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NAVIGATION AND VESSEL INSPECTION CIRCULAR NO.

Subj: CARBON DIOXIDE FIRE EXTINGUISHING SYSTEM SAFETY

1. PURPOSE. This Circular provides safety information for personnel performing repairs, testing and maintenance on installed carbon dioxide fire extinguishing systems and equipment.

2. DIRECTIVES AFFECTED. None

3. BACKGROUND. Coast Guard-approved carbon dioxide fire extinguishing systems are very effective for the protection of shipboard machinery spaces and cargo holds. The concentration of carbon dioxide needed to extinguish fires, however, exceeds the level to which humans can be safely exposed. There have been a number of casualties where crewmembers and inspectors have died as the result of an inadvertent operation or malfunction of a carbon dioxide system while the system was being serviced. The casualties occurred as a result of varying root causes; however, most of them could have been avoided if the personnel involved were more familiar with the design and operation of approved carbon dioxide systems and had followed pre-planned safety precautions. The purpose of this Circular is to alert marine industry personnel to the risks involved with carbon dioxide fire extinguishing equipment, and to recommend basic safety guidelines whenever system testing or repairs are being performed.

4. IMPLEMENTATION. Enclosure (1) is a generic safety guide for persons performing inspection, testing, maintenance or repair of installed carbon dioxide fire extinguishing systems. Officers in Charge, Marine Inspection, are encouraged to bring this Circular to the attention of appropriate individuals in the marine industry within their zones. Coast Guard personnel routinely exposed to installed carbon dioxide extinguishing systems should become familiar with this circular and apply the recommended safety procedures, as necessary, in their regular work activities.

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SAFETY GUIDE FOR INSTALLED CARBON DIOXIDE FIRE EXTINGUISHING SYSTEMS

1. INTRODUCTION. This safety guide is provided for persons witnessing or performing testing, maintenance, repair or other service work on installed carbon dioxide fire extinguishing systems. It is generic in nature and is not intended to supersede any Federal or local safety regulations or manufacturer's instructions. It is provided as supplemental information for personnel to evaluate the safety of individual workplace conditions aboard vessels. In addition to the safety information contained in this guide, a sample checklist is provided that may be used to verify the completeness of the evaluation. The guide covers high-pressure carbon dioxide systems where the extinguishing agent is stored in Department of Transportation (DOT) approved cylinders. This guide also addresses low-pressure systems, however the specialized nature of these systems makes it very important that approved manufacturer's instructions be obtained before beginning work on them.

2. HEALTH HAZARDS OF CARBON DIOXIDE. Carbon dioxide is a colorless, odorless atmospheric gas. When used in fire extinguishing systems, the gas is liquefied and either stored in DOT approved cylinders at a high pressure or in a large refrigerated American Society of Mechanical Engineers (ASME) approved pressure vessel at a lower pressure. At 70° F (21° C), high-pressure carbon dioxide cylinders are under a pressure of approximately 850 psi (5860 kPa). Refrigerated low-pressure systems maintain their supply of carbon dioxide at 0° F (-18° C), at a pressure of 300 psi (2069kPa). When released into the protected space, each pound of carbon dioxide liquid expands to form approximately nine cubic feet (0.254 cubic meters) of carbon dioxide gas at ambient temperature. Carbon dioxide gas is 1.5 times heavier than air of the same temperature.

Carbon dioxide gas is present in the atmosphere at a concentration of approximately 0.03 %. Shipboard fire extinguishing systems are designed for a minimum concentration of 34 %. If humans are exposed to elevated levels of carbon dioxide, an increase in respiration rate will happen when the concentration of carbon dioxide exceeds 3 %. The increase in breathing rate will continue until a level of approximately 6 to 7% is reached. A carbon dioxide concentration of 6 to 7% is considered the maximum level that humans can be exposed to without harmful effects. Exposure to concentrations approaching 9 to 10% will cause a rapid decrease in the breathing rate, resulting in unconsciousness and ultimately death. Because the quantity of carbon dioxide required for fire extinguishing systems is well above that required to cause serious injury or death to humans, spaces that are protected by such systems must be evacuated before the extinguishing agent is released. Careful attention must also be paid to areas where carbon dioxide could be inadvertently discharged. On marine systems, the agent storage containers are typically located in a separate storage room outside the protected spaces, and the extinguishing gas is piped to the protected spaces. If a malfunction occurs that releases carbon dioxide into the storage room or if a leak occurs in another intermediate area, dangerous carbon dioxide concentrations could result.

