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CARBON DIOXIDE EXTINGUISHING SYSTEMS 1977

NFPA

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See Inside Back Cover for Official NFPA Definitions

SC-AM-77

Standard on

Carbon Dioxide Extinguishing Systems

NFPA 12 — 1977

1977 Edition of 12

The 1977 edition of the Standard for Carbon Dioxide Extinguishing Systems incorporates changes proposed by the Committee on Carbon Dioxide and adopted at the 1977 Annual Meeting of the National Fire Protection Association in Washington, DC, May 16–19, 1977. It supersedes the 1973 edition.

This 1977 edition of NFPA 12 is being submitted to the American National Standards Institute for approval as an ANSI standard. Earlier editions have been so approved, the latest being designated ANSI A54.1 — 1974. The ANSI designation and date of approval of the 1977 edition will be printed on the front cover of copies of this edition printed after approval has been received.

Origin and Development of 12

Work on this standard was initiated in 1928 by the then 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, and 1973. Revisions adopted 1945–1949 were proposed by the Committee on Special Extinguishing Systems, and those in 1956 and subsequently were proposed by the Committee on Carbon Dioxide.

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

Contents

Standard on

Carbon Dioxide Extinguishing Systems

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NOTICE: An asterisk (*) following the number or letter designating a subdivision indicates explanatory material on that subdivision in Appendix A.

Chapter 1 General Information and Requirements

1-1 Scope. This standard contains minimum requirements for carbon dioxide fire extinguishing systems. It includes only the necessary essentials to make the standard workable in the hands of those skilled in this field.

NOTE: Portable carbon dioxide equipment is covered in NFPA 10, *Standard for Portable Fire Extinguishers.* The use of carbon dioxide for inerting is covered in NFPA 69, *Standard on Explosion Prevention Systems* (*see Appendix C*).

1-2 Purpose. This standard is prepared for the use and guidance of those charged with the purchasing, designing, installing, testing, inspecting, approving, listing, operating or maintaining carbon dioxide fire extinguishing systems, in order that such equipment will function as intended throughout its life.

1-2.1 Only those skilled in the field are competent to design and install this equipment. It may be necessary for many of those charged with the purchasing, inspecting, testing, approving, operating and maintaining this equipment to consult with an experienced and competent fire protection engineer in order to effectively discharge their respective duties.

1-3 Arrangement. This standard is arranged as follows:

Introduction.

Chapter 1 — General Information and Requirements.

Chapter 2 — Total Flooding Systems.

Chapter 3 — Local Application Systems.

Chapter 4 — Hand Hose Line Systems.

Chapter 5 — Standpipe Systems and Mobile Supply.

Appendix A — Explanatory.

Appendix B — Examples of Hazard Protection.

Appendix C — Reference Publications.

Chapters 1 through 5 constitute the body of the standard and contain the rules and regulations necessary for properly designing, installing, inspecting, testing, approving, operating and maintaining carbon dioxide fire extinguishing systems.

The Appendixes contain educational and informative material that will aid in understanding and applying this standard.

1-4 Definitions and Units.

1-4.1 Definitions. For purpose of clarification, the following general terms used with special technical meanings in this standard are defined:

1-4.1.1 Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office, or individual responsible for "approving" equipment, an installation, or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA standards 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, 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 delegated agent assumes the role of the "authority having jurisdiction"; at government installations, the commanding officer or a departmental official may be the "authority having jurisdiction."

1-4.1.2 High Pressure is used to indicate that the carbon dioxide is stored in pressure containers at atmospheric temperatures. At 70°F (21°C), the pressure in this type of storage is 850 psi (58.6 bars).

1-4.1.3 Low Pressure is used to indicate that the carbon dioxide is stored in pressure containers at controlled low temperatures, at 0°F (−18°C). At 0°F (−18°C), the pressure in this type of storage is 300 psi (20.7 bars).

1-4.1.4 Other terms used with special technical meaning are defined or explained where they occur in the standard.

1-4.2 Units. Metric units of measurement in this standard are in accordance with the modernized metric system known as the

International System of Units (SI). Two units (litre and bar), outside of but recognized by SI, are commonly used in international fire protection. These units are listed in Table 1-4.2 with conversion factors.

1-4.2.1 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 may be approximate.

1-4.2.2 The conversion procedure for the SI units has been to multiply the quantity by the conversion factor and then round the result to the appropriate number of significant digits.

Table 1-4.2

Name of Unit	Unit Symbol	Conversion Factor
litre	l	1 gal. = 3.785l
litre per minute per square metre	$l/\text{min.m}^2$	1 gpm/ft^2 = 40.746$l/\text{min.m}^2$
cubic decimetre	dm^3	1 gal. = 3.785 dm^3
pascal	Pa	1 psi = 6894.757 Pa
bar	bar	1 psi = 0.0689 bar
bar	bar	1 bar = 10^5 Pa

For additional conversions and information see ASTM E380-76, *Standard for Metric Practice* (*see Appendix C*).

1-5 General Information and Requirements.

1-5.1 Chapter 1 contains general information, and the design and installation requirements for all features that are generally common to all carbon dioxide systems.

1-5.2* Carbon Dioxide. Carbon dioxide is a colorless, odorless, electrically nonconductive inert gas that is a suitable medium for extinguishing fires.

1-5.2.1 Carbon dioxide extinguishes fire by reducing the concentrations of oxygen and/or the gaseous phase of the fuel in the air to the point where combustion stops.

1-5.3 Use and Limitations. Carbon dioxide fire extinguishing systems are useful within the limits of this standard in extinguishing fires in specific hazards or equipment, and in occupancies where an inert electrically nonconductive medium is essential or desirable, where cleanup of other media presents a problem, or where they are more economical to install than systems using other media.

1-5.3.1 All areas or parts of a hazard to which or from which a fire may spread shall be simultaneously protected.

1-5.3.2 Some of the more important types of hazards and equipment that carbon dioxide systems may satisfactorily protect include:

(a) Gaseous and liquid flammable materials.

(b) Electrical hazards, such as transformers, oil switches and circuit breakers, and rotating equipment.

(c) Engines utilizing gasoline and other flammable fuels.

(d) Ordinary combustibles such as paper, wood and textiles.

(e) Hazardous solids.

1-5.3.3 The discharge of liquid carbon dioxide is known to produce electrostatic charges which, under certain conditions, could create a spark. Carbon dioxide fire extinguishing systems protecting areas where explosive atmospheres could exist shall utilize metal nozzles and shall be properly grounded.

1-5.3.4* Carbon dioxide will not extinguish fires where the following materials are actively involved in the combustion process:

(a) Chemicals containing their own oxygen supply such as cellulose nitrate.

(b) Reactive metals such as sodium, potassium, magnesium, titanium and zirconium.

(c) Metal hydrides.

1-5.4 Types of Systems. There are four types of systems recognized in this standard:

Total Flooding Systems.

Local Application Systems.

Hand Hose Line Systems.

Standpipe Systems and Mobile Supply.

1-5.4.1 A Total Flooding System consists of a fixed supply of carbon dioxide normally connected to fixed piping with nozzles arranged to discharge carbon dioxide into an enclosed space or enclosure about the hazard.

1-5.4.2 A Local Application System consists of a fixed supply of carbon dioxide normally connected to fixed piping with nozzles arranged to discharge carbon dioxide directly on the burning material.

1-5.4.3 A Hand Hose Line System consists of a fixed supply of carbon dioxide supplying hose lines.

1-5.4.4 A Standpipe System and Mobile Supply consists of a mobile supply of carbon dioxide capable of being quickly moved to position and connected to a system of fixed piping supplying fixed nozzles or hose lines or both that may be used for either total flooding or local application.

1-5.5 Carbon Dioxide System. A carbon dioxide system may be used to protect one or more hazards or groups of hazards by means of directional valves (with the permission of the authority having jurisdiction). Where two or more hazards may be simultaneously involved in fire by reason of their proximity, each hazard shall be protected with an individual system with the combination arranged to operate simultaneously or be protected with a single system that shall be sized and arranged to discharge on all potentially involved hazards simultaneously.

1-5.6 Package Systems (Kits). Package systems consist of system components designed to be installed according to pretested limitations as approved or listed by a nationally recognized testing laboratory.

1-5.6.1 Package systems may incorporate special nozzles, flow rates, methods of application, nozzle placement, and quantities of carbon dioxide which may differ from those detailed elsewhere in this standard since they are designed for very specific hazards. All other requirements of the standard apply.

1-5.6.2 Package systems shall be installed to protect hazards within the limitations which have been established by the testing laboratories where listed.

1-6 Personnel Safety.

1-6.1* Hazards to Personnel. The discharge of large amounts of carbon dioxide can create hazards to personnel such as oxygen deficiency and reduced visibility.

1-6.1.1 The dilution of the oxygen in the air, by the carbon dioxide concentrations that will extinguish fire, will create atmospheres that will not sustain life. Such atmospheres will be produced in spaces protected by total flooding and will be produced by any large volume discharges drifting and settling in adjacent low places such as cellars and pits. Persons rendered unconscious in these atmospheres can usually be revived without any permanent ill effects when promptly removed from such atmospheres.

1-6.1.2 Large volume discharges of carbon dioxide may seriously interfere with visibility during and immediately after the discharge period.

1-6.2* Safety Requirements. In any proposed use of carbon dioxide where there is a possibility that men could be trapped in, or enter into atmospheres made hazardous by a carbon dioxide discharge, suitable safeguards shall be provided to insure prompt evacuation of and to prevent entry into such atmospheres and also to provide means for prompt rescue of any trapped personnel. Suitable safeguards may include personnel training, warning signs, discharge alarms, pre-discharge alarms and breathing apparatus.

1-6.3 Electrical Clearances. All system components shall be so located as to maintain minimum clearances from live parts as shown in Table 1-6.3.

Table 1-6.3
Clearance from Equipment to
Live Uninsulated Electrical Components

Nominal Line Voltage (kv)	Nominal Voltage to Ground (kv)	Design BIL (kv)	Minimum Clearance* (inches)	mm
To 15	To 9	110	7	178
23	13	150	10	254
34.5	20	200	13	330
46	27	250	17	432
69	40	350	25	635
115	66	550	37	940
138	80	650	44	1118
161	93	750	52	1321
196–230	114–132	900	63	1600
		1050	76	1930
287–380	166–220	1175	87	2210
		1300	98	2489
		1425	109	2769
		1550	120	3048
500	290	1675	131	3327
		1800	142	3607
500–700	290–400	1925	153	3886
		2100	168	4267
		2300	184	4674

*For voltages up to 69 kv the clearances are taken from NFPA 70, *National Electrical Code* (*see Appendix C.*)

NOTE 1: 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.

NOTE 2: 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.

As used in this standard, "clearance" is the air distance between equipment, including piping and nozzles, and unenclosed or uninsulated live electrical components at other than ground potential.

The clearances given are for altitudes of 3,300 ft (1007m) or less. At altitudes in excess of 3,300 ft (1007m), the clearance shall be increased at the rate of 1 percent for each 330 ft (100.7m) increase in altitude above 3,300 ft (1007m).

The clearances are based upon minimum general practices related to design Basic Insulation Level (BIL) values. To coordinate the required clearance with the electrical design, the design 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.

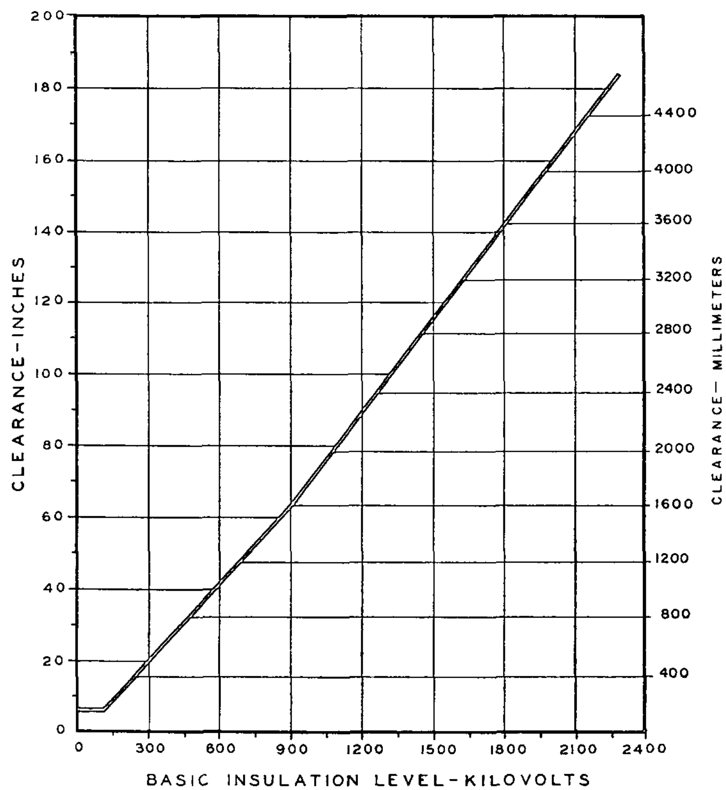

Figure 1-6.3. Clearance from Carbon Dioxide Equipment to Live Uninsulated Electrical Components.

Up to electrical system voltages of 161 kv the design BIL kv and corresponding minimum clearances, phase to ground, have been established through long usage.

At voltages higher than 161 kv, uniformity in the relationship between design BIL kv and the various electrical system voltages has not been established in practice and is dependent upon several variables so that the required clearances to ground shall be based upon the design BIL used rather than on the nominal line or ground voltage.

Possible design variations in the clearance required at higher voltages are evident in the Table, where a range of voltages is indicated opposite the various BIL test values in the high voltage portion of the Table. However, the clearance between uninsulated energized parts of the electrical system equipment and any portion of the carbon dioxide system shall not be less than the minimum clearance provided elsewhere for electrical system insulations on any individual component.

1-7 Specifications, Plans and Approvals.

1-7.1* Purchasing Specifications. Specifications for carbon dioxide fire extinguishing systems shall be drawn up with care and with the advice of the authority having jurisdiction.

1-7.1.1 The specifications shall designate the authority having jurisdiction and indicate whether plans are required.

1-7.1.2 The specifications shall state that the installation shall conform to this standard and meet the approval of the authority having jurisdiction.

1-7.1.3 The specifications shall include the specific tests that may be required to meet the approval of the authority having jurisdiction, and indicate how cost of testing is to be borne.

1-7.1.4 These specifications shall require the provision of equipment listed for the use intended.

1-7.2 Plans and Approvals. Plans and calculations shall be submitted for approval to the authority having jurisdiction before the work starts. Their preparation shall be entrusted to none but fully experienced and qualified persons.

1-7.2.1 These plans shall be drawn to an indicated scale or be suitably dimensioned and shall be made so they can be easily reproduced.

1-7.2.2 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. The details shall include the materials involved in the protected hazards, location of the hazards, the enclosure or limits and isolation of the hazards, and the area surrounding which might affect the protected hazards.

1-7.2.3 The detail on the system shall include information and calculations on the amount of CO_2; the location 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 CO_2 storage facility. Information shall be submitted pertaining to the location and function of the detection devices, operating devices, auxiliary equipment, and electrical circuitry, if used. Sufficient information shall be indicated to identify properly the apparatus and devices used. Any special features shall be adequately explained.

1-7.2.4 When field conditions necessitate any material change from approved plans, the change shall be submitted to the authority having jurisdiction for approval.

1-7.2.5 When such material changes from approved plans are made, corrected "as installed" plans shall be supplied to the owner and the authority having jurisdiction.

