FM Approvals®

Member of the FM Global Group

Examination Standard
for
Heavy Duty Mobile Equipment Fire Protection Systems

Class Number 5970

February 2022

Foreword

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

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

Table of Contents

1 INTRODUCTION

1.1 Purpose

1.1.1 This standard describes requirements for fire protection systems for heavy duty mobile equipment (hereinafter called "HDME") which use a variety of suppressants. These include, but are not limited to, dry chemical, wet chemical, foam, and gaseous agents. The following product categories and class numbers are included in the scope of this standard.

Table 1.1.1 – *Product Categories and Class Numbers*

Class	***Product Category***
5971	Complete HDME Fire Protection Systems
5972	Suppressant Storage and Delivery Systems for HDME Protection
5973	Detection and Control Systems for HDME Protection

1.1.2 Testing and certification criteria may include, but are not limited to, performance requirements, marking requirements, examination of manufacturing and filling facilities, audit of quality assurance procedures, and a surveillance audit program.

1.2 Scope

1.2.1 HDME includes a large range of sizes and complexity. The smallest examples may carry a single operator and have an open cockpit. These include such types as front-end loaders, haulage trucks, and logging vehicles. The largest include mining equipment that may have several floors, a multiplicity of hazards, and multiple occupants. These include power shovels, walking crushers, wheel excavators, and draglines. Accordingly, the environments on the various types of equipment can range from relatively clean light hazard occupancies such as cockpits, break rooms, and other occupiable spaces to machinery spaces containing various ignitable liquid hazards. Electrical cabinets may present hazards requiring separate, specific extinguishing systems. Otherwise unprotected occupiable spaces may require special hazard protection systems for specific objects. Protection system components installed outside of the vehicle and exposed to weather, dust, moisture, and debris thrown by tires and tracks require specific evaluations for that service. They also shall be evaluated for resistance to cleaning procedures such as pressure washing and steam cleaning.

1.2.2 This standard requires the examination of complete systems: either storage and delivery, detection and control, or combined detection, control, storage, and delivery. Complete systems shall be submitted for certification along with design, installation, operation, and maintenance instructions. However, the manufacturer may, at any time, submit additional components or auxiliary equipment for use on the certified system. Purchased devices such as thermostats, releases, and timers must also be submitted by the system manufacturer for evaluation as a part of the system, even though such devices may already be certified. Purchased devices that have been certified as standalone products need only be subjected to any evaluations required by this standard that were not conducted as a part of their original examinations. They shall also only be allowed to be used within the parameters established in their certifications. At minimum, a storage and delivery system shall consist of those components and auxiliary equipment considered necessary by the certification agency for the system to operate properly, either as a standalone or when connected to a certified detection and control system. Incomplete systems shall not be certified.

1.2.3 HDME fire protection systems are classified into one of two general categories according to protection type: total flooding or local application. Total flooding systems are designed to uniformly discharge suppressant throughout the entire protected volume and are intended to be used for the protection of Class A hazards, Class B hazards, or both. Local application systems are designed to discharge suppressant directly onto a specific area of protection and are intended to be used for the protection of Class A hazards, Class B hazards, or both. Either type shall be designed for automatic and manual control to protect single or multiple hazard areas using the appropriate detection method for the hazard being protected. These systems are typically pre-engineered designs.

1.2.4 A HDME protection system comprises one or more agent storage containers, discharge valves arranged for automatic or manual/automatic control, lock-out valves (when required), distribution configurations, discharge nozzles, and detection and control. Integral detection and control capability shall be evaluated as a part of the complete HDME system, using the criteria of this standard. Otherwise, a separate certified Class 5973 detection and control system must be compatible to provide any applicable automatic electrical operation of a system, though it need not be submitted as part of a suppressant storage and delivery system. Detectors shall meet certification agency requirements, e.g. thermal (Class 3210) or flame (Class 3260) detectors and shall meet the relevant requirements of this standard. Harsh environments in certain locations within the HDME may limit the effectiveness of some detection technologies.

1.2.5 An HDME protection system may use a single suppressant or combine multiple suppressants in a coordinated system. Multiple suppressants may be used serially or simultaneously to protect the same space. Further, different areas of the same piece of heavy duty mobile equipment may use different extinguishing systems using the same or different suppressants. Such complex or multiple systems shall be evaluated to ensure that they are compatible with one another, and that each does not interfere with the operation of the other.

1.2.6 The HDME protection system shall be capable of independent actuation by both automatic and manual means. Manual actuation can be mechanical. Typically, mechanical means are used to enable system actuation in the event of some failure to operate when actuation has been attempted by automatic means. This capability involves some combination of detection, control, indication, notification, and releasing functions. The related requirements primarily apply to systems, or portions of systems, using electrical power. This does not preclude the use of mechanical or pneumatic equipment and the appropriate application of these requirements to such operation. Specific hazards may not be amenable to automatic operation of systems. Such hazards may be protected by systems providing only manual actuation.

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 HDME fire protection systems (hereinafter referred to as “systems”) for the purpose of obtaining certification. Systems having characteristics not anticipated by this standard may be certified if performance equal, or superior to that required by this standard is demonstrated.

1.4 Basis for Certification

Certification is based on satisfactory evaluation of the product and the manufacturer in the following major areas:

1.4.1 Examination and tests on production samples shall be performed to evaluate:

- The suitability of the product
- The performance of the product as specified by the manufacturer and required for certification; and as far as practical
- The durability and reliability of the product

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

1.5 Basis for Continued Certification

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

- Production or availability of the product as currently certified
- Continued use of acceptable quality assurance procedures
- Satisfactory field experience
- Compliance with the terms stipulated in the certification
- Satisfactory re-examination of production samples for continued conformity to requirements.
- Satisfactory surveillance audits conducted as part of the certification agency’s product follow up program

1.6 Effective Date

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

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

1.7 System of Units

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

1.8 Normative References

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

ANSI/IEEE/ASTM SI 10, *American National Standard for Metric Practice*
AS 5062, *Fire Protection for Mobile and Transportable Equipment*
ASME BPVC-CC-N, *Boiler and Pressure Vessel Code*
ASTM B 117, *Standard Practice for Operating Salt Spray (Fog) Apparatus*
ASTM D 412, *Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers*
ASTM E–1, *Standard Specification for ASTM Thermometers*
ASTM G 36, *Standard Practice for Evaluating Stress-Corrosion-Cracking Resistance of Metals and Alloys in a Boiling Magnesium Chloride Solution*
ASTM G 155, *Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials*
CGA S-1.1, *Pressure Relief Standards Part 1 - Cylinders for Compressed Gases*, Edition 12
DS/EN 50130-4, *Immunity Requirements for Components of Fire, Intruder, Hold Up, CCTV, Access Control and Social Alarm Systems*
DS/EN 61000-4-2, *Electrostatic Discharge Immunity Test*
DS/EN 61000-4-3, *Radiated, radio-frequency, electromagnetic field immunity test*
DS/EN 61000-4-4, *Electrical fast transient / burst immunity test*
DS/EN 61000-4-5, *Surge immunity test*
DS/EN 61000-4-6, *Immunity to conducted disturbances, induced by radio-frequency fields*
FM 3010, *Fire Alarm Signaling Systems*
FM 3210, *Heat Detectors for Automatic Fire Alarm Signaling*
FM 3260, *Radiant Energy-Sensing Fire Detectors for Automatic Fire Alarm Signaling*
FM 3600, *Electric Equipment for Use in Hazardous (Classified) Locations General Requirements*
FM 3610, *Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, and Class I, Zone 0 and 1 Hazardous (Classified) Locations*

FM 3611, *Nonincendive Electrical Equipment for Use in Class I and II, Division 2, and Class III, Divisions 1 and 2, Hazardous (Classified) Locations*
FM 3615, *Explosionproof Electrical Equipment General Requirements*
FM 5130, *Foam Extinguishing Systems*
FM 5320, *Dry Chemical Extinguishing Systems*
FM 5420, *Carbon Dioxide Extinguishing Systems*
FM 5560, *Water Mist Systems*
FM 5600, *Clean Agent Extinguishing Systems*
ANSI/NFPA 72, *National Fire Alarm and Signaling Code*
SAE J400, *Test for Chip Resistance of Surface Coatings*
Title 49, Code of Federal Regulations (CFR), *Hazardous Materials Regulations of the Department of Transportation*

1.9 Definitions

For the purposes of this standard, the following terms shall apply:

Accepted
Installations acceptable to the authority having jurisdiction and enforcing the applicable installation rules. Acceptance is based on an overall evaluation of a specific installation. Factors other than the use of certified equipment may impact the decision to accept the equipment. Acceptance is not a characteristic of a product; acceptance is installation specific. A product accepted for one installation may not be acceptable elsewhere.

Actuation Device
A means of initiating the HDME fire protection system discharge that is installed on the agent storage container discharge valve or actuation cartridge and is capable of operation by electrical means, manual actuation, or pneumatic pressure, or other means deemed acceptable by the certification agency.

Agent Storage Container
The assembly holding the suppressant supply for the HDME protection system. This includes the pressure vessel and various accessories necessary for management of the supply, such as valves, siphon tubes, pressure gauges, and pressure relief devices. Also known as "Suppressant Storage Container".

Agent Storage Cylinder
See "Agent Storage Container"

Alarm Condition
An abnormal condition, such as the occurrence of a fire, which necessitates warning indication and other appropriate actions.

Amplitude
The maximum displacement of sinusoidal motion from position of rest, or one-half the total table displacement, during a vibration test.

Area of Coverage
The maximum area that can be protected by an HDME suppressant discharge nozzle or automatic extinguisher unit.

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

Automatic Control
Operation which does not require human intervention. Automatic control typically uses a control unit that monitors fire detection devices and releases the agent when pre-established conditions have been met.

Automatic Extinguisher Unit
A total flooding HDME suppressant storage container that discharges following the operation of a heat responsive element or similar actuation device as the primary detection means. Automatic extinguisher units may also include optional mechanical manual controls. A single automatic extinguisher unit shall be used to protect each hazard

volume, unless it is possible to configure multiple units such that operation of anyone will operate all others simultaneously.

CAF

See "Compressed Air Foam"

Carbon Dioxide

A colorless, odorless, electrically non-conductive fire extinguishing gas with a density of approximately 50% greater than air.

Certification

The process of recognition, per examination by an impartial third-party organization, that a product or system has met the performance requirements of a test standard.

Class A Fires

Fires in ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics.

Class B Fires

Fires in ignitable liquids (also known as flammable liquids), combustible liquids, petroleum greases, tars, oils, oil-based paints, solvents, lacquers, alcohols, and flammable gases.

Clean Agent

A fire extinguishing liquified gas, elemental gas, or gas blend that is electrically non-conductive and does not leave a residue subsequent to evaporation.

Compressed Air Foam

Foam produced by combining a low expansion foam solution with compressed air or an inert gas in a mixing device and typically having a very small and uniform bubble size.

Control Unit

An electrical, system component that monitors and responds to changes in the system condition, initiating appropriate system action in response to alarm, supervisory, and fault conditions, as applicable. It may comprise separate, interconnected parts and may also provide visual text display, audible and/or visual indicators, and means for operator (inter)action.

Corrosion Resistant

A material that can withstand damage caused by oxidization or other chemical reactions.

Detection and Control System

A system comprising of automatic fire detection devices, manual activation devices, and a control unit capable of recognizing inputs from the detection/activation devices and generating appropriate output signals, e.g. to actuate the release of the agent. Such systems also monitor devices for readiness and provide notification by audible and visual means of system faults or actuation. Such systems may either be certified as standalone products for use with compatible certified HDME fire protection systems or supplied as integral subsystems of complete HDME fire protection systems. An integral system is packaged by the manufacturer with a storage and delivery system and is intended for use only as a part of that specific HDME fire protection system.

Discharge Nozzle

A device with one or more orifices that is connected to a termination of a pipe network for the purpose of controlling the discharge rate and uniformly distributing the suppressant.

Dry Chemical

A powder composed of very small particles, typically sodium bicarbonate, potassium bicarbonate, or ammonium phosphate based with added particulate material. These powders are also generally supplemented to provide resistance to packing and moisture absorption and maintain proper flow capabilities.

Dual Agent System

An HDME protection system using two different suppressants, discharged either simultaneously or serially, from two different piping networks, but controlled by the same detection and control system.

Effective Discharge Time

The time interval between the first appearance of suppressant at the discharge nozzle or unit and the time at which the discharge becomes predominantly gaseous. Also known as "Discharge Time".

Element Operating Temperature

The nominal temperature in degrees Fahrenheit (°F) or Celsius (°C) at which a heat responsive element operates when subjected to the influence of heat.

Expellant Gas

The medium used to facilitate the discharge of the suppressant from the agent storage container.

Flow Rate

The quantity of extinguishing agent passing through a nozzle or other device in a unit time. When a minimum discharge rate is indicated, reference is made to the minimum quantity of agent discharged per unit time, measured within ±1 second.

Foam

A stable aggregation of bubbles produced from an aqueous solution of foam concentrate that has a sufficiently low density and enough fluidity to allow it to float on top of and form a blanket on the surface of a liquid being protected.

Gas Cartridge

The container used to store the expellant gas in a gas cartridge operated extinguishing system.

Gas Cartridge Operated

A type of HDME protection system that utilizes expellant gas stored in a separate container from the suppressant storage container.

Heat Responsive Operating Device

A device incorporating a heat responsive element to trigger a function that does not require human intervention. This device includes an operating element to trigger a function such as suppressant discharge automatically.

Heat Responsive Element

An operating device that does not require human intervention. This device includes an operating element that, when subjected to the influence of heat, ruptures, bursts, or otherwise functions, to cause the release of suppressant.

Heavy Duty Mobile Equipment (HDME)

Equipment capable of some degree of movement with its onboard systems that is used for various industrial and commercial purposes, such as construction, mining, excavation, timber harvesting, and transport, and which may or may not be licensed for over the road usage.

Indicating Device

A system element which may be integral to the control unit, e.g. LED, sounder, or a circuit connected notification appliance that provides audible and/or visual indication associated with the condition of the system.

Initiating Device

A system device whose activation causes the system to enter fire alarm condition with resultant functions, e.g. suppressant release.

Local Application System

An extinguishing system with a supply of suppressant permanently connected to fixed piping with nozzles arranged to discharge directly onto a specific hazard area.

Lock-Out Valve

A supervised, lockable, manually operated valve located in the discharge line between the suppressant supply and the nozzle(s), which can be used to isolate the agent supply from all or part of the system during maintenance and service.

Machinery Space

An enclosed or semi-enclosed portion of HDME with oil pumps, oil tanks, fuel filters, transformer vaults, electrical cabinets, switchgear, gear boxes, drive shafts, lubrication skids, and other similar equipment using liquid hydrocarbon fuel and/or hydraulic, heat transfer, and lubrication fluids. Additionally, these spaces may store combustible and flammable materials.

Maintenance

Any work performed to ensure that the equipment operates as intended.

Manual Control

An operating device, or arrangement of devices that requires action by a human operator to initiate system operation or release. Manual/mechanical type requires no electric power to perform its function and operates independently from the control unit. Manual/electrical includes electrical contacts or other means for connection to a circuit to send an alarm signal to the control unit. Manual/integral uses an operating means that is a part of the control unit.

Maximum Working Pressure

The pressure in a suppressant storage container associated with the maximum installation temperature.

Maximum Bend Angle

The largest angle (expressed in degrees) and specified by the manufacturer, to which a flexible hose is safely allowed to bend without damage.

Minimum Bending Radius

The smallest radius (expressed in inches [mm]) specified by the manufacturer to which a flexible hose is safely allowed to bend without damage.

Minimum Working Pressure

The pressure in a suppressant storage container associated with the minimum installation temperature.

Operable Pressure Range

The minimum and maximum pressures of the suppressant storage container over which the system is intended to be functional. These pressures result from the minimum and maximum storage temperatures and the physical characteristics of the suppressant and expellant gas.

Operating Device

See “Actuation Device”

Operating Pressure

See “Working Pressure”

Pilot Container

One or more pressurized containers in an HDME protection system that are directly actuated by an operating device, and that supply pressure to initiate full system discharge.

Pilot Cylinder

See “Pilot Container”

Pilot Line

Pneumatic piping or tubing used to connect pilot containers with suppressant containers.

Pipe

Circular conduit used to transport the suppressant from the agent storage container to the discharge nozzles. Wherever pipe or piping is used in this standard, it is also understood to refer to any tubing, flexible piping, or hose used for the same purpose.

Pre-Engineered System
A fire extinguishing system with predetermined flow rates, nozzle pressures, and quantities of suppressant, using specific piping specifications and number and types of nozzles.

Proof Test Pressure
The factory test pressure used to verify the structural integrity of the suppressant storage container.

Resonance
The maximum magnification of applied vibration during a vibration test.

Secondary Cylinder
One or more cylinders in an HDME fire protection system that are operated by pressure supplied from a pilot cylinder, rather than directly by an operating device.

Signal
An audible, visual, electrical or other type of communication of a condition of the system or a part thereof.

Signaling Line Circuit (SLC)
A circuit between components of a system over which multiple signals can be carried.

Specified
The value of a design parameter set by the manufacturer that shall be equal to, or more conservative than, the limiting values of this standard.

Stored Pressure
A type of HDME protection system that utilizes expellant gas stored in the suppressant storage container.

Supervised
Having an attribute that is electrically monitored for integrity. Examples are a power supply input or interconnecting conductors. The supervision allows the state to be displayed or an appropriate indication to be provided by the control equipment.

Supervisory Condition
An abnormal condition, such as loss of agent container pressure, that could affect the proper operation of the system and which is monitored by an associated device that responds to the condition and signals the control unit to provide an appropriate indication.

Suppressant
The extinguishing agent or agents used by the HDME protection system to extinguish fire. Such agents may include, but are not limited to, traditional dry chemical, wet chemical, or foam solutions.

Total Flooding System
An extinguishing system with a supply of suppressant permanently connected to fixed piping with nozzles designed to uniformly discharge agent throughout the enclosed volume surrounding the hazard.

Trouble Condition
An abnormal condition in the detection and control system due to a fault in a monitored circuit, component, etc., that may compromise the functional capability of the system and requires an appropriate response.

Water Mist
Very fine water droplets, less than 1,000 microns, used to extinguish fire by cooling and oxygen displacement.

Wet Chemical
An aqueous solution that is discharged in a liquid state as droplets or a mist and can extinguish Class A and B fires. It remains in a liquid state at temperatures below the freezing point of pure water.

Working Pressure

The pressure in a fully charged suppressant storage container or gas cartridge, as applicable, at a defined nominal temperature, typically at 70° F (21° C). Also known as "Normal Working Pressure".

2 GENERAL INFORMATION

2.1 Certification Application Requirements

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

- a complete list of all models, types, sizes, and options for the products or services being submitted for certification consideration
- general assembly drawings, complete set of manufacturing drawings, materials list, anticipated marking format, piping and electrical schematics, nameplate format, brochures, sales literature, specification sheets, installation, operation, and maintenance procedures
- the number and location of manufacturing facilities
- all documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level.

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

2.1.3 All documents shall be provided with English translation.

2.2 Requirements for Samples for Examination

2.2.1 Following authorization of a certification examination, the manufacturer shall submit samples for examination and testing.

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

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

2.2.4 The manufacturer shall be responsible for providing any necessary test fixtures that may be required to evaluate the system and specialized samples where needed for particular tests. Samples for detection and control testing (typically including a control unit) must be able to demonstrate maximum and minimum system configurations and circuit loading, and operation of the release function using actual actuation devices (use of simulated means may be allowed for certain tests at the discretion of the certification agency).

3 GENERAL REQUIREMENTS

3.1 Review of Documentation

During the initial investigation and prior to physical testing, the manufacturer's specifications, technical datasheets, and design details shall be reviewed to assess the ease and practicality of installation and use. The system and its components shall be suitable for use within the defined limits of the certification investigation.

3.2 Physical or Structural Construction Features and Operation

3.2.1 Operating Range

The HDME protection system shall be capable of operating satisfactorily, performing its functions, over its stated operating temperature range and at elevated humidity as described in Section 4.16. As a minimum, the system and all of its components shall operate within the temperature ranges of Table 3.2.1. System and component evaluations will be based on the specified minimum and maximum operating temperatures. Operating temperatures outside these limits shall be specified at discrete 5 degree increments of the primary units used, Fahrenheit or Celsius.

Table 3.2.1 *Required Operation Temperature Range*

System Type	***Allowable Minimum Operating Temperature °F (°C)***	***Allowable Maximum Operating Temperature °F (°C)***
Detection and Control Equipment	-40°F (-40°C), or lower	140°F (60°C), or higher
CAF-Foam	-40°F (-40°C), or lower	120°F (49°C), or higher
Dry Chemical	-40°F (-40°C), or lower	140°F (60°C), or higher
Wet Chemical	-40°F (-40°C), or lower	140°F (60°C), or higher
Clean Agent	32°F (0°C), or lower	120°F (49°C), or higher
Carbon Dioxide	32°F (0°C), or lower	130°F (54.4°C), or higher
Water Mist	40°F (4.4°C), or lower	130°F (54.4°C), or higher

Exception: Systems with higher minimum temperatures may, at the discretion of the certification agency, be certified for use in applications having continuously higher ambient temperatures. Such systems shall be so identified in their listings and shall be clearly marked with the certified temperature range.

3.2.2 Materials

3.2.2.1 All components shall be made of materials suitably corrosion resistant for their intended use.

3.2.2.2 Any seals used in the system shall be compatible with the suppressant and expellant gas. Compatibility shall be determined by successful performance when subjected to the requirements listed in Sections 4.4.2 (Long Term Leakage Test), 4.4.3 (30-Day Maximum Temperature Leakage Test), and 4.4.4 (30-Day Minimum Temperature Leakage Test).

3.2.3 General

3.2.3.1 Means shall be provided for both automatic and manual actuation of the HDME protection system. Electrical, mechanical, or pneumatic alarm initiation or release actuation is permitted. Two independent power supplies, one designated primary and the other secondary, are required for electrically powered equipment.

3.2.3.2 The system shall have the capability of providing at least two means of manual actuation, e.g., for the operator’s compartment and a second location easily accessible to personnel at ground level or in the path of egress.

3.2.3.3 Control units are not required to be submitted for examination as a part of a complete system. However, a certified HDME protection system design shall provide the applicable functions and features associated with control equipment or be compatible for use with a minimum of one certified detection and control system meeting the requirements of this standard. In order for separate Class 5972 and Class 5973 products to be combined as a system that is in compliance with this standard, their compatibility must be verified. This may necessitate an operational evaluation of a system containing all or part of both products. Test requirements herein for control units are applicable to control portion of systems with integral control and detection systems.

3.2.3.4 A means to shut down the HDME, e.g. engine, fuel, and hydraulic systems, with the actuation of the extinguishing system shall be required as a part of the manufacturer's available options for the system. The use of this feature is subject to the requirements of the authority having jurisdiction.

3.2.3.5 A time delay between system alarm detection and extinguishing system actuation shall be permitted, subject to the restrictions herein.

3.2.3.6 An audible alarm indication shall be provided at the operator's compartment.

3.2.3.7 Operating parameters (operating temperature, voltage range, etc.) of control equipment shall meet or exceed the parameter ranges specified by the HDME protection system manufacturer for use of the product in the system.

3.2.3.8 Means shall be provided for secure mounting of the HDME protection system which shall withstand vibration and shock resistance tests as described herein.

3.2.3.9 The HDME protection system shall be suitable for the expected environmental exposures. The installation instructions shall identify the intended mounting locations, i.e. internal or external to the HDME, and whether in engine compartments and other machinery spaces.

Components, e.g. electrical enclosures, wiring connectors, actuation devices, shall meet the requirements for the appropriate environmental ratings for prevention of corrosion and water and dust entry in accordance with applicable national or international standards. Ratings shall be specified for the system components and shall be appropriate for the intended installation as described in the system instructions. Unless otherwise protected from exposure to external conditions, the minimum rating shall be IP65.

3.2.3.10 EMI – The HDME protection system shall provide resistance to electromagnetic interference per the immunity type tests specified herein and described in EN 50130-4 and the individual EN 61000-4 series standard identified for each test. Alternate tests that are based on other national or international standards and that are deemed equivalent may be accepted, at the discretion of the certification agency.

3.2.3.11 Software / firmware versions in control equipment shall be identifiable and protected from unauthorized changes. The revision/release level shall be permanently marked on or be capable of being displayed by the product. Protection from unauthorized changes is intended to include both the executive firmware and the site specific functional configuration settings of the control's operation.

3.2.3.12 Control equipment shall meet the requirements of System Operation in Sections 3.2.26 through 3.2.30.

3.2.3.13 A manufacturer may utilize a certified special hazard protection system, e.g. clean agent, carbon dioxide, dry chemical, etc., for HDME protection provided that the requirements of both certification standards are addressed satisfactorily.

3.2.4 Electrical Power Supply

3.2.4.1 The power supplies shall be permitted to be independent of the HDME protection system.

3.2.4.2 The primary and secondary power supplies shall be independently capable of operating the system under its maximum load. Any reduced functionality when powered by the secondary supply must be clearly identified in the system instructions and must comply with the requirements of this certification standard.

3.2.4.3 The primary power supply, if other than the vehicle battery, shall be capable of either being maintained in a charged state by trickle charge from the vehicle or operating the system continuously for a minimum period of 6 months over the operating temperature range of the system.

