

CARBON DIOXIDE EXTINGUISHING SYSTEMS 1963



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NATIONAL FIRE PROTECTION ASSOCIATION
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National Fire Protection Association

International

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This is one of a large number of publications on fire safety issued by the Association. All NFPA standards and recommended practices, including this text, are prepared by the technical committees of the NFPA and adopted at an Annual Meeting of the Association. They are intended to prescribe reasonable measures for minimizing losses of life and property by fire.

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SHALL is intended to indicate requirements.

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Standard on Carbon Dioxide Extinguishing Systems

NFPA No. 12 — 1963

1963 Edition of No. 12

The 1963 edition of the Standard for Carbon Dioxide Extinguishing Systems incorporates changes proposed by the Committee on Carbon Dioxide and adopted at the 1963 Annual Meeting of the National Fire Protection Association. It supersedes the 1962 edition. For 1963 amendments see page 12-79.

Origin and Development of No. 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, and 1963. 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.

Committee on Carbon Dioxide

H. T. Johnson, *Chairman*,

Illinois Inspection and Rating Bureau, 175 W. Jackson Blvd., Chicago 4, Ill.

Douglas R. Abbey, Don Mills, Ont., Canada. (Personal)

C. V. Batley, Bethlehem Steel Co. (Personal)

J. A. Bono, Underwriters' Laboratories, Inc.

Donald A. Diehl, Compressed Gas Assn., Inc.

W. G. Goodwin, Fire Extinguisher Manufacturers' Institute of Canada.

P. E. Johnson, Factory Mutual Engineering Division.

Professor Willis G. Labes, Illinois Institute of Technology. (Personal)

C. H. Lindsay, American LaFrance, Div. of Sterling Precision Corp. (Personal)

J. A. McGuckin, Edison Electric Institute.

E. J. Meyers, National Paint, Varnish & Lacquer Assn.

Robert Roos, Fire Equipment Mfrs. Assn. Inc.

Gilbert L. Toppin, Underwriters' Laboratories of Canada.

E. E. Williams, Factory Insurance Assn.

H. V. Williamson, Cardox Division, Chemetron Corp. (Personal)

Alternates.

Stewart Boal, Fire Equipment Mfrs. Assn. Inc. (Alternate to Robert Roos.)

P. L. Murdoch, Fire Extinguisher Manufacturers' Institute of Canada. (Alternate to W. G. Goodwin.)

George Schrank, Compressed Gas Assn., Inc. (Alternate to Donald A. Diehl.)

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Standard on
Carbon Dioxide Extinguishing Systems

NFPA No. 12 — 1963

INTRODUCTION.

1. 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.

2. 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. Portable carbon dioxide equipment is covered in NFPA No. 10, Portable Fire Extinguishers. Other associated NFPA standards involving the use of carbon dioxide include the following:

No. 69 Inerting for Fire and Explosion Prevention.

No. 302 Motor Craft.

No. 306 Control of Hazards on Vessels to be Repaired.

No. 403 Fire Fighting Services 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. 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.

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 Appendix contains educational and informative material that will aid in understanding and applying this Standard.

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 this Standard. 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 Engineering Division, 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 Standard.

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 cleanup 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:

*See Appendix A.

1. Chemicals containing their own oxygen supply such as cellulose nitrate.
2. Reactive metals such as sodium, potassium, magnesium, titanium, and zirconium.
3. Metal hydrides.

114. 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.

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.

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.

1143. A HAND HOSE LINE SYSTEM consists of a fixed supply of carbon dioxide supplying hose lines.

1144. 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.

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.

*See Appendix A.

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 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. 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.

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

***See Appendix A.**

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.

1323. The detail on the system shall include information and calculations on the amount of CO₂; 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 CO₂ 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 should be adequately explained.

133. Approval of Plans. Plans and calculations shall be submitted 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 should be so arranged that there will be immediate indication of 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 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 Section 411.

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.

*See Appendix A.

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 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. Cylinders in service shall be hydrostatically retested for continuing service at least every 12 years in accordance with the test procedure and apparatus set forth in the regulations of the Interstate Commerce Commission.

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. For local application systems general ambient storage temperatures shall not exceed 120° F nor be less than 32° F 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.

***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, ap-

* See Appendix A.

