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Fire Extinguishing Appliances

Standard for

CARBON DIOXIDE EXTINGUISHING SYSTEMS

May

1957

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NATIONAL FIRE PROTECTION ASSOCIATION
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The National Fire Protection Association was organized in 1896 to promote the science and improve the methods of fire protection and prevention, to obtain and circulate information on these subjects and to secure the cooperation of its members in establishing proper safeguards against loss of life and property by fire. Its membership includes two hundred national and regional societies and associations (list on outside back cover) and seventeen thousand individuals, corporations, and organizations. Anyone interested may become a member; membership information is available on request.

This pamphlet is one of a large number of publications on fire safety issued by the Association including periodicals, books, posters and other publications; a complete list is available without charge on request. All NFPA standards adopted by the Association are published in six volumes of the **National Fire Codes** which are re-issued annually and which are available on an annual subscription basis. The standards, prepared by the technical committees of the National Fire Protection Association and adopted in the annual meetings of the Association, are intended to prescribe reasonable measures for minimizing losses of life and property by fire. All interests concerned have opportunity through the Association to participate in the development of the standards and to secure impartial consideration of matters affecting them.

NFPA standards are purely advisory as far as the Association is concerned, but are widely used by law enforcing authorities in addition to their general use as guides to fire safety.

Definitions

The official NFPA definitions of shall, should and approved are:

Shall is intended to indicate requirements.

Should is intended to indicate recommendations, or that which is advised but not required.

Approved refers to approval by the authority having jurisdiction.

Units of measurements used here are U. S. standard. 1 U. S. gallon = 0.83 Imperial gallons = 3.785 liters.

Approved Equipment

The National Fire Protection Association does not "approve" individual items of fire protection equipment, materials or services. The standards are prepared, as far as practicable, in terms of required performance, avoiding specifications of materials, devices or methods so phrased as to preclude obtaining the desired results by other means. The suitability of devices and materials for installation under these standards is indicated by the listings of nationally recognized testing laboratories, whose findings are customarily used as a guide to approval by agencies applying these standards. Underwriters' Laboratories, Inc., Underwriters' Laboratories of Canada and the Factory Mutual Laboratories test devices and materials for use in accordance with the appropriate standards, and publish lists which are available on request.

Carbon Dioxide Extinguishing Systems.

NFPA No. 12—1957

The present edition of this standard, developed by the Committee on Carbon Dioxide with the concurrence of the Committee on Special Extinguishing Methods, was adopted by the National Fire Protection Association at its Annual Meeting on May 23, 1957.

Work on this standard was initiated in 1928 by the then Committee on Manufacturing Risks and Special Hazards. The first complete edition was adopted in 1929 and new or revised editions were issued in 1933, 1939, 1940, 1941, 1942 (January and May), 1945, 1946, 1948 and 1949. A complete revision was adopted in 1956.

A summary of changes adopted May 23, 1957 and incorporated in the present edition, will be found on page 12-64.

Successive editions of these standards have been adopted and published by the National Board of Fire Underwriters as NBFU pamphlet No. 12.

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FOREWORD

Carbon dioxide has been used for many years in fire extinguishing systems. It is effective and efficient in extinguishing the rapidly spreading surface fire typical of flammable liquids and its greatest use has been protecting this type of hazard. Because carbon dioxide is an inert smothering, electrically nonconductive gas, it is often a highly desirable medium to use on other types of fires. As a result the rules and regulations for the installation of systems have become more complex.

The complete revision of the standards for carbon dioxide fire extinguishing systems in 1956 was prepared to meet better the expanding uses of these equipments. The complexities introduced by these new uses are many and varied and, to reduce them all to specific rules, would be an almost impossible task and would produce a most unworkable standard. Instead of attempting this, emphasis has been placed on the fundamentals established by experimental work and experience. The fundamentals are supplemented by general guidance in their application, and much of the detail has been left to the engineering ability and judgment of those designing these systems and to the authority having jurisdiction. Some will criticize this fact but it appeared to be a practical way of producing a workable standard that could be kept up to date with simple revisions.

Our knowledge is quite extensive and is backed by many years of experience. However, as more experimental work is done to improve this type of protection, to simplify methods of design, and keep up with new hazards, it is hoped that the results of this experimental work will be made known to the Committee charged with these standards. Also it is hoped that a better system of reporting operations will be established. Only with the knowledge gained from experimental work and from experience, can the standards be kept adequate for their purpose.

INTRODUCTION.

1. Purpose. These Standards are 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.

2. Scope. These Standards are minimum requirements for carbon dioxide fire extinguishing systems. They contain only the necessary essentials to make them workable in the hands of those skilled in this field. Portable carbon dioxide equipment is covered in NFPA No. 10, First Aid Fire Appliances.* Other associated NFPA standards involving the use of carbon dioxide include the following:

No. 69 Fire and Explosion Prevention by Inerting.*
No. 302 Motor Craft.*
No. 306 Control of Hazards on Vessels to be Repaired.*
No. 403 Fire Fighting Equipment for Airports.*
No. 409 Aircraft Hangars.*

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.

3. Arrangement. These Standards are arranged as follows:

Introduction.
Chapter 1 — General Information and Requirements.
Chapter 2 — Total Flooding Systems.
Chapter 3 — Local Application Systems.
Chapter 4 — Special Systems — Extended Discharge.
Chapter 5 — Hand Hose Line Systems.
Chapter 6 — Standpipe Systems and Mobile Supply.
Appendix.

*See Appendix B for availability.

Chapters 1 through 6 constitute the body of the Standards and contain the rules and regulations necessary for properly designing, installing, inspecting, testing, approving, operating and maintaining carbon dioxide fire extinguishing systems.

The Appendix contains educational and informative material that will aid in understanding and applying these Standards.

4. Definitions. For purpose of clarification, the following general terms used with special technical meanings in this Standard are defined:

APPROVED refers to approval by authority having jurisdiction.

AUTHORITY HAVING JURISDICTION is usually the purchaser or the competent engineer or organization appointed by him to interpret and make decisions as set forth in these Standards. Where insurance is involved, the inspection department representing the insurance carrier generally becomes the authority having jurisdiction. In some cases, civil or military authorities may have final jurisdiction.

HIGH PRESSURE is used to indicate that the carbon dioxide is stored in pressure containers at atmospheric temperatures. At 70° F., the pressure in this type of storage is 850 psi.

LOW PRESSURE is used to indicate that the carbon dioxide is stored in pressure containers at controlled low temperatures, at 0° F. At 0° F., the pressure in this type of storage is 300 psi.

