NFPA® 12

Standard on Carbon Dioxide Extinguishing Systems

2022 Edition

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NFPA® 12

Standard on

Carbon Dioxide Extinguishing Systems

2022 Edition

This edition of NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, was prepared by the Technical Committee on Gaseous Fire Extinguishing Systems. It was issued by the Standards Council on March 18, 2021, with an effective date of April 8, 2021, and supersedes all previous editions.

This document has been amended by one or more Tentative Interim Amendments (TIAs) and/or Errata. See "Codes & Standards" at www.nfpa.org for more information.

This edition of NFPA 12 was approved as an American National Standard on April 8, 2021.

Origin and Development of NFPA 12

Work on this standard was initiated in 1928 by the Committee on Manufacturing Risks and Special Hazards. The standard was first adopted in 1929 and was revised in 1933, 1939, 1940, 1941, 1942 (January and May), 1945, 1946, 1948, 1949, 1956, 1957, 1961, 1962, 1963, 1964, 1966, 1968, 1972, 1973, 1977, and 1980. Revisions adopted between 1945 and 1949 were proposed by the Committee on Special Extinguishing Systems, and those in 1956 and subsequent revisions were proposed by the Committee on Carbon Dioxide. The standard was again revised in 1985 and 1989.

The standard was completely rewritten for the 1993 edition to more clearly state the requirements and to separate the mandatory requirements from the advisory text in an effort to make the document more usable, enforceable, and adoptable.

The standard was revised for the 1998 edition and again in 2000 in order to add a new chapter on marine systems.

The 2005 edition of this standard was revised with a focus on safety.

The 2008 edition of the standard was a partial revision.

The 2015 edition incorporated a general update of references and other minor improvements. In addition, a new system acceptance report was added to permit compliance with the commissioning procedures of NFPA 3.

The 2018 edition introduced a new requirement to conduct testing of integrated fire protection and life safety systems in accordance with NFPA 4. In addition, a new section on pipe hangers and supports and a new annex section on full discharge testing were also added. Finally, the equivalency statement was revised to use the standard text, which specifies that the authority having jurisdiction is responsible for approving an equivalent system, method, or device.

The 2022 edition is a partial revision that incorporates several clarifications and corrections.

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NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This committee shall have primary responsibility for documents on the installation, maintenance, and use of carbon dioxide systems for fire protection. This committee shall also have primary responsibility for documents on fixed fire extinguishing systems utilizing bromotrifluoromethane and other similar halogenated extinguishing agents, covering the installation, maintenance, and use of systems. This committee shall also have primary responsibility for documents on alternative protection options to Halon 1301 and 1211 fire extinguishing systems. It shall not deal with design, installation, operation, testing, and maintenance of systems employing dry chemical, wet chemical, foam, aerosols, or water as the primary extinguishing media.

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Standard on

Carbon Dioxide Extinguishing Systems

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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. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

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

Chapter 1 Administration

1.1* Scope.

1.1.1 This standard contains minimum requirements for carbon dioxide fire-extinguishing systems.

1.1.2 This standard includes only the necessary essentials to make it workable in the hands of those skilled in this field.

1.2 Purpose.

1.2.1 This standard is prepared for the use and guidance of those charged with the purchasing, designing, installing, testing, inspecting, approving, listing, operating, or maintaining of carbon dioxide fire-extinguishing systems, in order that such equipment will function as intended throughout its life.

1.2.2 Equivalency. Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard.

1.2.2.1 Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency.

1.2.2.2 The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.

1.2.3 Only those with the proper training and experience shall design, install, inspect, and maintain this equipment.

1.3 Retroactivity. The provisions of this standard reflect a consensus of what is necessary to provide an acceptable degree of protection from the hazards addressed in this standard at the time the standard was issued.

1.3.1 Unless otherwise specified, the provisions of this standard shall not apply to facilities, equipment, structures, or installations that existed or were approved for construction or installation prior to the effective date of the standard. Where specified, the provisions of this standard shall be retroactive.

1.3.2 In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard deemed appropriate.

1.3.3 The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction and only where it is clearly evident that a reasonable degree of safety is provided.

1.3.4* Existing systems shall meet the requirements for safety signs in 4.3.2, lockout valves in 4.3.3.4 and 4.3.3.4.1, and pneumatic time delays and pneumatic predischarge alarms in 4.5.6.2.

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

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 4, *Standard for Integrated Fire Protection and Life Safety System Testing*, 2021 edition.

NFPA 70®, National Electrical Code®, 2020 edition.

NFPA 72®, National Fire Alarm and Signaling Code®, 2022 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 Z535.2, *Standard for Environmental and Facility Safety Signs*, 2011.

2.3.2 API Publications. American Petroleum Institute, 200 Massachusetts Avenue NW, Suite 1100, Washington, DC 20001-5571.

API-ASME *Code for Unfired Pressure Vessels for Petroleum Liquids and Gases*, Pre–July 1, 1961.

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

ASME B31.1, *Power Piping Code*, 2020.

Δ **2.3.4 ASTM Publications.** ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM A53, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*, 2020.

ASTM A106, *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service*, 2019.

ASTM A120, *Specification for Pipe, Steel, Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless for Ordinary Uses*, 1984 (withdrawn 1987).

ASTM A182, *Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service*, 2020.

2.3.5 CGA Publications. Compressed Gas Association, 14501 George Carter Way, Suite 103, Chantilly, VA 20151-2923.

CGA G-6.2, *Commodity Specification for Carbon Dioxide*, 2011.

Δ **2.3.6 CSA Group Publications.** CSA Group, 178 Rexdale Blvd., Toronto, ON M9W 1R3, Canada.

CSA C22.1, *Canadian Electrical Code, Part 1 Safety Standard for Electrical Installations*, 24th Edition, May 2020.

2.3.7 IEEE Publications. IEEE, 3 Park Avenue, 17th Floor, New York, NY 10016-5997.

ANSI/IEEE C2, *National Electrical Safety Code*, 2017.

Δ **2.3.8 US Government Publications.** US Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001.

Coward, H. F., and G. W. Jones, *Limits of Flammability of Gases and Vapors*, U.S. Bureau of Mines Bulletin 503, 1952.

Title 46, Code of Federal Regulations, Part 58.20.

Title 46, Code of Federal Regulations, Part 72.

Title 49, Code of Federal Regulations, Parts 171–190 (Department of Transportation).

Zabetakis, Michael G., *Flammability Characteristics of Combustible Gases and Vapors*, U.S. Bureau of Mines Bulletin 627, 1965.

2.3.9 Other Publications.

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

2.4 References for Extracts in Mandatory Sections.

NFPA 1, *Fire Code*, 2021 edition.

NFPA 122, *Standard for Fire Prevention and Control in Metal/Nonmetal Mining and Metal Mineral Processing Facilities*, 2020 edition.

NFPA 820, *Standard for Fire Protection in Wastewater Treatment and Collection Facilities*, 2020 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 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.4* 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.

3.2.5 Shall. Indicates a mandatory requirement.

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

3.2.7 Standard. An NFPA Standard, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase "standards development process" or "standards development activities," the term "standards" includes all NFPA Standards, including Codes, Standards, Recommended Practices, and Guides.

3.3 General Definitions.

3.3.1 Alarms and Indicators. Any device capable of providing audible, visible, or olfactory indication.

Δ **3.3.2 Fire Watch.** The assignment of a person or persons to an area for the express purpose of notifying the fire department, the building occupants, or both of an emergency; preventing a fire from occurring; extinguishing small fires; protecting the public from fire and life safety dangers. [**1,** 2021]

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3.3.3 Inspection. A visual examination of a system or portion thereof to verify that it appears to be in operating condition and is free of physical damage. [**820,** 2020]

3.3.4 Lockout. A manually operated valve in the discharge pipe between the nozzles and the supply, which can be locked in the closed position to prevent flow of carbon dioxide to the protected area.

