American National Standard
for
Water Mist Systems

ANSI/FM Approvals 5560-2017
Revision of ANSI/FM Approvals 5560-2007
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Foreword

NOTE: This foreword is introductory only and is not part of American National Standard FM 5560.

This standard is intended to be used to evaluate the components and fire performance of water mist systems.

Appendixes L, M and N to this American National Standard are informative and are not part of the requirements of the standard. Appendixes A, B, C, D, E, F, G, H, I, J and K are fire test procedures and are informative for the performance of the tests and associated pass/fail criteria.

This American National Standard has been developed by the canvass method of standards development of the American National Standards Institute (ANSI). FM Approvals is an ANSI-accredited standards developing organization (SDO).

Approval of an American National Standard requires verification by ANSI that the principles of openness and due process have been followed and that a consensus of those directly and materially affected by the standard has been achieved. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution. Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached.

The American National Standards Institute does not develop standards nor will it in any circumstances give an interpretation of any American National Standard. Requests for interpretations of this test standard shall be addressed to FM Approvals.

ANSI regulations require that this American National Standard shall be revised, reaffirmed or withdrawn within five years of the date of publication.

FM Approvals
1151 Boston-Providence Turnpike
P. O. Box 9102
Norwood, MA 02062
U. S. A.

Phone: 781-762-4300
Fax: 781-762-9375
E-mail: Approvals@fmglobal.com

Table of Contents

1. INTRODUCTION

1.1 Purpose

1.1.1 This standard states the examination and test requirements for water mist systems for use as fire control and/or extinguishing systems.

1.2 Scope

1.2.1 This standard encompasses the performance requirements for water mist systems for use as fire control and/or extinguishing systems designed and installed per NFPA 750. Examinations are limited to use in the occupancies described sections 1.2.3.1 through 1.2.3.9. 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. 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.

1.2.3 Water mist systems are designed 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 combustion turbines in enclosures with volumes up to, and including, 2825 ft^3 (80 m^3). Combustion turbines included under the scope of this total flooding 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. For primary protection consideration; see Section 1.7, (Primary Protection).

1.2.3.2 Protection of combustion turbines in enclosures with volumes up to, and including, 9175 ft^3 (260 m^3). Combustion turbines included under the scope of this total flooding application shall be protected for a minimum of to 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. For primary protection consideration; see Section 1.7, (Primary Protection).

1.2.3.3 Protection of combustion turbines in enclosures with volumes exceeding 9175 ft^3 (260 m^3). Combustion turbines included under the scope of this total flooding 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 1.7, (Primary Protection).

1.2.3.4 Protection of wet benches and other similar processing equipment. 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 10 minutes or double the time needed to extinguish the worst case fire scenario, whichever is greater.

1.2.3.5 Protection of local application occupancies. Water mist systems which successfully pass the fire scenarios described in Appendix E shall be limited to extinguishing the following types of fires:

A. Ignitable 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 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 pool fires where the percentage of obstructed surface is limited to that tested.

D. Spray fires up to 6 MW fueled by ignitable liquids.

E. Spray and pool fire combinations where confined to a diked area.

F. Ignitable liquid residues (ink and paper dust) on printing presses.

Applicants who desire to protect special hazard equipment with ignitable liquids with volatilities less than or equal to those of Heptane will need to conduct the fire scenarios substituting as a fuel, Heptane for diesel 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.

1.2.3.6 Protection of industrial oil cookers. 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 shall be given and the use of such caps shall be included in the fire test and nozzle performance test requirement programs. The required extinguishing agent quantity is double the time needed to extinguish the worst case fire scenario, time to shut down heating and process equipment, or 10 minutes, whichever is greater.

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 a few 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 can be hydraulically operated.

The hood is generally in a closed position in a normal operation period; however, the hood can be open from time-to-time as part of a 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). Even though installing an interlocking system to prevent the oil from reaching its AIT is a normal practice in the industry, the AIT fire can, and does, happen 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 shall be interlocked to automatically shut down upon fire detection or operation of the water mist system. Exhaust duct protection is required and shall be so stated in the manufacturer's design, installation, operation and maintenance manual. (Note: Water spray protection for the ducts would be needed if the duct system were required to operate when the water mist system operates. Automatic sprinkler protection is recognized as being an effective alternative to water spray.)

Commonly used cooking oils, their flash points, and AITs are listed in Table 1.2.3.6 as a reference only. Canola oil is considered a representative vegetable oil and shall be used as the testing medium in the Appendix F fire tests. Its nominal density is 7.8 lb/gal (0.93 kg/L) and nominal specific heat is 0.59 BTU/lb≅°F (2.5 kJ/kg≅°C).

Table 1.2.3.6. *Nominal Flash Point 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)

1.2.3.7 Protection of continuous wood board presses. 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.

1.2.3.8 Protection of ventilated bench-top chemical fume laboratory hoods or enclosures using ignitable liquids. 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. All hazards included under the scope of this application shall be protected for a minimum of 10 minutes.

1.2.3.9 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. 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 maximum burning rates comparable to those used in the fire performance testing. 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.

1.3 Basis for Requirements

1.3.1 The requirements of this standard are based on experience, research and testing, and/or the standards of other organizations. The advice of manufacturers, users, trade associations, jurisdictions and/or loss control specialists was also considered.

1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of water mist systems. Water mist systems having characteristics not anticipated by this standard might be acceptable if performance equal, or superior, to that required by this standard is in the sole opinion of testing organization, demonstrated, or if the intent of the standard is met. Alternatively, water mist systems that meet all of the requirements identified in this standard might not be acceptable if in the sole opinion of testing organization, other conditions which adversely affect performance exist or if the intent of this standard is not met.

1.4 Basis for ANSI Specification

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 by the testing organization; and, as far as practical,
- The durability and reliability of the product.

1.4.2 A thorough review of the proposed water mist system “Design, Installation, Operation and Maintenance” manual.

1.5 System of Units

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

1.6 Applicable Documents

The following standards, test methods, and practices are referenced in this Standard:

ANSI Publications

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

ANSI/IEEE/ASTM SI 10, *American National Standard for Metric Practice*, 2016
ANSI/ASME, *Boiler and Pressure Vessel Code*, 2017
ANSI/Hydraulic Institute (HI) Standard 3.1-3.6, *Rotary Pump Standards*, 2008

ASME Publications

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

ASME *Boiler and Pressure Vessel Code*, 2017
ASME B31.1, *Power Piping Code*, 2016

ASTM Publications

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

ASTM B117, *Standard Practice for Operating Salt Spray (Fog) Apparatus*, 2016
ASTM D 395, Standard Test Methods for Rubber Property – Compression Set, 2016
ASTM D 573, Standard Test Method for Rubber – Deterioration in an Air Oven, 2015
ASTM E 8, Standard Test Methods for Tension Testing of Metallic Materials, 2016
ASTM E 290, Standard Test Methods for Bend Testing of Material for Ductility, 2014
ASTM G155, *Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials*, 2013

Compressed Gas Association

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

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

FM Global

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

Property Loss Prevention Data Sheets

FM Approvals

1151 Boston-Providence Turnpike, P.O. Box 9102, Norwood, MA 02062 USA
http://www.fmglobal.com/approvals/resources/standards.asp

FM Approvals' Approval Standards
Quality Assurance Guidelines for Manufacturers of FM Approved and Specification Tested Products, October 2003

ISO Publications

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

ISO 10380, *Pipework - Corrugated metal hoses and hose assemblies*, 1994

NFPA Publications

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

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*, 2015
NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, 2016
NFPA 750, *Standard on Water Mist Protection Systems*, 2015

U.S. Dept. of Transportation

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

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

1.7 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 not a characteristic of a product. It is installation specific. A product accepted for one installation might 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
Local code enforcement authority having jurisdiction (AHJ).

Automatic Water Mist Nozzles
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 operates independently of other nozzles by means of a detection/activation device built into the nozzle.

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

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

Conductivity Factor (C-Factor)
A measure of the conductance between the nozzle’s heat responsive element and the other components of the nozzle expressed in units of $(ft/s)^{1/2}$ 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 (bar).

Dry Pipe Water Mist System

A water mist system using automatic nozzles attached to a piping system containing air, nitrogen, or 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 out 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, Dv0.50 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.

Fusible Element Nozzle

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

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

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

Heat Responsive Element
The component of a 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.

Ignitable 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.

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 can 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.

Local-Application Water Mist System
A water mist system arranged to discharge directly on, or around, an object or hazard. Where water mist nozzles are directed at the hazard and containment or confinement area needed to prevent spread of fire beyond the hazard protected. Water mist is considered as a special protection system when there is a limited supply of agent. An example is when it serves as an alternate to 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 hazards such as auxiliary turbine rooms, oil pumps, oil reservoirs, fuel filters, gear boxes, drive shafts, lubrication skids and diesel engine rooms where the hazard is an ignitable liquid with volatilities similar those of light diesel fuel.

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 the flexible hose is safely allowed to bend, as specified by the manufacturer.

Nationally Recognized Testing Laboratory (NRTL)

A laboratory which is listed and recognized by the United States Department of Labor, Occupational Safety & Health Administration's (OSHA) Directorate of Science, Technology, and Medicine program. The program recognizes private sector organizations as NRTL's, and recognition signifies that an organization has met the necessary qualifications specified in the regulations for the Program. The NRTL determines that specific equipment and materials ("products") meet consensus-based standards of safety to provide the assurance, required by OSHA, that these products are safe for use in the U.S. workplace.

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 the component functions under normal conditions.

Operating Temperature

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

Ordinary Hazard Occupancy

An occupancy where quantity and combustibility of contents is greater than that of a Light Hazard Occupancy.

Orientation, Best Case

When testing nozzles for sensitivity in the Testing organization plunge tunnel, the orientation of a nozzle which results in the fastest operating time, or the lowest Response Time Index (RTI) if the nozzle were a pendent nozzle. 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 Testing organization 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 that contains air that may, or may not, be under pressure, with a supplemental detection system installed in the same areas as the mist nozzles. The actuation of the detection system opens a valve that allows water to flow into the piping system. Individually, activated nozzles, discharge the water.

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 is the installation of a water mist system for the protection of light hazard occupancies, where the system is designed for the protection of the occupancy and building. The agent supply shall be equivalent to an automatic sprinkler system for the same hazard per the applicable AHJ fire protection codes.

Propellant

Compressed gas used as a prime mover 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 in accordance with the applicable Water Mist Nozzles for Fire Protection Service ANSI standard.

Rated Working Pressure

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

Relief Valve

A relief valve is 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 = $\vartheta(u)^{1/2}$ where ϑ 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 ϑ 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 $(ft \cong s)^{1/2}$ or $(m \cong s)^{1/2}$.

Sidewall Nozzle

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

Single Fluid System

A water mist system utilizing only water to supply each nozzle. An inert gas to supply a separate distribution system can also be utilized, in addition to the water mist distribution supply.

Special Protection Systems

Where a limited agent supply system such as CO2, Dry Chemical or Clean Agent would be acceptable protection. The agent supply shall be adequate for a minimum of:

a) twice the time to extinguish a worst case test fire in an accepted fire test scenario
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.

Special Hazard Machinery Space
These areas include occupancies such as internal combustion engines and machinery spaces where the hazard is from a ignitable liquid or from incidental use or storage of ignitable liquids with volatilities similar to Heptane.

Standard Response Nozzle
A nozzle having a Response Time Index (RTI) and C-factor combination in accordance with the applicable Water Mist Nozzles for Fire Protection Service ANSI standard.

Total Flooding System
A system designed to protect all the hazards in an enclosure. An example is the use of water mist systems for the total flooding protection of combustion turbines and associated equipment in enclosures.

Twin Fluid System
A water mist system in which water and atomizing media are supplied to the water mist nozzle. These systems can utilize separate piping systems or a single piping system. For effervescent flow atomizers, the gas is injected into the tubing upstream of the nozzle.

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

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

Water Mist Nozzle
A special purpose device containing one or more orifices designed to produce and deliver an atomized water spray meeting the definition of Water Mist or meeting the specific requirements of the appropriate ANSI standard for water mist nozzles and fire test protocols. 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 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 weep point pressure is 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 Application Requirements

The manufacturer shall provide the following preliminary information that gives a full and correct specification of the critical construction aspects of the system, with any request for examination consideration. One copy (except as noted) of the following documentation as it pertains to the examination request shall be assembled in an organized manner. All documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level.

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

2.2.1 Marketing/Ordering Literature - Showing general specifications and functions of the system. These are generally very useful in determining project estimates and can also be used as attachments to the final report for examined system projects.

2.2.2 Model Number Breakdown - A specification or drawing showing all system variations and options to be examined.

2.2.3 Instruction Manual - Design, installation, operation, and maintenance instructions.

2.2.4 Quality Control Procedures - Document(s) detailing routine testing and final inspection procedures: receiving inspection; in-process inspection; final inspection, and calibration of measuring and testing equipment used. In addition, procedures must detail the system acceptance testing once the water mist system is installed.

2.2.5 Documentation Control Specification - Proposed method of controlling critical documents which shall be identified in the Documentation Section of the Test Report. These drawings shall be listed in the report issued at the conclusion of the Test Program. The testing organization shall be notified of changes to these documents.

2.2.6 Production Drawings - The following drawings shall 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.

2.3 Requirements for Samples for Examination

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

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 examination investigation.

3.2 Physical or Structural Construction Features

3.2.1 In order to ensure the success of the water mist system in suppressing the fire, and to minimize the chance of re-ignition, enclosures and/or hazards provided with water mist systems tested in accordance with applicable ANSI standards 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, and
- Ventilation system shutdown or the maximum ventilation rate per the system manufacturer’s manual and shall be fire tested at this ventilation rate.
- Containment for ignitable liquid releases.
- Water Mist System protection over the entire area of the containment or hazard.

Upon a manufacturer’s request, some, or all, of these restrictions can be relaxed with additional testing and review and/or acceptance of documentary evidence 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. If, following the results of testing, 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 applicable AHJ recognized standards or the *ASME Boiler and Pressure Vessel Code*, as applicable. (Water mist systems for sale in countries other than the United States can 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 utilize potable water sources. For wet bench applications, circulating de-ionized water shall be used.

3.2.6 Air / Nitrogen / other gas cylinder(s) shall meet the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII (or equivalent national standard of the country of use, reference section 4.9).

3.2.7 For all components downstream of any high pressure cylinders, the test pressures will 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 will be based on 150 percent of the maximum system operating pressure but not less than 700 psi (4827 kPa).

3.2.9 Functional operating pressure of components and systems will be based on a pressure of no less than 175 psi (1207 kPa). Leakage pressure testing will be based 120 percent of the maximum system pressure and temperature but not less than 500 psi (3447 kPa).

3.2.10 Generally, no plastic or elastomeric components are to be used. (These parts be utilized at the sole discretion of testing organization; however, additional testing will be required.) 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 Use of specification tested fire detection devices are required for deluge water mist systems. Fire detection devices and manual pull stations used in the system shall be specification tested to applicable ANSI standards.

3.2.12 The examinations for use in the following types of unapproved electrical components including automatic release devices, control panels, sequence boxes, etc., will be included within the scope of the testing organization project examination.

3.2.13 Documented use of components tested in accordance with appropriate and applicable ANSI standards, if evaluated for the same system characteristics, can be sufficient reason to waive the tests described below for those components, based on the sole discretion of the testing organization.

3.2.14 Placement of all system components, with the exception of the nozzles and piping, shall be in a non-hazardous location outside the protected area.

3.2.15 Galvanized piping shall not be utilized for Water Mist Systems.

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 of use. A component need not comply with a specific requirement that involves a feature or characteristic not needed in the application of the component in the water mist system product covered 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 can be of the constant or cycled water delivery type with a minimum permitted water cycle of 50 percent. Water mist systems utilizing a pause in the extinguishing supply are not permitted. Water mist system design shall 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 component, over-design, de-rating, or other means demonstrating equivalent reliability.

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 where it shall be easily visible. 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;
- Manufacturing location source code where necessary.

3.4.1.2 Each deluge and preaction 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 standard to which the system is manufactured shall be permanently marked on a suitable data plate.

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

3.4.2 All nozzles shall be marked in accordance with the applicable ANSI standard for water mist nozzles.

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 testing organization as a part of the examination of a system. The design manual shall describe in detail the scaling parameters utilized for the smaller room sizes and different configurations than those tested. Reference Section 4.36 for manual details.

3.6 Calibration

All examinations and tests performed in evaluation to this standard shall use calibrated measuring instruments traceable and certified to acceptable national standards.

3.7 Test Facilities

If review of all required information indicates suitability for examination, 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 testing organization. The manufacturer shall provide facilities and all properly calibrated instrumentation required to perform the tests deemed necessary by the appropriate authority if the testing cannot be conducted at a certified facility. If other standards are contemplated, they shall be forwarded 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. For testing not conducted at a testing organization facility, a representative of the testing organization shall witness all the tests and shall receive copies of the data and calibration certificates. All the tests shall be conducted at normal room temperatures as noted in the fire performance testing requirements in the Appendix.

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 shall be conducted for an individual component, component assembly or as an entire system, as deemed necessary at the sole opinion of the testing organization. Electrical components that require a hazardous location rating will be evaluated under the scope of the testing examination, with evaluations and required testing performed by the testing organization. Upon request for a program, and appropriate system documentation, the testing organization 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 manufacturers design calculations, stated performance requirements, as well as component functionality and reliability will be verified.

4.1 General Examination and Performance Requirement Test Procedures

Tests described in Section 4.1 are utilized throughout the component performance requirements. They are described here 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. Unless specifically indicated, tolerances are ± 5 percent of the specified numerical value.

4.1.1 Examination

4.1.1.1 Requirements

The water mist system shall conform to the manufacturer’s drawings and specifications and to examination requirements.

4.1.1.2 Test/Verification

A water mist system, and all its individual components, representative of the manufacturer’s final production equipment are to be tested in accordance with the applicable ANSI standards, 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, but not less then 500 psi (34.5 bar).

4.1.2.2 Test/Verification

With the inlet 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, but not less then 500 psi (34.5 bar), to prove the sealing ability. The test pressures shall each be held for five minutes, with no leakage allowed.

4.1.3 Hydrostatic Strength

4.1.3.1 Requirements

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

4.1.3.2 Test/Verification

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

4.1.4 Operating Pressure

4.1.4.1 Requirements

Operational components of each size shall be tested in an as received condition to determine its pressure operating characteristics and its 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 its pressure operating characteristics and the recommended minimum operating pressure. It shall be determined that it is capable of operating between 80 to 150 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 on a representative size component, measurable 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. If applicable, the sample component 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 downstream 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 upstream 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 about 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 measurable wear or damage. Post testing can 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

A minimum of one sample component of each type and size will be subjected to an extreme temperatures operation test. The component will be subjected to the minimum operational temperature for 24 hours. At the conclusion of the temperature exposure, the component will 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. The same component shall then be subjected to a maximum operational temperature for 24 hours. At the conclusion of the temperature exposure, the component will be evaluated for proper operation with the inlet pressurized if applicable, to the maximum system operating pressure. The component shall 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. Post testing can include 4.1.2 (Valve Seat Leakage), 4.1.3 (Hydrostatic Strength) and 4.1.4 (Operating Pressure).

The component 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. Post testing can include 4.1.2 (Valve Seat Leakage), 4.1.3 (Hydrostatic Strength) and 4.1.4 (Operating Pressure).

4.1.7 Salt Spray Corrosion

4.1.7.1 Requirements

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

4.1.7.2 Test/Verification

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

If necessary, the component shall be filled with deionized water and sealed with a non-reactive material (e.g., plastic cap) so as to prevent the introduction of salt fog into the waterway of the component. The component shall be supported in its intended installation position.

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

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

Following the exposure to the salt fog, the sample shall be removed from the test chamber and permitted to air dry for a two- to four-day drying period. Following this drying period, the component shall be fully operable under rated operating pressure conditions. Post testing can 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 system shall be subjected to vibration testing. The component, or component assemblies, shall withstand vibration without leakage, joint separation, or measurable wear to the sealing components as a result of this test.

4.1.8.2 Tests/Verification

Compliance shall be verified by testing one of each type or size of each component under examination. 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 can 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 and the plate 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) is detected, the component, or component assemblies 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 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 ***inch***	***(mm)***	***Frequency Hz***	***Time 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 component, or component assemblies intended position.

4.1.9.2 Tests/Verification

Submitted sample valves will 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 show 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 will be measured for sufficient flow rates to determine the friction loss characteristics of the valve. This test can be waived at the examining engineer's option if drawing and calculation reviews of manufacturer's flow data are satisfactory.

4.1.11 Seals and O-Rings

4.1.11.1 Requirements

Certificates of compatibility shall be submitted for the material compounds for use at the prescribed temperature and pressure ranges as well as with the fluids and gases utilized in the water mist system. If this documentation is not available, then the following testing shall be conducted:

A. Parts shall have a tensile set of the material in the as-received condition of not more than 19 percent. Parts constructed with silicone rubber (rubber having poly-organosiloxane as its characteristic constituent) shall have a tensile strength of not less than 500 psi (34.5 bar) and at least 100 percent ultimate elongation. Parts constructed with material other than silicone rubber shall have a tensile strength of not less than 1500 psi (103.4 bar) and at least 200 percent ultimate elongation. Tensile strength, ultimate elongation, and tensile set shall be determined in accordance with ASTM D 412, *Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension, Method A* with exceptions as stated in Section 4.1.11.2A.

B. A compression set of the material in the as-received condition shall be not more than 15 percent, as determined in Section 4.1.11.2B.

C. Seals formed using a rubber material or synthetic elastomer shall be subjected to an accelerated aging test, as described in Section 4.1.11.2C. Following the test the material shall have not less than 80 percent of the as-received tensile strength and 50 percent of the as-received ultimate elongation.

4.1.11.2 Tests/Verification

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

B. Testing shall be conducted in accordance with ASTM D 395, *Standard Test Methods for Rubber Property - Compression Set, Method B*. Type I specimens of the material shall be prepared and then exposed for 22 hours at 70 °F ± 2 °F (21 °C ± 1 °C).

C. Specimens shall be prepared in the same manner as for tensile strength and ultimate elongation tests, except that benchmarks spaced 1 in. (25 mm) apart shall be stamped on the specimens after the test exposure. Specimens shall be tested at 212 °F (100 °C) for 70 hours in accordance with ASTM D 573, *Standard Test Method for Rubber - Deterioration in an Air Oven*.

4.1.12 Pipe Coupling Gaskets

4.1.12.1 Requirements

Certificates of compatibility shall be submitted for the sealing compounds for use at the prescribed temperature and pressure ranges as well as with the fluids and gases utilized in the water mist system. If this documentation is not available, then the following testing shall be conducted:

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.

4.1.12.2 Tests/Verifications

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 will then be pneumatically pressurized to 50 psi (3.5 bar) and submerged in water. No leakage shall occur. The gasket, after removal of the assembly, shall not crack when squeezed from any two opposite points.

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 shall not crack when squeezed from any two opposite points.

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 requirements specified in the applicable ANSI standard. 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 no less than a minimum pressure 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 testing organization. These nozzles shall be compared to those supplied for component testing.

Additional tests can be required, depending on design features, results of any tests, material application, or to verify the integrity and reliability of the sprinkler, at the sole discretion of the testing organization. Unexplainable failures shall not be permitted. A re-test shall only be acceptable at the sole discretion of the testing organization and with adequate technical justification of the conditions and reasons for failure; otherwise, a design change shall be required.

4.3 Automatic Releases

The automatic release will be evaluated and tested for compatibility with electrical specifications of the actuating device and control panel of the water mist system as well as functionality. The examination shall be in accordance with the requirements of the applicable ANSI standard. Manufacturers are strongly encouraged to utilize existing Automatic Releases that are listed and compatible for their intended purpose with the water mist system.

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 can 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 500 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, from one to five seconds. 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

4.4.5.1 Requirements

General Performance Requirements: 4.1.1.1 (Examination), 4.1.2.1 (Valve Seat Leakage), 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: 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 seat leakage requirements in Section 4.1.2.1 (Valve Seat Leakage) and the stem seal requirements in 4.4.2.1. The valve shall then be disassembled and moving parts shall be visibly examined for signs of measurable 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 150 percent of the maximum system operating pressure, or 700 psi (48.3 bar), whichever is greater. During, and at the conclusion of the test, no fracture, permanent distortion, or functional impairment shall occur. After this test, the valve shall be fully operable and shall comply with the leakage requirements in Section 4.1.2.1 (Valve Seat Leakage).

4.5.1.2 Tests/Verification

A hydrostatic pressure of 150 percent of the maximum system operating pressure, or 700 psi (48.3 bar), whichever is greater, 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 Section 4.1.1.2 (Examination), 4.1.2.1 (Valve Seat Leakage) is required after the clapper - poppet strength test.

4.5.2 Additional Performance Tests

4.5.2.1 Requirements

General Performance Requirements: 4.1.1.1 (Examination), 4.1.2.1 (Valve Seat Leakage) 4.1.4.1 (Operating Pressure), 4.1.5.1 (Durability - 20,000 Cycling), 4.1.6.1 (Extreme Temperatures Operation), 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: 4.1.1.1 (Examination), 4.1.2.2 (Valve Seat Leakage), 4.1.4.2 (Operating Pressure), 4.1.5.2 (Durability - 20,000 Cycling), 4.1.6.2 (Extreme Temperatures Operation), 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

4.6.1.1 Requirements

General Performance Requirements: 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) (if applicable).

4.6.1.2 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) and 4.1.12.2 (Pipe Coupling Gaskets).

4.7 Control Panel

The control panel will be evaluated and tested for compatibility with electrical specifications of the associated electrically operated equipment, including the actuating solenoid, fire detection automatic releases, etc., of the water mist system as well as functionality. The examination shall be in accordance with the applicable ANSI standards.

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 and 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

Documentation shall be submitted to verify that the construction and size of the burst disc assembly comply with the flow capacity requirements.

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/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 comply with the flow capacity requirements as 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 shall 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 VIII, 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/installation temperature.

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

Verification that the pressure vessel standard is adequate for the system storage pressure, and appropriate to the jurisdiction in which the equipment will be used. If the standard does not meet this requirement, there can be additional minimum criteria established by the testing organization.

Verification that the design is in accordance with the standard. Typical verification would include review of certification to manufacture to standard, minimum wall thickness calculations, authorized materials, material tests, and general chemical analysis tests.

4.9.1.2 Test/Verification

Verification that the manufacturer is capable of producing cylinders in accordance with the design is required. Typical verification would include volumetric expansion and hydrostatic pressure tests. Hydrostatic pressure tests would be conducted as necessary for the appropriate pressure of either the extinguishing agent/medium stored in the pressure vessel, or in accordance with the applicable published standard, whichever is greater. Cylinder designs consisting of the same diameter, wall thickness, and material of construction, but with differing heights, can be evaluated by testing of selected representative samples rather than samples of all cylinder heights.

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

Permanent volumetric expansion testing is required under some cylinder standards. If required by the standard to which the cylinder is designed, such tests shall be conducted in conformance to that standard. If the cylinder manufacturer is required by the authority having jurisdiction to be under recognized third party surveillance, permanent volumetric expansion testing might not require witnessing by the testing organization. Instead, at the discretion of the testing organization, certifications of tests witnessed by the recognized third party can be reviewed by the testing organization 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.

4.9.2 One Year Leakage Loss Test

4.9.2.1 Requirement

A sample cylinder and valve of each size and pressure rating shall be monitored for pressurized weight loss. The cylinder pressure weight loss after 6 and 12 months of weighing shall be compared to the manufacturer's allowable pressure weight loss or 0.25 percent for a 12 month period, if none is specified. If differences are found, appropriate action will be taken on any systems released for production.

4.9.2.2 Test/Verification

A sample cylinder and valve of each size and pressure rating shall be fully pressurized and weighed for record. The cylinder and valve assembly will be stored in the Hydraulics Laboratory wet lab and weighed after 1, 3, 6 and 12 months. After six months, the final estimated weight of the pressurized cylinder will be calculated. The one year weight loss will be extrapolated and the results shall be evaluated. The test will continue for another six months. The 12 month weight shall be recorded as the final weight.

4.9.3 Extreme Low Temperature Test

4.9.3.1 Requirement

One sample cylinder and valve of each size and pressure rating will be subjected to an extreme low temperature operation test. The cylinder and valve will be subjected to the minimum operation temperature for 30 days. At the conclusion of the temperature exposure, the cylinder will be evaluated for proper weight and pressure. The cylinders shall then be visually examined and, if deemed necessary, shall be subjected to any of the appropriate tests as detailed in Section 4.1. The acceptable weight loss shall not exceed the manufacturer's allowable pressure weight loss, or 1/12 of 0.25 percent of the original weight.

4.9.3.2 Test/Verification

A sample cylinder and valve shall be conditioned in a conditioning chamber set at 40 °F (4.4 °C) for a period of 30 days. Immediately upon removal from the conditioning chamber the pressurized cylinder will be observed for pressure, weighed and be visually examined and tested as needed per Section 4.1.

4.9.4 Extreme High Temperature Test

4.9.4.1 Requirement

One sample cylinder valve of each size and pressure rating will be subjected to an extreme high temperature operation test. The cylinder and valve will be subjected to the maximum operation temperature for 30 days. At the conclusion of the temperature exposure, the cylinder will be evaluated for proper weight and pressure. The cylinder and valve shall then be visually examined and, if deemed necessary, shall be subjected to any of the appropriate tests as detailed in Section 4.1. After exposure, the cylinder weight loss shall not exceed the manufacturer's allowable pressure weight loss, or 1/12 of 0.25 percent of the original cylinder weight.

4.9.4.2 Test/Verification

A sample cylinder and valve shall be conditioned in a conditioning chamber set at 130 °F (54.4 °C) for a period of 30 days. Immediately upon removal from the conditioning chamber, the cylinder will be observed for pressure, weighed and be visually examined and tested as needed per Section 4.1.

4.9.5 Extreme Temperatures Variance Test

4.9.5.1 Requirement

One sample cylinder and valve of each size and pressure rating will be subjected to an extreme temperatures operation test. Each cylinder and valve will be subjected to the minimum operation temperature and maximum operation temperature, each for 24 hours. At the conclusion of the temperature exposures, the cylinder will be evaluated for proper weight and pressure. The cylinders and valves shall then be visually examined and, if deemed necessary, shall be subjected to any of the appropriate tests as detailed in Section 4.1. Following the exposures, the cylinder weight loss shall not exceed the manufacturer's allowable pressure weight loss, or 0.001 percent of the original cylinder weight.

4.9.5.2 Test/Verification

A sample cylinder and valve shall be conditioned in a conditioning chamber set at 40 °F (4.4 °C) for a period of 24 hours. Immediately upon removal from the conditioning chamber the pressurized cylinder will be placed in a chamber set at 130 °F (54 °C) for a period of 24 hours. Immediately upon removal from the conditioning chamber, the cylinder will be observed for pressure, weighed and be visually examined and tested as needed per Section 4.1.

4.9.6 Hydrostatic Integrity

4.9.6.1 Requirements

Pressure 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 upon the intended market for the system. Examinations will 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.

4.9.6.2 Tests/Verification

The pressurizing medium shall be water. 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.

4.10 Cylinder Valve Assembly with Solenoid Actuator

4.10.1 Equipment Assembly Rating (Voltage Variation)

4.10.1.1 Requirement

A sample solenoid valve of each voltage rating shall operate properly over a primary source voltage range of 85 to 120 percent of the rated voltage. There shall be no change in operating characteristics, or failure to respond to limit alarms and trip points.

4.10.1.2 Test/Verification

A sample solenoid valve of each voltage rating will be mounted in the position of normal use and shall be subjected to a source voltage range from 85 to 120 percent of the rated voltage.

4.10.2 Dielectric Strength

4.10.2.1 Requirement

Electrical components shall be capable of withstanding a dielectric strength test without arcing or breakdown.

4.10.2.2 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. There shall be no evidence of arcing or breakdown.

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

4.10.3 Additional Performance Tests

4.10.3.1 Requirements

General Performance Requirements: 4.1.1.1 (Examination), 4.1.4.1 (Operating Pressure), 4.1.5.1 (Durability - 500 Cycling), followed by 4.1.2.1 (Valve Seat Leakage), 4.1.7.1 (Salt Spray - Corrosion), 4.1.8.1 (Vibration Resistance), 4.1.11.1 (Seals & O-rings), 4.9.2 (One Year Leakage Loss), 4.9.3 (Extreme Low Temperature), 4.9.4 (Extreme High Temperature), and 4.9.6 (Hydrostatic Integrity).

4.10.3.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.1.2 (Examination), 4.1.4.2 (Operating Pressure), 4.1.5.2 (Durability - 500 Cycling), followed by 4.1.2.2 (Valve Seat Leakage), 4.1.7.2 (Salt Spray - Corrosion), 4.1.8.2 (Vibration Resistance), 4.1.11.2 (Seals & O-rings), 4.9.2 (One Year Leakage Loss), 4.9.3 (Extreme Low Temperature), 4.9.4 (Extreme High Temperature), and 4.9.6 (Hydrostatic Integrity).

4.11 Detection Devices (Fire & Smoke)

Detection devices will be evaluated and tested for compatibility with electrical specifications of the associated electrically operated equipment, including the actuating solenoid, fire detection automatic releases, etc., of the water mist system as well as functionality. The examination shall be in accordance with the applicable ANSI standards for Thermostats -Spot Type, Fixed Temperature Thermostats, Combination Fixed Temperature & Rate of Rise Thermostats and Smoke Detectors.

4.12 Drain/Fill Valve

4.12.1 Performance Tests

4.12.1.1 Requirements

General Performance Requirements: 4.1.1.1 (Examination), 4.1.2.1 (Valve Seat Leakage), 4.1.3.1 (Hydrostatic Strength) 4.1.5.1 (Durability - 500 Cycling), 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray - Corrosion), 4.1.8.1 (Vibration Resistance), 4.1.10.1 (Friction Loss Determination) and 4.1.11.1 (Seals & O-rings).

4.12.1.2 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), 4.1.5.2 (Durability - 500 Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion), 4.1.8.2 (Vibration Resistance), 4.1.10.2 (Friction Loss Determination) and 4.1.11.2 (Seals & O-rings).

4.13 Fittings and Piping (Including Couplings and Tubing)

All fittings and couplings, and piping and tubing in low, intermediate and high pressure systems shall be assembled in accordance with appropriate ANSI or NRTL standards. Fittings and couplings, and piping and tubing will be examined and evaluated. The examination shall be in accordance with the requirements of a NRTL for product certification. Manufacturers are strongly encouraged to utilize existing pipe and fittings that are listed and suitable for their intended purpose with the water mist system. Galvanized piping shall not be utilized for water mist systems.

4.13.1 Joining Methods

4.13.1.1 Requirement

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

4.13.1.2 Test/Verification

Documentation detailing all allowable joining methods shall be submitted by the client and reviewed, possible examination and testing.

4.13.2 Bending Moment and Rotation Bending Moment Resistance

4.13.2.1 Requirements

Sample assemblies with the test joints, in each size, shall demonstrate resistance to the bending moments in accordance with applicable ANSI or NRTL standards as appropriate. The samples shall be evaluated while internally pressurized to the greater of the minimum system pressure of the assembly, or a minimum of 175 psi (12.1 bar). There shall be no leakage, cracking, or fitting or coupling pull-off as a result of this test.

4.13.2.2 Tests/Verification

Compliance shall be verified by testing an assembly of pipe joined by each style of joint under consideration for examination. Assemblies shall be constructed for each size, and model of gasketed pipe coupling or pipe fitting under evaluation. This test will be conducted in accordance with applicable ANSI or NRTL standards as appropriate.

4.13.3 Additional Performance Tests

4.13.3.1 Requirements

General Performance Requirements: 4.1.3.1 (Hydrostatic Strength), 4.1.5.1 (Durability - 500 Cycling), 4.1.6.1 (Extreme Temperatures Operation), 4.1.8.1 (Vibration Resistance) and 4.1.11.1 (Seals & O-rings).

4.13.3.2 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), 4.1.8.2 (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 can 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, 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, decreasing signal for a low limit. This test shall be repeated for a minimum of five times. Adjustable types 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 a dielectric strength test without arcing or breakdown.

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. There shall be no evidence of arcing or breakdown.

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

4.14.3 Additional Performance Tests

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 - 500 Cycling), 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray - Corrosion), 4.1.8.1 (Vibration Resistance) and 4.1.10.1 (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 - 500 Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion), 4.1.8.2 (Vibration Resistance) and 4.1.10.2 (Friction Loss Determination). Following tests 4.1.5.2 (Durability - Cycling), 4.1.6.2 (Extreme Temperatures Operation) and 4.1.8.2 (Vibration Resistance), a post test 4.1.4.2 (Operating Pressure) shall be conducted.

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

4.15.1 General

A. At a minimum, a water mist system utilizing 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 examination.

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

C. Foam concentrate component certification is granted only for use in water mist foam extinguishing systems which have been performance tested specifically with that concentrate. Certification for systems using tested concentrates are granted separately, subsequent to the component examination of the concentrate. Component examined concentrates need only be listed separately from the systems with which they are examined if the concentrate and system manufacturer are different corporate entities, or if the concentrate manufacturer so specifically requests.

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

E. Similarly, mechanical components for foam systems might only be component examined for use in systems with which they have been performance tested.

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

4.15.1.1 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 16, *Standard for the Installation of Foam-Water Sprinklers and Foam-Water Spray Systems*, is also referenced with regard to general information about the acceptable configurations and applications of these systems. However, the improved effectiveness of foam-water mist systems over conventional water mist and nozzle systems is highly dependent upon the commodities and configurations being protected, as well as the specifics of the distribution system design. As a result, it will be necessary to conduct full-scale fire tests.

C. The manufacturer of a system to be tested 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 examination will offer essentially the same performance as that originally tested.

This can be accomplished in two ways:

1. The manufacturer can manufacture all components and the concentrate and demonstrate effective quality control, or the manufacturer can enter into written agreements with

component or concentrate manufacturers to control the designs and formulations per the testing organization agreement, and The testing organization shall be permitted to periodically audit this “outside” manufacturer (either on behalf of the manufacturer or as a result of component listing of the outsourced items), or

2. The manufacturer can demonstrate sufficient quality control of the critical characteristics of the outsourced components as to ensure system performance. Generally, this will include a minimum of some performance testing. System configuration and application shall be prescribed by appropriate design, installation, and operation information to be provided by the manufacturer. The testing organization will review such information to verify completeness and conformance and the limits of the certification to be granted.

4.15.1.2 Tests/Verifications

Examinations of systems employing a tested concentrate shall include the following evaluations to assess concentrate-hardware compatibility and effectiveness in fire suppression. These tests are also required to complete the examination of the concentrate, but can only be conducted in conjunction with the evaluation of specific system components.

A. The system submitted for examination 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. Performance, Foam Quality and Fire Testing shall be conducted at each mixture strength to be examined as follows:

B. Performance – Film Forming Test

B.1 A film forming foam liquid concentrate shall have a spreading coefficient (reference B.5) greater than zero when tested as described in B.2 - B.5.

B.2 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 01331-89, *Standard for Test Methods for Surface and Interfacial Tension of Solutions of Surface-Active Agents*.

B.3 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).

B.4 The interfacial tension of the foam solution and cyclohexane shall be determined as described in B.2 and B.3 except that alter immersion of the tensiometer ring in the foam solution, a layer of reagent grade (not less than 99 percent) cyclohexane shall be carefully added on top of the foam solution. Contact between the tensiometer ring and the cyclohexane shall be avoided. After waiting 5 minutes, the interfacial tension shall be determined.

B.5 The spreading coefficient of the foam liquid concentrate shall 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

C. Foam Quality Tests

C.1 General

C.1.1 Foam produced using the specific combination(s), as specified by the manufacturer, of foam liquid concentrate, fresh water, and full-scale equipment shall have:

a. A 25 percent drain time not more than 1 minute shorter (or not more than 10 percent shorter. if this is a greater amount) nor more than 2 minutes longer (or not more than 20 percent longer, if this is a greater amount) than the 25 percent drain time obtained for the foam demonstrating successful performance in the fire tests. In addition, in no case shall the 25 percent drain time for the full scale equipment be:

1. Less than 30 seconds, or

2. Less than the dram time value obtained from the successfully fire tested foam, whichever is less.

b. A foam expansion value not more than one expansion unit below (or more than 10 percent below, if this is a greater amount) nor more than two expansion units above (or not more than 20 percent above. if this is a greater amount) the value obtained using special fire test equipment selected by the manufacturer for use in the fire tests (Reference C.3.2 for the formula for calculating foam expansion unit). An expansion unit is defined as a multiple of the original solution volume. Foam exhibiting a 5:1 expansion ratio is considered to demonstrate 5 “expansion units”.

C.2 Twenty-five percent drain time test

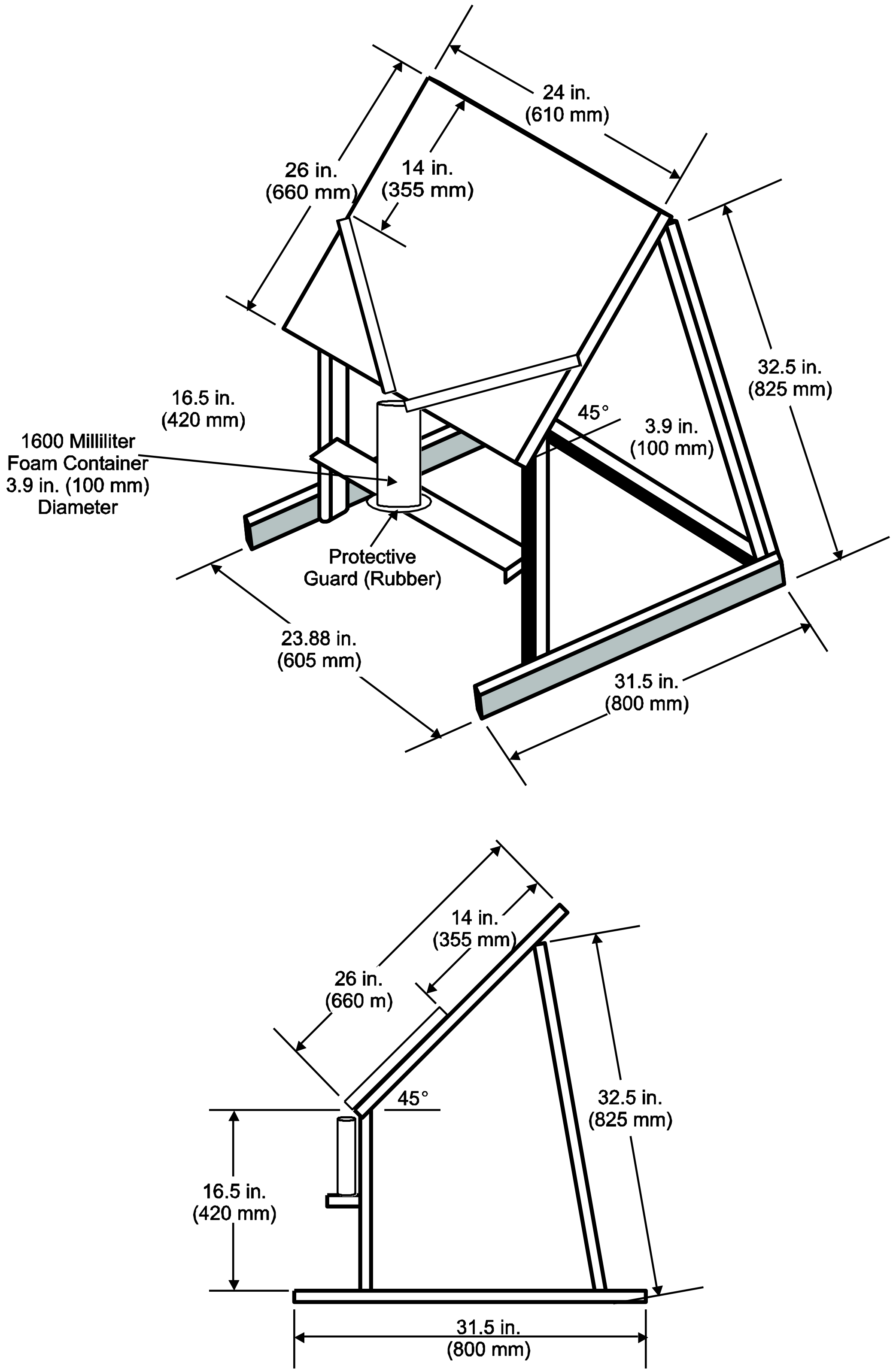
C.2.1 To determine compliance with the requirements of C.1.1, a sample of the foam shall be obtained by directing foam discharging from generating equipment onto a foam slider (reference C.2.3).

C.2.2 The foam shall be discharged at the following pressures:

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

C.2.3 A foam slider shall be used to collect foam for determining foam quality. A typical “slider” is illustrated in Figure C.1 and 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 shall be guided into a foam sample container placed at the bottom of the sheet. To prevent foam agitation in the container, overflowing of foam solution shall be avoided.

