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**TRANSFILLING AND
SAFE HANDLING OF SMALL
CARBON DIOXIDE CYLINDERS**

THIRD EDITION

CGA

Compressed Gas Association

The Standard For Safety Since 1913



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NOTE—Technical changes from the previous edition are underlined.

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1 Introduction

This publication is one of a series compiled by the Compressed Gas Association, Inc. to satisfy the demand for information on the production, handling, storage, transportation, and use of compressed and liquefied gases, cryogenic liquids, and related products.

2 Scope and purpose

This publication covers the filling of small carbon dioxide cylinders having a maximum capacity of 110 in³ (1.80 L) of water. Its primary purpose is to provide information to personnel engaged in transfilling, handling, and transporting small carbon dioxide cylinders that have been transfilled from another uninsulated cylinder.

WARNING: All persons handling pressurized carbon dioxide shall follow appropriate Occupational Safety and Health Administration (OSHA), U.S. Department of Transportation (DOT), and local regulations and shall be properly trained. Failure to follow proper procedures in handling compressed gases can cause serious injury or death.

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 Can

Indicates a possibility or ability.

3.1.4 May

Indicates that the procedure is optional.

3.2 Technical definitions

3.2.1 Authorized retester

Facility registered with and approved by DOT and/or Transport Canada (TC) for the requalification of cylinders or containers.

3.2.2 Bar

Metric unit of pressure, 1 bar = 100 kPa.^{1, 2}

NOTE—1 bar is equal to approximately 14.5 psi. To convert psi to bar, multiply by 0.06895.

3.2.3 Blow-down valve

Valve used to depressurize lines or systems.

3.2.4 Capacity

Maximum weight of carbon dioxide a cylinder holds when filled to the proper level.

¹ kPa shall indicate gauge pressure unless otherwise noted as (kPa, abs) for absolute pressure or (kPa, differential) for differential pressure. All kPa values are rounded off per [CGA P-11](#), *Metric Practice Guide for the Compressed Gas Industry* [1].

² References are shown by bracketed numbers and are listed in order of appearance in the reference section.

3.2.5 Composite cylinder

Cylinder manufactured with a combination of metal and fiber-reinforced plastic resin to withstand the internal pressure.

3.2.6 Condemned cylinder

Cylinder no longer fit for service.

3.2.7 Fill weight

Weight of cylinder, valve, hose, and carbon dioxide in the cylinder.

3.2.8 Filling density

Ratio between the weight of the contents in a cylinder compared to the weight of its water capacity.

3.2.9 Gross weight

Weight of an empty cylinder and valve assembly plus the weight of carbon dioxide when filled.

NOTE—This is the cylinder tare weight added to the contents weight without the hose attached.

3.2.10 Hydrostatic test

Procedure that measures the expansion of a cylinder pressurized with water to a given pressure.

3.2.11 Liquid carbon dioxide

Carbon dioxide that exists as a liquid only at pressures between 60.4 psi and 1055.9 psi (416 kPa and 7280 kPa) and temperatures between -69.9 °F and 87.9 °F (-56.6 °C and 31.1 °C).

3.2.12 Net weight

Maximum allowable carbon dioxide capacity.

3.2.13 Receiving cylinder

Uninsulated cylinder into which carbon dioxide is transferred.

3.2.14 Service pressure

Rated pressure marked on a cylinder.

3.2.15 Supply cylinder

Cylinder from which liquid carbon dioxide is withdrawn for the purpose of filling small cylinders.

3.2.16 Tare weight

Indicates the cylinder weight including the valve and any other permanent attachments, but not the contents;

NOTE—This is marked as the T mass on TC cylinders. See CSA B339, *Cylinders, Spheres and Tubes for the Transportation of Dangerous Goods* [2]. For example, TC cylinders would be marked "T ?? kg" where ?? equals the tare weight of the cylinder, including the valve and any other permanent attachments.

3.2.17 Transfill

Process of transferring carbon dioxide from the supply cylinder to the receiving cylinder.

3.2.18 Triple point

Temperature and pressure at which a material exists simultaneously as a solid, liquid, and gas,

NOTE—For carbon dioxide, the triple point is -69.9 °F (-56.6 °C) and 75.1 psia (518 kPa, abs).

3.2.19 Uninsulated cylinder

Cylindrically shaped pressure containing device with a minimum rated service pressure of 1800 psi (12 410 KPa) and a water capacity no greater than 1000 lb (454 kg).

4 Physiology of carbon dioxide

4.1 General

The physiological effects of carbon dioxide are unique because carbon dioxide is a product of normal metabolism, a requirement of the body's normal internal chemical environment, and an active messenger substance in the linking of respiration, circulation, and vascular response to the demands of metabolism both at rest and in exercise.

The respiratory control system maintains carbon dioxide pressure at a relatively high level of approximately 50 mm Hg pressure in the arterial blood and tissue fluids. This maintains the acidity of the tissue and cellular fluids at the proper level for essential metabolic reactions and membrane functions. Changes in the normal carbon dioxide tissue pressure can be damaging. If tissue pressure becomes excessively low, which can occur from hyperventilation, failure of critical neuromuscular function or loss of consciousness can occur.

Inhaled carbon dioxide produces the same physiological effects as metabolically produced carbon dioxide. As the carbon dioxide tissue pressure rises from inhaling carbon dioxide, the body responds by using respiratory and adaptive processes to adjust to the change. These adaptive processes are limited and cannot cope with severe exposures that cause pH change to the body fluids. Toxic effects of carbon dioxide, namely severe and disruptive acidosis, occur when high concentrations of carbon dioxide are inhaled.

