GUIDELINES FOR SEA TRANSPORT OF MULTIPLE ELEMENT GAS CONTAINERS (MEGCS) AND PORTABLE TANKS FOR GASES

AIGA 072/20

(Revision of AIGA 072/11)

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GUIDELINES FOR SEA TRANSPORT OF MULTIPLE ELEMENT GAS CONTAINERS (MEGCS) AND PORTABLE TANKS FOR TRANSPORT OF GASES

As part of a program of harmonization of industry standards, the Asia Industrial Gases Association (AIGA) has published AIGA 072, "*Guidelines for Sea Transport of Multiple Element Gas Containers (MEGCS) and Portable Tanks for Gases*", jointly produced by members of the International Harmonization Council and originally published as EIGA Doc 41 by European Industrial Gases Association (EIGA) as "*Guidelines for Sea Transport of Multiple Element Gas Containers (MEGCS) and Portable Tanks for Gases*".

This publication is intended as an international harmonised standard for the worldwide use and application of all members of the Asia Industrial Gases Association (AIGA), Compressed Gas Association (CGA), European Industrial Gases Association (EIGA), and Japan Industrial and Medical Gases Association (JIMGA). Each association's technical content is identical, except for regional regulatory requirements and minor changes in formatting and spelling.

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Amendments from AIGA 072/11

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	Editorial to align style with IHC associations
3.1	Addition of Publication terminology
3.2.10	Definition of Pressure relief device added
6.6	Holding time amended
6.7	Requirement to mark portable tanks that have a nitrogen shield
Appendix c	Amended for calculation of holding time for filled and discharged tanks

Note: Technical changes from the previous edition are underlined

1 Introduction

This publication provides guidance for the safe sea transport of portable tanks and multiple element gas containers (MEGCs) containing gases of Class 2 that are compressed, liquefied, or refrigerated, see Appendix A.

The publication addresses product characteristics, general safety aspects, preparation for shipment, stowage on board ship, transport of containers, and emergency response.

Normally during sea transport, a skilled operator does not accompany these containers, so this publication has been written for the guidance of parties involved in their preparation and subsequent sea transportation. Compliance with this publication helps ensure their safe transport.

2 Scope and purpose

2.1 Scope

This publication applies to the sea transport of portable tanks and MEGCs that are used in the industrial, medical, and specialty gases industry for the worldwide transport of Class 2 gases.

2.2 Purpose

To provide guidelines for the safe sea transport of insulated and non-insulated portable tanks and MEGCs, to reduce the potential for unintentional releases of the contents for the duration of a defined journey, and to recommend actions in case of an accidental release.

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 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Bundles of cylinders

Assembly of cylinders that are fastened together, are interconnected by a manifold, and transported as a unit. The total water capacity shall not exceed 3000 L, except that bundles intended for the transport of Class 2.3 gases shall be limited to 1000 L water capacity.

3.2.2 Compressed gas

Gas when packaged under pressure for transport is entirely gaseous at –50 °C (–58 °F), this category includes all gases with a critical temperature less than or equal to –50 °C (–58 °F).

3.2.3 Container

Portable tank or MEGC designed for multimodal use and fitted with devices permitting its ready stowage and handling particularly when being transloaded from one mode of transport to another.

3.2.4 Cylinders

Transportable pressure receptacles with a water capacity not exceeding 150L.

3.2.5 Holding time

Time that will elapse from the establishment of the initial filling condition until the pressure has risen due to heat influx to the lowest set pressure of the pressure limiting device(s).

3.2.6 Liquefied gas

Gas when packaged under pressure for transport is partially liquid at temperatures greater than –50 °C (–58 °F). A distinction is made between:

- high pressure liquefied gas, which is a gas with a critical temperature between –50 °C and 65 °C (–58 °F and 149 °F); and

- low pressure liquefied gas, which is a gas with a critical temperature greater than 65 °C (149 °F).