Figure 4.15.C.1 ***Typical Foam Slider***



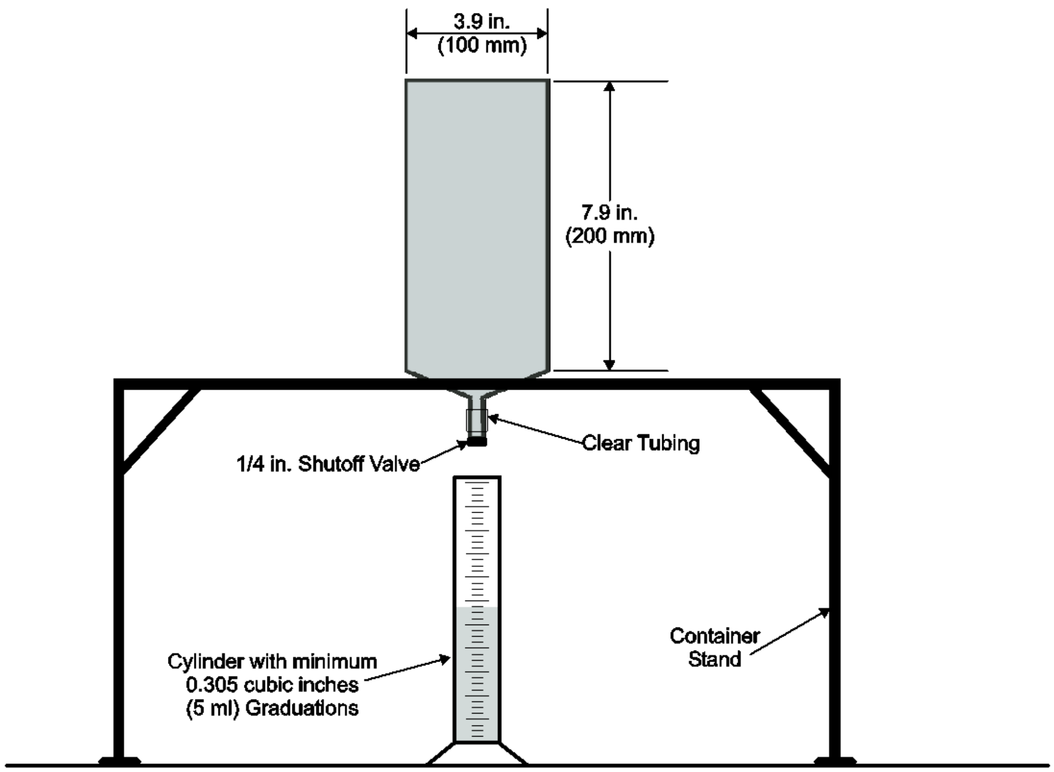
C.2.4 The foam container used with the foam slider shown in Figure C.1 shall be the 54.1 oz (1600 ml) cylindrical container as illustrated in Figure C.2.

C.2.5 The volume of liquid collected shall be recorded at regular intervals, and the data shall be used as described in C.2.6.

C.2.6 The time required to drain 25 percent of the volume of the liquid foam solution from the foam sample in the container shall be determined by interpolation of liquid volume against the time needed to collect that volume. Zero time shall be that time when a sufficient volume of foam has accumulated to fill the sample container.

C.2.7 As an alternative to the method described in C.2.6, the 25 percent drain time shall be determined by recording the time required to drain the volume of liquid having a weight equal to 25 percent of the weight of the foam sample, as determined in C.3.2.

Figure 4.15.C.2 ***54.1 oz (1600 ml) Foam Container***



C.3 Expansion Test

C.3.1 Following completion of the twenty-five percent drain time test described in C.2.1 - C.2.7, all of the liquid drained from the foam sample shall be returned to the foam container. The weight of the container shall be determined to the nearest gram. The weight of the foam sample shall be determined by subtracting the weight of the container from the total weight.

C.3.2 The foam expansion unit value can be approximated for test purposes as the reciprocal of the specific gravity of the foam generated. It shall be calculated using the following equation:

$$\text{Foam Expansion Unit} = \frac{\text{Volume of Container (ml of water)}}{\text{Weight}_{full}(g) - \text{Weight}_{empty}(g)^{1}}$$

Note: [1]Since 1 gram of foam solution occupies a volume of essentially 1 ml, the volume of foam solution equals the number of grams.

C.4 Verification of liquid-concentrate concentration

C.4.1 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 in C.3.1 and C.3.2 and in the 25 percent drain time test in C.2.1 - C.2.7. Concentration determinations shall be based upon weight or volume measurements of the water and concentrate when premixed foam solutions are used.

C.4.2 The instrument reading obtained shall be corrected. as necessary, for temperature. The foam solution concentration shall then be determined using a calibration chart. To prepare a calibration chart, instrument readings shall 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.

D. The water mist foam system shall successfully complete all appropriate Appendix specific performance fire tests with the designated foam concentrate and percentage during a fixed amount of time period or to extinguishment.

4.15.2 Additional Foam Equipment Component Performance Tests

4.15.2.1 Requirements

Any individual components, such as proportioner, foam injection pump, foam storage tank, etc., shall also be further examined or tested to investigate any safety or reliability concern 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) as applicable and needed.

4.15.2.2 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) as applicable and needed.

4.16 High Pressure Flexible Distribution Hose

4.16.1 Fatigue Test

4.16.1.1 Requirements

Flexible hose with threaded end fittings shall be subjected to 20,000 cycles of repeated flexing at a rate of 5 to 30 cycles/min in a direction parallel with the axis of the end fittings while pressured to their rated working pressure. 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 will be conducted in accordance with Section 8.3 of ISO Standard 10380 Pipework -- Corrugated metal hoses and hose assemblies, - 1994. A minimum of two samples of flexible hose with fittings, of the longest size submitted for examination, shall be subjected to required number of cycles of repeated flexing at a rate of 5 to 30 cycles/min in a direction parallel with the axis of the end fittings while pressurized to their rated working pressure, as shown in Figure N-1. 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, r, of the hose, as defined by the manufacturer’s literature. One end of the sample shall be held in a fixed position and the other end shall be flexed in the vertical plane a distance of 4 times the nominal diameter of the nozzle fittings above and below the position of the fixed end for a total vertical movement of 8 times the nominal diameter. After completion of the cycles, if deemed necessary by visual inspection, deterioration of the performance characteristics shall be evaluated, if necessary, by use of 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).

The test sample will be filled with water and pressurized to the maximum system operating pressure 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 by the use of 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

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, 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, if necessary, by the use of 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 (-40 °C) and 275 °F (135 °C) or to 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:

A. Hydrostatically tested to confirm that there is no leakage at four times the rated working pressure.

B. Then the hose shall be drained and subjected to a high temperature oven-air exposure of 275 °F (135 °C) or to 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) and submerged in water. No leakage shall occur.

C. The sealing mechanism, after removal from the hose, shall not crack when squeezed together from any two diametrically opposite points.

D. One sample of the flexible hose with threaded end fittings and sealing mechanism, for each sealing mechanism material under examination, shall be hydrostatically tested to confirm that there is no leakage at four times the rated working pressure.

E. Then the hose shall be drained and subjected to a low temperature exposure of -40 °F (-40 °C) or to manufacturer's specifications, for 4 days. Immediately after exposure, the hose shall be submerged in -40 °F (-40 °C) or to manufacturer's specifications, antifreeze and shall be pneumatically pressurized to 50 psi (3.5 bar). No leakage shall occur. 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 and its method of attachment to a ceiling assembly shall be able to withstand the effects of a high pressure flow, from an operated nozzle. 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 fitted with a water mist nozzle and secured in a commercial ceiling frame assembly. The water mist system shall be operated using a suitable heat source. 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

4.16.5.1 Requirements

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

4.16.5.2 Tests/Verifications

General Performance Requirement Test Procedures 4.1.3.2 (Hydrostatic Strength) (There shall be no deterioration of the flexible hose performance characteristics) and 4.1.8.2 (Vibration Resistance) (The test sample will 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 by the use of 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 4.1.3.2 (Hydrostatic Strength), and 4.1.10.2 (Friction Loss Determination).

4.17 Injectors (Gas or Liquid)

4.17.1 Clogging Test

4.17.1.1 Requirements

Two sample injectors of each model and size will be subject to a clogging test.

4.17.1.2 Test/Verification

Using non-potable water, three previously untested samples shall be individually operated 500 times using a suitable heat source. Water to each injector shall be provided by means of a sump pump taking suction from a reservoir containing an agitator (to minimize settling of particles). The water/particle mixture shall be created per Table 4.17. The water pressure to the injector shall be 20 ± 10 psi (1.4 bar ± 0.7 bar) at full water flow. In each cycle, the device shall demonstrate a full open and full close condition. The period of cycling shall be determined by the testing organization.

Table 4.17 *Water/Particle Mixture for Cycling Test*

ASTM Sieve Mesh Designation	***Nominal Sieve Opening***		***Pipe Scale***		***Top Soil***		***Sand***	
	in.	***(mm)***	***lb***	***(g)***	***lb***	***(g)***	***Lb***	***(g)***
25	0.0278	(0.70)	0	(0)	1.01	(460)	0.44	(200)
50	0.0117	(0.30)	0.18	(82)	0.19	(84)	0.73	(330)
100	0.0059	(0.15)	0.19	(84)	0.01	(3)	0.20	(90)
200	0.0029	(0.07)	0.18	(81)	0	(0)	0.06	(25)
325	0.0017	(0.04)	0.34	(153)	0	(0)	0.01	(5)
Total:			0.89	(400)	1.21	(550)	1.44	(650)

4.17.2 Additional Performance Tests

4.17.2.1 Additional Performance Tests

General Performance Requirements: 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) and 4.1.10.1 (Friction Loss Determination).

4.17.2.2 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) and 4.1.10.2 (Friction Loss Determination).

4.18 Level Switch (Water)

4.18.1 Equipment Assembly Rating (Voltage Variation)

4.18.1.1 Requirement

The level switch shall operate properly over a primary source voltage range of 85 to 120 percent of the rated voltage. There shall be no change in operating characteristics, or failure to respond to level limit alarms and trip points.

4.18.1.2 Test/Verification

A sample level switch will be mounted in the position of normal use and shall be subjected to a source voltage range from 85 to 120 percent of the rated voltage.

4.18.2 Dielectric Strength

4.18.2.1 Requirement

Electrical components shall be capable of withstanding a dielectric strength test without arcing or breakdown.

4.18.2.2 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. There shall be no evidence of arcing or breakdown.

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

4.18.3 Additional Performance Tests

4.18.3.1 Requirements

General Performance Requirements: 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), 4.1.7.1 (Salt Spray - Corrosion) and 4.1.8.1 (Vibration Resistance).

4.18.3.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.3.2 (Hydrostatic Strength), 4.1.4.2 (Operating Pressure) (by changing water level at maximum pressure for functionality check) 4.1.5.2 (Durability - 20,000 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) and 4.1.6.2 (Extreme Temperatures Operation) the switch shall function as intended. In no case, shall the electromechanical relay contacts fuse in the closed position.

4.19 Manual Pull Station/Manual Release

Manual Pull Stations will be evaluated and tested for compatibility with electrical specifications of the associated electrically operated equipment, including the actuating solenoid, fire detection automatic releases, etc., of the water mist system as well as functionality. The examination shall be in accordance with the requirements of the applicable ANSI standard. Manufacturers are strongly encouraged to utilize existing products that are listed and suitable for their intended purpose with the water mist system.

The testing organization reserves the right to modify this outline as required to suit the specific tests needs of a given piece of equipment. Performance requirement testing can include; Enclosures, Normal Operation, Voltage Variation, Environmental Conditioning, Vibration, Dielectric, Cycles of Operation, Radio Frequency Interference, Surge Line Transient Tests, and Marking Requirements.

4.20 Mounting Cylinder Bracket

4.20.1 High Pressure Discharge Test

4.20.1.1 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.

4.20.1.2 Test/Verification

A high pressure discharge test will be conducted on the mounting cylinder bracket assembly with discharge hose. The water mist system unit is to be filled with extinguishing agent and super pressurized with nitrogen 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 will be confirmed by conducting a Leakage Test (4.1.2) 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.

4.20.2 Catastrophic Failure Test

4.20.2.1 Requirements

Brackets or clamps used for securing cylinders shall ensure that components are not damaged in the event of a catastrophic pressurized gas release. At the end of the discharge, the cylinder shall be firmly attached to the bracket and mounting surface. (This test procedure and components utilized, including secondary testing securement, as well as the location of the test, shall be carefully considered and well documented.)

4.20.2.2 Test/Verification

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

4.21 Pneumatic Actuated Plastic Valves

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

4.21.1 Quick Burst Test

4.21.1.1 Requirement

One sample actuator of each type 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.

4.21.1.2 Test/Verification

An open valve shall be hydrostatically pressurized from 0 to 150 percent of the maximum system operating pressure in not less than 54 and not more than 70 seconds.

4.21.2 Threaded Connection Torque Test

4.21.2.1 Requirement

One sample actuator of each type 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.

4.21.2.2 Test/Verification

A plastic fitting will be threaded (per the manufacturer's instructions) into the valve. 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.

4.21.3 Water Immersion Test

4.21.3.1 Requirements

One sample actuator of each type and size shall be subjected to a water immersion test. Weight change at each interval shall not exceed 2 percent of the initial weight. No leakage or deformation is allowed.

4.21.3.2 Test/Verification

The valve shall continue to cycle with minimal change (+ 0, - 10 percent) in the required inlet air pressure for the pneumatic actuator.

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

- The valve and actuator assembly shall be weighed.
- 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 inlet unpressurized, (0 psi), 100 times utilizing the minimum inlet air pressure.

A seat leakage test (Section 4.1.2) shall be conducted with inlet hydrostatically pressurized to the maximum system operating pressure for 5 minutes.

4.21.4 Ultraviolet Light and Water Test

4.21.4.1 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 G 155, 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. Following exposure, all functions shall operate properly as described in Section 4.21.

4.21.4.2 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 ± 0.9 °F (63 °C ± 0.5 °C).

4.21.5 Air-Oven Aging Test

4.21.5.1 Requirements

A plastic valve of each model and size shall be subjected to air-oven aging tests at 158 °F (70 °C). The valve shall then be subjected to post testing per Section 4.21.1. There shall be no cracking or crazing as a result of this test.

4.21.5.2 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) at 50 percent relative humidity. The sample plastic valves shall then be subjected to Section 4.21.1 (Quick Burst Test). At the conclusion of the test, the valve shall be inspected for cracking or crazing.

4.21.6 Additional Performance Tests

4.21.6.1 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 - 20,000 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 utilized to various corrosive atmospheres shall be included in the manufacturer's installation and operating instructions.

4.21.6.2 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 - 20,000 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 - 20,000 Cycling), the valve shall be operated and tested separately under no pressure and at 150 percent of the maximum system operating pressure. After 4.21.4 (Ultraviolet Light), 4.21.5 (Air-Oven Aging), 4.1.5.2 (Durability - 20,000 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 Pneumatic Actuator

4.22.1 Pressure Requirement Activation Test

4.22.1.1 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.

4.22.1.2 Test/Verification

The actuator will 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.

4.22.2 Additional Performance Tests

4.22.2.1 Requirements

General Performance Requirements: 4.1.3.1 (Hydrostatic Strength) (if possible), 4.1.5.1 (Durability - 20,000 Cycling), 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray - Corrosion), 4.1.8.1 (Vibration Resistance), 4.1.11.1 (Seals & O-rings) and 4.4.3.1.

4.22.2.2 Tests/Verifications

General Performance Requirement Test Procedures: 4.1.3.2 (Hydrostatic Strength) (if possible), 4.1.5.2 (Durability - 20,000 Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion), 4.1.8.2 (Vibration Resistance), 4.1.11.2 (Seals & O-rings) and 4.4.3.2. After 4.1.5.2 (Durability - 20,000 Cycling) and 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.

4.23 Pneumatic Valve Assembly (Valve, Solenoid and Pressure Switch)

4.23.1 Burst Disc Pressure Operation

4.23.1.1 Requirement

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

4.23.1.2 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.

4.23.2 Pressure Relief Calculations

4.23.2.1 Requirement

Documentation shall be submitted to verify that the construction and size of the burst disc assembly comply with the flow capacity requirements.

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 storage temperature.

4.23.2.2 Test/Verification

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

4.23.3 Additional Performance Tests

4.23.3.1 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 - 20,000 Cycling), 4.1.6.1 (Extreme Temperatures Operation), 4.1.7.1 (Salt Spray - Corrosion), 4.1.9.1 (Valve Locking/Supervision Ability), 4.1.10.1 (Friction Loss Determination) and 4.1.11.1 (Seals & O-rings).

4.23.3.2 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 - 20,000 Cycling), 4.1.6.2 (Extreme Temperatures Operation), 4.1.7.2 (Salt Spray - Corrosion), 4.1.9.2 (Valve Locking/Supervision Ability), 4.1.10.2 (Friction Loss Determination) (unless done elsewhere in this standard) and 4.1.11.2 (Seals & O-rings). The tested united shall be in the normal expected mounting position during the testing procedures. All tests shall be carried out with the assembled unit.

4.24 Pressure Gauges

4.24.1 General

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

4.24.2 Durability

4.24.2.1 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.

4.24.2.2 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.

4.24.3 Readability

4.24.3.1 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 shall be provided with the color indications, such as; green for "normal" and red for "re-charging" shall be provided.

4.24.3.2 Test/Verification

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

4.24.4 Accuracy

4.24.4.1 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.

4.24.4.2 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.

4.24.5 Hysteresis

4.24.5.1 Requirements

The required accuracy level per 4.24.4, above, shall be met in both increasing and decreasing pressure readings.

4.24.5.2 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.

4.24.6 Overpressure

4.24.6.1 Requirements

No decrease in the accuracy requirements of 4.24.4, above, is permitted after the gauge has been over pressurized.

4.24.6.2 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 5 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.

4.24.7 Hydrostatic Strength

4.24.7.1 Requirements

The gauge shall be subjected to a hydrostatic pressure equal to four times its maximum scale range. The gauge shall withstand this pressure 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. In evaluating this hazard, consideration will be given to the safety factor between 400 percent scale pressure level and the failure pressure. Generally, no debris shall be thrown outside of a 6 ft (1.8 m) cylindrical volume centered on the vertical centerline of the gauge.

4.24.7.2 Test/Verification

Increasing pressure shall be applied until failure occurs. Failure shall be defined as inability to contain pressure.

4.24.8 Vibration

4.24.8.1 Requirements

The gauge accuracy shall be rechecked and remain in accordance with 4.24.4 after the gauge has been vibrated.

4.24.8.2 Test/Verification

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

4.24.9 Wear

4.24.9.1 Requirements

The gauge shall retain accuracy within the limits of 4.24.4 above after completion of 20,000 pressure cycles.

4.24.9.2 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.

4.24.10 Salt Spray Corrosion

4.24.10.1 Requirements

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

4.24.10.2 Test/Verification

The gauge shall have its inlet sealed and be subjected to the Salt Spray Corrosion test per 4.1.7.2. After removal from the container, the gauge shall dry in room atmosphere for five days in an upright position. The gauge will then be disassembled and examined for evidence of stress corrosion cracking of its parts. If no stress corrosion cracking is evident, the gauge movement will be cleaned as necessary. After cleaning and reassembly the gauge shall be operated.

4.24.11 Moisture

4.24.11.1 Requirements

The accuracy of the gauge shall remain within the limits specified in 4.24.4.2 after exposure to moisture.

4.24.11.2 Test/Verification

The gauge shall be mounted in its normal position and approximately one gallon (3.79 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 normal room atmosphere for five days.

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

Pressure control devices will be evaluated and tested for compatibility with hydraulically and electrical specifications of the associated hydraulically and electrically operated equipment, including the actuating solenoid, fire detection automatic releases, etc., of the water mist system as well as functionality. The examination shall be in accordance with the applicable ANSI standard for pressure control devices

4.26 Pressure Switches

4.26.1 Dielectric Strength

4.26.1.1 Requirement

Electrical components shall be capable of withstanding a dielectric strength test without arcing or breakdown.

4.26.1.2 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. There shall be no evidence of arcing or breakdown.

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

4.26.2 Additional Performance Requirements

4.26.2.1 Requirements

General Performance Requirements: 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), 4.1.7.1 (Salt Spray - Corrosion) and 4.1.8.1 (Vibration Resistance).

4.26.2.2 Tests/Verifications

General Performance Tests/Verification Procedures: 4.1.3.2 (Hydrostatic Strength), 4.1.4.2 (Operating Pressure), 4.1.5.2 (Durability - 20,000 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 - 20,000 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.

4.27 Sequence (Cycle) Box (Fire Alarm Signaling System)

Detection devices will be evaluated and tested for compatibility with electrical specifications of the associated electrically operated equipment, including the actuating solenoid, fire detection automatic releases, fire alarm signaling system, etc., of the water mist system as well as functionality. The examination shall be in accordance with the requirements of applicable ANSI standards. Manufacturers are strongly encouraged to utilize existing Automatic Releases that are listed and suitable for their intended purpose with the water mist system.

Performance requirement testing can 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 can need to be examined and evaluated are; 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.

Note: Other original international testing laboratory test data can possibly be used in lieu of testing.

4.28 Sight Glass

4.28.1 Hydrostatic Pressure Test

4.28.1.1 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.

4.28.1.2 Test/Verification

A sample liquid sight glass will 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.

4.28.2 Impact Test

4.28.2.1 Requirement

A liquid sight glass shall withstand, without cracking or damage, the impact as outlined in Section 4.28.2.2.

4.28.2.2 Test/Verification

The sample will be conditioned to its minimum usage temperature as specified by the manufacturer. The sample will 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 can be affected. No location need be subjected to more than one impact. Subsequent to the impact, the liquid sight glass will be examined for cracks or damage and subjected to a leakage test at the maximum working pressure.

4.29 Solenoid Valves

4.29.1 Equipment Assembly Ratings

4.29.1.1 Requirement

The primary circuit current or power shall be measured and shown not to exceed 120 percent of the marked equipment load rating.

4.29.1.2 Test/Verification

Three samples of the actuating solenoid will be mounted in the position of normal use. The operating load and operating voltage will be verified with the maximum working pressure applied to the valve.

4.29.2 Dielectric Strength

4.29.2.1 Requirement

Electrical components shall be capable of withstanding a dielectric strength test without arcing or breakdown.

4.29.2.2 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. There shall be no evidence of arcing or breakdown.

Exception: For operating voltages of 54 V or less the test voltage shall be 500 V, AC. Testing can be conducted on the equipment in the fully assembled condition or on complete sub-assemblies.

4.29.3 Additional Performance Tests

4.29.3.1 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 - 20,000 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).

4.29.3.2 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 - 20,000 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). For 4.1.4.2 (Operating Pressure), two samples of the actuating solenoid will be conditioned to their minimum operating temperatures for sixteen hours and operated at 85 and 120 percent of the rated actuation voltage. The associated pressure for the minimum temperature will be applied to the valve seat. Activation voltage and current will be documented. Two samples of the actuating solenoid will be conditioned to the maximum usage temperature for sixteen hours and will operate at 85 and 120 percent of the rated actuation voltage. The associated pressure for the maximum temperature will be applied to the valve seat. Activation voltage and current will be documented.

4.30 Suction Filters/Strainers

4.30.1 Hydrostatic Pressure Test

4.30.1.1 Requirement

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

4.30.1.2 Test/Verification

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

4.30.2 Filter Rating or Strainer Mesh Opening

4.30.2.1 Requirement

The filter rating or strainer mesh openings shall be 80 percent of the minimum nozzle waterway dimension and shall be sized to include the head loss for the required supply flow and duration, taking into account, 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.

4.30.2.2 Test/Verification

A sample filter or strainer will be subjected to an optical examination for size determination, and shall be subjected to a Friction Loss Determination test (4.1.10.1).

4.31 Water Mist System Pumps

4.31.1 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 shall be arranged and configured in accordance with AHJ recognized codes or standards such as NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection* and NFPA 750, *Standard on Water Mist Fire Protection Systems*. No automatic fire pump shut-off features are permitted in the fire pump installation design.

4.31.2 Hydraulic Pump Performance

4.32.2.1 Requirements

- The pump shall develop its rated pressure when delivering its rated capacity
- A sample pump shall be dry run for 10 minutes with no damage
- The self priming capability of the pump will be verified
- A sample pump shall be subjected to a 24 hour endurance test at rated capacity with no damage
- Pressure relief valves shall comply with the requirements outlined elsewhere in this standard

4.31.2.2 Test/Verification

The pump shall be configured to discharge through the maximum number of operating nozzles for the hydraulically most remote installation design allowed by the manufacturer's installation instructions, plus required hose stream demands, if fed from same system or per the AHJ recognized installation code or standard requirements, whichever is greater. This flow test shall be repeated for each nozzle type if different K Factors are utilized. The pump performance characteristics as well as water mist system demand duration, specified by the manufacturer, shall be verified. Hydraulic performance will be verified by test flows which will be measured with corresponding power requirements and discharge pressure recorded and data speed corrected to rated speed by means of the affinity relationships.

4.31.3 One Hour Test

4.31.3.1 Requirement

No rubbing of the pump mechanisms and casing wear rings or equivalent mechanism is permitted when the pump assemblies shown to have the greatest shaft deflection are run as close to zero flow as possible (maximum radial load) at the maximum suction pressure for one hour.

4.31.3.2 Test/Verification

The pump assemblies selected for this test shall be of the pump mechanisms maximum allowable diameter and speed shown to have the greatest shaft deflection by calculation. Calculations shall be submitted for review prior to scheduling testing. A sample pump of each different model submitted for system approval shall be examined prior to the test for any rubbing of the pump mechanism and casing wear rings. This pump shall be run as close to zero flow (maximum radial load) as possible without boiling the water, and at the maximum allowable suction pressure, specified by the pump manufacturer, for one hour. In no case shall the maximum allowable suction pressure be less than 75 psi (5.2 bar). Subsequently, the pump shall be disassembled and the pump mechanism and casing wear rings examined for evidence of rubbing.

4.31.4 Flange and Gasket Tightness

4.31.4.1 Requirement

No leakage, except at the shaft packing, shall be observed in a 5 minute test when hydrostatically tested at the required pressure.

4.31.4.2 Test/Verification

A sample pump casing and cover of each model and material shall be hydrostatically tested to a pressure equal to, or greater than, the sum of the maximum shutoff pressure of the pump plus a maximum allowable suction pressure specified by the pump manufacturer (P_{max} + $P_{max.\ Suction}$). The maximum shutoff pressure, P_{max}, is the highest shutoff pressure obtained in testing the range of impeller diameters and speeds submitted for approval. The test pressure shall be held 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 less than 250 psi (17.3 bar). Casing bolts normally provided shall be used for this test.

4.31.5 Hydrostatic Strength

4.31.5.1 Requirements

No rupture, cracking or permanent distortion of any part of the pump shall be observed in a 5 minute test when hydrostatically tested at the required pressure, or two times the safety relief valve pressure, whichever is greater.

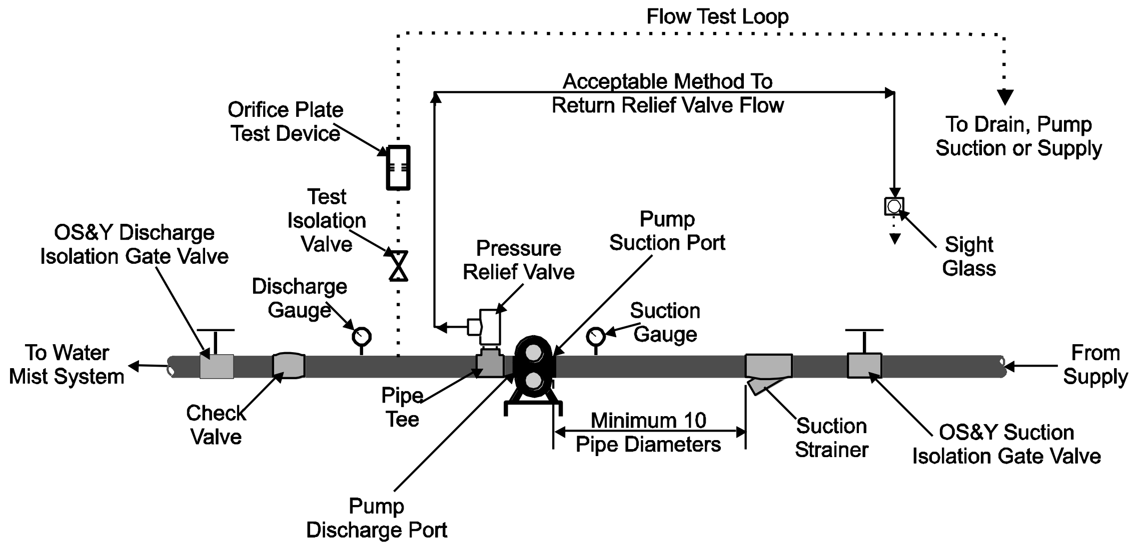
4.31.5.2 Tests/Verification

A sample casing of each model and material shall be hydrostatically tested to a pressure equal to, or greater than, twice the sum of the maximum shutoff pressure of the pump plus a maximum allowable suction pressure specified by the pump manufacturer, 2 x (P_{max} + $P_{max\ Suction}$). The maximum shutoff pressure, P_{max}, is the highest shutoff pressure obtained in testing the range of impeller diameters and speeds submitted for examination. The test pressure shall be held 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 700 psi (48.3 bar), or two times the safety relief valve pressure setting, whichever is greater. Casing bolts normally provided shall be used for this test.

4.31.6 Pressure Relief Valves

Pressure relief valves shall comply with the requirements outlined in the applicable ANSI standards or the AHJ recognized codes or standards, such as; NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*; NFPA 750, *Standard on Water Mist Protection Systems*; and Section 4.25 (Pressure Control Devices - Automatic - Dump - Reducing - Reducing Station - Regulating - Relief - Restricting - Safety - Unloader Valves).

Figure 4.31 *Typical Water Mist System Pump Piping and Fittings*



4.32 Water Storage Tanks

4.32.1 Documentation Review

4.32.1.1 Requirements

Documentation shall be submitted prior to testing to verify that the manufacturer of the water tank is authorized to fabricate a pressure vessel meeting the requirements of *ASME Boiler and Pressure Vessel Code, Section VIII, Division 1*, or equivalent.

4.32.1.2 Test/Verification

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

Labeling shall be provided of high pressure containers in accordance with recognized international standards, such as the *U.S. Dept. of Transportation, Title 49, Code of Federal Regulations, Parts 171 to 190 Sections 178.36 and 178.37, with specifications for DOT-3A, 3AA-1800*, or higher, seamless steel cylinders.

The storage cylinder shall be fabricated, tested, approved, equip and provided with labeling of storage containers 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 must comply with the regulations of the country in which it is to be installed.

4.32.2 Additional Performance Tests

4.32.2.1 Requirements

Should documentation be insufficient, the following General Performance Requirements can be require: 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) and 4.1.11.1 (Seals & O-rings).

4.32.2.2 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) and 4.1.11.2 (Seals & O-rings).

4.33 Water Valves (Control)

Water control valves devices will be evaluated and tested for compatibility with hydraulically and electrical specifications of the associated hydraulically and electrically operated equipment, including the actuating solenoid, fire detection automatic releases, etc., of the water mist system as well as functionality. The examination shall be in accordance with the applicable ANSI standard for water control valves devices.

4.34 Pipe Hangers and Hydraulic Tube Clamping Components

Water mist distribution piping support hangers and components shall be tested in accordance with the appropriate NRTL standard(s). Hydraulic tube clamping and components and other water mist or gas agent piping attachments will be evaluated and tested for compatibility with manufacturer's distribution system for the water mist system as well as functionality. The examination shall be in accordance with the requirements of a NRTL for product certification. Manufacturers are strongly encouraged to utilize existing products that are listed and suitable for their intended purpose with the water mist system.

4.35 Hydraulic Calculations Method

4.35.1 Calculation Method

Use the Hazen-Williams calculation method for hydraulic calculations for low pressure systems with no additives. The Hazen-Williams method also can be used for intermediate and high pressure systems having a minimum pipe size of 3/4 in. (20 mm) if the maximum flow velocity does not exceed 25 ft/s (7.6 m/s).

For copper and stainless steel piping or tubing, Hazen-Williams C values of 150 shall be used.

Use the Darcy-Weisbach Calculation method for hydraulic calculations for intermediate and high pressure, single fluid; single phase systems that cannot be calculated using the Hazen-Williams method (see Chapter 9 of *NFPA 750 Standard on Water Mist Protection Systems*).

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

1. Determine water pressure required at the most remote nozzle using nozzle specifications supplied by the manufacturer. Determine flow rates and pressure at each nozzle location.

2. Determine 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.

4.35.2 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 verified against the design criteria and will be reviewed for verification.

4.35.3 Verification of Flow

Representative water mist fire systems shall be subject to verification of flow calculation tests. These tests will be conducted to verify the accuracy of the hydraulic calculations to the actual event. The following parameters will 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 Nozzles
- Maximum and Minimum Pipe Diameter Decrease
- Maximum Variance in Nozzles Pressure

4.36 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 shall be submitted in electronic form.

The review will verify compliance to the requirements as outlined by the NFPA 750, *Standard on Water Mist Protection Systems*, Chapter 13 (System Maintenance), Table 13.2.2 (Maintenance of Water Mist Systems) and Table 13.3.4 (Maintenance Frequencies) 2006 Edition Standard and shall also reflect those 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 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 will be discussed in detail including the limitations and restrictions of each system. The manuals will clearly identify which configurations are ANSI specification tested.

- The manual(s) shall specify all nozzle(s) performance criteria including, 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 the requirements for detection and actuation. Placement of the detectors shall be specified in detail.

- 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 will be accomplished.

- The manual(s) shall state the operating ambient temperature range of the fire protection system. If the nozzles and delivery system have different temperature ranges, these will 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, at the minimum and maximum operating temperatures.

- The manual(s) shall specify the required inspection and maintenance for the system. In addition, the manual(s) will specify the frequency and method of the inspections and maintenance.

- The manual(s) will contain detailed instructions for restoring the complete system to full operation after a complete or partial discharge. In addition, the manual shall specify the estimated time to return the system to operation.

- The manual(s) shall identify either a date or revision to the manual along with a designation number and 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 shall be included or summarized so that information needed for proper installation is available.

4.37 System Acceptance and Commissioning Documentation

4.37.1 All water mist systems shall successfully meet all system acceptance and commissioning procedures and shall be documented with copies to the system owner and manufacturer (at a minimum).

4.37.2 All acceptance and commissioning procedures shall be reviewed by the Authority Having Jurisdiction. The Authority Having Jurisdiction shall be given advance notice of such testing and be present for commissioning of the system.

4.37.3 Acceptance and commissioning testing shall include the following:

4.37.3.1 A trained manufacturer’s representative shall be present to properly test and reset the system following the acceptance test.

4.37.3.2 Conduct a full flow test where practical to verify nozzle layout and discharge pattern. Flow tests also are intended to determine whether obstructions would interfere with the operation of the system and whether smaller piping and nozzles flow free and clear. Replace one of the nozzles with a pressure gauge and observe gauge readings to verify proper discharge pressure.

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

4.37.3.4 Test all operating parts of the system to verify they function properly.

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

4.37.3.6 Document and test all required interlocks required by the Authority Having Jurisdiction for emergency power off, enclosure ventilation and exhaust fan shut down, and damper closures.

4.37.3.7 Where forced ventilation of an enclosure remains in service during discharge, as accepted by the Authority Having Jurisdiction verify by airflow measurements that the allowable limits in the design manual are met.

4.38 Fire Tests

All 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 K.

4.39 Additional Tests

Additional tests, including performance tests of any accessories or full scale fire tests, can 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 testing organization.

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

FIRE PERFORMANCE TESTING REQUIREMENTS

APPENDIX A through K

General Instrumentation and Test Equipment Requirements

The following measurements shall be recorded to within a ± 5 percent tolerance level at intervals not exceeding one second during each of the tests using a computerized data acquisition system. Measurements shall begin and end at least one minute prior to ignition and after extinguishment.

A. Fuel pressure and flow at the outlet of fuel pump. (Fuel flow and pressure shall be measured prior to each test series.)

B. Fuel temperature within the fuel storage container.

C. Temperature of fuel in pools with thermocouple located in the approximate center of the initial fuel layer.

D. Test enclosure temperatures with the test enclosure temperature measured in the center portion of the room at the 1/3, 2/3 and ceiling heights.

E. Test laboratory of adequate size with natural or minimal ventilation that is natural or minimal so as to not interfere with the fire testing within the enclosure or about the mockup.

F. With exception of the Spray Cooling tests, mock up temperatures are measured away from the direct flame impingement.

G. Temperature of air into the spray fires, measured ~20 in. (~50 cm) horizontally behind fuel spray nozzle with bare bead thermocouples welded from 28 gauge chromel-alumel wire.

H. Pool fire temperatures with a thermocouple located ~1 in. (~2.5 cm) above the initial pool surface and 10 in. (25 cm) within the pool rim.

I. Spray fire temperatures with a thermocouple located ~10 in. (~25 cm) ahead of flame stabilizer at the cone radius.

J. Extinguishing agent flow and pressure in the extinguishing system, measured continuously on the high pressure side of the pump, cylinder or equivalent equipment.

K. Water supply pressure (including tank pressure, if appropriate) and nozzle discharge pressures, monitored at the source (pump and/or cylinder) and at the distribution piping manifold.

L. Extinguishing agent pressure at the two most remote nozzle branch lines.

M. Gas pressure at its storage outlet and distribution sources.

N. Oxygen, Carbon Monoxide and Carbon Dioxide concentrations, measured ~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 shall not be less than 15 percent during the entire period of each test].

O. Consumption of foam concentrate shall be controlled by means of a weighing cell on which the foam tank is placed during the tests.

P. Gas consumption, measured by means of pressure or weighing cell on which the gas tank is placed, during the tests.

Q. In the wood crib fires a total of four thermocouples shall be installed as follows: approximately 4 in. (100 mm) above and centered over the wood crib surface, at the center of the wood-crib approximately 2 in. (50 mm) above liquid fuel surface, and two 4 in. (100 mm) from the pool tray rim with one 2 in. (50 mm) above the liquid fuel surface and one within the liquid fuel, 0.4 in. (10 mm) above the base water layer surface.

R. For the spray fires, conventional oil burner nozzles are utilized, meeting the following requirements:

Fire Type	***Low Pressure***	***Low Pressure - Low Flow***	***High Pressure***
Spray Nozzle	Wide spray angle (120 to 125°) full cone type	Wide spray angle (80°) full cone type	Standard angle at 87psi (6 bar) full cone type
Fuel Type	Light Diesel	Heptane	Light Diesel
Nominal Oil Pressure	116 psi (8 bar)	123 psi (8.5 bar)	2176 psi (150 bar)
Fuel Flow	(0.16 ± 0.01 kg/s) 0.35 ± 0.02 lb/s	(0.03 ± 0.005 kg/s) 0.07 ± 0.01 lb/s	(.050 ± 0.002 kg/s) 0.11 ± 0.004 lb/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)
Nominal Heat Release Rate	5.8 ± 0.6 MW	1.1 ± 0.1 MW	1.8 ± 0.2 MW

- Example – Low Pressure: Monarch specifications, F-80, 24.00, 80 degrees; PLP Lechler 460.728
- Example - Low Pressure, Low Flow: Lechler 460.406
- Example - High Pressure: Spraying Systems TG 0.7
- Fuel pressure for a 1MW fire - nozzle model is “24 GPH @ 100 psi”; operating pressure of 125 psi.
- (Fuel pressure for a 1MW fire - nozzle model is “90.9 liter/hour @ 6.9 bar”; operating pressure of 8.6 bar.)
- Fuel pressure for a 2MW fire - nozzle model is “50 GPH @ 100 psi”; operating pressure of 125 psi.
- (Fuel pressure for a 2MW fire - nozzle model is “189.3 liter/hour @ 6.9 bar”; operating pressure of 8.6 bar.)

S. The fixture stand for the spray fire arrangements shall 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).

T. General pool or tray specifications:

Pan or trays shall be square, of steel construction, 0.068 in. (1.73 mm) thickness by 3.9 in. (10 cm) high, length and width as indicated, 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 shall be used. Freeboard shall be 1.2 in. (3 cm). Freeboard can be greater than 1.2 in. (3 cm) high, if a constant freeboard height is utilized for all application fire tests. Pan surfaces shall be smooth and edges shall be free of imperfections. After each pool fire test, the fuel left in the pool or tray shall be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

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.

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 for the spray fires.

H. The time when the test is finished.

I. Registration will be by means of a written laboratory test and computer log.

J. Visual registration of the fire extinguishment by means of a thermal imaging camera is strongly recommended.

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 prove the existence of fuel presence.

Requirements for all Appendix Fire Testing

A. The minimum operating nozzle pressure (as specified by the manufacturer) shall be utilized for all tests. System operating pressures shall be repeatable to within ± 5 percent. If the system pressures cannot be controlled within the specified tolerance, fire tests will be conducted at the minimum and maximum pressures by using external means to control the system pressure.

B. 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.

C. The ceiling nozzle arrangement shall have uniform spacing. The ceiling nozzle spacing from the wall shall be uniform, preferably one half the main spacing.

D. 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. Additional fire testing to prove the effect of door nozzles on enhancing the heat release rate or increase in the fire intensity will be at the sole discretion of the testing organization.

E. For all fire tests, the ceiling, floor, and walls shall be as dry as possible, with only ambient moisture content allowed. The relative humidity in the test enclosure shall not differ from that of the ambient relative humidity.

F. 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.

G. All fuels shall be at an ambient temperature of 68 °F ± 18 °F (20 °C ± 10 °C).

H. The water mist system, operating without manual intervention, shall successfully complete all described performance fire tests for their specific applications. During the fire tests, all systems shall operate without manual intervention.

I. Placement of additional baffles or obstructions might be needed to prevent the direct impact of mist on the pool or spray test fires, at the sole discretion of the testing organization.

J. Extinguishment, if desired, shall 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. The tests will be conducted for the specific length of time or until the fire is extinguished or the length of time to discharge fifty percent of the water agent, whichever is shorter. There is no minimum extinguishing agent discharge time. The fuel spray, when used, shall be shut off 15 seconds after the fire extinguishment. The water mist discharge shall be shut off 45 seconds after the fuel spray is shut off.

L. 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 will be conducted using the specifications from the manufacturer's design manual in regard to nozzle placement, spray flux, and spray duration. Sprays can be continuous or intermittent in time. In the case of intermittent sprays, the time between the consecutive spray shots shall not be greater than 50 percent of the total time, or the temperature recovery time (minimum time required between water mist system discharges to avoid damaging turbine cooling), to be determined by the testing organization, as related to a specific water mist system. The time between any two water mist discharges shall not exceed the time it is not discharging.

Requirements for Appendixes A through C Enclosures

A. The water mist system shall be capable of extinguishing any fire greater than 1 MW in intensity even when the fire is shielded from the direct water mist interaction.

B. Intermediate ceiling level or wall mounted nozzles are permitted for the combustion turbine occupancies.

C. Fire preburn (prefire) times shall be as follows:

Heptane Pool and Spray Fires:	15 seconds
Diesel Spray Fires:	15 seconds
Diesel Pool Fires:	30 seconds [enclosures less than or equal to 9175 ft^3 (260 m^3) in size]
Diesel Pool Fires:	120 seconds [enclosures greater than 9175 ft^3 (260 m^3) in size]
Wood Crib fire:	30 seconds

D The optional insulation mats shall be cut to the same dimensions as the pool tray and will be placed in a dry pan. The mineral wool insulation mat shall be 2 in. (51 mm) in thickness (Rockwood, Class 36 or equivalent). The fuel will then be poured on top of the mat for soaking and absorption. The insulation mat will be fully saturated so that finger depression creates an instant small pool.

E. For greater than 9175 ft^3 (260 m^3) enclosures, the mockup temperatures shall be measured by one thermocouple on the right sidewall of the mockup and one on the right side of the pipe on top of the mockup.

F. A small louvered vent shall be provided for the smaller 2825 ft^3 (80 m^3) and 9175 ft^3 (260 m^3) enclosures to allow the intake of air to prevent possible suctioning of the walls and ceiling and maintain structural integrity of the fire test enclosure.

APPENDIX A: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF COMBUSTION TURBINES WITH VOLUMES UP TO, AND INCLUDING, 2825 FT^3 (80 M^3)

A.1 Test Enclosure (see Figure A-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 shall be constructed of wood or metal frame with an inner lining of minimum 0.5 in. (13 mm) gypsum or 0.03 in. (0.7mm) 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 (0.81 m by 2.03 m high) personnel door shall be installed with a locking mechanism. A minimum of two hinged ceiling hatches measuring approximately 3 ft by 6 ft (0.91 m by 1.83 m) shall be installed in opposite diagonal corners for heat and smoke release after the conclusion of the fire test.

