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Examination Standard for Clean Agent Extinguishing Systems

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Foreword

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

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

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1. INTRODUCTION

1.1 PURPOSE

1.1.1 This standard states testing and certification requirements for fixed fire extinguishing systems that use vaporizing liquid or inert gas clean agents as the extinguishant.

1.1.2 Testing and certification criteria may include performance requirements, marking requirements, examination of manufacturing and filling facilities, audit of quality assurance procedures, and a surveillance program.

1.2 SCOPE

1.2.1 This standard contains requirements for vaporizing liquid and inert gas clean agent extinguishing systems for total flooding protection. Extinguishing systems shall be designed for automatic control to protect single or multiple hazard areas. The following product categories and class numbers are included in the scope of this standard.

***Table 1.2.1* - Product Categories and Class Numbers**

Class	Product Category
5611	Inert Gas Extinguishing Systems
5612	Liquefied Gas Extinguishing Systems
5613	Clean Agents

1.2.2 A basic vaporizing liquid or inert gas clean agent extinguishing system comprises one or more agent storage containers, discharge control valves arranged for automatic or manual/automatic control, lockout valves (when required), piping, and discharge nozzles. Compatible certified detectors and detection and release controls are required for automatic electrical operation of these systems but are not included in the scope of this standard. If a system uses an integral detection and actuation system, it may be evaluated as a part of that system, using criteria derived from those used for standalone detection and control systems.

1.2.3 With the exception of Class 5613 clean agents, this standard requires the examination of complete systems. Complete systems shall be submitted along with design, installation, operation, and maintenance instructions for certification. 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 shall also be submitted by the system manufacturer for evaluation as a part of the system, even though such devices may already be certified and listed by the certification agency. Incomplete systems shall not be certified.

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 clean agent fire extinguishing 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,
- the durability and reliability of the product.

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

1.5 BASIS FOR CONTINUED CERTIFICATION

The basis for continued certification may include the following based upon the certification scheme and requirements of the certification agency:

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

1.6 EFFECTIVE DATE

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

The effective date of this standard is eighteen (18) months after the publication date of the standard for full 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 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 12.53/1-2011; ISO 3743-1:2010, *Acoustics – Determination of Sound Power Levels of Noise Sources Using Sound Pressure – Engineering Methods for Small, Movable Sources in Reverberant Fields – Part 1: Comparison Method for a Hard-Walled Test Room*

ANSI 12.53/2-1999; ISO 3743-2:1994, *Acoustics – Determination of Sound Power Levels of Noise Sources Using Sound Pressure – Engineering Methods for Small, Movable Sources in Reverberant Fields – Part 2: Methods for Special Reverberation Test Rooms*

ANSI 12.54-2011; ISO 3744:2010, *Acoustics – Determination of Sound Power Levels and Sound Energy Levels of Noise Sources Using Sound Pressure – Engineering Methods for an Essentially Free Field Over a Reflecting Plane*

ANSI/ASA S1.4, *Specification for Sound Level Meters*

ANSI/ASME B40.1, *Gauges – Pressure Indicating Dial Type – Elastic Element*

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

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 E1354, *Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*

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

ASTM G36, *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*

BPVC-CC-N, *Boiler and Pressure Vessel Code*

CGA G-10.1, *Commodity Specification for Nitrogen*

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

ISO 12136, *Reaction to fire tests – Measurement of material properties using a fire propagation apparatus*

ISTA 3E, *Similar Packaged-Products in Unitized Loads for Truckload Shipment*

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

NIST Technical Note 1278, *Preliminary Screening Procedures and Criteria for Replacements for Halons 1211 and 1301*

SAE J517, *Hydraulic Hose*

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:

Actuation Device	A means of initiating clean agent fire extinguishing system discharge by opening the discharge valve.
Agent Storage Container	The assembly holding the clean agent supply for a fire extinguishing system. This includes the agent vessel and various accessories necessary for management of the supply, such as valves, siphon tubes, pressure gauges, and pressure relief devices.
Agent Storage Cylinder	See "Agent Storage Container"
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 a single clean agent 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	An operating device, or arrangement of devices, that does not require human intervention. The automatic control includes a control panel that monitors fire detection devices and releases the agent when pre-established conditions have been met.
Automatic Extinguisher Unit	A clean agent extinguishing storage container that discharges following the operation of a heat responsive element. Automatic extinguisher units may also include optional mechanical manual controls. A single automatic extinguisher unit shall be used to protect each hazard area unless it is possible to configure multiple units such that operation of any single unit will operate all others simultaneously.
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 or combustible liquids), petroleum greases, tars, oils, oil-based paints, solvents, lacquers, alcohols, and flammable gases.
Class C Fires	Fires that involve energized electrical equipment and during which the electric power is maintained, thereby continuously adding electrical energy.
Clean Agent	Volatile or gaseous fire extinguishant that is electrically nonconducting and that does not leave a residue upon evaporation.
Corrosion Resistant	A material that can withstand damage caused by oxidization or other chemical reactions.
Discharge Head	A removable portion of a discharge valve assembly that is required to be installed for system operation.
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 extinguishing agent within a specific volume.
Discharge Time	The time interval between the first appearance of extinguishing agent at the discharge nozzle or unit and the time at which 95 percent of the agent has been discharged from the nozzle or unit.

Element Operating Temperature	The nominal temperature at which a heat responsive element operates when subjected to the influence of heat.
Engineered System	A clean agent fire extinguishing system designed using hydraulic calculations to predict mass flows and pressures at individual nozzles. These calculations analyze the entire piping system, considering variables such as friction loss in piping, nozzles, and other components.
Expellant Gas	The medium used to facilitate the discharge of the extinguishing agent from the agent storage container.
Flow Rate	The quantity of fluid passing through a pipe, nozzle, or other device in a unit time.
Fully Mechanical Manual Control	A manual control that can function in the absence of electric power or other energy sources other than stored system pressure.
Halocarbon Clean Agent	A gaseous fire extinguishant, electrically nonconducting and volatile, that does not leave a residue after evaporation. The material is delivered by a fire extinguishing system and acts to suppress or extinguish a fire and includes as primary components one or more organic compounds containing the elements fluorine, chlorine, bromine, and iodine. Such an agent is more properly and more generally called a Vaporizing Liquid Clean Agent.
Heat Responsive Element	An operating device that does not require human intervention and includes an operating element that, when subjected to the influence of heat, ruptures, bursts, or otherwise functions, to cause the release of clean agent into the protected space.
Hydraulic Hose	A hose consisting of three parts: An inner tubing that carries the fluid/agent, typically made of rubber, but may also be constructed from thermoplastics or similar materials. A reinforcement layer consisting of one more sheaths, typically made of braided wire, spiral-wound wire, textile yarn or similar materials. An outer encasing layer used to help protect the hose from the environment.
Inert Gas Clean Agent	A gaseous, electrically nonconducting fire extinguishant that does not leave a residue after discharge. The agent is delivered by a fire extinguishing system and acts to suppress or extinguish a fire and includes as primary components one or more elemental gases such as helium, neon, argon, and nitrogen. Blends of inert gases may also contain carbon dioxide as a secondary component.
Lockout Valve	A supervised, lockable, manually operated valve located in the discharge line between the supply and the nozzles, that can be used to isolate the agent supply from all or part of the system during maintenance and service.
Manual Control	An operating device, or arrangement of devices, that requires action by a human operator. The manual control may be initiated either mechanically or electrically.
Master Agent Cylinder	One or more agent storage containers in a clean agent extinguishing system using multiple agent storage containers that are directly actuated by an operating device, then supply pressure to actuate one or more secondary agent cylinders.
Maximum Discharge Time	The longest allowable discharge time at 70°F (21°C) specified by the manufacturer. This time cannot be longer than 10 seconds for vaporizing liquid agents; for inert gas agents this time cannot exceed 120 seconds for the protection of Class A or Class C fire hazards, or 60 seconds for the protection of Class B fire hazards.
Maximum Working Pressure	The pressure in an agent storage container or other pressurized container, as applicable, associated with the maximum installation temperature.
Minimum Bending Radius	The smallest radius specified by the manufacturer to which a flexible hose is safely allowed to bend without damage.

Minimum Design Concentration	The concentration a system is required to deliver to a given installation, the value of which is the minimum extinguishing concentration multiplied by any applicable safety factors.
Minimum Extinguishing Concentration	The lowest concentration of a clean agent at which extinguishment is consistently achieved for a given fuel or hazard class.
Minimum Working Pressure	The pressure in an agent storage container or other pressurized container, as applicable, associated with the minimum installation temperature.
Operable Pressure Range	The minimum and maximum pressures of the agent storage container or other pressurized container, as applicable, over which the system is specified to be functional. These operating pressures result from the minimum and maximum storage temperatures and the physical characteristics of the agent and/or expellant gas, as applicable.
Operating Device	See “Actuation Device”
Pneumatic Control Assembly	A pressurized cylinder, or other assembly, separate from the agent storage containers, in a clean agent extinguishing system that is directly actuated by an operating device and subsequently supplies pressure to actuate either a master agent cylinder or one or more secondary agent cylinders, or pneumatically controlled selector valves.
Pre-Engineered System	A clean agent fire extinguishing system designed using a predetermined range of piping and nozzle characteristics and configurations to determine individual nozzle flow rates.
Proof Test Pressure	The factory test pressure used to verify the structural integrity of the agent storage containers or other pressurized cylinders used in the system.
Resonance	The maximum magnification of applied vibration during a vibration test.
Secondary Agent Cylinder	One or more cylinders in a clean agent fire extinguishing system using multiple agent storage containers that are operated by pressure supplied from a pneumatic control assembly or master agent cylinder, rather than directly by an operating device.
Selector Valve	A supervised valve normally operated automatically, but that also includes an emergency fully mechanical manual control, that can be used to restrict agent discharge to one of multiple zones protected by the same agent supply. Selector valves are controlled by the detection and control system, and are used to direct the discharge of the clean agent only into the space(s) in which the agent is required.
Siphon Tube	A tube inside a vaporizing liquid clean agent storage container that is attached to the inlet of the discharge valve and extends to near the bottom of the container in order to allow the expellant gas to drive all or most of the liquid agent out of the discharge valve without vapor breakthrough.
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.
Superpressurized	Pressurization of a vaporizing liquid clean agent with expellant gas above the level of the vapor pressure of the agent alone.
Supervised	A type of device, such as a valve, that is equipped with switches, or is otherwise electrically monitored, to allow its state to be displayed or to initiate an alarm via a control panel.
Total Flooding System	An extinguishing system designed to protect an enclosed hazard volume by discharging clean agent throughout the enclosed volume to reach and maintain an extinguishing concentration for the specific fuels for which it has been designed for a sufficient period of time to extinguish fires in those fuels.

Vaporizing Liquid Clean Agent	An electrically nonconducting, compressed liquid fire extinguishant that is vaporized at discharge and does not leave a residue after evaporation. The material is delivered by a fire extinguishing system and acts to suppress or extinguish a fire and includes as primary components one or more organic compounds containing the elements fluorine, chlorine, bromine, and iodine.
Normal Working Pressure	The pressure in a fully charged agent storage container or other pressurized container, as applicable, at 70° F (21° C) or other temperature appropriate for the local jurisdiction.
Zone	A segment of a fire extinguishing system distribution piping supplied through a selector valve that delivers clean agent to one of the spaces protected by the system.

2. GENERAL INFORMATION

2.1 APPLICATION REQUIREMENTS

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 being submitted for certification consideration
- General assembly drawings, component drawings, materials list, anticipated marking format, nameplate format, brochures, sales literature, specification sheets, and design, installation, operation and maintenance instructions
- The number and location of manufacturing and filling facilities

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

2.2 REQUIREMENTS FOR SAMPLES FOR EXAMINATION

2.2.1 Following authorization of a certification examination, the manufacturer shall submit samples for examination and testing based on the following:

Sample requirements are to be determined by the certification agency

2.2.2 Requirements for samples may vary depending on design features, results of prior or similar testing, and results of any foregoing tests.

2.2.3 The manufacturer shall submit samples representative of production.

2.2.4 It is the manufacturer's responsibility to provide any necessary test fixtures, such as those that may be required to evaluate the system.

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 final certification.

3.2 PHYSICAL OR STRUCTURAL CONSTRUCTION FEATURES

3.2.1 Operating Range

All system 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 10ºF or 5ºC increments, as applicable.

Table 3.2.1 *Required Operation Temperature Range*

Allowable Minimum Operating Temperature ***ºF (ºC)***	***Allowable Maximum Operating Temperature**** ***ºF (ºC)***
32°F (0°C), or lower	120°F (49°C), or higher

* Automatic extinguisher units only may specify a 100ºF (37.8ºC) maximum storage temperature.

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 clean extinguishing agent. Compatibility shall be determined by successful performance when subjected to the requirements listed in Sections 4.9.2 (Long Term Leakage Test), 4.9.3 (30-Day Maximum Temperature Leakage Test), and 4.9.4 (30-Day Minimum Temperature Leakage Test).

3.2.3 Controls

3.2.3.1 For normal operation, a system shall be either automatically controlled or operable from a manual control, easily accessible to the hazard, or both. If the normal manual means of actuation incorporates electric power, the source of that power shall be completely independent of any electric power source used for automatic operation. A power source used for both normal manual and automatic operation shall be provided with an independent backup, such as a battery. All systems shall be provided with an alternate means of fully mechanical manual emergency control, regardless of their normal means of operation. Fully mechanical manual emergency controls shall not require an electric power source but may make use of the clean agent extinguishing system's working pressure to operate the release. These emergency controls shall be located at or near the device being controlled.

3.2.3.2 Control panels shall comply with NFPA 72 and Certification Standards FM 3010 and FM 3810. Control panels are not required to be submitted as a part of a system. However, system design shall be such that the system is operable by a minimum of one certified detection and release panel that is compatible for use with the clean agent extinguishing system.

3.2.3.3 Automatic extinguisher units that are not operable by a certified detection and release panel and/or do not have an alternate means of fully mechanical manual emergency control may only be certified for the protection of Class B (ignitable liquids) hazards.

3.2.4 Pressure Vessels

3.2.4.1 Storage containers shall conform to the appropriate regulations for the installation location. In the U.S.A. DOT Title 49 CFR, Parts 171 through 180 are applicable for clean agent storage containers that are shipped under pressure.

3.2.4.2 In a system utilizing multiple storage containers, all containers supplying the same manifold shall be of the same size and design, allowing for interchangeability of position.

3.2.4.3 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 standard, with appropriate supporting references as necessary
- Certificate of chemical analysis of materials
- Certificate of physical properties of materials

3.2.4.4 The pressurization level(s) and the minimum and maximum filling densities shall be specified by the manufacturer for vaporizing liquid clean agents. The pressurization level(s) and filling volume(s) shall be specified by the manufacturer for inert gas agents.

3.2.5 Valves

3.2.5.1 Discharge valves shall incorporate varying sizes or connection designs for all ports to minimize the likelihood of improper connection during installation.

3.2.5.2 Selector, check, and other 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.

3.2.5.3 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.

3.2.5.4 If applicable, equivalent tube or pipe length of valves shall be measured to allow accurate calculations for system design; the reference pipe size shall be specified to complete an equivalent pipe length measurement.

3.2.6 Gauges and Indicators

3.2.6.1 Pressure gauges(s) shall be included with all extinguishing systems to indicate the pressure in each agent storage container or other pressurized container as applicable, and for mechanical gauges, 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
- A pressure 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 clean agent with which it is specified to be used

Pressure gauges are not required for non-superpressurized agent storage containers or containers with the contents stored at vapor pressure.

3.2.6.2 For systems arrangements that utilize a pneumatic control assembly or master agent cylinder, those assemblies shall include a supervisory pressure switch, or equivalent device, that detects leakage beyond the acceptable level, as applicable, and is monitored via the supervisory circuit of the control panel.

3.2.6.3 When the storage container cannot be easily weighed due to size or installation location, liquid level indicators or an alternative method of determining agent storage container fill level shall be provided for vaporizing liquid agents. When provided, liquid level indicators shall meet the requirements of Section 4.15 (Liquid Level Indicators)

3.2.7 Siphon Tubes

3.2.7.1 Systems containing a siphon tube to discharge the clean extinguishing agent from the storage container shall be configured so that the discharge end of the siphon tube is mechanically locked and sealed to remain in place during all conditions of use.

3.2.7.2 Vaporizing liquid clean agents are stored as liquids and superpressurized to the working pressure. Siphon tubes in these systems shall be designed to prevent gas discharge until the liquid level drops below the opening on the free end of the siphon tube.

3.2.7.3 The free end of the siphon tube shall be configured to prevent restriction of flow by contact with the cylinder wall. If the minimum clearance between the end of the siphon tube and the cylinder wall is less than 0.25 times the tube's inside diameter, equivalent length measurements for the system discharge valve shall be performed with the siphon tube in place and installed in the normal design proximity to the cylinder wall. 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.

3.2.8 Pressure Relief Devices

3.2.8.1 Calculations shall be submitted to verify that the pressure relief device used in the agent storage container or other pressurized container is designed to comply with the flow capacity and operating pressure requirements specified in CGA S-1.1, or equivalent local regulations. 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.