1-7.3* Approval of Installations. The completed system shall be tested by qualified personnel to meet the approval of the authority having jurisdiction. These tests shall be adequate to determine that the system has been properly installed and will function as intended. Only listed or approved equipment and devices shall be used in the systems.

1-8 Operation and Control of Systems.

1-8.1 Methods of Actuation. Systems shall be classified as automatic or manual in accordance with the following methods of actuation:

(a) Automatic Operation — Operation that does not require any human action.

(b) Normal Manual Operation — Operation of the system requiring human action where the device used to cause operation is located so as to be easily accessible at all times to the hazard. (*See 1-8.3.4.*) Operation of one control shall be all that is required to bring about the full operation of the system.

(c) Emergency Manual Operation — 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. Fully mechanical may incorporate the use of system pressure to complete operation of the device.

1-8.2 Detection of Fires. Fires or conditions likely to produce fire may be detected by visual (human senses) or by automatic means.

1-8.2.1 Reliance on visual detection shall be permitted only with permission of the authority having jurisdiction, where fires or conditions likely to produce fire can be readily detected by such means.

1-8.2.2* 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.

1-8.2.3 An adequate and reliable source of energy shall be used in detection systems.

1-8.3 Operating Devices. Operating devices include carbon dioxide releasing devices or valves, discharge controls, and shutdown equipment, all of which are necessary for successful performance of the system.

1-8.3.1 Operation shall be by listed or approved mechanical, electrical, or pneumatic means. An adequate and reliable source of energy shall be used.

1-8.3.2 All devices shall be designed for the service they will encounter and shall not be readily rendered inoperative or susceptible to accidental operation. Devices shall be normally designed to function properly from −20°F to 150°F (−29°C to 66°C) or marked to indicate temperature limitations.

1-8.3.3 All devices shall be located, installed or suitably protected so that they are not subject to mechanical, chemical, or other damage which would render them inoperative.

1-8.3.4 The normal manual control for actuation shall be located so as to be conveniently and easily accessible at all times including the time of fire. This control shall cause the complete system to operate in its normal fashion.

1-8.3.5 All valves controlling the release and distribution of carbon dioxide shall be provided with an emergency manual control. This does not apply to slave high pressure cylinders.

It is possible for the normal manual control to qualify as the emergency manual control if the provisions of 1-8.1 are satisfied.

The emergency means, preferably mechanical, shall be easily accessible and located close to the valves controlled. If possible, the system should be designed so that emergency actuation can be accomplished from one location. This does not apply to slave high pressure cylinders.

1-8.3.6 Manual controls shall not require a pull of more than 40 lbs (force) (178N) nor a movement of more than 14 inches (356mm) to secure operation.

1-8.3.7 Where gas pressure from pilot cylinders is used as a means for releasing remaining slave cylinders and the supply consists of less than three cylinders, one cylinder shall be used for such operation. If the supply consists of three cylinders or more, not less than two cylinders shall be used for such operation.

1-8.3.8 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. All shutdown devices shall be considered integral parts of the system and shall function with the system operation.

1-8.3.9 All manual operating devices shall be identified as to the hazard they protect.

1-8.4 Supervision. Where supervision of any or all of the following — automatic detection system, the electrical actuation circuit, the electrical power supply — is provided, it shall be arranged to give immediate indication of failure.

1-8.5 Alarms and Indicators. Alarms or indicators, or both, are used to indicate the operation of the system, hazard to personnel, or failure of any supervised device or equipment. The device may be audible, visual or olfactory. The type, number and location of the devices shall be such that their purpose is satisfactorily accomplished. The extent and type of alarm or indicator equipment, or both, shall be approved.

1-8.5.1 An alarm or indicator shall be provided to show that the system has operated, that personnel response may be needed, and that the system is in need of recharge.

1-8.5.2 An alarm should be provided to indicate the operation of automatic systems in case an immediate personnel response is desired.

1-8.5.3 Alarms shall be provided to give positive warning of a discharge where hazard to personnel may exist. Such alarms shall function to warn against personnel entry into hazardous areas as long as such hazards exist or until such hazards are properly recognized. (*See Section 1–6.*)

1-8.5.4 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.

1-9 Carbon Dioxide Supply.

1-9.1 Quantities. The amount of carbon dioxide in the system shall be at least sufficient for the largest single hazard protected or group of hazards which are to be protected simultaneously.

1-9.1.1 Where hand hose lines may be used on a hazard protected by a fixed system, separate supplies shall be provided unless sufficient carbon dioxide is provided to insure that the fixed protection for the largest single hazard upon which the hose lines may be used will not be jeopardized. (*See 4-1.1.*)

1-9.1.2 Where continuous protection is required, the reserve quantity shall be as many multiples of these minimum amounts as the authority having jurisdiction considers necessary. (*See 1-9.3.*)

1-9.1.3 Both primary and reserve supplies for fixed storage shall be permanently connected to the piping and arranged for easy change-over, except where the authority having jurisdiction permits an unconnected reserve.

1-9.2* Quality. Carbon dioxide used for initial supply and replenishment shall be of good commercial grade, free of water and other contaminants that might cause container corrosion or interfere with free discharge through nozzle orifices. In general, carbon dioxide obtained by converting dry ice to liquid will not be satisfactory unless it is properly processed to remove excess water and oil.

1-9.2.1 The vapor phase shall be not less than 99.5 percent carbon dioxide with no detectable off-taste or odor.

1-9.2.2 The water content of the liquid phase shall be not more than 0.01 percent by weight (−30°F [−34°C] dew point).

1-9.2.3 Oil content shall be not more than 10 ppm by weight.

1-9.3 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.

1-9.4 Storage Containers. Storage containers and accessories shall be so located and arranged that inspection, testing, recharging and other maintenance is facilitated and interruption to protection is held to a minimum.

1-9.4.1 Storage containers shall be located as near as possible to the hazard or hazards they protect, but they should not be located where they will be exposed to a fire or explosion in these hazards.

1-9.4.2 Storage containers shall not be located so as to be subject to severe weather conditions or be subject to mechanical, chemical, or other damage.

1-9.4.3 When excessive climatic or mechanical exposures are expected, suitable guards or enclosures shall be provided.

1-9.5* High Pressure Storage Containers. The carbon dioxide supply shall be stored in rechargeable containers designed to hold pressurized carbon dioxide in liquid form at atmospheric temperatures, corresponding to a nominal pressure of 850 psi (58.6 bars) at 70°F (21°C).

1-9.5.1 High pressure containers or cylinders shall be constructed, tested and marked in accordance with U.S. Department of Transportation specifications[1] (in current effect upon date of manufacture and test) for DOT-3A, 3AA-1800, or higher, seamless steel cylinders. Charged cylinders shall be tested for tightness before shipment in accordance with an approved procedure.

1-9.5.2 High pressure cylinders used in fire extinguishing systems shall not be recharged without hydrostatic test (and remarking) if more than five years has elapsed from the date of last test. Cylinders continuously in service without discharging may be retained in service for a maximum of twelve years from the date of last hydrostatic test. At the end of twelve years, they shall be discharged and retested before returning them to service.

1-9.5.3 Each cylinder shall be provided with a safety device to relieve excess pressures, safely in advance of the rated cylinder test pressure. I.C.C. approved, frangible safety discs shall be accordingly fitted.

1-9.5.4 When manifolded, cylinders shall be adequately mounted and suitably supported in a rack provided for the purpose,

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[1]Secs. 178.36 and 178.37 of Title 49, Transportation, Code of Federal Regulations. Parts 171–190 (DOT). Available from the Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20401.

including facilities for convenient individual servicing or content weighings. 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.

1-9.5.5 Individual cylinders shall be used having a standard weight capacity of 5, 10, 15, 20, 25, 35, 50, 75 or 100 lbs (2.3, 4.5, 6.8, 9.1, 11.4, 15.9, 22.7, 34.1 or 45.4 kg) of carbon dioxide contents except for special temperature charges. (*See 1-9.5.6.*) In a multiple cylinder system, all cylinders supplying the same manifold outlet for distribution of agent shall be interchangeable and of one select size.

1-9.5.6 The general ambient storage temperatures for (a) local application systems shall not exceed 120°F (49°C) nor be less than 32°F (0°C) and (b) total flooding systems shall not exceed 130°F (54°C) nor be less than 0°F (−18°C) unless the system is designed for proper operation with storage temperatures outside of this range. External heating or cooling may be used to keep the temperature within this range. When special cylinder charges are used the cylinders shall be appropriately marked.

1-9.6* Low Pressure Storage Containers. Low pressure storage containers shall be designed to maintain the carbon dioxide supply at a nominal pressure of 300 psi (20.7 bars) corresponding to a temperature of approximately 0°F (−18°C).

1-9.6.1 The pressure container shall be made, tested, approved, equipped and marked in accordance with the current specifications of the American Society of Mechanical Engineers (ASME) *Code for Unfired Pressure Vessels.*[1] The design working pressure shall be at least 325 psi (22.4 bars).

1-9.6.2* In addition to the code requirements, each pressure container shall be equipped with a liquid level gauge, a pressure gauge, and a high-low pressure supervisory alarm set at approximately 315 and 250 psi (21.7 and 17.2 bars).

1-9.6.3 The pressure container shall be insulated and equipped with refrigeration or heating or both means if necessary. Heating need not be provided unless known meteorological data indicates the occurrence of ambient temperatures which will cool the contents of the tank sufficiently to reduce the pressure below 250 psi (17.2 bars) (approximately −10°F [−23°C]).

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[1]*Code for Unfired Pressure Vessels for Petroleum Liquids and Gases* (ASME; API-ASME). Available from The American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017. 285 pages.

1-9.6.4 The refrigeration system shall be capable of maintaining 0°F (−18°C) in the pressure container under the highest expected ambient temperature. Operation shall be automatically controlled within practical limits.

1-9.6.5 The heating system when required shall be capable of maintaining 0°F (−18°C) in the pressure container under the lowest expected ambient temperature. Operation shall be automatically controlled within practical limits.

1-10 Distribution Systems.

1-10.1 Piping. Piping shall be of noncombustible material having physical and chemical characteristics such that its deterioration under stress can be predicted with reliability. Special corrosion-resistant materials or coatings may be required in severely corrosive atmospheres. Examples of materials for piping and the standards covering these materials are:

(a) Ferrous Piping: Black or Galvanized Steel Pipe: ASTM A-53 or A-106, ANSI B-36.10. (*See Appendix C.*)

(b) Nonferrous Piping (Drawn, Seamless), Copper: ASTM B-88. Flexible Metallic Hose: ANSI B140.1. (*See Appendix C.*)

The above listed materials do not preclude the use of other materials such as stainless steel or other pipe or tubing, which will also satisfy the requirements of this section.

1-10.1.1 Ordinary cast iron pipe and fittings shall not be used. Steel pipe conforming to ASTM A-120 shall not be used.

1-10.1.2* Flexible piping, tubing or hoses (including connections) where used shall be of approved materials and pressure ratings. It shall be inspected regularly and replaced at certain intervals.

1-10.1.3 Generally, welded joints, screwed or flanged fittings (malleable iron, steel, or ductile iron) are used. Flush bushings shall not be used. When hex bushings are used, more than one pipe size reduction shall be provided to maintain adequate strength. Suitable flared, compression-type, or brazed fittings shall be used with copper or brass tubing. Where brazed joints are used, the brazing alloy shall have a melting point of 1000°F (538°C) or higher.

1-10.1.4* In systems using high pressure supply, pipe and fittings shall have a minimum bursting pressure of 5000 psi (413.7 bars).

1-10.1.5* In systems using low pressure supply, pipe and fittings shall have a minimum bursting pressure of 1800 psi (124.1 bars).

1-10.2 Arrangement and Installation of Piping and Fittings. Piping shall be installed in accordance with good commercial practices.

1-10.2.1* All piping shall be laid out to reduce friction losses to a reasonable minimum and care shall be taken to avoid possible restrictions due to foreign matter or faulty fabrication.

1-10.2.2 The piping system shall be securely supported with due allowance for expansion and contraction and shall not be subject to mechanical, chemical, or other damage. Where explosions are possible, the piping system shall be hung from supports that are least likely to be displaced.

1-10.2.3 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.

1-10.2.4 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. The pressure relief devices shall operate between 2400 and 3000 psi (165.5 and 206.9 bars) on systems supplied with high pressure storage, and at 450 psi (31.0 bars) on systems supplied by low pressure storage. Where pressure operated cylinder valves are used, a means shall be provided to vent any cylinder gas leakage from the manifold but which will prevent loss of gas when the system operates.

1-10.2.5 All pressure relief devices shall be of such design and so located that the discharge of CO_2 therefrom will not injure personnel or be otherwise objectionable.

1-10.3 Valves. All valves shall be suitable for the intended use, particularly in regard to flow capacity and operation. They shall be used only under temperatures and other conditions for which they are listed or approved.

1-10.3.1 Valves used in systems with high pressure storage and constantly under pressure shall have a minimum bursting pressure of 6000 psi (413.7 bars) while those not under constant pressure shall have a minimum bursting pressure of, at least, 5000 psi (344.8 bars).

1-10.3.2 Valves used in systems using low pressure storage shall withstand a hydrostatic test to 1800 psi (124.1 bars) without permanent distortion.

1-10.3.3 Valves shall not be subject to mechanical, chemical or other damage.

1-10.3.4 Valves shall be rated for equivalent length in terms of the pipe or tubing sizes with which they will be used. The equivalent length of cylinder valves shall include siphon tube, valve, discharge head and flexible connector.

1-10.4 Discharge Nozzles. Discharge nozzles shall be suitable for the use intended and shall be listed or approved for discharge characteristics. The discharge nozzle consists of the orifice and any associated horn, shield, or baffle.

Table 1-10.4.4(a) Equivalent Orifice Sizes.

Orifice Code No.	Equivalent Single Orifice Diameter — inches	mm	Equivalent Single Orifice Area–sq. in.	mm^2
—	.026	0.66	.00053	0.34
—	1/16	1.59	.00307	1.98
—	.070	1.78	.00385	2.48
—	.076	1.93	.00454	2.93
—	5/64	1.98	.0048	3.10
—	.081	2.06	.00515	3.32
—	.086	2.18	.00581	3.75
3	3/32	2.38	.0069	4.45
3+	7/64	2.78	.0094	6.06
4	⅛	3.18	.0123	7.94
4+	9/64	3.57	.0155	10.00
5	5/32	3.97	.0192	12.39
5+	11/64	4.37	.0232	14.97
6	3/16	4.76	.0276	17.81
6+	13/64	5.16	.0324	20.90
7	7/32	5.56	.0376	24.26
7+	15/64	5.95	.0431	27.81
8	¼	6.35	.0491	31.68
8+	17/64	6.75	.0554	35.74
9	9/32	7.14	.0621	40.06
9+	19/64	7.54	.0692	44.65
10	5/16	7.94	.0767	49.48
11	11/32	8.73	.0928	59.87
12	⅜	9.53	.1105	71.29
13	13/32	10.32	.1296	83.61
14	7/16	11.11	.1503	96.97
15	15/32	11.91	.1725	111.29
16	½	12.70	.1964	126.71
18	9/16	14.29	.2485	160.32
20	⅝	15.88	.3068	197.94
22	11/16	17.46	.3712	239.48
24	¾	19.05	.4418	285.03
32	1	25.40	.785	506.45
48	1½	38.10	1.765	1138.71
64	2	50.80	3.14	2025.80

1-10.4.1 Discharge nozzles shall be of adequate strength for use with the expected working pressures, be able to resist normal mechanical damage, and constructed to withstand expected temperatures without deformation.