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

3.3.6 Normally Occupied Enclosure or Space. An enclosure or space where one or more persons are present under normal conditions.

3.3.7* Normally Unoccupied Enclosure or Space. An enclosure or space not normally occupied but one that could be entered occasionally by one or more persons for brief periods.

3.3.8 Occupiable Enclosure or Space. An enclosure or space that has dimensions and physical characteristics such that it could be entered by a person.

3.3.9 Pressure.

3.3.9.1* ***High Pressure.*** Indicates that the carbon dioxide is stored in pressure containers at ambient temperatures.

3.3.9.2* ***Low Pressure.*** Indicates that the carbon dioxide is stored in pressure containers at a controlled low temperature of 0°F (–18°C).

3.3.10 Standpipe System and Mobile Supply. A system consisting of a mobile supply of carbon dioxide, designed to be quickly moved into position and connected to a system of fixed piping, supplying fixed nozzles or hose lines or both that are designed for either total flooding or local application.

3.3.11 System.

3.3.11.1 ***Hand Hose Line System.*** A hose and nozzle assembly connected by fixed piping or connected directly to a supply of extinguishing agent. [**122,** 2020]

3.3.11.2 ***Local Application System.*** A system consisting of a supply of extinguishing agent arranged to discharge directly on the burning material.

3.3.11.3* ***Pre-Engineered System.*** A system that has predetermined flow rates, nozzle placement, and quantities of carbon dioxide and that incorporates specific nozzles and methods of application that can differ from those detailed elsewhere in this standard and those that are listed by a testing laboratory.

3.3.11.4 ***Total Flooding System.*** A system consisting of a supply of carbon dioxide arranged to discharge into, and fill to the proper concentration, an enclosed space or enclosure around the hazard.

3.3.12 Unoccupiable Enclosure or Space. An enclosure or space that has dimensions and physical characteristics such that it could not be entered by a person.

3.4 Special Definitions.

3.4.1 Marine Systems. Systems installed on ships, barges, offshore platforms, motorboats, and pleasure craft.

3.4.2 Marine System Spaces.

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

3.4.2.2 ***Electrical Equipment Space.*** A space containing electrical propulsion, power generating, or power distribution equipment.

3.4.2.3 ***Machinery Space.*** A space that contains mechanical equipment for handling, pumping, or transferring flammable or combustible liquids as a fuel.

3.4.2.4 ***Vehicle Space.*** A space that is designed for the carriage of automobiles or other self-propelled vehicles.

Chapter 4 General Information

4.1 Restrictions for Normally Occupied Enclosures.

4.1.1 New total flooding carbon dioxide systems shall not be installed in normally occupied enclosures except as permitted in 4.1.1.1, 4.1.1.2, 4.1.1.3, 4.1.1.4, or 4.1.1.5.

4.1.1.1 New total flooding carbon dioxide systems shall be permitted to be installed in normally occupied enclosures where it is determined that an inerting concentration is required and the inerting concentration required using alternate gaseous agents results in a concentration above the lowest observed adverse effect level (LOAEL) or the oxygen concentration is less than 8 percent.

4.1.1.2 New total flooding carbon dioxide systems shall be permitted to be installed in normally occupied enclosures for fires involving energized electrical equipment >400 volts and grouped electrical cables where no gaseous alternative agent has been successfully tested.

4.1.1.3 New total flooding carbon dioxide systems shall be permitted to be installed in normally occupied enclosures where design methods or hardware, or both, for unencloseable openings or extended discharge are not available for other gaseous agents.

4.1.1.4 New total flooding carbon dioxide systems shall be permitted to be installed in marine cargo holds.

4.1.1.5 New total flooding carbon dioxide systems shall be permitted to be installed in normally occupied enclosures in marine engine rooms where it is determined that an inerting concentration is required and the inerting concentration required using alternate gaseous agents results in a concentration above the LOAEL or the oxygen concentration is less than 8 percent.

4.1.2 Existing Systems. Existing total flooding carbon dioxide systems shall be permitted in normally occupied enclosures equipped with system lockout valves, pneumatic predischarge alarms, and pneumatic time delays specified in 4.5.6.

4.2 Carbon Dioxide Use and Limitations. See also Annex G.

4.2.1* Carbon dioxide fire-extinguishing systems protecting areas where explosive atmospheres could exist shall utilize metal nozzles, and the entire system shall be grounded.

4.2.2 In addition, objects exposed to discharge from carbon dioxide nozzles shall be grounded to dissipate possible electrostatic charges.

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4.3* Personnel Safety.

4.3.1* Hazards to Personnel.

4.3.1.1 Consideration shall be given to the possibility of carbon dioxide drifting and settling into adjacent places outside the protected space. *(See 4.3.1.3.)*

4.3.1.2 Consideration shall also be given to where the carbon dioxide can migrate or collect in the event of a discharge from a safety relief device of a storage container.

4.3.1.3* In any use of carbon dioxide, consideration shall be given to the possibility that personnel could be trapped in or enter into an atmosphere made hazardous by a carbon dioxide discharge.

4.3.1.3.1 Safeguards shall be provided to ensure prompt evacuation, to prevent entry into such atmospheres as described in 4.3.1.3, and to provide means for prompt rescue of any trapped personnel.

4.3.1.3.2 Personnel training shall be provided.

4.3.2 Signs.

4.3.2.1 Warning signs shall be affixed in a conspicuous location in every protected space; at every entrance to protected spaces; in spaces near the protected spaces where it is determined that carbon dioxide could migrate, creating a hazard to personnel; and at each entrance to carbon dioxide storage rooms and where carbon dioxide can migrate or collect in the event of a discharge from a safety device of a storage container.

4.3.2.2 The safety sign format, color, letter style of signal words, message panel lettering, lettering size, and the safety provisions of symbols shall be in accordance with ANSI Z535.2.

4.3.2.3 Safety signs and message wording shall be provided using a three-panel format as required by 4.3.2.3.1 through 4.3.2.3.6.2.

4.3.2.3.1 The sign in Figure 4.3.2.3.1 shall be used in every protected space.

4.3.2.3.2 The sign in Figure 4.3.2.3.2 shall be used at every entrance to protected space.

4.3.2.3.3 The sign in Figure 4.3.2.3.3 shall be used at every entrance to protected space for systems provided with a wintergreen odorizer.

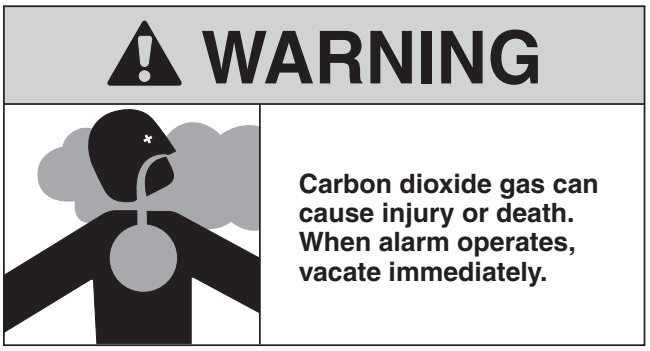

FIGURE 4.3.2.3.1 Sign in Every Protected Space.

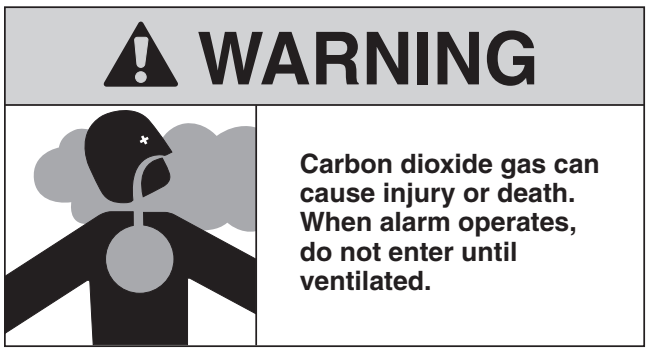

FIGURE 4.3.2.3.2 Sign at Every Entrance to Protected Space.