† Secs. 78.36 and 78.37 of Title 49, Transportation, Code of Federal Regulations. Parts 71-78 (ICC). Available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. 601 pages.

proved, 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.

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. Ductile iron fittings may be used if listed and properly marked for identification. Special corrosion resistant materials should be used for corrosive atmospheres. Piping shall be noncombustible 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

* Code for Unfired Pressure Vessels for Petroleum Liquids and Gases (ASME; API-ASME). Available from The American Society of Mechanical Engineers, 29 West 39th Street, New York 18, New York. 285 pages.

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 $\frac{3}{4}$ inch IPS and extra heavy (Schedule 80) should be used in sizes over $\frac{3}{4}$ inch IPS. Standard malleable iron banded fittings may be used up through $\frac{3}{4}$ 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 CO₂ 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. 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 syphon tube, valve, discharge head and flexible connector.

164. 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.

1641. 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.

1642. Discharge orifices shall be of corrosion-resistant metal.

Table 1. Equivalent Orifice Sizes.

Orifice Code No.	Equivalent Single Orifice Diameter — Inches	Equivalent Single Orifice Area—Sq. In.
—	.026	.00053
—	1/16	.00307
—	.070	.00385
—	.076	.00454
—	5/64	.0048
—	.081	.00515
—	.086	.00581
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 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).

1643. Discharge nozzles used in local application systems should be so connected and supported that they may not readily be put out of adjustment.

1644. 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 2 and 3. For equivalent orifice diameters, the code given in Table 1 may be used.

1645. 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.

Table 2. Discharge Rate Per Square Inch of Equivalent Orifice Area for Low Pressure Storage (300 Psia).

<u>Orifice Pressure psia</u>	<u>Discharge Rate Lbs./Min./Sq. In.</u>
300	4220
290	2900
280	2375
270	2050
260	1825
250	1655
240	1525
230	1410
220	1305
210	1210
200	1125
190	1048
180	977
170	912
160	852
150	795
140	741
130	689
120	638
110	589
100	542

Table 3. Discharge Rate Per Square Inch of Equivalent Orifice Area for High Pressure Storage (750 psia).

Orifice Pressure psia	Discharge Rate Lbs./Min./Sq. In.
750	4630
725	3845
700	3415
675	3090
650	2835
625	2615
600	2425
575	2260
550	2115
525	1985
500	1860
475	1740
450	1620
425	1510
400	1400
375	1290
350	1180
325	1080
300	980
250	780
200	595

***165. 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.

1651. 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-165.

*See Appendix A

1652. For systems with low pressure storage, flow shall be calculated on the basis of an average storage pressure of 300 psia during discharge. The discharge rate for equivalent orifices shall be based on the values given in Table 2. Design nozzle pressures should not be less than 125 psia.

1653. For systems with high pressure storage, flow shall be calculated on the basis of an average storage pressure of 750 psia during discharge for normal 70° F storage. The discharge rate through equivalent orifices shall be based on the values given in Table 3. Design nozzle pressures at 70° F storage should not be less than 200 psia.

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 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 semiannually, 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 prevent fire from spreading through openings to adjacent hazards or work areas which may be possible re-ignition 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 Sub-section 3436. Where such confinement of gas is impracticable, protection shall be extended to include these adjacent hazards or work areas.

2214. 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 Sub-section 3436 is required.

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 Sub-sections 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 4 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 4. Minimum Carbon Dioxide Concentrations for Extinguishment.

Material	Theoretical Min. CO ₂ Concen- tration (%)	Minimum Design CO ₂ Concen- tration (%)
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 5.

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

* Limits of Flammability of Gases and Vapors (Bulletin 503, Bureau of Mines). Available from U. S. Government Printing Office, Washington 25, D. C. 155 pages.

Table 5. Volume 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
501 - 1600	16	.063
1601 - 4500	18	.056
4501 - 50000	20	.050
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 5.

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 not less than 1 pound of carbon dioxide per square foot of opening. This amount of carbon dioxide shall be applied through the regular distribution system. See Sub-section 2211.

2352. 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

* See Appendix A.