3.2.4.4 The secondary power supply, typically an integral, internal supply, shall be capable of operating the system for the manufacturer's specified period, which shall be a minimum of 4 hours, over the operating temperature range of the system. This time of operation shall be clearly identified in the product operating instructions. The secondary power supply is permitted to be rechargeable as described in Section 4.14.1.

3.2.4.5 Loss of either power supply or reduction in voltage/capacity of either power supply to the point at which it can no longer provide required system functionality, e.g. release actuation, shall result in a trouble indication in the operator's compartment. The primary supply will be considered as incapable of providing required functionality if, while it is present, the secondary supply is also providing power.

3.2.4.6 The HDME protection system shall be capable of proper operation over the primary and secondary power supplies' voltage range(s). The range(s) shall be at minimum 85 to 110 percent of a nominal, rated (input) voltage value. The tested range(s) shall be extended as necessary to account for any range affecting operating characteristic. Examples are charging voltage being in excess of the 110 percent value, operation on primary power supply continuing below the 85 percent value until the supply transfer value is reached, and onset of low voltage trouble condition for the secondary supply being below the 85 percent value.

3.2.4.7 For the primary supply, a reduction or loss of the supply as described in Section 3.2.4.5, shall result in automatic and immediate transfer of operation to the secondary power supply without loss of state or incoming signals.

3.2.5 Electrical Interconnections

3.2.5.1 Circuits connecting portions of the system shall be monitored for integrity such that the occurrence of a single open or a single ground-fault condition, if applicable, shall result in a trouble condition. Restoration of the conductors to normal shall also be automatically indicated. Additional requirements may apply for certain circuit types.

3.2.5.2 A wire-to-wire short circuit fault on an alarm indicating device circuit or a signaling line circuit, e.g. circuit interconnecting separate portions of a multi-part control, shall result in a trouble condition. Restoration of the conductors to normal shall also be automatically indicated.

3.2.5.3 For a system with multiple alarm indicating device circuits, an open, ground or short circuit fault on one indicating device circuit shall not affect the operation of any other alarm indicating device circuit.

3.2.5.4 Monitoring for integrity shall not be required for circuits not exceeding 20 ft (6.1m) in length and whose conductors are installed in a conduit or equivalent physical protection against mechanical damage.

3.2.5.5 Inputs/outputs of circuit connected devices shall be electrically compatible with the circuits on which they are installed.

3.2.6 Detection Devices

3.2.6.1 All detection devices shall be certified in accordance with the applicable detector standard(s) and meet the requirements of this standard. A device's certified parameters (operating temperature, voltage range, etc.) shall meet or exceed the parameter ranges specified by the HDME protection system manufacturer for use of the product in the system.

3.2.6.2 Optical flame detectors shall include a "Through Lens Supervision" feature that activates a trouble signal when the detector lens is obscured, indicating the need for maintenance/cleaning. The detector manufacturer shall define the detectable obscuration.

Exception: Optical detectors without this feature can be evaluated if they are used solely to supplement heat detectors used for primary detection. This shall be clearly identified in all descriptive and instructional product information. Secondary power supply is not required for such detectors; however, if not provided, that omission must be indicated in the product instructions.

3.2.7 Manual Actuation Type Initiating Devices

3.2.7.1 Manual/Mechanical actuation type initiating devices shall meet the operation requirements of Section 4.9.3 (Manual/Mechanical Operated Devices). These include limit restrictions on the activation pull or push force, strike energy, and the amount of movement required.

3.2.7.2 Manual/Electrical devices shall meet the limit restrictions on the activation pull or push force requirements of Section 4.9.5 (Manual/Electrical Operated Devices).

3.2.7.3 Manual/Integral device construction shall be such as to prevent unintended system actuation. Means may include protection with a cover.

3.2.8 Indication

3.2.8.1 Operating parameters (operating temperature, voltage range, etc.) of remote, circuit connected alarm indicating devices shall meet or exceed the parameter ranges specified by the HDME protection system manufacturer for use of the product in the system.

3.2.8.2 Sound intensity of audible signals shall meet the HDME protection system manufacturer specifications.

3.2.8.3 Silencing of required audible signals where allowed herein shall require intentional manual action.

3.2.8.4 Required indications, audible and visual, shall be permitted to be intermittent. Intermittent signals shall sound/illuminate at least once every 10 seconds, with a minimum "on" duration of 0.3 second.

Exception: If silenced, the loss of primary power indication shall be at least once every 30 seconds.

3.2.9 Pressure Vessels

3.2.9.1 Storage containers shall conform to the appropriate regulations for the region or country of use. In the U.S.A., DOT Title 49, CFR, Parts 171 through 180 are applicable for storage containers that are shipped under pressure.

3.2.9.2 The following documents shall be submitted for each storage container design, to demonstrate compliance with the relevant design standard:

- Calculation of wall thicknesses per the method specified in the applicable design standard, with appropriate supporting references as necessary
- Certificate of chemical analysis of materials
- Certificate of physical properties of materials

3.2.9.3 The pressurization level shall be specified by the manufacturer.

3.2.10 Valves

3.2.10.1 Discharge valves shall incorporate varying sizes or connection designs for all ports to minimize the likelihood of improper connection during installation. Other types of valves not designed for mounting directly on a storage container may use inlet and outlet connections of the same size and design but shall be marked to indicate correct direction of flow.

3.2.10.2 For pressure operated valves, the manufacturer shall provide data for the minimum available force or torque for each actuator and the maximum required operating force or torque for the corresponding valve. Proper operation of the most adverse combinations shall be verified by test.

3.2.11 Gauges and Indicators

A pressure gauge shall be included with all extinguishing systems to indicate the pressure in the suppressant storage container and/or pilot container, as applicable, and shall comply with the following requirements:

- The face of the gauge shall indicate the appropriate units of pressure for which it is calibrated
- The range of the gauge shall be based on the system's operable pressure range
- The minimum indicated gauge pressure shall be marked on the left side of the gauge's range
- The corresponding temperature value shall be marked at the system's working pressure
- The maximum gauge pressure shall be between 150 and 250 percent of the system working pressure and shall be marked on the right side of the gauge's range
- The gauge shall be provided with a means of pressure relief to allow venting in the event of an internal leak
- The face of the gauge shall identify the agent with which it is intended to be used

3.2.11.1 Pressure gauges are not required when pressures are monitored constantly by pressure transducers and can be displayed locally or at the control unit.

3.2.11.2 Sealed pressure gas cartridges need not be provided with pressure gauges if they can be readily removed and weighed.

3.2.12 Siphon Tubes

3.2.12.1 Systems containing a siphon tube to discharge the agent from the storage container shall be configured so that the end of the siphon tube that is connected to the discharge valve is mechanically fastened and sealed to remain in place during all conditions of use.

3.2.12.2 Siphon tubes shall be designed to prevent expellant gas discharge until the suppressant level drops below the opening on the free end of the siphon tube.

3.2.12.3 The free end of the siphon tube shall be configured to prevent restriction of flow by contact with the cylinder wall. The minimum clearance between the end of the siphon tube and the cylinder wall shall be at least 0.25 times the tube's inside diameter for tubes with an end cut 90°to the tube's axis. As an option the tube end may be cut at an angle to its axis to provide equivalent free area. Compliance with this requirement shall be demonstrated by drawings showing the calculated assembly clearance, based on worst case dimensional tolerance stack-ups. Alternatively, the manufacturer's assembly process may contain controlled procedures for verifying the minimum required clearance.

3.2.13 Pressure Relief Devices

Calculations shall be submitted to verify that pressure relief devices used on agent storage containers are designed to comply with the flow capacity and operating pressure requirements specified in CGA S-1.1, or equivalent regulations acceptable to the authority having jurisdiction. The construction and size of the pressure relief device shall, at a minimum, be appropriate for the system pressure at the maximum specified operating temperature.

3.2.14 Anti-Recoil Devices

The discharge valve outlet of an agent storage container shall be provided with an anti-recoil device for the purpose of shipping, handling, and storage. The device shall be an integral part of or attached to the container via a chain, or otherwise designed to minimize the likelihood of removal from the container.

3.2.15 Pilot Line Connections

When a pilot line must be disconnected from a container during maintenance operations provisions shall be made to seal the disconnected end of the line from potential debris ingress. Appropriate warnings shall be displayed on these devices to caution the user regarding the high pressure discharge hazard and the proper procedure for mitigating this hazard. The manufacturer's maintenance instructions shall include this requirement.

3.2.16 Suppressant Distribution Connectors, and Piping and Hose

3.2.16.1 Suppressant distribution connectors of proprietary designs used in place of standard pipe and fittings shall have minimum internal diameters greater than or equal to that of the corresponding pipe sizes.

3.2.16.2 Flexible hose used for distribution of suppressant shall be of one of the following types:

- Corrosion-resistant metallic hose
- Polymeric hose with metallic reinforcement
- Polytetrafluoroethylene hose with metallic or non-metallic reinforcement

Polymeric flexible hose assemblies that are 5 ft (1.52 m) or less in length do not require metallic reinforcement if they are used only for connecting the discharge valve to the suppressant distribution piping and are routed to avoid contact with a hot surface above the hose's melting point.

3.2.16.3 Flexible hose used for distribution of suppressant shall be suitable for the pressure generated at the time of suppressant discharge.

3.2.17 Suppressant Storage Container Supports

Equipment which supports multiple cylinder installations shall be designed to facilitate the removal of individual cylinders for inspection and servicing.

3.2.18 Protective Covering

All valves and control devices with movable external parts that are vulnerable to obstruction or physical damage shall be protected. Operating, levers, handles, or buttons requiring manual access for operation shall be exempt from this requirement to the extent necessary to allow for their unimpeded operation. Unless otherwise protected from exposure to mechanical damage, electrical cables and wires and pneumatic detection tubing shall be provided with conduit or equivalent physical protection against mechanical damage that is acceptable to the authority having jurisdiction. Pneumatic detection tubing may be exposed in the areas being monitored but shall be enclosed where not performing this function and vulnerable to mechanical damage. Mechanical cables shall be sheathed or otherwise protected to minimize the likelihood of damage or mechanical interference with operation.

3.2.19 Actuation Devices

3.2.19.1 The device which opens a cylinder discharge valve or gas cartridge shall either be an independent actuation device attached to the valve, or an internal component of the valve assembly itself.

3.2.19.2 Actuation devices shall be actuated automatically by a compatible certified detection and control system, or by a fully manual emergency release device.

3.2.19.3 Handles or levers on manual controls shall not require a force to operate exceeding 40 lb (178 N), a travel distance of more than 14 in. (355 mm), or a rotation of more than 270 degrees.

3.2.19.4 Where puncturing mechanisms are used, all parts subject to movement and open to the surrounding environment shall be made of corrosion resistant material.

3.2.19.5 Strike knobs shall not require energy to operate exceeding 27.1 Joules.

3.2.20 Auxiliary Manual Controls

An alternate manual control shall be provided for all systems using automatic-only controls. The alternate manual control shall not be impaired by any fault in the automatic control.

3.2.21 Nozzles

Discharge nozzles shall be evaluated for the intended use, including flow characteristics and area of coverage. Nozzles or outlets shall be made of metallic, corrosion resistant materials that will not deform or otherwise be damaged by fire exposure or discharge pressure. Nozzles shall be permanently marked with their part number or with an identification that will unambiguously identify them with reference to the manufacturer's manual.

3.2.22 Nozzle Caps or Frangible Seals

Caps or frangible seals shall be provided on nozzles for installations in which the nozzles are subject to clogging from external materials. Such caps or seals shall release under the most adverse system conditions and shall not obstruct flow from the outlet subsequent to release. Hinged nozzle caps that close automatically after discharge are permitted, provided that any obstruction from the caps does not adversely affect discharge, as verified by successful performance in the tests of Sections 4.1 (Flow Distribution Tests) and 4.2 (Fire Extinguishing Tests).

3.2.23 Suppressants

All extinguishing agents used shall comply with the fire extinguishment tests as specified in Sections 4.2 (Fire Extinguishing Tests). All agent storage containers shall be filled at a location examined by the certification agency. Proposed procedures for field refilling of agent storage containers shall be evaluated for viability, only at the system manufacturer's request. Considerations such as personnel training, mechanical practicality, proper container cleaning, agent contamination prevention, and moisture exclusion from dry chemicals shall be addressed to the satisfaction of the certification agency before any such procedures shall be allowed for certified systems.

3.2.24 Expellant Gases

Nitrogen used in an HDME protection system shall have a dew point of no greater than -60°F (-51.1°C) and shall have a purity greater than or equal to 99.99 % (mole/mole). The use of any other expellant gas shall be evaluated at the discretion of the certification agency.

3.2.25 Auxiliary Equipment

Auxiliary equipment includes those devices required in a system to protect against a specific hazard. The need for these devices shall be determined by the certification agency according to the nature of the hazard. The devices listed below may be required for the system to attain certification for specific applications. Other devices not included below may also be required.

3.2.25.1 Pressure Operated Release

A pressure operated release shall be provided on all doors and windows in a hazard area which is to be sealed off in the event of fire. The release shall operate at a maximum pressure of 50 psi (3.5 bar) of expellant gas from the extinguishing system. The release shall not permit the escape of excessive gas from the system. It shall automatically reset and may have a control for manual operation.

3.2.25.2 Pressure Operated Switches

Pressure operated switches may be used to shut down propulsion systems, fans, or other electrical equipment in or near the hazard area, as well as to activate alarm and indicator circuits. These switches shall operate at a maximum pressure of 50 psi (3.5 bar) of expellant gas from the extinguishing system. The release shall not permit the escape of excessive gas from the system. They may also have an alternate manual control and shall be designed for manual resetting only.

3.2.25.3 Alarms and Indicators

Alarms and/or indicators shall be provided to show that the system is operating, warn personnel of the forthcoming discharge of suppressant, and signal the failure of any supervised equipment. Indicators that show the system has been used and requires service shall operate following actuation of the system and require manual resetting.

3.2.25.4 Venting Valves

Devices shall be provided to prevent the premature operation of discharge valves by residual pressures that may leak into actuation devices. They shall vent at a pressure no higher than 0.25 of the minimum operating pressure of the actuation device. These vents shall be closed when the control is in operation and open when the control is inoperative.

3.2.25.5 Connected Reserve

Connected reserve devices, such as valve or switch assemblies, shall be provided on automatic systems having both primary and connected reserve agent storage containers. This will direct the command of the automatic fire detection device to the proper container. The changeover device shall be suitably protected and labeled and shall indicate which container is subject to operation.

3.2.25.6 Pressure Regulator

Where a pressure regulator is used to fix the flow of expellant gas at a constant pressure, it shall be factory preset and pinned, or otherwise mechanically locked, in order to reduce the risk of tampering or unauthorized adjustment.

3.2.26 System Operation - General

3.2.26.1 A visual indication that the system is in normal operating condition is required. This is permitted to be at the control unit.

3.2.26.2 Fire alarm, supervisory and trouble signals shall be distinctively and descriptively annunciated.

Exception: Where supervisory circuit operation is such that the supervisory signal is initiated by opening of the supervisory device contacts, annunciation of an open circuit condition on that circuit can be the same as that for operation of the supervisory device. Such functionality must be described in the product manual.

3.2.26.3 Alarm signals shall take precedence over supervisory and trouble signals.

3.2.27 System Operation - Alarm Condition

3.2.27.1 Alarm conditions shall be latching, requiring manual action to restore the system to normal condition. The latching function can be provided either by the control unit or initiation device.

3.2.27.2 The HDME protection system shall provide both audible and visual indication of alarm condition so as to provide operator notification. Visual indication shall be red in color.

3.2.27.3 The elapsed time between activation of an alarm initiating device and the initial automatic response, e.g. activation of indications and output circuits, of the HDME protection system shall not exceed 10 seconds.

3.2.27.4 Systems with multiple zones shall be capable of displaying each zone in alarm. Systems with a single display for all zones shall also indicate that multiple zones are in alarm and the display shall be scrollable when a multiple alarm condition is present to determine which zones are in alarm.

3.2.27.5 Deactivation (silencing) of any audible alarm indication shall be allowed if a visual means provides a continuing indication of the alarm condition. Access to the silencing means shall be restricted (locating the means within the operator's compartment is considered acceptable limited access). While silenced, initiation of an alarm on a separate zone shall activate the audible alarm indication. The visible alarm indication shall continue until the alarm condition has been reset.

3.2.27.6 For systems providing agent release, indications associated with the release operation may replace the alarm indications when the release function is initiated. Silencing of audible indications shall be subject to the same requirements as in Section 3.2.27.5.

3.2.28 System Operation – Supervisory Condition

3.2.28.1 The HDME protection system shall provide both audible and visual indication of a supervisory condition to provide operator notification.

3.2.28.2 The elapsed time between operation of a supervisory initiating device and the automatic response of the HDME protection system shall not exceed 90 seconds. Restoration to normal shall be visually indicated within 90 seconds.

3.2.28.3 The audible indication is permitted to be the same as that for the trouble signal. Limitations are stated in the exception described in Section 3.2.26.2.

3.2.28.4 Deactivation (silencing) of any audible supervisory indication shall be allowed if a visual means provides a continuing indication of the supervisory condition. Access to the silencing means shall be restricted (locating the means within the operator's compartment is considered acceptable limited access). While silenced, a supervisory signal from a separate zone shall activate the audible supervisory indication. The visible supervisory indication shall continue until the supervisory condition has been reset.

3.2.28.5 A Supervisory signal shall be annunciated as a result of operation of an extinguishing system disconnect switch.

3.2.29 System Operation – Trouble Condition

3.2.29.1 The HDME protection system shall provide both audible and visual indication of a trouble condition. Indications shall be provided in the operator's compartment.

3.2.29.2 The elapsed time between onset of a trouble condition and the automatic response of the HDME protection system shall not exceed 100 seconds. Restoration to normal shall be visually indicated within 100 seconds.

3.2.29.3 Deactivation (silencing) of any audible trouble indication shall be allowed if a visual means provides a continuing indication of the trouble condition. Access to the silencing means shall be restricted (locating the means within the operator's compartment is considered acceptable limited access). The visible trouble indication shall continue until the trouble condition has been restored to normal. If manual action is required to discontinue the trouble silencing function, then there shall be an audible trouble signal if the silencing function is engaged while no trouble condition exists.

3.2.30 System Operation – Release Function

3.2.30.1 Audible and visual indication shall be distinctively and descriptively provided to show that the system has initiated the release function.

3.2.30.2 In addition to the releasing circuits, the actuation devices shall be monitored for circuit integrity (supervised). Loss of integrity shall result in a trouble indication.

3.2.30.3 A delay in activating outputs for extinguishing system actuation and vehicle shutdown as described in Section 3.2.3.5 shall be permitted.

3.2.30.4 Audible and visual indication shall be provided to indicate that the system is in a time delay condition.

3.2.30.5 Extension of the time delay from its initial value is permitted and shall require manual action. Access to the means shall be restricted; location within the operator's compartment is considered acceptable.

3.2.30.6 The total time delay including any extensions shall not exceed 30 seconds.

3.2.30.7 A disconnect switch or other means of disabling the system release function during testing or servicing shall be key-locked or equivalently access restricted and shall cause a supervisory signal when enabled.

3.2.31 Other Electrical Component Features

An HDME protection system shall be permitted to include additional components or features that do not affect the required operation or performance of the system as described herein.

3.2.32 Hazardous Location Rating of Components

Components designed for use in hazardous (classified) locations shall be certified only if successfully evaluated for compliance to the relevant requirements of one or more of the following certification standards:

Table 3.2.32 *Hazardous Location Electrical Equipment Standards*

FM Approvals Class Number	***Standard Title***
3600	Electric Equipment for use in Hazardous (Classified) Locations General Requirements
3610	Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, & III, Division 1, and Class I, Zone 0 & 1 Hazardous (Classified) Locations

FM Approvals Class Number	*Standard Title*
3611	Nonincendive Electrical Equipment for Use in Class I and II, Division 2, and Class III, Divisions 1 and 2, Hazardous (Classified) Locations
3615	Explosionproof Electrical Equipment General Requirements
3620	Purged and Pressurized Electrical Equipment for Hazardous (Classified) Locations

3.3 Markings

3.3.1 Easily visible nameplates shall be affixed to the agent storage container assembly of HDME protection systems and shall display the following markings at a minimum. Any additional markings required by the authority having jurisdiction shall also be provided:

- Manufacturer's name and address
- System type and model number
- Agent identification
- System working pressure
- Allowable ambient storage temperature range
- Factory test pressure of storage container
- Year of manufacture of the storage container (if not directly stamped on the container)
- Reference to the relevant NFPA standard and/or any other relevant local standards
- Reference to the manufacturer's design, installation, operation, recharge, and maintenance instructions
- Container empty weight, weight of agent, and total container weight

3.3.2 Combination instruction and identification plates shall be mounted on or next to all control devices. All components or assemblies that are required for system operation shall also individually bear an identification mark, such as a part, catalog, or pattern number.

3.3.3 Detection and control system components shall be marked at minimum with the following information:

- The manufacturer's name and address, or equivalent
- The model or type designation, which shall uniquely identify the product and correspond to the manufacturer's catalog designation
- The serial number or an equivalent means to identify date of manufacture, e.g. a code traceable to date of manufacture or lot identification
- Identification of controls and indicators
- Operational and environmental suitability ratings (if not possible due to size, this information must be provided in other included installation and use materials)

  Requirements related to software and firmware are stated in Section 3.2.3.11.

3.3.4 All marking plates shall be made of materials which will not corrode or otherwise become illegible due to system liquids or vapors, or normal environmental conditions as verified by Sections 4.25 (Corrosion – Salt Spray) and 4.28.2 (Ultraviolet Light and water Test).

3.3.5 When hazard warnings are required by the authority having jurisdiction, the markings should conform to the authority's requirements and if possible, be universally recognizable.

3.3.6 The system's model or type identification shall correspond to the manufacturer's catalog designation and shall uniquely identify the certification agency's mark of conformity.

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

3.3.8 All markings shall be legible and durable.

3.4 Manufacturer's Design, Installation, Operation, and Maintenance Instructions

3.4.1 The manufacturer shall provide information required to properly design, install, operate, and maintain the system. These instructions shall be submitted to the certification agency prior to the examination of a system.

3.4.2 The manufacturer's design instructions for a system submitted for certification shall be evaluated based on relevant standards e.g. NFPA 17, NFPA 120, NFPA 122.

3.4.3 Section 5.5 (Design, Installation, Operation, and Maintenance Manual) provides further guidance on the requirements for design, installation, operation, and maintenance manuals.

3.5 Calibration

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

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

3.6 Tolerances

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

4 PERFORMANCE REQUIREMENTS

4.1 Flow Distribution Tests

4.1.1 Requirement

The measured flow rate and amount of agent discharged out of each nozzle under the most adverse distribution configuration(s) as specified in the manufacturer's installation instructions shall establish those used in the fire tests performed in accordance with Section 4.2 (Fire Extinguishing Tests). Additional testing may be required to determine the most adverse configurations, as determined by the certification agency. All nozzle designs shall be examined.

4.1.2 Tests/Verification

The system shall be assembled to include a piping configuration with the maximum number of discharge nozzles and piping/hose/tubing lengths; these shall be representative of the maximum specified limitations for each agent storage container size so as to result in the minimum possible flow rate. Multiple tests shall be required to address all system limits. All fittings/components used for agent distribution shall be included at their maximum system limitation(s).

For each test, the agent storage container shall be filled with the suppressant to its rated capacity and shall be pressurized to its working pressure. It shall then be conditioned to the minimum specified operating temperature, for a minimum of 16 hours, and maintained at this temperature until the system is discharged.

For gas cartridge operated systems, both the agent storage container and the gas cartridge shall be conditioned to the minimum specified operating temperature, for a minimum of 16 hours, and maintained at this temperature until the system is discharged.

The system shall be actuated, and the agent quantity discharged from each nozzle and the discharge time shall be measured. The lowest single nozzle agent quantity discharged, among all tests, and its associated discharge time shall be the maximum used for all fire test scenarios.

A minimum of two test configurations shall include nozzle caps or frangible seals that are not integrated into the nozzle design, if applicable. These configurations shall include the smallest and largest systems to be tested. All nozzle caps and seals shall be examined. Nozzles shall be free of extinguishing agent and dry and nozzle caps and frangible seals shall be new.

4.2 Fire Extinguishing Tests

HDME protection systems shall successfully extinguish all fires for each application requested for certification according to the test methods below.

Engine Compartment
Superheated surfaces in close proximity to combustible/flammable materials

Description	*Typical Suppressant(s)*	*Application Method*	*Test Method*	*System Scaling Method*
Enclosed Engine Compartment (Total uncloseable openings less than 25% of engine compartment surface area)	CAF-Foam, Water Mist, Dry Chemical	Total Flood	Section 4.2.1 & 4.2.2	See Appendix G
Open Engine Compartment	Wet Chemical, Dry Chemical	Local Application	Section 4.2.3	Area of Coverage per Nozzle

Machinery Spaces
Electrical Cabinets/Switchgear Rooms, Flammable and Combustible Liquid Storage, Ring Gear/Slip Ring, etc.