LISTED refers to the listing for the use intended, of devices and materials that have been examined by and meet the recognized standards of such testing laboratories as the Factory Mutual Laboratories, the Underwriters' Laboratories, Inc., and the Underwriters' Laboratories of Canada. All equipment should bear a label or some other identifying mark.

SHALL is intended to indicate requirements.

SHOULD is intended to indicate recommendations or that which is advised but not required.

Other terms used with special technical meaning are defined or explained where they occur in the Standards.

CHAPTER 1.

GENERAL INFORMATION AND REQUIREMENTS.

11. General Information.

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

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

1121. 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.

113. 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 clean-up of other media presents a problem, or where they are more economical to install than systems using other media.

1131. Some of the more important types of hazards and equipment that carbon dioxide systems may satisfactorily protect include:

1. Gaseous and liquid flammable materials.
2. Electrical hazards such as transformers, oil switches, and circuit breakers, and rotating equipment.
3. Engines utilizing gasoline and other flammable fuels.
4. Ordinary combustibles such as paper, wood and textiles.
5. Hazardous solids.

1132. Carbon dioxide should not be used to extinguish fires involving the following materials:

1. Chemicals containing their own oxygen supply such as cellulose nitrate.

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*See Appendix A.

2. Reactive metals such as sodium, potassium, magnesium, titanium, and zirconium.

3. Metal hydrides.

114. Types of Systems. There are five types of carbon dioxide systems recognized in these Standards:

Total Flooding Systems.
Local Application Systems.
Extended Discharge Systems.
Hand Hose Line Systems.
Standpipe Systems and Mobile Supply.

1141. 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. This type of system shall be arranged to operate automatically and/or manually by those normally in the vicinity of the hazard.

1142. 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. This type of system shall be arranged to operate automatically and/or manually by those normally in the vicinity of the hazard.

1143. An EXTENDED DISCHARGE SYSTEM consists of a fixed supply of carbon dioxide normally connected to a system of piping arranged to discharge at an initial high rate followed by an extended discharge at a lower rate for either total flooding or local application.

1144. A HAND HOSE LINE SYSTEM consists of a fixed supply of carbon dioxide normally connected to a system of fixed piping supplying hose lines that may be used manually either for total flooding or local application by those normally in the vicinity of the hazard.

1145. 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 and/or hose lines that may be used for either total flooding or local application by fire brigade, fire department personnel or other qualified personnel.

12. Personnel Safety.

*121. **Hazards to Personnel.** The discharge of large amounts of carbon dioxide to extinguish fire may create hazards to personnel such as oxygen deficiency and reduced visibility.

1211. The dilution of the oxygen in the air, by the carbon dioxide concentrations that will extinguish fire, may create atmospheres that will not sustain life. Such atmospheres will be produced in spaces protected by total flooding and may 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.

1212. Large volume discharges of carbon dioxide may seriously interfere with visibility during and immediately after the discharge period.

*122. **Safety Requirements.** In any proposed use of carbon dioxide where there is a possibility that men may be trapped in, or enter into atmopheres 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. Such safety items as personnel training, warning signs, discharge alarms, pre-discharge alarms and breathing apparatus shall be considered.

*123. **Electrical Clearances.** All system components shall be so located as to maintain standard electrical clearances from live parts. See Appendix A for a table of clearances.

13. Specifications, Plans and Approvals.

131. **Purchasing Specifications.** Specifications for carbon dioxide fire extinguishing systems shall be drawn up with care under supervision of a competent engineer and with the advice of the authority having jurisdiction. To insure a satisfactory system, the following items should be included in the specifications.

1311. The specifications should designate the authority having jurisdiction and indicate whether plans are required.

*See Appendix A.

1312. The specifications should state that the installation shall conform to these Standards and meet the approval of the authority having jurisdiction.

1313. 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.

1314. These specifications should require the provision of equipment listed for the use intended.

132. Plans. Where plans are required, their preparations shall be entrusted to none but fully experienced and responsible persons.

1321. These plans shall be drawn to an indicated scale or be suitably dimensioned and shall be made so they can be easily reproduced.

1322. 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 detail on the hazards shall include the materials involved in the hazards, the location of the hazards, the enclosure or limits and isolation of the hazards, and the exposures to the hazard. The detail on the system shall include basic calculations for the amount of carbon dioxide, approximate rate and/or duration of discharge proposed for each hazard or hazards; the location and size of storage, and how connected; the location and sizes of piping, nozzles, hose lines, detection devices, operating devices, and auxiliary equipment; and wiring diagrams where electrical power is used. Sufficient information shall be indicated to identify properly the apparatus and devices used. Any special features should be adequately explained.

133. Approval of Plans. Where plans are required, they shall be submitted by the purchaser to the authority having jurisdiction for approval before work starts.

1331. When field conditions necessitate any material change from approved plans, the change must be approved.

1332. When such material changes from approved plans are made, corrected "as installed" plans shall be supplied to the owner and the authority having jurisdiction.

134. 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.

1341. Such tests should include a test for tightness up to the selector valve, and for continuity of piping with free unobstructed flow beyond the selector valve. The labeling of devices with proper designations and instructions shall be checked. Operational tests should be conducted on all devices except cylinder valves in multi-cylinder high pressure systems. Where conditions prevail that make it difficult to determine adequately the system requirements or design, a suitable discharge and analysis test should be made. See Sub-section 1313.

14. Operation and Control of Systems.

141. Methods of Actuation. Systems shall be classified as manual or automatic in accordance with the method of actuation.

1411. A manual system is one in which human agency is required for actuation, although it may have other features that are automatic.

1412. An automatic system is one which is actuated by automatic means. Such systems shall also have means for manual actuation.

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

1421. Visual detection may be used only with permission of the authority having jurisdiction, except in manually actuated systems where fire or conditions likely to produce fire can be readily detected by such means.

1422. Automatic detection may 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.

1423. An adequate and reliable source of energy shall be used in detection systems.

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

1431. Operation shall be by listed or approved mechanical, electrical, or pneumatic means. An adequate and reliable source of energy shall be used.

1432. 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. or marked to indicate temperature limitations.

1433. 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.

1434. 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.

1435. All automatically operated valves controlling the release and distribution of carbon dioxide shall be provided with approved independent means for emergency manual operation. If the means for manual actuation of the system required in Subsection 1412 provides approved positive operation independent of the automatic actuation, it may be used as an emergency means. 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 secondary high pressure cylinders.

1436. Manual controls shall not require a pull of more than 40 lbs. (force) nor a movement of more than 14 inches to secure operation.

1437. Where gas pressure from cylinders is used as a means for releasing remaining cylinders and the supply consists of more than two cylinders not less than two cylinders shall be used for such operation.

