

Contents	Page
1 Introduction.....	1
2 Scope and purpose.....	1
2.1 Scope.....	1
2.2 Purpose.....	1
3 Definitions.....	1
4 Basis.....	3
5 Warning.....	3
6 Properties of carbon dioxide.....	4
7 Temperature and pressure.....	10
8 Physiological effects of carbon dioxide.....	11
8.1 General.....	11
8.2 Effects of inhaled carbon dioxide.....	11
8.3 Physical effects of overexposure to carbon dioxide.....	12
8.4 Regulatory standard.....	12
8.5 Safety precautions.....	12
8.6 Rescue and first aid.....	13
9 Specific hazards.....	13
9.1 General.....	13
9.2 Dry ice blocking.....	13
9.3 Low temperature effects on materials.....	13
9.4 Trapped liquid.....	13
9.5 Overfilling containers.....	14
9.6 Personnel overexposure.....	14
9.7 Thermal expansion and contraction.....	14
10 Hazards of carbon dioxide container repressurization.....	14
10.1 Movement of transportable containers.....	14
10.2 Hazards.....	15
10.3 Specific precautions.....	16
11 Preliminary procedures for returning a depressurized container to service.....	17
11.1 Personnel requirements.....	18
11.2 Provisions for alternate source.....	18
11.3 Depressurized container evaluation.....	18
11.4 Facts to consider in evaluating repressurization methods.....	18
12 Guidelines for evaluation of the condition of a depressurized container.....	20
12.1 Container pressure greater than 200 psi (1380 kPa).....	20
12.2 Container pressure less than 200 psi (1380 kPa) but greater than 60.4 psi (416 kPa).....	20
12.3 Container pressure less than 60.4 psi (416 kPa).....	21
12.4 Special low-temperature containers.....	21
12.5 Uninterruptible applications.....	21
13 Recommended repressurization methods.....	21
13.1 Recommendations and continuous monitoring.....	21
13.2 Carbon dioxide gas pressurization up to 100 psi (690 kPa) (Method 1).....	22
13.3 Recirculation of warmed liquid (Method 2).....	23
13.4 Hot gas warming at no pressure (Method 3).....	25
13.5 Unassisted natural repressurization (Method 4).....	25
14 Repressurization methods—not recommended.....	26
14.1 Transfer liquid carbon dioxide into the container to melt the dry ice and warm the liquid—not recommended.....	26
14.2 Pressure building vaporizer/internal heater method only—not recommended.....	26

14.3	Transferring carbon dioxide vapor into the vapor connection of the depressurized container—not recommended	26
14.4	Remove liquid carbon dioxide from the container and transfer to cargo tanks—not recommended	27
14.5	Manual removal of dry ice—not recommended	27
15	Suggested measures to prevent container depressurization	27
15.1	Backpressure regulating valve	27
15.2	Direct to process vaporizer	27
15.3	Low pressure alarm	27
15.4	Remote monitoring	27
15.5	Diverter valve on pressure relief devices	27
15.6	Pressure relief device discharge piping design	27
15.7	Signage	28
16	References	28
17	Additional references	29

Tables

Table 1	—Physical constants of carbon dioxide	5
Table 2	—Thermodynamic properties of saturated carbon dioxide solid, liquid, and vapor phases (U.S. customary units)	7
Table 3	—Thermodynamic properties of saturated carbon dioxide solid, liquid, and vapor phases (SI units)	9
Table 4	—Carbon dioxide container pressure/wall stress relationships	15
Table 5	—Typical quantities of carbon dioxide and times needed for container repressurization	19

Figures

Figure 1	—Phase diagram for carbon dioxide	6
Figure 2	—Typical caution sign	12
Figure 3	—Examples of incorrect and preferred pressure relief device installations on liquid carbon dioxide piping	14
Figure 4	—Allowable pressure-temperatures in an ASME liquid carbon dioxide container (pre-1976 safety factor 4X)	16
Figure 5	—Allowable pressure-temperature in an ASME liquid carbon dioxide container (pre-1998 safety factor 4X, post-1998 safety factor 3.5X)	16
Figure 6	—Depressurized container evaluation form	18
Figure 7	—Method 1, Step 1 partial reliquification of solid carbon dioxide (dry ice) container pressurization with vapor up to 100 psi (690 kPa)	23
Figure 8	—Recirculation of warmed liquid to 100 psi (1380 kPa)	24

Appendices

Appendix A	—EN pressure vessel material design information (Informative)	30
Appendix B	—ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 Rules for Construction of Pressure Vessels [1] (Informative)	33
Appendix C	—Flow chart for Methods 1 through 4	36

Appendices Figures

Figure A-1	—EN allowable MDMT conditions for a carbon dioxide container being repressurized	30
Figure A-2	—Design reference and impact test temperatures as welded condition for and EN pressure vessel, $310 \text{ N/mm}^2 < R_p \leq 360 \text{ N/mm}^2 : 27\text{J}$	31
Figure B-1	—Allowable MDMT conditions for the carbon dioxide container in this example being repressurized	34
Figure C-1	—Decision process for tank repressurization per Section 12 and 13	36
Figure C-2	—Method 1 repressurization with vapor then Method 2, circulate liquid per 13.2 and 13.3	37
Figure C-3	—Method 3 repressurization by hot warming at no pressure per 13.4	38
Figure C-4	—Method 4 repressurization by natural ambient heat gain per 13.5	39

Appendix Table

Table B-1	—Example on UCS-66 curve selection	34
-----------	--	----