When carbon dioxide is discharged, part of the liquid forms a vapor while some of the liquid converts to snow or dry ice. The temperature of the dry ice is around -110° F (-79° C). If the dry ice comes into skin contact it may result in a “frost-burn” type injury. Personnel should be instructed not to handle any residual snow or dry ice which might remain after a system discharge.

3. SYSTEM DESIGN CONSIDERATIONS. When carbon dioxide systems are installed and maintained in accordance with their Coast Guard approved design manuals and system drawings, they are considered very safe and reliable. Problems have occurred when the systems are improperly tested or are field modified or incorrectly returned to operation after servicing. To prevent these problems, all personnel that are involved with maintenance and testing of carbon dioxide systems should have a basic understanding of their design, and of how the remote releasing controls are intended to operate.

The most common types of carbon dioxide systems encountered on inspected vessels are high pressure system that consist of a bank of 100 pound cylinders connected to a common manifold. The manifold connects to the discharge piping and nozzles in the protected space. These systems are generally installed for the protection of spaces such as paint lockers, generator rooms, main and auxiliary machinery spaces and cargo holds. Very large areas, such as ro-ro decks, are usually protected by low pressure type carbon dioxide systems, described below. Low pressure systems are mainly used when a significant quantity of extinguishing agent is needed.

Coast Guard design criteria for both types of systems typically require two separate manual actions to discharge a system. Automatic release is permitted only on “small systems,” which protect a maximum hazard of 6,000 cubic feet (145 cubic meters). The manual discharge actions consist of operating two manual pull cables or two pressure operated controls from a remote release station. The remote releasing controls function only to release the system. If the controls are operated, the system discharge cannot be terminated from the remote release station.

On high pressure systems, one remote control operates the discharge heads on the pilot cylinders. Most systems have two pilot cylinders that provide the primary gas pressure to release the remainder of the cylinders connected to the manifold. Operation of the remote release causes the discharge of the carbon dioxide in the pilot cylinders into the manifold. The pressure builds up in the manifold and backfeeds into the other connected cylinders, causing their discharge. There is no other way to release the main cylinder bank. The manifold holds the carbon dioxide until the other remote release is operated to open the manifold stop valve. When the stop valve is opened, the agent in the manifold is released into the discharge piping. The normally closed stop valve is located on the discharge side of the cylinder manifold. Both manual controls must be operated to discharge the system. Thus, if one control is accidentally operated the carbon dioxide may fill the manifold, but will not pass the normally closed stop valve.

On systems where more than one space is protected by a common system, multiple stop valves or selector valves are installed on the manifold to admit the agent to the protected spaces. When the

system controls are operated, one discharges the cylinders into the manifold, and the other opens only the stop valve to the space where the fire is located. The stop valves for the unaffected spaces remain in the closed position to prevent the inadvertent discharge of carbon dioxide into these areas

For the safety of the occupants of the protected spaces, two additional safety features are required: a time delay device and a pre-discharge warning siren. Both of these devices are located in the system between the manifold and the stop valve. They are activated when the cylinder control is operated. The time delay is a carbon dioxide pressure-operated device that is installed in the manifold to cause a delay of at least 20 seconds before the agent is released, even if the stop valve is operated. The pressure operated warning sirens are arranged so that gas pressure is supplied to the sirens to warn personnel in the protected space of the imminent discharge during the time delay cycle, and allow evacuation before the discharge of agent commences. Note that on vessels where multiple hazards are protected, the warning sirens will only sound in the affected space. There are no valves between the manifold and the sirens.

There are many variations between manufacturers in the design of their high pressure systems and approved releasing controls. Some systems use only pull cables which mechanically open the agent pilot cylinders, while others may use remote pressure operated controls, where gas pressure from small releasing cylinders cause the pilot cylinder valves and system stop valve to open. Almost all systems use two main agent cylinders as pilot cylinders. The pilot cylinders are operated by direct connection to the remote releasing controls. The pilot cylinders and stop valves must also be capable of local manual control in the event the remote controls do not function properly. The remainder of the cylinders connected to the manifold can only be released by the pilot cylinder gas pressure backfeeding from the manifold.