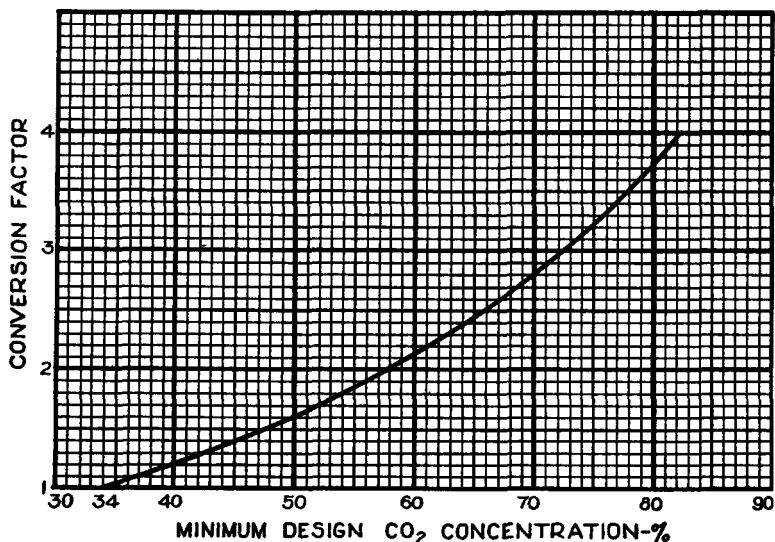


Figure 1. Material conversion factors.

by the material conversion factor (determined in Section 234) when the design concentration is greater than 34 per cent.

*2353. 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.

* 2354. 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.

2355. 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.

* See Appendix A.

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 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 6 have been established for specific hazards under average use and storage conditions.

Table 6. Flooding Factors for Specific Hazards.

Design Concentration	Flooding Factor		Specific Hazard
	Ft./Lb. CO ₂)	(Cu. Lb. CO ₂ /Cu. Ft.)	
50	12	.083	Dry electrical, wiring insulation hazards in general.
50	10	.100	Small elec. machines, wire enclosures, under 2000 Cu. Ft.
65	8	.125	Record (bulk paper) storage.
75	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 Section 253. 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.** The minimum design rate of application shall be based on the quantity of carbon dioxide and the maximum time to achieve design concentration.

2521. For surface fires the design concentration shall be achieved within one minute.

2522. 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 Sub-section 3323.

2523. 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 per cent in 2 minutes.

253. 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.

*See Appendix A.

2531. 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.

2532. The minimum design concentration shall be obtained within the time limits specified in Section 252.

2533. The extended rate of discharge shall be sufficient to maintain the minimum concentration. *

*2534. For enclosed rotating electrical equipment a minimum concentration of 30 per cent should be maintained for the deceleration period but not less than 20 minutes.

254. Piping Systems. Piping shall be designed in accordance with Section 165 to deliver the required rate of application at each nozzle.

2541. High pressure storage temperatures may range from 0° F to 130° F without requiring special methods of compensating for changing flow rates.

2542. For high pressure storage temperatures below 0° F or above 130° F, special design features may be required to assure proper flow rates.

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.

26. Venting Consideration.

261. General. The venting of flammable vapors and pressure build-up from the discharge of quantities of carbon di-

*See Appendix A

oxide 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 storage rooms, 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 CO₂/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 7 for considering the normal strength and allowable pressures of average enclosures.

Table 7. Strength and Allowable Pressures for Average Enclosures.

<u>Type Construction</u>	<u>Windage</u>	<u>Pressure</u>	<u>In. Water</u>	<u>PSI</u>
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.

x

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 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.

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 quantity of carbon dioxide required for local application systems shall be based on the total rate of

*See Appendix A

discharge needed to blanket the area or volume protected and the time that the discharge must be maintained to assure complete extinguishment.

*3311. For systems with high pressure storage, the computed quantity of carbon dioxide shall be increased by 40 per cent 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.

*3312. 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.

332. Rate of Discharge. Nozzle discharge rates shall be determined by either the surface method or the volume method as covered in Articles 34 and 35.

3321. 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.

3322. 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.

3323. 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.

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

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

* See Appendix A.

***333. 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.

3331. 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. This is especially important with paraffin wax and other materials having low autoignition temperatures.

34. Rate by Area Method.

341. 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.

342. 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.

*3421. The discharge rate for overhead type nozzles shall be determined solely on the basis of distance from the surface each nozzle protects.