A.2 Combustion Turbine Mockup

The combustion turbine casing mockup is simulated with a horizontal flat steel plate and steel baffles (see Figure A-1). The specific details and thermal mass of the obstructions are not simulated.

The combustion turbine mockup unit will be centered along the longer wall dimension in the test enclosure. The testing organization 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 39.5 in. by 79 in. 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 legs at the four corners of the steel plate. This is located in the center of the room or at a location within the test cell [to be selected by the testing organization after the nozzles are installed (as per manufacturer's design criteria)]. This allows the fire to be placed in an area deemed to be the most challenging to the specific water mist 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 different depths.

To determine the cooling rate of the combustion turbine spray cooling steel plate mockup, caused by the discharge of the water mist system one thermocouple shall each be embedded near the center of the plate at approximately 0.47 in., 0.98 in. and 1.50 in., (12 mm, 25 mm and 38 mm) below the plate's top surface. The three inconel-sheathed thermocouples shall be embedded in the plate by removing cylindrical plugs from the plate. The thermocouples shall 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 shall be applied, and the steel cylindrical plugs shall be replaced and welded to the plate around the top periphery of the plugs.

This can be accomplished by using a 1.0 in. (25.4 mm) diameter miller tool, installing the thermocouples, and then refilling the hole welded 1.0 in. (25.4 mm) round bar stock.

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 shall be a minimal gap between the various steel table and sheet metal surfaces to permit water run-off. For ease of testing procedures during 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 shall be of 22 gauge (0.85 mm) thick galvanized sheet metal construction and removable. They shall be installed on support legs and kept in place by being pinched between the underside of the steel plate table and the 45° angle extensions and the floor for ease of removal.

Pool or Tray specifications are: 39.4 in. by 39.4 in. (1m by 1m) and 12 in. by 12 in. (0.1m by 0.1m). After each pool or tray fire test, the diesel fuel left in the pool or tray shall be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

The enclosure, mockup and the plate shall initially be at ambient temperature for all tests with the exception of Fire Test A.3.5.

A.3 Fire Tests

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 damaging deformation.

The water mist system, operating without manual intervention, shall successfully complete all four (4), A.3.1 through A.3.4, performance fire tests and the spray cooling-heat transfer test, A.3.5. An additional option for combustion turbine applications is to protect insulated turbines. Two additional fires tests, A.3.6 and A.3.7 (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 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 1.7, Definitions). For primary protection, agent supply shall be equivalent to that required for an automatic sprinkler protection system for the hazard protected.

All fires shall utilize diesel fuel.

A.3.1 Unshielded 1 MW Diesel Spray Fire

Criterion: The fire is to be extinguished.

The test fire will be located above the plate at a location to be selected by the testing organization. The fuel nozzle is located at least 1.0 ft. to 5.5 ft (30.5 cm to 167.6 cm) above the table at the baffle end, away from the access door, with the spray fire aimed towards the center of the shorter wall with the access door. However, the testing organization judgment will be used to pick the most challenging fire extinguishing area based on water mist discharge.

A.3.2 Shielded 1 MW Diesel Spray Fire

Criterion: The fire is to be extinguished.

The test fire will be located 20 in. (50 cm) above the floor, centered between the baffles, away from the access door, underneath the test plate with the fuel spray nozzle aimed horizontally. The spray fire shall be directed towards the center of the shorter wall with the access door.

A.3.3 Shielded 10.8 ft^2 (1 m^2) Diesel Pool Fire

Criterion: The fire is to be extinguished.

The pool test fire will be centered below the steel plate and located between the baffles, with the baffles located 20 in. (50 cm) from the far end of the steel plate away from the access door.

A.3.4 Shielded 2 MW Diesel Spray Fire, System Performance under Limited Natural Ventilation

Criterion: The fire is to be extinguished.

This test will be 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 will be ignited in the enclosure with the personnel access door open. The test fire will be located 20 in. (50 cm) above the floor, centered between the baffles, away from the access door, underneath the test plate with the fuel spray nozzle aimed horizontally. The spray fire shall be directed towards the center of the shorter wall with the access door.

A.3.5 Spray Cooling (No Fire)

Criteria: Determine if the heat flux resulting from a water mist system discharge will adversely affect the turbine. Such assessment is to be made in accordance with methodology developed by the testing organization to assess the damage potential of water mist systems being tested. This test, combined with the applicable NRTL heat transfer calculations, will determine the extent of the cooling of the turbine casing during the operation of the water mist system. Calculations will be based on the manufacturer’s recommended diameter sized turbines to be installed within the enclosure.

A spray fire will be necessary to heat the steel plate. The spray fire will be located between the baffles underneath the test table with the fuel spray nozzle aimed at the table at a 30° grazing angle with the flames centered and impinging on the steel table mid point. When all three steel plate thermocouples reach 572 °F (300 °C), the spray fire will be shut off, and the steel plate will be allowed to cool. To avoid excess heating of the test enclosure, the ceiling hatches and the access door shall be left open only during the heating of the plate. When the last of three thermocouple readings drops to 572 °F (300 °C), then the water mist system will be activated and the temperature history of the plate will be recorded for a total of 15 minutes (See Figure A-4).

The spray cooling test shall have the available recorded data in Microsoft Excel format. The data can be reviewed by the appropriate NRTL for the heat transfer calculation analysis. 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.

The heat flux is also affected by the stand-off distance of the water mist nozzles. The testing organization will conduct this test at the minimum and maximum nozzle stand-off distance specified in the client's design manual. (The design manual shall also specify no direct spray impingement).

A.3.6 Saturated Insulation Mat and Spray Fire (Optional Test)

Criteria: Both the spray and insulation mat fires are to be extinguished.

A 1 ft^2 (0.1 m^2) insulation mat of mineral wool composition shall be saturated with diesel fuel and placed in a 1 ft^2 (0.1 m^2) pan. When slightly depressing the mat, a liquid fuel pool shall occur. The mat is to be located below the steel plate, between the baffles located at the far end of the steel plate away from the access door, and ignited under a spray fire identical to that used in Fire Test A.3.2. The tray will be placed so that it is centered between baffles, with the edge of the table.

A.3.7 Large Saturated Insulation Mat (Optional Test)

Criterion: The insulation mat fire is to be controlled (only flamlets at the surface of the mat).

An 11 ft^2 (1 m^2) insulation mat of mineral wool composition shall be saturated with diesel fuel and placed in an 11 ft^2 (1.0 m^2) pan. When slightly depressing the mat, a liquid fuel pool shall occur. The mat will be centered below the steel plate, located between the baffles, with the baffles located 20 in. (50 cm) from the far end of the steel plate away from the access door. The mat is to be ignited in a position identical to the pool fire used in Fire Test A.3.3.

A.3.8 Additional Fire Test

Based on the results of Fire Tests A.3.1 through A.3.7, additional fire testing can 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 testing organization.

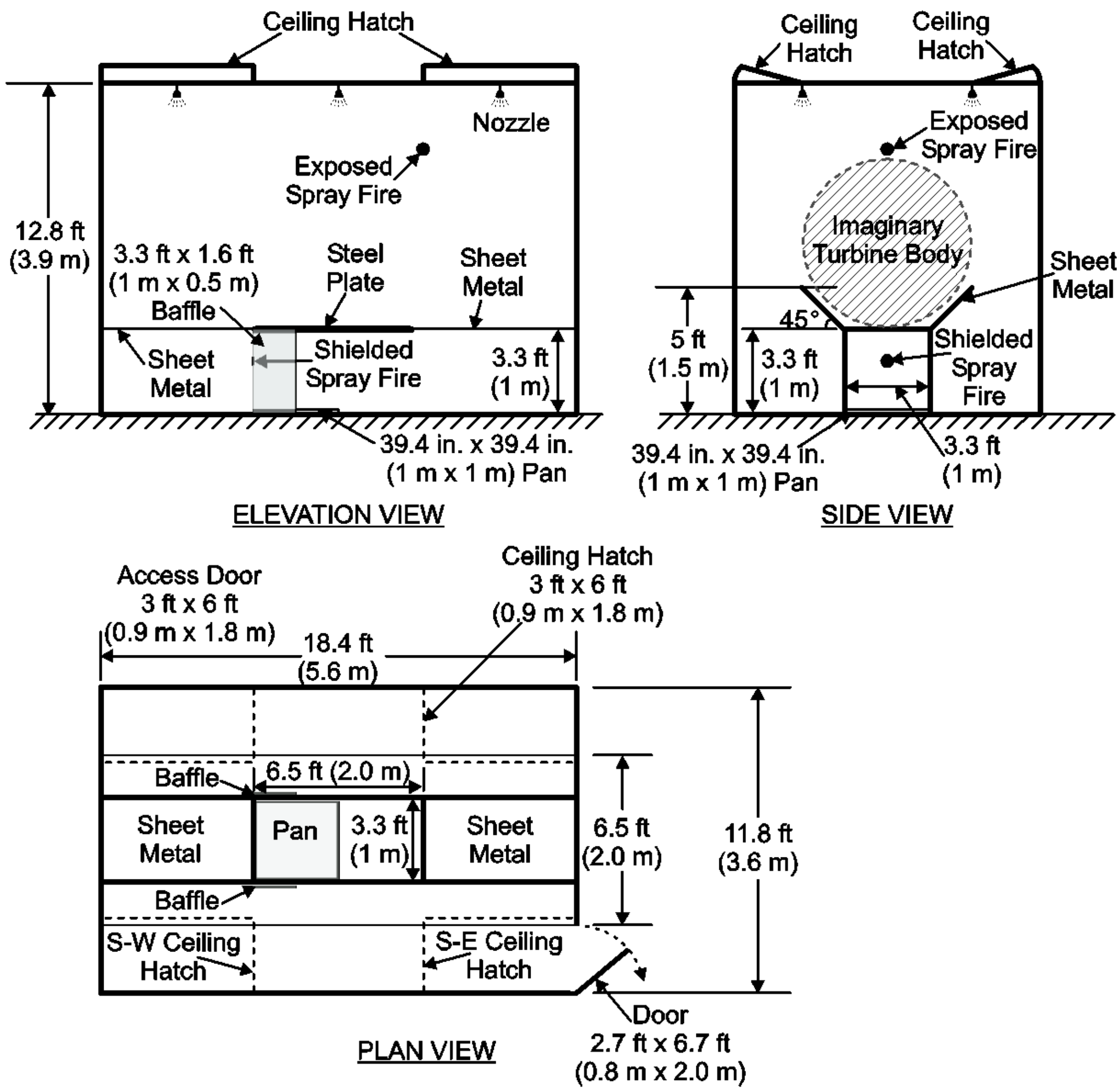


Figure A-1. Test Enclosure and Combustion Turbine Simulator Steel Plate

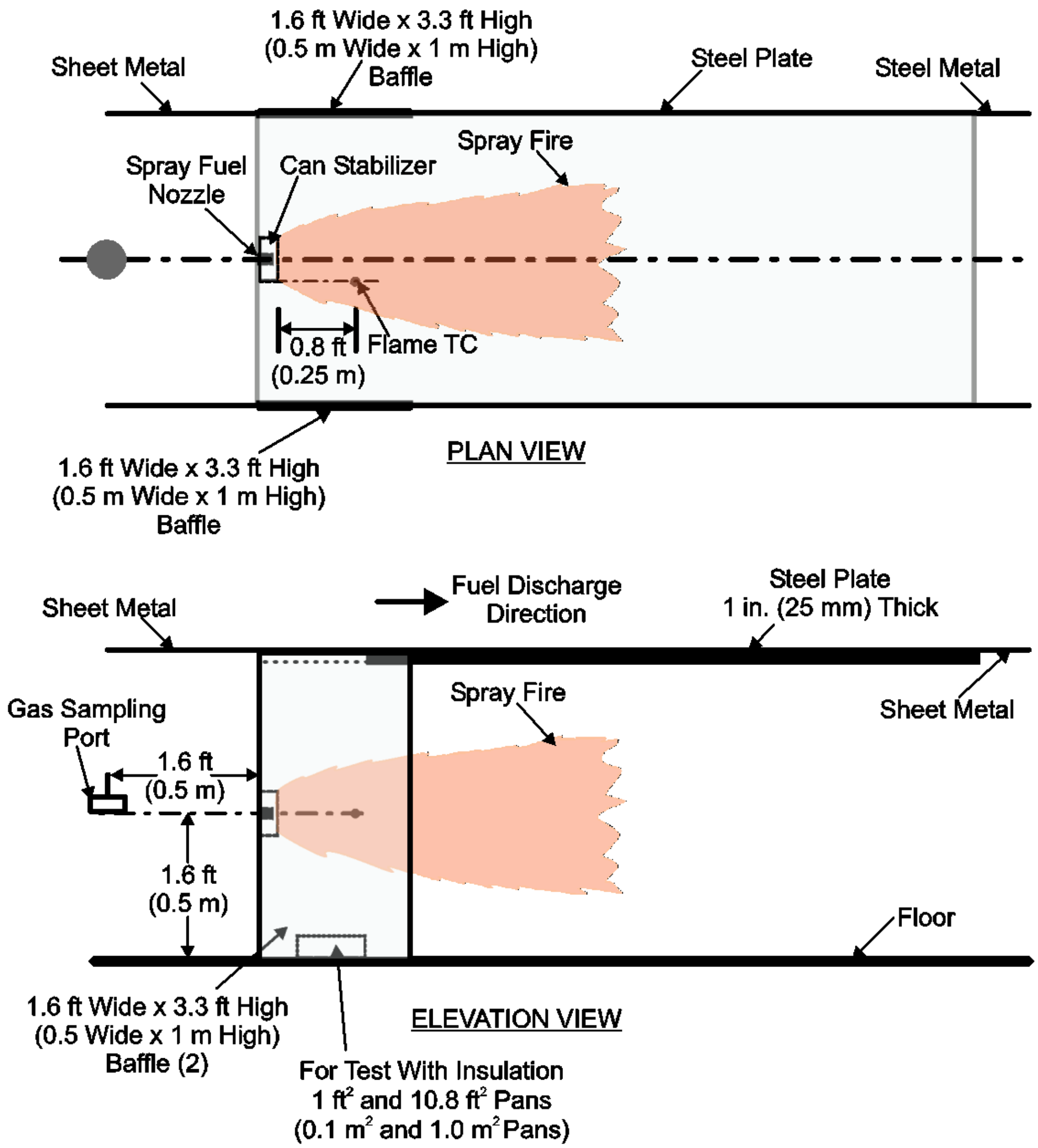


Figure A-2. Fire Source Configuration and Instrumentation for Shielded Spray Fire Testing

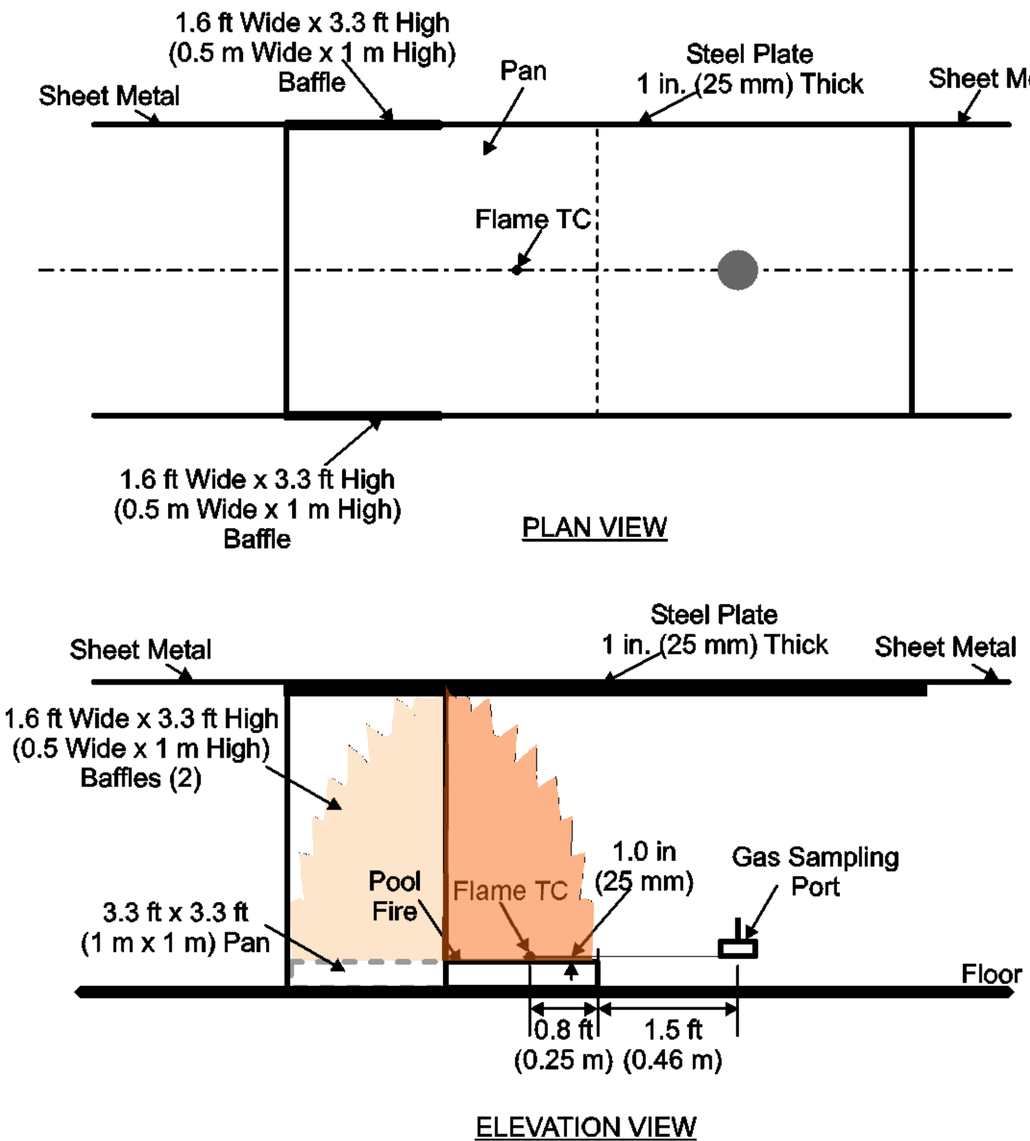


Figure A-3. Fire Source Configuration and Instrumentation for Shielded Pool Fire Testing

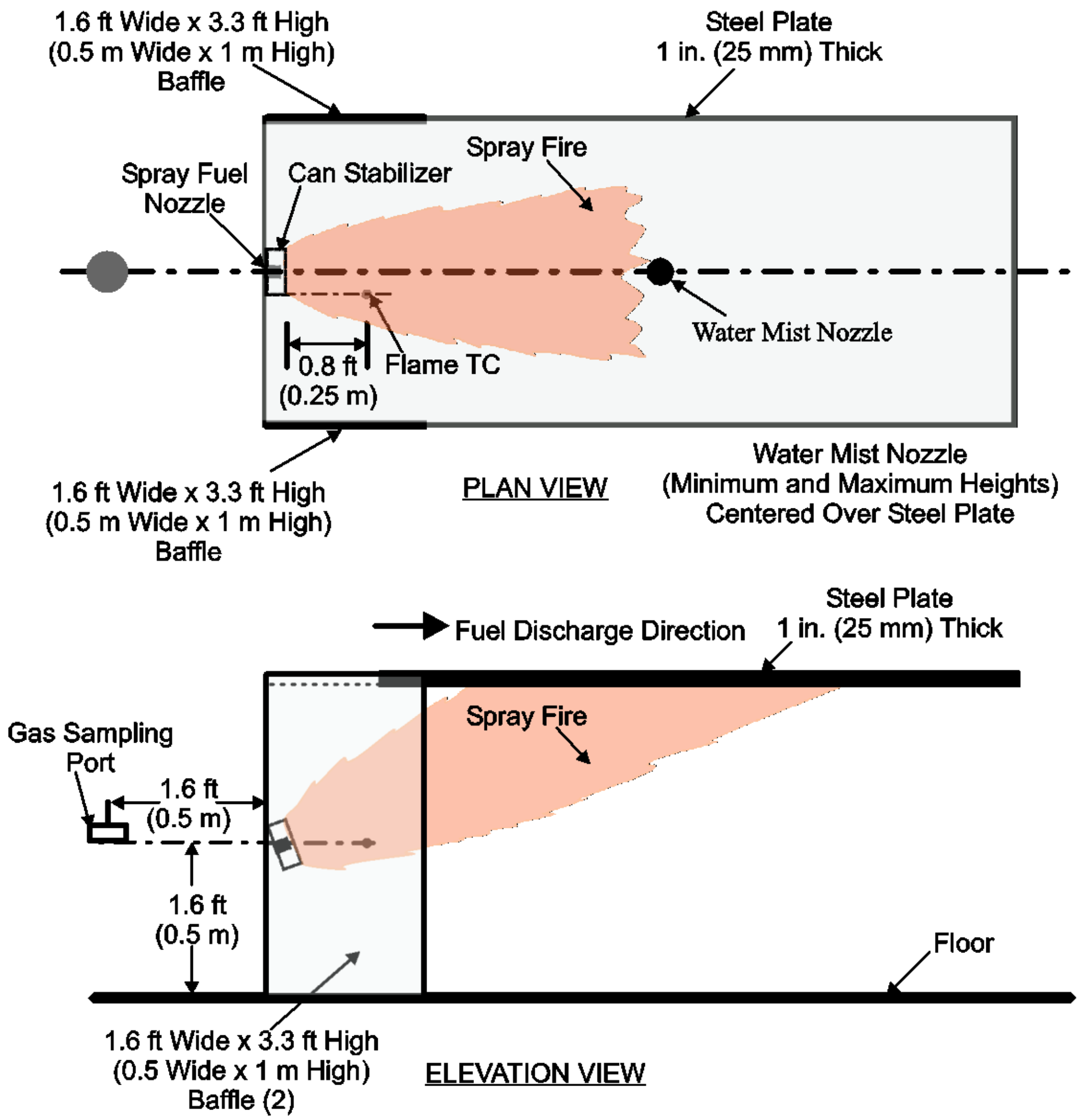


Figure A-4. Fire Source Configuration for Spray Cooling (No Fire) Testing

APPENDIX B: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF COMBUSTION TURBINES WITH VOLUMES UP TO, AND INCLUDING, 9175 FT^3 (260 M^3)

B.1 Test Enclosure (see Figure B-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 shall be constructed of wood or metal frame with an inner lining of minimum 1/2 in. (13 mm) gypsum or 0.03 in. (0.7mm) galvanized steel. To minimize leakages, all joints and gaps shall be sealed. At 9 ft (2.74 m) from one of the enclosure corners, a 2.7 ft by 6.7 ft high (0.81m by 2.03 m high) personnel door shall be installed near the center portion of one of the longer walls with a locking mechanism. Also, in of one of the longer walls a 4.0 ft by 8.0 ft high (1.22 m by 2.44 m high) removable panel shall also be installed for test enclosure access (The personnel door can be constructed within this panel). A minimum of two hinged ceiling hatches measuring approximately 3 ft by 6 ft (0.91 m by 1.83 m) shall be installed in opposite diagonal corners for heat and smoke release after the conclusion of the fire test. The floor shall be noncombustible and any floor drainage or vent openings shall be sealed during testing.

B.2 Combustion Turbine Mockup

The combustion turbine casing mockup is simulated with a horizontal flat steel plate and steel baffles (see Figure B-1). The specific details and thermal mass of the obstructions are not simulated.

The combustion turbine mockup unit will be centered along the longer wall dimension in the test enclosure. The testing organization 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, 39.5 in. by 79 in. 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 legs at the four corners of the steel plate. This is located in the center of the room or at a location within the test cell to be selected by the testing organization after the nozzles are installed (as per manufacturer's design criteria). This allows the fire to be placed in an area deemed to be the most challenging to the specific water mist 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 different depths as described below.

To determine the cooling rate of the combustion turbine spray cooling steel plate mockup caused by the discharge of the water mist system, one thermocouple shall each be embedded near the center of the plate at approximately, 0.47, 0.98 and 1.50 in., (12, 25 and 38 mm) below the plate’s top surface. The three inconel-sheathed thermocouples shall be embedded in the plate by removing cylindrical plugs from the plate.

The thermocouples shall 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 shall be applied, and the steel cylindrical plugs shall be replaced and welded to the plate around the top periphery of the plugs. This can be accomplished by using a 1.0 in. (25.4 mm) diameter miller tool, installing the thermocouples, and then refilling the hole welded 1.0 in. (25.4 mm) round bar stock.

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 shall be a minimal gap between the various steel table and sheet metal surfaces to permit water run-off. For ease of testing procedures during 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 shall be of 22 gauge 0.85 mm thick galvanized sheet metal construction and removable. They shall be installed on support legs and kept in place by being pinched between the underside of the steel plate table and the 45° angle extensions and the floor for ease of removal.

Pool or Tray specifications: 39.4 in. by 39.4 in. (1m by 1m). After each pool or tray fire test, the diesel fuel left in the pool or tray shall be measured, if possible, and reignited to ensure that sufficient fuel remained in the pan.

The enclosure, mockup and the plate shall initially be at ambient temperature for all tests with the exception of Fire Test B.3.6.

B.3 Fire Tests

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 damaging deformation.

The water mist system, operating without manual intervention, shall successfully complete all five (5), B.3.1 through B.3.5, performance fire tests and the spray cooling-heat transfer test, B.3.5. An additional option for combustion turbine applications is to protect insulated turbines. Two additional fires tests, B.3.7 and B.3.8 (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 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 1.7, Definitions). For primary protection, agent supply shall be equivalent to that required for an automatic sprinkler protection system for the hazard protected.

All tests shall be conducted utilizing diesel fuel.

B.3.1 Unshielded 1 MW Diesel Spray Fire

Criterion: The fire is to be extinguished.

The test fire will be located above the plate at a location to be selected by the testing organization. The fuel nozzle is located at least 1.0 ft. to 5.5 ft (30.5 cm to 167.6 cm) above the table at the baffle end, away from the access door, with the spray fire aimed towards the center of the shorter wall with the access door. However, the testing organization judgment will be used to pick the most challenging fire extinguishing area based on water mist discharge.

B.3.2 Shielded 1 MW Diesel Spray Fire

Criterion: The fire is to be extinguished.

The test fire will be located 20 in. (50 cm) above the floor, centered between the baffles, away from the access door, underneath the test plate with the fuel spray nozzle aimed horizontally. The spray fire shall be directed towards the center of the shorter wall with the access door.

B.3.3 Shielded 10.8 ft^2 (1 m^2) Diesel Pool Fire

Criterion: The fire is to be extinguished.

The pool test fire will be centered below the steel plate and located between the baffles, with the baffles located 20 in. (50 cm) from the far end of the steel plate away from the access door.

B.3.4 Shielded 2 MW Diesel Spray Fire, System Performance Under Limited Natural Ventilation

Criterion: The fire is to be extinguishment.

This test will be 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 will be ignited in the enclosure with the personnel access door open. The test fire will be located 20 in. (50 cm) above the floor, centered between the baffles, away from the access door, underneath the test plate with the fuel spray nozzle aimed horizontally. The spray fire shall be directed towards the center of the shorter wall with the access door.

B.3.5 Shielded 2 MW Diesel Spray Fire, System Performance at Smaller Enclosure Volumes

Criterion: The fire is to be extinguished.

This test will be conducted to determine the capability of the water mist system to perform acceptably in smaller volumes. A shielded 2 MW spray fire will be ignited in the enclosure with an access door (approximate area of 17.2 ft^2 [1.6 m^2]) open in an enclosure with a volume of 4590 ft^3 (130 m^3). The smaller volume will be created by erecting a wall within the enclosure, or relocating one of the walls parallel to the turbine mockup. Only the nozzles within the 4590 ft^3 (130 m^3) volume are to be activated. The test fire will be located 20 in. (50 cm) above the floor, centered between the baffles, away from the access door, underneath the test plate with the fuel spray nozzle aimed horizontally. The spray fire shall be directed towards the center of the shorter wall with the access door.

B.3.6 Spray Cooling (No Fire)

Criteria: Determine if the heat flux resulting from a water mist system discharge will adversely affect the turbine. Such assessment is to be made in accordance with methodology developed by the testing organization to assess the damage potential of water mist systems being tested. This test, combined with the applicable NRTL heat transfer calculations, will determine the extent of the cooling of the turbine casing during the operation of the water mist system. Calculations will be based on the manufacturer's recommended diameter sized turbines to be installed within the enclosure.

A spray fire will be necessary to heat the steel plate. The spray fire will be located between the baffles underneath the test table with the fuel spray nozzle aimed at the table at a 30° grazing angle with the flames centered and impinging on the steel table mid point. When all three steel plate thermocouples reach 572°F (300°C), the spray fire will be shut off, and the steel plate will be allowed to cool. To avoid excess heating of the test enclosure, the ceiling hatches and the access door shall be left open only during the heating of the plate. When the last of three thermocouple readings drops to 572°F (300°C), then the water mist system will be activated and the temperature history of the plate will be recorded for a total of 15 minutes (See Figure B-4).

The spray cooling test shall have the available recorded data in Microsoft Excel format. The data will be reviewed by the appropriate NRTL for the heat transfer calculation analysis. 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.

The heat flux is also affected by the stand-off distance of the water mist nozzles. The testing organization will conduct this test at the minimum and maximum nozzle stand-off distance specified in the client's design manual. (The design manual shall also specify no direct spray impingement).

B.3.7 Saturated Insulation Mat and Spray Fire (Optional Test)

Criteria: Both the spray and insulation mat fires are to be extinguished.

A 1 ft^2 (0.1 m^2) insulation mat of mineral wool composition shall be saturated with diesel fuel and placed in a 1 ft^2 (0.1 m^2) pan. When slightly depressing the mat, a liquid fuel pool shall occur. The mat is to be located below the steel plate, between the baffles located at the far end of the steel plate away from the access door, and ignited under a spray fire identical to that used in Fire Test B.3.2. The tray will be placed so that it is centered between baffles, with the edge of the table.

B.3.8 Large Saturated Insulation Mat (Optional Test)

Criterion: The insulation mat fire is to be controlled (only flamlets at the surface of the mat).

An 11 ft^2 (1 m^2) insulation mat of mineral wool composition shall be saturated with diesel fuel and placed in an 11 ft^2 (1.0 m^2) pan. When slightly depressing the mat, a liquid fuel pool shall occur. The mat will be centered below the steel plate, located between the baffles, with the baffles located 20 in. (50 cm) from the far end of the steel plate away from the access door. The mat is to be ignited in a position identical to the pool fire used in Fire Test B.3.3.

B.3.9 Additional Fire Tests

Based on the results of Fire Tests B.3.1 through B.3.8, additional fire testing can 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 testing organization.

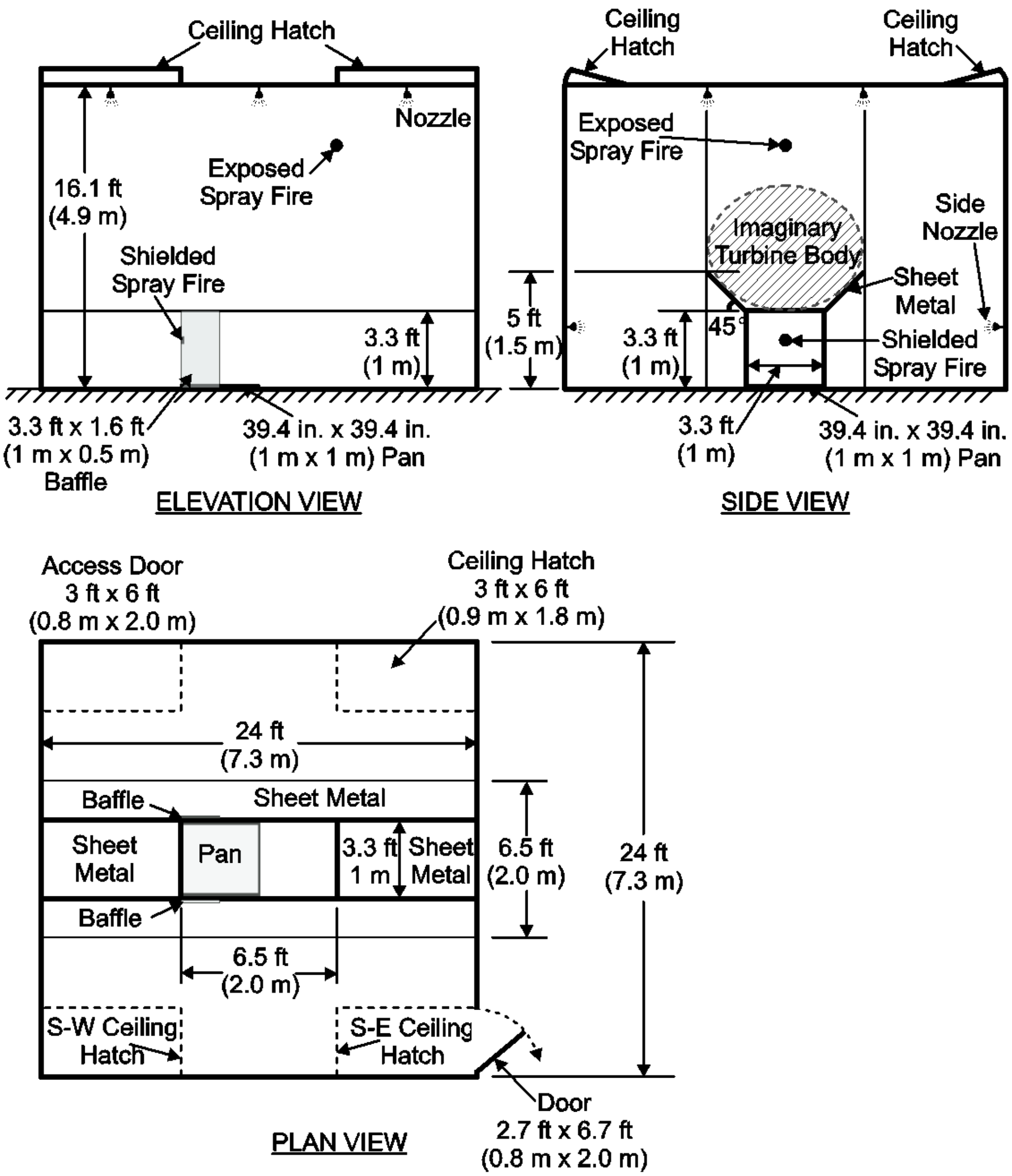


Figure B-1. Test Enclosure and Combustion Turbine Simulator Steel Plate

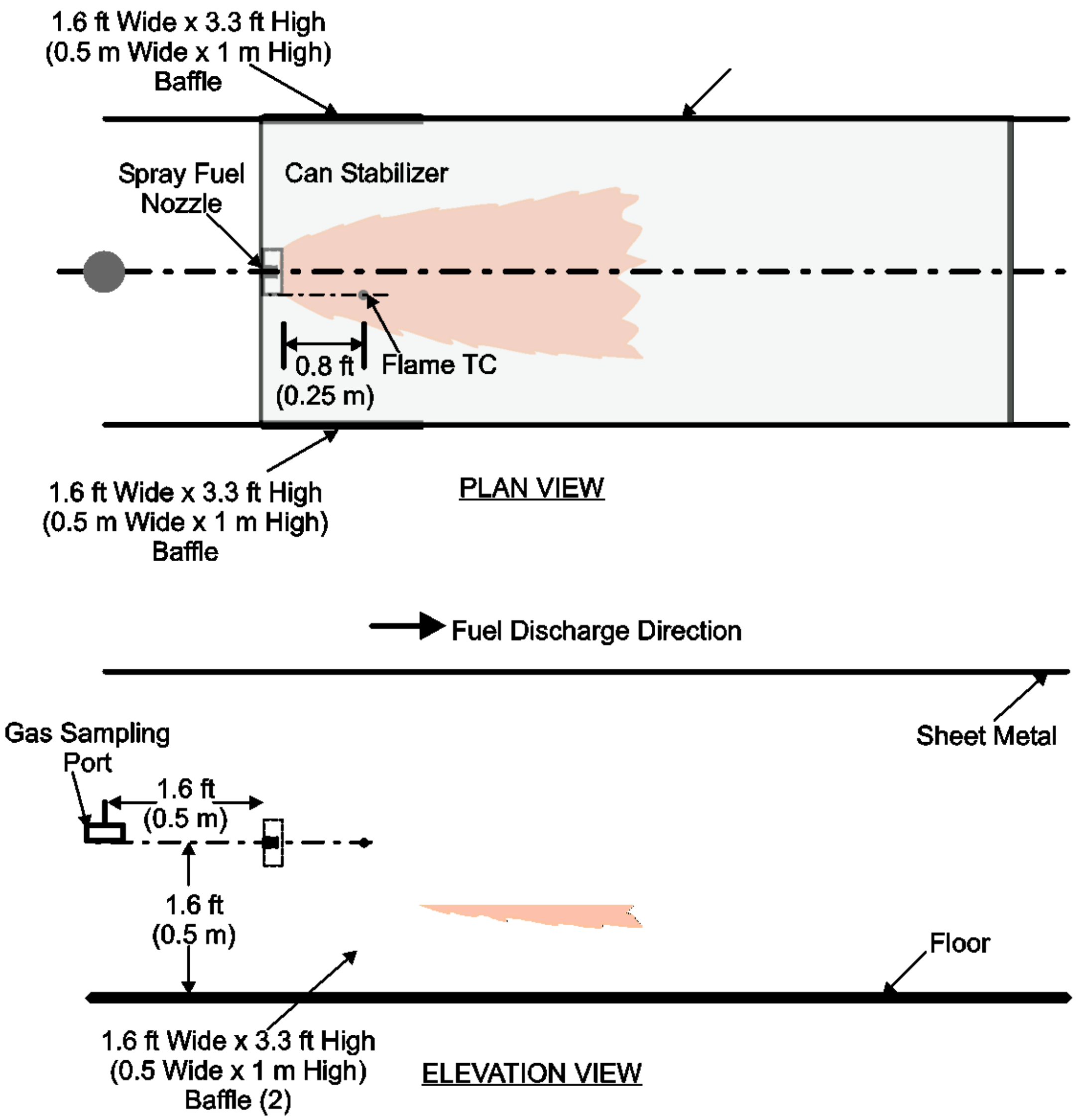


Figure B-2. Fire Source Configuration and Instrumentation for Shielded Spray Fire Testing

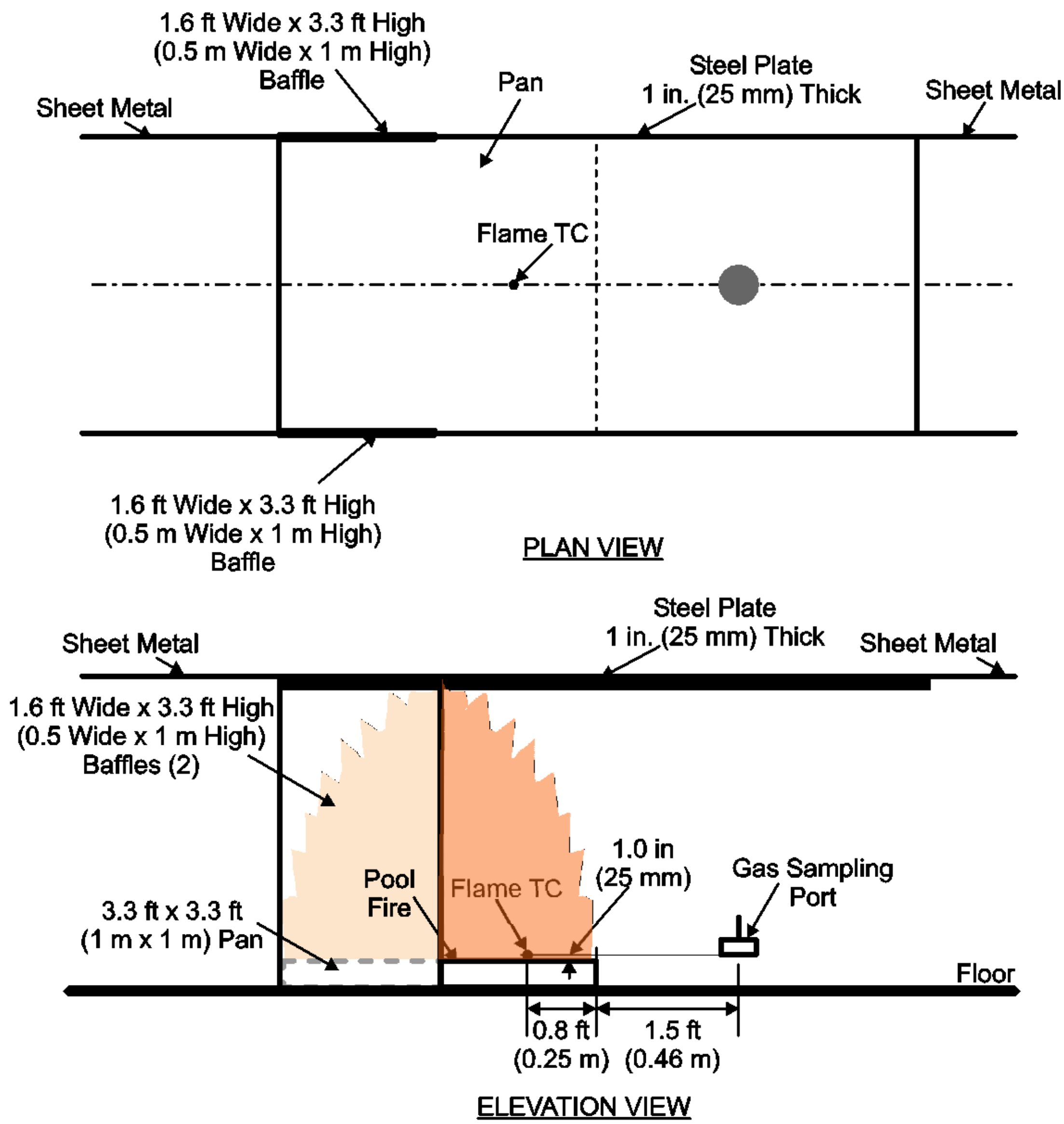


Figure B-3. Fire Source Configuration and Instrumentation for Shielded Pool Fire Testing

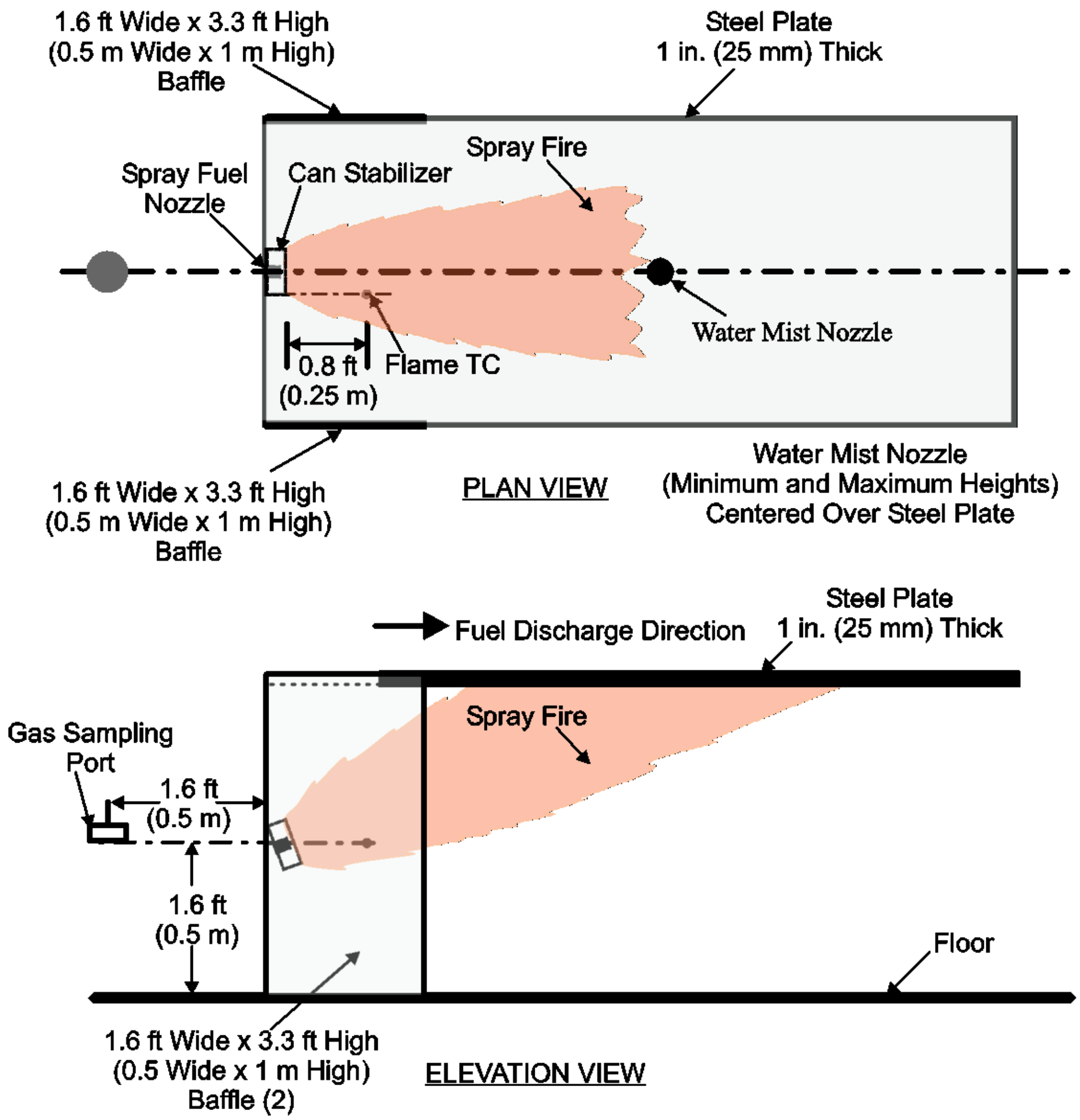


Figure B-4. Fire Source Configuration for Spray Cooling (No Fire) Testing

APPENDIX C: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF COMBUSTION TURBINES WITH VOLUMES EXCEEDING 9175 FT^3 (260 M^3)

C.1 Test Enclosure (see Figure C-1)

The maximum enclosure area (as specified by the manufacturer) shall be tested. Enclosures shall have equal length sides: however, rectangular areas will be considered. Ceiling heights shall be restricted to either 16.4 ft (5 m) or 24.6 ft (7.5 m). The enclosure shall be constructed of wood or metal frame with an inner lining of minimum 0.5 in. (13 mm) gypsum or 0.03 in. (0.7mm) galvanized steel. To minimize leakages, all joints and gaps shall be sealed. In addition, the testing organization can restrict the scope of the examination to a limited range of aspect ratios depending upon the outcome of the fire tests conducted in non-symmetric enclosures. 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 one wall, as shown in Figure C-1. A minimum of two hinged ceiling hatches measuring approximately 3 ft by 6 ft (0.91 m by 1.83 m) shall be installed in opposite diagonal corners for heat and smoke release after the conclusion of the fire test.

