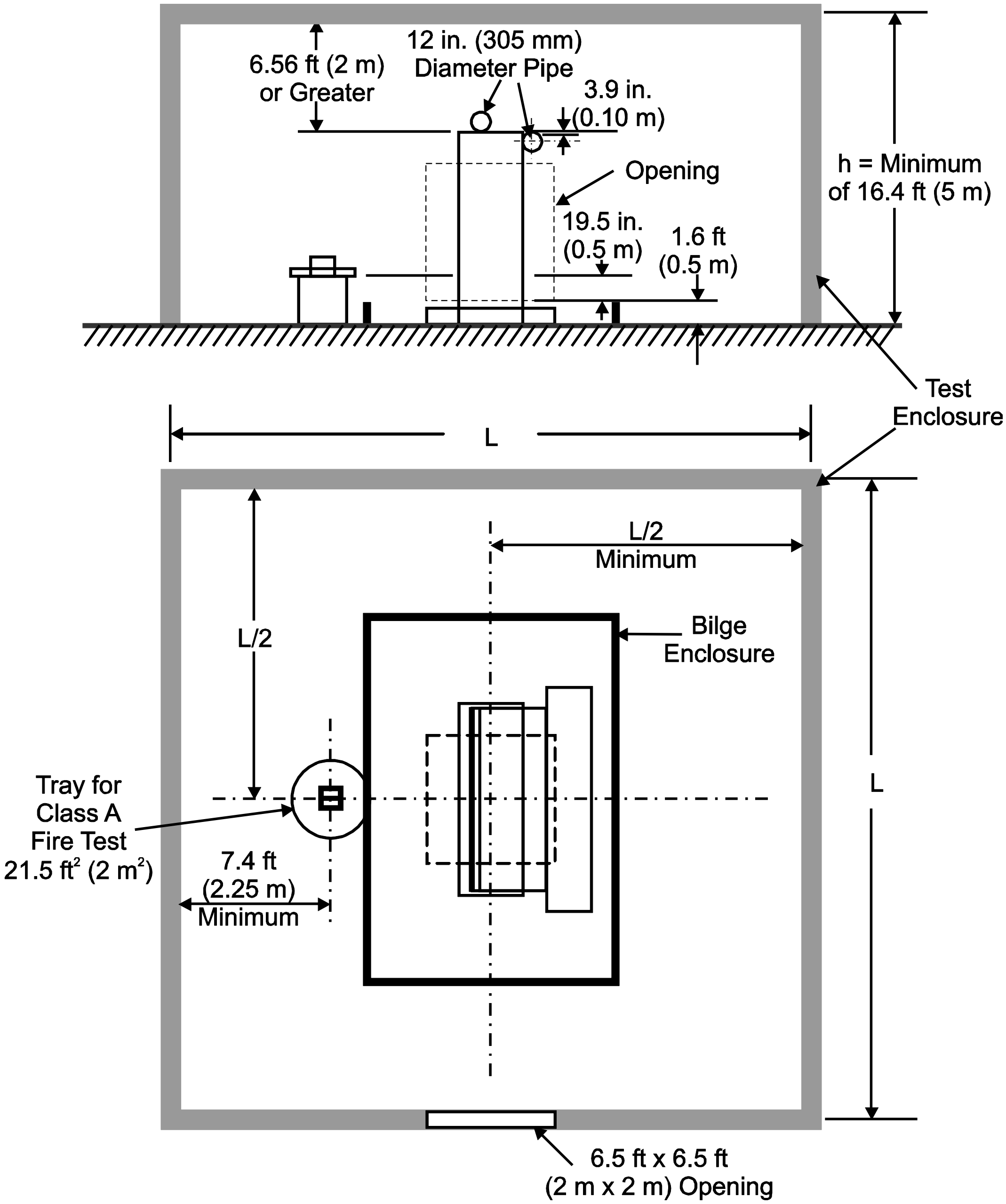


Figure F-1. Machinery and Gas Turbine Test Enclosure

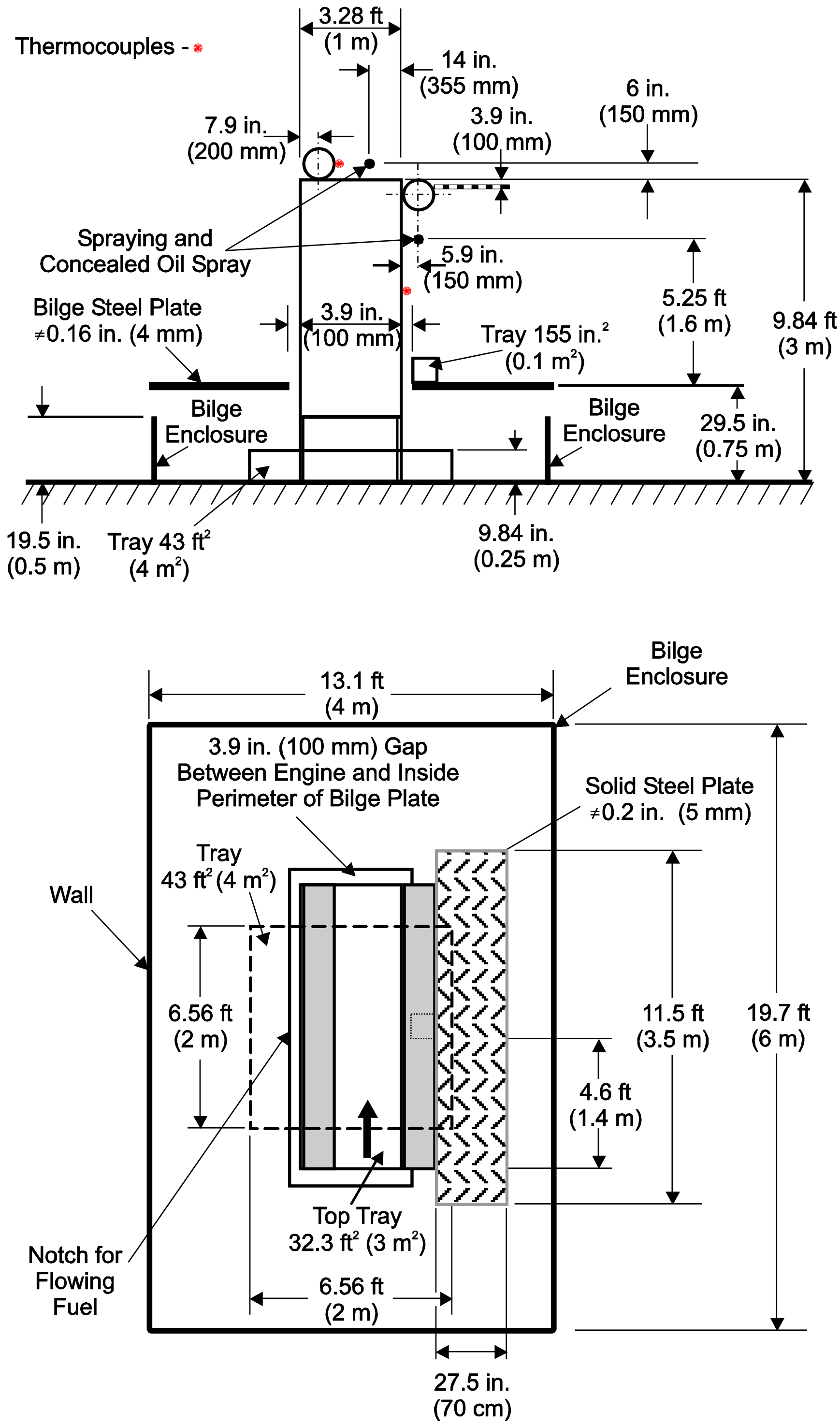


Figure F-2. Machinery and Gas Turbine Mockup Unit

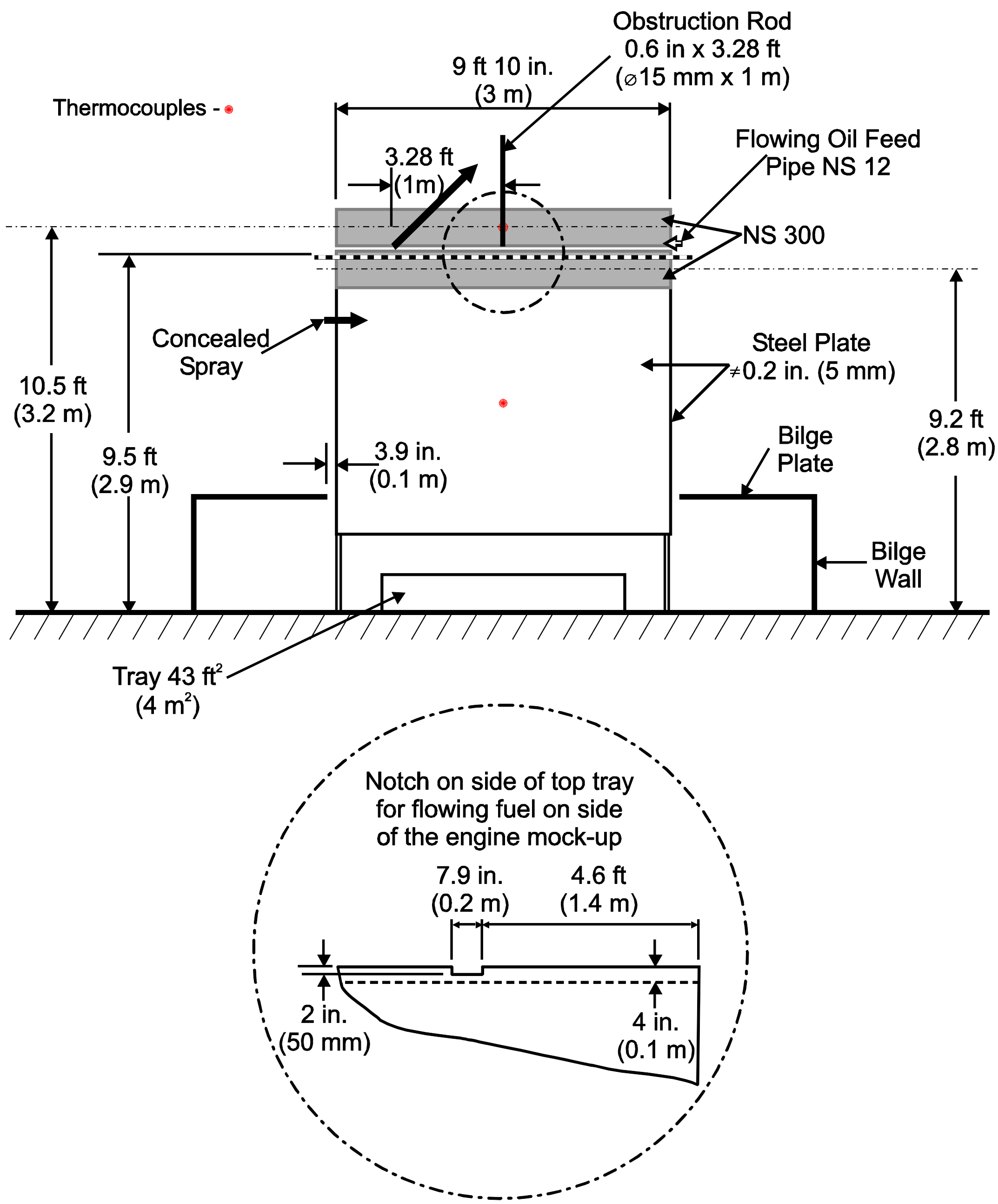


Figure F-3. Machinery and Gas Turbine Mockup Unit (Continued)

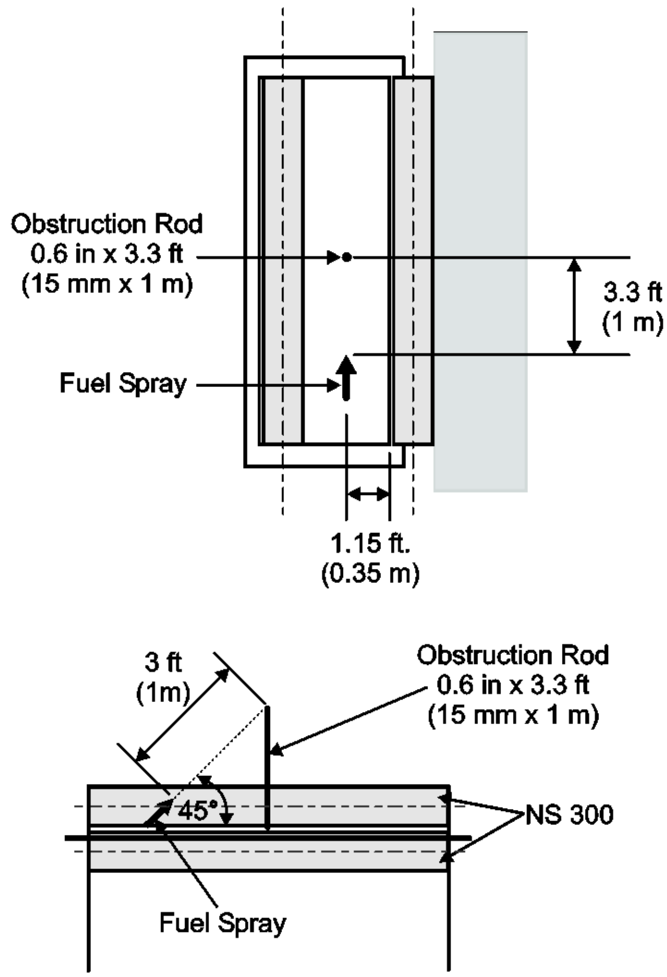


Figure F-4. Fire Test F.5.2, Position of Fuel Spray Nozzle and Obstruction Rod

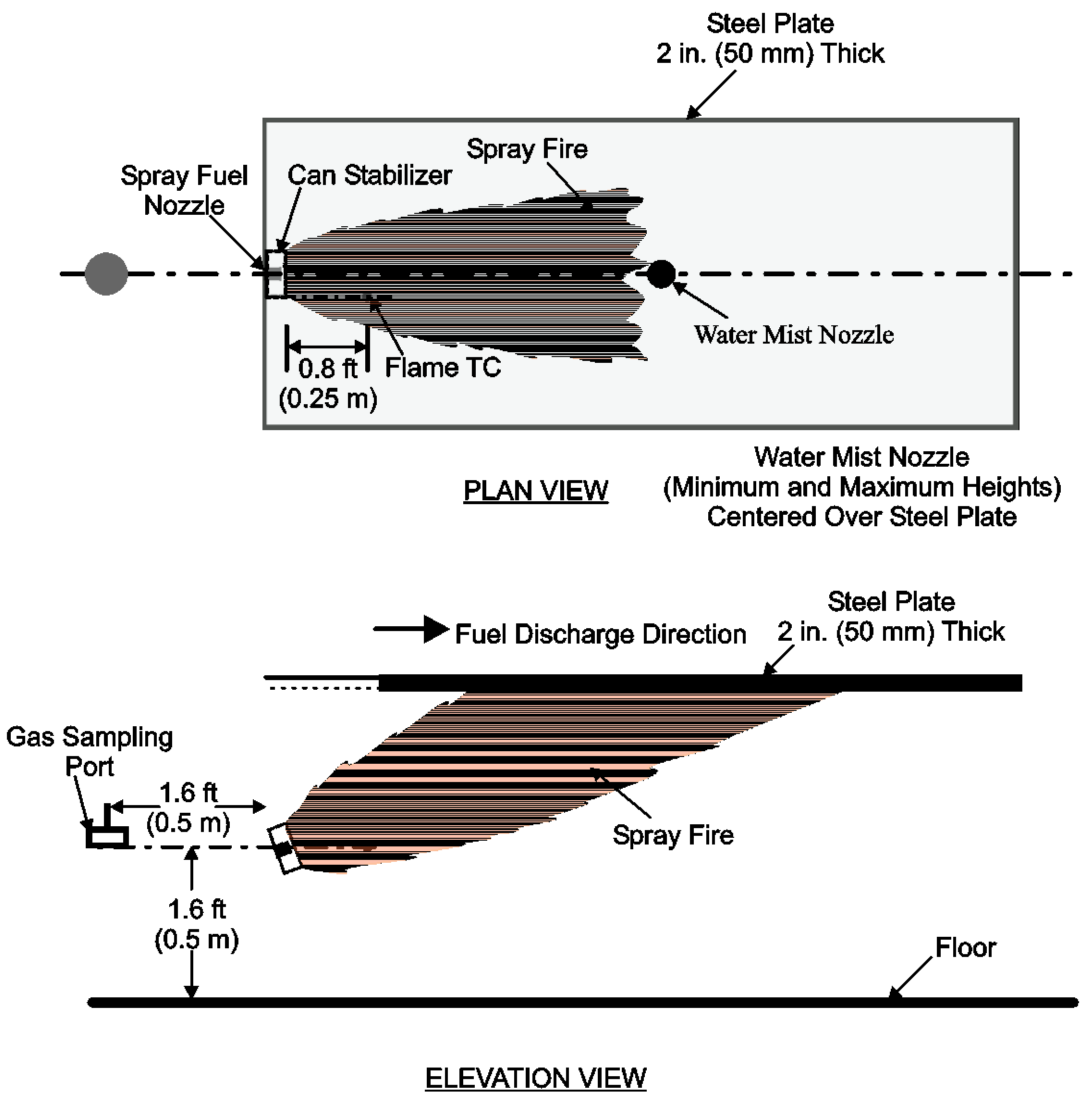


Figure F-5. Fire Source Configuration for Spray Cooling (No Fire) Testing

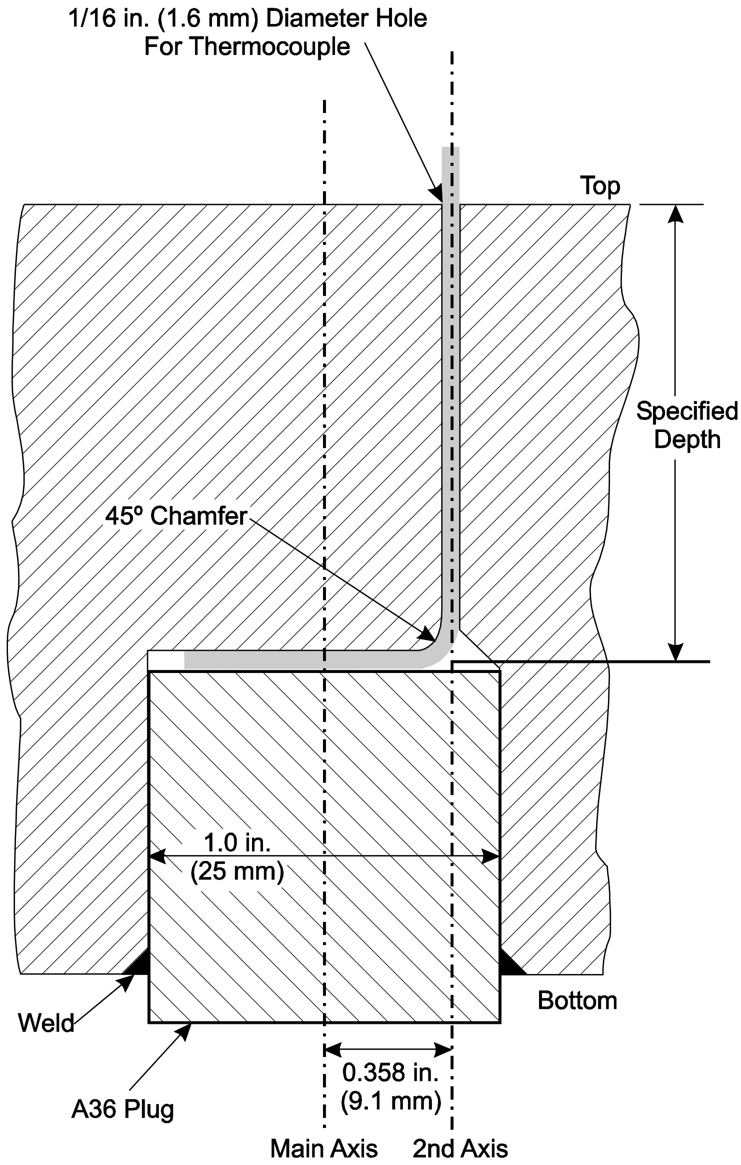


Figure F-6. Detail of Embedded Thermocouple for Spray Cooling Test

APPENDIX G: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF NON-STORAGE OCCUPANCIES, HAZARD CATEGORY 1 (HC-1) [FORMERLY LIGHT HAZARD OCCUPANCIES]

G.1 GENERAL TESTING REQUIREMENTS

In addition to the instrumentation and test requirements described previously under "General Instrumentation and Test Equipment Requirements," the following criteria shall be met:

A. The manufacturer shall provide the certification agency with design, installation, operation, and maintenance manuals for the complete water mist system. The design manual shall describe in detail the scaling parameters required for different room configurations. The same nozzle design shall be used for all required fire tests.

B. The individual nozzles shall include either a fusible or glass bulb assembly and meet quick response nozzle criteria (refer to Sections 4.2.26 to 4.2.28). The heat responsive element and temperature rating of the nozzles used in all fire tests shall be identical. The nominal operating temperature of the nozzle shall not exceed 225°F (107°C).

EXCEPTION: If requested by the manufacturer, and at the sole discretion of the certification agency, the fire test protocol may be conducted using nozzles having the highest nominal temperature rating for the small compartment and open space tests, and a combination of nozzles having the lowest and highest nominal temperature ratings for the large compartment test. Refer to Sections G.2.2, G.4.1, and G.4.3 through G.4.5 for additional information.

C. The maximum nozzle spacing, not to exceed 16.4 ft (5 m), as specified by the manufacturer, shall be used for all tests with the exception of Fire Test G.4.1. This includes the maximum spacing of the nozzles from the walls which shall be one-half the nozzle spacing.

D. The corridor nozzles shall be installed at the maximum spacing, not to exceed 16.4 ft (5 m), as specified by the manufacturer, at an equal distance from the centerline of the small compartment doorway.

E. Certification Options

1. Restricted Certification
   A water mist system shall successfully complete fire tests G.4.1 and G.4.2 for certification in restricted areas. Restricted certification may apply to water mist systems using upright, pendent, or sidewall nozzles, including flush, recessed, and concealed pendent and sidewall nozzles.
2. Unrestricted Certification
   A water mist system evaluated for unrestricted areas shall successfully complete all five fire performance tests, G.4.1 through G.4.5. Unrestricted certification may apply to water mist systems using upright or pendent nozzles, including flush, recessed, and concealed pendent nozzles. Unrestricted certification is not permitted for water mist systems using sidewall nozzles.

F. System components, component locations, and operating conditions shall remain unaltered throughout all of the fire tests, and the system shall operate without manual intervention. All fire tests shall be conducted using the spray specifications from the manufacturer's design manual in regard to nozzle placement, spray flux, and spray duration.

G. All fire tests shall be conducted for 10 minutes after the activation of the first nozzle. After this 10 minute period, any remaining fire should be extinguished manually.

H. For all fire tests, the system should be:

1. Pressurized to the minimum operating pressure specified by the manufacturer. Following activation of the first nozzle, the flowing water pressure should be maintained at the minimum system operating pressure; or

2. Pressurized to the minimum stand-by pressure specified by the manufacturer. Following activation of the first nozzle, the flowing water pressure should be gradually increased to the minimum system operating pressure specified by the manufacturer. The delay time until the minimum system operating pressure is reached should correspond to the delay time expected in an actual installation. The delay time recorded during the tests should be documented and included in the system specifications.

G.2 TEST ROOM CONFIGURATIONS

G.2.1 Test Room G-1 - Small Compartment (See Figure G-1)

The small compartment shall measure 10 ft by 13 ft (3 m by 4 m) and shall be 8 ft (2.4 m) in height. A 3.9 ft by 3.9 ft (1.2 m by 1.2 m) compartment shall be built within this space to simulate a lavatory. The compartment shall be fitted with a doorway with dimensions of 2 ft 6 in. (0.8 m) wide and 7 ft 2 in. (2.2 m) high. This doorway shall not include a door.

The walls of the compartment shall be fabricated from a 0.5 in. (13 mm) nominal thickness non-combustible wall board backed with 2 in. (45 mm) nominal thickness of mineral wool insulation. The wall board is to be covered with 0.125 in. (3 mm) nominal thickness decorative paneling having a maximum flame spread index (FSI) of 200 when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*. Certification of this characteristic is required for documentation purposes.

The ceiling of the compartment shall be constructed of cellulose acoustical tiles. The ceiling tiles shall be 5/8 in. (16 mm) thick and have a rated maximum flame spread index of 25 when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*. For each fire test, new acoustical panels shall be installed in the 8 ft x 8 ft (2.4 m x 2.4 m) area directly over the fire source.

Two thermocouples, fabricated from 28 gauge chromel-alumel wire, shall be centered directly over the ignition source as shown in Figures G-1 and G-2. One thermocouple shall be embedded within the ceiling tiles, such that the thermocouple bead is located 0.25 in. (6.5 mm) above the bottom surface of the ceiling. A second thermocouple shall be located 3 in. (76 mm) below the ceiling surface. Temperatures shall be continuously recorded during the test period. To prevent water impingement from affecting thermocouple measurements, thermocouples subject to water mist shall be protected with a shield which is large enough to cover the thermocouple ends. The shield may be made from metallic tape which is formed into an umbrella shape and attached to the wire above each thermocouple end.

Prior to each test, the room shall be dried and all water from previous testing shall be removed. There shall be no visible water on the floor, ceiling, or walls. The air in the test enclosure shall be conditioned to an ambient temperature of 68°F ± 18°F (20°C ± 10°C) as measured at the thermocouple located 3 in. (76 mm) below the ceiling (see Figures I-1 and I-2).

G.2.2 Test Room G-2 - Large Compartment (See Figures G-3 and G-4)

For water mist systems using pendent or upright nozzles, including flush, recessed, and concealed pendent nozzles, the large compartment shall be the minimum required room size for four nozzles at the maximum nozzle spacing, with one half the maximum nozzle spacing to the walls, and 8 ft (2.4 m) in height. The compartment shall have equal length sides, as specified by the manufacturer, and shall include a minimum area of 400 ft^2 (37 m^2). For systems being evaluated for restricted certification, this area shall define the maximum room size permitted for certification.

For water mist systems using sidewall nozzles, including flush, recessed, and concealed sidewall nozzles, the large compartment shall be the minimum required room size for one nozzle to be installed in the center of each wall at the maximum nozzle spacing (four total nozzles). The room height shall be 8 ft (2.4 m). The compartment shall have equal length sides, as specified by the manufacturer. This area shall define the maximum room size permitted for certification.

The compartment shall be fitted with two doorways located in diagonally opposite corners of the room as shown in Figures G-3 and G-4. Each doorway shall measure 2 ft 6 in. (0.8 m) wide and 7 ft 2 in. (2.2 m) high. These doorways shall not include doors. A target, automatic closed nozzle with a thermo-sensitive component rating equal to the four nozzles installed in the enclosure should be located in the two adjacent exit doorways, as shown in Figures G-3 and G-4, to determine potential operation of these nozzles. For upright, pendent and sidewall nozzles, the target nozzles shall be installed 4 in (102 mm) inside the doorway, in the pendent position, such that the center of the heat responsive element is 2 in. (51 mm) below the ceiling.

If requested by the manufacturer, and at the sole discretion of the certification agency, the large compartment test may be conducted with the ceiling mounted nozzles having the highest nominal temperature rating and the target nozzles having the lowest nominal temperature rating. Such test conditions are intended to enable fire testing of multiple nominal temperature ratings at once.

The test enclosure ceiling shall be covered with acoustical panels or gypsum board attached to furring strips. Acoustical panels shall be used in the 8 ft by 8 ft (2.4 m by 2.4 m) area directly over the fire source and shall measure 2 ft by 4 ft (0.6 m by 1.2 m). The panels shall be 5/8 in. (16 mm) thick, have a density of 13.5 lb/ft^3 ± 1.5 lb/ft^3 (216 kg/m^3 ± 24 kg/m^3), and have a rated maximum flame spread index of 25 when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*. For each fire test, new acoustical panels shall be installed in the 8 ft by 8 ft (2.4 m by 2.4 m) area directly over the fire source.

The walls of the compartment shall be fabricated from a 0.5 in. (13 mm) nominal thickness non-combustible wall board backed with 2 in. (45 mm) nominal thickness of mineral wool insulation. Sheets of Douglas fir, three-ply paneling measuring 4 ft x 8 ft (1.2 m x 2.4 m) shall cover two of the test enclosure walls at a common corner. The paneling shall be 0.25 in. (6 mm) thick with each ply constructed of Douglas fir, and shall conform to the requirements specified in Table G-2.2. Certification of these characteristics is required for documentation purposes. The paneling shall be conditioned at 70°F ± 5°F (21.1°C ± 2.8°C) and 50 ± 10 percent relative humidity for at least 72 hours prior to test. Two sheets shall be attached to each wall at the common corner using 0.5 in. (12.7 mm) thick wood furring strips (see Figures G-3 and G-4).

Table G.2.2. Required Burning Characteristics of Douglas Fir Three-Ply Paneling

Property	***Test Method***	***Requirement***
Critical Heat Flux	ASTM E2058-02a, *Standard Test Methods for Measurement of Synthetic Polymer Material Flammability Using a Fire Propagation Apparatus (FPA)*, with imposed radiant heat fluxes between 10 and 60 kW/m^2	11 kW/m^2 ± 20 percent
Thermal Response Parameter		220 kW-s$^{1/2}$/m^2 ± 50 kW-s$^{1/2}$/m^2
Chemical Heat of Combustion	ASTM E2058-02a, *Standard Test Methods for Measurement of Synthetic Polymer Material Flammability Using a Fire Propagation Apparatus (FPA)*, with an imposed heat flux of 50 kW/m^2	11 ± 1 kJ/g
Peak Heat Release Rate		450 kW/m^2 ± 10 percent

Two thermocouples, fabricated from 28 gauge chromel-alumel wire, shall be centered directly over the ignition source as shown in Figures G-3 and G-4. One thermocouple shall be embedded within the ceiling tiles, such that the thermocouple bead is located 0.25 in. (6.5 mm) above the bottom surface of the ceiling. A second thermocouple shall be located 3 in. (76 mm) below the ceiling surface. Temperatures shall be continuously recorded during the test period. To prevent water impingement from affecting thermocouple measurements, thermocouples subject to water mist shall be protected with a shield which is large enough to cover the thermocouple ends. The shield may be made from metallic tape which is formed into an umbrella shape and attached to the wire above each thermocouple end.

Prior to each test, the room shall be dried and all water from previous testing shall be removed. There shall be no visible water on the floor, ceiling, or walls. The air in the test enclosure shall be conditioned to an ambient temperature of 68°F ± 18°F (20°C ± 10°C) as measured at the thermocouple located 3 in. (76 mm) below the ceiling (see Figures G-3 and G-4).

G.2.3 Test Room G-3 - Open Space

The test area shall include a ceiling of at least 860 ft^2 (80 m^2) in order to simulate an uninterrupted open space, and shall be 16 ft 5 in. (5 m) in height. The test area shall be inside a laboratory of sufficient area and height with natural or minimal ventilation so as to not influence the testing. The ceiling directly over the fire, for a minimum of 10.8 ft^2 ($1m^2$) of area, shall be constructed of cellulose acoustical tiles. The ceiling tile thickness shall be 5/8 in. (16 mm), and have a rated maximum flame spread index of 25 when tested in accordance with ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*.

Two thermocouples, fabricated from 28 gauge chromel-alumel wire, shall be centered directly over the ignition source as shown in Figure G-6. One thermocouple shall be embedded within the ceiling tiles, such that the thermocouple bead is located 1/4 in. (6.5 mm) above the bottom surface of the ceiling. A second thermocouple shall be located 3 in. (76 mm) below the ceiling surface. Temperatures shall be continuously recorded during the test period. To prevent water impingement from affecting thermocouple measurements, thermocouples subject to water mist shall be protected with a shield which is large enough to cover the thermocouple ends. The shield may be made from metallic tape which is formed into an umbrella shape and attached to the wire above each thermocouple end.

Prior to each test, the room shall be dried and all water from previous testing shall be removed. There shall be no visible water on the floor or ceiling. The air in the test enclosure shall be conditioned to an ambient temperature of 68°F ± 18°F (20°C ± 10°C) as measured at the thermocouple located 3 in. (76 mm) below the ceiling (see Figure I-6).

G.3 FUEL PACKAGE CONFIGURATIONS

G.3.1 Fuel Package G-1 Bunk Beds (See Figure G-2)

The bunk bed consists of two units designated as the upper and lower bunks. Each bunk consists of three components: a steel frame, a mattress, and a pillow.

The steel frame for the bunk beds should be constructed of rectangular stock, 0.08 in. (2 mm) thick, steel. The primary supporting structure should be constructed to adequately support the two mattress frames and bunk beds (see Figure G-2). The top and bottom mattress frames shall be constructed of similar steel stock, with dimensions equal to 6.5 ft by 31 in. (2.0 m by 0.8 m). Eleven gauge (3 mm) sheet steel, with dimensions equal to 6.5 ft by 31 in. (2.0 m by 0.8 m), shall be welded to the top and bottom mattress frames. These two assemblies should be attached to the primary bunk bed support structure in an appropriate manner that will not interfere with placement of the mattresses or other aspects of the fire test. Additional brackets may be provided on the primary frame to provide support for the vertical mattress. The bottom mattress frame assembly shall be located such that the top of the frame is 1 ft in. (mm) above the floor. The top mattress frame assembly shall be located 3 ft 4 in. above the bottom mattress frame assembly.

Each mattress consists of a 6 ft 6 in. by 2 ft 7 in. by 4 in. thick (2 m by 0.8 m by 0.1 m thick) piece of polyether foam with a cotton fabric cover. Each pillow is a 1 ft 8 in. by 2 ft 7 in. by 4 in. thick (0.5 by 0.8 by 0.1 m thick) piece of polyether foam with a cotton fabric cover cut from the end of a mattress. The cut end of the pillow is positioned such that it faces the doorway of the small compartment. The lower bunk has an additional mattress with a cotton fabric cover positioned as a back rest (see Figure G-2). Two bunk beds shall be used in the small compartment, one on each side of the room.

The cotton fabric covers shall not be fire retardant treated and shall have an area weight of 0.03 lb/ft^2 to 0.04 lb/ft^2 (140 g/m^2 to 180 g/m^2). The covers shall be one ply and contain a thread count of approximately 120 (threads per square inch).

Certification of the foam mattress material is required for documentation purposes. The mattress/pillow material shall be made of non-fire-retardant polyether and shall have a density of approximately 2.0 lb/ft^3 (33 kg/m^3). Five samples of the foam (required samples can be adjusted for material purchased by the certification agency at the discretion of the certification agency) shall be tested for burning characteristics and the average properties shall conform to the requirements specified in Table G.3.1.

Table G.3.1 – Required Burning Characteristics of Foam Mattress Material

Property	*Test Method*	*Requirement*
Chemical Heat of Combustion	ASTM E2058-02a, *Standard Test Methods for Measurement of Synthetic Polymer Material Flammability Using a Fire Propagation Apparatus (FPA)*, at 30 kW/m^2	17 kJ/g ± 3 kJ/g
Peak Heat Release Rate (HRR)		190 kW/m^2 ± 30 kW/m^2

The fuel package shall be ignited with a lighted match using an igniter made of some porous material. The igniter may either be square or cylindrical, 2.4 in. (60 mm) square or 3.0 in. (75 mm) in diameter. The length shall be 3.0 in. (75 mm). Prior to the test, the igniter shall be soaked in 4 ounces (120 mL) of heptane and wrapped in a plastic bag and positioned as shown in Figures G-1 and G-2.

G.3.2 Fuel Package G-2 Corner Crib and Simulated Furniture (See Figures G-3, G-4, and G-5)

The large compartment corner fuel package shall consist of a wood crib and simulated furniture (see Figure G-5).

The wood crib shall be dimensioned approximately 12 in. by 12 in. by 6 in. high (300 mm by 300 mm by 150 mm high) and shall consist of four layers of lumber. Each layer shall consist of four 12 in. (300 mm) long pieces of 2 in. by 2 in. trade size [approximately 1.5 in. by 1.5 in. (38 mm by 38 mm) actual size] kiln-dried spruce or fir lumber. The lumber in each layer shall be placed at right angles to the adjacent layers. Individual wood members in each layer shall be evenly spaced along the 12 in. (300 mm) length and stapled to adjacent layers. The crib weight shall be 5.5 to 7 lb (2.5 to 3.2 kg).

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

The wood crib shall be placed on top of a nominal 12 in. by 12 in. by 4 in. high (300 mm by 300 mm by 100 mm), 12 gauge [0.10 in. (2.5 mm) thick] steel pan (see Figure I-5) located on the floor in a corner of the test enclosure. The wood crib shall be centered on the pan and positioned 2 in. (55 mm) from each wall (see Figures G-3 and G-4).

The simulated furniture shall be made up of foam cushions attached to a plywood backing and supported by a steel frame. The cushions shall consist of two pieces of uncovered pure polyether foam having a density of 1.7 lb/ft^3 to 1.9 lb/ft^3 (27.2 kg/m^3 to 30.4 kg/m^3) and measuring 34 in. wide by 30 in. high by 3 in. thick (860 mm wide by 760 mm high by 76 mm thick). Five samples of the polyether foam (required samples can be adjusted for material purchased by the certification agency at the discretion of the certification agency) shall be tested for burning characteristics and the average properties shall conform to the requirements specified in Table G.3.2.

Table G.3.2 – Required Burning Characteristics of Polyether Foam

Property	***Test Method***	***Requirement***
Chemical Heat of Combustion	ASTM E2058-02a, *Standard Test Methods for Measurement of Synthetic Polymer Material Flammability Using a Fire Propagation Apparatus (FPA)*, at 30 kW/m^2	22 kJ/g ± 3 kJ/g
Peak Heat Release Rate (HRR)		230 kW/m^2 ± 50 kW/m^2

Each foam cushion shall be fixed to a 35 in. by 31 in. (890 mm by 790 mm), nominal 0.5 in. (12.7 mm) thick plywood backing using an aerosol urethane foam adhesive. Location of the foam on the plywood shall result in a 0.5 in. (13 mm) gap between the sides of the cushion and the sides of the backing, and a 1 in. (25 mm) gap between the bottom of the cushion and the bottom of the backing, as illustrated in Figure G-5.

The foam cushion and plywood backing assembly shall be conditioned at 70°F ± 5°F (21.1 °C ± 2.8 °C) and 50 percent ± 10 percent relative humidity for at least 24 hours prior to testing. Before each test, the foam and plywood backing assembly shall be placed in a steel support frame that holds the assembly in the vertical position.

The simulated furniture, wood crib, and steel pan shall be placed as illustrated in Figures G-3 and G-4 on a piece of cement board sheathing or equivalent noncombustible sheathing material measuring 4 ft by 4 ft by 0.25 in. thick (1.2 m by 1.2 m by 6 mm thick). For each test, a new or dry sheathing shall be used.

Two 6 in. by 2 in. by 1.25 in. (150 mm by 50 mm by 30 mm) bricks shall be placed on the cement board sheathing against the foam cushions, with their ends flush with the edge of the foam. Two 6 in. (150 mm) long by 0.25 in. (6 mm) diameter cotton wicks shall be soaked in commercial grade heptane and placed on bricks, with their ends flush with the edge of the bricks and foam (see Figures G-3 and G-4).

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

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

G.3.3 Fuel Package G-3 Sofas (See Figure G-6)

Each of the four sofas consists of three components: two mattresses and a steel frame. Each mattress consists of a 6 ft. 6 in. by 2 ft. 7 in. by 4 in. (2 m by 0.8 m by 0.1 m) piece of polyether foam with a cotton fabric cover. The sofa test configuration, consisting of four sofas, is shown in Figure G-6.

The steel frames for the sofas should consist of rectangular bottom and backrest frames constructed of steel angles, channels, or rectangular stock of at least 0.12 in. (3 mm) thickness. The frame dimensions should be 6.5 ft by 25.6 in. (2.0 m by 0.65 m). The seat and backrest cushions should be supported on each frame by three steel bars, 0.8 in.- to 1.2 in. (20 mm to 30 mm) wide by 25.6 in. (0.65 m) long, spaced every 19.7 in. (0.5 m) and welded to the frames. Steel plates should not be used to support the cushions. The assembled frames should be supported by four legs constructed of similar steel stock. The two rear legs should be 19.7 in. (500 mm) in height and the front legs should be 22.8 in. (580 mm) in height. Each sofa should have rectangular armrest on each end. The armrest should be constructed of similar steel stock and should be 7.9 in. (0.2 m) in height and 19.7 in. (0.5 m) in length. The rear section of the armrest should be attached to the bottom frame 2.0 in. (50 mm) from the backrest.

Each mattress consists of a 6 ft 6 in. by 2 ft 7 in. by 4 in. thick (2 m by 0.8 m by 0.1 m thick) piece of polyether foam with a cotton fabric cover. The cotton fabric covers shall not be fire retardant treated and shall have an area weight of 0.03 lb/ft^2 to 0.04 lb/ft^2 (140 g/m^2 to 180 g/m^2). The covers shall be one ply and contain a thread count of approximately 120 (threads per square inch). Certification of the foam mattress material is required for documentation purposes. The mattress/pillow material shall be made of non-fire-retardant polyether and shall have a density of approximately 2.0 lb/ft^3 (33 kg/m^3). Five samples of the foam (required samples can be adjusted for material purchased by the certification agency at the discretion of the certification agency) shall be tested for burning characteristics and the average properties shall conform to the requirements specified in Table G.3.3.

Table G.3.3 – Required Burning Characteristics of Foam Mattress Material

Property	***Test Method***	***Requirement***
Chemical Heat of Combustion	ASTM E2058-02a, *Standard Test Methods for Measurement of Synthetic Polymer Material Flammability Using a Fire Propagation Apparatus (FPA)*, at 30 kW/m^2	17 kJ/g ± 3 kJ/g
Peak Heat Release Rate (HRR)		190 kW/m^2 ± 30 kW/m^2

The mattresses shall be positioned in each sofa frame such that the vertical mattress rests on top of the horizontal mattress. The fuel package shall be ignited with a lighted match using an igniter made of some porous material. The igniter may either be square or cylindrical, 2.4 in. (60 mm) square or 3.0 in. (75 mm) in diameter. The length shall be 3.0 in. (75 mm). Prior to the test, the igniter shall be soaked in 4 ounces (120 mL) of heptane and wrapped in a plastic bag and positioned as shown in Figure G-6.

G.4 FIRE TESTS

G.4.1 Small Compartment with Fuel Package G-1 (Bunk Beds)

Criteria: The corridor nozzles shall not operate. Damage to the cushions of the lower bunk bed is to be limited to 40 percent by volume or dry weight. The horizontal mattress, pillow, and vertical mattress are included in this calculation. The maximum ceiling surface temperature over ignition is not to exceed 500°F (260°C). In addition, the maximum gas temperature over ignition 3 in. (76 mm) below the ceiling is not to exceed 600°F (315°C). [Note: Testing has shown that sprinklers will not typically provide this level of protection. Therefore, this test is a means of differentiating water mist systems from sprinkler systems for light hazard protection.]

Test Procedure: For upright and pendent nozzles, a single nozzle shall be placed in the center of Test Room G-1 (see Figure G-1). For sidewall nozzles, a single nozzle shall be placed at the center of the wall opposite the fire location (see Figure G-1). The test fire shall be ignited in the lower bunk of Fuel Package G-1 as shown in Figure G-2. For other nozzle arrangements, the fire source may be relocated as deemed necessary at the discretion of the certification agency.

If requested by the manufacturer, and at the sole discretion of the certification agency, the test may be conducted with a nozzle having the highest nominal temperature rating. Such a test condition is intended to enable evaluation of multiple nominal temperature ratings at once.

If the nozzle spray pattern is not uniform or the worst case orientation cannot be identified at the time of the test, the test shall be conducted two times, with a different nozzle orientation being used in each test.

G.4.2 Large Compartment with Fuel Package G-2 (Corner Crib)

Criteria: The target doorway nozzles shall not operate. The maximum ceiling surface temperature over ignition is not to exceed 500°F (260°C). In addition, the maximum gas temperature over ignition, 3 in. (76 mm) below the ceiling, is not to exceed 600°F (315°C).

Test Procedure: Nozzles shall be installed in Test Room G-2, as described in Section G.2.2. Fuel package G-2 shall be ignited, as described in Section G.3.2. If the nozzle spray pattern is not uniform or the worst case orientation cannot be identified at the time of the test, the test shall be conducted two times, with a different nozzle orientation being used in each test.

G.4.3 Open Space with Fuel Package G-3 (Sofas) - Under One Nozzle

Criteria: No more than five nozzles shall operate and at least one nozzle shall remain un-actuated beyond each operating nozzle. Damage to Fuel Package G-3 shall not exceed 50 percent by volume or dry weight. The maximum ceiling surface temperature over ignition is not to exceed 500°F (260°C). In addition, the maximum gas temperature over ignition 3 in. (76 mm) below the ceiling is not to exceed 600°F (315°C).

Test Procedure: A minimum of sixteen nozzles shall be installed in the ceiling at the maximum nozzle spacing (per the manufacturer's design instructions). If requested by the manufacturer, and at the sole discretion of the certification agency, the test may be conducted with a nozzle having the highest nominal temperature rating. Such a test condition is intended to enable evaluation of multiple nominal temperature ratings at once. Fuel package G-3 shall be ignited, as described in Section G.3.3. The ignition source (as shown in Figure G-6) shall be centered under one nozzle.

G.4.4 Open Space with Fuel Package G-3 (Sofas) - Between Two Nozzles

Criteria: No more than five nozzles shall operate and at least one nozzle shall remain un-actuated beyond each operating nozzle. Damage to Fuel Package G-3 shall not exceed 50 percent by volume or dry weight. The maximum ceiling surface temperature over ignition is not to exceed 500°F (260°C). In addition, the maximum gas temperature over ignition 3 in. (76 mm) below the ceiling is not to exceed 600°F (315°C).

Test Procedure: A minimum of sixteen nozzles shall be installed in the ceiling at the maximum nozzle spacing (per the manufacturer's design instructions). If requested by the manufacturer, and at the sole discretion of the certification agency, the test may be conducted with a nozzle having the highest nominal temperature rating. Such a test condition is intended to enable evaluation of multiple nominal temperature ratings at once. Fuel package G-3 shall be ignited, as described in Section G.3.3. The ignition source (as shown in Figure G-6) shall be centered between two nozzles.

G.4.5 Open Space with Fuel Package G-3 (Sofas) - Between Four Nozzles

Criteria: No more than five nozzles shall operate and at least one nozzle shall remain un-actuated beyond each operating nozzle. Damage to Fuel Package G-3 shall not exceed 50 percent (by volume). The maximum ceiling surface temperature over ignition is not to exceed 500°F (260°C). In addition, the maximum gas temperature over ignition 3 in. (76 mm) below the ceiling is not to exceed 600°F (315°C).

Test Procedure: A minimum of sixteen nozzles shall be installed in the ceiling at the maximum nozzle spacing (per the manufacturer's design instructions). If requested by the manufacturer, and at the sole discretion of the certification agency, the test may be conducted with a nozzle having the highest nominal temperature rating. Such a test condition is intended to enable evaluation of multiple nominal temperature ratings at once. Fuel package G-3 shall be ignited, as described in Section G.3.3. The ignition source (as shown in Figure G-6) shall be centered between four nozzles.