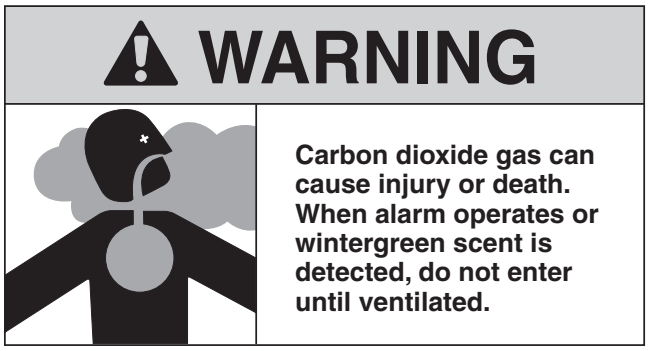

FIGURE 4.3.2.3.3 Sign at Every Entrance to Protected Space for Systems Provided with a Wintergreen Odorizer.

4.3.2.3.4 The sign in Figure 4.3.2.3.4 shall be used in every nearby space where carbon dioxide could accumulate to hazardous levels.

4.3.2.3.5 The sign in Figure 4.3.2.3.5 shall be used outside each entrance to carbon dioxide storage rooms.

4.3.2.3.6 Signs for Manual Operation.

4.3.2.3.6.1 Warning signs shall be placed at every location where manual operation of the system could occur.

4.3.2.3.6.2 The sign in Figure 4.3.2.3.6.2 shall be used at each manual actuation station.

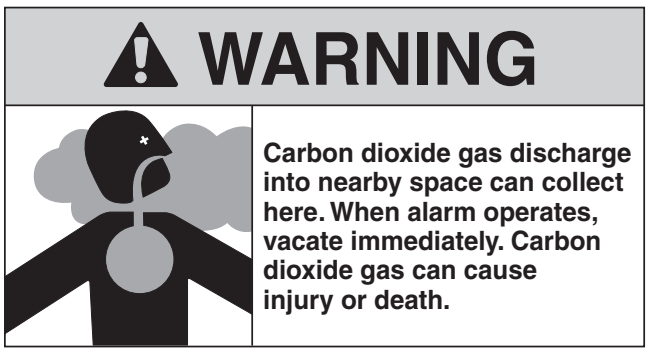

FIGURE 4.3.2.3.4 Sign in Every Nearby Space Where Carbon Dioxide Could Accumulate to Hazardous Levels.

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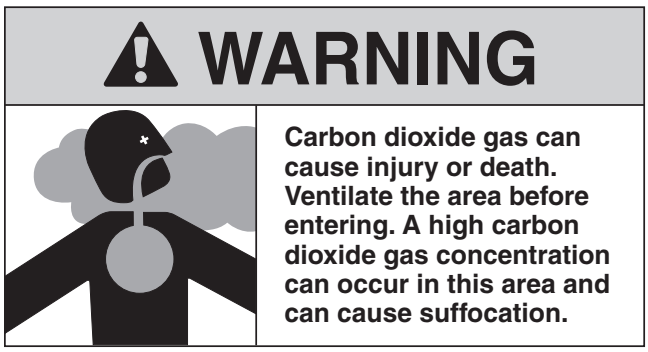

FIGURE 4.3.2.3.5 Sign Outside Each Entrance to Carbon Dioxide Storage Rooms.

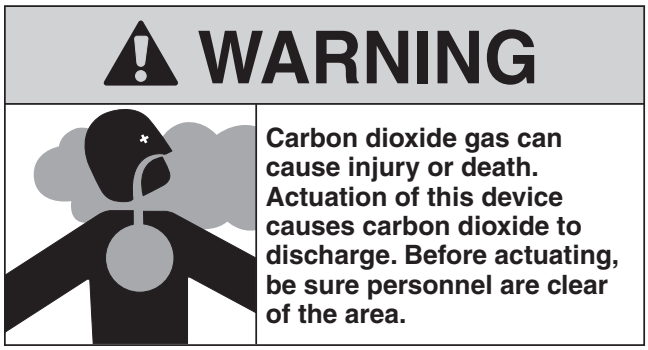

FIGURE 4.3.2.3.6.2 Sign at Each Manual Actuation Station.

4.3.2.4 For installations that have existing signs that differ from those required by 4.3.2.3 but that meet the requirements of 4.3.2.1, the existing signage shall be considered acceptable if the facility has a signage training program in place covering all suppression system–related signage, with all personnel with access to the protected space either trained on the signage or accompanied when in the protected space at all times by a person who has received the training required. New installations in facilities covered by this paragraph shall be equipped with the same type of signage as used in existing signage in the facility. All signs within the facility shall have the same style and format.

4.3.3 Evacuation Procedures.

4.3.3.1 All persons who can at any time enter a space protected by carbon dioxide shall be warned of the hazards involved and provided with safe evacuation procedures.

4.3.3.1.1 Provisions shall be made to prohibit entry of unprotected personnel to spaces made unsafe by a carbon dioxide discharge until the space is ventilated and appropriate tests of the atmosphere have verified that it is safe for unprotected persons to enter. Persons who are not properly trained in the use of and equipped with self-contained breathing apparatus (SCBA) shall not remain in spaces where the concentration exceeds 4 percent.

4.3.3.2 Audible and visible alarms shall be provided in accordance with 4.5.6.

4.3.3.3* All personnel shall be informed that discharge of carbon dioxide gas from either high- or low-pressure systems directly at a person will endanger the person's safety by causing eye injury, ear injury, or even falls due to loss of balance upon the impingement of the high-velocity discharging gas.

4.3.3.4 A lockout shall be provided on all systems except where dimensional constraints prevent personnel from entering the protected space.

4.3.3.4.1 Lockout valves shall be installed on all systems where carbon dioxide could migrate, creating a hazard to personnel.

4.3.3.4.2 In a low-pressure system, the tank shutoff valve shall not be considered as a lockout valve, except as permitted by 4.3.3.4.3.

4.3.3.4.3 Where a single low-pressure storage tank supplies single or multiple systems protecting interrelated hazards, and when none of the hazards require protection if the equipment being protected is shut down, the storage tank shutoff valve shall be permitted to be used as a lockout valve for the entire system.

4.3.3.4.4* A service disconnect switch shall not be used as a means of preventing agent discharge in lieu of a lockout valve. *(See 4.5.4.12.)*

4.3.3.4.5 When maintenance or testing is being conducted on the system, it shall be locked out, or the protected space and affected spaces (migration) shall be evacuated.

4.3.3.4.6 When protection is to be maintained during the lockout period, a person(s) shall be assigned as a "fire watch" with suitable portable or semiportable fire-fighting equipment or means to restore protection.

4.3.3.4.6.1 The fire watch shall have a communication link to a constantly monitored location.

4.3.3.4.6.2 Authorities responsible for continuity of fire protection shall be notified of the lockout and subsequent restoration of the system.

4.3.3.5* Safe handling procedures shall be followed when transporting system cylinders.

4.3.4 Electrical Clearances.

4.3.4.1* All system components shall be located so as to maintain minimum clearances from live parts as shown in Table 4.3.4.1 and Figure 4.3.4.1.

4.3.4.2* At altitudes in excess of 3300 ft (1000 m), the clearance from live parts shall be increased at the rate of 1 percent for each 330 ft (100 m) increase in altitude above 3300 ft (1000 m).

