Contents

NFPA 2010

Standard for

Fixed Aerosol Fire-Extinguishing Systems

2006 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in mandatory sections of the document are given in Chapter 2 and those for extracts in informational sections are given in Annex D. Editorial changes to extracted material consist of revising references to an appropriate division in this document or the inclusion of the document number with the division number when the reference is to the original document. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced publications can be found in Chapter 2 and Annex D.

Chapter 1 Administration

1.1 Scope.

1.1.1 This standard contains the requirements for the design, installation, operation, testing, and maintenance of condensed and dispersed aerosol fire-extinguishing systems for total flooding applications.

1.1.2 This standard also covers performance requirements and methods of testing for condensed aerosol systems, dispersed aerosol systems, and associated components.

1.2 Purpose. This standard is prepared for the use by and guidance of those charged with purchasing, designing, installing, testing, inspecting, approving, listing, operating, and maintaining fixed aerosol fire-extinguishing systems, so that such equipment will function as intended throughout its life.

1.3 Retroactivity.

1.3.1 The provisions of this document are considered necessary to provide a reasonable level of protection from loss of life and property from fire. They reflect situations and the state of the art at the time the standard was issued.

1.3.2 Unless otherwise noted, it is not intended that the provisions of this document be applied to facilities, equipment, structures, or installations that were existing or approved for construction or installation prior to the effective date of this document.

1.4 Equivalency. Nothing in this standard is intended to prevent the use of new methods or devices, provided sufficient technical data are submitted to the authority having jurisdiction to demonstrate that the new method or device is equivalent in quality, effectiveness, durability, and safety to that prescribed by this standard.

1.5 Units and Formulas.

1.5.1* Metric units of measurement in this standard are in accordance with the modernized metric system known as the International System of Units (SI).

1.5.2 If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated is to be regarded as the requirement. A given equivalent value could be approximate.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 70, *National Electrical Code®*, 2005 edition.
NFPA 72®, *National Fire Alarm Code®*, 2002 edition.
NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2004 edition.

2.3 Other Publications.

2.3.1 ANSI Publications. American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

ANSI B1.20.1, *Standard for Pipe Threads, General Purpose*, 2001

ANSI C2, *National Electrical Safety Code*, 2001.

2.3.2 ASME Publications. American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

ASME *Boiler and Pressure Vessel Code*, 2004.

ASME B31.1, *Power Piping Code*, 2001.

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

ASTM A53/A53M, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*, 2004.

2.3.4 CGA Publication. Compressed Gas Association, 4221 Walney Road, 5th Floor, Chantilly, VA 20151-2923.

CGA C-6, *Standard for Visual Inspection of Steel Compressed Gas Cylinders*, 2001.

2.3.5 IMO Publication. International Maritime Organization, 4 Albert Embankment, London, SE1 7SR, United Kingdom.

IMO MSC/Circ.1007, *Guidelines for the Approval of Fixed Aerosol Fire-Extinguishing Systems Equivalent to Fixed Gas Fire-Extinguishing Systems, as Referred to in SOLAS 74, for Machinery Spaces*, 2001.

2.3.6 ISO Publication. International Organization for Standardization, 1, rue de Varembé, Case postale 56, CH-1211 Geneve 20, Switzerland.

ISO/IEC Guide 7, *Requirements for Standards Suitable for Use for Conformity Assessment*, 1994.

2.3.7 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

Title 29, Code of Federal Regulations, Part 1910, Subpart S.

Title 46, Code of Federal Regulations, Subchapter C, Parts 24–28.

Title 46, Code of Federal Regulations, Subchapter J, "Electrical Engineering."

Title 49, Code of Federal Regulations, Parts 171–190.

Title 49, Code of Federal Regulations, Part 172.101, Subpart B.

Title 49, Code of Federal Regulations, Part 173.34(e)(01).

Title 49, Code of Federal Regulations, Parts 178.36 and 178.37.

2.3.8 Other Publication. *Merriam-Webster's Collegiate Dictionary,* 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Mandatory Sections.

NFPA 10, *Standard for Portable Fire Extinguishers,* 2002 edition.
NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2002 edition.
NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,* 2003 edition.
NFPA 72®, National Fire Alarm Code®, 2002 edition.
NFPA *101®, Life Safety Code®,* 2006 edition.
NFPA 820, *Standard for Fire Protection in Wastewater Treatment and Collection Facilities,* 2003 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary,* 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.4 Shall. Indicates a mandatory requirement.

3.2.5 Should. Indicates a recommendation or that which is advised but not required.

3.2.6 Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix or annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

3.3 General Definitions.

3.3.1 Actuating Mechanism. A mechanism whose automatic or manual operation leads to the discharge of extinguishing agent.

3.3.2 Aerosol.

3.3.2.1 *Condensed Aerosol.* An extinguishing medium consisting of finely divided solid particles, generally less than 10 microns in diameter, and gaseous matter, generated by a combustion process of a solid aerosol-forming compound.

3.3.2.2 *Dispersed Aerosol.* An extinguishing medium consisting of fine particles of chemicals, generally less than 10 microns in diameter, already resident inside a pressurized agent storage container, suspended in a halocarbon or an inert gas.

3.3.3 Agent Quantity. Mass of solid aerosol-forming compound required to achieve the design application density within the protected volume within the specified discharge time.

3.3.4 Automatic. That which provides a function without the necessity of human intervention. [***101***, 2006]

3.3.5* Automatic/Manual Switch. Means of converting the system from automatic to manual actuation.

3.3.6 Classifications for Fires.

3.3.6.1 *Class A Fires.* Fires in ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics. [**10,** 2002]

3.3.6.2 *Class B Fires.* Fires in flammable liquids, combustible liquids, petroleum greases, tars, oils, oil-based paints, solvents, lacquers, alcohols, and flammable gases. [**10,** 2002]

3.3.6.3 *Class C Fires.* Fires that involve energized electrical equipment. [**10,** 2002]

3.3.7 Clearance.

3.3.7.1 *Electrical Clearance.* The unobstructed air distance between extinguishing system equipment, including piping and nozzles, and unenclosed or uninsulated live electrical components not at ground potential.

3.3.7.2 *Thermal Clearance.* The air distance between a condensed aerosol generator and any structure or components sensitive to the temperature developed by the generator.

3.3.8 Coolant. A heat-absorbing medium or process.

3.3.9 Density.

3.3.9.1* *Design Application Density (g/m^3).* Extinguishing application density, including a safety factor, required for system design purposes.

3.3.9.2* *Extinguishing Application Density (g/m^3).* Minimum mass of a specific aerosol-forming compound per cubic meter of enclosure volume required to extinguish fire involving particular fuel under defined experimental conditions excluding any safety factor.

3.3.9.3 ***Particulate Density.*** The density of solid particulate in grams per cubic meter after discharge of the aerosol system at the design application density. This information is used to assess the degrees of visibility obscuration and the potential health effects of accidental exposure to the agent.

3.3.10 Discharge Port. A passage such as nozzles or openings on an aerosol generator where aerosol is released when the generator is actuated.

3.3.11 Disconnect Switch. A manually operated switch, electrically supervised and secured from unauthorized use, that prevents the automatic or manual electrical actuation of the aerosol generators during maintenance by electrically opening the releasing circuit.

3.3.12 Generator. In condensed aerosol systems, a device for creating a fire-extinguishing medium by pyrotechnical means.

3.3.13 Generator Casing. The surface of the generator, excluding the surface containing the discharge ports.

3.3.14 Hold Time. Period of time during which an extinguishant is required to maintain an even distribution throughout the protected volume in an amount at least at the extinguishing application density.

3.3.15 Hot Work. Work involving burning, welding, or a similar operation that is capable of initiating fires or explosions. [**51B,** 2003]

3.3.16* Inspection. A visual examination of a system or portion thereof to verify that it appears to be in operating condition and free of physical damage. [**820,** 2003]

3.3.17* Maintenance. Work performed to ensure that equipment operates as directed by the manufacturer.

3.3.18 Manual. Requiring intentional intervention to accomplish a function.

3.3.19* Mass Median Aerodynamic Diameter (MMAD). The measurement, with the geometric standard deviation, used to describe the particle size distribution of any aerosol statistically, based on the weight and size of the particles.

3.3.20 Normally Occupied. An area or space where, under normal circumstances, persons are present.

3.3.21 Normally Unoccupied. An area or space not normally occupied by people but that can be entered occasionally for brief periods.

3.3.22 Protected Volume. Volume enclosed by the building elements around the protected enclosure, minus the volume of any permanent impermeable building elements within the enclosure.

3.3.23 Release. The physical discharge or emission of aerosol as a consequence of the condensed aerosol generator's actuation or operation of the dispersed aerosol agent container.

3.3.24 Solid Aerosol-Forming Compound. A solid mixture of oxidant, combustible component and technical admixtures that produces a condensed aerosol upon actuation.

3.3.25 Total Flooding Extinguishing System. A system arranged to discharge an extinguishant into an enclosed space to achieve a uniform distribution of that extinguishant, at or above the design application density, throughout the space.

3.3.26* Unoccupiable. An area or space that cannot be occupied due to dimensional or other physical constraints.

3.4 Special Definitions for Marine Systems. The following definitions shall be applicable to marine aerosol extinguishing systems.

3.4.1* A-60 Class Division. A bulkhead or deck designed to resist the passage of smoke and flame for 1 hour, including limiting the temperature rise on the unexposed side to 180°C (325°F).

3.4.2 Heat-Sensitive Material. A material whose melting point is below 1700°F (926.7°C). [**13,** 2002]

3.4.3 Marine System. An aerosol system installed on a merchant vessel, ship, barge, boat, pleasure craft, offshore platform, or other floating structure.

3.4.4 Space.

3.4.4.1 ***Cargo Space.*** A space for the carriage or storage of items or products that are transported by the vessel.

3.4.4.2 ***Machinery Space.*** A space protected by an aerosol system containing an internal combustion engine or mechanical equipment for handling, pumping, or transferring flammable or combustible liquids as a fuel to internal combustion engines.

3.4.5 Supervisory Signal. A signal indicating the need for action in connection with the supervision of guard tours, the fire suppression systems or equipment, or the maintenance features of related systems. [**72,** 2002]

3.4.6 Vessel.

3.4.6.1 ***Inspected Vessel.*** A vessel operated on the navigable waterways of the United States that is subject to the regulations in 46 CFR, which require it to be certificated and inspected as a passenger ship, cargo ship, oceanographic ship, or tank vessel.

3.4.6.2 ***Uninspected Vessel.*** A vessel operated on the navigable waterways of the United States that is subject to the regulations in 46 CFR Subchapter C, Parts 24–28, including pleasure craft, tugboats, towing vessels, and certain fishing vessels.

Chapter 4 General

4.1 General Information.

4.1.1 The fire extinguishing agents addressed in this standard shall be electrically nonconductive.

4.1.2 The design, installation, service, and maintenance of aerosol systems shall be performed by persons skilled in aerosol fire-extinguishing system technology.

4.2 Use and Limitations.

4.2.1 Aerosol Systems.

4.2.1.1 All aerosol systems shall be installed to protect hazards within the limitations that have been established by the listing.

4.2.1.2 Aerosol systems shall be listed to one of the following types:

(1) Systems consisting of components designed to be installed according to pretested limitations by a testing laboratory

(2) Automatic extinguishing units, installed according to pretested limitations by a testing laboratory, incorporating special nozzles, flow rates, methods of application, nozzle placement, actuation techniques, piping materials, discharge times, mounting techniques, and pressurization levels that could differ from those detailed elsewhere in this standard

4.2.1.2.1 The aerosol systems described in 4.2.1.2(1) shall be permitted to incorporate special nozzles, flow rates, methods of application, nozzle placement, and pressurization levels that could differ from those detailed elsewhere in this standard.

4.2.1.2.2 With the exception of the requirement in 4.2.1.2.1, all other requirements of the standard shall apply to the aerosol systems described in 4.2.1.2(1).

4.2.2 Aerosol fire-extinguishing agents shall not be used on fires involving the following materials unless the agents have been tested to the satisfaction of the authority having jurisdiction:

(1) Deep-seated fires in Class A materials
(2) Certain chemicals or mixtures of chemicals, such as cellulose nitrate and gunpowder, that are capable of rapid oxidation in the absence of air
(3) Reactive metals such as lithium, sodium, potassium, magnesium, titanium, zirconium, uranium, and plutonium
(4) Metal hydrides
(5) Chemicals capable of undergoing autothermal decomposition, such as certain organic peroxides and hydrazine

4.2.3 Condensed aerosol generators shall not be used to protect classified hazards or similar spaces containing flammable liquids or dusts that can be present in explosive air–fuel mixtures unless the generators are specifically listed for use in those environments.

4.2.4 The aerosol generators shall not be employed at less than the minimum safe distances specified in the listing of the product.

4.2.4.1 The minimum safe distance between the condensed aerosol generator discharge ports and personnel shall be based on an aerosol agent discharge temperature, at that distance, not exceeding 75°C (167°F).

4.2.4.2 The minimum safe distance between the condensed aerosol generator discharge ports and combustible materials shall be based on an aerosol agent discharge temperature, at that distance, not exceeding 200°C (392°F).