1-10.4.2 Discharge orifices shall be of corrosion-resistant metal.

1-10.4.3 Discharge nozzles used in local application systems shall be so connected and supported that they may not readily be put out of adjustment.

1-10.4.4 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. 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. The marking shall be readily discernible after installation. The "Standard" orifice is an orifice having a rounded entry with a coefficient of discharge not less than 0.98 and flow characteristics as given in Tables 1-10.4.4(b) and 1-10.4.4(c).

Table 1-10.4.4(b) Discharge Rate Per Square Inch of Equivalent Orifice Area for Low Pressure Storage (300 psia [20.7 bars]).

Orifice Pressure psia	bars	Discharge Rate lbs/min/sq in.	kg/min/mm²
300	20.7	4220	2.970
290	20.0	2900	2.041
280	19.3	2375	1.671
270	18.6	2050	1.443
260	17.9	1825	1.284
250	17.2	1655	1.165
240	16.5	1525	1.073
230	15.9	1410	0.992
220	15.2	1305	0.918
210	14.5	1210	0.851
200	13.8	1125	0.792
190	13.1	1048	0.737
180	12.4	977	0.688
170	11.7	912	0.642
160	11.0	852	0.600
150	10.3	795	0.559
140	9.7	741	0.521
130	9.0	689	0.485
120	8.3	638	0.449
110	7.6	589	0.414
100	6.9	542	0.381

For equivalent orifice diameters, see Table 1-10.4.4(a). The orifice code number indicates the equivalent single orifice diameter in 1/32-inch increments. A plus sign following this number indicates equivalent diameters 1/64 inch greater than that indicated by the numbering system (e.g., No. 4 indicates an equivalent orifice diameter of 4/32 of an inch; a No. 4+, 9/64 of an inch).

Table 1-10.4.4(c) Discharge Rate Per Square Inch of Equivalent Orifice Area for High Pressure Storage (750 psia [51.7 bars]).

Orifice Pressure psia	bars	Discharge Rate lbs/min/sq in.	kg/min/mm²
750	51.7	4630	3.258
725	50.0	3845	2.706
700	48.3	3415	2.403
675	46.5	3090	2.174
650	44.8	2835	1.995
625	43.1	2615	1.840
600	41.4	2425	1.706
575	39.6	2260	1.590
550	37.9	2115	1.488
525	36.2	1985	1.397
500	34.5	1860	1.309
475	32.8	1740	1.224
450	31.0	1620	1.140
425	29.3	1510	1.063
400	27.6	1400	0.985
375	25.9	1290	0.908
350	24.1	1180	0.830
325	22.4	1080	0.760
300	20.7	980	0.690
250	17.2	780	0.549
200	13.8	595	0.419

1-10.4.5 Discharge nozzles shall be provided with frangible discs or blow-out caps where clogging by foreign materials is likely. These devices shall provide an unobstructed opening upon system operation.

1-10.5* 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.

1-10.5.1 The following equation or curves developed therefrom shall be used to determine the pressure drop in the pipe line:

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

Where Q = Flow rate in lbs/min.
D = Inside pipe diameter (actual) in inches.
L = Equivalent length of pipeline in feet.
Y & Z = Factors depending on storage and line pressure.

NOTE: For further explanation see Appendix A-1-10.6.

1-10.5.2 For systems with low pressure storage, flow shall be calculated on the basis of an average storage pressure of 300 psia (20.7 bars) during discharge. The discharge rate for equivalent orifices shall be based on the values given in Table 1-10.4.4(b). Design nozzle pressures shall not be less than 125 psia (8.6 bars).

1-10.5.3 For systems with high pressure storage, flow shall be calculated on the basis of an average storage pressure of 750 psia (51.7 bars) during discharge for normal 70°F (21°C) storage. The discharge rate through equivalent orifices shall be based on the values given in Table 1-10.4.4(c). Design nozzle pressure at 70°F (21°C) storage shall not be less than 200 psia (13.8 bars).

1-11 Inspection, Maintenance and Instruction.

1-11.1* A manufacturer's test and maintenance procedure shall be provided to the owner for testing and maintenance of the system. The procedure shall provide for the initial testing of the equipment as well as for periodic inspection and maintenance.

1-11.2* Inspection and Tests. At least annually, all carbon dioxide systems shall be thoroughly inspected and tested for proper operation by competent personnel. (*See 1-11.4.*)

1-11.2.1 The goal of this inspection and testing shall be not only to insure that the system is in full operating condition but shall indicate the probable continuance of that condition until the next inspection.

1-11.2.2 Suitable discharge tests shall be made when any inspection indicates their advisability.

1-11.2.3 An inspection report with recommendations shall be filed with the owner.

1-11.2.4 Between the regular service contract inspection or tests, the system shall be inspected visually or otherwise by approved or competent personnel, following an approved schedule.

1-11.2.5 At least semiannually, all high pressure cylinders shall be weighed and the date of the last hydrostatic test noted (*see 1-9.5.2*). If, at any time, a container shows a loss in net content of more than 10 percent, it shall be refilled or replaced.

1-11.2.6 At least weekly the liquid level gauges of low pressure containers shall be observed. If at any time a container shows a loss of more than 10 percent, it shall be refilled, unless the minimum gas requirements are still provided.

1-11.3 Maintenance. These systems shall be maintained in full operating condition at all times. Use, impairment, and restoration of this protection shall be reported promptly to the authority having jurisdiction.

1-11.3.1 Any troubles or impairments shall be corrected at once by competent personnel.

1-11.4 Instruction. All persons who may be expected to inspect, test, maintain, or operate carbon dioxide fire extinguishing systems shall be thoroughly trained and kept thoroughly trained in the functions they are expected to perform.

1-11.4.1 Training programs approved by the authority having jurisdiction shall be established to accomplish this.

Chapter 2 Total Flooding Systems

2-1* General Information.

2-1.1 Description. A total flooding system consists of a fixed supply of carbon dioxide permanently connected to fixed piping, with fixed nozzles arranged to discharge carbon dioxide into an enclosed space or enclosure about the hazard.

2-1.2 Uses. This type of system may be used where there is a permanent enclosure about the hazard that is adequate to enable the required concentration to be built up, and to be maintained for the required period of time to insure the complete and permanent extinguishment of the fire in the specific combustible material or materials involved.

2-1.2.1 Examples of hazards that may be successfully protected by total flooding systems include rooms, vaults, enclosed machines, ovens, containers, and the contents thereof.

2-1.3 General Requirements. Total flooding systems shall be designed, installed, tested, and maintained in accordance with the applicable requirements in the previous chapter and with the additional requirements set forth in this chapter.

2-2 Hazard Specifications.

2-2.1 Enclosure. Under this class of protection, a reasonably well-enclosed space is assumed in order to minimize the loss of the extinguishing medium. The area of allowable unclosable openings depends upon the type of combustibles involved.

2-2.1.1 For flash or surface-type fires such as will be present with flammable liquids, the total square foot (m^2) area of unclosable openings not exceeding 3 percent of the cubic foot (m^3) volume of the space or 10 percent of the total square foot area of all sides top and bottom of the enclosure, whichever is smaller, shall be compensated for by additional carbon dioxide as specified in 2-3.5.1. If this area is exceeded the system shall be tested to assure proper performance.

2-2.1.2 For deep-seated fires such as will be involved with solids, unclosable openings shall be restricted to small openings near or in the ceiling unless the system is tested to assure proper performance.

2-2.1.3 To prevent fire from spreading through openings to adjacent hazards or work areas which may be possible reignition sources, such openings shall be provided with automatic closures or screening nozzles. The gas required for such protection shall be in addition to the normal requirement for total flooding.

(*See 3-4.3.6.*) Where such confinement of gas is impracticable, protection shall be extended to include these adjacent hazards or work areas.

2-2.1.4 In the case of process and storage tanks where safe venting of flammable vapors and gases cannot be realized, the use of external local application systems outlined in 3-4.3.6 is required.

2-2.2 Leakage and Ventilation. Since the efficiency of carbon dioxide systems depends upon the maintenance of an extinguishing concentration of carbon dioxide, leakage of gas from the space shall be kept to a minimum and compensated for by applying extra gas.

2-2.2.1 Where possible, openings such as doorways, windows, etc., shall be arranged to close automatically before or simultaneously with the start of the carbon dioxide discharge, or 2-3.5.1 and 2-4.4.1 shall be followed.

2-2.2.2 Where forced air ventilating systems are involved, they shall be preferably shut down or closed, or both, before or simultaneously with the start of the carbon dioxide discharge, or additional compensating gas be provided. (*See 2-3.5.2.*)

2-2.3* Types of Fires. Fires which can be extinguished by total flooding methods may be divided into two categories: namely, (a) surface fires involving flammable liquids, gases and solids and (b) deep-seated fires involving solids subject to smoldering.

2-2.3.1 Surface fires are the most common hazard particularly adaptable to extinguishment by total flooding systems. They are subject to prompt extinguishment when carbon dioxide is quickly introduced into the enclosure in sufficient quantity to overcome leakage and provide an extinguishing concentration for the particular materials involved.

2-2.3.2 For deep-seated fires, the required extinguishing concentration shall be maintained for a sufficient period of time to allow the smoldering to be extinguished and the material to cool to a point at which reignition will not occur when the inert atmosphere is dissipated. In any event, it is necessary to inspect the hazard immediately thereafter to make certain that extinguishment is complete and to remove any material involved in the fire.

2-3* Carbon Dioxide Requirements for Surface Fires.

2-3.1 General. The quantity of carbon dioxide for surface type fires is based on average conditions assuming fairly prompt extinguishment. A reasonable allowance for normal leakage is included in the basic volume factors but corrections shall be made for the type material involved and any other special conditions.

2-3.2 Flammable Materials. Proper consideration shall be given to the determination of the design concentration of carbon dioxide required for the type of flammable material involved in the hazard. The design concentration is determined by adding a suitable factor (20 percent) to the minimum effective concentration.

2-3.2.1 Table 2-3.2.1 gives the theoretical minimum carbon dioxide concentration and the suggested minimum design carbon dioxide concentration to prevent ignition of some common liquids and gases.

Table 2-3.2.1 Minimum Carbon Dioxide Concentrations for Extinguishment.

Material	Theoretical Min. CO_2 Concentration (%)	Minimum Design CO_2 Concentration (%)
Acetylene	55	66
Acetone	26*	31
Benzol, Benzene	31	37
Butadiene	34	41
Butane	28	34
Carbon Disulphide	55	66
Carbon Monoxide	53	64
Coal or Natural Gas	31*	37
Cyclopropane	31	37
Dowtherm	38*	46
Ethane	33	40
Ethyl Ether	38*	46
Ethyl Alcohol	36	43
Ethylene	41	49
Ethylene Dichloride	21	25
Ethylene Oxide	44	53
Gasoline	28	34
Hexane	29	35
Hydrogen	62	74
Isobutane	30*	36
Kerosene	28	34
Methane	25	30
Methyl Alcohol	26	31
Pentane	29	35
Propane	30	36
Propylene	30	36
Quench, Lube Oils	28	34

NOTE: The theoretical minimum extinguishing concentrations in air for the above materials were obtained from Bureau of Mines Limits of Flammability of Gases and Vapors (Bulletin 503). Those marked with * were calculated from accepted residual oxygen values.

2-3.2.2 For materials not given in Table 2-3.2.1, the minimum theoretical carbon dioxide concentration shall be obtained from some recognized source or determined by test. If maximum residual oxygen values are available, the theoretical carbon dioxide concentration may be calculated by the following formula:

$$\% CO_2 = \frac{(21 - O_2)}{21} \times 100$$

2-3.3 Volume Factor. The volume factor used to determine the basic quantity of carbon dioxide to protect an enclosure containing a material requiring a design concentration up to 34 percent shall be in accordance with Table 2-3.3.

Table 2-3.3 Flooding Factors

(A) Volume of Space (cu ft Incl.)	(B) Volume Factor (cu ft/lb CO_2)	(lb CO_2/cu ft)	(C) Calculated Quan. (lb) Not Less Than
Up to 140	14	.072	—
141– 500	15	.067	10
501– 1600	16	.063	35
1601– 4500	18	.056	100
4501–50,000	20	.050	250
Over 50,000	22	.046	2500

Table 2-3.3(M) Flooding Factors

(A) Volume of Space (m^3 Incl.)	(B) Volume Factor (m^3/kg CO_2)	(kg CO_2/m^3)	(C) Calculated Quan. (kg) Not Less Than
Up to 3.96	0.86	1.15	—
3.97– 14.15	0.93	1.07	4.5
14.16– 45.28	0.99	1.01	15.1
45.29–127.35	1.11	0.90	45.4
127.36–1415.0	1.25	0.80	113.5
Over 1415.0	1.38	0.77	1135.0

2-3.3.1 In figuring the net cubic capacity to be protected, due allowance may be made for permanent nonremovable impermeable structures materially reducing the volume.

2-3.3.2 As the average small space has proportionately more boundary area per enclosed volume than a larger space, greater proportionate leakages are anticipated and accounted for by the graded volume factors in Table 2-3.3.

2-3.3.3 The least gas quantities for the smallest volumes are tabulated in order to clarify the intent of Column B and thus avoid possible overlapping at borderline volumes.

2-3.3.4 In two or more interconnected volumes where "free flow" of carbon dioxide can take place, the carbon dioxide quantity shall be the sum of the quantities calculated for each volume, using its respective volume factor from Tables 2-3.3 or 2-3.3(M). If one volume requires greater than normal concentration (*see 2-3.4*), the higher concentration shall be used in all interconnected volumes.

2-3.4 Material Conversion Factor. For materials requiring a design concentration over 34 percent, the basic quantity of carbon dioxide calculated from the volume factor given in 2-3.3 shall be increased by multiplying this quantity by the appropriate conversion factor given in Figure 2-3.4.

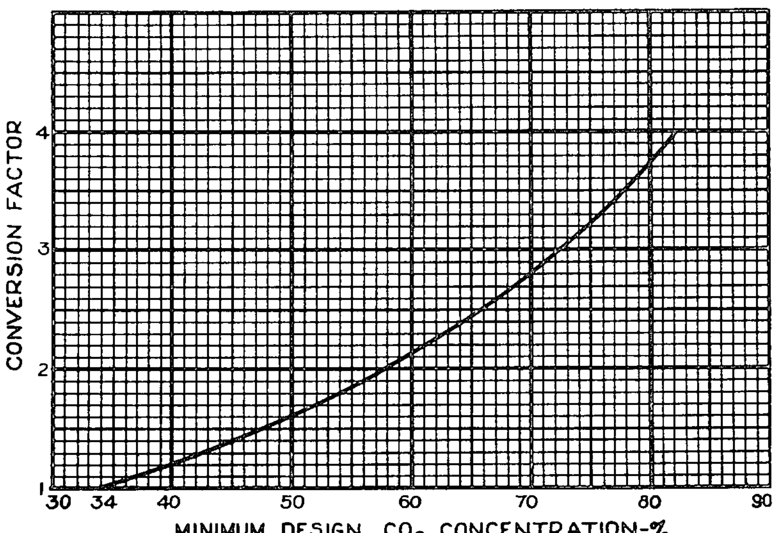


Figure 2-3.4 Material conversion factors.

2-3.5 Special Conditions. Additional quantities of carbon dioxide shall be provided to compensate for any special condition that may adversely affect the extinguishing efficiency.