4.3.4.3* To coordinate the required clearance with the electrical design, the design basic insulation level (BIL) of the equipment being protected shall be used as a basis, although this is not material at nominal line voltages of 161 kV or less.

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

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

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Δ Table 4.3.4.1 Clearance from Carbon Dioxide Equipment to Live Uninsulated Electrical Components

Nominal System Voltage (kV)	Maximum System Voltage (kV)	Design BIL* (kV)	Minimum† Clearance	
			in.	mm
≤13.8	14.5	110	7	178
≤23.0	24.3	150	10	254
≤34.5	36.5	200	13	330
≤46.0	48.3	250	17	432
≤69.0	72.5	350	25	635
≤115.0	121	550	42	1067
≤138.0	145.0	650	50	1270
≤161.0	169.0	750	58	1473
≤230.0	242.0	900	76	1930
		1050	84	2134
≤345.0	362.0	1050	84	2134
		1300	104	2642
≤500.0	550.0	1500	124	3150
		1800	144	3658
≤765.0	800.0	2050	167	4242

*Basic insulation level (BIL) values are expressed as kilovolts (kV), the number being the crest value of the full wave impulse test that the electrical equipment is designed to withstand. For BIL values that are not listed in the table, clearances can be found by interpolation.
†For voltages up to 161 kV, the clearances are taken from *NFPA 70*. For voltages 230 kV and above, the clearances are taken from Table 124 of ANSI/IEEE C2. In Canada, refer to CSA C22.1.

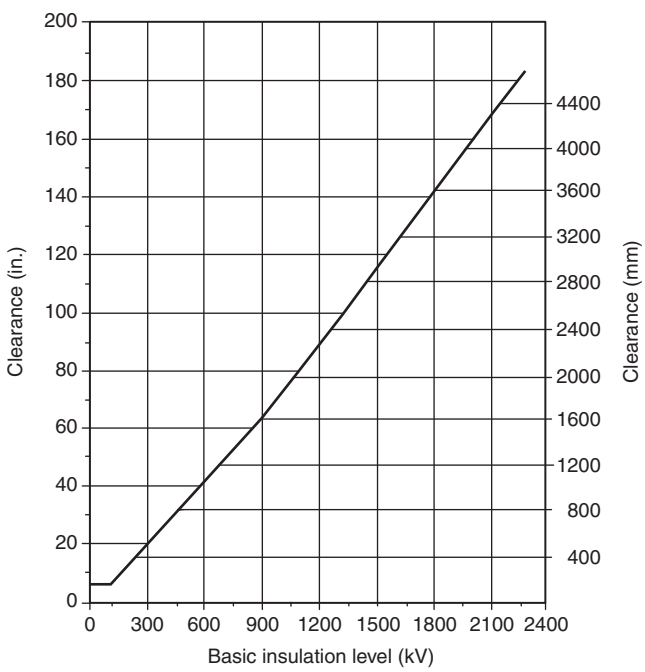

FIGURE 4.3.4.1 Clearance from Carbon Dioxide Equipment to Live Uninsulated Electrical Components.

4.3.4.6 When the design BIL is not available, and when nominal voltage is used for the design criteria, the highest minimum clearance listed for this group shall be used.

4.3.5* Duration of Protection. An effective agent concentration for total flooding systems shall be achieved and maintained for a period of time to allow effective emergency action by trained personnel.

4.3.6* Visible predischarge alarms shall comply with the following:

(1) They shall be visible throughout the protected space.
(2) They shall be distinct from the building fire alarm signal and other alarm signals.
(3) Visible appliances, except for strobes, shall not be required to be synchronized with each other or with the building fire alarms.

4.4 Specifications, Plans, and Approvals.

4.4.1 Specifications.

4.4.1.1 Specifications for carbon dioxide fire-extinguishing systems shall be prepared under the supervision of a person fully experienced and qualified in the design of carbon dioxide extinguishing systems and with the advice of the authority having jurisdiction.

4.4.1.2 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, and the type and extent of approval testing to be performed after installation of the system.

4.4.1.3 Integrated fire protection and life safety system testing shall be in accordance with NFPA 4.

4.4.2 Plans.

4.4.2.1 Plans and calculations shall be submitted for approval to the authority having jurisdiction before the installation begins.

4.4.2.2 Plans and calculations shall be prepared by persons fully qualified in the design of carbon dioxide fire-extinguishing systems.

4.4.2.3 These plans shall be drawn to an indicated scale or be dimensioned.

4.4.2.4 The plans shall be so made that they can be easily reproduced.

4.4.2.5 These plans shall contain sufficient detail to enable the authority having jurisdiction to evaluate the hazard or hazards and to evaluate the effectiveness of the system.

4.4.2.6 The details of the plans shall include the following:

(1) Materials involved in the protected hazards
(2) Location of the hazards
(3) Enclosure or limits and isolation of the hazards
(4) Surrounding area that could affect the protected hazards

4.4.2.7 The details on the system shall include the following:

(1) Information and calculations on the amount of carbon dioxide
(2) Location and flow rate of each nozzle, including orifice code number and actual orifice diameter

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(3) Location, size, and equivalent lengths of pipe, fittings, and hose
(4) Location and size of the carbon dioxide storage facility

4.4.2.8 Details of pipe size reduction method (reducing couplings or bushings) and orientation of tees shall be clearly indicated.

4.4.2.9 Information shall be submitted pertaining to the location and function of the detection devices, operating devices, auxiliary equipment, and electrical circuitry, if used.

4.4.2.10 Information shall be indicated to identify the apparatus and devices used.

4.4.2.11 Any special features shall be adequately explained.

4.4.2.12 When field conditions necessitate any substantial change from approved plans, the change shall be submitted to the authority having jurisdiction for approval.

4.4.2.13 If the final installation varies from the prepared drawings and calculations, new drawings and calculations representing the "as-built" installation shall be prepared.

4.4.2.13.1 As-built drawings shall indicate interconnections of required equipment shutdowns and fuel shutoffs with the fire extinguishing system.

4.4.2.14 The system owner shall maintain an instruction and maintenance manual that includes a full sequence of operation, and a full set of system drawings and calculations shall be maintained in a protective enclosure.

4.4.3* Approval of Installations.

4.4.3.1* The completed system shall be inspected, tested, and documented by qualified personnel to meet the approval of the authority having jurisdiction.

4.4.3.1.1 The acceptance testing required by 4.4.3.1 shall be documented in a test report.

4.4.3.1.2 The acceptance test report shall be maintained by the system owner for the life of the system.

4.4.3.2* Only listed or approved equipment and devices shall be used in the system.

4.4.3.3 To determine that the system has been properly installed and will function as specified, the procedures given in 4.4.3.3.1 through 4.4.3.3.4.2 shall be performed.

4.4.3.3.1 Visual Inspection. A thorough visual inspection of the installed system and hazard area shall be conducted.

4.4.3.3.1.1 The piping, operational equipment, and discharge nozzles shall be inspected for proper size and location.

4.4.3.3.1.2 The locations of alarms and manual emergency releases shall be confirmed.

4.4.3.3.1.3 The configuration of the hazard shall be compared to the original hazard specification.

4.4.3.3.1.4 The hazard shall be inspected closely for unclosable openings and sources of agent loss that could have been overlooked in the original specification.

4.4.3.3.2 Labeling.

4.4.3.3.2.1 A check of labeling of devices for proper designations and instructions shall be performed.

4.4.3.3.2.2 Nameplate data on the storage containers shall be compared to specifications.

4.4.3.3.3 Operational Tests. Nondestructive operational tests on all devices necessary for the functioning of the system, including detection devices, actuation devices, and notification appliances, shall be conducted.

4.4.3.3.4* Full Discharge Test.