3.2.8.2 In pipe sections where valve arrangements introduce the possibility of closed sections of pipe, such sections shall be equipped with pressure relief devices.

3.2.9 Anti-Recoil Devices

The discharge valve outlet of an agent storage container shall be provided with a metallic 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.

3.2.10 Discharge Heads and Connectors

3.2.10.1 If a system discharge head shall be removed from the valve assembly during weighing or recharging operations, the assembly shall contain a check valve.

3.2.10.2 When a pneumatic control line connector shall be removed, a plug or cap shall be provided to seal the disconnected end of the loop.

3.2.10.3 Appropriate warnings shall be displayed on these devices to caution the user about the high pressure discharge hazard and the proper procedure for mitigating this hazard.

3.2.11 Manifolds and Piping

3.2.11.1 Manifolds 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.

3.2.11.2 All cylinders in a manifold arrangement shall be of the same size and design.

3.2.12 Cylinder Supports

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

3.2.13 Protective Coverings

3.2.13.1 All valves and control devices with exterior movable parts that are vulnerable to obstruction or physical damage in their installed configuration 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.

3.2.13.2 Conduit shall be used for electrical cables and wires, or pressurized tubes outside the enclosures.

3.2.13.3 Tubing used for heat detection may be exposed in the areas being monitored but shall be enclosed where not performing this function and vulnerable to mechanical damage.

3.2.13.4 Mechanical cables shall be sheathed or otherwise protected to minimize the likelihood of damage or mechanical interference with operation.

3.2.14 Actuation Devices

3.2.14.1 The device that operates a cylinder discharge valve shall either be an independent actuation device attached to the valve, or an internal component of either the discharge head or the discharge valve assembly.

3.2.14.2 One action shall actuate all the cylinders in a manifold arrangement appropriate to the zone being protected. This shall be accomplished automatically by the connection of the pneumatic control assembly to agent storage containers, or by a mechanical system acting simultaneously on all cylinder valves. In the former arrangement, pressure from a pneumatic control assembly acts through some mechanism in the agent storage container actuation device, valve assembly, or discharge head, typically to unseat the valve disk and open the valve. Such pistons shall have sufficient area such that, when acted upon by the minimum pneumatic control pressure, sufficient force is generated to overcome the force generated by the maximum system pressure acting over the valve disk sealing area. Compliance shall be demonstrated by testing or by the submission of appropriately annotated drawings displaying the area ratio calculation. Mechanical systems shall be configured to provide sufficient force to operate agent storage containers pressurized to the maximum system pressure when actuated by the minimum available force.

3.2.14.3 Actuation devices on pneumatic control assemblies shall be designed for single or simultaneous multiple unit operation. They shall be actuated automatically by a compatible certified detection and control system, or by a fully manual emergency release device. 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.

3.2.14.4 Electric actuation devices shall be designed with a provision for remote supervision of proper installation onto the valve or device they control, or operability for actuators integrated into the discharge valve. Supervisory devices shall be compatible with the appropriate certified control equipment.

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

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

3.2.15 Auxiliary Manual Controls

3.2.15.1 Auxiliary manual controls shall be provided for systems using automatic-only actuation devices or mechanical release devices that do not incorporate a fully mechanical manual control. These auxiliary controls shall be used for remote, manual operation or in emergencies due to failure of the automatic control.

3.2.15.2 Auxiliary manual controls that are not located within the protective enclosures provided for other components shall be protected against accidental operation by a suitable enclosure or other means.

3.2.15.3 Corner pulleys shall be provided for smooth operation of control devices that require cables.

3.2.16 Selector and Lockout Valves

3.2.16.1 The actuation of one selector valve shall not open other selector valves in the system.

3.2.16.2 Lockout valves shall be designed with a provision for remote supervision of valve position.

3.2.16.3 Selector valves shall be designed with a provision for remote supervision of electric actuation device installation, or operability for actuators integrated into the valve. Supervisory devices shall be compatible with the appropriate certified control equipment.

3.2.17 Nozzles

3.2.17.1 Discharge nozzles or assemblies shall be evaluated for the specified use, including flow characteristics and area of coverage.

3.2.17.2 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.

3.2.17.3 Nozzles shall be permanently marked with their part number. When the part number alone does not identify orifice size, the orifice size shall also be permanently marked on the nozzle.

3.2.17.4 Nozzles specified for use in acoustically sensitive environments shall have their sound pressure levels evaluated and documented for installations.

3.2.18 Nozzle Caps, Frangible Seals, and Material Plugs

3.2.18.1 Caps or frangible seals shall be provided on nozzles for installations in which the nozzles are subject to clogging from external materials, including outdoor vent nozzles used to discharge excess agent. Such caps or seals shall have a maximum releasing pressure no greater than half of the system minimum nozzle pressure as installed and shall not obstruct flow from the outlet subsequent to release.

3.2.18.2 For nozzles concealed by a plug of material in an installation (e.g., installations for the protection of anechoic chambers), the maximum allowable releasing force for the plug shall be verified at worst-case system conditions and specified for the certified system. This verification shall consider the following factors:

- Minimum nozzle flow rate
- Minimum nozzle pressure
- Nozzle orientation
- Discharge time
- Plug geometry
- Plug mass
- Plug orientation
- Dimensions of recessed enclosure for discharge nozzle

3.2.19 Clean Agents

3.2.19.1 Clean extinguishing agents for use in fire extinguishing systems shall be recognized under the United States Environmental Protection Agency's Significant New Alternatives Program, shall meet the requirements of NFPA 2001 or equivalent local standard, and shall either be certified as a clean agent system component or shall be examined for the system manufacturer to the same extent as an agent submitted for component certification.

3.2.19.2 All agent storage containers shall be filled at a certified filling location that is included in the certification agency's Surveillance Audit Program.

3.2.20 Expellant Gases

Nitrogen used in a clean agent system shall have a dew point of no greater than -60°F (-51.1°C), water content of no more than 4 ppm, and purity greater than or equal to 99.99% (mol/mol).

3.2.21 Auxiliary Equipment

Auxiliary equipment includes those devices required in a system to protect against a specific 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.

3.2.21.1 Pressure Operated Releases

A pressure operated release shall be provided for all doors and windows in a hazard area that is to be sealed off in the event of fire. The release shall operate at a maximum pressure of 50 psi (3.1 bar) from a piston or plunger driven by clean agent 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.

3.2.21.2 Pressure Operated Switches

Pressure operated switches may be used to shut down fans, conveyors, or other electrical equipment in or near the hazard area, as well as to activate alarm and indicator circuits. These switches shall not require a pressure of more than 40 psi (2.8 bar) to operate and shall not release excessive gas from the system. They may also have an alternate manual control and shall be designed for manual resetting only.

3.2.21.3 Time Delays

A delay device may be installed on systems when the evacuation of personnel from the hazard area prior to system discharge is required. This device may allow discharge to be aborted or immediately initiated through a manual override during the delay period. The duration of delay is a function of both the specific clean agent used and the design concentration.

3.2.21.4 Alarms

Alarms and/or indicators shall be provided to show that the system is operating, warn personnel of the forthcoming discharge of clean agent or of its presence in unventilated areas, 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. When pneumatically operated alarms are powered by a vaporizing liquid clean agent, the discharge of agent from the device shall be piped outside of the protected area to minimize potentially damaging products of decomposition prior to system operation.

3.2.21.5 Check Valves

Check valves shall be provided in the manifold piping on system installations incorporating multiple storage containers. They shall open at a maximum pressure of 0.1 times the system pressure at maximum storage temperature.

3.2.21.6 Pressure Venting Devices (Pneumatic Control Lines)

Devices shall be provided to prevent the premature operation of discharge or selector valves by residual pressures that may leak into enclosed manifolds, actuation devices, or discharge heads. They shall have closing pressures of 25 to 100 psi (1.7 to 6.9 bar). If these vents are incorporated in actuation devices, they shall be closed when the control is in operation and open when the control is inoperative.

3.2.21.7 Changeover Devices

Changeover 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 series of containers. The changeover device shall be suitably protected and labeled and shall indicate which containers are subject to operation.

3.2.22 Hazardous Location Rating of Components

Components designed for use in hazardous locations shall be certified only if successfully evaluated for compliance to the relevant requirements of one or more of the following Certification Standards:

Table 3.2.22 *Hazardous Location Electrical* Equipment *Standards*

FM Approvals Standard Number	*Examination 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
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
3810	Electrical and Electronic Test, Measuring, and Process Control Equipment

3.3 MARKINGS

3.3.1 Nameplates that are easily visible in the installed configuration shall be affixed to the agent storage container assembly of clean agent extinguishing systems and shall display the following markings at a minimum:

- Manufacturer's name and address
- System type and model number
- The certification agency’s mark of conformity
- Clean 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 NFPA 2001, and/or any other relevant local standards
- Reference to the manufacturer’s design, installation, operation, recharge, and maintenance instructions
- Weight of agent charge and/or charge pressure at nominal temperature, as applicable
- Total container weight (actual is required for vaporizing liquids, nominal acceptable for inert gases)

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

3.3.3 All marking plates shall be made of materials that will not corrode or otherwise become illegible due to system liquids or vapors, or normal environmental conditions.

3.3.4 When hazard warnings are needed, the markings shall be universally recognizable.

3.3.5 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.

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

3.3.7 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 NFPA 2001 and any other relevant local standards.

3.4.3 Further guidance on the requirements for design, installation, operation, and maintenance instructions can be found in Section 5.6 (Design, Installation, Operation, and Maintenance Manual).

3.5 CALIBRATION

3.5.1 Each piece of equipment used to verify the test parameters shall be calibrated within an interval determined based on stability, purpose, and usage. A copy of the calibration certificate for each piece of test equipment is required. The certificate shall indicate that the calibration was performed against working standards whose calibration is certified and traceable to an acceptable reference standard and certified by an ISO/IEC 17025 accredited calibration laboratory. Unless already provided in the individual calibration certificates, additional documentation showing measurement uncertainty values for each instrument being used in the test program (Confidence Level 95%, k=2) shall also be provided. A copy of each applicable service provider's accreditation certificate as an ISO/IEC 17025 accredited calibration laboratory shall be provided. The test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date.

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 thus equipment.

3.6 TOLERANCES

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

4. PERFORMANCE REQUIREMENTS

4.1 CLASS A AND B FIRE EXTINGUISHMENT TESTS

4.1.1 Requirement

4.1.1.1 Class A Fire Extinguishment Tests

Clean agent extinguishing systems shall successfully extinguish each Class A fire within 600 seconds after the end of system discharge. For the purposes of these tests, the end of discharge shall be considered to be at the maximum discharge time. Following a 600 second soak period, there shall be no signs of re-ignition of the materials defined in Sections 4.1.2.1.A and 4.1.2.1.B. For the polymeric material tests, the weight loss of each sample between 10 seconds and 600 seconds after the end of discharge shall not exceed 15 grams. This test is used to confirm the minimum extinguishing concentration (MEC) for a clean agent for Class A combustible materials. Certified systems shall specify a Class A minimum design concentration based on 1.2 times the maximum MEC determined between these tests and those in Section 4.2 (Nozzle Distribution Verification Tests), if applicable, for the specific agent and system configuration.

4.1.1.2 Class B Fire Extinguishment Tests

Clean agent extinguishing systems shall successfully extinguish each Class B fire within 30 seconds after the end of system discharge. For the purposes of these tests, the end of discharge shall be considered to be at the maximum discharge time. This test is used to confirm the minimum extinguishing concentration for a clean agent for Class B ignitable liquids (also known as flammable or combustible liquids).

Certified systems shall specify Class B minimum design concentrations for the specific agent and system configuration based on 1.3 times on the greater of:

- The MEC per the cup burner value for n-heptane per NFPA 2001 or equivalent local standard, or
- The highest MEC determined between these tests and those in Section 4.2 (Nozzle Distribution Verification Tests).

4.1.1.3 For clean agent extinguishing systems that have a maximum protected volume limitation less than 3531 ft^3 (100 m^3), the minimum extinguishing concentration shall be determined from the tests described in Section 4.2 (Nozzle Distribution Verification Tests), and shall be the same for Class A and Class B hazards.

4.1.2 Tests/Verification

The test enclosure shall be constructed of, or sheathed internally with, plywood with a minimum thickness of 3/8 inch (9.5 mm), or an equivalent material. The internal material shall be such that it does not reflect heat back into the test enclosure. The enclosure shall contain a minimum volume of 3531 ft^3 (100 m^3), with a minimum ceiling height of 11.5 ft (3.5 m), and each wall shall be a minimum of 13.1 ft (4 m) long. Openings shall be provided for the purpose of venting prior to system discharge. Additionally, a pressure relief opening shall be provided in the enclosure. Provisions for visual observations of the interior of the enclosure shall be provided. Prior to each fire test, the enclosure shall be maintained at 70°F ± 5°F (21°C ± 3°C) throughout the enclosure.

Each test shall include a piping and discharge nozzle configuration resulting in the minimum specified nozzle design pressure at 70°F (21°C). The same calculation methodology used to determine the nozzle pressure for these tests shall also be used, or the appropriate correlation demonstrated, for Section 4.2 (Nozzle Distribution Verification Tests) and Section 4.6 (Verification of Flow Calculation Method Tests).

The agent storage container shall be conditioned to 70°F ± 5°F (21°C ± 3°C) and maintained at this temperature for the duration of each fire test.

The clean agent concentration used in each fire test shall be the specified minimum extinguishing concentration for Class A or Class B hazards, as applicable, at an ambient temperature of 70°F (21°C), and shall be calculated for each test using the appropriate formula, as follows:

For vaporizing liquid clean agents:

$$W = \left[\frac{V}{s}\right] \times \left[\frac{C}{100 - C}\right]$$

For inert gas clean agents:

$$W = \left[\frac{V}{s}\right] \times \ln\left[\frac{100}{100 - C}\right]$$

Where:

W = Agent quantity [lb or kg*]
V = Volume of the test enclosure [ft^3 or m^3*]
s = Specific volume of clean agent at 70°F (21°C) [ft^3/lb or m^3/kg*]
C = Agent volume concentration [percent]

*These equations work for either U.S. customary or SI units if units of one type are used consistently throughout the calculation.

Further information regarding the specific volume of various clean extinguishing agents can be found in NFPA 2001.

Where barometric pressure deviates from the normal sea-level value of 29.92 inHg (760 mmHg) by more than 5 percent, the required weight of agent shall be adjusted by multiplying the weight calculated from the formula above by the ratio [barometer actual/barometer norm] to address the corresponding differences in oxygen concentration in the test enclosure.

4.1.2.1 Class A Fire Extinguishment Tests

A. Wood Crib

The crib shall be constructed of four layers of six 1-1/2 x 1-1/2 x 18 in. long (38 x 38 x 460 mm long) wood members. The wood shall be kiln dried spruce or fir lumber having an average moisture content between 9 and 13 percent using at least one measurement taken from each side of the wood crib. Within each layer, the wood members shall be evenly spaced to form an 18 in. x 18 in. (460 mm x 460 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.

The test enclosure shall include provisions for oxygen concentration measurements. The measurements shall be recorded at the following locations:

- At the height of the bottom of the wood crib, centered from the edge of the wood crib to the wall;
- At 0.1 H, where H is the height of the test enclosure, centered from the edge of the wood crib to the wall;
- At 0.9 H, where H is the height of the test enclosure, centered from the edge of the wood crib to the wall.

A 2.5 ft^2 (0.23 m^2) square steel pan, a minimum of 4 in. (100 mm) in height, shall be placed on the floor of the enclosure, 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 fully exposed to the atmosphere except where supported. The square pan shall be filled with a sufficient quantity of heptane, as defined in Table 4.1.2.2, to provide a minimum of 3 minutes of burning. The heptane shall be ignited, and the crib shall be allowed to burn freely outside of the test enclosure for 6 minutes. 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. Alternatively, pre-burn of the heptane and crib may occur within the enclosure if adequate ventilation provisions are provided. Ventilation shall ensure that the

oxygen content within the enclosure, measured at the height of the bottom of the wood crib, is not reduced by more than 0.5 volume percent below atmospheric conditions prior to system discharge.

15-30 seconds prior to the end of the 6 minute pre-burn period, the wood crib shall be placed on a stand inside of the test enclosure so that the bottom surface of the crib is 24 in. to 30 in. (610 mm to 760 mm) above the floor of the test enclosure and fully exposed to the atmosphere except where supported. The crib shall be positioned in the test enclosure prior to the completion of the pre-burn period. The enclosure door and vents shall be closed, and the system discharged. The oxygen concentration, measured at the height of the bottom of the wood crib, at the time of discharge shall be within 0.5 volume percent of atmospheric conditions.

Observations shall be made for extinguishment of the crib fire and the time of extinguishment and shall be recorded. Following discharge, the test enclosure shall remain sealed for 600 seconds. The crib shall then be removed from the enclosure, and observations of the crib shall be made for signs of reignition. The presence of a flame after removal from the enclosure constitutes reignition; embers are acceptable if they do not produce flames within 10 minutes after removal from the enclosure.

Three successful tests using the same system configuration shall be required.

B. Polymeric Materials

The tests shall be conducted using polymethyl methacrylate (PMMA), polypropylene (PP), and acrylonitrile-butadiene-styrene polymer (ABS), demonstrated to meet the properties of Table 4.1.2.1.B.