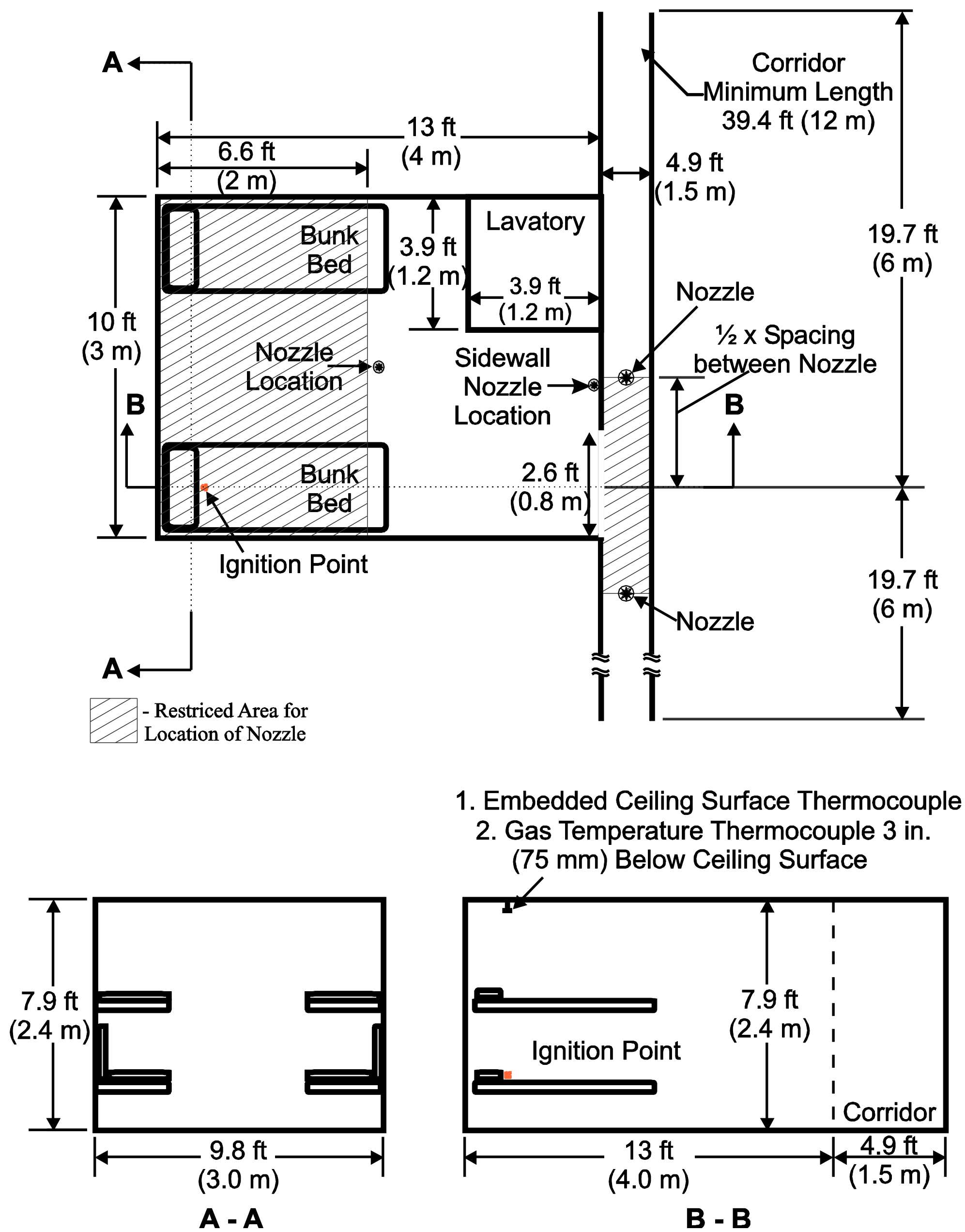


Figure G-1. Small Compartment Test Room

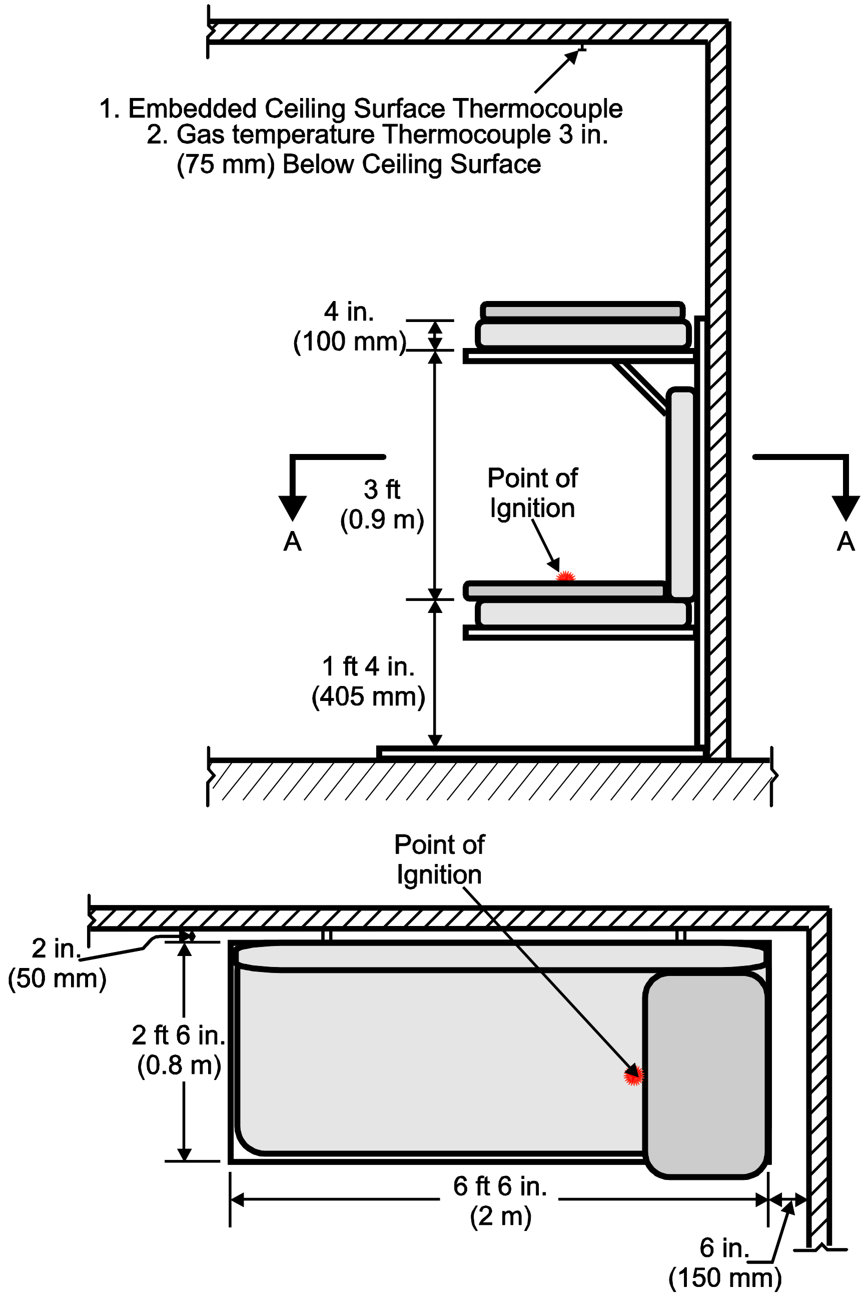


Figure G-2. Fuel Package G-1 Bunk Beds

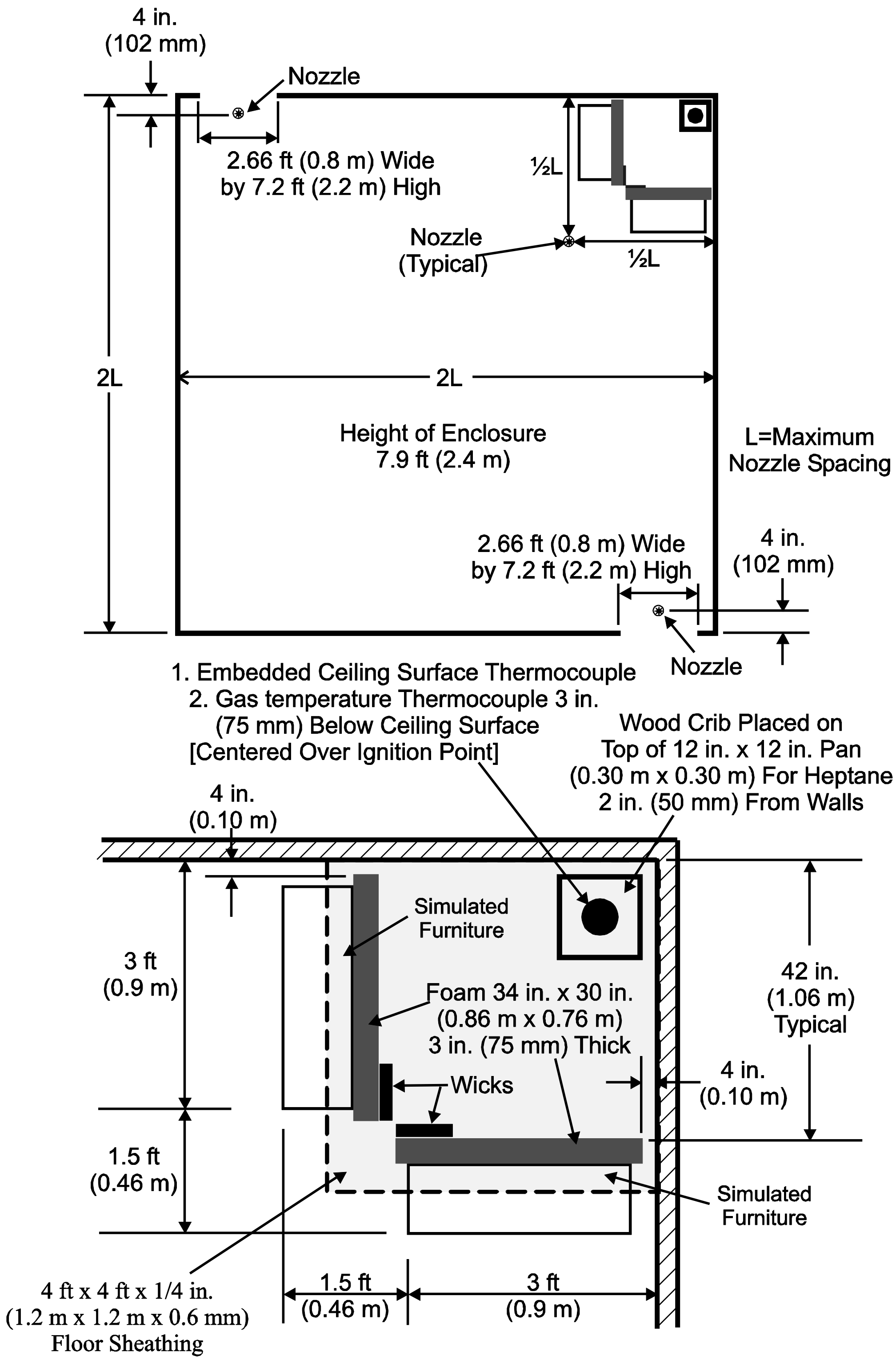


Figure G-3. Large Compartment Test Room and Simulated Fuel Package G-2 Locations (Pendent and Upright Nozzles)

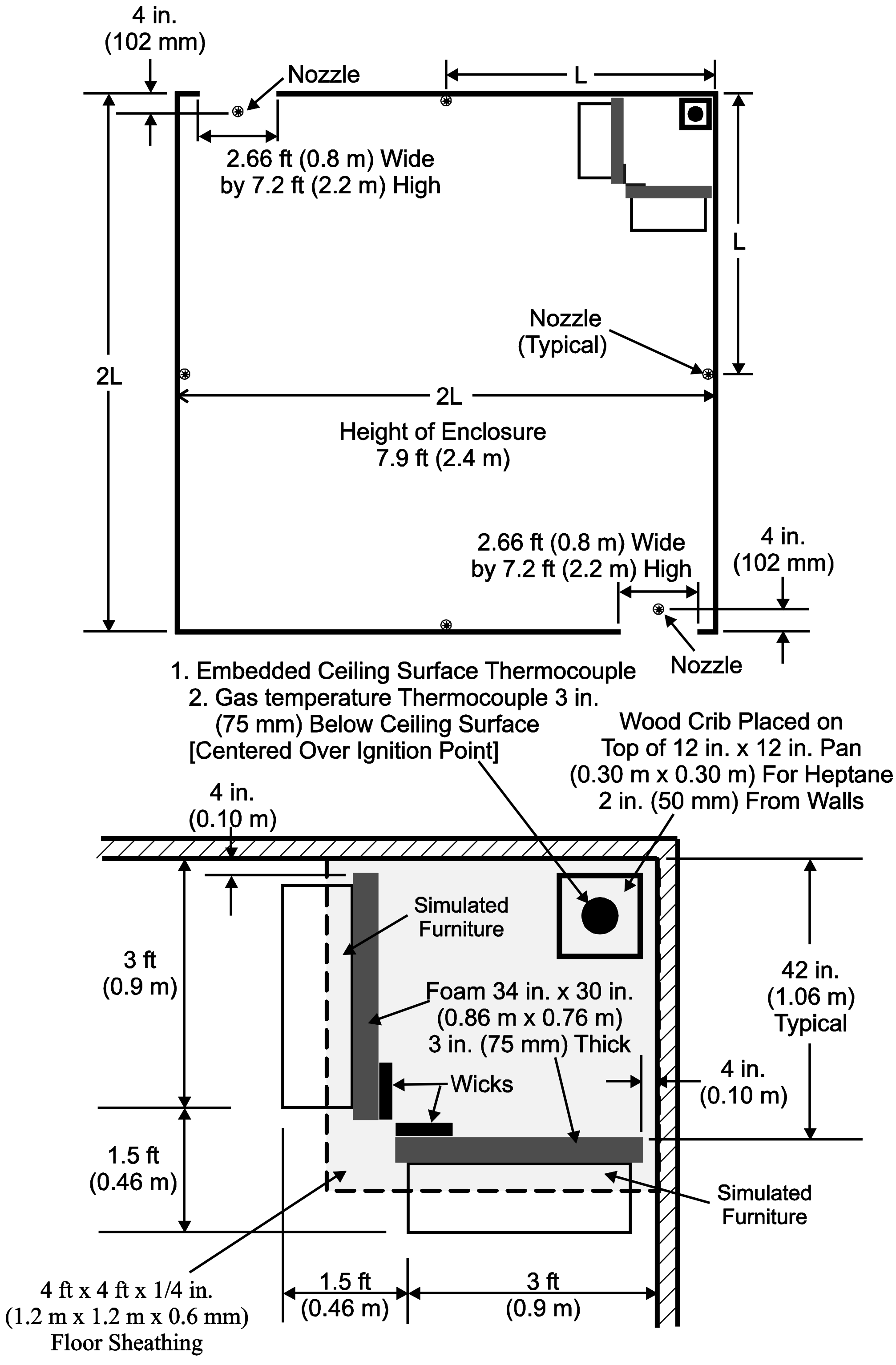


Figure G-4. Large Compartment Test Room and Simulated Fuel Package G-2 Locations (Sidewall Nozzles)

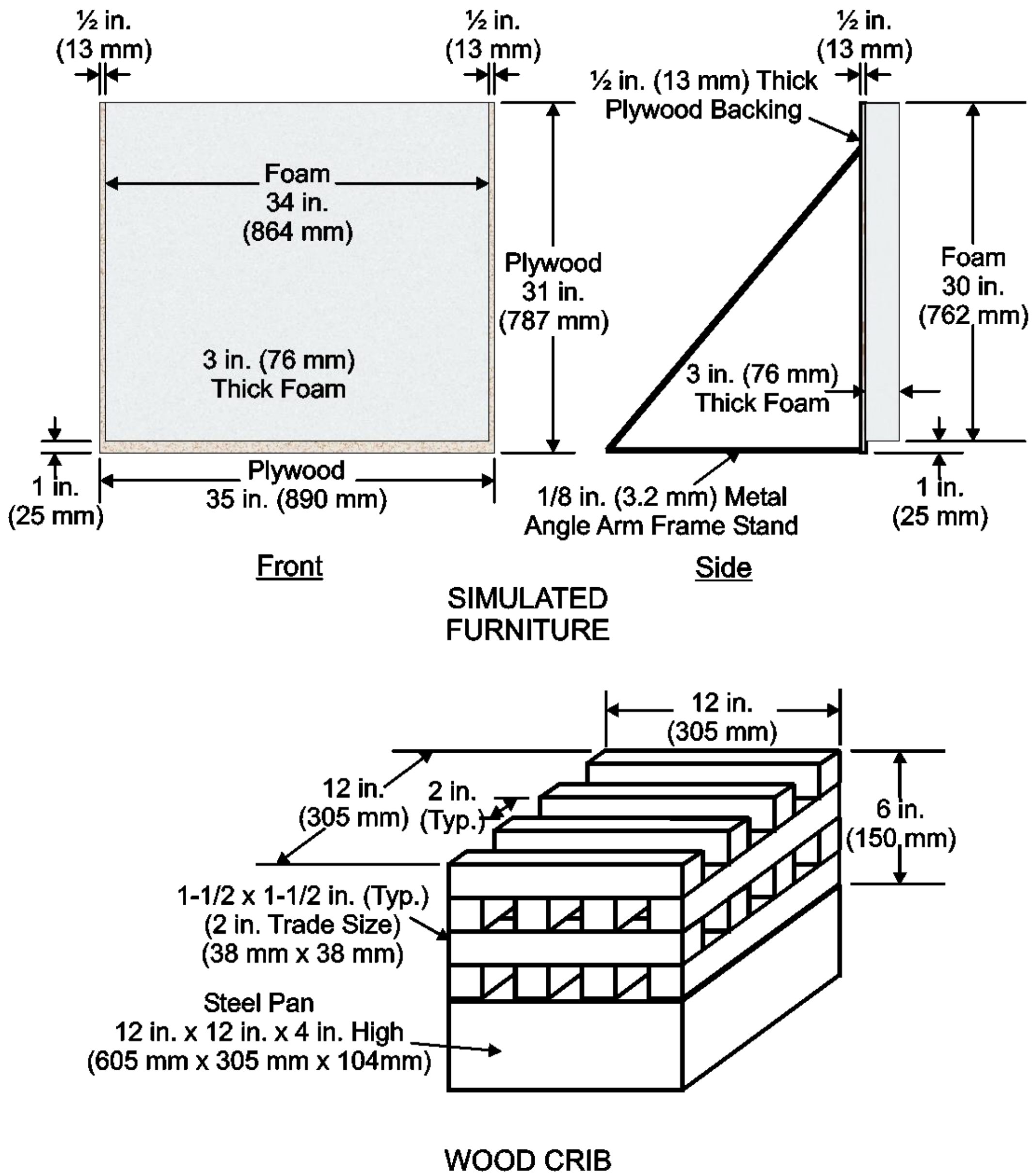


Figure G-5. Fuel Package G-2 Corner Crib and Simulated Furniture

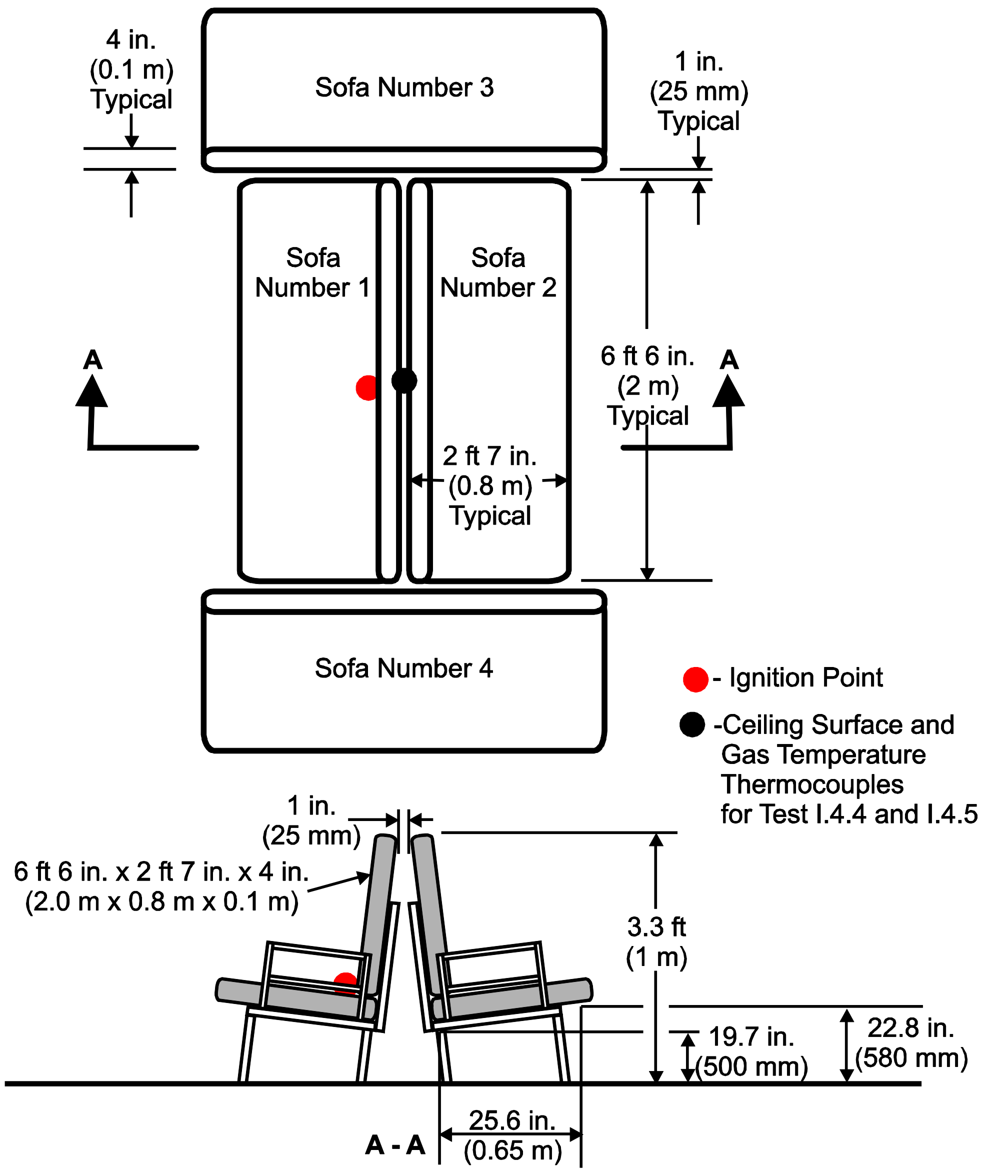


Figure G-6. (Fuel Package G-3 Sofas)

APPENDIX H: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF WET BENCHES AND OTHER SIMILAR PROCESSING EQUIPMENT

H.1 TEST ENCLOSURE (SEE FIGURES H-1 THROUGH H-3)

The simulated clean room facility should be constructed in a large open test hall. The enclosure shall be 12 ft (3.7 m) wide by 18 ft (5.5 m) long by 12 ft (3.7 m) in height. 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. 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 in one of the walls. 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).

The ceiling of the enclosure shall be constructed of a porous plate to allow inflow of air from the open test hall at the ceiling level. The plate should include 0.25 in. (6.3 mm) diameter perforations at 1 in. (25 mm) spacing. This will result in an open area of approximately 6 percent.

The floor of the enclosure shall be raised. The floor should be constructed with close mesh 12 gauge steel grating (bearing bar size of 1 in. (25.4 mm) tall by 0.13 in. (3.2 mm) thick). The mesh opening shall be 0.31 in. (8 mm) by 4 in. (102 mm). A porous steel plate shall be placed below the steel grating. The plate should include 0.25 in. (6.3 mm) diameter perforations at 1 in. (25 mm) spacing. This will result in an open area of approximately 6 percent.

A sub-floor shall be constructed underneath the primary enclosure, to allow airflow through the test enclosure floor openings, creating a realistic flow environment surrounding the wet bench mockup. The sub-floor shall be 12 ft (3.7 m) wide by 18 ft (5.5 m) long by 4 ft (1.2 m) deep, and 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.

The front and back 18 ft (5.5 m) walls of the sub-floor shall include 7 ft 6 in. (2.3 m) wide by 2 ft 3 in. (0.7 m) high openings. The openings should be horizontally and vertically centered in each wall of the sub-floor. Each opening should be ducted to the open test hall (see Figures H-1 through H-3), and shall include blowers to generate a downward flow in the upper test enclosure. The ductwork and blowers serve as the primary wet bench air flow.

The air flow in the test enclosure shall be the maximum air flow specified by the manufacturer. An average downward velocity in a typical cleanroom facility is approximately 60 to 90 fpm (0.30 to 0.46 m/s). The minimum permitted air flow shall be 150 ft^3/min (14 m^3/min) per linear ft (m) of wet bench. Higher flow rates shall be in 50 ft^3/min/linear ft (4.5 m^3/min/linear m) increments. The primary blowers shall be set so that 91 percent of the required airflow is evenly distributed between the two blowers.

H.2 WET BENCH MOCKUP UNIT (SEE FIGURES H-4 THROUGH H-9)

The wet bench mockup shall be centered in the back 18 ft (5.5 m) wall of the simulated clean room facility. The overall unit should measure 4 ft 6 in. (1.4 m) wide by 7 ft 6 in. (2.3 m) long by 6 ft 6 in. (2 m) tall. The bottom 11 in. (0.27 m) of the mockup shall incorporate a raised area to separate the mockup from the floor (refer to Figures H-4, H-5, and H-7 through H-9).

The wet bench shall include an overhead compartment located above a working surface. The working surface should be 2 ft 11 in. (0.87 m) above the floor and extend the entire length of the wet bench and back 2 ft 7 in. (0.8 m). The bottom of the overhead compartment should be located the maximum distance above the working surface specified by the manufacturer. The front edge of the overhead compartment should be set back 11 in. (0.27 m) from the front edge of the working surface and extend back 1 ft 8 in. (0.5 m). The vertical wall behind the working surface, connecting the working surface to the overhead compartment, should include two rows of 15 slots. Each slot should have dimensions of 1 in. (25 mm) by 5 in. (127 mm), and shall communicate with the plenum space below.

The plenum, or subsurface, should be located directly below the working surface and above the raised area of the mockup, and have dimensions of 2 ft 7 in. (0.8 m) wide by 7 ft 6 in. (2.3 m) long by 2 ft (0.6 m) high. The working surface described above serves as the cover of the plenum. The working surface should be constructed of a 0.25 in. (6 mm) thick aluminum plate, with five slots evenly spaced along the wet bench and located 2.5+ in. (64 mm) from the front edge of the mockup. These slots should be 5 in. (130 mm) wide by 9 in. (230 mm) long. Five identical slots shall be spaced along the back wall of the plenum, allowing the plenum space to communicate with the two rows of 15 slots in the back wall of the working surface described previously. The floor and walls of the plenum should be lined with insulation to prevent accidental ignition of the wet bench during fire testing. The front and end walls of the wet bench should include windows to allow cameras to record the fire suppression dynamics inside the plenum.

The two rows of 15 slots in the back wall of the mockup and the five slots in the plenum cover serve to allow ventilation into the plenum space. Approximately 45 percent of the flow will enter the plenum through the slots on the working surface, while the remainder will enter the slots on the back wall behind the surface area. An opening, or openings, with an approximate area of 1 ft^2 (0.1 m^2) shall be provided in the back wall of the mockup to allow secondary flow from the plenum space. The opening should be ducted outside of the test enclosure to the open test hall (see Figures H-1 through H-3), and shall include a blower to generate a secondary airflow to the primary flow described above. The secondary blower shall be set to deliver 9 percent of the required airflow.

The back 1 ft 6 in. (0.47 m) width of the mockup shall be separated from the front of the mockup, and shall extend the entire 6 ft 6 in. (2 m) height of the mockup.

H.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 ± 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. Test enclosure temperature. The enclosure shall initially be at an ambient temperature 68°F ± 18°F (20°C ± 10°C) for all tests. The room shall be at as uniform an ambient temperature as reasonably possible. Localized hot or cold spots are not permitted. All non-fire induced or test specified drafts shall be eliminated.

B. Ambient temperature surrounding the water mist nozzle. Temperatures shall be continuously recorded during the test period. To prevent water impingement from affecting thermocouple measurements, thermocouples subject to water spray shall be protected with a shield which is large enough to cover the thermocouple ends. The shield may be made from metallic tape which is formed into an umbrella shape and attached to the wire above each thermocouple end.

C. Temperature of the fire source with thermocouple located in the approximate center of the initial fuel layer. All fuels shall initially be at an ambient temperature of 68°F ± 18°F (20℃ ± 10°C).

D. Four thermocouples shall be placed in the following locations: the center of the plenum at mid height, one end of the plenum at mid height, the mockup secondary exhaust duct, and in the sub-floor area at mid height.

E. A velocity anemometer, or equivalent device, shall be used to verify the velocity of the air flow in front of the wet bench mockup and in the primary and secondary airflow ductwork prior to each test series.

F. Video and thermal imaging cameras shall be placed in front of the applicable wet bench mockup windows to document the fire tests and verify extinguishment.

G. General dish specifications:

The dishes shall be standard polystyrene, circular Petri dishes, with diameters of 4 in. (102), 6 in. (152 mm), 8 in. (203 mm), 10 in. (254 mm), and 12 in. (305 mm), and a height equal to 1 in. (25 mm). For the polypropylene fuel fires, the polypropylene beads shall be filled to a depth of 0.75 in. (19 mm), and the polypropylene coupons shall be placed on top of the beads. For the ignitable liquid (also known as flammable liquid) fuel fires, the fuel shall be filled to a depth of 0.75 in. (19 mm).

H.4 VENTILATED SUBSURFACE (PLENUM) FIRE TESTS (SEE FIGURES H-7 AND H-8)

H.4.1 Nominal 4 in. (102 mm) Diameter Polypropylene Pool Fire

Criterion:	Fire extinguishment in 60 seconds or less (timed from system activation)
Fuel:	The polypropylene fuel shall consist of polypropylene beads, approximately 0.08 to 0.12 in. (2 to 3 mm) in diameter, filled to a depth of 0.75 in. (19 mm) in a 4 in. (102 mm) diameter dish. Three 0.5 by 2 in. (13 by 51 mm) polypropylene coupons shall be placed on top of the beads (see Figure H-10).
Fire Location:	The solid polypropylene fuel shall be placed within the subsurface space at a location chosen by the certification agency.
Fire Preburn Time:	Minimum 30 seconds
Test Procedure:	The fuel shall be ignited using a 12 V, 9 A glow plug. Ignition will typically occur within 15 to 30 seconds, but the glow plug should remain on for a period of time to ensure ignition of the fuel. The burning shall be allowed to reach a steady state condition. An initial slow fire growth period (20 to 30 minutes) will occur, followed by rapid growth and the development of a steady state fire within a period of approximately 3 minutes. Once steady state burning is achieved, the preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.4.2 Nominal 6 in. (152 mm) Diameter Polypropylene Pool Fire

Criterion:	Fire extinguishment in 60 seconds or less (timed from system activation)
Fuel:	The polypropylene fuel shall consist of polypropylene beads, approximately 0.08 to 0.12 in. (2 to 3 mm) in diameter, filled to a depth of 0.75 in. (19 mm) in a 6 in. (152 mm) diameter dish. Three 0.5 by 2 in. (13 by 51 mm) polypropylene coupons shall be placed on top of the beads (see Figure H-10).
Fire Location:	The solid polypropylene fuel shall be placed within the subsurface space at a location chosen by the certification agency.
Fire Preburn Time:	Minimum 30 seconds.
Test Procedure:	The fuel shall be ignited using a 12 V, 9 A glow plug. Ignition will typically occur within 15 to 30 seconds, but the glow plug should remain on for a period of time to ensure ignition of the fuel. The burning shall be allowed to reach a steady state condition. An initial slow fire growth period (20 to 30 minutes) will occur, followed by rapid growth and the development of a steady state fire within a period of approximately 3 minutes. Once steady state burning is achieved, the preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.4.3 Nominal 8 in. (203 mm) Diameter Polypropylene Pool Fire

Criterion:	Fire extinguishment in 60 seconds or less (timed from system activation)
Fuel:	The polypropylene fuel shall consist of polypropylene beads, approximately 0.08 to 0.12 in. (2 to 3 mm) in diameter, filled to a depth of 0.75 in. (19 mm) in an 8 in. (203 mm) diameter dish. Three 0.5 by 2 in. (13 by 51 mm) polypropylene coupons shall be placed on top of the beads (see Figure H-10).
Fire Location:	The solid polypropylene fuel shall be placed within the subsurface space at a location chosen by the certification agency.
Fire Preburn Time:	Minimum 30 seconds.
Test Procedure:	The fuel shall be ignited using a 12 V, 9 A glow plug. Ignition will typically occur within 15 to 30 seconds, but the glow plug should remain on for a period of time to ensure ignition of the fuel. The burning shall be allowed to reach a steady state condition. An initial slow fire growth period (20 to 30 minutes) will occur, followed by rapid growth and the development of a steady state fire within a period of approximately 3 minutes. Once steady state burning is achieved, the preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.4.4 Nominal 10 in. (254 mm) Diameter Polypropylene Pool Fire

Criterion:	Fire extinguishment in 60 seconds or less (timed from system activation)
Fuel:	The polypropylene fuel shall consist of polypropylene beads, approximately 0.08 to 0.12 in. (2 to 3 mm) in diameter, filled to a depth of 0.75 in. (19 mm) in a 10 in. (254 mm) diameter dish. Three 0.5 by 2 in. (13 by 51 mm) polypropylene coupons shall be placed on top of the beads (see Figure H-10).
Fire Location:	The solid polypropylene fuel shall be placed within the subsurface space at a location chosen by the certification agency.
Fire Preburn Time:	Minimum 30 seconds
Test Procedure:	The fuel shall be ignited using a 12 V, 9 A glow plug. Ignition will typically occur within 15 to 30 seconds, but the glow plug should remain on for a period of time to ensure ignition of the fuel. The burning shall be allowed to reach a steady state condition. An initial slow fire growth period (20 to 30 minutes) will occur, followed by rapid growth and the development of a steady state fire within a period of approximately 3 minutes. Once steady state burning is achieved, the preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.4.5 Nominal 12 in. (305 mm) Diameter Polypropylene Pool Fire

Criterion:	Fire extinguishment in 60 seconds or less (timed from system activation)
Fuel:	The polypropylene fuel shall consist of polypropylene beads, approximately 0.08 to 0.12 in. (2 to 3 mm) in diameter, filled to a depth of 0.75 in. (19 mm) in a 12 in. (305 mm) diameter dish. Three 0.5 by 2 in. (13 by 51 mm) polypropylene coupons shall be placed on top of the beads (see Figure H-10).
Fire Location:	The polypropylene fuel shall be placed within the subsurface space at a location chosen by the certification agency.
Fire Preburn Time:	Minimum 30 seconds.
Test Procedure:	The fuel shall be ignited using a 12 V, 9 A glow plug. Ignition will typically occur within 15 to 30 seconds, but the glow plug should remain on for a period of time to ensure ignition of the fuel. The burning shall be allowed to reach a steady state condition. An initial slow fire growth period (20 to 30 minutes) will occur, followed by rapid growth and the development of a steady state fire within a period of approximately 3 minutes. Once steady state burning is achieved, the preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.4.6 Ignitable Liquid (also Known as Flammable Liquid) Pool Fires

Criterion: Fire extinguishment in 60 seconds or less (timed from system activation)

Fuels: At a minimum, the ignitable liquid (also known as flammable liquid) pool fire fuels shall consist of Acetone, Isopropyl Alcohol (IPA), and heptane. A minimum of one test is to be conducted with each of these fuels. The fuels are to have the following nominal properties:

Table H.4.6 Ignitable Liquid (also Known as Flammable Liquid) Pool Fuel Properties

Formula	***Flash Point - Closed Cup***		***Flash Point - Open Cup***		***Burning Rate Nominal 6 in. (150 mm) Diameter Pool Fire***	
	°F	***(°C)***	***°F***	***(°C)***	***kW***	***(BTU/sec)***
Acetone (CH3)CO	0	(-17.8)	15	(-9.4)	18	(17.1)
Isopropyl Alcohol (IPA) (CH3)2CHOH	53	(11.7)	60	(15.6)	12	(11.4)
Heptane CH3(CH2)5CH3	25	(-3.9)	30	(-1.1)	58	(55.0)

Fire Location: The ignitable liquid (also known as flammable liquid) fuel pool fires shall be placed in the wet bench subsurface space using a pan size and location chosen by the certification agency (multiple pan sizes and locations may be tested at the sole discretion of the certification agency).

Fire Preburn Time: Minimum 30 seconds

Test Procedure: The fuel shall be ignited and allowed to reach a steady state condition. Once steady state burning is achieved, the preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.4.7 Polypropylene Pool Fire Utilizing a Single Nozzle in a Ventilated Subsurface Space

Criterion: Fire extinguishment in 60 seconds or less (timed from system activation)

Fuel: The polypropylene fuel shall consist of polypropylene beads, approximately 0.08 to 0.12 in. (2 to 3 mm) in diameter, filled to a depth of 0.75 in. (19 mm) in a dish size to be selected by certification agency. Three 0.5 by 2 in. (13 by 51 mm) polypropylene coupons shall be placed on top of the beads (see Figure H-10).

Fire Location: The polypropylene fuel shall be placed within the subsurface space at a location chosen by the certification agency.

Fire Preburn Time: Minimum 30 seconds

Test Procedure: In order to determine the effectiveness of a single nozzle, one nozzle shall be installed in the largest ventilated space specified by the manufacturer. A partition should be erected in the subsurface space to reduce the volume of the space to an appropriate size. Suitable cylindrical barriers (simulating actual obstructions), measuring 7 in. (178 mm) in diameter and 12 in (305 mm) in height, shall be placed within the space to prevent the nozzle discharge from directly impacting the fire (See Figure H-7). The fuel shall be ignited using a 12 V, 9 A glow plug. Ignition will typically occur within 15 to 30 seconds, but the glow plug should remain on for a period of time to ensure ignition of the fuel. The burning shall be allowed to reach a steady state condition. An initial slow fire growth period (20 to 30 minutes) will occur, followed by rapid growth and the development of a steady state fire within a period of approximately 3 minutes. Once steady state burning is achieved, the preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.4.8 Ignitable Liquid (also Known as Flammable Liquid) Pool Fires Utilizing a Single Nozzle in a Ventilated Subsurface Space

Criterion:	Fire extinguishment in 60 seconds or less (timed from system activation)
Fuel:	At a minimum, the ignitable liquid (also known as flammable liquid) pool fire fuels shall consist of Acetone, Isopropyl Alcohol (IPA), and heptane. A minimum of one test is to be conducted with each of these fuels. The fuels are to have the nominal properties listed in Table H.4.6.
Fire Location:	The ignitable liquid (also known as flammable liquid) fuel pool fires shall be placed in the wet bench subsurface space using a pan size and location chosen by the certification agency. (multiple pan sizes and locations may be tested at the sole discretion of the certification agency.)
Fire Preburn Time:	Minimum 30 seconds.
Test Procedure:	In order to determine the effectiveness of a single nozzle, one nozzle shall be installed in the largest ventilated space specified by the manufacturer. A partition should be erected in the subsurface space to reduce the volume of the space to an appropriate size. Suitable cylindrical barriers (simulating actual obstructions), measuring 7 in. (178 mm) in diameter and 12 in (305 mm) in height, shall be placed within the space to prevent the nozzle discharge from directly impacting the fire (See Figure H-7). The fuel shall be ignited and allowed to reach a steady state condition. Once steady state burning is achieved, the preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.4.9 Other Ventilated Subsurface Fire Tests

Based on the results of the ventilated subsurface tests, additional testing may be required. The certification agency reserves the right to conduct additional testing to resolve any anomalies based on an analysis of the fire test results. At the sole discretion of the certification agency, fires tests may be repeated to determine the adequacy and/or limitations of the fire protection system.

H.5 WET BENCH WORKING SURFACE FIRE TESTS (SEE FIGURE H-9)

The working surface protection water mist system shall be installed as specified in the manufacturer's design manual for surface protection.

1. Fire tests shall be conducted with the nozzles installed at the minimum and maximum vertical distances from the surface. It is permissible to change nozzle configurations for the difference in height provided it is based upon the manufacturers' design specifications to be included as part of the certified system.

2. Systems modified to reflect a difference in height may be subjected to additional testing to determine the limitations of a given system configuration.

H.5.1 Nominal 4 in. (102 mm) Diameter Polypropylene Pool Fire

Criterion:	Fire extinguishment in 60 seconds or less (timed from system activation)
Fuel:	The polypropylene fuel shall consist of polypropylene beads, approximately 0.08 to 0.12 in. (2 to 3 mm) in diameter, filled to a depth of 0.75 in. (19 mm) in a 4 in. (102 mm) diameter dish. Three 0.5 by 2 in. (13 by 51 mm) polypropylene coupons shall be placed on top of the beads (see Figure H-10).
Fire Location:	The solid polypropylene fuel shall be placed within the subsurface space at a location chosen by the certification agency.

Fire Preburn Time:	Minimum 30 seconds
Test Procedure:	The fuel shall be ignited using a 12 V, 9 A glow plug. Ignition will typically occur within 15 to 30 seconds, but the glow plug should remain on for a period of time to ensure ignition of the fuel. The burning shall be allowed to reach a steady state condition. An initial slow fire growth period (20 to 30 minutes) will occur, followed by rapid growth and the development of a steady state fire within a period of approximately 3 minutes. Once steady state burning is achieved, the preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.5.2 Nominal 6 in. (152 mm) Diameter Polypropylene Pool Fire

Criterion:	Fire extinguishment in 60 seconds or less (timed from system activation)
Fuel:	The polypropylene fuel shall consist of polypropylene beads, approximately 0.08 to 0.12 in. (2 to 3 mm) in diameter, filled to a depth of 0.75 in. (19 mm) in a 6 in. (152 mm) diameter dish. Three 0.5 by 2 in. (13 by 51 mm) polypropylene coupons shall be placed on top of the beads (see Figure H-10).
Fire Location:	The solid polypropylene fuel shall be placed within the subsurface space at a location chosen by the certification agency.
Fire Preburn Time:	Minimum 30 seconds.
Test Procedure:	The fuel shall be ignited using a 12 V, 9 A glow plug. Ignition will typically occur within 15 to 30 seconds, but the glow plug should remain on for a period of time to ensure ignition of the fuel. The burning shall be allowed to reach a steady state condition. An initial slow fire growth period (20 to 30 minutes) will occur, followed by rapid growth and the development of a steady state fire within a period of approximately 3 minutes. Once steady state burning is achieved, the preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.5.3 Nominal 8 in. (203 mm) Diameter Polypropylene Pool Fire

Criterion:	Fire extinguishment in 60 seconds or less (timed from system activation)
Fuel:	The polypropylene fuel shall consist of polypropylene beads, approximately 0.08 to 0.12 in. (2 to 3 mm) in diameter, filled to a depth of 0.75 in. (19 mm) in an 8 in. (203 mm) diameter dish. Three 0.5 by 2 in. (13 by 51 mm) polypropylene coupons shall be placed on top of the beads (see Figure H-10).
Fire Location:	The solid polypropylene fuel shall be placed within the subsurface space at a location chosen by the certification agency.
Fire Preburn Time:	Minimum 30 seconds.
Test Procedure:	The fuel shall be ignited using a 12 V, 9 A glow plug. Ignition will typically occur within 15 to 30 seconds, but the glow plug should remain on for a period of time to ensure ignition of the fuel. The burning shall be allowed to reach a steady state condition. An initial slow fire growth period (20 to 30 minutes) will occur, followed by rapid growth and the development of a steady state fire within a period of approximately 3 minutes. Once steady state burning is achieved, the preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.5.4 Nominal 10 in. (254 mm) Diameter Polypropylene Pool Fire

Criterion:	Fire extinguishment in 60 seconds or less (timed from system activation)
Fuel:	The polypropylene fuel shall consist of polypropylene beads, approximately 0.08 to 0.12 in. (2 to 3 mm) in diameter, filled to a depth of 0.75 in. (19 mm) in a 10 in. (254 mm) diameter dish. Three 0.5 by 2 in. (13 by 51 mm) polypropylene coupons shall be placed on top of the beads (see Figure J-10).

Fire Location:	The solid polypropylene fuel shall be placed within the subsurface space at a location chosen by the certification agency.
Fire Preburn Time:	Minimum 30 seconds
Test Procedure:	The fuel shall be ignited using a 12 V, 9 A glow plug. Ignition will typically occur within 15 to 30 seconds, but the glow plug should remain on for a period of time to ensure ignition of the fuel. The burning shall be allowed to reach a steady state condition. An initial slow fire growth period (20 to 30 minutes) will occur, followed by rapid growth and the development of a steady state fire within a period of approximately 3 minutes. Once steady state burning is achieved, the preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.5.5 Nominal 12 in. (305 mm) Diameter Polypropylene Pool Fire

Criterion:	Fire extinguishment in 60 seconds or less (timed from system activation)
Fuel:	The polypropylene fuel shall consist of polypropylene beads, approximately 0.08 to 0.12 in. (2 to 3 mm) in diameter, filled to a depth of 0.75 in. (19 mm) in a 12 in. (305 mm) diameter dish. Three 0.5 by 2 in. (13 by 51 mm) polypropylene coupons shall be placed on top of the beads (see Figure J-10).
Fire Location:	The polypropylene fuel shall be placed within the subsurface space at a location chosen by the certification agency.
Fire Preburn Time:	Minimum 30 seconds.
Test Procedure:	The fuel shall be ignited using a 12 V, 9 A glow plug. Ignition will typically occur within 15 to 30 seconds, but the glow plug should remain on for a period of time to ensure ignition of the fuel. The burning shall be allowed to reach a steady state condition. An initial slow fire growth period (20 to 30 minutes) will occur, followed by rapid growth and the development of a steady state fire within a period of approximately 3 minutes. Once steady state burning is achieved, the preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.5.6 Ignitable Liquid (also Known as Flammable Liquid) Pool Fires

Criterion:	Fire extinguishment in 60 seconds or less (timed from system activation)
Fuels:	At a minimum, the ignitable liquid (also known as flammable liquid) pool fire fuels shall consist of Acetone, Isopropyl Alcohol (IPA), and heptane. A minimum of one test is to be conducted with each of these fuels. The fuels are to have the following nominal properties:

Table H.5.6 Ignitable Liquid (also Known as Flammable Liquid) Pool Fuel Properties

Formula	***Flash Point - Closed Cup***		***Flash Point - Open Cup***		***Burning Rate Nominal 6 in. (150 mm) Diameter Pool Fire***	
	°F	***(°C)***	***°F***	***(°C)***	***kW***	***(BTU/sec)***
Acetone (CH3)CO	0	(-17.8)	15	(-9.4)	18	(17.1)
Isopropyl Alcohol (IPA) (CH3)2CHOH	53	(11.7)	60	(15.6)	12	(11.4)
Heptane CH3(CH2)5CH3	25	(-3.9)	30	(-1.1)	58	(55.0)

Fire Location:	The ignitable liquid (also known as flammable liquid) fuel pool fires shall be placed on the working surface using a pan size and location chosen by the certification agency (multiple pan sizes and locations may be tested at the sole discretion of the certification agency).
Fire Preburn Time:	Minimum 30 seconds.
Test Procedure:	The fuel shall be ignited and allowed to reach a steady state condition. Once steady state burning is achieved, the preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.5.7 Splashing Test

Criterion:	The spray of a single nozzle, or combination of nozzles, shall not cause a pool of heated liquid to splash any of its contents outside a nominal 16 in. (406 mm) diameter circle, centered about the target pan.
Test Procedure:	A 12 in. (305 mm) diameter pan containing approximately 0.75 in. (19 mm) deep colored liquid (for example, water with a red dye) shall be placed directly under a single open nozzle. The pan shall be filled with the liquid such that the freeboard is 0.5 in. (13 mm). The test may be conducted using multiple nozzles if the certification agencydeems that condition to be a worst case scenario. The nozzle(s) shall be placed at the minimum vertical distance from the pan as permitted by the manufacturer's design manual. The system shall be manually discharged. The maximum flow rate or system pressure shall be used**.** Observations shall be made for splashing of the liquid as a result of the water mist discharge.

H.5.8 Other Working Surface Fire Tests

Based on the results of the working surface tests, additional testing may be required. The certification agency reserves the right to conduct additional testing to resolve any anomalies based on an analysis of the fire test results. At the sole discretion of the certification agency, fires tests may be repeated to determine the adequacy and/or limitations of the fire protection system.

H.6 UNVENTILATED SPACES FIRE TESTS

H.6.1 Polypropylene Pool Fire Utilizing a Single Nozzle in an Unventilated Space

Criterion:	Fire extinguishment in 60 seconds or less (timed from system activation)
Fuel:	The polypropylene fuel shall consist of polypropylene beads, approximately 0.08 to 0.12 in. (2 to 3 mm) in diameter, filled to a depth of 0.75 in. (19 mm) in a dish size to be selected by the certification agency. Three 0.5 by 2 in. (13 by 51 mm) polypropylene coupons shall be placed on top of the beads (see Figure H-10).
Fire Location:	The polypropylene fuel shall be placed within the subsurface space at a location chosen by the certification agency.
Fire Preburn Time:	Minimum 30 seconds.
Test Procedure:	In order to determine the effectiveness of a single nozzle, one nozzle shall be installed in the largest unventilated space specified by the manufacturer. A partition should be erected in the subsurface space to reduce the volume of the space to an appropriate size. Suitable cylindrical barriers (simulating actual obstructions), measuring 7 in. (178 mm) in diameter and 12 in (305 mm) in height, shall be placed within the space to prevent the nozzle discharge from directly impacting the fire (See Figure H7). The fuel shall be ignited using a 12 V, 9 A glow plug. Ignition will typically occur within 15 to 30 seconds, but the glow plug should remain on for a period of time to ensure ignition of the fuel. The burning shall be allowed to reach a steady state condition. An initial slow fire growth period (20 to 30 minutes) will occur, followed by rapid growth and the development of a steady state fire within a period of approximately 3 minutes. Once steady state burning is achieved, the

preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.6.2 Ignitable Liquid (also Known as Flammable Liquid) Pool Fire Utilizing a Single Nozzle in an Unventilated Space

Criterion:	Fire extinguishment in 60 seconds or less (timed from system activation)
Fuel:	At a minimum, the ignitable liquid (also known as flammable liquid) pool fire fuels shall consist of Acetone, Isopropyl Alcohol (IPA), and heptane. A minimum of one test is to be conducted with each of these fuels. The fuels are to have the nominal properties listed in Table H.4.6.
Fire Location:	The ignitable liquid (also known as flammable liquid) fuel pool fires shall be placed in the wet bench subsurface space using a pan size and location chosen by the certification agency. (multiple pan sizes and locations may be tested at the sole discretion of the certification agency.)
Fire Preburn Time:	Minimum 30 seconds
Test Procedure:	In order to determine the effectiveness of a single nozzle, one nozzle shall be installed in the largest unventilated space specified by the manufacturer. A partition should be erected in the subsurface space to reduce the volume of the space to an appropriate size. Suitable cylindrical barriers (simulating actual obstructions), measuring 7 in. (178 mm) in diameter and 12 in (305 mm) in height, shall be placed within the space to prevent the nozzle discharge from directly impacting the fire (See Figure H-7). The fuel shall be ignited and allowed to reach a steady state condition. Once steady state burning is achieved, the preburn time shall begin, and the water mist system should be manually activated subsequent to the required preburn time.

H.6.3 Other Unventilated Space Fire Tests

Based on the results of the unventilated space fire tests, additional testing may be required. The certification agency reserves the right to conduct additional testing to resolve any anomalies based on an analysis of the fire test results. At the sole discretion of the certification agency, fires tests may be repeated to determine the adequacy and/or limitations of the fire protection system.

