

II. CARBON DIOXIDE

A. DISCUSSION

A.1 GENERAL

Carbon dioxide as an extinguishing agent has many desirable properties. It will not damage cargo or machinery and leaves no residue to be cleaned up after a fire. Even if the ship is without power a charged CO₂ system can be released. Since it is a gas, CO₂ will penetrate and spread to all parts of the space. It does not conduct electricity and therefore can be used on live electrical equipment. It can be effectively used on most combustible materials.

There are two disadvantages to carbon dioxide. It has little cooling effect on materials that have been heated by the fire, and the quantity available in a system is limited.

Carbon dioxide extinguishes fires by reducing the oxygen concentration to a point where the atmosphere will no longer support combustion. The CO₂ concentration must be maintained for a sufficient period to allow the maximum temperature to be reduced below the autoignition temperature of the burning material. Carbon dioxide is most effective against flammable liquid fires. In enclosed spaces, burning class A combustible (wood, paper, etc.) fires may not be completely extinguished but may be controlled. For most flammable liquids, reduction of the oxygen concentration to 15% (from the normal 21%) will be sufficient to extinguish the fire. For class A combustibles, a reduction to 15% will control the fire. Some materials, such as acetylene and ethylene oxide, require a greater reduction of oxygen concentration for extinguishment. Still other materials, such as cellulose nitrate and metal hydrides, which do not require environmental oxygen as they burn, cannot be extinguished by use of carbon dioxide.

A.2. TYPES OF MARINE SYSTEMS

There are two basically different systems for the protection of spaces with carbon dioxide, depending upon the hazardous material involved. These two systems may be classified as "cargo" systems and "total flooding" systems.

A.2.1. Cargo System

Fires in class A combustibles carried in cargo holds generally start with some smoldering and production of large quantities of smoke. Only when sufficient heat is developed to reach the "flash over" temperature (temperature at which solid combustibles give off sufficient gases to support continued rapid combustion) will rapid burning occur. Until this time the rate of burning is relatively slow. Time to flash-over for ship's holds would perhaps be at least 20 minutes depending upon oxygen available and other circumstances. This allows time to prepare fire fighting operations and techniques. Carefully sealing the hold prior to release of CO₂ is extremely important. Cargo Systems are intended for use against this type of fire. The correct fire fighting technique with a cargo system is to secure all openings to the space and manually release an initial charge of CO₂ (this quantity will be contained in the instruction book carried aboard the vessel - the instruction book should be prepared in accordance with Coast Guard recommendations, and submitted for Coast Guard approval) until sufficient concentration is developed to bring the fire under control. The hatch covers are maintained in place and additional CO₂ released from time to time (according to the system instruction booklet) to maintain the concentration. This method

also allows control of the amount of CO₂ released depending upon how much and what type of cargo is in hold. Extinguishment of a class A type fire with carbon dioxide is difficult due to the thermal insulating properties of the material. Therefore, the hold is kept closed until the vessel reaches a port or other convenient facility where the hold can be opened, cargo removed, and final extinguishment accomplished. Usually such an operation involves removing cargo from spaces not involved in the fire while retaining an inert blanket on the portion of the hold involved. The fire-space is then opened, with charged firemain nozzles and water spray applicators at the ready. The cargo, e.g. baled cotton, is unloaded, cooled with water or broken open if necessary to extinguish the fire.

A.2.2. Cargo Tank System

Cargo tanks aboard cargo and passenger vessels may be protected by a type of cargo system. No specific requirements are enumerated in the passenger and cargo regulations for these systems. Installation requirements should be based upon the subparagraph 34.15-90(a)(3) of the Tank Vessel Regulations. This regulation calls for discharge of the required quantity of carbon dioxide within 5 minutes. The quantity of carbon dioxide required to protect a given space is based upon a volume factor of 30 (one pound of CO₂ per 30 cubic feet of space). Operating instructions should state the minimum number of carbon dioxide bottles to be released as related to the amount of cargo in the tank.