4.2.4.3 In addition to the requirements in 4.2.4.1 and 4.2.4.2, the minimum safe distance requirements in 6.1.4.2.1 addressing the generator casing temperature shall apply.

4.2.5 The aerosol generators shall not be employed at less than the minimum safe distances specified in the listing of the product.

4.2.6 Where a total flooding system is used, a fixed enclosure shall be provided about the hazard that allows a specified agent design application density to be achieved and maintained for a specified period of time.

4.2.7 The potential adverse effects of agent particulate residue on sensitive equipment and other objects shall be considered where aerosol extinguishing agents are used in spaces containing that type of equipment.

4.3* Environmental Factors. When a type of agent is being selected to protect a hazard area, the potential adverse effects of the agent on the environment shall be considered.

4.4 Compatibility with Other Agents.

4.4.1* Mixing of agents in the same container shall be permitted only if the system is listed.

4.4.2 Unless specifically approved as an agent blend or mixture, systems employing the simultaneous discharge of different agents to protect the same enclosed space shall not be permitted.

4.4.3 Where unrelated extinguishing or suppression systems are provided and can operate prior to or during the hold time of the aerosol system, the other agent shall not adversely affect the aerosol.

Chapter 5 Safety Requirements

5.1* Review Requirement.

5.1.1* Any agent that is to be recognized by this standard or proposed for inclusion in this standard shall first be evaluated in a manner equivalent to the process used by the U.S. Environmental Protection Agency's (EPA) SNAP Program.

5.1.2 Health Effects.

5.1.2.1 Determination for use of an agent in spaces that are normally occupied or normally unoccupied shall include a thorough evaluation of the potential adverse health effect(s) of the agent.

5.1.2.2 Potential adverse health effects shall be assessed for the particulate density, the size of the particulates (i.e., mean mass aerodynamic diameter), and the concentration of gases expected after actuation of the aerosol extinguishing system at the design application density.

5.2 Hazards to Personnel.

5.2.1* Potential Hazards. The following potential hazards shall be considered for individual systems: noise, turbulence, reduced visibility, cold temperature, potential toxicity, thermal hazard, and irritation to persons in the protected space and other areas where the aerosol agent can migrate.

5.2.2 Unnecessary Exposure. Unnecessary exposure to aerosol agent, even at concentrations below an adverse-effect level, and to their decomposition products shall be avoided.

5.2.3 Predischarge Alarms and Time Delays.

5.2.3.1 To prevent human exposure to the aerosol agents by providing a warning of a pending discharge and a delay in the discharge to allow personnel to exit the protected space, a predischarge alarm and time delay shall be provided in accordance with the requirements of 6.4.5.6.

5.2.3.2 Alarm Failure.

5.2.3.2.1 In the event of failure of the predischarge alarm and time delay, means shall be provided to limit exposure to agents approved for use in normally occupied spaces to no longer than 5 minutes.

5.2.3.2.2 The effect of reduced visibility on egress time shall be considered.

5.2.4* Toxicity.

5.2.4.1 General. No fire suppression system shall be used that is carcinogenic, mutagenic, or teratogenic at application densities expected during use.

5.2.4.2* Condensed Aerosols. Condensed aerosol extinguishing systems approved for normally occupied spaces shall be permitted in amounts where the aerosol particulate density does not exceed the adverse-effect level as determined by a scientifically accepted technique and any aerosol agent produced does not exceed the excursion limit for the critical toxic effect.

5.2.4.3 Dispersed Aerosols. Dispersed aerosol extinguishing systems approved for normally occupied spaces shall be permitted in amounts where the aerosol particulate concentration does not exceed the adverse-effect level as determined by a scientifically accepted technique, and any carrier gas used shall meet the safe exposure requirements in accordance with NFPA 2001.

5.2.5* Reduced Visibility. Safety measures shall be used such that occupants can evacuate under conditions of low visibility caused by the discharged agent.

5.2.6 Thermal Hazards.

5.2.6.1 Condensed aerosol generators shall not be employed at less than the minimum safe distance from personnel and combustible materials as specified in the listing of the product.

5.2.6.2 Protective gloves shall be worn by personnel removing discharged condensed aerosol generators.

5.2.7 Safety Requirements.

5.2.7.1 Personnel shall not enter a protected space during or after agent discharge.

5.2.7.2* Safeguards shall be provided to ensure prompt evacuation of and prevent entry into post–system discharge atmospheres and also to provide means for prompt rescue of any trapped personnel.

5.2.7.3* Consideration shall be given to the possibility of an aerosol agent migrating to adjacent areas outside of the protected space.

5.3 Electrical Clearances.

5.3.1 All system components shall be located to maintain no less than minimum clearances from energized electrical parts.

5.3.1.1 The following references shall be considered as the minimum electrical clearance requirements for the installation of aerosol extinguishing systems:

(1) ANSI C2
(2) NFPA 70
(3) 29 CFR 1910, Subpart S

5.3.2 Where the design basic insulation level (BIL) is not available, and where nominal voltage is used for the design criteria, the highest minimum clearance listed for this group shall be used.

5.3.3 The selected clearance to ground shall satisfy the greater of the switching surge or BIL duty, rather than being based on nominal voltage.

5.3.4 The clearance between uninsulated, energized parts of the electrical system equipment and any portion of the aerosol extinguishing system shall not be less than the minimum clearance provided elsewhere for electrical system insulations on any individual component.

Chapter 6 Components

6.1 Condensed Aerosol System Agent Supply.

6.1.1 Quantity.

6.1.1.1 Primary Agent Supply. The primary agent supply shall be determined by calculating the required mass of the solid aerosol-forming compound needed to meet the design application density and shall be at least sufficient for the largest single hazard protected or group of hazards to be protected simultaneously.

6.1.1.2 Reserve Agent Supply. Where required, a reserve agent supply shall consist of as many multiples of the primary agent supply as the authority having jurisdiction considers necessary.

6.1.2 Quality. Agent properties shall meet the standards of quality of the agent's listing.

6.1.2.1 Each batch of agent manufactured shall be tested and certified to the specifications of its listing.

6.1.2.2 Agents shall maintain their integrity for the useful life limits established by the listing within the approved temperature range and conditions of service that they will encounter.

6.1.3 Aerosol Generator Arrangement.

6.1.3.1 Aerosol generators and accessories shall be located and arranged so that inspection, testing, and other maintenance activities are facilitated and interruption of protection is held to a minimum.

6.1.3.2 Aerosol generators shall be located within or as close as possible to the hazard or hazards they protect.

6.1.3.3 Aerosol generators shall not be located where they can be rendered inoperable or unreliable due to mechanical damage or exposure to chemicals or harsh weather conditions unless enclosures or protective measures are employed.

6.1.3.4 Aerosol generators shall be securely installed according to the manufacturer's listed installation manual.

6.1.4 Condensed Aerosol Generators.

6.1.4.1 Safety.

6.1.4.1.1 The aerosol-forming compound shall be stored in aerosol generators designed to safely contain the pyrotechnic reaction required to produce the aerosol agent.

6.1.4.1.2 The aerosol generators shall discharge aerosol within the temperature and minimum safe distance parameters from personnel and combustibles established in the listing tests.

6.1.4.2 Minimum Safe Distance.

6.1.4.2.1 The generator shall not be installed at less than the minimum safe distances as specified in the manufacturer's installation instructions.

6.1.4.2.2 In addition to the requirements of 6.1.4.2.1, the minimum safe distance requirements in 4.2.4 addressing the agent stream temperature shall apply.

6.1.4.2.2.1 The minimum safe distance between the generator casing and personnel shall be the distance from the generator casing to where the temperature does not exceed 75°C (167°F) during and after discharge.

6.1.4.2.2.2 The minimum safe distance between the generator casing and combustible materials shall be the distance from the generator casing to where the temperature does not exceed 200°C (392°F) during and after discharge.

6.1.4.3 Aerosol generators shall be listed for the intended use.

6.1.4.3.1 Listing criteria shall include area coverage, height limits, placement, storage temperature limits, useful lifetime limits, thermal safety parameters, and orientation.

6.1.4.3.2 Aerosol generators shall be sealed in a manner that is corrosion resistant to the atmosphere in the intended application.

6.1.4.3.3 Sealing methods shall provide an unobstructed opening upon system operation.

6.1.4.4 Each aerosol generator shall have a permanent nameplate or other permanent marking that indicates the mass of aerosol-forming compound contained within, the manufacturer, date of manufacture, and date of mandatory replacement of the generator based on useful life limits established in the listing.

6.1.4.5 The aerosol generators used in these systems shall comply with the requirements of the U.S. Department of Transportation (DOT) or the Canadian Transport Commission and shall be classified IAW 49 CFR 172.101, Subpart B, or the Canadian equivalent.

6.1.4.6 Storage and use temperatures shall be within the manufacturer's listed limits.

6.2 Dispersed Aerosol System Agent Supply.

6.2.1 Quantity.

6.2.1.1 Primary Agent Supply. The amount of agent in the system primary agent supply needed to meet the design application density shall be at least sufficient for the largest single hazard protected or group of hazards to be protected simultaneously.

6.2.1.2 Reserve Agent Supply. Where required, a reserve agent supply shall consist of as many multiples of the primary agent supply as the authority having jurisdiction considers necessary.

6.2.2 Quality. Agent properties shall meet the standards of quality of the agent's listing.

6.2.2.1 Each batch of agent manufactured shall be tested and certified to the specifications of its listing.

6.2.2.2 Agent shall remain homogeneous in storage and use within the listed temperature range and conditions of service that it will encounter for the useful life of the material.

6.2.3 Storage Container Arrangement.

6.2.3.1 Storage containers and accessories shall be located and arranged so that inspection, testing, recharging, and other maintenance activities are facilitated and interruption of protection is held to a minimum.

6.2.3.2* Storage containers shall be located as close as possible to or within the hazard or hazards they protect.

6.2.3.3 Agent storage containers shall not be located where they can be rendered inoperable or unreliable due to mechanical damage or exposure to chemicals or harsh weather conditions unless enclosures or protective measures are employed.

6.2.3.4 Storage containers shall be securely installed and secured according to the manufacturer's listed installation manual and in a manner that provides for convenient individual servicing or content weighing.

6.2.3.5 Where storage containers are connected to a manifold, automatic means, such as a check valve, shall be provided to prevent agent loss and to ensure personnel safety if the system is operated when any containers are removed for maintenance.

6.2.4 Agent Storage Containers.

6.2.4.1 Container Description.

6.2.4.1.1 Agent shall be stored in containers designed to hold that specific agent throughout the intended operating and storage temperature ranges.

6.2.4.1.2 Containers shall be charged to a fill density or superpressurization level within the range specified in the manufacturer's listed manual.

6.2.4.2 Each dispersed aerosol agent storage container shall have the following information:

(1) The type and net weight of aerosol-forming material marked on a permanent nameplate or other permanent marking
(2) The type and net weight of halocarbon-dispersing medium or the type and pressurization level of the inert gas–dispersing medium
(3) The name of the manufacturer
(4) The date of manufacture
(5) The date of mandatory replacement of the contents based on useful life limits established in the listing

6.2.4.3 The containers used in these systems shall be designed to meet the requirements of the DOT or the Canadian Transport Commission, if used as shipping containers.

6.2.4.3.1* If not used as shipping containers, the containers shall be designed, fabricated, inspected, certified, and stamped in accordance with Section VIII of the ASME *Boiler and Pressure Vessel Code*.

6.2.4.3.2 The design pressure shall be suitable for the maximum pressure developed at 55°C (130°F) or at the maximum controlled temperature limit.

6.2.4.4 A reliable means of indication shall be provided to determine the pressure in refillable superpressurized containers.

6.2.4.5 The dispersed aerosol containers connected to a manifold shall be interchangeable and of one select size and charge.

6.2.4.6 Storage Temperatures.

6.2.4.6.1 Storage temperatures shall be within the manufacturer's listed limits.

6.2.4.6.2 External heating or cooling shall be used to keep the temperature of the storage container within desired ranges.

6.3 Dispersed Aerosol System Distribution Components.

6.3.1 Pipe.

6.3.1.1 Pipe shall be noncombustible material having physical and chemical characteristics such that its integrity under stress can be predicted with reliability.

6.3.1.1.1 Special corrosion-resistant materials or coatings shall be required in severely corrosive atmospheres.

6.3.1.1.2 The thickness of the piping shall be calculated in accordance with ASME B31.1.

6.3.1.1.3 The internal pressure used for the calculation given in 6.3.1.1.2 shall not be less than the greater of either of the following values:

(1) The normal charging pressure in the agent container at 21°C (70°F)
(2) Eighty percent of the maximum pressure in the agent container at the maximum storage temperature of not less than 55°C (130°F), using the equipment manufacturer's maximum allowable fill density, if applicable

6.3.1.2 Cast-iron pipe, steel pipe conforming to ASTM A53/A53M, or nonmetallic pipe shall not be used.

6.3.1.3 Stenciled pipe identification shall not be painted over, concealed, or removed prior to approval by the authority having jurisdiction.

6.3.1.4 Where used, flexible pipe, tubing, or hoses, including connections, shall be of approved materials and pressure ratings.