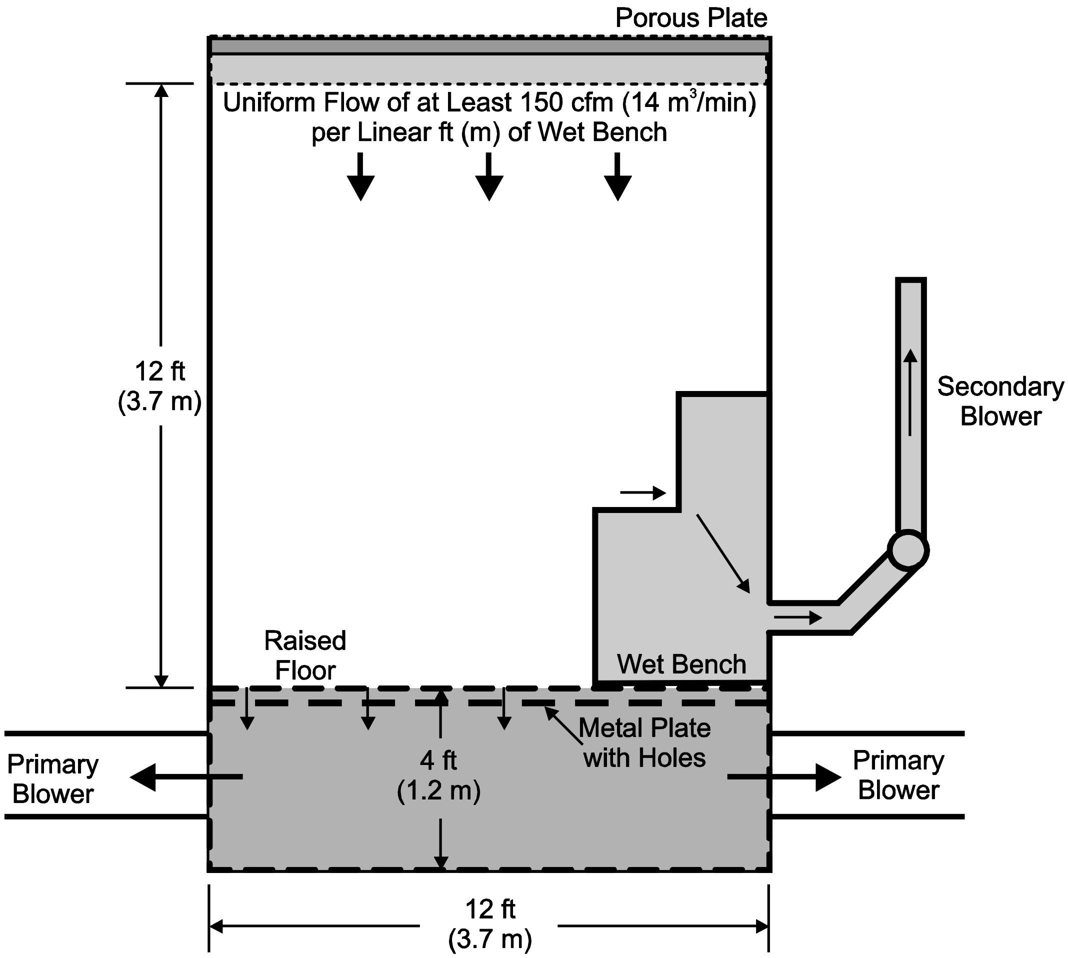


Figure H-1. Clean Room Simulation Facility - Side View

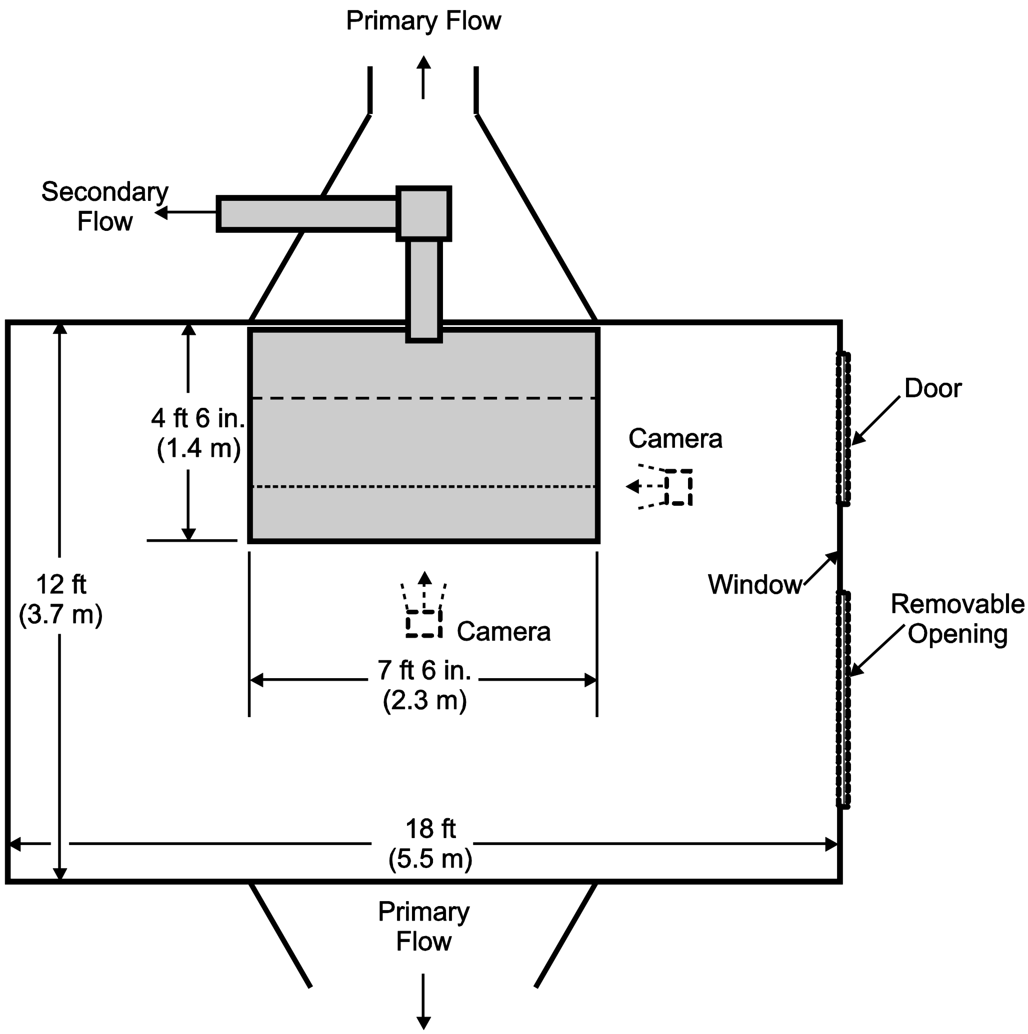


Figure H-2. Clean Room Simulation Facility - Top View

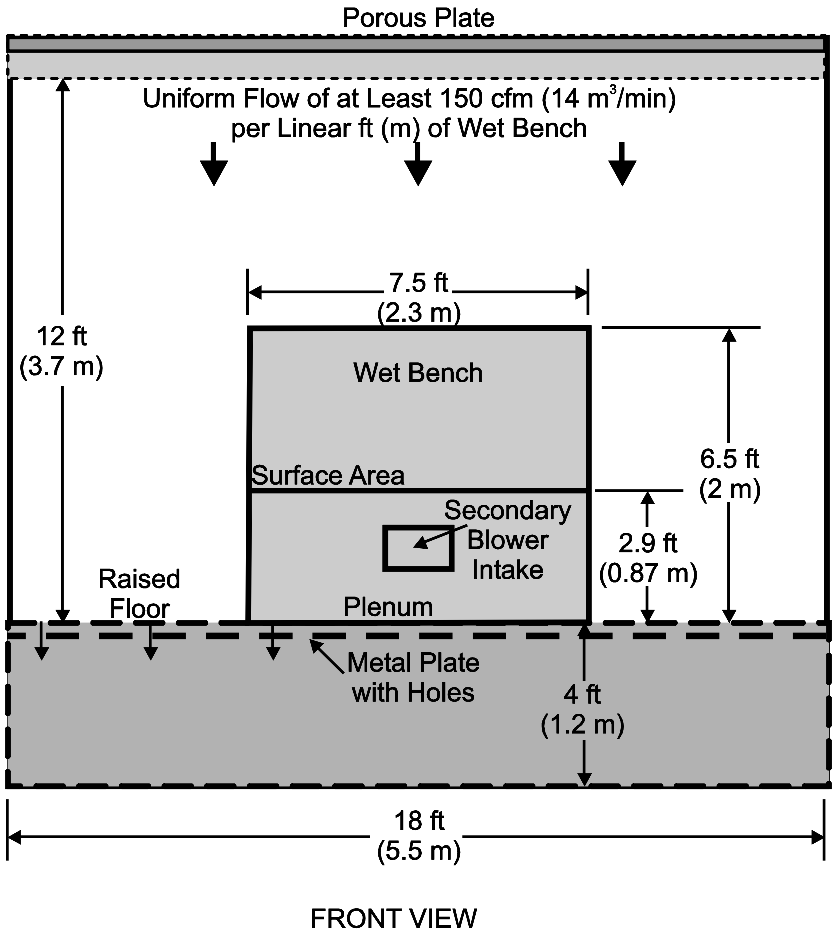


Figure H-3. Clean Room Simulation Facility - Front View

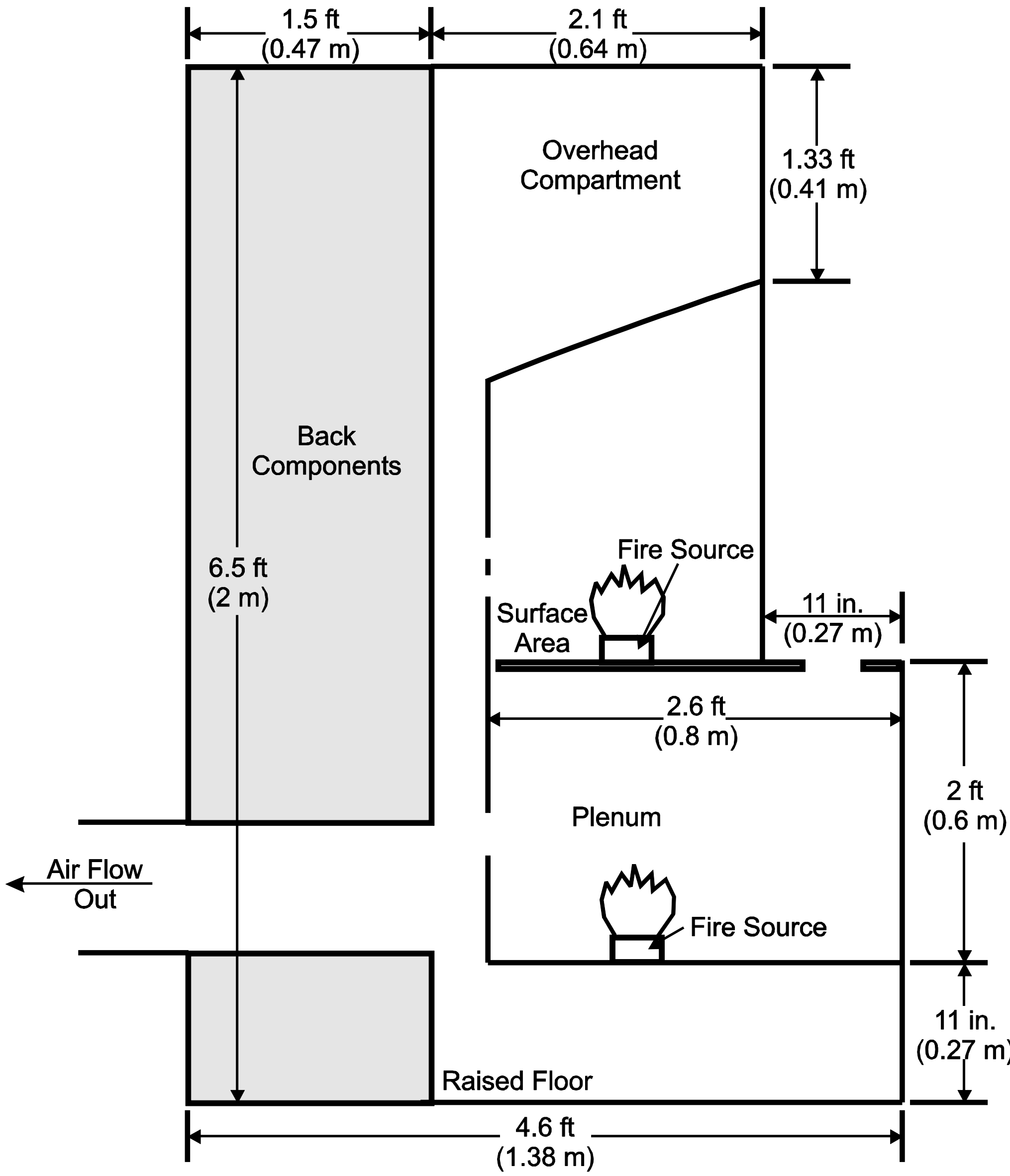


Figure H-4. Wet Bench Test Apparatus - Side View

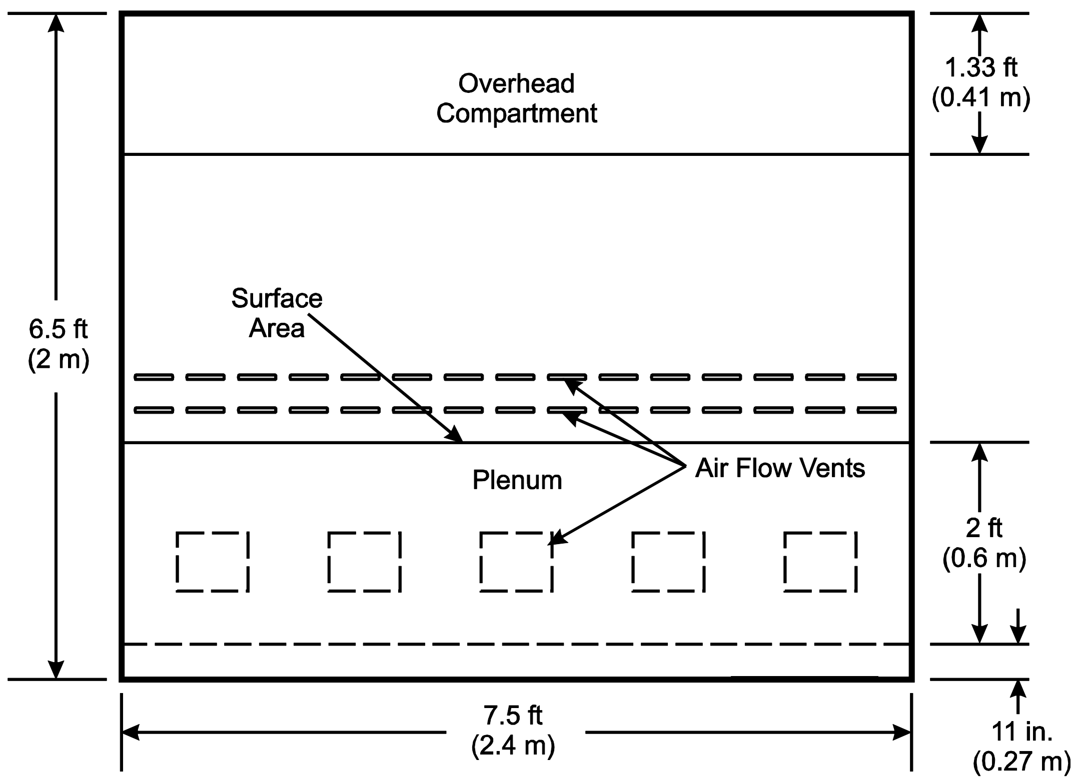


Figure H-5. Wet Bench Test Apparatus - Front View

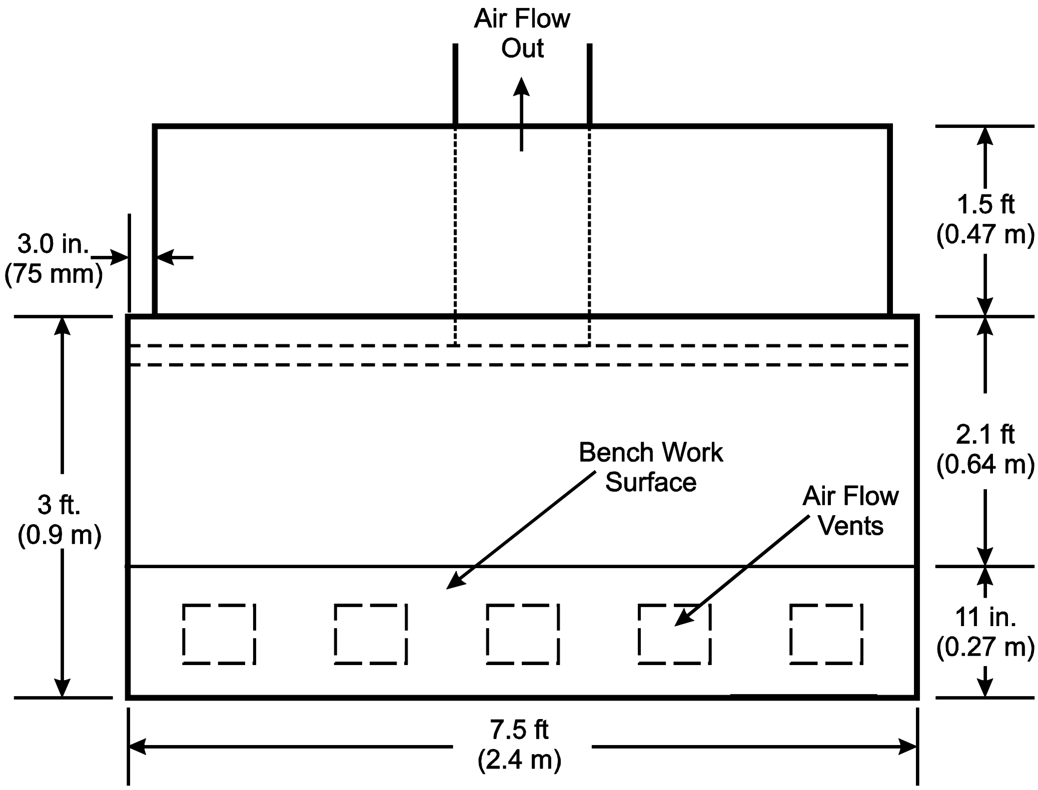


Figure H-6. Wet Bench Test Apparatus - Top View

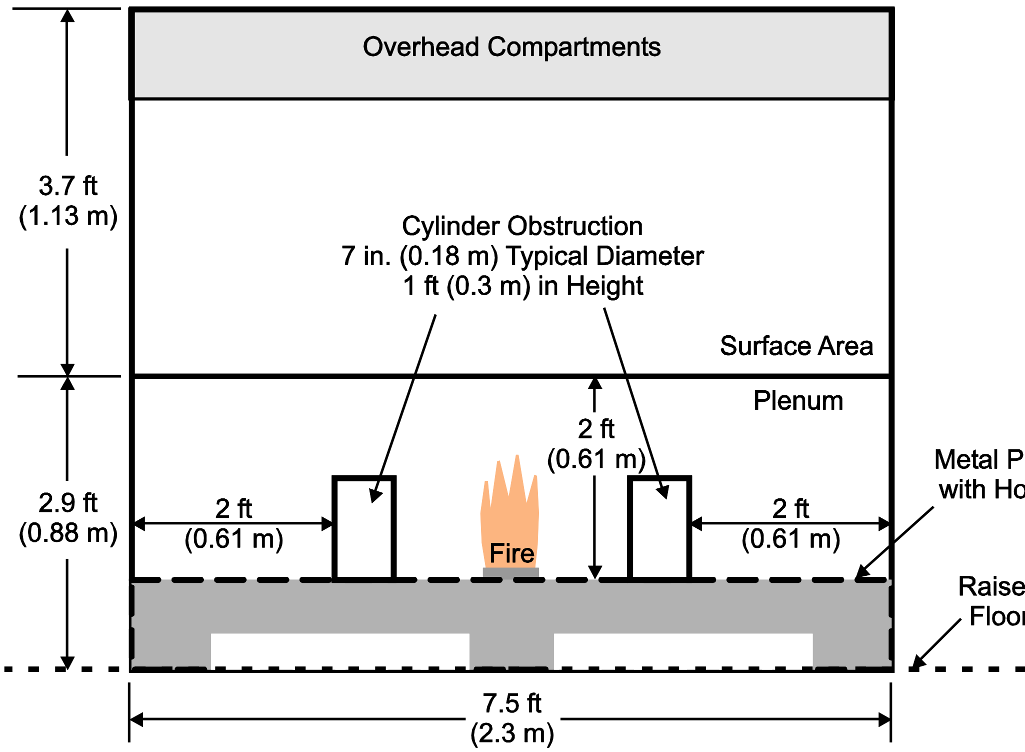


Figure H-7. Wet Bench Test Apparatus for Plenum Fire Subsurface Testing with Obstructions - Front View

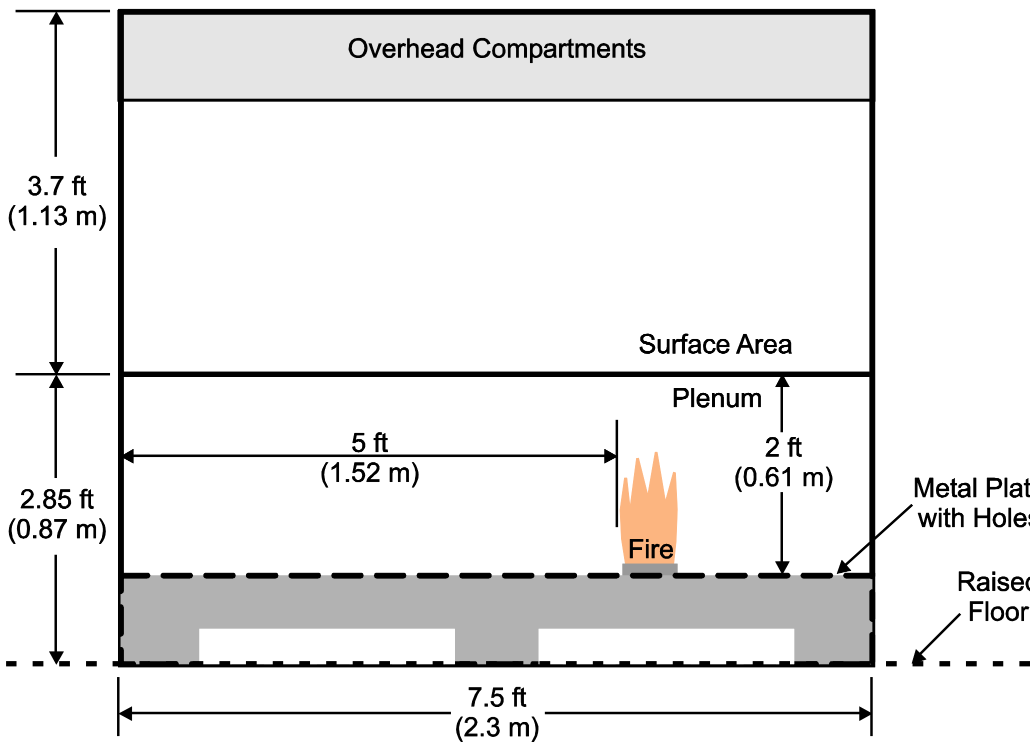


Figure H-8. Wet Bench Test Apparatus for Plenum Fire Subsurface Testing without Obstructions - Front View

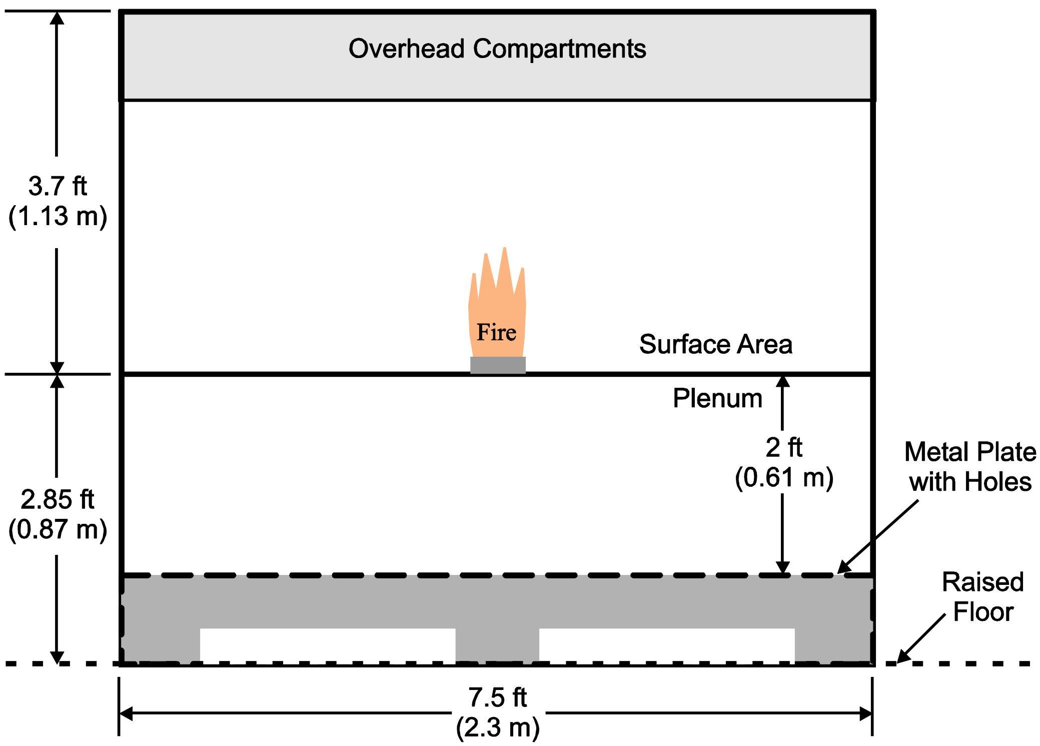


Figure H-9. Wet Bench Test Apparatus for Surface Area Fire Testing- Front View

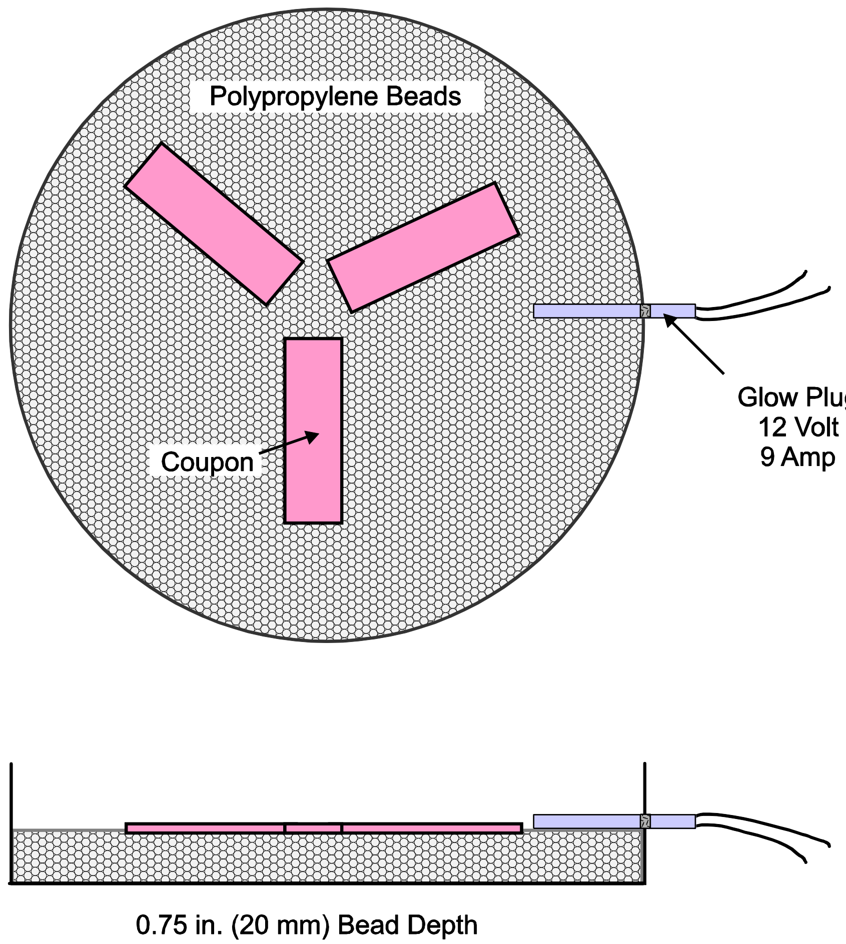


Figure H-10. Polypropylene Pool Fire for Wet Bench Fire Testing

APPENDIX I: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF LOCAL APPLICATIONS

I.1 GENERAL TESTING REQUIREMENTS

The certification criteria for the fire tests are as follows:

A. The water mist system shall be capable of extinguishing the fire scenarios in this Appendix that are required based on the type of local application being requested by the water mist system manufacturer. It is the responsibility of the water mist system manufacturer to inform the certification agency of the type(s) of local application in which certification is being requested. Based on this information the certification agency will formulate the fire performance test requirements. Table I-1 will be used as a guideline in determining the fire performance test requirements. The system components, component locations, and operating conditions shall remain unaltered throughout the fire tests. All fire tests shall be conducted using the spray specifications from the manufacturer's design manual in regard to nozzle placement, spray flux and spray duration.

		Application Type			
Fire Test Description	**Fire Test Number**	*2D Ignitable Liquid Pool Fire Protection*	*Combination 2D Ignitable Liquid Pool Fire & Spray Fire Protection*	*Spray Fire - Point Protection*	*2D Ignitable Liquid Channel Protection*
Square Pool Fires					
X by X - Maximum Nozzle Height	I.3.1.1	X	X		
2X by 2X - Maximum Nozzle Height	I.3.1.2	X	X		
3X by 3X - Maximum Nozzle Height	I.3.1.3	X	X		
3X by 3X - Minimum Nozzle Height	I.3.1.4	X	X		
Channel Pool Fires					
Y by Y - Maximum Nozzle Height	I.3.2.1				X
Y by 2Y - Maximum Nozzle Height	I.3.2.2				X
Y by 3Y - Maximum Nozzle Height	I.3.2.3				X
Y by Y - Minimum Nozzle Height	I.3.2.4				X
Spray Fires					
Horizontal Spray - Maximum Nozzle Distance from Spray	I.3.3.1			X	
Horizontal Spray - Minimum Nozzle Distance from Spray	I.3.3.2			X	
Vertical Spray - Maximum Nozzle Distance from Spray	I.3.3.3			X	
Vertical Spray - Minimum Nozzle Distance from Spray	I.3.3.4			X	
Combined Pool and Spray Fires					
Arrangement A - Maximum Nozzle Height	I.3.4.1		X		
Arrangement B - Maximum Nozzle Height	I.3.4.2		X		
Arrangement C - Maximum Nozzle Height	I.3.4.3		X		
Arrangement D - Maximum Nozzle Height	I.3.4.4		X		
Arrangement E - Maximum Nozzle Height	I.3.4.5		X		
Obstructed Pool Fire					
3X by 3X Obstructed - Maximum Nozzle Height	I.3.5.1	X	X		
3X by 3X Obstructed - Minimum Nozzle Height	I.3.5.2	X	X		
Offset Square Pool Fire					
X by X Offset - Maximum Nozzle Height	I.3.6.1	X	X		
X by X Offset - Minumum Nozzle Height	I.3.6.2	X	X		
Combined Pool and Spray Fire w/ External Igntion Source					
Horizontal Spray w/ External Igntion Source - Maximum Nozzle Height	I.3.7.1		X		
Horizontal Spray w/ External Igntion Source - Minimum Nozzle Height	I.3.7.2		X		

Table I-1. Fire performance test selection guideline matrix.

B. The fire tests should be conducted in a large open test hall, greater than 17,657 ft^3 (500 m^3) in volume, with a minimum ceiling height of 16.4 ft (5.0 m). Ventilation for between tests and cooling of the enclosure should be provided by louver vents located on the roof of test hall and a side wall doorway.

C. All nozzles shall be installed at their maximum spacing.

D. The fire scenarios described in Section I.3 shall be conducted using either heptane or diesel as the test fuel. Applicants desiring to protect equipment with ignitable liquids (also known as flammable liquids) with volatilities less than or equal to those of diesel should conduct the fire scenarios using diesel fuel. Applicants desiring to protect special hazard equipment with ignitable liquids (also known as flammable liquids) with volatilities less than or equal to that of heptane should substitute heptane for diesel as the test fuel. In cases where the test series is run using heptane as the test fuel, it is unnecessary to repeat the required tests with diesel.

I.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 ± 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. Test hall temperature. The enclosure shall initially be at an ambient temperature 68°F ± 18°F (20°C ± 10°C) for all tests.

C. Fuel temperature within the fuel storage container. All fuels shall be at an ambient temperature of 68°F ± 18°F (20°C ± 10°C).

D. 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°F ± 18°F (20°C ± 10°C).

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°F (100°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 4 in. (100 mm) horizontally behind and below the fuel spray nozzle, and between 6.6 ft and 9.8 ft (2 m and 3 m) away from the pool and at the same elevation as the rim of the pan. The measurements should be taken away from any open doorways or ventilation sources. Ventilation rates shall be monitored and recorded if constantly provided for the enclosure.

J. For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

Spray Nozzle	Lechler 460.728	Lechler 460.728
Fuel Type	Light diesel	Heptane
Nominal Oil Pressure	120 psi (8.2 bar)	120 psi (8.2 bar)
Heat Release Rate	5.8 ± 0.6 MW	5.8 ± 0.6 MW

Nominal Fuel Flow	0.35 ± 0.02 lb/s (0.16 ± 0.01 kg/s)	0.31 ± 0.02 lb/s (0.14 ± 0.01 kg/s)
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 the certification agency.

K. 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. 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.

I.3 FIRE SCENARIOS AND TEST CONFIGURATIONS

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

Agent supply needed for twice the extinguishment time for the longest fire scenario will be reported and considered as one of the requirements when water mist is used as a special protection system (see Section 1.9, Definitions).

I.3.1 Square Pool Fires

Criteria: The fires are to be extinguished and the extinguishment time shall not be affected by pool size to within ± 30 percent for each of the fire tests.

Fuel: Diesel or heptane

Type: Square pool fires with dimensions of X by X, 2X by 2X, and 3X by 3X.

General system specifications (see Figure I-1):

A. The nozzles shall be in a uniform grid pattern above the pool.
B. Nozzles shall be oriented vertically downward. Nozzles along the perimeter of the grid may be angled towards the hazard, but should remain constant regardless of pool size.
C. The ratio of total number of nozzles in the grid versus the pool area shall remain constant. (i.e., one nozzle for the X by X pool, four nozzles for the 2X by 2X pool, and nine nozzles for the 3X by 3X pool.
D. The nozzle grid elevation above the pool shall remain constant for all pool sizes.
E. The ratio of total spray coverage area on the pool surface versus the pool area shall remain constant (the mist flux shall remain constant).
F. The horizontal offset between the perimeter water mist nozzles in the grid and the edges of the pool shall remain constant.

Preburn Time: Diesel: 30 seconds after the fire is fully developed on the pool.
Heptane: 15 seconds after the fire is fully developed on the pool.

Fire Test I.3.1.1:	X by X pool	maximum nozzle height
Fire Test I.3.1.2:	2X by 2X pool	maximum nozzle height
Fire Test I.3.1.3:	3X by 3X pool	maximum nozzle height
Fire Test I.3.1.4:	3X by 3X pool	minimum nozzle height

Test Procedure: The nozzle installation criteria shall remain unchanged for the tested pool fires. Each test shall be repeated, for a total of eight tests for Fire Scenario I.3.1. The pool fire shall be ignited, and the water mist system should be manually 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.

I.3.2 Channel Pool Fires

Criteria: The fires are to be extinguished and the extinguishment time shall not be affected by channel length to within ±30 percent for each of the fire tests.

Fuel: Diesel or heptane
Type: Channel pool fires with dimensions of Y by Y, Y by 2Y, and Y by 3Y, where Y is the water mist system manufacturer's specified maximum channel width.

General system specifications (See Figure I-2):

A. The nozzles shall be located along the two opposite sides of the channel. The longitudinal and latitudinal spacing is not required to be equal, but should remain constant.
B. Nozzles shall be oriented vertically downward. Nozzles along the perimeter of the grid may be angled towards the hazard, but must remain constant regardless of pool size.
C. The ratio of total number of nozzles versus the channel area shall remain constant. (i.e., two nozzles for a 10.8 ft^2 ($1m^2$) channel, four nozzles for a 21.6 ft^2 ($2\ m^2$) channel, and six nozzles for a 32.3 ft^2 ($3\ m^2$) channel.)
D. The nozzle elevation above the channel shall remain constant for all channel sizes.
E. The ratio of total spray coverage area on the channel surface versus the channel area shall remain constant (the mist flux shall remain constant).
F. The horizontal offset between the perimeter water mist nozzles in the grid and the edges of the pool shall remain constant.

Preburn Time: Diesel: 30 seconds after the fire is fully developed in the channel.
Heptane: 15 seconds after the fire is fully developed on the pool.

Fire Test I.3.2.1:	Y by Y channel	maximum nozzle height
Fire Test I.3.2.2:	Y by 2Y channel	maximum nozzle height
Fire Test I.3.2.3:	Y by 3Y channel	maximum nozzle height
Fire Test I.3.2.4:	Y by 3Y channel	minimum nozzle height

Test Procedure: The nozzle installation criteria shall remain unchanged for the tested channel fires. Each test shall be repeated for a total of eight tests for Fire Scenario I.3.2. The pool fire shall be ignited, and the water mist system should be manually 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.

I.3.3 Spray Fires

Criteria: The fires are to be extinguished.

Fuel: Diesel or heptane
Type: Spray fires
Fire size: 6 MW

General System Specifications (See Figure I-3):

A. All applications shall be protected using a minimum of two nozzles.
   i. For applications using two nozzles, the nozzles shall be placed in a column on one side of the hazard. The vertical distance between the nozzles shall be specified by the manufacturer and shall remain constant.
   ii. For applications using more than two nozzles, the nozzles shall be configured symmetrically on either side of the hazard. For example, for applications using four nozzles, two nozzles shall be placed on one

side of the hazard as described in I.3.3.A.i. The remaining two nozzles shall be configured as a mirror image on the opposite side of the hazard. The vertical distance between the nozzles shall be specified by the manufacturer and shall remain constant.

B. The manufacturer shall specify a minimum and maximum horizontal distance between the nozzles and the hazard.

C. Nozzles may be angled directly towards the hazard.

Preburn Time: 15 seconds after the spray is ignited.

Spray fire arrangement: The tests should be conducted with the spray axis oriented horizontally and vertically (See Figure I-3).

Fire Test I.3.3.1:	horizontal spray	maximum nozzle distance from spray
Fire Test I.3.3.2:	horizontal spray	minimum nozzle distance from spray
Fire Test I.3.3.3:	vertical spray	maximum nozzle distance from spray
Fire Test I.3.3.4:	vertical spray	minimum nozzle distance from spray

Test Procedure: Each test shall be repeated for a total of eight tests for Fire Scenario I.3.3. For applications using only two nozzles, the horizontal spray fires (tests I.3.3.1 and I.3.3.2) shall be repeated with the spray directed horizontally away from the nozzles and horizontally towards the nozzles, for a total of 12 tests for Fire Scenario I.3.3. The spray fire shall be ignited, and the water mist system should be manually activated subsequent to the required preburn time.

I.3.4 2X by 2X Square Pool Fire Combined with a 6 MW Spray Fire

Criteria: The pool and spray fires are to be extinguished.

Fuel: Diesel or heptane

Type: 2X by 2X pool fire and 6 MW spray fire

General system specifications (see Figures I-4 through I-8):

The system configuration shall be identical to that used for the 2X by 2X square pool fire (Fire Test I.3.1.2).

Preburn Time: For diesel, the spray fire above the pool surface should be initiated and ignited 30 seconds after the flames have spread to the entire pool area. For heptane, the spray above the pool surface should be initiated and ignited 15 seconds after the flames have spread to the entire pool area. Fifteen seconds after the spray fire has been ignited, the water mist system should be activated.

Spray fire arrangement above the pool surface:

A. Pointed horizontally and centered 3.3 ft (1.0 m) above the pool (See Figure I-4).
B. Pointed 45 degrees above horizontal and centered 3.3 ft (1.0 m) above the pool (See Figure I-5).
C. Pointed horizontally, 3.3 ft (1.0 m) above the pool, and offset 1.6 ft (0.50 m) edgewise from the pool center (See Figure I-6).
D. Pointed 45 degrees above horizontal, 3.3 ft (1.0 m) above the pool, and offset 1.6 ft (0.50 m) edgewise from the pool center (See Figure I-7).
E. Pointed horizontally, 1 ft (0.30 m) above the pool, and offset 1.6 ft (0.50 m) edgewise from the pool center (See Figure I-8).

Fire Test I.3.4.1:	as described in A above	maximum nozzle height
Fire Test I.3.4.2:	as described in B above	maximum nozzle height
Fire Test I.3.4.3:	as described in C above	maximum nozzle height

Fire Test I.3.4.4:	as described in D above	maximum nozzle height
Fire Test I.3.4.5:	as described in E above	maximum nozzle height

Test Procedure: The nozzle installation criteria shall remain unchanged for the tested fires. Each test shall be repeated for a total of ten tests for Fire Scenario I.3.4. The pool fire shall be ignited. The spray fire should be ignited 15 seconds after flames have spread to the entire pool area. The water mist system should then be activated 15 seconds after ignition of the spray fire (30 seconds after the pool fire is ignited). 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.

I.3.5 Obstructed 3X by 3X Square Pool Fire

Criteria: The fires are to be extinguished.

Fuel: Diesel or heptane
Type: 3X by 3X pool fire with an obstruction

General system specifications (see Figures I-4 through I-8):

The system configuration shall be identical to that used for the 3X by 3X square pool fire (Fire Tests I.3.1.3 and I.3.1.4).

Preburn Time: Diesel: 30 seconds after the fire is fully developed on the pool.
Heptane: 15 seconds after the fire is fully developed on the pool.

Test I.3.5.1: maximum nozzle height
Test I.3.5.2: minimum nozzle height

Test Procedure: The nozzle installation criteria shall remain unchanged for the tested pool fires. Each test shall be repeated for a total of four tests for Fire Scenario I.3.5. An empty closed-top-and-bottom metal drum, 55 gal (208 L) in capacity, 2 ft diameter by 3 ft high (0.6 m diameter by 0.9 m high) of standard 0.05 in. (1.27 mm) nominal thickness, shall be placed 1.6 ft (0.50 m) over the center of the pool. The drum shall be mounted on steel legs (See Figure I-9). Small ventilation holes are to be dispersed in the side of the drum to prevent over pressurization of the drum.

The pool fire shall be ignited, and the water mist system should be manually 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.

I.3.6 Offset X by X Square Pool Fire

Criteria: The fires are to be extinguished.

Fuel: Diesel or heptane
Type: X by X pool fire with an obstruction

General system specifications (see Figures I-4 through I-8):

The system configuration shall be identical to that used for the 2X by 2X square pool. (Fire test scenario I.3.1.2).

Fire location: To be placed at the location with the least mist flux in the protected area, as determined by certification agency.

Preburn Time:	Diesel:	30 seconds after the fire is fully developed on the pool.
	Heptane:	15 seconds after the fire is fully developed on the pool.

Fire Test I.3.6.1: maximum nozzle height

Fire Test I.3.6.2: minimum nozzle height

Test Procedure: The intent of these tests is to verify that weak spray coverage areas do not exist. The X by X pool shall be placed under the nozzle grid used in Fire Test I.3.1.2, in the area considered to have the least mist flux.

The nozzle installation criteria shall remain unchanged for the tested pool fires. Each test shall be repeated for a total of four tests for Fire Scenario I.3.6. The pool fire shall be ignited, and the water mist system should be manually 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.

I.3.7 6 MW Spray Fire with an External Ignition Source

Criteria: The spray fires are to be extinguished.

Fuel: Diesel or heptane

Type: 3.3 ft by 3.3 ft (1 m by 1 m) pool fire with an obstruction

General system specifications (see Figure I-10):

The system configuration shall be identical to that used for the 2X by 2X square pool. (Fire test scenario I.3.1.2)

Preburn Time: 15 seconds after the spray is ignited.

Spray fire arrangement: Pointed horizontally, centered in the protected area, and 3.3 ft (1.0 m) above the floor (See Figure I-10).

External Ignition Source: An ordinary utility propane torch is to be positioned in a vertical plane perpendicular to the spray nozzle axis and 9.3 ft (2.85 m) from the nozzle. The base of the 10 in. (0.25m) long torch flame shall be 1 in. (20 mm) in diameter and shall be 2.5 ft (0.75 m) above the floor. The propane flame shall be slanted upward by 30° from horizontal. A 10 in. (0.25 m) wide by 4.1 ft (1.25 m) high by 0.125 in. (3 mm) minimum thickness steel plate shall be placed in between the spray nozzle and the propane torch, 1 ft (0.30 m) in front of the propane supply line (See Figure I-10).

Fire Test I.3.7.1: maximum nozzle height

Fire Test I.3.7.2: minimum nozzle height

Test Procedure: The nozzle installation criteria shall remain unchanged for the tested pool fires. Each test shall be repeated for a total of four tests for Fire Scenario I.3.7. The propane torch shall be ignited prior to ignition of the pool fire. The pool fire shall then be ignited, and the water mist system should be manually 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.

I.3.8 Other

At the sole discretion of the certification agency, additional fire test scenarios may be required based on the performance demonstrated in the preceding fire scenarios.