A.2.3. Total Flooding System

Fires in machinery and similar spaces are generally class B (flammable liquids). In this type of fire the heat build-up is rapid. -The safety of the ship depends to a great extent upon the contents of the machinery space. For this reason, it is important to introduce the extinguishing gas quickly. This also prevents heat from possibly causing failure of bulkheads, making it impossible to maintain CO₂ concentration. Quick release keeps structural members from reaching high temperatures. It also prevents heat updraft from the fire from carrying away the carbon dioxide, as well as limiting damage to equipment. discharge of 35% of the required quantity of CO₂ in these systems should be completed within two minutes; slow release might result in no extinguishment. The separate and deliberate operations are required to avoid unintentional release of the gas. one control shall release at least the required amount of CO₂. Another control is required to operate the stop valve or direction valve.

Systems protecting enclosed ventilation system for motors and generators of electric propelling machinery are of the total flooding type. In addition, the required concentration of CO₂ must be maintained until the machinery can be stopped; this may require release of additional gas at delayed intervals. Such systems are described as "delayed discharge, total flooding" systems.

A.2.4. Special Suitable Space System

Ordinary cargo vessel fire extinguishment systems are not designed for protection against flammable liquid type of fires. To protect against the possibility of releasing the required quantity of CO₂ within a relatively short period. This would result in an increase over ordinary cargo vessel extinguishment system requirements by requiring an increased amount of piping and carbon dioxide nozzles. The amount of CO₂ required is based upon the gross volume of the largest "tight" space divided by a volume factor of 22 (one pound

of CO₂ per 22 cubic feet of space). The “tight space” allows for small openings in hatches. Therefore, in designing a system for a volume factor of 22 for the “tight space” in 2 minutes, there is sufficient CO₂ available for a volume factor of 30 for the whole hold. The discharge of the required CO₂ is to be completed within 2 minutes.

A.3. CARBON DIOXIDE CONCENTRATION

Reduction of oxygen content to 15% is sufficient to extinguish most fires. Developing a CO₂ concentration of 28.5% in the atmosphere will reduce the oxygen content to 15%. The volume of carbon dioxide required to develop a given concentration in the atmosphere, assuming free efflux¹¹, is expressed by

$$x = \frac{\log_{10} \left(\frac{100}{100 - \% CO_2} \right)}{.434} \quad (\text{NFPA No. 12 - Carbon Dioxide Extinguishing Systems, page 12-64})$$

where x = volume of CO₂ added per volume of space. Although Coast Guard regulations were actually developed empirically, it is of interest to see how this relates to Coast Guard requirements. To apply this formula, assume that one pound of carbon dioxide expands to 9 cubic feet when released and apply a volume factor of 22 (from Coast Guard regulations for machinery spaces over 50,000 ft³) to determine the pounds of CO₂ required. The concentration of CO₂ developed in such a space (per 100 ft³) may be calculated as follows:

$$100ft^3 \times \frac{lbCO_2}{22ft^3} \times \frac{9ft^3}{lbCO_2} = 40.9ft^3 CO_2 / 100ft^3 space = x$$

$$\frac{40.9}{100} = \frac{\log_{10} \left(\frac{100}{100 - \% CO_2} \right)}{.434} \quad \% CO_2 = 33.5\%$$

This concentration is sufficient to reduce the to approximately. 13.9%.

For cargo spaces, a volume factor of 30 (based upon gross volume of largest hold) is used to determine the quantity of CO₂ required. This is equivalent to

$$100ft^3 \times \frac{lbCO_2}{30ft^3} \times \frac{9ft^3}{lbCO_2} = 30ft^3 CO_2 / 100ft^3 space = x$$

$$30 = \frac{\log_{10} \left(\frac{100}{100 - \% CO_2} \right)}{.434} \quad \% CO_2 = 25.9\%$$

¹¹ “Free efflux” means application of carbon dioxide in which the displaced atmosphere is exhausted freely through various small openings as carbon dioxide is injected. Some carbon dioxide is therefore lost with the vented atmosphere. The loss is greater at higher concentrations.