Typical Suppressant(s)	*Application Method*	*Test Method*	*System Scaling Method*
Clean Agents	Total Flood	Section 0	Maximum Volume / Maximum Area of Coverage per Nozzle
CAF-Foam, Dry Chemical	Total Flood	Section 4.2.5	Maximum Volume / Maximum Area of Coverage per Nozzle
Carbon Dioxide	Total Flood (Non Occupied Spaces)	Section 4.2.6	Maximum Volume / Maximum Area of Coverage per Nozzle
Water Mist	Total Flood	Section 4.2.5	Maximum Volume / Maximum Area of Coverage per Nozzle

Hydraulic/Propulsion/Brake Systems
Drive Motors, Differentials Units, Transmission Units, Brake Systems, Hydraulic Pump and Control Valves, etc.

Typical Suppressant(s)	***Application Method***	***Test Method***	***System Scaling Method***
Dry Chemical, Wet Chemical, Water Mist	Local Application	Section 4.2.3	Area of Coverage per Nozzle

Class A Materials
Combustible Materials, Wood, Refuse, etc.

Typical Suppressant(s)	***Application Method***	***Test Method***	***System Scaling Method***
CAF-Foam, Wet Chemical, Water Mist, Dry Chemical	Local Application	Section 4.2.7	Area of Coverage per Nozzle

Specialty Nozzles
Wedge, Fan, Screening, etc.

Typical Suppressant(s)	***Application Method***	***Test Method***	***System Scaling Method***
All	Local Application and/or Total Flood	Section 4.2.8	Area of Coverage per Nozzle and/or Maximum Volume / Maximum Area of Coverage per Nozzle

The applicability of each test and system scaling method to each HDME protection system under examination will be determined at the discretion of the certification agency, in collaboration with the system manufacturer.

All test setups shall be thoroughly cleaned after each test to remove any residual fuel and extinguishing agent.

4.2.1 Engine Compartment Fire Tests (Total Flooding)

4.2.1.1 Requirement

Total flooding engine compartment HDME protection systems with total uncloseable openings less than 25% of engine compartment surface area shall successfully extinguish all fires in each Class B hazard fire scenario when designed and installed as specified by the manufacturer.

For each test, the agent storage container shall be filled with the suppressant to its rated capacity and shall be pressurized to its normal working pressure. It shall be conditioned to the minimum specified operating temperature, for a minimum of 16 hours, and maintained at this temperature until the system is discharged.

For gas cartridge operated systems, both the agent storage container and the gas cartridge shall be conditioned to the minimum specified operating temperature, for a minimum of 16 hours, and maintained at this temperature until the system is discharged.

The agent distribution configuration producing the lowest single nozzle quantity of extinguishing agent from Section 4.1 (Flow Distribution Tests) shall be used. The most hydraulically disadvantaged nozzle(s) shall be used in the fire test scenarios. The quantity of agent discharged shall not deviate more than 10% from the amount collected in the flow distribution tests.

4.2.1.2 Tests/Verification

4.2.1.2.1 The Engine Compartment Mock-Up

Figure 4.2.1.2.1a shows a schematic of the complete setup of the engine compartment test apparatus, which consists of:

- A variable speed blower capable of producing 20,000 ft^3/min (566 m^3/min) maximum air flow and equipped with an approximately 3 ft (0.9 m) long reducer, transitioning from the rectangular outlet of the blower to a 24 in. (0.6 m) diameter cross section
- A horizontal duct assembly 24 in. (0.6 m) in diameter
- An expander transitioning from the duct assembly to an opening 59 in. (1.5 m) wide x 39 in. (1.m) high
- The engine compartment mock-up
- A steel pan 60 in (1.52 m) square and 4 in. (100 mm) high sitting on the laboratory floor, and centered below the compartment floor opening situated in the downstream half of the floor

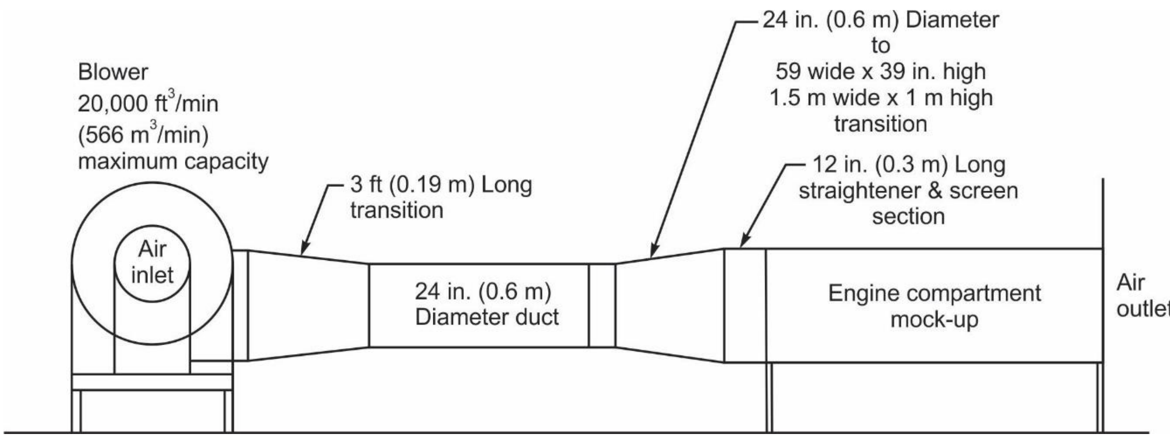


Figure 4.2.1.2.1a - Schematic of Engine Compartment Test Apparatus

The descriptions of the expander and the engine compartment mock-up are provided below.

Figure 4.2.1.2.1b shows a perspective view of the duct expander. The expander comprises three integrated sections:

- A 24 in. (0.6 m) diameter section 8 in. (0.2 m) long
- A 30 in. (0.76 m) long diffuser
- A 12 in. (0.3 m) long air flow straightener 59 in. (1.5 m) wide x 39 in. (1.0 m) high

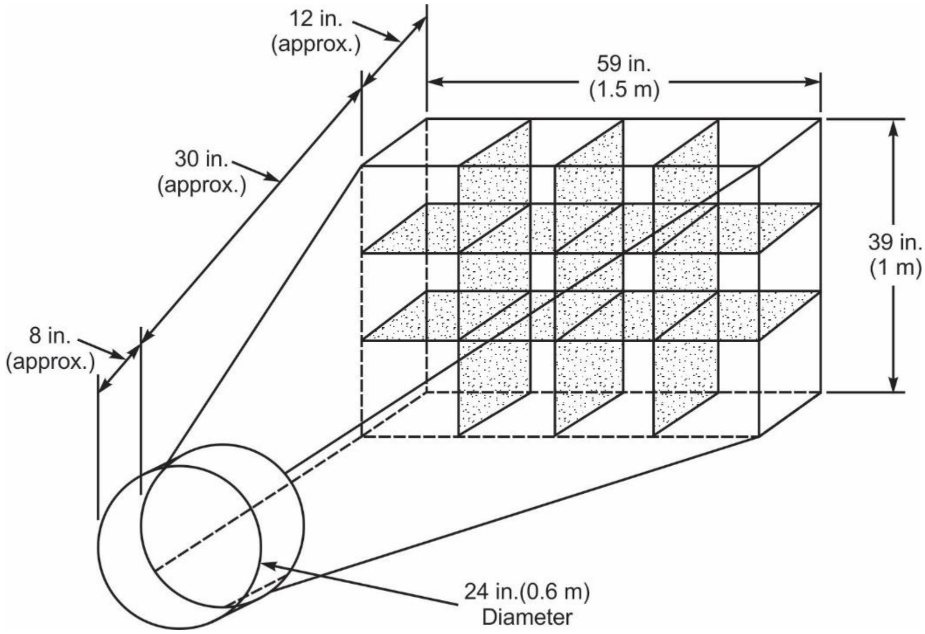


Figure 4.2.1.2.1b - Perspective View of Duct Expander from Inlet Side

The interior of the air flow straightener is partitioned with steel dividers into 12 equal volumes in a configuration 4 wide x 3 high. The divider thickness is 14 gauge (1.9 mm). The upstream and downstream cross-sections of the air flow straightener are fitted with a wire screen. The screen is made of steel 0.063 in. (1.6 mm) diameter wire arranged in a 1/2 in. (12.7 mm) mesh. The screen opening area is approximately 76 percent.

The engine compartment mock-up is pictorially illustrated in Figure 4.2.1.2.1c. It consists of a compartment housing, an engine block, a simulated exhaust manifold on each side of the engine block, two propane line burners below the simulated manifolds to raise the manifold temperature before a test (not shown), two rectangular metal shields above the manifolds, and a horizontal air filter drum mock-up adjacent to the downstream end of the engine block. Also shown in the figure are the arrangements to produce spray and spill fires in the compartment. Either the spill or spray fire will produce pool fires on the engine compartment floor and/or the collection pan if the ignitable fluid falls in these areas. The simulated engine block is shown in Figure 4.2.1.2.1d.

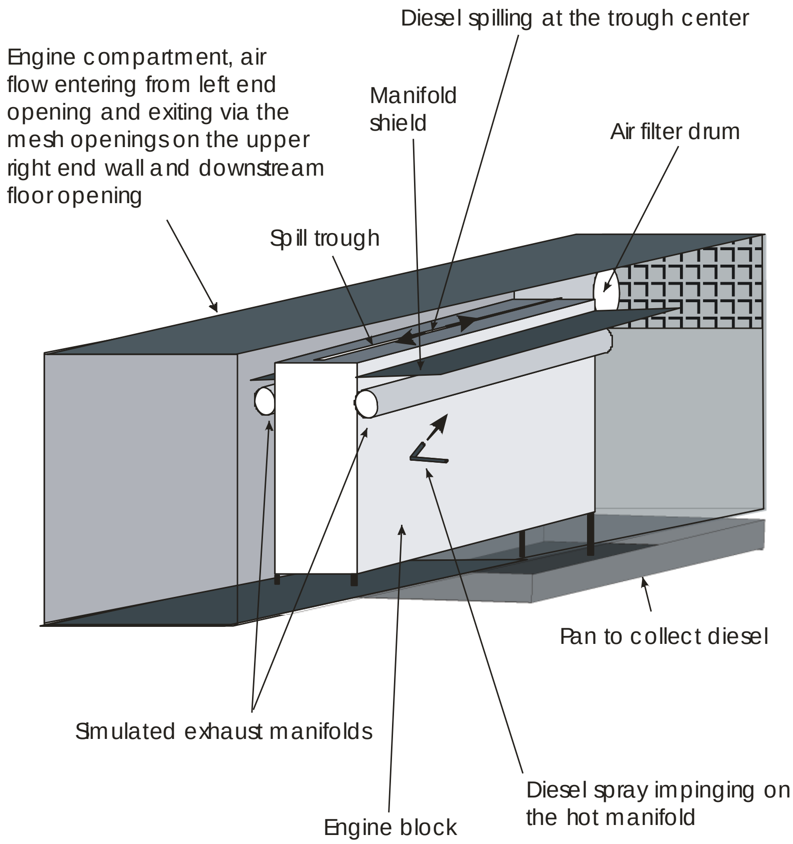


Figure 4.2.1.2.1c - Pictorial View of Engine Compartment Mock-Up

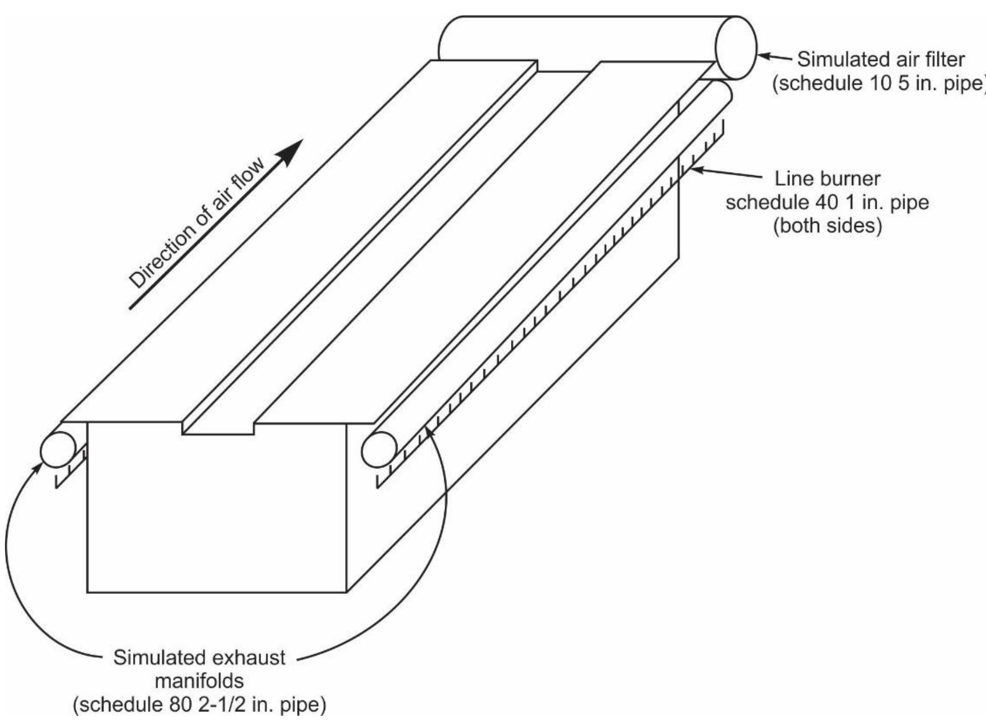


Figure 4.2.1.2.1d - Pictorial View of Simulated Engine Block

The engine compartment shall be 98 in. (2.5 m) long by 59 in. (1.5 m) wide by 39 in. (1.0 m) high and be fabricated of 14 gauge (1.9 mm) carbon or stainless steel. The compartment shall have three openings to allow air flow through the enclosure: the entire upstream end (i.e., the left end of the compartment shown in Figure 4.2.1.2.1c), the downstream half of the compartment floor, and the upper one third of the downstream wall. The opening on the downstream wall shall be fitted with the same type of mesh screen used in the duct expander. During a test, the air flow enters from the upstream end of the compartment and exits through the floor and downstream wall openings.

The engine block mock-up shall be an enclosed rectangular box made of 11 gauge (3 mm) carbon or stainless steel, measuring 83 in. (2.11 m) long by 45 in. (1.15 m) wide by 28 in. (0.7 m) high. Consequently, the clearances between the engine block and compartment's ceiling, floor, and front wall are approximately 6 in. (150 mm) and approximately 7 in. (176 mm) between the engine block and the compartment's two side walls. The clearance between the engine block and back wall is slightly larger at 9 in. (240 mm) to accommodate the air filter drum. A 4 in. (100 mm) wide rectangular horizontal shield shall be located along the full length of each longitudinal side of the engine block, level with and contiguous with the top edge of the engine block. Figures F-1 through F-4 of Appendix F provide dimensional details of the engine block and compartment.

Each manifold shall be provided with a propane line burner to raise its temperature to a minimum of 900°F (482°C) evenly across the length of the manifold before the suppressant is discharged. The line burner shall be positioned approximately 2.5 in. (64 mm) below the manifold. The propane shall be supplied at the downstream end of the burner, where a maintenance drain shall be provided to empty condensate accumulated inside the burner. Additionally, the propane supply line to each burner shall be equipped with a flame arrestor right before the burner.

A 2 in. (25mm) diameter opening shall be provided at the bottom center of the engine block for venting during testing. After each fire test, the engine block interior shall be purged with nitrogen to expel any accumulated combustible gases or extinguishing agent. Figure F-4 in Appendix F shows the locations of the vent and the inlet and outlet locations for the nitrogen purge. The purge connections shall be 1/2 in. NPT. The purge outlet shall be connected via 3/8 in. (9.5 mm) tubing into a water bath remote from the engine compartment to condense fuel vapor trapped in the engine block during testing for disposal.

The simulated air filter drum, functioning as an obstruction, shall be positioned near the downstream end of the engine block. It shall be fabricated of schedule 10, 5 in. pipe, approximately 5.6 in. diameter and its length shall be the entire 45 in. (1.15 m) width of the engine block, as shown in Figures F-2 and F-3 in Appendix F. The drum's centerline shall be at the same elevation as the engine block's top surface. The closest gap between the drum and the engine block shall be 1 in. (25mm).

4.2.1.2.2 Engine Compartment Spray Fire Extinguishment Tests

Fuel spray fires shall be produced by injecting diesel fuel through a Monarch 15.5 gal/h (58.7 L/h) 70 degree semi-hollow cone nozzle, or equivalent. The diesel fuel shall be supplied to the nozzle via 3/8 in. (9.5 mm) tubing, fittings, and adaptors. The supply line shall enter from the compartment's front wall, when facing the apparatus with the blower to the left 25 in. (640mm) from the left end of the compartment, and 18.5 in. (470 mm) below the compartment's top surface. Figure F-5 in Appendix F shows the line connections required from the compartment wall to the nozzle, to position the nozzle approximately 7 in. (175 mm) below the manifold. The nozzle orientation is 45^o upward from the horizontal plane.

- The system manufacturer may position the discharge nozzles in any manner consistent with the specified design constraints. Dual agent systems may be installed for simultaneous or serial operation per the manufacturer's specifications.
- The two simulated exhaust manifolds shall be heated to 900°F (482°C) minimum evenly across the length of the line burner with the propane burners.
- The diesel spray shall be initiated at 0.25 gal/min (1 L/min).
- The propane feed to the burners shall be shut off after the diesel spray has ignited.
- The blower shall be started, and the air flow brought to 20 ft/s (6 m/s). Note: The blower

speed shall be measured prior to each test, at the center of the straightener at approximately 1 foot away from the face of the screen before the engine compartment is installed. The blower speed setting shall be noted and used for the required tests.

- Suppressant discharge shall be initiated after the air flow has been stabilized, but no sooner than 30 seconds after the blower was started.
- If the fire is extinguished, diesel fuel spray shall continue for an additional 30 seconds after extinguishment and any reignition noted.
- If the fire is not extinguished by the end of effective discharge, the diesel fuel spray shall be terminated after the end of discharge.
- The blower shall be run for 10 minutes to cool the test apparatus.
- The engine block shall be purged with nitrogen before the engine compartment is opened.
- If extinguishment is achieved, the test apparatus shall be thoroughly cleaned of all suppressant and the test repeated at zero air velocity.
- Subsequent to the trial at zero velocity, the blower shall be run for 10 minutes to cool the enclosure.
- Successful extinguishment is required in both moving and still air conditions without repositioning of the suppressant nozzles.

4.2.1.2.3 Engine Compartment Spill Fire Extinguishment Tests

A channel shall be built into the top of the engine block to produce a consistent simulated spill of diesel fuel. The channel shall be 6 in. (152 mm) wide and 1/2 in. (13 mm) deep and be centered on top of the engine block along the longitudinal centerline. Weirs 1/4 in. (6 mm) high shall be provided on both ends of the channel to maintain the fuel level. 3/8 in. (9.5 mm) stainless steel tubing shall be used to feed diesel fuel to the channel through a circular cup located at the channel center. Diesel then fills the channel and spills out at both ends. The circular cup shall be made of a 1 in. (25 mm) long, piece of 2-1/2 in. schedule 40 pipe, centrally welded onto a 3/16 in. (5 mm) thick, 4 x 4 in. (102 x 102 mm) steel plate. The diesel fuel flow rate into the cup shall be maintained at 0.25 gal/min (1L/min) during spill fire testing.

- The suppressant nozzles shall be positioned in the same locations as for the engine compartment spray fire tests.
- The two simulated exhaust manifolds shall be heated to 900°F (482°C) minimum evenly across the length of the manifolds with propane line burner burners.
- The diesel spill shall be initiated on top of the engine block at 0.25 gal/mi (1 L/min). Note: The fuel channel shall not be prefilled with fuel.
- The propane feed to the burners shall be shut off after the diesel spill has ignited.
- The blower shall be started, and the air flow brought to 20 ft/s (6 m/s). Note: The blower speed shall be measured prior to each test, at the center of the straightener at approximately 1 foot (0.3m) away from the face of the screen before the engine compartment is installed. The blower speed setting shall be noted and used for the required tests.
- Suppressant discharge shall be initiated after the air flow has been stabilized, but no sooner than 30 seconds after the blower was started.
- If the fire is extinguished, diesel fuel spill shall continue for an additional 30 seconds after extinguishment and any reignition noted.
- If the fire is not extinguished by the end of effective discharge, the diesel fuel spill shall be terminated after the end of discharge.
- The blower shall be run for 10 minutes to cool the test apparatus.
- The engine block shall be purged with nitrogen before the engine compartment is opened.
- If extinguishment is achieved, the test apparatus shall be thoroughly cleaned of all suppressant and the test repeated at zero air velocity.
- Subsequent to the trial at zero velocity, the blower shall be run for 10 minutes to cool the enclosure.
- Successful extinguishment is required in both moving and still air conditions without repositioning of the suppressant nozzles.

4.2.1.3 Engine Compartment Fire Extinguishment Test Instrumentation

The following parameters shall be monitored or verified during each test:

- Time and duration of preburn
- Air flow over the cross sectional area of the apparatus
- Temperature of the simulated exhaust manifolds
- Fuel flow rate
- Duration of suppressant discharge
- Time for extinguishment after beginning of discharge
- Time and duration of any reignition
- Quantity of suppressant discharged

4.2.1.4 Translation of Test Results to System Design

All fire extinguishment tests shall be conducted with systems conforming to the manufacturer's design manual, which may require revision to conform to test results based upon the precepts of Sections 4.2.1.4.1 through 4.2.1.4.5.

4.2.1.4.1 Fire tests per Section 4.2.1 (Engine Compartment Fire Tests -Total Flooding) shall be used to determine baseline static and dynamic volume requirements for compartments.

4.2.1.4.2 Static volume requirement shall be, at minimum, the total rate of flow of suppressant into the space (by weight or volume) divided by the compartment's free volume, approximately 70.6 ft^3 ($2m^3$).

4.2.1.4.3 Dynamic volume requirement shall be, at minimum, the total rate of flow of suppressant into the space divided by the volume flow rate of air through the space, approximately 12,900 ft^3/min ($365m^3/min$).

4.2.1.4.4 These baseline values shall be used by the manufacturer to scale protection for larger volumes and air flow rates, with the more conservative of the two values so derived used to determine the design. Appendix G provides examples of scaling calculations.

4.2.1.4.5 The manufacturer's design manual shall be reviewed to verify that these parameters have been incorporated into the design requirements.

4.2.2 Total Flooding Engine Compartment Single Nozzle Fire Extinguishment Tests

4.2.2.1 Requirement

Total flooding engine compartment HDME protection systems shall successfully extinguish the fires in all three single nozzle hazard scenarios when installed per the system manufacturer's design requirements. Due to the congested layout of engine compartments, nozzles may be isolated from others, and may need to perform as local application protection. For all test scenarios, successful extinguishment shall be demonstrated under conditions of both 20 ft/s (6 m/s) air flow, also referred to as "cross wind", and still air, without repositioning of the extinguishing nozzle, using the blower arrangement referenced in Section 4.2.1.2.1.

The agent distribution configuration producing the lowest single nozzle quantity of extinguishing agent from Section 4.1 (Flow Distribution Tests) shall be used. The most hydraulically disadvantaged nozzle shall be used in the fire test scenario. The quantity of agent discharged shall not deviate more than 10% from the amount collected in the flow distribution tests.

Alternatively, a single nozzle system replicating the flow rate and agent quantity from the worst performing nozzle from the flow distribution tests may be used. A “no fire” discharge shall be conducted to confirm the system flow rate to remove the potential thermal effects on the nozzle caused by the fire exposure. The agent delivered to the apparatus shall be no more than the amount collected from the worst performing nozzles in the flow distribution tests.

For each test, the agent storage container shall be filled with the suppressant to its rated capacity and shall be pressurized to its normal working pressure. It shall be conditioned to the minimum specified operating temperature, for a minimum of 16 hours, and maintained at this temperature until the system is discharged.

For gas cartridge operated systems, both the agent storage container and the gas cartridge shall be conditioned to the minimum specified operating temperature, for a minimum of 16 hours, and maintained at this temperature until the system is discharged.

Each nozzle type and size shall be examined.

4.2.2.2 Tests/Verification

4.2.2.2.1 Scenario A – Spray Fire Partially Shielded by Hot Object

Figure 4.2.2.2.1a shows a simplified view of Scenario A, an outward spray fire in the vicinity of a vehicle surface, such as that of an engine block, which is partially shielded by an adjacent hot object. For this scenario, the heated object shall be a simulated exhaust manifold preheated to 900°F (482°C) minimum evenly across the length of the manifold using a propane line burner.

The blower arrangement shall be positioned with the long edge of the air straightener collinear with the vehicle surface and shall be centered vertically on the simulated exhaust manifold. The placement of the blower arrangement shall not interfere with the discharge of the agent. The air flow shall be measured at the intersection of the center of the air straightener and the perpendicular centerline of the fuel spray nozzle as shown in Figure 4.2.2.2.1a. The suppressant shall be discharged towards the heated manifold and from a nozzle located in the plane of its centerline, subjecting both the suppressant discharge and the spray fire to a cross wind.