4.4.3.3.4.1 A full discharge test shall be performed on each installed system.

4.4.3.3.4.2 Where multiple hazards are protected from a common supply, a full discharge test shall be performed for each hazard.

4.4.3.4 Prior to testing, safety procedures shall be reviewed. *(See Section 4.4.)*

4.4.4 Testing of Systems. Systems shall be tested as stated in 4.4.4.1 through 4.4.4.3.

4.4.4.1 Local Application. A full discharge of the design quantity of carbon dioxide through system piping shall be conducted to ensure that carbon dioxide effectively covers the hazard for the full period of time required by the design specifications and that all pressure-operated devices function as intended.

4.4.4.2 Total Flooding. A full discharge of the entire design quantity of carbon dioxide through system piping shall be conducted to ensure that carbon dioxide is discharged into the hazard, that the concentration is achieved and maintained for the period of time required by the design specifications, and that all pressure-operated devices function as intended.

4.4.4.3 Handheld Hose Lines.

4.4.4.3.1 A full discharge test of handheld hose line systems shall be conducted.

4.4.4.3.2 Evidence of liquid flow from each nozzle with an adequate pattern of coverage shall be required.

4.5 Detection, Actuation, and Control.

4.5.1 Classification. Systems shall be classified as automatic or manual in accordance with the methods of actuation described in 4.5.1.1 through 4.5.1.3.2.

4.5.1.1 Automatic Operation. Operation that does not require any human action shall be considered automatic operation.

4.5.1.2 Normal Manual Operation.

4.5.1.2.1 Operation of the system requiring human action where the location of the device used to cause operation makes it easily accessible at all times to the hazard shall be considered normal manual operation. *(See 4.5.4.5.)*

4.5.1.2.2 Operation of one control shall be all that is required to bring about the full operation of the system.

4.5.1.3* Emergency Manual Operation.

4.5.1.3.1 Operation of the system by human means where the device used to cause operation is fully mechanical in nature and is located at or near the device being controlled shall be considered emergency manual operation.

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4.5.1.3.2 A fully mechanical device shall be permitted to incorporate the use of system pressure to complete operation of the device. *(See 4.5.4.6.)*

4.5.2* Automatic Detection and Automatic Actuation. Automatic detection and automatic actuation shall be used, except in the following situations:

(1) Manual-only actuation shall be permitted if acceptable to the authority having jurisdiction where automatic release could result in an increased risk.
(2) Automatic detection and automatic actuation shall not apply to hand hose line and standpipe systems.
(3) Automatic detection and automatic actuation shall not apply to marine systems except as permitted in 9.3.3.

4.5.2.1* Automatic actuation controls shall be arranged to require a sustained fire alarm initiation signal prior to actuation of predischarge alarms and to require actuation of any electrically operated predischarge time delays and electrically operated predischarge alarms prior to actuation of releasing devices.

4.5.3* Automatic Detection. Automatic detection shall be by any listed or approved method or device that is 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.

4.5.4 Operating Devices. Operating devices shall include carbon dioxide releasing devices or valves, discharge controls, and equipment shutdown devices, all of which are necessary for successful performance of the system.

4.5.4.1 Listed and Approved.

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

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

4.5.4.2 Device Design.

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

4.5.4.2.2 Devices shall be normally designed to function from −20°F to 150°F (−29°C to 66°C) or marked to indicate temperature limitations.

4.5.4.3 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.

4.5.4.4 Devices with manufacturer-specific connections used to control the release of carbon dioxide shall have connections that are distinctive or distinctively marked where there is a potential for improper installation of the devices.

4.5.4.4.1 New devices introduced after January 1, 2008, shall comply with this requirement.

4.5.4.5* The normal manual controls for actuation shall be located for easy accessibility at all times, including the time of fire.

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

4.5.4.5.2 The manual control(s) shall cause the complete system to operate in its normal fashion.

4.5.4.5.3 Operation of this manual control shall not cause the time delay to recycle. *(See 4.5.6.2.2.)*

4.5.4.6* All valves controlling the release and distribution of carbon dioxide shall be provided with an emergency manual control.

4.5.4.6.1 The emergency manual control shall not be required of slave high-pressure cylinders.

4.5.4.6.2 The emergency means shall be easily accessible and located close to the valves controlled.

4.5.4.6.3 These devices shall be clearly marked with a warning placard to indicate the concept in 4.5.4.6.2.

4.5.4.7* Cylinders.

4.5.4.7.1 Where gas pressure from pilot cylinders fed through the system discharge manifold (i.e., using back pressure rather than a separate pilot line) is used to release remaining slave cylinders and the supply consists of fewer than three cylinders, at least one cylinder shall be used for such operation.

4.5.4.7.2 Where gas pressure from pilot cylinders that is fed through the system discharge manifold (i.e., using back pressure rather than a separate pilot line) is used to release remaining slave cylinders, and where the supply consists of three or more cylinders, there shall be at least one pilot cylinder more than the minimum required to actuate the system.

4.5.4.7.3 During the full discharge acceptance test, the extra pilot cylinder shall be arranged to operate as a slave cylinder.

4.5.4.7.4* Automatic actuation controls shall be arranged as follows:

(1) To require a sustained fire alarm initiation signal prior to activation of predischarge alarms.
(2) To require activation of any electrically operated predischarge time delays and electrically operated predischarge alarms prior to activation of releasing devices.

4.5.4.8 Manual Controls.

4.5.4.8.1 Manual controls shall not require a pull of more than 40 lbf (178 N) nor a movement of more than 14 in. (356 mm) to secure operation.

4.5.4.8.2 At least one manual control for actuation shall be positioned not more than 4 ft (1.2 m) above the floor.

4.5.4.9 Where the continuing operation of equipment associated with a hazard being protected could contribute to sustaining the fire in that hazard, the source of power or fuel shall be automatically shut off.

4.5.4.9.1 All shutdown devices shall be considered integral parts of the system and shall function with the system operation.

4.5.4.9.2 The requirement in 4.5.4.9 shall not apply to lubricating oil systems associated with large rotating equipment, where an extended discharge system is provided that is designed to operate for the deceleration/cooldown period.

4.5.4.10 All manual operating devices shall be identified as to the hazard they protect, the function they perform, and their method of operation.

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4.5.4.11 Abort switches shall not be used on carbon dioxide systems.

4.5.4.12 For electrically operated systems, a service disconnect switch shall be provided to allow the system to be tested without actuating the fire suppression system. The service disconnect switch, when operated, shall interrupt the releasing circuit to the suppression system and shall cause a supervisory signal at the suppression system releasing panel.

4.5.4.13 Discharge Pressure Switch.

4.5.4.13.1 A discharge pressure switch shall be installed between the carbon dioxide supply and the lockout valve.

4.5.4.13.2 For low-pressure CO_2 systems where the manual, supervised, main shutoff valve can be considered a lockout valve (i.e., meets the requirements of 4.3.3.4 through 4.3.3.4.5), the pressure switch shall be located downstream of the automatic valve (master-selector, selector valve) supplying the hazard or hazards.

4.5.4.13.3 The discharge pressure switch shall provide an alarm-initiating signal to the releasing panel to operate electric/electronic alarm appliances.

4.5.5 Supervision and Lockout Valves.

4.5.5.1 Supervision of automatic systems and manual lockout valves shall be provided unless specifically waived by the authority having jurisdiction.

4.5.5.2* Interconnections between the components that are necessary for the control of the system and life safety shall be supervised.

4.5.5.3 Normally unpressurized interconnections of pipe and tube shall not be required to comply with 4.5.5.2.

4.5.5.4 An open circuit, ground-fault condition, or loss of integrity in the pneumatic control lines that would impair full system operation shall result in a trouble signal.