1438. All shut-down devices shall be considered integral parts of the system and shall function with the system operation.

1439. All manual operating devices shall be identified as to the hazard they protect.

144. Supervision. Supervision of automatic systems is advisable where the possible loss because of any delay of actuation may be high and/or where the detection or control systems are so extensive and complex that they cannot be readily checked by visual or other inspection. When supervision is provided it should be so arranged that there will be immediate indication of failure. The extent and type of supervision shall be approved by the authority having jurisdiction.

145. Alarms and Indicators. Alarms and/or indicators may be needed to indicate the operation of a system, hazards to personnel or failure of any supervised device or equipment. Such devices should be of such a type and should be provided in such numbers and at such locations as are necessary to accomplish satisfactorily their purpose subject to approval of the authority having jurisdiction. They may be audible, visual or olfactory.

1451. A positive alarm or indicator should be provided to show that the system has operated and must be reserviced.

1452. An alarm should be provided to indicate the operation of automatic systems in case an immediate personnel response is desired.

1453. Alarms should be provided to give positive warning of a discharge where hazard to personnel may exist. Such alarms should function to warn against personnel entry into hazardous areas as long as such hazards exist or until such hazards are properly recognized. See Article 12.

1454. 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.

15. Carbon Dioxide Supply.

151. 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.

1511. 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 Chapter 5.

1512. Where continuous protection is required, the reserve quantity shall be as many multiples of these minimum amounts as the authority having jurisdiction considers necessary.

1513. 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.

152. Quality. The carbon dioxide shall be of good commercial grade sufficiently free of water to prevent the formation of water ice in the discharge.

153. 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.

154. 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.

1541. 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.

1542. Storage containers should not be located so as to be subject to severe weather conditions or be subject to mechanical, chemical or other damage.

1543. When excessive climatic or mechanical exposures are expected, suitable guards or enclosures shall be provided.

***155. 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 at 70° F.

1551. High pressure containers or cylinders shall be constructed, tested and marked in accordance with the Interstate Commerce Commission specifications† (in current effect upon date

*See Appendix A.

†Secs. 78.36 and 78.37 of Title 49, Transportation, Code of Federal Regulations. See Appendix B for availability.

of manufacture and test) for ICC–3A, 3AA–1800, or higher, seamless steel cylinders. Charged cylinders shall be tested for tightness before shipment in accordance with an approved procedure.

1552. 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.

1553. When manifolded, cylinders shall be adequately mounted and suitably supported in a rack provided for the purpose 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.

1554. Individual cylinders shall be used having a standard weight capacity such as 35, 50, 75, or 100 lbs. of carbon dioxide content. For very small systems smaller capacity cylinders may be used. Only interchangeable cylinders of one selected size shall be manifolded within a system to provide the required total supply.

1555. General ambient storage temperatures shall not exceed 130° F. nor be less than 32° F. unless compensating methods are provided by special engineering, special cylinder chargings and markings or by the use of suitable external cooling or heating devices.

***156. Low Pressure Storage Containers.** Low pressure storage containers shall be designed to maintain the carbon dioxide supply at a nominal pressure of 300 psi corresponding to a temperature of approximately 0° F.

1561. The pressure container shall be made, tested, approved, equipped and marked in accordance with the current specifications of the American Society of Mechanical Engineers (A. S. M. E.) Code for Unfired Pressure Vessels.† The design working pressure shall be at least 325 psi.

1562. 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. 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.

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*See Appendix A.
†See Appendix B for availability.

1563. The pressure container shall be insulated and equipped with refrigeration and/or heating 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 (approximately –10°F.).

1564. The refrigeration system shall be capable of maintaining 0° F. in the pressure container under the highest expected ambient temperature. Operation shall be automatically controlled within practical limits.

1565. The heating system when required shall be capable of maintaining 0° F. in the pressure container under the lowest expected ambient temperature. Operation shall be automatically controlled within practical limits.

16. Distribution Systems.

161. Pipe and Fittings. Threaded pipe and fittings should preferably be galvanized malleable iron, galvanized steel, copper, or brass or equivalently corrosion protected inside and out. Copper tubing with suitable flared or brazed connections can also be used. Black steel pipe may be used with welded joints when the atmosphere is relatively noncorrosive. Special corrosion resistant materials should be used for corrosive atmospheres. Piping shall be non-combustible and shall withstand the expected temperatures without deformation. Because of low temperatures encountered in these systems, investigation should be made of the low temperature characteristics of the piping proposed. Steel pipe which complies with A.S.T.M. specification A-53 has been found to have satisfactory low temperature characteristics.

1611. Cast iron pipe and fittings shall not be used.

1612. In systems using high pressure supply, pipe and fittings shall have a minimum bursting pressure of 5000 psi. 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 may be used up through ¾ inch IPS. Extra heavy malleable iron fittings should be used through 2 inch IPS; and forged steel fittings in all larger sizes.

1613. In systems using low pressure supply, pipe and fittings shall have a minimum bursting pressure of 1800 psi. 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 lb. malleable 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 lb. malleable iron fittings.

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

1621. 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.

1622. 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.

1623. 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.

1624. 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 on systems supplied with high pressure storage, and at 450 psi 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.

1625. 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.

163. 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.

1631. Valves used in systems with high pressure storage and constantly under pressure shall have a minimum bursting pressure of 6000 psi while those not under constant pressure shall have a minimum bursting pressure of, at least, 5000 psi.

1632. Valves used in systems using low pressure storage shall withstand a hydrostatic test to 1800 psi without permanent distortion.

1633. Valves shall not be subject to mechanical, chemical or other damage.

1634. Release devices of containers used for high pressure storage, including the connector to the manifold, shall have an opening sufficient to discharge 85 per cent of the carbon dioxide in the cylinder in not more than 30 seconds, at a temperature of 70° F., nor at a rate of less than 1½ lbs. per second for the first 85 per cent of the container contents.

164. Discharge Nozzles. Discharge nozzles shall be suitable for the use intended in accordance with applicable requirements of subsequent chapters.

1641. Discharge nozzles shall be of adequate strength for use with the expected working pressures.

1642. Discharge nozzles shall be of corrosion resistant materials or be protected inside and out against corrosion. They shall not be made of combustible materials and shall withstand the expected temperatures without deformation.

1643. Discharge nozzles shall be able to resist normal mechanical, chemical, or other damage.

1644. Discharge nozzles used in local application systems should be so connected and supported that they may not readily be put out of adjustment.

1645. Discharge nozzles shall be permanently marked 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 single orifice type nozzle having the same flow rate as the nozzle in question. This marking shall be readily discernible after installation. For equivalent orifice diameters greater than 3/32 inch the code given in Table 1 may be used.