Table 4.1.2.1.B *Polymeric Materials* Properties*

Fuel	*Color*	*Density g/cm³*	*Ignition Time*		*180 Second Average Heat Release Rate*		*Effective Heat of Combustion*	
			Value sec	*Tolerance percent*	*Value kW/m²*	*Tolerance percent*	*Value MJ/kg*	*Tolerance percent*
PMMA	Black	1.19	77	± 30	286	± 25	23.3	± 15
PP	Natural (White)	0.905	91	± 30	225	± 25	39.8	± 15
ABS	Natural (Cream)	1.04	115	± 30	484	± 25	29.1	± 15

* 25 kW/m² exposure in cone calorimeter per ASTM E 1354.

Each polymeric fuel array shall be constructed with four sheets of 3/8 in. (9.5 mm) ± 10% thick by 16 in. (405 mm) tall by 8 in. (205 mm) wide. The sheets shall be fixed 8 in. (205 mm) above the floor of the test enclosure, at the spacing specified in Figures E-1 through E-4.

A 15 in. (380 mm) wide by 33.5 in. (850 mm) high by 24 in. (610 mm) deep fuel shield, as shown in Figures E-1 and E-2, shall be placed around two sides and at the top of the fuel array. The shield shall be constructed with a metal frame. The 24 in. (610 mm) wide by 33.5 in. (850 mm) high sides and the 24 in. (610 mm) by 15 in. (380 mm) top shall be fabricated from sheet steel. The remaining two sides and the bottom of the fuel array shall not be covered by the fuel shield. The fuel array shall be positioned such that the 8 in. (200 mm) sides of the polymeric sheets are parallel to the 24 in. (610 mm) side of the shield.

Two square baffles shall be placed centered around the exterior of the fuel shield, as shown in Figure E-5. Each baffle shall measure between 37.5 and 40.0 in (950 and 1016 mm) on a side and 12 in. (300 mm) tall. One baffle shall be placed at 3.5 in. (90 mm) above the test enclosure floor. The second baffle shall be placed on top of the other and rotated 45 degrees with respect to the bottom baffle. The test enclosure shall include provisions for oxygen concentration measurements. The measurements shall be recorded at the following locations:

- At the height of the bottom of the fuel array, centered from the edge of the array to the nearest wall of the enclosure;
- At 0.1 H, where H is the height of the test enclosure, centered from the edge of the array to the nearest wall of the enclosure;
- At 0.9 H, where H is the height of the test enclosure, centered from the edge of the array to the nearest wall of the enclosure.

A 2 in. (50 mm) by 2 in. (50 mm) by 0.875 in. (22 mm) deep steel pan shall be centered below the fuel array, with a distance of 0.5 in. (13 mm) between the bottom of the array and the top of the pan. The square pan shall be filled with a sufficient quantity of heptane meeting the requirements specified in Table 4.1.2.2 to provide a minimum of 90 seconds of burning. The heptane shall be ignited and burn freely for 90 seconds.

210 seconds after ignition of the heptane, the vents shall be closed, and the system discharged. The oxygen concentration in the enclosure at the time of discharge, measured at the level of the fuel array, shall be within 0.5 volume percent of atmospheric conditions.

Observations shall be made for extinguishment of the polymeric fuel array. Following discharge, the test enclosure shall remain sealed for 600 seconds. The array shall then be removed from the enclosure, and observations of the array shall be made for signs of reignition.

The following data shall be recorded using an automated data acquisition system throughout the duration of the fire test:

- Oxygen concentrations
- Instantaneous fuel mass
- The following events shall be recorded:
- Time of heptane ignition
- Time of polymeric fuel array ignition
- Time of system discharge
- Time of end of discharge
- Time of visible fire extinguishment

Three successful tests using the same system configuration shall be required for each polymeric material.

4.1.2.2 Class B Fire Extinguishment Tests

A 2.5 ft^2 (0.23 m^2) square steel pan shall be used. It 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 top of the pan shall be 26 in. - 30 in. (660 mm - 760 mm) above the test enclosure floor. The test enclosure shall include provisions for oxygen concentration measurements. The measurements shall be taken using a calibrated instrument, and shall be recorded at the following locations:

- At the height of the top of the steel pan, centered from the edge of the pan to the nearest wall of the enclosure;
- At 0.1 H, where H is the height of the test enclosure, centered from the edge of the pan to the nearest wall of the enclosure;
- At 0.5 H, where H is the height of the test enclosure, centered from the edge of the pan to the nearest wall of the enclosure;

The steel pan shall be filled with a minimum of 2 in. (50 mm) of heptane and centered in the test enclosure. The heptane level shall be a minimum of 2 in. (50 mm) below the top of the pan. The heptane may be floated on top of a layer of water provided the above dimensions are met and there is enough heptane remaining at the end of the test to fully reignite the surface. The heptane shall exhibit the properties specified in Table 4.1.2.2.

Table 4.1.2.2 *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

The heptane shall be ignited and allowed to burn freely for 30 seconds. The vents shall be closed, and the system discharged. The average oxygen concentration in the enclosure at the time of discharge shall be within 0.5 volume percent of atmospheric conditions. Observations shall be made for extinguishment of the heptane fire.

Three successful tests using the same system configuration shall be required.

4.1.3 Verification of Fire Extinguishment Test Concentration

4.1.3.1 Requirement

The test enclosure should be sufficiently tight to ensure that the weight of agent supplied results in achievement of the intended concentration. This test is only required in instances where the test enclosure is not sufficiently tight to maintain the delivered agent concentration, requiring quantified adjustments to measured test values.

4.1.3.2 Test/Verification

For a minimum of one of each of the fire extinguishment tests, the scenario shall be repeated with no fire present. The enclosure volume shall be monitored by means of oxygen concentration meters, as specified in Section 4.1.2.1.A. One minute after the end of discharge, the oxygen concentration shall be reduced to a level no less than that corresponding to the agent concentration used in the appropriate equation from Section 4.1.2. The actual agent concentration shall be calculated per the following equation:

$$C_a = 100 \times \left(1 - \frac{O_{2(f)}}{O_{2(s)}}\right)$$

Where:

Ca is the actual extinguishing concentration achieved (volume percent),

O2(f) is the final average volume percent oxygen concentration in the enclosure after 1 minute, and

O2(s) is the starting volume percent oxygen concentration in the enclosure.

4.2 NOZZLE DISTRIBUTION VERIFICATION TESTS

4.2.1 Requirement

Engineered and pre-engineered clean agent extinguishing system nozzles or assemblies and automatic extinguisher units shall successfully achieve the extinguishing concentration throughout the test enclosures within 30 seconds after the end of system discharge. For vaporizing liquid systems only, where the discharge time at the minimum specified operating temperature exceeds 30 seconds, the extinguishing concentration shall be achieved within 60 seconds after the start of system discharge.

Certified systems shall specify Class B minimum design concentrations for the specific agent and system configuration based on 1.3 times on the greater of:

- The MEC per the cup burner value for n-heptane per NFPA 2001 or equivalent local standard, or
- The highest MEC determined between these tests and those in Section 4.1 (Class A and B Fire Extinguishment Tests).

For instances where the maximum Class B agent extinguishing concentration determined from these tests is greater than the MEC per the maximum cup burner value for n-heptane per NFPA 2001 or equivalent local standard, those certified systems shall specify minimum design concentrations based on MECs that are increased for all hazard classes by the same proportion required to achieve extinguishment in these tests.

4.2.2 Tests/Verification

The test enclosures shall be constructed of, or sheathed internally with, plywood with a minimum thickness of 3/8 inch (9.5 mm), or an equivalent material. The internal material shall be such that it does not reflect heat back into the test enclosure. Openings in the enclosures shall be provided for the purpose of venting prior to system discharge. Additionally, a pressure relief opening shall be provided in the top of the enclosure. Provisions for visual observations of the interior of the enclosure shall be provided. Prior to each fire test, the enclosure shall be maintained at 70°F ± 5°F (21°C ± 3°C) throughout the enclosure, and the ambient temperature outside the enclosure shall be maintained at 70°F ± 30°F (21°C ± 17°C).

One test enclosure shall be constructed based on the specified minimum protected height and maximum area of coverage limitations for the system or nozzle being tested. A second test enclosure shall be constructed based on the maximum protected height limitation for the system or nozzle being tested. For pre-engineered and engineered extinguishing systems, this second enclosure shall be a minimum of 13.1 ft (4 m) wide by 13.1 ft (4 m) long and include a volume of a minimum of 3531 ft^3 (100 m^3). For automatic extinguisher units, the second enclosure shall include the maximum specified protected volume for the unit. Nozzles or assemblies designed to protect smaller spaces only shall be tested in the manufacturer's specified maximum volume enclosure, and their certification shall state this limitation.

Each enclosure's footprint shall be rectangular and shall contain a rigidly mounted vertical baffle that shall extend the full height of the enclosure. If the nozzle is centered in the enclosure or on one of the walls, the baffle shall be parallel to two of the walls and its width shall be 20 percent of the width of the walls to which it is parallel. It shall be centered on the centerline of the nozzle, perpendicular to the nozzle discharge, and located halfway between the nozzle and the far wall. If the enclosure's footprint is not square, separate tests shall be conducted with appropriate width baffles parallel to both the long and short walls. See Figure E-6. If the nozzle is not centered in the enclosure or on one of the walls, the baffle shall be centered on the centerline of the nozzle, perpendicular to the nozzle discharge, and located halfway between nozzle and the farthest corner of the enclosure. In these cases, the baffle width shall be 20 percent of the width of the largest enclosure cross section to which it is parallel.

Delivered agent concentration in the test enclosures shall be measured through the use of telltale heptane can fires. Steel test cans, having a maximum nominal thickness of 0.216 in., 3.0 to 3.5 in. (76 to 89 mm) in diameter, and at least 4 in. (102 mm) tall, shall be placed in the sampling locations described below. These cans shall be filled with a minimum of 2 in. of heptane meeting the requirements specified in Table 4.1.2.2, to a level a minimum of 2 in. below the top of the can. Provisions shall be made to automatically monitor each can for extinguishment; manual data collection shall not be acceptable. The heptane in each can shall be ignited and allowed to burn freely for 30 seconds with the enclosure door and/or vents open. The vents shall be closed, and the system discharged.

Ten sampling locations shall be located as follows:

- One point within 2 in. (50 mm) of each wall at each corner of the enclosure, located vertically within 12 in. (300 mm) of the top or bottom of the enclosure (eight total);
- Two points centered on the opposite side of the baffle from the nozzle: one at mid height and one within 12 in. (300 mm) of the floor of the enclosure;
- For enclosure heights less than 3 ft (1 m), only one level of sampling points is required (five total).

Each can shall be extinguished within 30 seconds after the end of discharge, or within 60 seconds after the start of system discharge for vaporizing liquid systems where the discharge time at the minimum specified operating temperature exceeds 30 seconds.

Alternatively, agent concentration may be measured by appropriately selected and calibrated oxygen or other gas analyzers. Continuous data logging of the gas analyzer readings shall be required for a minimum of 195 seconds from discharge initiation for inert gases, or 85 seconds from discharge initiation for vaporizing liquids. The sample locations shall be as described above. Each sampling location shall reach the required concentration within 30 seconds after the end of discharge, or within 60 seconds after the start of system discharge for vaporizing liquid systems where the discharge time at the minimum specified operating temperature exceeds 30 seconds.

The test configurations shall be designed to evaluate the most adverse specified configurations of the extinguishing system with respect to the following:

All configurations of extinguisher units, discharge nozzles, or assemblies, including both 360º, sidewall, and corner versions, recessed versions (e.g., for the protection of anechoic chambers), as well as any deflectors or other ancillary devices used with the discharge nozzles

- Maximum area of coverage of extinguishers units, discharge nozzles, or assemblies
- Minimum system operating temperature
- Location and orientation of the extinguisher unit outlet or discharge nozzles or assemblies in the protected volume (tests performed with the extinguisher unit outlet, nozzle, or assembly located within 0 to 12 in (0 to 304.8 mm) of the ceiling or wall will be considered acceptable for that installation range for the certified system)
- For pre-engineered systems, the maximum piping and discharge nozzle limitations, including the most conservative piping configuration, length of pipe, number of fittings, and discharge nozzle configuration
- For engineered systems, the piping and discharge nozzle configuration resulting in 90 percent of the minimum nozzle design pressure at 70°F (21°C); the same calculation methodology used to determine the nozzle pressure shall also be used, or the appropriate correlation demonstrated, for Section 4.1 (Class A and B Fire Extinguishing Tests) and Section 4.6 (Verification of Flow Calculation Method Tests)
- For automatic extinguisher units, the maximum protected enclosure volume
- Agent storage container fill density and/or pressurization level that results in the lowest discharge nozzle pressure and lowest available amount of expellant gas
- Maximum discharge time, ± 1 second for vaporizing liquids or ± 10 seconds for inert gases; the same calculation methodology used to determine the discharge time shall also be used, or the appropriate correlation demonstrated, for Section 4.6 (Verification of Flow Calculation Method Tests)
- Most adverse combinations of interdependent parameters, such as maximum height and maximum discharge time or maximum area and minimum discharge time. The necessity of evaluating such combinations shall be subject to the judgment of the certification agency in consultation with the manufacturer and, if necessary, verified by exploratory testing

The clean agent concentration used in each test shall be equal to the specified minimum extinguishing concentration for Class B hazards at an ambient temperature of 70°F (21°C), and shall be calculated for each test using the formula shown in Section 4.1.2.

4.2.2.1 Minimum Room Height/Maximum Nozzle Area of Coverage Tests

Tests shall be conducted with all configurations of extinguisher units, discharge nozzles, or assemblies, and as described in Section 4.2.2.

4.2.2.2 Maximum Room Height Tests

Tests shall be conducted with all configurations of extinguisher units, discharge nozzles, or assemblies, and as described in Section 4.2.2.

The baffle shall be removed from the enclosure, and a 2.5 ft^2 (0.23 m^2) square steel pan shall be centered in the test enclosure. The pan shall be as described in Section 4.1.2.2. The top of the pan shall be 26 - 30 in. (660 - 760 mm) above the test enclosure floor. For systems designed to protect smaller spaces being tested in the manufacturer's specified maximum volume enclosure, the pan size may be scaled down, but the pan area shall be a minimum of 1.45 percent of the enclosure's footprint area.

The steel pan shall be filled with a minimum of 2 in. (50 mm) of heptane meeting the requirements specified in Section 4.1.2.2. The heptane level shall be a minimum of 2 in. (50 mm) below the top of the pan. The heptane may be floated on top of a layer of water provided the above dimensions are met and there is enough heptane remaining at the end of the test to fully reignite the surface. The heptane shall be ignited and allowed to burn freely for 30 seconds with the enclosure door and vents open. The door and vents shall be closed, and the system discharged. Observations shall be made for extinguishment of the heptane fire.

4.2.2.3 Automatic Extinguisher Unit Automatic Operation Fire Tests

For automatic extinguisher units, the tests described in Sections 4.2.2.1 (Minimum Room Height/Maximum Nozzle Area of Coverage Test) and 4.2.2.2 (Maximum Room Height Test) shall be supplemented by a minimum of two of the automatic operating extinguishment tests described below. These tests shall be conducted at the design concentration, rather than the minimum extinguishing concentration, and in the maximum room height test enclosure, that shall include the maximum specified protected volume for the unit. The heat responsive element with the highest available temperature rating for the system under examination shall be used for these tests. Pneumatic detection tubing and heat detection cable shall be installed at the manufacturer's maximum specified limitations, including but not limited to spacing of tubing/cable, length, and height above hazard, as applicable.

A 2.5 ft^2 (0.23 m^2) square steel pan, as described in Section 4.1.2.2, shall be centered in the test enclosure. For systems designed to protect smaller spaces being tested in the manufacturer's specified maximum volume enclosure, the pan size may be scaled down, but the pan area shall be a minimum of 1.45 percent of the enclosure's footprint area. An opening with an area equal to 1 ft^2 (0.09 m^2) shall be provided on a wall directly across from the steel pan for the purpose of venting prior to system discharge. The top of the opening shall be within 2 in. (50 mm) of the top of the enclosure.

The steel pan shall be filled with a minimum of 2 in. (50 mm) of heptane meeting the requirements specified in Table 4.1.2.2. The heptane level shall be a minimum of 2 in. (50 mm) below the top of the pan. The heptane may be floated on top of a layer of water provided the above dimensions are met and there is enough heptane remaining at the end of the test to fully reignite the surface. The heptane shall be ignited and allowed to burn freely with the vent open. Observations shall be made for the time of automatic operation of the extinguisher unit and time of extinguishment of the heptane fire.

The automatic operating extinguishment test shall be repeated, with the 2.5 ft^2 (0.23 m^2) square steel pan placed within 2 in. (50 mm) of the corner of the enclosure that is most remote from the location of the automatic extinguisher unit. The 1 ft^2 (0.09 m^2) opening shall be located in the corner wall of the enclosure, next to the steel pan. The heptane shall be ignited and allowed to burn freely with the vent open. Observations shall be made for the time of automatic operation of the extinguisher unit and time of extinguishment of the heptane fire.