4.5.5.5 The alarm and trouble signals shall be transmitted by one of the methods described in *NFPA 72*.

4.5.5.6 High-pressure pneumatic-operated slave cylinder connections immediately adjacent to pilot cylinders shall not be required to be supervised.

4.5.5.7 Where manual bypasses are provided and such bypasses are capable of being left in an open position, these bypasses shall be supervised.

4.5.6* Alarms. Audible and visible warning alarms shall be provided for the following purposes:

(1) To alert personnel not to enter a space, because the atmosphere in the space could be hazardous due to the presence of a high concentration of carbon dioxide
(2) To provide personnel the opportunity to evacuate spaces that could be made unsafe by the discharge of a carbon dioxide system

4.5.6.1 Audible and visual carbon dioxide system alarms shall be distinct from all other alarms, including the building fire alarm system.

4.5.6.2 Predischarge Alarm and Time Delay. A pneumatic predischarge alarm and pneumatic time delay and visible predischarge alarm shall be provided for the following enclosures:

(1) Normally occupied and occupiable enclosures protected by total flooding systems except as outlined in 4.5.6.2.3
(2) Local application systems protecting hazards where the discharge exposes personnel to concentrations of carbon dioxide in excess of 7.5 percent by volume of agent in air for longer than 5 minutes

4.5.6.2.1 The predischarge alarms, where required, shall be located within the enclosure.

4.5.6.2.2 The predischarge time delay shall provide a time delay for purpose of predischarge alarm of sufficient duration to allow evacuation of personnel from areas within the spaces most remote from the exits.

4.5.6.2.3* Time delays shall be permitted to be eliminated for occupiable hazard areas where the provision of a time delay would result in unacceptable risk to personnel or unacceptable damage to critical pieces of equipment.

4.5.6.2.4 Where time delays are omitted, provision shall be made to ensure that the carbon dioxide system is locked out any time personnel are present in the protected area or space.

4.5.6.2.5 Dry runs shall be made to determine the minimum time needed for persons to evacuate the hazard area, allowing time to identify the warning signal.

4.5.6.2.6 Audible signal appliances shall have either sound levels in accordance with 4.5.6.2.6.1 and 4.5.6.2.6.2 or acoustic characteristics in accordance with 18.4.6 of *NFPA 72*.

4.5.6.2.6.1 Audible predischarge alarms shall be at least 15 dB above ambient noise level or 5 dB above maximum sound level, whichever is greater, measured 5 ft (1.5 m) above the floor of the occupiable area.

4.5.6.2.6.2 Audible signal appliances shall have a sound level not more than 120 dB at the minimum hearing distance from the audible appliance.

4.5.6.2.6.3 The predischarge alarm shall have a minimum decibel rating of 90 dBA at 10 ft (3 m).

4.5.6.3 Visible and audible alarms shall be located outside each entrance to the following:

(1) Normally occupied and occupiable space protected by a total flooding carbon dioxide system
(2) Normally occupied and occupiable enclosures where the discharge from a local application system will expose personnel to hazardous concentrations of carbon dioxide
(3) Normally occupied and occupiable spaces where carbon dioxide could migrate, creating a hazard to personnel

4.5.6.3.1 These alarms shall begin operation prior to or at the start of the discharge.

4.5.6.3.2* These alarms shall continue to operate after agent discharge until one of the following occurs:

(1) Other positive action has been taken to prevent entry of personnel to the space containing an atmosphere made unsafe by the carbon dioxide discharge.
(2) The space is ventilated and the safety of the atmosphere for entry by unprotected persons has been verified.

4.5.6.3.3 Silencing of audible alarms while keeping visual notification appliances activated shall be permitted after the action described in 4.5.6.3.2(1) is accomplished.

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4.5.6.3.4 Visual alarms shall remain activated until the space is ventilated as required in 4.5.6.3.2(2).

4.5.6.4 An alarm or indicator shall be provided to show that the system has operated and needs recharging.

4.5.6.5* An alarm shall be provided to indicate the operation of automatic systems and that immediate personnel response is desired.

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

4.5.7 Power Sources.

4.5.7.1 The primary source of energy for the operation and control of the system shall have the capacity for intended service and shall be reliable.

4.5.7.1.1 Where failure of the primary source of energy will jeopardize protection provided for the hazard or for life safety, or for both, an independent secondary (standby) power supply shall supply energy to the system in the event of total failure or low voltage (less than 85 percent of the nameplate voltages) of the primary (main) power supply.

4.5.7.1.2 The secondary (standby) supply shall be capable of operating the system under maximum normal load for 24 hours and then be capable of operating the system continuously for the full design discharge period.

4.5.7.1.3 The secondary (standby) power supply shall automatically transfer to operate the system within 30 seconds of the loss of the primary (main) power supply.

4.5.7.2 All electrical devices shall be operable between 85 percent and 105 percent of rated voltage.

4.6 Carbon Dioxide Supply.

4.6.1* Quantities. The amount of the main supply of carbon dioxide in the system shall be at least sufficient for the largest single hazard protected or group of hazards that are to be protected simultaneously.

4.6.1.1 Where hand hose lines are provided for use on a hazard protected by a fixed system, separate supplies shall be provided unless sufficient carbon dioxide is provided to ensure that the fixed protection for the largest single hazard on which the hose lines can be used will not be jeopardized. *(See Section 7.4 and A.7.1.1.)*

4.6.1.2 Where the authority having jurisdiction determines that continuous protection is required, the quantity of reserve supply shall be as many multiples of the quantities required in 4.6.1 and 4.6.1.1 as the authority having jurisdiction considers necessary.

4.6.1.3 Both main and reserve supplies for fixed storage systems shall be permanently connected to the piping and arranged for easy changeover, except where the authority having jurisdiction permits an unconnected reserve.

4.6.2 Replenishment. The time needed to obtain carbon dioxide for replenishment to restore systems to operating condition shall be considered as a major factor in determining the reserve supply needed.

4.6.3* Quality. Carbon dioxide shall have the following minimum properties:

(1) The vapor phase shall be not less than 99.5 percent carbon dioxide with no detectable off-taste or odor.
(2) The water content of the liquid phase shall comply with CGA G-6.2.
(3) Oil content shall be not more than 10 ppm by weight.

4.6.4 Storage Containers.

4.6.4.1 Storage containers and accessories shall be so located and arranged to facilitate inspection, maintenance, and recharging.

4.6.4.2 Interruption to protection shall be held to a minimum.

4.6.4.3 Storage containers shall be located as near as possible to the hazard or hazards they protect, but they shall not be located where they will be exposed to a fire or explosion in these hazards.

4.6.4.4 Storage containers shall not be located where they will be subject to severe weather conditions or to mechanical, chemical, or other damage.

4.6.4.5 Where excessive climatic or mechanical exposures are expected, guards or enclosures shall be provided.

4.6.5* High-Pressure Cylinders. The carbon dioxide supply shall be stored in rechargeable cylinders designed to hold carbon dioxide in liquid form at ambient temperatures.

4.6.5.1 The containers used in these systems shall be designed to meet the requirements of the U.S. Department of Transportation, the Canadian Transport Commission, or the equivalent governing agency.

4.6.5.2* High-pressure cylinders used in fire-extinguishing systems shall not be recharged without a hydrostatic test (and remarking) if more than 5 years have elapsed from the date of the last test.

4.6.5.2.1 Cylinders continuously in service without discharging shall be permitted to be retained in service for a maximum of 12 years from the date of the last hydrostatic test.

4.6.5.2.2 At the end of 12 years, cylinders continuously in service without discharging shall be discharged and retested before being returned to service.