1646. Discharge nozzles shall be provided with frangible discs where clogging by foreign materials is likely.

17. Inspection, Maintenance and Instruction.

171. Inspection and Tests. At least annually, all carbon dioxide systems shall be thoroughly inspected and tested for proper operation by a competent engineer or inspector. Regular

Table 1. Carbon Dioxide Discharge Nozzles.

Nozzle Code No.	Equivalent Single Orifice Diameter — Inches	Equivalent Single Orifice Area–Sq. In.
—	.026	.00053
—	1/16	.00307
—	5/64	.0048
3	3/32	.0069
3+	7/64	.0094
4	1/8	.0123
4+	9/64	.0155
5	5/32	.0192
5+	11/64	.0232
6	3/16	.0276
6+	13/64	.0324
7	7/32	.0376
7+	15/64	.0431
8	1/4	.0491
8+	17/64	.0554
9	9/32	.0621
9+	19/64	.0692
10	5/16	.0767
11	11/32	.0928
12	3/8	.1105
13	13/32	.1296
14	7/16	.1503
15	15/32	.1725
16	1/2	.1964
18	9/16	.2485
20	5/8	.3068
22	11/16	.3712
24	3/4	.4418
32	1	.785
48	1 1/2	1.765
64	2	3.14

NOTE: The nozzle 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).

service contracts with the manufacturer or installing company are recommended.

1711. 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.

1712. Suitable discharge tests shall be made when any inspection indicates their advisability.

1713. The engineer's report with recommendations shall be filed with the owner.

1714. 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.

1715. At least annually, all high pressure cylinders shall be weighed. If, at any time, a container shows a loss in net content of more than 10 per cent, it shall be refilled or replaced.

1716. At least annually, the liquid level gages of low pressure containers should be checked for accuracy. If, at any time, a container shows a loss of more than 10 per cent, it shall be refilled, unless the minimum gas requirements are still provided.

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

1721. Any troubles or impairments shall be corrected at once by competent personnel.

173. 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.

1731. Training programs approved by the authority having jurisdiction shall be established to accomplish this.

CHAPTER 2. TOTAL FLOODING SYSTEMS.

*21. General Information.

211. 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.

212. 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.

2121. Examples of hazards that may be successfully protected by Total Flooding Systems include rooms, vaults, enclosed machines, ovens, containers, and the contents thereof.

213. 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.

22. Hazard Specifications.

221. 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.

2211. For flash or surface type fires such as will be present with flammable liquids, the total square foot area of unclosable openings should not exceed 3 per cent of the cubic foot volume of the space or 10 per cent of the total square foot area of all sides, top and bottom of the enclosure, whichever is smaller. These unclosable openings shall be compensated for by additional carbon dioxide as specified in Sub-section 2351. If this area is exceeded the system should be tested to assure proper performance.

2212. For deep seated fires such as will be involved with solids, unclosable openings should be restricted to small openings

*See Appendix A.

near or in the ceiling. If any other openings than ceiling openings are involved, the system should be tested to assure proper performance.

2213. To be adequately protected by carbon dioxide, the enclosure shall be so arranged that the fire will be confined within the enclosure or protection shall be provided for such adjacent hazards which may be possible re-ignition sources.

2214. The discharge of carbon dioxide into a closed space may cause egress of flammable vapors and gases and their safe venting to atmosphere without their spreading to adjacent fire hazards or work areas shall be considered. Where safe venting of flammable vapors and gases cannot be realized, such as in the case of process and storage tanks, the use of external local application systems outlined in Chapter 3 is required. Section 332 details the carbon dioxide requirements for this latter type of hazard.

222. 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.

2221. 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 Subsections 2351 and 2441 shall be followed.

2222. Where forced air ventilating systems are involved, they shall be preferably shut down and/or closed before or simultaneously with the start of the carbon dioxide discharge or additional compensating gas be provided. See Sub-sections 2351 and 2441.

223. Types of Fires. Fires which can be extinguished by total flooding methods may be divided into two categories; namely, (1) surface fires involving flammable liquids, gases and solids and (2) deep seated fires involving solids subject to smoldering.

2231. 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.

2232. For deep seated fires, the required extinguishing concentration must 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.

*23. Carbon Dioxide Requirements for Surface Fires.

231. 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 must be made for the type of material involved and any other special conditions.

232. 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 safety factor (20%) to the minimum effective concentration.

2321. Table 2 gives the theoretical minimum carbon dioxide concentration and the suggested minimum design carbon dioxide concentration to prevent ignition of some common liquids and gases.

2322. For materials not given in the above table, 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:

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

*See Appendix A.

Table 2. 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, Bulletin 503†. Those marked * were calculated from accepted residual oxygen values.

233. 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 per cent shall be in accordance with Table 3.

2331. In figuring the net cubic capacity to be protected, due allowance may be made for permanent nonremovable impermeable structures materially reducing the volume.

†See Appendix B for availability.

Table 3. Volume Factors.

(A) Volume of Space (Cu. Ft. Incl.)	(B) Volume Factor (Cu. Ft./Lb. CO_2)	(B) Volume Factor (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 – 50000	20	.050	250
Over 50000	22	.046	2500

2332. 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 3.

2333. 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.

234. Material Conversion Factor. For materials requiring a design concentration over 34 per cent, the basic quantity of carbon dioxide calculated from the volume factor given in Section 233 shall be increased by multiplying this quantity by the appropriate conversion factor given in Figure 1.

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

2351. Any openings that cannot be closed at the time of extinguishment shall be compensated for by the addition of 1 lb. of carbon dioxide per sq. ft. For ventilating systems which cannot be shut down the additional carbon dioxide shall be based upon the volume of air moved in 1 minute and the same volume factor as used to determine the basic quantity of gas needed. This shall be multiplied by the material conversion factor (determined in Section 234) when the design concentration is greater than 34 per cent. This amount of carbon dioxide may be applied through screening nozzles if desired or it may be applied through the regular distribution system. See Sub-section 2211.