All fires shall be extinguished within one minute after test fuel ignition.

4.3 DISCHARGE TESTS

4.3.1 Requirement

Pre-engineered and engineered clean agent extinguishing systems shall be capable of discharging 95 percent of the extinguishing agent within the maximum discharge time. Additionally, systems designed for use with a material plug concealing the nozzle (e.g., for the protection of anechoic chambers) shall be capable of fully ejecting the plug and discharging 95 percent of the extinguishing agent within the maximum discharge time.

4.3.2 Test/Verification

Pre-engineered systems shall be assembled to include a piping configuration and discharge nozzles representative of the maximum specified limitations, as well as the maximum specified fill density. The agent storage container shall be conditioned to 70°F ± 5°F (21°C ± 3°C) and maintained at this temperature until the system is discharged. The system shall be discharged, and the discharge time recorded. This test shall be performed successfully with the maximum amount of agent specified for each valve size.

Engineered systems shall be designed and assembled with a piping configuration producing no more than 90 percent of the minimum nozzle design pressure at 70ºF (21ºC), as well as the maximum specified fill density. The agent storage container shall be conditioned to 70°F ± 5°F (21°C ± 3°C) and maintained at this temperature until the system is discharged. The system shall be discharged, and the discharge time recorded. This test shall be performed successfully with the maximum amount of agent specified for each valve size.

Additionally, systems designed for use with a material plug concealing the nozzle (e.g., for the protection of anechoic chambers) shall be designed per above, as appropriate. The agent storage container shall be conditioned to the minimum system operating temperature and maintained at this temperature until the system is discharged. The system shall be discharged, and the discharge time recorded. The plug shall be completely ejected within one second of the start of discharge and not impede agent flow. This test shall be performed successfully two times each for the smallest and largest nozzle sizes and allowable plug surface areas, as applicable. The minimum force required to dislodge each plug shall be measured, and certified systems shall specify the lowest measured force as the maximum allowable releasing force.

4.4 HIGH PRESSURE DISCHARGE INTEGRITY TEST

4.4.1 Requirement

All components in the system flow path shall be subjected to a maximum flow rate discharge test to determine their ability to withstand the reaction forces without damage that would impede the performance of the system. Following the test, discharge valves, selector valves, and check valves, as applicable, shall meet the requirements of Section 4.10 (Valve Leakage Test).

4.4.2 Tests/Verification

The agent storage container and valve assembly shall be filled with the applicable clean agent. For vaporizing liquid agents, the minimum specified fill density shall be used in testing. The assembly shall either be pressurized with nitrogen to the maximum working pressure or pressurized with nitrogen to the working pressure and conditioned to the maximum specified storage temperature for a minimum of 24 hours.

Alternatively, vaporizing liquid systems may substitute water as the test medium. Calculations shall be submitted by the manufacturer, deriving the appropriate quantity of water necessary to simulate the clean extinguishing agent at minimum fill density. The water density used in the calculations shall be 62.4 lb/ft^3 (1000 kg/m^3).

The assembly shall be configured using the appropriate mounting brackets and connected to a minimum piping configuration and discharge nozzle resulting in the maximum system flow rate. The configuration shall incorporate all components in the system flow path, including discharge valves, selector valves, check valves, and all other mechanical and electrical elements normally connected to the discharge piping and subject to agent flow. At minimum, the largest and

smallest representative size of each valve design shall be tested. Selector valves and check valves shall be tested in both the direction of normal flow and in the reverse direction. Selector and check valves shall be monitored for downstream leakage during this test. Any leakage through a check or selector valve that does not result in a pressure increase sufficient to actuate the system shall be deemed acceptable. All components shall be mounted and supported as specified by the manufacturer's published instructions.

Following the discharge test, the system shall be visually inspected for damage. Discharge valves, selector valves, and check valves included in the test shall be subjected to the requirements of Section 4.10 (Valve Leakage Test) at the system's working pressure.

4.5 VERIFICATION OF FLOW CALCULATION LIMITS

4.5.1 Requirement

The manufacturer's flow calculation method shall accurately predict the discharge time, nozzle pressure, and distribution of the clean extinguishing agent within established limiting parameters. The manufacturer shall provide and justify those limits to assist in the evaluation of the flow calculations.

4.5.2 Test/Verification

The manufacturer shall submit a table of limiting parameters for the flow calculation software, including, at minimum:

- The name of each parameter
- The minimum or maximum value for each parameter, as appropriate
- The engineering significance of each parameter to the calculation
- The engineering justification for the limiting value(s) of each parameter

The limit of testing conducted to date shall be an acceptable justification for a limiting value of a parameter. However, all limitations should generally be based on fluid mechanics and the properties of the agent.

The following list of parameters commonly addressed in such calculations shall be included in the manufacturer's table of limits, and technical justification shall be submitted for any exclusions; acceptable technical justifications include that the parameter has been addressed by another parameter, or that it is not relevant to the specific agent or calculation methodology:

- Minimum and maximum discharge time
- Minimum nozzle pressure
- Minimum and maximum agent storage container fill density
- Minimum and maximum pipe flow velocities
- Minimum and maximum nozzle orifice area ratio to pipe inlet area
- Proportion of piping volume to each nozzle
- Maximum variance in nozzle pressures in each piping configuration
- Type of pipe and pipe schedules
- Type of fittings
- Type of tee splits
- Minimum and maximum flow split for each type of tee split
- Maximum length of straight pipe sections
- Elevation changes

- Maximum imbalance in agent arrival time among nozzles
- Maximum imbalance in agent discharge time among nozzles
- Enclosure and pipe system temperature range
- Agent storage temperature range
- Protected enclosure temperature range
- Available working pressures
- Selector valve piping limitations for systems designed to protect multiple zones

4.6 VERIFICATION OF FLOW CALCULATION METHOD TESTS

4.6.1 Requirement

The manufacturer's flow calculation method shall predict the discharge time, nozzle pressure(s), and distribution of the clean extinguishing agent as follows:

- The predicted discharge time shall be within ±1.0 second of the measured discharge time for vaporizing liquid agents, or within ± 10 seconds for inert gas agents
- Each predicted nozzle pressure shall be within ±10 percent of the measured value
- The predicted weight of clean agent discharged from each nozzle shall be within ±10 percent of the measured value, or the value calculated from concentration measurements, as applicable
- The standard deviation of the percentage differences between each predicted agent weight from a nozzle and the measured agent weight shall not exceed ±5 percent relative to zero for each independent set of test results

4.6.2 Test/Verification

The manufacturer shall design and test various multiple nozzle systems, to be designed for enclosures of various volumes, that each incorporate limiting values for a minimum of two parameters. Each system shall include at least three nozzles and shall contain at least one unbalanced split. All predicted values for tested parameters shall meet or exceed the respective limiting values. Enough configurations shall be designed and tested to address all flow calculation limiting parameters. Dimensioned as-built piping schematics, experimental test results, and flow calculations for all such tests shall be submitted to the certification agency for review; a minimum of five such results summaries, addressing all limits in aggregate, shall be submitted. If the results of these pre-tests are acceptable, the certification agency shall designate a minimum of two of the pre-tests to be re-run for witnessing to validate acceptance of the manufacturer's pre-testing. A minimum of an additional three tests shall be designed in collaboration with the certification agency for further witnessing to demonstrate all of the outstanding limiting parameters. Modifications to individual limiting parameter for existing flow calculation methods shall be examined using a reduced number of systems, and added to the existing data set for evaluation.

The piping configuration, lengths, and sizes shall be verified against the schematic to ensure that the calculations accurately model the as-tested configuration.

The agent storage container shall be filled with the appropriate quantity of clean agent and pressurized to the working pressure. The system and enclosure shall be maintained at a temperature equal to 70°F ± 5°F (21°C ± 3°C). Alternatively, if the environment is maintained at a temperature other than 70°F ± 5°F (21°C ± 3°C), appropriate temperature correction calculations shall be applied. Testing with the system and enclosure at 70°F ± 5°F (21°C ± 3°C) will be considered sufficient for a certified system with an agent container storage and enclosure temperature range of 60°F to 80°F (15.6 °C to 26.7°C) for unbalanced systems.

The extinguishing system shall be discharged, and pressure measurements shall be recorded at the agent storage container(s) and discharge nozzles throughout the discharge period. The pressure readings shall be recorded using a calibrated automated data acquisition system at a minimum sampling rate of 10 Hz for each individual measuring channel.

The calculation methodology used to determine the nozzle pressure shall also be used, or the appropriate correlation demonstrated, for Section 4.1 (Class A and B Fire Extinguishing Tests) and Section 4.2 (Nozzle Distribution Verification Tests). The calculation methodology used to determine the discharge time shall also be used, or the appropriate correlation demonstrated, for Section 4.2 (Nozzle Distribution Verification Tests).

After the completion of discharge, the quantity of discharged clean agent shall be measured. The agent discharged from each nozzle shall be collected in such a manner as to not affect the discharge and weighed, or otherwise measured to determine quantities. Data and/or analysis to validate the collection methodology shall be provided by the manufacturer for review prior to testing. Alternatively, the concentration of clean agent from each nozzle may be measured using a calibrated concentration measuring device.

The test results shall be compared to the calculated projections to verify whether the accuracy requirements of Section 4.6.1 have been met.

4.7 CYCLE OPERATION TESTS

4.7.1 Requirement

All components required for system operation having moving parts shall operate through a total of 500 cycles at the working pressure without damage. Following the test, discharge valves, actuation devices, selector valves, and check valves shall continue to operate, and, if applicable, shall meet the requirements of Section 4.10 (Valve Leakage Test). Valves shall be successfully actuated via all applicable operating devices and shall not display any increase in required force for mechanical operating devices or in actuation pressure for pneumatic operating devices. Individual components that are connected upon installation, such as actuation devices and discharge valves, shall be tested together in their installed configuration or tested under conditions to simulate the installed configuration.

4.7.2 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; indicators; etc. 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 selector 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.

After the cycle operation test, each component shall be visually inspected for damage. Discharge valves, selector valves, and check valves included in the test shall continue to operate and be subjected to Section 4.10 (Valve Leakage Test) at the system's working pressure. All cycled actuation components shall be used to actuate representative discharge valves at the system's working pressure. The pressure required for pneumatic operating devices shall be recorded, and manual controls shall be subjected to Section 4.16.3 (Manually Operated Controls).

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

4.8 EQUIVALENT LENGTH DETERMINATION

4.8.1 Requirement

The equivalent length for all components that cause resistance to flow and are in the flow path of an engineered clean agent system, other than discharge nozzles, shall be determined for incorporation into system design calculations. For components included in witnessed tests per Section 4.6 (Verification of Flow Calculation Tests), these tests may be waived. The equivalent lengths for all applicable components shall be included in the manufacturer's manual or flow calculation software, as applicable.

4.8.2 Tests/Verification

Each sample shall be installed between two test pipes equipped with pressure measurement devices. The test pipes shall be of the same nominal diameters as the sample. Using water as a test medium, the friction loss between the piezometer rings shall be measured at a minimum of four flow rates. The test sample shall be removed from the test configuration, and the friction losses at the same flow rates determined. The friction loss of the sample is determined by subtracting the loss of the pipe from the loss for the pipe and test sample combination. The minimum flow velocity used in testing shall be that required for completely turbulent flow, based upon the nominal pipe size of the component under test and schedule 40 pipe actual inside diameters.

A Reynolds Number above 4000 is indicative of turbulent flow. For a circular cross-section pipe, the Reynolds Number (Re) can be calculated as follows:

For U.S. Customary units:

$$\mathrm{Re} = 7741.9\frac{ud}{v}$$

Where:

Re = Reynolds Number, non-dimensional

u = velocity, ft/s

d = diameter of the fully-filled pipe, in

v = kinematic viscosity, cSt, where 1 cSt = 10^{-6} m^2/s, = approximately 1, for water at 68.4ºF (20ºC)

For SI units:

$$\mathrm{Re} = \frac{ud}{v}$$

Where:

Re = Reynolds Number, non-dimensional

u = velocity, m/s

d = diameter of the fully-filled pipe, m

v = kinematic viscosity, m^2/s

The friction loss of the sample shall be converted to an equivalent length in feet (meters) of pipe, using a Hazen-Williams coefficient of 130. For systems whose flow can have multiple phases, the use of equivalent pipe length shall be in accordance with the flow calculation method. If component designs are proportional over a range of sizes, the manufacturer may submit equivalent length data for the range. In this case, the smallest and largest sizes from this range shall be tested to verify the manufacturer's data. Alternatively, equivalent length may be determined by actual discharge of agent from the agent storage container.

Hazen-Williams Equation:

$$p = \frac{cQ^{1.85}}{C^{1.85}d^{4.87}}$$

Where:

p loss per unit length, psi/ft (kPa/m)

c constant = 4.52 for U.S. customary units (= 10.67 in SI units.)

Q flow rate, gal/min (m^3/min)

C Hazen-Williams pipe coefficient = 130

d internal pipe diameter, in (m)

4.9 AGENT STORAGE CONTAINERS

4.9.1 Construction Design

4.9.1.1 Requirements

Agent storage containers and other pressurized containers shall be fabricated, tested, certified, equipped, and provided with markings and labeling in accordance with recognized international standards, such as the current specifications of the ASME BPVC-CC-N Section VIII, U.S. Department of Transportation, Title 49, Code of Federal Regulations, Parts 171 to 180, or equivalent local standard. The container's working pressure shall be suitable for the pressure at the manufacturer's maximum specified installation temperature.

4.9.1.2 Tests/Verification

All documentation concerning the fabrication and testing of the containers 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.
- Verification that the design is in accordance with the standard. Typical verification includes a review of manufacturing certification to the standard, minimum wall thickness calculations, authorized materials, material tests, and general chemical analysis tests.

4.9.2 Long Term Leakage Test

4.9.2.1 Requirement

Agent storage container assemblies for vaporizing liquid agents shall not leak in excess of 0.5 percent of the minimum system charge weight when monitored over a one year period at 70°F ± 5°F (21°C ± 3°C). The allowable leakage value is based upon a 2 to 1 safety factor applied to a maximum 5 percent total leakage over a five year inspection period. Agent storage container assemblies for inert gas agents shall not leak in excess of the mass equivalent to 0.5 percent of the nominal storage pressure, based upon the minimum size container specified 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 five year inspection period

4.9.2.2 Tests/Verification

For vaporizing liquid agents, a minimum of three sample agent storage container assemblies representative of each valve design and size shall be filled with the applicable clean agent at the maximum specified fill density and pressurized to the system's working pressure. For inert gas agents, containers shall be pressurized to the system's working pressure. Test sample assemblies shall incorporate all components subjected to the working pressure, including any operating devices that are exposed to the system pressure upon installation. For vaporizing liquid agents, the test shall be performed for all agent storage container installation orientations specified by the manufacturer.

Each sample shall be weighed at 0, 1, 3, 6, and 12 months, and where applicable, the projected weight loss over a one year period shall be extrapolated. The test shall be suspended if the calculated leakage at any time exceeds the allowable quantity. Subsequent to the 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 for minor modifications to previously certified configurations, such as a new seal or any change to a leak path, shall be reduced to 6 months.

4.9.3 30-Day Maximum Temperature Leakage Test

4.9.3.1 Requirements

Agent storage container assemblies shall not leak in excess of 0.042 percent 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 4.9.2.1.

4.9.3.2 Tests/Verification

A minimum of three agent storage container assemblies representative of each valve design and size shall be prepared as described in Section 4.9.2.2. For vaporizing liquid agents, the test shall be performed for all agent storage container installation orientations specified by the manufacturer.

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 be weighed to determine the amount of extinguishing agent lost. One sample representative of each design and size shall be successfully discharged using one of the manufacturer's compatible operating devices.

4.9.4 30-Day Minimum Temperature Leakage Test

4.9.4.1 Requirements

Agent storage container assemblies shall not leak in excess of 0.042 percent when conditioned to the specified minimum 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 4.9.2.1. For vaporizing liquid agents, the test shall be performed for all agent storage container installation orientations specified by the manufacturer.

4.9.4.2 Tests/Verification

A minimum of three sample agent storage container assemblies representative of each valve design and size shall be prepared as described in Section 4.9.2.2. For vaporizing liquid agents, the test shall be performed for all agent storage container installation orientations specified by the manufacturer.

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 be weighed to determine the amount of extinguishing agent lost. One sample representative of each design and size shall be successfully discharged using one of the manufacturer's compatible operating devices.

4.9.5 Hydrostatic Integrity

4.9.5.1 Requirement

Agent storage containers shall be hydrostatically tested without failure at a pressure equal to 1.5 times the rated pressure of the agent storage container pressure relief device, or in accordance with the standard to which it is designed, whichever pressure is greater. No cracking, fracture, or failure to retain the test pressure shall be allowed.

4.9.5.2 Tests/Verification

Each sample shall be subjected to the required test pressure, using water as the pressurizing medium. For the 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 specified 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 4.1.1.2) 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.

Physical testing may be waived for pressure vessels being manufactured under continuous surveillance to a recognized pressure vessel regulation. In these circumstances, in lieu of physical testing, the manufacturer shall provide documentation detailing continuous oversight of the pressure vessel manufacturing, sample test results appropriate to the regulation, and certification documentation for the overseeing body.