2-3.5.1* Any openings that cannot be closed at the time of extinguishment shall be compensated for by the addition of a quantity of carbon dioxide equal to the anticipated loss during a one minute holding time. This amount of carbon dioxide shall be applied through the regular distribution system. (*See 2-2.1.1 and A-2-5.3.3.*)

2-3.5.2 For ventilating systems which cannot be shut down, additional carbon dioxide shall be added to the space through the regular distribution system in an amount computed by dividing the volume moved during the liquid discharge period by the flooding factor. This shall be multiplied by the material conversion factor (determined in 2-3.4) when the design concentration is greater than 34 percent.

2-3.5.3* For applications where the normal temperature of the enclosure is above 200°F (93°C), a one percent increase in the calculated total quantity of carbon dioxide shall be provided for each additional 5°F (−15°C) above 200°F (93°C).

2-3.5.4 For applications where the normal temperature of the enclosure is below 0°F (−18°C) a one percent increase in the calculated total quantity of carbon dioxide shall be provided for each degree below 0°F (−18°C).

2-3.5.5 Under normal conditions, surface fires are usually extinguished during the discharge period. Except for unusual conditions, it will not be necessary to provide extra carbon dioxide to maintain the concentration.

2-4 Carbon Dioxide Requirements for Deep-seated Fires.

2-4.1 General. The quantity of carbon dioxide for deep-seated type fires is based on fairly tight enclosures because the concentration must be maintained for a substantial period of time to assure complete extinguishment. Any possible leakage shall be given special consideration since no allowance is included in the basic flooding factors.

2-4.2 Combustible Materials. For combustible materials capable of producing deep-seated fires, the required carbon dioxide concentrations cannot be determined with the same accuracy possible with surface burning materials. The extinguishing concentration will vary with the mass of material present because of the thermal insulating effects. Flooding factors have, therefore, been determined on the basis of practical test conditions.

2-4.2.1 The flooding factors in Table 2-4.2.1 have been found to provide proper design concentrations for the rooms and enclosures listed.

Table 2-4.2.1 Flooding Factors for Specific Hazards

	Flooding Factor				
Design Concentration	(Cu ft/lb CO_2)	$m^3/kg\ CO_2$	(lb CO_2/cu ft)	$kg\ CO_2/m^3$	Specific Hazard
50	12	0.75	.083	1.33	Dry electrical, wiring insulation hazards in general (not less than 200 lbs [91 kg]).
50	10	0.62	.100	1.60	Small elec. machines, wire enclosures, under 2000 cu ft ($56.60m^3$).
65	8	0.50	.125	2.00	Record (bulk paper) storage, ducts, and mechanically ventilated covered trenches.
75	6	0.38	.166	2.66	Fur storage vaults, dust collectors.

2-4.2.2 Flooding factors for other deep-seated fires shall be justified to the satisfaction of the authority having jurisdiction before use. Proper consideration shall be given to the mass of material to be protected because the rate of cooling is reduced by the thermal insulating effects.

2-4.3 Volume Consideration. The volume of the space shall be determined in accordance with 2-3.3.1. The basic quantity of carbon dioxide required to protect an enclosure shall be obtained by treating the volume of the enclosure by the appropriate flooding factor given in 2-4.2.

2-4.4 Special Conditions. Additional quantities of carbon dioxide shall be provided to compensate for any special condition that may adversely affect the extinguishing efficiency. (*See 2-3.5.2, 2-3.5.3 and 2-3.5.4.*)

2-4.4.1 Any openings that cannot be closed at the time of extinguishment shall be compensated for by the addition of carbon dioxide equal in volume to the expected leakage volume during the extinguishing period. If leakage is appreciable, consideration shall be given to an extended discharge system as covered in 2-5.3. (*Also see 2-2.1.2.*)

2-5 Distribution System.

2-5.1 General. The distribution system for applying carbon dioxide to enclosed hazards shall be designed with due consideration for the materials involved and the nature of the enclosure since these items may require various discharge times and rates of application.

2-5.2* Rate of Application. The minimum design rate of application shall be based on the quantity of carbon dioxide and the maximum time to achieve design concentration.

2-5.2.1 For surface fires the design concentration shall be achieved within one minute.

2-5.2.2 For high pressure systems, if a part of the hazard is to be protected by total flooding, the discharge rate for the total flooding portion shall be computed as specified in 3-3.2.3.

2-5.2.3 For deep-seated fires the design concentration shall be achieved within seven minutes but the rate shall not be less than that required to develop a concentration of 30 percent in two minutes.

2-5.3 Extended Rate of Application. Where leakage is appreciable and the design concentration must be obtained quickly and maintained for an extended period of time, carbon dioxide provided for leakage compensation may be applied at a reduced rate.

2-5.3.1 This type of system is particularly applicable to enclosed rotating electrical apparatus, such as generators, motors and convertors, but it may also be used on ordinary total flooding applications where suitable.

2-5.3.2 The minimum design concentration shall be obtained within the time limits specified in 2-5.2.

2-5.3.3* The extended rate of discharge shall be sufficient to maintain the minimum concentration.

2-5.3.4* For enclosed rotating electrical equipment a minimum concentration of 30 percent shall be maintained for the deceleration period, but not less than 20 minutes.

2-5.4 Piping Systems. Piping shall be designed in accordance with 1-10.6 to deliver the required rate of application at each nozzle.

2-5.4.1* High pressure storage temperatures may range from 0°F (−18°C) to 130°F (54°C) without requiring special methods of compensating for changing flow rates. (*See A-2-5.4.1.*)

2-5.5 Nozzle Sizing and Distribution. Nozzles used in connection with total flooding systems with either high or low pressure supply shall be of a type suitable for the intended purpose, and shall be located to achieve the best results.

2-5.5.1 The type of nozzles selected and their placement shall be such that the discharge will not unduly splash flammable liquids or create dust clouds that might extend the fire, create an explosion, or otherwise adversely affect the contents of the enclosure. Nozzles vary in design and discharge characteristics and shall be selected on the basis of their adequacy for the use intended.

2-6 Venting Consideration.

2-6.1 General. The venting of flammable vapors and pressure buildup from the discharge of quantities of carbon dioxide into closed spaces shall be considered. Venting of flammable vapors is covered in 2-2.1.4. The pressure venting consideration involves such variables as enclosure strength and injection rate.

2-6.2 Pressure Relief Venting. Porosity and leakages such as at doors, windows, and dampers, though not readily apparent or easily calculated, have been found to provide sufficient relief for the normal carbon dioxide flooding systems without need for additional venting. Record storage rooms, refrigerated spaces, and duct work have also been found to need no additional venting when tested under their average system conditions.

2-6.2.1 For very tight enclosures, the area necessary for free venting shall be calculated from the following formula. Assuming the expansion of carbon dioxide to be 9 cu ft/lb ($0.56 m^3/kg$) will give satisfactory results.

$$X = \frac{Q}{1.3\sqrt{P}}$$

where: X = Free venting area in sq in.

Q = Calculated carbon dioxide flow rate in lbs/min.

P = Allowable strength of enclosure in lbs/sq ft.

For SI Units

$$X_M = \frac{23.9\ Q_M}{\sqrt{P_M}}$$

X_M = Free venting area sq mm.
Q_M = Calculated carbon dioxide flow rate in kg/min.
P_M = Allowable strength of enclosure, bars — gauge.

2-6.2.2 In many instances, particularly when hazardous materials are involved, relief openings are already provided for explosion venting. These and other available openings often provide adequate venting.

2-6.2.3 General construction practices provide the guide in Table 2-6.2.3 for considering the normal strength and allowable pressures of average enclosures.

Table 2-6.2.3 Strength and Allowable Pressures for Average Enclosures.

Type Construction	Windage	Pressure	In. Water	PSI	Bars-Gauge
Light Building	100 MPH	25 lb/sq ft[1]	5	.175	0.012
Normal Building	140 MPH	50 lb/sq ft[2]	10	.35	0.024
Vault Building	200 MPH	100 lb/sq ft	20	.70	0.048

[1]Venting sash remains closed.

[2]Venting sash designed to open freely.

Chapter 3 Local Application Systems

3-1* General Information.

3-1.1 Description. A local application system consists of a fixed supply of carbon dioxide permanently connected to a system of fixed piping with nozzles arranged to discharge directly into the fire.

3-1.2 Uses. Local application systems may be used for the extinguishment of surface fires in flammable liquids, gases, and shallow solids where the hazard is not enclosed or where the enclosure does not conform to the requirements for total flooding.

3-1.2.1 Examples of hazards that may be successfully protected by local application systems include dip tanks, quench tanks, spray booths, oil-filled electric transformers, vapor vents, etc.

3-1.3 General Requirements. Local application systems shall be designed, installed, tested and maintained in accordance with the applicable requirements in previous chapters and with the additional requirements set forth in this chapter.

3-2 Hazard Specifications.

3-2.1 Extent of Hazard. The hazard shall be so isolated from other hazards or combustibles that fire will not spread outside the protected area. The entire hazard shall be protected. The hazard shall include all areas that are or may become coated by combustible liquids or shallow solid coatings such as areas subject to spillage, leakage, dripping, splashing, or condensation, and all associated materials or equipment such as freshly coated stock, drain boards, hoods, ducts, etc., that might extend fire outside or lead fire into the protected area.

3-2.1.1 A series of interexposed hazards may be subdivided into smaller groups or sections with the approval of the authority having jurisdiction. Systems for such hazards shall be designed to give immediate independent protection to adjacent groups or sections as needed.

3-2.2 Location of Hazard. The hazard may be indoors, partly sheltered or completely out of doors. It is essential that the carbon dioxide discharge shall be such that winds or strong air currents do not impair the protection.

3-3 Carbon Dioxide Requirements.

3-3.1* General. The quantity of carbon dioxide required for local application systems shall be based on the total rate of discharge needed to blanket the area or volume protected and the time that the discharge must be maintained to assure complete extinguishment.

3-3.1.1* For systems with high pressure storage, the computed quantity of carbon dioxide shall be increased by 40 percent to determine nominal cylinder storage capacity since only the liquid portion of the discharge is effective. This increase in cylinder storage capacity is not required for the total flooding portion of combined local application-total flooding systems.

3-3.1.2* Where long pipelines are involved or where the piping may be exposed to higher than normal temperatures, the quantity shall be increased by an amount sufficient to compensate for liquid vaporized in cooling the piping.

3-3.2 Rate of Discharge. Nozzle discharge rates shall be determined by either the surface method or the volume method as covered in Sections 3-4 and 3-5.

3-3.2.1 The total rate of discharge for the system shall be the sum of the individual rates of all the nozzles or discharge devices used on the system.

3-3.2.2 For low pressure systems, if a part of the hazard is to be protected by total flooding, the discharge rate for the total flooding part shall be sufficient to develop the required concentration in not more than the discharge time used for the local application part of the system.

3-3.2.3 For high pressure systems, if a part of the hazard is to be protected by total flooding, the discharge rate for the total flooding part shall be computed by dividing the quantity required for total flooding by the factor 1.4 and by the time of the local application discharge in minutes.

$$Q_F = \frac{W_F}{1.4\ T_L}$$

Where: Q_F = Rate of flow for the total flooding portion in lbs/min (kg/min).

W_F = Total quantity of carbon dioxide for the total flooding portion in pounds (kg).

T_L = Liquid discharge time for the local application portion in minutes.

3-3.3* Duration of Discharge. The minimum effective discharge time for computing quantity shall be 30 seconds. The minimum time shall be increased to compensate for any hazard condition that would require a longer cooling period to assure complete extinguishment.

3-3.3.1 Where there is a possibility that metal or other material may become heated above the ignition temperature of the fuel, the effective discharge time shall be increased to allow adequate cooling time.

3-3.3.2* Where the fuel has an auto-ignition point, below its boiling point, such as paraffin wax and cooking oils, the effective discharge time shall be increased to permit cooling of the fuel to prevent re-ignition. The minimum discharge time shall be three minutes.

3-4 Rate by Area Method.

3-4.1 General. The area method of system design is used where the fire hazard consists primarily of flat surfaces or low level objects associated with horizontal surfaces.

3-4.1.1 System design shall be based on listing or approval data for individual nozzles. Extrapolation of such data above or below the upper or lower limits shall not be permitted.

3-4.2 Nozzle Discharge Rates. The design discharge rate through individual nozzles shall be determined on the basis of location or projection distance in accordance with specific approvals or listings.

3-4.2.1* The discharge rate for overhead type nozzles shall be determined solely on the basis of distance from the surface each nozzle protects.

3-4.2.2* The discharge rate for tankside nozzles shall be determined solely on the basis of throw or projection required to cover the surface each nozzle protects.

3-4.3 Area per Nozzle. The maximum area protected by each nozzle shall be determined on the basis of location or projection distance and the design discharge rate in accordance with specific approvals or listings.

3-4.3.1 The same factors used to determine the design discharge rate shall be used to determine the maximum area to be protected by each nozzle.

3-4.3.2 The portion of the hazard protected by individual overhead type nozzles shall be considered as a square area.

3-4.3.3 The portion of the hazard protected by individual tankside or linear nozzles may be either a rectangular or a square area in accordance with spacing and discharge limitations stated in specific approvals or listings.

3-4.3.4 When coated rollers or other similar irregular shapes are to be protected, the projected wetted area may be used to determine nozzle coverage.

3-4.3.5 Where coated surfaces are to be protected, the area per nozzle may be increased by 40 percent over the areas given in specific approvals or listings. Coated surfaces are defined as those designed for drainage which are constructed and maintained so that no pools of liquid will accumulate over a total area exceeding 10 percent of the protected surface. This subsection does not apply where there is a heavy buildup of residue. (*See 3-1.2.*)

3-4.3.6 Where local application nozzles are used for protection across openings as defined in 2-2.1.3 and 2-2.1.4, the area per nozzle given by specific approval or listing may be increased 20 percent.

3-4.3.7 When deep layer flammable liquid fires are to be protected, a minimum freeboard of six inches (152mm) shall be provided unless otherwise noted in approvals or listings of nozzles.

3-4.4 Location and Number of Nozzles. A sufficient number of nozzles shall be used to adequately cover the entire hazard area on the basis of the unit areas protected by each nozzle.

3-4.4.1 Tankside or linear type nozzles shall be located in accordance with spacing and discharge rate limitations stated in specific approvals or listings.

3-4.4.2 Overhead type nozzles shall be installed perpendicular to the hazard and centered over the area protected by the nozzle. They may also be installed at angles between 45 and 90 degrees from the plane of the hazard surface as prescribed in 3-4.4.3. The height used in determining the necessary flow rate and area coverage shall be the distance from the aiming point on the protected surface to the face of the nozzle measured along the axis of the nozzle.

3-4.4.3 When installed at an angle, nozzles shall be aimed at a point measured from the near side of the area protected by the nozzle, the location of which is calculated by multiplying the fractional aiming factor in Table 3-4.4.3 by the width of the area protected by the nozzle.

Table 3-4.4.3 Aiming Factors for Angular Placement of Nozzles, Based on 6-inch (152mm) Freeboard.

Discharge Angle[1]	Aiming Factor[2]
45–60°	¼
60–75	¼–⅜
75–90	⅜–½
90 (perpendicular)	½ (center)

[1]Degrees from plane of hazard surface.

[2]Fractional amount of nozzle coverage area.

3-4.4.4 Nozzles shall be located so as to be free of possible obstructions that could interfere with the proper projection of the discharged carbon dioxide.

3-4.4.5 Nozzles shall be located so as to develop an extinguishing atmosphere over coated stock extending above a protected surface. Additional nozzles may be required for this specific purpose particularly if stock extends more than two feet (0.6m) above a protected surface.