*3422. 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.

343. 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.

3431. The same factors used to determine the design discharge rate shall be used to determine the maximum area to be protected by each nozzle.

3432. The portion of the hazard protected by individual overhead type nozzles should be considered as a square area.

* See Appendix A.

3433. 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.

3434. When coated rollers or other similar irregular shapes are to be protected, the projected wetted area may be used to determine nozzle coverage.

3435. Where coated surfaces are to be protected, the area per nozzle may be increased by 40 per cent 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 per cent of the protected surface. This Sub-section does not apply where there is a heavy build-up of residue. See Sub-section 312.

3436. Where local application nozzles are used for protection across openings as defined in Sub-sections 2213 and 2214, the area per nozzle given by specific approval or listing may be increased 20 per cent.

3437. When deep layer flammable liquid fires are to be protected, a minimum freeboard of 6 inches shall be provided unless otherwise noted in approvals or listings of nozzles.

344. 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.

3441. Tankside or linear type nozzles shall be located in accordance with spacing and discharge rate limitations stated in specific approvals or listings.

3442. 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 Sub-section 3443. 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.

3443. 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 multiply-

ing the fractional aiming factor in Table 8 by the width of the area protected by the nozzle.

Table 8. Aiming Factors for Angular Placement of Nozzles.

Discharge Angle†	Aiming Factor*
45-60°	$\frac{1}{4}$
60-75	$\frac{1}{4}$ - $\frac{3}{8}$
75-90	$\frac{3}{8}$ - $\frac{1}{2}$
90 (perpendicular)	$\frac{1}{2}$ (center)

†Degrees from plane of hazard surface.

*Fractional amount of nozzle coverage area.

3444. Nozzles shall be located so as to be free of possible obstructions that could interfere with the proper projection of the discharged carbon dioxide.

3445. 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 2 feet above a protected surface.

3446. 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.

35. Rate by Volume Method.

351. 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.

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

3521. The assumed enclosure shall be based on an actual closed floor unless special provisions are made to take care of bottom conditions.

3522. The assumed walls and ceiling of this enclosure shall be at least 2 feet from the main hazard unless actual walls are

involved and shall enclose all areas of possible leakage, splashing or spillage.

3523. No deductions shall be made for solid objects within this volume.

3524. A minimum dimension of 4 feet shall be used in calculating the volume of the assumed enclosure.

3525. 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.

353. System Discharge Rate. The total discharge rate for the basic system shall be equal to 1 lb./min./cu. ft. of assumed volume.

3531. If the assumed enclosure has a closed floor and is partly defined by permanent continuous walls extending at least 2 feet 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. for actual walls completely surrounding the enclosure.

354. 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.

3541. 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.

3542. Nozzles shall be located so as to compensate for any possible effects of air currents, winds or forced drafts.

3543. 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.

3544. Special purpose nozzles may have discharge rates based on other factors.

36. Distribution System.

361. 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.

3611. The carbon dioxide supply should be located as near to 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.

3612. The system shall be designed for automatic operation. Systems designed for manual operation may only be permitted by the authority having jurisdiction.

362. Piping Systems. Piping shall be designed in accordance with Section 165 to deliver the required rate of application at each nozzle.

3621. High pressure storage temperatures may range from 32° F to 120° F without requiring special methods of compensating for changing flow rates.

3622. Where high pressure storage temperatures may fall below 32° F or rise above 120° F special features shall be incorporated to assure proper flow rate.

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

3631. The equivalent orifice size used in each nozzle shall be determined in accordance with Section 165 to match the design discharge rate.

3632. Nozzles shall be accurately located and directed in accordance with the system design requirements as covered in Sections 34 and 35.

CHAPTER 4. HAND HOSE LINE SYSTEMS.

41. General Information.

411. 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.

412. 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.

413. 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.

42. Hazard Specifications.

421. 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.

43. Location and Spacing.

431. 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.

432. 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.

44. Carbon Dioxide Requirements.

441. 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.

442. 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.

443. 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.

45. Equipment Specifications.

451. 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.

452. 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.

453. 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.

454. 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.

4541. All controls for actuating the system shall be located in the immediate vicinity of the hose reel.

4542. 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.

4543. Except when in actual use, pressure should not be permitted to remain in the hose line.

46. Training.

461. 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.