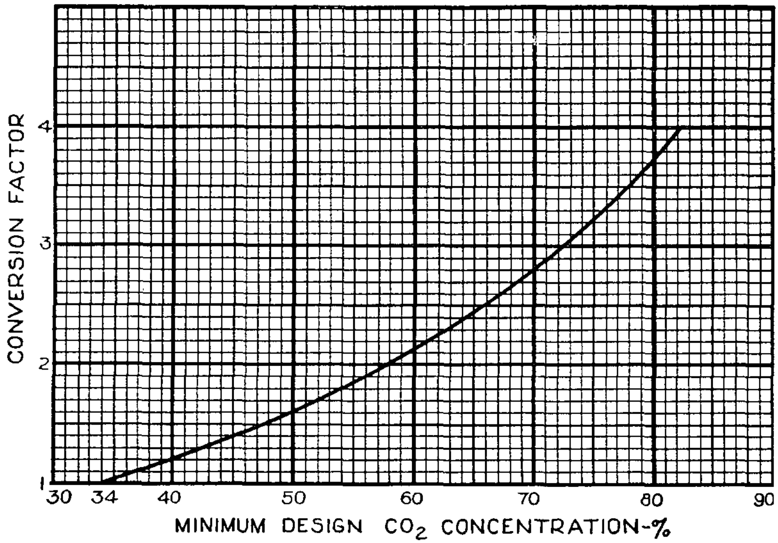

Figure 1. Material conversion factors.

*2352. For applications where the normal temperature of the enclosure is above 200° F., a 1 per cent increase in the calculated total quantity of carbon dioxide is recommended for each additional 5° F. above 200° F.

2353. For applications where the normal temperature of the enclosure is below 0° F., a 1 per cent increase in the calculated total quantity of carbon dioxide is recommended for each degree below 0° F.

2354. 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.

24. Carbon Dioxide Requirements for Deep Seated Fires.

241. 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

*See Appendix A.

to assure complete extinguishment. Any possible leakage must be given special consideration since no allowance is included in the basic flooding factors.

242. 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.

2421. The flooding factors in Table 4 have been established for specific hazards under average use and storage conditions.

Table 4. Flooding Factors for Specific Hazards.

Flooding Factor (Cu. Ft./Lb. CO_2)	(Lb. CO_2/Cu. Ft.)	Specific Hazard
12	.083	Dry electrical, wiring insulation hazards in general.
10	.100	Small elec. machines, wire enclosures, under 2000 Cu. Ft.
8	.125	Record (Bulk paper) storage.
6	.166	Fur storage vaults, dust collectors.

2422. 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.

243. Volume Consideration. The volume of the space shall be determined in accordance with Sub-section 2331. 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 Section 242.

244. Special Conditions. Additional quantities of carbon dioxide shall be provided to compensate for any special condition that may adversely affect the extinguishing efficiency. See also Sub-sections 2352 and 2353.

2441. 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 Chapter 4. Also see Sub-section 2212.

25. Distribution System.

251. 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.

***252. Rate of Application.** For surface fires the carbon dioxide shall be applied at a rate that will achieve the design concentration within two minutes. For deep seated fires the carbon dioxide shall be applied at a rate that will achieve the design concentration within 7 minutes.

*2521. Since the releasing devices of high pressure cylinders including manifold connections are required to conform to Sub-section 1634 and since this may be accomplished by varied valve and manifold connection designs, a factor of 0.0022 sq. in. per lb. of carbon dioxide required shall be used to determine the nominal cylinder outlet area, (i.e., 0.110 sq. in. for 50 lbs. of carbon dioxide; 0.165 sq. in. for 75 lbs. of carbon dioxide; 0.220 sq. in. for 100 lbs. of carbon dioxide). This nominal area or the area of the supply pipe line as tabulated in Section 253, whichever is smaller, shall be used to determine the required nozzle area.

2522. On systems of low pressure supply, the releasing devices on containers, including manifold connections, shall have a free flow area equivalent to the supply pipe area. Nozzle discharge outlets have pressures and flow rates depending on the length and size of piping, as shown in Section 254. Nozzle sizes can be determined on the basis of desired discharge rates.

EXAMPLE: 1 sq. in. of nozzle outlet area at 150 psi discharges 600 lbs. CO_2 per min.; at 125 psi, 500 lbs. per min.; etc.

253. Piping For Systems with High Pressure Supply. The size of supply piping shall conform to Table 5. Several small pipes can be used in lieu of pipe size specified when aggregate proportionate areas are provided, based on the correct areas tabulated. The number of nozzles that may be supplied by any branch line of a system is determined by the total orifice area of the nozzles supplied by the particular branch pipe. The total orifice area of the nozzles supplied by any branch pipe shall not exceed the cross sectional area of the particular branch pipe times the "nozzle-orifice ratio" of the system as determined in Sub-section 2552.

2531. Table 5 applies to pipe runs of under 250 ft. Pipe sizes for larger runs or greater discharge rates shall require special consideration.

Table 5. Supply Piping Sizes for High Pressure Supply Systems.

(E) Surface Fires CO_2 Required (Lb.)	(F) Nominal Pipe Size (In.)	(G) Internal Pipe Area (Sq. In.)	(H) Deep Seated Fires CO_2 Required (Lb.)
100	½ std. wt.*	.304	1800
225	¾ " "	.533	3200
300	1 xtra. hvy.**	.719	4350
600	1¼ xtr. hvy.	1.282	7750
1000	1½ " "	1.767	10750
2450	2 " "	2.953	over 10750, use
2500	2½ " "	4.238	.000165 sq. in.
4450	3 " "	6.605	pipe area/lb.
7100	3½ " "	8.888	CO_2
10450	4 " "	11.497	
15000	4½ " "	14.455	
20900	5 " "	18.194	
33600	6 " "	26.067	

over 33600, use .000775 sq. in. pipe area/lb. CO_2

* Schedule 40 ** Schedule 80

2532. For surface fires, such as those involving flammable liquids and gases, or flash fires on shallow combustible materials, Column E in Table 5 shall be used with Columns F and G.

2533. For deep seated fires, such as those involving slow burning combustible materials (dust collectors, silos, record and fur storage vaults), Column H in Table 5 shall be used with Columns F and G except as provided in Sub-section 2535. The reduced pipe sizes listed for this class of materials are permissible since the required prolonged discharge period is accomplished by restricted nozzle outlets thereby eliminating the necessity for larger piping.

2534. Column E shall be used for shallow quantities of slow burning materials to allow normal flow rates for flash fire extinguishment and also a modified prolonged discharge of the excess gas for the desired soaking and cooling period.

2535. Column E may be used for deep seated fires where flash fire extinguishment rates are desired.

254. Piping For Systems With Low Pressure Supply. Piping for systems with low pressure supply shall be determined in accordance with the required rate of flow and length of pipe involved. Table 6 can be used as a guide to indicate proper pipe size for the average system.

2541. In using Table 6, the length of run should be estimated as the average pipe length from the storage tank to the hazard including the branch lines. The size of the main supply pipe can then be determined from the table.

2542. The total branch line area shall be at least equal to the area of the main supply pipe.

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

2551. 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.