3-4.4.6 The possible effects of air currents, winds and forced drafts shall be compensated for by properly locating nozzles or by providing additional nozzles to adequately protect the outside areas of the hazard.

3-5 Rate by Volume Method.

3-5.1 General. The volume method of system design is used where the fire hazard consists of three-dimensional irregular objects that cannot be easily reduced to equivalent surface areas.

3-5.2 Assumed Enclosure. The total discharge rate of the system shall be based on the volume of an assumed enclosure entirely surrounding the hazard.

3-5.2.1 The assumed enclosure shall be based on an actual closed floor unless special provisions are made to take care of bottom conditions.

3-5.2.2 The assumed walls and ceiling of this enclosure shall be at least two feet (0.6m) from the main hazard unless actual walls are involved and shall enclose all areas of possible leakage, splashing or spillage.

3-5.2.3 No deductions shall be made for solid objects within this volume.

3-5.2.4 A minimum dimension of four feet (1.2m) shall be used in calculating the volume of the assumed enclosure.

3-5.2.5 If the hazard may be subjected to winds or forced drafts, the assumed volume shall be increased to compensate for losses on the windward sides.

3-5.3 **System Discharge Rate.** The total discharge rate for the basic system shall be equal to 1 lb/min/cu ft (16kg/min/m^3) of assumed volume.

3-5.3.1 If the assumed enclosure has a closed floor and is partly defined by permanent continuous walls extending at least two feet (0.6m) above the hazard (where the walls are not normally a part of the hazard), the discharge rate may be proportionately reduced to not less than 0.25 lbs/min/cu ft (4kg/min/m^3) for actual walls completely surrounding the enclosure.

3-5.4 **Location and Number of Nozzles.** A sufficient number of nozzles shall be used to adequately cover the entire hazard volume on the basis of the system discharge rate as determined by the assumed volume.

3-5.4.1 Nozzles shall be located and directed so as to retain the discharged carbon dioxide in the hazard volume by suitable cooperation between nozzles and objects in the hazard volume.

3-5.4.2 Nozzles shall be located so as to compensate for any possible effects of air currents, winds or forced drafts.

3-5.4.3 The design discharge rates through individual nozzles shall be determined on the basis of location or projection distance in accordance with specific approvals or listings for surface fires.

3-5.4.4 Special purpose nozzles may have discharge rates based on other factors.

3-6 Distribution System.

3-6.1 **General.** The system shall be designed to provide an effective discharge of carbon dioxide promptly before excessive amounts of heat can be absorbed by materials within the hazard.

3-6.1.1 The carbon dioxide supply shall be located as near to the hazard as practicable and yet not exposed to the fire, and the pipe line shall be as direct as practicable with a minimum number of turns in order to get carbon dioxide to the fire promptly.

3-6.1.2 The system shall be designed for automatic operation except where the authorities having jurisdiction permit manual operation.

3-6.2 Piping Systems. Piping shall be designed in accordance with 1-10.6 to deliver the required rate of application at each nozzle.

3-6.2.1* High pressure storage temperatures may range from 32°F to 120°F (0°C to 67°C) without requiring special methods of compensating for changing flow rates.

3-6.3 Discharge Nozzles. The nozzles used shall be listed or approved for rate of discharge, effective range, and pattern or area coverage.

3-6.3.1 The equivalent orifice size used in each nozzle shall be determined in accordance with 1-10.6 to match the design discharge rate.

3-6.3.2 Nozzles shall be accurately located and directed in accordance with the system design requirements as covered in Sections 3-4 and 3-5.

Chapter 4 Hand Hose Line Systems

4-1 General Information.

4-1.1 Description. Hand hose line systems consist of a hose reel or rack, hose, and discharge nozzle assembly connected by fixed piping to a supply of carbon dioxide. A separate carbon dioxide supply can be provided for hand hose line use or carbon dioxide can be piped from a central storage unit which may be supplying several hose lines or fixed manual or automatic systems. (*See 1-9.1.1.*)

4-1.2 Uses. Hand hose line systems may be used to supplement fixed fire protection systems or to supplement first aid fire extinguishers for the protection of specific hazards for which carbon dioxide is a suitable extinguishing agent. These systems shall not be used as a substitute for other fixed carbon dioxide fire extinguishing systems equipped with fixed nozzles, except where the hazard cannot adequately or economically be provided with fixed protection. The decision as to whether hose lines are applicable to the particular hazard shall rest upon the authority having jurisdiction.

4-1.3 General Requirements. Hand hose line systems shall be installed and maintained in accordance with the applicable requirements of Chapters 1, 2, and 3, except as outlined below.

4-2 Hazard Specifications.

4-2.1 Hand hose line systems may be used to combat fires in all hazards covered under Chapter 1, except those which are inaccessible and beyond the scope of manual fire fighting.

4-3 Location and Spacing.

4-3.1 Location. Hand hose line stations shall be placed such that they are easily accessible and within reach of the most distant hazard which they are expected to protect. In general, they shall not be located such that they are exposed to the hazard.

4-3.2 Spacing. If multiple hose stations are used, they shall be spaced so that any area within the hazard may be covered by one or more hose lines.

4-4 Carbon Dioxide Requirements.

4-4.1 Rate and Duration of Discharge. The rate and duration of discharge and consequently the amount of carbon dioxide shall be determined by the type and potential size of the hazard. A hand hose line shall have a sufficient quantity of carbon dioxide to permit its use for at least one minute.

4-4.2 Provision for Use by Inexperienced Personnel. The possibility of these hose lines being used by inexperienced personnel shall be considered and adequate provision made so that there will be a sufficient supply of carbon dioxide to enable them to effect extinguishment of the hazards that they are likely to encounter.

4-4.3 Simultaneous Use of Hose Lines. Where simultaneous use of two or more hose lines is possible, a sufficient quantity of carbon dioxide shall be available to supply the maximum number of nozzles that are likely to be used at any one time for at least one minute.

4-5 Equipment Specifications.

4-5.1 Hose. Hose lines on systems with high pressure supply shall have a minimum bursting pressure of 5000 psi (344.8 bars) and hose lines of systems with low pressure supply shall have a minimum bursting pressure of 1800 psi (124.1 bars).

4-5.2 Discharge Nozzle Assembly. Hose lines shall be equipped with a discharge nozzle assembly which can be easily handled by one man and which contains a quick opening shutoff valve to control the flow of carbon dioxide through the nozzle and a suitable handle for directing the discharge. The attachment of the discharge nozzle assembly to the hose by means of a swivel connection is desirable for providing more ease of manipulation.

4-5.3 Hose Line Storage. The hose shall be coiled on a hose reel or rack such that it will be ready for immediate use without the necessity of coupling and such that it may be uncoiled with a minimum of delay. If installed outdoors, it shall be protected against the weather.

4-5.4 Charging the Hose Line. Operation of hand hose line systems depends upon manual actuation and manual manipulation of a discharge nozzle. Speed and simplicity of operation is, therefore, essential for successful extinguishment.

4-5.4.1 All controls for actuating the system shall be located in the immediate vicinity of the hose reel.

4-5.4.2 The carbon dioxide supply shall be located as close to the hose reel as possible so that liquid carbon dioxide will be supplied to the hose line with a minimum of delay after actuation.

4-5.4.3 Except when in actual use, pressure shall not be permitted to remain in the hose line.

4-6 Training. Successful extinguishment of fire with hand hose lines is greatly dependent upon the individual ability and technique of the operator. All personnel who are likely to use this equipment at the time of a fire shall be properly trained in its operation and in the fire fighting techniques applicable to this equipment.

Chapter 5 Standpipe Systems and Mobile Supply

5-1 General Information.

5-1.1 Description. A standpipe system is a fixed total flooding, local application, or hand hose line system without a permanently connected carbon dioxide supply. The carbon dioxide supply is mounted on a mobile vehicle which can be towed or driven to the scene of a fire and quickly coupled to the standpipe system protecting the involved hazard. Mobile supply is primarily fire brigade or fire department equipment requiring trained personnel for effective use.

5-1.2 Uses. Standpipe systems and mobile supply may be used to supplement complete fixed fire protection systems or may be used alone for the protection of the specific hazards outlined below. Mobile supply may be used as a reserve to supplement a fixed supply. Mobile supply may also be outfitted with hand hose lines for the protection of scattered hazards. These systems shall be installed only with the approval of the authority having jurisdiction.

5-1.3 General Requirements. Standpipe systems and mobile supply shall be installed and maintained in accordance with the requirements in Chapters 1, 2, 3 and 4, in addition to those outlined below. Piping shall be installed in accordance with the requirements applicable for the system if a permanently connected supply were used. Appreciable lengths of piping on the portable supply shall be taken into account.

5-2 Hazard Specifications.

5-2.1 Standpipe systems and mobile supply may be used to protect hazards included in Chapters 1, 2, 3 and 4, where extinguishment will not be adversely affected by the delay in obtaining effective discharge of carbon dioxide while the mobile supply is being brought to the scene and coupled to the standpipe system.

5-3 Standpipe Requirements.

5-3.1 The supply piping of standpipe systems shall be equipped with quick-change couplings and shall terminate in an easily accessible and well-marked location for connection to the mobile supply. This location shall also be marked with the amount of carbon dioxide required and the required duration of discharge.

5-4 Mobile Supply Requirements.

5-4.1 Capacity. The mobile supply shall have a capacity in accordance with the provisions of Chapters 1, 2, 3 and 4. Extra quantities may be required to compensate for delay in getting mobile supply to the hazard.

5-4.2 Coupling. The mobile supply shall be provided with suitable means for transferring carbon dioxide into the standpipe system. Quick-change couplings shall be provided to permit these connections to be made as rapidly as possible.

5-4.3 Mobility. The storage container or containers of carbon dioxide shall be mounted on a movable vehicle which may be brought to the scene of the fire by manual means, by a separate motor vehicle, or under its own power. The means of transporting the mobile supply shall be dependable and capable of getting to the fire with a minimum of delay.

5-4.4 Location. The mobile supply shall be kept close at hand to the hazards it is intended to protect in order that fire extinguishment may be started as soon as possible after the fire breaks out.

5-4.5 Accessories. Mobile supply for standpipe systems may be provided with hand hose lines as accessory equipment for the protection of small scattered hazards, or as a supplement to standpipe systems or other fixed protection.

5-5 Training. The effectiveness of fire protection provided by standpipe systems and mobile supply depends upon the efficiency and ability of the manpower which handles the mobile supply. It is therefore imperative that those persons assigned to the units shall be properly trained in its use and maintenance. Generally, this equipment is in the category of fire brigade or fire department equipment requiring a regularly assigned crew.

Appendix A Explanatory

The following notes bearing the same number as the text of the *Standard on Carbon Dioxide Extinguishing Systems* to which they apply contain useful explanatory material and references to standards.

(*This Appendix is not a part of this NFPA Standard for Carbon Dioxide Extinguishing Systems but is included for information purposes only.*)

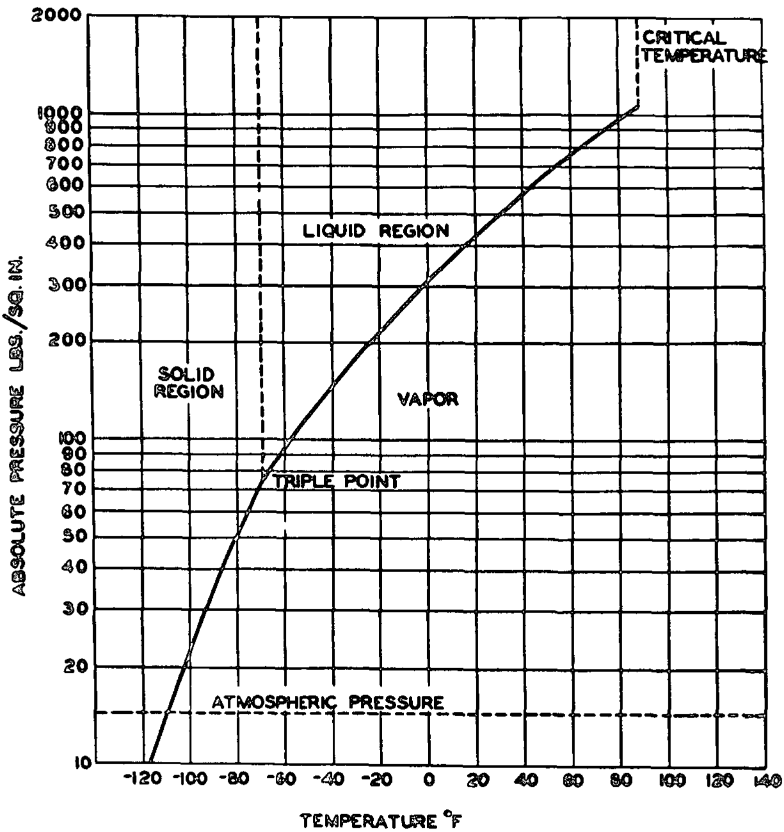
A-1-5.2 Carbon Dioxide. Carbon dioxide is a standard commercial product with many uses. It is perhaps most familiar as the gas that gives the "tingle" in soda pop and other carbonated beverages. In other industrial applications it may be used for its chemical properties, for its mechanical properties as a pressurizing agent, or for its refrigerating properties as dry ice.

For fire extinguishing applications carbon dioxide has a number of desirable properties. It is noncorrosive, nondamaging and leaves no residue to clean up after the fire. It provides its own pressure for discharge through pipes and nozzles. Since it is a gas, it will penetrate and spread to all parts of a hazard. It will not conduct electricity and can therefore be used on live electrical hazards. It can be effectively used on practically all combustible materials except for a few active metals and metal hydrides and materials such as cellulose nitrate, which contain available oxygen.

Under normal conditions carbon dioxide is an odorless, colorless gas with a density about 50 percent greater than the density of air. Many insist they can detect an odor of carbon dioxide, but this may be due to impurities or chemical effects in the nostrils. Carbon dioxide is easily liquefied by compression and cooling. By further cooling and expansion it can be converted to the solid state.

The relationship between the temperature and the pressure of liquid carbon dioxide is shown on the curve given in Figure A-1-5.2. It will be noted that as the temperature of the liquid increases, the pressure also increases. As the pressure increases, the density of the vapor over the liquid increases. On the other hand, the liquid expands as the temperature goes up and its density decreases. At 87.8°F. (31°C) the liquid and vapor have the same density, and of course the liquid phase disappears. This is called the critical temperature for carbon dioxide.

An unusual property of carbon dioxide is the fact that it cannot exist as a liquid at pressures below 60 psi gage (75 psi absolute [5.2 bars]). This is the triple point pressure where carbon dioxide may be present as a solid, liquid or vapor. Below this pressure it must be either a solid or gas, depending on the temperature.



For SI Units
1psi = 0.0689 bars
°C = 5/9 (°F-32)

Figure A-1-5.2. Variation of pressure of carbon dioxide with change in temperature (constant volume). Below the critical temperature (87.8°F [31°C]), carbon dioxide in a closed container is part liquid and part gas. Above the critical temperature it is entirely gas.

If the pressure in a storage container is reduced by bleeding off vapor, some of the liquid will vaporize and the remaining liquid will become colder. At 60 psi (75 psi absolute [5.2 bars]) the remaining liquid will be converted to dry ice at a temperature of −69°F (−56°C). Further reduction in the pressure to atmospheric will lower the temperature of the dry ice to the normal −110°F (−79°C).