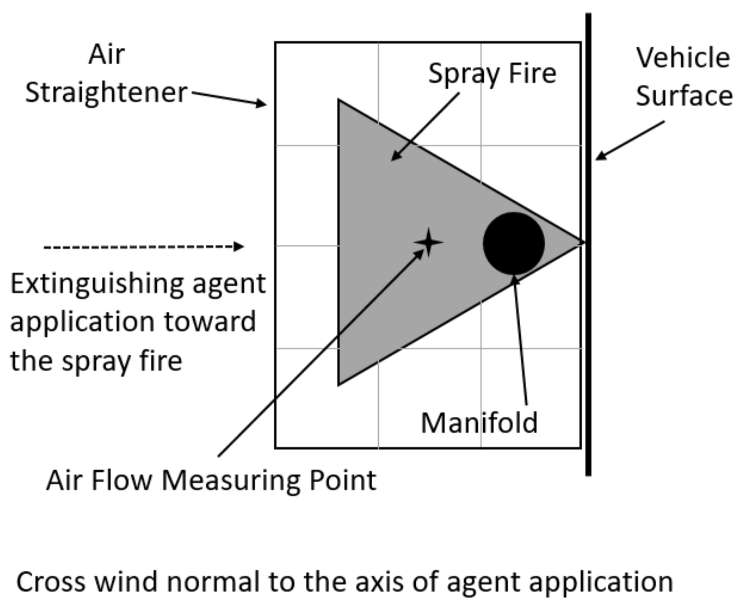


Figure 4.2.2.2.1a - Simplified Side View of the Scenario A Single Nozzle Fire Extinguishment Test

Figures 4.2.2.2.1b and 4.2.2.2.1c show the setup for the single nozzle fire extinguishment Scenario A. A Monarch 15.5 gal/h (58.7 L/h) 70 degree semi-hollow cone nozzle, or equivalent, shall be located at the center of a 96 x 96 x 0.2 in. thick (2440 x 2440 x 5 mm thick) steel plate. The plate may be scaled up or down but must be larger than the developed nozzle spray area. The diesel fuel spray discharge rate shall be 0.25 gal/min (1 L/min). The steel plate shall be vertical and supported approximately 36 in. (0.9m) above the floor.

The simulated exhaust manifold shall be a section of 2-1/2 in. schedule-80 steel pipe, 48 in. (1.2m) long, capped at both ends, and installed horizontally in front of the nozzle. The distance between the pipe and the vertical steel plate shall be approximately 3.5 in. (89 mm.). A line burner shall be positioned approximately 2.5 in. (64 mm) below the simulated exhaust manifold to preheat it. The construction of the line burner shall be basically the same as that for the engine compartment mock-up, except with a shorter length of approximately 48 in. (1.2 m).

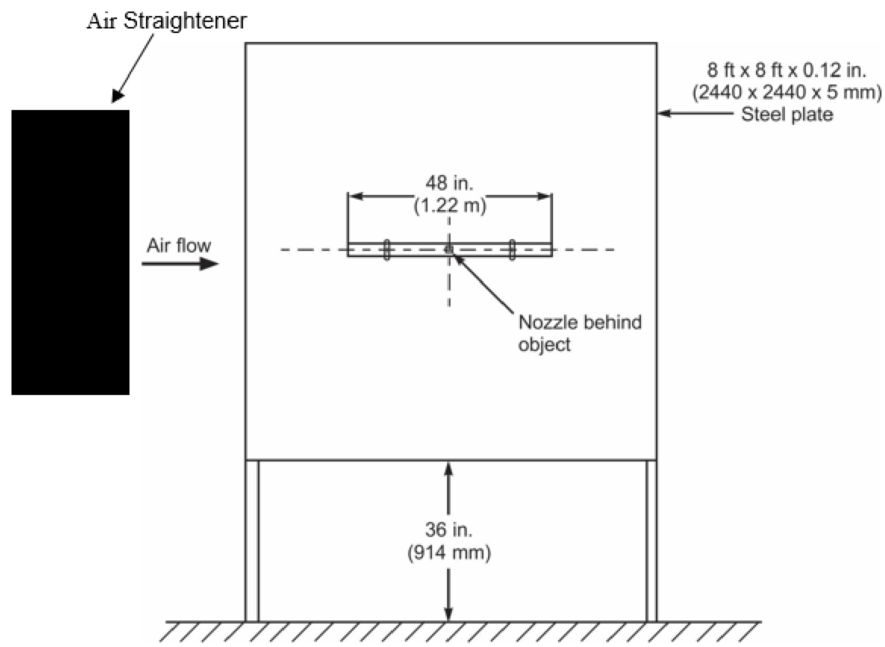


Figure 4.2.2.2.1b - Front View of Scenario A Single Nozzle Fire Extinguishment Test Apparatus

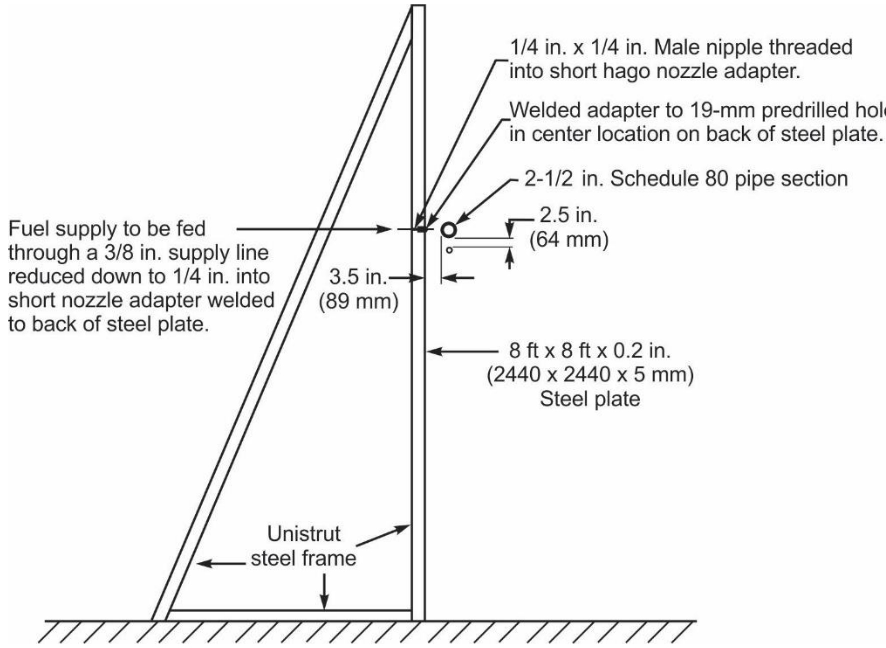


Figure 4.2.2.2.1c - Side View of Scenario A Single Nozzle Fire Extinguishment Test Apparatus

4.2.2.2.2 Scenario B – Pool Fire Shielded Below a Large Object

Figures 4.2.2.2.2a and 4.2.2.2.2b show a simplified view of the Scenario B single nozzle fire extinguishment test. A pool fire is situated below and partially shielded by an overhanging object, such as the perimeter of an engine.

The blower arrangement shall be positioned with the long edge of the air straightener collinear with the vertical face of the object surface and the bottom edge of the air straightener collinear with the top of the fire test pan. The air flow shall be measured at the intersection of the center of the air straightener and the perpendicular vertical plane created by the extinguishing nozzle as shown in Figures 4.2.2.2.2a and 4.2.2.2.2b. The placement of the blower arrangement shall not interfere with the discharge of the agent. The extinguishing agent shall be applied diagonally downward in proximity to the object. Both the fire and the suppressant discharge shall be subjected to the cross wind.

Figure 4.2.2.2.2c shows a side-view of the test setup. The object surfaces shall be constructed of two 96 x 48 x 0.2 in. thick (2440 x 1219 x 5 mm thick) steel plates welded to form a 90° structure. The diesel pool shall be contained in a steel pan 24 in. (610mm) wide x 36 in. (914mm) long x 12 in. (305 mm) high.

The pool shall be prepared by first filling the pan with water to a 2 in. (50 mm) depth, and then adding 0.25 in. (6.4 mm) of diesel fuel. The pan shall be positioned 5 in. (152 mm) below the horizontal plate with a 3 in. (76 mm) offset beyond the corner of the object and centered on the vertical centerline of the vertical plate. The pool fire ignition shall be expedited by applying 100 cc of heptane, as defined in Table 4.2.7.2, on top of the diesel fuel, before ignition is attempted. The suppressant nozzle shall be positioned at the manufacturer's specified range to cover a 36 in. (914 mm) wide area and aimed downward at a 45°angle from the horizontal and centered on a line intersecting the center of the lower corner of the obstruction.

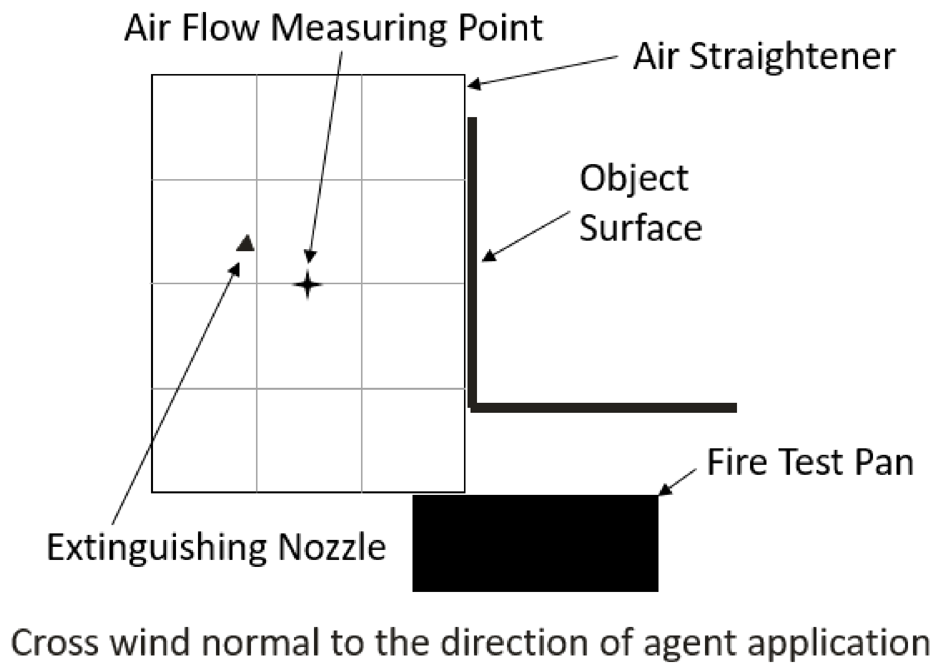


Figure 4.2.2.2.2a – Simplified Side View of Scenario B Single Nozzle Fire Extinguishment Test

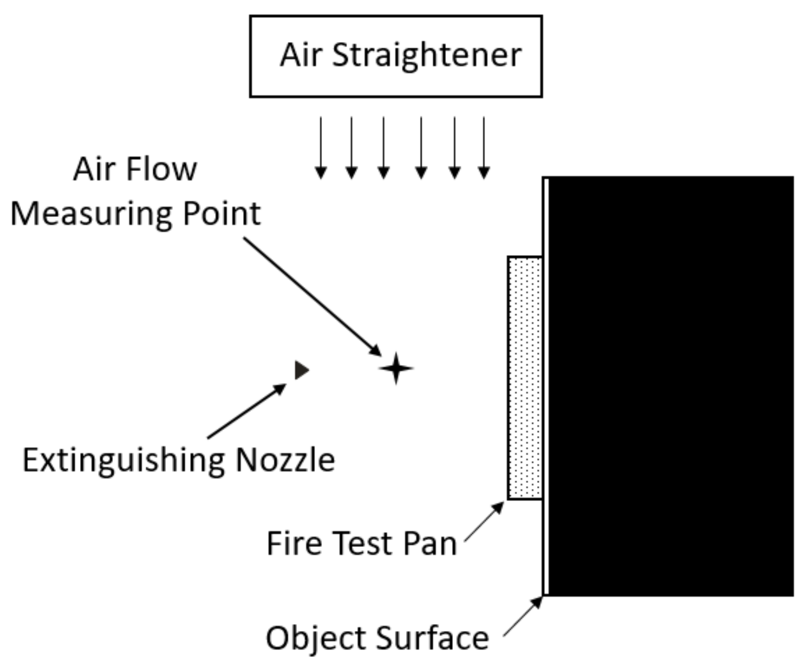


Figure 4.2.2.2.2b – Simplified Plan View of Scenario B Single Nozzle Fire Extinguishment Test

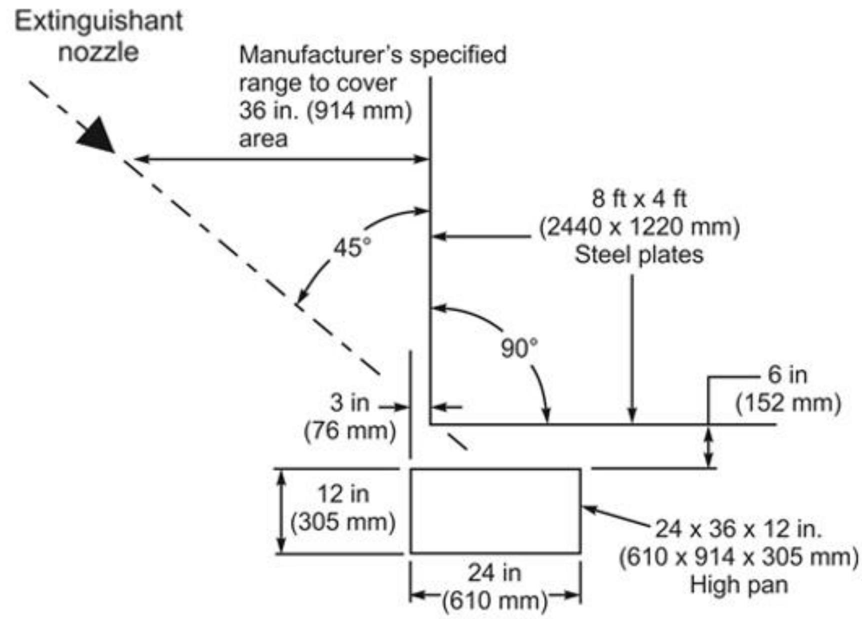


Figure 4.2.2.2.2c – Scenario B Single Nozzle Fire Extinguishment Test Apparatus

4.2.2.2.3 Scenario C – Combined Spray and Pool Fires

Figures 4.2.2.2.3a and 4.2.2.2.3b depicts a simplified view of the Scenario C single nozzle fire extinguishment test. Both the fires and suppressant discharge shall be subjected to the cross wind. Figure 4.2.2.2.3c describes the apparatus used for the Scenario C test. This includes the same diesel fuel spray nozzle as used in Scenario A and fire pan as used in Scenario B. The fuel spray nozzle shall be protected within and centered at the closed end of a cylindrical metal can measuring 3 in. (76 mm) in diameter by 2 in. (51mm) long to stabilize the diesel spray fire in the cross wind and suppressant application.

The blower arrangement shall be centered on the width of the fire test pan with the bottom short edge of the air straightener collinear with the top of the main fire test pan. The placement of the blower arrangement shall not interfere with the discharge of the agent. The air flow shall be measured at the intersection of the center of the air straightener and the perpendicular vertical plane created by the extinguishing nozzle as shown in Figures 4.2.2.2.3a and 4.2.2.2.3b.

The nozzle outlet shall be oriented horizontally and positioned 12 in. (305 mm) above top of the pan. The nozzle tip shall be located 9 in. (229 mm) from the 24 in. (610 mm) pan edge in a plane intersecting the center of that pan edge and the vertical centerline of the pan. The diesel fuel spray flow rate shall be 0.25 gal/min (1 L/min). The pan shall be fueled as in Scenario B. The suppressant shall be discharged downward towards the fuel spray and pan fire.

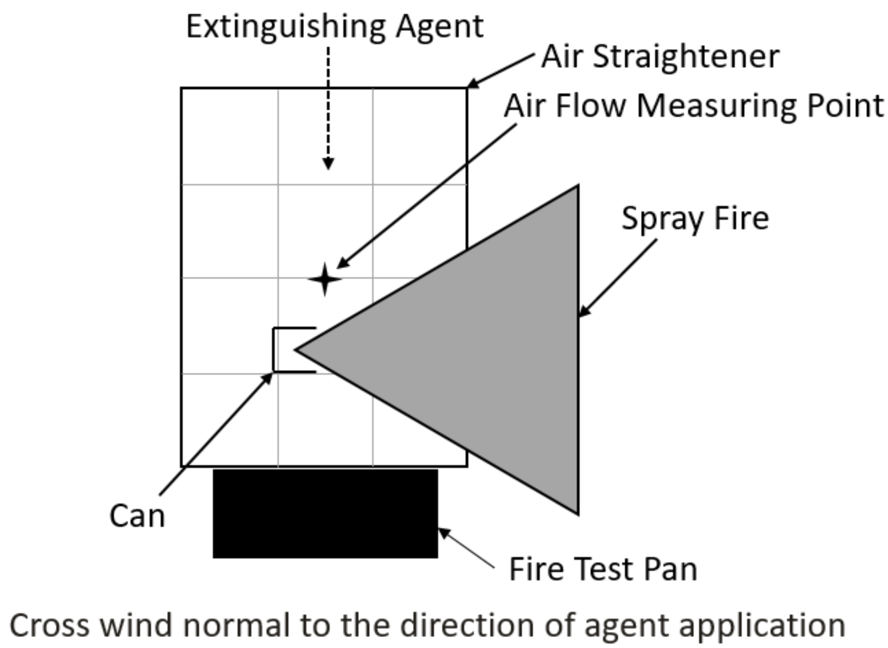


Figure 4.2.2.2.3a – Simplified Side View of Scenario C Single Nozzle Fire Extinguishment Test

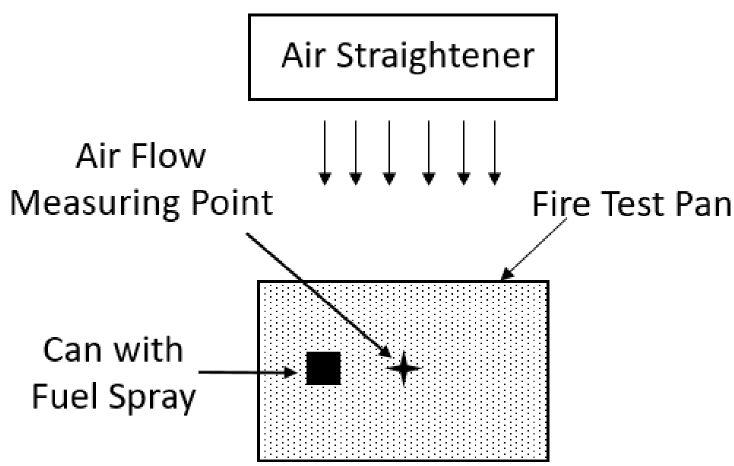


Figure 4.2.2.2.3b – Simplified Plan View of Scenario C Single Nozzle Fire Extinguishment Test

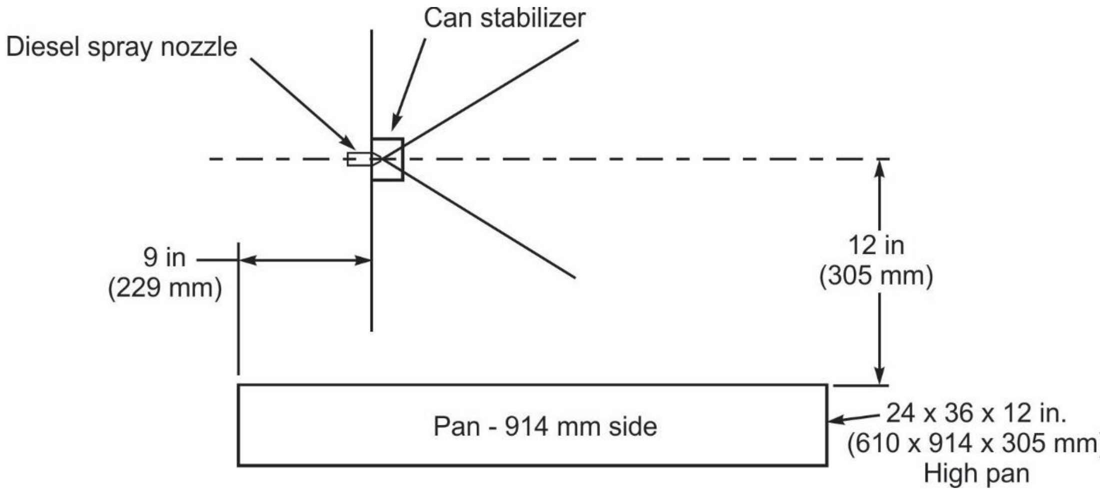


Figure 4.2.2.2.3c – Scenario C Single Nozzle Fire Extinguishment Test Apparatus

4.2.2.2.4 Test Sequence for Single Nozzle Fire Extinguishment Tests

Action	***Scenario***
The simulated exhaust manifold shall be evenly heated to 900°F (482°C) minimum	A
The diesel spray shall be initiated at 0.25 gal/mi (1 l/min).	A & C
The propane feed to the line burners shall be shut off after the diesel spray has ignited	A
The blower shall be started, and the air flow brought to 20 ft/s (6m/s)	All
Suppressant discharge shall be initiated after the air flow has been stabilized, but no sooner than 30 seconds after the blower was started	All
If the fire is extinguished, diesel fuel flow shall continue for an additional 30 seconds after extinguishment and any reignition noted	A & C
If the fire is not extinguished by the end of discharge, the diesel fuel flow shall be terminated after the end of discharge.	A & C
The blower shall be run for 1 minute to cool the test apparatus	All
If extinguishment is achieved, the test apparatus shall be thoroughly cleaned of all suppressant and the test repeated at zero air velocity	All
Subsequent to the trial at zero velocity, the blower shall be run for 1 minute to cool the test apparatus	All

Successful extinguishment is required in both moving and still air conditions without repositioning of the suppressant nozzles.

4.2.2.2.5 Instrumentation for Single Nozzle Fire Extinguishment Tests

The following parameters shall be monitored or verified during each test:

- Air flow over the cross sectional area of the apparatus
- Temperature of the simulated exhaust manifold Scenario A, only

- Fuel flow rate (Scenarios A and C)
- Duration of suppressant discharge
- Time for extinguishment after beginning of discharge
- Time and duration of any reignition
- Quantity of suppressant discharged

4.2.2.2.6 Clarification of Single Nozzle Terminology

When a system design uses two suppressants in a design, and the two suppressants are discharged separately from nozzles of different designs, the "single nozzle" tests may be conducted using a separate nozzle for each suppressant positioned in conformance to the manufacturer's design criteria. If the manufacturer's design specifies simultaneous discharge of the two suppressants, both may be used in each trial of these tests.

4.2.3 Local Application Fire Extinguishing Tests

4.2.3.1 Requirement

Local application engine compartment HDME protection systems shall successfully extinguish all fire scenarios before end of effective discharge to the test methods described in Appendix E of AS 5062, and modified as described in Section 4.2.3.2 of this standard. For all test scenarios, successful extinguishment shall be demonstrated under conditions of both 20 ft/s (6 m/s) air flow and still air, without repositioning of the nozzle.

4.2.3.2 Tests/Verification

Local application engine compartment HDME protection systems shall successfully extinguish, without reignition, both Test 1 – Fuel Spill Extinguishment and Re-Ignition Test – Direct Application, and Test 2 – Fuel Spill Extinguishment and Re-ignition Test – Indirect Application. These tests shall utilize the same blower arrangement referenced in Section 4.2.1.2.1.

The blower arrangement for each test scenario shall be centered on the width of the fire pan, with the bottom short edge of the air straightener collinear with the top of the main fire pan. The placement of the blower arrangement shall not interfere with the discharge of the agent. The air flow shall be measured at the intersection of the center of the fire test pan at the height of the fuel spray nozzle or center of the air straightener as shown in Figures 4.2.3.2a and 4.2.3.2b. For the indirect fire scenario, the air flow shall be measured prior to installation of the vertical plate.

The vertical plate may be reinforced, as needed, to prevent warpage from repeated tests. The design of the reinforcement material shall not increase the thickness of the plate and shall be designed in a manner that will not collect fuel or suppressant.

The agent distribution configuration producing the lowest single nozzle quantity of extinguishing agent from Section 4.1 (Flow Distribution Tests) shall be used. The most hydraulically disadvantaged nozzle shall be used in the fire test scenario. The quantity of agent discharged shall not deviate more than 10% from the amount collected in the flow distribution tests.

Alternatively, a single nozzle system replicating the flow rate and agent quantity from the worst performing nozzle from the flow distribution tests may be used. A "no fire" discharge shall be conducted to confirm the system flow rate to remove the potential thermal effects on the nozzle caused by the fire exposure. The agent delivered to the apparatus shall be no more than the amount collected from the worst performing nozzles in the flow distribution tests.

Each nozzle type and size shall be examined. The single extinguishing nozzle shall be placed at the manufacturer's maximum range to the reignition plate/fuel surface, measured along the aiming point/centerline, to cover the maximum area of the fire test pan. The nozzle may be positioned to discharge perpendicular to, with, or against the air flow in each plane, as applicable, per the system manufacturer's design requirements, but shall remain fixed for each test scenario. The aiming point/centerline of the extinguishing nozzle shall be confined within the vertical surface of the reignition plate (indirect application) or fuel surface of the fire test pan (direct application). The diesel spray for the indirect scenario may be positioned to flow with or against the air flow but shall be aimed at the center of the reignition plate and remain fixed for each test. See Figures 4.2.3.2a and 4.2.3.2b.