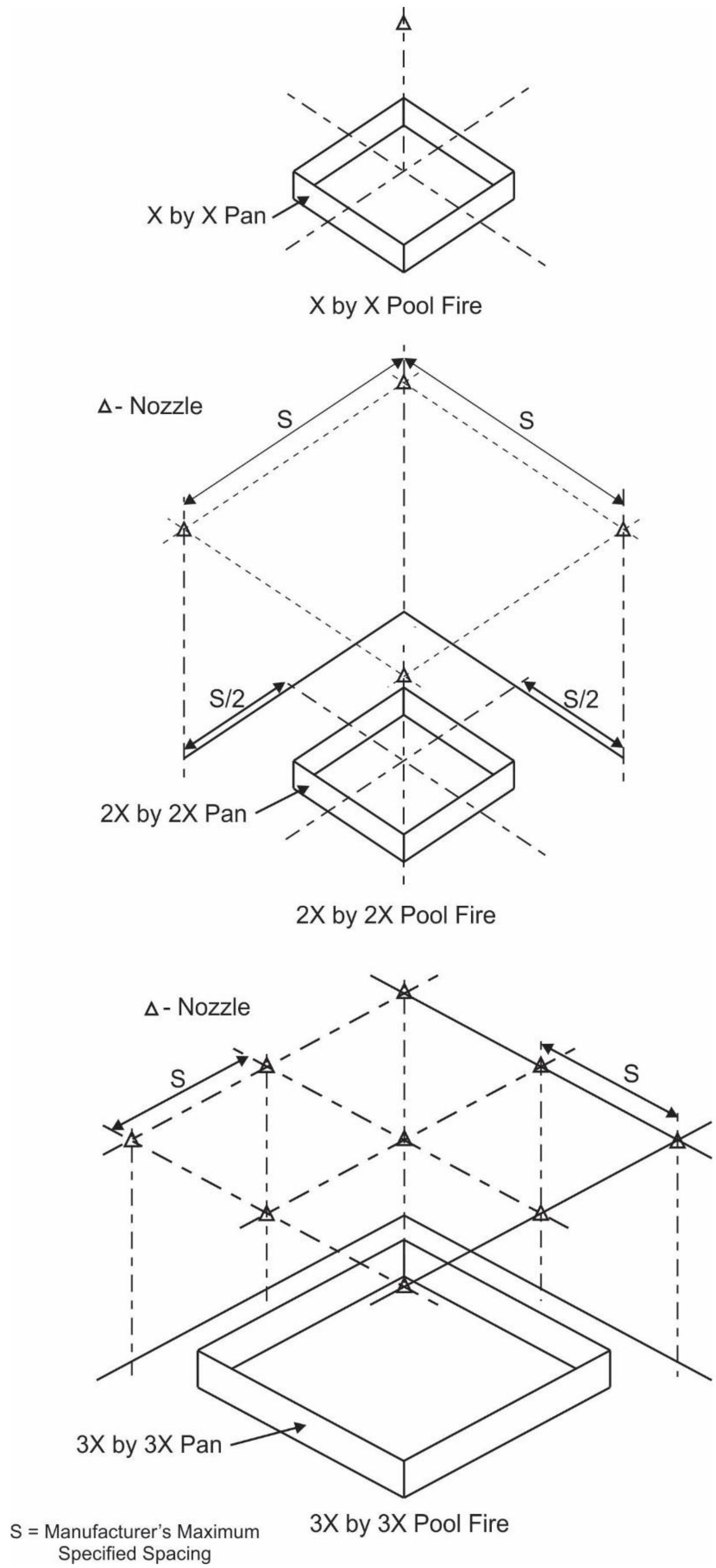


Figure I-1. Pool Fires for Fire Scenario I.3.1

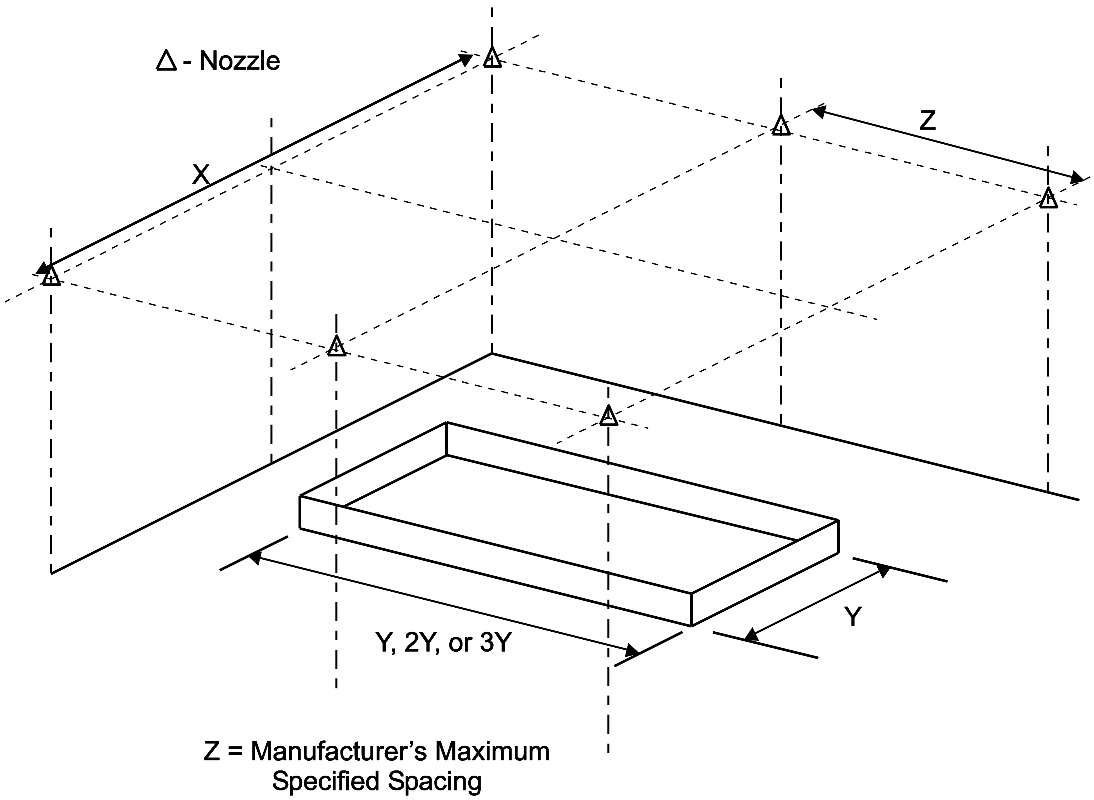


Figure I-2. Channel Pool Fire for Fire Scenario I.3.2

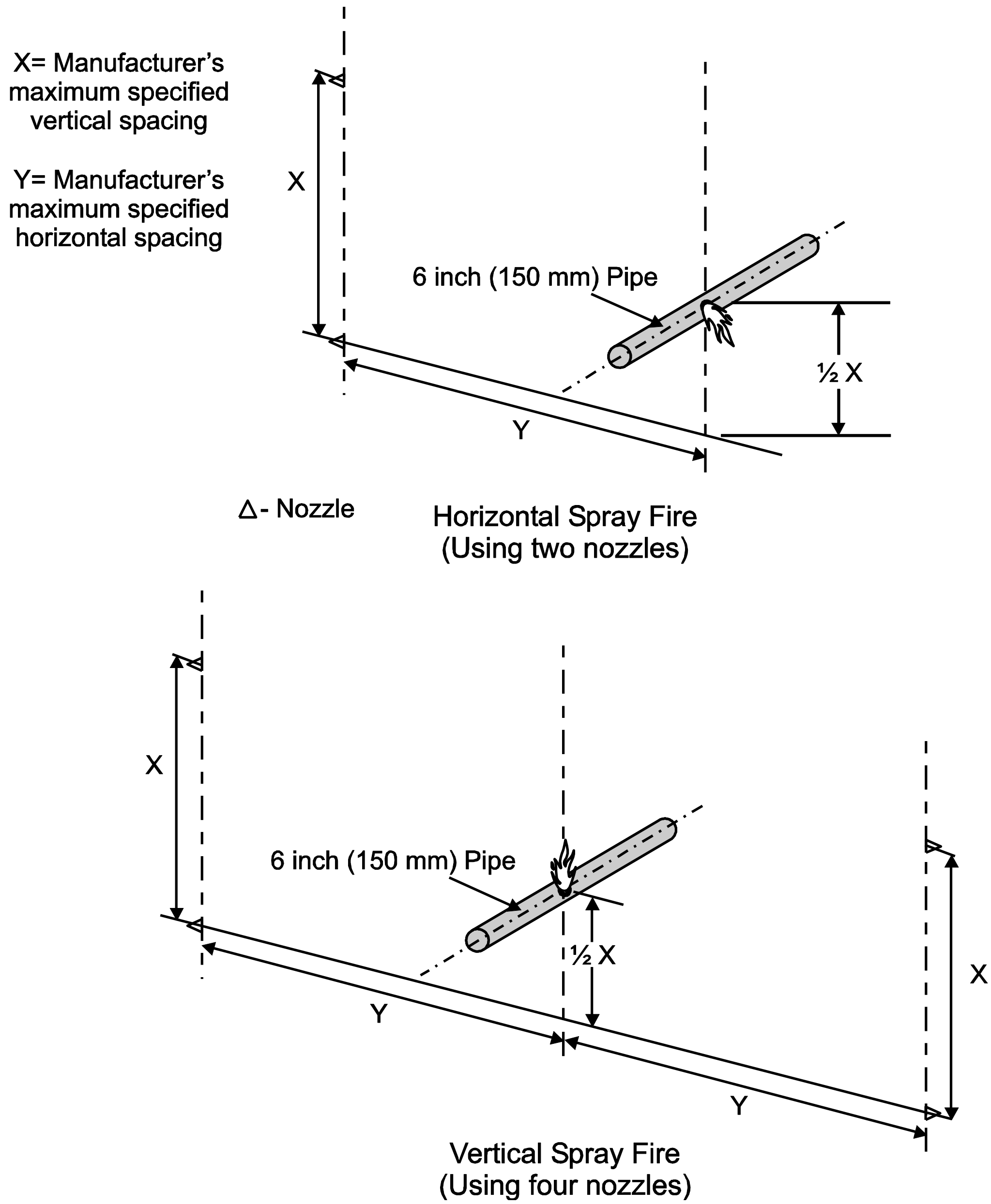


Figure I-3. Spray Fires for Fire Scenario I.3.3

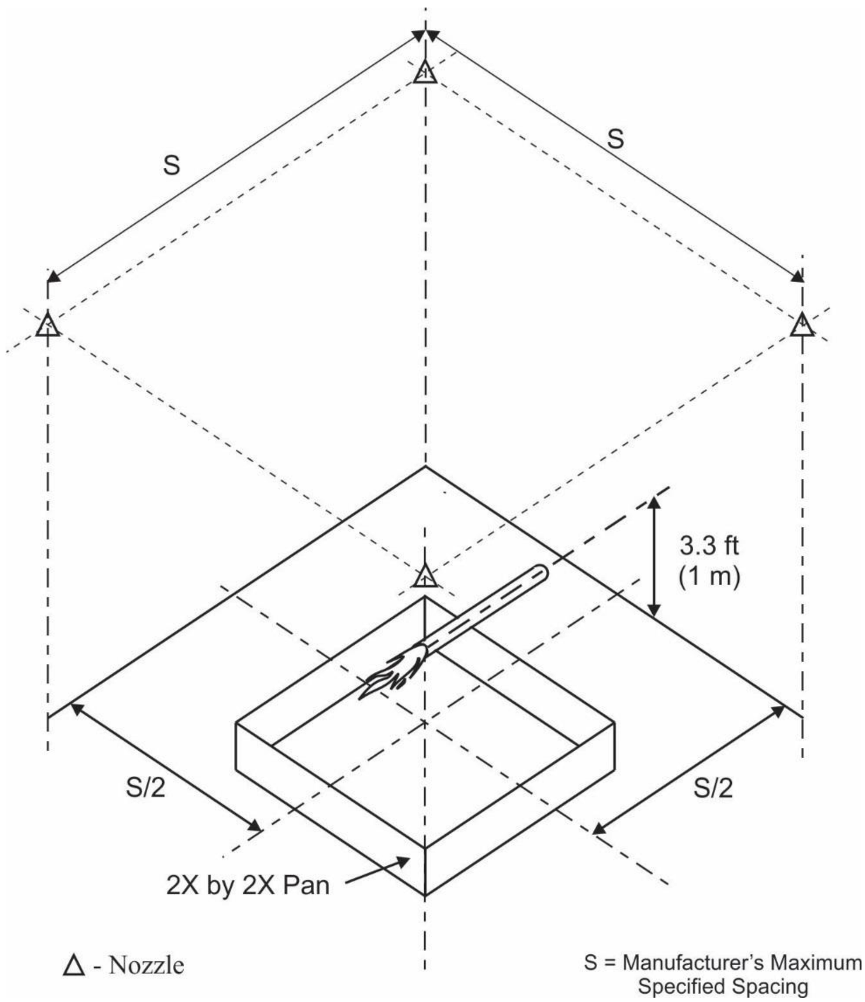


Figure I-4. Pool and Spray Fire for Fire Scenario I.3.4.A

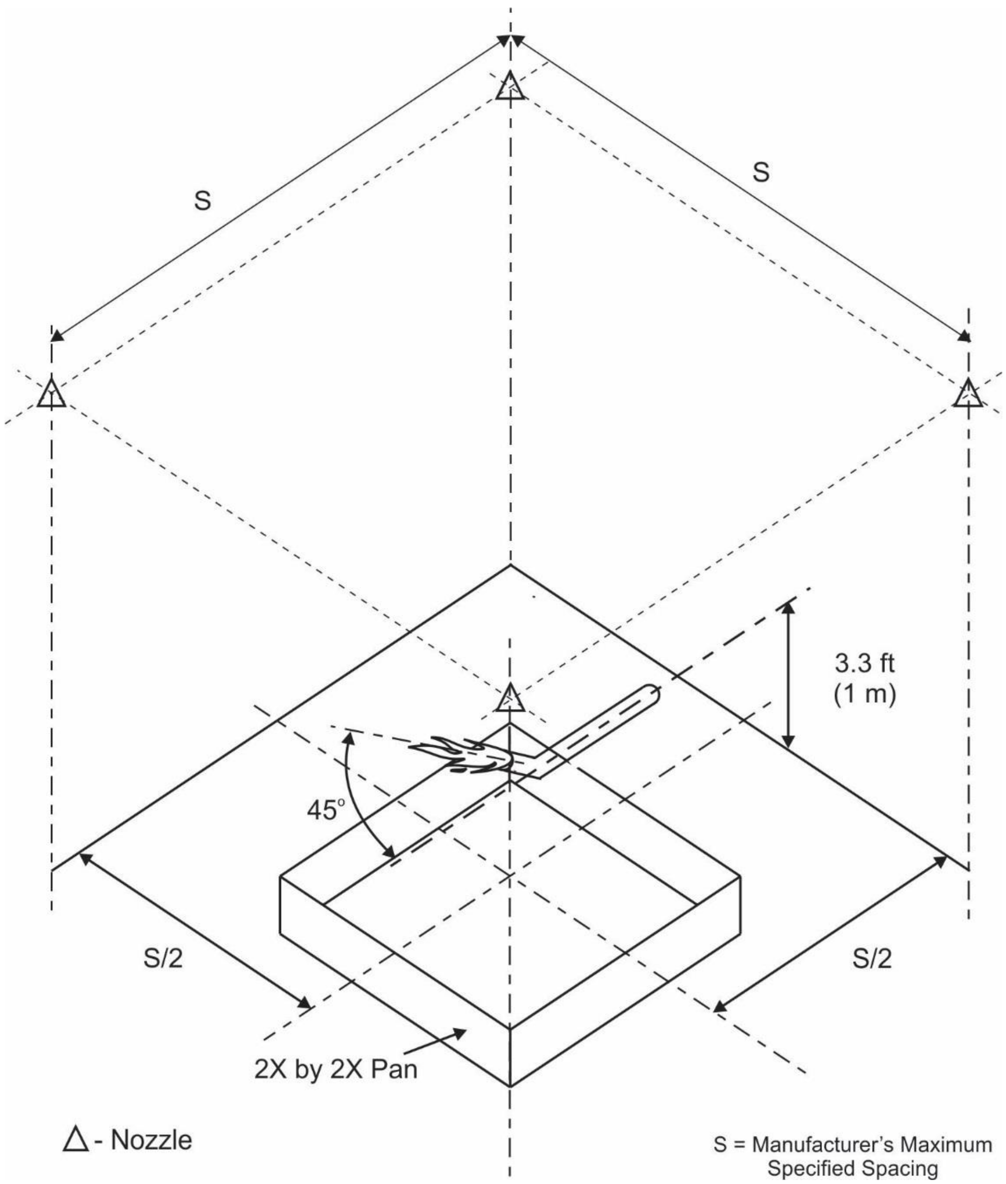


Figure I-5. Pool and Spray Fire for Fire Scenario I.3.4.B

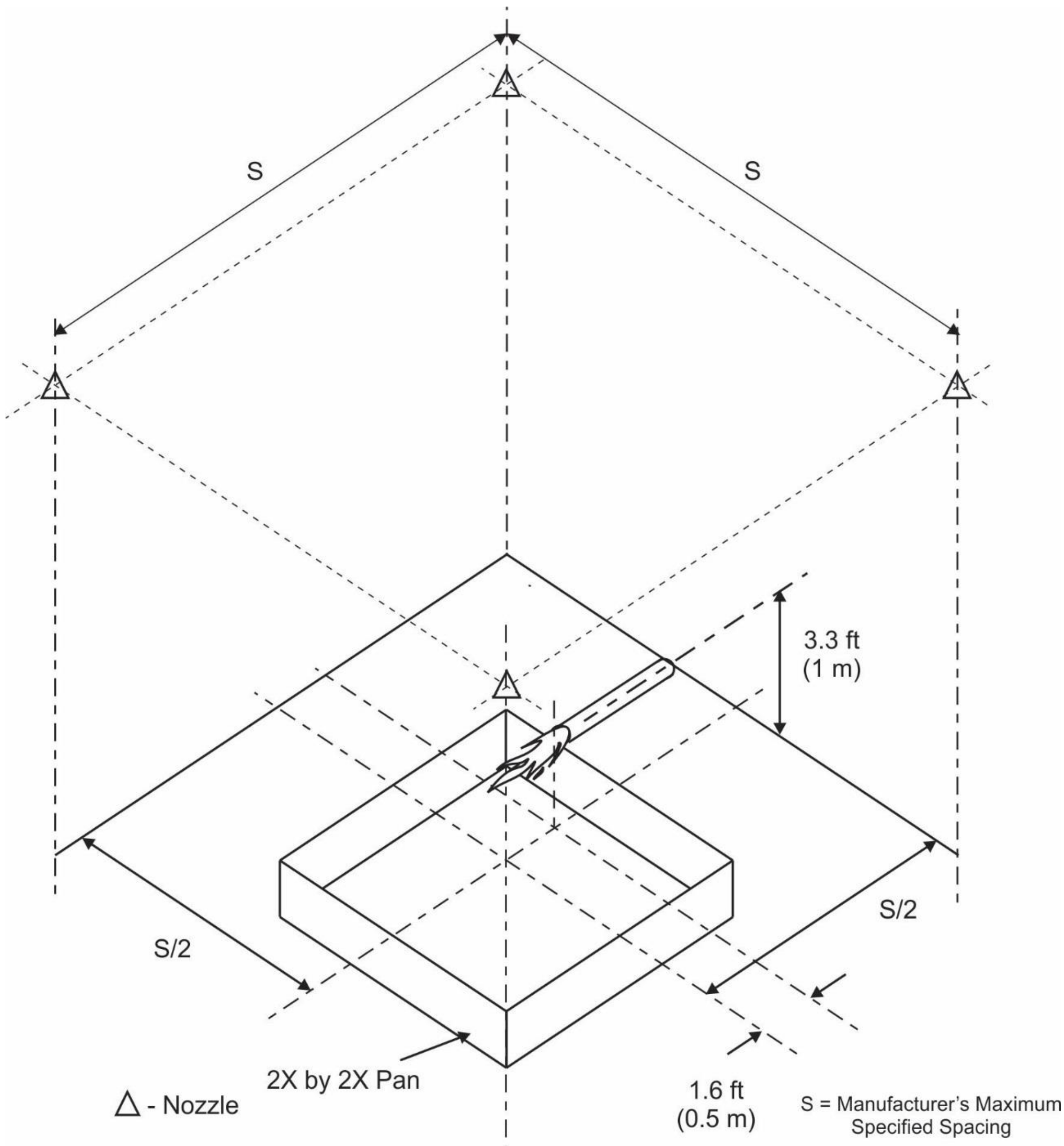


Figure I-6. Pool and Spray Fire for Fire Scenario I.3.4.C

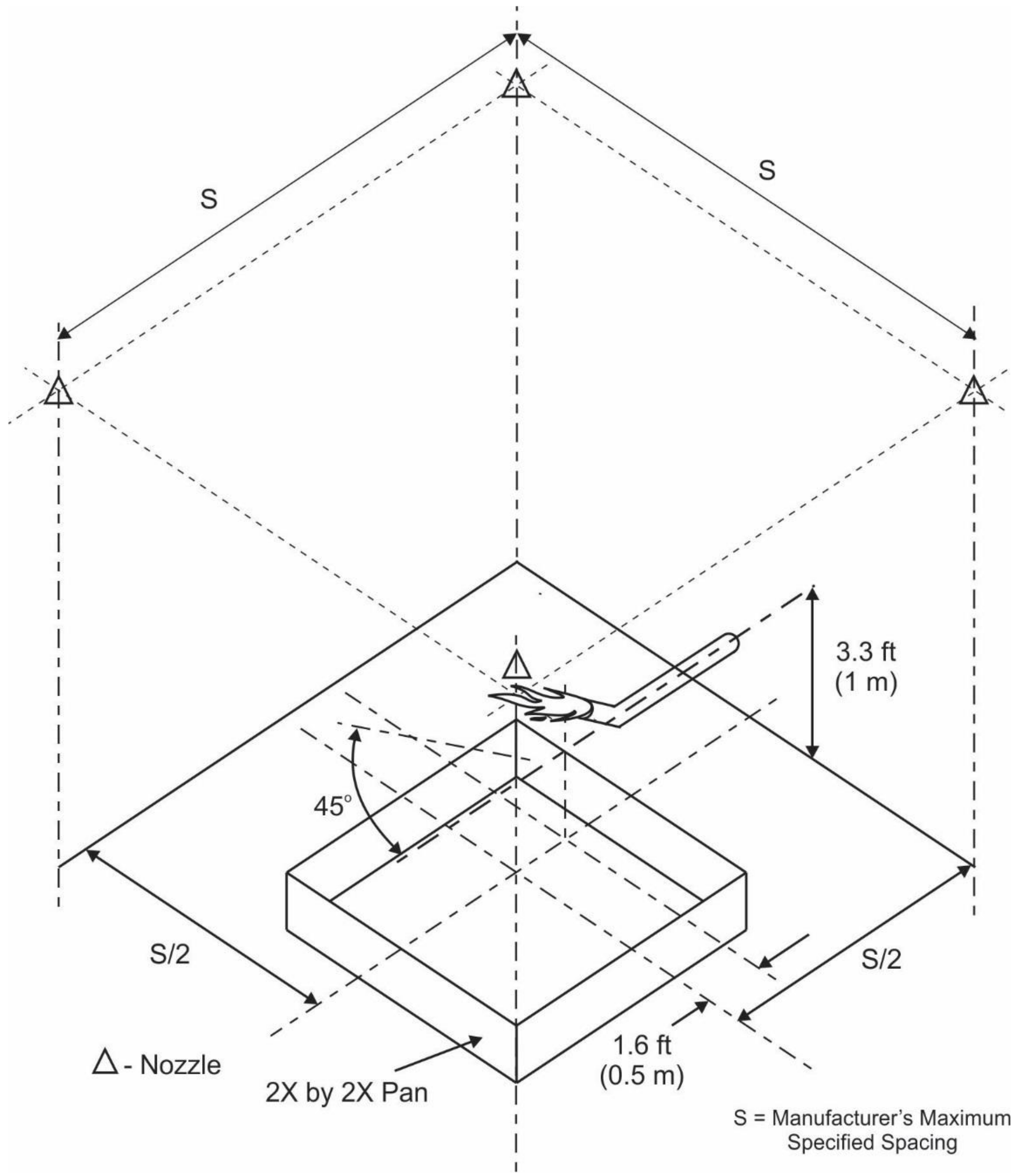


Figure I-7. Pool and Spray Fire for Fire Scenario I.3.4.D

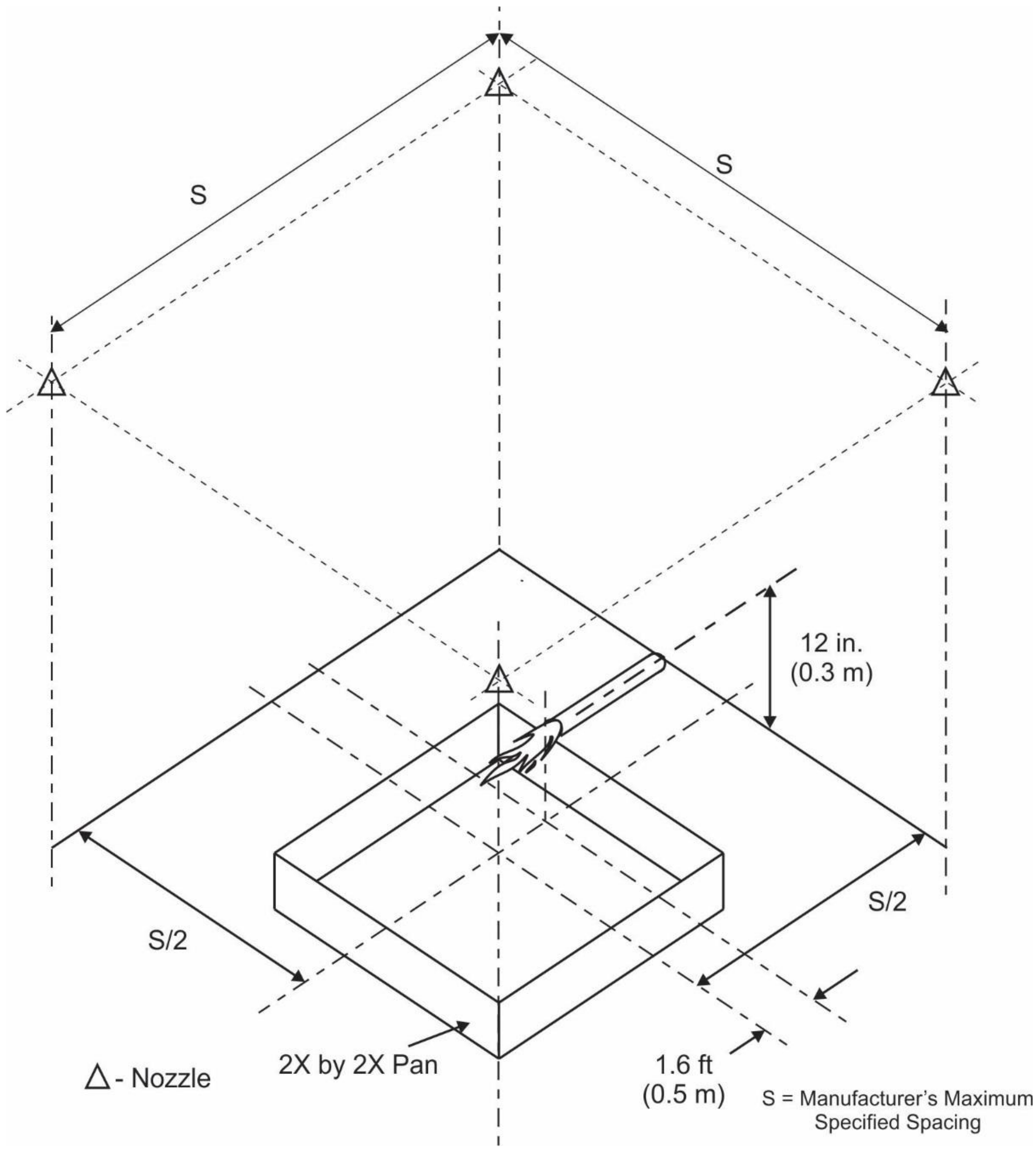


Figure I-8. Pool and Spray Fire for Fire Scenario I.3.4.E

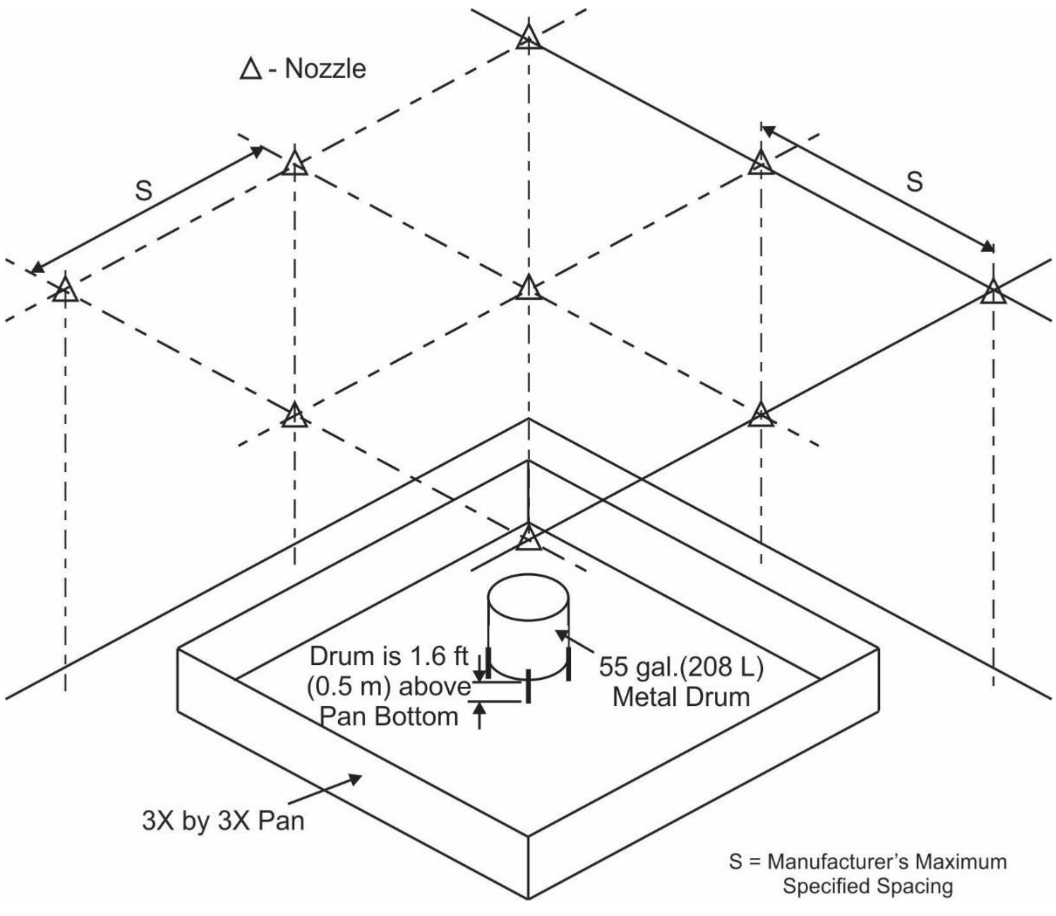


Figure I-9. Shielded Pool Fire for Fire Scenario I.3.5

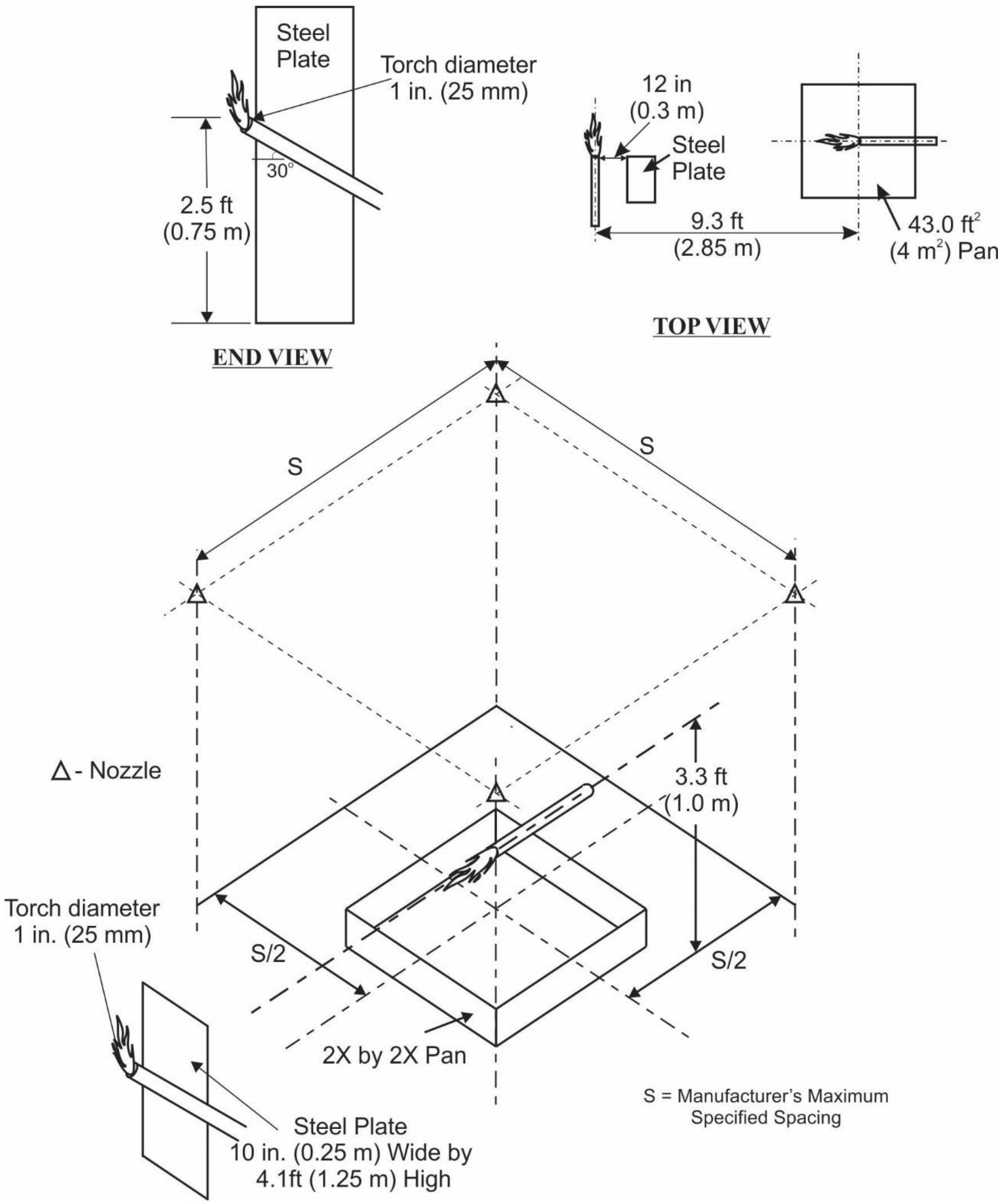


Figure I-10. Spray Fire Arrangement for Fire Scenario I.3.6

APPENDIX J: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF INDUSTRIAL OIL COOKERS

J.1 GENERAL TESTING REQUIREMENTS

The certification criteria for the fire tests are as follows:

A. The nozzles may be placed inside or outside the industrial oil cooker and shall be located in accordance with the Design, Installation, and Maintenance Manual supplied by the manufacturer.

B. Consideration of the application and use of nozzle protection caps to prevent or reduce the amount of nozzle contamination should be given. The use of such caps shall be included in the fire test and nozzle performance test requirement programs. If nozzle caps are not provided, an alternative method is needed to prevent grease vapors, moisture, or other foreign matter from entering the piping and/or plugging the nozzle orifice.

C. The fire tests should be conducted in a large open test hall of sufficient area, and with a minimum ceiling height of 16.4 ft (5.0 m), to avoid impacting the results of the tests. Tests involving larger oil cooker mockups may require a higher ceiling height. Ventilation for between tests and cooling of the enclosure should be provided by louver vents located on the roof of test hall and a side wall doorway.

D. The fire scenarios described in Section J.4 should be conducted using a cooking oil specified by the manufacturer. Selection of an appropriate cooking oil should be based on the manufacturer’s intended applications for protection, and should be discussed with the certification agency prior to testing. Commonly used cooking oils, their flash points, and AITs are listed below as a reference only. Technical information regarding the specific cooking oil used during the fire testing shall be provided by the manufacturer, and certification shall be limited to cooking oils with flash points and AITs less than or equal to the tested oil.

	Flash Point		*Auto Ignition Temperature (AIT)*	
Cooking Oil	***°F***	***(°C)***	***°F***	***(°C)***
Canola	641	(338)	686	(363)
Corn	647	(342)	684	(362)
Cotton Seed	633	(334)	690	(366)
Peanut	659	(348)	698	(370)
Soybean (Soya)	631	(333)	710	(377)
Sunflower	644	(340)	678	(359)
Palm	623	(328)	710	(377)

E. New cooking oil shall be used for each test.

F. The performance tests should be comprised of three stages, each stage using a different size industrial oil cooker mockup. At each stage, there shall be two tests; one to evaluate the fire extinguishment and cooling performance with the hood down and the other test with hood up.

Stage 1: Tests conducted with the smallest mockup of dimensions X wide by Y long, such that Y is greater than or equal to X. These dimensions shall be specified by the manufacturer.
Stage 2: Tests conducted with a mockup of dimensions X wide by 2Y long.
Stage 3: Tests conducted with a mockup of dimensions X wide by 3Y long.

The water mist system shall successfully complete both performance tests at each stage before it can be considered for certification for the protection of an industrial oil cooker up to the size tested. Testing may not proceed to the next stage without successful completion of the tests in the previous stage.

G. System components, component locations, and operating conditions shall remain unaltered throughout the fire tests at each stage. All fire tests shall be conducted using the spray specifications from the manufacturer's Design, Installation, Operation, and Maintenance Manual in regard to nozzle placement, spray flux, and spray duration.

H. Since exhaust air fans are required to be interlocked with the detection system to shut down the ventilation, and given the expectation that a water mist system may not prevent a fire from entering the exhaust duct if the fans remain on, power ventilated exhaust tests are not conducted as part of this certification standard. Use of supplementary exhaust duct protection is required, and should be so stated in the manufacturer's Design, Installation, Operation, and Maintenance Manual.

J.2 INDUSTRIAL OIL COOKER MOCKUPS

There should be three industrial oil cooker mockups denoted as Mockup A, Mockup B and Mockup C (see Figures J-1, J-2 and J-3). Each mockup shall be fabricated from nominal 0.44 in. (11 mm) thick steel and shall consist of a pan and a hood. Certification will be limited to these tested dimensions, including oil depth and free board, and configurations. Alternative pan and hood dimensions, and configurations, may be used at the request of the manufacturer, resulting in an expanded range of certification. This includes mockup configurations to allow for lesser minimum nozzle distance to oil surface and greater maximum distance to oil surface than those achieved using the standard mockup dimensions. Any variations from the standard mockup should be discussed with the certification agency prior to testing. Allowance of these variations will be based on the discretion of the certification agency.

Mockup A: The inside dimensions of the pan shall be X ft (m) wide, Y ft (m) long, and minimum 13.5 in. (34.3 cm) deep (Note: Y shall be greater than or equal to X). The inside dimensions of the hood shall be X ft (m) + 2 in. (5.1 cm) wide, Y ft (m) + 2 in. (5.1 cm) long, and 30 in. (76.2 cm) deep*. Both ends of the hood along the X dimension shall be open. In addition, there shall be a 20 in. (50.8 cm) diameter hole on top of the hood simulating the exhaust duct. The distance from the centerline of the hole to either end of the hood shall be Y/2 ft (m) + 1 in. (2.5 cm).

Mockup B: The inside dimensions of the pan shall be X ft (m) wide, 2Y ft (m) long, and minimum 13.5 in. (34.3 cm) deep (Note: Y shall be greater than or equal to X). The inside dimensions of the hood shall be X ft (m) + 2 in. (5.1 cm) wide, 2Y ft (m) + 2 in. (5.1 cm) long, and 30 in. (76.2 cm) deep*. Both ends of the hood along the X dimension shall be open. In addition, there shall be two 20 in. (50.8 cm) diameter holes on top of the hood simulating the exhaust ducts. The distance from the centerline of the holes to the closest respective end of the hood shall be 0.7Y ft (m) + 0.75 in. (1.9 cm).

Mockup C: The inside dimensions of the pan shall be X ft (m) wide, 3Y ft (m) long, and minimum 13.5 in. (34.3 cm) deep (Note: Y shall be greater than or equal to X). The inside dimensions of the hood shall be X ft (m) + 2 in. (5.1 cm) wide, 3Y ft (m) + 2 in. (5.1 cm) long, and 30 in. (76.2 cm) deep*. Both ends of the hood along the X dimension shall be open. In addition, there shall be three 20 in. (50.8 cm) diameter holes on top of the hood simulating the exhaust ducts. The distance between the centerline of the holes shall be 0.75Y ft (m) + 0.5 in. (1.3 cm). The distance from the centerline of the two holes closest to the ends of the hood and the closest respective end of the hood shall be 0.75Y ft (m) + 0.5 in. (1.3 cm).

*Depth of the mockup hood can be increased if a greater maximum nozzle distance from oil surface is requested by the manufacturer or decreased if a lesser minimum nozzle distance from oil surface is requested by the manufacturer.

Legs should be attached along the length of the hood so that the hood position can be adjusted vertically before each test. The legs should be located outside of the pan (see Figures J-1 through J-3).

The oil inside the pan should be heated to its auto-ignition temperature by several evenly spaced gas burners placed under the pan.

If an oil depth greater than the standard 5 in (12.7 cm) is requested for certification additional oil cooling testing shall be conducted to validate certification criteria specified in Section J.4.D. Testing shall be conducted in accordance with Section J.5.8.

J.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 ± 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 the oil in the pans (see Figures J-1 through J-3).

   a. All thermocouples shall be Type K, 18 gauge.

   b. One row of thermocouples shall be located 2 in. (5.1 cm) above the bottom of the industrial oil cooker mockup.

   c. A second row of thermocouples shall be located 4 in. (10.2 cm) above the bottom of the industrial oil cooker.

   d. The thermocouples shall be placed along the centerline of the industrial oil cooker mockup at 2 ft (0.61 m) intervals starting 2 ft (0.61 m) from the end of the industrial oil cooker mockup.

   e. All oil shall initially be at an ambient temperature of 68°F ± 18°F (20°C ± 10°C).

B. Test hall temperature. The enclosure shall initially be at an ambient temperature 68°F ± 18°F (20°C ± 10°C) for all tests.

C. Registration of fire extinguishment by means of thermal imaging equipment is strongly encouraged. Additionally, extinguishment may be registered by monitoring the pan fire temperatures, with thermocouples located along the length of the pan and approximately 1 in. (2.5 cm) above the initial oil surface. The fire can be considered to be extinguished when temperature registration drops below 212°F (100°C) and does not increase.

D. Oxygen concentrations, measured between 6.6 and 9.8 ft (2 and 3 m) away from the pan, and at the same elevation as the rim of the pan. Oxygen concentrations during each test should be maintained above 16 percent.

J.4 CERTIFICATION CRITERIA

J.4.1 The certification criteria for all the fire tests are as follows:

A. The water mist system shall be capable of extinguishing any auto-ignition fire (AIT) fire inside the industrial oil cooker mockup, regardless of its hood position.

B. All open flames shall be extinguished within one minute from the discharge of mist from any nozzle. This criterion may be verified visually.

C. The water mist system shall prevent, and not cause, any significant thermal damage to the industrial oil cooker by ensuring sufficient cooling of the oil. At the completion of system discharge, the average oil temperature inside the pan, using all thermocouples, shall be below the oil's flash point.

D. The required extinguishing agent quantity shall be double the total time needed to extinguish the worst case fire scenario and subsequently cool the oil to a temperature below its flash point, or 10 minutes, whichever is greater. Consideration shall be given to potential oil spillover from the pan during system discharge.

E. For water mist systems designed to operate at constant pressures, the system pressures shall be automatically controlled by the water mist system to within ± 5 percent. If the system pressures cannot be controlled within this specified tolerance, fire tests shall be conducted at both the minimum and the maximum pressures for each fire test by using external means to control the system pressure. For water mist systems designed to operate with decaying pressures, the starting pressures shall be within ± 5 percent of the manufacturer's designated starting pressures. For water mist systems designed to cycle between two pressure limits, both the higher and lower pressures shall be within ± 5 percent of their respective designated pressures, and the periods pertaining to the higher and lower pressure in each cycle shall be within ± 3 seconds of their designated durations.

F. During the discharge of the water mist system, there should be no excessive fire flare-ups, micro explosions of oil reacting with water, or splashing of the burning oil. At a minimum, activation of the system shall not create any additional fire hazard by spreading out the burning oil in the vicinity of the industrial oil cookers. To ensure that this criterion is met, there shall be no appreciable quantity of oil spilling, or frothing over, from the pan during the period of fire extinguishment and subsequent cooling of the oil to a temperature below its flashpoint. Verification of this requirement shall be conducted visually.

J.4.2 The certification criteria for the cooling test (J.5.8) is as follows:

A. The water mist system shall prevent, and not cause, any significant thermal damage to the industrial oil cooker by ensuring sufficient cooling of the oil. At the completion of system discharge, the average oil temperature inside the pan, using all thermocouples, shall be below the oil's flash point.

B. The required extinguishing agent quantity shall be double the total time needed to extinguish the worst case fire scenario and subsequently cool the oil to a temperature below its flash point, or 10 minutes, whichever is greater. Consideration shall be given to potential oil spillover from the pan during system discharge.

C. For water mist systems designed to operate at constant pressures, the system pressures shall be automatically controlled by the water mist system to within ± 5 percent. If the system pressures cannot be controlled within this specified tolerance, fire tests shall be conducted at both the minimum and the maximum pressures for each fire test by using external means to control the system pressure. For water mist systems designed to operate with decaying pressures, the starting pressures shall be within ± 5 percent of the manufacturer's designated starting pressures. For water mist systems designed to cycle between two pressure limits, both the higher and lower pressures shall be within ± 5 percent of their respective designated pressures, and the periods pertaining to the higher and lower pressure in each cycle shall be within ± 3 seconds of their designated durations.

J.5 FIRE EXTINGUISHMENT AND COOLING TESTS

Each test should be conducted in the following manner:

1. The oil shall be heated evenly to its auto-ignition temperature. The oil temperatures shall be monitored during the heating period.
2. The surface of the oil should ignite at approximately the same time that the thermocouples inside the pan indicate that the oil has reached its auto-ignition temperature. At ignition, small, blue flamelets may initially appear over the surface of the oil. As the fire develops, resulting in a more incomplete combustion process, the flamelets will develop into larger, orange and yellow flames.
3. Once the oil surface is completely involved in these larger flames, based on visual observation, the heaters shall be shut off.
4. Thirty (30) seconds after shutting off the heaters, the water mist system shall be activated manually.
5. At the end of each test, the burned oil shall be completely drained, and new oil used for the next test.

Certification will be limited to the tested dimensions and configurations. Alternative pan dimensions (length, width, depth), hood dimensions, and cooking oil depths may be used at the request of the manufacturer, resulting in an expanded range of certification. Allowance of these variations will be based on the discretion of the certification agency.

J.5.1 Hood Up Position with Mockup A

The bottom of the lip of the hood of Mockup A shall be positioned 18 in. (45.7 cm) above the top of the pan of Mockup A (see Figure J-4). Fresh oil shall be introduced into the pan to provide a minimum depth of 5 in. (12.7 cm) [8.5 in. (21.6 cm) free board]. In order for the test to be considered successful, all previously stated certification criteria shall be met.

J.5.2 Hood Down Position with Mockup A

Fire Test J.5.2 shall not be conducted without the successful completion of J.5.1. The bottom of the lip of the hood of Mockup A shall be positioned 2 in. (5.1 cm) above the top of the pan of Mockup A (see Figure J-4). Fresh oil shall be introduced into the pan to provide a minimum depth of 5 in. (12.7 cm) [8.5 in. (21.6 cm) free board]. In order for the test to be considered successful, all previously stated certification criteria shall be met.

J.5.3 Hood Up Position with Mockup B

Fire Test J.5.3 shall not be conducted without the successful completion of J.5.2. The bottom of the lip of the hood of Mockup B shall be positioned 18 in. (45.7 cm) above the top of the pan of Mockup B (see Figure J-4). Fresh oil shall be introduced into the pan to provide a minimum depth of 5 in. (12.7 cm) [8.5 in. (21.6 cm) free board]. In order for the test to be considered successful, all previously stated certification criteria shall be met.

J.5.4 Hood Down Position with Mockup B

Fire test J.5.4 shall not be conducted without the successful completion of fire test J.5.3. The bottom of the lip of the hood of Mockup B shall be positioned 2 in. (5.1 cm) above the top of the pan of Mockup B (see Figure J-4). Fresh oil shall be introduced into the pan to provide a minimum depth of 5 in. (12.7 cm) [8.5 in. (21.6 cm) free board]. In order for the test to be considered successful, all previously stated certification criteria shall be met.

J.5.5 Hood Up Position with Mockup C

Fire test J.5.5 shall not be conducted without the successful completion of fire test J.5.4. The bottom of the lip of the hood of Mockup C shall be positioned 18 in. (45.7 cm) above the top of the pan of Mockup C (see Figure J-4). Fresh oil shall be introduced into the pan to provide a minimum depth of 5 in. (12.7 cm) [8.5 in. (21.6 cm) free board]. In order for the test to be considered successful, all previously stated certification criteria shall be met.

J.5.6 Hood Down Position with Mockup C

Fire Test J.5.6 shall not be conducted without the successful completion of fire test J.5.5. The bottom of the lip of the hood of Mockup C shall be positioned 2 in. (5.1 cm) above the top of the pan of Mockup C (see Figure J-4). Fresh oil shall be introduced into the pan to provide a minimum depth of 5 in. (12.7 cm) [8.5 in. (21.6 cm) free board]. In order for the test to be considered successful, all previously stated certification criteria shall be met.

J.5.7 Other

Based on the results of Fire Tests J.5.1 through J.5.6, additional fire testing may be required to ensure that the water mist system being evaluated meets the intent of this section of the standard. This testing will be performed at the sole discretion of the certification agency.

J.5.8 Oil Cooling Verification Test [For Oil Depths Greater than 5 in. (12.7 cm)]

The mockup and water mist system specifications from Fire Test J.5.1 shall be used. The only exception is modification to the depth of the mockup pan in order to accommodate the additional cooking oil while maintaining the proper freeboard. The depth of the mockup pan is to be increased by the difference between the oil depth requested and the standard oil depth of 5 in. (12.7 cm). Fresh oil shall be introduced to the pan at the requested depth and heated until reaching the bulk oil temperature at the time of extinguishment during Fire Test J.5.1. The bulk oil temperature is the average oil temperature of all thermocouples in the oil. Once this temperature is reached the heating is to be turned off and the water mist system shall be activated and continue to discharge until the oil has been cooled below its flash point. The test shall be conducted twice, at minimum, to ensure a consistent result. Water mist system discharge duration criteria will be determined in step-wise increments based on the oil depths tested.

J.6 EXTRAPOLATION OF TEST DATA

Should a need arise to apply a water mist system to the protection of an industrial oil cooker that is longer than Mockup C, test data may be extrapolated on a case-by-case basis by the certification agency. 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 certification.

Systems shall be judged suitable for extrapolation beyond the length tested if all of the following criteria are met:

A. The number of nozzles per unit area of the industrial oil cooker is unchanged for the fire tests.

B. The nozzle discharge per unit area of the industrial oil cooker is unchanged for the fire tests.

C. The difference in extinguishment times between Fire Test J.5.1, Fire Test J.5.3 and Fire Test J.5.5 is less than 30 percent for those extinguishing times greater than 30 seconds, and a maximum of 10 seconds if all extinguishing times are less than 30 seconds. Additionally, the extinguishment times should not indicate an increasing time trend.

D. The difference in extinguishment times between Fire Test J.5.2, Fire Test J.5.4 and Fire Test J.5.6 is less than 30 percent for those extinguishing times greater than 30 seconds, and a maximum of 10 seconds if all extinguishing times are less than 30 seconds. Additionally, the extinguishment times should not indicate an increasing time trend.

Extrapolation beyond the width tested (dimension X) is not permitted.

J.7 LARGER PROTECTION WIDTHS

For applications with larger pan widths (dimension X), it may be possible to remove fire tests using Mockup C from the test series. This exception shall only apply to pan widths greater than or equal to 8 ft (2.4 m). Additionally, this exception shall only apply to water mist systems employing overhead nozzle installations, will be based on an evaluation of the system configuration, and will be permitted at the sole discretion of the certification agency.

Following the completion of the fire tests using Mockups A and B (Fire Tests J.5.1 through J.5.4), the test data and extinguishment times will be examined for consistency. The difference in extinguishment times between Fire Test J.5.1 and J.5.3 shall be less than 30 percent for those extinguishing times greater than 30 seconds, and a maximum of 10 seconds if both extinguishing times are less than 30 seconds. The difference in extinguishment times between Fire Test J.5.2 and J.5.4 shall be less than 30 percent for those extinguishing times greater than 30 seconds, and a maximum of 10 seconds if both extinguishing times are less than 30 seconds. The extinguishment times shall not indicate an increasing time trend.

If the completion of Fire Tests J.5.1 through J.5.4 do not yield consistent results, as described above, intermediate tests using a third mockup size may be required. The inside dimensions of the intermediate test pan should be X ft (m) wide, 1.5 Y (m) long, and 13.5 in. (34.3 cm) deep (Note: Y shall be greater than or equal to X). The inside dimensions of the hood should be X ft (m) + 2 in. (5.1 cm) wide, 1.5Y ft (m) + 2 in. (5.1 cm) long, and 30 in. (76.2 cm) deep. Both ends of the hood along the X dimension shall be open. Dimensioning of the circular holes simulating the exhaust ducts will be dependent on the size of the pan and will be selected by the certification agency.

Should a need arise to apply a water mist system to the protection of an industrial oil cooker that is longer than the mockups that were tested, test data may be extrapolated on a case-by-case basis by the certification agency as described in Section J.6. Extrapolation beyond the width tested (dimension X) is not permitted.

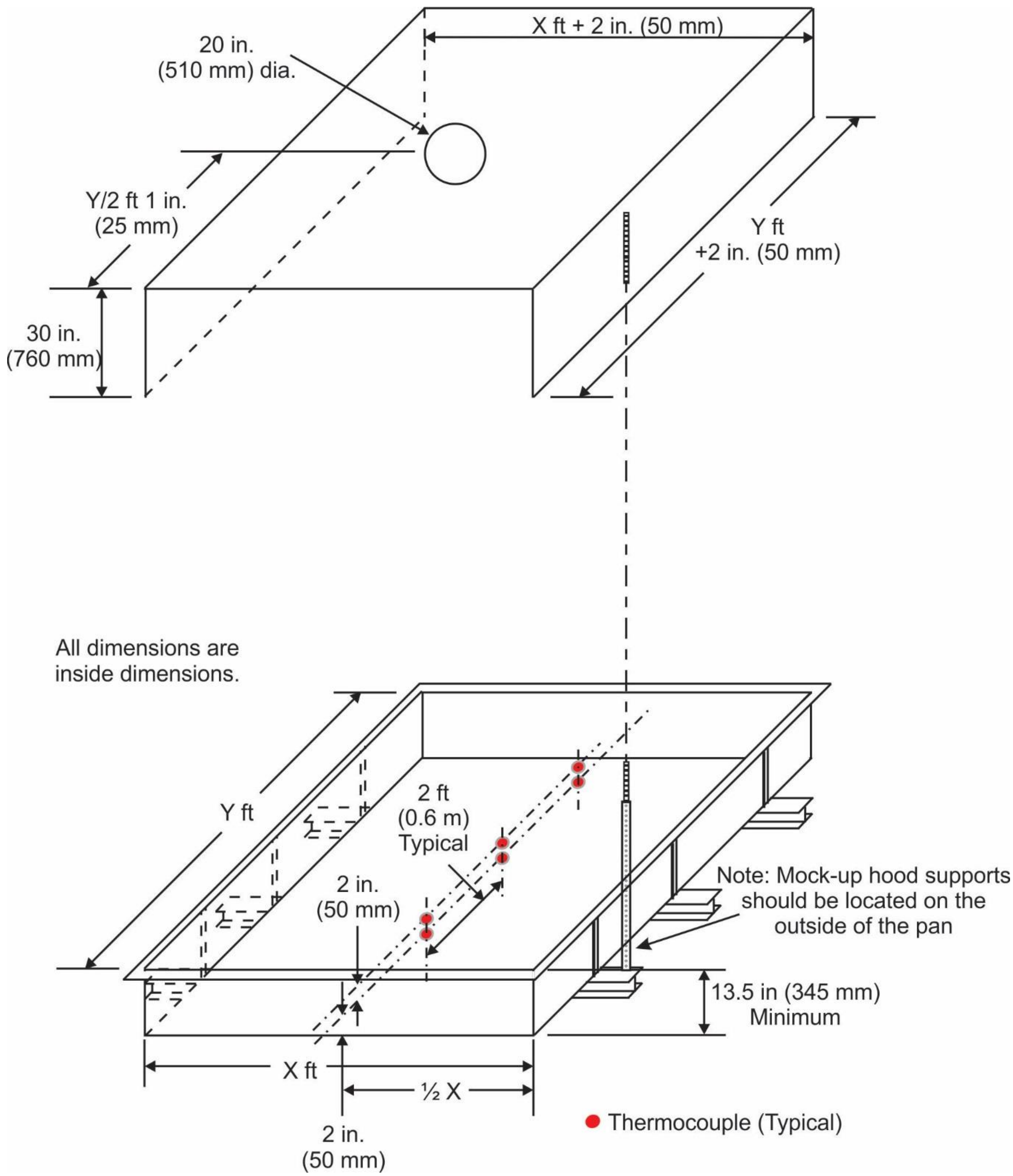


Figure J-1. Schematic Figure of Mockup A (Pan and Hood)

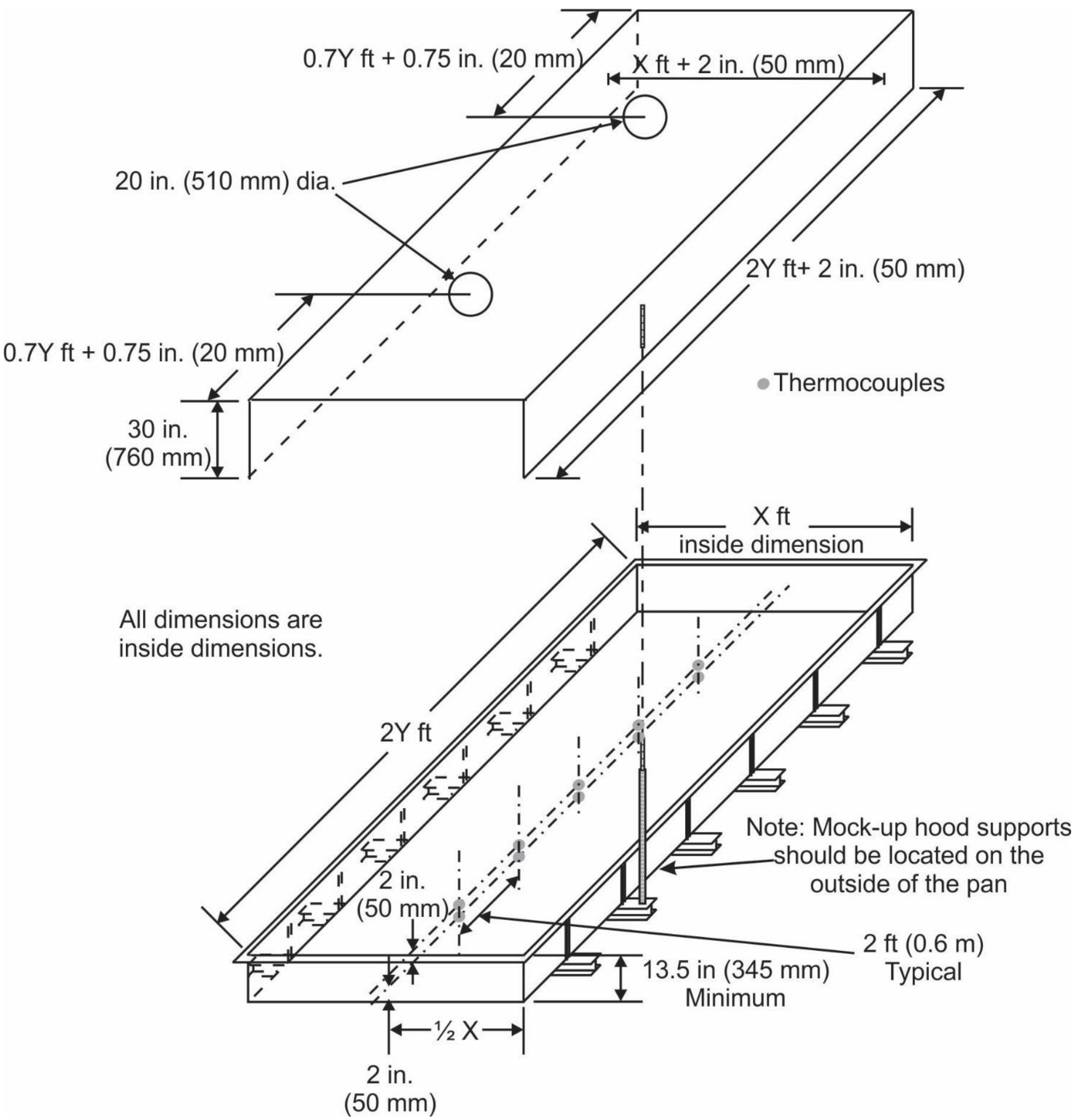


Figure J-2. Schematic Figure of Mockup B (Pan and Hood)

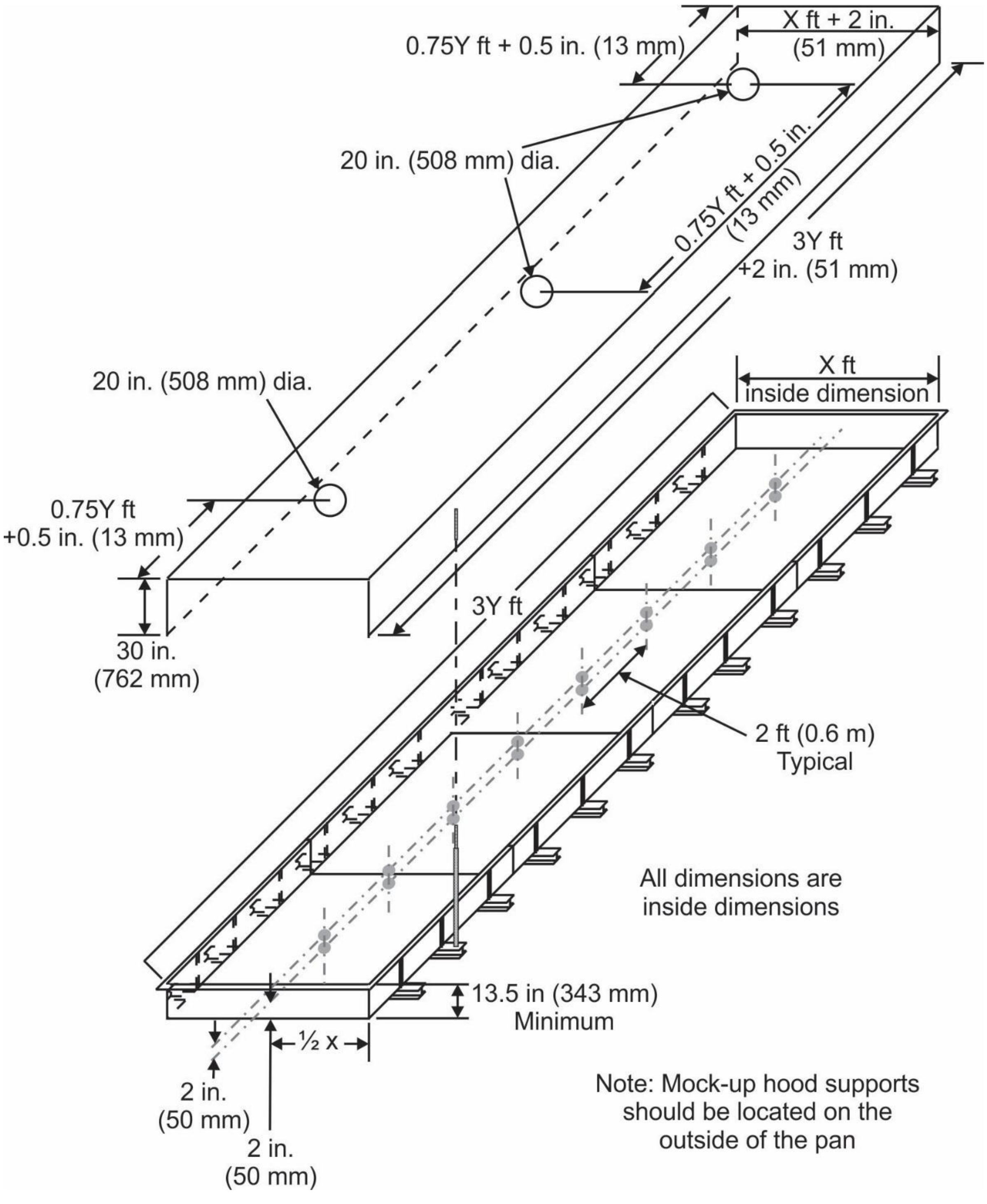


Figure J-3. Schematic Figure of Mockup C (Pan and Hood)

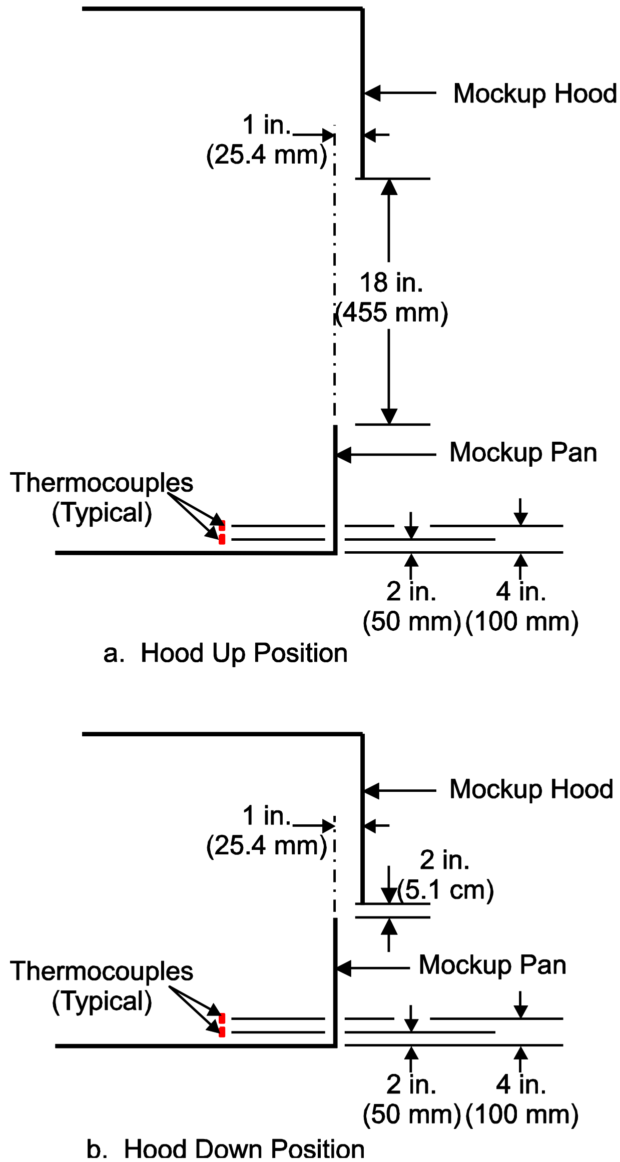


Figure J-4. Schematic of Hood Up and Down Positions

APPENDIX K: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF CONTINUOUS WOOD BOARD PRESSES

K.1 GENERAL TESTING REQUIREMENTS

The certification criteria for the fire tests are as follows:

A. The fire tests should be conducted in a large open test hall of sufficient area, and with a minimum ceiling height of 16.4 ft (5.0 m), to avoid impacting the results of the tests. Ventilation for between tests and cooling of the enclosure should be provided by louver vents located on the roof of test hall and a side wall doorway.