6.3.1.5 Pipe Cleaning.

6.3.1.5.1 Each pipe section shall be cleaned internally after preparation and before assembly by means of swabbing, utilizing a nonflammable cleaner.

6.3.1.5.2 The pipe network shall be free of particulate matter and oil residue before installation of nozzles or discharge devices.

6.3.1.6 In sections where valve arrangement introduces sections of closed piping, such sections shall be equipped with pressure relief devices, or the valves shall be designed to prevent entrapment of agent.

6.3.1.6.1 In systems using pressure-operated container valves, means shall be provided to vent any container leakage that could build up pressure in the pilot system and cause unwanted opening of the container valve.

6.3.1.6.2 The means of pressure venting shall be arranged so as not to prevent reliable operation of the container valve.

6.3.1.7 All pressure relief devices shall be designed and located so that the discharge from the device will not injure personnel or pose a hazard.

6.3.2 Pipe Joints. Pipe joints other than threaded, welded, brazed, flared, compression, or flanged type shall be listed or approved.

6.3.3 Fittings.

6.3.3.1 Minimum Pressure.

6.3.3.1.1 Fittings shall have a minimum rated working pressure equal to or greater than the minimum design working pressure specified in 6.3.1, for the agent being used, or as otherwise listed or approved.

6.3.3.1.2 For systems that employ the use of a pressure-reducing device in the distribution piping, the fittings downstream of the device shall have a minimum rated working pressure equal to or greater than the maximum anticipated pressure in the downstream piping.

6.3.3.2 Fittings Not to Be Used.

6.3.3.2.1 Cast-iron fittings shall not be used.

6.3.3.2.2 Class 150 lb fittings shall not be used unless it can be demonstrated that they comply with the appropriate American National Standards Institute (ANSI) stress calculations.

6.3.3.3 Threads.

6.3.3.3.1 All threads used in joints and fittings shall conform to ANSI B1.20.1 or ISO/IEC Guide 7.

6.3.3.3.2 Joint compound, tape, or thread lubricant shall be applied only to the male threads of the joint.

6.3.3.4 Welding and brazing alloys shall have a melting point above 538°C (1000°F).

6.3.3.5 Welding shall be performed in accordance with Section IX, "Qualification Standard for Welding and Brazing Procedures, Welders, Brazers and Welding and Brazing Operators," of the ASME *Boiler and Pressure Vessel Code*.

6.3.3.6 Where copper, stainless steel, or other tubing is jointed with compression-type fittings, the listed pressure and temperature ratings of the fitting shall not be exceeded.

6.3.4 Valves.

6.3.4.1 All valves shall be listed or approved for the intended use.

6.3.4.2 All gaskets, O-rings, sealants, and other valve components shall be constructed of materials that are compatible with the agent.

6.3.4.3 Valves shall be protected against mechanical, chemical, or other damage.

6.3.4.4 Special corrosion-resistant materials or coatings shall be used in severely corrosive atmospheres.

6.3.5 Discharge Nozzles and Systems.

6.3.5.1 Discharge nozzles and systems shall be listed for the intended use.

6.3.5.1.1 Listing criteria shall include flow characteristics, area coverage, height limits, and minimum pressures.

6.3.5.1.2 Discharge orifices and discharge orifice plates and inserts shall be of a material that is corrosion resistant to the agent used and the atmosphere in the intended application.

6.3.5.2 Special corrosion-resistant materials or coatings shall be required in severely corrosive atmospheres.

6.3.5.3 Discharge nozzles shall be permanently marked to identify the manufacturer as well as the type and size of the orifice.

6.3.5.4 Clogging.

6.3.5.4.1 Where clogging by external foreign materials is likely, discharge nozzles shall be provided with frangible discs, blowoff caps, or other approved devices.

6.3.5.4.2 The devices described in 6.3.5.4.1 shall provide an unobstructed opening upon system operation and shall be located so they will not injure personnel.

6.4 Detection, Actuation, Alarm, and Control Systems.

6.4.1 General.

6.4.1.1* Detection, actuation, alarm, and control systems shall be installed, tested, and maintained in accordance with NFPA 70 and *NFPA 72*.

6.4.1.2 Automatic detection and automatic actuation shall be used unless manual-only actuation is approved by the authority having jurisdiction.

6.4.1.3 Raceways.

6.4.1.3.1 Initiating and releasing circuits shall be installed in raceways.

6.4.1.3.2 Unless shielded and grounded, alternating current (ac) and direct current (dc) wiring shall not be combined in a common conduit or raceway.

6.4.2 Automatic Detection.

6.4.2.1 Automatic detection shall be by any listed method or device capable of detecting and indicating heat, flame, smoke, combustible vapors, or an abnormal condition in the hazard, such as process trouble, that is likely to produce fire.

6.4.2.2 Reliable primary and 24-hour minimum standby sources of energy shall be used to provide for operation of the detection, signaling, control, and actuation requirements of the system.

6.4.3 Operating Devices.

6.4.3.1 Operating devices shall include agent-releasing devices or valves, discharge controls, and shutdown equipment necessary for successful performance of the system.

6.4.3.2 Operation.

6.4.3.2.1 Operation shall be by listed mechanical, electrical, or pneumatic means.

6.4.3.2.2 A reliable source of energy shall be used.

6.4.3.3 All devices shall be designed for the service they will encounter and shall not readily be rendered inoperative or susceptible to accidental operation.

6.4.3.3.1 Devices shall be designed to function within their listed temperature ranges.

6.4.3.4 All devices shall be located, installed, or protected so that they are not subject to mechanical, chemical, or other damage that would render them inoperative.

6.4.3.5 A means of manual release of the system shall be provided.

6.4.3.5.1 Manual release shall be accomplished by a mechanical manual release or by an electrical manual release when the control equipment monitors the battery condition and will provide a low-battery signal.

6.4.3.5.2 The release shall cause simultaneous operation of actuators that control agent release and distribution.

6.4.3.6 Manual control(s) for actuation shall be located for easy accessibility at all times, including at the time of a fire.

6.4.3.6.1 The manual control(s) shall be of distinct appearance and clearly recognizable for the purpose intended.

6.4.3.6.2 Operation of any control station shall cause the complete system to operate.

6.4.3.7 Manual Controls.

6.4.3.7.1 Manual controls shall not require a pull of more than 178 N (40 lb) or a movement of more than 356 mm (14 in.) to secure operation.

6.4.3.7.2 At least one manual control station for activation shall be located not more than 1.2 m (4 ft) above the floor.

6.4.3.8 Where gas pressure from the system or pilot containers is used as a means for releasing the remaining containers, the supply and the discharge rate shall be designed for releasing all the remaining containers.

6.4.3.9 All devices for shutting down supplementary equipment shall be considered integral parts of the system and shall function with the system operation.

6.4.3.10 All manual operating devices shall be identified as to the hazard they protect.

6.4.4 Control Equipment.

6.4.4.1 Electric Control Equipment.

6.4.4.1.1 The control equipment shall supervise the actuating devices and associated wiring and, as required, cause actuation.

6.4.4.1.2 The control equipment shall be specifically listed for the number and type of actuating devices utilized, and their compatibility shall be listed.

6.4.4.2 Pneumatic Control Equipment.

6.4.4.2.1 Where pneumatic control equipment is used, the lines shall be protected against crimping and mechanical damage.

6.4.4.2.2 Where installations could be exposed to conditions that could lead to loss of integrity of the pneumatic lines, special precautions shall be taken to ensure that no loss of integrity will occur.

6.4.4.2.3 The control equipment shall be specifically listed for the number and type of actuating devices utilized, and their compatibility shall be listed.

6.4.5 Operating Alarms and Indicators.

6.4.5.1 Alarms or indicators or both shall be used to indicate the operation of the system, hazards to personnel, or failure of any supervised device.

6.4.5.1.1 The type (audible, visual, or olfactory), number, and location of the devices shall be such that their purpose is satisfactorily accomplished.

6.4.5.1.2 The extent and type of alarms or indicator equipment or both shall be approved.

6.4.5.2 Warning Devices.

6.4.5.2.1 Audible and visual predischarge alarms shall be provided within the protected area to give positive warning of impending discharge.

6.4.5.2.2 The operation of the warning devices shall continue after agent discharge until positive action has been taken to acknowledge the alarm and proceed with appropriate action.

6.4.5.3* Abort Switches. Where provided, the abort switches shall be located within the protected area and shall be located near the means of egress for the area.

6.4.5.3.1 An abort switch shall not be operated unless the cause for the condition is known and corrective action can be taken.

6.4.5.3.2 The abort switch shall be of a type that requires constant manual pressure to cause abort.

6.4.5.3.3 The abort switch shall not be of a type that would allow the system to be left in an aborted mode without personnel present.

6.4.5.3.4 In all cases, the manual emergency control shall override the abort function.

6.4.5.3.5 Operation of the abort function shall result in both audible and distinct visual indication of system impairment.

6.4.5.3.6 The abort switch shall be clearly recognizable for the purpose intended.

6.4.5.4 Alarms indicating failure of supervised devices or equipment shall give prompt and positive indication of any failure and shall be distinct from alarms indicating operation or hazardous conditions.

6.4.5.5 Warning and instruction signs at entrances to and inside protected areas shall be provided.

6.4.5.6 Predischarge Alarms and Time Delays.

6.4.5.6.1 For aerosol extinguishing systems, a predischarge alarm and time delay, sufficient to allow personnel evacuation prior to discharge, shall be provided.

6.4.5.6.2* For hazard areas subject to fast-growth fires, where the provision of a time delay would seriously increase the threat to life and property, a time delay shall be permitted to be eliminated.

6.4.5.6.3 Time delays shall be used only for personnel evacuation or to prepare the hazard area for discharge.

6.4.5.6.4 Time delays shall not be used as a means of confirming operation of a detection device before automatic actuation occurs.

6.4.6* Unwanted System Operation. Care shall be taken to thoroughly evaluate and correct any factors that could result in unwanted discharges.

6.4.6.1 To avoid unwanted discharge of an aerosol system during maintenance, a supervised disconnect switch shall be provided.

6.4.6.2 The disconnect switch shall interrupt the releasing circuit to the aerosol system.

Chapter 7 System Design

7.1 Specifications, Plans, and Approvals.

7.1.1 Specifications.

7.1.1.1 Specifications for total flooding aerosol fire-extinguishing systems shall be prepared under the supervision of a person fully experienced and qualified in the design of such systems and with the advice of the authority having jurisdiction.

7.1.1.2 The specifications shall include all pertinent items necessary for the design of the system, such as the designation of the authority having jurisdiction, variances from the standard to be permitted by the authority having jurisdiction, design criteria, system sequence of operations, the type and extent of the approval testing to be performed after installation of the system, and owner training requirements.

7.1.2 Working Plans.

7.1.2.1 Working plans and calculations shall be submitted for approval to the authority having jurisdiction before system installation or remodeling begins.

7.1.2.1.1 These documents shall be prepared only by persons fully experienced and qualified in the design of total condensed or dispersed aerosol extinguishing systems.

7.1.2.1.2 Deviation from these documents shall require permission of the authority having jurisdiction.

7.1.2.2 Working plans shall be drawn to an indicated scale and shall show the following items that pertain to the design of the system:

(1) Name of owner and occupant
(2) Location, including street address
(3) Point of compass and symbol legend
(4) Location and construction of protected enclosure walls and partitions
(5) Location of fire walls
(6) Enclosure cross-section, full-height or schematic diagram, including location and construction of building floor/ceiling assemblies above and below, raised access floor, and suspended ceiling
(7) Aerosol agent being used
(8) Design application density
(9) Description of occupancies and hazards being protected, designating whether or not the enclosure is normally occupied
(10) Description of exposures surrounding the enclosure
(11) For dispersed aerosol systems, a description of the agent storage containers used, including internal volume, storage pressure, and nominal capacity expressed in units of agent mass
(12) For condensed aerosol systems, a description of the generator used, including nominal capacity expressed in units of agent mass
(13) A description of nozzle(s) used, including size, orifice port configuration, and equivalent orifice area
(14) A description of pipe and fittings used, including material specifications, grade, and pressure rating
(15) Description of wire or cable used, including classification, gauge [American Wire Gauge (AWG)], shielding, number of strands in conductor, conductor material, and color coding schedule, with the segregation requirements of various system conductors clearly indicated and the required method of making wire terminations detailed
(16) Description of the method of detector mounting
(17) Equipment schedule or bill of materials for each piece of equipment or device showing device name, manufacturer, model or part number, quantity, and description
(18) Plan view of protected area showing enclosure partitions (full and partial height); detection, alarm, and control system, including all devices and schematic of wiring interconnection; end-of-line device locations; location of controlled devices such as dampers and shutters; location of instructional signage; agent distribution system, including the location of condensed aerosol generators or, for dispersed aerosol systems, the location of the agent storage containers, piping, and nozzles together with type of pipe hangers and rigid pipe supports

(19) For dispersed aerosol systems, isometric view of agent distribution system showing the length and diameter of each pipe segment; node reference numbers relating to the flow calculations; fittings, including reducers and strainers; orientation of tees; and nozzles, including size, orifice port configuration, flow rate, and equivalent orifice area
(20) Scale drawing showing the layout of the annunciator panel graphics if required by the authority having jurisdiction
(21) For dispersed aerosol systems, details of each unique rigid pipe support configuration showing method of securement to the pipe and to the building structure
(22) Details of the method of container or generator securement showing method of securement to the container or generator and to the building structure
(23) Complete step-by-step description of the system sequence of operations, including functioning of abort and maintenance disconnect switches, delay timers, and emergency power shutdown
(24) Point-to-point wiring schematic diagrams showing all circuit connections to the system control panel, to the graphic annunciator panel, and to external or add-on relays
(25) Complete calculations to determine enclosure volume, quantity of agent, and size of backup batteries and method used to determine number and location of audible and visual indicating devices and number and location of detectors
(26) For condensed aerosols, the minimum clearances to combustible materials and the means of egress
(27) Details of any special features

7.1.2.3 Information shall be submitted for approval to the authority having jurisdiction pertaining to the location and function of the detection devices, operating devices, auxiliary equipment, and electrical circuitry, if used.