4.6.5.3 Pressure Relief Device.

4.6.5.3.1 Each cylinder shall be provided with a pressure relief device of the rupture disk type.

4.6.5.3.2 The pressure relief device shall be sized and fitted in accordance with the requirements specified in Department of Transportation (DOT) regulations 49 CFR 171–190.

4.6.5.4 Manifolded Cylinders.

4.6.5.4.1 When manifolded, cylinders shall be mounted and supported in a rack provided for the purpose, including facilities for convenient individual servicing and content weighing.

4.6.5.4.2 Automatic means shall be provided to prevent the loss of carbon dioxide from the manifold if the system is operated when any cylinder is removed for maintenance.

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4.6.5.4.3 In a multiple-cylinder system, all cylinders supplying the same manifold outlet for distribution of agent shall be interchangeable and of one select size.

4.6.5.5 The ambient storage temperatures for local application systems shall not exceed 120°F (49°C) nor be less than 32°F (0°C).

4.6.5.5.1 For total flooding systems, the ambient storage temperatures shall not exceed 130°F (54°C) nor be less than 0°F (–18°C) unless the system is designed for operation with storage temperatures outside of this range.

4.6.5.5.2 External heating or cooling shall be permitted to be used to keep the temperature within the range given in 4.6.5.5.1.

4.6.5.5.3 Where special cylinder charges are used to compensate for storage temperatures outside the ranges stated in 4.6.5.5 and 4.6.5.5.1, the cylinders shall be marked in a permanent manner.

4.6.6* Low-Pressure Storage Containers. Low-pressure storage containers shall be designed to maintain the carbon dioxide supply at a nominal pressure of 300 psi (2068 kPa) corresponding to a temperature of approximately 0°F (–18°C).

4.6.6.1 Container Requirements.

4.6.6.1.1 The pressure container shall be made, tested, approved, equipped, and marked in accordance with the current specifications of API-ASME *Code for Unfired Pressure Vessels for Petroleum Liquids and Gases*, or, in the case of mobile supply containers, if applicable, the requirements of DOT 49 CFR 171–190, or both.

4.6.6.1.2 The design pressure shall be at least 325 psi (2241 kPa).

4.6.6.2* In addition to the ASME and DOT code requirements referenced in 4.6.6.1.1, each pressure container shall be equipped with a liquid level gauge, a pressure gauge, and a high/low-pressure supervisory alarm set to alarm at no more than 90 percent of the pressure vessel's design maximum allowable working pressure (MAWP) and no less than 250 psi (1724 kPa).

4.6.6.3 The pressure container shall be insulated and equipped with automatically controlled refrigeration or heating, or both, if necessary.

4.6.6.4 The refrigeration system shall be capable of maintaining 300 psi (2068 kPa) in the pressure container under the highest expected ambient temperature.

4.6.6.5 Heating.

4.6.6.5.1 The heating system, where required, shall be capable of maintaining 0°F (–18°C) in the pressure container under the lowest expected ambient temperature.

4.6.6.5.2 Heating shall not be required to be provided unless known meteorological data indicate the likely occurrence of ambient temperatures that will cool the contents of the tank to reduce the pressure below 250 psi (1724 kPa) [approximately –10°F (–23°C)].

4.7* Distribution Systems.

4.7.1* Piping shall be of metallic noncombustible material having physical and chemical characteristics such that its deterioration under stress can be predicted with reliability.

4.7.1.1 Where piping is installed in severely corrosive atmospheres, special corrosion-resistant materials or coatings shall be used.

4.7.1.2 Materials for piping and the standards covering these materials shall be as described in 4.7.1.2.1 through 4.7.1.2.5.

4.7.1.2.1 Black or galvanized steel pipe shall be either ASTM A53 seamless or electric welded, Grade A or B; or ASTM A106, Grade A, B, or C.

4.7.1.2.1.1 ASTM A120 and ordinary cast-iron pipe shall not be used.

4.7.1.2.1.2 Stainless steel shall be TP304 or TP316 for threaded connections or TP304, TP316, TP304L, or TP316L for welded connections.

4.7.1.2.2 In systems using high-pressure supply, ¾ in. (20 mm) and smaller pipe shall be permitted to be Schedule 40.

4.7.1.2.2.1 Pipe that is 1 in. (25 mm) through 4 in. (100 mm) shall be a minimum of Schedule 80.

4.7.1.2.2.2 Furnace butt-weld ASTM A53 pipe shall not be used.

4.7.1.2.3 In systems using low-pressure supply, pipe shall be a minimum of Schedule 40.

4.7.1.2.3.1 Furnace butt-weld ASTM A53 pipe shall be permitted to be used.

4.7.1.2.4 A dirt trap consisting of a tee with a capped nipple, at least 2 in. (51 mm) long, shall be installed at the end of each pipe run.

4.7.1.2.5 Piping sections not normally opened to atmosphere shall not be required to have corrosion-resistant finish on the inside.

4.7.1.3* Flexible piping system components not specifically covered in this standard shall have a minimum burst pressure of 5000 psi (34,474 kPa) for high-pressure systems or 1800 psi (12,411 kPa) for low-pressure systems.

4.7.1.4 Class 150 and cast-iron fittings shall not be used.

4.7.1.5 Fittings for high- and low-pressure systems shall be as described in 4.7.1.5.1 and 4.7.1.5.2.

4.7.1.5.1 High-Pressure Systems.

4.7.1.5.1.1 Class 300 malleable iron fittings shall be used through 2 in. nominal pipe size (NPS) and forged steel fittings in all larger sizes.

4.7.1.5.1.2 Flanged joints upstream of any stop valves shall be Class 600.

4.7.1.5.1.3 Flanged joints downstream of stop valves or in systems with no stop valves shall be permitted to be Class 300.

4.7.1.5.1.4 Threaded unions shall, as a minimum, be equivalent to Class 2000 forged steel.

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4.7.1.5.1.5 Stainless steel fittings shall be Type 304 or 316, wrought or forged in accordance with ASTM A182, threaded or socket weld, for all sizes, ⅛ in. (3 mm) through 4 in. (100 mm).

4.7.1.5.2 Low-Pressure Systems.

4.7.1.5.2.1 Class 300 malleable or ductile iron fittings shall be used through 3 in. (80 mm) nominal pipe size (NPS) and forged steel fittings in all larger sizes.

4.7.1.5.2.2 Flanged joints shall be Class 300.

4.7.1.5.2.3 Stainless steel fittings shall be Type 304 or 316 for threaded connections or Type 304, 316, 304L, or 316L for welded connections, wrought or forged in accordance with ASTM A182, Class 2000, threaded or socket weld, for all sizes, ⅛ in. (3 mm) through 4 in. (100 mm).

Δ **4.7.1.6 Pipe Connections.**

N **4.7.1.6.1** Welded joints and screwed or flanged fittings (malleable iron or ductile iron) shall be permitted to be used.

4.7.1.6.2 Mechanical grooved couplings and fittings shall be permitted to be used if they are specifically listed for carbon dioxide service.

4.7.1.6.3 Flush bushings shall not be used.

4.7.1.6.4 Where hex bushings are used for one pipe size reduction, a Class 3000 steel bushing shall be provided to maintain adequate strength.

4.7.1.6.5 Where hex bushings are used for more than one pipe size reduction, 4.7.1.5 shall be followed.

4.7.1.6.6 Flared, compression-type, or brazed fittings shall be used with compatible tubing.

4.7.1.6.7 Where brazed joints are used, the brazing alloy shall have a melting point of 1000°F (538°C) or higher.

4.7.1.7 High-Pressure Supply.

4.7.1.7.1* In systems using high-pressure supply with pipe other than that specified in 4.7.1, the thickness of the pipe shall be calculated in accordance with ASME B31.1.