B. System components, component locations, and operating conditions shall remain unaltered throughout the fire tests. All fire tests shall be conducted using the spray specifications from the manufacturer's design manual with regard to nozzle placement, spray flux, and spray duration.

C. All nozzles shall be installed at their maximum spacing.

D. The minimum operating nozzle pressure (as specified by the manufacturer) shall be used for all fire tests. The maximum operating nozzle pressure (as specified by the manufacturer) shall be used for the cooling test.

E. The manufacturer's design manual shall describe in detail the scaling parameters used for the protection of larger continuous wood board presses.

K.2 CONTINUOUS WOOD BOARD PRESS MOCKUPS (FIGURE K-1)

Continuous wood board presses can include dimensions of up to 14.75 ft (4.5 m) wide by 14.75 ft (4.5 m) high by 164 ft (50 m) long. The press is usually located above a pit extending the full length of the press, which provides access for maintenance and collection of wood chips and lubricant leaking from the press above the pit.

The press consists of a series of individual frame sections (pockets), each with its own hydraulic rams to control the board thickness in the fabrication process. The mixture of glue and wood chips/fiber is continually fed to, and pressed between the moving stainless steel belts of the upper and lower halves of the press. Each continuous belt is supported by a steel rolling rod carpet, which is driven by sprockets located near the press's two ends. The carpet rolls across stationary, contiguous hot platens heated by heat transfer fluid circulating through the platens. Pressure is exerted on the hot platens by the hydraulic rams via thick steel plates immediately above (in the upper half of the press) or below (in the lower half of the press) the hot platens. Heat tunnels are located above the upper belt and below the lower belt by enclosing the space around the belts to conserve heat. The typical height of the heat tunnels is approximately 3.3 ft (1 m).

K.2.1 Press Pocket Space Mockup (Figure K-2)

The press pocket space mockup, simulating an individual press pocket space in the lower half of a continuous board press, shall be constructed of 14 gauge (2 mm) sheet steel. The bottom of the mockup shall include dimensions equal to the maximum pocket space length and width to be protected, as specified by the manufacturer. The walls should extend the entire length and width of the mockup, with a height equal to 2 ft (0.6 m) less than the maximum pocket space height to be protected, as specified by the manufacturer.

The ceiling of the mockup, simulating the obstruction of steel ram plates, hot platens, rolling rod carpet, and the stainless steel belt, shall be located 2 ft (0.6 m) above the top of the mockup walls. The width of the ceiling shall be 8 ft (2.45 m), and the length shall be 2 ft (0.6 m) shorter than the length of the bottom and walls of the mockup. Five thermocouples shall be evenly spaced along the centerline of the ceiling, on the upper surface, to monitor the ceiling temperature. If direct water mist spray impingement on the thermocouple(s) cannot be avoided, the location(s) where the thermocouple(s) are welded to the belt should be shielded from the spray. The ceiling shall be centered over the lower portion of the mockup in both horizontal directions.

K.2.2 Heat Tunnel Mockup (Figures K-3 and K-4)

The heat tunnel mockup, simulating the areas enclosing the upper and lower belts to conserve heat within the press, shall be constructed of 14 gauge (2 mm) sheet steel. The mockup length, width, and height shall be equal to the maximum heat tunnel dimensions to be protected, as specified by the manufacturer.

A stainless steel press belt sample shall be cut from the actual continuous wood board press to be protected by the water mist system. If the system will be installed to protect multiple wood board press applications, the worst case stainless steel belt sample, as determined by the certification agency, should be used. The length and width of the belt sample shall each be 1 ft (0.3 m) less than the dimensions of the mockup. Five thermocouples shall be evenly spaced along the centerline of the belt sample, on the upper surface, to monitor the temperature. If direct water mist spray impingement on the thermocouple(s) cannot be avoided, the location(s) where the thermocouple(s) are welded to the belt should be shielded from the spray. The belt sample shall be centered along all three axes within the heat tunnel mockup.

K.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 ± 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 ± 18°F (20°C ± 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°F ± 18°F (20°C ± 10°C).

D. Mockup temperatures, as described in Section N.2. The mockup shall initially be at an ambient temperature 68°F ± 18°F (20°C ± 10°C) for all tests. The thermocouple locations should be adjusted as necessary to avoid direct flame impingement.

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°F (100°C) and does not increase. Registration by means of thermal imaging equipment, in addition to the thermocouples, is strongly encouraged.

I. Oxygen 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. Oxygen should generally be no less than 16 percent during the entire period of each test.

J. For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

Spray Nozzle	***Monarch F-80, 24.00***
Fire Size	5.8 ± 0.6 MW
Fuel Type	Light Diesel
Nominal Oil Pressure	120 psi (8.2 bar)
Nominal Fuel Flow	0.35 ± 0.02 lb/s (0.16 ± 0.01 kg/s)
Fuel Temperature	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 the certification agency.

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:

The heat tunnel channel shall be 1.6 ft (0.5 m) wide and extend the entire length of the stainless steel belt. The tray shall be 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). Tray surfaces should be smooth and edges should be free of imperfections.

K.4 FIRE TESTS

The water mist system shall successfully complete all six performance fire tests described in this section. During the fire tests, all systems shall operate without manual intervention. Agent supply needed for twice the extinguishment time for the longest fire scenario will be reported and considered as one of the requirements when water mist is used as a special protection system (see Section 1.9, Definitions).

K.4.1 Press Pocket Pool Fire

Criteria: Suppression of the pool fire.

The maximum one-minute mockup ceiling temperature average following activation of the water mist system shall not exceed 995°F (535°C).

Fuel: Diesel

Type: Pool fire. A water base of 2.1 in. (5 cm) in height shall be added to the press pocket floor, with a fuel load of at least 0.8 in. (2 cm) above the water.

Fire Location: Within the press pocket floor.

Fire Preburn Time: 30 seconds after the entire surface is involved in fire.

Test Procedure: The pool fire shall be ignited in the mockup floor. The water mist system should be activated subsequent to the required preburn time. Following extinguishment, if applicable, the fuel left in the pool or tray should be measured, if possible, and reignited to verify that sufficient fuel remained in the pan.

K.4.2 Unobstructed Press Pocket Spray Fire (Angled Upward)

Criteria: Suppression of the spray fire.

The maximum one-minute mockup ceiling temperature average following activation of the water mist system shall not exceed 995°F (535°C).

Fuel:	Diesel
Type:	Spray fire to simulate a pressurized leak from a hydraulic or thermal oils system
Fire Size:	6 MW
Fire Location:	The spray fire nozzle should be located in the center of the longer wall of the press pocket mockup, in the same plane as the wall, and centered vertically between the top of the wall and the ceiling. The nozzle shall be angled such that the spray fire is directed at the center of the mockup ceiling (see Figure K-5).
Fire Preburn Time:	15 seconds
Test Procedure:	The spray fire shall be ignited. The water mist system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment, if applicable. The water mist discharge should be shut off 45 seconds after the fuel spray is shut off.

K.4.3 Unobstructed Press Pocket Spray Fire (Angled Downward)

Criteria:	Suppression of the spray fire. The maximum one-minute mockup ceiling temperature average following activation of the water mist system shall not exceed 995°F (535°C).

Fuel:	Diesel
Type:	Spray fire to simulate a pressurized leak from a hydraulic or thermal oils system
Fire Size:	6 MW
Fire Location:	The spray fire nozzle should be located in the center of the longer wall of the press pocket mockup, in the same plane as the wall, and centered vertically between the top of the wall and the ceiling. The nozzle shall be angled such that the spray fire is directed at the center of the pocket wall opposite from the spray fire origin (see Figure K-5).
Fire Preburn Time:	15 seconds
Test Procedure:	The spray fire shall be ignited. The water mist system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment, if applicable. The water mist discharge should be shut off 45 seconds after the fuel spray is shut off.

K.4.4 Obstructed Press Pocket Spray Fire (Angled Upward)

Criteria:	Suppression of the spray fire. The maximum one-minute mockup ceiling temperature average following activation of the water mist system shall not exceed 995°F (535°C).

Fuel:	Diesel
Type:	Spray fire to simulate a pressurized leak from a hydraulic or thermal oils system
Fire Size:	6 MW
Fire Location:	The spray fire nozzle should be located in the center of the longer wall of the press pocket mockup, in the same plane as the wall, and centered vertically between the top of the wall and the ceiling. The nozzle shall be angled such that the spray fire is directed at the center of the mockup ceiling (see Figure K-6).
Fire Preburn Time:	15 seconds
Test Procedure:	Two 8.7 in. (220 mm) outside diameter steel pipes, with lengths equal to the length of the press pocket, shall be installed in the press pocket space. The pipes shall be located in a position determined to be the most challenging based on the water mist discharge (see Figure K-6).

The spray fire shall be ignited. The water mist system should be activated subsequent to the required preburn time. The fuel spray should be shut off 15 seconds after the fire extinguishment, if applicable. The water mist discharge should be shut off 45 seconds after the fuel spray is shut off.

K.4.5 Heat Tunnel Channel Fire

Criteria: Suppression of the pool fire.

The maximum one-minute mockup ceiling temperature average following activation of the water mist system shall not exceed 500°F (260°C).

Changes in the length or width of the stainless steel press belt due to the fire test shall be negligible.

There shall be no observable physical deformation, such as warping, to the belt as a result of the fire test.

Variations to the ultimate tensile strength, tensile yield strength, and ultimate elongation test results before and after the fire test shall not exceed 5 percent.

Fuel: Diesel

Type: Channel pool fire.

Fire Location: The channel should be located on one side of the heat tunnel (see Figure K-3).

Fire Preburn Time: 30 seconds after the entire surface is involved in fire.

Test Procedure: Prior to the fire test, 1 in. (2.5 cm) by 12 in. (30.5 cm) coupons of the stainless steel press belt shall be subjected to ultimate tensile strength, tensile yield strength, and ultimate elongation tests in accordance with ASTM E8, *Standard Test Methods for Tension Testing of Metallic Materials*.

The dimensions of the mockup's steel belt shall be measured to an accuracy of 0.04 in. (1 mm) prior to the fire test.

The channel fire shall be ignited. The water mist system should be activated subsequent to the required preburn time. Following extinguishment, if applicable, the fuel left in the pool or tray should be measured, if possible, and reignited to verify that sufficient fuel remained in the pan.

Following the fire test, the steel belt shall be allowed to cool to ambient temperature, and measured to an accuracy of 0.04 in. (1 mm). The belt shall also be visually examined for signs of damage.

One in. (2.5 cm) by 12 in. (30.5 cm) coupons of the stainless steel press belt shall be cut from the belt and subjected to ultimate tensile strength, tensile yield strength, and ultimate elongation tests in accordance with ASTM E8, *Standard Test Methods for Tension Testing of Metallic Materials*.

K.4.6 Heat Tunnel Belt Cooling (No Fire)

Criteria: The maximum rate of belt temperature decrease caused by water mist application should not be greater than the safety limit information for the belt. If safety limit information is not available, the following examinations should be conducted:

- Variations to the ultimate tensile strength, tensile yield strength, and ultimate elongation test results before and after the cooling test shall not exceed 5 percent.
- Changes in the length or width of the stainless steel press belt due to the cooling test shall be negligible.

- There shall be no observable physical deformation, such as warping, to the belt as a result of the cooling test. A sample shall be examined for cracks and other defects following guided bend testing in accordance with ASTM E290, Standard Test Methods for Bend Testing of Material for Ductility. Cracks occurring in the corners of the bent portion of the material as a result of this test shall not exceed the nominal thickness of the specimen.

Test Procedure: Gas ring burners, fueled by natural gas or propane, shall be used to heat the stainless steel press belt. When all five steel press belt thermocouples are above 392°F (200°C), heating of the belt shall be discontinued, and the water mist system shall be activated. The cooling test data should be recorded in Microsoft Excel format. The data will be analyzed to determine the maximum rate of cooling, and compared to the safety limit for the belt.

If safety limit information is not available, the following examinations should be conducted:

- Prior to the cooling test, 1 in. (2.5 cm) by 12 in. (30.5 cm) coupons of the stainless steel press belt shall be subjected to ultimate tensile strength, tensile yield strength, and ultimate elongation tests in accordance with ASTM E8, *Standard Test Methods for Tension Testing of Metallic Materials*. Following the test, 1 in. (2.5 cm) by 12 in. (30.5 cm) coupons of the stainless steel press belt shall be cut from the belt and subjected to ultimate tensile strength, tensile yield strength, and ultimate elongation tests in accordance with ASTM E8, *Standard Test Methods for Tension Testing of Metallic Materials*.
- The dimensions of the mockup's steel belt shall be measured to an accuracy of 0.04 in. (1 mm) prior to the cooling test. Following the test, the steel belt shall be allowed to cool to ambient temperature, and measured to an accuracy of 0.04 in. (1 mm).
- Following the test, the belt shall be visually examined for signs of damage. A sample of the belt shall be subjected to the guided bend test in accordance with ASTM E290, *Standard Test Methods for Bend Testing of Material for Ductility*.

K.5 EXTRAPOLATION OF TEST DATA

Should a need arise to apply a water mist system to the protection of a continuous wood board press larger than the individual pocket space and heat tunnel that was tested, test data may be extrapolated on a case-by-case basis by the certification agency. 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 certification.

Systems shall be judged suitable for extrapolation beyond the mockups tested if all of the following criteria are met:

A. For the protection of press pocket spaces, the nozzle configuration, orientation, and spacing that was tested is repeated in each individual pocket space.

B. For heat tunnel protection, the nozzle configuration, orientation, and spacing that was tested is repeated along the entire length of the space.

Extrapolation to larger individual press pocket spaces or wider or taller heat tunnels is not permitted.

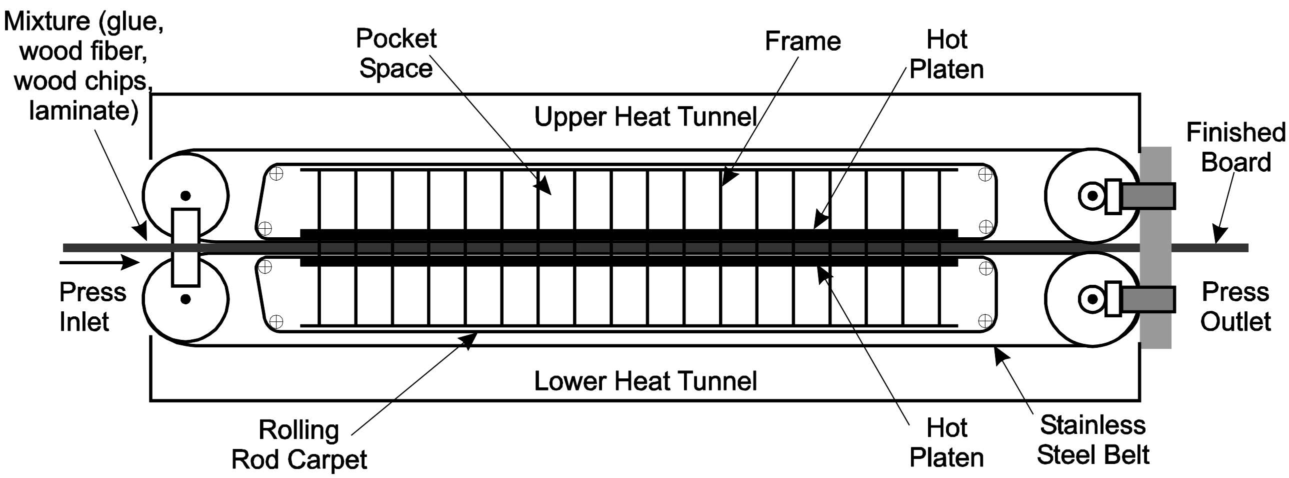


Figure K-1. Schematic Illustration of a Continuous Board Press

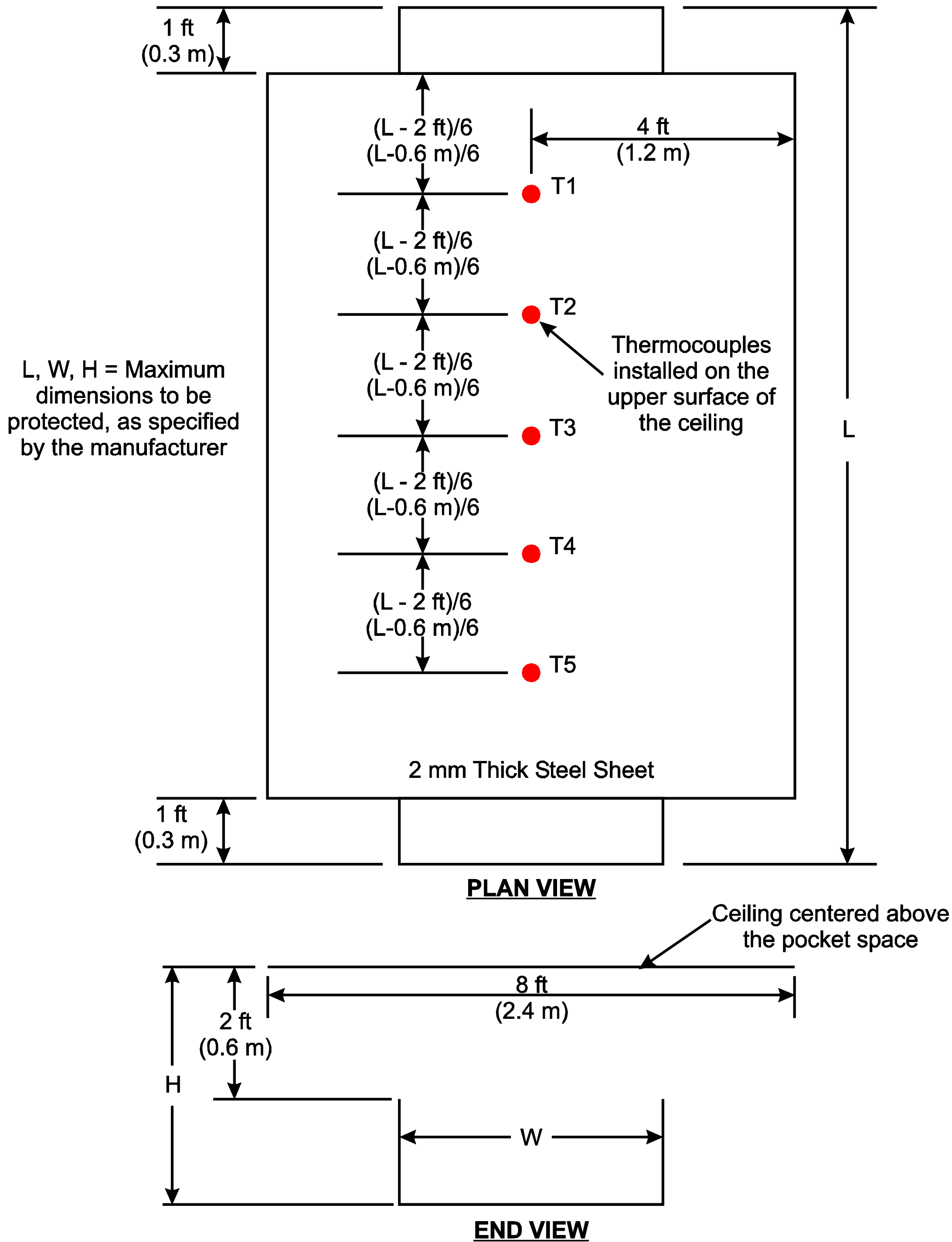


Figure K-2. Press Pocket Space Mockup

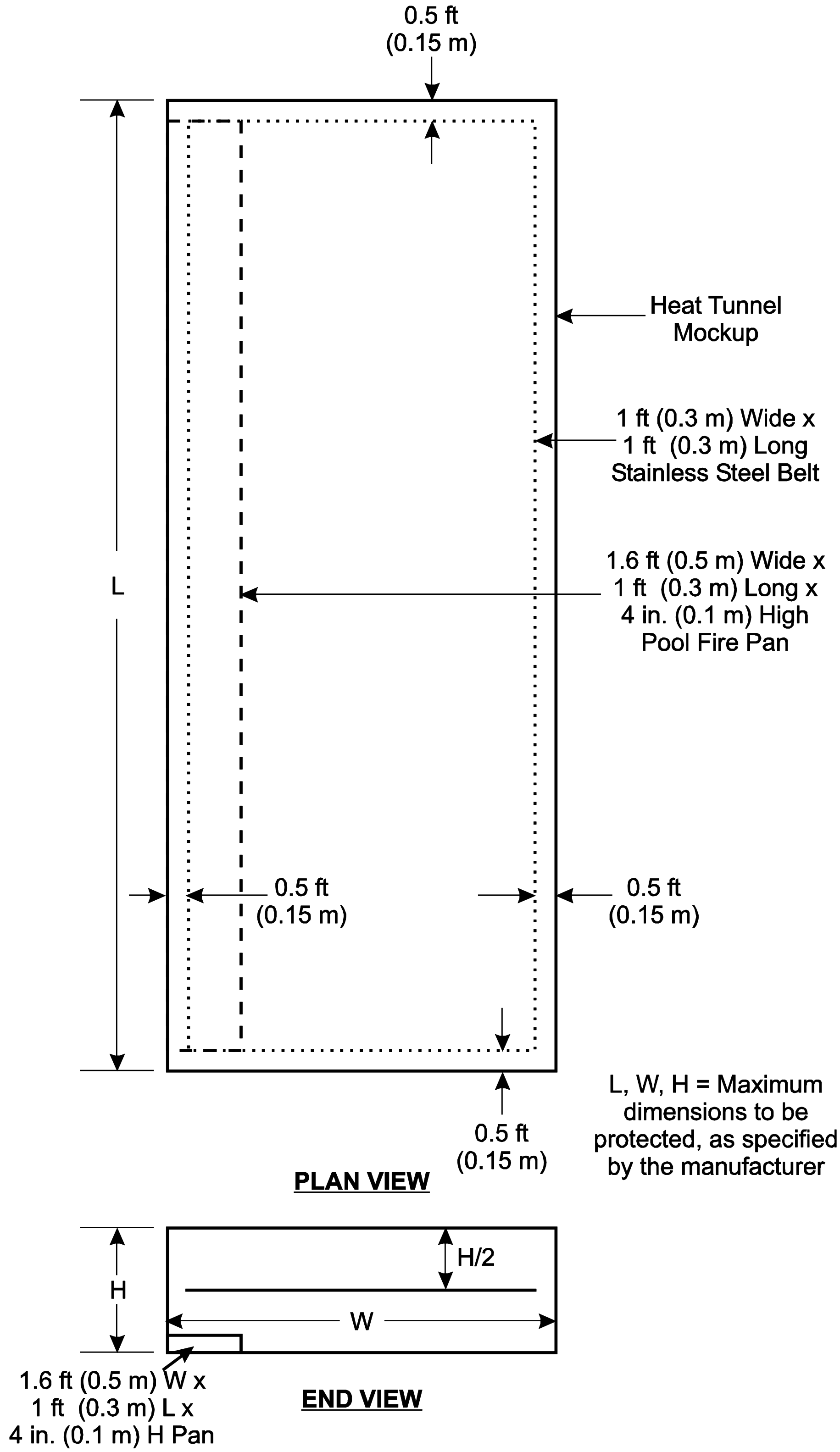


Figure K-3. Press Heat Tunnel Mockup

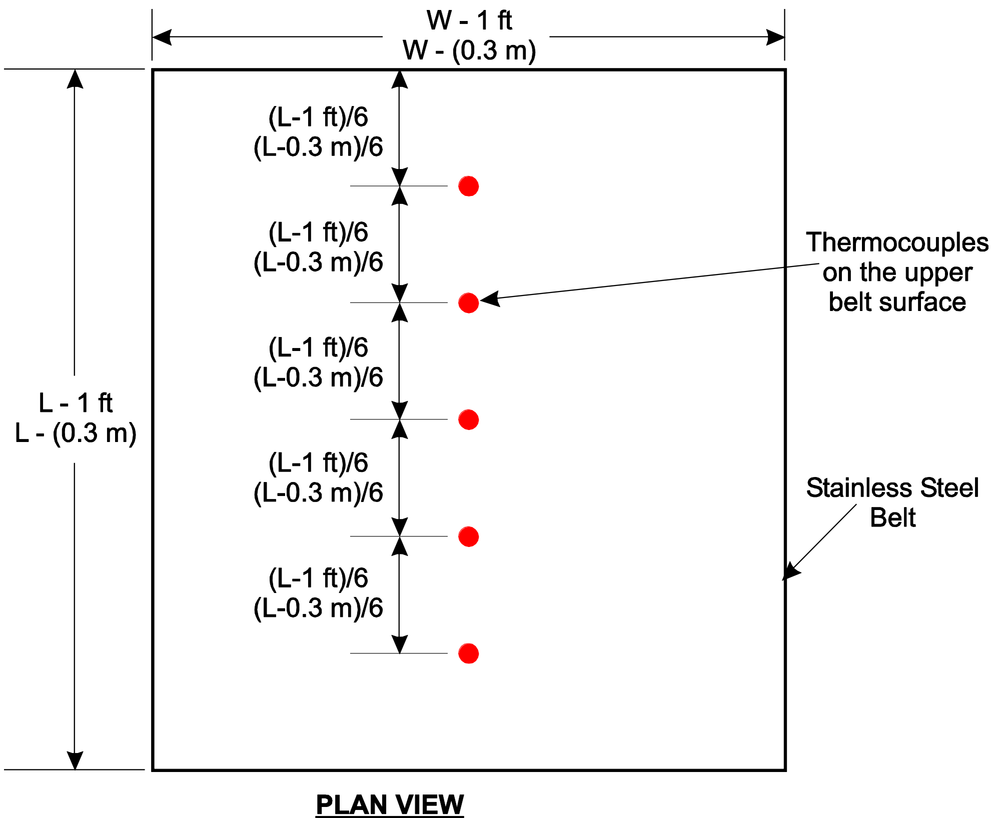


Figure K-4. Thermocouple Layout on the Stainless Steel Belt Installed in the Heat Tunnel Mockup

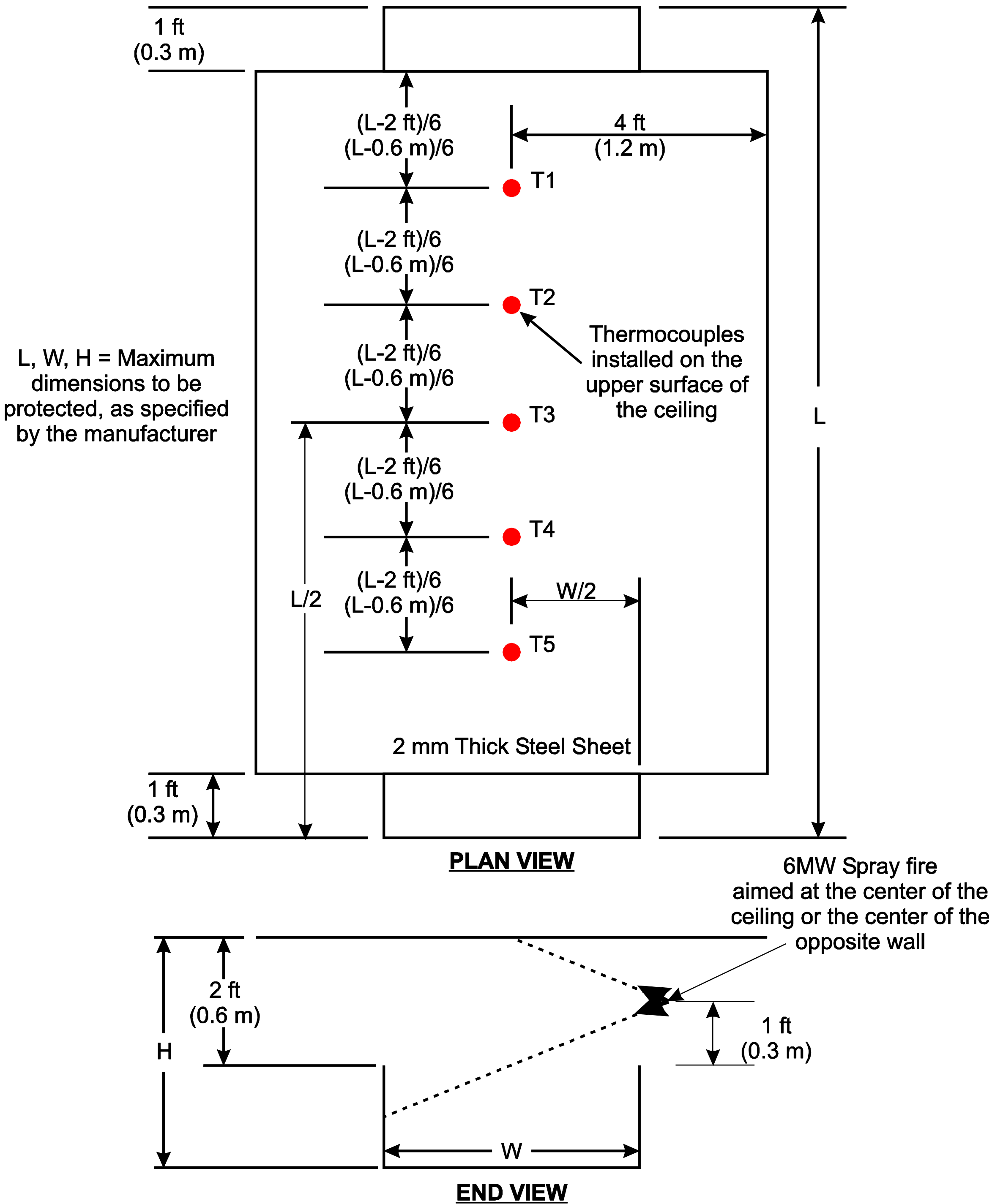


Figure K-5. Test Setup for the 6MW Spray Fire Scenario in the Press Pocket Space

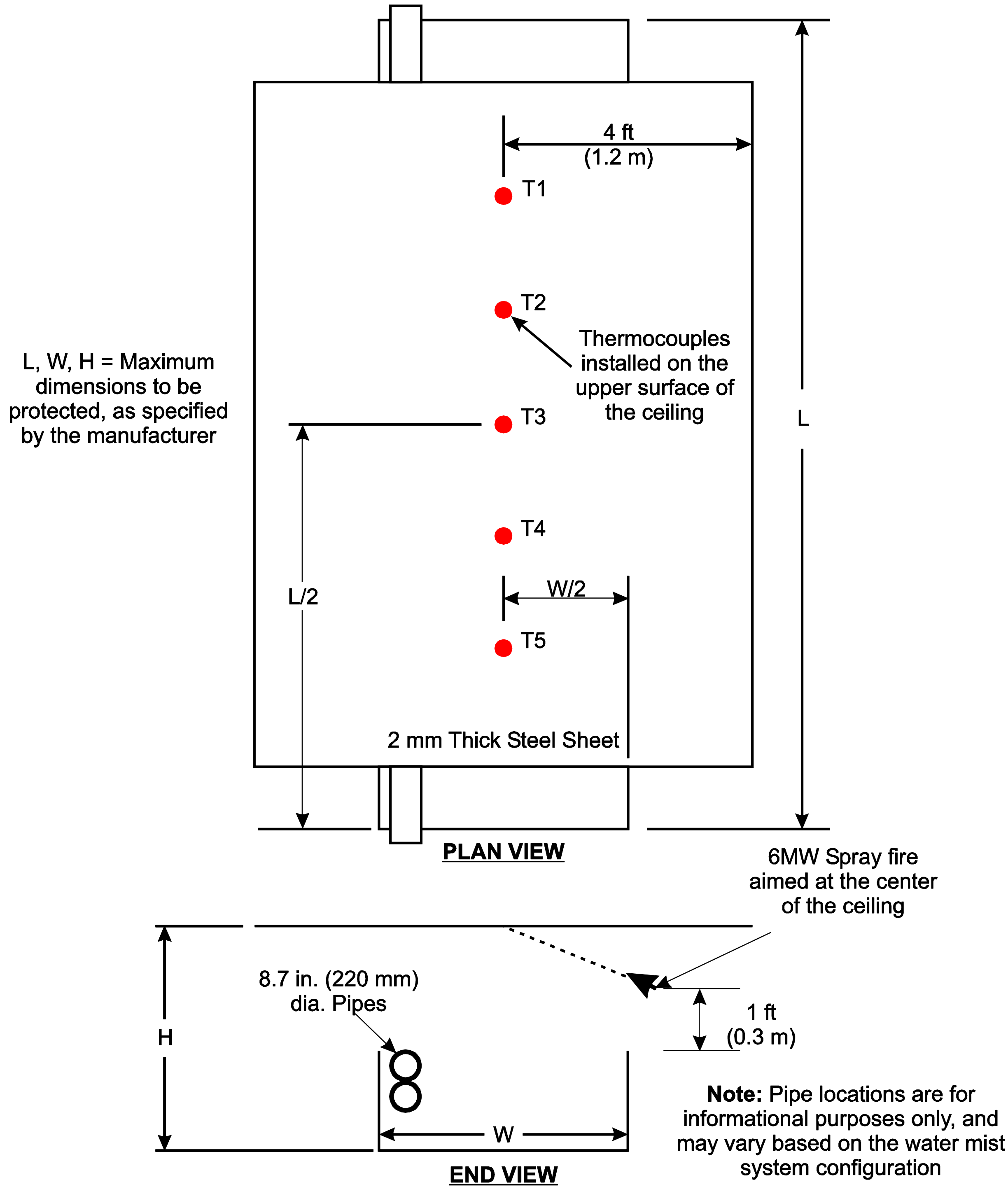


Figure K-6. Test Setup for the Obstructed 6MW Spray Fire Scenario in the Press Pocket Space

APPENDIX L: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF CHEMICAL FUME HOODS

L.1 GENERAL TESTING REQUIREMENTS

The following criteria shall be met:

A. The manufacturer shall provide the certification agency with design, installation, operation, and maintenance manuals for the complete water mist system. The design manual shall describe in detail the system parameters for different chemical fume hood sizes.

B. The water supply shall be capable of supplying 10 minutes of water to all nozzles in the fume hood.

C. The maximum nozzle spacing shall be used for all tests. This includes using the maximum spacing between nozzles, maximum spacing from sidewalls, maximum spacing from ceiling and maximum spacing from front sash.

D. The minimum operating nozzle pressure (as specified by the manufacturer) shall be used for all tests, unless specified otherwise. The pressure shall be established and maintained by means of a by-pass flow line.

E. Minimum and maximum face velocities shall be used in all fire tests and shall become part of the requirements of the certification. As a minimum, a face velocity of 90 feet per minute shall be used. The maximum face velocity shall be selected by the manufacturer. Face velocity is defined as the exhaust rate of the fume hood divided by the open area of the sash.

F. The manufacturer shall specify the size of the fume hood desired to be protected with their water mist system. The maximum size, length and depth, shall be used in all fire tests. Nozzle installation parameters for smaller fume hoods than that tested will be determined based on the nozzle spacings used in the successful fire tests on the maximum size fume hood per the discretion of the certification agency.

G. The individual nozzles shall include either a fusible or glass bulb assembly and meet quick response nozzle criteria (refer to Sections 4.2.26 to 4.2.28). The heat responsive element and temperature rating of the nozzles used in all fire tests shall be identical. The nominal operating temperature of the nozzle shall not exceed 155°F (68°C).

H. Nozzle guards shall be used for all tests and shall be required for certification.

I. All fire tests shall be conducted with a minimum sash opening of 7 ft^2 (0.65 m^2) with an exhaust rate set to provide the required face velocities. For fume hoods with one sash opening, the sash shall be opened to achieve the minimum opening area. For fume hoods with two sashes, the sashes shall both be opened to the same point to achieve the minimum opening area. For fume hoods with three sashes, the middle sash shall be opened to achieve the minimum opening area.

J. Hexane with 95 percent purity shall be used for all fire tests. Documentation of the fuel shall be provided to the certification agency.

K. The glass bottle used in test M.4.4 shall be Cole-Parmer catalog number WU-08922-75. The bottle has a 1 gallon (4 liter) capacity with a height of approximately 13.4 in (34 cm) and an outside diameter of 6.3 in (16 cm).

L. All fire tests shall be conducted for 10 minutes after activation of the first nozzle. After this 10 minute period, any remaining fire should be extinguished manually.

M. The water mist system, operating without manual intervention, shall successfully complete all fire tests for certification. System components, component locations, and operating conditions shall remain unaltered throughout all of the fire tests.

L.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 ± 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 the gases escaping from the hood sash opening, with the thermocouple located 12 in. (30.5 cm) from the front and 12 in. (30.5 cm) down from the top of the hood.

B. Fuel temperature within the fuel storage container. All fuels shall initially be at an ambient temperature of 68°F ± 18°F (20°C ± 10°C).

C. Temperature in the test hall, measured by a thermocouple located 6 ft. (1.8 m) from the hood opening at the same height as the hood.

D. A means of determining the exhaust rate through the test mockup to validate the face velocities using temperature and pressure in the exhaust duct.

E. Gas temperatures shall be measured using stainless steel sheathed, exposed junction type K thermocouples, 0.6 in. (16 mm) in diameter.

F. Extinguishment should be determined by visual observation. Registration by means of thermal imaging equipment is strongly encouraged.

L.3 TEST MOCKUP

A fume hood test mockup shall be either constructed or represented by a purchased fume hood. The fume hood test mockup shall be the maximum size sought for certification. The test mockup shall include an exhaust system capable of achieving the minimum and maximum face velocities sought for certification. The manufacturer shall determine the test mockup that will be used for the fire testing and submit drawings and specifications to the certification agency for verification prior to testing. The certification agency will review the test mockup along with the manufacturer's requested certification limitations (for example: size, combustible or non combustible, nozzle locations, etc.) and accept the submitted test mockup at their discretion.

L.4 FIRE TESTS CONFIGURATIONS

The water mist system shall successfully complete all fire tests described in this section. Agent supply needed for twice the extinguishment time for the longest fire scenario will be reported and considered as one of the requirements when water mist is used as a special protection system (see Section 1.9, Definitions).

L.4.1 Pool Fire Test

Criteria:	The fire is to be extinguished within 20 seconds of the first nozzle activation.
Fuel:	Hexane
Type:	The pan shall be fabricated out of 15 gauge sheet metal, with an inside diameter of 15 in. (38 cm), and height of 3 in. (7.6 cm). The pan shall be filled with 0.26 gallons (1000 ml) of hexane.
Fire Location:	The pan shall be placed in the center of the hood countertop behind open sash.
Test Procedure:	The fume hood exhaust shall be activated and the data acquisition system shall be started. Following 2 minutes of data collection the hexane pan shall be manually ignited. Following extinguishment, the fuel left in the pan should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan. The test shall be conducted with the maximum and minimum face velocities.

L.4.2 Counter Top Spill Fire Test

Criteria: The maximum temperature outside of the fume hood shall not exceed 375°F (190°C).

Fuel: Hexane

Fire Location: The spill fire shall be made by fabricating a lip around the periphery of the counter top. The lip shall be located 5 in. (12.7 cm) from each wall forming a confined spill are on the counter top. The amount of hexane required is determined based on the confined spill area as follows:

$$Fuel\ required\ [gal] = \frac{(0.028)\ Spill\ Area\ [in^2]}{231} \quad [US\ Units]$$

$$Fuel\ required\ [ml] = \frac{(14.021)\ Spill\ Area\ [cm^2]}{197} \quad [SI\ Units]$$

Test Procedure: The fume hood exhaust shall be activated and the data acquisition system shall be started. Following 2 minutes of data collection the hexane pan shall be manually ignited. Following extinguishment, the fuel left in the pan should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

The test shall be conducted with the maximum and minimum face velocities.

L.4.3 Splash Fire Test

Criteria: The water mist system operating with the maximum nozzle pressure shall not splash the burning test fuel outside of the fume hood.

Fuel: Hexane

Fire Location: The fire as described for test L.4.2 shall be used.

Test Procedure: The fume hood exhaust shall be activated and the data acquisition system shall be started. Following 2 minutes of data collection the hexane pan shall be manually ignited. Following extinguishment, the fuel left in the pan should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

L.4.4 Bottle Breakage Fire Test

Criteria: The water mist system shall prevent a solvent bottle from breaking during the test.

Fuel: Hexane

Fire Location: The fire as described for test L.4.2 shall be used. Additionally, a one gallon (4 liter) glass solvent bottle filled with water shall be placed in the corner of the fume hood counter top.

Test Procedure: The fume hood exhaust shall be activated and the data acquisition system shall be started. Following 2 minutes of data collection the hexane pan shall be manually ignited. Following extinguishment, the fuel left in the pan should be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

The test shall be conducted with the maximum and minimum face velocities.

L.4.5 Additional Fire Tests

Based on the results of Fire Tests L.4.1 through L.4.4, additional fire testing may be required to ensure that the water mist system being evaluated meets the intent of this section of the standard. This testing will be performed at the sole discretion of the certification agency.

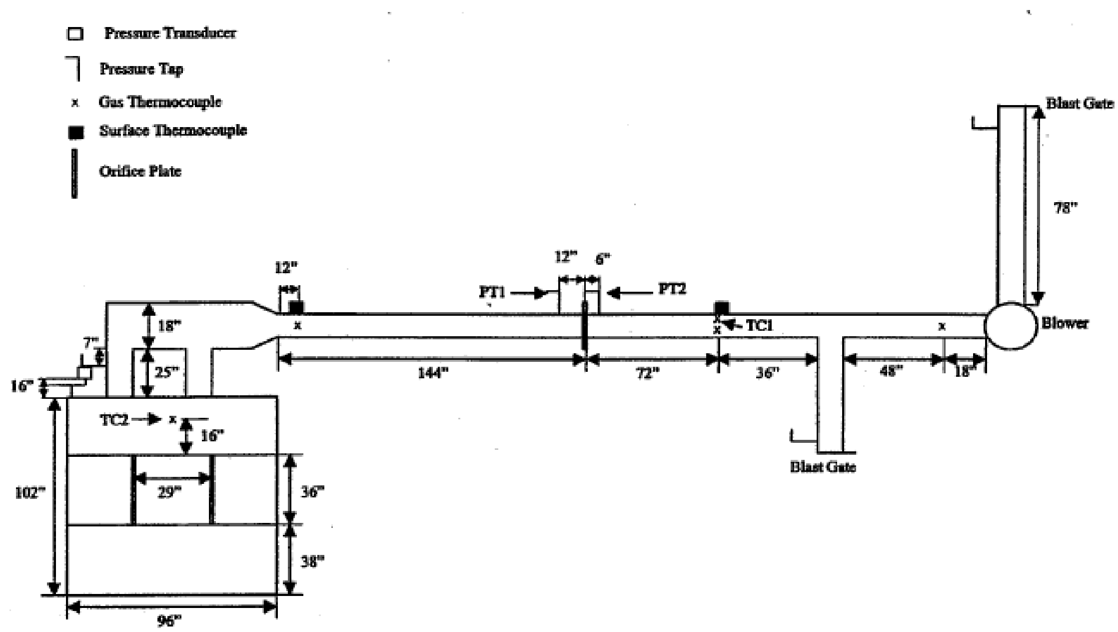


Figure L-1. Sketch of Example Mockup Arrangement for Fume Hood (Front View)

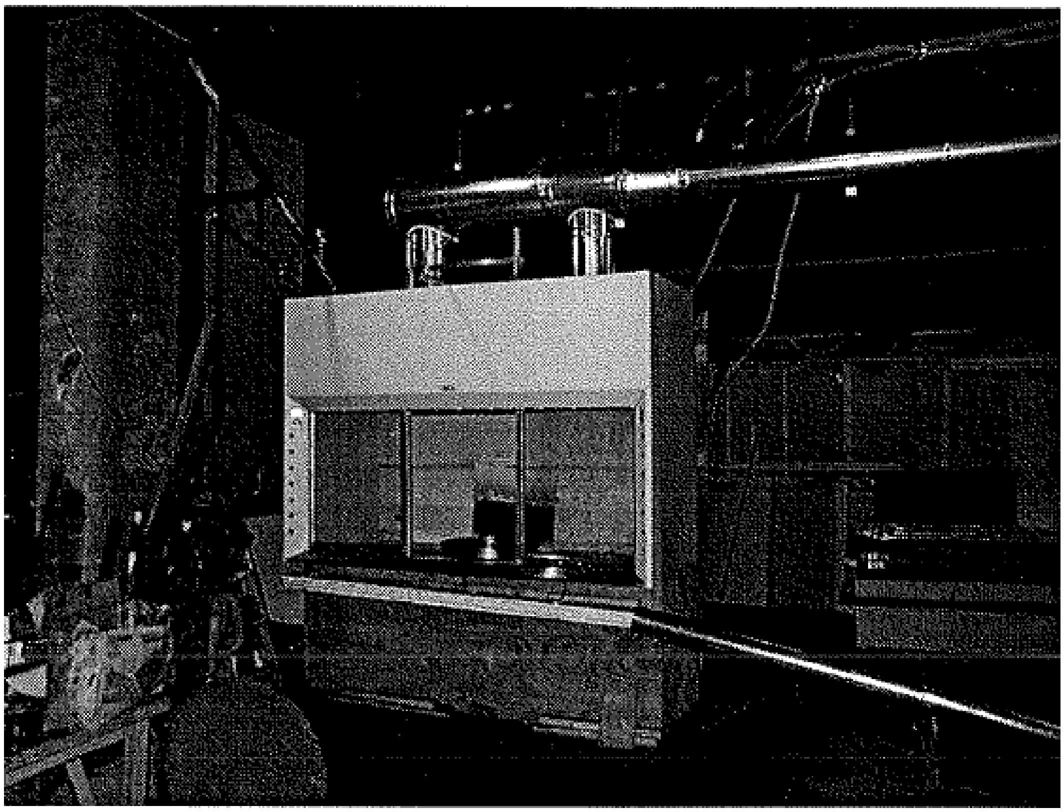


Figure L-2. Photograph of Sample Mockup Arrangement for Fume Hood

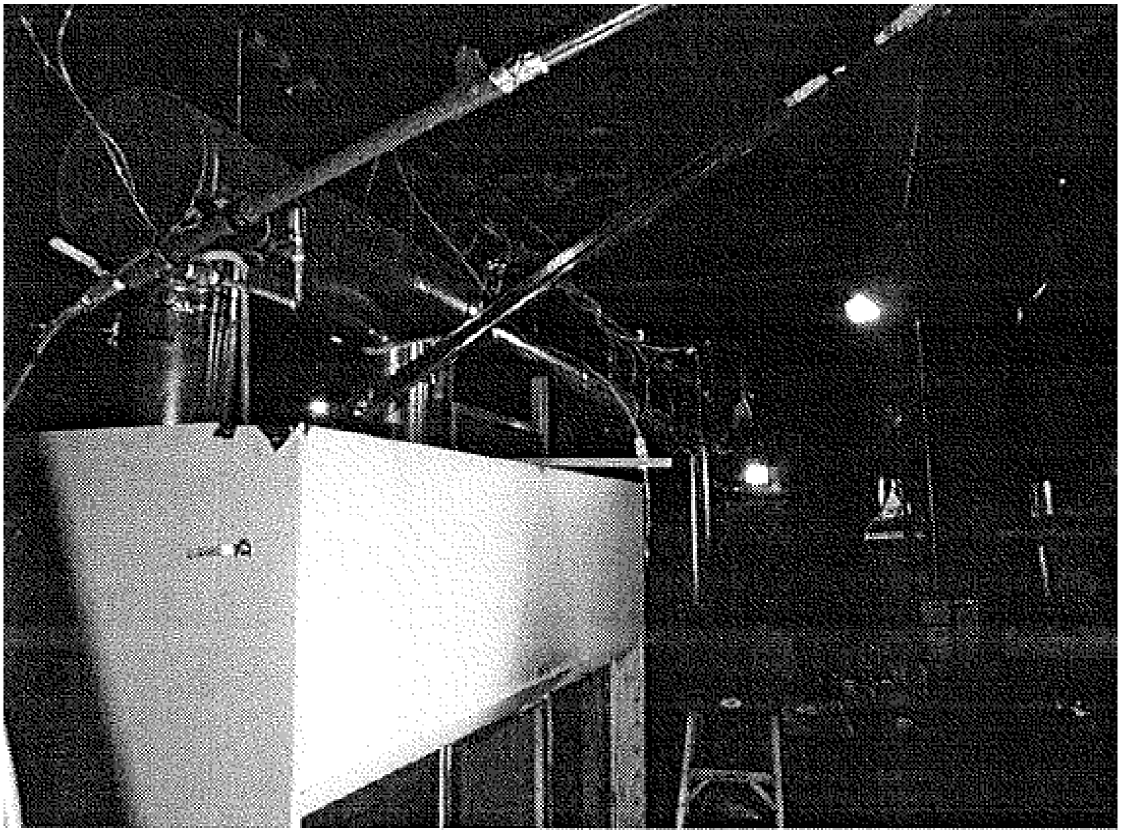


Figure L-3. Photograph of Sample Mockup Exhaust Arrangement for Fume Hood

APPENDIX M: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF DATA PROCESSING EQUIPMENT ROOMS/HALLS – ABOVE RAISED FLOOR

M.1 GENERAL TESTING REQUIREMENTS

In addition to the instrumentation and test requirements described previously under "General Instrumentation and Test Equipment Requirements," the following criteria shall be met:

A. The manufacturer shall provide the certification agency with design, installation, operation, and maintenance manuals for the complete water mist system. The same nozzle design shall be used for all required fire tests.

B. The individual nozzles shall include either a fusible or glass bulb assembly and meet quick response nozzle criteria (refer to Sections 4.2.26 to 4.2.28). The heat responsive element and temperature rating of the nozzles used in all fire tests shall be identical. The nominal operating temperature of the nozzle shall not exceed 225°F (107°C). If multiple temperature ratings and/or response sensitivities are requested for certification each will require fire performance testing.

C. The maximum nozzle spacing, not to exceed 16.4 ft (5 m), as specified by the manufacturer, shall be used for all tests. This includes the maximum nozzle spacing from walls.