7.1.2.3.1 Apparatus and devices used shall be identified.

7.1.2.3.2 Any special features shall be explained.

7.1.2.3.3 The details on the system shall include information and calculations on the amount of agent.

7.1.2.3.4 For dispersed aerosol systems, information shall be provided describing container storage pressure; internal volume of the container; the location, type, and flow rate of each nozzle, including equivalent orifice area; the location, size, and equivalent lengths of pipe, fittings, and hose; and the location and size of the storage facility.

7.1.2.3.5 Pipe size reduction and orientation of tees shall be clearly indicated.

7.1.2.4 An as-built instruction and maintenance manual that includes a full sequence of operations and a full set of drawings and calculations shall be maintained on site.

7.1.2.5 Flow Calculations.

7.1.2.5.1 Flow calculations along with the working plans shall be submitted to the authority having jurisdiction for approval.

7.1.2.5.2 The version of the flow calculation program shall be identified on the computer calculation printout.

7.1.2.6 Where field conditions necessitate any material change from approved plans, the change shall be submitted to the authority having jurisdiction for approval.

7.1.2.7 When such material changes from approved plans are made, corrected "as installed" plans shall be provided to the authority having jurisdiction.

7.1.3 Approval of Plans.

7.1.3.1 Plans and calculations shall be approved prior to installation.

7.1.3.2 Where field conditions necessitate any change from approved plans, the change shall be approved prior to implementation.

7.1.3.3 When such changes from approved plans are made, the working plans shall be updated to accurately represent the system as installed.

7.2 Dispersed Aerosol System Flow Calculations.

7.2.1 System flow calculations shall be performed using a calculation method listed or approved by the authority having jurisdiction.

7.2.2 The system design shall be within the manufacturer's listed limitations.

7.3 Enclosure.

7.3.1 In the design of a total flooding system, the integrity of the protected enclosure shall be considered.

7.3.2 The area of unclosable openings in the protected enclosure shall be kept to a minimum.

7.3.3 Loss of Agent.

7.3.3.1 To prevent loss of agent through openings to adjacent hazards or work areas, openings shall be permanently sealed or equipped with automatic closures.

7.3.3.2 Where reasonable confinement of agent is not practicable, protection shall be expanded to include the adjacent connected hazards or work areas, or additional agent shall be introduced into the protected enclosure using an extended discharge configuration.

7.3.4 Forced-air ventilating systems shall be shut down or closed automatically where their continued operation would adversely affect the performance of the fire-extinguishing system or result in propagation of the fire.

7.3.4.1 Completely self-contained recirculating ventilation systems shall not be required to be shut down.

7.3.4.2 The volume of the ventilation system and associated ductwork shall be considered part of the total hazard volume when determining the quantity of agent.

7.3.5 The protected enclosure shall have the structural strength and integrity necessary to contain the agent discharge.

7.3.5.1 If the developed pressures present a threat to the structural strength of the enclosure, venting shall be provided to prevent excessive pressures.

7.3.5.2 Designers shall consult the system manufacturer's recommended procedures relative to enclosure venting.

7.4 Design Application Density.

7.4.1 Determining Design Application Density.

7.4.1.1 The extinguishing application density shall be used in determining the agent design application density for a particular fuel.

7.4.1.2 For combinations of fuels, the extinguishment value for the fuel requiring the greatest design application density shall be used unless tests are made on the actual mixture.

7.4.2 Extinguishment.

7.4.2.1* Class B Fuels. The extinguishing application density for Class B fuels shall be determined by test as part of a listing program.

7.4.2.1.1 The minimum design application density for a Class B fuel hazard shall be the extinguishing application density, as determined in 7.4.2.1, multiplied by a safety factor of 1.3.

7.4.2.2* Class A Fuels. The extinguishing application density for Class A fuels shall be determined by test as part of a listing program.

7.4.2.2.1 The minimum design application density for a Class A surface fire hazard shall be the extinguishing application density, as determined in 7.4.2.2, multiplied by a safety factor of 1.3.

7.4.2.3 Class C Fuels. The minimum design application density for Class C hazards shall be at least that for the class of fire hazard being protected as defined in 3.3.6.1 and 3.3.6.2.

7.4.2.4 Fuel Combinations. For combinations of Class A and Class B fuels, the design application density shall be the value for the fuel requiring the greater design application density.

7.5 Total Flooding Quantity.

7.5.1 Quantity Calculation. The mass of aerosol-forming compound required shall be calculated from the following formula:

$$m = d_a \times f_a \times V$$

where:
m = total flooding quantity [g(lb)]
d_a = design application density [g/m^3 (lb/ft^3)]
f_a = additional design factors *(see 7.5.2)*
V = protected volume [m^3 (ft^3)]

7.5.2 Additional Design Factors. In addition to the agent quantity determined by the design application density, additional quantities of agent are required through the use of additional design factors to compensate for any special conditions that would affect the extinguishing efficiency.

7.5.2.1 Tee Design Factor for Dispersed Aerosol Systems.

7.5.2.1.1 Where a single agent supply is used to protect multiple hazards, a design factor from Table 7.5.2.1.1 shall be applied.

7.5.2.1.2 For the application of Table 7.5.2.1.1, the design factor tee count shall be determined for each hazard the system protects as follows:

(1) Starting from the point where the pipe system enters the hazard, the number of tees in the flow path returning to the agent supply (do not include tees used in a manifold) shall be included in the design factor tee count for the hazard.
(2) Any tee within the hazard that supplies agent to another hazard shall be included in the design factor tee count for the hazard.

7.5.2.1.3 The hazard with the greatest design factor tee count shall be used in Table 7.5.2.1.1 to determine the design factor.

Table 7.5.2.1.1 Additional Design Factors for Piping Tees

Design Factor Tee Count	Tee Design Factor
0–4	1.00
5	1.01
6	1.02
7	1.03
8	1.04
9	1.05
10	1.06
11	1.07
12	1.07
13	1.08
14	1.09
15	1.09
16	1.10
17	1.11
18	1.11
19	1.12

7.5.2.2 Other Design Factors. The designer shall assign and document other design factors for each of the following:

(1) Unclosable openings and their effects on distribution and design application density
(2) Height of protected volume
(3) Control of acid gases
(4) Re-ignition from heated surfaces
(5) Fuel type, configurations, scenarios not fully accounted for in the extinguishing application density, enclosure geometry, and obstructions and their effects on distribution
(6) Ambient pressures that vary more than 11 percent [equivalent to approximately 915 m (3000 ft) of elevation change] from standard sea level pressures

7.6* Duration of Protection. The agent design application density shall be maintained for the specified period of time to prevent re-ignition of the fire before effective emergency action can be taken by trained personnel.

7.7 Distribution System.

7.7.1 Rate of Application.

7.7.1.1 The minimum design rate of application shall be based on the quantity of agent required for the desired design application density and the time allotted to achieve that desired design application density within the protected space.

7.7.1.2 Discharge Time.

7.7.1.2.1 For condensed aerosol systems, the discharge time required to achieve 95 percent of the design application density shall not exceed 60 seconds or as otherwise required by the authority having jurisdiction.

7.7.1.2.2 For dispersed aerosol systems using halocarbon agents as the dispersing means, the discharge time required to achieve 95 percent of the design application density shall not exceed 10 seconds or as otherwise required by the authority having jurisdiction.

7.7.1.2.3 For dispersed aerosol systems using inert gas as the dispersing agent, the discharge time required to achieve 95 percent of the minimum design application density, including a 30 percent safety factor, shall not exceed 60 seconds or as otherwise required by the authority having jurisdiction.

7.7.1.2.4 The discharge time period is defined as the time required to discharge from the nozzles (for dispersed aerosols) or the generator (for condensed aerosols) 95 percent of the agent mass, at 20°C (68°F), necessary to achieve the minimum design application density.

7.7.1.2.5 Flow calculations performed in accordance with Section 7.2 or in accordance with the listed pre-engineered systems instruction manuals shall be used to demonstrate compliance with 7.7.1.2.

7.7.2 Extended Discharge. When an extended discharge is necessary to maintain the design application density for the specified period of time, additional agent quantities shall be applied.

7.7.2.1 The initial discharge shall be completed within the limits specified in 7.7.1.2.

7.7.2.2 The performance of the extended discharge system shall be confirmed by test.

7.8 Nozzle or Generator Choice and Location.

7.8.1 Nozzles or aerosol generators shall be of the type listed for the intended purpose and shall be placed within the protected enclosure in compliance with listed limitations with regard to spacing, floor coverage, thermal clearances, and alignment.

7.8.2 The type of nozzles or generators selected, their number, and their placement shall be such that the design application density will be established in all parts of the hazard enclosure.

Chapter 8 Approval of Installations

8.1 General.

8.1.1 The completed system shall be reviewed and tested by qualified personnel to meet the approval of the authority having jurisdiction.

8.1.2 Only listed equipment and devices shall be used in the systems.

8.1.3 To determine that the system will function as specified, the requirements in Section 8.2 shall be met.

8.2 Installation Acceptance.

8.2.1 General. It shall be determined that the protected enclosure is in general conformance with the construction documents.

8.2.2 Review Mechanical Components.

8.2.2.1 The piping distribution system shall be inspected to determine that it is in compliance with the design and installation documents.

8.2.2.2 Pipe Size.

8.2.2.2.1 Nozzles and pipe size shall be in accordance with system drawings.

8.2.2.2.2 Means of pipe size reduction and attitudes of tees shall be checked for conformance to the design.

8.2.2.3 Fastening.

8.2.2.3.1 Piping joints, discharge nozzles, and piping supports shall be securely fastened to prevent unacceptable vertical or lateral movement during discharge.

8.2.2.3.2 Discharge nozzles shall be installed in such a manner that piping cannot become detached during discharge.

8.2.2.4 During assembly, the piping distribution system shall be inspected internally to detect the possibility of any oil or particulate matter soiling the hazard area or affecting the agent distribution due to a reduction in the effective nozzle orifice area.

8.2.2.5 The discharge nozzle shall be oriented in such a manner that optimum agent dispersal can be effected.

8.2.2.6 If nozzle deflectors are installed, they shall be positioned to obtain maximum benefit.

8.2.2.7 The discharge nozzles, piping, and mounting brackets shall be installed in such a manner that they will not potentially cause injury to personnel.

8.2.2.7.1 Agent shall not directly impinge on areas where personnel could be found in the work area.

8.2.2.7.2 Agent shall not directly impinge on any loose objects or shelves, cabinet tops, or similar surfaces where loose objects could be present and become missiles.

8.2.2.8 All agent storage containers shall be located in accordance with an approved set of system drawings.

8.2.2.9 All containers and mounting brackets shall be fastened securely in accordance with the manufacturer's requirements.

8.2.2.10 If a discharge test is to be conducted, containers for the agent to be used shall be weighed before and after discharge.

8.2.2.10.1 Fill weight of container shall be verified by weighing or other approved methods.

8.2.2.10.2 For dispersed aerosol agents, container pressure shall be recorded before and after discharge.

8.2.2.11 Adequate quantity of agent to produce the desired specified design application density shall be provided.

8.2.2.11.1 The actual room volumes shall be checked against those indicated on the system drawings to ensure the proper quantity of agent.

8.2.2.11.2 Fan coastdown and damper closure time shall be taken into consideration.

8.2.2.12 Testing.

8.2.2.12.1 The piping shall be pneumatically tested in a closed circuit for a period of 10 minutes at 150 percent of the maximum system working pressure.

8.2.2.12.2 At the end of 10 minutes, the pressure drop shall not exceed 20 percent of the test pressure.

8.2.2.13 A flow test using nitrogen or an inert gas shall be performed on the piping network to verify that flow is continuous and that the piping and nozzles are unobstructed.

8.2.3 Review Enclosure Integrity.

8.2.3.1* All total flooding systems shall have the enclosure examined and tested to locate and then effectively seal any air leaks that could result in a failure of the enclosure to hold the specified agent design application density for the specified holding period.

8.2.3.2 Quantitative results shall be obtained and recorded to indicate that the specified agent design application density for the specified duration of protection is in compliance with Section 7.6, using an approved blower fan unit or other means as approved by the authority having jurisdiction.