The combustion turbine and engine mockup unit will be centered in the test enclosure. In the case of rectangular enclosures, the testing organization reserves the right to alter the placement of the machinery mockup unit with respect to the aspect ratio of the enclosure.

At the sole discretion of the testing organization, additional fire tests in smaller enclosures can be performed to validate the manufacturer’s scaling parameters.

C.2.1 Combustion Turbine and Engine Mockup Unit (see Figures C-2 and C-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). Two 12 in. (0.3 m) 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.

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 surrounding the mockup with three trays, 21.5 ft^2, 21.5 ft^2 and 43.1 ft^2 by 0.8 ft high (2 m^2, 2 m^2, and 4 m^2 by 0.25 m high) equaling a total area of 86.1 ft^2 (8m^2), located underneath.

C.2.2 Combustion Turbine Spray Cooling Mockup Unit (see Figure C-5)

The combustion turbine spray cooling mockup is simulated with a horizontal flat steel plate and steel baffles (see Figure C-5). The specific details and thermal mass of the obstructions are not simulated.

The combustion turbine spray cooling mockup unit will be located along the longer length of the engine mockup solid shelf dimension and centered below a ceiling water mist nozzle in the test enclosure. The testing organization 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 39.5 in. by 79 in. 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 legs at the four corners of the steel plate. This is located as described above or at a location within the test cell [to be selected by the testing organization after the nozzles are installed (as per manufacturer's design criteria)]. This allows the fire to be placed in an area deemed to be the most challenging to the specific water mist 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 different depths.

To determine the cooling rate of the combustion turbine spray cooling steel plate mockup, caused by the discharge of the water mist system one thermocouple shall each be embedded near the center of the plate at approximately 0.47 in., 0.98 in. and 1.50 in., (12 mm, 25 mm and 38 mm) below the plate’s top surface. The three inconel-sheathed thermocouples shall be embedded in the plate by removing cylindrical plugs from the plate. The thermocouples shall 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 shall be applied, and the steel cylindrical plugs shall be replaced and welded to the plate around the top periphery of the plugs.

This can be accomplished by using a 1.0 in. (25.4 mm) diameter miller tool, installing the thermocouples, and then refilling the hole welded 1.0 in. (25.4 mm) round bar stock.

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 shall be of 22 gauge (0.85 mm) thick galvanized sheet metal construction and removable. They shall be installed on support legs and kept in place by being pinched between the underside of the steel plate table and the 45° angle extensions and the floor for ease of removal.

The enclosure, engine mockup and the steel plate shall initially be at ambient temperature for all tests.

C.3 Fire Tests

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 damaging deformation.

The water mist system, operating without manual intervention, shall successfully complete all eight (8), C.3.1 through C.3.8, and the spray cooling-heat transfer test, C.3.11. An additional option for combustion turbine applications is to protect insulated turbines. Two additional fire tests, C.3.9 and C.3.10 (involving insulation mats of mineral wool composition) are required for this application extension. During the fire tests, all systems shall operate without manual intervention.

Agent supply needed for 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 1.7, Definitions). For primary protection, agent supply shall be equivalent to that required for an automatic sprinkler protection system for the hazard protected.

C.3.1 Low Pressure, Exposed, Diesel Spray Fire

Criterion: Extinguishment of the spray fire

Fuel: Low pressure diesel fuel
Type: Horizontal spray
Spray Nozzle: Wide spray angle (120 to 125°), full cone
Oil Pressure: 120 psi (825 kPa) (nominal)
Oil Flow Rate: 0.07 lb/s (0.16 kg/s) (nominal)
Fire Size: 6 MW (nominal)
Fire Location: On top of the machinery mockup unit

C.3.2 Low Pressure, Angled, Diesel Spray Fire

Criterion: Extinguishment of the spray fire

Fuel: Low pressure diesel fuel
Type: Horizontal spray, nozzle at 45° relative to the top plane of the machinery mockup unit, such that the spray strikes a 0.5 in. (13 mm) diameter rod, 3 ft 3 in. (1 m) from the nozzle (Reference Figure C-4)
Spray Nozzle: Wide spray angle (120 to 125°), full cone
Oil Pressure: 120 psi (825 kPa) (nominal)
Oil Flow Rate: 0.07 lb/s (0.16 kg/s) (nominal)
Fire Size: 6 MW (nominal)
Fire Location: On top of the machinery mockup unit

C.3.3 Low Pressure, Concealed, Diesel Spray Fire

Criterion: Extinguishment of the spray fire

Fuel: Low pressure diesel fuel
Type: Horizontal spray
Spray Nozzle: Wide spray angle (120 to 125°), full cone
Oil Pressure: 120 psi (825 kPa) (nominal)
Oil Flow Rate: 0.07 lb/s (0.16 kg/s) (nominal)
Fire Size: 6 MW (nominal)
Fire Location: Located under the shelf with the nozzle 4 in. (0.1 m) from the end of the machinery mockup unit

C.3.4 High Pressure Diesel Spray

Criterion: Extinguishment of the spray fire

Fuel: High pressure diesel fuel
Type: Horizontal spray
Spray Nozzle: Standard spray angle (at 90 psi), full cone
Oil Pressure: 2200 psi (15.2 MPa) (nominal)
Oil Flow Rate: 0.02 lb/s (0.05 kg/s) (nominal)
Fire Size: 2 MW (nominal)
Fire Location: On top of the machinery mockup unit

C.3.5 Low Pressure, Concealed, Diesel Spray and Pool Fires

Criterion: Extinguishment of the spray fire and suppression of the pool fire

Fuel: Low pressure diesel fuel (spray) / diesel fuel (pool)
Type: Horizontal spray and 1 ft^2 (0.1 m^2) pool fire
Spray Nozzle: Wide spray angle (80°), full cone
Oil Pressure: 125 psi (860 kPa) (nominal)
Oil Flow Rate: 0.01 lb/s (0.03 kg/s) (nominal)
Fire Size: 1 MW (nominal)
Fire Location: Spray fire located under the shelf with the nozzle 4 in. (0.1 m) from the end of the machinery mockup unit. Pool fire located 4 ft 7 in. (1.4 m) from the end of the machinery mockup unit.

C.3.6 Concealed, Heptane Pool Fire

Criterion: Suppression of the pool fire

Fuel: Heptane
Type: 8.7 ft^2 (0.81 m^2) pool fire
Fire Size: 2.4 MW (nominal)
Fire Location: Centered under the shelf

C.3.7 Flowing Fire

Criterion:	Extinguishment of the fire
Fuel:	Heptane
Type:	Flowing
Fuel Flow Rate:	0.11 lb/s (0.25 kg/s) (nominal)
Fire Size:	28 MW (nominal)
Ignition:	Should occur as the mockup top tray just begins to overflow with fuel and pour down the vertical side of the mockup.

C.3.8 Crib 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)
Fire Location:	The crib is in a 21.5 ft^2 (2 m^2) pool with the fuel level up to half its height. The pan is located 2.5 ft (0.75 m) off the floor.

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 shall not exceed 5 percent prior to the fire test.

C.3.9 Saturated Insulation Mat and Spray Fire (Optional Test)

Criteria: Extinguishment of the spray fire and suppression of the insulation mat fire

A 1 ft^2 (0.1 m^2) insulation mat of mineral wool composition shall be saturated with diesel fuel and placed in a 1 ft^2 (0.1 m^2) pan. When slightly depressing the mat, a liquid fuel pool shall occur. The pan with mat is to be ignited under a spray fire identical to that used in Fire Test C.3.5.

C.3.10 Saturated Insulation Mat Fire (Optional Test)

Criteria: Suppression (only flamlets on surface of the insulation mat) of the insulation mat fire

An 11 ft^2 (1 m^2) insulation mat of mineral wool composition shall be saturated with diesel fuel and placed in an 11 ft^2 (1.0 m^2) pan. When slightly depressing the mat, a liquid fuel pool shall occur. The pan with mat is to be ignited in a position identical to the pool fire used in Fire Test C.3.6.

C.3.11 Spray Cooling (No Fire)

Criteria: Determine if the heat flux resulting from a water mist system discharge will adversely affect the turbine. Such assessment is to be made in accordance with methodology developed by the testing organization to assess the damage potential of water mist systems being tested. This test, combined with the applicable NRTL heat transfer calculations, will determine the extent of the cooling of the turbine casing during the operation of the water mist system. Calculations will be based on the manufacturer's recommended diameter sized turbines to be installed within the enclosure.

A spray fire will be necessary to heat the steel plate. The spray fire will be located between the baffles underneath the test table with the fuel spray nozzle aimed at the table at a 30º grazing angle with the flames centered and impinging on the steel table mid point. When all three steel plate thermocouples reach 572 ºF (300 ºC), the spray fire will be shut off, and the steel plate will be allowed to cool. To avoid excess heating of the test enclosure, the ceiling hatches and the access door shall be left open only during the heating of the plate. When the last of three thermocouple readings drops to 572 ºF (300 ºC), then the water mist system will be activated and the temperature history of the plate will be recorded for a total of 15 minutes.

The spray cooling test shall have the available recorded data in Microsoft Excel format. The data will be reviewed by appropriate NRTL for the heat transfer calculation analysis. 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.

The heat flux is also affected by the stand-off distance of the water mist nozzles. The testing organization will conduct this test at the minimum and maximum nozzle stand-off distance specified in the client's design manual. (The design manual shall also specify no direct spray impingement).

C.3.12 Additional Fire Test

Based on the results of Fire Tests C.3.1 through C.3.11, additional fire testing can 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 testing organization.

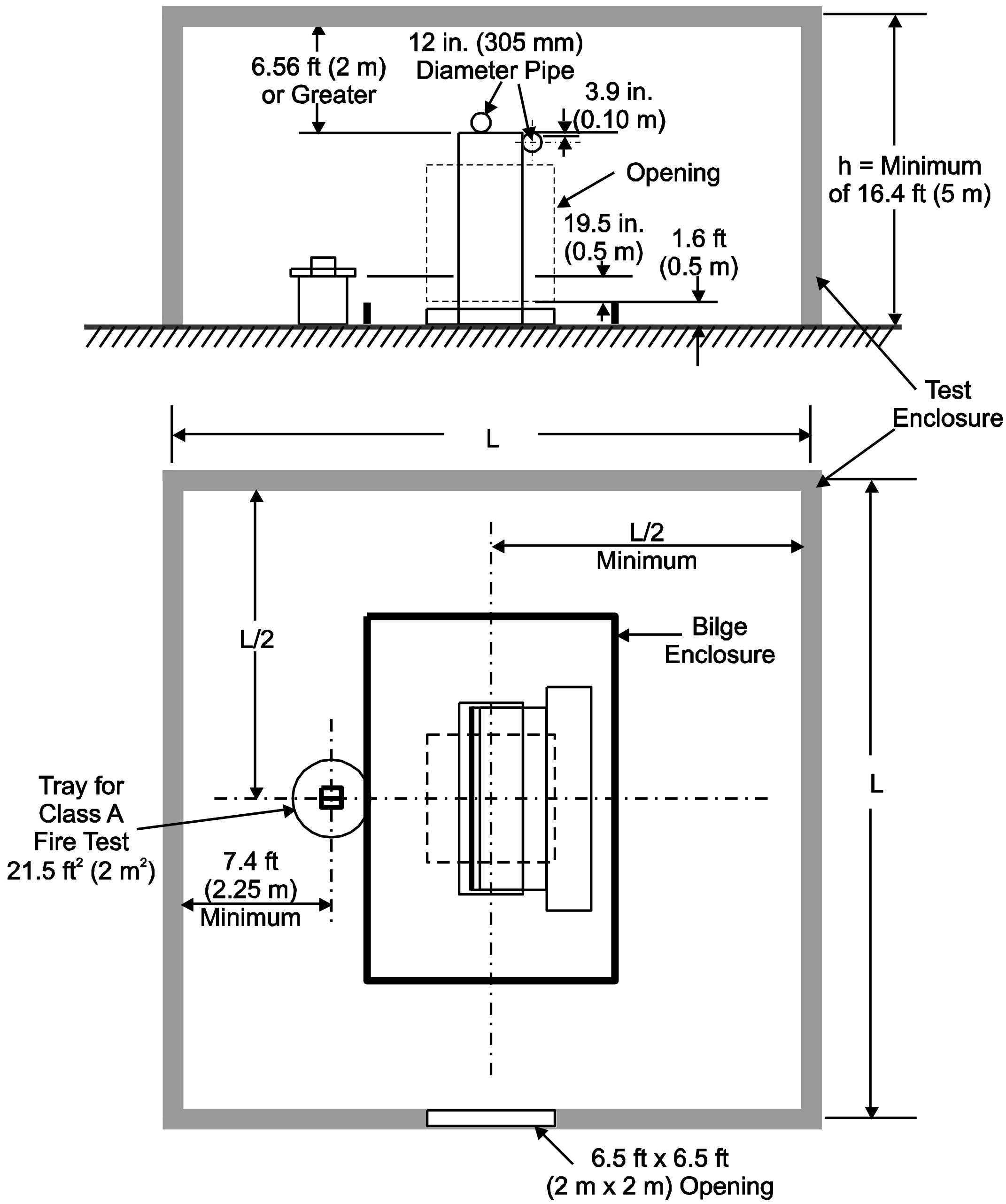


Figure C-1. Machinery and Combustion Turbine Test Enclosure

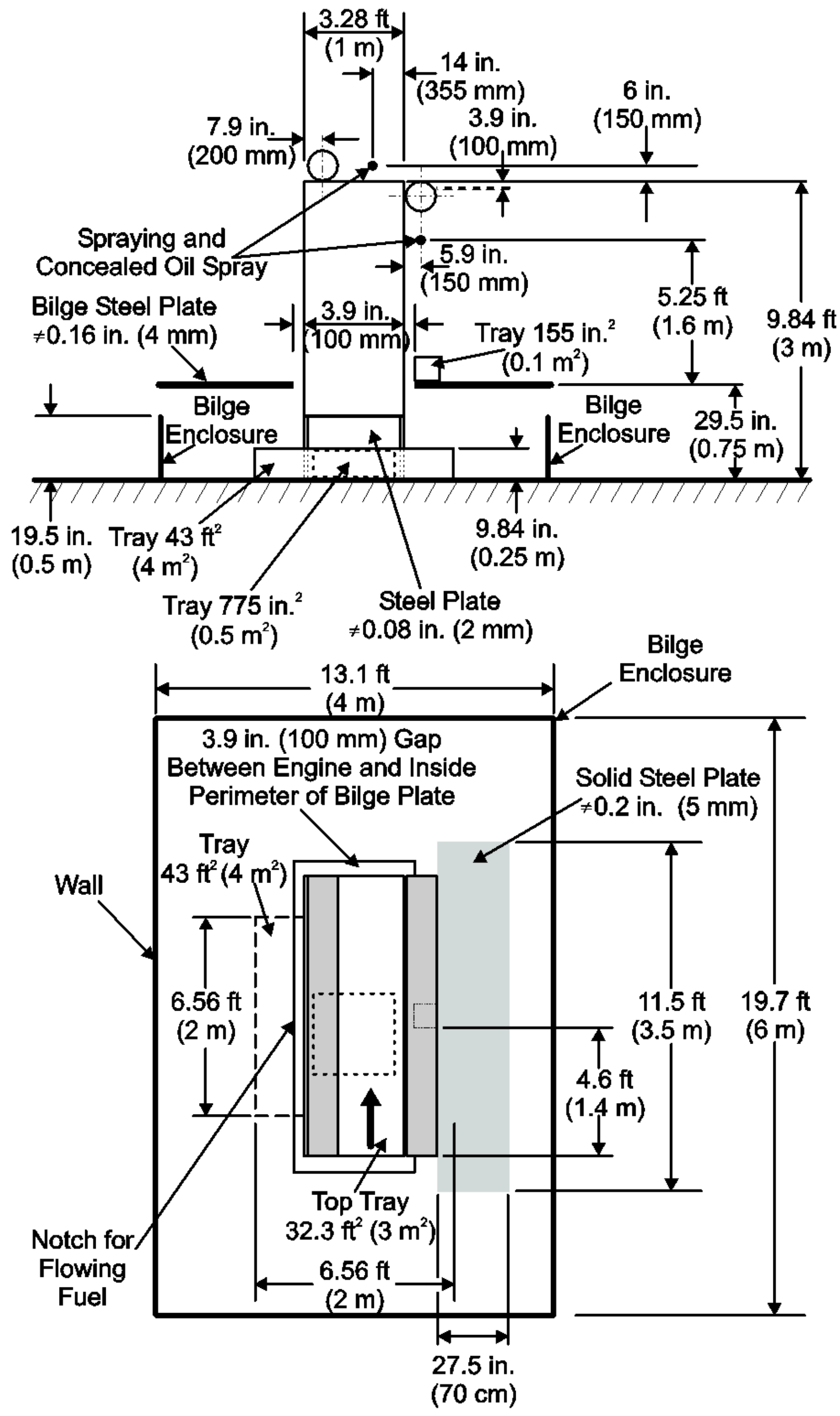


Figure C-2. Machinery and Combustion Turbine Mockup Unit

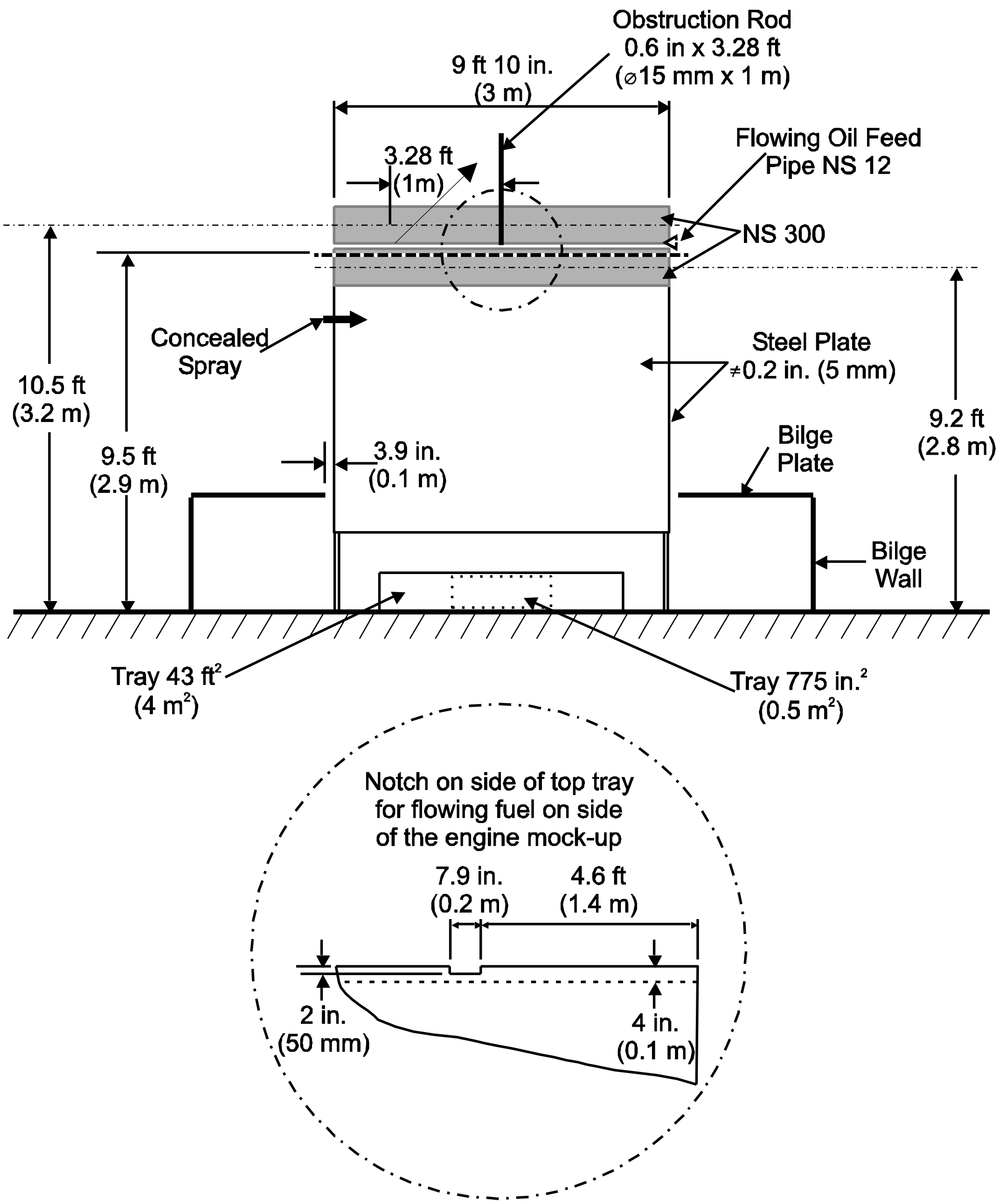


Figure C-3. Machinery and Combustion Turbine Mockup Unit (continued)

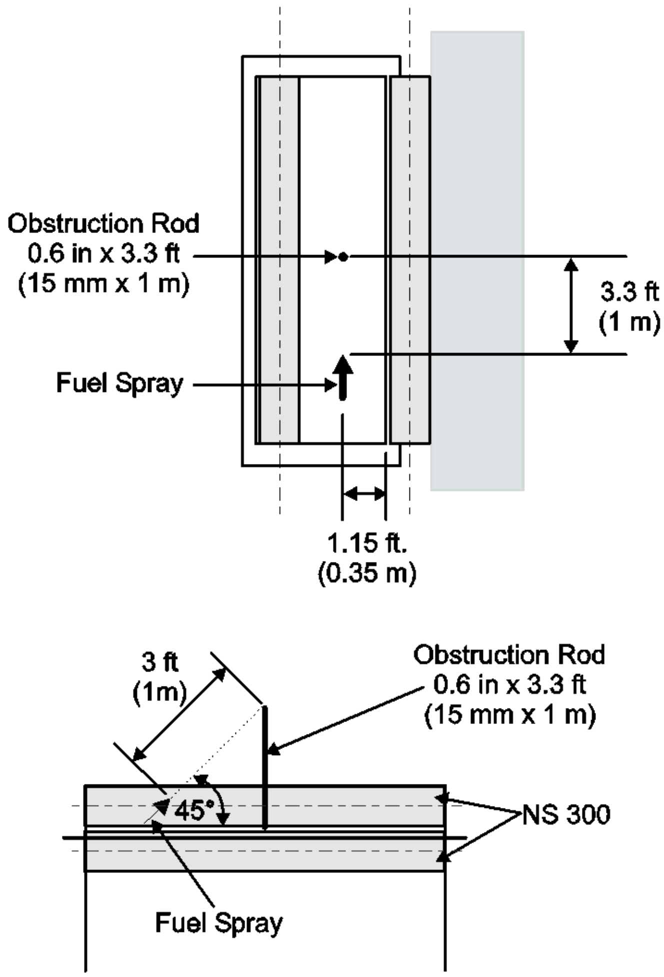


Figure C-4. Fire Test C-3-2, Position of Fuel Spray Nozzle and Obstruction Rod

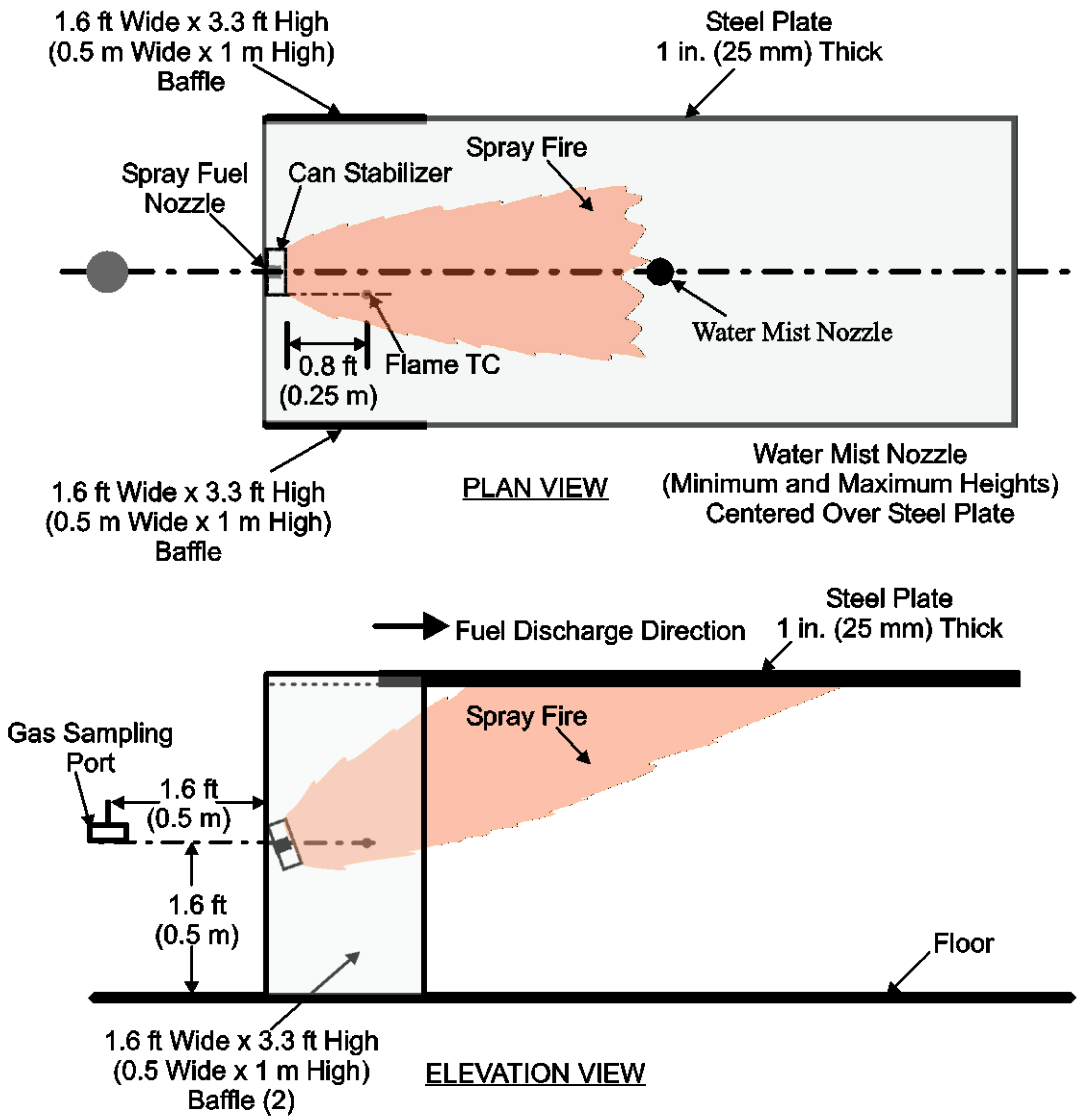


Figure C-5. Fire Source Configuration for Spray Cooling (No Fire) Testing

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

D.1 General Testing Requirements

A. For the ventilated subsurface (plenum) tests;

1. The wet bench mockup shall be installed in the testing organization simulated clean room facility. (See Figures D-1 through D-8)

2. The air flow of the open face wet bench shall be the maximum air flow as specified by the manufacturer. The minimum permitted air flow shall be 150 ft^3/min/linear ft (14 m^3/min/linear m).

3. Higher flow rates shall be in 50 ft^3/min/linear ft (4.5 m^3/min/linear m) increments.

4. The solid polypropylene fuel shall be a combination of polypropylene beads and polypropylene coupons (See Figure D-8).

5. The ignitable liquids shall consist of Acetone, Isopropyl Alcohol (IPA), and Heptane.

B. The working surface protection water mist system shall be installed as specified in the manufacturer's design manual for surface protection. (See Figures D-1 through D-4 and D-7)

1. Fire tests shall be conducted 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 system.

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

C. Instrumentation for the wet bench fire testing shall include six thermocouples, five turbidimeters, a load cell, a video and thermal imaging camera. Of the six thermocouples, one shall record the temperature history around the water mist nozzle, one thermocouple shall be placed near the fire source, and the remaining thermocouples shall be located in the mid-plenum, the right end of the plenum (from front view), the exhaust duct, and under the floor of the simulation room. The turbidimeters shall be placed in the plenum, on the surface area of the wet bench, on the floor of the simulation room, under the floor and in the exhaust duct. The turbidimeters shall be for measurement of the particulate density in the fire environment. The load cell shall have a capacity of 2.0 lb (0.91 kg) and shall be used to monitor the fuel mass loss in all fire tests.

D. The testing organization simulated clean room facility shall be at an ambient temperature of 68°F ± 18°F (20°C ± 10°C) prior to the start of the test. 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.

E. All fuels shall be at an ambient temperature of 68°F ± 18°F (20°C ± 10°C).

D.2 Ventilated Subsurface (Plenum) Fire Tests (See Figures D-3, D-5 and D-6)

D.2.1 Nominal 4 in. (102 mm) Diameter Polypropylene Pool Fire

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

A nominal 4 in. (102 mm) diameter dish of solid polypropylene fuel shall be placed within the subsurface space at a location chosen by the testing organization. The fuel shall be ignited and allowed to reach a steady state condition. For systems using open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn.

D.2.2 Nominal 6 in. (152 mm) Diameter Polypropylene Pool Fire

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

A nominal 6 in. (152 mm) diameter dish of solid polypropylene fuel shall be placed within the subsurface space at a location chosen by the testing organization. The fuel shall be ignited and allowed to reach a steady state condition. For systems using open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn.

D.2.3 Nominal 8 in. (203 mm) Diameter Polypropylene Pool Fire

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

A nominal 8 in. (203 mm) diameter dish of solid polypropylene fuel shall be placed within the subsurface space at a location chosen by the testing organization. The fuel shall be ignited and allowed to reach a steady state condition. For systems using open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn.

D.2.4 Nominal 10 in. (254 mm) Diameter Polypropylene Pool Fire

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

A nominal 10 in. (254 mm) diameter dish of solid polypropylene fuel shall be placed within the subsurface space at a location chosen by the testing organization. The fuel shall be ignited and allowed to reach a steady state condition. For systems using open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn.

D.2.5 Nominal 12 in. (305 mm) Diameter Polypropylene Pool Fire

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

A nominal 12 in.(305 mm) diameter dish of solid polypropylene fuel shall be placed within the subsurface space at a location chosen by the testing organization. The fuel shall be ignited and allowed to reach a steady state condition. For systems using open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn.

D.2.6 Ignitable Liquid Pool Fires

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

A series of ignitable liquid fuel pool fires shall be placed in the wet bench subsurface space using a pan size and location chosen by the testing organization. (Multiple pan sizes and locations can be tested at the sole discretion of testing organization.) The fuel shall be ignited and allowed to reach a steady state condition. For systems utilizing open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn. At a minimum, the ignitable 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 D.2.6 Ignitable 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)

D.2.7 Polypropylene Pool Fire Utilizing a Single Nozzle in a Ventilated Subsurface Space

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

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 polypropylene pool fire (pan size and location selected by the testing organization) shall be placed within the enclosure. Suitable barriers (simulating actual obstructions) shall be placed within the space to prevent the nozzle discharge from directly impacting the fire (See Figure D-5). The fuel shall be ignited and allowed to reach a steady state condition. For systems using open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn.

D.2.8 Ignitable Liquid Pool Fire Utilizing a Single Nozzle in a Ventilated Subsurface Space

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

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 ignitable liquid pool fire (fuel, pan size, and location selected by the testing organization) shall be placed within the enclosure. Suitable barriers (simulating actual obstructions) shall be placed within the space to prevent the nozzle discharge from directly impacting the fire (See Figure D-5). The fuel shall be ignited and allowed to reach a steady state condition. For systems using open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn.

D.2.9 Other Ventilated Subsurface Fire Tests

Based on the results of the ventilated subsurface tests, additional testing can be required. The testing organization 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 testing organization, fires tests can be repeated to determine the adequacy and/or limitations of the fire protection system.

D.3 Wet Bench Working Surface Fire Tests (See Figures D-1 through D-4 and D-7)

D.3.1 Nominal 4 in. (102 mm) Diameter Polypropylene Pool Fire

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

A nominal 4 in. (102 mm) diameter dish of solid polypropylene fuel shall be placed on the wet bench surface at a location chosen by the testing organization. The fuel shall be ignited and allowed to reach a steady state condition. For systems using open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn.

D.3.2 Nominal 6 in. (152 mm) Diameter Polypropylene Pool Fire

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

A nominal 6 in. (152 mm) diameter dish of solid polypropylene fuel shall be placed on the wet bench surface at a location chosen by the testing organization. The fuel shall be ignited and allowed to reach a steady state condition. For systems using open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn.

D.3.3 Nominal 8 in. (203 mm) Diameter Polypropylene Pool Fire

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

A nominal 8 in. (203 mm) diameter dish of solid polypropylene fuel shall be placed on the wet bench surface at a location chosen by the testing organization. The fuel shall be ignited and allowed to reach a steady state condition. For systems using open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn.

D.3.4 Nominal 10 in. (254 mm) Diameter Polypropylene Pool Fire

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

A nominal 10 in. (254 mm) diameter dish of solid polypropylene fuel shall be placed on the wet bench surface at a location chosen by the testing organization. The fuel shall be ignited and allowed to reach a steady state condition. For systems using open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn.

D.3.5 Nominal 12 in. (305 mm) Diameter Polypropylene Pool Fire

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

A nominal 12 in. (305 mm) diameter dish of solid polypropylene fuel shall be placed on the wet bench surface at a location chosen by the testing organization. The fuel shall be ignited and allowed to reach a steady state condition. For systems using open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn.

D.3.6 Ignitable Liquid Pool Fires

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

A series of ignitable liquid fuel pool fires shall be placed on the working surface utilizing a pan size and location chosen by the testing organization. (Multiple pan sizes and locations can be tested at the sole discretion of the testing organization.) The fuel shall be ignited and allowed to reach a steady state condition. For systems using open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn. At a minimum, the ignitable 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 properties:

Table D.3.6 Ignitable 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)

D.3.7 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.

A nominal 12 in. (305 mm) diameter pan containing approximately 0.75 in. (19 mm) deep colored liquid [with a 0.5 in. (13 mm) freeboard] shall be placed directly under a single open nozzle. [Note: At the sole discretion of the testing organization, this test can be conducted using multiple nozzles if the testing organization deems 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 manufacturers' design. The maximum flow rate or system pressure shall be used.

D.3.8 Other Working Surface Fire Tests

Based on the results of the working surface tests, additional testing can be required. The testing organization 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 testing organization, fires tests can be repeated to determine the adequacy and/or limitations of the fire protection system.

D.4 Unventilated Spaces Fire Tests

D.4.1 Polypropylene Pool Fire Utilizing a Single Nozzle in an Unventilated Space

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

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 polypropylene pool fire (pan size and location selected by the testing organization) shall be placed within the enclosure. Suitable barriers (simulating actual obstructions) shall be placed within the space to prevent the nozzle discharge from directly impacting the fire (See Figure D-5). The fuel shall be ignited and allowed to reach a steady state condition. For systems using open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn.

D.4.2 Ignitable Liquid Pool Fire Utilizing a Single Nozzle in an Unventilated Space

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

In order to determine the effectiveness of a single nozzle, one nozzle shall be installed in the largest unventilated space specified by the manufacturer. An ignitable liquid pool fire (fuel, pan size, and location selected by the testing organization) shall be placed within the enclosure. Suitable barriers (simulating actual obstructions) shall be placed within the space to prevent the nozzle discharge from directly impacting the fire (See Figure D-5). The fuel shall be ignited and allowed to reach a steady state condition. For systems using open nozzles with detector initiated water mist release, the detector(s) shall be deactivated and the water mist system shall be manually activated after a 30 second preburn.

D.4.3 Other Unventilated Space Fire Tests

Based on the results of the unventilated space fire tests, additional testing can be required. The testing organization 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 testing organization, fires tests can be repeated to determine the adequacy and/or limitations of the fire protection system.