Low-pressure systems consist of a large storage tank that is kept at 0° F by a refrigeration system. A manually operated tank shutoff valve and a master valve are installed on the discharge manifold. The tank shutoff valve is normally locked open except during system servicing. The master valve is normally closed and is operated by the remote manual release stations. One or more selector or stop valves are installed in the discharge piping downstream of the master valve. The selector valves direct the carbon dioxide flow into the correct protected spaces. Each selector valve is operated by a remote manual release control. Low pressure systems have two manual controls at each remote release station. One control opens the master valve, permitting carbon dioxide pressure to flow into the manifold up to the selector valves. Operation of the second control typically supplies pressure to the warning sirens in the affected space, pressure operated switches to stop ventilation fans and fuel pumps and the pre-discharge time delay. After the time delay cycle is completed, the gas pressure is then applied to the operating mechanism of the selector valve, causing it to open and discharge carbon dioxide into the protected space. Because low-pressure systems are usually designed for the protection of multiple spaces, the quantity of agent discharged will vary between the protected spaces. The pneumatic timer for each selector valve also includes a discharge timer which keeps the selector valve open for a pre-determined length of time and then automatically closes the selector valve. To permit discharge of the system in case of failure of the normal control devices, both the master valves and the selector valves are equipped with devices which by-pass the normal operating mechanisms and

directly cause discharge of carbon dioxide into the protected space. Over the years, various control arrangements have been used for low pressure systems. Many variations can be found still in service; it is therefore essential for the service technicians to fully understand the operation of the system before beginning work.

4. SAFETY CONSIDERATIONS. Whenever carbon dioxide systems are taken out of service for testing or recharge, strict safety precautions must be followed to prevent the possibility that individuals performing or witnessing the activities are placed at risk. The following paragraphs offer general safety recommendations to avoid accidental exposure to personnel. Because each carbon dioxide system is engineered for the particular vessel on which it is installed, it is difficult to envision all possible safety risks. This guide provides general information that should be considered and applied on a case-by-case basis.

- Most accidents related to the testing or recharge of installed carbon dioxide systems are attributable to personnel errors. It is therefore critical that all persons working on the system must be fully knowledgeable in its operation and repair. The service technicians should be able to demonstrate previous experience with marine carbon dioxide systems, and in particular must be knowledgeable with the specific components and equipment used on the installed system. Factory training or approval as a factory authorized service agent by the manufacturer of the system is recommended.
- If the system protects multiple spaces, be aware of the possibility of split discharges. In some instances, stop valve failures or crossed releasing controls have resulted in the discharge of carbon dioxide into the wrong protected space. As a precaution, personnel must be evacuated from all of the protected spaces, not just the space being tested. This consideration is particularly important for low pressure systems, where the agent storage tank typically remains connected to the discharge piping during servicing. High pressure systems where the cylinders are disconnected from the manifold do not pose a similar risk.
- All personnel must be evacuated from the protected spaces while any service, however minimal, is performed. Only trained personnel wearing self contained breathing apparatus (SCBA), should be permitted in the protected spaces, if absolutely necessary. Despite taking all precautions when servicing a system, there is always a possibility of a component malfunction that could result in a system release. In cases where the agent storage tank or high pressure cylinders are completely disconnected from the manifold before testing, the need for evacuation should be determined on a case-by-case basis. Generally, extinguishing systems are tested in port while other maintenance activities are being performed on the vessel. During these maintenance activities, timely evacuation from the protected spaces may be hindered by temporary equipment stowed in the passageways, or because the work is being performed in the bilges or in other restricted locations. By removing all personnel from the protected spaces before work is begun, the chances of a life threatening accident are limited. Consideration should also be given to areas where the carbon dioxide could leak. Because it is heavier than air, the gas will travel to the lower levels of the vessel.