D. System components, component locations, and operating conditions shall remain unaltered throughout all of the fire tests, and the system shall operate without manual intervention. All fire tests shall be conducted using the spray specifications from the manufacturer's design manual in regard to nozzle placement, spray flux, and spray duration.

E. For all wet system fire tests, the system should be:

   1. Pressurized to the minimum operating pressure specified by the manufacturer. Following activation of the first nozzle, the flowing water pressure should be maintained at the minimum system operating pressure.

F. For all preaction system fire tests, the system should be:

   1. Pressurized to the minimum operating pressure specified by the manufacturer to an electric or manually controlled valve in order to simulate a water delay. Following operation of the electric or manual valve after the 30 second water delay period, the flowing water pressure should be maintained at the minimum system operating pressure.

G. Satisfactory fire performance test results based on the testing in this Appendix can be applied to the protection of hot and cold aisle containment systems. For a hot aisle containment system with an open ceiling to the air return plenum, the water mist nozzles are to be spaced a distance of no more than 4 ft (1.2 m) inside the containment aisle.

M.2 TEST CONFIGURATION

M.2.1 Test Mockup (See Figures M-1 and M-2)

The fire test facility shall consist of a movable ceiling with a length and width of a minimum of four nozzle spacings. Under the ceiling two rows of server cabinet mockups arranged on a 1 m (3.3 ft) high raised floor, are to be centered below the movable ceiling. The entire facility is to be constructed in a fire test laboratory to nominally replicate a section of the typical data hall for the evaluation of water mist protection.

Figures M-1 and M-2 below detail the schematics of the test facility in the elevation and plan view, respectively. The 3.3 ft (1.0 m) high raised floor is to be constructed with 70% perforated steel grating, and topped with non-combustible boards, as shown in the figures, to form five alternating non-perforated and perforated floor areas, with a total floor area of 20.0 by 24.0 ft (6.0 by 7.3 m), centered below the much larger ceiling. The width of each perforated floor area is 4.0 ft (1.2 m). Two parallel rows of server cabinet mockups are positioned on the central non-perforated floor area, with their backs facing each other and their fronts aligning to the edges of the respective perforated areas. Each cabinet mockup measures

4.0 ft (1.2 m) wide, 8.9 ft (2.7 m) high and 3.0 ft (0.9 m) deep. The aisle between these two rows of cabinet mockups is 4.0 ft (1.2 m). The space below the raised floor is enclosed with non-combustible boards to form a plenum. The air exhaust from the servers is simulated with a horizontal air flow of 4 ft/sec (1.2 m/s) through a vertical opening of 0.5 ft wide by 8.9 ft high (0.15 m wide by 2.7 m high) near one of each cabinet's back corners. As shown in Figures N-1 and N-2, the air flow through each cabinet is facilitated with an exhaust fan located at each cabinet's front panel to draw air from the room to a square-cross-sectioned vertical shaft behind the fan. The square vertical shaft, which is in line with the rectangular vertical shaft leading to the 0.5 ft by 8.9 ft (0.15 m by 2.7 m) high opening at the back, measures 1.1 ft by 1.1 ft by 8.9 ft (0.34 m by 0.34 m by 2.7 m) high. A perforated plate with 23% opening is fitted between the square and rectangular shafts to help even out the air exhaust from the back opening.

To obtain a nominal upward air velocity of 3.3 ft/sec (1 m/s) through the perforated floor openings, blowers are to be used to supply air to the plenum below the raised floor. Blower(s) with capacity up to 20,000 cfm are required.

In front of each row of cabinet mockups, a 8.9 ft (2.7 m) high wall, representing the front surface of the adjacent row of server cabinets, is erected on the other side of the respective perforated floor area to maintain the upward air flow from the sub-floor plenum.

M.3 FUEL PACKAGE CONFIGURATION

M.3.1 Cables (See Figure M-3)

Figure M-3 shows the test setup for the cable fire scenario, which consists of two horizontal 1.5 ft (0.46 m) wide by 3.5 in (0.09 m) deep cable trays located 1.5 ft (0.46 m) above the corresponding row of server cabinets. Each cable tray runs the entire row length, and is offset 6.0 in (0.15 m) from the back of the server cabinets. Only one tray will be loaded with cables. As shown in Figure N-3, a vertical cable bundle 6 in (0.15 m) wide by 2 in (0.05 m) thick, consisting of 128 cables, is located at the back of the central cabinet in the setup, aligning to the cabinet's vertical air exhaust opening. The vertical cable bundle is routed into the horizontal cable tray. The cable loading in the tray is to be about 1.5 ft (0.46 m) wide by 4 in (0.1 m) deep, consisting of 636 cables, and run to both ends of the raised floor as shown in the Figure N-3. An empty cable tray, lined with sheet metal at the bottom and both sides, on the other cabinet row is provided to serve as an obstruction for direct water mist sprays to the fire.

The data cable to be used in the tests is representative of the cables used in data halls, i.e., UBiQUiTI TOUGHCable Pro Cat5e. This cable uses polyethylene for the outside jacket and high density polyethylene for the insulation of the copper wires inside the jacket. The outside diameter of the cable is about 0.24 in (6 mm). The UBiQUiTI TOUGHCable Pro Cat5e has an *FPI* value of 26 in the metric unit when tested in accordance with FM Approvals Examination Standard Class 3972, *Cable Fire Propagation*. Verification of the *FPI* value of samples of the cable being used in the fire testing is at the discretion of the certification agency.

The air velocity coming out of the raised floor is to be a minimum 3.3 ft/sec (1.0 m/s).

In addition to the fire scenarios water mist distribution tests may be conducted at the discretion of the certification agency to ensure that the water application rates are comparable, with respect to the fire locations in the fire scenarios, at the manufacturer's minimum and maximum ceiling heights.

M.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 ± 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. Nozzle operating pressure at the two most remote nozzles.

B. First nozzle actuation time.

C. Oxygen concentration in the laboratory space. Oxygen concentration shall not drop below 20 percent by volume. The elevation(s) and location(s) of the gas intake(s) shall be at the discretion of the certification agency. The operating range of the analyzers is to be 0 to 25 percent by volume.

D. Two steel angles are to be installed beneath the ceiling and directly above the fire to assess the building ceiling integrity with the fire exposure and water mist protection.

E. Target water mist nozzles shall be placed at the maximum nozzle spacing as a second ring, at a minimum, around the four piped water mist nozzles. These nozzles shall be the same model nozzles being used for the piped water mist nozzles. The target nozzles will be used to determine if, and how many, additional water mist nozzles would be actuated beyond the nozzle-deployed area. *Note: If any of the target nozzles operated in the second ring a third ring of nozzles will be required in order to assess possible further nozzle actuations.*

F. Extinguishment should be determined by visual observation. Registration by means of thermal imaging equipment is strongly encouraged.

M.5 FIRE PERFORMANCE TESTING

M.5.1 Fire Test Procedure

A baseline test is to be conducted first to evaluate the protection provided by the water mist system as a wet system with no discharge delay. Fire test M.5.2.1 shall be used for the wet system baseline test. If the baseline test demonstrates successful protection, a subsequent full test series can be conducted with a 30-s water delivery transit time for a preaction configuration.

Tests are to be conducted as follows:

1. Maximum ceiling height, not lower than 16.4 ft (5 m), with the water mist nozzles installed at the minimum specified distance from the ceiling.

2. Maximum ceiling height, not lower than 16.4 ft (5 m), with the water mist nozzles installed at the maximum specified distance from the ceiling.

3. Minimum ceiling height with the water mist nozzles installed at the maximum or minimum specified distance from the ceiling at the discretion of the certification agency based on the maximum ceiling height test results. The nozzle spacing may be reduced for consideration of the nozzle design and reduced clearance to the cable tray. The minimum nozzle spacing is not to be less than that determined from the Impingement Test (FM 5560 4.2.31).

The worst performing successful fire test, with respect to the number of nozzle operations, shall be repeated.

Ignition is initiated at the base of the vertical cable bundle using one standard full igniter, which is made of a cellucotton roll of 3.0 in (7.6 cm) in diameter and 6 in (15.2 cm) long, soaked with 8 fl. oz (235 cc) of gasoline and enclosed in a polyethylene bag. Immediately after ignition, the blowers and fans providing the forced ventilation from the two perforated floor areas and through each cabinet mockup are to be started and continue to run throughout each test.

As shown in the Figures M-1 through M-3, the combustibles are approximately centered among four nozzles in this configuration. If the water mist nozzle discharge is not uniform or has “blind” spots the fire tests will be required to be conducted with the water mist nozzles in additional locations at the discretion of the certification agency. If a reduced nozzle spacing is utilized for fire test M.5.2.3 further testing at intermediate ceilings heights may be required at the discretion of the certification agency.

M.5.2 Fire Tests

M.5.2.1 Cable Fire Test – Maximum Ceiling Height – Minimum Nozzle Distance from Ceiling

Criteria: The temperature of the steel angles beneath the ceiling cannot exceed 1000°F (538°C). The fire cannot spread to either end of the loaded cable tray. Fire must be extinguished in 30 minutes timed from first nozzle activation. If the nozzles do not operate in the tests, the nozzle spacing and nozzle elevation below the ceiling are not appropriate for the data center fire hazards and ventilation condition.

M.5.2.2 Cable Fire Test – Maximum Ceiling Height – Maximum Nozzle Distance from Ceiling

Criteria: The temperature of the steel angles beneath the ceiling cannot exceed 1000°F (538°C). The fire cannot spread to either end of the loaded cable tray. Fire must be extinguished in 30 minutes timed from first nozzle activation. If the nozzles do not operate in the tests, the nozzle spacing and nozzle elevation below the ceiling are not appropriate for the data center fire hazards and ventilation condition.

M.5.2.3 Cable Fire Test – Minimum Ceiling Height – Minimum or Maximum Nozzle Distance from Ceiling (at the discretion of the certification agency)

Criteria: The temperature of the steel angles beneath the ceiling cannot exceed 1000°F (538°C). The fire cannot spread to either end of the loaded cable tray. Fire must be extinguished in 30 minutes timed from first nozzle activation. If the nozzles do not operate in the tests, the nozzle spacing and nozzle elevation below the ceiling are not appropriate for the data center fire hazards and ventilation condition.

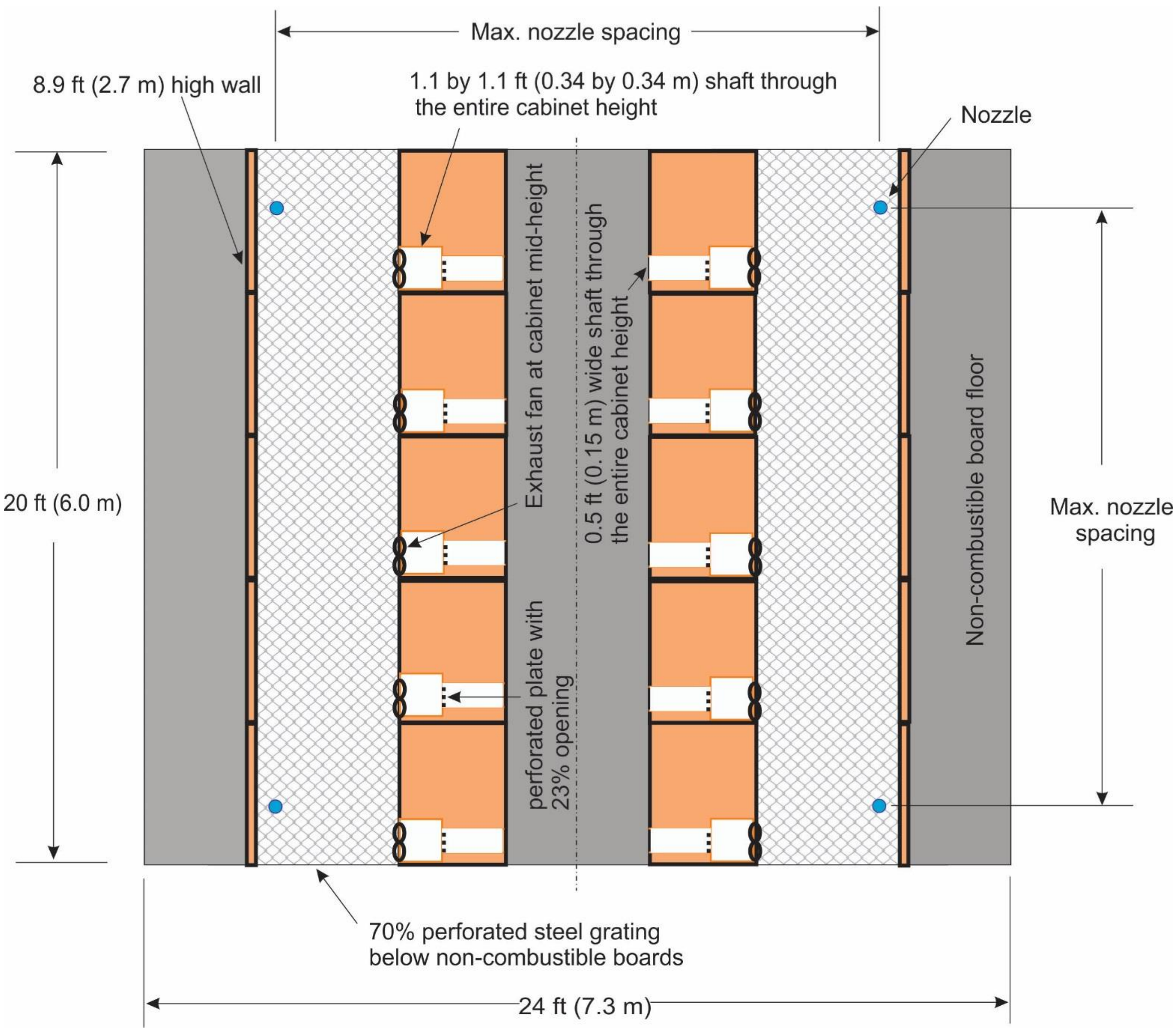


Figure M-1. Test Configuration in Plan View.

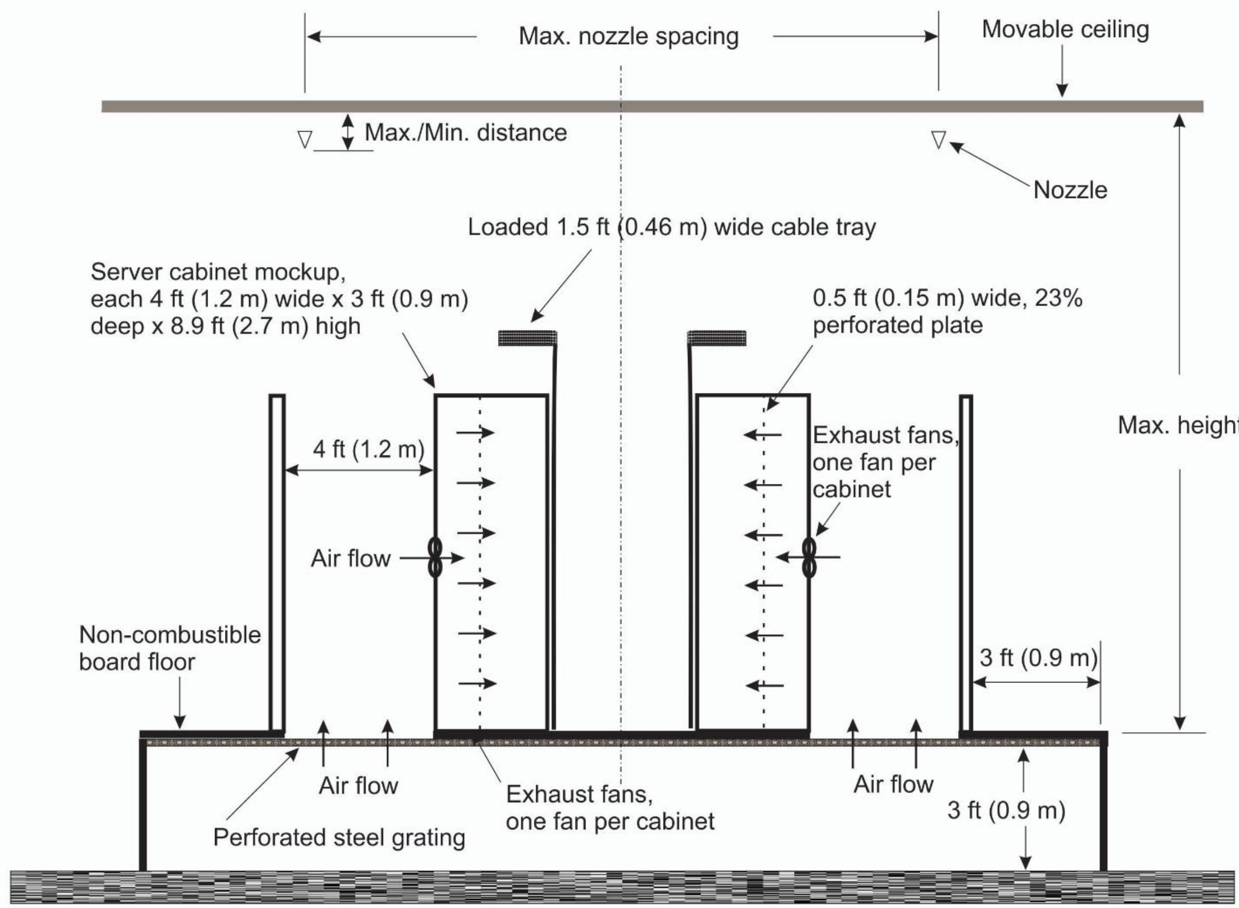


Figure M-2. Test Configuration in Elevation View.

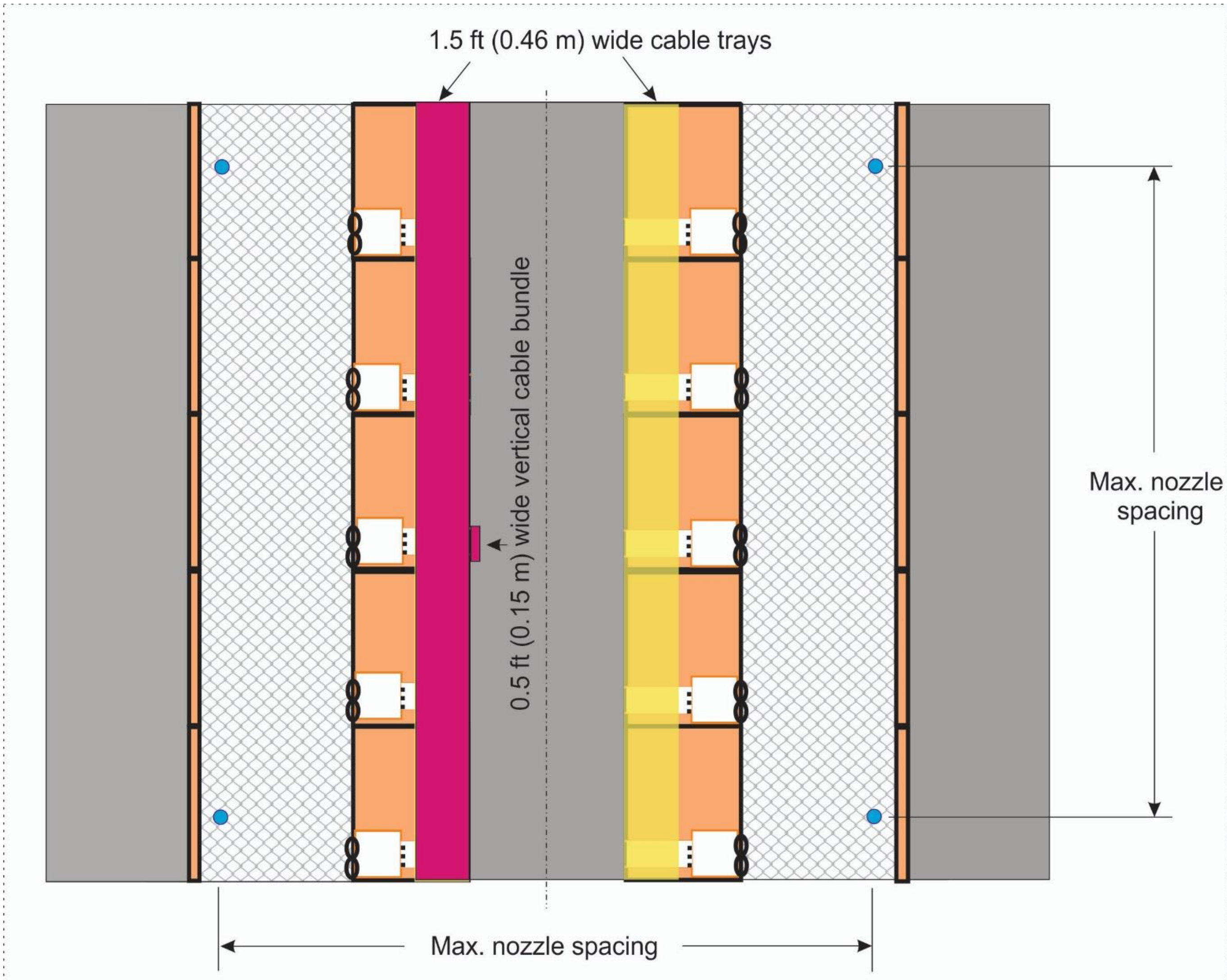


Figure M-3. Cable Fire Test Configuration.

Figure M-4. Photograph of Test Configuration.

Figure M-5. Photograph of Exterior Aisles of Test Configuration.

Figure M-6. Photograph of Interior Aisle of Test Configuration.

APPENDIX N: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF DATA PROCESSING EQUIPMENT ROOMS/HALLS – BELOW RAISED FLOOR

N.1 GENERAL TESTING REQUIREMENTS

In addition to the instrumentation and test requirements described previously under “General Instrumentation and Test Equipment Requirements,” the following criteria shall be met:

A. The manufacturer shall provide the certification agency with design, installation, operation, and maintenance manuals for the complete water mist system. The same nozzle design shall be used for all required fire tests.

B. The individual nozzles shall include either a fusible or glass bulb assembly and meet quick response nozzle criteria (refer to Sections 4.2.26 to 4.2.28). The heat responsive element and temperature rating of the nozzles used in all fire tests shall be identical. The nominal operating temperature of the nozzle shall not exceed 225°F (107°C). If multiple temperature ratings are requested for certification each rating will require fire performance testing.

C. The maximum nozzle spacing, not to exceed 16.4 ft (5 m), as specified by the manufacturer, shall be used for all tests. This includes the maximum nozzle spacing from walls.

D. System components, component locations, and operating conditions shall remain unaltered throughout all of the fire tests, and the system shall operate without manual intervention. All fire tests shall be conducted using the spray specifications from the manufacturer’s design manual in regard to nozzle placement, spray flux, and spray duration.

E. For all wet system fire tests, the system should be:

   1. Pressurized to the minimum operating pressure specified by the manufacturer. Following activation of the first nozzle, the flowing water pressure should be maintained at the minimum system operating pressure.

F. For all preaction system fire tests, the system should be:

   1. Pressurized to the minimum operating pressure specified by the manufacturer to an electric or manually controlled valve in order to simulate a water delay. Following operation of the electric or manual valve after the 30 second water delay period, the flowing water pressure should be maintained at the minimum system operating pressure.

G. If the water mist system for the protection of the below raised floor hazard is intended to be configured on the same preaction valve as the water mist system for the protection of the above raised floor hazard (Appendix M) the fire testing for the below floor hazard must be conducted with the same water delivery configuration (i.e., wet or 30-s delay).

H. The fire testing can be conducted using an area of coverage design or a local application design. In the area of coverage design two nozzles are required and are spaced at the maximum nozzle spacing. In the local application design one nozzle is required and placed centered along the length of the cable tray and offset to the side of the cable tray per the manufacturer’s instruction. The nozzle cannot be located above the cable tray in order to provide clearance for cable maintenance operations.

N.2 TEST CONFIGURATION

N.2.1 Test Mockup (See Figures N-1, N-2, N-3, and N-4)

A raised floor test enclosure shall be constructed. The enclosure shall be rectangular with an internal width of two times the maximum nozzle spacing sought for certification and an internal length of 1.5 times the maximum nozzle spacing sough for certification. The enclosure shall have an internal height of 3.3 ft (1.0 m). The enclosure shall be provided with viewing ports allowing a clear sightline to the cable fires.

A 10 ft (3 m) long by two nozzle spacing wide air supply plenum shall be constructed abutting the fire test enclosure. The air supply plenum is to be separated from the fire test enclosure with vertical steel plates with an open area of 23 percent. The air supply into the plenum is to be dispersed evenly into the air supply plenum with baffles as necessary.

The sides of the enclosure shall be covered with non-combustible gypsum board or similar. The top of the enclosure shall be covered with non-combustible floor plates/tiles. In order to simulate surface openings in normal data hall operation, some of the plates/tiles shall be replaced with steel grating. Two steel grates are required to cover a width of 4 ft (1.2 m) and a length of 16 ft (4.9 m). The steel grates shall have an open area of 70 percent. To obtain a nominal upward air velocity of 3.3 ft/sec (1.0 m/sec) through the perforated floor openings, blowers will be used to supply air to below floor space. Blower(s) with capacity up to 20,000 cfm are required.

See Figures N-1, N-2, N-3, and N-4 for further details on the construction and arrangement of the raised floor test enclosure.

N.3 FUEL PACKAGE CONFIGURATION

N.3.1 Cables (See Figures N-1, N-2, N-3, and N-4)

Figures N-1, N-2, N-3, and N-4 illustrate the setup for the cable fire scenarios, which consist of one or two horizontal, non-combustible, 2.0 ft (0.6 m) wide cable trays. In the single-tier scenario the cable tray is located 1.0 ft (0.3 m) above the floor. In the double-tier scenario the bottom cable tray is located 1.0 ft (0.3 m) above the floor and the top cable tray is located 1.7 ft (0.50 m) above the floor. In all scenarios the cable tray length is equal to the maximum nozzle spacing sought for certification. Cables tray(s) are to be loaded to a depth of approximately 3 in (7.6 cm), consisting of 700 cables, along the entire length of the tray(s).

The data cable to be used in the tests is representative of the cables used in data halls, i.e., UBiQUiTI TOUGHCable Pro Cat5e. This cable uses polyethylene for the outside jacket and high density polyethylene for the insulation of the copper wires inside the jacket. The outside diameter of the cable is about 0.24 in (6 mm). The UBiQUiTI TOUGHCable Pro Cat5e has an *FPI* value of 26 in the metric unit when tested in accordance with FM Approvals Test Standard Class 3972, *Cable Fire Propagation*. Verification of the *FPI* value of samples of the cable being used in the fire testing is at the discretion of certification.

The air velocity coming out of the raised floor is to be a minimum 3.3 ft/sec (1.0 m/s).

N.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 ± 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. Nozzle operating pressure at all nozzles.

B. First nozzle actuation time.

C. Oxygen concentration in the laboratory space. Oxygen concentration shall not drop below 20 percent by volume. The elevation(s) and location(s) of the gas intake(s) shall be at the discretion of the certification agency. The operating range of the analyzers is to be 0 to 25 percent by volume.

D. Thermocouples will be deployed strategically along ceiling perimeter and over the cable tray. The thermocouple measurements will be used to ensure the cooling by water mist system application is sufficient. Thermocouples shall be stainless steel sheathed, exposed junction 20 gauge type K thermocouples. For thermocouple locations see Figure N-5. Thermocouples 1 through 6 (TC1 through TC6 as referenced in Figure O-5) shall be used to evaluate the gas temperature below the ceiling. Thermocouple 7 and 8 (TC7 and TC8 as referenced in Figure N-5) are intended to be used as a means of fire registration. Thermocouples should be located at the same elevation as the thermal elements of the water mist nozzles employed.

E. Extinguishment should be determined by visual observation. Registration by means of thermal imaging equipment is strongly encouraged.

N.5 FIRE PERFORMANCE TESTING

N.5.1 Fire Test Procedure

A baseline test is to be conducted first to evaluate the protection provided by the water mist system as a wet system with no discharge delay. Fire test N.5.2.1 shall be used for the wet system baseline test. If the baseline test demonstrates successful protection, a subsequent full test series can be conducted with a 30-s water delivery transit time for a preaction configuration.

The baseline test series, and subsequent test series using a 30-s maximum water delivery transit time, are to be conducted first with the single-tier cable tray fire test scenarios. If these tests are successful the double-tier cable tray fire test scenarios can be conducted at the manufacturer's discretion. If the single-tier cable tray fire test scenarios meet the test criteria but further testing in the double-tier cable tray fire test scenarios does not meet the test criteria certification will be granted for single-tier cable tray loading only. If both the single-tier and double-tier cable tray fire test scenarios meet the test criteria certification will be granted for both scenarios.

The worst performing successful fire test, with respect to fire extinguishment time, shall be repeated.

For the cable fire scenarios, ignition will be initiated at the end of the cable tray nearest to the side of the enclosure where the forced ventilation is being introduced. Ignition will be done using two standard full igniters, which are made of a cellucotton roll of 3.0 in (7.6 cm) in diameter and 6 in (15.2 cm) long, soaked with 8 fl. oz (235 cc) of gasoline and enclosed in a polyethylene bag. For the single-tier cable tray fire tests the igniters are to be placed horizontally below the end of the cable tray, centered across the width of the tray, with a distance of 3.0 in (7.6 cm) from the top of the igniter to the bottom of the tray, and 6.0 in (15.2 cm) from the tray's leading edge. For the double-tier cable tray fire tests the igniters are to be placed below the bottom cable tray in the same orientation as for the single-tier test.

Immediately after ignition, the blowers providing the forced ventilation through the steel grating are to be started and continue to run throughout the duration of each test scenario.

As shown in the Figures N-1, N-2, N-3, and N-4, the combustibles are centered among two nozzles when using an area of coverage configuration. If the water mist nozzle discharge is not uniform or has "blind" spots the fire tests will be required to be conducted with the water mist nozzles in additional locations at the discretion of the certification agency.

N.5.2 Fire Tests

N.5.2.1 Cable Fire Test – Between Steel Grates – Single-Tier - Maximum Nozzle Distance from Ceiling

Criteria: Gas temperature beneath the ceiling at the perimeter thermocouples cannot exceed 1000°F (538°C). The fire cannot spread to the end of the loaded cable tray. Fire must be extinguished in 30 minutes timed from first nozzle water discharge. If the nozzle(s) do not operate in the tests, the nozzle spacing and nozzle elevation below the ceiling are not appropriate for the data center fire hazards and ventilation condition.

N.5.2.2 Cable Fire Test – Under Steel Grate – Single-Tier - Maximum Nozzle Distance from Ceiling

Criteria: Gas temperature beneath the ceiling at the perimeter thermocouples cannot exceed 1000°F (538°C). The fire cannot spread to the end of the loaded cable tray. Fire must be extinguished in 30 minutes timed from first nozzle water discharge. If the nozzle(s) do not operate in the tests, the nozzle spacing and nozzle elevation below the ceiling are not appropriate for the data center fire hazards and ventilation condition.

N.5.2.3 Cable Fire Test – Between Steel Grates – Double-Tier - Maximum Nozzle Distance from Ceiling (Optional)

Criteria: Gas temperature beneath the ceiling at the perimeter thermocouples cannot exceed 1000°F (538°C). The fire cannot spread to the end of the loaded cable tray. Fire must be extinguished in 30 minutes timed from first nozzle water discharge. If the nozzle(s) do not operate in the tests, the nozzle spacing and nozzle elevation below the ceiling are not appropriate for the data center fire hazards and ventilation condition.

N.5.2.4 Cable Fire Test – Under Steel Grate – Double-Tier - Maximum Nozzle Distance from Ceiling (Optional)

Criteria: Gas temperature beneath the ceiling at the perimeter thermocouples cannot exceed 1000°F (538°C). The fire cannot spread to the end of the loaded cable tray. Fire must be extinguished in 30 minutes timed from first nozzle water discharge. If the nozzle(s) do not operate in the tests, the nozzle spacing and nozzle elevation below the ceiling are not appropriate for the data center fire hazards and ventilation condition.

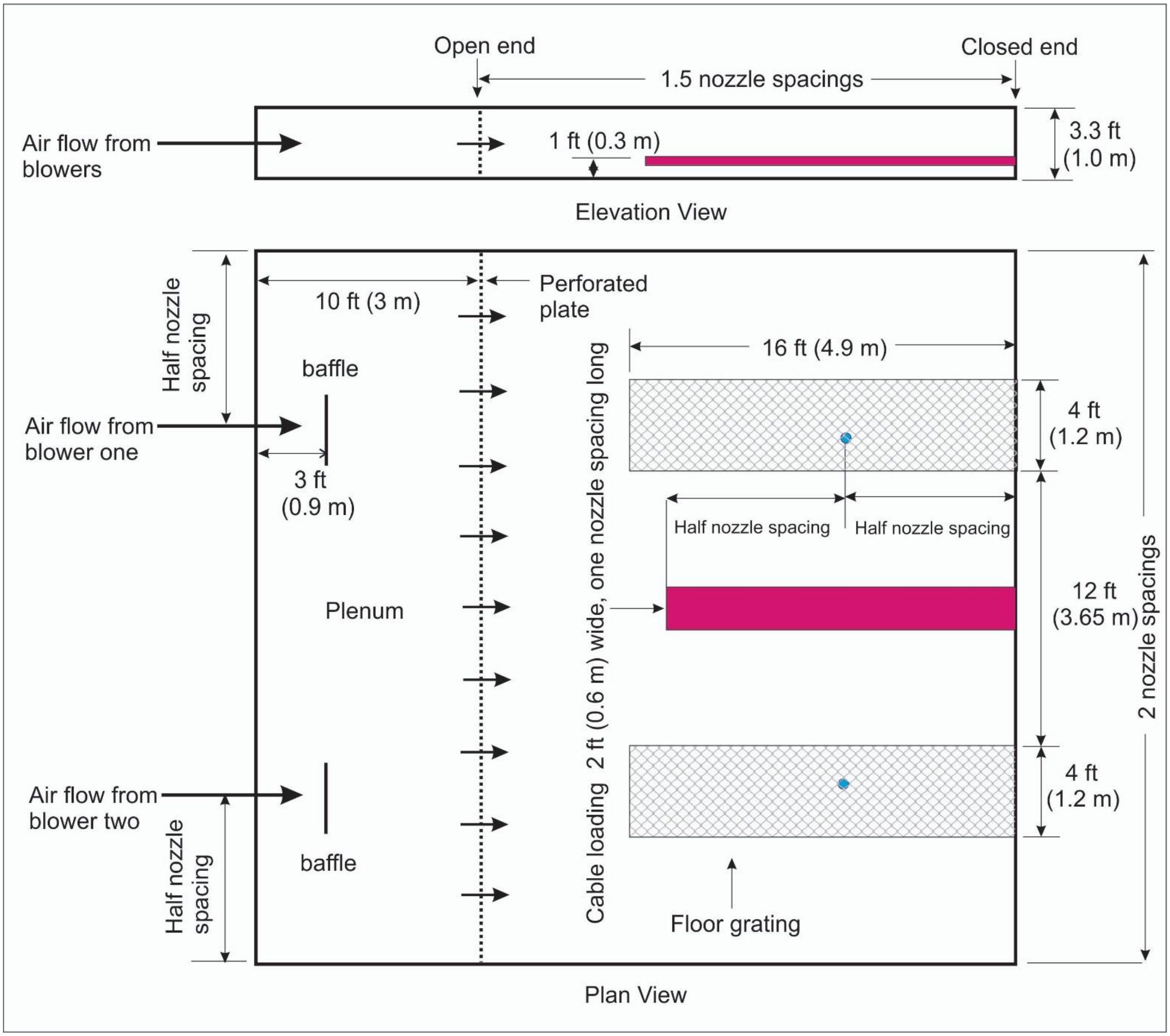


Figure N-1. Test N.5.2.1 Configuration Shown with Area of Coverage Nozzle Layout.

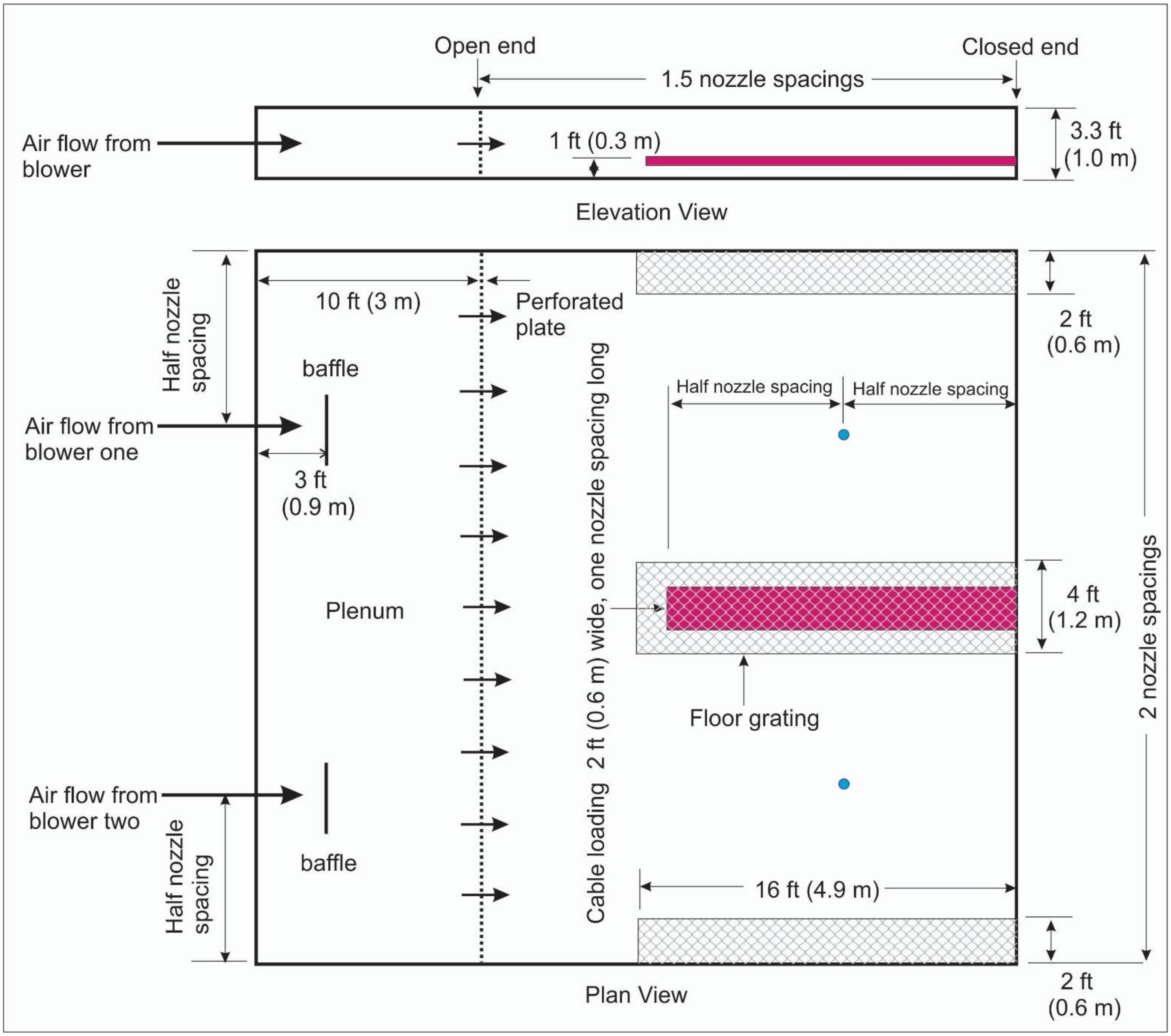


Figure N-2. Test N.5.2.2 Configuration Shown with Area of Coverage Nozzle Layout.

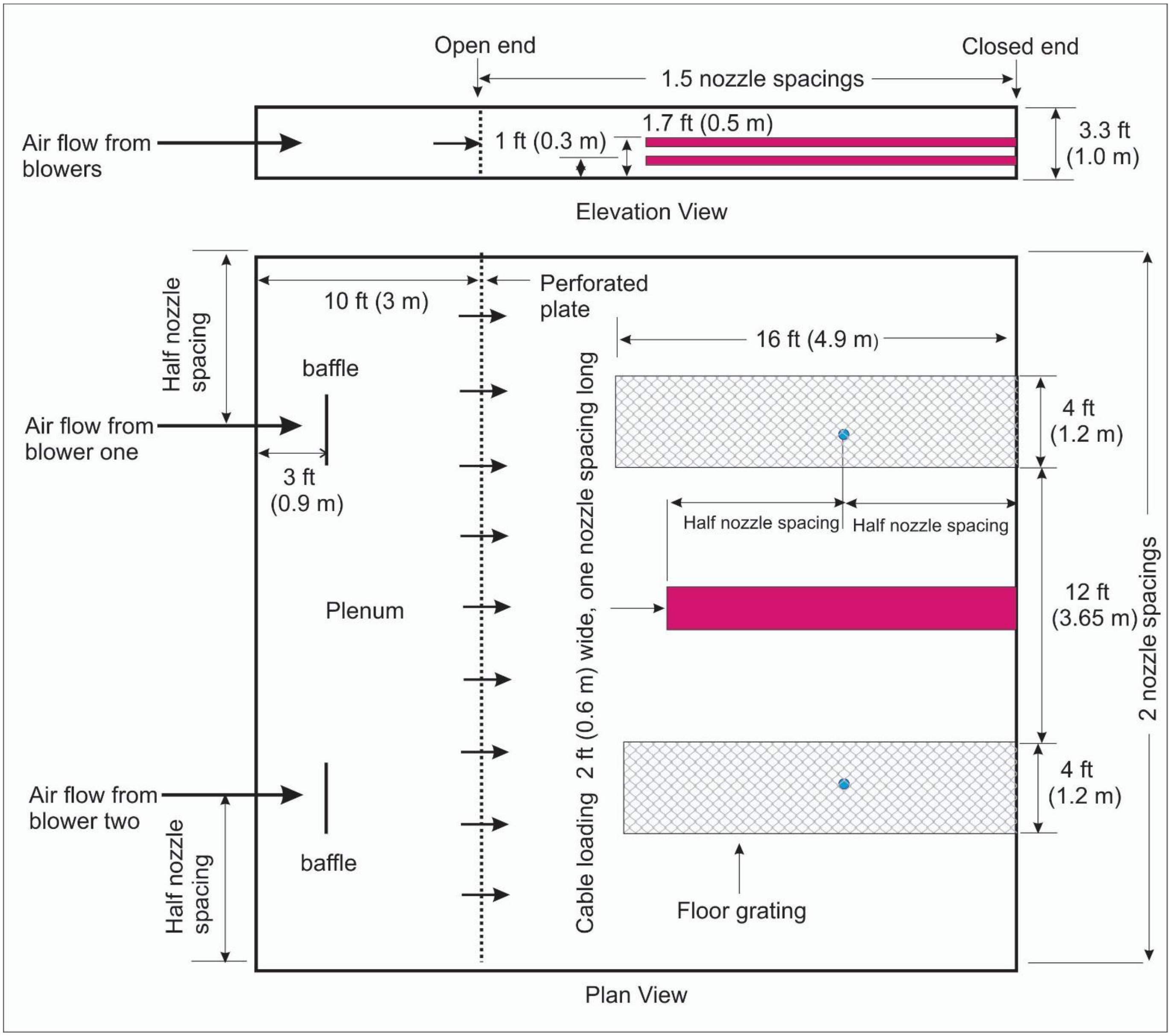


Figure N-3. Test N.5.2.3 Configuration Shown with Area of Coverage Nozzle Layout.

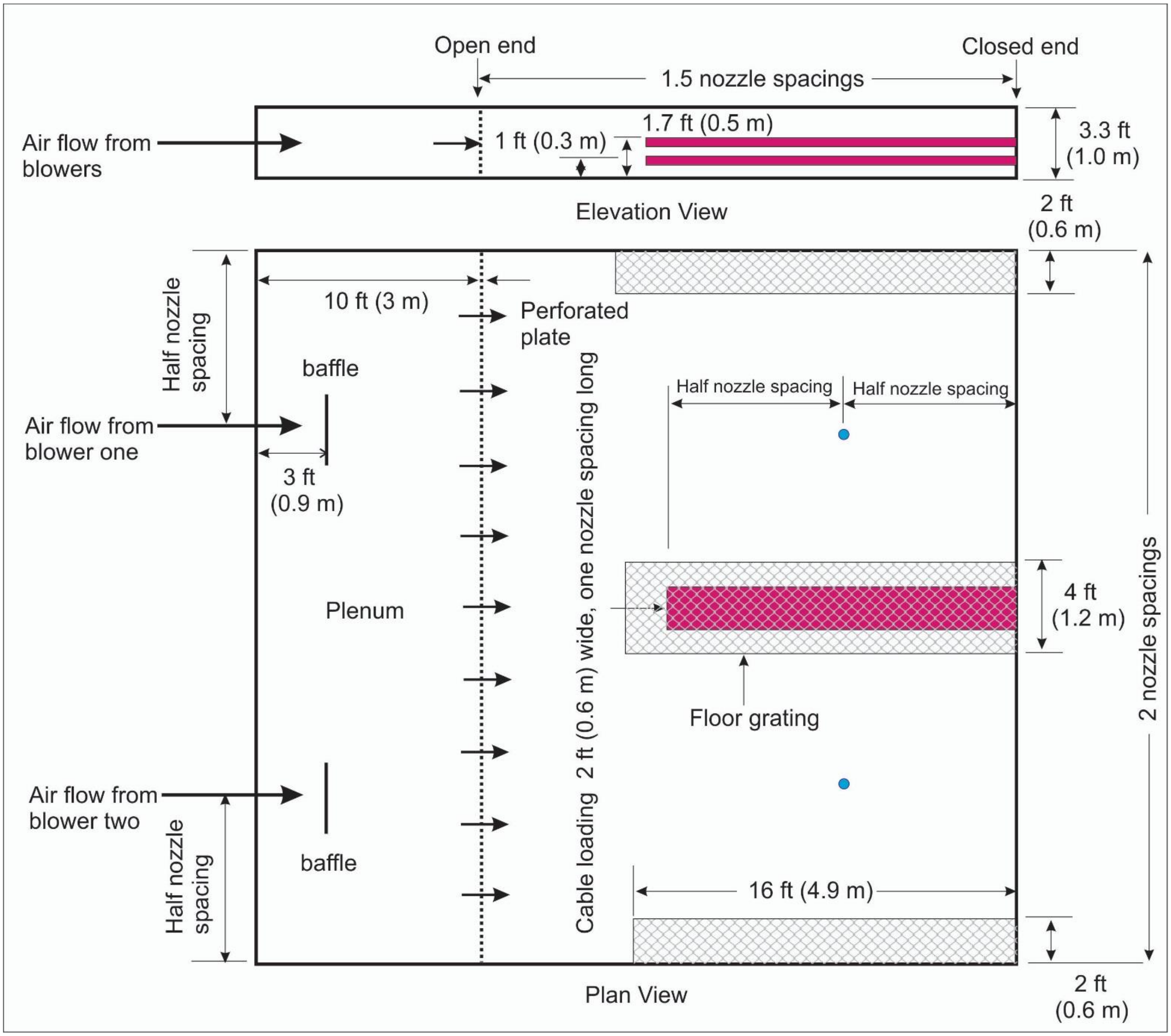


Figure N-4. Test N.5.2.4 Configuration Shown with Area of Coverage Nozzle Layout.

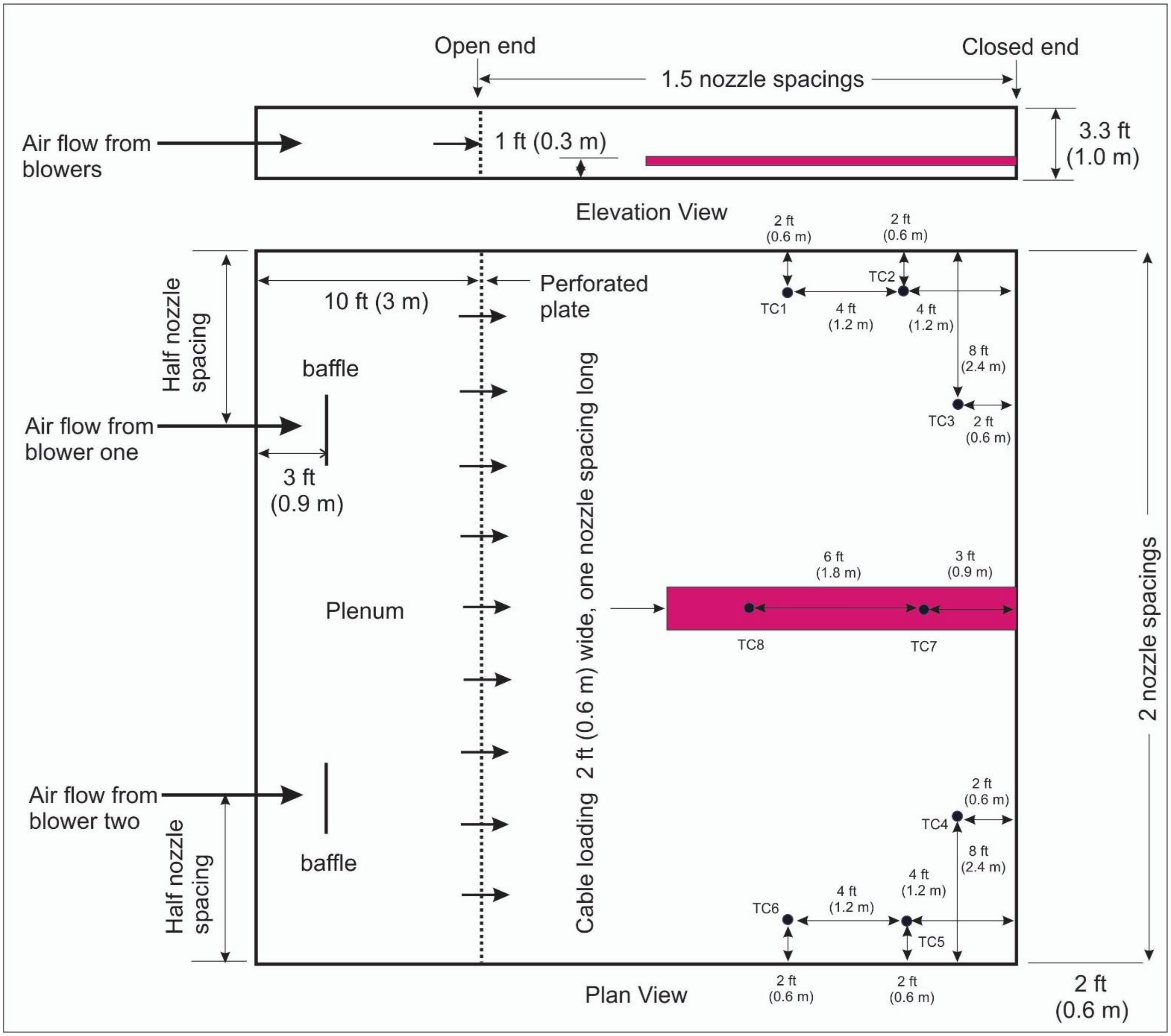


Figure N-5. Thermocouple Location Map.

APPENDIX O: SCALING METHODOLOGY: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF MACHINERY AND GAS TURBINES IN ENCLOSURES IN ½-SCALE

O.1 SCALING METHODOLOGY BACKGROUND

Fire suppression by water sprays involves the following processes: 1) spray formation, 2) water drop transport from the discharging nozzles to the fire and fuel surfaces, 3) water transport on and in the fuel, and 4) fire suppression or extinguishment through direct or indirect interactions between fire and water application. The above processes are more or less associated with or affected by the interaction of fire plume and water sprays.

If the interaction of fire plume and water sprays is properly scaled, it is possible to reproduce the spray pattern, fire gas flow field, and vaporizing process of the water drops before they land on the solid surfaces. To do this, a proper scaling of spray characteristics is essential. The reproduced spray pattern provides the same water distribution in the fire environment for fire suppression. Since the vaporization process is reproduced, it is possible to reproduce the thermal and inerting conditions in the fire environment. Based on this it is expected that the fire suppression result can be reproduced if by also scaling the water-spray-fire-plume interaction.

The principles of Froude modeling of spray-fire-plume interaction are to conserve: 1) the Froude number of gas flow in different scales; 2) the momentum transfer characteristics between water drops and gas medium; 3) the drop vaporization characteristics, and 4) the scalar quantities, such as temperature and concentrations, in the control volume.

The Froude number is the ratio of the momentum force versus the buoyancy force per unit volume in the gas flow, and is defined as:

$$Fr = \frac{\rho_g {u_g}^2}{gL(\rho_\infty - \rho_g)}$$

where:

ρ_g =fire gas density
ρ_∞ = ambient air density
g = gravitational acceleration
L = characteristic dimension of the fire environment
u_g = scalar value of the gas velocity vector, u_g.