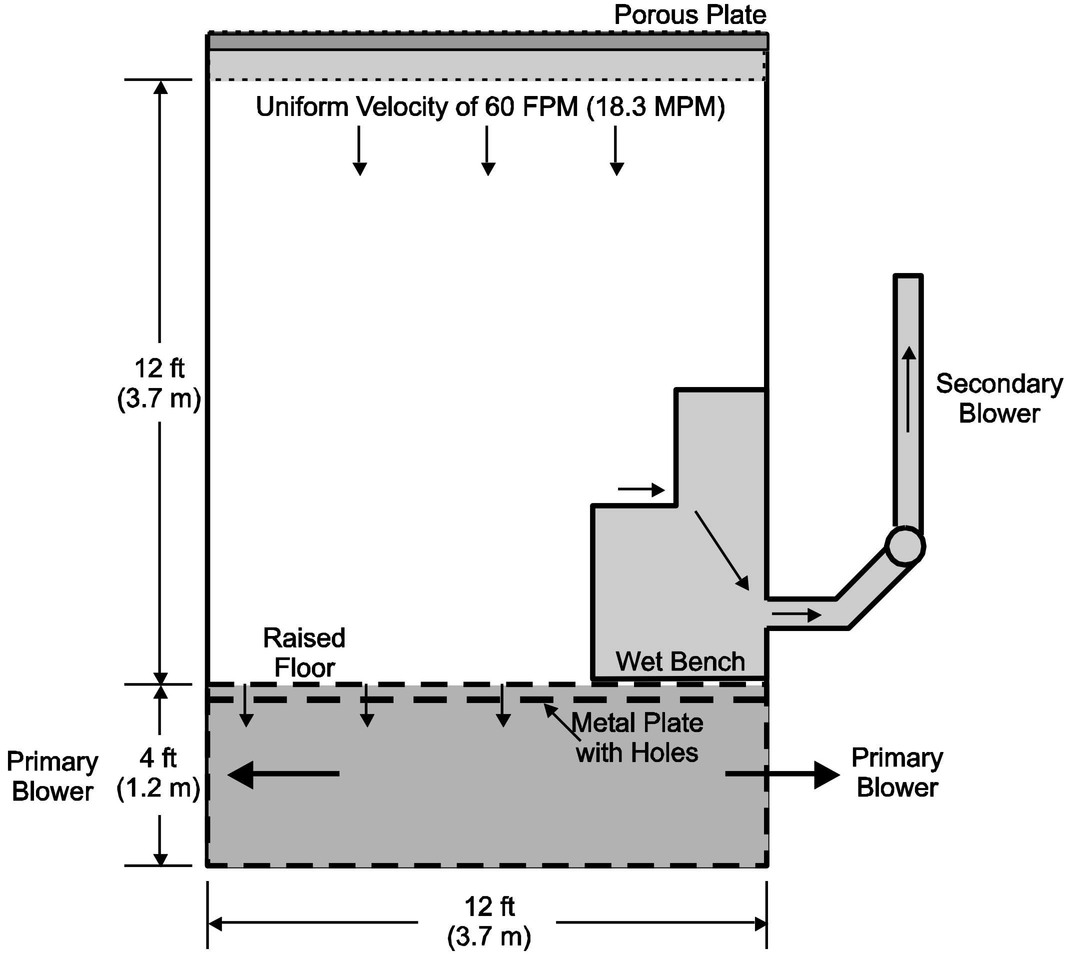


Figure D-1. Clean Room Simulation Facility - Side View

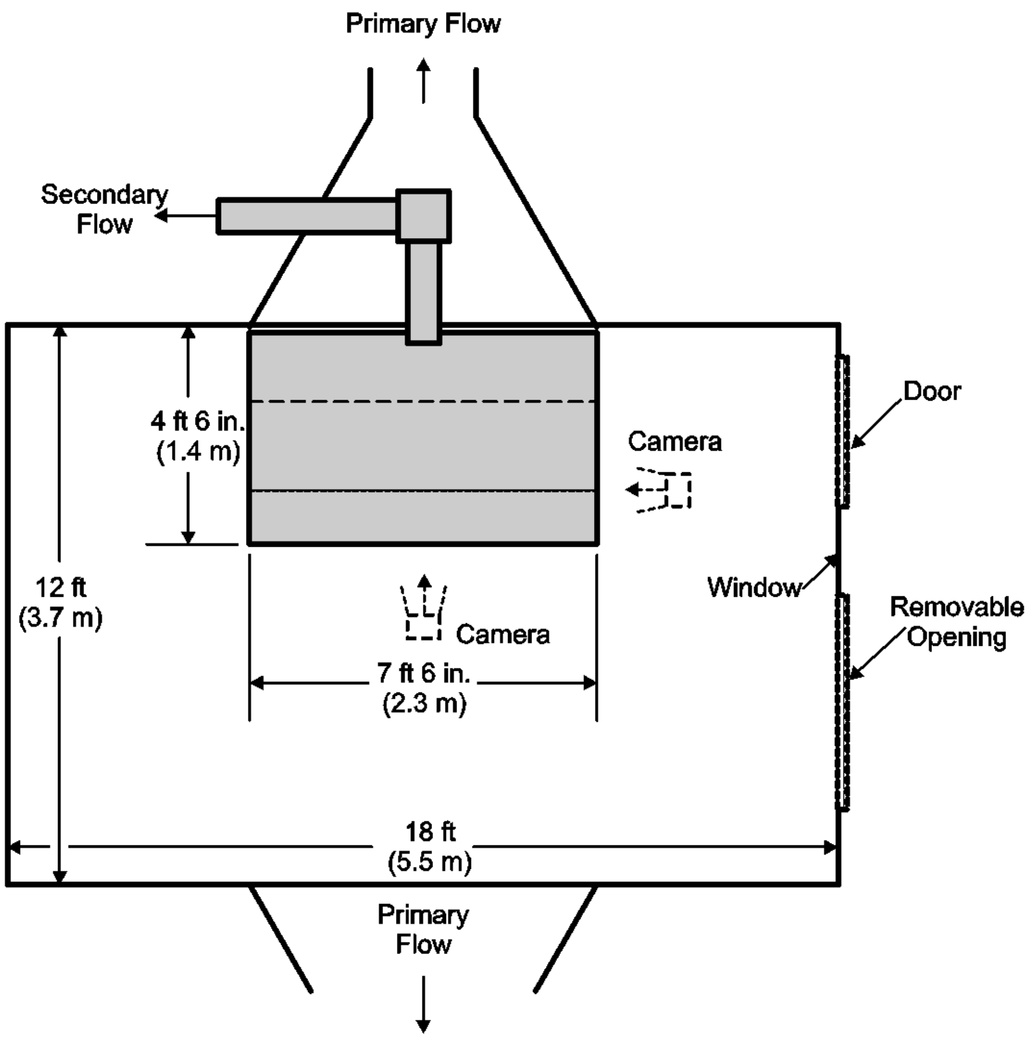


Figure D-2. Clean Room Simulation Facility - Top View

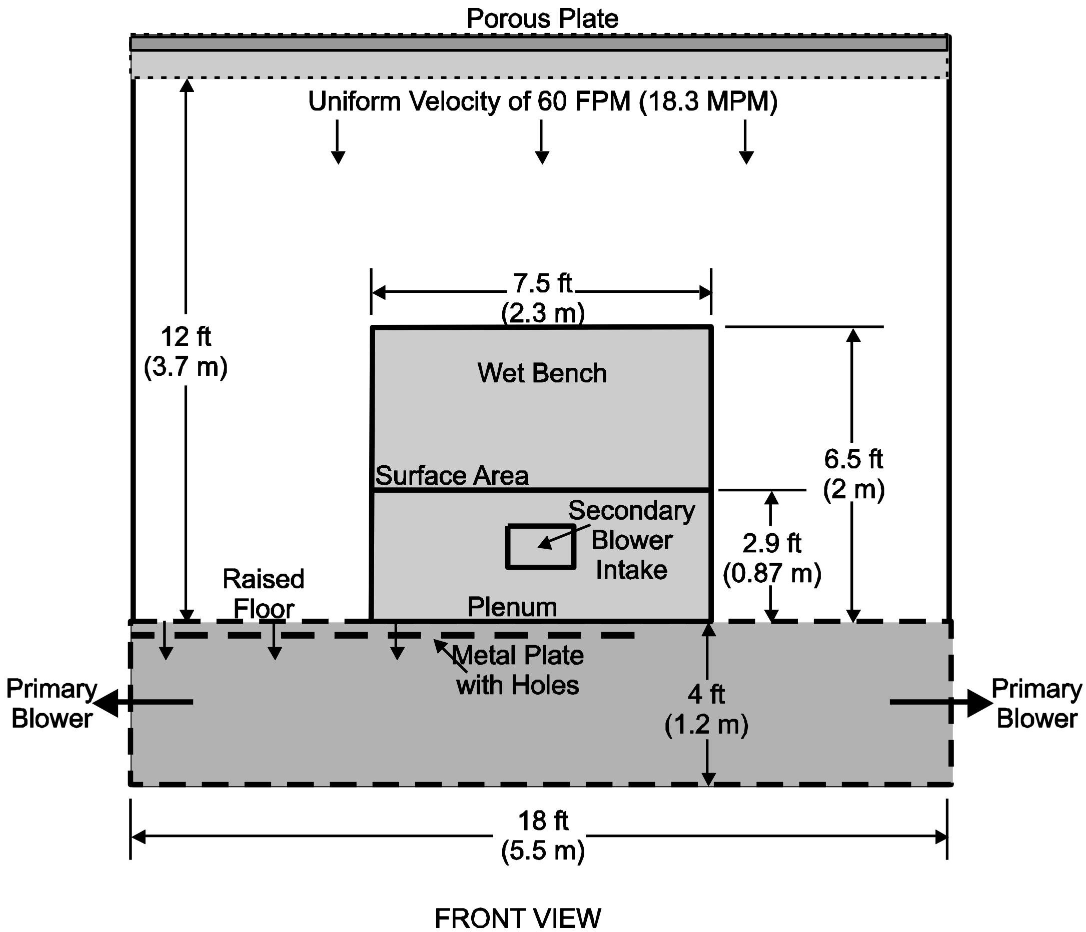


Figure D-3. Clean Room Simulation Facility - Front View

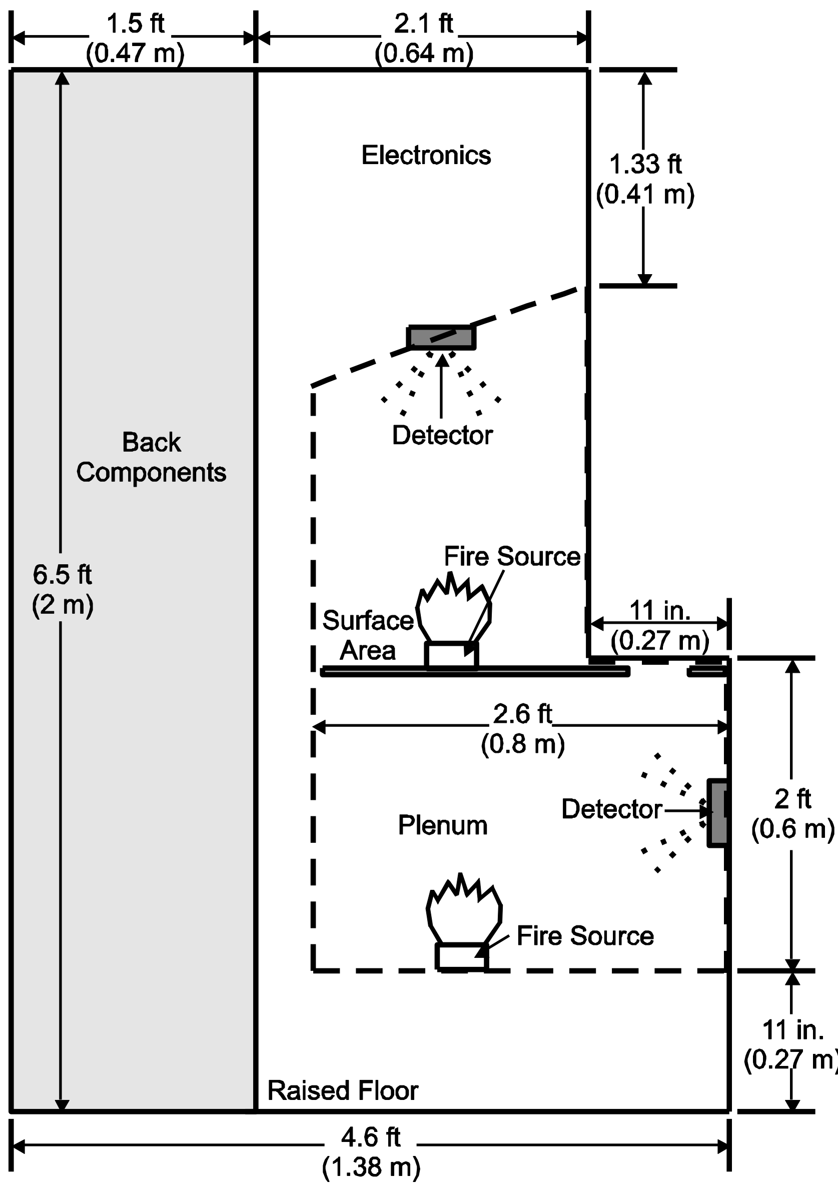


Figure D-4. Wet Bench Test Apparatus - Side View

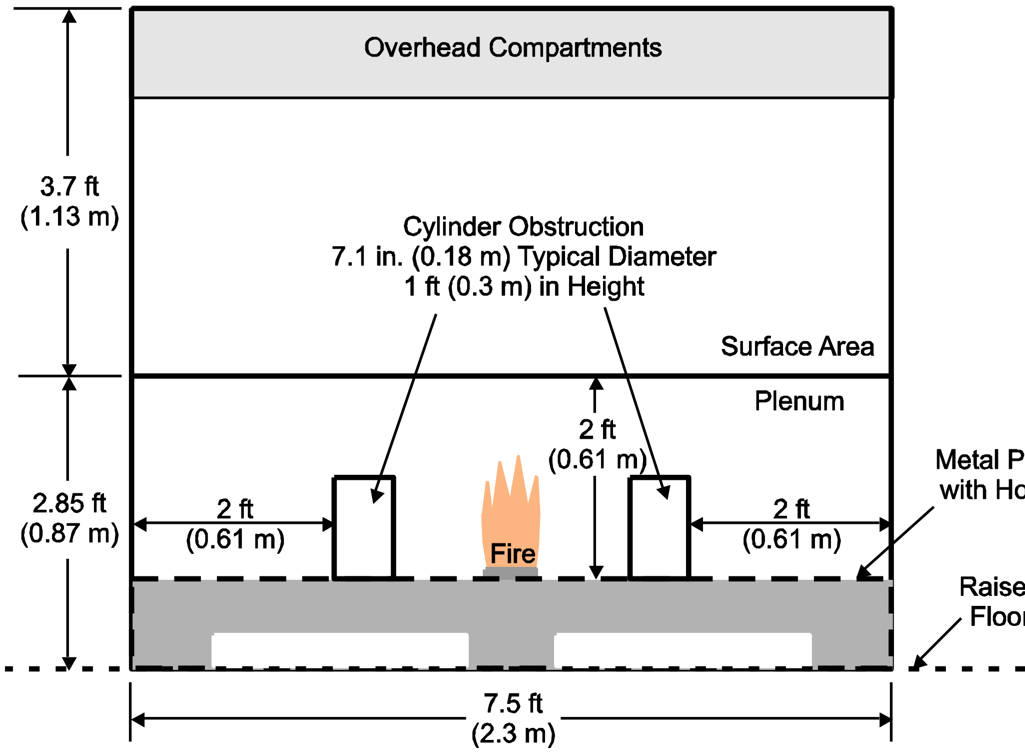


Figure D-5. Wet Bench Test Apparatus for Plenum Fire Subsurface Testing with Obstructions - Front View

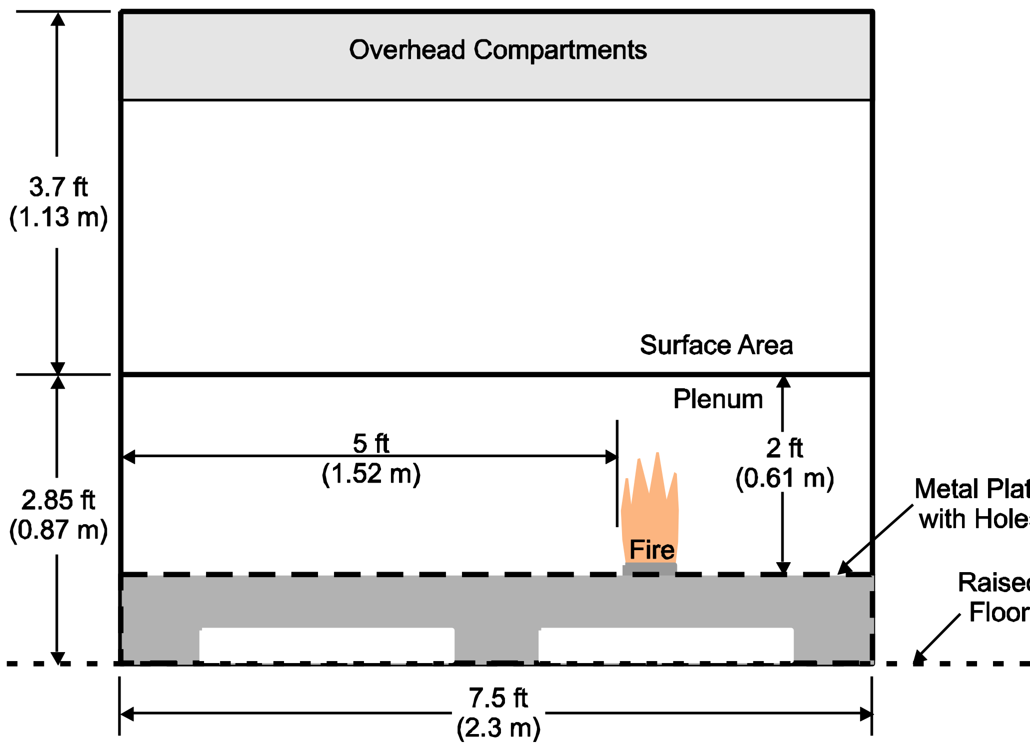


Figure D-6. Wet Bench Test Apparatus for Plenum Fire Subsurface Testing without Obstructions - Front View

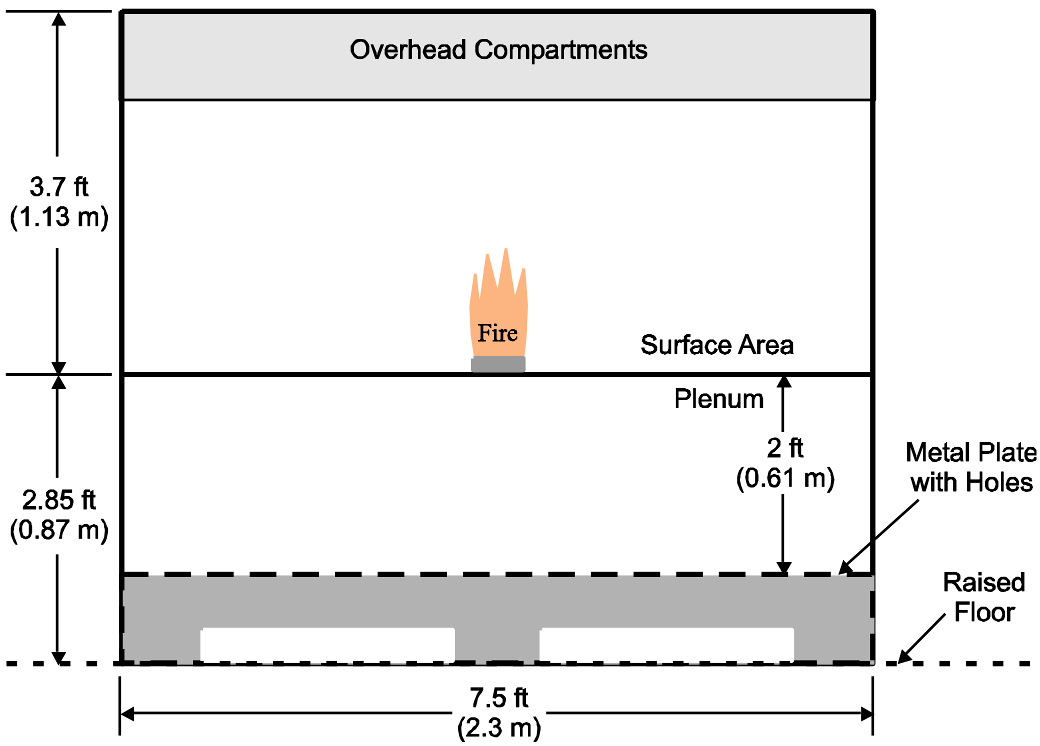


Figure D-7. Wet Bench Test Apparatus for Surface Area Fire Testing - Front View

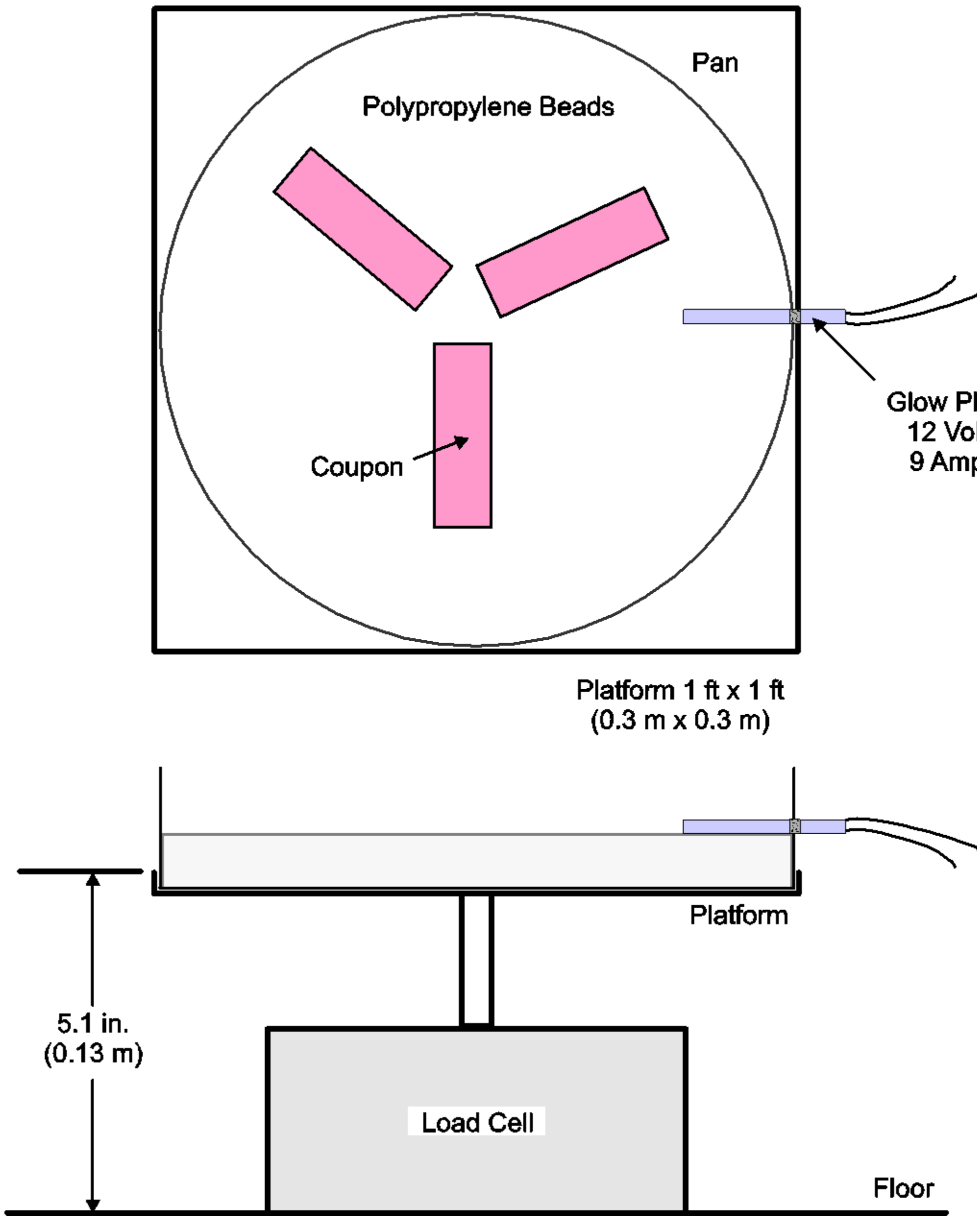


Figure D-8. Polypropylene Pool Fire for Wet Bench Fire Testing

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

E.1 General Testing Requirements

The examination criteria for the fire tests are as follows:

A. The water mist system shall be capable of extinguishing all seven of the fire scenarios in this appendix. For each fire scenario, 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. Sprays shall be continuous or intermittent in time in accordance with Section L under the Requirements for all Appendix Fire Testing.

B. The fire tests shall be conducted in a large open test hall, greater than 17,657 ft^3 (500 m^3) in area with a minimum ceiling height of 16.4 ft (5.0 m). Ventilation for between tests and cooling of the enclosure shall be provided by a minimum of two 10 ft^2 (0.93 m^2) louver vents located on the roof of test hall and a side wall doorway measuring at least 12 ft by 14 ft (3.66 m by 4.26 m) to be left partially open during fire testing for an minimum area of 12 ft by 6 ft (3.66 m x 1.82 m) with protection by baffles, if necessary, from outside winds.

C. The water mist system shall be manually activated after the designated preburn time.

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

E. For the Fire Scenarios E.3.3, E.3.4 and E.3.7, the fuel spray nozzle for the 6 MW spray fire is as specified in the Fire Performance Testing Requirements, General Instrumentation and Test Equipment Requirements, Section R.

E.2 Instrumentation

Oxygen is to be measured 4 in. (100 mm) behind and below the spray fire nozzle, and 6.6 ft. to 9.8 ft. (2 m to 3 m) from, and at the elevation of, the rim of the pan pool fires, and away from any open doorways or ventilation sources. Ventilation rates shall be monitored and recorded if constantly provided for the enclosure.

E.3 Fire Scenarios and Test Configurations

E.3.1 Square Diesel Pool Fires

Pool size: X by X, 2X by 2X, and 3X by 3X where X is specified by the water mist system manufacturer.

General system specifications (see Figure E-1):

A. The nozzles shall be in a uniform grid pattern above the pool.
B. 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.
C. The nozzle grid elevation above the pool shall remain constant for all pool sizes.
D. The ratio of spray coverage area versus pool area shall remain constant.
E. The ratio of the total spray coverage area on the pool surface elevation versus the pool area shall be constant.

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

Pass/Fail 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.

Fire Test E.3.1.1: X by X pool maximum nozzle height

Fire Test E.3.1.2: 2X by 2X pool maximum nozzle height

Fire Test E.3.1.3: 3X by 3X pool maximum nozzle height

Fire Test E.3.1.4: 3X by 3X pool minimum nozzle height

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 E.3.1.

E.3.2 Channel Diesel Pool Fires

Pool size: 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 E-2):

A. The nozzles shall be located along the two opposite sides of the channel.
B. The ratio of total number of nozzles versus the channel area shall remain constant. (i.e., two nozzles for the Y by Y channel, four nozzles for the Y by 2Y channel, six nozzles for the Y by 3Y channel.
C. The nozzle elevation above the channel shall remain constant for all channel sizes.
D. The ratio of spray coverage area versus channel area shall remain constant.

Preburn Time: 30 seconds after the fire is fully developed in the channel.

Pass/Fail 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.

Fire Test E.3.2.1: Y by Y channel maximum nozzle height

Fire Test E.3.2.2: Y by 2Y channel maximum nozzle height

Fire Test E.3.2.3: Y by 3Y channel maximum nozzle height

Fire Test E.3.2.4: Y by 3Y channel minimum nozzle height

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 E.3.2.

E.3.3 Heptane Spray Fire

Fire size: A single 6 MW spray fire.

Preburn Time: 15 seconds after the Heptane spray is ignited.

Pass/Fail Criteria: The fire is to be extinguished.

The tests will be conducted with the Heptane spray axis oriented horizontally and vertically (See Figure E-3).

Fire Test E.3.3.1: horizontal spray maximum nozzle height

Fire Test E.3.3.2: horizontal spray minimum nozzle height

Fire Test E.3.3.3: vertical spray maximum nozzle height

Fire Test E.3.3.4: vertical spray minimum nozzle height

Each test shall be repeated for a total of eight tests for Fire Scenario E.3.3.

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

Spray fire nozzle tip arrangement above the pool surface:

A. Pointed horizontally and centered 3.3 ft (1.0 m) above the pool (See Figure E-4).
B. Pointed 45° from horizontal and centered 3.3 ft (1.0 m) above the pool (See Figure E-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 E-6).
D. Pointed 45° from 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 E-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 E-8).

Water mist system configuration: Identical to that for the 2X by 2X square diesel pool. (Fire test scenario E.3.1.)

Preburn Time: Fifteen seconds after the flames have spread to the entire pool area; the diesel spray above the pool surface is initiated and ignited. Fifteen seconds later, the water mist system is activated.

Pass/Fail Criteria: Both the pool fire and the spray fire are to be extinguished.

Test E.3.4.1: as described in A above maximum nozzle height

Test E.3.4.2: as described in B above maximum nozzle height

Test E.3.4.3: as described in C above maximum nozzle height

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

Test E.3.4.5: as described in E above maximum nozzle height

Each test shall be repeated for a total of ten tests for Fire Scenario E.3.4.

E.3.5 Obstructed 3X by 3X Square Diesel Pool Fire

Obstruction: An empty closed-top-and-bottom metal drum,* 55 gal. (208 L) in capacity, 2 ft diameter by 3 ft high (0.6 m by 0.9 m) of standard 0.05 in. (1.27 mm) nominal thickness, is placed 1.6 ft (0.50 m) over the center of the pool. The drum shall be mounted on steel legs (See Figure E-9).

* Small ventilation holes are to be dispersed in the side of the drum to prevent over pressurization of the drum.

Water mist system configuration: Identical to that for the 3X by 3X square diesel pool. (Fire test scenario E.3.1.)

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

Pass/Fail Criteria: The fire is to be extinguished.

Test E.3.5.1: maximum nozzle height

Test E.3.5.2: minimum nozzle height

Each test shall be repeated for a total of four tests for Fire Scenario E.3.5.

E.3.6 Offset X by X Square Diesel Pool Fire

Water mist system configuration: Identical to that for the 2X by 2X square diesel pool. (Fire test scenario E.3.1. See Figure E-1).

Fire location: To be placed at the location with the least mist flux in the protected area as determined by the testing organization.

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

Pass/Fail Criteria: The fire is to be extinguished.

Test E.3.6.1: maximum nozzle height

Test E.3.6.2: minimum nozzle height

Each test shall be repeated for a total of four tests for Fire Scenario E.3.6.

E.3.7 6 MW Diesel Spray Fire with an External Ignition Source

Water mist system configuration: Identical to that for the 2X by 2X square diesel pool. (Fire test scenario E.3.1)

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

External Ignition Source: An ordinary utility propane torch is to be positioned in a vertical plane perpendicular to the diesel 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 directly in front of the propane supply line. The horizontal standoff distance between the torch flame and the steel plate shall be 1 ft (0.30 m).

Preburn Time: 15 seconds as soon as the Heptane spray is ignited.

Pass/Fail Criteria: The spray fire is to be extinguished.

Test E.3.7.1: maximum nozzle height

Test E.3.7.2: minimum nozzle height

Each test shall be repeated for a total of four tests for Fire Scenario E.3.7.

E.3.8 Other

At the sole discretion of the testing organization, additional fire test scenarios shall be required based on the performance demonstrated in the preceding fire scenarios.