The same process takes place when discharging liquid carbon dioxide to the atmosphere. A large portion of the liquid flashes to vapor with a considerable increase in volume. The rest is converted to finely divided particles of dry ice at −110°F (−79°C). It is this dry ice or snow that gives the discharge its typical white cloudy appearance. The low temperature also causes the condensation of water from the entrained air so that ordinary water fog tends to persist for a while after the dry ice has evaporated.

A-1-5.3.4. While carbon dioxide will not extinguish these fires, it will not react dangerously with these materials or increase their burning rate. Carbon dioxide, if used in this type of situation in a total flooding system, will provide protection for adjacent combustibles or can be successfully used if the reactive metals or hydride are first covered by another material. Examples of this later condition would be:

(a) Sodium stored or used under kerosene.

(b) Cellulose nitrate in solution of lacquer thinner.

(c) Magnesium chips covered with heavy oil.

Local application systems with attendant high velocity directed discharge should not be used.

A-1-6.1 Hazards to Personnel. Although carbon dioxide is only mildly toxic, it will definitely produce unconsciousness and death when present in fire extinguishing concentrations. The action in this case is more related to suffocation than it is to any toxic effect of the carbon dioxide itself.

Carbon dioxide is naturally present in the exhaled breath of all animal life. By holding the breath as long as possible it has been found that concentrations in the order of 6 percent carbon dioxide by volume are easily attained. As a matter of fact, it is the increasing concentration of carbon dioxide in the body that activates the automatic impulse to breathe. For this reason carbon dioxide is frequently administered with oxygen for resuscitation purposes.

It has been determined by test that atmospheres containing 3 or 4 percent carbon dioxide will cause one to breathe rapidly but will otherwise have no important effect for relatively short exposures. A concentration of about 9 percent is about all most people can withstand without losing consciousness within a few minutes.

At carbon dioxide concentrations above 9 percent personnel would quickly lose consciousness. At concentrations of about 20 percent death would follow in about 20 to 30 minutes unless the victim was removed to a source of fresh air. Recovery with artificial respiration is usually rapid because of the natural tendency of carbon monoxide to promote breathing.

Aside from the normal effect of carbon dioxide causing unconsciousness, it should be noted that even before this happens there may be a marked inability to think clearly and take prompt action. This effect is important because inexperienced personnel may fail to take proper action if suddenly exposed to relatively high concentrations of carbon dioxide.

In most cases the actual hazard to personnel is rather small. The hazard will be greater where the enclosure is large and where carbon dioxide may enter unsuspected areas such as pits or basements. The difficulty of escaping from a given location, and the possibility of reduced visibility because of a discharge of carbon dioxide may also be important factors. In any case, the extent and type of warning to personnel should be designed to meet the particular requirements of each situation.

A-1-6.2 Safety Requirements. The steps and safeguards necessary to prevent injury or death to personnel in areas whose atmospheres will be made hazardous by the discharge of carbon dioxide may include the following:

(a) Provision of adequate aisleways and routes of exit and keeping them clear at all times.

(b) Provision of the necessary additional or emergency lighting, or both, and directional signs to insure quick, safe evacuation.

(c) Provision of alarms within such areas that will operate immediately upon activation of the system on detection of the fire, with the discharge of the carbon dioxide and the activation of automatic door closures delayed for sufficient time to evacuate the area before discharge begins.

(d) Provision of only outward swinging self-closing doors at exits from hazardous areas, and where such doors are latched provision of panic hardware.

(e) Provision of continuous alarms at entrances to such areas until atmosphere has been restored to normal.

(f) Provision for adding an odor to the carbon dioxide so that hazardous atmospheres in such areas may be recognized.

(g) Provision of warning and instruction signs at entrances to and inside such areas.

(h) Provision for prompt discovery and rescue of persons rendered unconscious in such areas. This may be accomplished by having such areas searched immediately after carbon dioxide discharge stops by trained men equipped with proper breathing equipment. Those rendered unconscious by carbon dioxide can be restored without permanent injury, by artificial respiration, if removed quickly from the hazardous atmosphere. Self-contained breathing equipment and personnel trained in its use, and in rescue practices, including artificial respiration, should be readily available.

(i) Provision of instruction and drills of all personnel within or in the vicinity of such areas, including maintenance or construction people who may be brought into the area, to insure their correct action when carbon dioxide protective equipment operates.

(j) Provision of means for prompt ventilation of such areas. Forced ventilation will often be necessary. Care should be taken to really dissipate hazardous atmospheres and not merely move them to another location. Carbon dioxide is heavier than air.

(k) Provision of such other steps and safeguards that a careful study of each particular situation indicates are necessary to prevent injury or death.

A-1-7.1. To insure a satisfactory system, the following items should be included in the specifications.

(a) The specifications should designate the authority having jurisdiction and indicate whether plans are required.

(b) The specifications should state that the installation shall conform to this standard and meet the approval of the authority having jurisdiction.

(c) The specifications should include the specific tests that may be required to meet the approval of the authority having jurisdiction, and indicate how cost of testing is to be borne.

(d) These specifications should require the provision of equipment listed for the use intended.

A-1-7.3. Where piping is not normally under pressure it may not be bubble tight. However, where a slow discharge is involved, or if under continual pressure, bubble tightness should be a requirement.

A-1-8.2.2. For additional information on detectors refer to NFPA 72E, *Standard for Automatic Fire Detectors.* (*See Appendix C.*)

A-1-9.2. Carbon Dioxide Quality. Carbon dioxide, as normally manufactured, is an extremely pure product. In general, the industry produces only one grade or quality. This grade is considered suitable for all applications, including food and medical uses.

Dry carbon dioxide gas or liquid is completely noncorrosive to the containers. Carbon dioxide containing excess water may cause some corrosion in high pressure cylinders, particularly in the light-weight cylinders that are highly stressed. Excess water is present when the amount exceeds the normal solubility in liquid carbon dioxide so that actual water may condense out on the walls of the container.

Carbon dioxide produced in modern low pressure plants must necessarily have a very low water content to avoid operating difficulties. The normal practice is to maintain the water content below about 0.01 percent by weight. If this dry product is stored and transported in clean bulk low pressure equipment, the quality will be maintained until it is used.

Dry ice normally contains more water and oil than does liquid carbon dioxide. It also tends to freeze moisture and other impurities from the atmosphere, because of its very low temperature of −110°F (−79°C). When dry ice is placed in a converter and allowed to warm up so that it becomes liquid carbon dioxide, the liquid so produced will obviously contain an excess amount of water. This liquid should not be used to charge fire extinguishing cylinders, unless it is further processed through a dehydrating unit to remove the excess water. It should also be noted that such dehydrating units may become ineffective unless the drying agent is renewed or reactivated as necessary to maintain its drying ability.

There are still a few high pressure carbon dioxide production plants in service. The carbon dioxide produced in these plans may also contain excess water, unless the dehydrating equipment is kept in good condition. The only positive way to be assured of proper quality is to periodically analyze the carbon dioxide supply used for charging fire protection systems.

A-1-9.5. High Pressure Storage Containers. In high pressure storage systems the temperature of the contained carbon dioxide will depend on the ambient temperature at the storage location. The containers must therefore be capable of withstanding the pressures developed at the highest expected temperature.

The maximum pressure in the cylinder is also affected by the filling density or percent filling. This is the ratio expressed in percent of the carbon dioxide weight to the water capacity in pounds. The filling density commonly used is between 60 and 68 percent, the latter being the maximum allowed by the U.S. Department of Transportation.[1] Proper filling is determined by weight stamped on the valve body.

[1]Sec. 173.308 of Title 49, Transportation, Code of Federal Regulations. Parts 171–190 (DOT). Available from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20401.

cated by the Manufacturer's data, usually shown in the listing information for a particular system. Other areas of concern are resistance to the effects of vibration, flexure, tension, torsion, temperature, flame, compression, and bending. It is also necessary for the hose to have the strength to contain the carbon dioxide during discharge, and be made of materials that will be resistant to atmospheric corrosion.

A-1-10.1.4. In the case of steel pipe, standard weight (Schedule 40) may be used in sizes up through ¾ inch IPS and extra heavy (Schedule 80) should be used in sizes over ¾ inch IPS. Standard malleable iron banded fittings or ductile iron fittings may be used up through ¾ inch IPS. Extra heavy malleable iron or ductile iron fittings should be used through 2 inch IPS; and forged steel fittings in all larger sizes.

A-1-10.1.5. In the case of steel piping; it is recommended that for piping under continuous pressure extra heavy pipe be used with forged steel fittings. Piping between the master valve and selector valves should be extra heavy using 300-pound malleable iron or ductile iron screwed fittings or standard weight pipe with welded connections using standard weight welded fittings. On open end pipe, screwed connections may be used with standard weight pipe and 300-pound malleable iron or ductile iron fittings.

A-1-10.2.1 A dirt trap consisting of a tee with a capped nipple, at least two inches (51mm) long, should be installed at the end of each pipe run.

A-1-10.5. Pipe and Orifice Size Determination. The problem of computing pipe sizes for carbon dioxide systems is complicated by the fact that the pressure drop is nonlinear with respect to the pipeline. Carbon dioxide leaves the storage vessel as a liquid at saturation pressure. As the pressure drops because of pipeline friction, the liquid boils so as to produce a mixture of liquid and vapor. Because of this the volume of the flowing mixture increases and the velocity of flow must also increase. Thus, the pressure drop per unit length of pipe is greater near the end of the pipeline than it is at the beginning.

Pressure drop information for designing piping systems can be best obtained from curves of pressure versus equivalent length for various flow rates and pipe sizes. Such curves can be plotted using the theoretical equation given in 1-10.5.1. The Y and Z factors in the equation depend on storage pressure and line pressure. These can be evaluated from the following equations:

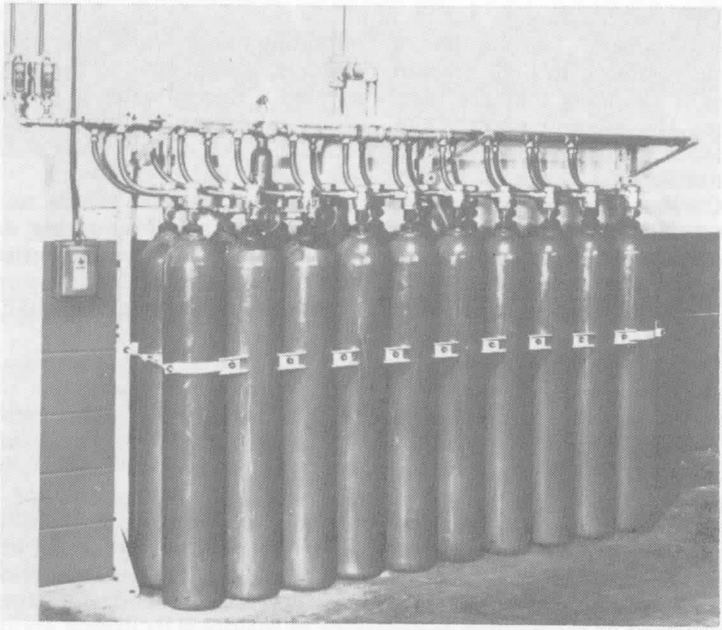


Figure A-1-9.5. A typical high pressure storage facility.

A typical high pressure storage facility using a number of cylinders is shown on Figure A-1-9.5. Flexible connectors are used between each cylinder and the common manifold. This is to facilitate the problem of check weighing cylinders and replacing cylinders after use. Each cylinder is provided with its own valve with a dip tube extending to the bottom. Some older types of cylinders do not have dip tubes and are installed upside down to insure discharge of liquid carbon dioxide.

A-1-9.6. Low Pressure Storage Containers. In low pressure storage systems the temperature of the contained carbon dioxide is controlled at about 0°F (−18°C) by means of insulation and refrigeration. The normal pressure is thus maintained at about 300 psi (20.7 bars). Welded pressure vessels are used for this service, and there is no special limitation so far as size is concerned.

The filling density will have no effect on the pressure so long as there is sufficient vapor space to allow for expansion of the liquid at the maximum storage temperature and pressure. This would be determined by the setting of the pressure relief valves. In general, the filling density may range from 90 to 95 percent. The maximum

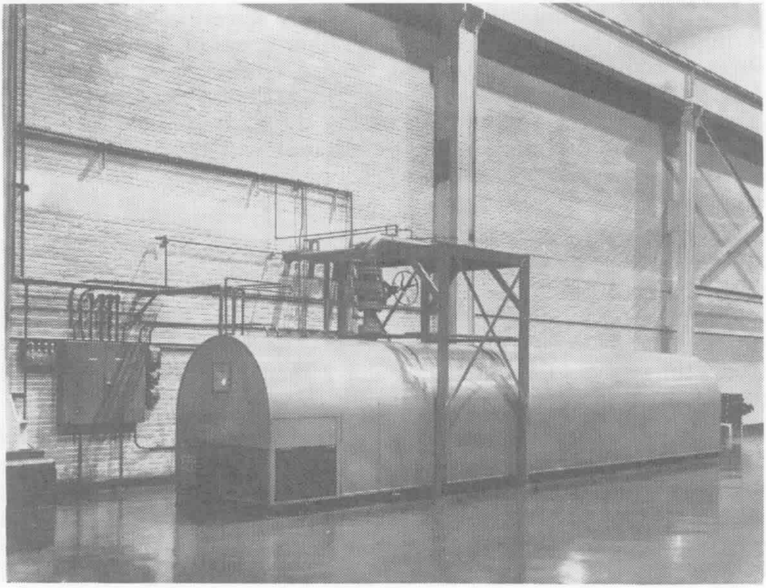


Figure A-1-9.6. A typical low pressure storage facility.

liquid level is controlled, when filling, by means of a short dip tube which returns excess liquid to the delivery unit when the liquid reaches the maximum filling level in the storage unit. A liquid level gauge is also provided to indicate the quantity of carbon dioxide in storage.

A typical low pressure storage facility is shown on Figure A-1-9.6. In this unit the insulated pressure vessel is covered with an outer metal housing which is sealed to keep out water moisture. A standard air cooled refrigeration unit is mounted at one end with its cooling coils mounted within the pressure vessel. This unit is electrically powered and automatically controlled by means of a pressure switch.

A-1-9.6.2. A special relief valve (in addition to code requirements) may be provided for controlled bleed-off at a pressure below the setting of the main safety valve.

A-1-10.1.2 The use of flexible piping or hoses in a carbon dioxide system introduces a number of things to be considered that do not affect rigid piping. One of these is the nature of any changes of direction. The minimum radius of curvature for any flexible hose to be used in a carbon dioxide system should not be less than indi-

$$Y = -\int_{P_1}^{P} \rho dP$$

$$Z = -\int_{\rho_1}^{\rho} \frac{d\rho}{\rho} = \ln \frac{\rho_1}{\rho}$$

Where P_1 = Storage pressure in psia
P = Pressure at end of pipeline in psia
ρ_1 = Density at pressure P_1 in lbs/cubic foot
ρ = Density at pressure P in lbs/cubic foot
ln = Natural logarithm

The storage pressure is an important factor in carbon dioxide flow. In low pressure storage the starting pressure in the storage vessel will recede to a lower level depending on whether all or only a part of the supply is discharged. Because of this, the average pressure during discharge will be about 285 psi (19.7 bars). The flow equation is based on absolute pressure; therefore, 300 psia (20.7 bars) is used for calculations involving low pressure systems.

In high pressure systems the storage pressure depends on the ambient temperature. Normal ambient temperature is assumed to be 70°F (21°C). For this condition the average pressure in the cylinder during discharge of the liquid portion will be about 750 psia (51.7 bars). This pressure has therefore been selected for calculations involving high pressure systems.