4.9.6 Permanent Volumetric Expansion

4.9.6.1 Requirement

Permanent volumetric expansion testing is required under some pressure vessel standards. If required by the standard to which the storage container 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 local standard. 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.

4.9.6.2 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 specified 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.

Physical testing may be waived for pressure vessels being manufactured under continuous surveillance to a recognized pressure vessel regulation. In these circumstances, in lieu of physical testing, the manufacturer shall provide documentation detailing continuous oversight of the pressure vessel manufacturing, sample test results appropriate to the regulation, and certification documentation for the overseeing body.

4.9.7 Shock and Vibration for Horizontal Transport

4.9.7.1 Requirement

For agent storage container assemblies that utilize a siphon tube and are specified to allow horizontal transport, a representative fully charged agent storage container shall withstand exposure to shock and vibration to simulate truckload shipment. The system shall remain operable, shall not experience dislodgement or deformation of the system's siphon tube, shall resist leakage or cracking, and shall not experience other damage or deterioration that requires repair or replacement of the unit.

Following the completion of these tests, the system shall be successfully discharged using one of the manufacturer's compatible operating devices and disassembled to confirm the siphon tube has not dislodged or deformed.

This test does not apply to agent storage container assemblies that have been successfully tested to Section 4.25.3 (Vibration and Shock Resistance Tests).

4.9.7.2 Tests/Verification

At minimum, the agent storage container assembly of each design and diameter with the longest siphon tube shall be tested. Each sample shall be filled with the appropriate clean agent to the minimum specified fill density and pressurized to the working pressure. Each sample shall be representatively packaged and subjected to the test sequences #1, #3 (Horizontal Impact), and #6, in order and as described in ISTA 3E. All applicable tests shall be run in the horizontal orientation on the same sample.

4.10 VALVE LEAKAGE TEST

4.10.1 Requirement

Discharge valves shall not display visible leakage when subjected to a pressure equal to the nominal rating of the system's pressure relief device for one minute. Selector and check valves shall not leak more than 1 fluid ounce (29.6 ml) per inch of nominal valve size per hour when subjected to a pressure equal to one-half the nominal rating of the pressure relief device by which it is protected or one-half of the cylinder test pressure, as applicable, whichever is higher.

4.10.2 Tests/Verification

The outlet of the valve shall remain open and the valve inlet shall be pressurized using water as the pressurizing medium until the required pressure is achieved. The required pressure shall be maintained for one minute for discharge valves, or at least one minute for selector and check valves. If leakage is observed in selector or check valves during the initial one minute test period, the test shall be continued for an amount of time needed to capture enough water for a measurement.

These tests may alternatively be performed using nitrogen as the pressurizing medium with the component completely submerged in a water bath. If this method is used, no visible leakage shall be allowed for a one minute test period.

If a valve design is such that leakage is likely to occur at a lower pressure than half the pressure relief device's setting, the valve shall also be tested at the lowest appropriate pressure.

4.11 HYDROSTATIC PRESSURE TEST

4.11.1 Requirement

All system components subjected to pressure, either during storage or during system discharge, shall withstand the appropriate pressure described in Section 4.11.2 for one minute. No cracking, fracture, or failure to retain the test pressure shall be permitted.

4.11.2 Tests/Verification

The required test pressure for each system component is as follows:

- For discharge valves and other components subject to a pressurized container and/or full flow or pneumatic control line conditions, the pressure equal to 1.5 times the rated pressure of the pressurized container's pressure relief device, or the test pressure in accordance with the applicable published pressure vessel standard, whichever is greater
- For other components protected by a pressure relief device, the pressure equal to 1.5 times the rated pressure of the pressure relief device by which it is protected
- For components subjected to a reduced pressure (e.g., by a constant pressure discharge valve, regulator, pressure reducing orifice, etc.), the pressure equal to four times the maximum reduced pressure to which it is subjected
- For components protected by a pressure relief device and subjected to a reduced pressure, the lower of the two pressures described above
- For components not protected by a pressure relief device, four times the maximum pressure to which it is subjected

Each sample shall be subjected to the required test pressure. 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 shall be acceptable during the hydrostatic pressure tests if the pressure source can maintain the required test pressure for the duration.

4.12 PRESSURE RELIEF DEVICES

4.12.1 Pressure Relief Operation

4.12.1.1 Requirement

For each pressure relief device used to protect pressurized containers, the average operating pressure 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 maximum operating pressure of the container. In addition, no individual tested sample shall operate outside of these pressure constraints.

For all other pressure relief devices used in the system, the operating pressure of the device shall be within ±10 percent of the manufacturer's specified rating.

4.12.1.2 Test/Verification

A minimum of 30 pressure relief device assemblies of each type 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, and then shall be increased until operation at a rate no greater than 10 percent per minute. The operating pressure shall be recorded.

4.12.2 Pressure Relief Calculations

4.12.2.1 Requirement

The ratings for pressure relief devices for pressurized containers and valve assemblies shall be selected as specified in Section 3.2.8. Documentation shall be submitted to verify that the construction and size of the 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.

4.12.2.2 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 S-1.1 or equivalent.

4.13 MOUNTING DEVICE TEST

4.13.1 Requirement

An extinguishing system mounting bracket or assembly shall not show evidence of permanent distortion or other damage when subjected to a static load equal to five times the fully charged weight of the extinguishing system.

4.13.2 Test/Verification

A representative extinguishing system mounting bracket or assembly shall be assembled in its specified orientation. A static load equal to five times the fully charged weight of the system, but not less than 100 pounds (45.3 kg), shall be applied vertically downward on the appropriate loading point, and 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 components that are specified to be directly supported by the floor.

4.14 FLEXIBLE HOSES

4.14.1 Low Temperature Resistance

4.14.1.1 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 4.11 (Hydrostatic Pressure Test) for a period of one minute. No cracking, fracture, or failure to retain the test pressure shall be permitted.

4.14.1.2 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. Bending shall be performed smoothly and continuously within an approximate 10 second time interval.

The flexible hose shall be visually inspected for cracking or other damage. Subsequent to this inspection, 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.

4.14.2 Resilience

4.14.2.1 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 4.11 (Hydrostatic Pressure Test) for one minute. No cracking, fracture, or failure to retain the test pressure shall be permitted.

For hydraulic hoses only that are manufactured to an internationally recognized standard, such as SAE J517 or equivalent local standard, and suitably rated for the system working pressure, this test shall be waived.

4.14.2.2 Test/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.

The flexible hose shall be visually inspected for cracking or other damage. Subsequent to this inspection, 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.

4.15 LIQUID LEVEL INDICATORS

4.15.1 Requirements

For vaporizing liquid agents only, a liquid level indicator shall accurately indicate the quantity of clean agent contained in an agent storage container within a tolerance of ± 2.5 percent. Other methods for monitoring the agent quantity in an agent storage container (e.g., continuous weight monitoring devices) shall be evaluated to the same tolerance.

4.15.2 Tests/Verification

Sample agent storage containers shall be individually filled with the minimum and maximum specified fill densities. The containers shall be weighed, and the agent weight shall be recorded. 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.

The samples shall be 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 24 hours. Subsequent to each conditioning period, the liquid level in the container shall be measured, and the agent weight calculated based on the manufacturer's liquid level indicator charts, tables, or equations. The calculated weight shall be compared to the actual agent weight in the container. The calculated weight shall be within ± 2.5 percent of the measured value.

4.16 CONTROL AND ACTUATOR OPERATION

4.16.1 General

4.16.1.1 Requirement

All control devices necessary for system operation shall operate under the most adverse system pressure when conditioned to the maximum and minimum specified installation temperatures, as applicable.

4.16.1.2 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 a representative valve for which it is designed at the pressure corresponding to the test temperature, if applicable, and operated and shall display no hesitation, 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.

4.16.2 Electrically Operated Devices

4.16.2.1 Requirement

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

4.16.2.2 Tests/Verification

A minimum of one sample of each device shall be conditioned in accordance with the parameters described in Section 4.16.1.2. 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.

4.16.3 Manually Operated Controls

4.16.3.1 Requirement

Manually operated control devices 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.

4.16.3.2 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's 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.

4.16.4 Pneumatically Operated Controls

4.16.4.1 Requirement

Pneumatically operated control devices and pneumatically operated master-secondary agent cylinder arrangements of the most adverse specified configuration(s) shall operate all connected agent storage containers within one second of each other.

4.16.4.2 Tests/Verification

The pneumatic control assembly or master agent cylinder shall be pressurized to its working pressure and conditioned to the minimum specified storage temperature for 16 hours; inert gas cylinders only may instead be pressurized to the pressure corresponding to the minimum specified storage temperature. Secondary agent cylinders shall be pressurized to their working pressures and conditioned to the maximum specified storage temperature for 16 hours, or pressurized to the pressure corresponding to the maximum specified storage temperature. The maximum number of secondary agent cylinders shall be connected to the pneumatic control assembly or master agent cylinder through the most restrictive piping arrangement permitted by the manufacturer's installation instructions.

An automated data acquisition system, capable of recording pressure readings for the pneumatic control assembly and/or the master agent cylinder, as applicable, and most remote secondary agent cylinder at a minimum of 10 Hz, shall be used to record the timing. For systems actuated by a pneumatic control assembly, the pneumatic control assembly be actuated, and the time interval between the operation of the first secondary agent cylinder and the last secondary agent cylinder shall be measured. For systems actuated by a pneumatically operated master-secondary agent cylinder arrangement, the master agent cylinder shall be actuated, and the time interval between operation of the master agent cylinder and the last secondary agent cylinder shall be measured. The most remote secondary agent cylinder shall operate within one second of the first significant pressure decrease in the master agent cylinder or first secondary agent cylinder, as applicable.

For inert gas systems using back pressure actuation, if the maximum number of secondary agent cylinders exceeds 20, the data obtained from tests of 10 and 20 cylinders can be extrapolated to the maximum number of cylinders to determine whether operation can be expected within the maximum allowable 1 second interval.

4.16.5 Mechanical Time Delay Assemblies

4.16.5.1 Requirement

Mechanical time delay assemblies shall delay the actuation of a system within -0/+20 percent of the manufacturer's specified delay time, throughout the stated operational temperature range and range of time delay settings.

4.16.5.2 Tests/Verification

The time delay unit shall be adjusted to the minimum delay time setting, if applicable, and conditioned at the minimum specified installation temperature for 16 hours. While still at the minimum installation temperature, the assembly shall be pressurized to the minimum working pressure, and the time delay until release of the pressure shall be recorded. The test shall be repeated with the assembly adjusted to the maximum time delay setting, and then again with the assembly adjusted to an intermediate setting.

The assembly shall be adjusted to the minimum delay time setting, if applicable, and conditioned at the maximum specified installation temperature for 16 hours. While still at the maximum installation temperature, the assembly shall be pressurized to the maximum working pressure, and the time delay until release of the pressure shall be recorded. The test shall be repeated with the assembly adjusted to the maximum time delay setting, and then again with the assembly adjusted to an intermediate setting.

These tests shall be all be performed on the same sample if the delay time is adjustable, or on two separate samples representing the minimum and maximum delay times if the delay time is fixed.

4.16.6 Pressure Operated Audible Alarm Devices

4.16.6.1 Requirement

Pressure operated audible alarm devices shall operate effectively and continuously without failure throughout their operable pressure range, with a minimum sound level of 90 decibels measured 10 feet (3.05 m) from the device.

4.16.6.2 Tests/Verification

The device shall be mounted not less than 10 ft (3.05 m) above the ground in its normal orientation. A sound level meter shall be positioned in a vertical plane through the device's centerline, 10 ft (3.05 m) away from the mounting plane, and 5 ft (1.5 m) above the ground. The meter shall be oriented to obtain the strongest response.

The sound meter shall comply with ANSI/ASI S1.4. Measurements are to be made using "C" weighting network and the fast response setting.

The test shall be conducted in a free field environment having an ambient noise level a minimum of 10 decibels below the measured level produced by the alarm. The alarm shall be operated at its minimum specified pressure for five hours and at the maximum specified pressure for one hour.

4.17 DIELECTRIC WITHSTAND

4.17.1 Requirement

Electrical components shall withstand an applied voltage between all terminals provided for external connections and ground, as well as between all combinations of individual connections. There shall be no dielectric breakdown or leakage current greater than 0.5mA during the exposure. Components shall continue to function normally after this test.

4.17.2 Tests/Verification

For devices with a rated voltage not exceeding 30 VAC (42.4 VDC), the test voltage shall be equal to 500 VAC (707 VDC). For all other devices, the test voltage shall be calculated as 1000 VAC plus two times the rated voltage of the circuit (1.414 times the rated voltage of the circuit for VDC). The required voltage shall be applied between each terminal and ground, and between all individual terminals. The voltage shall be increased steadily to the specified value in a period of not less than 10 seconds and maintained for a minimum of 60 seconds.

4.18 CORROSION – SALT SPRAY

4.18.1 Requirement

System components shall withstand a 240 hour exposure to the test described in Section 4.18.2 without incurring damage that would impair function. Following the exposure period, the system shall be successfully discharged using one of the manufacturer's compatible operating devices.

4.18.2 Tests/Verification

Test samples shall be selected to represent all critical material combinations, paint systems, and configurations. A minimum of one agent storage container assembly with the nameplate affixed and including the mounting bracket in the installed configuration, 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 at maximum, but need not contain the actual agent. Due to safety considerations, test sample agent storage containers may be tested unpressurized if they can be later pressurized for the required post-exposure testing

without compromising the post-exposure conditions. Discharge nozzles manufactured from a corrosion resistant material are not subject to salt fog testing if material specifications are submitted to the certification agency for review and found acceptable.

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, each sample shall remain fully functional and exhibit no corrosion, galvanic action, loss of legibility of markings, or separation of protective coatings that 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 operating devices.

4.19 CORROSION – STRESS CRACKING

4.19.1 Requirement

Extinguishing system components critical to system function shall be resistant to stress corrosion cracking resulting from exposure to the processes described in Section 4.19.2. Following the exposure period, the samples shall not show evidence of cracking, delamination, or degradation that could impair function.

4.19.2 Test/Verification

4.19.2.1 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) so as 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 the test. The samples shall be tested in their specified 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 5.86×10^{-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.

4.19.2.2 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 G36.

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.

4.19.2.3 Parts Manufactured from Other Materials

Parts manufactured from other materials shall withstand comparable tests, based on the type of material employed.

4.20 HIGH TEMPERATURE EXPOSURE

4.20.1 Requirement

Components, such as nozzles, that are exposed to the protected space and are subject to clean agent flow, shall not show significant deformation, blistering, or fracture following exposure to an elevated temperature as detailed in Section 4.20.2. In the case of a nozzle, no cracking or distortion that would potentially alter discharge characteristics shall be allowed.

4.20.2 Test/Verification

The component shall be placed in an oven and heated to 1470 ± 20 ºF (800 ± 11ºC) for a period of 15 minutes. Components that are used on the same assembly as a heat responsive element, or that are only allowed for use in applications where smoke detection is the primary means of detection, shall be placed in an oven and heated to 450 ± 20 ºF (230 ± 11ºC) for a period of 15 minutes. Following the appropriate exposure, the component shall be removed and promptly submerged in a water bath with a temperature of 60 ± 10 ºF (15 ± 6ºC).

4.21 AGING TESTS – PLASTIC MATERIALS

4.21.1 Air-Oven Aging Test

4.21.1.1 Requirements

Nonmetallic components critical to system function, including valves, valve parts, siphon tubes and other parts subjected to the flow of clean agent, and mounting brackets, shall be subjected to air-oven aging tests at 212ºF (100ºC). 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 4.11 (Hydrostatic Pressure Test), agent storage containers shall be subjected to the requirements of Section 4.9.5 (Hydrostatic Integrity), and mounting brackets shall be subjected to the requirements of Section 4.7 (Mounting Device Test).

4.21.1.2 Test/Verification

Samples shall be subjected to air-oven aging tests for 180 days at 212ºF (100ºC), and then allowed to cool a minimum of 24 hours in air at 74ºF (23ºC) at 50 percent relative humidity. This test may be accelerated by increasing the test temperature in increments on 10ºC; for every 10ºC increase, the test duration may be reduced by half. 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 4.21.1.1.

4.21.2 Ultraviolet Light and Water Test

4.21.2.1 Requirements

Nonmetallic components critical to system function, 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 4.11 (Hydrostatic Pressure Test). Mounting brackets shall be subjected to the requirements of Section 4.13 (Mounting Device Test).

4.21.2.2 Test/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 4.21.2.1.

4.21.3 Exposure to Clean Agent Test

4.21.3.1 Requirements

Plastic siphon tubes or other plastic components subject to the flow of clean agent shall not show any signs of degradation following exposure to the clean extinguishing agent.

4.21.3.2 Test/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 clean extinguishing agent. Non-cylindrical samples 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 90 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 signs of degradation.

4.22 SOUND POWER LEVEL DETERMINATION FOR NOISE-REDUCING DISCHARGE NOZZLES

4.22.1 Requirement

Discharge nozzles and assemblies specified for use in acoustically sensitive environments shall be evaluated to determine the sound power level of the nozzle within a range of relevant frequencies at worst-case conditions, or at other manufacturer-defined conditions.