8.2.4 Review Electrical Components.

8.2.4.1 Wiring.

8.2.4.1.1 All wiring systems shall be installed in compliance with local codes and the system drawings.

8.2.4.1.2 Alternating current (ac) and direct current (dc) wiring shall not be combined in a common conduit or raceway unless shielded and grounded.

8.2.4.2 All field circuits shall be free of ground faults and short circuits.

8.2.4.2.1 Where field circuitry is being measured, all electronic components, such as smoke and flame detectors or special electronic equipment for other detectors or their mounting bases, shall be removed, and jumpers shall be installed to prevent the possibility of damage within these devices.

8.2.4.2.2 Components shall be replaced after measuring.

8.2.4.3 Power shall be supplied to the control unit from a separate dedicated source that will not be shut down on system operation.

8.2.4.4 Reliable primary and 24-hour minimum standby sources of energy shall be used to provide for operation of the detection, signaling, control, and actuation requirements of the system.

8.2.4.5 Auxiliary Functions.

8.2.4.5.1 All auxiliary functions such as alarm-sounding or alarm-displaying devices, remote annunciators, air-handling shutdown, and power shutdown shall be checked for operation in accordance with system requirements and design specifications.

8.2.4.5.2 If possible, all air-handling and power-cutoff controls shall be of the type that, once interrupted, require manual restart to restore power.

8.2.4.6 Silencing of alarms, if desirable, shall not affect other auxiliary functions such as air handling or power cutoff if required in the design specification.

8.2.4.7 The detection devices shall be checked for proper type and location as specified on the system drawings.

8.2.4.8 Location.

8.2.4.8.1 Detectors shall not be located near obstructions or air ventilation and cooling equipment that would appreciably affect their response characteristics.

8.2.4.8.2 Where applicable, air changes for the protected area shall be taken into consideration.

8.2.4.9 The detectors shall be installed in a professional manner and in accordance with technical data regarding their installation.

8.2.4.10 Manual pull stations shall be installed, readily accessible, accurately identified, and protected to prevent damage.

8.2.4.11 All manual stations used to release agents shall require two separate and distinct actions for operation.

8.2.4.11.1 All manual stations used to release agents shall be identified.

8.2.4.11.2 Particular care shall be taken where manual release devices for more than one system are in close proximity and could be confused or the wrong system actuated.

8.2.4.11.3 Manual stations in this instance shall be clearly identified as to which zone or suppression area they affect.

8.2.4.12 For systems with a main/reserve capability, the main/reserve switch shall be installed, readily accessible, and clearly identified.

8.2.4.13 For systems using abort switches, the switches shall be of the deadman type requiring constant manual pressure, installed, readily accessible within the hazard area, and clearly identified.

8.2.4.13.1 Switches that remain in the abort position when released shall not be used for this purpose.

8.2.4.13.2 Manual pull stations shall always override abort switches.

8.2.4.14 The control unit shall be installed and readily accessible.

8.2.5 Functional Testing.

8.2.5.1 Preliminary Functional Tests. The following preliminary functional tests shall be provided:

(1) If the system is connected to an alarm-receiving office, notify the alarm-receiving office that the fire system test is to be conducted and that an emergency response by the fire department or alarm station personnel is not desired.
(2) Notify all concerned personnel at the end user's facility that a test is to be conducted and instruct personnel as to the sequence of operation.
(3) Disable each agent storage container release mechanism so that activation of the release circuit will not release agent.
(4)*Reconnect the release circuit with a functional device in lieu of each agent storage container release mechanism.
(5) Check each detector for response.
(6) Check that polarity has been observed on all polarized alarm devices and auxiliary relays.
(7) Check that all end-of-line resistors have been installed across the detection and alarm bell circuits where required.
(8) Check all supervised circuits for trouble response.

8.2.5.2 System Functional Operational Test. The following system functional operational tests shall be performed:

(1) Operate detection initiating circuit(s).
(2) Verify that all alarm functions occur according to design specification.
(3) Operate the necessary circuit to initiate a second alarm circuit if present.
(4) Verify that all second alarm functions occur according to design specifications.
(5) Operate manual release.
(6) Verify that manual release functions occur according to design specifications.
(7) Operate abort switch circuit if supplied.

(8) Verify that abort functions occur according to design specifications.
(9) Confirm that visual and audible supervisory signals are received at the control panel.
(10) Test all automatic valves unless testing the valve will release agent or damage the valve (destructive testing).
(11) Check pneumatic equipment, where required, for integrity.

8.2.5.3 Remote Monitoring Operations. The following testing of remote monitoring operations, if applicable, shall be performed:

(1) Operate one of each type of input device while on standby power.
(2) Verify that an alarm signal is received at remote panel after device is operated.
(3) Reconnect primary power supply.
(4) Operate each type of alarm condition on each signal circuit and verify receipt of trouble condition at the remote station.

8.2.5.4 Control Panel Primary Power Source.

8.2.5.4.1 The following testing of the control panel primary power source shall be performed:

(1) Verify that the control panel is connected to a dedicated circuit and labeled.
(2) Test a primary power failure in accordance with the manufacturer's specification with the system fully operated on standby power.

8.2.5.4.2 The control panel shall be readily accessible, yet restricted from unauthorized personnel.

8.2.5.5 Return of System to Operational Condition. When all predischarge work has been completed, each agent storage container shall be reconnected so that activation of the release circuit will release the agent.

8.2.5.5.1 The system shall be returned to its fully operational design condition.

8.2.5.5.2 The alarm-receiving office and all concerned personnel at the end user's facility shall be notified that the fire system test is complete and that the system has been returned to full service condition.

Chapter 9 Inspection, Maintenance, Tests, Training, and Safety

9.1 Inspection. At least every 30 days, an inspection shall be conducted to assess the aerosol system's operational condition.

9.1.1 Enclosure Inspection. At least every 12 months, the enclosure protected by the aerosol system shall be thoroughly inspected to determine if penetrations or other changes have occurred that could adversely affect agent leakage or change volume of hazard or both.

9.1.1.1 Where the inspection indicates conditions that could result in inability to maintain the aerosol design application density, they shall be corrected.

9.1.1.2 If uncertainty still exists, the enclosures shall be retested for integrity in accordance with 8.2.3.

9.2 Maintenance.

9.2.1 At least annually, all systems shall be subjected to the manufacturer's test and maintenance procedures by competent personnel.

9.2.2 The maintenance report with recommendations shall be filed with the owner.

9.2.3 At least semiannually, the agent quantity and pressure of refillable containers shall be checked.

9.2.3.1 For dispersed aerosol systems, if a container shows a loss in pressure (adjusted for temperature) of more than 10 percent, it shall be refilled or replaced.

9.2.3.2 Where the amount of agent in the container is determined by special measuring devices, these devices shall be listed.

9.2.4 All halocarbon and aerosol material removed from refillable containers during service or maintenance procedures shall be collected and recycled or disposed of in an environmentally sound manner and in accordance with existing laws and regulations.

9.2.5 Factory-charged, nonrefillable containers for dispersed aerosol systems that do not have a means of pressure indication shall have the agent quantity checked at least semiannually.

9.2.5.1 If a container shows a loss in agent weight of more than 5 percent, it shall be replaced.

9.2.5.2 All factory-charged, nonrefillable containers removed from useful service shall be returned to the manufacturer for recycling of the agent or disposed of in an environmentally sound manner and in accordance with existing laws and regulations.

9.2.6 For dispersed aerosol systems, the date of inspection, gross weight of cylinder plus agent, net weight of agent, type of agent, person performing the inspection, and, where applicable, the pressure at a recorded temperature shall be recorded on a tag attached to the container.

9.2.7 Dispersed aerosol systems shall be maintained in full operating condition at all times.

9.2.8 Actuation, impairment, and restoration of dispersed aerosol systems shall be reported promptly to the authority having jurisdiction.

9.2.9 Any troubles or impairments shall be corrected in a timely manner consistent with the hazard protected.

9.2.10 Penetrations.

9.2.10.1 Any penetrations made through the enclosure protected by the aerosol system shall be sealed immediately.

9.2.10.2 The method of sealing shall restore the original fire resistance rating of the enclosure.

9.3 Tests.

9.3.1 Container Test.

9.3.1.1 Retesting.

9.3.1.1.1 U.S. Department of Transportation (DOT), Canadian Transport Commission (CTC), or similar design dispersed aerosol agent containers shall not be recharged without retesting if more than 5 years have elapsed since the date of the last test and inspection.

9.3.1.1.2 For halocarbon agent storage containers, the retest shall be permitted to consist of a complete visual inspection as described in 49 CFR 173.34(e)(10).

9.3.1.2 Dispersed aerosol agent storage containers continuously in service without discharging shall be given a complete external visual inspection every 5 years or more frequently if required.

9.3.1.2.1 The visual inspection shall be in accordance with Section 3 of CGA C-6, except that the cylinders need not be emptied or stamped while under pressure.

9.3.1.3 Inspections shall be made only by competent personnel and the results recorded on both of the following:

(1) A record tag permanently attached to each cylinder
(2) An inspection report

9.3.1.3.1 A completed copy of the inspection report shall be furnished to the owner of the system or an authorized representative, and the records shall be retained by the owner for the life of the system.

9.3.1.3.2 Where external visual inspection indicates that the container or generator has been damaged, additional strength tests shall be required.

9.3.2 Hose Test.

9.3.2.1 General.

9.3.2.1.1 All system hose shall be examined annually for damage.

9.3.2.1.2 If visual examination shows any deficiency, the hose shall be immediately replaced or tested as specified in 9.3.2.2.

9.3.2.2 Testing.

9.3.2.2.1 All hose shall be tested every 5 years at 150 percent of the maximum container pressure at 55°C (130°F).

9.3.2.2.2 The testing procedure shall be as follows:

(1) The hose is removed from any attachment.
(2) The hose assembly is then placed in a protective enclosure designed to permit visual observation of the test.
(3) The hose is completely filled with water before testing.
(4) Pressure then is applied at a rate-of-pressure rise to reach the test pressure within a minimum of 1 minute.
(5) The test pressure is maintained for 1 full minute.
(6) Observations are made to note any distortion or leakage.
(7) If the test pressure has not dropped or if the couplings have not moved, the pressure is released.
(8) The hose assembly is considered to have passed the hydrostatic test if no permanent distortion has taken place.
(9) Hose assembly passing the test must be completely dried internally.
(10) If heat is used for drying, the temperature must not exceed the manufacturer's specifications.
(11) Hose assemblies failing a hydrostatic test must be marked and destroyed and then replaced with new assemblies.
(12) Each hose assembly passing the hydrostatic test is marked to show the date of test.

9.4 Training.

9.4.1 All persons who could be expected to inspect, test, maintain, or operate fire-extinguishing systems shall be thoroughly trained and kept thoroughly trained in the functions they are expected to perform.

9.4.2 Personnel working in an enclosure protected by an aerosol system shall receive training regarding agent safety issues.

9.5 Safety. Safe procedures shall be observed during installation, servicing, maintenance, testing, handling, and recharging of aerosol systems and components.

Chapter 10 Marine Systems

10.1 Scope. This chapter shall be limited to applications using marine systems with aerosol fire extinguishing agents on commercial vessels and pleasure craft.

10.2 General.

10.2.1 Chapter 10 outlines the deletions, modifications, and additions that shall be required for marine applications.

10.2.2 All other requirements of this standard shall apply to marine systems except as modified by this chapter.

10.3 Special Definitions. See Section 3.4.

10.4 Inspected Vessels.

10.4.1 Use and Limitations.

10.4.1.1 Aerosol fire-extinguishing systems used to protect hazards that are partially or totally enclosed or equipment that is partially or totally enclosed on inspected vessels shall comply with the requirements of this section.

10.4.1.2 Aerosol fire-extinguishing systems used to protect normally occupied spaces shall have a time delay and audible and visual predischarge alarms that sound in the protected space for at least 20 seconds prior to discharge.

10.4.2 Agent Storage Containers Located Outside the Protected Space.

10.4.2.1 Agent storage containers shall be located outside the protected space except as permitted by 10.4.3.

10.4.2.2 The agent storage containers shall be stored in an accessible room that is ventilated to maintain the ambient temperature below 55°C (130°F).

10.4.2.3 Common boundaries between the agent storage container room and the protected space shall be constructed as A-60 Class divisions.

10.4.2.4 The agent container storage room shall be accessible without having to pass through the protected area or any area common to the protected area that could become untenable from a fire in the protected area.

10.4.2.5 Access doors to the agent storage container room shall open outward.

10.4.2.6 Agent storage containers located where they could be subjected to moisture shall be installed at least 50 mm (2 in.) above the deck.

10.4.3 Agent Storage Containers Located Inside the Protected Space.

10.4.3.1 Agent storage containers shall be permitted to be located inside the protected space if the arrangements are in accordance with 10.4.3.2 through 10.4.3.7.

10.4.3.2 An automatic fire detection system in accordance with 10.4.5 shall be installed in the protected space to provide early warning of fire conditions.

10.4.3.3 Electrical power circuits connecting the containers shall be supervised for fault conditions and loss of power.

10.4.3.4 Visual and audible alarms shall be provided on the navigating bridge to warn of the fault conditions in 10.4.3.3.