Because shipboard installations generally have fewer openings (portholes, etc.) than land installations, and they are at higher levels in the space, the carbon dioxide is not readily diluted but tends to remain near the bottom of the space where burning is likely to occur. This is a preferred condition.

Introduction of this percentage of carbon dioxide will reduce the oxygen Content of the space to 15.5%. It might appear at first glance that the oxygen content cannot be reduced enough, using a factor of 30, to extinguish the fire. However, in computing the volume of the space protected 110 reduction in volume is allowed for items of bulk which may be stowed in the space. As fires in cargo holds ordinarily occur with some stowage in the hold, the actual volume of atmosphere to be inerted is less than the gross volume of the hold. In addition, and most importantly, no consideration is given to the fact that once a hold is sealed up, the fire itself will consume a portion of the oxygen, thereby reducing the O₂ concentration of the atmosphere prior to CO₂ release. Consequently, the oxygen content of the atmosphere actually in the hold would be reduced considerably below 15%. In the case of cargo tanks, it may be desirable to require sufficient CO₂ to reduce the oxygen content to 15%. The above discussion is not applicable to machinery spaces as reduction in the volume of the protected space is allowed for boiler casings, etc. which extend into the space.

A.4. VOLUME FACTOR

As the volume of a space increases the proportional amount of CO₂ required to protect that space decreases (the volume factor in Coast Guard regulations increases). The smaller the volume of a space the greater the ratio of surface area to volume and consequently the greater the ratio of access openings to volume. Therefore, for smaller spaces there is a relatively greater chance of CO₂ leakage from the space. An additional factor is that of ventilation. While mechanical ventilation Systems are required to be shut down and ventilators closed upon actuation of a system, the presence of a ventilation system allows loss of some extinguishing gas.

A.5. NOZZLE SPACING

Coast Guard regulations state that nozzles should be spaced to give a "relatively uniform" discharge. In enclosed spaces, such as aboard ship, the location of nozzles is not so critical as for foam and water spray Systems. The carbon dioxide will disperse to all portions of the hazard within a relatively short period. Spacing the nozzles in some uniform pattern simply reduces the time necessary for the gas to mix with the air and completely inert the space. In a machinery space location of nozzles at a height equal to one-third to one-half the height of the space is adequate. since CO₂ is heavier than air it will tend to remain in the lower portions of the space and the air forced out the top will contain little CO₂.¹² Nozzles should not be located near ventilation or other openings as there is a relatively greater chance of CO₂ being forced out of the opening.