4.22.2 Tests/Verification

The manufacturer shall submit available documentation specifying the sound power level of the nozzle as a function of frequency for specific system configurations and operating conditions. The certification agency will review this information to determine the appropriate test conditions at which to perform the verification tests.

Sound power levels shall be determined according to ANSI 12.53/ISO 3743 or ANSI 12.54/ISO 3744, or equivalent.

Sound power levels shall be determined in one-third octave bands over a range of mid-band frequencies from 500 to 10,000 Hz. This range may be adjusted depending on the intended application. In addition, the Z-weighted sound power level shall be determined.

Each measurement shall consider the entire duration of the discharge and a suitable time interval shall be selected for determining the sound power levels. It shall be demonstrated that this interval captures the peak sound power levels observed during the discharge.

The system configuration(s) and operating condition(s) necessary to obtain the worst-case sound power level, or to reproduce the manufacturer-defined conditions, shall be determined with consideration to factors including:

- Discharge flow rate
- Nozzle pressure
- Nozzle orifice size
- Type of extinguishing agent
- Agent storage container working pressure
- Agent storage container storage temperature

The following information shall be reported:

- Sound power levels in one-third octave bands across the required frequency range, in decibels (dB re 1 pW)
- Z-weighted sound power level, in decibels (dB re 1 pW)

4.23 PRESSURE GAUGES AND INDICATORS AND SUPERVISORY PRESSURE SWITCHES

4.23.1 Accuracy

4.23.1.1 Requirement

Agent supply container and pneumatic control assembly pressure gauges or indicators shall exhibit accuracy within the limits of Table 4.23.1.1.

Table 4.23.1.1 *Pressure Gauge Limits*

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

Supervisory pressure switches shall activate within ±6 percent of the low pressure alarm point under falling pressure. Supervisory pressure switch samples shall 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.

4.23.1.2 Test/Verification

Readings of a minimum of three sample agent storage container gauges 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. Supervisory pressure switches shall be activated under falling pressure and the activation point shall be compared to the reading of a calibrated test gauge having a minimum accuracy of ±1 percent. All sample gauge readings and pressure switch activation points shall match those of the test gauge within the tolerances specified in Section 4.23.1.1.

4.23.2 Impulse Resistance

4.23.2.1 Requirement

Pressure gauge and supervisory pressure switch accuracy shall remain within the limits of Table 4.23.1.1 after 1000 cycles of pressure impulse as follows:

- from 40 to 175 percent of the system's working pressure for vaporizing liquid systems
- over the operable pressure range for inert gas systems

4.23.2.2 Test/Verification

One representative sample gauge and switch of each design shall be connected to an apparatus capable of varying pressure from over the range described in Section 4.23.2.1 and cycled over the applicable range. After 1000 cycles have been completed, the sample shall be retested for accuracy as described in Section 4.23.1.

4.24 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.

4.24.1 Assembly Load/Frame Strength

4.24.1.1 Requirements

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.

4.24.1.2 Test/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 working pressure. The amount of permanent set after the load application shall be determined.

4.24.2 Strength of Heat Responsive Element

4.24.2.1 Requirements

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 D.

4.24.2.2 Test/Verification

The results of Section 4.24.1 (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 that conform to the actual mating components of the automatic operating device. The inserts shall have a hardness within the range Rockwell C 38-50 (see Figure E-7). 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 D, Tolerance Limit Calculations.

4.24.3 Hydrostatic Strength

4.24.3.1 Requirements

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

4.24.3.2 Test/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.

4.24.4 Operating Temperature (Liquid Bath)

4.24.4.1 Requirements

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.

4.24.4.2 Test/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 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.

4.24.5 Pneumatic Detection Tubing

4.24.5.1 Requirements

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

4.24.5.2 Tests/Verification

Pneumatic detection tubing shall be subjected to Sections 4.2.2.3 (Automatic Extinguisher Unit Automatic Operation Fire Tests), 4.9.2 (Long Term Leakage Test), 4.9.3 (30-Day Maximum Temperature Leakage Test), 4.9.4 (30-Day Minimum Temperature Leakage Test), and 4.21 (Aging Tests – Plastic Materials), as applicable, as part of the 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.

4.25 SUPPLEMENTAL TESTS FOR MARINE APPLICATIONS

Based on design features or installation requirements, the following performance requirements shall supplement those listed elsewhere in this standard for marine applications. Additional tests may be required depending on design features, results of any tests, or material application.

4.25.1 Wiring

System wiring in a protected volume that is necessary for the system to operate and maintain the specified clean agent design concentration shall be mineral insulated.

4.25.2 Controls and Indicators

4.25.2.1 An actuation indicator, designating system discharge, shall be provided outside of an unoccupied protected space in a readily visible location. The actuation indicator is not required where the pressure gauge of an agent storage container is located outside of the protected space in a visible location. Units in unoccupied spaces shall also be provided with a pressure switch that, when operated, activates a warning light or provides a means for ventilation or engine shutdown.

4.25.2.2 A reset mechanism, located at the helm, capable of restarting the engine(s) in a protected space following engine shutdown, shall be provided for installations incorporating an engine shutdown device.

4.25.3 Vibration and Shock Resistance Tests

4.25.3.1 Requirements

A fully charged extinguishing system 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 that requires repair or replacement of the unit, mounting bracket, or system components. At minimum, the largest unit using a given bracket shall be tested.

All applicable shock and vibration tests shall be run 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.

Vibration testing is required for all systems specified for marine applications. Shock testing is only required for automatic extinguisher units and pre-engineered systems.

4.25.3.2 Test/Verification

4.25.3.2.1 Vibration Test

The test sample shall be assembled in either the horizontal, lateral, or vertical orientation. The sample shall then be vibrated over the range of 10 – 60 Hz at intervals of 2 Hz at the table displacement specified below. Each frequency of vibration shall be maintained for 5 minutes.

Table 4.25.3.2.1 *Amplitude of Vibration*

Frequency of Vibration, Hertz	Table Displacement inch	(mm)	Amplitude inch	(mm)
10 – 19	0.060 ± 0.006	(1.52 ± 0.15)	0.030 ± 0.003	(0.76 ± 0.08)
20 – 39	0.040 ± 0.004	(1.02 ± 0.10)	0.020 ± 0.006	(0.51 ± 0.05)
40 – 60	0.020 ± 0.002	(0.51 ± 0.05)	0.010 ± 0.001	(0.25 ± 0.03)

The sample shall subsequently be vibrated for 2 hours at the frequency that produced the maximum resonance observed during the initial vibration. If no resonance was initially observed, the sample shall be vibrated for 2 hours at a frequency of 60 Hz. In either case, the table displacement shall be as specified in Table 4.25.3.2.1.

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.

4.25.3.2.2 Shock Resistance Test

The test sample shall be mounted on a shock machine and subjected to 5000 shock impacts. Each impact shall have an acceleration of 10g, or 322 ft/s2 (98 m/s2), and a duration of 20 – 25 milliseconds as measured at the base of the half sine shock envelope.

4.25.3.2.3 Vibration and Shock Resistance Post Tests

Subsequent to the completion of the vibration and shock resistance tests, the sample shall be successfully discharged using one of the manufacturer's compatible operating devices. The sample shall then be disassembled and visually inspected for damage. Mounting brackets shall be subjected to Section 4.13 (Mounting Device Test).

4.25.4 Nozzle Distribution Verification Tests

For extinguishing systems or automatic extinguisher units that are limited by a maximum volume of protection, the performance requirements described in Section 4.2 (Nozzle Distribution Verification Tests) shall be repeated with an air flow equal to one air change per minute.

For these tests, the test enclosures shall additionally include one opening with an area equal to 1 ft^2 (0.09 m^2) within 12 in (0.3 m) of the top of the enclosure, and another opening with an area equal to 1 ft^2 (0.09 m^2) 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.

These tests shall be conducted at the design concentration, rather than the minimum extinguishing concentration. Testing shall performed in both the minimum room height test enclosure, that shall include the maximum area of coverage for the unit, and the maximum room height test enclosure, that shall include the maximum specified protected volume for the unit. The extinguisher shall be conditioned to 70°F ±5°F (21°C ±1.8°C) for these tests.

4.25.5 Minimum Floor Clearance

Extinguishing systems specified for marine applications that are floor supported shall be designed to have a minimum of 2 in. (50.8 mm) of clear space between the bottom of the container and the deck to address potential corrosion concerns.

4.26 AGENT COMPONENT CERTIFICATION TESTS

In addition to displaying successful performance in the Class A and B fire extinguishment tests of Section 4.1, a new clean agent shall undergo additional evaluations, as described below to secure component certification. Any agent used in a system submitted for certification shall either be component certified for that purpose or shall be evaluated as follows on the system manufacturer's behalf.

4.26.1 Agent Acceptability for Use

4.26.1.1 Requirement

Clean agents shall be acceptable for use as a prerequisite to consideration for certification.

4.26.1.2 Tests/Verification

The agent shall be specifically included in NFPA 2001 or equivalent local standard.

4.26.2 Metals Compatibility

4.26.2.1 Requirement

New clean extinguishing agents shall be compatible with metals commonly used in fire protection systems or intended for use with the agent.

4.26.2.2 Tests/Verification

Two 1 in. (25 mm) diameter or square coupons of each test metal shall be exposed to 100 percent extinguishing agent vapors in an enclosed chemically inert vessel with working pressure sufficient to contain the agent vapor pressure at ambient pressure and temperature for 7 days. At minimum, test coupons will include 0.002 in. (0.05 mm) thick copper, 0.002 in. (0.05 mm) thick steel, and 0.001 in. (0.03 mm) thick aluminum. Weight change of each coupon shall be measured. There are no pass/fail criteria for this test. Results are used to assess the need for further testing when the agent is used in systems if the agent appears aggressive toward a general type of metal used in the system under evaluation.

4.26.3 Polymer Compatibility

4.26.3.1 Requirement

New clean extinguishing agents shall be compatible with polymers commonly used in fire protection systems or intended for use with the agent.

4.26.3.2 Tests/Verification

Two 1 in. (25 mm) diameter or square, 0.0625 in. thick (25 mm diameter x 1.6 mm) coupons of each polymer shall be exposed to 100 percent extinguishing agent vapors in an enclosed chemically inert vessel with working pressure sufficient to contain the agent vapor pressure at ambient pressure and temperature for 7 days. At minimum, Viton (fluorocarbon), Neoprene, Silicon, and Polyurethane rubbers shall be tested. Change in weight (gain or loss) shall be measured. There are no pass/fail criteria for this test. Results are used to assess the need for further testing when the agent is used in systems if the agent appears aggressive toward a general type of polymer used in the system under evaluation.

4.26.4 Agent Quality

4.26.4.1 Requirement

Clean agents shall meet the quality requirements of Table 4.26.4.1 at minimum.

Table 4.26.4.1 *Clean Agent Quality Requirements*

Agent Type	Property	Requirement
Halocarbon	Purity, mole percent, minimum	99.0
Halocarbon	Acidity, ppm, by weight (HCl equivalent), maximum	3.0
Halocarbon	Water content, weight percent, maximum	0.001
Halocarbon	Nonvolatile residues, g/100 ml, maximum	0.05
Inert Gas (monomolecular)	Purity, volume percent, minimum	99.9
Inert Gas (blend)	Blend component percentages	Manufacturer's Specification
Inert Gas (all)	Water content, weight percent, maximum	0.005

4.26.5 Agent Identification Benchmarking

4.26.5.1 Requirement

The agent shall be subjected to a Fourier transform infrared spectroscopy (FTIR) analysis to obtain a benchmark profile for future reexamination reference.

4.26.5.2 Tests/Verification

A sample of each clean agent submitted for certification shall be subjected to a Fourier Transform Infrared (FTIR) analysis. This sample shall be taken from the same lot of agent as used in the fire extinguishment tests. The resulting spectrum shall 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.

4.26.6 Class A Extinguishing Capability

4.26.6.1 Requirement

New clean agents shall be evaluated to determine the Class A extinguishing capability.

4.26.6.2 Tests/Verification

The extinguishing concentration (volume percent) shall be determined for diffusion flames of black PMMA (3.75 in. diameter and 1 in. thick in a standard insulated sample holder) in the Fire Propagation Apparatus (ASTM E2058/ISO 12136). The PMMA sample surrounded by a 6.5-in. diameter quartz tube will be exposed to a maximum 40 kW/m^2 radiant heat flux. When the chemical heat release rate reaches a steady value, an increasing volume percent of the extinguishing agent will be introduced into the quartz tube of the test apparatus until flame extinction occurs to determine the extinguishing concentration.

4.27 CLASS C EXTINGUISHING CAPABILITY AND PRODUCTS OF DECOMPOSITION

4.27.1 Requirement

Clean Agents shall be used to protect Class C hazards in concentrations proven to be suitable for the specific hazard and only in situations where the products of decomposition are tolerable.

4.27.2 Tests/Verification

Certification agencies and others in the fire protection community are attempting to develop appropriate tests to assess energy augmented combustion Class C extinguishing capability for clean agents. At present, no clear consensus exists on a test method. There is also concern with the products of decomposition that are generated when clean agents are used on hazards involving persistent sources of ignition energy. Until acceptable methodology is developed, there will be no required evaluation for these characteristics, but guidelines for the protection of low voltage (equal or less than 480 volts) Class C hazards established in NFPA 2001 for or equivalent local standard shall be followed.

Appendix G describes the method used to evaluate the ability of various clean agents to suppress combustion in PMMA sheathes on the electrodes, and to generate products of decomposition for analysis and quantification. This testing is available to interested clean agent manufacturers who wish to compare the performance of their products to that of Halon 1301, or establish a minimum extinguishing concentration for high power equipment (2000 W or greater), but this is not a requirement for certification.

When appropriate test methodology has been developed for low voltage energy augmented combustion, this section will be revised to address Class C extinguishing capability and measurement of products of decomposition. This testing will then become a requirement for certification of clean agents.

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
- Final inspection and tests
- Equipment calibration
- Drawing and change control
- Packaging and shipping
- Handling and disposition of non-conforming materials

5.1.3 Documentation/Manual

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

5.1.4 Records

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

5.1.5 Drawing and Change Control

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

5.2 SURVEILLANCE AUDITS – GENERAL

5.2.1 An audit of the manufacturing facility 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 which was tested and certified.

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

5.3 SURVEILLANCE AUDITS – FILLING FACILITIES

5.3.1 All facilities utilized by a manufacturer to fill certified clean agent systems shall have an initial surveillance audit performed as part of the certification examination.

5.3.2 Each facility shall then remain part of the certification agency's surveillance program as a condition of ongoing certification.

5.3.3 Each filling facility shall be audited to ensure they meet the following requirements, at a minimum:

5.3.3.1 Facilities shall have and utilize documentation for the filling of clean agent storage containers, including drawings and procedure(s), as applicable, controlled by the manufacturer of the certified system. This procedure should address assembly, temperature compensation, leak checking, proper blending for inert gas agents, and/or pressurization for liquefied gas agents, including agitation and hold period, as applicable.

5.3.3.2 Facilities shall demonstrate quality control of critical components such as seals, valves, and agent storage containers, and have a procedure in place for non-conforming material. Alternatively, the manufacturer of the certified system may supply complete assemblies for filling.

5.3.3.3 Agent storage containers being filled shall be up to date on all qualifications and examinations in accordance with the recognized international standard(s) appropriate to each container.

5.3.3.4 The clean agent shall be traceable as certified through lot/batch numbers and/or agent manufacturer's quality reports, as applicable.

5.3.3.5 Facilities shall have a procedure in place to avoid contamination during the filling process.

5.3.3.6 Any instrumentation used for filling shall be properly calibrated and be of the appropriate range and legibility to ensure accurate measurements.

5.3.3.7 At a minimum, the following information should be recorded for each fill and properly maintained for traceability:

- Unique agent storage container or system/assembly serial number
- Order number and customer (may be recorded at a later date, as long as its traceable back to the fill)
- Fill date
- Employee name
- Empty agent storage container assembly weight
- Ambient Temperature
- Agent Temperature
- Agent fill weight and/or pressurization level, as applicable
- Filled agent storage container assembly weight
- Leak test results

5.4 MANUFACTURER'S RESPONSIBILITIES

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.

5.5 MANUFACTURING AND PRODUCTION

5.5.1 The manufacturer shall design systems in accordance with NFPA 2001 and/or any other standard specifically referenced in the certification report and listing.

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

5.5.3 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.

5.5.4 The manufacturer shall only fill storage containers with clean agent meeting the requirements of NFPA 2001.

5.6 DESIGN, INSTALLATION, OPERATING, AND MAINTENANCE MANUAL

5.6.1 A design, installation, operation, and maintenance manual, or equivalent collection of manuals, shall be provided with each extinguishing system, or be made available upon request. A copy of the manual(s) shall be provided to the certification agency as a reference prior to the examination and testing of the system. After the successful completion of the examination, an electronic copy of the manual(s) shall be provided to the certification agency for reference. Updated electronic copies of the manual shall be provided to the certification agency as revisions are made.