- Establish and implement a plan to prevent personnel entry into the protected spaces until testing is completed and the spaces have been ventilated and determined to be safe for human occupancy. There have been cases where personnel have entered the protected spaces without knowing that a test was in progress. There have also been cases where persons have entered the protected space immediately after testing was performed not realizing the atmosphere inside the space was still hazardous. It is recommended that readily apparent warning notices be posted at each entrance to the protected spaces until the testing is completed.
- Before beginning, determine that a means of communication is available to summon help if it is needed. Confirm that the means of communication is operable and effective throughout the areas where personnel will be stationed. Anytime work is being performed on a carbon dioxide system, the master or person in charge should be notified of the type of service being performed and the number of people participating. The service technicians should have their own set of radios and it is strongly suggested that a member of the crew with a ship's radio be present whenever servicing is performed.
- Provide ready access to self-contained breathing apparatus. If there is an accidental release, the SCBA may be needed for escape, or could be necessary to rescue persons overcome by the carbon dioxide. An adequate number of SCBA should be provided for all test personnel. Before any work is begun, the SCBA should be verified functional, and the involved test personnel should be instructed on how to use the equipment.
- Determine what shipboard equipment will be disabled or operated if the system discharges. Carbon dioxide systems are typically fitted with pressure operated switches located on the manifold to shut down operating equipment that could prevent the fire from being extinguished. Usually this includes ventilation fans and fuel pumps. In some cases, the extinguishing system may secure the generators, in which case electrical power and lighting will be lost. There also may be power-operated doors that are closed, which could affect a ready escape from the area. Before conducting any work, it is vital to check with the chief engineer to determine what ship's equipment will be shut down by the testing. It may be necessary to have the ship's electrician disconnect the interlock circuits before beginning the work. Any ship's circuits that are disconnected during the servicing must be re-connected and functionally tested when the servicing is completed to ensure the extinguishing system is operable.
- Before beginning, evaluate the location of the agent storage room and plan an escape route. If a valve or component on the manifold fails during testing or servicing, the agent storage room could rapidly fill with carbon dioxide. Because systems are sized to protect areas much larger than the storage room, the release of even one cylinder could form a lethal concentration. Evaluate the width of the passageway or doors that must be passed in order to exit the storage room. If escape is through watertight doors, they should be fully undogged and secured open. The door from the storage room should swing out or should be secured in the open position. The release of carbon dioxide in a small room could cause a pressure increase of up to 0.5 psi (3.5kPa). When applied over the surface area of a standard door, the

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pressure increase will require a door opening force of around 1400 pounds (6200 Newtons). Thus it is not possible for a person in the room to open an inward swinging door if it is closed. Also consider that carbon dioxide gas is heavier than air and will travel to and remain in low-lying areas. If the escape path is through such areas, SCBA should be readily available.

- The overall condition of the system should be evaluated before beginning any work. The service technicians should evaluate the physical condition of the equipment and should also carefully observe the installed configuration of valves and control heads. It is possible that previous service work may have installed the control heads incorrectly on the pilot cylinders or connected the releasing controls to the wrong stop valves. Any non-standard components should be carefully scrutinized. Rust and corrosion of the cylinders may indicate the potential for leakage or rupture if they are disconnected and moved. The cylinder brackets and piping supports should be checked to see that the equipment is properly restrained and will not fall during servicing. Any improperly installed equipment must be evaluated for its potential to release the system before servicing begins. Check the labeling and arrangement of all controls and stop valves to verify that the protected space is correctly identified and the controls are properly matched to the correct devices. Before the remote pull cables are disconnected from the stop valves for servicing, they should be field labeled with the name of the space protected to prevent confusion when they are re-installed.
- Protect exposed high pressure cylinder valves. When the cylinder releasing controls are serviced, it is necessary to remove the control heads from the pilot cylinder valves. The cylinder valves have a central piston or gas release plunger that is pushed down by the control head to discharge the carbon dioxide. When the control head is removed, the plunger is exposed and the carbon dioxide in the cylinder will discharge into the storage room if the piston is pushed down or accidentally struck. Protective safety caps are provided to avoid this, and should be used to replace the control heads whenever they are disconnected from the pilot cylinders.
- Disconnect all high-pressure cylinders from the manifold if the system distribution piping is to be pressure tested, or if an actuation test will be performed. Generally the system piping will be visually checked to ensure that there are no internal obstructions. The servicing agency may also blow air or gas from a small carbon dioxide cylinder through the piping to verify that the nozzles are clear. The actuation sequence of the system may also be tested by flowing a small quantity of carbon dioxide into the control piping to verify operation of the alarms and pressure switches. Because the valves on the carbon dioxide cylinders are pressure-operated, the introduction of this small amount of gas pressure into the manifold could cause the complete discharge of the system. Also note that the warning sirens are directly connected to the manifold. If the piping to the siren is pressurized it could also discharge the system.
- On low-pressure systems, verify that the tank shutoff valve is closed during testing. A small quantity of carbon dioxide is released into the manifold prior to conducting the service tests. It is important to verify that the mechanically operated tank shutoff valve is completely

closed after the manifold has been filled with the test pressure. This valve should be carefully examined to ensure that is properly assembled and installed such that it can be completely closed for testing purposes.