A.6. NOZZLE DESIGNATION

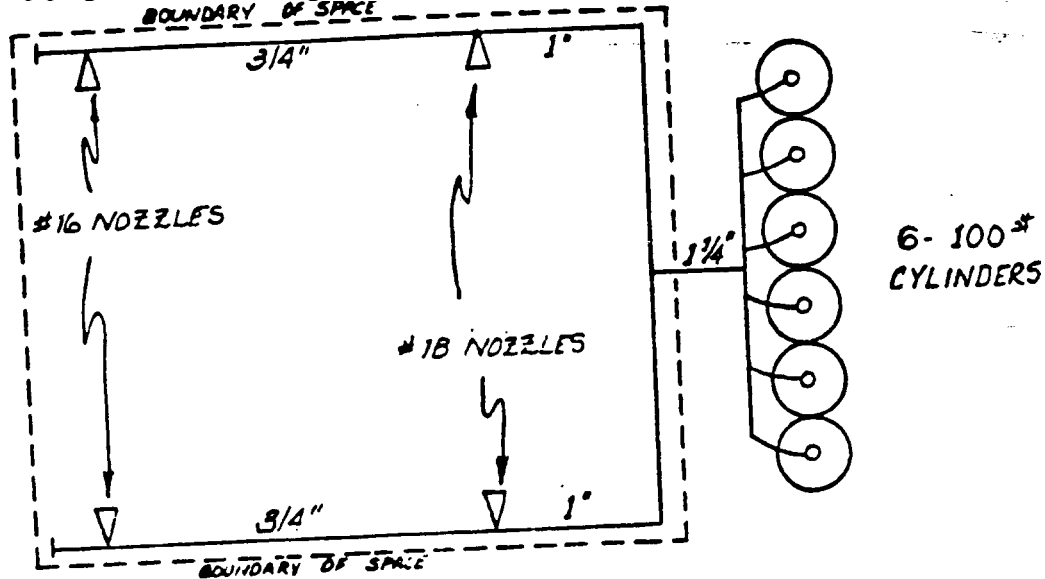
Discharge nozzles should be permanently marked to identify the nozzle and show the equivalent single orifice diameter. This equivalent diameter refers to the orifice diameter of the "standard" single orifice having the same flow rate as the nozzle in question. The equivalent orifice code number refers to the "standard" orifice diameter in 1/32" increments. For example a #16 nozzle has a discharge equivalent to a "standard" orifice 16/32" or 1/2" in diameter. A plus sign following the code number indicates equivalent diameters 1/64" greater than that indicated by the numbering system. For example, an 8+ nozzle has the equivalent discharge of a 17/64" standard orifice. See NFPA No. 12⁴ for complete listing.

A.7. PIPE SIZING, NOZZLE SIZING, DISCHARGE TIME

¹² During fire conditions, updraft from fire will tend to carry CO₂ away, making prompt action and closure of openings essential.

If the pipe and nozzle sizes are in accordance with the regulations for machinery and similar spaces, the required quantity of carbon dioxide will be discharged in less than two minutes. A satisfactory method for estimating the flow in branch lines is to assume that the gas will flow through the nozzles in direct proportion to the nozzle areas.

For example, assume a 12,000 ft³ (12000 ft³ / 20 ft³ / lb = 600 lb CO₂ reqd) machinery type space with piping and nozzles arranged as follows:



The nominal cylinder area is: 600 x .0022 = 1.32 in².

The area of 1 1/4 of extra heavy main supply pipe is: 1.283 in².

Since the area of the main supply pipe is smaller, the nozzle orifice area should be based upon this area. The total equivalent orifice area is:

$$\begin{aligned}
 \#16 &= .1964 \text{ in}^2 \times 2 = .3928 \text{ in}^2 \\
 \#18 &= 2485 \text{ in}^2 \times 2 = \underline{.4970 \text{ in}^2} \\
 \text{TOTAL} & \quad \quad \quad .8898 \text{ in}^2 \\
 .8898 \text{ in}^2 / 1.283 \text{ in}^2 &= 69.9\% \text{ of pipe area.}
 \end{aligned}$$

Since this is between 35% (40% for cargo) and 85% of the pipe area the nozzle orifice size is satisfactory.

The flow through individual nozzles may then be approximated to be proportional to the orifice area, or:

$$\begin{aligned}
 \text{flow}\#16 &= 600\text{lb} \times \frac{.1964}{.8898} = 132.4\text{lb} \\
 \text{flow}\#18 &= 600\text{lb} \times \frac{.4970}{.8898} = 167.6\text{lb}
 \end{aligned}$$

The carbon dioxide passed through the 3/4" pipe is then 132.4 lb vs. 225 lb allowable, flow through the 1 inch pipe is 300 lb vs. 300 lb allowable, and flow through the 1 1/4" pipe is 600 lb vs. 600 lb allowable. Pipe sizing is, therefore, also satisfactory.