51. General Information.

511. 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.

512. 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.

513. 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.

52. Hazard Specifications.

521. 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.

53. Standpipe Requirements.

531. 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.

54. Mobile Supply Requirements.

541. 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.

542. 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.

543. 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.

544. 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.

545. 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.

55. Training.

551. 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 this Standard is based, to help interpret or elaborate on the intent of this Standard 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

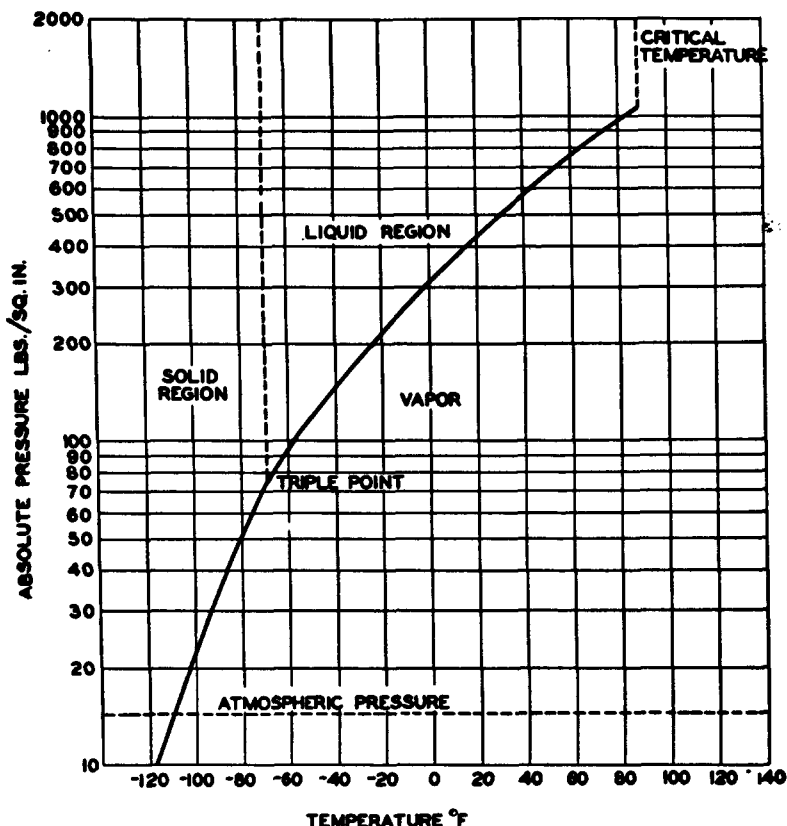


Figure A-1. Variation of pressure of carbon dioxide with change in temperature (constant volume). Below the critical temperature (87.8° F.), carbon dioxide in a closed container is part liquid and part gas. Above the critical temperature it is entirely gas.

may be present as a solid, liquid or vapor. Below this pressure it must be either a solid or a gas, depending on the temperature.

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) the remaining liquid will be converted to dry ice at a temperature of -69° F. Further reduction in the pressure to atmospheric will lower the temperature of the dry ice to the normal -110° F.

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. 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-121. 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 per cent 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 per cent carbon dioxide will cause one to breathe rapidly but will otherwise have no important effect for relatively short exposures. A concentration of about 9 per cent is about all most people can withstand without losing consciousness within a few minutes.

At carbon dioxide concentrations above 9 per cent personnel would quickly lose consciousness. At concentrations of about 20 per cent 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 dioxide 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 must be designed to meet the particular requirements of each situation.

A-122. 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:

1. Provision of adequate aiseways and routes of exit and keeping them clear at all times.
2. Provision of the necessary additional and/or emergency lighting and directional signs to insure quick, safe evacuation.
3. Provisions of alarms within such areas that will operate immediately upon 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.
4. Provision of only outward swinging self-closing doors at exits from hazardous areas, and where such doors are latched provision of panic hardware.
5. Provision of continuous alarms at entrances to such areas until atmosphere has been restored to normal.
6. Provision for adding an odor to the carbon dioxide so that hazardous atmospheres in such areas may be recognized.
7. Provision of warning and instruction signs at entrances to and inside such areas.
8. 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.

9. 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.

10. 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.