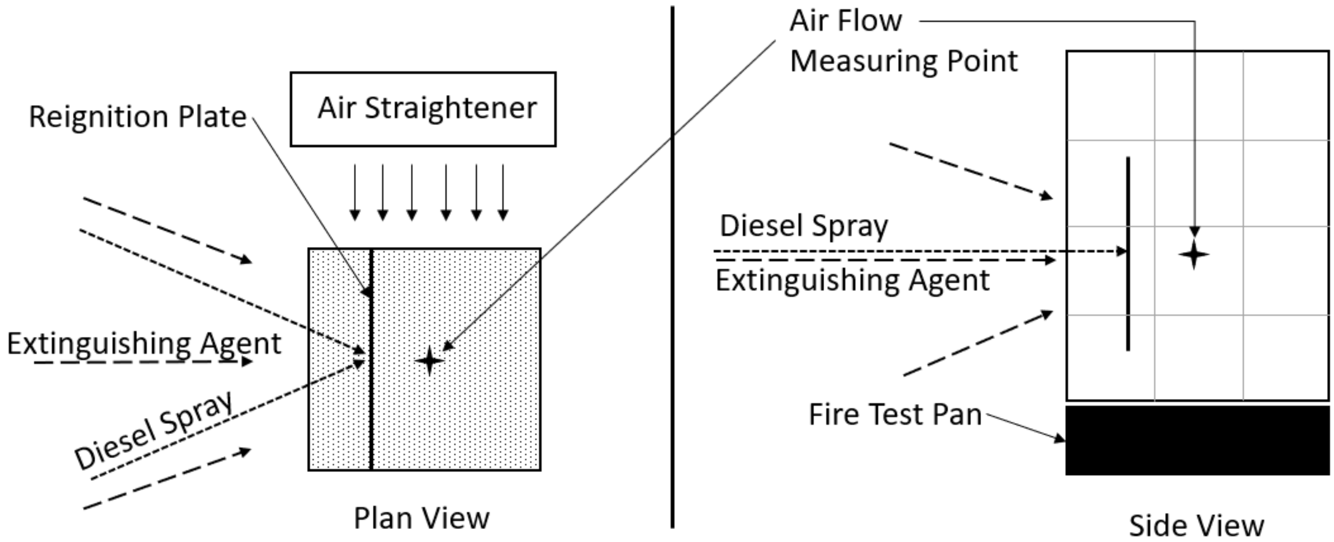


Figure 4.2.3.2a – Simplified Views of Local Application Fire Extinguishing Tests (Indirect)

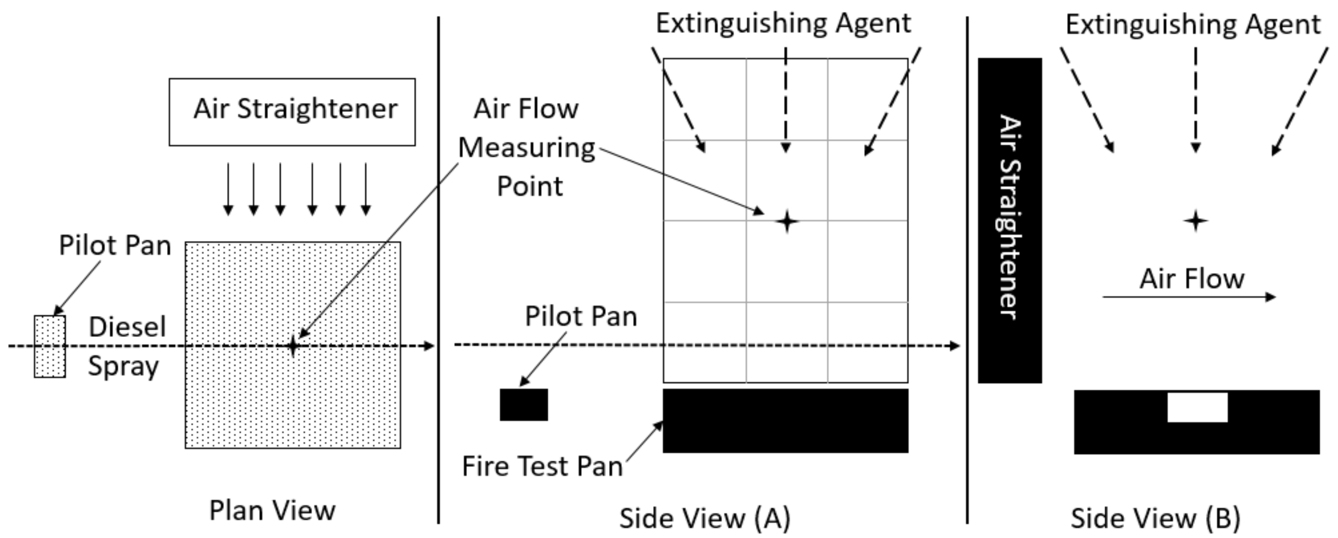


Figure 4.2.3.2b – Simplified Views of Local Application Fire Extinguishing Tests (Direct)

For each test, the agent storage container shall be filled with the suppressant to its rated capacity and shall be pressurized to its normal working pressure. It shall be conditioned to the minimum specified operating temperature, for a minimum of 16 hours, and maintained at this temperature until the system is discharged.

For gas cartridge operated systems, both the agent storage container and the gas cartridge shall be conditioned to the minimum specified operating temperature, for a minimum of 16 hours, and maintained at this temperature until the system is discharged.

The timing sequence below shall be followed:

Action	*Direct Application (min:sec)*	*Indirect Application (min:sec)*
Main Fire Pan Ignited*	0:00	0:00
Pilot pan Ignited	0:00	Not Applicable
Air Flow Initiated	0:05, when required	0:05, when required
Diesel Spray Ignited	0:45	0:00
System Discharged	1:00	1:00
Diesel Spray Shut Off	+30 seconds after effective discharge	At end of effective discharge, restart for 15 seconds

*The ignition time starts when the fire pan is fully engulfed

The test apparatus shall be fully cleaned of suppressant and diesel fuel between each test as necessary.

4.2.4 Protection of Machinery Spaces (Total Flooding) – Clean Agents

Clean agent total flooding HDME protection systems for machinery spaces shall successfully extinguish all fires when subjected to FM 5600 Sections 4.2 (Nozzle Distribution Verification Tests) and 4.25.4 (Nozzle Distribution Verification Tests - Marine).

Additionally, automatic extinguisher units shall successfully flood the test enclosure and extinguish each Class B hazard fire scenario within one minute of test fuel ignition when operated by the automatic means provided. Pneumatic tubing and heat detection cable shall be installed at the manufacturer’s maximum limitations, e.g. spacing of tubing/cable, length, height above hazard.

4.2.5 Protection of Machinery Spaces (Total Flooding) - CAF-Foam, Dry Chemical, etc.

4.2.5.1 Requirement

CAF-Foam, Dry Chemical, and similar total flooding HDME protection systems for machinery spaces shall successfully extinguish all fires before end of effective discharge when subjected to FM 5320 Section 4.1 (Total Flooding Fire Tests) for Class A & B hazards, and modified as described in Section 4.2.5.2. For all test scenarios, successful extinguishment shall be demonstrated under conditions of both one enclosure air change per minute, and still air, without repositioning of the nozzle. All nozzle designs and sizes shall be examined.

Additionally, automatic extinguisher units shall successfully flood the test enclosure and extinguish each Class B hazard fire scenario within one minute of test fuel ignition when operated by the automatic means provided. Pneumatic tubing and heat detection cable shall be installed at the manufacturer’s maximum limitations, e.g. spacing of tubing/cable, length, height above hazard.

4.2.5.2 Tests/Verification

The agent distribution configuration producing the lowest single nozzle quantity of extinguishing agent from Section 4.1 (Flow Distribution) shall be used. The most hydraulically disadvantaged nozzle shall be used in the fire test scenario. The quantity of agent discharged shall not deviate more than 10% from the amount collected in the flow distribution tests.

Alternatively, a single nozzle system replicating the flow rate and agent quantity from the worst performing nozzle from the flow distribution tests may be used. A “no fire” discharge shall be conducted to confirm the system flow rate. The agent delivered to the apparatus shall be no more than the amount collected from the worst performing nozzles in the flow distribution tests.

Each nozzle type and size shall be examined.

For each test, the agent storage container shall be filled with the suppressant and shall be pressurized to its normal working pressure. It shall be conditioned to the minimum specified operating temperature, for a minimum of 16 hours, and maintained at this temperature until the system is discharged.

For gas cartridge operated systems, both the agent storage container and the gas cartridge shall be conditioned to the minimum specified operating temperature, for a minimum of 16 hours, and maintained at this temperature until the system is discharged.

For the tests with air flow, the test enclosures shall additionally include one 1 ft^2 (0.09 m2) opening at the top of the enclosure, and one 1 ft^2 (0.09 m2) opening within 2 ft (0.6 m) of the bottom of the enclosure; these opening sizes may not be scaled based on enclosure volume. The fan being used to provide the air exchange can either be located in the upper 1 ft^2 opening, or in a separate opening, but not in the lower 1 ft^2 opening.

4.2.6 Protection of Non Occupied Machinery Spaces (Total Flooding) – Carbon Dioxide

Total flooding carbon dioxide HDME protection systems for unoccupied machinery spaces shall successfully extinguish all fires when subjected to FM 5420 Sections 4.17 (Area of Coverage for Total Flooding Systems) and 4.18 (Area of Coverage for Overhead Local Application Systems).

Additionally, automatic extinguisher units shall successfully flood the test enclosure and extinguish each Class B hazard fire scenario within one minute of test fuel ignition when operated by the automatic means provided. Pneumatic tubing and heat detection cable shall be installed at the manufacturer's maximum limitations, e.g. spacing of tubing/cable, length, height above hazard.

4.2.7 Protection of Class A Materials (Local Application)

4.2.7.1 Requirement

HDME protection systems for Class A hazards shall successfully extinguish a wood crib fire before end of the effective discharge.

4.2.7.2 Tests/Verification

The agent distribution configuration producing the lowest single nozzle quantity of extinguishing agent from Section 4.1 (Flow Distribution Tests) shall be used. The most hydraulically disadvantaged nozzle shall be used in the fire test scenario. The quantity of agent discharged shall not deviate more than 10% from the amount collected in the flow distribution tests.

Alternatively, a single nozzle system replicating the flow rate and agent quantity from the worst performing nozzle from the flow distribution test may be used. A "no fire" discharge shall be conducted to confirm the system flow rate to remove the potential thermal effects on the nozzle caused by the fire exposure. The agent delivered to the apparatus shall be no more than the amount collected from the worst performing nozzles in the flow distribution tests.

The extinguishing nozzle shall be centered over the wood crib and placed at the manufacturer's maximum range.

For each test, the agent storage container shall be filled with the suppressant and shall be pressurized to its normal working pressure. It shall be conditioned to the minimum specified operating temperature, for a minimum of 16 hours, and maintained at this temperature until the system is discharged.

For gas cartridge operated systems, both the agent storage container and the gas cartridge shall be conditioned to the minimum specified operating temperature, for a minimum of 16 hours, and maintained at this temperature until the system is discharged.

A wood crib shall be constructed of four layers of six 1-1/2 x 1-1/2 x 19 in. long (3.8 x 3.8 x 483 mm long) wood members, representing a surface area of 2.5 ft^2 (0.23 m^2). The wood shall be kiln dried spruce or fir lumber having an average moisture content between 9 and 13 percent. Within each layer, the wood members shall be evenly spaced to form a 19 in. x 19 in. (483 mm x 483 mm) square. The members of successive layers shall be positioned at right angles to those of the adjacent layer. The outside edge of the outer members of each layer shall be placed flush with the ends of the members of each adjacent layer. The wood members shall be stapled or nailed together at the outside edges of the crib.

A 2.5 ft^2 (0.23 m^2) square steel pan, a maximum of 6 in. (153 mm) in height, shall be centered below the wood crib, with a distance of 12 in. (305 mm) between the bottom of the crib and the top of the pan. The test stand shall be constructed so that the bottom surface of the wood crib is exposed to the atmosphere. The square pan shall be filled with a sufficient quantity of commercial grade heptane, as defined in Table 4.2.7.2, to provide a minimum of 3 minutes of burning. The heptane shall be ignited, and the crib shall be allowed to burn freely for 6 minutes, and the system shall be discharged. Provisions shall be made to shield the heptane pan and wood crib from any ambient air flow that would prevent the heptane flames from directly contacting the wood crib during the pre-burn period.

Table 4.2.7.2 *Required Heptane Characteristics*

Characteristic	***Required Value***
Minimum Initial Boiling Point	190°F (88°C)
Maximum Dry Point	212°F (100°C)
Specific Gravity at 60°F (15.6°C)	0.67 – 0.73

Observations shall be made for extinguishment of the wood crib and the time of extinguishment shall be recorded. No reignition shall be permitted. The presence of a flame constitutes reignition. Embers are acceptable if they do not produce flames within 10 minutes after extinguishment.

The wood crib and heptane pan may be scaled up or down together depending on the maximum area of coverage required. The wood crib member shall maintain the 1-1/2 inch (3.8 mm) square profile and shall remain four layers tall. Wood crib member spacing shall maintain that of the 19 inch (483 mm) square wood crib.

4.2.8 Protection using Specialty Nozzles

HDME protection nozzles that do not conform to the fire test scenarios described in Sections 4.2.1 through 4.2.7 shall be evaluated at the discretion of the certification agency. The intended application type and hazard class shall be evaluated simulating installed conditions. Nozzle limitations such as manufacturer's maximum range, area of coverage, and maximum protected volumes shall be examined with and without air flow, without repositioning of the nozzle. Air flow within a machinery space shall be one enclosure air change per minute. All other applications shall be 20 ft/s (6 m/s).

The agent distribution configuration producing the lowest single nozzle quantity of extinguishing agent from Section 4.1 (Flow Distribution Tests) shall be used. The most hydraulically disadvantaged nozzle shall be used in the fire test scenario. The quantity of agent discharged shall not deviate more than 10% from the amount collected in the flow distribution tests.

Alternatively, a single nozzle system replicating the flow rate and agent quantity from the worst performing nozzle from the flow distribution tests may be used. A "no fire" discharge shall be conducted to confirm the system flow rate. The agent delivered to the apparatus shall be no more than the amount collected from the worst performing nozzles in the flow distribution tests.

For each test, the agent storage container shall be filled with the suppressant and shall be pressurized to its normal working pressure. It shall be conditioned to the minimum specified operating temperature, for a minimum of 16 hours, and maintained at this temperature until the system is discharged.
For gas cartridge operated systems, both the agent storage container and the gas cartridge shall be conditioned to the minimum specified operating temperature, for a minimum of 16 hours, and maintained at this temperature until the system is discharged.

4.3 Cycle Operation Test

4.3.1 Requirement

All components required for system operation having moving parts shall operate through a total of 500 cycles at the working pressure, or other applicable operating condition, without damage. Following the test, all components shall continue to operate normally.

4.3.2 Tests/Verification

The test samples shall include all components required for operation, including valves and other parts undergoing mechanical movement during system operation; electrical, pneumatic, and mechanical operating devices; switches; relays; and indicators. Valves shall be subjected to the working pressure and cycled from the fully closed to fully open position 500 times. At minimum, the largest and smallest valve sizes of each design shall be tested. Pressure actuated valves having the lowest ratio of available actuator torque to required operation torque shall also be tested. If applicable, manual actuators shall include the maximum length of cable, number of pulleys, etc.

Subsequent to the cycle operation test, each component shall be visually inspected for damage. All components included in the test shall show no sign of physical deterioration that would affect performance and shall continue to operate normally. Discharge valves shall be actuated by all available discharge devices. The pressure required for pneumatic operating devices shall be recorded, and manual controls shall be subjected to Section 4.9.3 (Manual/Mechanical Operated Devices).

Valves and other pressure containing devices shall be tested for leakage at their rated pressures for one minute subsequent to the cycle operation test. No leakage shall be visible.

Any system components that are replaced after each operation, such as rupture discs or pyrotechnic actuators, shall be evaluated by operation of a minimum of 30 samples. All shall operate within the manufacturer's specified parameters.

4.4 Agent Storage Containers

4.4.1 Construction Design

4.4.1.1 Requirements

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

4.4.1.2 Tests/Verification

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

- Verification that the pressure vessel standard is appropriate 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 may be additional minimum criteria established by the certification agency.
- Verification that the design is in accordance with the standard. Typical verification includes a review of certification to manufacture to the standard, minimum wall thickness calculations, authorized materials, material tests, and general chemical analysis tests.

Further verification that the manufacturer is capable of producing storage containers in accordance with the relevant standard shall be required at the discretion of the certification agency. Typically, verification includes volumetric expansion and hydrostatic pressure tests in accordance with the applicable standard(s).

4.4.2 Long Term Leakage Test

4.4.2.1 Requirement

Containers shall not leak in excess of the mass equivalent to 0.5 percent of the nominal storage pressure, based upon the minimum size container intended for use with a specific discharge valve. The allowable leakage value is based upon a 2 to 1 safety factor applied to a maximum 5 percent total leakage over a six year inspection period and is applied to the pressurizing gas.

Stored-pressure agent storage container assemblies for suppressants shall not leak in excess of a rate that would result in the pressure dropping below the minimum operating pressure over a six year period, when monitored over a one year period at 70°F ± 5°F (21°C ± 3°C).

Gas cartridge assemblies for cartridge pressurized systems shall not leak at a rate in excess of 0.5 percent of the charge weight when monitored over a one year period at 70°F ± 5°F (21°C ± 3°C).

4.4.2.2 Tests/Verification

A minimum of three stored-pressure agent storage container and valve assemblies of each leak path design and size shall be filled to the highest rated capacity with the applicable suppressant and pressurized to the working pressure. For gas cartridge operated systems, a minimum of three gas cartridge container assemblies shall be pressurized to the working pressure. Storage containers shall be tested in all storage, shipping, and installation orientations as specified by the manufacturer as applicable. Test sample assemblies shall incorporate all components subjected to the working pressure, including operating devices.

Each sample shall have the pressure checked or be weighed, as appropriate, at 0, 1, 3, 6, and 12 months, and where applicable, the projected weight or pressure loss over a one year period shall be extrapolated. The test shall be suspended if the calculated leakage at any time exceeds the allowable quantity, or any leakage is visible. Subsequent to the one year test period, one sample of each valve design and size shall be successfully discharged using one of the manufacturer's compatible operating devices. The duration of this test may be reduced at the sole discretion of the certification agency.

Detection tubing, if applicable, shall be connected to its associated components required for system actuation, e.g. connected to a pilot cylinder, agent storage container, etc. Samples shall be representative of all leak path designs.

4.4.3 30-Day Maximum Temperature Leakage Test

4.4.3.1 Requirement

Agent storage container assemblies shall not leak in excess of 0.042 percent of the pressurizing gas weight when conditioned to the specified maximum system operating temperature for a 30 day period. The allowable leakage value is 1/12 of the one year allowable leakage, as specified in Section 4.4.2.1 (Long Term Leakage Test – Requirement).

Stored-pressure agent storage container assemblies for suppressants, conditioned at the maximum operating temperature for 30 days, shall discharge not less than 85 percent (by weight) of the suppressant. There shall be no visible signs of leakage from the container, including any pressurized actuation devices, during or after the conditioning period.

4.4.3.2 Tests/Verification

A minimum of three stored-pressure agent storage container and valve assemblies of each leak path design and size shall be filled to their highest rated capacity with applicable suppressant and pressurized to the working pressure. For gas cartridge operated systems, a minimum of three gas cartridge container assemblies shall be pressurized to the working pressure. Storage containers shall be tested in all installed orientations as specified by the manufacturer. Samples shall incorporate all components subjected to the working pressure, including operating devices.

The samples shall be weighed prior to the elevated temperature exposure and shall be subjected to the maximum specified operating temperature for 30 days. Following the exposure period, the samples shall re-weighed and then discharged using one of the manufacturer's compatible operating devices, then re-weighed to determine compliance to Section 4.4.3.1.

Detection tubing, if applicable, shall be connected to its associated components required for system actuation, e.g. connected to a pilot cylinder, agent storage container, etc. Samples shall be representative of all leak path designs.

4.4.4 30-Day Minimum Temperature Leakage Test

4.4.4.1 Requirement

Agent storage container assemblies shall not leak in excess of 0.042 percent of the pressurizing gas weight when conditioned to the specified maximum system operating temperature for a 30 day period. The allowable leakage value is 1/12 of the one year allowable leakage, as specified in Section 4.4.2.1 (Long Term Leakage test - Requirement).

Stored-pressure agent storage container assemblies for suppressants, conditioned at the minimum operating temperature for 30 days, shall discharge not less than 85 percent (by weight) of the suppressant. There shall be no visible signs of leakage from the container, including any pressurized actuation devices, during or after the conditioning period.

4.4.4.2 Tests/Verification

A minimum of three stored-pressure agent storage container and valve assemblies of each leak path design and size shall be filled to their highest rated capacity with applicable suppressant and pressurized to the working pressure. For gas cartridge operated systems, a minimum of three gas cartridge container assemblies shall be pressurized to the working pressure. Storage containers shall be tested in all installed orientations as specified by the manufacturer. Samples shall incorporate all components subjected to the working pressure, including operating devices.

The samples shall be weighed prior to the low temperature exposure and shall be subjected to the minimum specified operating temperature for 30 days. Following the exposure period, the samples shall re-weighed and then discharged using one of the manufacturer's compatible operating devices, then re-weighed to determine compliance to Section 4.4.4.1.

Detection tubing, if applicable, shall be connected to its associated components required for system actuation, e.g. connected to a pilot cylinder, agent storage container, etc. Samples shall be representative of all leak path designs.

4.4.5 Hydrostatic Integrity

4.4.5.1 Requirement

Agent storage containers and gas cartridges shall be hydrostatically tested without failure at a pressure equal to 1.5 times the rated pressure of the pressure relief device, or in accordance with the applicable published standard, whichever pressure is greater. Allowable standards shall be those acceptable to the authority having jurisdiction, based on the intended market for the system. Certification shall be limited to installations within jurisdictions accepting the standard to which the containers have been manufactured. No cracking, fracture, or failure to retain the test pressure shall be allowed.

4.4.5.2 Tests/Verification

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

Two samples of each container size intended for use with the system shall be tested. Container designs consisting of the same diameter, wall thickness, and material of construction, but with differing heights, may be evaluated by testing selected representative samples rather than samples of all container heights.

Samples that deviate from the calculated minimum wall thickness (refer to Section 4.4.1.2, Construction/Design – Tests/Verification) may be accommodated by increasing the test pressure in proportion to the wall thickness. This may be used for up to a maximum difference of 20 percent.

At the sole discretion of the certification agency, physical testing may be waived for pressure vessels being manufactured under continuous third-party surveillance to a recognized and appropriate pressure vessel regulation. In these circumstances, in lieu of physical testing, the manufacturer shall provide adequate documentation detailing continuous (every lot) third-party oversight of the pressure vessel manufacturing, sample test results, and appropriate certification documentation for the overseeing body.

4.4.6 Permanent Volumetric Expansion

4.4.6.1 Requirement

Permanent volumetric expansion testing is required under some pressure vessel standards. If required by the standard to which the agent storage container or gas cartridge is designed, such tests shall be conducted in accordance with that standard.

When subjected to the proof test pressure, the permanent volumetric expansion of a storage container shall not exceed 10 percent of the total expansion. The proof test pressure shall be as specified in the ASME BPVC-CC-N, Section VII, or the U.S. Department of Transportation, Title 49, Code of Federal Regulations, Parts 171 to 180, or the equivalent national codes for the country of use. In cases where the pressure vessel is not tested or marked in accordance with one of these specifications, the proof test pressure shall be equal to three times the extinguishing system's working pressure.

4.4.6.2 Tests/Verification

Each sample shall be subjected to the required test pressure, using water as the pressurizing medium. For the final 20 percent of the required pressure, the rate of pressure increase shall be no more than

10 percent per minute. The required test pressure shall be maintained for a minimum of one minute, or in accordance with the applicable published standard, whichever is longer. The total expansion of the cylinder shall be measured. The applied pressure shall then be removed from the sample, and the permanent volumetric expansion shall be measured.

Two samples of each container size intended for use with the system shall be tested. Cylinder designs consisting of the same diameter, wall thickness, and material of construction, but with differing heights, may be evaluated by testing selected representative samples rather than samples of all cylinder heights.

At the sole discretion of the certification agency, physical testing may be waived for pressure vessels being manufactured under continuous third-party surveillance to a recognized and appropriate pressure vessel regulation. In these circumstances, in lieu of physical testing, the manufacturer shall provide adequate documentation detailing continuous (every lot) third-party oversight of the pressure vessel manufacturing, sample test results, and appropriate certification documentation for the overseeing body.

4.5 Hydrostatic Pressure Test

4.5.1 Requirement

All components subjected to system pressure, either during storage or system discharge, shall withstand the pressure described in Section 4.4.5 (Hydrostatic Integrity) for one minute. No cracking, fracture, or failure to retain the test pressure shall be permitted.

4.5.2 Tests/Verification

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

Leakage is acceptable during the hydrostatic tests, as long as the pressure source is adequate to maintain the required test pressure.

4.6 Pressure Relief Devices

4.6.1 Pressure Relief Operation

4.6.1.1 Requirement

The pressure relief device pressure ratings of agent storage container and gas cartridge assemblies shall be selected as specified in 3.2.13 (Pressure Relief Devices). The average operating pressure of the device plus two standard deviations shall not exceed the cylinder test pressure and the average operating pressure of the device less two standard deviations shall not fall below the container pressure at maximum temperature. In addition, no individual tested sample shall operate outside of those pressure constraints.