A.8. PRESSURE INCREASE

A simple and reasonably accurate method for estimating the pressure increase due to the release of carbon dioxide into very tight spaces is as follows:

Assumptions:

- (1) Carbon dioxide expands to 9 ft³ for each pound of CO₂ in bottle (this is at 86⁰F).
- (2) Constant enthalpy for expansion from 3000 psia to 14.7 psia for CO₂.
- (3) Complete and instantaneous mixing of CO₂ and air.

A.8.1 Determine the following conditions:

$$\text{Weight of CO}_2 = \frac{\text{Vol. of Void (ft}^3\text{)}}{\text{Vol. factor (ft}^3\text{ / lbCO}_2\text{)}}$$

For CO₂:

$$V_b = 9 \text{ ft}^3 / \text{lb} \times \text{wgt of CO}_2 = (\text{volume CO}_2)$$

$$T_b = -180^0 \text{ F} + 460 = 280^0 \text{ R}$$

For Void:

$$P_1 = 14.7 \text{ psia}$$

$$V_2 = \text{Volume of void}$$

$$T_a = \text{Temp. of void prior to release of CO}_2. \text{ If not known, estimate to be } 150^0 \text{ F. (610}^0 \text{ R).}$$

A.8.2. Calculate T₂ for mixture of air and CO₂ in void:

$$T_2 = \frac{KT_a + T_b}{K + 1}, \quad \text{where } K = \frac{\text{volume factor}}{13.14}$$

A.8.3. Calculate partial pressures (P₂CO₂ & P₂ air)

$$P_2 \text{ CO}_2 = \frac{P_1 V_b T_2}{T_b V_2} \qquad P_2 \text{ air} = \frac{P_1 T_2}{T_a}$$

A.8.4 Sum of partial pressures equals total absolute pressure in the space (P_T).

$$P_T = P_2 CO_2 + P_2 air$$

A.9.
VENTING

FREE

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 ft³/lb.

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

where: X = free venting area in square inches.

R = rate of injection in lbs/min/in² of orifice area (use 1400).

P = allowable strength of enclosure in lbs/ft² (use 25 if not known).

A = total orifice area in square inches.

A.10. CYLINDER LOCATION

Cylinders shall be located outside the protected space and shall not be subject to being cut off in event of fire. The only exception to this rule is that a total-flooding system of 300 pounds or less, with approved automatic release, may be installed in the protected space. Spaces containing the cylinders shall be designed and ventilated so as to preclude an ambient temperature in excess of 130°F. This is to prevent the carbon dioxide pre-sure in the cylinders from rising, and possibly breaking the rupture disc which protects the cylinder from over-pressure.

A similar over-pressuring situation might arise if cylinders are located immediately adjacent to the space which they protect. Heat from a fire in the protected space might readily be conducted through the bulkhead, over-pressuring the cylinders. This situation could occur if the fire has gained a considerable head start before discovery. In such a situation, rupture of the over-pressure disc would fill the cylinder room with CO₂, leaving none to fight the fire. To avoid such a situation, the CO₂ cylinder bank should be located in a space that is not contiguous with the space protected. If this is impossible, the common bulkhead(s) between the spaces should be protected with A-60 structural insulation.

A.11.

REMO

TE RELEASE

When remote stations are installed which will control either release of the required amount of carbon dioxide, or which will operate a direction valve to direct CO₂ into the proper compartment, design of the remote control system design should be carefully considered. Usually the remote control operation is accomplished by a cable system. A lever is pulled at the remote station, and this force is transmitted via the cable to the cylinder location where cylinders or valves are operated. Operation of the remote pulls should not require more than 40 pounds pull nor more than 14 inches movement to accomplish its purpose. Although the system may operate satisfactorily when new, kinks in the cable due to being kept in one position, or possible deterioration of pulleys, etc. may make the system more difficult, or impossible, to operate in the future. For this reason,

excessive lengths of control cable should not be used, and cables and other operating mechanisms should never be installed in locations where they will be subject to the weather.