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

A-123. Electrical Clearance. The clearances in Table A-1 were obtained from the National Electrical Code and publications of the National Electrical Manufacturers Association (NEMA).

Table A-1. Minimum Clearance of System Components from Live Electrical Apparatus.

Line Voltage	Distance (In.)	Line Voltage	Distance (In.)
600 or less	1*	92,000	30
2,500	2*	115,000	37
5,000	3*	138,000	44
15,000	6	161,000	52
25,000	8	196,000	63
34,500	12	230,000	76
46,000	15	287,500	98
69,000	23	345,000	120

*For interior dry locations.

NOTE: With the exception of those marked with an asterisk, the clearances given are for transformers operating at altitudes of 3,300 feet or less. For operation at altitudes in excess of 3,300 feet, the clearance shall be increased at the rate of 1 per cent per 330 feet increase in altitude in excess of 3,300 feet.

A-155. 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 per cent filling. This is the ratio expressed in

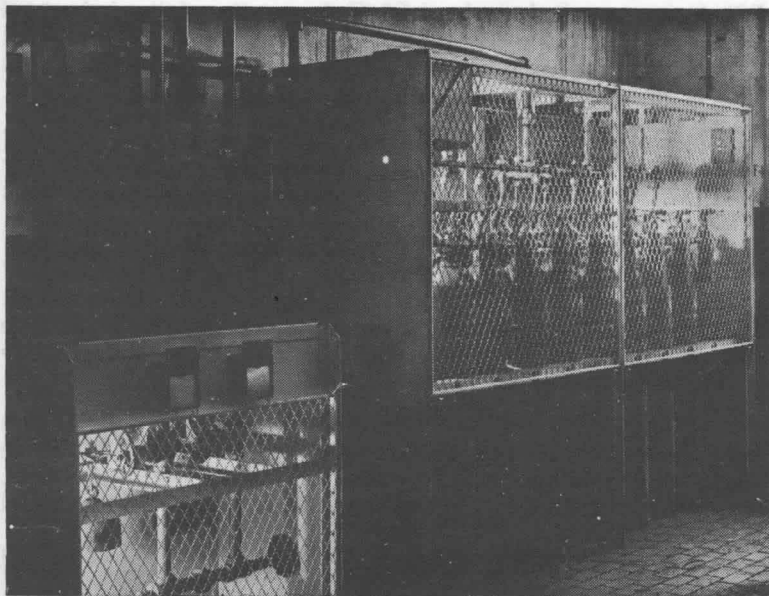


Figure A-2. A typical high pressure storage facility.

per cent of the carbon dioxide weight to the water capacity in pounds. The filling density commonly used is between 60 and 68 per cent, the latter being the maximum allowed by the Interstate Commerce Commission.* Proper filling is determined by weight stamped on the valve body.

A typical high pressure storage facility using a number of cylinders is shown on Figure A-2. 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-156. Low Pressure Storage Containers. In low pressure storage systems the temperature of the contained carbon

* Sec. 73.308 of Title 49, Transportation, Code of Federal Regulations. Parts 71-78 (ICC). Available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. 601 pages.

dioxide is controlled at about 0° F. by means of insulation and refrigeration. The normal pressure is thus maintained at about 300 psi. 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 per cent. The maximum 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-3. 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