Using the above base pressures of 300 psia (20.7 bars) and 750 psia (51.7 bars) values have been determined for the Y and Z factors in the flow equation. These are listed in Tables A-1-10.5(a) and A-1-10.5(b).

For practical application it is desirable to plot curves for each pipe size that may be used. However, it will be noted that the flow equation can be rearranged as given below.

$$\frac{L}{D^{1.25}} = \frac{3647\ Y}{(Q/D^2)^2} - 8.08\ Z$$

Thus by plotting values of $L/D^{1.25}$ and Q/D^2, it is possible to use one family of curves for any pipe size. Figure A-1-10.5(A) gives flow information for 0°F (−18°C) storage temperature on this basis. Figure A-1-10.5(B) gives similar information for high pressure storage at 70°F (21°C). For an inside pipe diameter of exactly one inch, D^2 and $D^{1.25}$ reduce to unity and cancel out. For other pipe sizes it is necessary to convert the flow rate and equivalent length by dividing or multiplying by these factors. Table A-1-10.5(a) gives values for D.

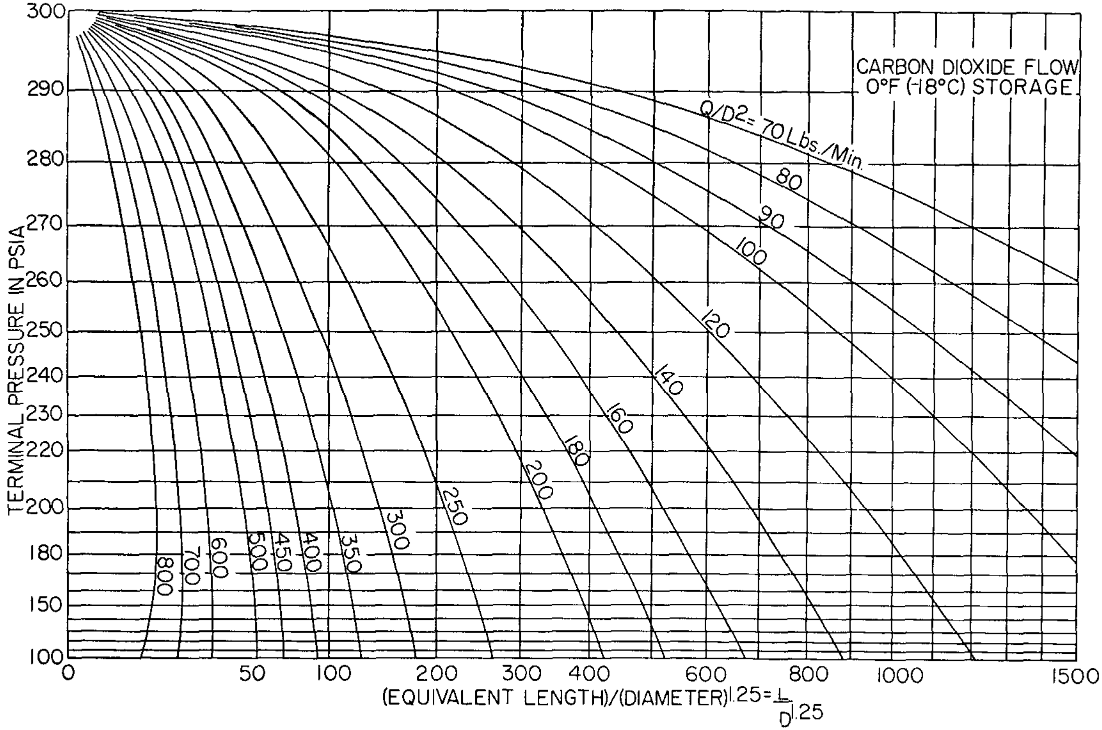


Figure A-1-10.5(A). Pressure drop in pipeline for 300 psia (20.7 bars) storage pressure.

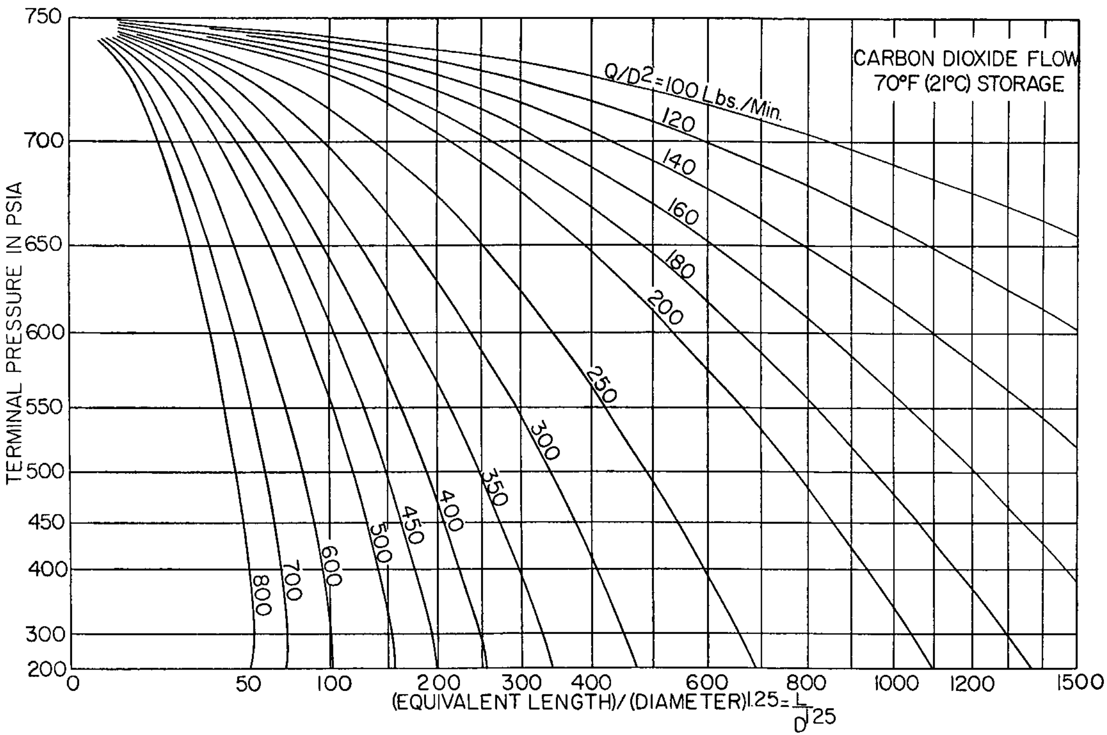


Figure A-1-10.5(B). Pressure drop in pipeline for 750 psia (51.7 bars) storage pressure.

Table A-1-10.5(a) Values of Y and Z for 300 psia (20.7 bars) Storage.

PSIA	Y	Z
300	0	0
290	603	0.12
280	1138	0.24
270	1613	0.36
260	2033	0.48
250	2406	0.60
225	3163	0.90
200	3723	1.20
175	4137	1.50
150	4443	1.80
125	4670	2.11
100	4837	2.41

Table A-1-10.5(b) Values of Y and Z for 750 psia (51.7 bars) Storage.

PSIA	Y	Z
750	0	0
725	1200	.0825
700	2300	.165
675	3320	.249
650	4280	.333
625	5130	.417
600	5960	.501
575	6710	.585
550	7370	.672
525	7980	.760
500	8530	.849
475	9060	.939
450	9530	1.033
425	9970	1.132
400	10400	1.237
375	10740	1.350
350	11020	1.479
325	11410	1.629
300	11560	1.844
250	11950	2.164
200	12150	2.623

Table A-1-10.5(c) Values of $D^{1.25}$ and D^2 for Various Pipe Sizes.

	I.D. Inches	$D^{1.25}$	D^2
½ Std.	.622	.5521	.3869
¾ Std.	.824	.785	.679
1 Std.	1.049	1.0615	1.100
1 XH	.957	.9465	.9158
1¼ Std.	1.380	1.496	1.904
1¼ XH	1.278	1.359	1.633
1½ Std.	1.610	1.813	2.592
1½ XH	1.500	1.660	2.250
2 Std.	2.067	2.475	4.272
2 XH	1.939	2.288	3.760
2½ Std.	2.469	3.09	6.096
2½ XH	2.323	2.865	5.396
3 Std.	3.068	4.06	9.413
3 XH	2.900	3.79	8.410
4 Std.	4.026	5.71	16.21
4 XH	3.826	5.34	14.64
5 Std.	5.047	7.54	25.47
5 XH	4.813	7.14	23.16
6 Std.	6.065	9.50	36.78
6 XH	5.761	8.92	33.19

These curves can be used for designing systems or for checking possible flow rates. For example, assume the problem is to determine the terminal pressure for a low pressure system consisting of a single 2-inch Schedule 40 pipeline with an equivalent length of 500 feet and a flow rate of 1,000 pounds per minute. The flow rate and the equivalent length must be converted to terms of Figure A-1-10.5(A) as follows:

$$\frac{Q}{D^2} = \frac{1000}{4.28} = 234 \text{ lbs/min}/D^2$$

$$\frac{L}{D^{1.25}} = \frac{500}{2.48} = 201 \text{ ft}/D^{1.25}$$

From Figure A-1-10.5(A) the terminal pressure is found to be about 228 psia at the point where the interpolated flow rate of 234 pounds per minute intersects the equivalent length scale at 201 feet.

If this line terminates in a single nozzle, the equivalent orifice area must be matched to the terminal pressure in order to control the flow rate at the desired level of 1,000 pounds per minute. Referring to Table 1-10.4.4(b) of 1-10.5.2, it will be noted that the discharge rate will be 1,410 lbs./min./sq. in. of equivalent orifice area when the orifice pressure is 230 psia. The required equivalent orifice area of the nozzle is thus equal to the total flow rate divided by the rate per square inch.

$$\text{Equivalent Orifice Area} = \frac{1{,}000 \text{ lbs/min}}{1{,}410 \text{ lbs/min/sq in}} = 0.709 \text{ sq in}$$

From a practical viewpoint the designer would select a standard nozzle having an equivalent area nearest to the computed area. If the orifice area happened to be a little larger, the actual flow rate would be slightly higher and the terminal pressure would be somewhat lower than the estimated 228 psia.

If, in the previous example, instead of terminating with one large nozzle the pipeline branches into two smaller pipelines, it will be necessary to determine the pressure at the end of each branch line. To illustrate this procedure, assume that the branch lines are equal and consist of 1½ inch Schedule 40 pipe with equivalent lengths of 200 feet and the flow in each branch line is to be 500 pounds per minute. Converting to terms used in Figure A-1-10.5(A)

$$\frac{Q}{D^2} = \frac{500}{2.592} = 193 \text{ lbs/min}/D^2$$

$$\frac{L}{D^{1.25}} = \frac{200}{1.813} = 110 \text{ ft}/D^{1.25}$$

From Figure A-1-10.5(A) the starting pressure of 228 psia (terminal pressure of main line) intersects the flow rate line (193 lbs/min) at an equivalent length of about 300 feet. In other words if the branch line started at the storage vessel, the liquid carbon dioxide would have to flow through 300 feet of pipeline before the pressure drops to 228 psia. This length thus becomes the starting point for the equivalent length of the branch line. The terminal pressure of the branch line is then found to be 165 psia at the point where the 193 lbs/min flow rate line intersects the total equivalent length line of 410 feet (300 + 110). With this new terminal pressure (165 psia) and flow rate (500 lbs/min) the required equivalent nozzle area at the end of each branch line will be approximately 0.567 square inches. It will be noted that this is about the same as the single large nozzle example except that the discharge rate is cut in half due to the reduced pressure.

The design of the piping distribution system is based on the flow rate desired at each nozzle. This in turn determines the required flow rate in the branch lines and the main pipeline. From practical experience it is possible to estimate the approximate pipe sizes required. The pressure at each nozzle can then be determined from suitable flow curves. The nozzle orifice sizes are then selected on the basis of nozzle pressure from the data given in 1-10.5.2.

In high pressure systems the main header is supplied by a number of separate cylinders. The total flow is thus divided by the number of cylinders to obtain the flow rate from each cylinder. The flow capacity of the cylinder valve and the connector to the header will vary with each manufacturer depending on design and size. For any particular valve, dip tube and connector assembly the equivalent length can be determined in terms of feet of standard pipe size. With this information the flow equation can be used to prepare a curve of flow rate versus pressure drop. This provides a convenient method of determining header pressure for a specific valve and connector combination.

Tables A-1-10.5(d) and A-1-10.5(e) list the equivalent lengths of pipe fittings for determining the equivalent length of piping systems. Table A-1-10.5(d) is for threaded joints and Table A-1-10.5(e) is for welded joints. Both tables were computed for Schedule 40 pipe sizes; however, for all practical purposes the same figures can also be used for Schedule 80 pipe sizes.

Table A-1-10.5(d) Equivalent Length in Feet of Threaded Pipe Fittings.

Pipe Size in.	Elbow Std. 45°	Elbow Std. 90°	Elbow 90° Long Rad. & Tee Thru Flow	Tee Side	Union Coupling or Gate Valve
3/8	0.6	1.3	0.8	2.7	0.3
1/2	0.8	1.7	1.0	3.4	0.4
3/4	1.0	2.2	1.4	4.5	0.5
1	1.3	2.8	1.8	5.7	0.6
1 1/4	1.7	3.7	2.3	7.5	0.8
1 1/2	2.0	4.3	2.7	8.7	0.9
2	2.6	5.5	3.5	11.2	1.2
2 1/2	3.1	6.6	4.1	13.4	1.4
3	3.8	8.2	5.1	16.6	1.8
4	5.0	10.7	6.7	21.8	2.4
5	6.3	13.4	8.4	27.4	3.0
6	7.6	16.2	10.1	32.8	3.5

Table A-1-10.5(e) Equivalent Length in Feet of Welded Pipe Fittings.

Pipe Size in.	Elbow Std. 45°	Elbow Std. 90°	Elbow 90° Long Rad. & Tee Thru Flow	Tee Side	Gate Valve
3/8	0.2	0.7	0.5	1.6	0.3
1/2	0.3	0.8	0.7	2.1	0.4
3/4	0.4	1.1	0.9	2.8	0.5
1	0.5	1.4	1.1	3.5	0.6
1 1/4	0.7	1.8	1.5	4.6	0.8
1 1/2	0.8	2.1	1.7	5.4	0.9
2	1.0	2.8	2.2	6.9	1.2
2 1/2	1.2	3.3	2.7	8.2	1.4
3	1.5	4.1	3.3	10.2	1.8
4	2.0	5.4	4.4	13.4	2.4
5	2.5	6.7	5.5	16.8	3.0
6	3.0	8.1	6.6	20.2	3.5

For nominal changes in elevation of piping the change in head pressure is negligible. However, if there is a substantial change in elevation this factor should be taken into account. The head pressure correction per foot of elevation depends on the average line pressure where the elevation takes place since the density changes with pressure. Correction factors are given in Tables A-1-10.5(f) and A-1-10.5(g) for low pressure and high pressure systems respectively.

The correction is subtracted from the terminal pressure when the flow is upward and added to the terminal pressure when the flow is downward.

Table A-1-10.5(f) Elevation Correction Factors for Low Pressure Systems.

Average Line Pressure psia	Elevation Correction psi/ft.
300	0.443
280	0.343
260	0.265
240	0.207
220	0.167
200	0.134
180	0.107
160	0.085
140	0.067
120	0.052
100	0.039

Table A-1-10.5(g) Elevation Correction Factors for High Pressure Systems.