The gas flow is strongly influenced by the momentum exchange between water drops and gas medium. The exchange is done through the counteracting forces between individual water drops and their surrounding gas medium, which can be determined with the following expression:

$$\vec{F} = \frac{1}{2} C_D A \rho_g \left| \vec{u}_d - \vec{u}_g \right| (\vec{u}_d - \vec{u}_g)$$

where:

A = drop's cross-sectional area
u_d = drop velocity vector
C_D = drag coefficient

The drop Reynolds number is defined as:

$$\mathrm{Re}_d = \frac{d \left| \vec{u}_d - \vec{u}_g \right|}{v_g}$$

where:

d = drop diameter
v_g = gas kinematic viscosity

For the case of water mist protection with drop sizes around 100 µm or less, the drop Reynolds number is typically around unity or less, due to the fact that mist tends to move with the gas current. In this low range, the drag coefficient is proportional to Re_d^{-1}. However, in other drop size ranges in which the scaling is to be performed, the drag coefficient can generally be expressed by the following power-law function:

$$C_d = k \, \mathrm{Re}_d^{-x}$$

where:

k and x = constants pertaining to the drop size range of interest

Table O.1 summarizes the general scaling relationships and the relationships specific for the conditions of $Re_d^{-1} \leq 1$. The table indicates that except for the drop number density and drop size, the scaling relationships for all other parameters are identical for different ranges of drop Reynolds numbers (i.e., drop sizes).

Scaling Parameters	**Any Re_d**	**$Re_d \leq 1$**
Drag Coefficient	$\propto Re_d^{-x}$	$\propto Re_d^{-1}$
Dimensions	S^1	S^1
Time	$S^{1/2}$	$S^{1/2}$
Water Discharge Pressure	S^1	S^1
Spray Angle	S^0	S^0
All Scalar Parameters except Drop Number Density	S^0	S^0
Drop Number Density	$S^{(3x-6)(2+2x)}$	$S^{-3/4}$
Velocity	$S^{1/2}$	$S^{1/2}$
Ventilation Rate	$S^{5/2}$	$S^{5/2}$
Fire Convective Heat Release Rate	$S^{5/2}$	$S^{5/2}$
Total Water Discharge Rate	$S^{5/2}$	$S^{5/2}$
Total Cooling Rate	$S^{5/2}$	$S^{5/2}$
Drop Size	$S^{(2-x)(2+2x)}$	$S^{1/4}$

Note: S is the scaling ratio. Therefore, in ½-scale S equals 0.5.

Table O.1: General scaling relationships.

O.2 ½-SCALE TESTING PROCESS

Based on the scaling methodology described in Section O.1, water mist system manufacturers have the option to conduct fire performance testing in ½-scale. The ½-scale fire performance testing described in this Appendix can be conducted as an option to the full-scale fire performance testing described in Appendix E and/or Appendix F. The following is the general process for using the scaling methodology for certification (Reference Chart O.2):

1. Water mist system manufacturer applies for certification with parameters for full-scale protection:
    a. Nozzle type and specifications
    b. Minimum nozzle operating pressure
    c. Maximum protected volume (length, width, and height)

2. Water mist system manufacturer submits full-scale nozzle and geometrically similar ½-scale nozzle samples to the certification agency with complete drawing packages.

3. The certification agency reviews construction of nozzles and conducts dimension measurements to verify that the ½-scale nozzle samples are indeed geometrically similar and in ½-scale. A tolerance of ± 0.001 in (0.025 mm) is required on the comparative measurements of the full-scale and ½-scale nozzle samples. *At the certification agency's discretion water mist nozzle spray characterization tests may be required on the full and ½-scale nozzles in order to verify the scaling relationships are correct for the ½-scale nozzles based on the results from the full-scale nozzles.*

4. Fire performance testing is conducted using the ½-scale nozzles in a ½-scale enclosure using ½-scale fire test specifications as described in this Appendix.

5. Certification is granted for full-scale protection by scaling up the ½-scale fire performance test results according to the scaling relationships. The required water mist system size and minimum discharge duration will be based on the longest fire extinguishment time.

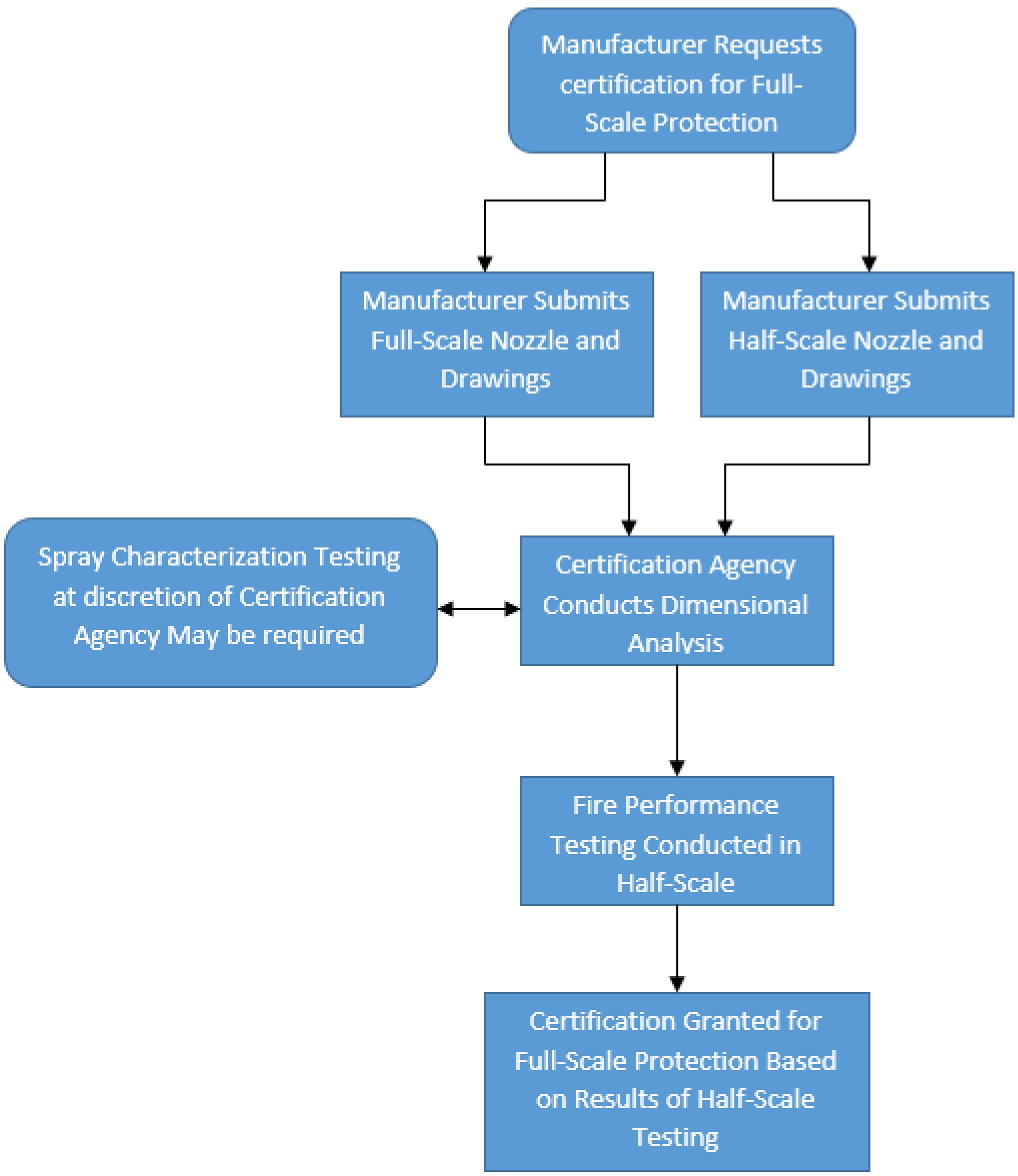


Chart O.2: Half-Scale Testing Process Flow Diagram

To provide further information on how the process works the following is an example scenario:

Manufacturer applies for certification with the following parameters:

- Nozzle type that includes five circular orifices with a diameter of 0.08 in (2 mm) and a spray angle of 120 degrees.
- Minimum nozzle operating pressure of 1450 psi (100 bar).
- Maximum nozzle spacing of 16.4 ft (5 m).
- Maximum protected volume of 35315 ft^3 (1000 m^3):
    - Length of 32.8 ft (10 m)
    - Width of 32.8 ft (10 m)
    - Height of 32.8 ft (10 m)

Based on the above parameters the manufacturer would submit the full-scale nozzle type as well as a ½-scale nozzle type to the certification agency for dimensional analysis. The ½-scale nozzle would be required to have five circular orifices with a diameter of 0.04 in (1 mm) and a spray angle of 120 degrees. After examination by the certification agency, if acceptable, the fire performance testing can be conducted in accordance with Appendix O. The fire performance testing would be conducted according to the following parameters:

- Test enclosure volume of 4415 ft^3 (125 m^3):
    - Length of 16.4 ft (5 m)
    - Width of 16.4 ft (5 m)
    - Height of 16.4 ft (5 m)
- Minimum nozzle operating pressure of 725 psi (50 bar).
- Maximum nozzle spacing of 8.2 ft (2.5 m).

All other parameters of the fire performance testing are detailed in this Appendix. Once the fire testing has been successfully completed the protection is scaled back up according to the scaling relationships. For example, if the longest extinguishment time from the fire performance testing in ½-scale was 21 minutes, this extinguishment time would scale up to 30 minutes in full-scale. In summary, certification of the water mist system would be based on the following parameters:

- Nozzle type that includes five circular orifices with a diameter of 0.08 in (2 mm) and a spray angle of 120 degrees.
- Minimum nozzle operating pressure of 1450 psi (100 bar).
- Maximum nozzle spacing of 16.4 ft (5 m).
- Maximum protected volume of 35315 ft^3 (1000 m^3).
- Minimum required discharge time of 60 minutes (two times the longest extinguishment time).

O.3 TEST ENCLOSURE (SEE FIGURE O-1)

The maximum enclosure area (as specified by the manufacturer) shall be tested in ½-scale. Enclosures should have equal length sides, although rectangular areas will be considered. The certification agency may restrict the scope of the certification to a limited range of aspect ratios depending on the outcome of the fire tests conducted in non-symmetric enclosures. The maximum enclosure height (as specified by the manufacturer) shall be tested in ½-scale. Enclosure heights shall be in 1 ft (0.3 m) increments. The enclosure should be constructed of wood or metal frame with an inner lining of minimum 0.375 in. (9.5 mm) gypsum or 0.019 in. (0.5 mm) galvanized steel. To minimize leakages, all joints and gaps shall be sealed. An opening measuring 3.25 ft by 3.25 ft (1 m by 1 m) and 0.8 ft (0.25 m) above the floor level shall be installed in the center of one wall, as shown in Figure P-1. A minimum of two hinged ceiling hatches measuring approximately 1.5 ft by 3 ft (0.45 m by 0.9 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 gas turbine and engine mockup unit should be centered in the test enclosure. In the case of rectangular enclosures, the certification agency reserves the right to alter the placement of the mockup unit based on the aspect ratio of the enclosure.

At the sole discretion of the certification agency, additional fire tests in smaller enclosures may be performed to validate the manufacturer's design parameters.

O.4 GAS TURBINE AND ENGINE MOCKUP UNIT (SEE FIGURES O-2 AND O-3)

The mockup unit measures 4 ft 11 in. (1.5 m) long by 1 ft 7.5 in. (0.5 m) wide by 4 ft 11 in. (1.5 m) high. It is fabricated from sheet steel with a nominal thickness of 0.1 in (2.5 mm). A tray with a depth of 2 in. (50 mm) is formed at the top of the mockup unit. Two 6 in. (15 cm) nominal diameter pipes, 4 ft 11 in. (1.5 m) in length, are attached to the unit to simulate obstructions. A 1 ft 1.5 in. (0.35 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 the certification agency.

A 4 in. (100 mm) by 1 in. (25 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 P-3).

The mockup unit is surrounded by a steel floor plate system, 9.9 ft (3 m) long by 6.6 ft (2.0 m) wide by 1.2 ft (0.375 m) high. A 10.8 ft^2 by 5 in. high (1 m^2 by 12.7 cm high) square pan should be located underneath the floor plate system.

O.5 GAS TURBINE SPRAY COOLING MOCKUP UNIT (SEE FIGURE O-5)

The gas turbine casing mockup is simulated with a horizontal flat steel plate (see Figure O-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 the certification agency 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 gas turbine steel plate mockup, caused by the discharge of the water mist 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 P-6).

O.6 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 ± 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 ± 18 °F (20 °C ± 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 °F ± 18 °F (20 °C ± 10 °C).

D Test enclosure temperatures measured in the center portion of the room at the 1/3, 2/3 and ceiling heights with 20 gauge Type K thermocouples. The enclosure shall initially be at an ambient temperature 68 °F ± 18 °F (20 °C ± 10 °C) for all tests.

E Mockup temperatures, with thermocouples placed on the surface of center of the 6 in. (15 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 P-3). The mockup shall initially be at an ambient temperature 68 °F ± 18 °F (20 °C ± 10 °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 10 in. (25 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 0.5 in. (1.25 cm) above the initial pool surface and 5 in. (12.5 cm) within the pool rim.

H Spray fire temperatures with a thermocouple located approximately 5 in. (12.5 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 2 in. (50 mm) above and centered over the wood crib surface, at the center of the wood crib and approximately 1 in. (25 mm) above the liquid fuel surface, 2 in. (50 mm) from the pool tray rim and approximately 1 in. (12.5 mm) above the liquid fuel surface, and 2 in. (50 mm) from the pool tray rim and within the liquid fuel, approximately 0.2 in. (5 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 °F (100 °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 10 in. (25 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. Due to the size of the test fires relative to the volume of the enclosure, consideration to the oxygen concentration is critical to verify that the test fires have not been self extinguished. Oxygen should generally be no less than 16 percent during the entire period of each test.

L For the spray fires, conventional oil burner nozzles are used, meeting the following requirements:

Fire Type	***Low Pressure***	***Low Pressure – Low Flow***	***High Pressure***
Spray Nozzle	Monarch F80 30.0 Type AR 120°	Monarch F80 5.5 Type AR 90°	Monarch F80 2.0 Type AR 60°
Fuel Type	Light diesel	Light diesel	Light diesel
Nominal Oil Pressure	110 psi (7.5 bar)	120 psi (8.3 bar)	2200 psi (150 bar)
Nominal Heat Release Rate	1.0 MW	0.2 MW	0.3 MW
Nominal Fuel Flow	0.062 ± 0.003 lb/s (0.028 ± 0.001 kg/s)	0.011 ± 0.0010 lb/s (0.005 ± 0.0005 kg/s)	0.020 ± 0.002 lb/s (0.009 ± 0.001 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 the certification agency.

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 3 in. diameter by 1.5 in. long (75 mm by 37.5 mm) with a thickness of 0.010 in. (0.25mm).

N General pool or tray specifications:

Pans or trays shall be of steel construction, 0.034 in. (0.86 mm) thickness by 2 in. (5 cm) high, with no lip. The two required pans shall be 21.2 in. (0.55 m) wide by 21.2 in. (0.55 m) long and 6.7 in. (0.17 m) wide by 6.7 in. (0.17 m) long. A water base of 0.8 in. (2 cm) in height with a fuel load of at least 0.6 in. (1.5 cm) above should be used. Freeboard should be 0.6 in. (1.5 cm). Freeboard may be greater than 0.6 in. (1.5 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 P.7.8) shall be 2.6 ft (0.78 m) in diameter, of steel construction, 0.034 in. (0.86 mm) thickness by 3.6 in. (9.2 cm) high, with no lip. A fuel load of at least 0.4 in. (1 cm) should be used with an appropriate water base so that the fuel level is 3 in. (7.6 cm) above the base of the pan. Freeboard should be at least 0.6 in. (1.5 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 1 in. (25 mm) in thickness, and contain a density of 6 to 8 lb/ft^3 (96 to 128 kg/m^3). 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.

O.7 FIRE TESTS

Intermediate pendent or upright nozzles that are not at ceiling level, or wall mounted nozzles, are not permitted for the protection of machinery in enclosures. Intermediate pendent or upright nozzles that are not at ceiling level, or wall mounted nozzles, are permitted for the protection of gas turbines in enclosures.

The water mist 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.

For the protection of machinery in enclosures, corresponding to Appendix E, the water mist system shall successfully complete the first eight (O.7.1 through O.7.8) fire performance tests. During the fire tests, all systems shall operate without manual intervention.

For the protection of gas turbines in enclosures, corresponding to Appendix F, the water mist system shall successfully complete the first eight (O.7.1 through O.7.8) fire performance tests and the Spray Cooling (heat transfer) test (O.7.9). An additional option for gas turbine applications is the protection of insulated turbines. Two additional fire tests (O.7.10 and O.7.11), involving insulation mats of mineral wool composition, are required for this application extension. During the fire tests, all systems shall operate without manual intervention.

The two worst performing successful fire performance tests, with respect to fire extinguishment time, shall be repeated.

Agent supply needed for the extinguishment time for the longest fire scenario will be reported and considered as one of the requirements when a water mist 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.

O.7.1 Low Pressure, Exposed, Diesel Spray Fire (Reference Full-Scale Test E.4.1/F.5.1)

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 7 in. (178 mm) from the edge of the longer side of the top tray (see

	Figure O-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:	11 seconds
Test Procedure:	The spray fire shall be ignited, and the water mist system should be activated subsequent to the required preburn time. The fuel spray should be shut off 11 seconds after the fire extinguishment. The system discharge should be shut off 32 seconds after the fuel spray is shut off.

O.7.2 Low Pressure, Angled, Diesel Spray Fire (Reference Full-Scale Test E.4.2/F.5.2)

Criterion:	Extinguishment of the spray fire
Fuel:	Diesel
Type:	Angled spray
Spray Nozzle:	Low pressure nozzle
Fire Location:	A 0.3 in. (7.5 mm) diameter rod shall be placed vertically on top of the mockup unit, at the centerline of the longer side of top tray and 7 in. (178 mm) from the edge of this longer side. The test fire shall be located on top of the mockup unit, 1 ft 7.5 in. (0.5 m) away from the rod and 7 in. (178 mm) from the edge of the longer side of the top tray (see Figures O-3 and O-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:	11 seconds
Test Procedure:	The spray fire shall be ignited, and the water mist system should be activated subsequent to the required preburn time. The fuel spray should be shut off 11 seconds after the fire extinguishment. The system discharge should be shut off 32 seconds after the fuel spray is shut off.

O.7.3 Low Pressure, Concealed, Diesel Spray Fire (Reference Full-Scale Test E.4.3/F.5.3)

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 2 in. (5 cm) from the end of the mockup unit, under the centerline of the 6 in. (15 cm) diameter pipe, and 2.63 ft (0.8 m) above the floor plate (See Figures O-2 and O-3). The spray fire should be positioned to spray along the length of the pipe, away from the test enclosure opening.
Fire Preburn Time:	11 seconds
Test Procedure:	The spray fire shall be ignited, and the water mist system should be activated subsequent to the required preburn time. The fuel spray should be shut off 11 seconds after the fire extinguishment. The system discharge should be shut off 32 seconds after the fuel spray is shut off.

O.7.4 High Pressure, Exposed, Diesel Spray (Reference Full-Scale Test E.4.4/F.5.4)

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 7 in. (178 mm) from the edge of the longer side of the top tray (see Figure O-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:	11 seconds
Test Procedure:	The spray fire shall be ignited, and the water mist system should be activated subsequent to the required preburn time. The fuel spray should be shut off 11 seconds after the fire extinguishment. The system discharge should be shut off 32 seconds after the fuel spray is shut off.

O.7.5 Low Pressure-Low Flow, Concealed, Diesel Spray and Pool Fires (Reference Full-Scale Test E.4.5/F.5.5)

Criterion:	Extinguishment of the spray fire and suppression of the pool fire
Fuel:	Diesel
Type:	Horizontal spray and 0.3 ft^2 (0.03 m^2) pool fire
Spray Nozzle:	Low pressure-low flow nozzle
Fire Location:	The spray fire shall be located under the shelf with the nozzle 2 in. (5 cm) from the end of the mockup unit, under the centerline of the 6 in. (15 cm) diameter pipe, and 2.63 ft (0.8 m) above the floor plate (see Figures O-2 and O-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, 2 ft 3.5 in. (0.7 m) from the end of the mockup unit (see Figure O-2).
Fire Preburn Time:	85 seconds
Test Procedure:	The pool fire shall be ignited. The spray fire should be ignited 74 seconds after ignition of the pool fire. The water mist system should then be activated 11 seconds after ignition of the spray fire (85 seconds after the pool fire is ignited). The fuel spray should be shut off 11 seconds after spray fire extinguishment. The system discharge should be shut off 32 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.

O.7.6 Concealed, Heptane Pool Fire (Reference Full-Scale Test E.4.6/F.5.6)

Criterion:	Suppression of the pool fire
Fuel:	Heptane
Type:	3.25 ft^2 (0.3 m^2) pool fire
Fire Size:	0.4 MW (nominal)
Fire Location:	The test fire shall be centered under the shelf, on top of the floor plates (see Figure O-2).
Fire Preburn Time:	11 seconds
Test Procedure:	The pool fire shall be ignited, and the water mist system should be activated subsequent to the required preburn time. The system discharge should be shut off 32 seconds after extinguishment. 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.

O.7.7 Flowing Fire (Reference Full-Scale Test E.4.7/F.5.7)

Criterion:	Extinguishment of the fire
Fuel:	Heptane
Type:	Flowing
Fuel Flow Rate:	0.097 lb/s (0.044 kg/s) (nominal)
Fire Size:	4.9 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:	11 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 water mist system should be activated subsequent to the required preburn time. The fuel flow should be shut off 11 seconds after

the fire extinguishment. The system discharge should be shut off 32 seconds after the fuel flow is shut off.

O.7.8 Wood Crib and Heptane Pool Fire (Reference Full-Scale Test E.4.8/F.5.8)

Criteria	Extinguishment of the crib fire and extinguishment of the pool fire
Fuel:	Wood crib and heptane
Type:	Pool fire with crib
Fire Size:	1.3 MW (nominal)
Wood Crib:	The wood crib is to be dimensioned approximately 5.5 in. by 5.5 in. by 5 in. (140 by 140 by 125 mm). The crib is to consist of five alternate layers of two trade size 1.0 by 1.0 in. (25 by 25 mm) kiln-dried spruce or fir lumber 5.5 in. (140 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 O-1). The crib should be placed in the center of the 5.4 ft^2 (0.5 m^2) pool with the fuel level up to one-half its height. The pan is located 1.25 ft (0.375 m) off the floor.
Fire Preburn Time:	21 seconds
Test Procedure:	The pool fire shall be ignited, and the water mist system should be activated subsequent to the required preburn time. The system discharge should be shut off 32 seconds after extinguishment. 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.

O.7.9 Spray Cooling (No Fire) (Reference Full-Scale Test F.5.9)

Note:	The Spray Cooling test must be conducted with the full-scale nozzle. The test must be conducted in open air, the half-scale enclosure shall not be used to run this test.
Criteria:	The heat flux resulting from a water mist system discharge shall not adversely affect the turbine. Such assessment is to be made in accordance with methodology developed by the certification agency to assess the damage potential of water mist systems. This test, combined with heat transfer calculations, will determine the extent of the cooling of the turbine casing during the operation of the water mist system. Calculations should be based on the manufacturer's recommended turbine size (diameter) to be installed within the enclosure and/or water mist 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 water mist 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 F-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 the certification agency 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 water mist 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.

O.7.10 Saturated Insulation Mat and Spray Fire (Optional Test) (Reference Full-Scale Test F.5.10)

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 2 in. (5 cm) from the end of the mockup unit, under the centerline of the 6 in. (15 cm) diameter pipe, and 2.63 ft (0.8 m) above the floor plate (see Figures O-2 and O-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, 2 ft 3.5 in. (0.7 m) from the end of the mockup unit (see Figure O-2).
Fire Preburn Time: 85 seconds
Test Procedure: A 1 in. (25 mm) thick insulation mat of mineral wool composition shall be cut to the same dimensions as the 0.3 ft^2 (0.03 m^2) 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 74 seconds after the insulation mat fire is fully developed over the entire area of the mat. The water mist system should then be activated 11 seconds after ignition of the spray fire (85 seconds after the insulation mat fire is fully developed). The fuel spray should be shut off 11 seconds after the fire extinguishment. The system discharge should be shut off 32 seconds after the fuel spray is shut off.

O.7.11 Saturated Insulation Mat Fire (Optional Test) (Reference Full-Scale Test F.5.10)

Criteria: Suppression (only flamlets on surface of the insulation mat) of the insulation mat fire

Fuel: Diesel fuel and insulation mat

Type: 3.1 ft^2 (0.3 m^2) 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 P-2).

Fire Preburn Time: 85 seconds

Test Procedure: A 1 in. (25 mm) thick insulation mat of mineral wool composition shall be cut to the same dimensions as the 3.1 ft^2 (0.3 m^2) 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 water mist system should be activated 85 seconds after the insulation mat fire is fully developed over the entire area of the mat.

O.7.12 Additional Fire Tests

Based on the results of Fire Tests O.7.1 through O.7.11, additional fire testing may be required to ensure that the water mist system being evaluated meets the intent of this section of the standard. This testing will be performed at the sole discretion of the certification agency.

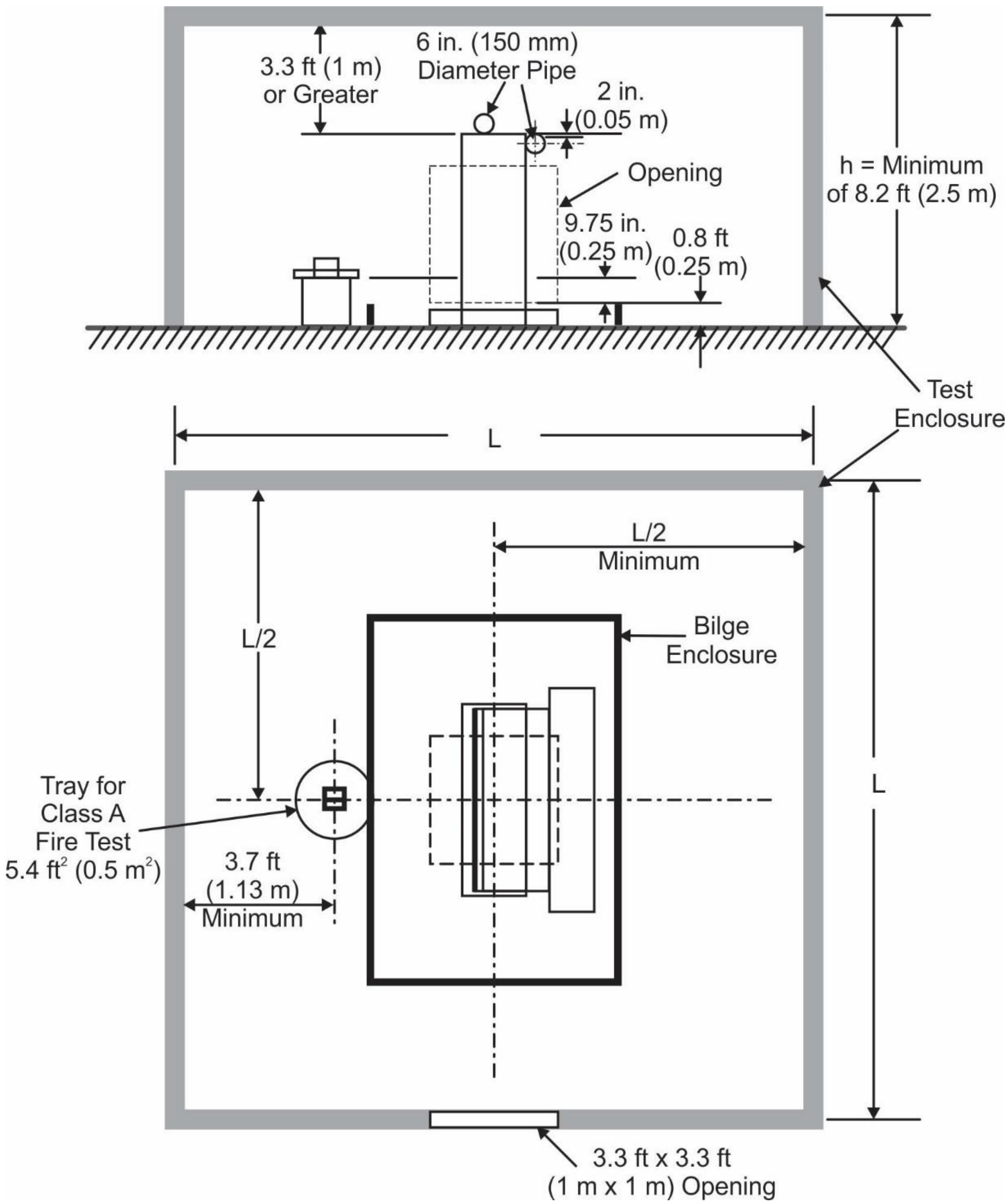


Figure O-1. Machinery and Gas Turbine Test Enclosure

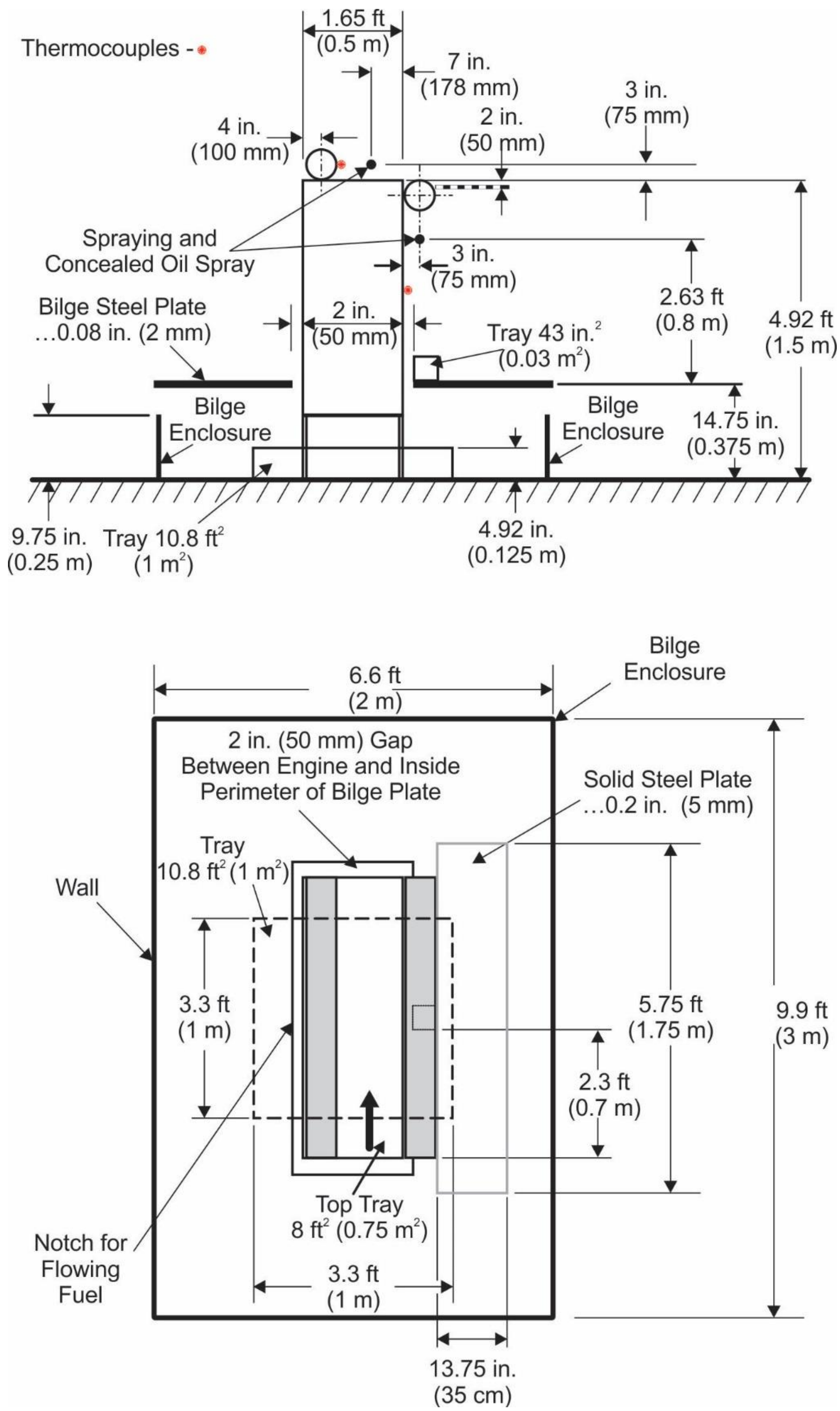


Figure O-2. Machinery and Gas Turbine Mockup Unit

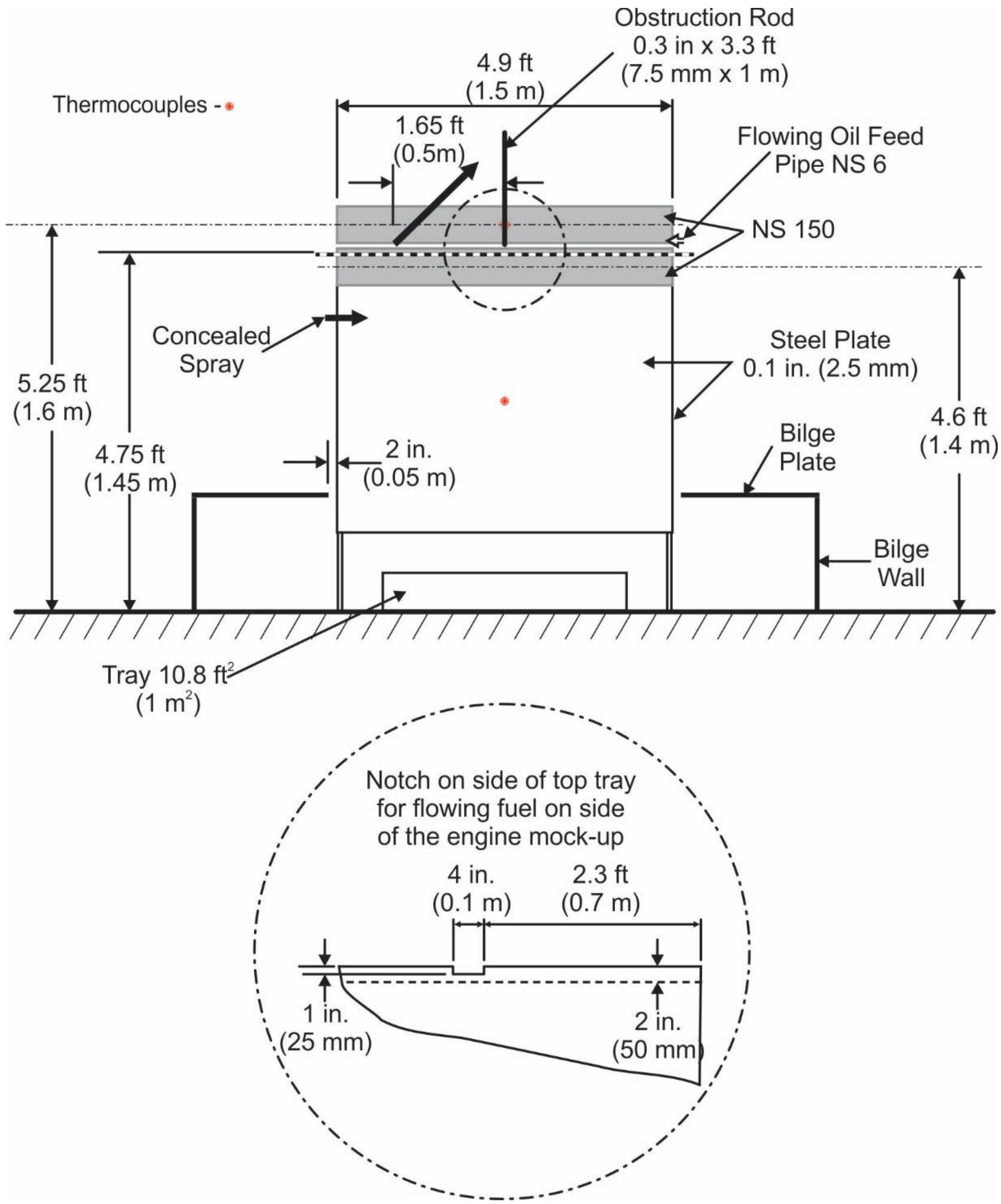


Figure O-3. Machinery and Gas Turbine Mockup Unit (Continued)

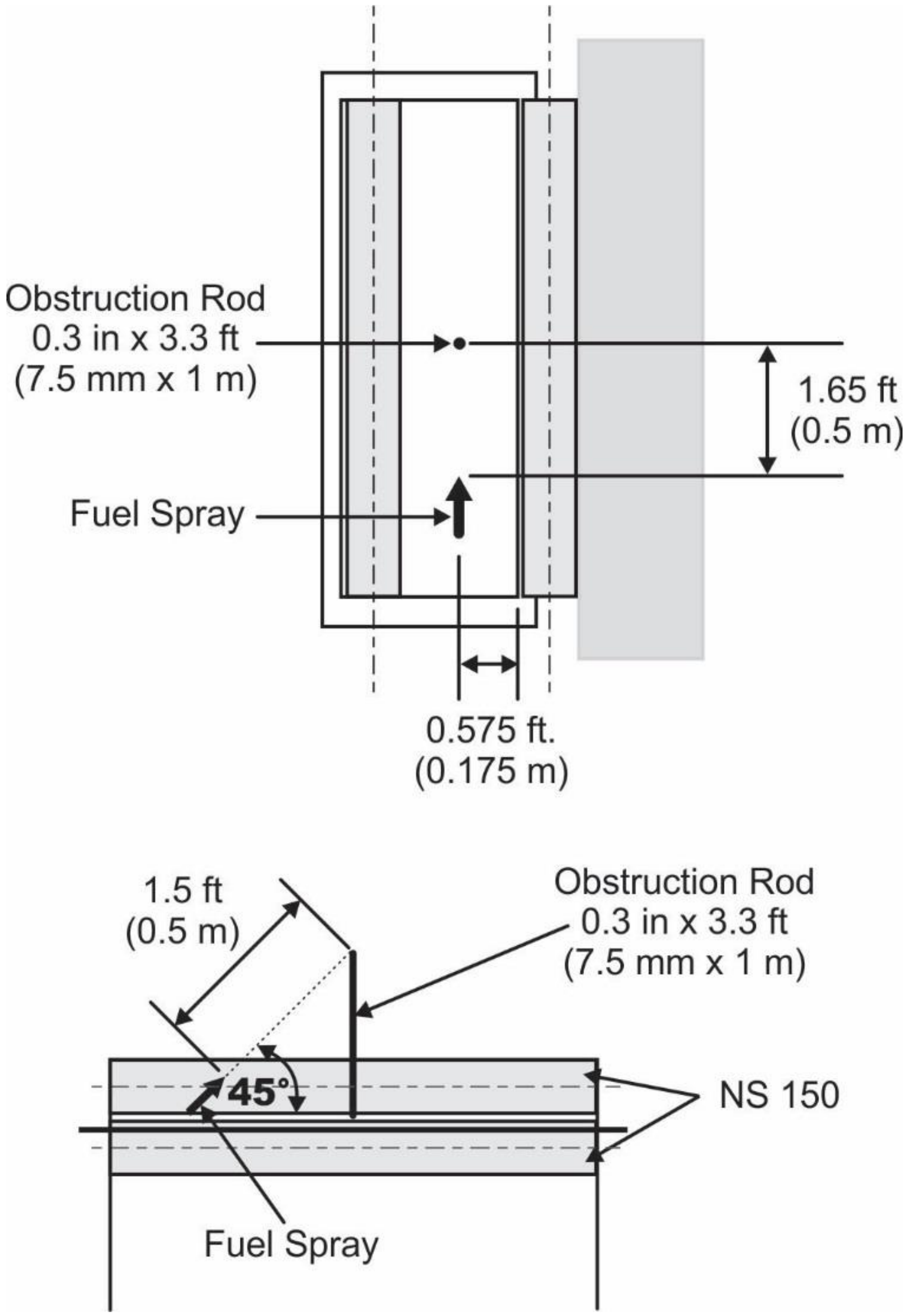


Figure O-4. Fire Test O.7.2, Position of Fuel Spray Nozzle and Obstruction Rod

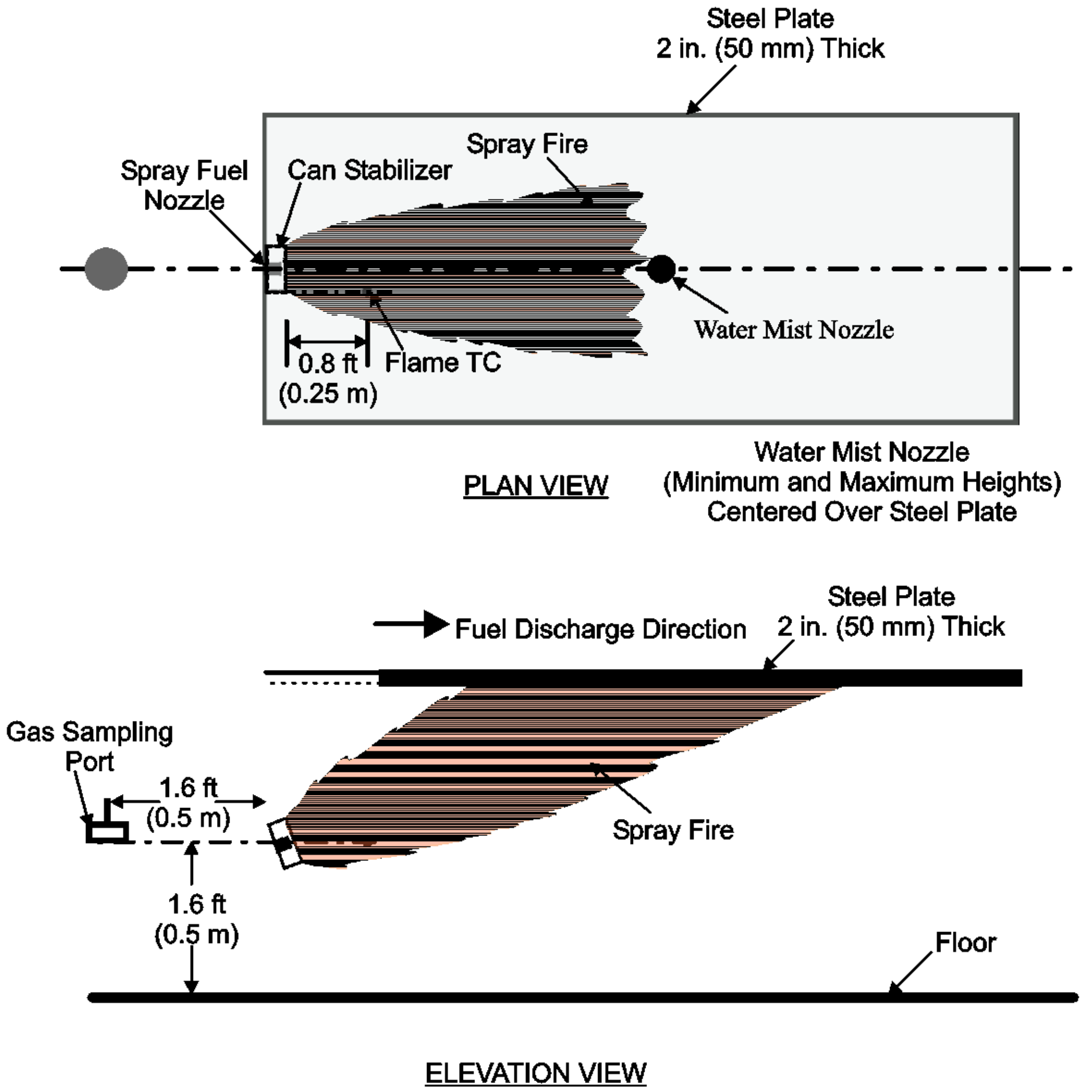


Figure O-5. Fire Source Configuration for Spray Cooling (No Fire) Testing

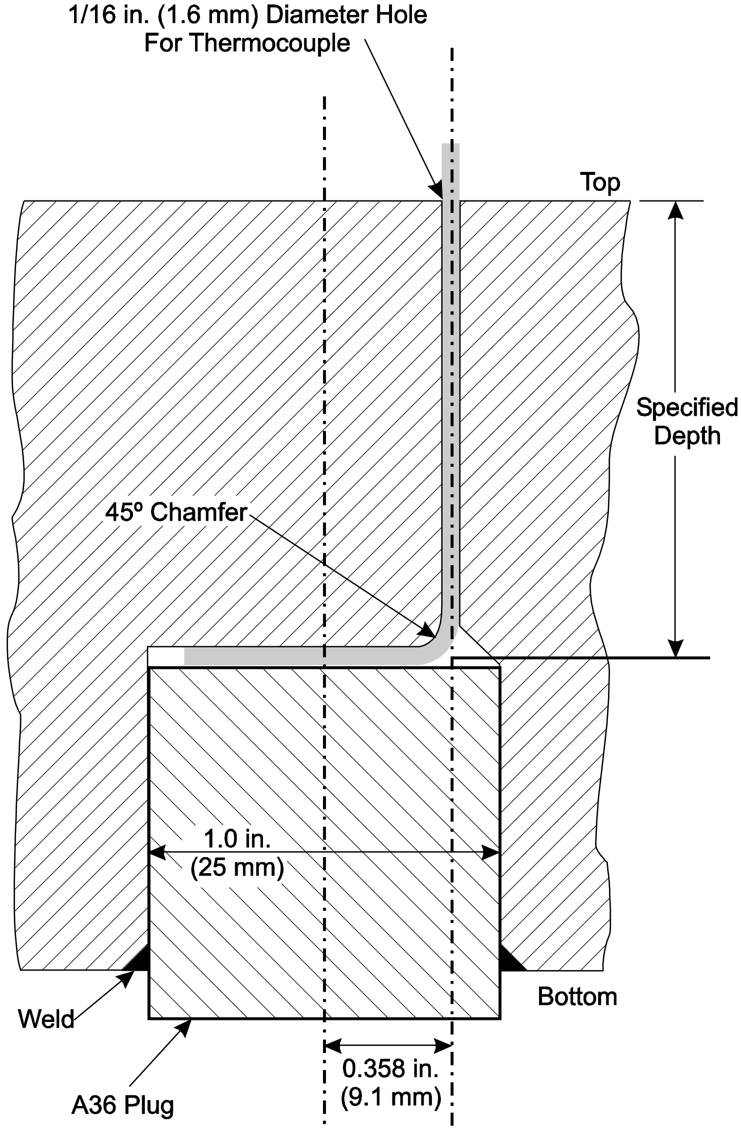


Figure O-6. Detail of Embedded Thermocouple for Spray Cooling Test

APPENDIX P: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF NON-STORAGE OCCUPANCIES, HAZARD CATEGORY 2 (HC-2) AND HAZARD CATEGORY 3 (HC-3)

P.1 GENERAL TESTING REQUIREMENTS

In addition to the instrumentation and test requirements described previously under "General Instrumentation and Test Equipment Requirements," the following criteria shall be met:

A. The manufacturer shall provide the certification agency with design, installation, operation, and maintenance manuals for the complete water mist system. The same nozzle design shall be used for all required fire tests for each hazard category.

B. The individual nozzles shall include either a fusible link or glass bulb assembly and meet quick response nozzle criteria (refer to Sections 4.2.26 to 4.2.28). The heat responsive element and temperature rating of the nozzles used in all fire tests shall be identical. The nominal operating temperature of the nozzle shall not exceed 225°F (107°C). If multiple temperature ratings are requested by the manufacturer tests will be required at both minimum and maximum temperature ratings.

C. The maximum nozzle spacing shall not exceed 16.4 ft (5 m) as specified by the manufacturer. This includes the maximum spacing of the nozzles from the walls which shall be one-half the nozzle spacing.

D. Nozzles shall be installed with their thermal element located at a distance of 6 in. (15 cm) below the ceiling. With this test specification nozzles will have a certification specification of 3 to 6 in. (7.5 to 15 cm) below the ceiling. If the manufacturer requests nozzle distance below ceiling specifications outside of this range tests will be required at both the minimum and maximum nozzle distance below the ceiling.

E. All fire performance tests shall be conducted at the maximum ceiling height. The lowest permitted maximum ceiling shall be 15 ft. (4.6 m). At the water mist system manufacturer's discretion, the maximum ceiling height may be increased in increments of 5 ft. (1.5 m). If a maximum ceiling height greater than 15 ft. (4.6 m) is specified by the manufacturer a test at a ceiling height of 15 ft. (4.6 m) will be required in addition to the tests at the maximum ceiling height. The test configuration shall be the worst case performing test at maximum ceiling height at the discretion of the certification agency.

F. The minimum ceiling height limitation will be based on water mist spray overlap at the minimum ceiling height, as specified by the manufacturer. At the minimum ceiling height, the water mist spray must overlap with no voids in coverage permitted. Additionally, the application rate at the midpoint between two nozzles cannot be less than 90 percent when compared to the same test at maximum ceiling height.

G. Certification Options

1. Hazard Category 2 (HC-2) only:
   A water mist system shall successfully complete fire tests P.4.1, P4.2, P.4.3 and P.4.4 according to the Certification Criteria stated in Section P.6.

2. Hazard Category 2 (HC-2) and Hazard Category 3 (HC-3):
   a. Protection with different systems:
      A water mist system shall successfully complete all fire performance tests, P.4.1, P.4.2, P.4.3, P.4.4, P.5.1, P.5.2, P.5.3 and P.5.4 according to Certification Criteria stated in Section P.6. Different nozzle designs, or system design specifications, may be used for each hazard category and the manufacturer's certification will state different designs for each hazard category.
   b. Protection with the same system:
      A water mist system shall successfully complete fire performance tests P.5.1, P.5.2, P.5.3 and P.5.4 according to the Certification Criteria stated in Section P.6. At the manufacturer's discretion only Hazard Category 3 (HC-3) fire performance tests can be conducted which will result in certification for Hazard Category 2 (HC-2) and Hazard Category 3 (HC-3) using the design from the successful HC-3 fire

performance testing.

3. Systems successfully completing fire performance tests for Hazard Category 2 (HC-2) or Hazard Category 3 (HC-3) are suitable for use for use on Hazard Category 1 (HC-1) with the same system specifications used for the higher hazard category as fire performance tested. [Fire performance tests specifically for Non-Storage Occupancies, Hazard Category 1 (HC-1) are detailed in Appendix G.]

H. System components, component locations, and operating conditions shall remain unaltered throughout all of the fire tests, and the system shall operate without manual intervention. All fire tests shall be conducted using the spray specifications from the manufacturer's design manual in regard to nozzle placement, spray flux, and spray duration.

I. All fire tests shall be conducted for 30 minutes after the activation of the first nozzle. After this 30 minute period the fuel package will be evaluated to Certification Criteria stated in Section P.6. Any remaining fire should be extinguished manually.

J. For all fire tests, the system should be:

1. Pressurized to the minimum operating pressure specified by the manufacturer. Following activation of the first nozzle, the flowing water pressure should be maintained at the minimum system operating pressure; or
2. Pressurized to the minimum stand-by pressure specified by the manufacturer. Following activation of the first nozzle, the flowing water pressure should be gradually increased to the minimum system operating pressure specified by the manufacturer. The delay time until the minimum system operating pressure is reached should correspond to the delay time expected in an actual installation. The delay time recorded during the tests should be documented and included in the system specifications.

P.2 TEST AREA CONFIGURATION

The test area shall include a smooth, continuous ceiling with minimum length and width dimensions of 80 ft. (24.4 m), or have dimensions adequate to accommodate a 7 by 7 grid of nozzles, in order to simulate an uninterrupted open space and shall be at minimum 15 ft. (4.6 m) in height. At the manufacturer's discretion the ceiling height may be increased in increments of 5 ft. (1.5 m) above the minimum required maximum ceiling height of 15 ft. (4.6 m). The test area shall be inside a laboratory of sufficient area and height with natural or forced ventilation. The ventilation shall not induce velocities, measured 10 ft. (3.0 m) away from the fuel package at any location, exceeding 3.3 ft/s (1.0 m/s).

A steel angle cross shall be constructed and centered beneath the ceiling in the north-south and east-west directions. Each 2 by 2 by ½ in. (51 by 51 by 6 mm) thick steel angle shall be 2 ft. (0.61 m) long, and in direct contact with the ceiling on one side. Nine 20-gage, K-type thermocouples shall be embedded in the cross at 6 in. (0.15 m) intervals, with the center thermocouple located at the cross center.