10.4.3.5 Additional agent storage containers or backup electrical circuits and controls necessary for the release of the system shall be provided to ensure that the required quantity of extinguishing agent can be discharged in the event of damage that causes the loss of the largest single actuation circuit.

10.4.3.6 All circuits essential for the release of the system located within the protected space shall be heat-resistant cables such as mineral-insulated cables compliant with Article 330 of NFPA 70 or Type CI fire alarm circuit integrity cables compliant with Article 760 of NFPA 70.

10.4.3.7 System discharge shall be indicated on the navigating bridge.

10.4.4 System Component Requirements.

10.4.4.1 System components shall be specifically listed or approved for marine applications.

10.4.4.2 The system and equipment shall be designed to withstand ambient temperature changes, vibrations, humidity, shock, impact, clogging, and corrosion normally encountered in ships.

10.4.4.3 Piping, valves, and fittings made of ferrous materials shall be protected inside and out against corrosion.

10.4.4.4 Heat-sensitive materials shall not be used for piping, valves, fittings, mounting brackets, agent storage containers, and welding fillers.

10.4.4.5 Aluminum components shall not be used for manually operated systems.

10.4.4.6 High-pressure cylinders shall comply with the requirements of the U.S. Department of Transportation (DOT), 49 CFR 171–190, 178.36, and 178.37, or other approved international standards.

10.4.4.7 Agent storage containers used as shipping containers shall be designed to meet the requirements of the DOT or of the Canadian Transport Commission or other approved international standards.

10.4.5 Detection, Actuation, and Control Systems.

10.4.5.1 Automatic detection systems shall initiate audible and visual alarms in the protected space and on the navigating bridge upon detection of fire.

10.4.5.2 Detection and alarm system components shall be electrically supervised for fault conditions.

10.4.5.3 Detection system trouble signals shall initiate audible and visual alarms on the navigating bridge.

10.4.5.4 Power Supplies.

10.4.5.4.1 Automatic detection, signaling, control, and actuation systems shall have at least two independent power supplies with automatic changeover.

10.4.5.4.2 One of the sources of power described in 10.4.5.4.1 shall be wholly provided from outside the protected space.

10.4.5.5 The backup power supply shall be sized to operate the system for at least 24 hours.

10.4.5.6 Automatic release of the extinguishing system shall not be permitted in spaces over 170 m^3 (6000 ft^3) where actuation of the system would interfere with the safe navigation of the vessel.

10.4.5.7 Every system shall have a remote manual actuation station located in the main egress route outside the protected space.

10.4.5.8 Instructions for the operation of the system shall be located in a conspicuous place at or near all manual actuation stations and in the agent storage room (if provided).

10.4.5.9 For systems with an agent storage room, the instructions required by 10.4.5.8 shall include a chart indicating the location of the emergency local control to be used if the remote controls fail to operate.

10.4.5.10 Manual actuation of the system shall require two separate actions, except for systems protecting spaces less than 170 m^3 (6000 ft^3).

10.4.5.11 Interlocks shall be provided to shut down any pressurized fuel systems and power-operated ventilation systems serving the protected space prior to agent discharge.

10.4.6 Enclosure.

10.4.6.1 All openings in the protected space shall be permanently sealed to prevent the loss of agent or shall comply with 10.4.6.2 or 10.4.6.3.

10.4.6.2 Openings in the protected space that cannot be permanently sealed to prevent the loss of agent shall be arranged to be automatically closed prior to the release of agent.

10.4.6.3 Additional quantities of agent shall be provided to compensate for any openings in the protected space that cannot be permanently sealed or equipped with automatic closures to prevent the loss of agent.

10.4.7 Agent Design Application Density.

10.4.7.1 For combinations of fuels, the agent design application density shall be determined for the fuel requiring the greatest design application density.

10.4.7.2 The agent design application density shall be determined at the lowest expected ambient temperature in the protected space.

10.4.7.2.1 The agent design application density for machinery spaces shall be determined at 0°C (32°F).

10.4.7.2.2 The agent design application density for cargo pump rooms shall be determined at −18°C (0°F).

10.4.7.3 The agent design application density shall be calculated based on the net volume of the protected space.

10.4.7.4 If the protected space includes a bilge or a machinery casing area, the volume of these areas shall be included in the net volume calculation.

10.4.7.5 If the protected space includes pressurized air receivers, their equivalent free air volume shall be included in the net volume calculation.

10.4.7.6 For flammable and combustible liquid hazards, the minimum agent design application density shall be determined by full-scale testing in accordance with IMO MSC/Circular 1007.

10.4.7.7 For ordinary combustible hazards, including electrical components, the minimum agent design application density shall be determined by testing acceptable to the authority having jurisdiction.

10.4.8 Distribution System. The spacing, area of coverage, ceiling height, and location of discharge outlets shall be within the limits determined by full-scale fire tests in accordance with IMO MSC/Circular 1007 for flammable and combustible liquids or in accordance with the testing required by 10.4.7.7 for ordinary combustibles.

10.4.9 Duration of Protection. The quantity of agent provided shall be sufficient to maintain the minimum agent design application density in the protected space for at least 15 minutes.

10.4.10 Compliance. Electrical systems shall comply with 46 CFR, Subchapter J, "Electrical Engineering."

10.5 Uninspected Vessels and Pleasure Craft.

10.5.1 Use and Limitations.

10.5.1.1 Aerosol fire-extinguishing systems used to protect unoccupied spaces on uninspected vessels and pleasure craft shall comply with the requirements of Section 10.5.

10.5.1.2 Aerosol fire-extinguishing systems used to protect normally occupied spaces and spaces larger than 57 m^3 (2000 ft^3) shall comply with the requirements of Section 10.4.

10.5.2 System Component Requirements.

10.5.2.1 Aerosol fire-extinguishing units and related system components shall be specifically listed or approved for use on uninspected vessels and pleasure craft.

10.5.2.2 The equipment shall be designed to withstand ambient temperature changes, vibrations, humidity, shock, impact, clogging, and corrosion normally encountered in marine applications.

10.5.3 Installation.

10.5.3.1 Aerosol fire-extinguishing units shall be installed in accordance with the manufacturer's listed instructions with approved brackets and mounting hardware.

10.5.3.2 Aerosol fire-extinguishing systems shall be installed within volume and spacing limits determined by testing acceptable to the authority having jurisdiction.

10.5.4 Actuation and Controls.

10.5.4.1 Aerosol fire-extinguishing systems shall be automatically actuated.

10.5.4.2 Aerosol fire-extinguishing systems installed in spaces larger than 28 m^3 (1000 ft^3) shall have a manual actuator in addition to the automatic means of actuation.

10.5.4.3 The discharge of an aerosol fire-extinguishing system shall be indicated by a visual signal at the operator's console.

10.5.4.4 Aerosol fire-extinguishing systems with the capability to automatically shut down the vessel's engines shall have a means to permit restart of the engines from the operator's console.

10.5.4.5 Aerosol fire-extinguishing systems without the capability to automatically shut down the vessel's engines must be supplemented with a warning label posted at the operator's console that states:

IF FIXED FIRE-EXTINGUISHING SYSTEM DISCHARGES, SHUT DOWN ENGINES, GENERATORS, AND BLOWERS.

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1.5.1 See IEEE/ASTM SI 10, *Standard for Use of the International System of Units (SI): The Modern Metric System.*

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.3 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.3.3.5 Automatic/Manual Switch. The means can be in the form of a manual switch on the control panel or other units or a personnel door interlock. In all cases, the switch changes the actuation mode of the system from automatic and manual to manual only and vice versa.

A.3.3.9.1 Design Application Density (g/m^3). Measuring the amount of solid aerosol particulate in the atmosphere after discharge of a system is technically difficult and resource intensive. Therefore, manufacturers use the extinguishing application density *(see 3.3.9.2)* and the design application density *(see 3.3.9.1)* as convenient proxies that can be used by system designers to calculate the amount of aerosol-forming compound that is necessary to protect a given space.

Extinguishing application density is calculated by taking the mass of solid aerosol-forming compound necessary to extinguish the fire over the volume of the protected space in a test fire. For example, in a 5 m^3 room, a hypothetical powdered aerosol could require 2 kg of solid aerosol-forming compound to extinguish a flame. Therefore, the extinguishing concentration in this example would be 485.5 g/m^3. The design application density is calculated by adding 30 percent to the extinguishing design density. Therefore, for this example, the design application density would be 631.15 g/m^3. Additional safety factors can be required depending on the specific characteristics of the hazard as specified by this standard. The system designer can then calculate the amount of solid aerosol-forming material needed to achieve the design application density and thus protect a given space by applying the formula in 7.5.1.

However, to assess the potential human health effects, manufacturers must conduct additional toxicity testing for use in normally occupied spaces. Such testing requires direct measurement of the particulates after discharge of the systems at the maximum design application density. The measurement is defined by this standard as the particulate density *(see 3.3.9.3)*.

A.3.3.9.2 Extinguishing Application Density (g/m^3). See A.3.3.9.1.

A.3.3.16 Inspection. This is done by seeing that the system is in place, that it has not been actuated or tampered with, and that there is no obvious physical damage or condition to prevent operation.

A.3.3.17 Maintenance. It includes a thorough examination and any necessary repair or replacement of system components.

A.3.3.19 Mass Median Aerodynamic Diameter (MMAD). Fifty percent of the particles by weight will be smaller than the median diameter and fifty percent of the particles will be larger. (For more information, see EPA Health Effects Test Guidelines, OPPTS 870.1300, Acute Inhalation Toxicity.)

A.3.3.26 Unoccupiable. Examples of unoccupiable areas include shallow void spaces and cabinets.

A.3.4.1 A-60 Class Division. This is determined when tested in accordance with ASTM E 119, or equivalent test method.

A.4.3 Many factors affect the environmental acceptability of a fire suppression agent. Uncontrolled fires pose significant impact by themselves. All extinguishing agents should be used in ways that eliminate or minimize the potential environmental impact. General guidelines to be followed to minimize that impact include the following:

(1) Do not perform unnecessary discharge testing.
(2) Consider the ozone depletion and global warming impact of the agent under consideration and weigh those impacts against the fire safety concerns.
(3) Recycle all agents where possible.
(4) Consult the most recent environmental regulations on each agent.

The unnecessary emission of aerosol extinguishing systems with the potential of ozone depletion, global warming, or both should be avoided. All phases of design, installation, testing, and maintenance of systems using such agents should be performed with the goal of no emission to the environment.

A.4.4.1 With regard to the use of carrier gases for dispersed aerosol extinguishing systems, it is generally believed, as stated in A.1.8.1 of NFPA 2001, that, because of the highly stable nature of the compounds that are derived from the families that include halogenated hydrocarbons and inert gases, incompatibility will not be a problem. These materials tend to behave in a similar fashion and, as far as is known, the reactions that could occur as the result of mixing of these materials within the container is not thought to be a real consideration with regard to their application to a fire protection hazard. Similarly, compatibility of the agents with components of the extinguishing system is not thought to be an issue.

A.5.1 The discharge of aerosol extinguishing systems to extinguish a fire could create a hazard to personnel from the natural form of the aerosol or from certain products of aerosol generation (including combustion products and trace gases from condensed aerosols). Acid by-products can also be formed and present a hazard to exposed personnel [see NFPA 2001, A.1.5.1.2 and A.5.7.1.2, for a discussion of hydrofluoric acid (HF)]. Unnecessary exposure of personnel to either the natural agent or the decomposition products should be avoided.

A.5.1.1 The SNAP Program was originally outlined in 59 CFR 13044.

A.5.2.1 Potential hazards to be considered for individual systems are the following:

(1) *Noise.* Discharge of a system can cause noise loud enough to be startling but ordinarily insufficient to cause traumatic injury.
(2) *Turbulence.* High-velocity discharge from nozzles could be sufficient to dislodge substantial objects directly in their path. System discharge can cause enough general turbulence in the enclosures to move unsecured paper and light objects.
(3) *Cold Temperature.* For dispersed aerosol extinguishing systems, direct contact with the vaporizing liquid being discharged from a system will have a strong chilling effect on objects and can cause frostbite burns to the skin. The liquid phase vaporizes rapidly when mixed with air and thus limits the hazard to the immediate vicinity of the discharge point.
(4) *Reduced Visibility.* When activated, condensed aerosol generators reduce visibility both during and after discharge period. This particular consideration is further addressed in A.5.2.5.
(5) *Potential Toxicity.* When activated, condensed aerosol generators may produce toxic levels of gases such as carbon monoxide, nitrogen oxides, and ammonia, which are typical by-products of the aerosol-generating reaction. Actual concentrations of these by-products depend on the chemical composition of the solid aerosol-forming compound and coolant, engineering design of the aerosol generators, and conditions in the enclosure under protection. This particular consideration is further addressed in Annex C.
(6) *Thermal Hazard.* A condensed aerosol discharges at elevated temperatures. Depending on the intended application(s) of the aerosol system, the temperature and minimum clearance from the discharge outlet are specified by the manufacturers of the aerosol generators. Immediately after discharge, aerosol generators can be hot; therefore, protective gloves should be worn by personnel handling generators after discharge.

(7) *Eye Irritation.* Direct contact with the particles being discharged from a system can result in irritation, tearing, and burning of the eyes. Exposure of the powdered aerosol to the eyes should be avoided. This particular consideration is addressed in Annex C.