2552. For systems with high pressure supply protecting surface fires, the total area of all discharge outlets shall not exceed 85 per cent nor be less than 35 per cent of the total release outlet area as determined in Sub-section 2521, or the minimum area of the supply pipe whichever is the smaller. For systems protecting deep seated fires, the total area of all discharge outlets shall not exceed 85 per cent of the supply pipe area as determined in Column H of Table 5 nor be less than 3 per cent of the total release outlet area as determined in Sub-section 2521.

Table 6. Typical Carbon Dioxide Flow Rate (Lbs./Min.) for Piping for Low Pressure Carbon Dioxide Systems*

Extra Heavy** Pipe Size Inches	Length of Run							
	50 ft.	100 ft.	200 ft.	300 ft.	400 ft.	500 ft.	600 ft.	700 ft.
½	80	63						
¾	165	135	105					
1	300	250	195	165				
1¼	610	510	405	345				
1½	880	750	600	515	460			
2	1550	1350	1120	980	880	800		
2½	2300	2050	1750	1530	1370	1270		
3	3800	3400	2950	2600	2380	2220	2080	
3½	5300	4850	4200	3750	3450	3200	3000	
4	7000	6400	5650	5100	4700	4400	4100	3870
5	11500	10800	9600	8800	8150	7700	7200	6800
6	16800	16000	14500	13400	12500	11800	11100	10600

* These values are typical for the flow rate after liquid carbon dioxide reaches the discharge nozzles. Before liquid carbon dioxide reaches the discharge nozzles the vapor average discharge rate is less. The time required for liquid carbon dioxide to reach the discharge nozzles is a function of the ambient temperature, and the piping size and weight.

**These values are based on extra heavy steel pipe with screwed fittings and two globe type valves. The flow rates are influenced by the actual pipe diameter, the type and number of fittings, and the care taken in avoiding restrictions.

NOTE: A minimum nozzle design pressure of 125 psig is recommended for outlet nozzle delivery rates of approximately 500 lbs./min./sq. in.

2553. For systems of high pressure supply, recommended ratios for best performance on various types of fires are included in Table 7.

2554. For systems with low pressure supply, the total equivalent orifice area of any nozzle or group of nozzles shall not be greater than the area of the pipe supplying it.

Table 7. Ratios of Discharge Outlet Area to Release Outlet Area.

Types of Fires	Ratio
Surface fires in liquids and gases	65 — 85%
Surface fires in solids	35 — 55%
Deep seated fires	3 — 10%

2555. For systems with low pressure supply, the flow rate through each nozzle may be estimated as 500 lbs. per minute for each square inch of orifice area. This is based on a minimum nozzle pressure of 125 psi. Nozzles that are closer to the source of supply will have a higher pressure and therefore a higher discharge rate.

26. Venting Consideration.

261. General. The venting of flammable vapors and pressure build-up from the discharge of quantities of carbon dioxide into closed spaces should be considered. Venting of flammable vapors is covered in Sub-section 2214. The pressure venting consideration involves such variables as enclosure strength and injection rate.

262. 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 vaults, refrigerated spaces, and duct work have also been found to need no additional venting when tested under their average system conditions.

2621. For very tight enclosures, the area necessary for free venting may be calculated from the following formula, assuming the expansion of carbon dioxide to be 9 cu. ft./lb.

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

where: X = Free venting area in sq. in.
R = Rate of injection in lbs./min./sq. in. of orifice area.
P = Allowable strength of enclosure in lbs./sq. ft.
A = Total nozzle orifice area in sq. in.

For average discharge systems, a rate of 600 lbs. of CO_2/min./sq. in. may be obtained while for special high rate systems a maximum of 2640 lbs./min./sq. in. may be obtained.

2622. 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.

2623. General construction practices provide the guide in Table 8 for considering the normal strength and allowable pressures of average enclosures.

Table 8. Strength and Allowable Pressures for Average Enclosures.

Type Construction	Windage	Pressure	In. Water	PSI.
Light Building	100 MPH	25 lb./sq. ft.*	5	.175
Normal Building	140 MPH	50 lb./sq. ft.**	10	.35
Vault Building	200 MPH	100 lb./sq. ft.	20	.70

*Venting sash remains closed.
**Venting sash designed to open freely.

CHAPTER 3. LOCAL APPLICATION SYSTEMS.

31. General Information.

311. 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.

312. 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.

3121. 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.

313. 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.

32. Hazard Specifications.

321. Extent of Hazard. The hazard must be so isolated from other hazards or combustibles that fire will not spread outside the protected area. The entire hazard must 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.

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

33. Carbon Dioxide Requirements.

331. General. The carbon dioxide required for local application systems may be determined by two basic methods; namely, (1) area method and (2) volume method. This quantity may then be adjusted due to other factors discussed in subsequent sections but in no case shall less than 10 lbs. be used for any individual hazard. The area method should be used except for special cases involving three dimensional objects such as oil-filled electric transformers.

332. Area Method. In this method, the amount of carbon dioxide is based upon the area of the surfaces of flammable liquids, solid surfaces wetted with flammable liquids, or area of flammable vapor exits and is particularly adaptable to flat surfaces which can be easily calculated. The factors used to calculate the amount of carbon dioxide required to protect surfaces of flammable liquids existing in depth such as in dip tanks, pools, and vats; to protect coated surfaces such as drain boards, rollers, and freshly coated stock; and to protect flammable vapor exits such as vents and hatches are shown in Table 9.

Table 9. Carbon Dioxide Requirements Per Unit Area.

	Sq. Ft./Lb.	Lb./Sq. Ft.
Liquid Surfaces	0.4	2.5
Coated Surfaces	0.6	1.7
Vapor Exits	0.5	2.0

3321. Coated stock hanging not more than 2 ft. above a liquid or coated surface and not containing crevices or indentations which will hold substantial amounts of flammable liquid may be considered as included within the protection based on the main hazard surface.

3322. If coated stock is hanging more than 2 ft. above a liquid or coated surface or is of such a nature as to hold substantial amounts of flammable liquids, the protection shall be extended to include those parts, and additional carbon dioxide shall be added on the basis of either the area or volume method.

3323. When coated rollers or lengths of coated materials are involved, the developed wetted area shall be used regardless of possible duplication by contacting or close proximity surfaces.

3324. A minimum dimension of 2 ft. shall be used in calculating the area of a given hazard even though an actual dimension may be less.

333. Volume Method. In this method the amount of carbon dioxide is based upon an assumed enclosure that would surround the entire hazard. The assumed walls and ceiling of this enclosure shall be at least 2 ft. from the hazard and shall enclose all areas of possible leakage, splashing or spillage. No deductions shall be made for objects within this volume.