- Verify that all control heads are correctly re-installed after the work is completed. As noted above, the control heads have a central rod or plunger that pushes a piston down to open the cylinder valve. If the rod in the control head is not correctly positioned when the head is replaced onto the cylinder, it will cause the system to discharge when the lock nut is tightened. Most equipment requires the pilot cylinder control heads to be connected to the pull cables in only one configuration to be operable. Because the control heads are not marked “open” or “closed,” a factory manual should be used to verify that all of the control equipment is correctly re-installed, and the system is left in an operable condition. Gas pressure-operated valves should be checked to ensure that the releasing lines are connected to the correct valve port.
- Verify that all stop valve or selector valve remote release controls are connected to the proper valves. It is particularly important to verify that stop valves are connected to the remote release controls for the space protected. Coast Guard regulations require all valves to be marked to indicate the spaces that are protected. On systems that protect multiple spaces, there is one agent supply connected to a manifold with multiple stop valves or selector valves that direct the flow of carbon dioxide to the protected spaces. If the remote releasing controls for the protected spaces are not connected to the correct stop valves, the agent will discharge into the wrong area if a fire occurs. If this happens, there may be no warning to the occupants, and a lethal concentration of agent could be rapidly reached, depending on the difference in volume between the two areas.
- If an accidental release occurs, immediately evacuate and do not re-enter the spaces affected until they have been ventilated and tested for an adequate oxygen concentration. If a release occurs, go immediately to a space that is not connected to the area where the carbon dioxide was released. It is preferable to evacuate to an on-deck open area. Do not allow anyone to re-enter the protected space without wearing an SCBA. Seek prompt medical attention for anyone exposed to the discharge, even if they appear to have recovered and are breathing normally. Both oxygen and carbon dioxide meters must be used to ensure the space is habitable before re-entry. Specifically test low-lying areas such as the bilges.

**INSTALLED CARBON DIOXIDE SYSTEM SERVICE SAFETY
CHECKLIST**

VESSEL
NAME _____

DATE OF
SERVICE _____

MANUFACTURER OF
SYSTEM _____

LOCATION OF PROTECTED
SPACES _____

NAMES OF
TECHNICIANS _____

PRE-SERVICE CHECKS

- The service technicians have demonstrated evidence of an adequate level of training and experience in this manufacturer's equipment.
- An approved system drawing and a factory manual are available for use during the work, and are understood by the technicians.
- All personnel have been evacuated from the protected spaces and warning signs or other means are posted at each door to prevent unauthorized re-entry until the atmosphere is declared safe for occupancy.
- The Master or person in charge has been notified that the service is about to begin and is expected to finish at approximately _____.
- Radios or other means of communication are readily available for the service technicians to contact the bridge. The radios have been tested from the both the cylinder room and the protected space and are operable.

- An adequate number of self-contained breathing apparatus are available. Each SCBA has been verified functional. All testing personnel have received instruction and have demonstrated proficiency on the use of the equipment.
- The related shipboard systems that are shut down by the extinguishing system have been verified and determined not to impact the work or prevent escape from the area. Emergency or portable lights are available if needed.
- A clear path of escape from the cylinder room or work area has been established. All necessary doors have been secured in the open position. No automatically closing doors are in the escape path.
- The overall system condition has been checked and found acceptable before starting work. Cylinders and piping are securely mounted.
- All components are factory approved. No after-market or altered devices observed.
- All releasing controls and associated stop valves are correctly identified as to the spaces protected.
- All of the pilot cylinder control heads and stop valves are properly installed.
- If the discharge piping, time delay, or warning sirens are to be pressure tested, the high pressure cylinder bank has been disconnected from the manifold.
- Protective safety caps are available to replace cylinder valve control heads.

POST-SERVICE CHECKS

- After the work is completed, verify that the system has been returned to service. All releasing controls are properly installed. All of the pilot cylinder heads and stop valve controls are in the correct or “set” position.

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- All manual pull cables have been checked to verify that the proper stop valve has been coordinated with the correct remote release control.
- All system release labels and warnings have been verified correct.
- All electrical circuits disconnected for testing have been re-connected and verified functional.
- All piping connections between the cylinder discharge heads and the manifold have been verified to be correctly tightened.
- On low pressure systems, the tank shutoff valve is verified locked in the full open position.