Average Line Pressure psia	Elevation Correction psi/ft.
750	0.352
700	0.300
650	0.255
600	0.215
550	0.177
500	0.150
450	0.125
400	0.105
350	0.085
300	0.070
250	0.055
200	0.040

A-1-11.1 Testing of Systems. Manufacturer's test and maintenance procedure should be guided by the following outline:

1. The System.
   - A. Overall physical appearance.
   - B. Check if there have been any changes in the size or type of hazard protected.
   - C. Disarm system prior to test.
2. Control Panel.
   - A. Exercise *ALL* functions.
   - B. Check supervision if applicable, of each circuit (including releasing devices) by disconnecting a wire to each for both visible/audible alarms.
3. Power Supply.
   - A. Check routing, circuit breakers, fuses, disconnects.
4. Emergency Power.
   - A. Battery condition.
   - B. Charger operation, check fuse.
   - C. Check automatic change over.
   - D. If generator, is it being properly maintained.
5. Detectors.
   - A. Test each (*ALL*) using heat or smoke or manufacturer's approved test device. (*See NFPA 72E, Automatic Fire Detectors.*)
   - B. Electric.
     1. Clean and adjust smoke detector and check sensitivity.
     2. Check wiring condition.
   - C. Pneumatic.
     1. Check tightness of tubing and operation of mercury checks using manometer.
6. Time Delay.
   - A. Exercise.
   - B. Check time limit.
   - C. Check that timer will complete its cycle even though wiring between it and the detector circuit is interrupted.

7. Alarms.
   A. Test for operation (audible and visual).

8. Selector (Directional) Valves.
   A. Exercise.
   B. Reset properly.

9. Release Devices.
   A. Dampers, check for complete closure.
   B. Doors; also check for any blocked open.

10. Equipment Shut-Down.
    A. Test.
    B. Check adequacy (all necessary equipment included).

11. Manual Releases.
    A. Mechanical.
       1. Check pull, force and length of pull required.
       2. Operate and adjust all devices.
       3. Tightness of connectors.
       4. Condition of conduit.
       5. Condition and operation of corner pulleys.
    B. Electric.
       1. Test.
       2. Covers in place.
    C. Accessibility during fire.
    D. Separate main and reserve manual pulls requiring only one operation to obtain discharge of either main or reserve supply of gas.

12. Piping.
    A. Security, adequately supported.
    B. Condition, any corrosion.

13. Nozzles.
    A. Orientation and orifice size unchanged from original design.
    B. Clean.
    C. Security.
    D. Seals where needed.

14. Containers.
   - A. Physical condition, any sign of corrosion.
   - B. Check the contents for weight by acceptable methods for each cylinder or low pressure tank. If the contents are more than 10% below the normal capacity, refilling is required.
   - C. Cylinders securely held in position.
   - D. Check hydrostatic test record.
   - E. Check cylinder connectors for integrity and condition.
   - F. Check weights and cables of mechanical release system.
   - G. Release devices, check for proper arrangement and security.
   - H. Explosive release devices, check replacement date and check condition.
15. Test.
   - A. Puff test, minimum for acceptance.
   - B. Full discharge test as required by owner.
   - C. Full discharge test recommended when hydrostatic test is required.
16. Return all parts of system to full service.
17. Certificate of Inspection to owner.

A-1-11.2 Regular service contracts with the manufacturer or installing company are recommended.

A-2-1 General Information on Total Flooding Systems.

From a performance viewpoint a total flooding system is designed to develop a carbon dioxide concentration that will extinguish fires in combustible materials located in an enclosed space. It should also maintain an effective concentration until the maximum temperature has been reduced below the reignition point.

The concentration of carbon dioxide required will depend on the type of combustible material involved. This has been accurately determined for most surface-type fires, particularly those involving liquids and gases. Most of this information has been obtained by the U. S. Bureau of Mines. For deep-seated fires the critical concentration required for extinguishment is less definite and has in general been established by practical test work.

The volume of carbon dioxide required to develop a given concentration will be greater than the final volume remaining in the enclosure. In most cases carbon dioxide should be applied in a manner that promotes progressive mixing of the atmosphere. The displaced atmosphere is exhausted freely from the enclosure through various small openings or through special vents, as carbon dioxide is injected. Some carbon dioxide is therefore lost with the vented atmosphere. This loss becomes greater at high concentrations. This method of application is called "free-efflux" flooding.

Under the above conditions the volume of carbon dioxide required to develop a given concentration in the atmosphere is expressed by the following equation:

$$e^x = \frac{100}{100 - \%\ CO_2} X = 2.303 \log 10 \frac{100}{100 - \%\ CO_2}$$

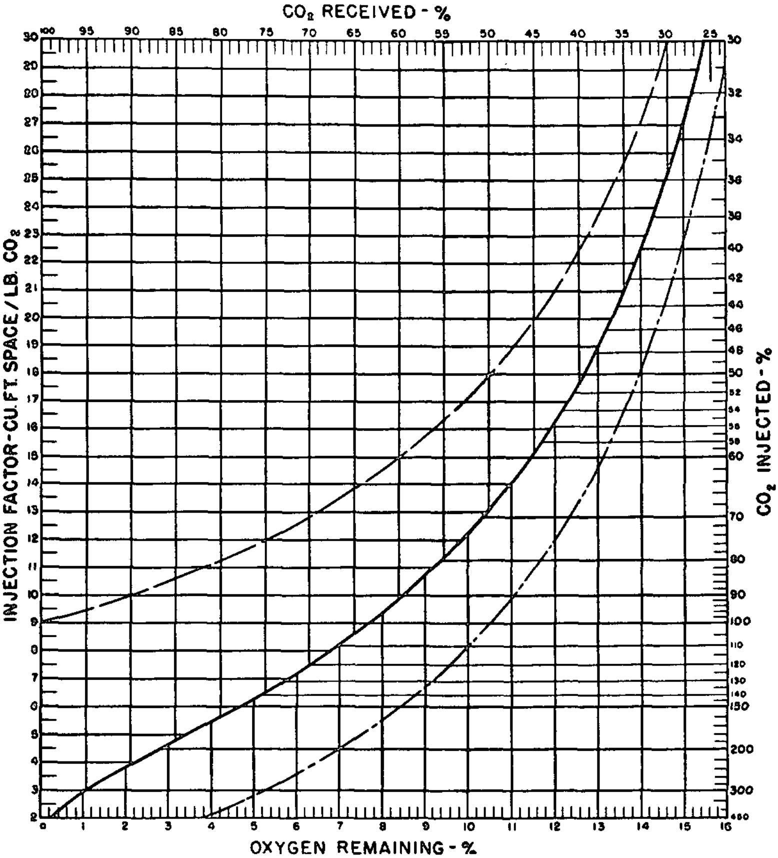
In the above formula x = Volume of CO_2 added per volume of space and e = 2.718 (natural logarithm base).

From the above formula the volume of carbon dioxide required to develop a given concentration can be calculated. This quantity of carbon dioxide can be expressed in terms of cubic feet of space protected per pound of carbon dioxide or pounds of carbon dioxide per 100 cubic feet. These results have been calculated and plotted for easy reference.

One such curve is shown on Figure A-2-1(A). On this curve it was assumed that the carbon dioxide would expand to a volume of 9 cubic feet per pound ($0.56m^3/kg$) at a temperature of 86°F (30°). Similar information is also given on Figure A-2-1(B) in the form of a nomograph. In this case, it was assumed that the final temperature would be about 50°F (10°C) giving a volume of 8.35 cubic feet per pound ($0.52m^3/kg$) of carbon dioxide. The nomograph will therefore indicate somewhat greater quantities of carbon dioxide for the same concentration. The data in Chapters 1 through 5 are based on an expansion of 9 cubic feet per pound ($0.56m^3/kg$) of carbon dioxide.

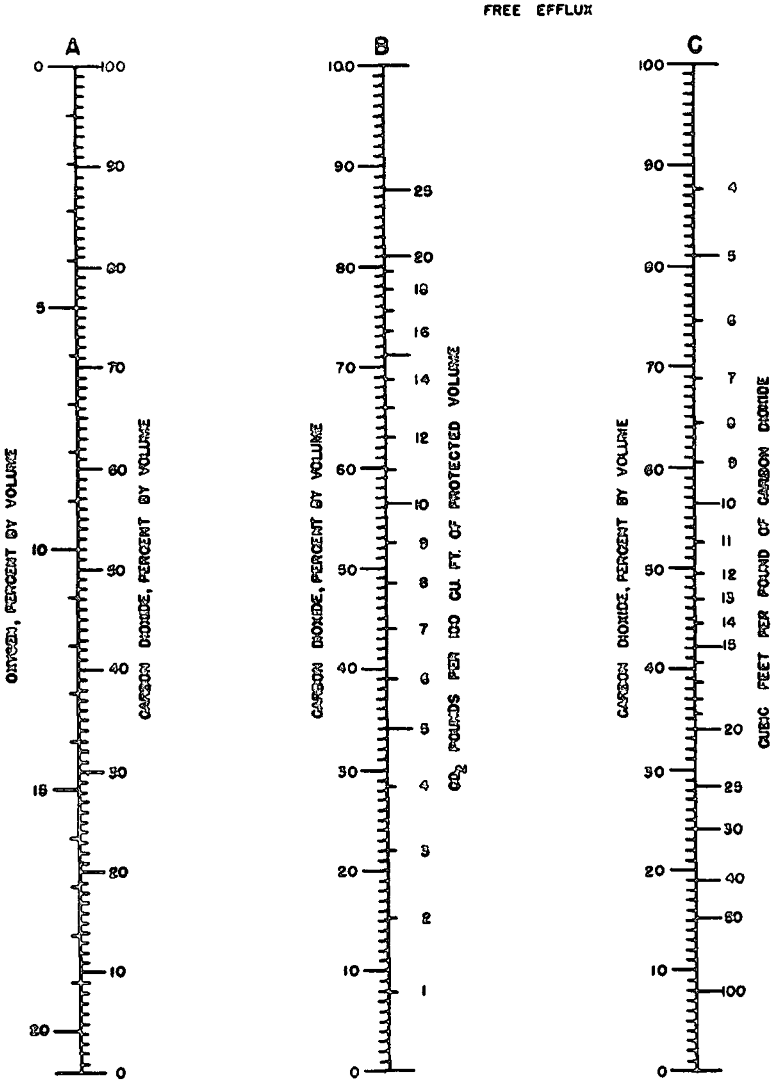
The time required for cooling below the reignition point depends on the type of fire and the insulating effect of the combustible material. For surface-type fires it can be assumed that the fire will be extinguished almost as soon as the desired concentration is obtained. The enclosure should of course retain a reasonable concentration for some time after the carbon dioxide has been injected. This provides an additional factor of safety.

For deep-seated fires the concentration should be maintained for a longer period of time because the hot material will cool off slowly. The cooling time will vary considerably, depending on the nature of the material. Since the cooling time will tend to be long, it is necessary to give considerable attention to the problem of maintaining the extinguishing concentration. Surface fires and deep-seated fires are therefore basically different and should be approached with somewhat different objectives in mind.



For SI Units
1 cu ft/lb = 0.0624 m^3/kg.

Figure A-2-1(A). Carbon dioxide requirements for inert atmospheres (based on a carbon dioxide expansion of 9 cubic feet per pound [0.56m^3/kg]). The top curve (complete displacement) and the bottom curve (no efflux) are theoretical extremes plotted for comparative purposes only. The middle curve (free efflux), the curve to be used, must be tempered by proper safety factors.



For SI Units

1lb/ft³ = 16.018kg/m³ 1ft³/lb = 0.0624m³/kg

Figure A-2-1(B). Carbon dioxide requirement for inert atmospheres (based on a carbon dioxide expansion of 8.35 cubic feet per pound [0.521m³/kg]). Column A shows oxygen content of air-carbon dioxide mixtures; column B shows weight of carbon dioxide in air-carbon dioxide mixtures; column C shows cubic feet per pound of carbon dioxide in air-carbon dioxide mixtures.

A-2-2.3 Types of Fires. Practically all hazards that contain materials that would produce surface fires may contain varying amounts of materials that would produce deep-seated fires. Proper selection of the type of fire that the system should be designed to extinguish is important and, in many cases, will require sound judgment after careful consideration of all the various factors involved.

Basically, such a decision will be based on the following:

(a) Will a deep-seated fire develop, considering the speed of detection and application of the contemplated system?

(b) If a deep-seated fire does develop, (1) will it be of a minor nature, (2) will the circumstances be such that it will not cause a re-flash of the material that produced the surface fire, and (3) can arrangements be set up to put it out manually after the CO_2 discharge before it causes trouble?

(c) Are the values involved, or the importance of equipment involved, such that the ultimate protection is justified regardless of the extra cost of providing a system that will extinguish deep-seated fires?

It will be seen that with a remote possibility of the deep-seated fire causing trouble there are many cases where taking this remote risk may be justified, and a system to extinguish surface fire may properly be selected. As an example, electrical transformers and other oil-filled electrical equipment have quite commonly been treated as producing surface fires, although there may be a chance that a heated core will produce a deep-seated fire in electrical insulation. On the other hand, the importance of some of the electrical equipment to production may be such that treating the hazard as a deep-seated fire will be justified.

Often a decision will involve consultation of the authority having jurisdiction, the owner and the engineers of the company supplying the equipment. The comparative costs between a system that is designed to extinguish a surface fire and one designed to extinguish a deep-seated fire may be the deciding factor. In all cases, it is advisable that all interested parties know clearly any risks involved if the system is designed only to extinguish a surface fire, and the additional costs that are involved if a system is designed to extinguish a deep-seated fire.

A-2-3 Carbon Dioxide Requirements for Surface Fires. The requirements given in Section 2-3 take into account the various factors that may affect the performance of the system. The following examples are intended to illustrate the use of these requirements:

Example 1

Volume of Space	2,000 cu ft
Type of Combustible	Gasoline
Ventilation Openings	
Air Outlet near ceiling	5 sq ft
Air Inlet centered @ 7 ft below ceiling	5 sq ft
Design Concentration (2-3.2.1)	34% CO_2
Volume Factor (2-3.3)	18 cu ft/lb CO_2
Basic Quantity of CO_2	$\frac{2000}{18} = 111$ lbs

Material Conversion Factor (2-3.4) — Since the design concentration is not over 34% no conversion is needed.

Special Conditions (2-3.5) — CO_2 will be lost through the bottom opening while air enters through the top opening. From Figure A-2-5.3.3 the loss rate will be 17 lbs/min/ft^2 for a concentration of 34% at 7 feet.

Additional CO_2 for openings (2-3.5.1) = $17 \times 5 = 85$ lbs

Total CO_2 required = $111 + 85 = 196$ lbs

Example 1 (Metric)

Volume of Space	60m^3
Type of Combustible	Gasoline
Ventilation Openings	
Air Outlet near ceiling	0.5m^2
Air Inlet centered @ 2.1m below ceiling	0.5m^2
Design Concentration (2-3.2.1)	34% CO_2
Volume Factor (2-3.3)	1.11m^3/kg CO_2
Basic Quantity of CO_2	$\frac{60}{1.11} = 54.1$kg

Material Conversion Factor (2-3.4) — Since the design concentration is not over 34% no conversion is needed.

Special Conditions (2-3.5) — CO_2 will be lost through the bottom opening while air enters through the top opening. From Figure A-2-5.3.3 the loss rate will be 85kg/min/m^2 for a concentration of 34% at 2.1m.

Additional CO_2 for openings (2-3.5.1) = $85 \times 0.5 = 42.5$kg

Total CO_2 required = $54.1 + 42.5 = 96.6$kg