3331. A minimum dimension of 4 ft. shall be used in calculating the volume of the assumed enclosure.

3332. The amount of carbon dioxide required shall be 0.5 lb./cu. ft. of the assumed volume.

334. Partial Enclosures. When the volume method is used, partial enclosures will aid in confining and holding the carbon dioxide about the hazard, and the following reduction in carbon dioxide requirements may be made where the floor or base is closed and the enclosing walls are permanent, and extend at least 2 ft. above the highest point in the hazard.

3341. The carbon dioxide requirements for percentage of the perimeter of the hazard continuously enclosed are as follows:

% Perimeter Continuously Enclosed	50%	75%	100%
CO_2 Requirement	0.33 lb./cu. ft.	0.25 lb./cu. ft.	0.125 lb./cu. ft.

3342. Any openings in the walls shall be limited to 10 per cent of the entire wall area and shall be compensated for by the addition of 1 lb. of carbon dioxide per sq. ft. of opening.

335. Windage Factor. The possible effects of air currents, winds and forced drafts shall be carefully studied for the particular hazard and proper consideration shall be given these effects.

3351. Where the hazard is subject to winds or drafts from 0 to 15 mi. per hour, no increase in the basic amount of carbon dioxide is necessary.

3352. Where the hazard is subject to winds or drafts over 15 mi. per hour, the basic amount of carbon dioxide shall be increased by 10 per cent for each additional 5 mi. per hour.

336. Cooling Factor. Where it is possible that metal or other material will become heated above the ignition temperatures of the fuel or fuels involved before the carbon dioxide is applied to the fire, additional carbon dioxide will be needed.

3361. The amount of carbon dioxide needed for cooling shall be increased, if necessary, to maintain the rate of discharge for the time necessary to cool heated materials to a point where reignition will not occur. The authority having jurisdiction shall be consulted.

34. Distribution System.

341. 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.

3411. The carbon dioxide supply should be located as near the hazard as possible, and yet not exposed to the fire, and the pipe lines should be direct with a minimum number of turns in order to get carbon dioxide to the fire promptly.

3412. The system should be designed for automatic operation unless manual operators are on hand to insure prompt application.

342. Rate of Discharge. The system shall be designed to discharge all the carbon dioxide within 1 minute except that needed for additional cooling.

343. Piping For Systems with High Pressure Supply. The supply piping shall conform to Table 10. Several small pipes can be used in lieu of pipe specified when aggregate proportionate areas are provided based on the correct areas tabulated. The number of nozzles that may be supplied by any branch line of a system is determined by the total orifice area of the nozzles supplied by the particular branch pipe. The total orifice area of the nozzles supplied by any branch pipe shall not exceed the cross sectional area of the particular branch pipe times the "nozzle-orifice ratio" of the system as determined in Sub-section 3453.

Table 10. Supply Piping Sizes For High Pressure Supply Systems.

Maximum Quantity Lbs. CO_2 Required	Nominal Pipe Size Inches	Internal Pipe Area Sq. In.
100	½" std. wt.	.304
225	¾" " "	.533
300	1" xtr. hvy.	.719
600	1¼" " "	1.282
800	1½" " "	1.767
1400	2" " "	2.953
2000	2½" " "	4.238
3000	3" " "	6.605

3431. Table 10 applies to pipe runs of under 125 ft. Pipe sizes for larger runs or greater discharge rates shall require special consideration.

344. Piping For Systems with Low Pressure Supply. Table 6 shall be used to determine pipe sizes for systems with low pressure supply. See also Sub-sections 2541 and 2542.

345. Nozzle Distribution and Sizing. The nozzles used shall be listed or approved for capacity or rate of discharge, pattern, effective range and nozzle coverage.

3451. The nozzles selected and their location shall be such that (1) all surfaces being protected will be subject to the required coverage by the discharge; (2) the discharge will not splash liquids or create dust clouds that would extend fire or cause an explosion, or otherwise adversely affect the contents of the protected area; (3) the discharge will not unduly aspirate air into the protected area; and (4) the discharge will tend to be held about the hazard.

3452. Nozzles vary in design and discharge characteristics which should be specifically determined and listed by a recognized testing laboratory.

3453. For systems with high pressure supply the total area of all discharge outlets shall not exceed 85 per cent or be less than 55 per cent of the area of the supply pipe, or of the total release outlet area as determined in Sub-section 2521, whichever is the smaller.

3454. For systems with low pressure supply Sub-section 2522 shall apply.

CHAPTER 4.

SPECIAL SYSTEMS — EXTENDED DISCHARGE.

41. General Information.

411. Description. An extended discharge system consists of a fixed supply of carbon dioxide connected to a system of piping arranged to discharge at an initial high rate followed by an extended discharge at a reduced rate.

4111. The purpose of this system is to develop quickly a high concentration and then to maintain an adequate concentration for an extended period of time.

4112. The extended discharge may be continuous or intermittent.

412. Uses. Extended discharge systems may be used on total flooding and local application systems where the extinguishing effect would otherwise be dissipated before extinguishment is complete.

4121. 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.

4122. Where acceptable end results can be obtained by using a greater initial discharge, it will not be necessary to use the extended discharge system.

413. General Requirements. Extended discharge systems shall be designed, installed and maintained in accordance with the applicable requirements in Chapters 1, 2, and 3 and with the additional requirements set forth in this chapter. Except as modified in Sections 451 and 452, piping shall be installed in accordance with Sections 253 and 254.

42. Hazard Specifications for Total Flooding.

421. Enclosure. A suitable enclosure is assumed, although some leakage is recognized, since that is the reason for the extended discharge.

422. Types of Combustibles. This type of system should be considered for the protection of combustibles or hazards requiring a prolonged cooling period.

43. Carbon Dioxide Requirements.

431. General. The carbon dioxide supply shall be at least sufficient for both the initial discharge and the extended discharge.

432. Initial Discharge. The quantity of carbon dioxide required for the initial discharge shall be determined in accordance with the applicable paragraphs of Chapters 2 and 3.

4321. For rotating electrical equipment, the initial discharge quantity shall not be less than 1 pound of gas for each 10 cubic feet of enclosed volume up to 2000 cubic feet. For larger volumes 1 pound of gas for each 12 cubic feet or a minimum of 200 lbs. shall be used.

433. Extended Discharge. The quantity of carbon dioxide for the extended discharge shall be determined on the basis of the estimated leakage rate from the enclosures and the desired concentration at the end of the extended extinguishing period.

4331. For rotating electrical equipment, the concentration at the end of the deceleration period shall be at least 30 per cent. In any case, this concentration shall be maintained for at least 20 minutes. Table 11 may be used as a guide to estimate average requirements for enclosed recirculating machinery. The quantity is based on the internal volume of the machine and the deceleration time assuming average leakage. For dampered, nonrecirculating type machines, add 35 per cent to the indicated quantities.