A.12. AUTOMATION

On automated vessels a centralized engineroom control station is provided. If the control station is enclosed, there are at least two major areas of concern:

- (1) If a fixed carbon dioxide extinguishing system is installed for protection of the machinery space, the predischarge warning alarm should be capable of being heard inside of the control station as well as in the machinery space.
- (2) The remote operating controls located at the engineroom" exit for the fixed extinguishing system should be duplicated within the control station enclosure.

B. DESIGN AND REVIEW OF SYSTEM

Application: Passenger & Tank Vessels contracted for on or after January 1, 1962

Cargo Vessels contracted for on or after November 19, 1952

Note: Numbers in brackets refer to applicable subparts of the regulations. (Passenger - Part 76; Cargo - Part 95; Tank - Part 34, unless otherwise noted)

In case of any doubt, applicable regulations should be consulted for exact wording of requirements.

- B.1. Check space to be protected and determine type of system to be installed (See chart, Subpart C).
- B.2. Check volume of protected space(s). Be certain boundaries are sufficiently tight to maintain CO₂ concentration (.15-5(e)(2), .15-5(c)(2)). M additional amount of one pound of CO₂ for every square foot of opening which cannot be closed at the time of extinguishing (clear door opening) is required Very tight spaces such as paint lockers, etc. may require pressure relief (.15-40(a)). (For estimate of pressure increase, see Subpart A, Discussion).
- B.3. Determine volume factor for space(s) and determine quantity of CO₂ required (see chart, Subpart C).
- B.4. Compare amount of CO₂ required for space requiring greatest amount, to quantity of CO₂ to be provided (.15-5(b)).
- B.5. Control and cylinder location shall be outside of the protected space and in an accessible location (control .15-10(a), cylinder .15-20(a)). In systems of 300 pounds or less, cylinders may be located inside of protected spaces if automatic discharge is provided (.15-20(b)). Such installations should also have a manual release operable from outside of the space, and not subject to being cut off.
- 8.6. Cylinders should be securely mounted (.15-20(d)) and easily removable for weighing (.15-20(e)). They should not be subject to an ambient temperature in excess of 130⁰F.(.15-20(c)). They should also be protected from excessive temperatures in event of fire in the protected space.

- B.7. Each cylinder must be provided with a safety device (rupture disc) to relieve excessive pressure. Similarly, where a distribution manifold is used, a pressure relief device is required (.15-15(d)) to protect the piping in event all branch line shut-off valves are closed.
- 8.8. Check whether nozzle locations will give a relatively uniform discharge (76., and 95.15-5(e)(S), 34.1S-S(e)(6)).
- 8.9. Compare nozzle outlet area (total) with main supply pipe size or nominal cylinder outlet area, whichever is smaller (7b., and 95.15-5 (e)(6), 34.15-5(e)(7)). The nominal cylinder outlet area (in square inches) is equal to the quantity of CO₂ required (in pounds) times 0.0022.
- 8.10. Compare the carbon dioxide flow in each section of piping to the maximum allowable by the pipe size tables (76., and 95.1-5(e)(3), 34.15-5(e)(4)). For method of estimating carbon dioxide flow in branch lines, see discussion, Subpart A.
- 8.11. For machinery and similar spaces and specially suitable spaces, discharge of the required amount of carbon dioxide must be completed within 2 minutes (76., and 95.15-S(e)(7), 34.15-5(e)(8)). This requirement will be met if nozzles and pipes are size according to (8) and (9).
- 8.12. Piping must extend at least 2 inches beyond the last orifice to reduce the danger of clogging the nozzle (.15-15(i)).
- 8.13. Piping passing through living quarters shall not be fitted with drains or openings in such spaces (.15-15(i)).
- 8.14. Location of controls must be outside of the protected space (.15-10 (a)) and convenient to one of the main means of escape (.15-10(c)).
- 8.15. CO₂ distribution piping shall be controlled from not over two stations (.15-10(c)). If cylinders are capable of remote release, provisions shall also be made for local release at the cylinders (.15-10(e)).
- 8.16. At least 2 pilot cylinders are required in systems of 3 or more cylinders (one pilot cylinder in two cylinder systems), which depend upon gas pressure for release of rest of cylinder bank (.15-10(e)). Manual controls shall require a pull of not more than 40 pounds (force) nor a movement greater than 14 inches. Estimate about 10 pounds per cylinder.
- 8.17. Machinery space shall have one control to operate the valve to the space and a separate control to release at least the required amount of CO₂ (.15-10(d)).
- 8.18. Complete but simple operating instructions should be located near the release control (.15-10(h)).
- 8.19. Check ventilation arrangement and shutdown. Mechanical ventilation requires automatic shutdown (.15-35(a)). Means must be provided for closing all natural ventilation openings (.15-35(b)). Canvas is satisfactory.
- 8.20. A delayed discharge and predischage alarm shall be provided for systems protecting spaces normally accessible to persons on board except lamp rooms, paint rooms, and similar spaces (.15-30(a)). The 20 second delay period prior to discharge of the carbon dioxide specified in, the