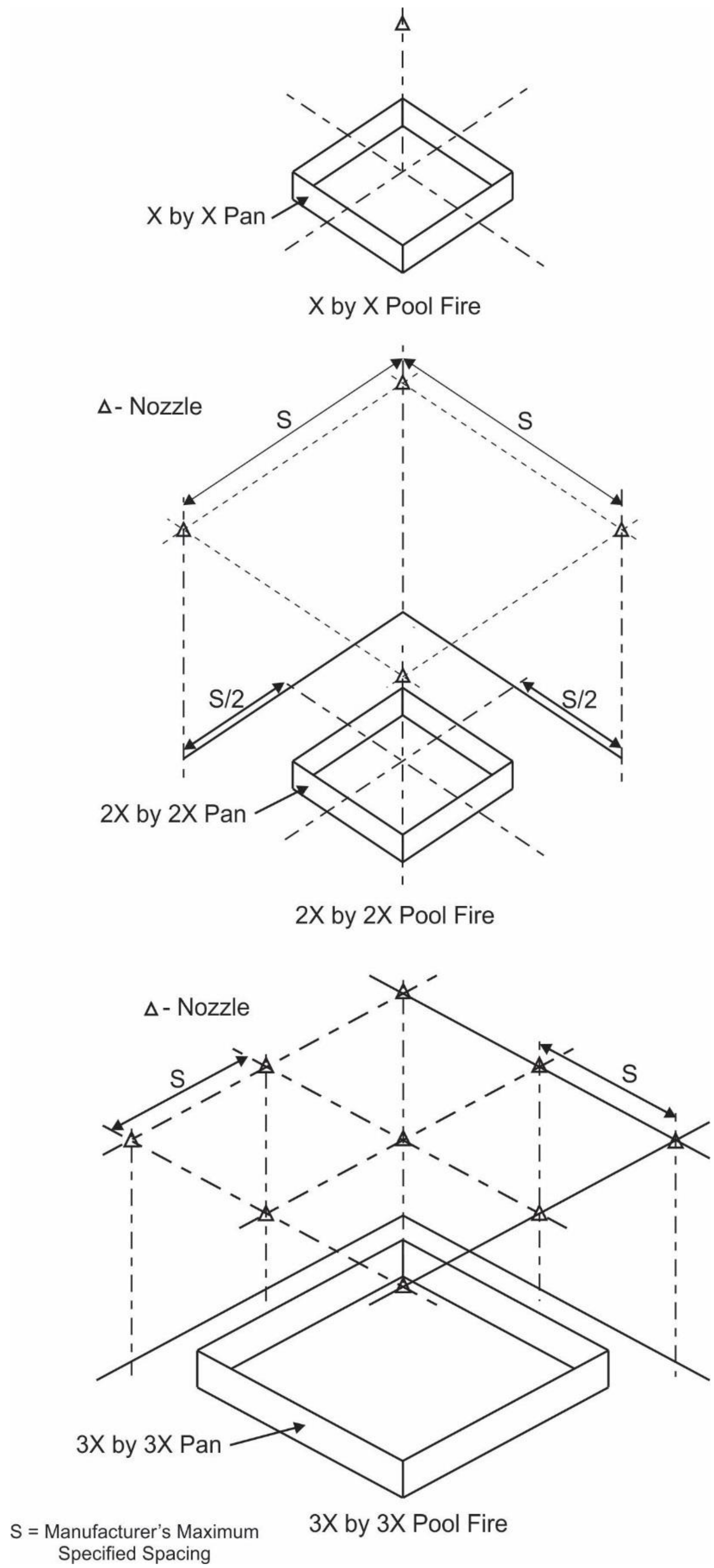


Figure E-1. Pool Fires for Fire Scenario E.3.1

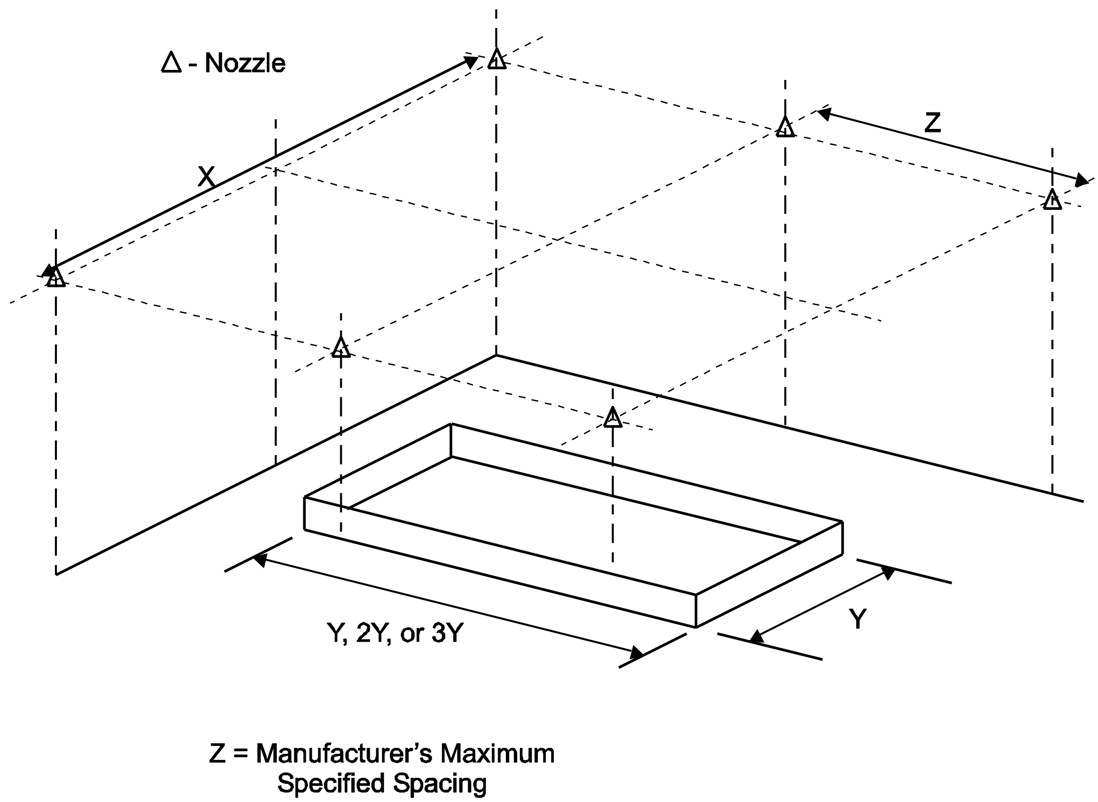


Figure E-2. Channel Pool Fire for Fire Scenario E.3.2

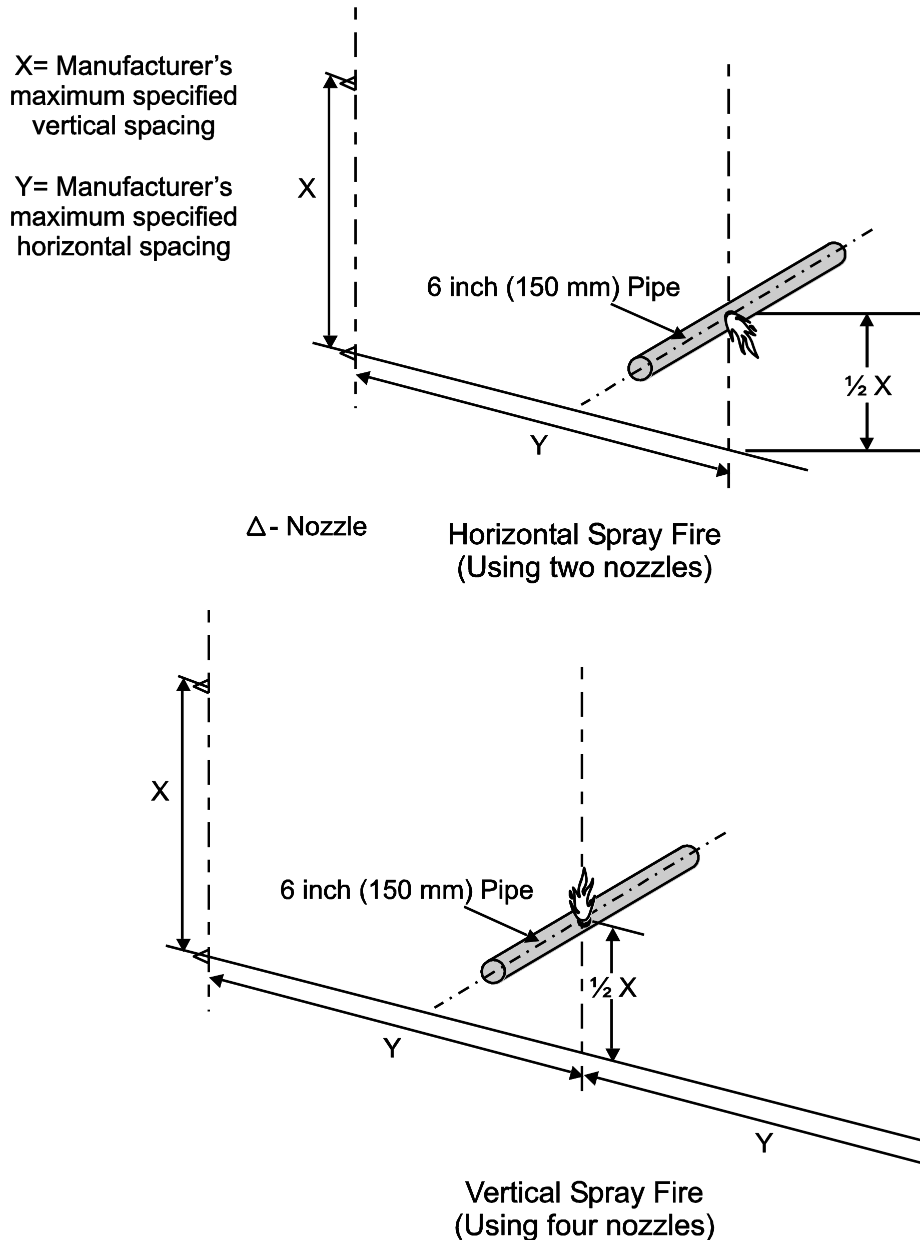


Figure E-3. Spray Fires for Fire Scenario E.3.3

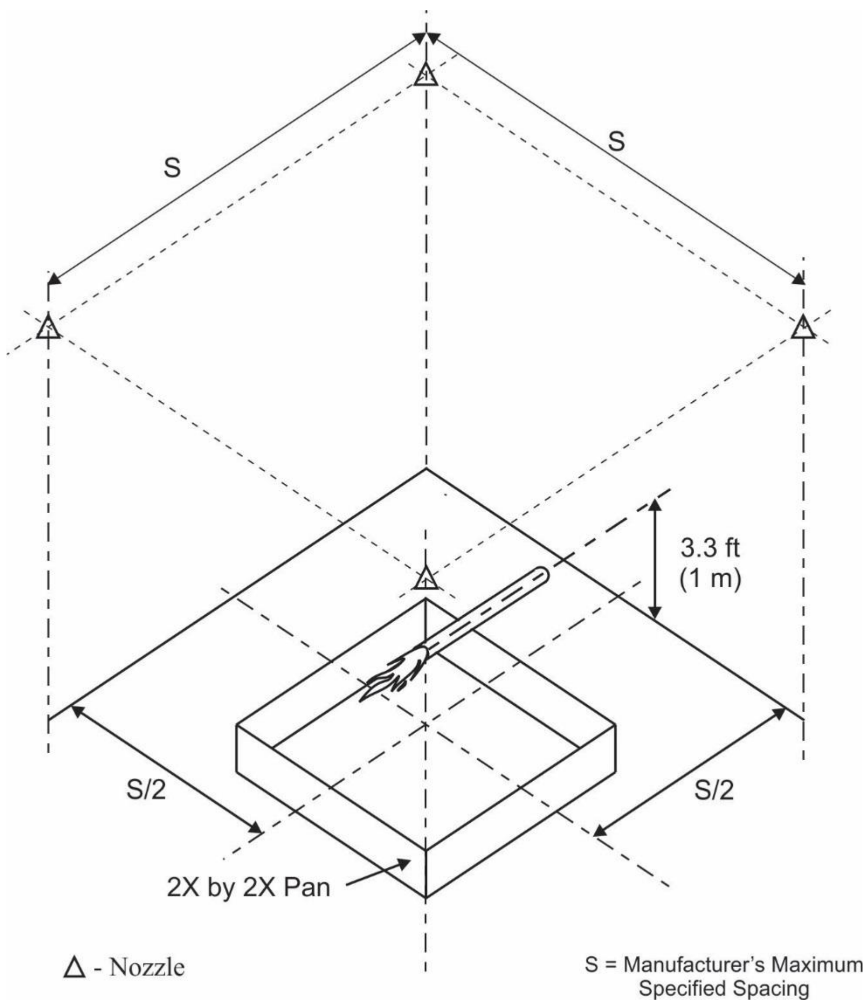


Figure E-4. Pool and Spray Fire for Fire Scenario E.3.4.A

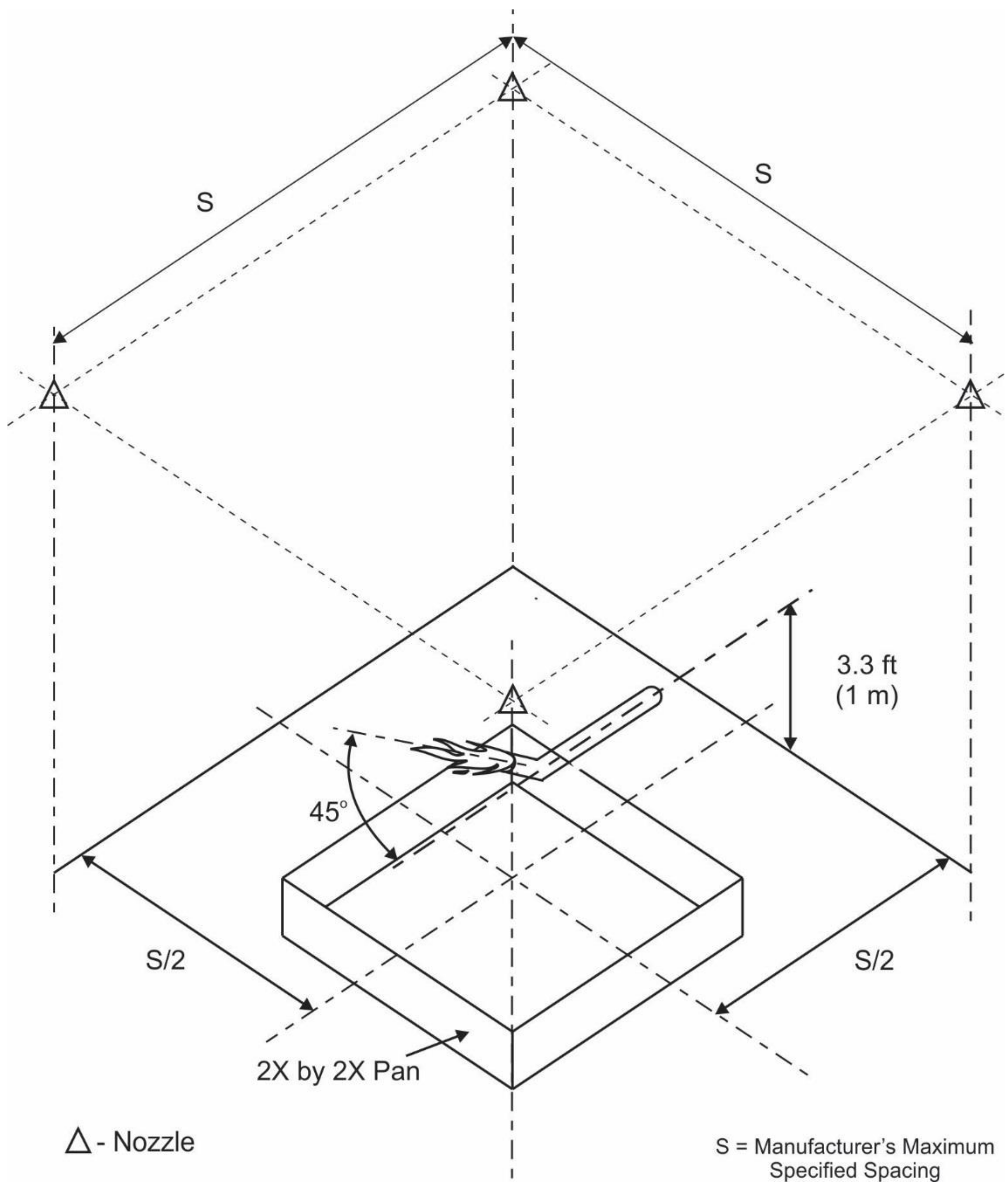


Figure E-5. Pool and Spray Fire for Fire Scenario E.3.4.B

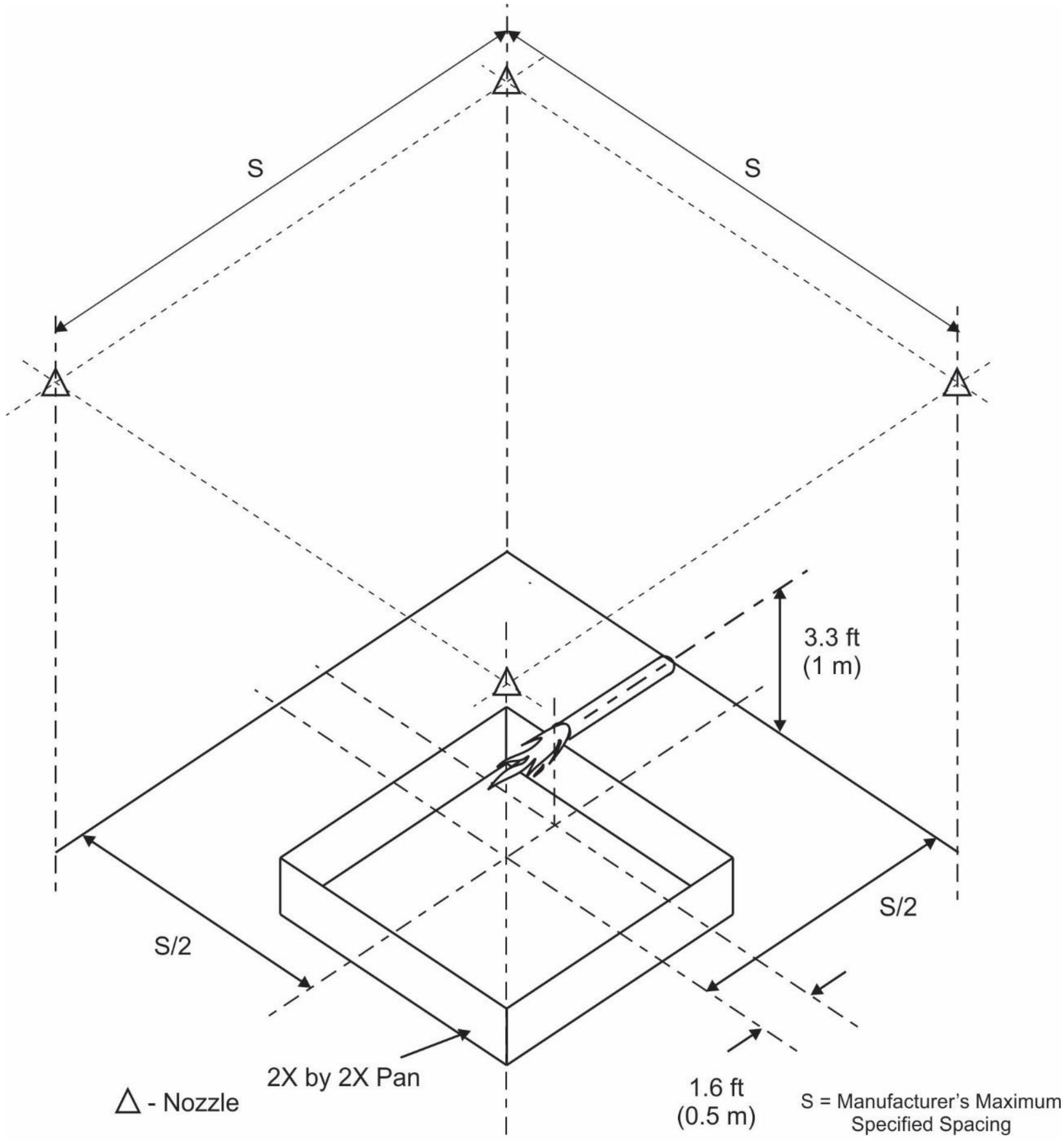


Figure E-6. Pool and Spray Fire for Fire Scenario E.3.4.C

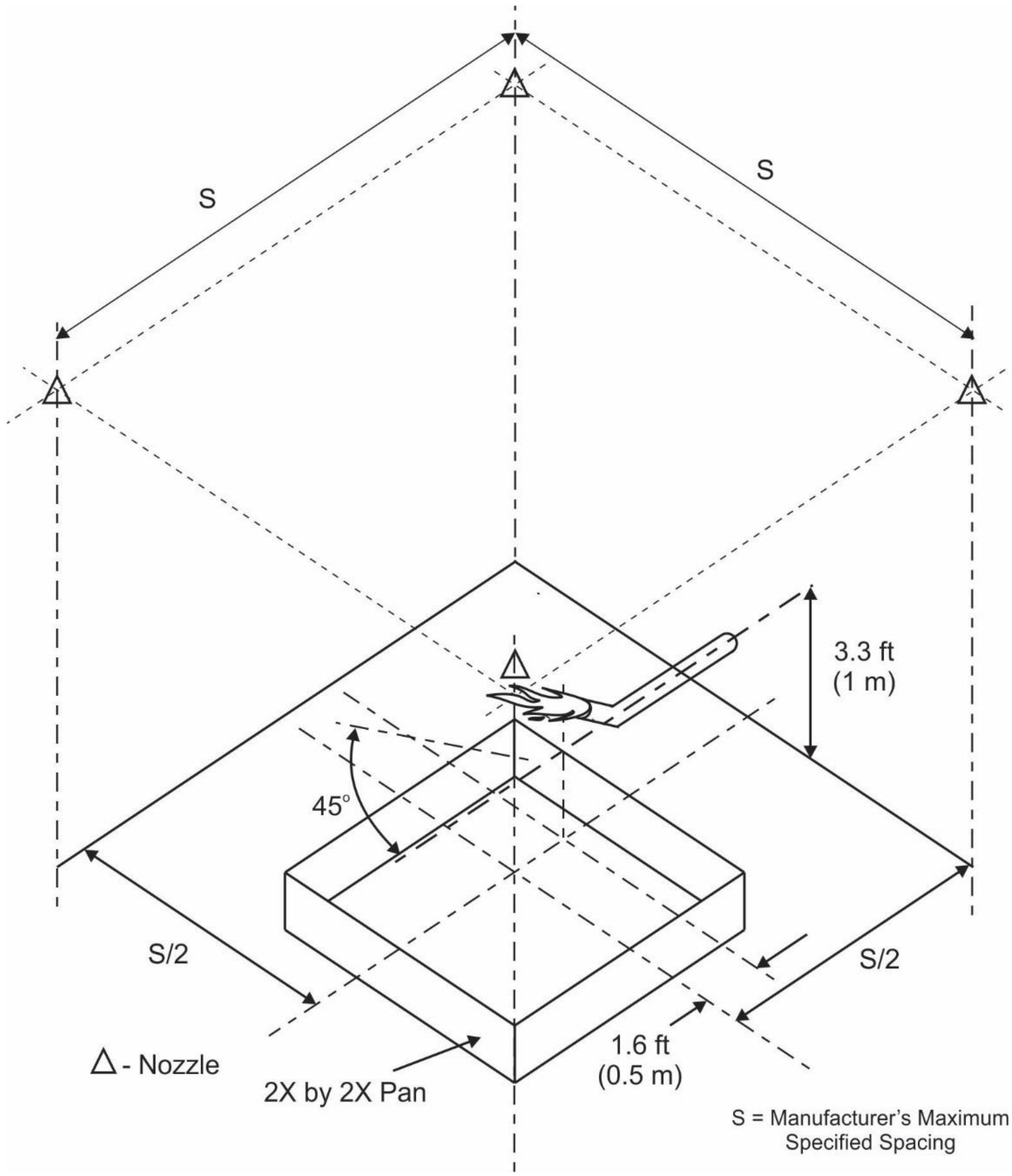


Figure E-7. Pool and Spray Fire for Fire Scenario E.3.4.D

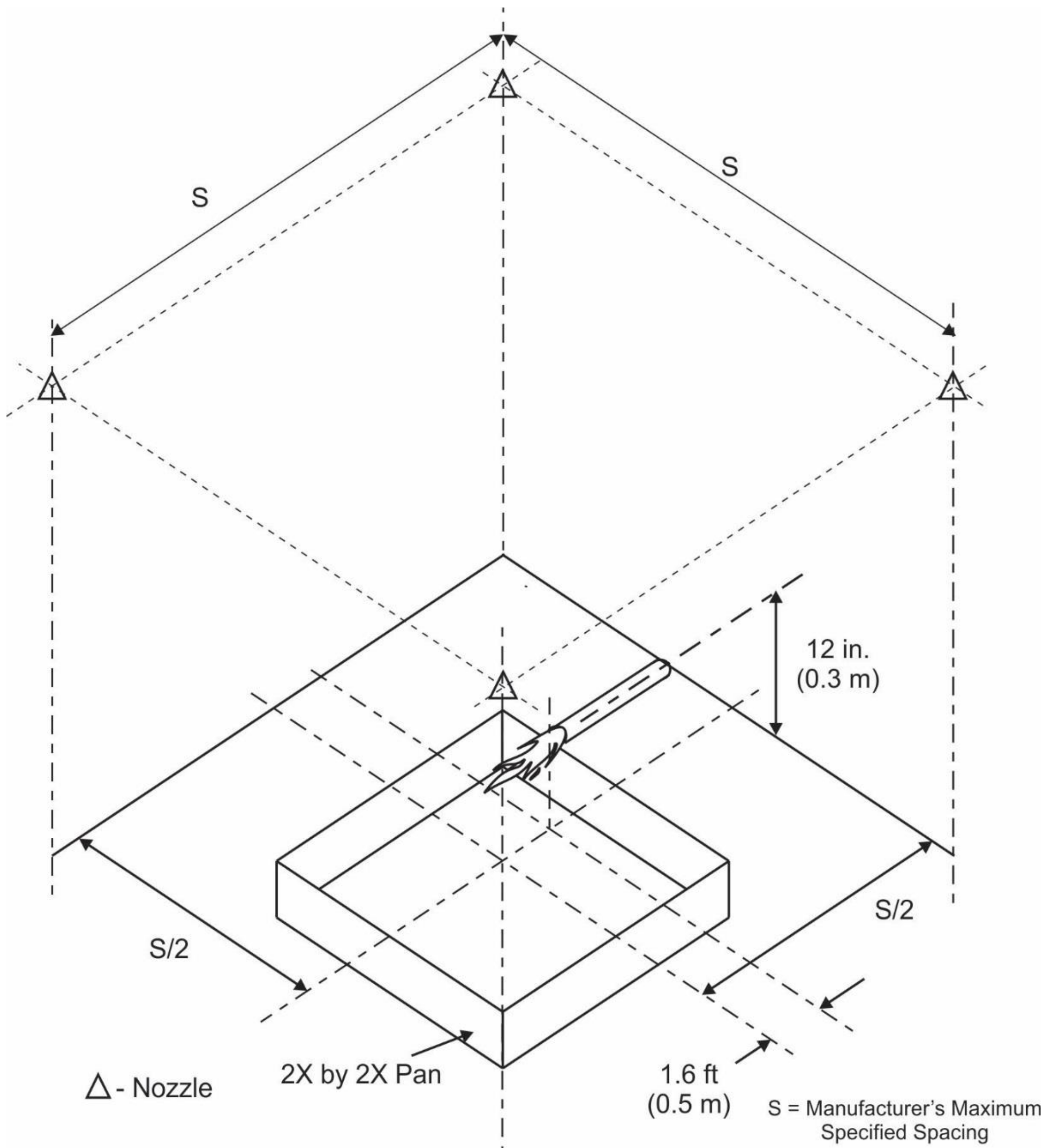


Figure E-8. Pool and Spray Fire for Fire Scenario E.3.4.E

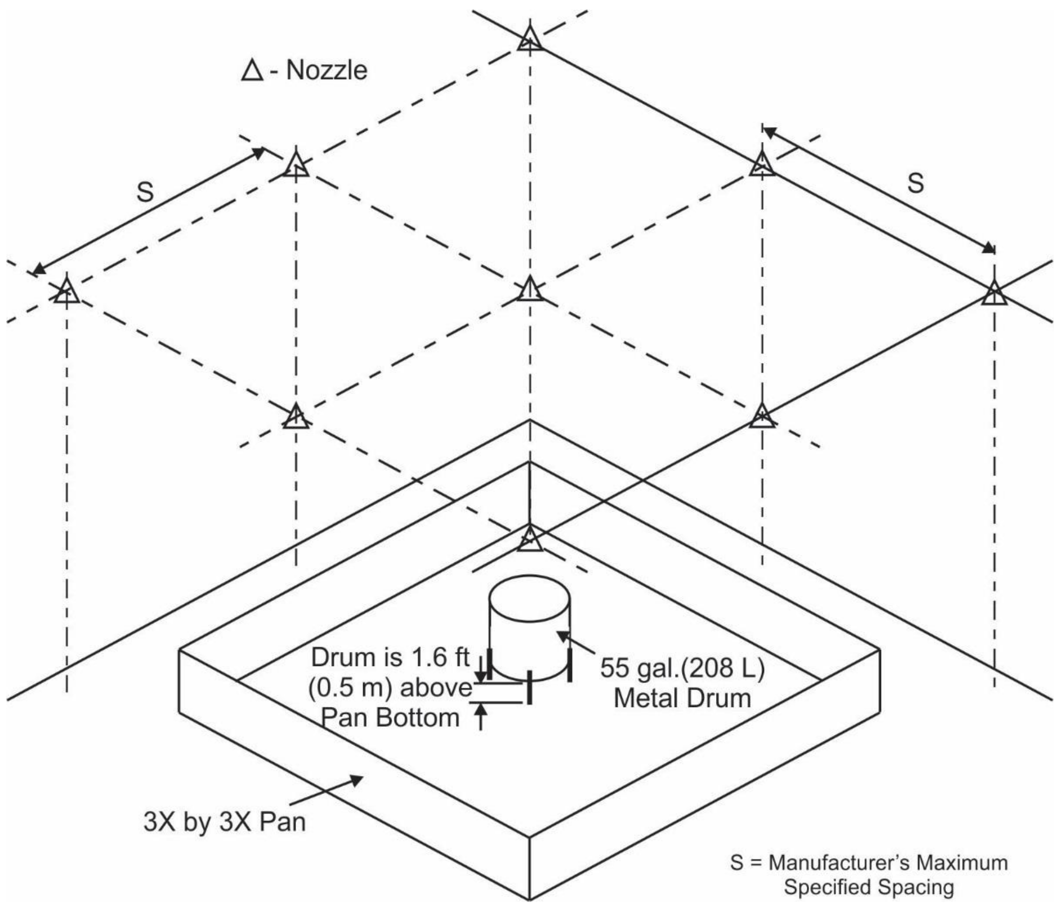


Figure E-9. Shielded Pool Fire for Fire Scenario E.3.5

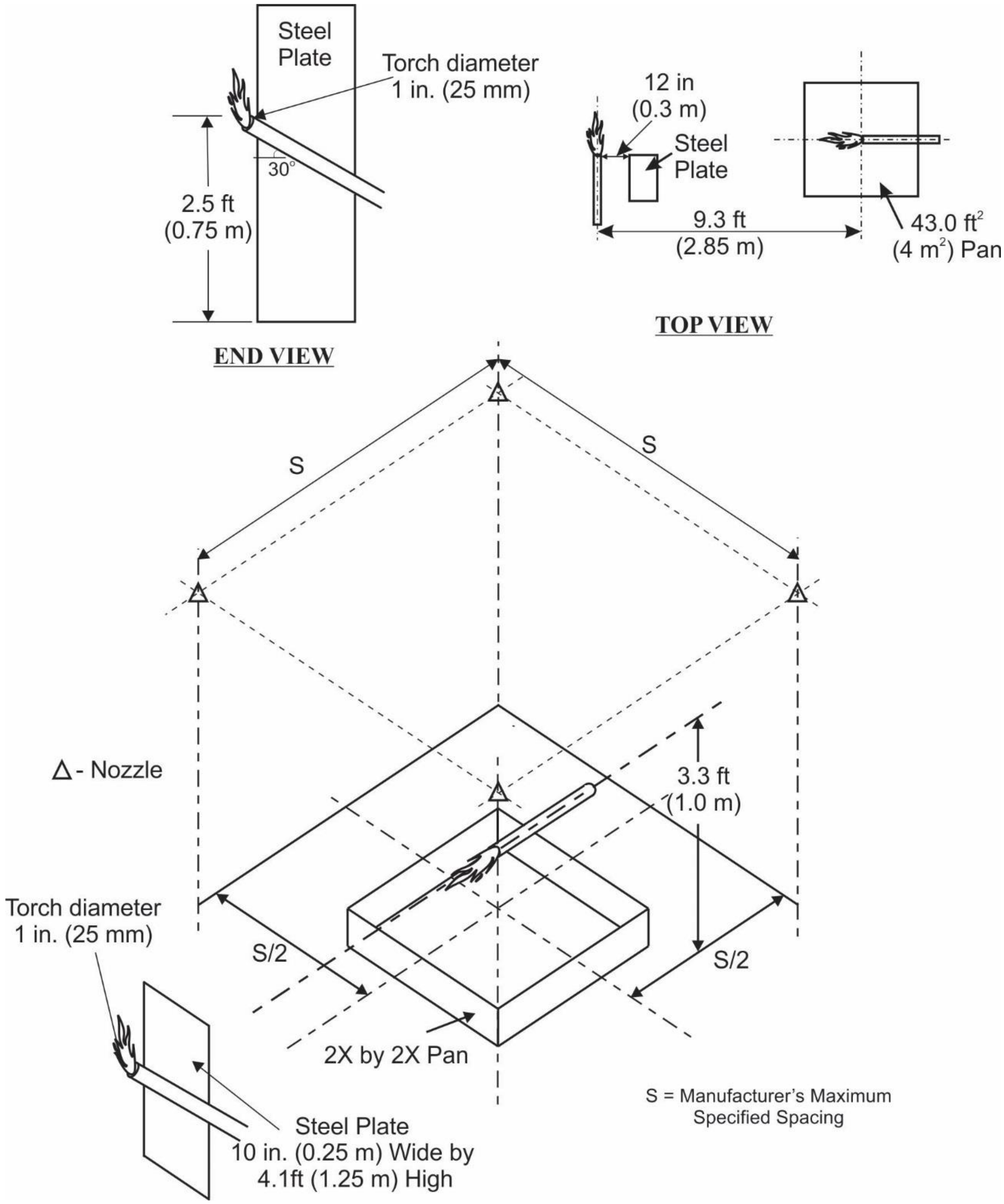


Figure E-10. Spray Fire Arrangement for Fire Scenario E.3.6

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

F.1 General Testing Requirements

The nozzles can 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. Consideration of the application and use of nozzle protection caps to prevent or reduce the amount of nozzle contamination shall be given and the use of such caps shall be included in the fire test and nozzle performance test requirement programs.

All testing shall be conducted within an enclosure with an ambient air temperature at the beginning of the test of 68°F ± 18°F (20°C ± 10°C). The testing area shall be of a sufficient volume as to not impact the results of the fire tests.

New oil shall be used for each test.

The performance tests shall be comprised of three stages, each stage using a different size industrial oil cooker mockup. The tests at the first stage shall be conducted with the smallest mockup of dimensions X wide by Y long; such that Y ≥ X. The water mist system manufacturer shall specify dimensions X and Y. The second stage shall be conducted with a mockup of dimensions X wide by 2Y long. The third stage shall be conducted with a mockup of dimensions X wide by 3Y long. 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.

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

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 might 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 standard. Use of supplementary exhaust duct protection is required, and shall be so stated in the manufacturer's Design, Installation, Operation, and Maintenance Manual.

F.2 Examination Criteria

The certification criteria of 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 shall be verified visually.

C. The water mist system shall prevent, and not cause, any thermal damage to the industrial oil cooker by ensuring that, at the completion of system discharge, the average oil temperature inside the pan, using all thermocouples, shall be lower than 392°F (200°C).

D. The required extinguishing agent quantity is double the time needed to extinguish the worst case fire scenario, time to shut down heating and process equipment, or 10 minutes, whichever is greater. The water mist system discharge shall not exceed 30 minutes.

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 the 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 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 shall be no 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, no appreciable quantity of oil shall be permitted to be expelled from the industrial oil cooker mockup during the fire test. Verification of this shall requirement shall be conducted visually.

F.3 Test Apparatus

Industrial Oil Cooker Mockups

There will be three industrial oil cooker mockups denoted as Mockup A, Mockup B and Mockup C (see Figures F-1, F-2 and F-3). Each mockup shall be fabricated from nominal 0.44 in. (1.1 cm) thick steel and shall consist of a pan and a hood.

The inside dimensions of the pan of Mockup A shall be X ft wide, Y ft long and 13.5 in. (34.3 cm) deep. (Note: $Y \geq X$) The inside dimensions of the hood shall be X ft + 2 in. (5.1 cm) wide, Y ft + 2 in. (5.1 cm) long and 30 in. (76.2 cm) deep. Both ends of the hood 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 + 1 in. (2.5 cm).

The inside dimensions of the pan of Mockup B shall be X ft wide, 2Y ft long and 13.5 in. (34.3 cm) deep. (Note: $Y \geq X$) The inside dimensions of the hood shall be X ft + 2 in. (5.1 cm) wide, 2Y ft + 2 in. (5.1 cm) long and 30 in. (76.2 cm) deep. Both ends of the hood 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 + 0.75 in. (1.9 cm).

The inside dimensions of the pan of Mockup C shall be X ft wide, 3Y ft long and 13.5 in. (34.3 cm) deep. (Note: $Y \geq X$) The inside dimensions of the hood shall be X ft + 2 in. (5.1 cm) wide, 3Y ft + 2 in. (5.1 cm) long and 30 in. (76.2 cm) deep. Both ends of the hood 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 + 0.5 in. (1.3 cm) and the distance from the centerline of the two holes closest to the ends of the hood shall be 0.75Y + 0.5 in. (1.3 cm) to the closest respective end of the hood.

Legs will be attached along the length of the hood so that the hood position can be adjusted vertically before each test. The oil inside the pan will be heated to its auto-ignition temperature by several evenly spaced gas burners placed under the pan. Thermocouples will be placed inside the pan at several locations to measure oil temperatures as shown in Figures F-1, F-2 and F-3.

Instrumentation – Thermocouples

All thermocouples shall be Type K, 18 gauge.

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

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

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.

F.4 Fire Tests

For each test, once the oil temperatures inside the pan indicate that the oil has reached its auto-ignition temperature (at all thermocouple locations) and oil surface is completely involved in flame (visually), the heaters will be shut off. Thirty (30) seconds after shutting off the heaters, the water mist system will be activated manually.

At the end of each test, the burned oil will be completely drained and new oil will be utilized for the next test.

F.4.1 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 F-4). Fresh oil shall be introduced into the pan to provide a 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 approval criteria shall be met.

F.4.2 Hood Down Position with Mockup A

Fire Test F.4.2 shall not be conducted without the successful completion of F.4.1. 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 F-4). Fresh oil shall be introduced into the pan to provide a 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 approval criteria shall be met.

F.4.3 Hood Up Position with Mockup B

Fire Test F.3 shall not be conducted without the successful completion of F.4.2. 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 F-4). Fresh oil shall be introduced into the pan to provide a 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 testing criteria shall be met.

F.4.4 Hood Down Position with Mockup B

Fire test F.4.4 shall not be conducted without the successful completion of fire test F.4.3. 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 F-4). Fresh oil shall be introduced into the pan to provide a 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 testing criteria shall be met.

F.4.5 Hood Up Position with Mockup C

Fire test F.4.5 shall not be conducted without the successful completion of fire test F-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 F-4). Fresh oil shall be introduced into the pan to provide a 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 testing criteria shall be met.

F.4.6 Hood Down Position with Mockup C

Fire Test F.4.6 shall not be conducted without the successful completion of fire test F.4.5. 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 F-4). Fresh oil shall be introduced into the pan to provide a 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 testing criteria shall be met.

F.5 Extrapolation of Test Data

Should a need arise to apply a water mist system to the protection of an industrial oil cooker that is larger than Mockup C, test data can, at the sole discretion of the testing organization, be extrapolated on a case-by-case basis by the testing organization. Such extrapolation shall be clearly defined by the manufacturer and shall become a part of the Examination and Test Report.

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 F.4.1, Fire Test F.4.3 and Fire Test F.4.5 is less than 30 percent the difference for those extinguishing times greater than 30 seconds, and a maximum of 10 seconds difference if all extinguishing times are less than 30 seconds, between the tests, and the extinguishment times are not indicating an increasing time trend.

D. The difference in extinguishment times between Fire Test F.4.2, Fire Test F.4.4 and Fire Test F.4.6 is less than 30 percent the difference for those extinguishing times greater than 30 seconds, and a maximum of 10 seconds difference if all extinguishing times are less than 30 seconds, between tests and the extinguishment times are not indicating an increasing time trend.

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

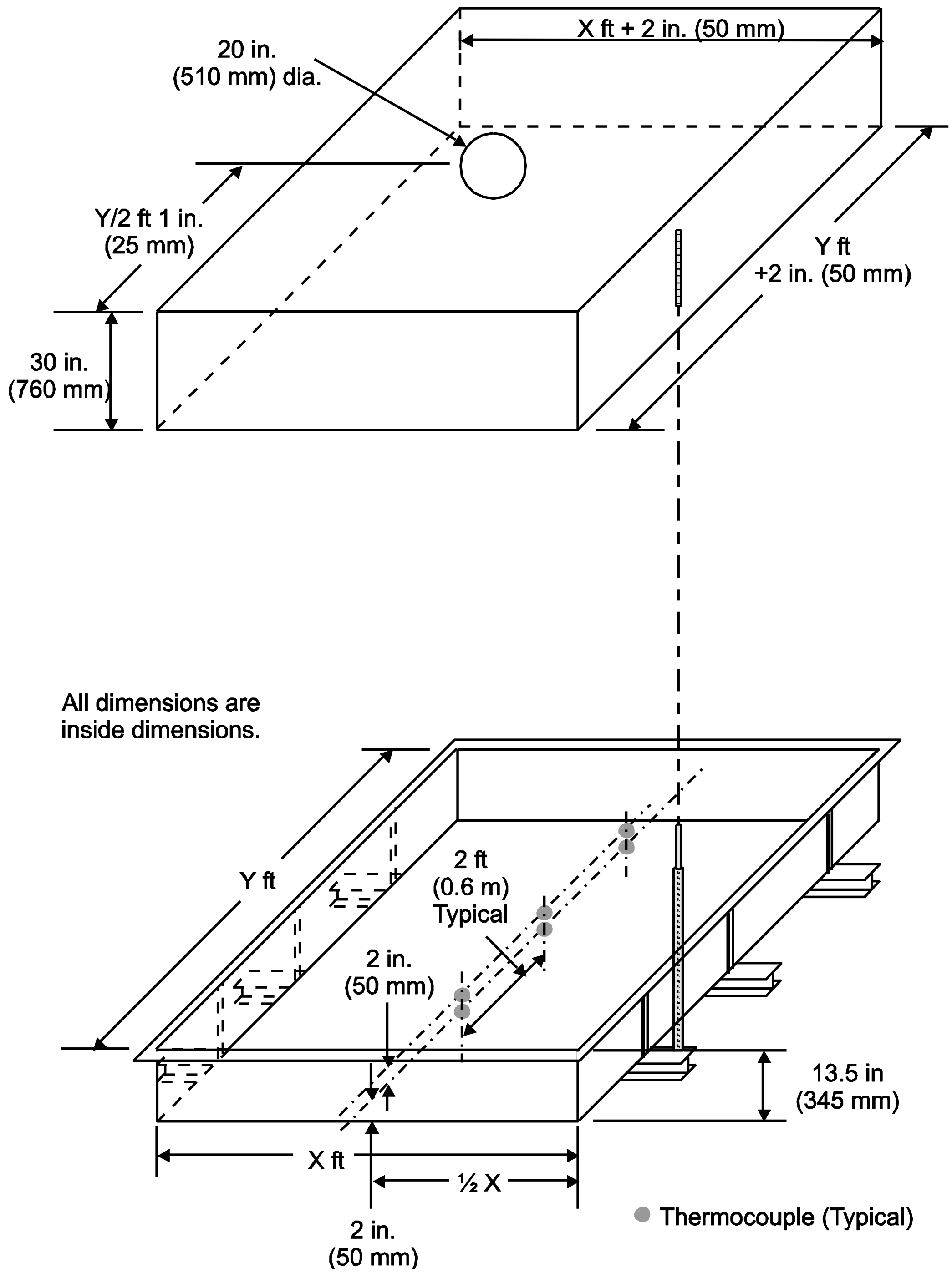


Figure F-1. Schematic Figure of Mockup A (Pan and Hood)

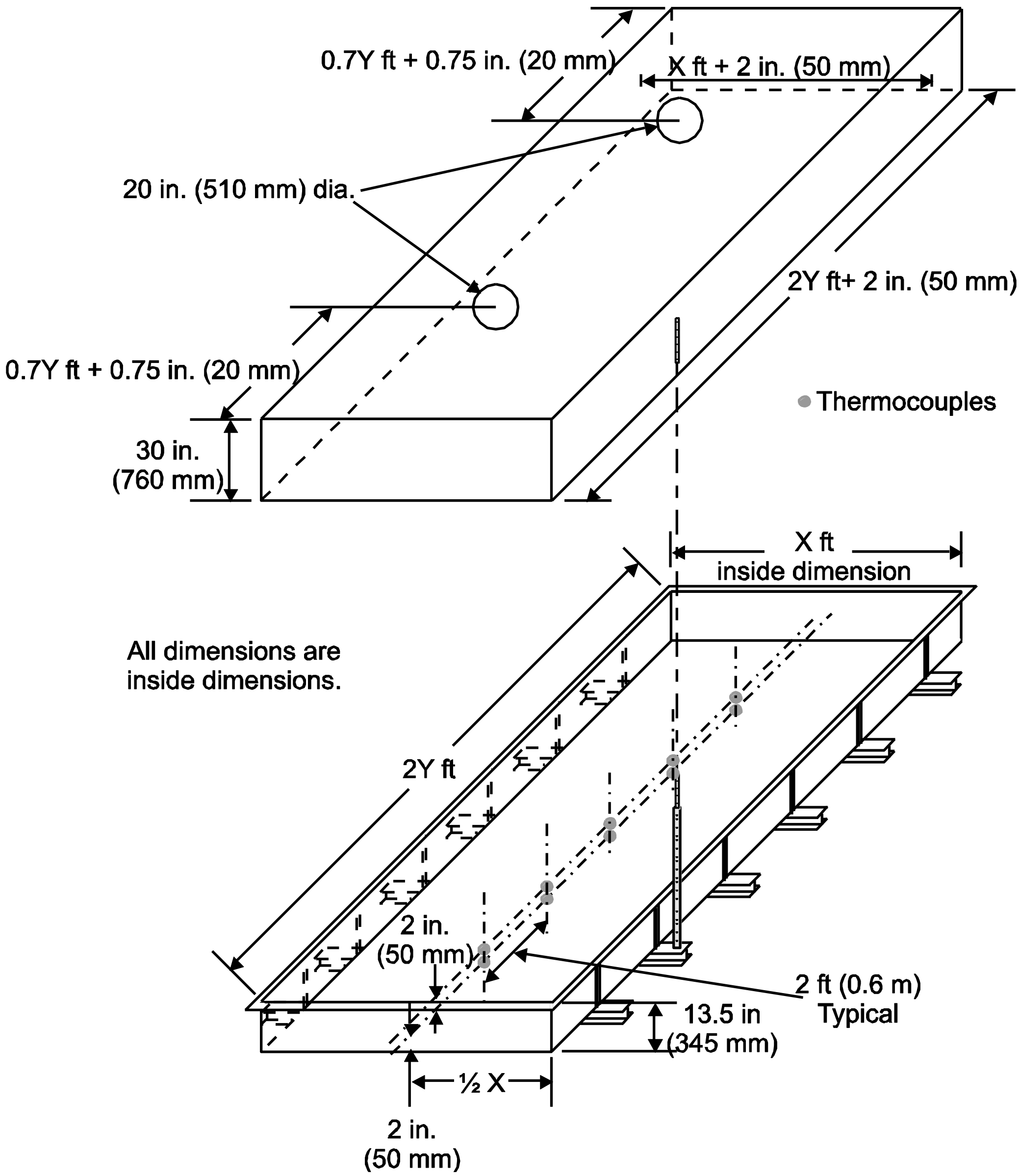


Figure F-2. Schematic Figure of Mockup B (Pan and Hood)

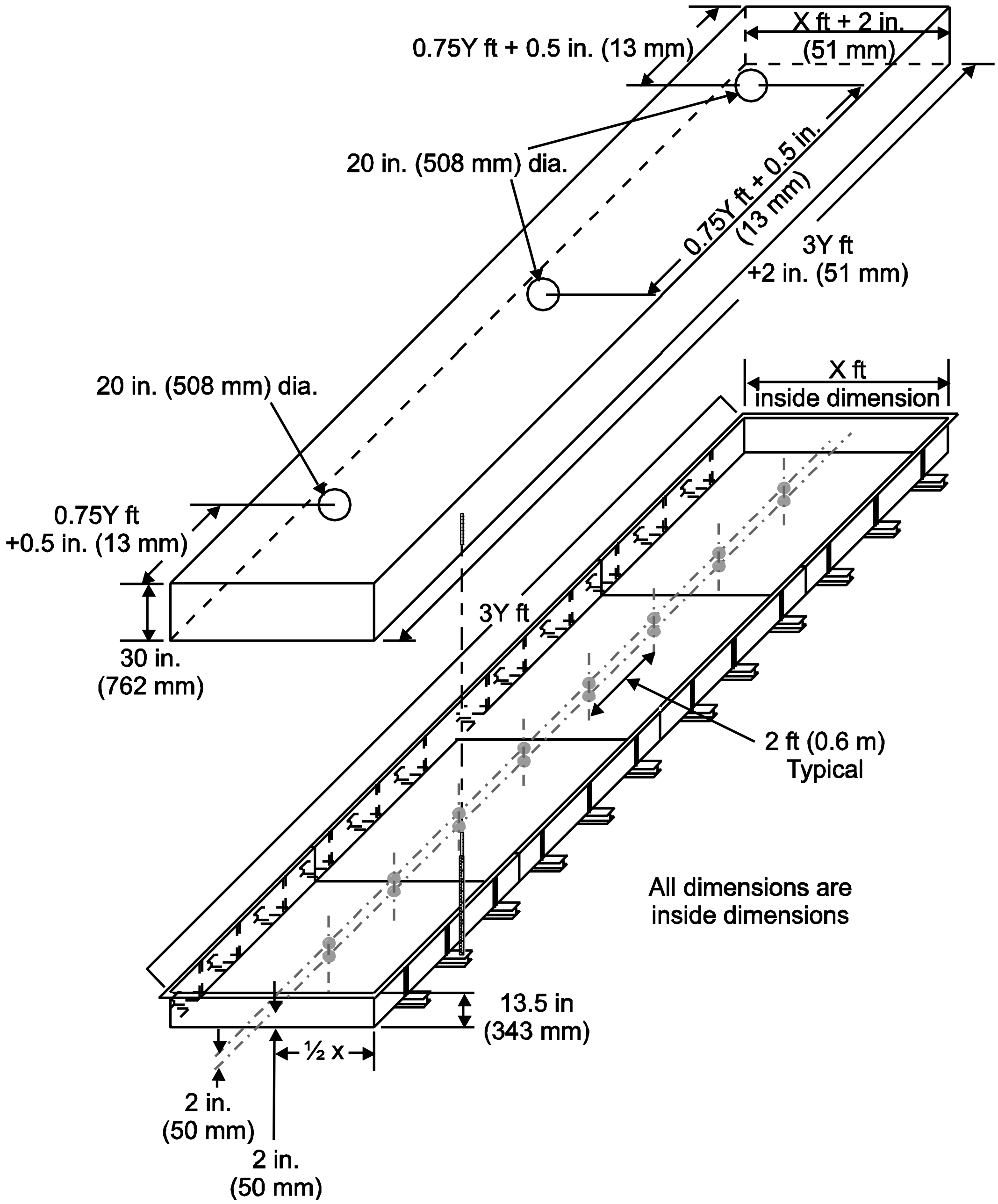


Figure F-3. Schematic Figure of Mockup C (Pan and Hood)

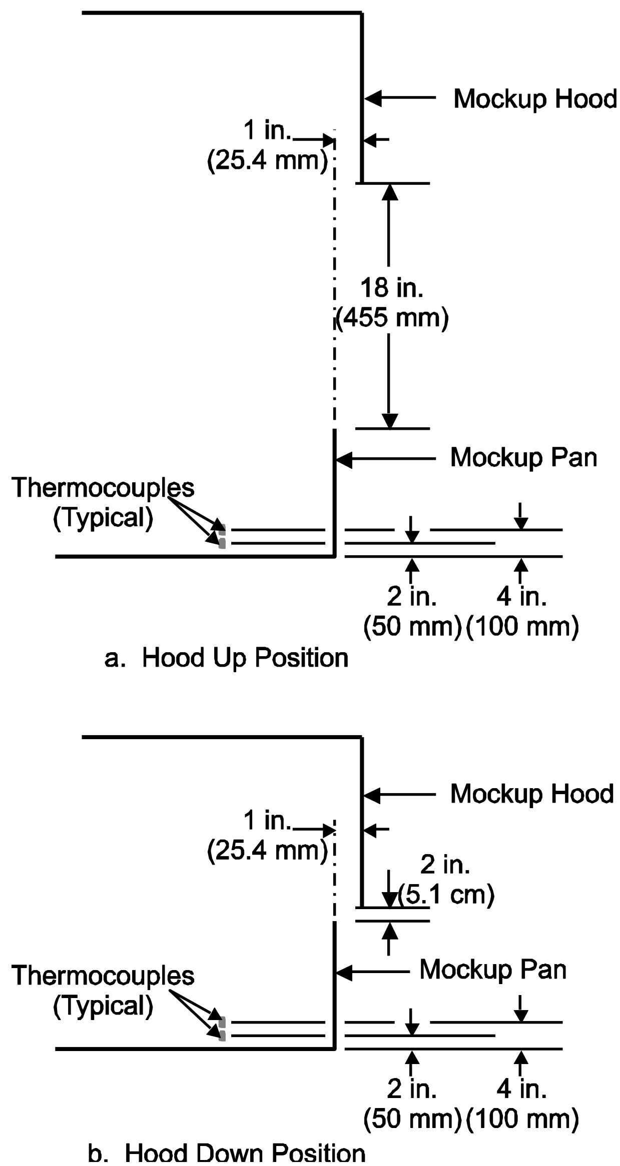


Figure F-4. Schematic of Hood Up and Down Positions

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

G.1 General Testing Requirements

The 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.

G.2 Continuous Wood Board Press Mockups (Figure G-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).

G.2.1 Press Pocket Space Mockup (Figure G-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.

G.2.2 Heat Tunnel Mockup (Figures G-3 and G-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 testing organization, 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.

G.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	Wide spray angle (120°) full cone type
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)

Example – Low Pressure Fuel Nozzle: PLP Lechler 460.728

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.

G.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.

G.4.1 Press Pocket Pool Fire

Criteria:	Suspression 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.

G.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 G-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.

G.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 G-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.

G.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 G-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 G-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.

G.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 G-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 E 8, *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 E 8, *Standard Test Methods for Tension Testing of Metallic Materials*.

G.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 E 290, 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 by the testing organization 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 E 8, *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 E 8, *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 E 290, *Standard Test Methods for Bend Testing of Material for Ductility*.

G.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 testing organization. Such extrapolation shall be clearly defined by the manufacturer and shall become a part of the manufacturer’s design, installation, operation, and maintenance manual.

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.

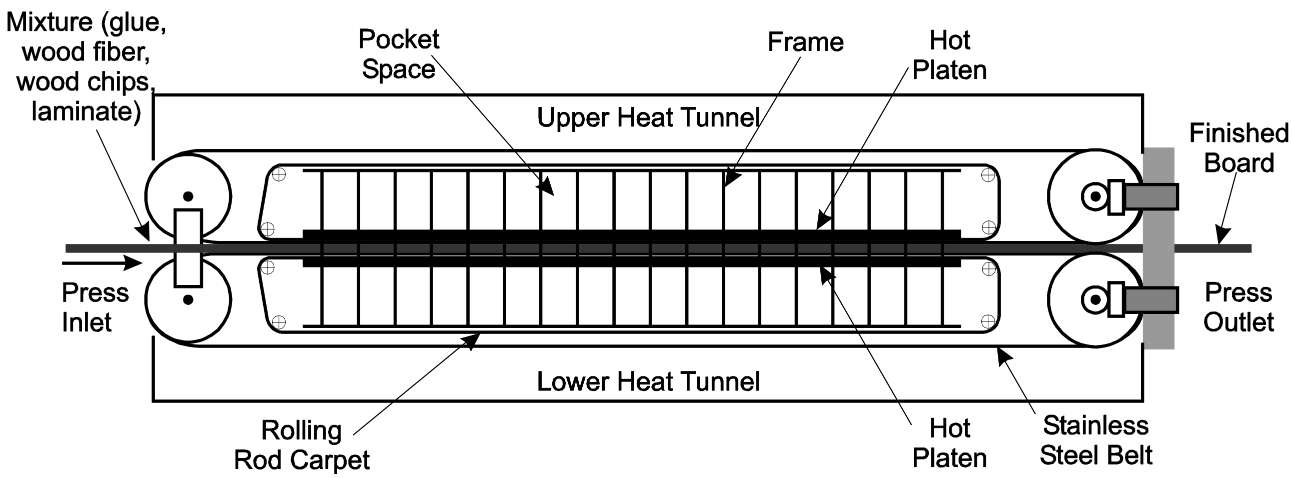


Figure G-1. Schematic Illustration of a Continuous Board Press

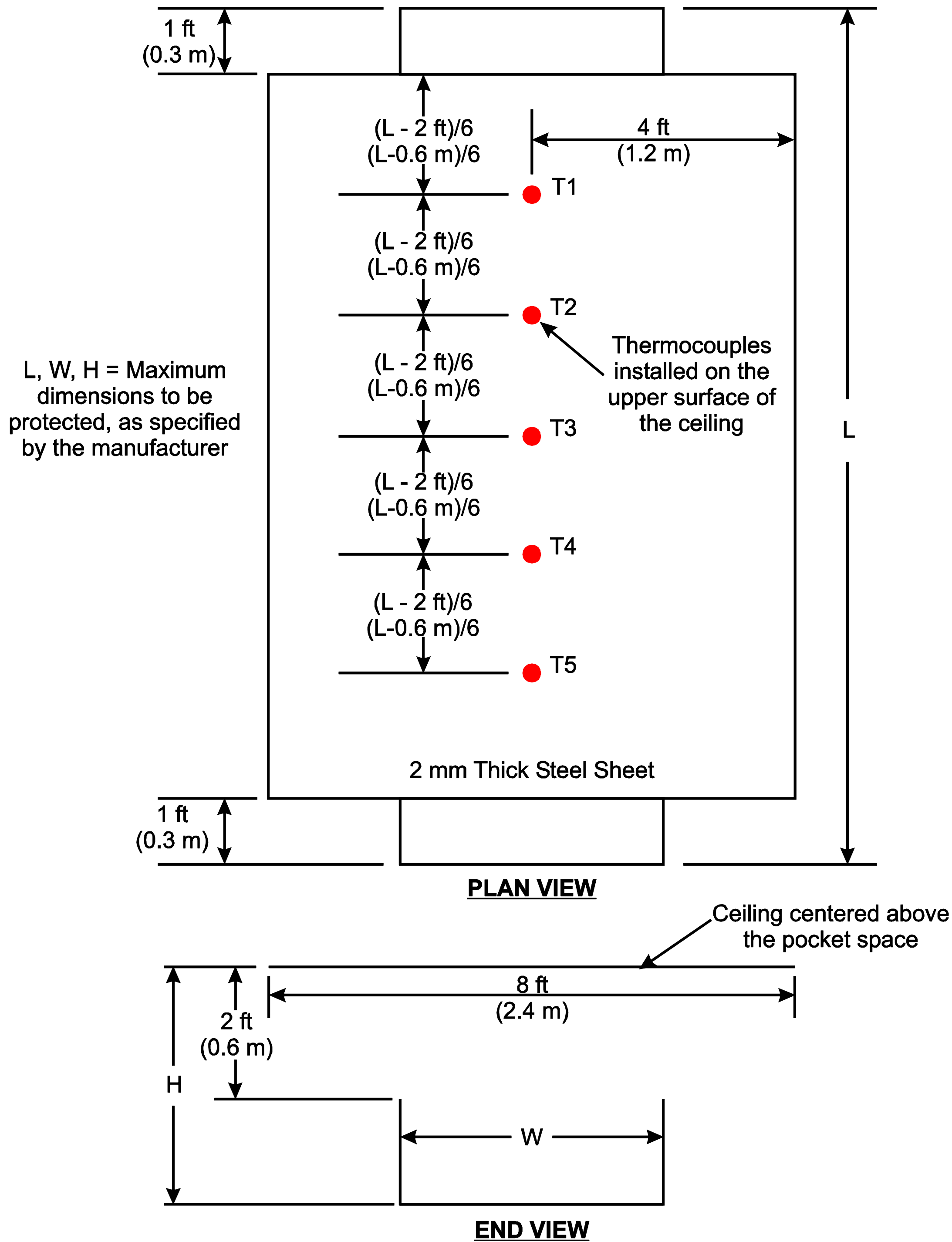


Figure G-2. Press Pocket Space Mockup

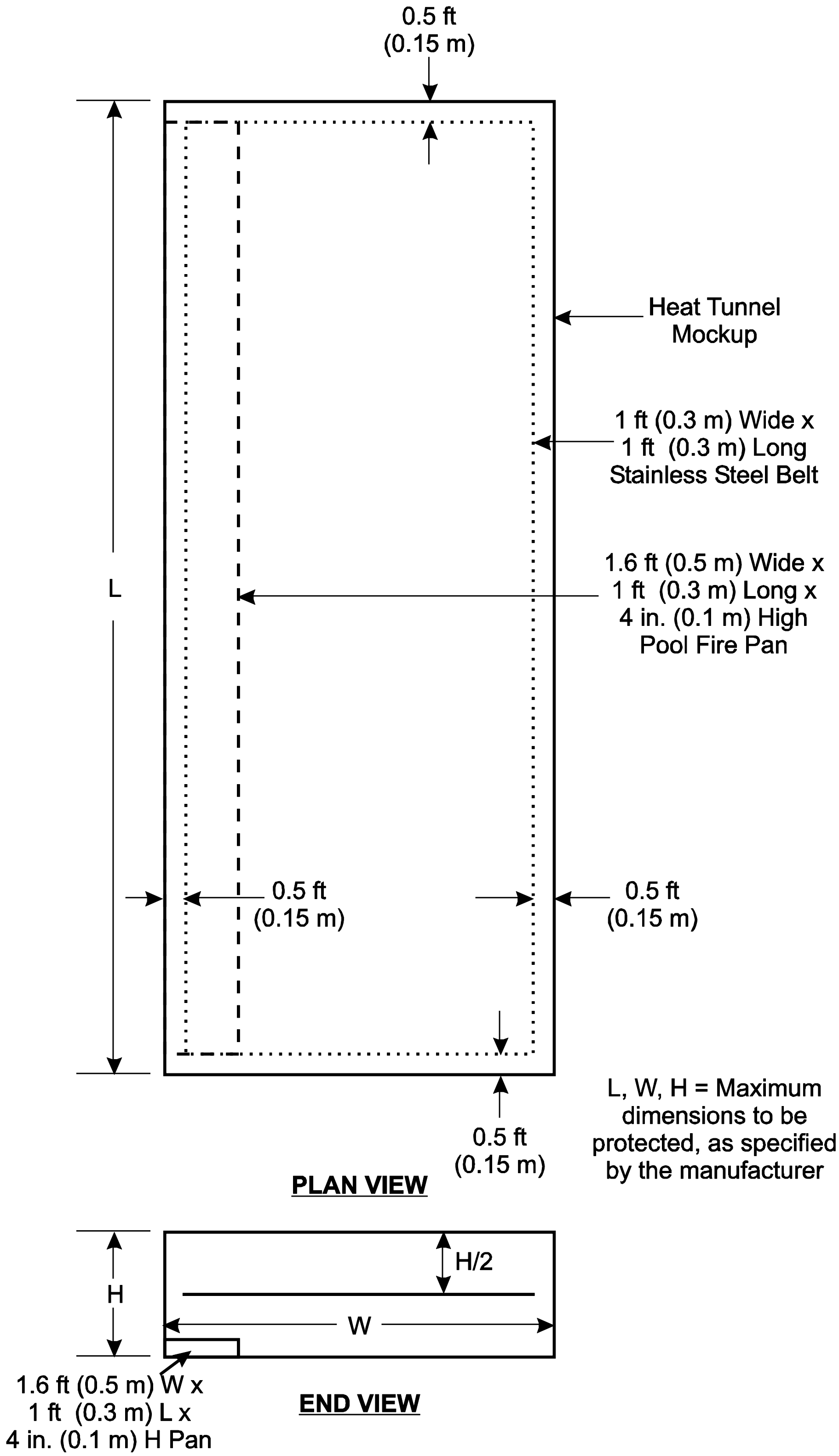


Figure G-3. Press Heat Tunnel Mockup

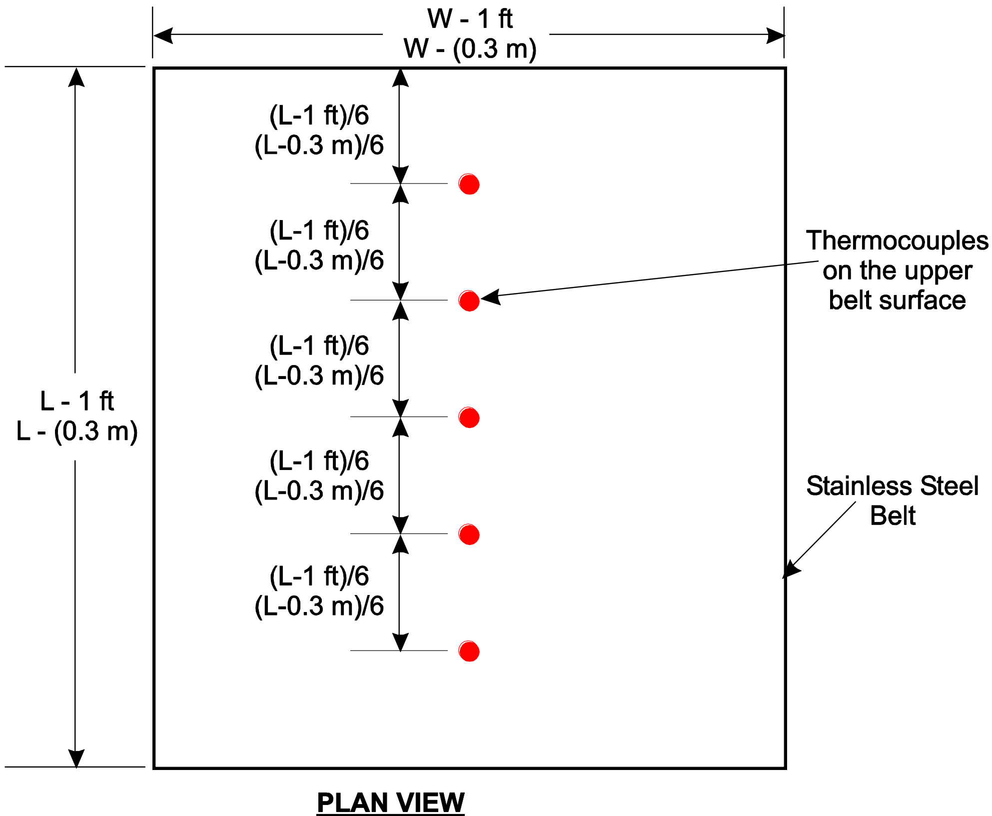


Figure G-4. Thermocouple Layout on the Stainless Steel Belt Installed in the Heat Tunnel Mockup