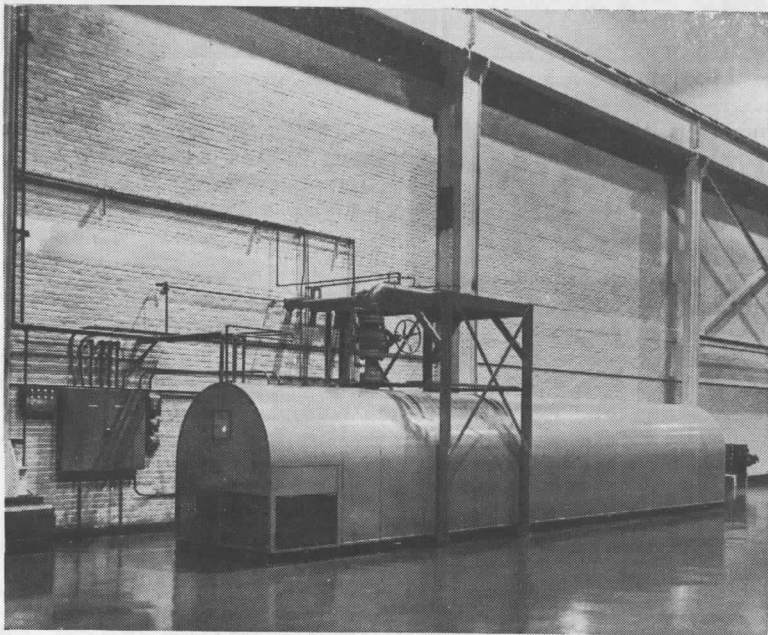


Figure A-3. A typical low pressure storage facility.

with its cooling coils mounted within the pressure vessel. This unit is electrically powered and automatically controlled by means of a pressure switch.

A-165. 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 pipe line 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 Sub-section 1651. The Y and Z factors in the equation depend on storage pressure and line pressure. These can be evaluated from the following equations:

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

$$Z = - \int_{P_1}^P \frac{d\rho}{\rho} = \ln \frac{\rho_1}{\rho}$$

Where P_1 = Storage pressure in psia

P = Pressure at end of pipe line 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. The flow equation is based on absolute pressure; therefore, 300 psia 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. For this condition the average pressure in the cylinder during discharge of the liquid portion will be about 750 psia. This pressure has therefore been selected for calculations involving high pressure systems.

Using the above base pressures of 300 psia and 750 psia, values have been determined for the Y and Z factors in the flow equation. These are listed in Tables A-2 and A-3.

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-4 gives flow information for 0° F storage temperature on this

Continued on page 12-59

Table A-2. Values of Y and Z for 300 psia Storage.

<u>PSIA</u>	<u>Y</u>	<u>Z</u>
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-3. Values of Y and Z for 750 psia Storage.

<u>PSIA</u>	<u>Y</u>	<u>Z</u>
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-4. Values of $D^{1.25}$ and D^2 for Various Pipe Sizes.

	<u>I.D. Inches</u>	<u>$D^{1.25}$</u>	<u>D^2</u>
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