4.7.1.7.2 The internal pressure for this calculation shall be 2800 psi (19,306 kPa).

4.7.1.8 Low-Pressure Supply.

4.7.1.8.1* In systems using low-pressure supply with pipe other than that specified in 4.7.1, the thickness of the pipe shall be calculated in accordance with ASME B31.1.

4.7.1.8.2 The internal pressure for this calculation shall be 450 psi (3103 kPa).

4.7.2 The piping system shall not be subject to damage.

4.7.2.1 Pipe shall be reamed and cleaned before assembly, and after assembly the entire piping system shall be blown out before nozzles or discharge devices are installed.

4.7.2.2 In systems 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 liquid carbon dioxide.

4.7.2.2.1 For high-pressure systems, the pressure relief devices shall operate at a pressure no less than 2400 psi (16,547 kPa) and no more than 3000 psi (20,684 kPa).

4.7.2.2.2 For low-pressure systems, the pressure relief devices shall operate at a pressure no higher than 450 psi (3103 kPa).

4.7.2.2.3 Where pressure-operated cylinder valves are used, a means shall be provided to vent any cylinder gas leakage from the manifold, but the means shall also prevent loss of gas when the system operates.

4.7.2.3 All pressure relief devices shall be of such design and so located that the discharge of carbon dioxide therefrom will not injure personnel.

4.7.3 Valves.

4.7.3.1 All valves shall be suitable for the intended use, particularly regarding flow capacity and operation.

4.7.3.2 All valves shall be used only under temperatures and other conditions for which they are listed or approved.

4.7.3.3 Valves used in systems with high-pressure storage and constantly under pressure shall have a minimum bursting pressure of 6000 psi (41,369 kPa), whereas those not under constant pressure shall have a minimum bursting pressure of at least 5000 psi (34,474 kPa).

4.7.3.4 Valves used in systems using low-pressure storage shall withstand a hydrostatic test to 1800 psi (12,411 kPa) without permanent distortion.

4.7.3.5 For flanged valves, the class and style of flanges required to match the valve's flanged connection shall be used.

4.7.3.6 Valves shall be located, installed, or suitably protected so that they are not subject to mechanical, chemical, or other damage that would render them inoperative.

4.7.3.7 Valves shall be rated for equivalent length in terms of the pipe or tubing sizes with which they will be used.

4.7.3.8 The equivalent length of cylinder valves shall include siphon tube, valve, discharge head, and flexible connector.

4.7.4* Discharge Nozzles. Discharge nozzles shall be for the use intended and shall be listed or approved for discharge characteristics.

4.7.4.1 Discharge nozzles shall be of proper strength for use with the expected working pressures, shall be able to resist nominal mechanical abuse, and shall be constructed to withstand expected temperatures without deformation.

4.7.4.2 Discharge orifices shall be of corrosion-resistant metal.

4.7.4.3 Discharge nozzles used in local application systems shall be connected and supported so that they cannot readily be put out of adjustment.

4.7.4.4* Discharge nozzles shall be permanently marked to identify the nozzle and to show the equivalent single-orifice diameter regardless of shape and number of orifices.

4.7.4.4.1 This equivalent diameter shall refer to the orifice diameter of the standard single-orifice-type nozzle having the same flow rate as the nozzle in question.

4.7.4.4.2 The marking shall be readily discernible after installation.

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4.7.4.4.3* The standard orifice shall be an orifice having a rounded entry with a coefficient of discharge not less than 0.98 and with the flow characteristics as given in Table 4.7.5.2.1 and Table 4.7.5.3.1.

4.7.4.4.4 Orifice sizes other than those shown in Table A.4.7.4.4.3 shall be permitted to be used and shall be permitted to be marked as decimal orifice equipment.

4.7.4.5 Discharge Devices.

4.7.4.5.1 Discharge nozzles shall be provided with frangible disks or blowout caps where clogging by foreign materials is likely.

4.7.4.5.2 These devices shall provide an unobstructed opening upon system operation.

4.7.5 Pipe and Orifice Size Determination. Pipe sizes and orifice areas shall be selected on the basis of calculations to deliver the required rate of flow at each nozzle.

4.7.5.1* The following equation or curves developed therefrom shall be used to determine the pressure drop in the pipeline:

[4.7.5.1]

$$Q^2 = \frac{(3647)\left(D^{5.25}Y\right)}{L + 8.08\left(D^{1.25}Z\right)}$$

where:

Q = flow rate [lb/min (kg/min)]
D = actual inside pipe diameter [in. (mm)]
L = equivalent length of pipeline [ft (m)]
Y and Z = factors depending on storage and line pressure

4.7.5.2 For systems with low-pressure storage, flow shall be calculated on the basis of an average storage pressure of 300 psi (2068 kPa) during discharge.

4.7.5.2.1 The discharge rate for equivalent orifices shall be based on the values given in Table 4.7.5.2.1.

4.7.5.2.2 Design nozzle pressures shall not be less than 150 psi (1034 kPa).

4.7.5.3 For systems with high-pressure storage, flow shall be calculated on the basis of an average storage pressure of 750 psi (5171 kPa) during discharge for normal 70°F (21°C) storage.

4.7.5.3.1 The discharge rate through equivalent orifices shall be based on the values given in Table 4.7.5.3.1.

4.7.5.3.2 Design nozzle pressure at 70°F (21°C) storage shall be greater than or equal to 300 psi (2068 kPa).

4.7.6* Pipe Hangers and Supports. Pipe hangers and supports shall be designed and installed in accordance with recognized industry practices and manufacturer's instructions.

4.7.6.1 All pipe hangers and supports shall be attached directly to a rigid, fixed structure.

4.7.6.2 All hangers and components shall be steel.

4.7.6.3 Ordinary cast-iron hangers/supports, conduit clamps, or "C" clamps shall not be used.

4.7.6.4 All pipe supports shall be designed and installed to prevent lateral movement of supported pipe during system discharge while permitting longitudinal movement to accommodate expansion and contraction caused by temperature changes.

4.7.6.4.1 Rigid hangers shall be installed wherever a change in elevation or direction occurs.

4.7.6.4.2 Nozzles shall be supported so as to prevent movement of the nozzle during discharge.

4.7.6.5 Where seismic bracing is required, bracing shall be in accordance with local codes and the authority having jurisdiction.

Table 4.7.5.2.1 Discharge Rate per Square Inch of Equivalent Orifice Area for Low-Pressure Storage [300 psi (2068 kPa)]

Orifice Pressure		Discharge Rate	
psi	kPa	lb/min·in.^{2}	kg/min·mm^2
300	2068	4220	2.970
290	1999	2900	2.041
280	1931	2375	1.671
270	1862	2050	1.443
260	1793	1825	1.284
250	1724	1655	1.165
240	1655	1525	1.073
230	1586	1410	0.992
220	1517	1305	0.918
210	1448	1210	0.851
200	1379	1125	0.792
190	1310	1048	0.737
180	1241	977	0.688
170	1172	912	0.642
160	1103	852	0.600
150	1034	795	0.559

Table 4.7.5.3.1 Discharge Rate per Square Inch of Equivalent Orifice Area for High-Pressure Storage [750 psi (5171 kPa)]

Orifice Pressure		Discharge Rate	
psi	kPa	lb/min·in.^{2}	kg/min·mm^2
750	5171	4630	3.258
725	4999	3845	2.706
700	4826	3415	2.403
675	4654	3090	2.174
650	4481	2835	1.995
625	4309	2615	1.840
600	4137	2425	1.706
575	3964	2260	1.590
550	3792	2115	1.488
525	3620	1985	1.397
500	3447	1860	1.309
475	3275	1740	1.224
450	3103	1620	1.140
425	2930	1510	1.063
400	2758	1400	0.985
375	2586	1290	0.908
350	2413	1180	0.830
325	2241	1080	0.760
300	2068	980	0.690

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