4.6.1.2 Tests/Verification

A minimum of 30 pressure relief device assemblies shall be pressurized until operation. If the device does not contain a rupturing component, but rather operates similarly to a pressure relief valve, the same device shall be subjected to all 30 trials. Pressure may be increased rapidly to 85 percent of the device's rated pressure, then shall be increased until operation at a rate no greater than 10 percent per minute. The operating pressure shall be recorded.

4.6.2 Pressure Relief Calculations

4.6.2.1 Requirement

Documentation shall be submitted to verify that the construction and size of agent storage container and gas cartridge pressure relief device complies with the flow capacity requirements. The construction and size of the burst disc and dispersion device shall, at a minimum, be appropriate for the system pressure at the maximum specified operating temperature.

4.6.2.2 Tests/Verification

Appropriate documentation and calculations shall be submitted to verify that the construction and size of the pressure relief device complies with the flow capacity requirements specified in CGA Pamphlet S-1.1, Safety Relief Devices Standards – Cylinders for Compressed Gases, or equivalent. Burst discs used as a part of the suppressant discharge system, and not intended to protect the agent storage container, shall not be evaluated per this requirement. Instead, their capacity shall be verified as a part of the Flow Distribution Tests of Section 4.1 (Flow Distribution Test).

4.7 Mounting Device Test

4.7.1 Requirement

Agent storage container and gas cartridge brackets shall not show evidence of permanent distortion or other damage when subjected to a static load equal to five times the weight of the extinguishing system at its highest rated capacity.

4.7.2 Tests/Verification

An extinguishing system mounting bracket shall be assembled in its intended orientation. A static load equal to five times the weight of the system at its highest rated capacity, but not less than 100 pounds (45.3 kg), shall be applied vertically downward to the bracket. The load shall be maintained for 5 minutes. The mounting bracket shall be observed for damage throughout the 5 minute period.

The mounting device test shall not apply to mounting brackets for containers that are intended to be directly supported by the floor or installed within the operator’s compartment. Physical testing may be waived if the mounting device has successfully completed the requirements of Section 4.37 (Vibration and Shock Resistance Test).

4.8 Flexible Hose

Flexible hose samples shall be representative of all materials of construction, design standards, and sizes, and shall be representative of all construction methods, both factory and field assembled.

4.8.1 Low Temperature Resistance

4.8.1.1 Requirement

Flexible hoses shall withstand damage when conditioned at the minimum specified extinguishing system storage temperature. Following the conditioning period, the flexible hose shall withstand the minimum specified bending radius, as well as the hydrostatic pressure described in Section 4.5 (Hydrostatic Pressure Test) for a period of one minute. No cracking, fracture, or failure to retain the test pressure shall be permitted.

4.8.1.2 Tests/Verification

One sample of each representative size flexible hose shall be tested. Each hose assembly shall be conditioned for 16 hours at the minimum specified storage temperature. The sample shall be maintained at the minimum temperature and bent to the minimum specified bending radius or maximum specified bending angle. Bending shall be performed smoothly and continuously within an approximate 10 second time interval. Custom length samples may be required to allow for a complete bend.

The flexible hose shall be visually inspected for cracking or other damage. Subsequent to this inspection, the hose shall be subjected to the required test pressure for a period of one minute, or in accordance with the applicable standard, whichever is longer. No rupture or separation from end connections shall occur.

4.8.2 Resilience

4.8.2.1 Requirement

Flexible hoses shall withstand damage and remain functional after 3000 cycles of flexure to the maximum specified angle from straight. Following the cycle test, flexible hose shall withstand the hydrostatic pressure described in Section 4.5 (Hydrostatic Pressure Test) for one minute. No cracking, fracture, or failure to retain the test pressure shall be permitted.

4.8.2.2 Tests/Verification

Each hose assembly shall be conditioned for 16 hours at 70°F ± 5°F (21°C ± 3°C). The sample shall be maintained at this temperature and bent to the minimum specified bending radius or to the maximum specified angle. Bending shall be performed smoothly and continuously. The sample shall then be straightened to complete one cycle. The bending and straightening cycle shall be repeated for a total of 3000 cycles. Custom length samples may be required to allow for a complete bend.

The flexible hose shall be visually inspected for cracking or other damage. Subsequent to this inspection, the hose shall be subjected to the required test pressure for a period of one minute, or in accordance with the applicable standard, whichever is longer. No rupture or separation from end connections shall occur.

4.8.3 Fire Exposure Resistance

4.8.3.1 Requirement

Flexible hoses installed within the protected space shall withstand damage and remain functional after exposure to the fire conditions described in Section 4.8.3.2, below. Following the fire exposure test, flexible hoses shall remain fully functional and withstand the hydrostatic pressure described in Section 4.5 (Hydrostatic Pressure Test) for one minute. No cracking, fracture, or failure to retain the test pressure shall be permitted. Additionally, flexible hoses shall not exhibit a reduction in flow area and maintain the system discharge flow rates determined in Section 4.1 (Flow Distribution Tests).

4.8.3.2 Tests/Verification

A pan with an area of at least 2.5 ft^2 (0.23 m^2), inside side dimensions of at least 19 in (482.6 mm), and an inside depth of at least 4 in (102 mm) shall be constructed from steel at least 1/4 in. (6.4 mm) thick, with the joints welded and liquid tight. A 1.5 in. (38 mm) by 1.5 in. (38 mm) by 3/16 in. (5 mm) thick reinforcing angle, forming a 1.75 in. (44 mm) wide turned out edge that is flush with the top edge of the pan, shall be provided along the perimeter of the pan. The reinforcing angle shall be continuously welded to the outside of the pan at the top edge, and tack welded at the edge of the lower leg of the angle. The pan shall be filled with at least 1 in (25.4 mm) of heptane meeting the requirements specified in Table 4.2.7.2.

The flexible hose sample is to be installed 36 ± 0.5 in (914 +/- 13 mm) above the bottom of the pan. The hose shall be installed in a straight line parallel to the pan and positioned to ensure full flame impingement for the exposure period. The heptane shall be ignited and burn freely for 60 seconds. The hose sample shall be removed from the fire source and allowed to cool. Custom length samples may be required to allow for post fire exposure testing.

Two flexible hose samples are to be subjected to this exposure. Subsequent to the fire exposure, one hose sample shall withstand the pressure described in Section 4.5 (Hydrostatic Pressure Test) for one minute. No cracking, fracture, or failure to retain the test pressure shall be permitted. The second sample shall be subjected to at least one representative flow distribution test in accordance with Section 4.1 (Flow Distribution Tests). Alternate post fire exposure flow tests will be considered at the discretion of the certification agency.

4.9 Actuation Device Operation

4.9.1 General

4.9.1.1 Requirement

All actuation devices shall operate under the most adverse system pressure when conditioned to the maximum and minimum specified installation temperatures.

4.9.1.2 Tests/Verification

A minimum of one sample of each device shall be conditioned to the minimum specified installation temperature for 16 hours. While still at that temperature, the device shall be installed on the valve for which it is designed and operated and display no hesitation/delay in normal actuation, partial operation, or other failure. Devices operated by pressure shall be tested at maximum or minimum working pressure, whichever is more conservative for the design of the specific component. If the most adverse condition is not easily discernable, the device shall be operated at both extremes of pressure.

A minimum of one sample of each device shall be conditioned at the maximum specified installation temperature for 16 hours, and the evaluations described above shall be repeated.

4.9.2 Electrically Operated Devices

4.9.2.1 Requirement

Electrically operated actuation devices shall operate properly at 85 and 110 percent of the rated voltage while at maximum and minimum specified installation temperatures.

4.9.2.2 Tests/Verification

A minimum of one sample of each device shall be conditioned in accordance with the parameters described in Section 4.9.1.2, above. Following the conditioning period, each sample shall operate when supplied with 85 percent of rated voltage, and again when supplied with 110 percent of rated voltage. The device shall display no hesitation, partial operation, or other failure.

4.9.3 Manual/Mechanical Operated Devices

4.9.3.1 Requirement

Manual controls shall operate properly with applied forces no greater than 40 lb (178 N), linear movement no more than 14 in. (355 mm), nor rotational movement of over 270 degrees when configured with the most adverse arrangement specified by the manufacturer's installation instructions. Strike knobs shall not require energy to operate exceeding 27.1 Joules.

4.9.3.2 Tests/Verification

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

4.9.4 Pilot Operated Devices

4.9.4.1 Requirement

Pneumatically operated pilot-secondary cylinder arrangements of the most adverse specified configuration shall operate all connected cylinders within one second.

4.9.4.2 Tests/Verification

The pilot container shall be pressurized to its working pressure and conditioned to the minimum specified storage temperature for 16 hours. Secondary cylinders shall be pressurized to their working pressures and conditioned to the maximum specified storage temperature for 16 hours. The maximum number of secondary cylinders shall be connected to the pilot cylinder through the most restrictive piping arrangement permitted by the manufacturer's installation instructions. The pilot cylinder shall be actuated, and the time interval between operation of the pilot cylinder and the last secondary cylinder shall be measured. A data acquisition system, capable of recording pressure readings for the pilot and most remote secondary cylinder at a minimum of 10 Hz, shall be used to record the timing. The last secondary cylinder shall operate within 1 second of the first significant pressure decrease in the pilot cylinder.

4.9.5 Manual/Electrical Operated Devices

4.9.5.1 Requirement

Manual controls shall operate properly with applied forces, pushing or pulling, no greater than 15 pounds (67 N).

4.9.5.2 Tests/Verification

A minimum of one sample of each device shall be tested using calibrated force gauge(s) to measure operational requirements.

4.10 Dielectric Withstand

4.10.1 Requirement

Electrical system components shall withstand for 1 minute an applied test voltage between all terminals provided for external connections and the component body or enclosure. Non-metallic components shall be wrapped in conductive foil for this test. There shall be no breakdown of the insulation between the test points. Components shall continue to function normally subsequent to this test.

4.10.2 Tests/Verification

For a device with a rated voltage not exceeding 60V dc, the test voltage shall be equal to 500 V ac (707V dc). For all other devices, the test voltage shall be calculated as 1000V ac plus two times the rated voltage of the circuit. Starting at 0V, the voltage shall be raised at a rate of 100V/s until the test voltage is obtained and then maintained for a minimum period of 60 seconds. There shall be no breakdown; leakage current shall not exceed 0.5mA.

4.11 Control Unit – Basic Operation

4.11.1 Requirement

Operation under normal, alarm, supervisory, and trouble conditions shall be as described in the HDME protection system operation manual and as in the System Operation sections of this standard.

4.11.2 Tests/Verification

Representative sample(s) of the HDME protection system shall be tested to verify operation in agreement with the system manual and compliance with the applicable requirements of Sections 3.2.26 through 3.2.31.

4.12 Control Unit - Power Supply Supervision

4.12.1 Requirement

The primary and secondary power supplies shall be supervised for the conditions of low power and lost power.

4.12.2 Tests/Verification

4.12.2.1 With one supply at rated or nominal range value, the other supply shall be removed. This shall result in a power supply trouble indication. Proper system operation shall be verified. This supply removal test shall be separately conducted for both supplies.

4.12.2.2 With one supply at rated or nominal range value, the other supply shall be reduced in voltage/capacity to the level at which a power supply trouble indication occurs. System operation shall be verified at that condition. This supply reduction test shall be separately conducted for each supply.

4.12.2.3 For the primary supply, if transfer of operation to the secondary power supply does not occur at the value in 4.12.2.2 above, the voltage will be further reduced until the transfer occurs. During and after the transfer, the system shall continue to operate without loss of state or incoming signals.

4.13 Control Unit - Power Supply Operation

4.13.1 Requirement

The primary and secondary power supplies shall be independently capable of operating the system.

4.13.2 Tests/Verification

4.13.2.1 The HDME protection system shall be tested for proper operation over its primary supply voltage range with secondary supply disconnected. Tested values shall cover, at minimum, 85 to 110 percent of the nominal, rated input voltage value.

4.13.2.2 The HDME protection system shall be tested for proper operation of its primary, external supply with secondary supply connected. Primary input voltage shall be reduced to a value just above the transfer voltage determined in Section 4.12.2.3. The value shall not exceed the transfer value by more than 0.5V. System operation shall be verified under that condition.

4.13.2.3 The HDME protection system shall be tested for proper operation over its external secondary supply voltage range with primary supply disconnected. Tested values shall cover, at minimum, 85 to 110 percent of the nominal, rated input voltage value.

4.13.2.4 The HDME protection system shall be capable of proper operation when powered solely by its integral, internal supply at both its fully charged value and at a value no greater than 0.1V above the level at which a trouble indication occurs.

4.14 Control Unit - Integral Dedicated Battery Supply

4.14.1 Requirement

Integral battery(ies) or other power source shall be capable of operating the system for a minimum of 4 hours. If rechargeable, the system shall be capable of recharging the battery(ies) or power source within a period no greater than two times the rated operating time of the secondary source and of maintaining the charged condition.

4.14.2 Tests/Verification

4.14.2.1 A system configured for maximum normal and alarm loads shall be operated with fully charged battery(ies) or power source and with primary power removed for the maximum specified operation time. At the end of this period, an alarm condition shall be initiated, and the system shall perform all resultant functions, including system release and it shall remain operational for a minimum 5 minutes.

4.14.2.2 For a rechargeable battery, after the discharge described in 4.14.2.1, primary power shall be returned and the system shall be operated in normal condition for the specified recharge period. The battery(ies) shall return to within 95 percent of its fully charged capacity at the end of that period.

4.15 Control Unit - Circuit Supervision

4.15.1 Requirement

Conductors interconnecting portions of the HDME protection system shall be supervised for integrity such that, at minimum, the occurrence of a single open or a single ground-fault condition shall result in a trouble condition. Restoration of the conductors to normal shall also be automatically indicated. Supervision of wire-to wire short circuit conditions shall not be required, except where specified in this standard.

4.15.2 Tests/Verification

All interconnecting circuits of the HDME protection system shall be tested by the simulation of circuit faults and their restoration to normal. These shall include, as applicable to the circuit type, single open, single ground, and wire-to-wire short circuit.

4.15.2.1 If a circuit is designated as complying with a circuit type and Class as defined in NFPA 72 or FM 3010, testing appropriate for that type and Class shall be conducted.

4.15.2.2 A wire-to-wire short circuit fault on an alarm indicating device circuit shall result in a trouble condition.

4.15.2.3 A wire-to-wire short circuit fault on a signaling line circuit, e.g. circuit connecting separate portions of a multi-part control unit, shall result in a trouble condition.

4.15.2.4 For a system with multiple alarm indicating device circuits, an open, ground, or short circuit fault on one indicating device circuit shall not affect the operation of any other alarm indicating device circuit.

4.15.2.5 Restoration of the conductors to normal after a fault condition shall be automatically indicated.

4.16 Control Unit - Operating Temperature and Relative Humidity

4.16.1 Requirement

The HDME protection system shall be capable of proper operation while exposed to its specified operating temperature extremes and to a condition of elevated temperature and relative humidity.

4.16.2 Tests/Verification

The HDME protection system shall remain functional with no false trouble signal or false alarm response during the following described exposures to its operating temperature extremes and to elevated relative humidity:

- A minimum period of 16 hours at the lower of the product’s minimum rated temperature and the allowable minimum operating temperature per Table 3.2.1 (See Section 3.2.1 Exception)
- A minimum period of 16 hours at the higher of the product’s maximum rated temperature and the allowable maximum operating temperature per Table 3.2.1
- A minimum period of 24 hours at a relative humidity of 95±3 percent and temperature of 140°F±3°F (60°C±2°C)

Before the end of each exposure, while still at the test conditions, the system shall operate as intended. For the temperature extremes, the verification shall be performed with the primary supply at its maximum and minimum voltage extremes and with the secondary power supply, e.g. integral battery(ies), operating the system without the primary.

4.17 Electrical Device and Circuit Compatibility

4.17.1 Requirement

Electrical devices shall be compatible with the circuits to which they are connected.

4.17.2 Tests/Verification

Compatibility of devices and circuits shall be verified by matching their input/output specifications and demonstrating proper operation over the range of installation and operation variables. These will vary depending on circuit type and include operating voltage and current, circuit loading, circuit line length, number of devices.

4.18 Power Supply – Reverse Polarity

4.18.1 Requirement

A reverse polarity condition on the external power supply connections shall not damage the equipment. Opening of a replaceable, protective component is acceptable.

4.18.2 Tests/Verification

An electrical power source of nominal rated voltage shall be connected with the polarity reversed for a period of 30 min or until the resultant condition has stabilized. The equipment shall not be damaged and shall function as intended when the electrical power is connected correctly and, if applicable, the protective component is replaced. This shall be separately conducted for each external power supply.

4.19 Polymeric Electrical Enclosure Integrity

4.19.1 Requirement

An electrical enclosure constructed of polymeric material shall not warp to an extent to impair the intended operation or expose high voltage components.

4.19.2 Tests/Verification

A sample shall be mounted as intended, placed in a circulating air-oven, and aged at 194°F (90°C) for seven days or at 158°F (70°C) for twenty eight days. The sample shall then be examined to the following criteria: There shall be no evidence of warping and distortion; there shall be no exposure to high voltage components; and the unit shall continue to operate normally.

4.20 Electrostatic Discharge Immunity Test

4.20.1 Requirement

The system shall demonstrate immunity to static electricity discharges from operators.

4.20.2 Tests/Verification

System equipment that can be normally reached by an operator shall be subjected to electrostatic pulses as described in EN 61000-4-2 and specified herein. Contact discharge testing (6 kV) shall be conducted on metallic surfaces; air discharge testing (2, 4, 8, 15 kV) shall be conducted on non-conductive surfaces. At each test voltage, there shall be 10 pulses per polarity with a 1 s interval between discharges. The equipment shall continue to operate as intended after the test. During the test, there shall be no false alarm output or non-self-restoring trouble signals.

4.21 Electromagnetic Field Immunity Test

4.21.1 Requirement

The system shall demonstrate immunity to radiated, radio-frequency electro-magnetic fields.

4.21.2 Tests/Verification

System equipment shall be subjected to electromagnetic fields as described in EN 61000-4-3 and specified herein. Tested frequency range shall be frequency range: 80 MHz to 2 GHz with modulation 80 percent AM at 1000 Hz, and field strength of 10 V/m. Dwell time shall be based on the response time of the equipment under test. During the test, there shall be no false alarm output or trouble signals and the equipment shall continue to operate as intended after the test.

4.22 Immunity to Conducted Disturbances Test

4.22.1 Requirement

The system control unit shall demonstrate immunity to conducted disturbances induced by radio frequency transmitters.

4.22.2 Tests/Verification

A sample control unit shall be subjected to conducted disturbances induced by an electric field of 3 Vrms from 150 kHz to 80 MHz with 80 percent AM at 1 kHz with frequency sweep rate of 1 percent/3 seconds. Dwell time will be based on control unit response time. Procedure shall be as described in standard EN 61000-4-6. The unit shall continue to operate as intended during and after the test.

4.23 Electrical Fast Transient / Burst Immunity Test

4.23.1 Requirement

The system control unit shall demonstrate immunity to transient disturbances.

4.23.2 Tests/Verification

A sample control unit shall be subjected to electrical fast transients of 0.5 kV at a 100 kHz repetition rate on the power, input, and output circuits for duration of 5 minutes at each polarity. Procedure shall be as described in standard EN 61000-4-4. The unit shall continue to operate as intended during and after the test.

4.24 Electrical Surge Immunity Test

4.24.1 Requirement

The system control unit shall demonstrate immunity to surges from switching and lightning transients.

4.24.2 Tests/Verification

The power line(s) of a sample control unit shall be subjected to +/- 0.5 kV surges, line to line and line to earth, as described in EN 61000-4-5. Each pulse shall be applied 5 times of at a rate of 1 pulse per minute. The control unit shall continue to operate as intended after the test. During the test, there shall be no false alarm output or non-self-restoring trouble signals.

4.25 Corrosion – Salt Spray

4.25.1 Requirement

System components shall withstand a 240 hour exposure to the test described in Section 4.25.2, below, without incurring damage that would impair function. Following the exposure period, the system shall be successfully discharged using one of the manufacturer’s compatible release devices.

4.25.2 Tests/Verification

Test samples shall be selected to represent all material combinations and configurations. A minimum of one suppressant storage container assembly, including the mounting bracket and labels, shall be included among the test samples. Actuation devices with moving parts subject to fouling from external corrosion shall also be subject to this test. Test sample agent storage containers shall be pressurized to the working pressure but need not contain the actual agent. Discharge nozzles manufactured from a corrosion resistant material are not subject to salt fog testing, provided that material specifications are submitted for review.

The samples shall be exposed to salt spray (fog) as specified by ASTM B117. 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 a specific gravity between 1.126 and 1.157.

Following the exposure to the salt fog, the sample shall remain fully functional and exhibit no corrosion, galvanic action, loss of legibility of markings, or separation of protective coatings which would impair future functionality. Superficial discoloration with no substantial attack of the underlying material shall be acceptable. The fully charged agent storage container and valve assembly shall be successfully discharged using one of the manufacturer’s compatible release devices.

Control devices shall continue to demonstrate proper function subsequent to this exposure.

4.26 Corrosion – Stress Cracking

4.26.1 Requirement

Critical extinguishing system components required for system actuation and agent release shall be resistant to stress corrosion cracking resulting from exposure to the processes described in Section 4.26.2, below. Following the exposure period, the samples shall not show evidence of cracking, delamination, or degradation. Representative samples shall be provided at the direction of the certification agency.

4.26.2 Tests/Verification

4.26.2.1 Copper Based Parts (Ammonia Test)

Devices manufactured of copper alloys with a zinc content exceeding 15 percent shall be exposed to a moist ammonia environment. The inlet end of each sample shall be filled with deionized water and sealed with a non-reactive material (e.g., plastic cap) to prevent the introduction of the ammonia atmosphere to the interior of the component. The samples to be tested shall be free from any non-permanent protective coating and, if necessary, shall be degreased. If a permanent coating is an inherent part of the design, such coating shall be subjected to tests as deemed necessary by the certification agency to evaluate its protective integrity. The samples shall be tested in their intended orientation. Samples shall be assembled using the manufacturer’s specified torque on threaded connections and flange bolts to replicate the as-installed loads.

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

The samples shall be exposed to the moist ammonia-air mixture maintained in a glass chamber with a volume of 0.73 ± 0.34 ft^3 (0.02 ± 0.01 m^3).

Aqueous ammonia having a density of $5.86x10^{-5}$ lb/ft^3 (0.94 g/cm^3) shall be maintained in the bottom of the chamber, approximately 1.5 in. (40 mm) below the bottom of the samples. The volume of ammonia to be used shall be determined by multiplying the enclosure volume in ft^3 (L) by 0.075 gal/ft^3 (10 L/m^3). This will result in approximately the following atmospheric concentrations: 35 percent ammonia, 5 percent water vapor, and 60 percent air. Prior to beginning the exposure, the chamber shall be conditioned to a temperature of 93°F ± 4°F (34°C ± 2°C) for a period of not less than one hour and shall be maintained at this temperature throughout the exposure period. The moist ammonia-air mixture shall be maintained at essentially atmospheric pressure. Provision shall be made for venting the chamber, such as using a capillary tube, to avoid buildup of pressure.

Following exposure to the moist ammonia environment for a period of 10 days, the samples shall be removed, rinsed in potable water, and air dried. Following a minimum two-day drying period, visual examination of the samples shall be made.

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

Samples shall be degreased and exposed to a boiling magnesium chloride solution for a period of 500 hours, in accordance with ASTM G 36.

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

Following exposure, the samples shall be removed and rinsed in potable water. Following a two-to four-day drying period, visual examination of the samples shall be made.

4.26.2.3 Parts Manufactured from Other Materials

Parts manufactured from other materials shall withstand comparable tests, based on the type of material employed, at the sole discretion of the certification agency.

4.27 High Temperature Exposure

4.27.1 Requirement

Components, such as nozzles, that are exposed to the protected space shall not show significant deformation, blistering, or fracture following exposure to an elevated temperature as detailed in Section 4.27.2, below. In the case of a nozzle, no cracking or distortion that would potentially alter discharge characteristics shall be allowed.

4.27.2 Tests/Verification

The component shall be placed in an oven and heated to 1470 ± 20 ºF (800 ± 11ºC) for a period of 15 minutes. Following this exposure, the nozzle shall be removed and promptly submerged in a water bath with a temperature of 60 ± 10 ºF (15 ± 6ºC).

4.28 Aging Tests – Plastic Materials

4.28.1 Air-Oven Aging Test

4.28.1.1 Requirements

Nonmetallic components, including valves, valve parts, siphon tubes and other parts subjected to the flow of suppressant, and mounting brackets, shall be subjected to air-oven aging tests at 212°F (100°C). There shall be no cracking or crazing as a result of this test. Subsequent to exposure, valves and valve parts shall then be subjected to the requirements of Section 4.5 (Hydrostatic Pressure Test), agent storage containers shall be subjected to the requirements of Section 4.4.5 (Hydrostatic Integrity), and mounting brackets shall be subjected to the requirements of Section 4.7 (Mounting Device Test).

4.28.1.2 Tests/Verification

Samples shall be subjected to air-oven aging tests for 180 days at 212°F (100°C), and then allowed to cool a minimum of 24 hours in air at 74°F (23°C) at 50 percent relative humidity. At the conclusion of the test, the samples shall be inspected for cracking or crazing. The samples shall then be subjected to the applicable tests listed in Section 4.28.1.1, above.