5.6.2 The manual(s) shall include the following information, at a minimum, as applicable:

- Manufacturer's name and address
- Part number and revision or date designation on each page of the manual
- Description of equipment and accessories, including part numbers and model numbers
- Description of the clean agent design concentration
- Safety Data Sheets
- Piping and fitting limitations
- Discharge nozzle limitations, including maximum area of coverage, minimum and maximum installation height, nozzle location, minimum design pressure, design and installation limitations for noise-reducing discharge nozzles, and design and installation limitations for the protection of anechoic chambers
- Nozzle cap and frangible seal requirements, including those used for outdoor "vent" nozzles to discharge excess agent
- Releasing force and dimensional requirements for material plugs for concealed nozzles (e.g., for the protection of anechoic chamber)
- For engineered systems, a description of the calculation method and a sample problem including all required input and calculated output, limitations on the percent of clean agent in the pipe, minimum and maximum flow rates in the pipe, and method for discharge nozzle selection including flow information and minimum and maximum orifice area limitations
- System configuration limitations and installation instructions
- Detection devices and control panels for use with the extinguishing system
- Range of filling weights for each agent storage container size
- Instructions regarding the connection of multiple agent storage containers
- System working pressure
- Allowable ambient storage temperature range, including pressure vs. temperature references for the range of fill densities
- Storage and transportation requirements, including agent storage container orientation
- Inspection requirements

- Maintenance requirements
- Recharge/refill instructions
- Reference to NFPA 2001 or other relevant local standards
- Venting requirements for the hazard enclosure to avoid damage due to excessive positive or negative pressure differentials (see Section 5.6.3 for further details)
- Acceptance test form to document satisfactory operational status of the system upon completion of installation
- Guidance on the design, installation, and usage of extract systems to ventilate enclosures after system discharge
- A clearly labeled section listing any part numbers included in the manual, but not within the scope of the certification
- A change log for revisions

5.6.3 The manufacturer shall provide guidance for the design or evaluation of protected enclosures to ensure that the pressurization caused by system design will not damage the enclosure. Such guidance shall include consideration of the minimum enclosure strength, required leakage area, and proper vent sizing requirements. For inert gas clean agents, enclosure pressurization calculations shall incorporate a discharge time 10 seconds less than that calculated in the system design to account for the allowable tolerance in the Verification of Flow Calculation Method Test of Section 4.6. For all systems, enclosure pressurization calculations shall be based upon maximum fill density agent storage containers at the manufacturer's maximum specified installation temperature.

6. BIBLIOGRAPHY

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CEA 4009, *Fire Protection Systems - Specifications for Fire Fighting Systems Using a Gaseous Extinguishant - Requirements and Test Methods for Selector Valves and Their Actuators*,.

CEA 4012, *Fire Protection Systems - Specifications for Fire Fighting Systems Using a Gaseous Extinguishant - Requirements and Test Methods for Check and Non-return Devices*.

CEA 4013, *Fire Protection Systems - Specifications for Fire Fighting Systems Using a Gaseous Extinguishant - Requirements and Test Methods for Hoses and Container Connection Pipes*

CEA 4014, *Fire Protection Systems - Specifications for Fire Fighting Systems Using a Gaseous Extinguishant - Requirements and Test Methods for Container and Valve Assemblies*

CEA 4016, *Fire Protection Systems - Specifications for Inert Gas Fire Fighting Systems: Requirements and Test Methods for Nozzles*

CEA 4045, *Fire Protection Systems - Specifications for Fire Extinguishing Systems Using Liquefied "Halocarbon" Gases - Planning and Installation*

FM 3010, *Fire Alarm Signaling Systems*

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*.

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FM Property Loss Prevention Data Sheet 4-0, *Special Protection Systems*.

FM Property Loss Prevention Data Sheet 4-9, *Clean Agent Fire Extinguishing Systems*.

ISO 14520-1, *Gaseous fire-extinguishing systems - Physical properties and system design*

ISO/IEC 17025: 2017 *General Requirements for the Competence of Testing and Calibration Laboratories*

ANSI/NFPA 72, *National Fire Alarm and Signaling Code*

ISO 9000, *Quality Management Principles*

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
Mass:	+0/-3 percent of value
Time:	+5/–0 seconds +0.1/–0 minutes +0.1/–0 hours +0.25/–0 days

Unless stated otherwise, all tests shall be carried out at a room (ambient) temperature of 68 ± 9ºF (20 ± 5ºC).

APPENDIX C:

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APPENDIX D: TOLERANCE LIMIT CALCULATIONS

Using the data obtained as described in Sections 4.24.1 (Assembly Load/Frame Strength) and 4.24.2 (Strength of Heat Responsive Element), the mean and standard deviation for the assembly load and the bulb strength shall be calculated using the following equatio n:

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

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 D1 where the degree of confidence is 0.99 and the proportion of samples is 0.99.

Table D1 γ *Factors for One-Sided Tolerance Limits for Normal Distributions (99 Percent of Samples)*

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 D1
$\sigma_{(n-1)B}$ = sample unbiased standard deviation for the bulb
$\bar{x}_S$ = mean assembly load
$\sigma_{(n-1)S}$ = sample unbiased standard deviation for the assembly load
γ_S = assembly load factor (γ) from Table D1

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

APPENDIX E: FIGURES

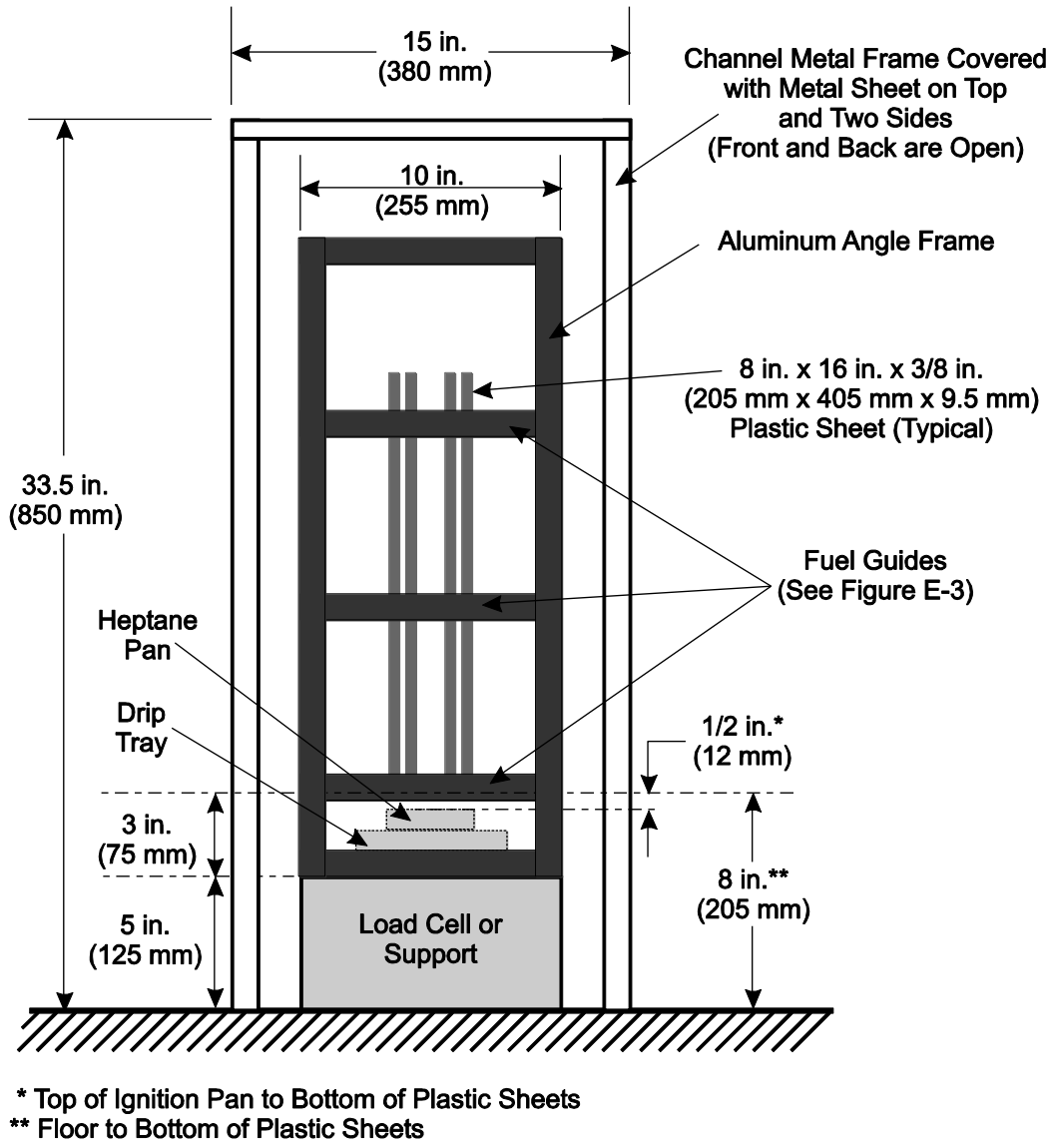


Figure E-1. Fuel Array and Inner Baffle - Front View

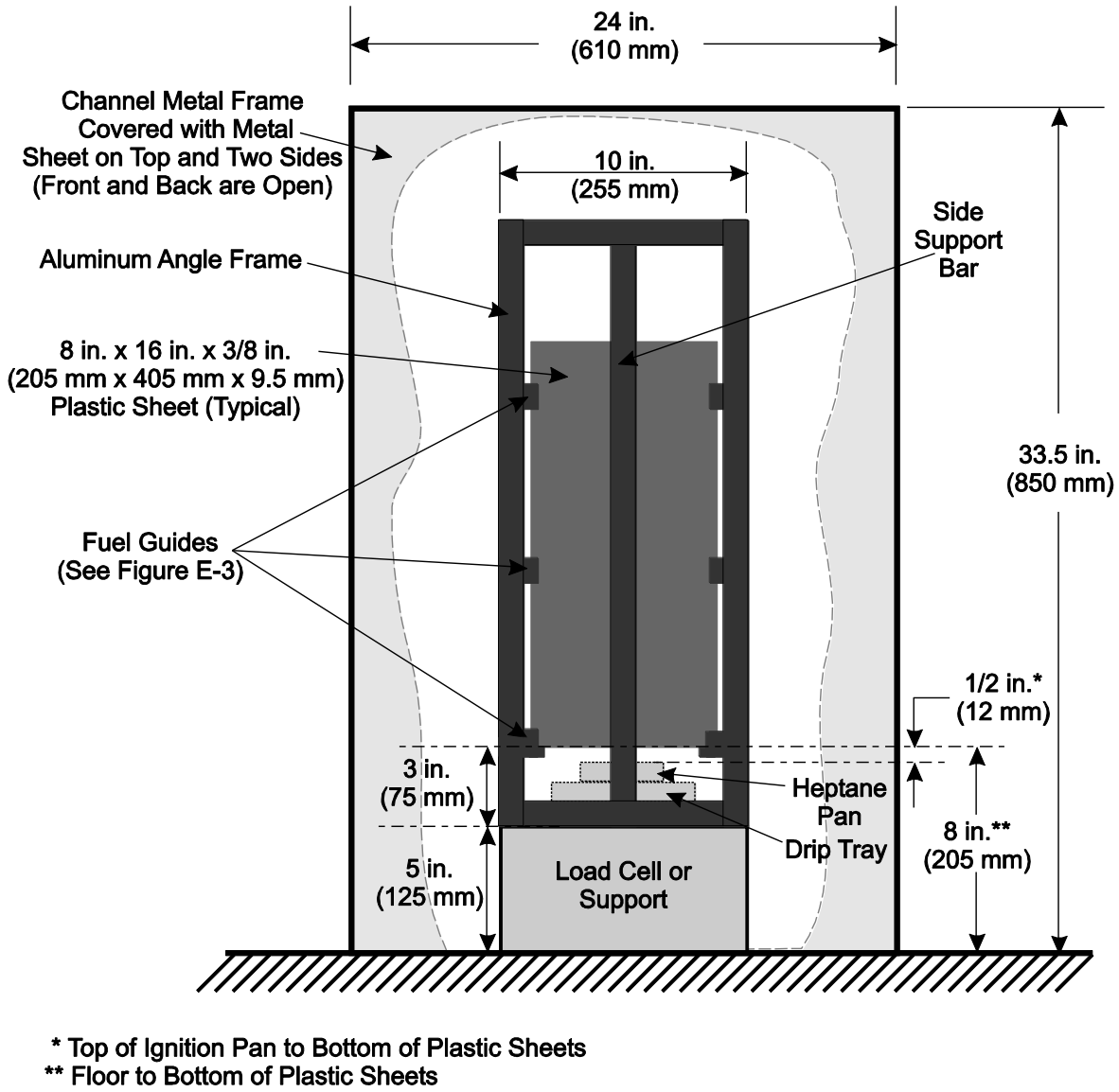


Figure E-2. Fuel Array and Inner Baffle - Side View

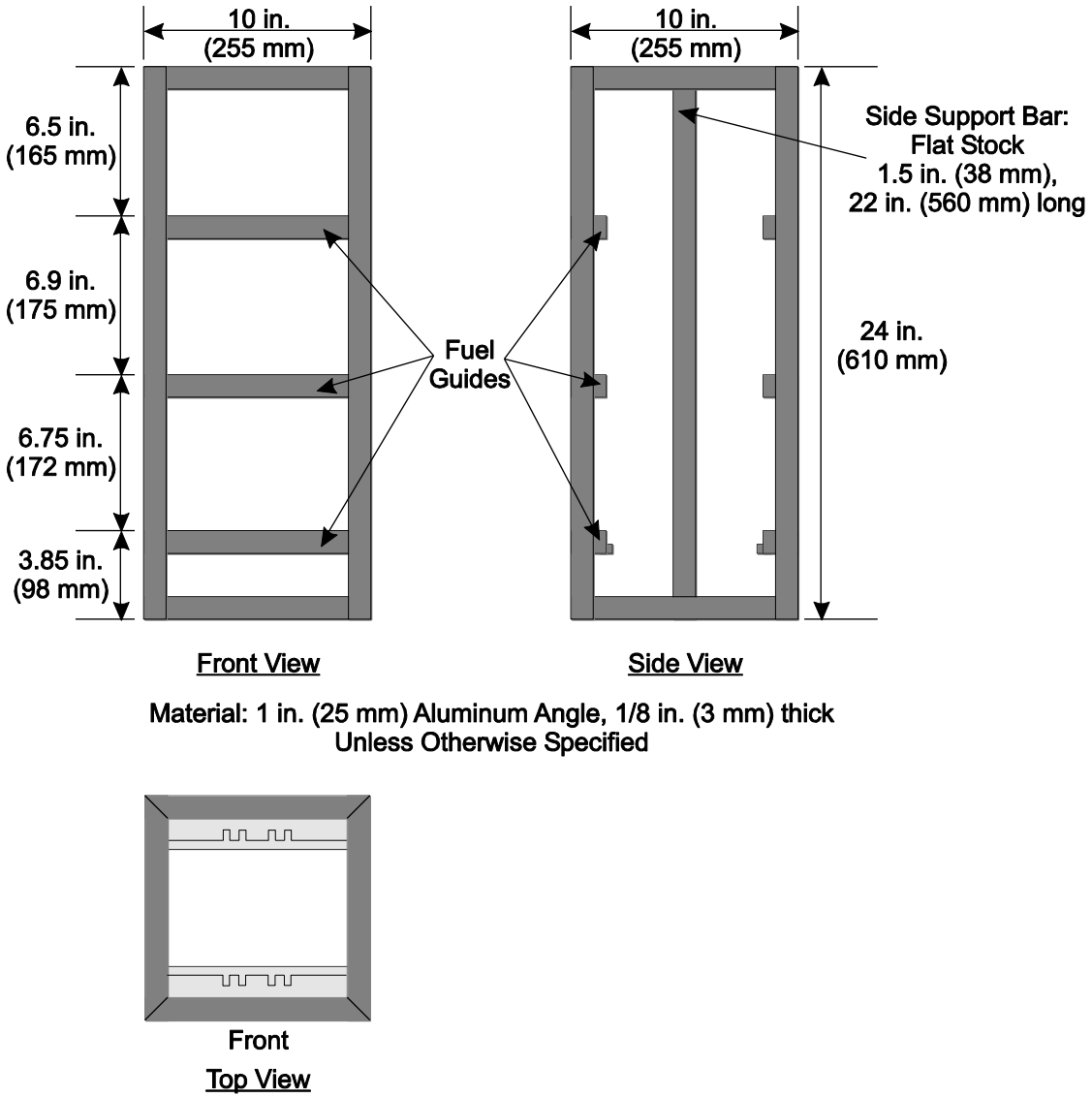
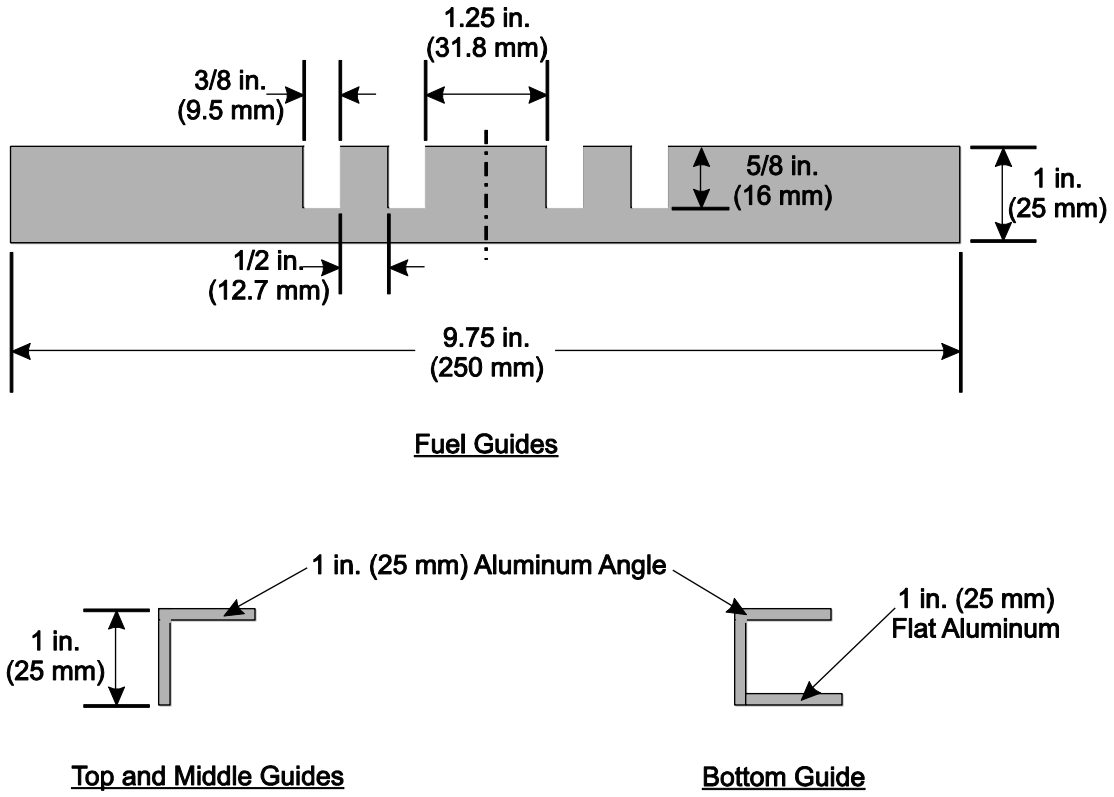
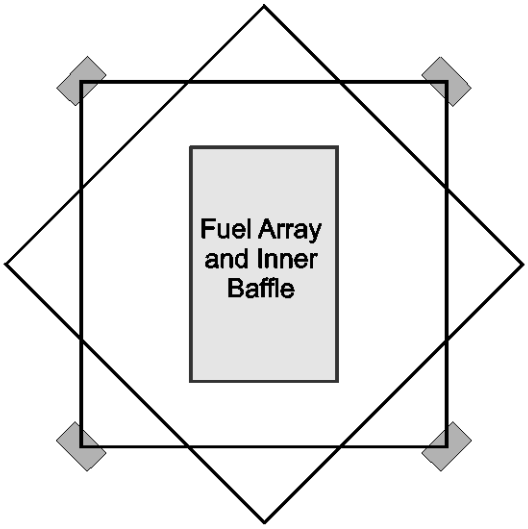