44. Application of Carbon Dioxide.

441. Application of Initial Discharge. The initial discharge shall be applied at the rate required in Chapter 2.

442. Application of Extended Discharge. The extended discharge shall be applied at a rate that will maintain the desired concentration throughout the extinguishing period.

45. Special Equipment Requirements.

451. Intermittent Discharge. When the extended discharge is provided by means of an intermittent discharge, the

Table 11. Cubic Feet Protected For Deceleration Times.

Lbs. CO_2	5 Min.	10 Min.	15 Min.	20 Min.	30 Min.	40 Min.	50 Min.	60 Min.
100	1200	1000	800	600	500	400	300	200
150	1800	1500	1200	1000	750	600	500	400
200	2400	1950	1600	1300	1000	850	650	500
250	3300	2450	2000	1650	1300	1050	800	600
300	4600	3100	2400	2000	1650	1300	1000	700
350	6100	4100	3000	2500	2000	1650	1200	900
400	7700	5400	3800	3150	2500	2000	1600	1200
450	9250	6800	4900	4000	3100	2600	2100	1600
500	10800	8100	6100	5000	3900	3300	2800	2200
550	12300	9500	7400	6100	4900	4200	3600	3100
600	13900	10900	8600	7200	6000	5200	4500	3900
650	15400	12300	9850	8300	7050	6200	5500	4800
700	16900	13600	11100	9400	8100	7200	6400	5600
750	18500	15000	12350	10500	9150	8200	7300	6500
800	20000	16400	13600	11600	10200	9200	8200	7300
850	21500	17750	14850	12700	11300	10200	9100	8100
900	23000	19100	16100	13800	12350	11200	10050	9000
950	24600	20500	17350	14900	13400	12200	11000	9800
1000	26100	21900	18600	16000	14500	13200	11900	10700
1050	27600	23300	19900	17100	15600	14200	12850	11500
1100	29100	24600	21050	18200	16600	15200	13750	12400
1150	30600	26000	22300	19300	17700	16200	14700	13200
1200	32200	27300	23550	20400	18800	17200	15600	14100
1250	33700	28700	24800	21500	19850	18200	16500	14900
1300	35300	30100	26050	22650	20900	19200	17450	15800
1350	36800	31400	27300	23750	22000	20200	18400	16650
1400	38400	32800	28550	24900	23100	21200	19350	17500
1450	39900	34200	29800	26000	24200	22200	20300	18350
1500	41400	35600	31050	27100	25250	23200	21200	19200

piping provided for the initial discharge may be used. The initial discharge piping shall be installed in accordance with Sections 253 and 254.

4511. The system shall be designed so as to avoid any possibility of freezing up because of repeated discharges and the accumulation of carbon dioxide snow.

452. Continuous Discharge. When the extended discharge is provided by means of a continuous discharge, a separate pipeline should be used.

4521. The initial discharge piping may be used for the extended discharge if suitable valves are provided to close surplus discharge outlets. The initial discharge piping shall be installed in accordance with Sections 253 and 254.

4522. Extended discharge piping shall contain no pipe smaller than ½-inch size. For systems with high pressure supply, the area of the pipe shall not be less than three times the total area of all outlets supplied by such piping.

453. Discharge Outlets. A minimum number of discharge outlets, consistent with proper distribution, and the desired discharge rate shall be used in order to reduce the possibility of blockage during a long or intermittent discharge.

4531. For the average system, a discharge rate of 600 lbs./min./sq. in. can be used for estimation. For systems using small sized nozzles which are adequately supplied, a discharge rate of 2640 lbs./min./sq. in. can be used. Such small nozzles are shown in Table 12.

Table 12. Discharge Rates for Small Nozzles.

Nozzle No.	Orifice Diam. In.	Area Sq. In.	Discharge Rate Lbs./Min.
.026	.026	.00053	1.4
.063	1/16	.00307	8.1
.070	.070	.00385	10.2
.076	.076	.00454	12.0
.078	5/64	.00479	12.7
.081	.081	.00515	13.6
.086	.086	.00581	15.3
3*	3/32	.00690	18.2

*Nozzle code number as suggested in subsection 1645.

CHAPTER 5. HAND HOSE LINE SYSTEMS.

51. General Information.

511. 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 Sub-section 1511.

512. 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 should 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.

513. 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. Piping shall be installed in accordance with Sections 343 and 254 and Sub-sections 2541 and 2542.

52. Hazard Specifications.

521. 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.

53. Location and Spacing.

531. 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.

532. 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.

54. Carbon Dioxide Requirements.

541. Rate and Duration of Discharge. The rate and duration of discharge and consequently the amount of carbon dioxide should be determined by the type and potential size of the hazard. A hand hose line should have a sufficient quantity of carbon dioxide to permit its use for at least 1 minute.

542. Provision For Use By Inexperienced Personnel. The possibility of these hose lines being used by inexperienced personnel must 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 they are likely to encounter.

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

55. Equipment Specifications.

551. Hose. Hose lines on systems with high pressure supply shall have a minimum bursting pressure of 5000 psi, and hose lines of systems with low pressure supply shall have a minimum bursting pressure of 1800 psi.

552. 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 shut-off 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.

553. 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 may be uncoiled with a minimum of delay. If installed outdoors it should be protected against the weather.

554. 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.

5541. All controls for actuating the system shall be located in the immediate vicinity of the hose reel.

5542. 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.

5543. Except when in actual use, pressure should not be permitted to remain in the hose line.

56. Training.

561. 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 6. STANDPIPE SYSTEMS AND MOBILE SUPPLY.

61. General Information.

611. 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.

612. 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.

613. General Requirements. Standpipe systems and mobile supply shall be installed and maintained in accordance with the requirements in Chapters 1, 2, 3, and 5 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.

62. Hazard Specifications.

621. Standpipe systems and mobile supply may be used to protect hazards, included in Chapters 1, 2, 3, and 5, 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.

63. Standpipe Requirements.

631. 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.

64. Mobile Supply Requirements.

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

642. 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.

643. 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.

644. 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.

645. 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. Since mobile supply is generally fire brigade or fire department equipment, self-contained breathing apparatus and other accessories may be carried.

65. Training.

651. 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 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 appendix material is provided to explain the background or development of some of the principles upon which these Standards are based, to help interpret or elaborate on the intent of these Standards and to illustrate the ways in which they may be used.

A–112. 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 per cent 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. 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. 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 can not exist as a liquid at pressures below 60 psi gage (75 psi absolute). This is the triple point pressure where carbon dioxide