regulations is the minimum delay period. In large or unusually arranged spaces, the delay period should be sufficient to allow escape from all portions of the protected space.

- B.21. The predischarge alarm must be marked with a warning sign (78.47-9,97.37-9, 35.40-7). predischarge alarm shall depend upon no source of power other than C02 flow (.15-35(a)). The alarm should be located so as to be audible throughout the space, while all machinery is operating.
- B.22. Check list of component part numbers as shown on the drawing against the Coast Guard approved parts list (.15-10(g), 15-15(a), (b) & (c), must be supplied by the same manufacturer. This will assure that the parts are compatible and will result in an effective system.
- 8.23. Pipe and fittings should be provided in accordance with the Coast Guard approved pipe drawing of the manufacturer. Where reference is made to specific approved drawings of piping and/or installations which are on file, additional copies must be provided for the use of the inspector in the field. In instances where pipe and fittings are provided by organizations other than the system vendor, a complete bill of materials for the system must be submitted.

C. SPACES PROTECTED BY CARBON DIOXIDE & TYPE OF SYSTEM REQUIRED

ABBREVIATIONS: R - Required
 O - Optional in lieu of other systems
 RII - CO₂ only system permitted, but not required
 e - Some exceptions see regs

Type of Vessel	Space Protected by Carbon Dioxide	Type of System (For definition of systems Subpart A)	Flooding Factor	Required or Optional	
CARGO & MISC.	Cargo Compartments	Cargo System	30	R*	
	Spaces Specially Suitable for Vehicles	Total Flooding	22	R**	
	Cargo Tanks	Cargo Tank System	30 (see Subpart A)	O	
	Lamp & Paint Lockers & Similar Spaces	Total Flooding	See Table 95.15-5 (e)(1)	R	
	Oil Fired Boilers and Associated Equipment	Total Flooding	See Table 95.15-5(e)(1)	O	
	Internal Combustion Propelling Machinery	Total Flooding		RII R ^e	
	Enclosed Ventilation Sys. for Motors & Generators of Elec. Propelling Mach.	Delayed Discharge Total Flooding	10(2000 ft ³ or less) 12(over 2000 ft ³) ^o	R	
	Dry Cargo Compartment	Cargo System	30	O	
TANK	Lamp & Paint Lockers & Similar Spaces	Total Flooding		O	
	Pump Rooms	Total Flooding	See Table 34.15-5(e)(1)	O	
	Boiler Rooms	Total Flooding		O	
	Machinery Spaces	Total Flooding		R-If Flash Pt. Less than 110°F RII R ^e	
	Internal Combustion Installations	Total Flooding		R	
	Enclosed Ventilation Sys. for Motors & Generators of Elec. Propelling Mach.	Delayed Discharge Total Flooding	10(2000 ft ³ or less) 12(over 2000 ft ³) ^o	R	
					II(CO)