A.5.2.4 See Annex C for toxicity information.

A.5.2.4.2 Reference is made to EPA/600/8-90/066F.

A.5.2.5 Such safety measures can include but are not limited to personnel training, goggles, audio devices, floor-mounted directional lighting, evacuation plans, and exit drills.

See Annex C for reduced visibility information.

A.5.2.7.2 The steps and safeguards necessary to prevent injury or death to personnel in areas whose atmospheres will be made hazardous by the discharge or thermal decomposition of aerosol agents can include the following:

(1) Provision of adequate aisleways and routes of exit and procedures to keep them clear at all times.
(2) Provision of emergency lighting and directional signs as necessary to ensure quick, safe evacuation.
(3) Provision of alarms in such areas that will operate immediately on detection of the fire.
(4) Provision of only outward-swinging, self-closing doors at exits from hazardous areas and, where such doors are latched, provision of panic hardware.
(5) Provision of continuous alarms at entrances to such areas until the atmosphere has been restored to normal.
(6) Provision of warning and instruction signs at entrances to and inside such areas. These signs should inform persons in or entering the protected area that an aerosol system is installed and should contain additional instructions pertinent to the conditions of the hazard.
(7) Provision for the prompt discovery and rescue of persons rendered unconscious in such areas. This should be accomplished by having such areas searched immediately by trained personnel equipped with proper breathing equipment. Self-contained breathing equipment and personnel trained in its use and in rescue practices, including cardiopulmonary resuscitation (CPR), should be readily available.
(8) Provision of instruction and drills for all personnel in or in the vicinity of such areas, including maintenance or construction people who could be brought into the area, to ensure their correct action when an aerosol system operates.
(9) Provision of means for prompt ventilation of such areas. Forced ventilation will often be necessary. Care should be taken to readily dissipate hazardous atmospheres and not merely move them to another location.
(10) Prohibition against smoking until the atmosphere has been determined to be free of the aerosol agent.
(11) Following a system discharge, removal, in accordance with the manufacturer's recommendations, of the aerosol that has settled. Protective clothing, including gloves and goggles, should be worn. A respirator or mask can be required.
(12) Provision of such other steps and safeguards that a careful study of each particular situation indicates is necessary to prevent injury or death.

A.5.2.7.3 A certain amount of leakage from a protected space to adjacent areas is anticipated during and following agent discharge. Consideration should be given to agent concentration [when above the no observed adverse effect level (NOAEL)], decomposition products, products of combustion, and relative size of adjacent spaces. Additional consideration should be given to exhaust paths when the enclosure is opened or vented after a discharge.

A.6.2.3.2 Storage containers should not be exposed to a fire in a manner likely to impair system performance.

A.6.2.4.3.1 Independent inspection and certification are recommended.

A.6.4.1.1 In Canada, refer to ULC S524-M91 and ULC S529-M87.

A.6.4.5.3 A telephone should be located near the abort switch.

A.6.4.5.6.2 Hazards associated with fast-growth fires would include but not be limited to flammable liquid storage or transfer and aerosol filling areas.

A.6.4.6 Accidental discharge can be a significant factor in unwanted aerosol agent emissions. Equipment lockout or service disconnects can be instrumental in preventing false discharges when the aerosol agent system is being tested or serviced. In addition, servicing of air-conditioning systems with the release of refrigerant aerosols, soldering, or turning electric plenum heaters on for the first time after a long period of being idle could trip the aerosol system. Where used, an equipment service disconnect switch should be of the keyed-access type if external to the control panel, or it can be a toggle type if it is within the locked control panel. Either type should annunciate at the panel when in the out-of-service mode. Written procedures should be established for taking the aerosol system out of service.

A.7.4.2.1 As a minimum, the listing program shall conform to the applicable requirements of UL 2127 or UL 2166, or the equivalent.

A.7.4.2.2 As a minimum, the listing program shall conform to the applicable requirements of UL 2127 or UL 2166, or the equivalent.

A.7.6 Because measuring the concentration of the actual aerosol presents certain difficulties, other physical properties proportional to the aerosol, such as optical transmittance, can be measured, provided adequate calibration between such properties and aerosol concentration can be effected. The measuring technique, procedure, and calibration method shall be endorsed by an appropriate authority.

A.8.2.3.1 The currently preferred method is to use a blower door fan unit and smoke pencil.

A.8.2.5.1(4) For electrically actuated release mechanisms, these devices can include 24 V lamps, flashbulbs, or circuit breakers. Pneumatically actuated release mechanisms can include pressure gauges. Refer to the manufacturer's recommendations in all cases.

Annex B Toxicity Information

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1 Design requirements of the powdered aerosol fire suppressants are such that the particles must be 10 μm for maximum effectiveness. Particles of this size are able to be inhaled, thus making potential exposure to the respiratory system (nasal passages, trachea, bronchus, and terminal bronchioles) a

Table B.1(a) Locations and Mechanisms of Deposition of Particles in the Human Respiratory Tract and Postdeposition Clearance Times

Particle Size (μm)	Mechanism of Deposition	Location	Clearance Mechanism	Clearance Time
>10	Impaction	Nasopharyngeal	Mucociliary transport	Hours to days
5–10	Impaction	Nasopharyngeal	Mucociliary transport	Hours to days
1–5	Sedimentation	Tracheobronchiolar	Mucociliary transport	Hours to weeks
<1–2.5	Diffusion	Alveolar	Alveolar macrophage	Hours

concern. For example, in humans, particles of size 5 μm to 30 μm are typically deposited in the nasopharyngeal (nose and throat) region due to impaction, while particles ranging from 1 μm to 5 μm will deposit by sedimentation within the trachea (windpipe) and bronchiolar (lower lung) region. Particles approximating 1 μm will diffuse into the alveolar region (gas exchange area) and can affect gas exchange and be absorbed into the bloodstream. The location of particle settling has a large effect on what happens to the particle following exposure and the types of adverse effects it might cause. For example, particles depositing in the upper nasal passages can be sneezed or breathed out, while those in the nasopharyngeal and tracheobronchial regions are removed via mucociliary transport [via the threadlike fringes (cilia) on cells lining these regions of the respiratory system]. Although the duration of exposure in an accidental release is very short (≤5 minutes), the large amounts of aerosol released by the suppressant mechanism suggests that exposures to aerosol components will be high. Further, because clearance of the deposited material does not occur rapidly (e.g., within days to weeks), the potential exists for injury even though the exposure time is very short.

Table B.1(a) shows the locations for deposition based on particle size and the clearance mechanisms and clearance times for deposited particles.

Powdered aerosols are typically composed of multiple soluble and insoluble compounds. As such, acute inhalation exposure to very high concentrations of these compounds can induce a variety of adverse effects in humans. Therefore, a limited battery of toxicity tests is required to determine the appropriateness of the powdered aerosol system for use in occupied spaces. These tests are the following:

(1) *Draize Eye Irritation Test.* This assay, using a rabbit model, is currently recommended for assaying the potential for eye irritation (reversible eye effects) and corrosion (irreversible damage to eye tissue) after exposure to a variety of toxicants.

(2) *Static Acute Inhalation Toxicity Test.* This assay is designed to determine the acute toxicity of an actual exposure to the powdered aerosol agent at its design concentration. The test assays the potential for suffocation and immediate pulmonary responses in the test animal induced by both insoluble and soluble particles in the powdered aerosol. Because exposure in this test is limited to a very short period (e.g., 15 minutes), it is necessary to model exposure to the powdered aerosol at its design concentration. Doing so ensures that the design concentration has been adequately tested with regard to immediate adverse effects (e.g., suffocation).

(3) *Additional Toxicity Tests as Needed.* In the event that a powdered aerosol comprises components with unknown toxicity, it can be appropriate to conduct a more extensive inhalation toxicity test to determine potential effects, particularly if the design concentration cannot be achieved or closely approximated in the static toxicity test. An example of an additional test is the acute inhalation limit test, which uses a 4-hour exposure duration.

It is important to have data on the aerodynamic properties of the powdered aerosol [e.g., the mass median aerodynamic diameter (MMAD) and geometric standard deviation, σg]. These values are necessary to determine where the particles can deposit within the airways of a rodent model and in a potentially exposed human. These values are important because the larger the number of particles (and thus increased total mass) capable of penetrating the lung, the greater the probability of a toxic effect. Table B.1(b) provides information regarding areas of the human respiratory tract where particulate matter can be deposited following exposure.

Table B.1(b) Deposition of Particles in the Human Respiratory Tract as a Function of Particle Size

Particle Size (μm)	Extrathoracic (Nose and Throat)	Tracheo-bronchial	Pulmonary Region (Gas Exchange)
>10	Yes	No	No
5–10	Yes	Yes	No
2.5–5	Yes	Yes	Some
<2.5	Yes	Yes	Yes

B.2 An appropriate protocol measures the effect in a stepwise manner such that the interval between the lowest observable adverse effect level (LOAEL) and the no observed adverse effect level (NOAEL) is sufficiently small to be acceptable to the competent regulatory authority. The EPA includes in its SNAP evaluation this aspect (of the rigor) of the test protocol. (The SNAP Program was originally outlined in 59 CFR 13044.) For powdered aerosols covered in this standard, the NOAEL and LOAEL are based on acute pulmonary toxicity. The measured endpoints can include suffocation, pulmonary edema, inflammation, and a myriad of other cellular responses, such as cytokine activation.

B.3 Because pulmonary responses in animal models following inhalation exposures to high concentrations of particulate matter can differ substantially from that in humans, it is necessary to extrapolate the response in the animal model to that of a human under the same exposure conditions. In this regard, an appropriate dosimetry model, such as the Regional

Deposited Dose Ratio model [1] or the Multiple Path Particle Dosimetry model [2] should be used. These models allow the extrapolation between inhalation concentrations in animal models to that of a human to predict responses at particular exposure concentrations.

B.4 Some components of powdered aerosols can have the potential for inducing extrarespiratory systemic toxicity. This means that they do not cause toxicity to the respiratory system but instead result in an adverse effect to another organ (e.g., liver, kidneys, central nervous system) following uptake into the body's circulatory system. Examples of extrarespiratory toxicants are potassium carbonate, potassium bromide, and sodium bicarbonate. Exposure concentrations should be compared to known occupational limits set by appropriate governing bodies. For example, short-term exposure limits (STELs) can be available for these chemicals and should be used to determine whether individual components of the aerosol can pose a risk to human health following acute accidental exposure. Further, any available toxicity information on the aerosol components, combustion products (for condensed aerosols), or trace gases should be used to determine the potential for toxic effects following such an acute exposure. When reviewing the toxicity data, the focus should be on the target organ(s) and most sensitive effects. For those compounds with limited or no available toxicity data, a reasonable surrogate compound (i.e., structurally similar compound) should be used.

B.5 References.

(1) EPA/600/8-90/066F, Regional Deposited Dose Ratio Program in "Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry," October 1994.

(2) CIIT/RIVM, Chemical Industry Institute of Toxicology/ National Institute for Public Health and the Environment, Multiple Path Particle Dosimetry Model, V1.0, October 2002.

Annex C Reduced Visibility Information

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 In the fire protection sector, safety and health depend on an individual's ability to escape a fire hazard. This ability could be impaired if a fire suppressant has an immediate toxic effect or decreases the visibility necessary to exit an occupied space. These factors can also pose risks in a nonfire situation. Visibility is of particular concern when powdered aerosols are used. The following discussion provides guidance to assist in the characterization of visibility. Authorities having jurisdiction might wish to consider this information when assessing powdered-aerosol fire extinguishers for occupied spaces.

C.2 Assessing Visibility for a Powdered Aerosol: A Model Approach. To ensure that powdered-aerosol products will meet the visibility requirements of the appropriate organizations, a brief assessment of visibility ratings as functions of concentration of agent and particle size is provided. Table C.2 provides an estimate of the distances an individual can see in a space where a powdered-aerosol fire extinguisher has been discharged in the absence of a fire. The distances are based on a standard contrast value of 0.02 for particulate matter with a given mass median aerodynamic diameter (MMAD) at varying concentrations, under sunlight conditions. If the release of the powdered aerosol restricts visibility in a room to 1 m or less, reengineering powdered-aerosol systems to improve visibility can be prudent. Manipulating particle size and concentration to increase visibility above 1 m is recommended because maneuvering around objects in a room to find an exit would be extremely problematic if vision is restricted to less than 1 m.

Table C.2 shows that visibility is a strong function of the powdered aerosol's concentration and MMAD. As the MMAD of the aerosol deviates (i.e., increases or decreases) from 0.6 μm and the concentration of the powdered aerosol remains constant, the visibility in the space improves. Additionally, as the concentration of the released powdered aerosol increases, the visibility in the space decreases.

The model is based on daylight conditions and might not precisely correspond to visibility in machinery spaces without natural light; however, the model can still be used as an approximate gauge for these circumstances. Note that if lighting is substantially below daylight conditions, then the values in Table C.2 overestimate visibility.