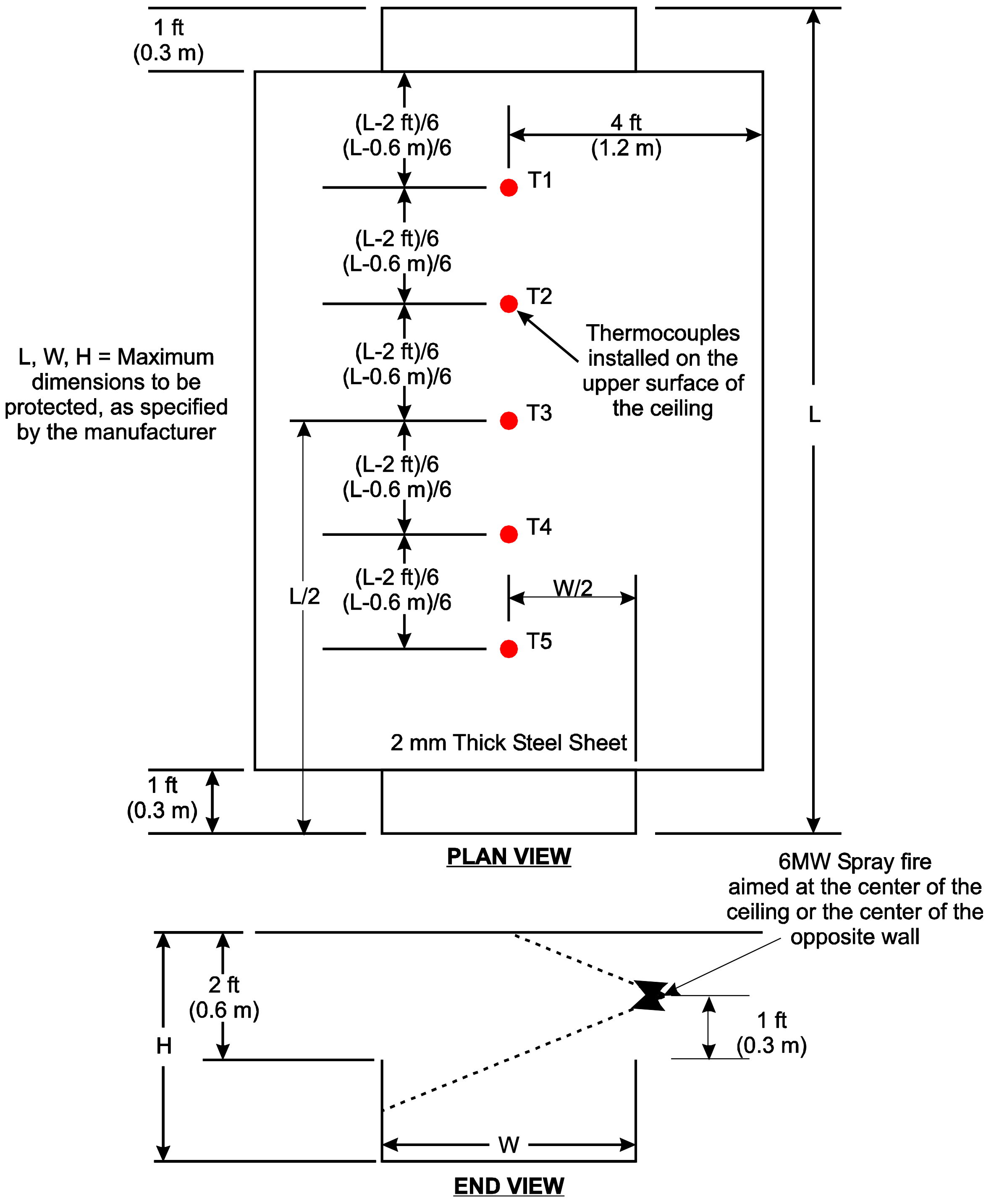


Figure G-5. Test Setup for the 6MW Spray Fire Scenario in the Press Pocket Space

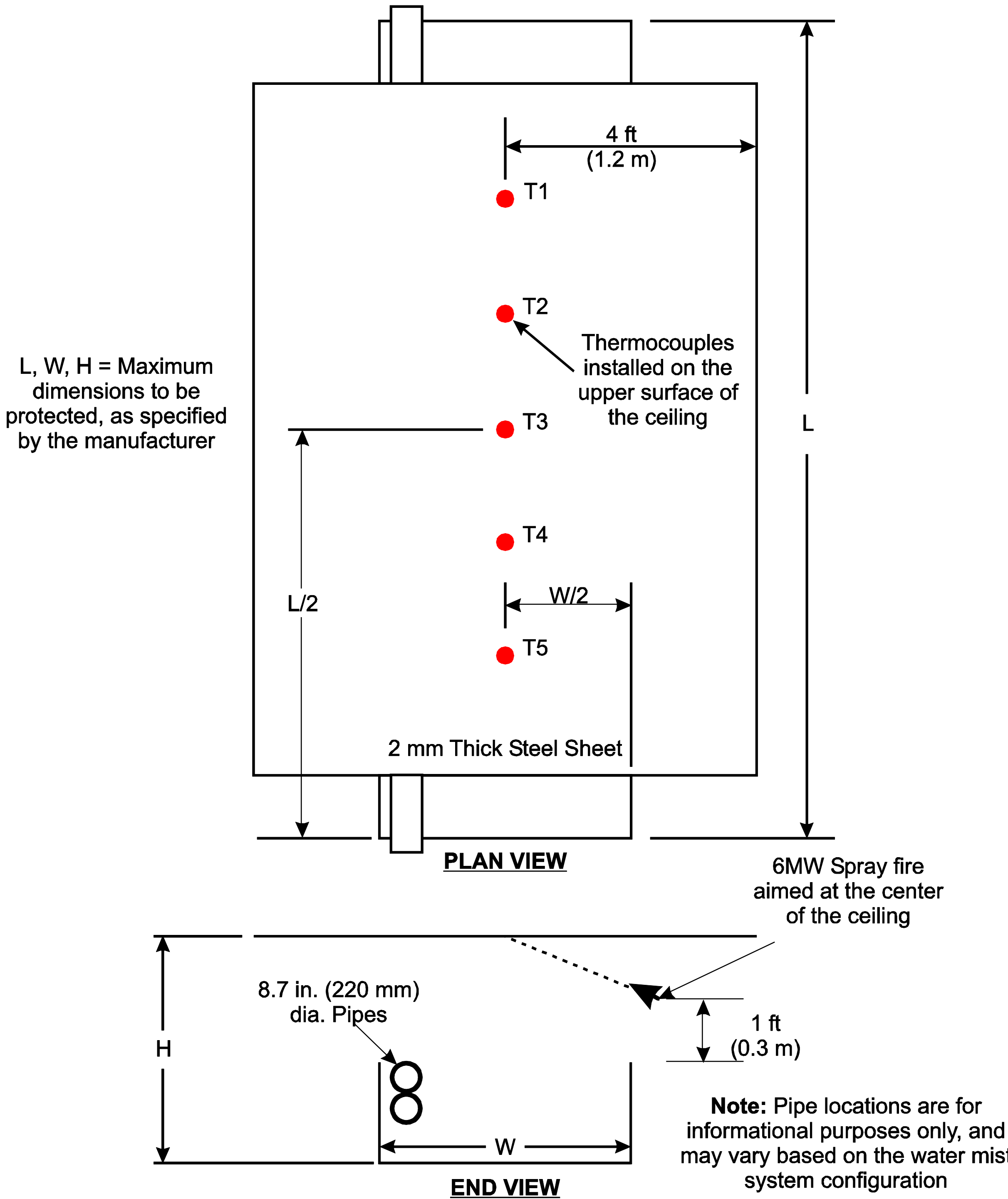


Figure G-6. Test Setup for the Obstructed 6MW Spray Fire Scenario in the Press Pocket Space

APPENDIX H: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF CHEMICAL FUME HOODS

H.1 General Testing Requirements

The following criteria shall be met:

A. The manufacturer shall provide the testing organization 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 in the water mist system design, installation, operation and maintenance manual. 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 spacing used in the successful fire tests on the maximum size fume hood per the discretion of the testing organization.

G. The individual nozzles shall include either a fusible or glass bulb assembly and be in the quick response (QR) category per the applicable ANSI standard. 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 in the manufacturer’s system design, installation, operation and maintenance manual.

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.

K. The glass bottle used in test H.4.4 shall have 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). Example - Cole-Parmer catalog number WU-08922-75.

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 Approval. System components, component locations, and operating conditions shall remain unaltered throughout all of the fire tests.

H.2 Instrumentation and Test Equipment Requirements

In addition to the instrumentation and test requirements described previously under "General Instrumentation and Test Equipment Requirements," the following measurements should be recorded to within a ± 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.

H.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 by the water mist system manufacturer for protection. The test mockup shall include an exhaust system capable of achieving the minimum and maximum face velocities sought selected by the water mist system manufacturer. The manufacturer shall determine the test mockup that will be used for the fire testing and submit drawings and specifications to the testing organization for verification prior to testing. The testing organization will review the test mockup along with the manufacturer's requested limitations (for example: size, combustible or non-combustible, nozzle locations, etc.) and accept the submitted test mockup at their discretion.

H.4 Fire Tests Configurations

The water mist system shall successfully complete all fire tests described in this section.

H.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.

H.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:

$$Fuel\ required\ [gal] = \frac{(0.028)\ Spill\ Area\ \left[in^2\right]}{231} \quad [US\ Units]$$

$$Fuel\ required\ [ml] = \frac{(14.021)\ Spill\ Area\ \left[cm^2\right]}{197} \quad [SI\ Units]$$

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.

H.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 H.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.

H.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 H.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.

H.4.5 Additional Fire Tests

Based on the results of Fire Tests H.4.1 through H.4.4, additional fire testing may be required to ensure that the water mist system being evaluated meets the intent of this test Appendix. This testing will be performed at the sole discretion of the testing organization.

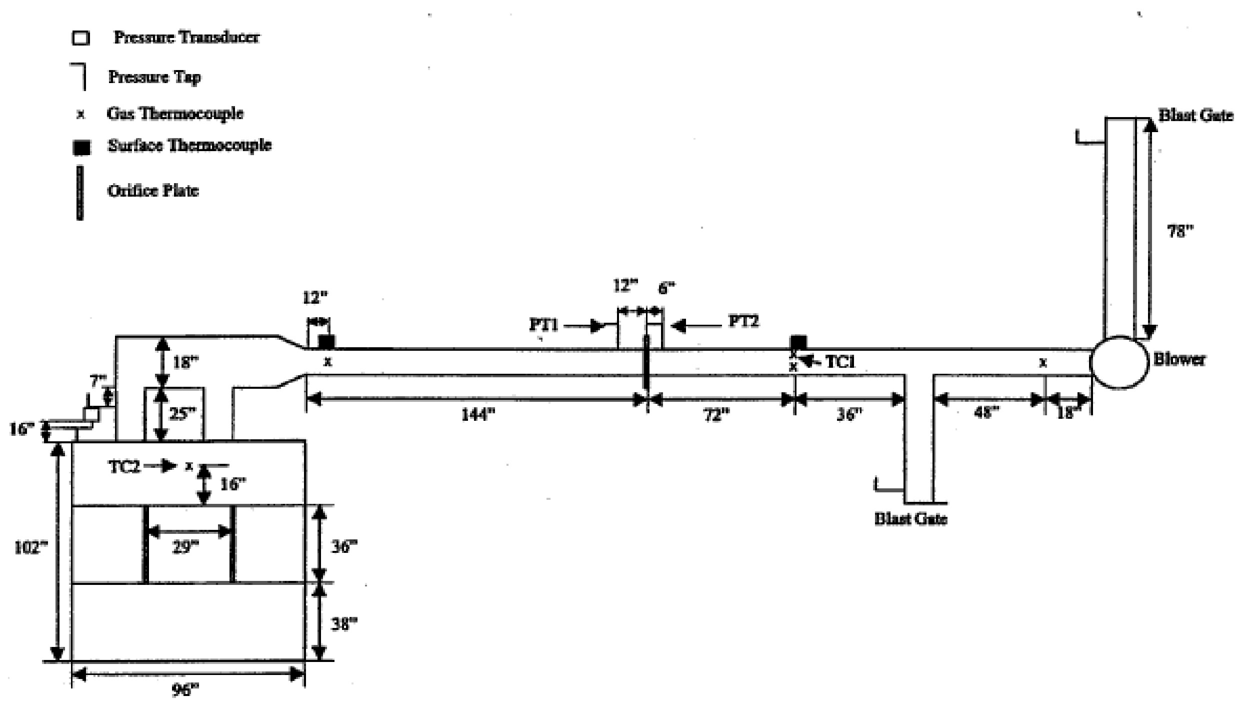


Figure H-1. Sketch of Example Mockup Arrangement for Fume Hood (Front View)

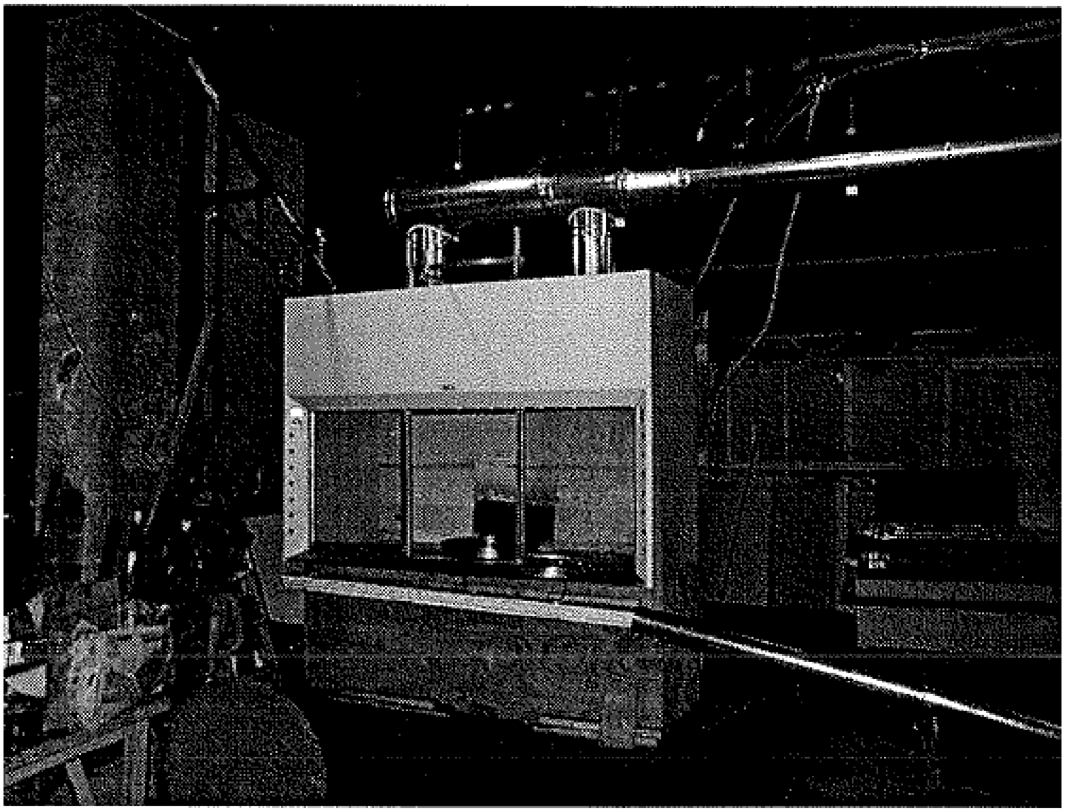


Figure H-2. Photograph of Sample Mockup Arrangement for Fume Hood

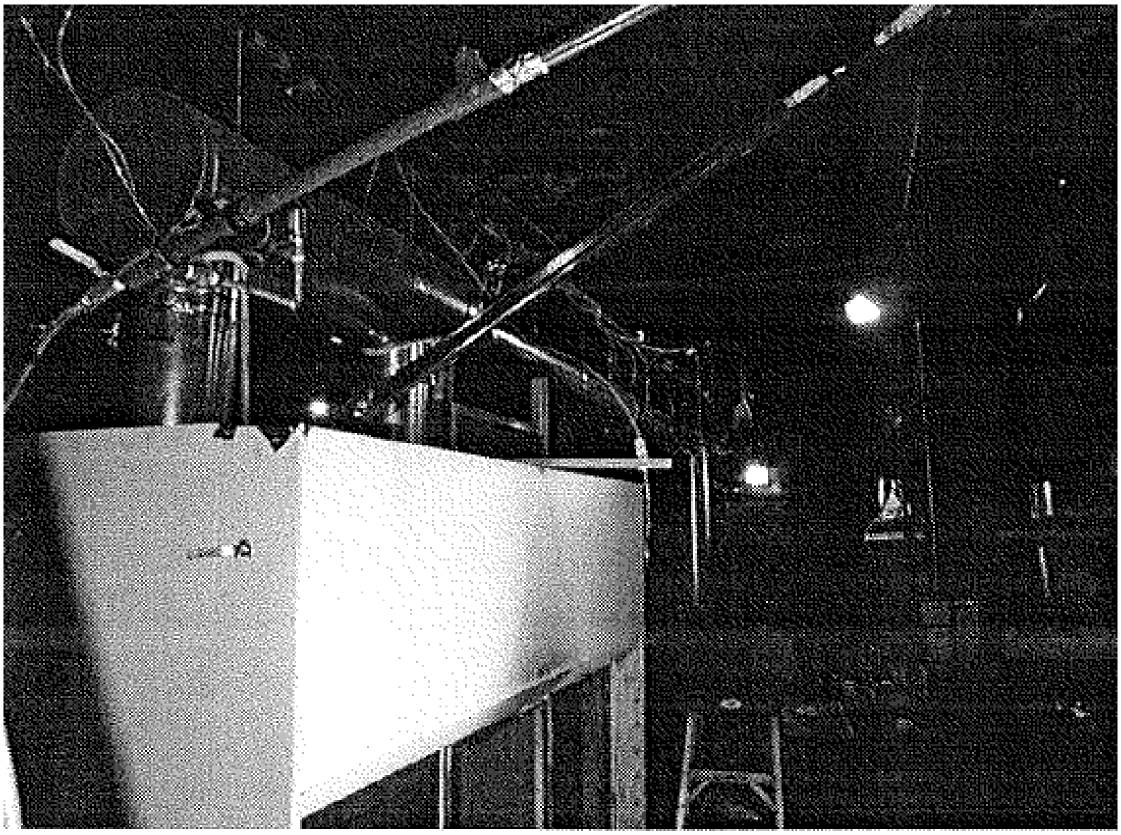


Figure H-3. Photograph of Sample Mockup Exhaust Arrangement for Fume Hood

APPENDIX I: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF DATA PROCESSING EQUIPMENT ROOMS/HALLS – ABOVE RAISED FLOOR

I.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 testing organization 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 link or glass bulb assembly and meet quick response (QR) nozzle criteria when tested per the applicable ANSI standard. 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 by the manufacturer 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.

I.2 Test Configuration

I.2.1 Test Mockup (See Figures I-1 and I-2)

The fire test facility shall consist of a movable ceiling with a length and width of a minimum of four nozzle spacing's. 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 I-1 and I-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 I-1 and I-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, an 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.

I.3 Fuel Package Configuration

I.3.1 Cables (See Figure I-3)

Figure I-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 I-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 I-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 shall be representative of the data cables used in data halls the manufacturer is intending to install water mist systems (for example - UBiQUiTI TOUGHCable Pro Cat5e). The cable should be constructed with 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 shall be 0.24 in (6 mm).

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 testing organization 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.

I.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 testing organization. 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.

I.5 Fire Performance Testing

I.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 I.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 with the water mist nozzles installed at the minimum specified distance from the ceiling.

2. Maximum ceiling height 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 testing organization 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 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 an 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 I-1 through I-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 testing organization. If a reduced nozzle spacing is utilized for fire test I.5.2.3 further testing at intermediate ceilings heights may be required at the discretion of the testing organization.

I.5.2 Fire Tests

I.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.

I.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.

I.5.2.3 Cable Fire Test – Minimum Ceiling Height – Minimum or Maximum Nozzle Distance from Ceiling (at the discretion of the testing organization)

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.

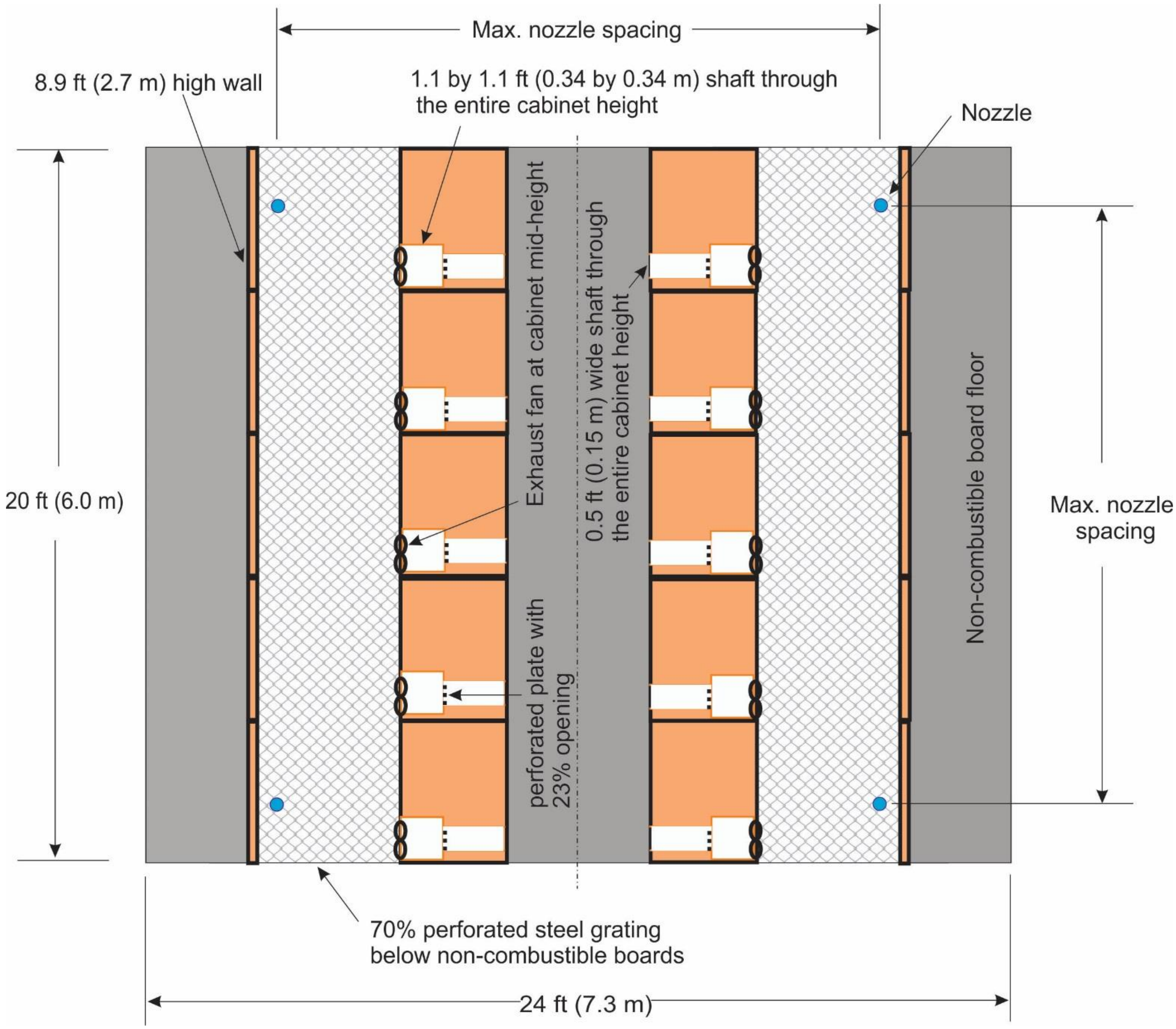


Figure I-1. Test Configuration in Plan View.

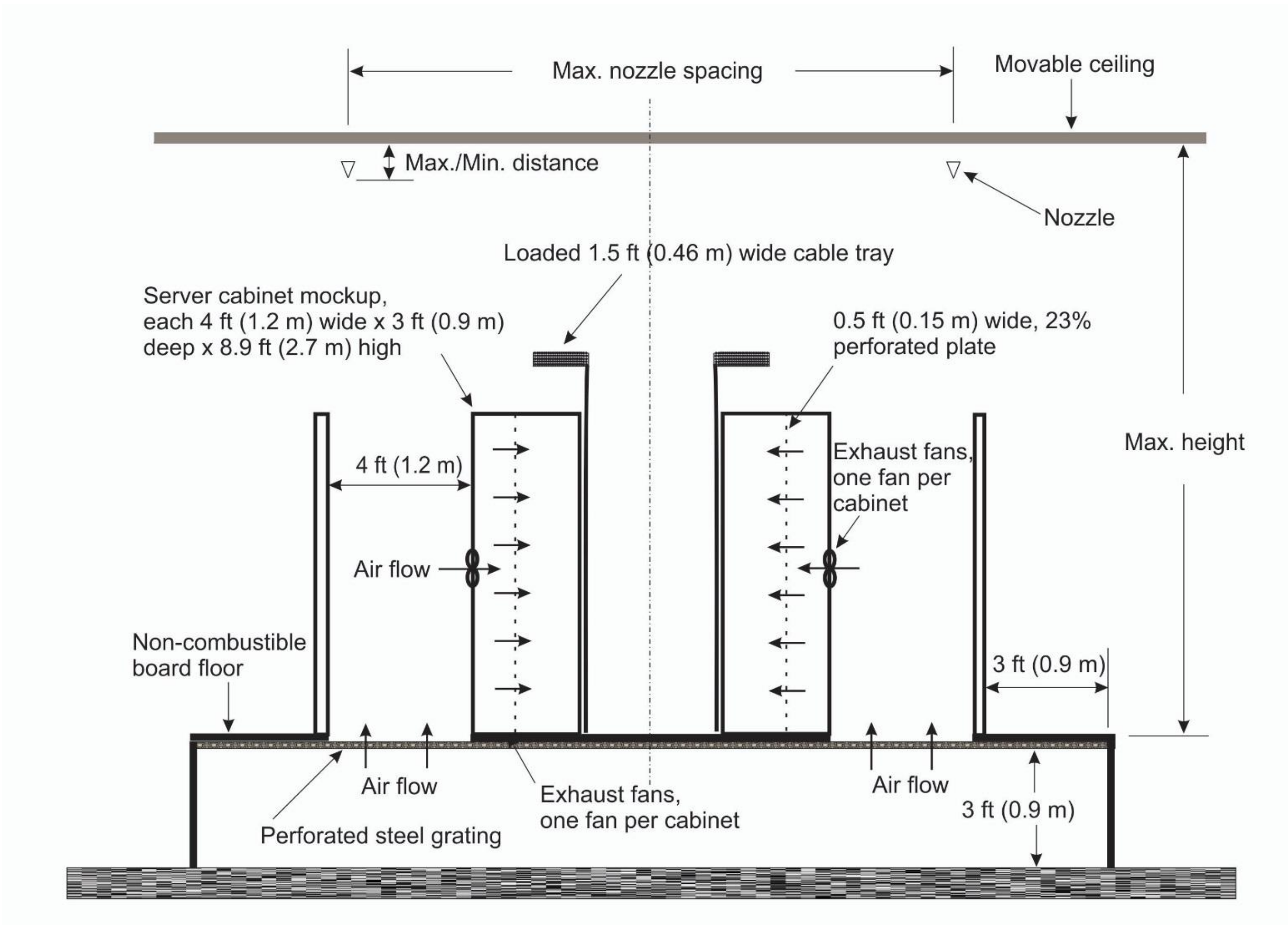


Figure I-2. Test Configuration in Elevation View.

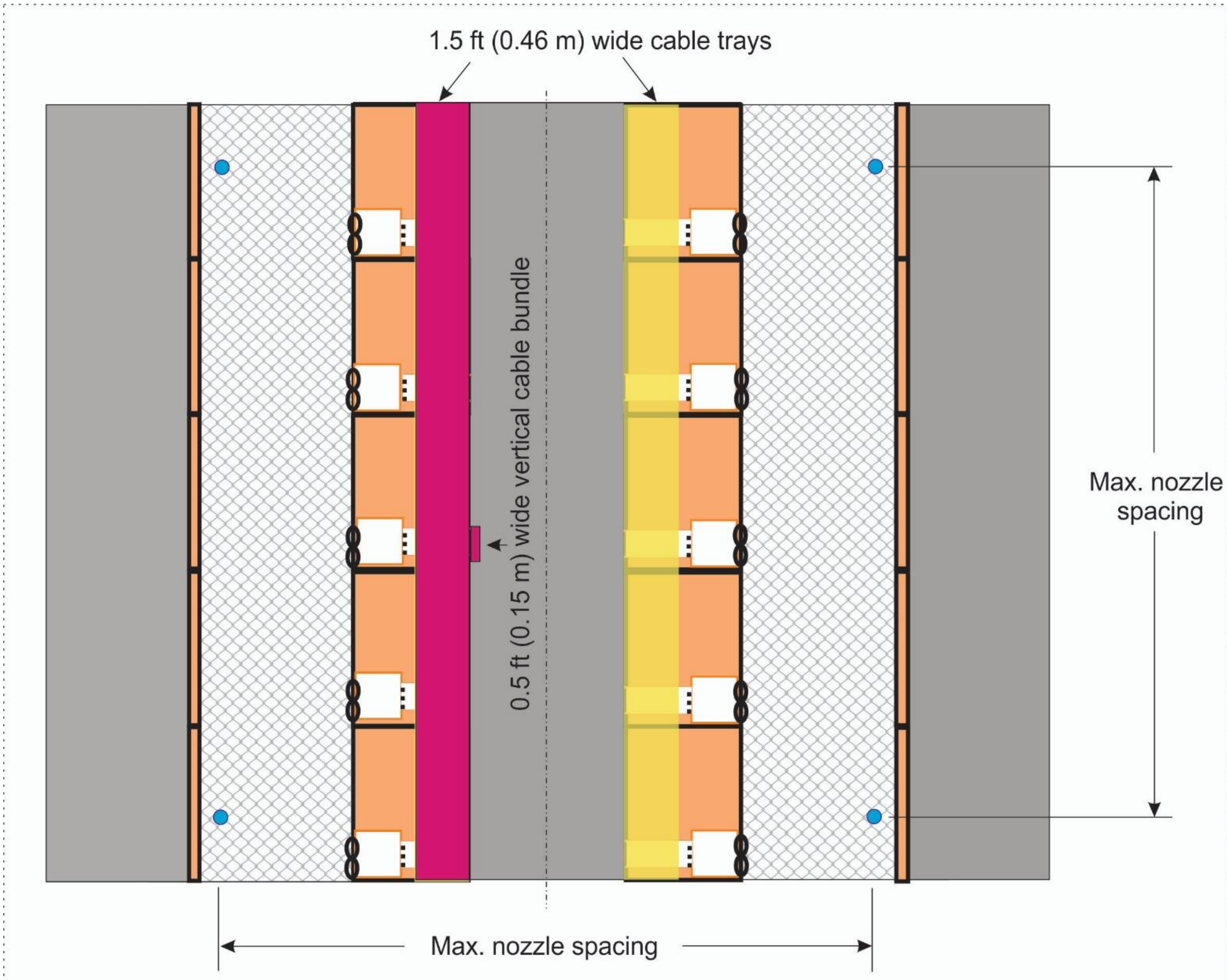


Figure I-3. Cable Fire Test Configuration.

Figure I-4. Photograph of Test Configuration.

Figure I-5. Photograph of Exterior Aisles of Test Configuration.

Figure I-6. Photograph of Interior Aisle of Test Configuration.

APPENDIX J: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF DATA PROCESSING EQUIPMENT ROOMS/HALLS – BELOW RAISED FLOOR

J.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 testing organization 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 link or glass bulb assembly and meet quick response (QR) nozzle criteria when tested per the applicable ANSI standard. 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 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 I) 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.

J.2 Test Configuration

J.2.1 Test Mockup (See Figures J-1, J-2, J-3, and J-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 and an internal length of 1.5 times the maximum nozzle spacing. 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 J-1, J-2, J-3, and J-4 for further details on the construction and arrangement of the raised floor test enclosure.

J.3 Fuel Package Configuration

J.3.1 Cables (See Figures J-1, J-2, J-3, and J-4)

Figures J-1, J-2, J-3, and J-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. 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 shall be representative of the data cables used in data halls the manufacturer is intending to install water mist systems (for example - UBiQUiTI TOUGHCable Pro Cat5e). The cable should be constructed with 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 shall be 0.24 in (6 mm).

The air velocity coming out of the raised floor is to be a minimum 3.3 ft/sec (1.0 m/s).

J.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 testing organization. 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 J-5. Thermocouples 1 through 6 (TC1 through TC6 as referenced in Figure J-5) shall be used to evaluate the gas temperature below the ceiling. Thermocouple 7 and 8 (TC7 and TC8 as referenced in Figure J-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.

J.5 Fire Performance Testing

J.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 J.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. The manufacturer’s water mist system design, installation, operation and maintenance manual shall include protection for only the amount of cable tray tiers in which fire performance testing was successful.

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 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 J-1, J-2, J-3, and J-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 testing organization.

J.5.2 Fire Tests

J.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.

J.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.

J.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.

J.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.

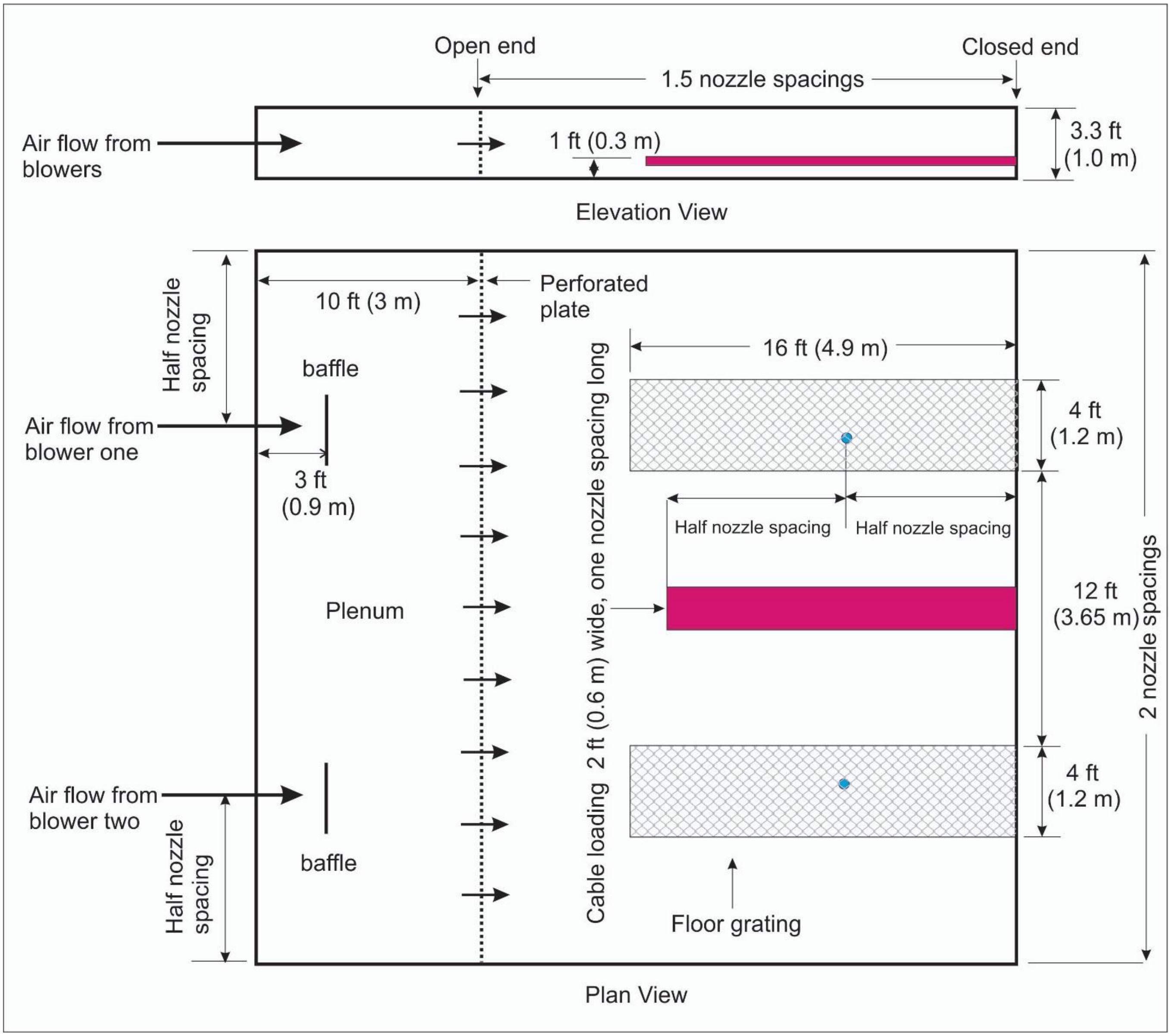


Figure J-1. Test J.5.2.1 Configuration Shown with Area of Coverage Nozzle Layout.

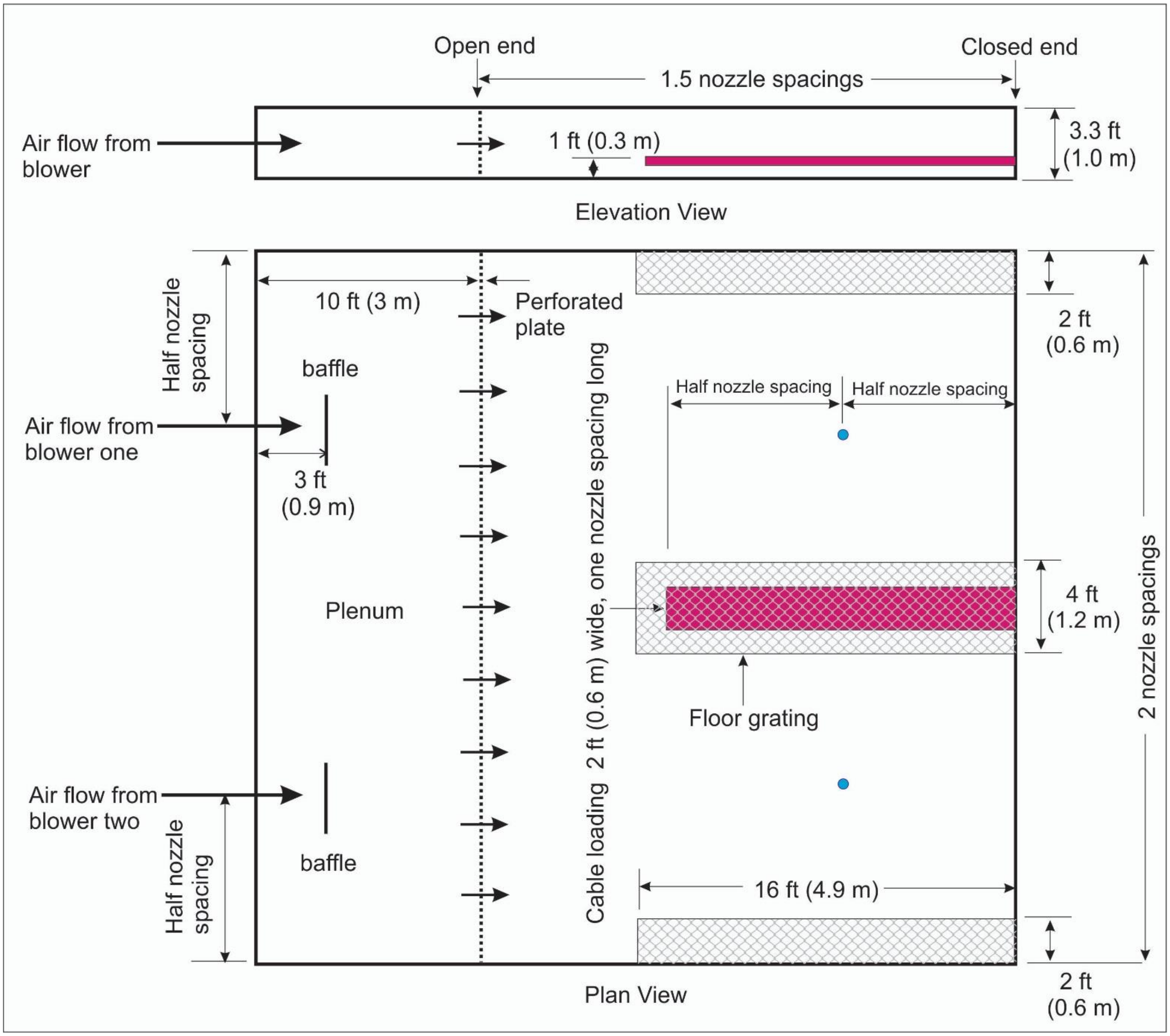


Figure J-2. Test J.5.2.2 Configuration Shown with Area of Coverage Nozzle Layout.