Blood and cellular fluids are actually solutions of sodium bicarbonate containing numerous other substances. Severe exposure to carbon dioxide forms carbonic acid in the blood for which the sodium bicarbonate is not a very effective buffer. The decrease in pH has a rapid toxic effect because the neural control systems are driven excessively.

NOTE—These effects are independent of the amount of oxygen in the atmosphere being breathed.

The effects produced by low and moderate concentrations of carbon dioxide are physiological and reversible, but the effects of high concentrations are toxic and damaging [3].

4.2 Physiological effects of carbon dioxide

The response to carbon dioxide inhalation depends on degree and duration of exposure, and it varies greatly even in healthy individuals. The medical term for the physiological effects of excess carbon dioxide in the blood is hypercapnia. Carbon dioxide can be dangerous, even when normal oxygen levels are present. Low concentrations of inspired carbon dioxide can be tolerated for a considerable period without noticeable effect or can merely cause an unnatural feeling of shortness of breath. Sustained exposure to 5% carbon dioxide produces stressful, rapid breathing. When the level of inspired carbon dioxide exceeds 7%, the rapid breathing becomes labored (dyspnea) and restlessness, faintness, severe headache, and dulling of consciousness occur. At 15%, unconsciousness accompanied by rigidity and tremors occurs in less than 1 minute, and in the 20% to 30% range it produces unconsciousness and convulsions in less than 30 seconds. These effects occur quickly because the carbon dioxide diffuses in the tissue fluids at a rate approximately 20 times more rapidly than oxygen. High concentrations of carbon dioxide can asphyxiate quickly without warning and with no possibility of self-rescue regardless of the oxygen concentration.

4.3 Physical effects of overexposure to carbon dioxide

Skin, mouth, or eye contact with solid carbon dioxide (dry ice), which has a temperature of -109.3°F (-78.5°C) can cause severe frostbite, skin lesions, corneal burn, or more serious injury from deep freezing of the tissues. Liquid discharging from a cylinder produces high-velocity carbon dioxide snow particles that are abrasive in addition to being cold and can cause similar injuries.

4.4 Regulatory standard

Carbon dioxide is present in the atmosphere at approximately 0.035% by volume. The OSHA standard for maximum allowable concentration in air in the workplace is 0.5% for 8 continuous hours of exposure. See Title 29 of the U.S. *Code of Federal Regulations* (29 CFR) [4].

4.5 Safety precautions

Appropriate warning signs shall be placed at the entrance to a confined area where high concentrations of carbon dioxide gas can accumulate. A typical warning follows:

CAUTION: CARBON DIOXIDE GAS

Ventilate the area before entering. A high carbon dioxide gas concentration can occur in this area and can cause asphyxiation.

Carbon dioxide monitoring and use of approved entry procedures shall be carried out prior to entering any area in which carbon dioxide gas could accumulate. If carbon dioxide accumulation is suspected, the area shall be cleared by ventilation or a supplied-air respirator worn while in the area.

WARNING: Cartridge-style respirators shall not be substituted for supplied-air respirators.

4.6 Rescue and first aid

Do not attempt to remove anyone exposed to high concentrations of carbon dioxide without using proper rescue equipment, or you can also become a casualty. Rescuers account for more than 60% of confined space fatalities. If the exposed person is unconscious, obtain assistance and use established emergency procedures.

If a person has inhaled large amounts of carbon dioxide and is exhibiting adverse effects, move the exposed individual to fresh air at once. If breathing has stopped, perform artificial respiration. Only qualified personnel shall give oxygen to the victim. Keep the affected person warm and at rest, and get medical attention as soon as possible. Fresh air and assisted breathing is appropriate for all cases of overexposure to gaseous carbon dioxide. With prompt response to a carbon dioxide emergency, recovery is usually complete and uneventful.

If dry ice or compressed carbon dioxide gas comes in contact with the skin or mouth, stop the exposure immediately. If frostbite has occurred, obtain medical attention. Immerse in warm water (100 °F to 105 °F [38 °C to 41 °C]). Do not rub the area.

5 Special hazards

5.1 General

Personnel handling liquid carbon dioxide should be thoroughly familiar with the hazards associated with this product. There are several conditions in which extreme danger to personnel and equipment can exist. The following describes these conditions and offers procedures and guidelines to prevent dangerous conditions from developing.

5.2 Personal protective equipment

Always wear heavy gloves and eye protection while filling cylinders. Contact between exposed skin and cold piping or carbon dioxide vapor can cause frost burns. Dry ice particles formed by depressurizing liquid carbon dioxide are extremely cold and can cause severe damage to unprotected eyes or skin.

5.3 Dry ice blocking or plugging

Dry ice plugs can form inside hoses and piping when liquid carbon dioxide is decreased below its triple point pressure of 60.4 psi (416 kPa). The dry ice can compact into a plug that can trap gas. The pressure behind or within a plug can increase as the dry ice sublimates until the plug is forcibly ejected or the hose or pipe ruptures. A dry ice plug can be ejected from an open end of any hose or pipe with enough force to cause serious injury from its impact or the sudden movement of the hose or pipe as the plug ejects.

Purge liquid carbon dioxide from the hose or pipe before reducing the pressure less than 60.4 psi (416 kPa). This can be done by supplying carbon dioxide vapor to one end of the hose or piping system to maintain the pressure above the triple point while removing the remaining liquid from the other end.