C.3 Design of the Model. This model is based on the standard visual range formula and Mie theory. (Mie theory is a mathematical-physical theory of the scattering of electromagnetic radiation by spherical particles.) [1] The following standard visual range formula is based on typical aerosol distribution in sunlight and the standard visual contrast:

$$L_v \approx \frac{1200}{C}$$

where:

L_v = visibility (km)

C = the concentration of the aerosol particles (μg/m^3) for particles with MMAD falling in the range of 0.1 μm to 1 μm

Figure C.3 is based on Mie scattering and shows how the amount of light scattering, represented by a scattering coefficient, is dependent on particle MMAD. The figure shows how solar light at sea level, which has its peak wavelength in the range 0.4 μm to 0.6 μm, is most effectively scattered by particles with similar dimensions (i.e., 0.4 μm to 0.6 μm in diameter). Thus, light is less effectively scattered by particles whose size is larger or smaller than this optimal size range, and the resulting visibility improves. Thus, the visibility for a powdered aerosol is approximated by a function of the concentration, as shown by the standard visual range formula, and the particle MMAD for a given characteristic standard distribution of solar light is based on Mie scattering functions.

The scattering coefficient has been calculated and is shown in Figure C.3 for a given characteristic standard distribution of solar light based on Mie scattering functions over typical ground level visual wavelengths (0.36 μm to 0.68 μm) for a typical refractive index of 1.5.

C.4 Potential Settling Rates and the Effect on Visibility. The scattering model described in Section C.3 does not include any adjustment for the velocity at which the particles settle. If the particles settle quickly, the concentration of the powdered aerosol in the air decreases and visibility increases. Table C.4 shows settling velocity for spherical particles based on Stokes law and adjustments for friction and slip corrections. The table shows that over the time period of interest (<10 minutes) the vast majority of particles will remain suspended for particles with MMAD <10 μm. Fire suppressant systems tend not to use particles having MMAD >10 μm because the particles

Table C.2 Visibility as a Function of Particle MMAD and Concentration

Particle Size MMAD (μm)	Visibility (cm) at Varying Concentrations										
	10 mg/m^3	1,000 mg/m^3	10,000 mg/m^3	20,000 mg/m^3	30,000 mg/m^3	40,000 mg/m^3	50,000 mg/m^3	70,000 mg/m^3	90,000 mg/m^3	110,000 mg/m^3	130,000 mg/m^3
10	285,600.0	2,856.0	285.6	142.8	95.2	71.4	57.1	40.8	31.7	26.0	22.0
9	248,400.0	2,484.0	248.4	124.2	82.8	62.1	49.7	35.5	27.6	22.6	19.1
8	207,600.0	2,076.0	207.6	103.8	69.2	51.9	41.5	29.7	23.1	18.9	16.0
7	177,600.0	1,776.0	177.6	88.8	59.2	44.4	35.5	25.4	19.7	16.1	13.7
6	156,000.0	1,560.0	156.0	78.0	52.0	39.0	31.2	22.3	17.3	14.2	12.0
5	139,200.0	1,392.0	139.2	69.6	46.4	34.8	27.8	19.9	15.5	12.7	10.7
4	123,600.0	1,236.0	123.6	61.8	41.2	30.9	24.7	17.7	13.7	11.2	9.5
3	114,000.0	1,140.0	114.0	57.0	38.0	28.5	22.8	16.3	12.7	10.4	8.8
2	81,600.0	816.0	81.6	40.8	27.2	20.4	16.3	11.7	9.1	7.4	6.3
1	25,200.0	252.0	25.2	12.6	8.4	6.3	5.0	3.6	2.8	2.3	1.9
0.8	15,600.0	156.0	15.6	7.8	5.2	3.9	3.1	2.2	1.7	1.4	1.2
0.6	12,000.0	120.0	12.0	6.0	4.0	3.0	2.4	1.7	1.3	1.1	0.9
0.1	163,200.0	1,632.0	163.2	81.6	54.4	40.8	32.6	23.3	18.1	14.8	12.6

agglomerate and fall out of suspension, rendering the fire suppressant less effective. Therefore, since the settling velocities are minimal for the size particles used in fire suppressants, the settling velocity will not significantly alter the visibilities presented in Table C.2.

C.5 Methods for Increasing Visibility and Ability to Exit Space. If the visibility resulting from use of a fire suppressant is <1 m, then mitigating activities should be performed to increase a person's ability to see the location of the exit in the protected space after the powdered aerosol extinguisher has been discharged. Methods for increasing visibility include re-engineering the powdered aerosol, designing the lighting and space to conform with physical properties of the powdered aerosol, and training the occupants to locate the exits in the event of a discharge.

C.6 Engineering Powdered Aerosol According to the Model. One way to increase the visibility resulting from use of a powdered aerosol is to engineer the fire suppressant so that the scattering of light is minimized. Light scattering can be reduced by manipulating particle size and concentration and by choosing chemical constituents with low refractive indexes.

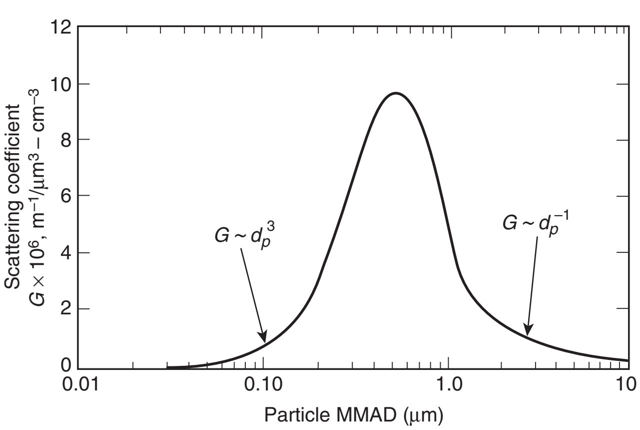

FIGURE C.3 Mie Scattering. (Source: Friedlander, *Smoke, Dust, and Haze: Fundamentals of Aerosol Dynamics*, Figure 5.8.)

Table C.4 Aerosol Settling Velocity for Spherical Particles in Air

MMAD (μm)	Settling Velocity (cm/s)
0.1	0.000086
0.2	0.00023
0.5	0.0010
1.0	0.0035
2.0	0.013
5.0	0.078
10	0.31
20	1.2
50	7.6

C.7 Manipulating Particle Size and Concentration. Calculations resulting from the Mie scattering visibility model presented in this annex indicate that a visibility of 1 m or more can be achieved by increasing the MMAD particle size above 0.6 μm and maintaining concentrations below 30,000 mg/m^3 *(see Table C.2)*. Adjusting the particle size below 0.6 μm also increases visibility but might not be feasible for most fire suppression systems. Engineers should manipulate particle size and design concentration to maximize visibility in an occupied space while maintaining the powdered aerosol's ability to effectively extinguish the fire.

C.8 Accounting for Refractive Index. The refractive index (i.e., the change in direction of light passing through the substance) of a particle also can influence visibility. This refractive index includes both scattering and absorption of light. If the particular powdered aerosol of concern has a relatively low refractive index (e.g., 1.2), then assuming spherical particles, the particles would be approximately five times less effective in scattering light than typical atmospheric aerosols. Conversely, if a powdered aerosol has a refractive index of 1.8, then for spherical aerosols the scattering would be five times greater. Fire suppressants containing powdered aerosols with a low refractive index yield better visibility in the space than those with a higher refractive index. Therefore, choosing chemicals (i.e., powdered aerosols) with a low refractive index for use in a fire suppressant is one means of increasing the visibility resulting from these types of materials.

C.9 Designing the Lighting and Space to Conform with Physical Properties of the Powdered Aerosol. Visibility in a room where a powdered aerosol has been discharged can also be increased by careful design of the environment in which the fire extinguisher is used. Through utilization of lights with specific wavelengths, rather than white light, and a room design that provides easily accessible exits, the chances for escape from a room where a powdered aerosol has been discharged can be improved.

C.10 Utilizing Light of Specific Wavelengths and Photoluminescent Marking Systems. Light is most effectively scattered by a particle size that is the same dimension as the incident light. As the wavelength of light deviates from the size of the powdered aerosol distributed in the air, interference between the particles and the light decreases and visibility increases. Because powdered aerosol products each have their own MMAD and refractive index, each fire suppressant will have particular wavelengths of light that penetrate through its suspended particles with minimal scattering. It is therefore possible to research the different types of light that can be used in the occupied spaces and determine which type of lighting is best suited for use with a particular powdered aerosol. For example, mercury or sodium vapor lamps can improve visibility depending on particle size.

During an emergency situation in which a powdered aerosol fire extinguisher is released, electrical or battery-powered lighting systems can be unreliable. In anticipation of power failure in emergency situations, a photoluminescent floor-lighting system has been developed as an alternative to traditional lighting. Photoluminescent lights, originally used in many of Norway's hydropower plants and the underground facilities of Oslo's airport, are now considered for use in high-rise towers and in planes to provide emergency lighting. [2]

Additionally, an FAA-sponsored study tested the efficacy of a photoluminescent escape path–marking system in an airplane. During a nighttime evacuation scenario in a cabin without identifier lights or illuminated signs (to mimic smoke-obscuring conditions in the cabin environment from the ceiling to 4 ft above the cabin floor), both zinc sulfide and strontium aluminate photoluminscent marking systems were tested. These materials absorb energy from natural light and the plane's standard aircraft lighting. Then, in emergency situations, when all other lighting is extinguished, the photoluminescent system emits the energy as visible light. The FAA study concluded that the strontium aluminate system, though it charges more slowly than the zinc sulfide material, emits more light and provides adequate lighting to mark a path of egress. [3] Thus, a photoluminescent floor-marking system would potentially help in marking an exit route in a scenario involving powdered aerosol discharge. The effectiveness of such a system would depend on the powdered aerosol concentration and particle size distribution.

C.11 Decreasing Distance to Exits. The rooms in which powdered-aerosol fire extinguishers are used can be designed such that the distance to the nearest exit is as short as possible. Other designs to consider are ones in which the distance to any wall that leads to an exit is minimized. A room constructed in this manner would allow one to see well enough to get to the wall and then feel his or her way to the closest exit.

C.12 Training. Increasing the ability of an individual to exit a space where a powdered aerosol has been released can also be achieved through training of the space's occupants. Workers who occupy areas in which powdered-aerosol fire extinguishers are present should be trained on how to react in the event that there is an accidental release of the fire suppressant. Personnel should be made aware of the locations of all the exits and the distance and direction of all doorways and other means of egress, even when a view of the exits is obscured by the released powdered aerosol.

C.13 Recommended Testing Procedures. After consideration of modeling and engineering adjustments identified in this annex leads to a determination that the powdered aerosol is likely to meet visibility standards, then physical testing of visibility should be performed. A nephelometer can be used to measure visibility. Usually used to assess visual air quality or particulate matter concentrations in air, a nephelometer measures the extinction of light, which is dependent on both the scattering and the absorption of light over some distance. [4] Using the scattering coefficient provided by the nephelometer and the design concentration, the visibility resulting from the discharge of the powdered aerosol can be assessed.

C.14 References.

(1) D. Glover, Jr., ed. *Dictionary of Technical Terms for Aerospace Use.* NASA Lewis Research Center, Cleveland, Ohio.

(2) G. Jensen "Wayfinding and Rescue in Heavy Smoke or Blackouts: Low Tech Marking Outperform Sophisticated Concepts." InterConsult Group ASA article for *Industrial Fire Journal*, GJ 9.11, 1999.

(3) DOT/FAA/AM-98/2, *Performance Demonstration of Zinc Sulfide and Strontium Aluminate Photoluminescent Floor Proximity Escape Path Marking Systems.* Office of Aviation Medicine, Washington, DC, February 1998.

(4) J. Parikh "Nepehelometer Procedure." Washington State Department of Ecology, Air Quality Program, February 2001.

Annex D Informational References

D.1 Referenced Publications. The documents or portions thereof listed in this annex are referenced within the informational sections of this standard and are not part of the requirements of this document unless also listed in Chapter 2 for other reasons.

D.1.1 NFPA Publication. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 2004 edition.

D.1.2 Other Publications.

D.1.2.1 ASTM Publication. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, 2000.

D.1.2.2 IEEE Publication. Institute of Electrical and Electronics Engineers, Three Park Avenue, 17th Floor, New York, NY 10016-5997.

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

D.1.2.3 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

UL 2127, *Standard for Inert Gas Clean Agent Extinguishing System Units*, 1999.

UL 2166, *Standard for Halocarbon Clean Agent Extinguishing System Units*, 1999.

D.1.2.4 ULC Publications. Underwriters' Laboratories of Canada, 7 Underwriters Road, Toronto, Ontario, M1R 3B4, Canada.

ULC S524-M91, *Standard for the Installation of Fire Alarm Systems*, 2001.

ULC S529-M87, *Smoke Detectors for Fire Alarm Systems*, 2002.

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Title 59, Code of Federal Regulations, Part 13044.

D.1.2.6 Other Publications.

CIIT/RIVM, Chemical Industry Institute of Toxicology/National Institute for Public Health and the Environment. Multiple Path Particle Dosimetry Model, V1.0, October 2002.

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Parikh, J. "Nepehelometer Procedure." Washington State Department of Ecology, Air Quality Program, February 2001.

D.2 Informational References. (Reserved)

D.3 References for Extracts in Informational Sections. (Reserved)

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