4.28.2 Ultraviolet Light and Water Test

4.28.2.1 Requirements

Nameplates and nonmetallic components, including valves, exposed valve parts, and mounting brackets, shall be exposed to ultraviolet light and water for 720 hours in accordance with Table X3.1, Condition 1, of ASTM G 155. At the conclusion of the test, there shall be no cracking or crazing of the component. Valves and valve parts shall then be subjected to the requirements of Section 4.5 (Hydrostatic Pressure Test). Mounting brackets shall be subjected to the requirements of Section 4.7 (Mounting Device Test).

4.28.2.2 Tests/Verification

Samples shall be exposed to ultraviolet light and water for 720 hours. The samples 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 109 ± 4.5ºF (43 ± 2.5ºC) and the relative humidity 30 ± 5 percent. At the conclusion of the test, the samples shall be inspected for cracking or crazing. The samples shall then be subjected to the applicable tests listed in Section 4.28.2.1, above.

4.28.3 Exposure to Suppressant Test

4.28.3.1 Requirement

Plastic siphon tubes or other plastic components exposed to the suppressant shall not show degradation following exposure to the agent at elevated temperature.

4.28.3.2 Tests/Verification

Three 1/2 in. (12.7 mm) wide ring samples shall be cut from a plastic siphon tube and immersed in a container filled with the suppressant. Samples of other non-cylindrical components shall be cut to expose their cross-sections and be of approximately 1/2 in. (12.7 mm) in length, perpendicular to the cut, if longer than that dimension in their initial configuration. The container shall be sealed and conditioned to the maximum specified operating temperature for a period of 210 days. The samples shall be subsequently rinsed in water and allowed to dry for 24 hours in air at 70°F ± 5°F (21°C ± 3°C) and 50 percent relative humidity. At the conclusion of the test, the samples shall be inspected for any signs of degradation. At the discretion of the certification agency, additional testing such as tensile or crush tests may be performed on the samples to verify that the exposed samples do not show degradation in excess of 40 percent of the original values.

4.29 Elastomeric Materials Tests

4.29.1 Requirement

Elastomers used in HDME protection systems shall have a tensile strength of not less than 500 psi (34.5 bar), an ultimate elongation of not less than 100 percent, and a tensile set of not more than 19 percent. Tensile strength, ultimate elongation, and tensile set shall be determined in accordance with ASTM D 412, Method A, with exceptions as stated in Section 4.29.2, below.

4.29.2 Tests/Verification

For standard elastomers, the material manufacturer's certificates of compliance verifying the conformance to the performance requirements listed in Section 4.29.1, above, shall be considered acceptable. The test certificates shall demonstrate that the tests were conducted by an ISO 9000 certified facility, and that the test equipment was calibrated by an ISO 17025 (*General Requirements for the Competence of Testing and Calibration Laboratories*) certified agency. Where such certifications are not available, tests of the elastomer shall be conducted.

Tensile strength, ultimate elongation, and tensile set shall be determined in accordance with ASTM D 412, 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 allowed if the measured strength and elongation values are within the minimum requirements.

Exception: The elastomeric materials test shall not apply to seals and gaskets used in detection or control equipment.

Physical testing may be waived if the elastomeric material has successfully completed the requirements of Section 3.2.2.2 (Materials) and Section 4.3 (Cycle Operation Test) as applicable.

4.30 Gravel Bombardment

4.30.1 Requirement

All paint systems, coatings, and material substrates for components mounted outside of the HDME and subject to impingement of gravel and debris shall be identified. Samples for each paint system, coating, and material substrate shall be subjected to SAE J400, Test for Chip Resistance of Surface Coatings at 70 ± 5 psi (4.8 ± 0.34 bar).

4.30.2 Tests/Verification

All test samples shall be subjected to gravel bombardment in accordance with Section 4.30.1. Three 7.5 ± 0.25" (191 mm ± 0.63 mm) tall by 5.75 ± 0.25" (146 mm ± 0.63 mm) wide samples shall be provided for each configuration. The thickness of the test sample shall not exceed 0.25" (0.63 mm). A 0.25" (0.63 mm) hole shall be provided along the centerline within 1” of the top or side.

Following the gravel bombardment, two samples shall be exposed to the salt spray corrosion test described in Section 4.25 (Corrosion – Salt Spray). The third sample shall be kept as a control sample for evaluation purposes. The samples shall exhibit no corrosion, galvanic action, or separation of protective coatings. Superficial discoloration with no substantial attack of underlying material shall be acceptable.

4.31 Resistance to Steam Cleaning and Pressure Washing

4.31.1 Requirement

Components that are steam cleaned or pressure washed as a part of normal HDME vehicle maintenance shall remain fully functional and legibly labeled when subjected to steam cleaning and pressure wash testing.

4.31.2 Tests/Verification

Relevant component samples shall be subjected to simulated steam cleaning and pressure washing on their exposed surfaces when mounted per the manufacturer’s instructions. Each tested sample shall be mounted on a rigid surface large enough to allow its normal attachment. Components shall be subjected to the minimum water spray requirements shown in Table 4.31.2. Each approximate 2 ft (0.6m) by 2 ft (0.6m) area shall be sprayed for a minimum of 30 seconds at a distance of 8 to 12 inches (20.3 to 30.5 cm), covering all sides of the mounted components using a standard 15 degree pressure washer fan nozzle. Agent storage containers shall be individually tested with a minimum water spray of 30 seconds focusing on the paint surface and corners of applied nameplates, if applicable. At the conclusion of this exposure, all samples shall remain fully functional and their markings fully legible. Electrical components shall be disconnected from the power source for a period of 5 minutes and powered back up to check for any system faults.

Table 4.31.2 *Required Steam Cleaning and Pressure Washing Parameters*

Characteristic	***Minimum Value***
Pressure (Spraying)	3400 psi (241.3 bar)
Flow Rate	6 gallons per minute (22.7 liters per minute)
Temperature	160°F (71.1°C)

4.32 Liquid Extinguishing Agent Stability

4.32.1 Requirement

Liquid Suppressants shall remain homogeneous solutions when stored at the maximum and minimum specified temperatures.

4.32.2 Tests/Verification

An approximately 0.16 gallon (0.6L) sample of the liquid suppressant shall be placed in a transparent closed container and stored at the manufacturer’s minimum specified temperature, but no higher than 35ºF (1.1ºC) and a second, similar sample at the manufacturer’s maximum specified temperature, but no less than 120ºF (49ºC). Both samples shall remain undisturbed for 90 days. At 30, 60, and 90 days the samples shall be examined for separation or stratification. No such separation or stratification shall be visible. Visible evidence of separation or stratification shall include the development of two or more distinct layers or the precipitation of any solids. Cloudiness or other changes in appearance without loss of homogeneity shall be acceptable if the tested samples provide identical results to virgin samples when examined by Fourier transform infrared spectroscopy (FTIR) analysis, or equivalent process, and their viscosity measured, as described in Section 4.34 (Foam Concentrate and Liquid Suppressant Identification Benchmarking).

4.33 Foam Concentrate or Solution Stability

4.33.1 Requirement

All foam concentrates or solutions, as applicable, shall remain homogeneous solutions when stored at the maximum and minimum specified temperatures if the tested samples exhibit identical results to virgin samples when examined by FTIR analysis, or equivalent process, and their viscosity measured, as described in Section 4.34 (Foam Concentrate and Liquid Suppressant Identification Benchmarking).

4.33.2 Test/Verification

An approximately 0.16 gallon (0.6L) sample of foam concentrate or solution shall be placed in a transparent closed container and stored at the manufacturer’s minimum specified temperature, but no higher than 35ºF (1.1ºC) and a second, similar sample at the manufacturer’s maximum specified temperature, but no less than 120ºF (49ºC). Both samples shall remain undisturbed for 90 days. If the HDME protection system stores the concentrate in an undiluted state, then this test shall be run with undiluted samples of the concentrate. If a foam solution is supplied to the system, then samples shall be of that solution, instead. At 30, 60, and 90 days the samples shall be examined for separation or stratification. No such separation or stratification shall be visible. Visible evidence of separation or stratification shall include the development of two or more distinct layers or the precipitation of any solids. Cloudiness or other changes in appearance without loss of homogeneity shall be acceptable.

4.34 Foam Concentrate and Liquid Suppressant Identification Benchmarking

4.34.1 Requirement

All foam concentrates and liquid suppressants shall be subjected to a viscosity measurement and FTIR analysis, or equivalent process, to obtain a benchmark profile for future re-examination reference.

4.34.2 Test/Verification

An approximately 0.25 gallon (1L) sample of foam concentrate or liquid suppressant shall be provided for viscosity measurement and benchmark profile analysis. The resulting spectrum may be retained by the certification agency for use in identifying deviations from the as certified composition, either through formulation changes, production process faults, or contamination of installed systems. Viscosity measurements shall be performed as described in Appendix E.

4.35 Pressure Gauges and Supervisory Pressure Switches

4.35.1 Accuracy

4.35.1.1 Requirement

Agent supply container pressure gauges shall exhibit accuracy within the limits of Table 4.35.1.1.

Table 4.35.1.1 *Pressure Gauge Limits*

Area of Range	***Accuracy Required, percent***
Zero Point	-0/+12
Low Pressure Alarm Point	± 6
Working Pressure	± 4
Full Scale	± 15

Supervisory pressure switches and discharge indicators shall activate within ±6 percent of the set point, under increasing or decreasing pressure as necessary. Samples must be tested after being conditioned at the minimum specified operating temperature, at 70°F ±10°F (21°C ±5.5°C), and at the maximum specified operating temperature for a period of four hours.

4.35.1.2 Tests/Verification

Readings of a minimum of three sample agent storage container gauges and switches of each type at each of the points specified shall be compared to readings of a calibrated test gauge having a minimum accuracy of ±1 percent. A test gauge having a minimum accuracy of ± 0.25 percent shall be used to evaluate an inert gas system maintenance gauge at each of its major scale divisions. Readings shall be taken in both ascending and descending order. All sample gauge readings and pressure switch activation points shall match those of the test gauge within the tolerances specified in Section 4.35.1.1, above.

4.35.2 Impulse Resistance

4.35.2.1 Requirement

Pressure gauge and supervisory pressure switch accuracy shall remain within the limits of Table 4.35.1.1 after 1000 cycles of pressure impulse from zero to 125 percent of the system's nominal operating pressure, or from zero to 60 percent of the gauge capacity, whichever is higher.

4.35.2.2 Tests/Verification

One sample gauge and switch of each type shall be connected to an apparatus capable of varying pressure over the range described in Section 4.35.2.1, above, at a rate of six times per minute. After 1000 cycles have been completed, the sample shall be retested for accuracy as described in Section 4.35.1 above.

4.36 Automatic Extinguisher Unit Tests

In addition to the applicable requirements listed elsewhere in this standard, operating devices associated with automatic extinguisher units, unless a certified automatic fire sprinkler, shall be subjected to the following performance requirements, as applicable.

4.36.1 Assembly Load/Frame Strength

4.36.1.1 Requirement

The frame of a heat responsive automatic operating device shall be capable of withstanding twice the assembly load without sustaining permanent elongation or deformation in excess of 0.2 percent of the distance between the load bearing parts of the device.

4.36.1.2 Tests/Verification

A minimum of ten previously untested samples shall be individually tested to determine the assembly load. With the threaded portion of the device restrained from movement, the heat responsive element of the test sample shall be removed and the negative axial deflection of the frame, due to the release of the assembly, recorded. A force necessary to return the deflection of the frame to the original zero position shall be reapplied and the value of the force recorded.

Each of the devices shall then be subjected momentarily (1 to 5 seconds) to twice the sum of the recorded force plus the force applied to the device as a result of the system's specified working pressure. The amount of permanent set after the load application shall be determined.

4.36.2 Strength of Heat Responsive Element

4.36.2.1 Requirement

The lower tolerance limit for bulb strength shall be greater than two times the upper tolerance limit for assembly load of a heat responsive automatic operating device based on calculations with a degree of confidence of 0.99. Calculations shall be based on the Normal or Gaussian distribution except where another distribution can be shown to be more applicable due to manufacturing or design factors. The method for calculating the upper and lower tolerance limits is shown in Appendix C.

4.36.2.2 Tests/Verification

The results of Section 4.36.1 (Assembly Load/Frame Strength) shall form the basis for the upper tolerance limit for the assembly load calculations. The lower tolerance limit for bulb strength shall be determined using the results obtained from subjecting a minimum of 20 sample bulbs to an increasing load until the bulbs fail. Each test shall be conducted with the bulb mounted in hardened steel inserts with seating surfaces or dimensions which conform to the actual mating components of the automatic operating device. The inserts shall have a hardness within the range Rockwell C 38-50 and be configured per Figure F-6 in Appendix F. They shall be provided by the manufacturer each time the test is specified. The load shall be applied at a rate of compression not exceeding 0.05 in./min (1.27 mm/min). The results obtained from the two sets of data shall be used for the tolerance limit calculations as described in Appendix C, Tolerance Limit Calculations.

4.36.3 Hydrostatic Strength

4.36.3.1 Requirements

Heat responsive automatic operating devices shall be capable of withstanding, without rupture, an internal hydrostatic pressure equal to the maximum specified working pressure or 700 psi (48.3 bar), whichever is higher, for a period of 1 minute.

4.36.3.2 Tests/Verification

Each sample shall be subjected to a gradually increasing hydrostatic pressure to the required test pressure at a rate not exceeding 300 psi (20.0 bar) per minute. The test pressure shall be maintained for 1 minute.

4.36.4 Operating Temperature (Liquid Bath)

4.36.4.1 Requirement

The operating temperature of a group of a minimum of 10 heat responsive automatic operating devices shall fall within the specified range of the nominal operating temperature. The operating temperature for all samples shall be within ±5 percent of the marked nominal temperature rating.

4.36.4.2 Tests/Verification

Ten previously untested samples shall be immersed in a vessel containing water or, for nominal temperature ratings in excess of 200°F (93°C), vegetable oil.

The samples shall be placed on a grate suspended above the bottom of the vessel. The liquid level shall not exceed 1 in. (25.4 mm) above the element. The vessel shall be provided with a source for heating the liquid, a means to agitate the liquid, and a device to measure the temperature of the liquid bath. The device used to measure the temperature of the liquid bath shall be calibrated in accordance with the ASTM Standard E-1, or the equivalent.

The temperature of the bath shall be raised until the liquid is 20°F (11.1°C) below the nominal temperature rating of the heat responsive element. The temperature rise shall then be controlled at a rate not exceeding 1°F (0.56°C) per minute until operation, or until a bath temperature ten percent above the nominal temperature of the sample is reached. The temperature of the liquid bath at the time of operation of each sample shall be recorded.

4.36.5 Pneumatic Detection Tubing

4.36.5.1 Requirement

Pneumatic detection tubing shall be tested in accordance with the manufacturer's limitations and specifications.

4.36.5.2 Tests/Verification

Pneumatic detection tubing shall be subjected to Sections 4.2 (Fire Extinguishing Tests), 4.4.2 (Long Term Leakage), 4.4.3 (30 Day Maximum Temperature Leakage), 4.4.4 (30 Day Minimum Temperature Leakage), 4.28 (Aging Tests – Plastic Materials), and 4.31 (Resistance to Steam Cleaning and Pressure Washing) as part of the HDME protection system.

Additionally, pneumatic detection tubing assemblies shall be subjected to a rate of rise oven test to verify the activation temperature. Samples shall be placed in an oven and held at 80% of the minimum activation temperature range for a minimum of 10 minutes and then subjected to a temperature rate of rise of 10°F (5.5°C) per minute until operation. All configurations, e.g. tubing material, pressure, activation temperature, detection fluid, etc. shall be examined.

Ten samples shall be tested and the average of all activation temperatures for a given configuration shall not exceed the manufacturer's stated range.

4.37 Vibration and Shock Resistance Tests

4.37.1 Requirement

A fully charged extinguishing system unit, control unit, and all auxiliary system components, including the system mounting bracket, shall withstand exposure to shock and vibration, as applicable. The system shall remain operable, shall not display a potential to cause injury, shall not experience dislodgement of the system's siphon tube or displacement to other system components, shall resist leakage or cracking, and shall not experience other damage or deterioration which requires repair or replacement of the unit, mounting bracket, or system components. At minimum, the largest unit using a given bracket configuration shall be tested. All suppressant storage container mounting configurations and orientations shall be tested.

All detection and control devices and related equipment shall also be subjected to these tests.

All applicable shock and vibration tests must be run sequentially on the same sample(s). Following the completion of these tests, the system shall be successfully discharged using one of the manufacturer's compatible operating devices and shall discharge at least 85 percent of the total suppressant charge.

4.37.2 Tests/Verification

4.37.2.1 Vibration Test

The test sample suppressant storage container(s) shall be assembled in either the horizontal, lateral, or vertical orientation. Detection and control devices and related equipment shall be mounted in their specified orientations. Hoses shall be installed and supported in conformance to the manufacturer's recommendations. The samples shall then be vibrated for four hours at a peak-to-peak amplitude of 0.060 ± 0.001 in, and the frequency shall be continuously varied at a uniform rate from 10 to 60 to 10 Hz in four minute cycles.

Following completion of the vibration test in the first plane, the test shall be repeated in the remaining two planes until the sample has been subjected to vibration tests in all three rectilinear orientation axes (horizontal, lateral, and vertical).

4.37.2.2 Shock Resistance Test

The test samples shall be mounted in its intended orientation on a shock machine and subjected to 5000 shock impacts in the vertical axis. Each impact shall have an acceleration of 10g, or 322 ft/s^2 (98 m/s^2), and a duration of 20 – 25 milliseconds as measured at the base of the half sine shock envelope.

4.37.2.3 Vibration and Shock Resistance Post Tests

Subsequent to the completion of the vibration and shock resistance tests, the sample suppressant storage containers shall be successfully discharged using one of the manufacturer's compatible operating devices, and the weight of agent discharged measured to verify compliance. The sample shall then be disassembled and visually inspected for damage. Mounting brackets shall be subjected to Section 4.7 (Mounting Device Test). Detection and control components and related equipment shall be examined to verify continued proper functionality. Hose assemblies shall be subjected to the Hydrostatic Pressure Test of Section 4.5 to verify continued integrity.

4.38 Gaseous Extinguishing Systems Used for HDME Protection

If a gaseous extinguishing system is used to protect a specific hazard in an HDME application, it must first be certified per the relevant certification standard, FM 5600 for clean agent extinguishing systems or FM 5420 for carbon dioxide extinguishing systems. Additional tests may be required, per this (HDME) certification standard, based upon the specifics of the application. For example, system components may require vibration and shock or gravel bombardment tests, based upon the type of vehicle in which they will be installed and the specified location within the vehicle. The required additional testing will be at the discretion of the certification agency.

4.39 Foam Extinguishing Systems Used for HDME Protection

If a foam extinguishing system including compressed air foam (CAF), low expansion, and high expansion is submitted for an HDME application, additional testing beyond that specified in this certification standard may be required. Such testing would typically be selected from certification standard FM 5130, at the discretion of the certification agency, depending on design features and the specified application.

4.40 Dry Chemical Extinguishing Systems Used for HDME Protection

If a dry chemical extinguishing system is submitted for an HDME application, additional testing beyond that specified in this certification standard may be required. Such testing would typically be selected from certification standard FM 5320, at the discretion of the certification agency, depending on design features and the specified application.

4.41 Water Mist Extinguishing Systems Used for HDME Protection

If a water mist extinguishing system is submitted for an HDME application, additional testing beyond that specified in this certification standard may be required. Such testing would typically be selected from certification standard FM 5560, at the discretion of the certification agency, depending on design features and the specified application.

4.42 Additional Tests

Additional tests may be required, at the discretion of the certification agency, depending on design features and results of any foregoing tests. A retest following a test failure shall be acceptable only at the discretion of the certification agency, and with adequate technical justification of the conditions or reasons for failure.

5 OPERATIONS REQUIREMENTS

5.1 Demonstrated Quality Control Program

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

- Design quality is determined during the examination and tests, and is documented in the certification report
- Continued conformance to this standard is verified by the certifier's surveillance program
- Quality of performance is determined by field performance and by periodic re-examination and testing

5.1.2 The manufacturer shall demonstrate a quality assurance program that specifies controls for, at minimum, the following areas:

- Existence of corporate quality assurance guidelines
- Incoming quality assurance, including testing
- In-process quality assurance, including testing (if applicable)
- Final inspection and tests
- Equipment calibration
- Drawing and change control
- Product labeling
- Packaging and shipping
- Handling and disposition of nonconforming materials

5.1.3 Documentation/Manual

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

5.1.4 Records

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

5.1.5 Drawing and Change Control

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

Records of all revisions to all certified products shall be maintained.

5.2 Surveillance Audits

5.2.1 An audit of the manufacturing facilities may be part of the certification agency's surveillance requirements to verify implementation of the quality assurance program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to ensure a uniform product consistent with that tested and certified.

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

5.3 Manufacturer's Responsibilities

5.3.1 The manufacturer shall provide complete instructions for the usage and recharge of systems. The instructions shall provide specific quality assurance procedures on the use of calibrated equipment, such as scales, pressure gauges, and other critical equipment, in the recharging of a system.

5.4 Manufacturing and Production

5.4.1 The manufacturer shall design systems in accordance with relevant standards such as NFPA 17, NFPA 120, NFPA 122 and/or any other standard specifically referenced in the certification report.

5.4.2 The manufacturer shall fabricate and test pressure cylinders in accordance with the standard(s) referenced in the certification report.

5.4.3 The manufacturer shall leak test all filled agent storage containers prior to release for shipment. The leak test method shall employ appropriately calibrated and sensitive leak detection devices.

5.5 Design, Installation, Operating, and Maintenance Manual

5.5.1 A design, installation, operation, and maintenance manual shall be provided with each protection system or be made available upon request. A copy of the manual shall be provided to the certification agency as a reference prior to the examination and testing of the system. Subsequent to the successful completion of the examination, an electronic copy of the manual shall be provided to the certification agency, with updated electronic copies of the manuals provided when revisions are made.

5.5.2 The required manual specified in Section 5.5.1 may detail the complete HDME protection system or be divided into multiple parts. Examples are dedicated manuals for the suppressant storage and delivery and for the detection and control portions of an HDME protection system, or an Operator's manual separate from the design, installation, operation, and maintenance manual.

5.5.3 All system manual(s) shall include the following information, at a minimum, if applicable:

- Manufacturer's name and address
- Date and part number designation on each page of the manual
- Description of equipment and accessories, including part numbers and model numbers
- Inspection requirements and frequency of inspection
- Maintenance requirements and frequency of maintenance
- Reference to any relevant national or local standards e.g. NFPA 17, NFPA 120, NFPA 122, NFPA 72, etc.
- A clearly labeled section listing any part numbers, applications, and designs included in the manual, but not

within the scope of the certification
- Revision history for subsequent manual updates with brief description of changes

5.5.4 Suppressant storage and delivery system manual(s) shall include the following information, at a minimum, if applicable:

- Safety Data Sheets
- Distribution hose, piping, and fitting limitations
- Methods for discharge and actuation hose and pipe securement
- Recommended routing for discharge and actuation hose
- Discharge nozzle limitations e.g. maximum area of coverage, maximum protected volume, minimum and maximum installation range, etc.
- System configuration limitations and installation instructions
- Compatible detection devices and control units for use with the HDME protection system
- Range of filling weights for each agent storage container size
- System working pressure
- Recharge instructions
- Acceptance test form to document satisfactory operational status of the system upon completion of installation stated in Section 5.5.7
- System scaling examples
- Example hazard analysis and system design
- Description of primary and connected reserve system installation
- Description of post-actuation servicing of system equipment, e.g. nozzles, actuators, distribution hose piping and fittings, etc.
- Description of the materials of construction, design standard, and size for all flexible hoses
- Description of manufacturing method(s), assembly, and final quality check for flexible hoses constructed at time of system installation
- Description of protective coverings for pneumatic tubing, if applicable

5.5.5 Detection and control system manual(s) shall include the following information, at a minimum, if applicable:

- Product specifications, including, but not limited to, operating temperature and relative humidity ranges, identification of intended power supply sources with ratings and connection details, and enclosure environmental ratings
- Description of all modes of product operation including function of controls and indicators, audible and visual
- Description of any selectable product configurations that are pre-installed by the manufacturer
- Description of audible and visual signals associated with the products' operating conditions, i.e. normal, alarm, trouble, supervisory, including details of any signals that are intermittent
- Identification of maximum and minimum system configurations, all input and output circuits, and circuit loading and supervision specifications
- Inter-equipment wiring diagrams and identification of wiring terminals
- Installation requirements related to providing ground fault detection capability
- Identification, including specifications and location, of necessary current limiting devices
- Start up and operating procedures
- Compatible suppressant storage and delivery systems for use with the HDME protection system
- Description of protective coverings for cables and wires

Additional requirements are stated in Sections 3.2.3.9, 3.2.4.2, 3.2.4.4, and 3.2.6.2.

5.5.6 The manual shall state that upon request the Authority Having Jurisdiction shall be provided with system plans and other installation documentation, e.g. NFPA 120, NFPA 122, for review and acceptance prior to installation. The plans shall contain details of the hazard, including the location and the materials involved, information describing the system including quantity of agent, nozzles, and piping arrangement, the types and location of detection devices, the operating devices, electrical circuity and auxiliary equipment.

5.5.7 The system startup and periodic operational tests shall be performed in accordance with the manual, and shall include testing of automatic detection, manual release and shutdown devices, and verification of compliance of the installation, e.g. nozzles and pipe sizes, with the manual and accepted plans. Verification shall include discharge of a test gas to test tightness of the piping.