Type of Vessel	Space Protected by Carbon Dioxide	Type of System (For definition of systems Subpart A)	Flooding Factor	Required or Optional
PASSENGER	Paint & Lamp Lockers & Similar Spaces	Total Flooding	See Table 76.15-5(e)(1)	R
	Boiler Spaces	Total Flooding		O
	Machinery Spaces (Internal Comb. & Gas Turbine)	Total Flooding		R
	Auxiliary Spaces (Internal Comb. & Gas Turbine)	Total Flooding		R ^e
	Cargo Spaces (Accessible During Voyage)	Not Permitted		
	Cargo Spaces (Inaccessible During Voyage)	Cargo System	30	R
	Cargo Oil Tanks	Cargo Tank System	30 (see Subpart A)	O
	Cargo Spaces Containing Autos with Gasoline	Total Flooding	22 ^{**}	R
	Enclosed Ventilation Sys. for Motors & Generators of Elec. Propelling Mach.	Total Flooding	10 (2000 ft ³ or less) 12 (over 2000 ft ³) [*]	R

* If accessible during voyage may be considered living space and sprinklers required.
 ** If space partially open, sprinklers may be required.

° In addition, must maintain 25% concentration until equipment can be stopped.

** If the deck is open at either or both ends, as found on ferry vessels, it is called a "vehicular deck" and a manual sprinkling system is required.

D. INSPECTION AND TESTING (Carbon Dioxide)

D.1. INSTALLATION TEST

In addition to determining that the system is installed in accordance with the regulations and approved plans, the following checks are suggested:

1. Piping should be pressure tested in accordance with paragraph 34.9 76., and 95.15-15(j).
 - D.1.2. Remote controls for release of carbon dioxide equipment should be operated. Excessive pull (over approximately 40 pounds) or movement (over approximately 14 inches) should not be permitted.
 - D.1.3. Protection of cylinders and controls from damage should be verified.

- D.1.4. Operation of discharge delay and alarm should be checked. Discharge of gas into spaces that may be occupied should be delayed for a period sufficient to allow escape from any portion of the space. Thought should be given to the audibility of CO₂ alarms in the engine room especially while the vessel is underway. It has been observed on occasion that the alarm could not be heard over the noise of an underway engine room. The alarm must be audible over all operating machinery to afford adequate protection to the crew.
- D.1.5. Operating levers, selector valves, etc. should be properly identified. Operating instructions should be examined.
- D.1.6. Switches for automatic shut down of ventilation should be operated.
- D.1.7. It should be verified that all openings into the space are capable of being secured.
- D.1.8. Check operating instruction book.

D.2.

INSPECTIONS FOR CERTIFICATION

- D.2.1. Weigh cylinders. Recharge if weight loss exceeds ten percent of charge.
- D.2.2. Predischarge alarm should be checked and test operated if necessary. The alarm should be audible throughout the space with the machinery operating.
- D.2.3. Compliance with items (1.2)) (1.6) and (1.7) above should be assured.
- D.2.4. Operating instructions should be in place and legible.
- D.2.5. Determine age of cylinders. If over 12 years old, cylinder should be discharged and hydrostatically tested. See 46 CFR 147.04-1(a). However, if cylinders are 5 years old or older and found underweight by D.2.1, then hydro must be conducted at the time cylinders are removed for recharging. Owners often have service contracts with carbon dioxide equipment manufacturers for maintenance of the system. A joint inspection is desirable, but does not relieve the Coast Guard of responsibility.
- D.2.6. If under D.2.5. any cylinders or piping are required to be inspected, then all flexible connections between the cylinders and the piping shall be renewed or subject to a pressure test of 1,000 pounds per square inch.
- D.2.7. Visually check all distribution lines for disformation, missing discharge heads, blanks, and breaks.