Figure E-3. Fuel Array and Inner Baffle - Detail View

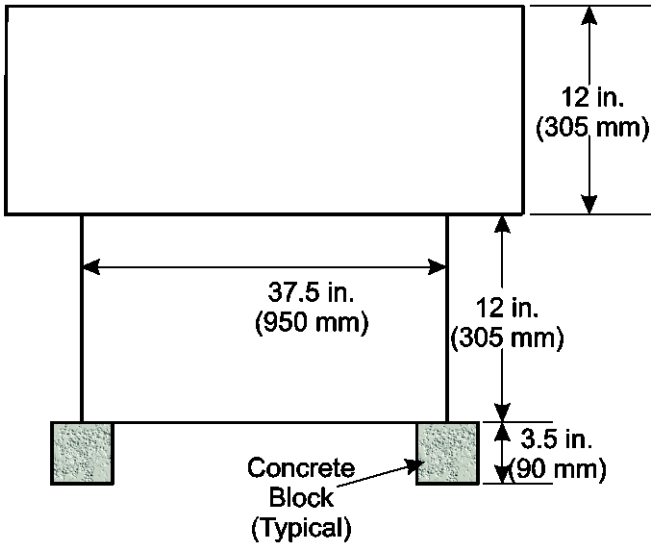


The fuel guides detailed above may use alternate construction to aide in removal of the polymeric material, provided that the spacing dimensions are maintained.

Figure E-4. Fuel Guides



Test Array Top View



Test Barrier Side View

Figure E-5. Outer Baffle

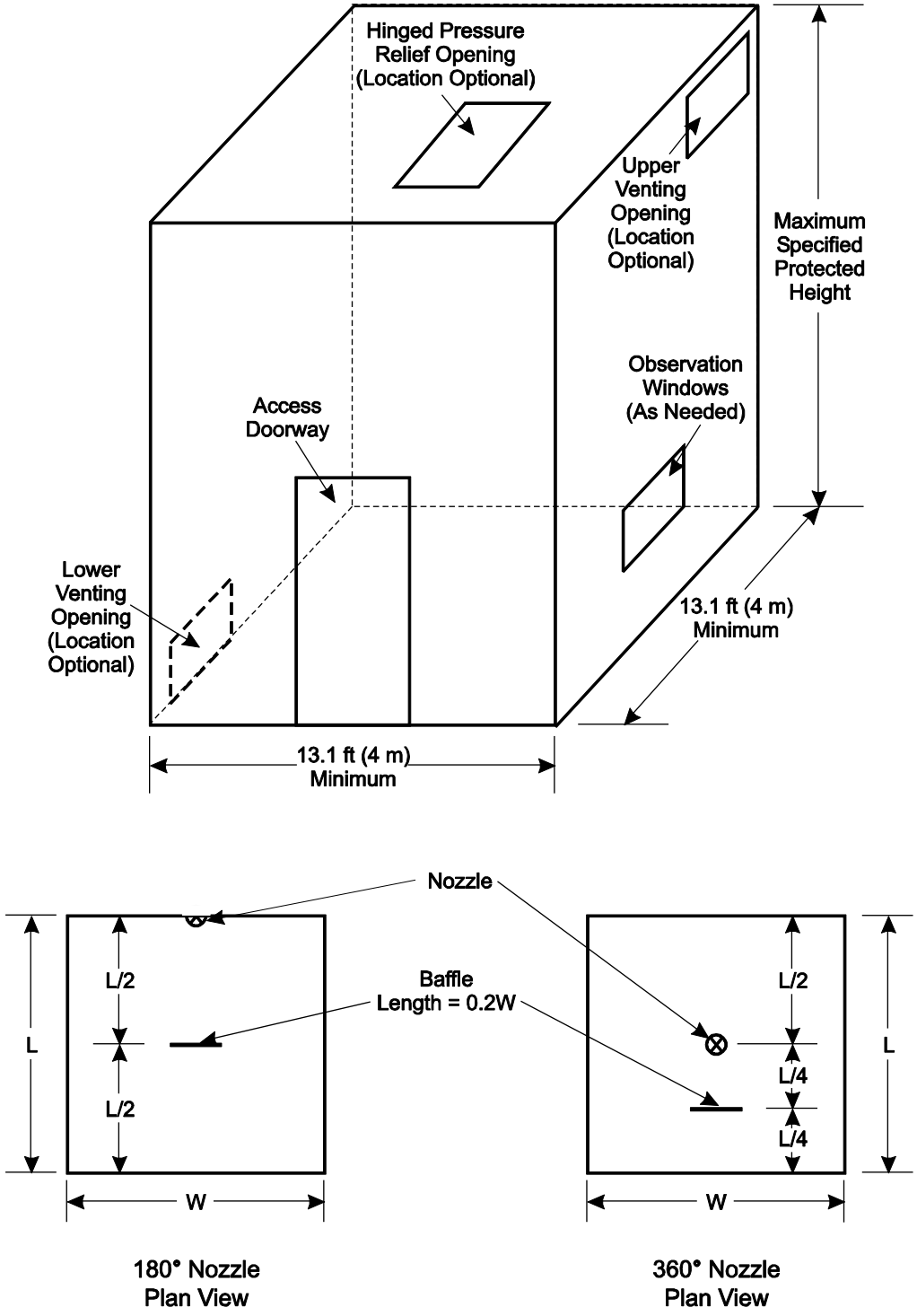
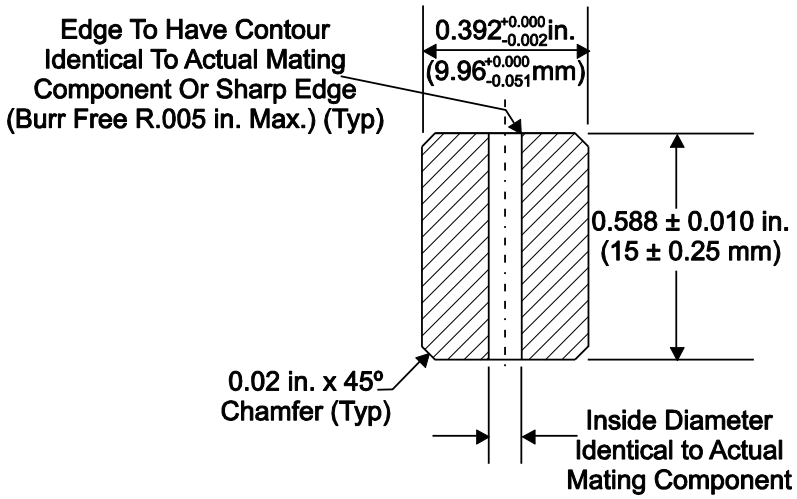
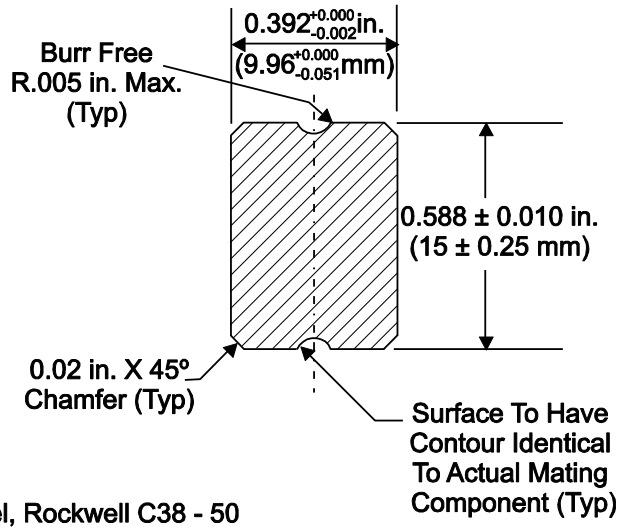


Figure E-6. Test Enclosure

For Designs with Line Contact:



Or: For Designs with Surface Contact:



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

Figure E-7: Bulb Crush Inserts For Strength of Element Test

APPENDIX F:

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APPENDIX G: A METHOD OF TESTING THE EFFECTIVENESS OF CLEAN AGENTS IN SUPPRESSING CABLE FIRES IGNITED BY A SUSTAINED ELECTRICAL ARC

A schematic diagram of the apparatus is shown in Figure G-1. The testing is to be conducted in an airtight test chamber constructed of 1/2 in. nominal thick polycarbonate panels cemented together to form a box with a removable, gasketed cover. The inside volume of the chamber is 1 ft^3 (0.0283 m^2).

A predetermined amount of the extinguishing gas is to be introduced through a port, using a calibrated flow meter. A vaporizing liquid extinguishant with a very low vapor pressure will be introduced as a weighed sample of liquid in an open dish and evaporated by use of a small fan until no liquid is visible in the dish. The same fan is to be used to maintain uniform agent-air mixture. The fan is to be rated at 9 ft^3/min (0.25 m^3/min). It is installed in one bottom corner of the chamber, blowing upward, and is operated throughout the duration of a test.

The mixture in the chamber is sampled through three ports, one each at the bottom, top, and mid height. The samples are monitored by a gas analyzer.

Two nominal 12 in. long, 1/4 in. diameter copperclad carbon electrodes are introduced approximately in the center of the chamber through sealed openings in opposite walls. One electrode is held fixed, while the other is connected to a linear positioning device, indicated as the arc adjuster in the schematic. The adjuster is used to control the gap between the two electrodes to sustain an arc.

A welding machine is used to supply direct current to generate continuous arcing. Input voltage and current are adjusted by use of the welder's controls and monitored by calibrated volt and ampere meters. The voltage is held a 50 V and the current at 40 A by use of the welder's controls and adjusting the gap between the electrodes. The gap may grow from approximately 1/16 in. to approximately 1/8 in. during the course of a test due to erosion of the electrodes.

PMMA (polymethylmethacrylate) sheathing approximately 3 in. long and 1/2 in. outside diameter x 1/4 in. inside diameter is placed around the electrodes. The sheathes are positioned approximately 1/4 in. from the ends of the electrodes.

Experiments are conducted at various agent concentrations. The times for ignition and extinguishment of the PMMA sheathes are visually observed. The minimum concentrations to extinguish the PMMA are determined by repeated experiments.

In addition, the decomposition products (F, Br, and Cl ions) are quantified.

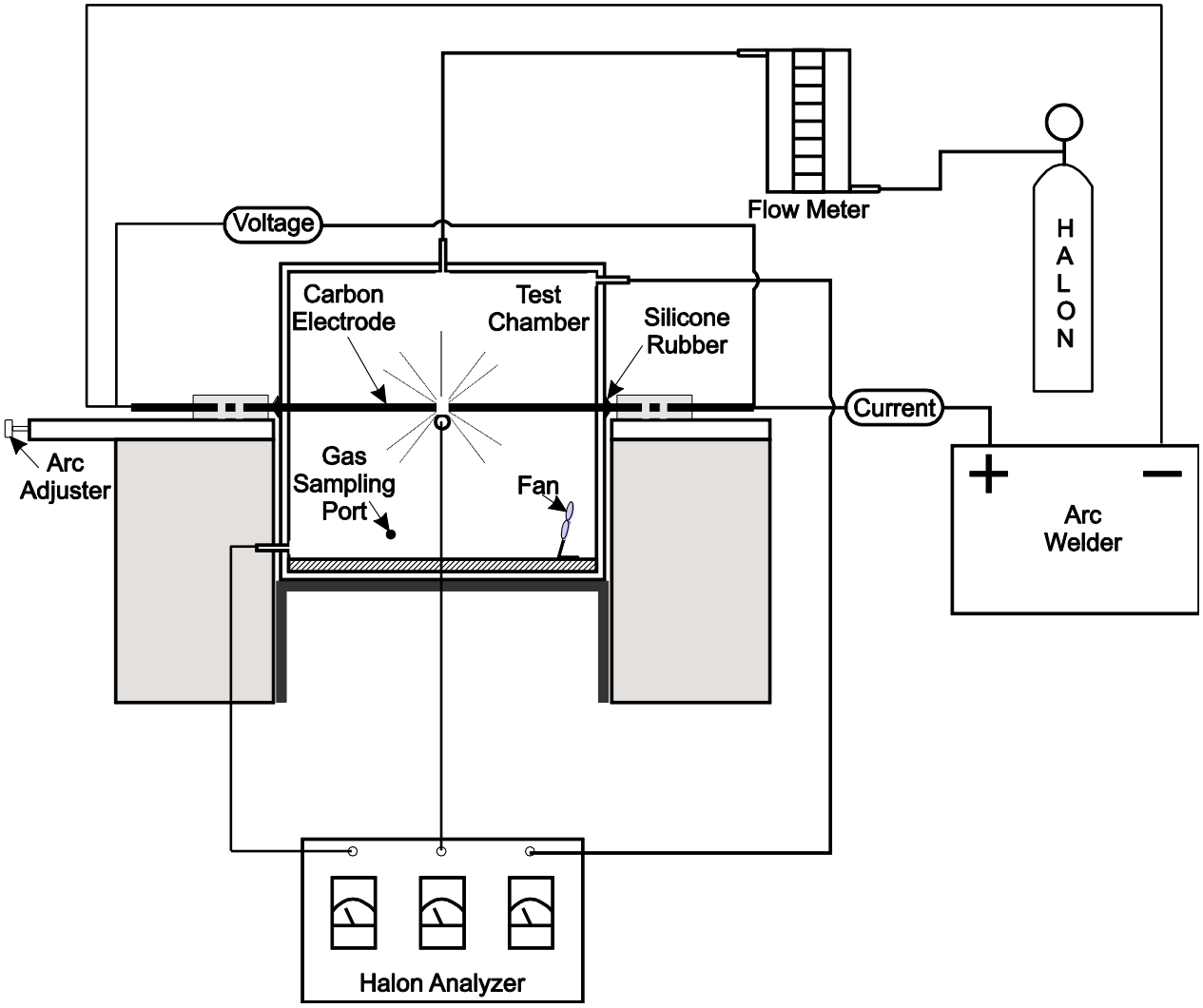


Figure G-1: Test Apparatus