5.5.8 System manual(s) shall describe the applicable inspection and maintenance requirements. These include, but are not limited to:

- No signs of physical damage, e.g. leaks, corrosion, exposed wiring, or a condition that would impair the system
- Tamper seals are installed and intact
- No unauthorized system component substitution
- Agent storage container pressure gauges are visible and display within the normal range
- Agent storage container brackets are secure and free of damage, welds, or repairs
- Manual actuators are undamaged, secure, and accessible
- Discharge nozzle caps are secure, intact, and free of external materials/build up
- Discharge nozzles are secure and positioned in accordance with the accepted system design
- Discharge nozzles have not been painted, unless done by the manufacturer
- Procedure for leak detection of gas cartridge assembly without pressure gauge
- Control units do not display trouble or alarm condition
- Control units are secure, undamaged, and accessible
- Detection and control wiring and connections are secure and undamaged
- Indicators and alarms are free of alteration and remain functional
- Battery capacity is within allowable range
- Detectors are clean and remain functional
- Time delay period for system actuation conforms to accepted system design
- HDME protection system remains within the accepted system design and that no modifications have been made to the system or the equipment being protected that would impair performance
- Water mist supply pressure, flow, quantity, and duration is in accordance with the accepted system design
- No loss of fluid in glass bulb style heat responsive elements
- System actuators are installed and connected to the discharge valve
- No penetrations in enclosures that may affect the ability to maintain the accepted total flooding concentration
- Procedure for system operational test as stated in Section 5.5.7
- Vehicle engine, fuel, braking, and hydraulic system shut down device remain functional
- Distribution and actuation hoses, piping, and fittings are free of obstruction

6 BIBLIOGRAPHY

ASTM E1354-04a, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*
FM 3230, *Smoke Actuated Detectors for Automatic Alarm Signaling*
FM 3810, *Electrical and Electronic test, Measuring, and Process Control Equipment*.
FM Approvals, *Quality Assurance Guidelines for Manufacturers of FM Approved and Specification Tested Products.*
ISO 7202, *Fire Extinguishing Media – Powder*
ISO/IEC 17025: 2017, *General Requirements for the Competence of Testing and Calibration Laboratories*
ISO 9000, *Quality Management Principles*
NFPA 17, *Standard on Dry Chemical Extinguishing Systems*
NFPA 120, *Standard for Fire Prevention and Control in Coal Mines*
NFPA 122, *Standard for Fire Prevention and Control in Metal/Nonmetal Mining and Metal Mineral Processing Facilities*
SAE Standard J1113-11, *Immunity to Conducted Transients on Power Leads*

APPENDIX A:

Appendix A is intentionally blank

APPENDIX B: Tolerances

Unless otherwise stated, the following tolerances shall apply:

Angle:	±2°
Frequency (Hz):	±5 percent of value
Length:	±2 percent of value
Volume:	±5 percent of value
Rotation:	±1 RPM
Pressure:	±3 percent of value
Temperature:	±3°F
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 ± 9°F (20 ± 5°C).

APPENDIX C: Tolerance Limit Calculations

Using the data obtained as described in Sections 4.36.1 (Assembly Load/Frame Strength) and 4.36.2 (Strength of Heat Responsive Element), the mean and standard deviation for the assembly load and the bulb strength shall be calculated using the following equation:

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

where:

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

Based on the number of devices or bulbs tested (n), a value, γ, shall be selected from Table C1 where the degree of confidence is 0.99 and the proportion of samples is 0.99.

Table C1 *γ Factors for One-Sided Tolerance Limits for Normal Distributions (99 Percent of Samples)*

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

Tolerance limits shall then be calculated as follows:

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

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

where:

LTL = lower tolerance limits for device strength
UTL = upper tolerance limit for assembly load
$\bar{x}_B$ = mean device strength
γ_B = device strength factor (γ) from Table C1
$\sigma_{(n-1)B}$ = sample unbiased standard deviation for the bulb
$\bar{x}_S$ = mean assembly load
$\sigma_{(n-1)S}$ = sample unbiased standard deviation for the assembly load
γ_S = assembly load factor (γ) from Table C1

Compliance with the requirement shall be confirmed if LTL > UTL.

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

APPENDIX D:

Appendix D is intentionally blank

APPENDIX E: Viscosity Test Procedure

Viscosity determinations shall be made at 65°F, +/-5°F (18°C, +/-2.7°F
The viscosity of the suppressant shall be measured at temperatures of 35, 70, and 120°F (2, 21, and 49°C) according to the following:

A Brookfield viscometer, Model LVT or LVF, or the equivalent, set at 60r/min with the appropriate spindle (Number 2 for viscosities from 1 to 500 centipoise and Number 4 for viscosities greater than 500 centipoise), shall be used to measure the viscosity.

A straight-sided container that contains approximately 27 oz (800mL) of the test sample shall be positioned under the viscometer, centered on its spindle

The spindle shall be immersed in the liquid to the indicated depth.

The viscometer shall then be turned on, and the spindle shall be allowed to rotate for 1 minute prior to taking the measurement.

Triplicate measurements shall be made, stirring gently between each measurement, and the viscosity of the sample shall be averaged and reported in centipoise.

APPENDIX F: Details of Test Apparatus

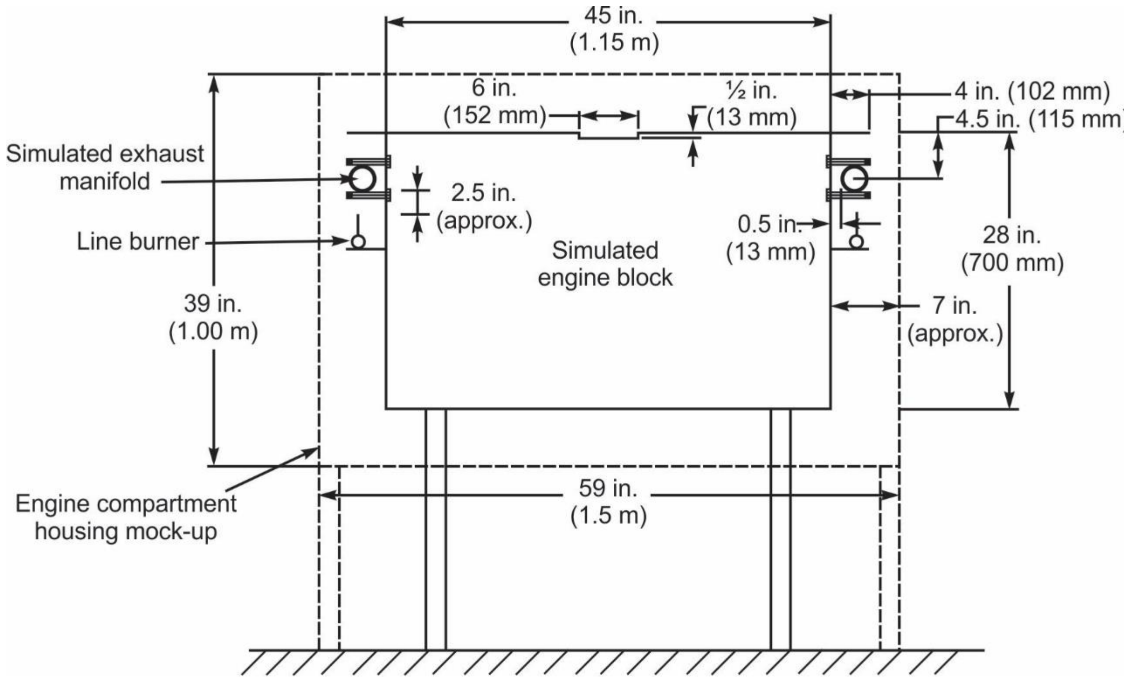


Figure F-1
End View Detail of Engine Compartment Fire Test Apparatus

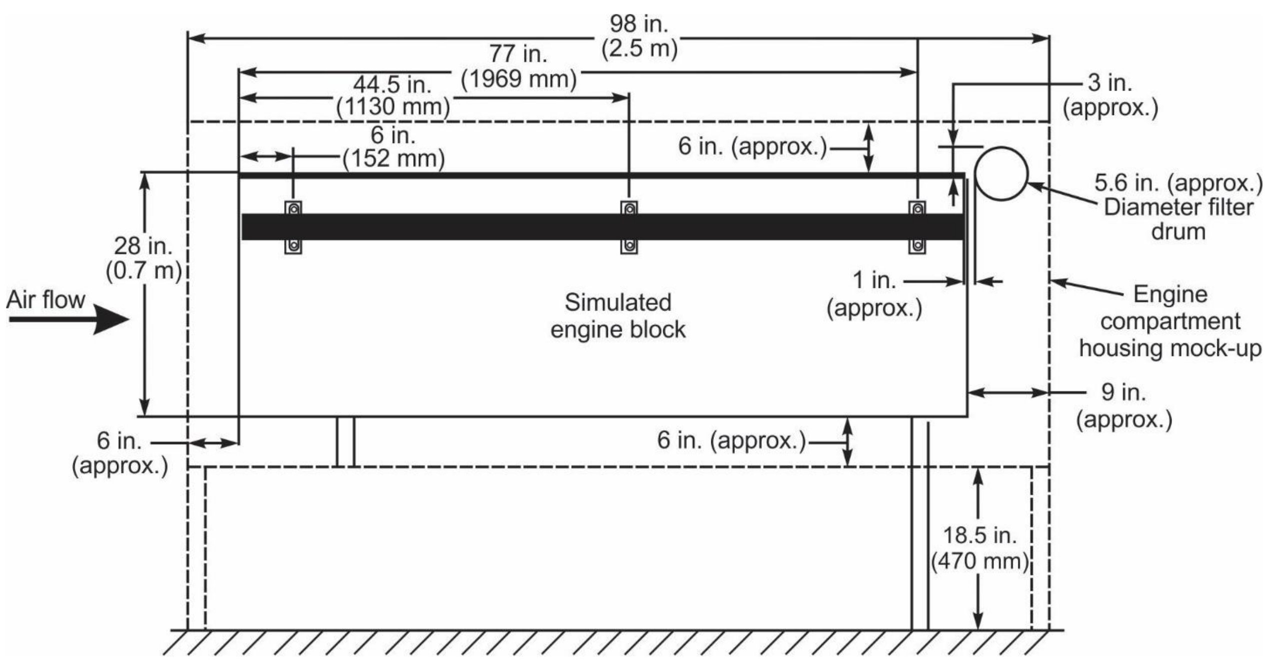


Figure F-2
Side View Detail of Engine Compartment Fire Test Apparatus

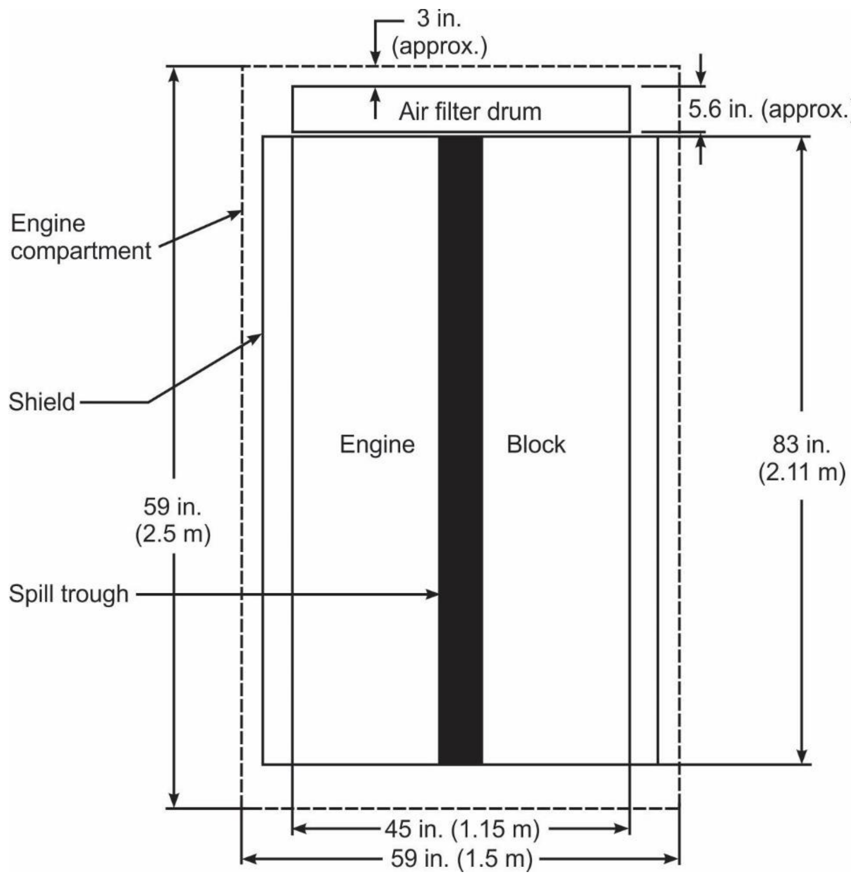


Figure F-3
Top View Detail of Engine Compartment Fire Test Apparatus

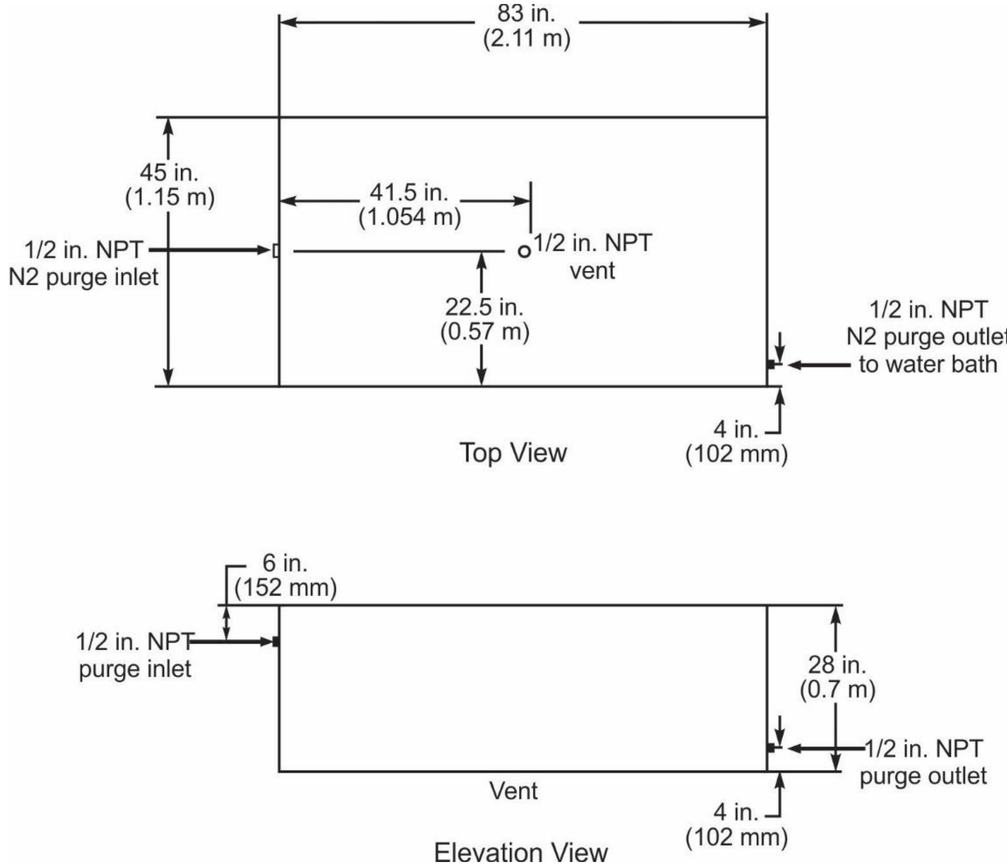


Figure F-4
Vent Openings and Purge Connections on Engine Block Mock-Up

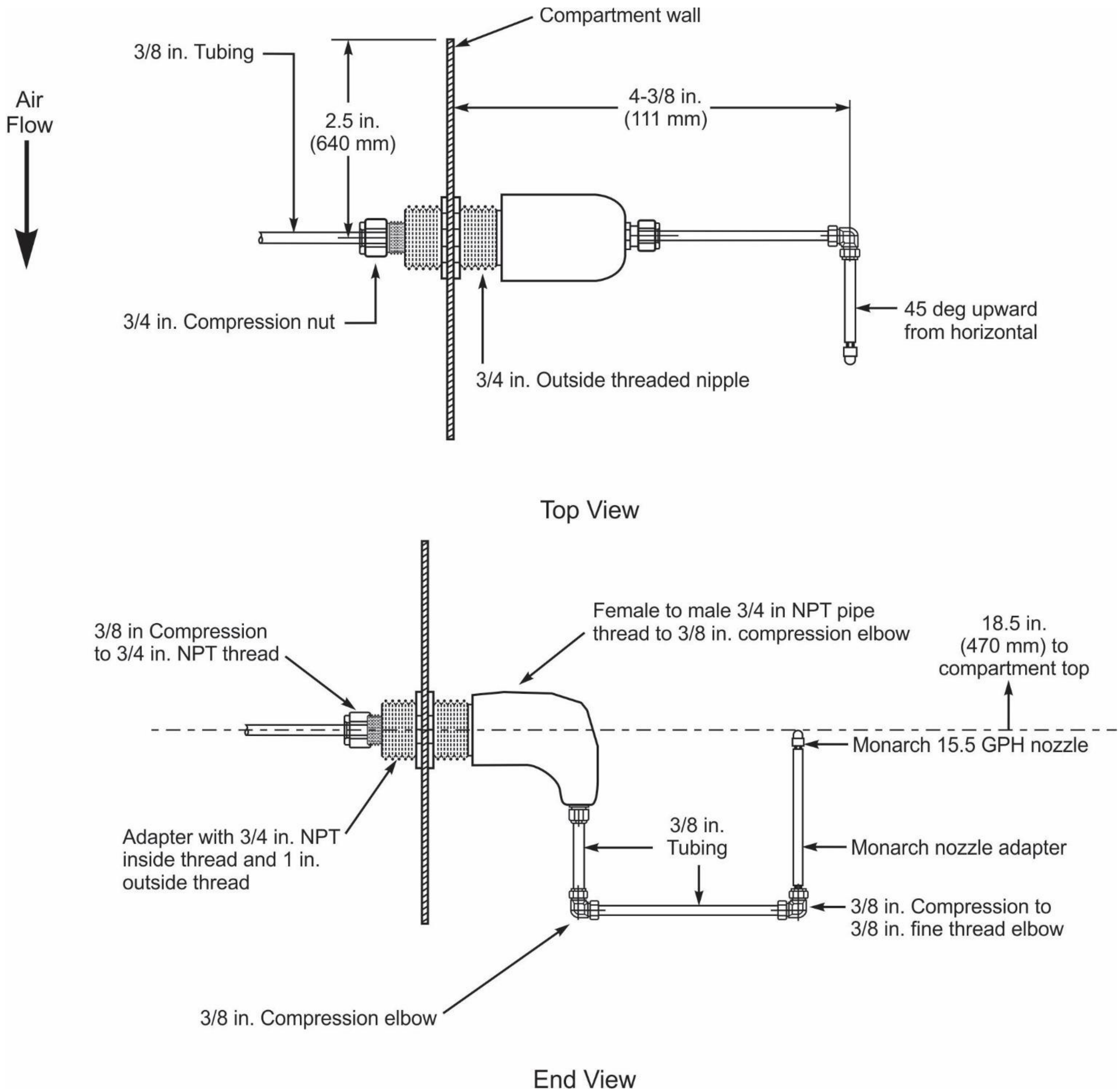
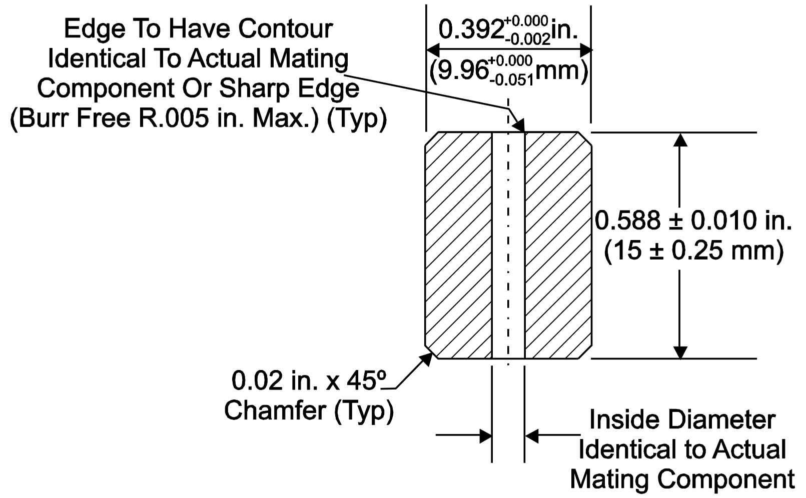
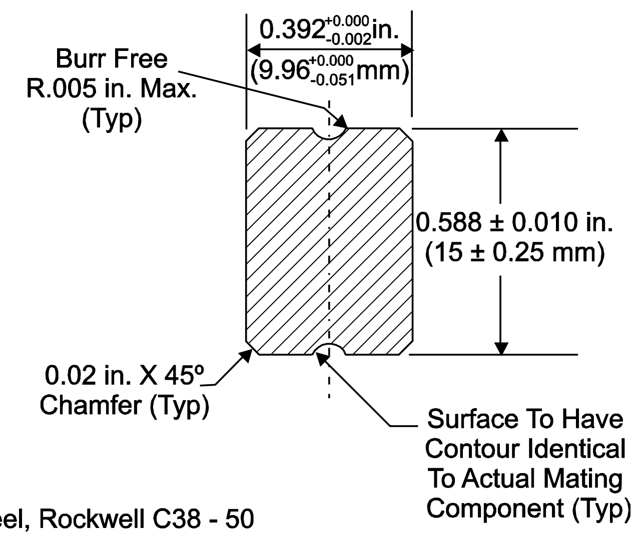


Figure F-5
Diesel Fuel Spray Arrangement inside Engine Compartment Mock-Up

For Designs with Line Contact:



Or: For Designs with Surface Contact:



<u>REQUIRED:</u>
* Material - Hardened Steel, Rockwell C38 - 50
* Markings - Manufacturer, Bulb Size, Seat Diameter

Figure F-6
Bulb Crush Inserts for Strength of Element Test

APPENDIX G: Engine Compartment Total Flooding Scaling Examples

Based Upon Successful Fire Extinguishment Performance

<u>Static Design</u>
The maximum amount of agent used among all engine compartment fire extinguishment tests shall be divided by the free volume of the test compartment to obtain the minimum amount of agent per unit volume to be used to design of systems. This shall be termed the static volume requirement (SVR).

The engine compartment mockup has a free volume of 70.6ft^3 (2m^3). Therefore, the calculation is:

SVR = agent quantity/70.6 ft^3 (2m^3)

<u>Dynamic Design</u>
The maximum agent discharge rate used among all engine compartment fire extinguishment tests shall be divided by the air flow through the test compartment to obtain the minimum agent discharge rate per air volume flow rate to be used in the design of systems. This shall be termed the dynamic volume requirement (DVR). This shall be expressed as discharge rate/1000ft^3/min to avoid extremely small factors.

The engine compartment mockup is operated at an airflow rate of 12,900ft^3/min (365m^3/min). Therefore, the calculation is:

DVR = agent flow rate/12.9 thousand ft^3/min (365m^3/min)

<u>Minimum Design Criterion</u>
SVR and DVR shall both be satisfied by all system designs.

<u>Duration of Discharge</u>
The discharge time shall be 1.5 times the maximum extinguishing time used among all engine compartment and single nozzle fire extinguishment tests according to Sections 4.2.1 (Engine Compartment Fire Tests - Total Flooding) and 4.2.2 (Total Flooding Engine Compartment Test Single Nozzle Fire Tests).

Sample Calculations

A system discharges 5 lb of agent in 45 seconds (0.75 min) with an extinguishment time of 15 seconds from start of discharge. This is the longest extinguishment time among all tests.

SVR = 5 lb / 70.6 ft^3 = 0.071 lb/ft^3

DVR = 5 lb / 0.75 min / 12.9 thousand ft^3/min = 0.517 lb/min per 1000 ft^3/min

The minimum design duration is 22.5 seconds (1.5 x 15 second maximum extinguishment time)

System Design Sample Calculation

Example 1:

Enclosure free volume is 200 ft^3 and airflow is 2000 ft^3/min.

Static design quantity required is 200 ft^3 x 0.071 lb/ft^3 = 14.2 lb

Dynamic design rate is 2.0 thousand ft^3/min x 0.517 lb/min per thousand ft^3/min = 1.03 lb/min

For a 22.5 second discharge, the agent quantity is 0.375 min x 1.03 lb/min = 0.386 lb

Therefore, the agent weight required would be determined by the static requirement to be 14.2 lb.

Example 2:

Enclosure free volume is 50 ft^3 and airflow is 25,000 ft^3/min.

Static design quantity required is 50 ft3 x 0.071 lb/ft3 = 3.55 lb

Dynamic design rate is 25 thousand ft3/min x 0.517 lb/min per thousand ft3/min = 12.92 lb/min

For a 22.5 second discharge, the agent quantity is 0.375 min x 12.92 lb/min = 4.84 lb

Therefore, the agent weight required would be determined by the dynamic requirement to be 4.84 lb