Oxygen concentration shall be measured in a location at the discretion of the certification agency based on the test area configuration to constantly monitor oxygen concentration throughout all fire performance tests. Oxygen concentration shall not go below 20 percent.

Prior to each test, the test area shall be dried and all water from previous testing shall be removed. There shall be no visible water on the floor or ceiling. The air in the test area shall be conditioned to an ambient temperature of 68°F ± 18°F (20°C ± 10°C) as measured at the thermocouple located below the ceiling center.

P.3 FUEL PACKAGE CONFIGURATIONS

P.3.1 Fuel Package Non-Storage Occupancies, Hazard Category 2 (HC-2)

The fuel package for fire performance tests for Hazard Category 2 (HC-2) shall be a Class 2 commodity. A Class 2 commodity consists of three nested double-wall corrugated cardboard cartons and a five-sided metal liner sitting on a wood pallet as one pallet-load unit. The dimensions of the outer, middle and inner cartons are 41.8 by 41.8 by 41.5 in. (1.06 by 1.06 by 1.05 m) high, 41.8 by 41.8 by 41.5 in (1.04 by 1.04 by 0.99 m) high, and 40.3 by 40.3 by 37.8 in. (1.02 by 1.02 by 0.96 m) high, with respective weights of about 27.3, 26.4, 25.1 lb. (12.4, 12.0, 11.4 kg). The thickness of the corrugated cardboard is about 0.29 in. (7.3 mm), and the flutes inside the vertical walls of each carton are oriented vertically. The metal liner measures about 38 by 38 by 37 in. (0.97 by 0.97 by 0.94 m) high, and weighs about 45.5 lb. (20.7 kg). The liner, with its open side facing down, is inserted inside the inner carton. The wood pallet is a two-way, slatted hardwood pallet and weighs about 51.0 lb. (23.0 kg); its overall dimensions are about 41.8 x 41.8 x 5.5 in. (1.06 x 1.06 x 0.14 m) high. As a result, the overall dimensions of a pallet-load of the Class 2 commodity are about 41.8 by 41.8 by 47.0 in. (1.06 by 1.06 by 1.19 m) high, with a gross weight of about 175.0 lb (79.6 kg), of which 45 percent is for cartons, 29 percent for the wood pallet, and 26 percent for the metal liner.

The Class 2 commodity is arranged in a 2 by 8 by 2 high rack storage as shown in Figure P-1. Steel racking shall be used to support the commodity. Steel racking vertical uprights have approximate cross sectional dimensions of 3.0 by 3.0 in. (7.6 by 7.6 cm) and horizontal steel racking rails have approximate cross sectional dimensions of 1.5 by 3.0 in. (3.8 by 7.6 cm). The horizontal rails of the steel rack shall be 5 ft. (1.52 m) above the floor, and the longitudinal and transverse flues shall be 6 in. (0.15 m) wide. The pallet-loads in the bottom tier shall be sitting on the floor. The overall dimensions of the 2 by 8 by 2 high array is approximately 7.5 by 31.5 by 9 ft (2.29 by 9.60 by 2.74 m) high. A target fuel array shall be located on each side, and centered on, the main array arranged in a 1 by 4 by 2 high rack storage as shown in Figure P-1. The aisle separation between each target fuel array and the main fuel array shall be 8.0 ft (2.4 m). At the start of each fire performance test the moisture content of the corrugated board commodity shall by between 4 and 8 percent (dry base measurement). A minimum of six moisture content measurements shall be taken including three from the main array and three from the target array nearest to ignition. Measurements shall be taken of the material within 30 minutes of test time, and beforehand as needed.

The fuel array is to be ignited with two half igniters located at the midpoint of the base of the central transverse flue on the east side of the fuel array, each igniter abutting the corresponding carton surface. As shown in Figure P-1 the steel rack's two middle uprights and their horizontal ties shall be located in the central transverse flues to obstruct water transport to the fire origin. To start a test, the two igniters shall be ignited with a propane torch. A half igniter is made of a cellucotton roll of 3.0 in (7.6 cm) in diameter and 3.0 in (7.6 cm) long, soaked with 4 fl. oz (118 cc) of gasoline and enclosed in a polyethylene bag.

P.3.2 Fuel Package Non-Storage Occupancies, Hazard Category 3 (HC-3)

The fuel package for fire performance tests for Hazard Category 3 (HC-3) shall be a CEP commodity. A CEP commodity is made of polystyrene meat trays nested inside 21 by 21 by 20 in. (0.53 by 0.53 by 0.51 m) high, single-wall corrugated cardboard cartons. The corrugated cardboard thickness of the carton is 0.17 in. (4.3 mm). Each carton weighs about 5.6 lb. (2.5 kg), with vertical flutes in the vertical walls. The dimensions of each meat tray are 10 by 8 by 1.1 in. (25 by 20 by 3 cm) high, with a nominal tray thickness of 0.2 in. (5.1 mm). Each tray weighs about 0.35 oz. (10 g). Two hundred eighty trays are arranged in four, sixty-tray stacks in each corner of the carton and four, ten-tray stacks placed vertically in the center of the carton. The trays stack to a nominal height of 16.5 in. (42 cm) leaving a 4.5 in. (11 cm) air gap at the top of the carton. To construct a pallet-load, meat-trays-filled cartons are stacked on the same type of hardwood pallet used for the Class 2 commodity in a 2 by 2 by 3 high configuration. The overall dimensions are 42 by 42 by 65.5 in. (1.07 by 1.07 by 1.68 m), with a gross weight of about 191.0 lb. (86.6 kg), of which about 35 percent is for cartons, 40 percent for meat trays, and 25 percent for the wood pallet.

The CEP commodity is arranged in a 2 by 8 by 1 high palletized configuration as shown in Figure P-2. Each pallet-load consisted of 12 cartons arranged in 2 by 2 by 3 high on a hardwood pallet. All the pallet-loads shall be sitting on the floor, with 6 in. (0.15 m) wide vertical flues in both the longitudinal and transverse directions. The overall dimensions of the 2 by 8 by 1 array are about 7.5 by 31.5 by 5.5 ft. (2.29 by 9.60 by 1.68 m) high. A target fuel array shall be located on each side, and centered on, the main array arranged in a 1 by 4 by 1 high rack storage as shown in Figure P-2. The aisle separation between each target fuel array and the main fuel array shall be 8.0 ft (2.4 m). At the start of each fire performance test the moisture content of the corrugated board commodity shall be between 4 and 8 percent (dry base measurement). A minimum of six moisture content measurements shall be taken including three from the main array and three from the target array nearest to ignition. Measurements shall be taken of the material within 30 minutes of test time, and beforehand as needed.

The fuel array is to be ignited with two half igniters located at the midpoint of the base of the central transverse flue on the east side of the fuel array with each igniter abutting the corresponding carton surface as shown in Figure P-2. To start a test, the two igniters shall be ignited with a propane torch. A half igniter is made of a cellucotton roll of 3.0 in (7.6 cm) in diameter and 3 in (7.6 cm) long, soaked with 4 fl. oz (118 cc) of gasoline and enclosed in a polyethylene bag.

P.4 FIRE TESTS NON-STORAGE OCCUPANCIES, HAZARD CATEGORY 2 (HC-2)

Table P.4. Fire tests for Non-Storage Occupancies – Hazard Category 2 (HC-2).

Test	**P.4.1**	**P.4.2**	**P.4.3**	**P.4.4**
Fuel (Standard Commodity)	Class 2	Class 2	Class 2	Class 2
Ignition Location	Under 1	Between 2	Between 4	Under 1
Nozzle Spacing	Maximum	Maximum	Maximum	Minimum

P.5 FIRE TESTS NON-STORAGE OCCUPANCIES, HAZARD CATEGORY 3 (HC-3)

Table P.5. Fire tests for Non-Storage Occupancies – Hazard Category 3 (HC-3).

Test	**P.5.1**	**P.5.2**	**P.5.3**	**P.5.4**
Fuel (Standard Commodity)	CEP	CEP	CEP	CEP
Ignition Location	Under 1	Between 2	Between 4	Under 1
Nozzle Spacing	Maximum	Maximum	Maximum	Minimum

P.6 CERTIFICATION CRITERIA

The following Certification Criteria shall be met for all fire performance tests stated in Section P.4 and Section P.5:

(1) The temperature of the steel angles, installed at ceiling level above ignition, cannot exceed 1000°F (538°C).
(2) The fire cannot spread to either end of the main fuel array.
(3) The fire cannot burn through or spread to either end of the target fuel array.
(4) There must be unoperated nozzles at the perimeter beyond each operated nozzle.

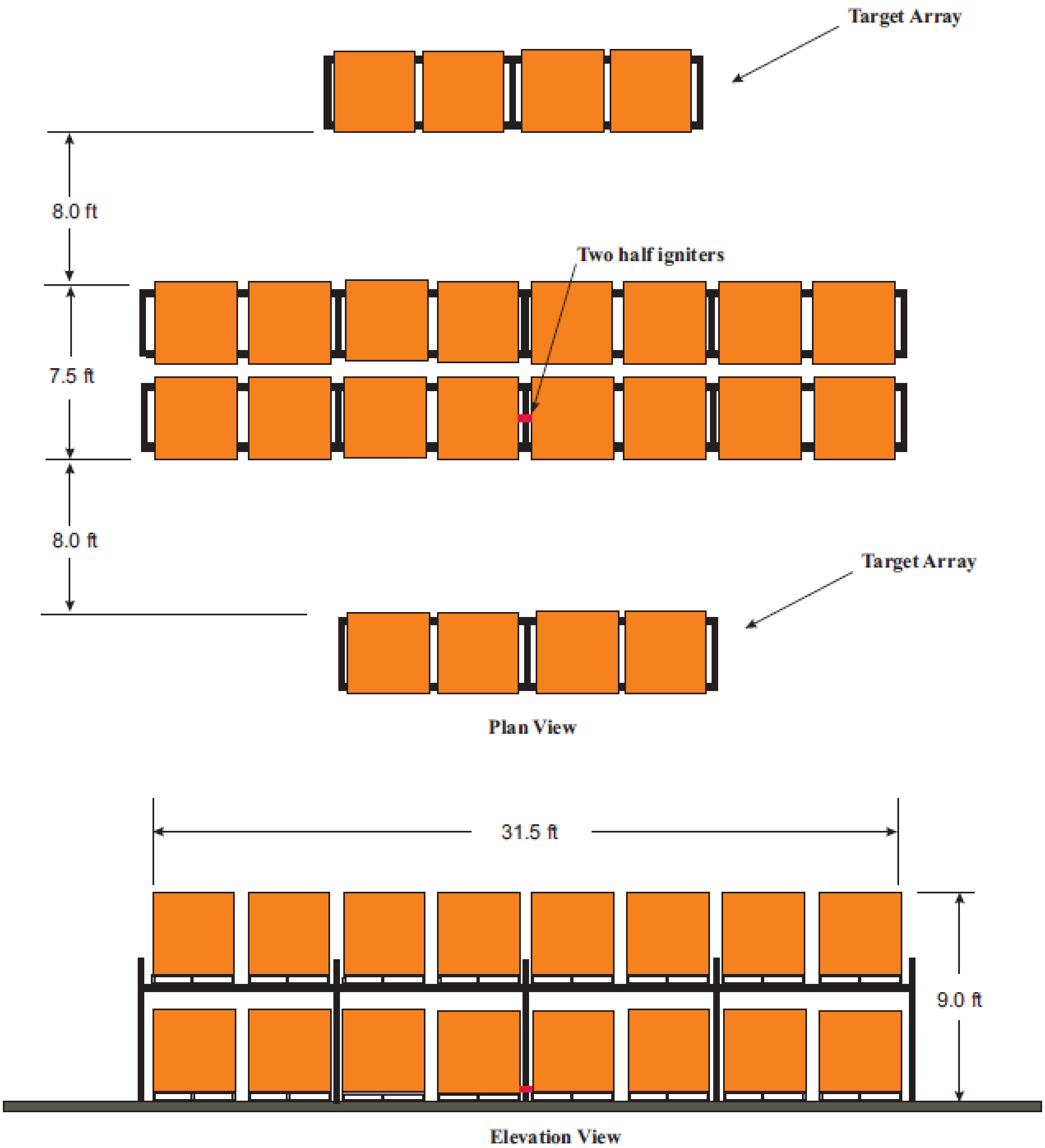


Figure P-1. HC-2 fuel array.

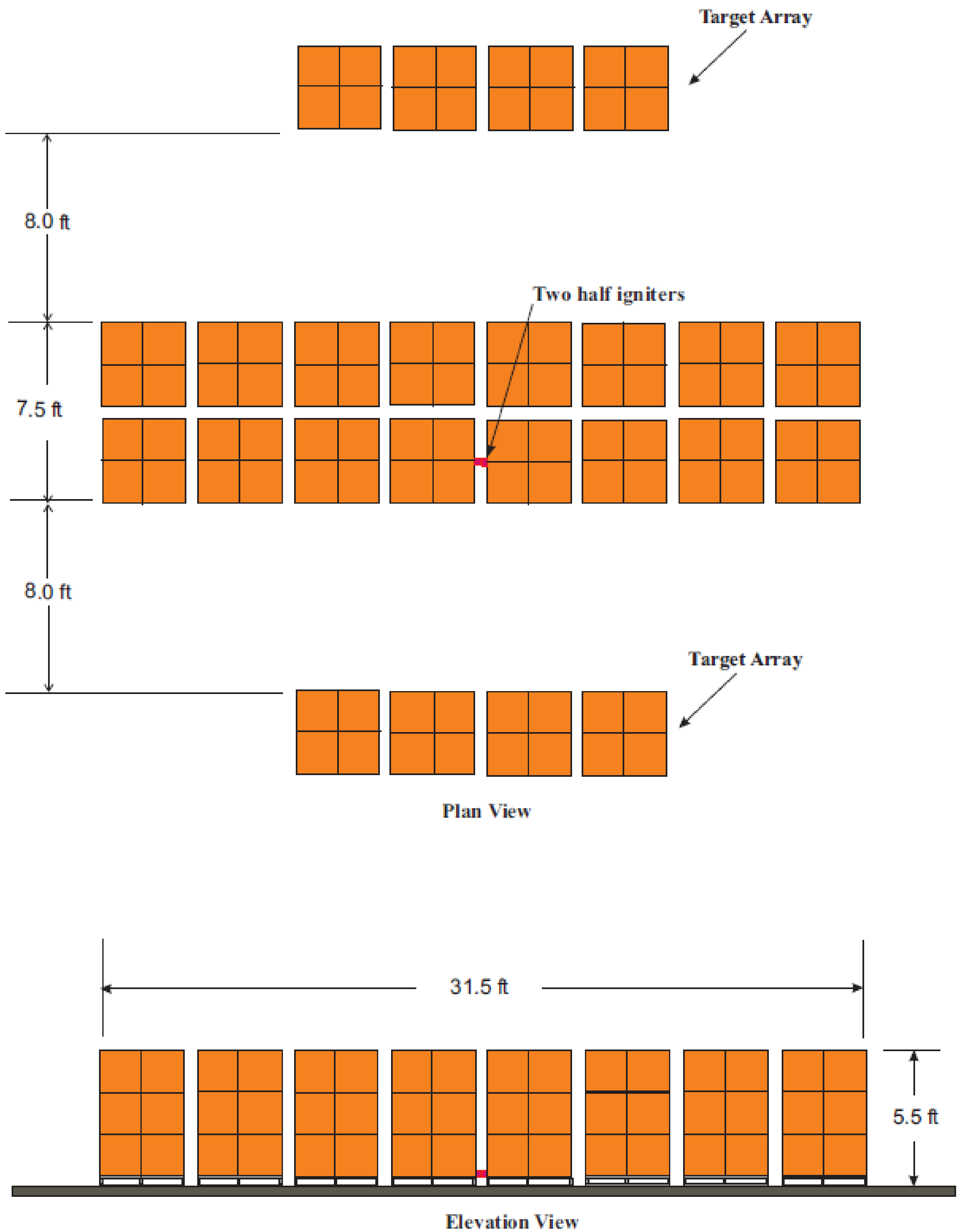


Figure P-2. HC-3 fuel array.

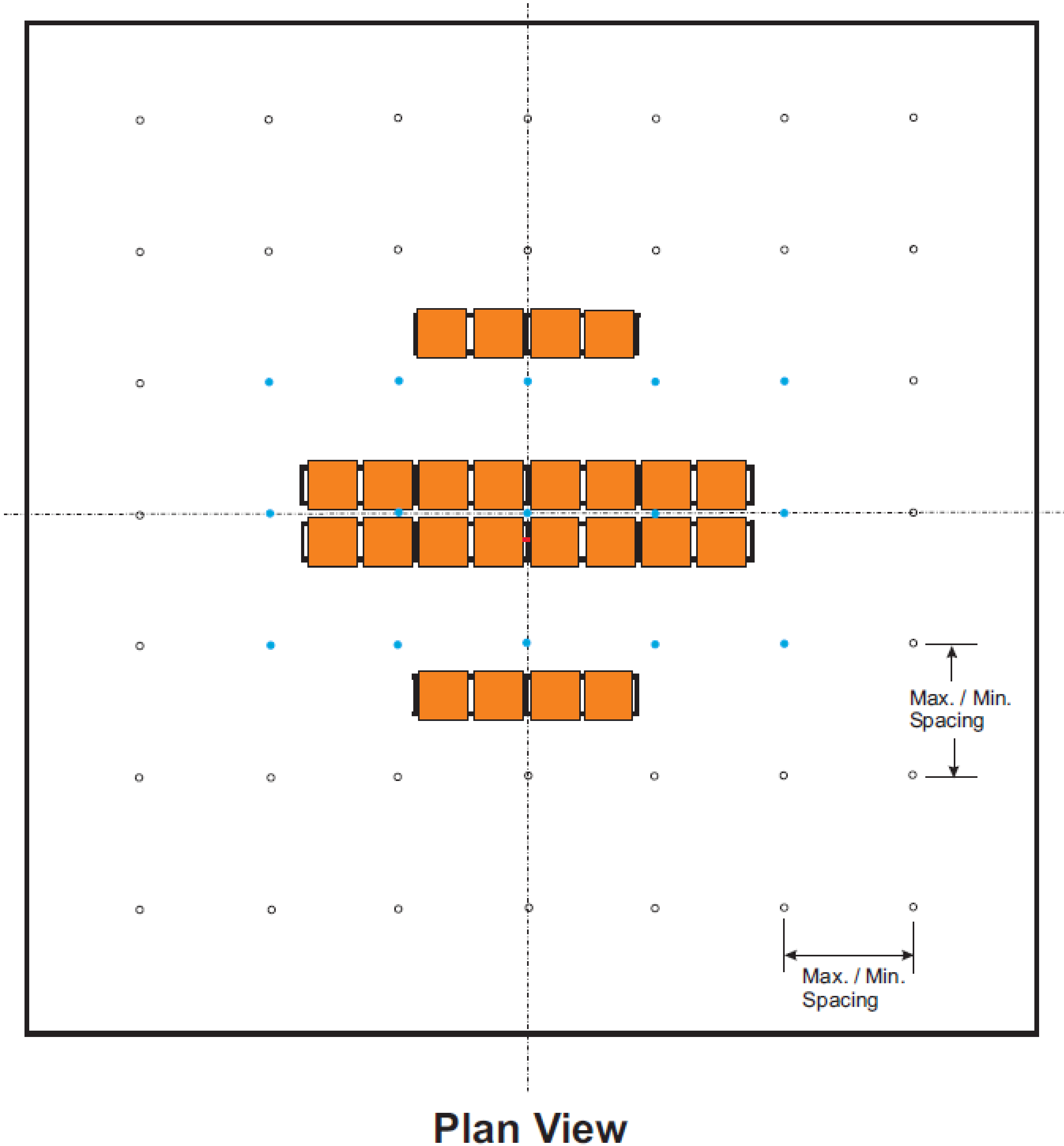


Figure P-3. HC-2 fuel array shown in ignition under one nozzle scenario.

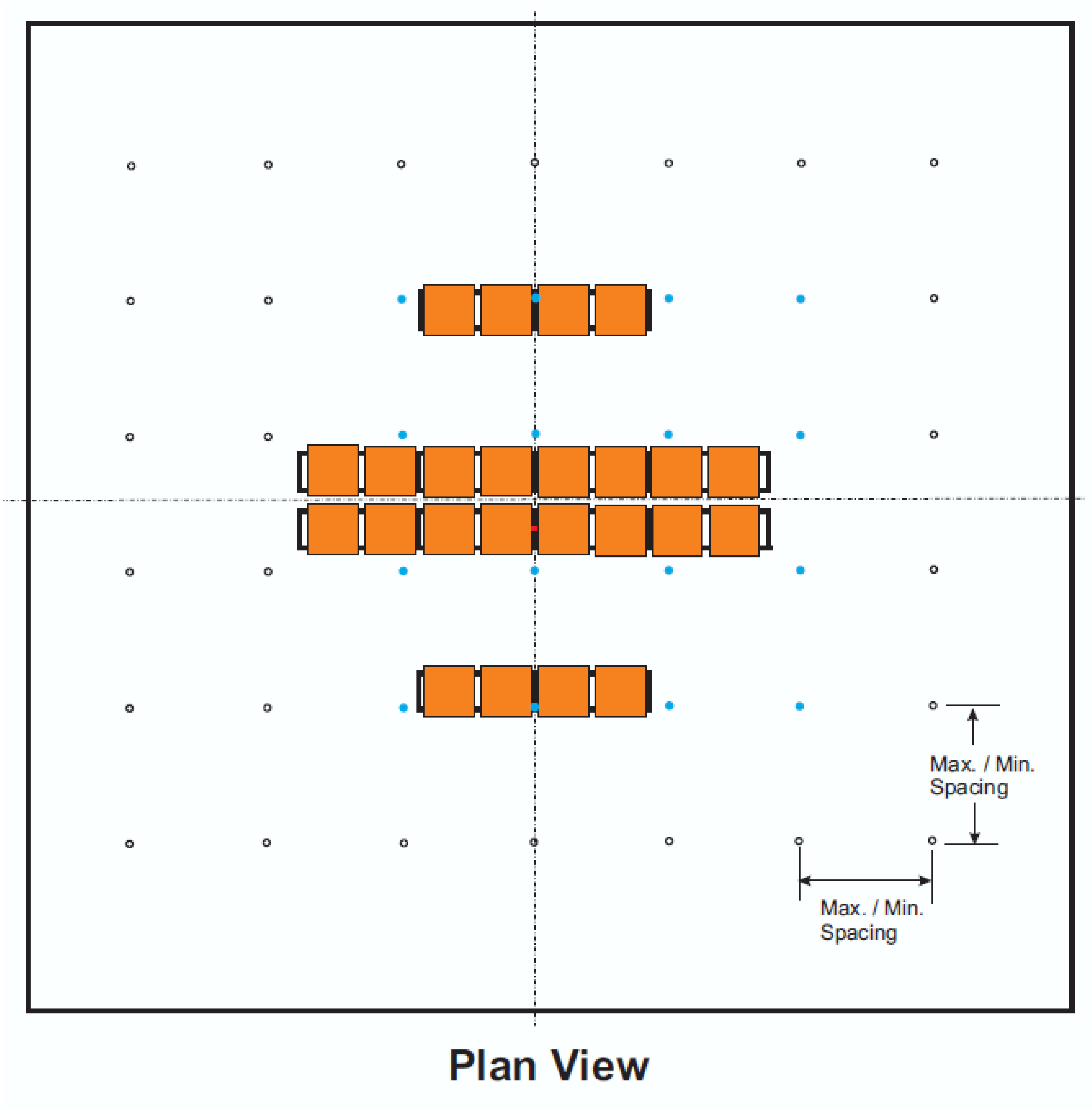


Figure P-4. HC-2 fuel array shown in ignition between two nozzles scenario.

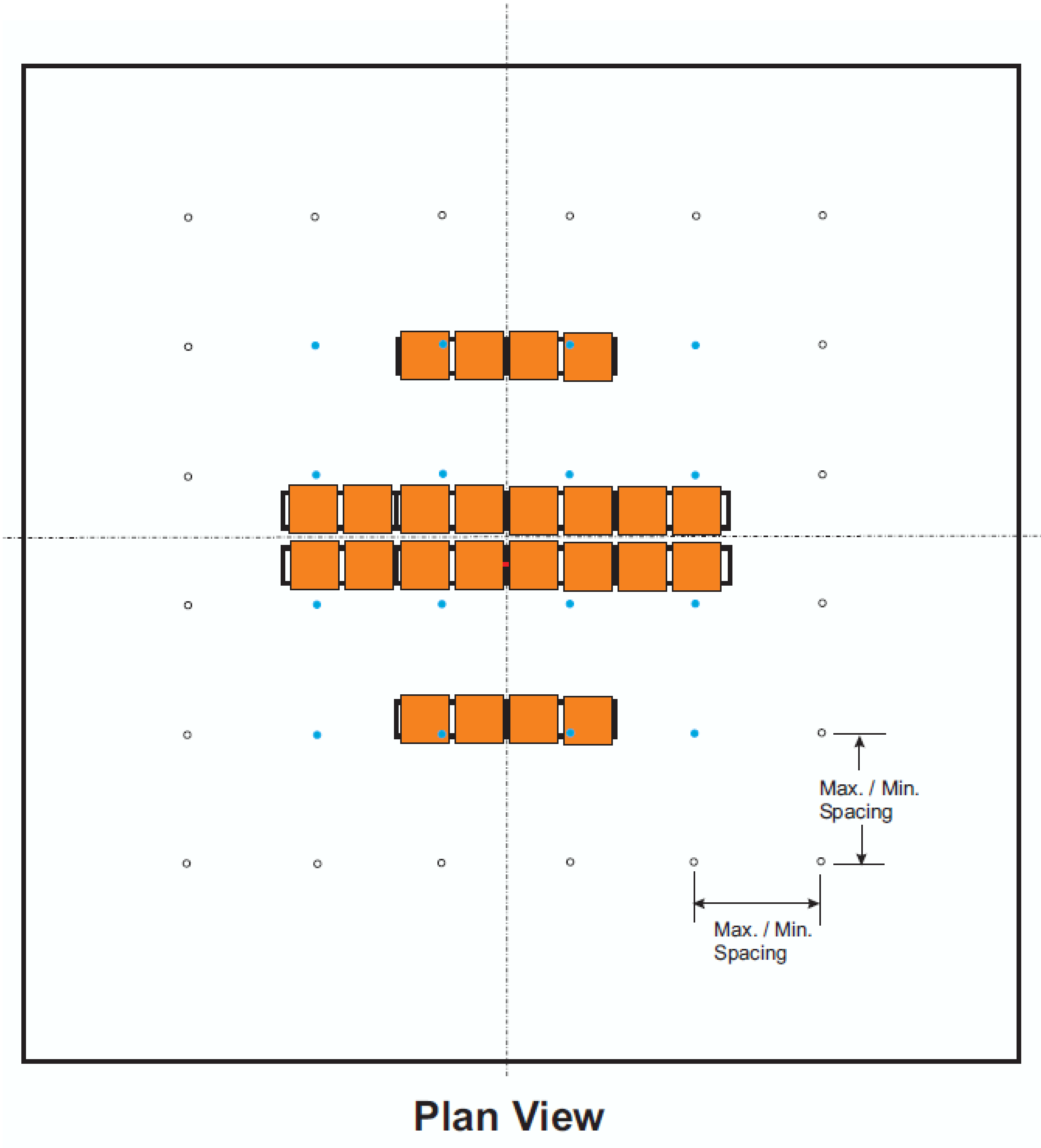


Figure P-5. HC-2 fuel array shown in ignition between four nozzles scenario.

APPENDIX Q: OTHER OCCUPANCIES OF INTEREST TO PROTECT WITH WATER MIST SYSTEMS

- Ignitable liquid (also known as flammable liquid) dispensing/distribution operations
- Ignitable liquid (also known as flammable liquid) storage in metal drums in storage rooms
- CNC Machines
- Engine Test Cells
- Cable Spreading Room/Cable Tunnel
- Flight Simulators

APPENDIX R: UNITS OF MEASUREMENT

AREA: in^2 - “square inches”; (mm^2 - “square millimeters”)
ft^2 - “square feet”; (m^2 - square meters”)
$mm^2 = in^2 \times 645.16$
$m^2 = ft^2 \times 0.0929$

C-FACTOR: $(ft/s)^{1/2}$ - “square root of feet per second”;
($[m/s]^{1/2}$ - “square root of meters per second”)
$(m/s)^{1/2} = (ft/s)^{1/2}$ *x* 0.552

DENSITY: lb/gal - “pounds per gallon”; (kg/L - “kilograms per liter”)
kg/L = lb/gal *x* 0.1198

ENERGY: Btu - “British thermal units”; (J - “joules”)
J = Btu *x* 1055.056

FLOW: gal/min - “gallon per minute”; (L/min - “liters per minute”)
L/min = gal/min *x* 3.7854

FORCE: lbf - “pounds-force”; (N - “newtons”)
N = lb *x* 4.4482

HEAT RELEASE RATE: Btu/min - “British thermal units per minute”; (kW - “kilowatts”)
kW = Btu/min *x* 0.0176

K-FACTOR: $gal/min/(psi)^{1/2}$ -“gallons per minute per square root of pounds per square inch”;
($L/min/(bar)^{1/2}$ - “cubic decimeters per minute per square root of bars”)
($L/min/(bar)^{1/2} = gal/min/(psi)^{1/2}$ *x* 1.442

LENGTH: in. - “inches”; (mm - “millimeters”)
mm = in. *x* 25.4
ft - “feet”; (m - “meters”)
m = ft *x* 0.3048

MASS: Lb - “pounds”; (kg - “kilograms”)
kg = lb *x* 0.454

PRESSURE: psi - “pounds per square inch”; (bar - “bars”)
bar = psi *x* 0.06895
psf -“pounds per square foot”; (bar - “bars”)
bar = psf *x* 0.00479

RTI: $(ft\cdot s)^{1/2}$ - “square root of foot seconds”; ($[m\cdot s]^{1/2}$ - “square root of meter seconds”)
$(m\cdot s)^{1/2} = (ft\cdot s)^{1/2}$ *x* 0.552

SPECIFIC HEAT: 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

TEMPERATURE: °F - “degrees Fahrenheit”; (°C - “degrees Celsius”)
°C = (°F - 32) *x* 0.556

TORQUE/MOMENT: lbf·ft - “pound-force foot”; (N·m - “newton meters”)
N·m = lbf·ft *x* 1.356

APPENDIX R: UNITS OF MEASUREMENT (CONTINUED)

VACUUM: inHg - “inches of mercury”; psi - “pounds per square inch”; (bar - “bars”)
psi = inHg *x* 0.4912
bar = inHg *x* 3.3864

VOLUME: gal - “gallons”; (L - “liters”)
L = gal *x* 3.7854

VOLUME PER UNIT AREA: gal/min/ft^2 - “gallons per minute per square feet”
(mm/min - “millimeters per minute”)
mm/min = gal/min/ft^2 *x* 40.75

APPENDIX S: TOLERANCES

Unless otherwise stated, the following tolerances shall apply:

Angle:	± 2°
Frequency (Hz):	± 5 percent of value
Length:	± 5 percent of value
Volume:	± 5 percent of value
Rotation:	± 1 RPM
Pressure:	± 5 percent of value
Temperature:	± 5 percent of value
Time:	+ 5/- 0 seconds + 0.1/- 0 minutes + 0.1/- 0 hours + 0.25/- 0 days

Unless stated otherwise, all tests shall be carried out at a room (ambient) temperature of 68°F ± 18°F (20°C ± 10°C).

APPENDIX T: 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:

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

Based upon the number of nozzles or bulbs tested (n), a value, γ, shall be selected from Table S.1 where the degree of confidence is 0.99 and the proportion of samples is 0.99.

Table S.1. γ Factors for One-Sided Tolerance Limits for Normal Distributions (99 Percent of Samples)

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

Tolerance limits shall then be calculated as follows:

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

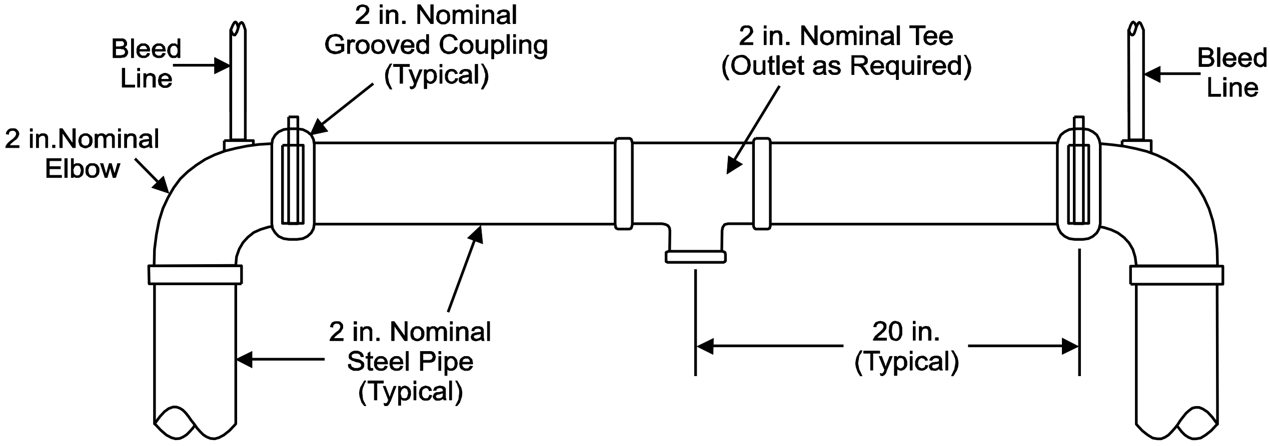
Where:

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

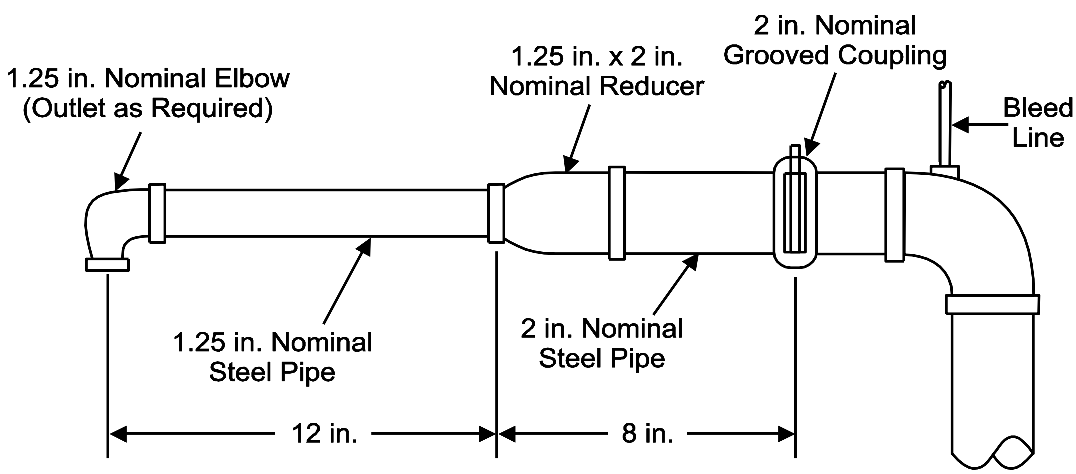
Compliance with the requirement shall be confirmed if LTL > UTL.

Outliers may be discarded from the sample base utilizing appropriate statistical techniques at the sole discretion of the certification agency.

APPENDIX U: FIGURES T-1 THROUGH T-6



Test Apparatus for Double-Fed Flow



Test Apparatus for Single-Fed Flow

Note: All dimensions are nominal size.

Figure U-1. Hang-Up of Operating Parts

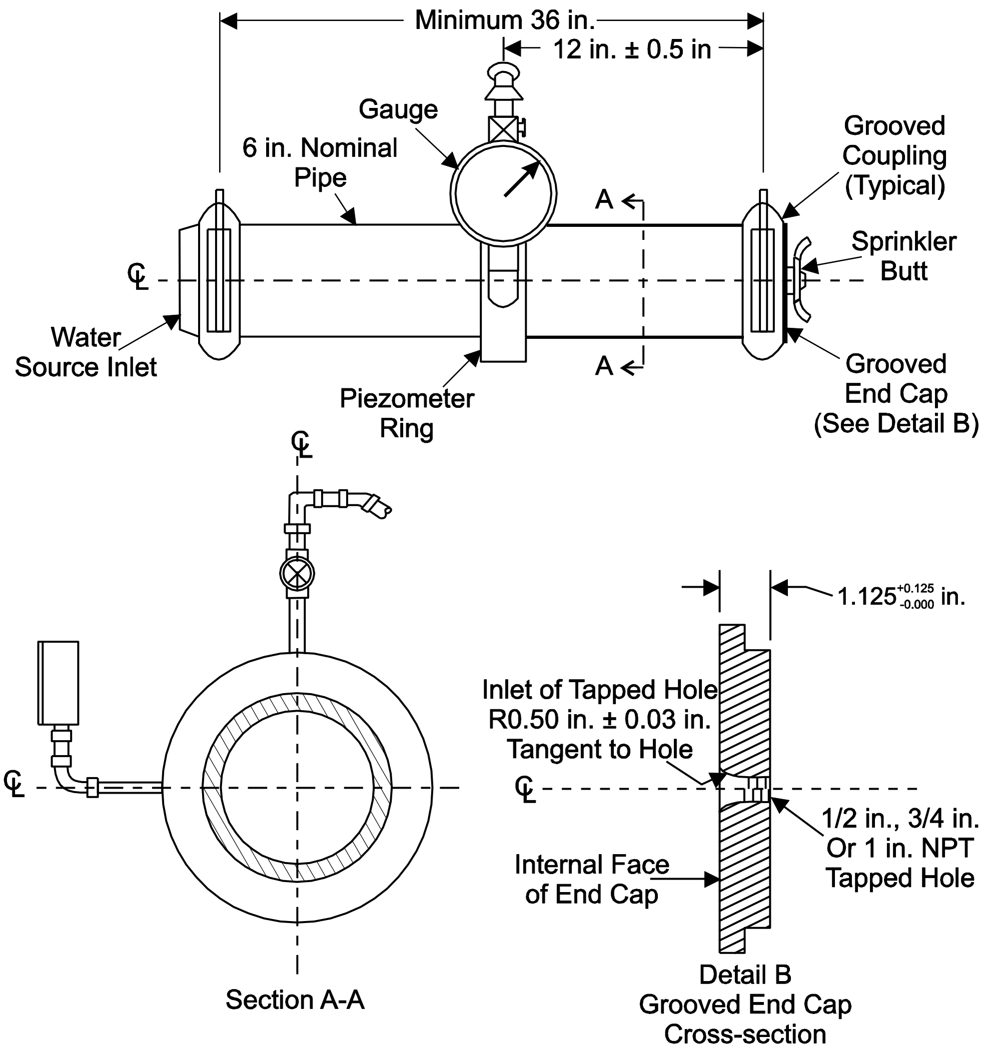


Figure U-2. Test Apparatus for Measuring Nominal K-Factors < 8.0 gal/min/psi (115.4 L/min/bar)

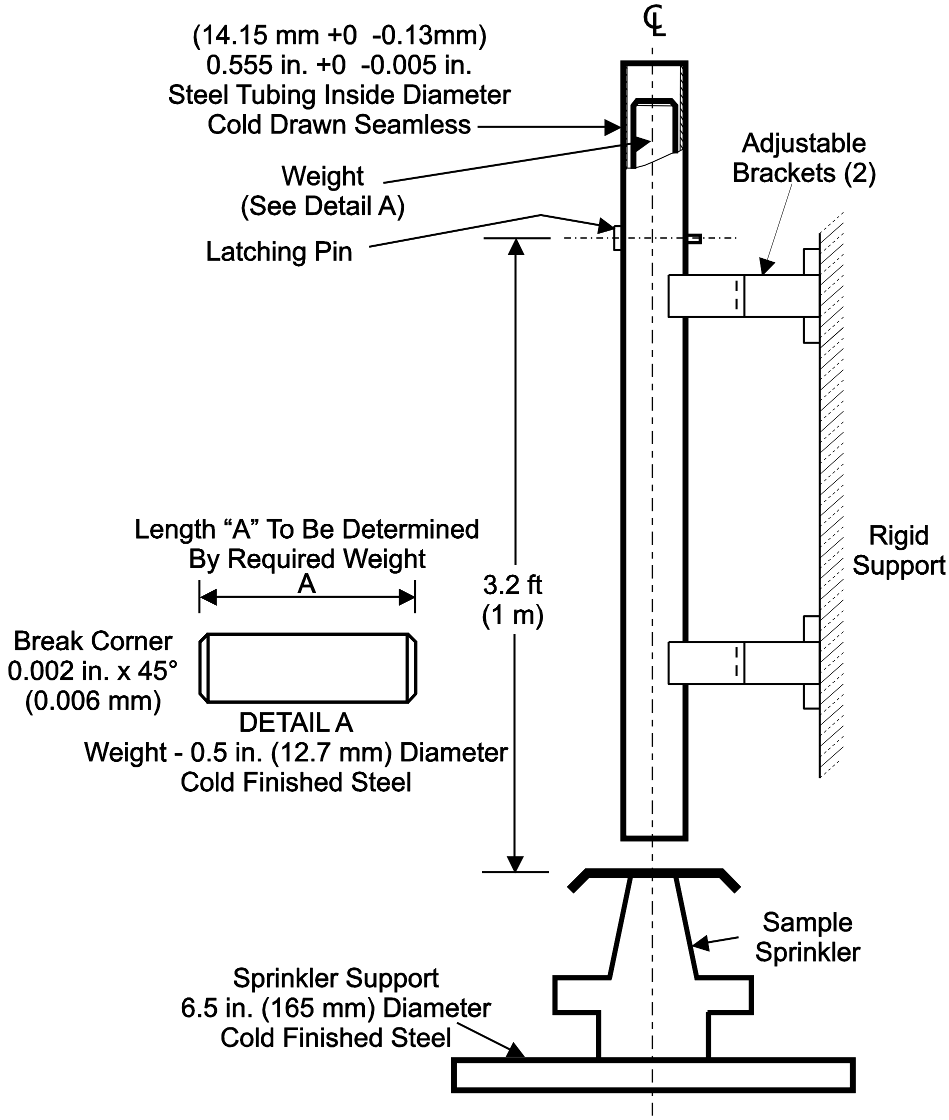


Figure U-3. Impact Test Apparatus

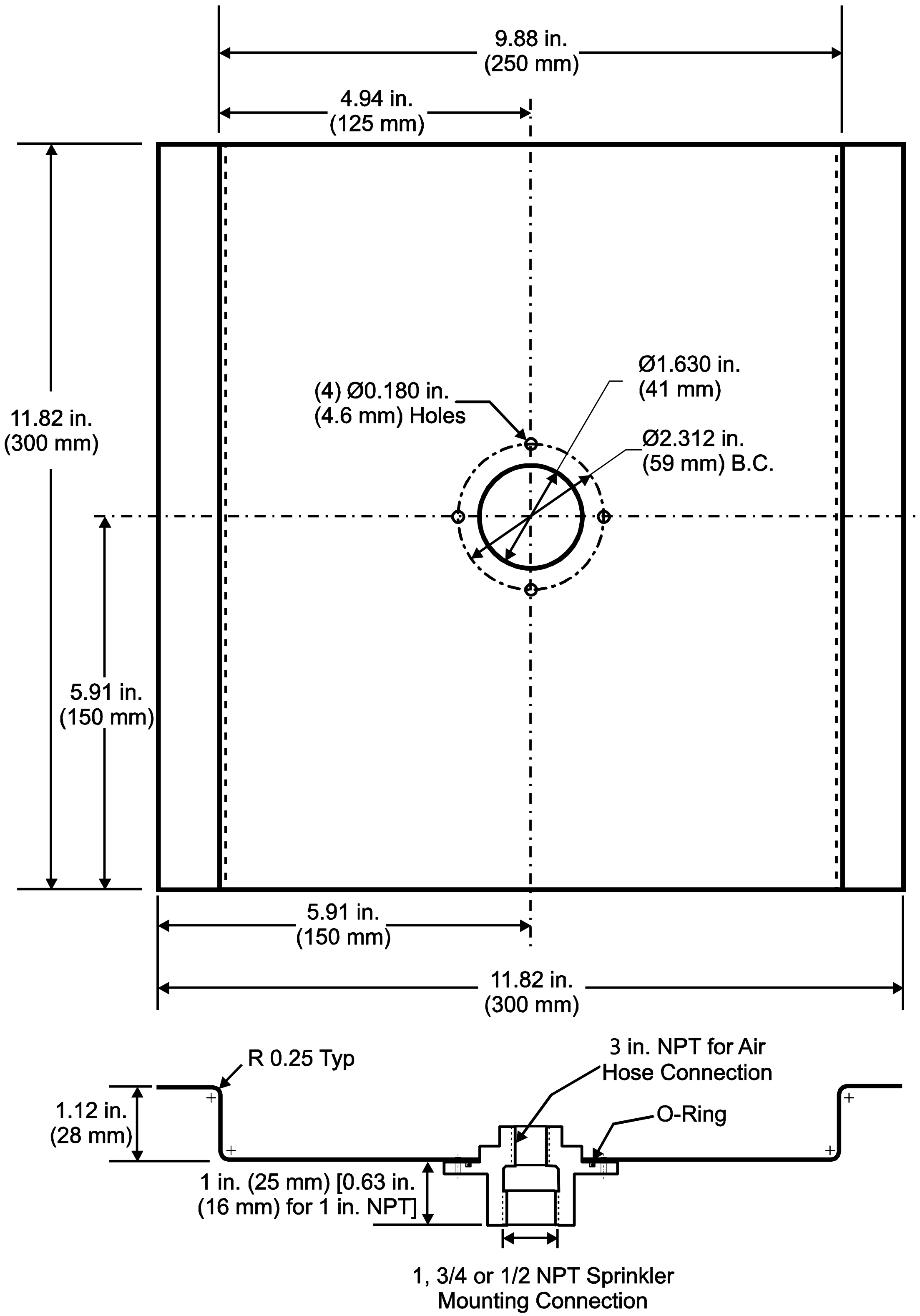


Figure U-4. Plunge Tunnel Test Plate (For Sensitivity - RTI Test)

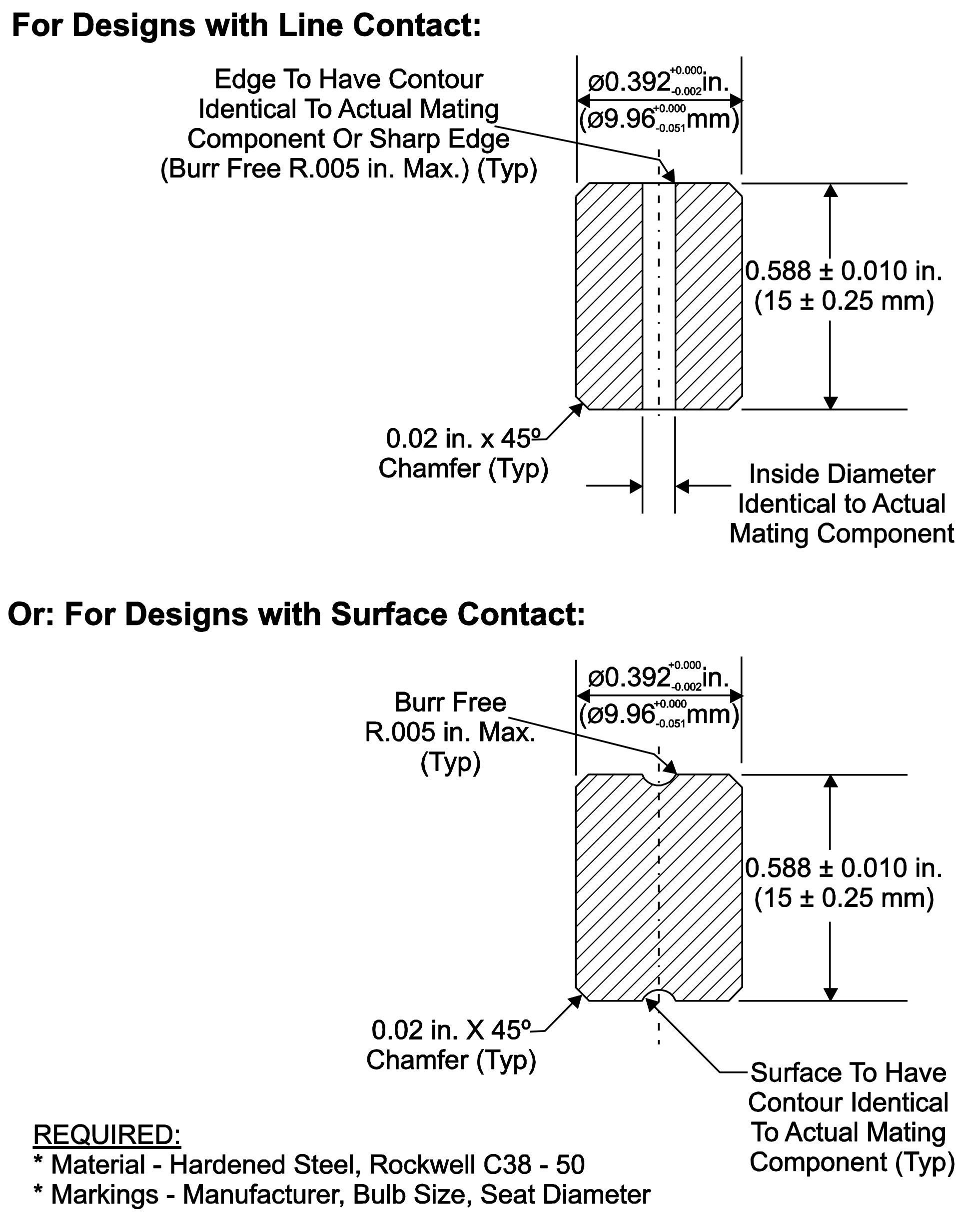


Figure U-5. Bulb Crush Inserts For Strength of Element Test

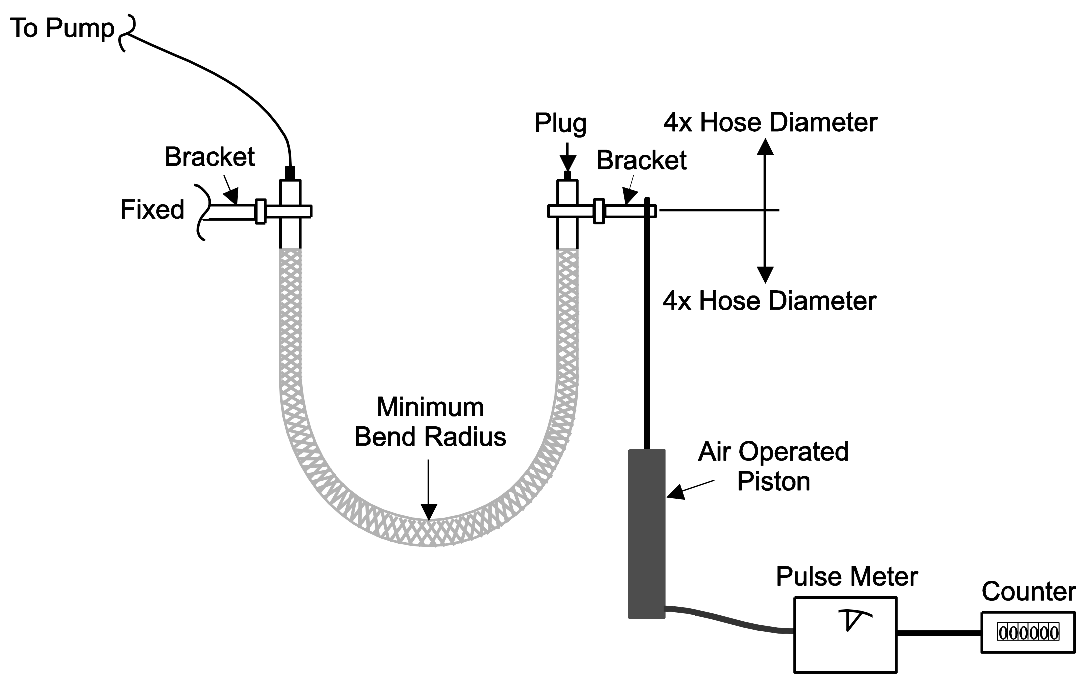


Figure U-6. Test Apparatus for Fatigue Test

APPENDIX V: SAMPLE CERTIFICATION LISTINGS

Certification listings for water mist systems shall include:

- Manufacturer's designation for system.
- Single fluid or twin fluid system.
- Continuous discharge or cycled system, and pertinent discharge parameters.
- Nozzle operating pressure and/or flow rate.
- If applicable, additive information (i.e., foam concentrate information).
- 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 certification or exceptions to the listed manuals, software, or other documents.
- Installation provisions.