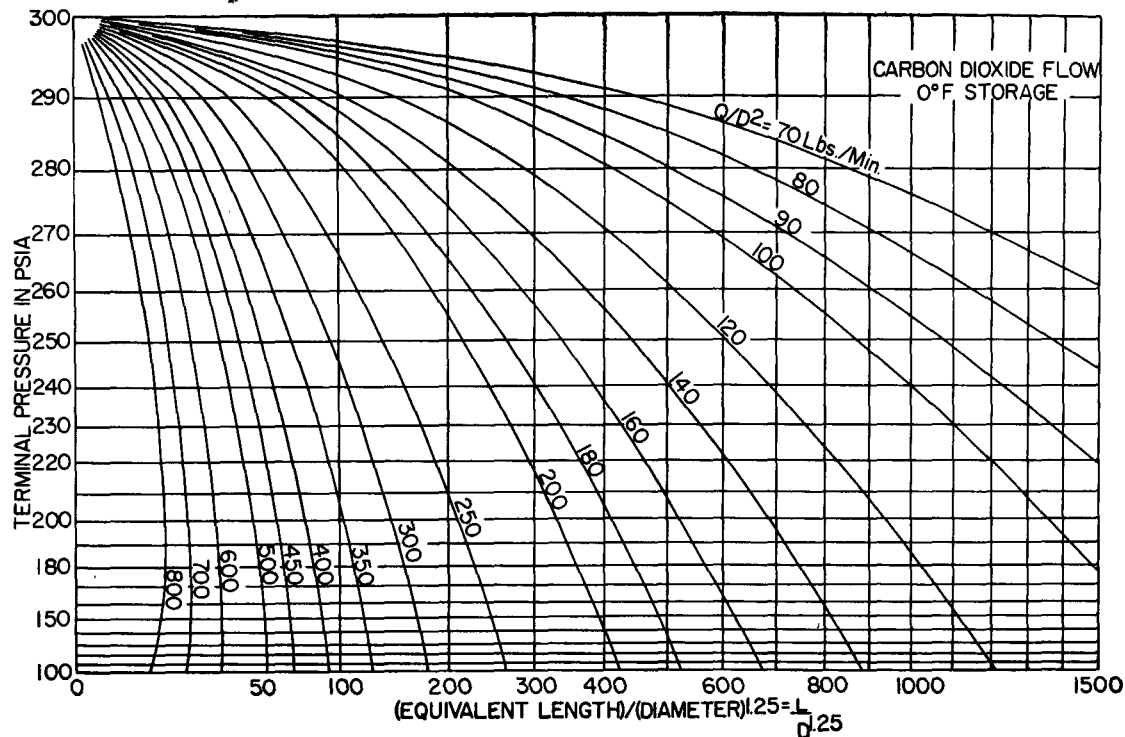


Figure A-4. Pressure drop in pipeline for 300 psia storage pressure.

basis. Figure A-5 gives similar information for high pressure storage at 70° F. 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-4 gives values for D .

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-4 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-4 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 2 of Sub-section 1652 it will be noted that the discharge rate will be 1,500 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.

$$\text{Equivalent Orifice Area} = \frac{1,000 \text{ lbs./minute}}{1,500 \text{ lbs./min./sq. in.}} = 0.67 \text{ sq. in.}$$

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 above 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

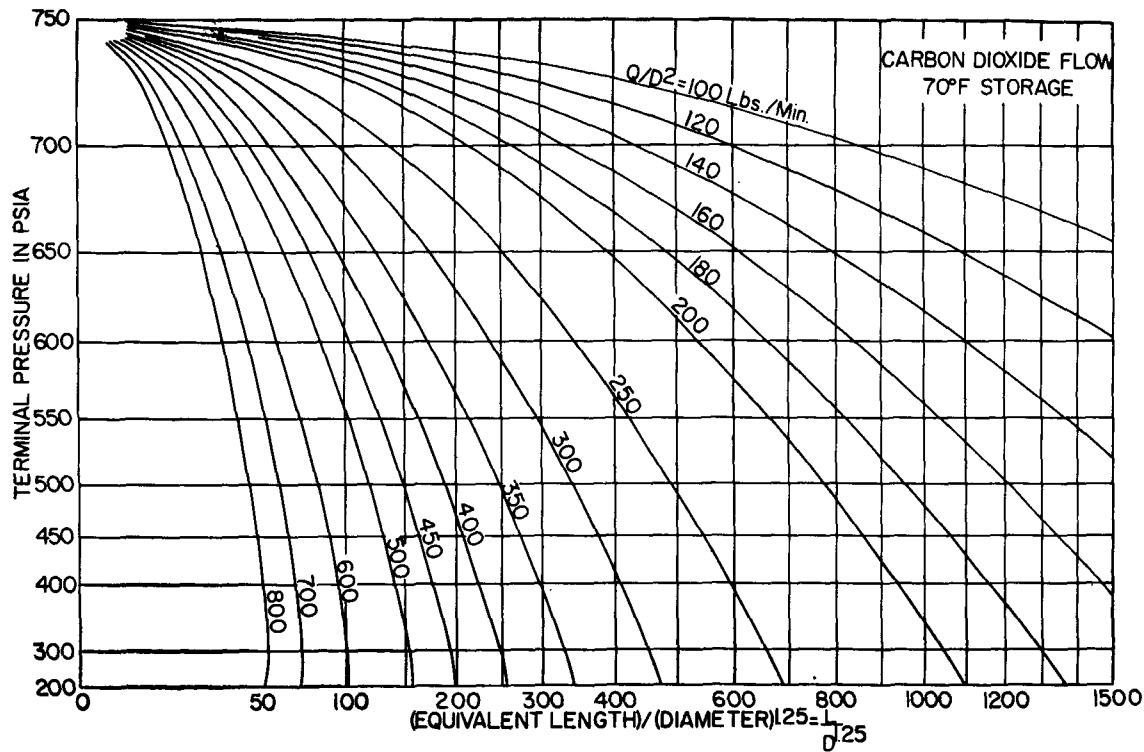


Figure A-5. Pressure drop in pipeline for 750 psia storage pressure.

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 of Figure A-4:

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

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

From Figure A-4 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 0.66 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 Sub-section 1652.

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-5 and A-6 list the equivalent lengths of pipe fittings for determining the equivalent length of piping systems. Table A-5 is for threaded joints and Table A-6 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-5. 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-6. 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