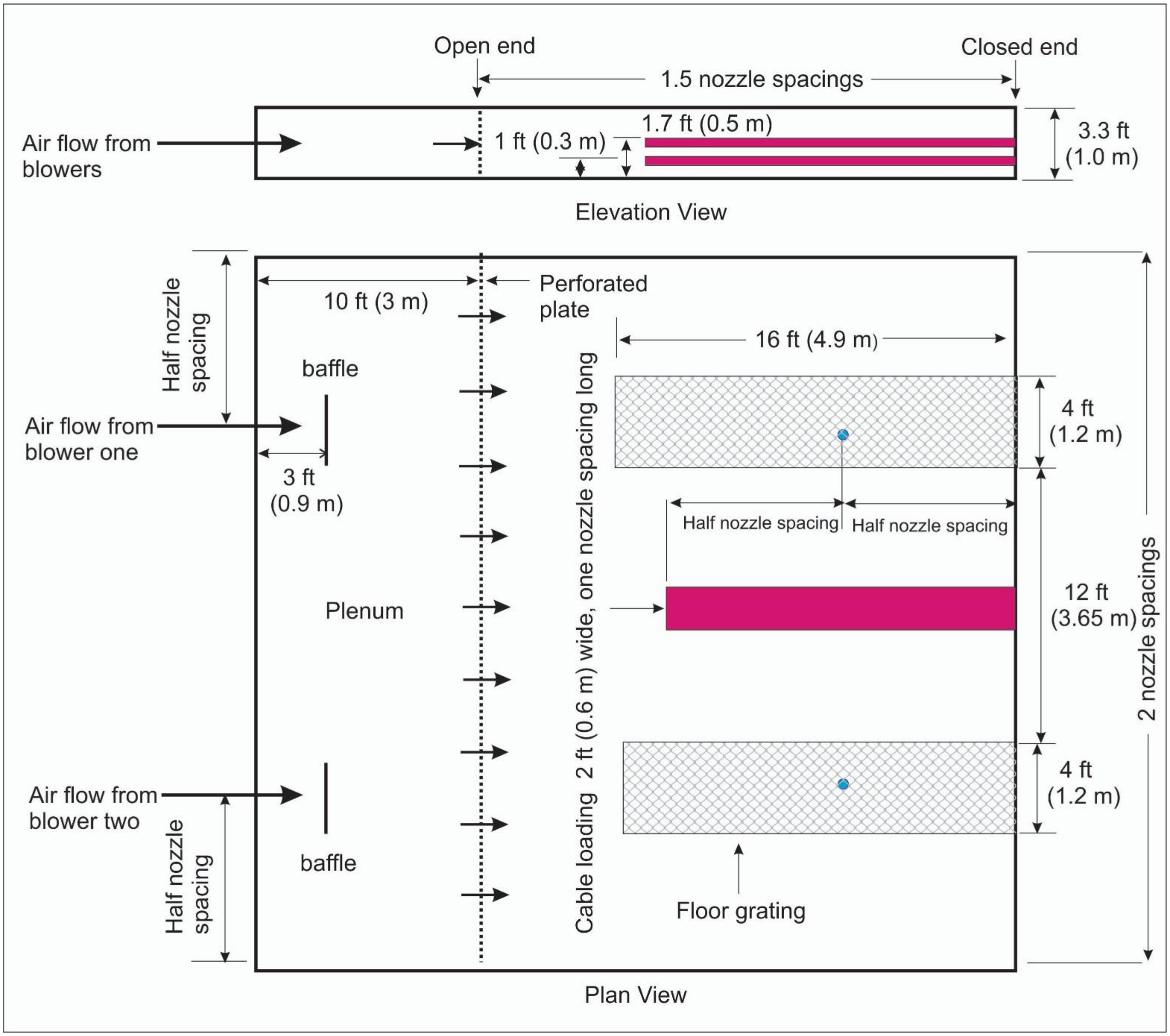


Figure J-3. Test J.5.2.3 Configuration Shown with Area of Coverage Nozzle Layout.

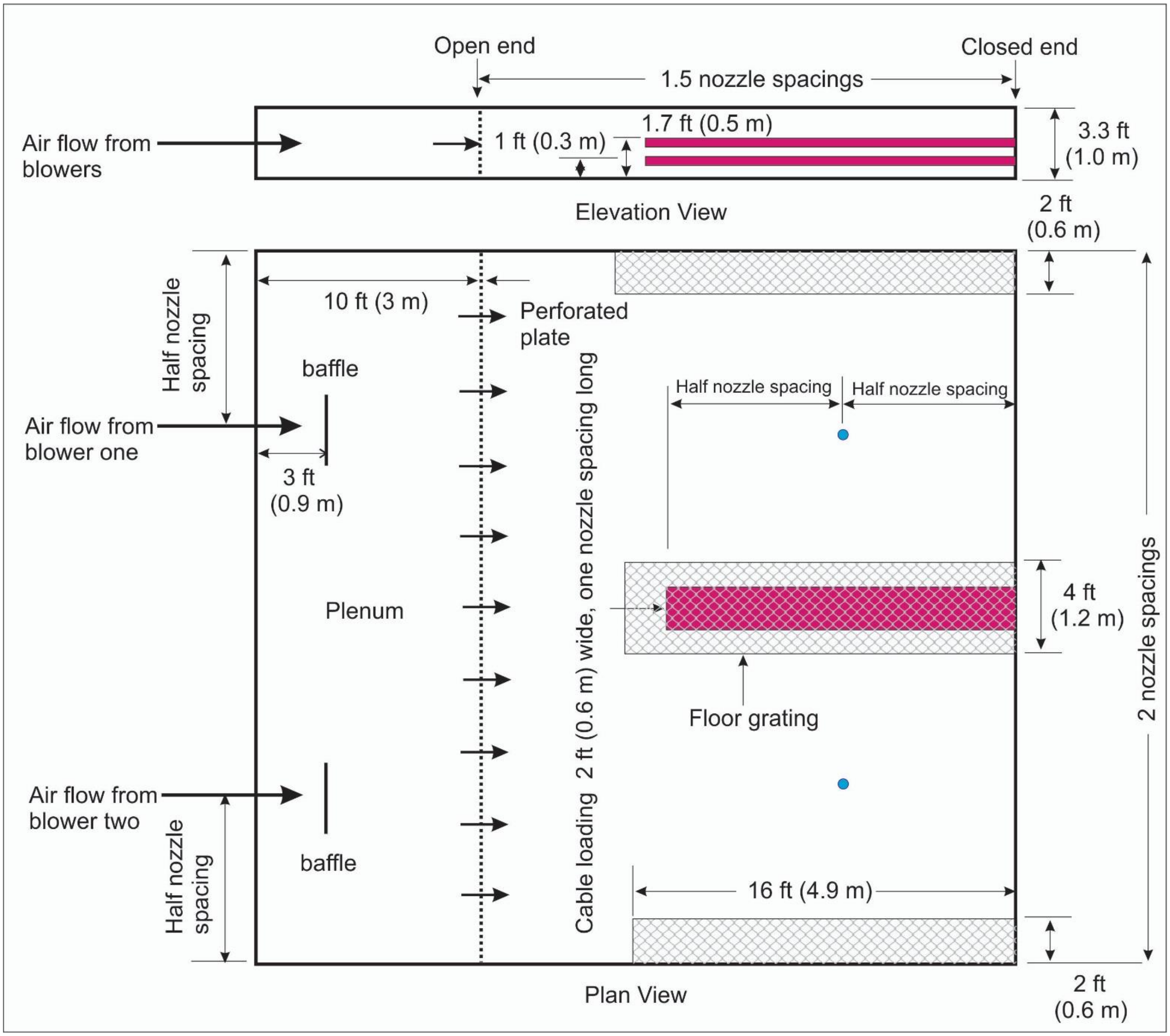


Figure J-4. Test J.5.2.4 Configuration Shown with Area of Coverage Nozzle Layout.

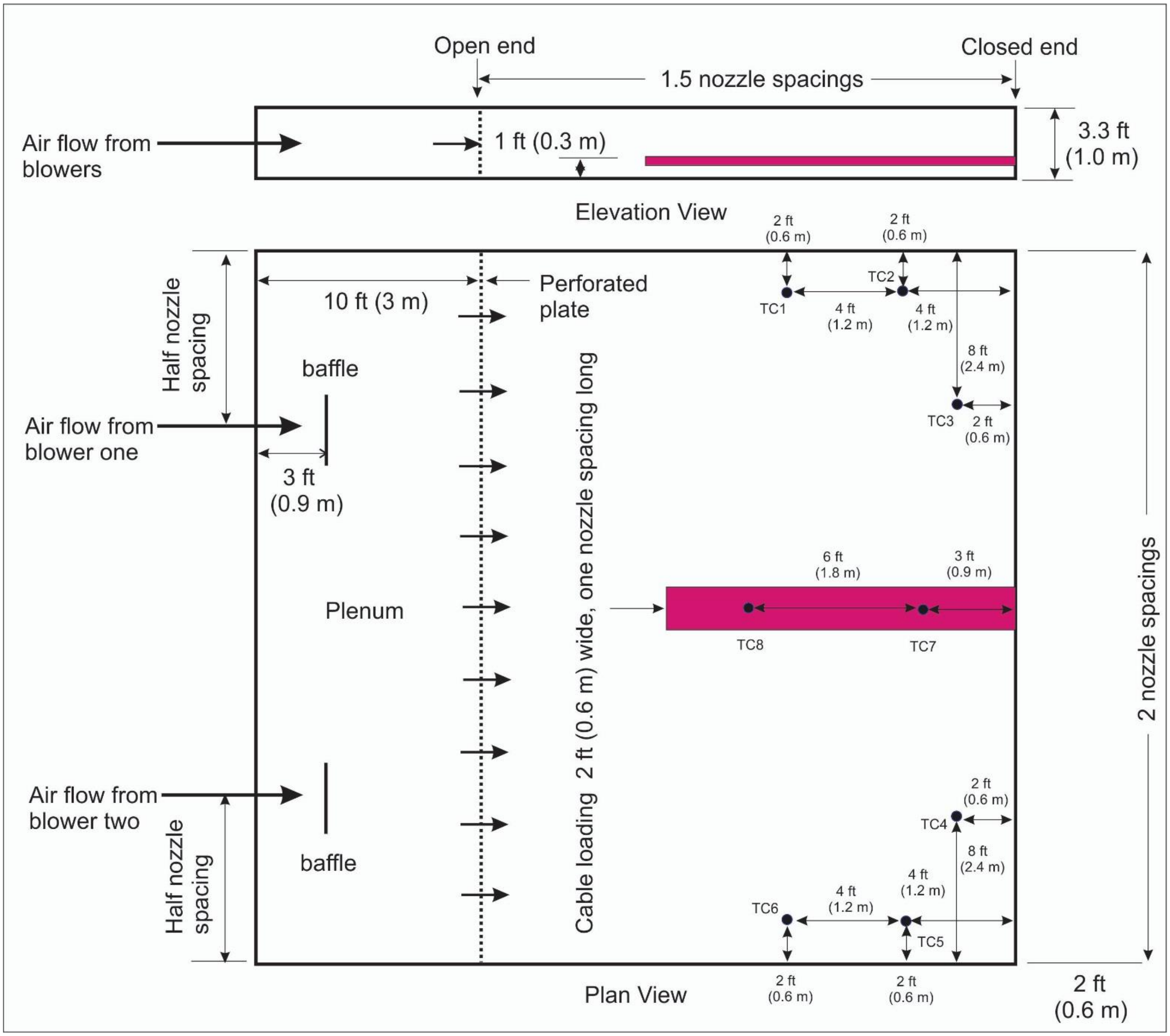


Figure J-5. Thermocouple Location Map.

APPENDIX K: SCALING METHODOLOGY: FIRE TESTS FOR WATER MIST SYSTEMS FOR THE PROTECTION OF COMBUSTION TURBINES IN ENCLOSURES IN ½-SCALE

K.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 K.1 summarizes the general scaling relationships and the relationships specific for the conditions of $\mathrm{Re}_d^{-1} \leq 1$. 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**	**$\mathrm{Re}_d \leq 1$**
Drag Coefficient	$\propto \mathrm{Re}_d^{-x}$	$\propto \mathrm{Re}_d^{-1}$
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 K.1: General scaling relationships.

K.2 ½-Scale Testing Process

Based on the scaling methodology described in Section K.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 C. The following is the general process for using the scaling methodology (Reference Chart K.2):

1. Water mist system manufacturer discusses with testing organization the parameters for full-scale protection based on the system design, installation, operation and maintenance manual:
    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 testing organization with complete drawing packages.

3. The testing organization 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 discretion of the testing organization 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. Full-scale protection by scaling up the ½-scale fire performance test results according to the scaling relationships can be used in the system design, installation, operation and maintenance manual. The required water mist system size and minimum discharge duration will be based on the longest fire extinguishment time.

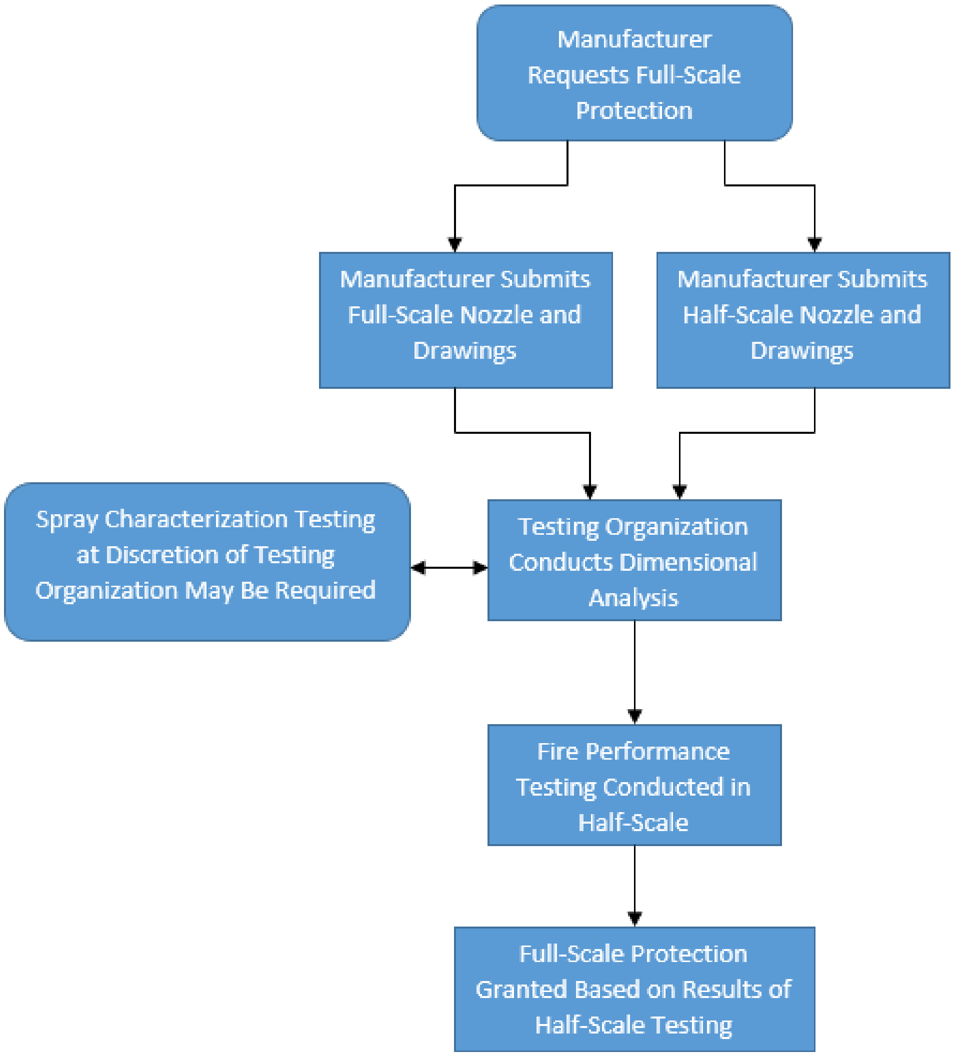


Chart K.2: Half-Scale Testing Process Flow Diagram

To provide further information on how the process works the following is an example scenario:

Manufacturer applies 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 testing organization 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 testing organization, if acceptable, fire performance testing can be conducted in accordance with Appendix K. 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, the application 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).

K.3 Test Enclosure (see Figure K-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 testing organization may restrict the scope of the system 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 K-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 combustion turbine and engine mockup unit should be centered in the test enclosure. In the case of rectangular enclosures, the testing organization 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 testing organization, additional fire tests in smaller enclosures may be performed to validate the manufacturer's design parameters.

K.4 Combustion Turbine and Engine Mockup Unit (see Figures K-2 and K-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 testing organization.

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.

K.5 Combustion Turbine Spray Cooling Mockup Unit (see Figure K-5)

The combustion turbine casing mockup is simulated with a horizontal flat steel plate (see Figure K-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 testing organization after the nozzles are installed (as per manufacturer's design criteria). In lieu of actual turbine casing material, which is typically ductile iron, the test plate is constructed of hot rolled ASTM A36 steel. The center of the plate is instrumented across its thickness with thermocouples placed at various depths, as described below.

To determine the cooling rate of the combustion turbine steel plate mockup, caused by the discharge of the 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).

K.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	Wide spray angle (120°) full cone type	Wide spray angle (90°) full cone type	Standard spray angle (60°) full cone type
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)

Example: Low Pressure Fuel Nozzle – Monarch F80 30.0 Type AR 120°
Example: Low Pressure – Low Flow Fuel Nozzle – Monarch F80 5.5 Type AR 90°
Example: High Pressure Fuel Nozzle – Monarch F80 2.0 Type AR 60°

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. (2.5 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 K.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.

K.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 combustion 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 combustion turbines in enclosures, corresponding to Appendix C, the water mist system shall successfully complete the first eight (K.7.1 through K.7.8) fire performance tests and the Spray Cooling (heat transfer) test (K.7.9). An additional option for combustion turbine applications is the protection of insulated turbines. Two additional fire tests (K.7.10 and K.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 1.7, Definitions). For primary protection, agent supply shall be equivalent to that required for an automatic sprinkler protection system for the hazard protected.

K.7.1 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 7 in. (178 mm) from the edge of the longer side of the top tray (see Figure K-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.

K.7.2 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 0.3 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 K-3 and K-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.

K.7.3 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 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 K-2 and K-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.

K.7.4 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 7 in. (178 mm) from the edge of the longer side of the top tray (see Figure K-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.

K.7.5 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 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 K-2 and K-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 K-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.

K.7.6 Concealed, Heptane Pool Fire

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 K-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.

K.7.7 Flowing Fire

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.

K.7.8 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:	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 K-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.

K.7.9 Spray Cooling (No Fire)

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:	Determine if the heat flux resulting from a water mist system discharge will adversely affect the turbine. Such assessment is to be made in accordance with methodology developed by the testing organization to assess the damage potential of water mist systems being tested. This test, combined with the applicable NRTL heat transfer calculations, will determine the extent of the cooling of the turbine casing during the operation of the water mist system. Calculations will be based on the manufacturer's recommended diameter sized turbines to be installed within the enclosure.
Test Procedure:	A spray fire will be necessary to heat the steel plate. The spray fire will be located between the baffles underneath the test table with the fuel spray nozzle aimed at the table at a 30º grazing angle with the flames centered and impinging on the steel table mid point. When all three steel plate thermocouples reach 572 ºF (300 ºC), the spray fire will be shut off, and the steel plate will be allowed to cool. To avoid excess heating of the test enclosure, the ceiling hatches and the access door shall be left open only during the heating of the plate. When the last of three thermocouple readings drops to 572 ºF (300 ºC), then the water mist system will be activated and the temperature history of the plate will be recorded for a total of 15 minutes. The spray cooling test shall have the available recorded data in Microsoft Excel format. The data will be reviewed by appropriate NRTL for the heat transfer calculation analysis. 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. The heat flux is also affected by the stand-off distance of the water mist nozzles. The testing organization will conduct this test at the minimum and maximum nozzle

stand-off distance specified in the client's design manual. (The design manual shall also specify no direct spray impingement).

K.7.10 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 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 K-2 and K-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 K-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.

K.7.11 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: 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.

K.7.12 Additional Fire Tests

Based on the results of Fire Tests K.7.1 through K.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 testing organization.

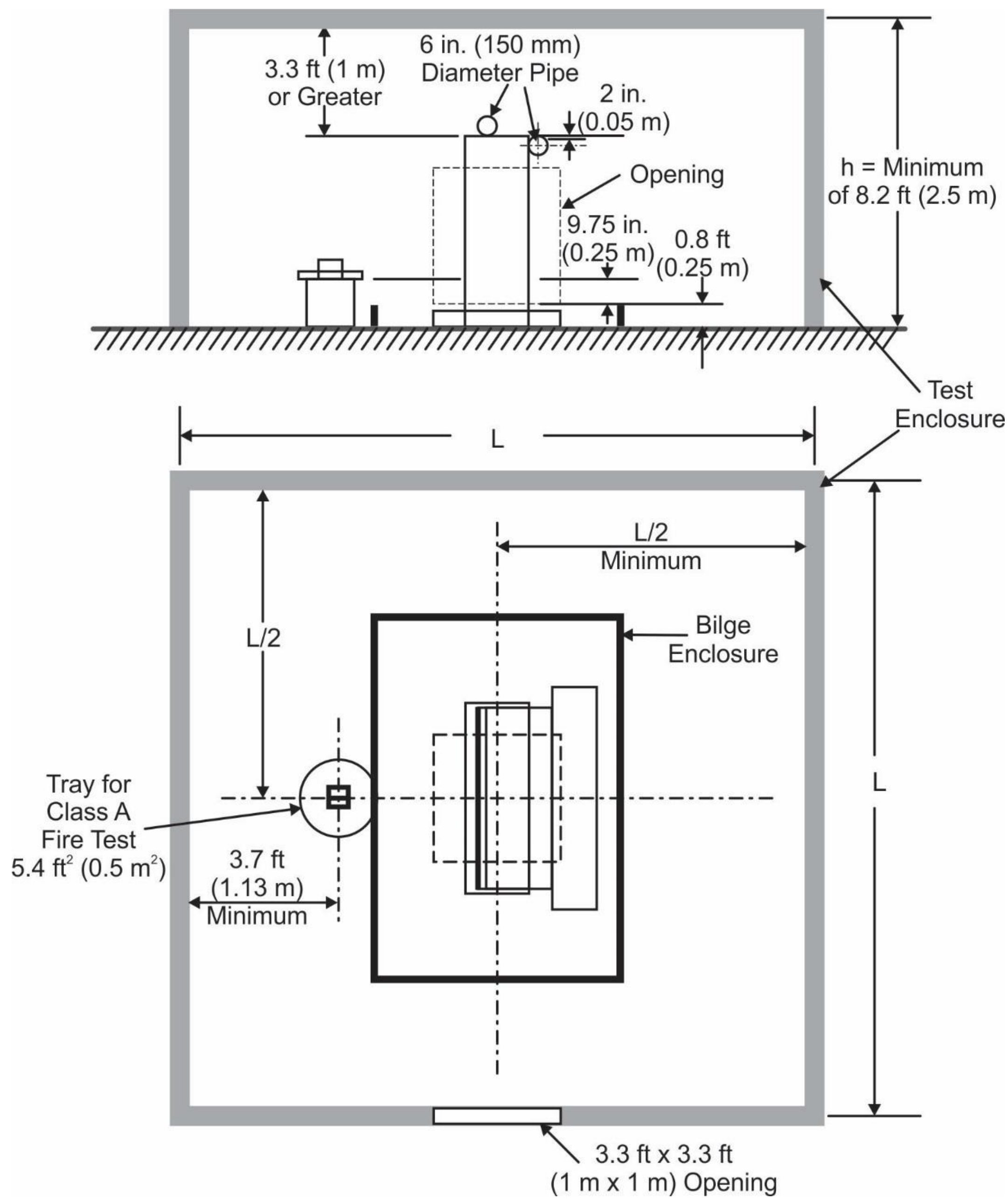


Figure K-1. Machinery and Combustion Turbine Test Enclosure

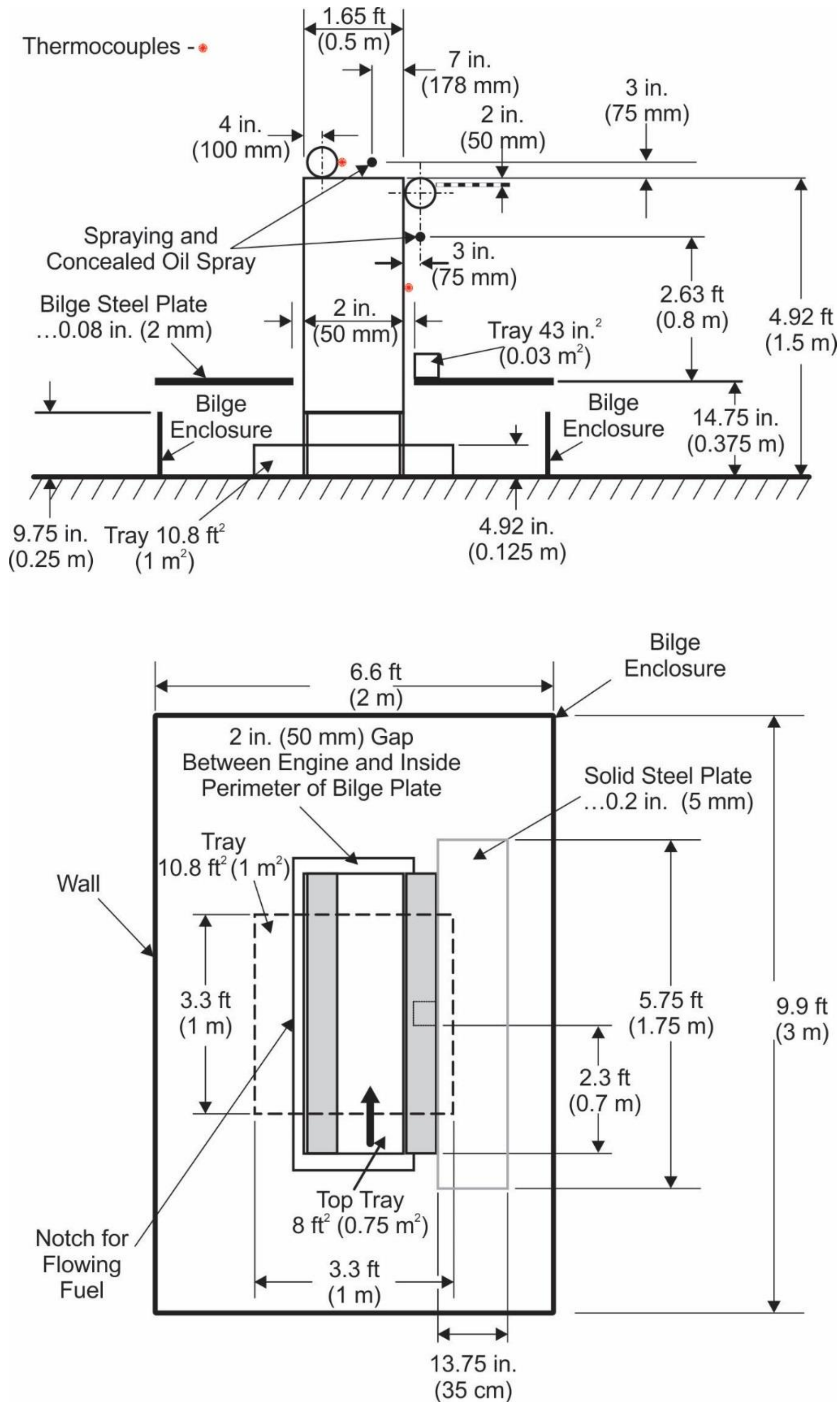


Figure K-2. Machinery and Combustion Turbine Mockup Unit

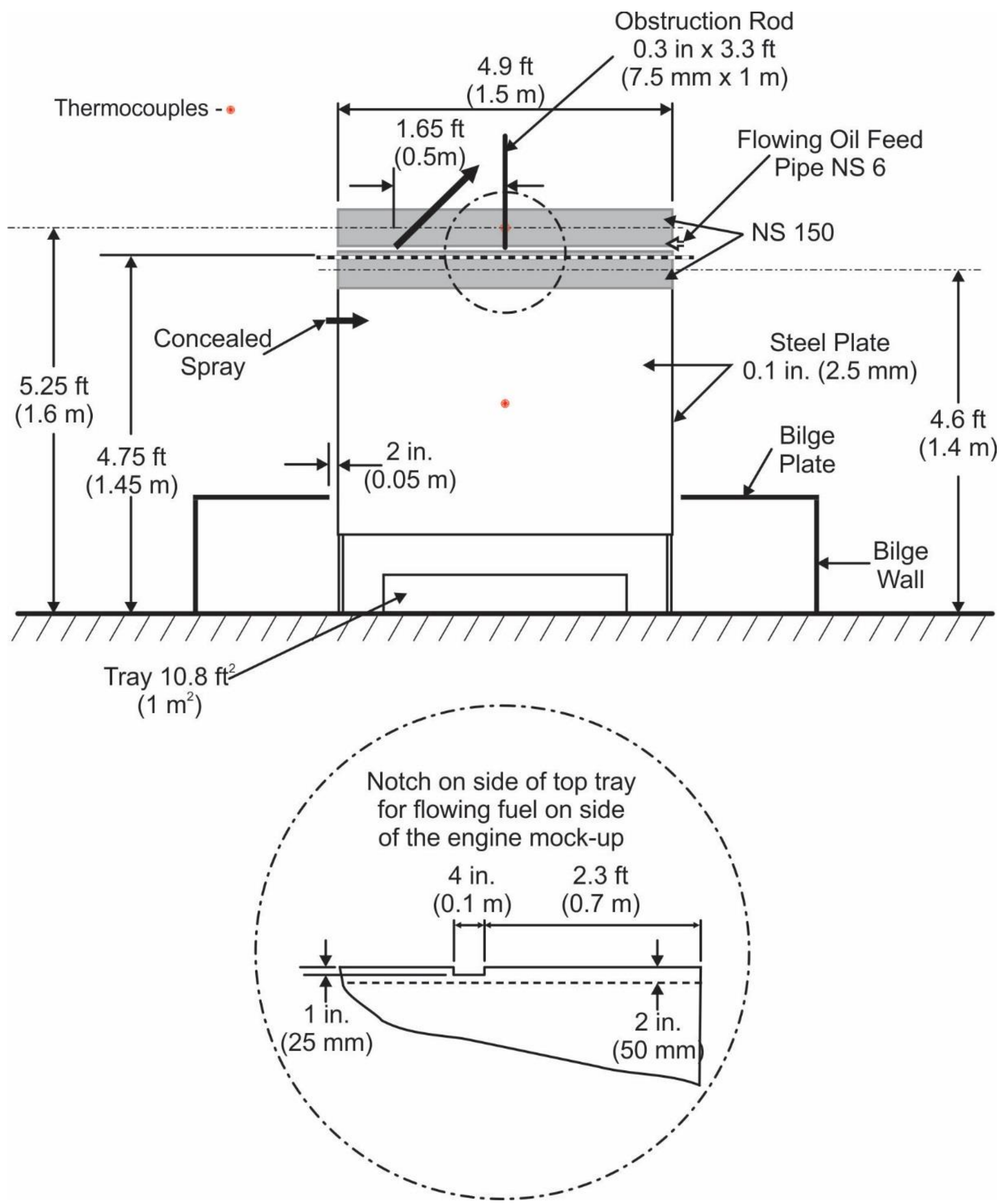


Figure K-3. Machinery and Combustion Turbine Mockup Unit (Continued)

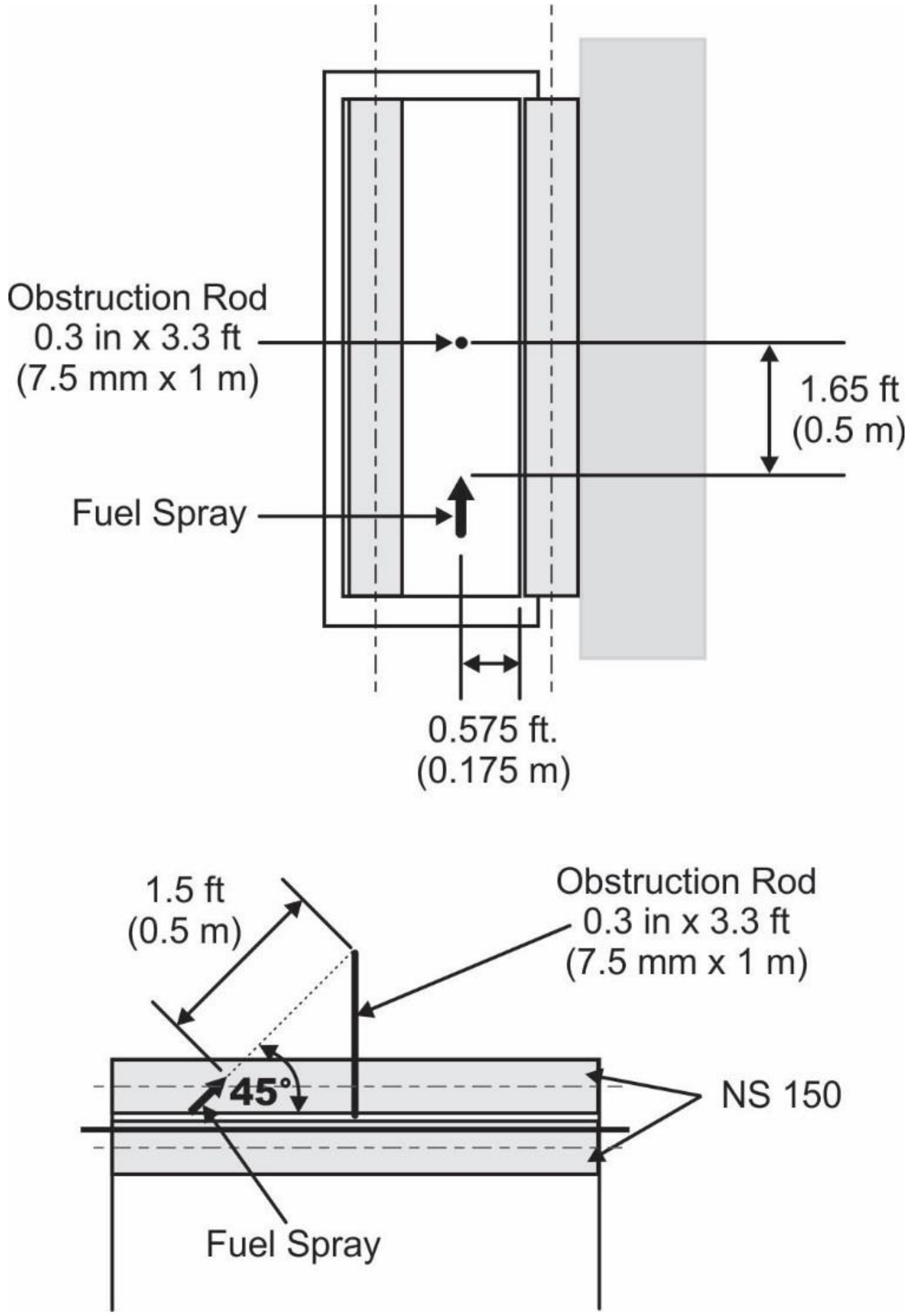


Figure K-4. Fire Test K.7.2, Position of Fuel Spray Nozzle and Obstruction Rod

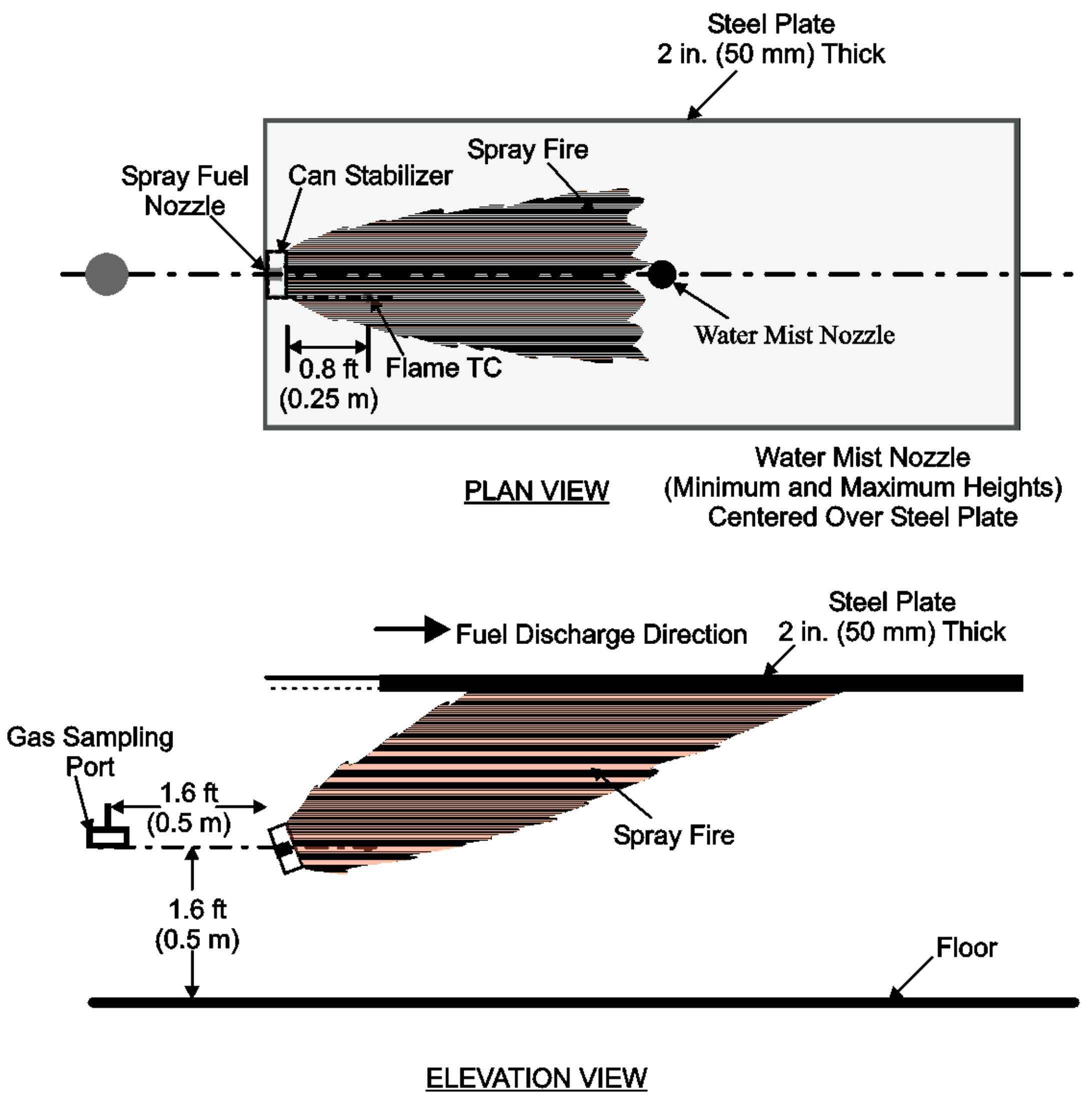


Figure K-5. Fire Source Configuration for Spray Cooling (No Fire) Testing

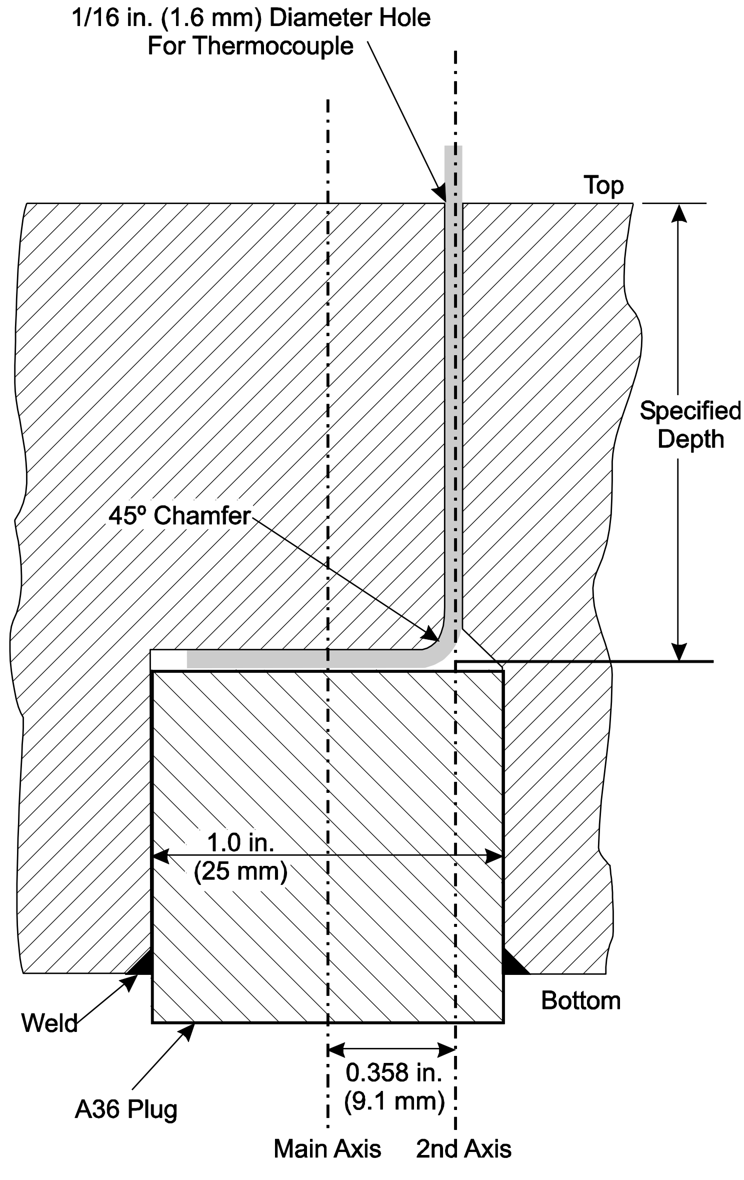


Figure K-6. Detail of Embedded Thermocouple for Spray Cooling Test

APPENDIX L: Units Of Measurement

AREA:	in^2 - "square inches"; (mm^2 - "square millimeters") ft^2 - "square feet"; (m2 - square meters") $mm^2 = in^2$ x 645.16 $m^2 = ft^2$ x 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"; $(L/min/(kPa)^{1/2}$ - "cubic decimeters per minute per square root of kilopascals") $(L/min/(kPa)^{1/2} = gal/min/(psi)^{1/2}$ 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"; (kPa - "kilopascals") 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
VACUUM:	inHg - "inches of mercury"; psi - "pounds per square inch"; (kPa - "kilopascals") psi = inHg x 0.4912 kPa = 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 M: 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 N: Figures

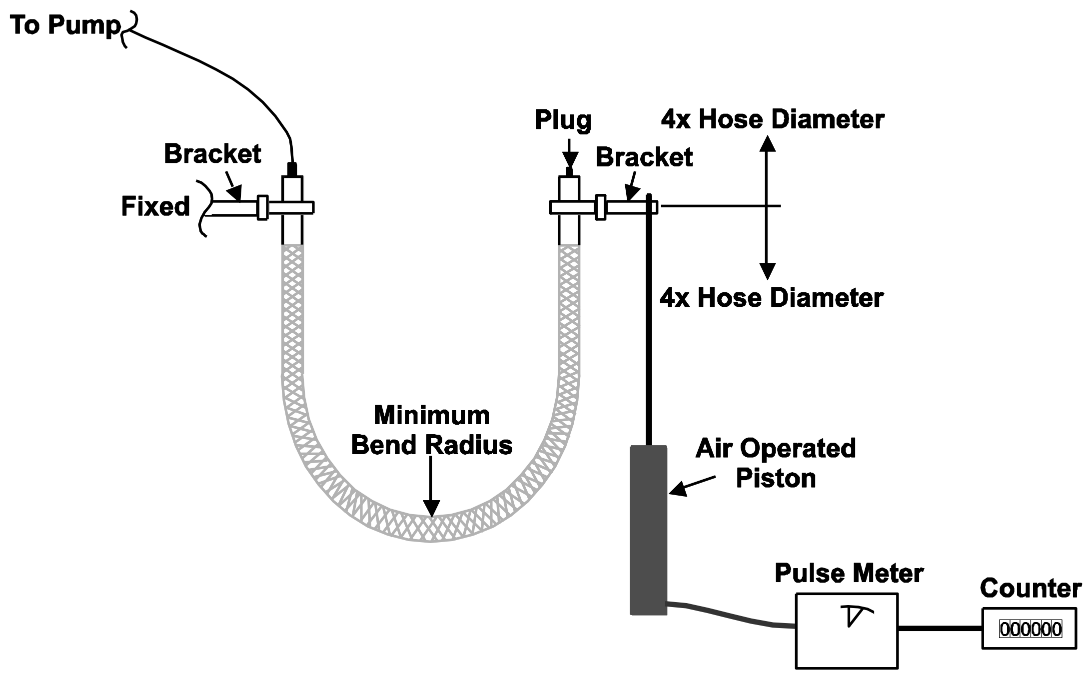


Figure N-1. Test Apparatus for Fatigue Test