3.2.7 Multiple-element gas containers MEGCs

Multimodal assemblies of cylinders, tubes, and bundles of cylinders, which are interconnected by a manifold and assembled within a framework. The MEGC includes service equipment and structural equipment necessary for the transport of gases. MEGCs may be equipped with pressure relief devices (PRD).

3.2.8 Portable tank

Multimodal tank having a capacity greater than 450 L fitted with service equipment and structural equipment necessary for the transport of refrigerated and non-refrigerated liquefied gases. The portable tank shall be capable of being filled and discharged without the removal of its structural equipment. It shall possess stabilizing members external to the shell and shall be capable of being lifted when full. Road tank vehicles, rail tank-wagons, non-metallic tanks, and intermediate bulk containers (IBCs) do not meet the definition of a portable tank.

3.2.9 Portable tank for refrigerated liquefied gases

Thermally insulated multimodal tank having a capacity greater than 450 L fitted with service equipment and structural equipment necessary for the transport of refrigerated liquefied gases.

This means a construction that normally consists of either:

- a jacket and one or more inner shells where the space between the shell(s) and the jacket is exhausted of air (vacuum insulation) and may incorporate a thermal insulation system and/or a nitrogen shield; or

- a jacket and an inner shell with an intermediate layer of solid thermally insulating material (for example, solid foam).

NOTE 1 The insulation in all systems is designed to reduce heat inleak so that the pressure will not normally rise to the set pressure of the inner vessel PRD during the duration of transport.

NOTE 2 All types of tanks are fitted with pressure gauges, liquid level gauges, and suitably sized PRDs. The gauges are usually located in a control cabinet together with valves, pipework, and couplings used for filling and the emptying operations. In most cases, the main tank PRDs or their outlets are positioned at the top of the portable tank. Control cabinets may be positioned at the end or the side of the portable tank.

3.2.10 Pressure relief device (PRD)

<u>Pressure or temperature activated device used to prevent the pressure in the container from rising greater than a predetermined maximum, thereby preventing rupture of the container.</u>

NOTE—The term PRD is synonymous with safety relief device as used in various applicable regulations, codes, standards, or specifications.

3.2.11 Pressure relief valve (PRV)

Type of PRD designed to relieve excess pressure and to reclose and reseal to prevent further flow of fluid from the container after resealing pressure is achieved.

NOTE It is characterized by a rapid opening pop action or by opening generally proportional to the increase in pressure over the opening pressure.

3.2.12 Refrigerated liquefied gas

Gas which when packaged for transport is made partially liquid because of its low temperature.

3.2.13 Tube

Seamless transportable pressure receptacles of seamless of composite construction having a water capacity exceeding 150 L but not more than 3000 L.

4 Product characteristics

If there is a product release, the following should be considered:

4.1 Volume of liquefied gases

When liquefied gases evaporate, they will produce approximately 700 to 800 times its volume in gas.

4.2 Gas release

A gas release can go unnoticed because some gases that are transported can be odourless, colourless, and/or non-corrosive. They can act as an asphyxiant in confined spaces. Care shall be taken in case of flammable or toxic gases. See Section 9.

In free air gases will disperse readily. When refrigerated liquefied gases are released into the air, their low temperature usually causes water vapour in the air to condense forming a fog.

4.3 Liquid spillage

Severe cold burns to personnel or cracking of certain materials particularly carbon steel, for example, ships deck plates, can be caused by liquid spillage or improperly controlled venting.

5 General safety aspects

5.1 Personal protection

If there is a requirement to operate the container during transit, as a minimum, the following personal protective equipment and clothing shall be worn:

- eye protection;
- thick gloves; and
- natural fibre clothing or flame-resistant clothing. Synthetic materials are not recommended.

5.2 Emergency response information

Relevant written information concerning the product should be made available to the shipping line. As a minimum, this should include a contact address/telephone number for technical assistance and any other information required by the mode of transport. For example, the *International Maritime Dangerous Goods Code* (IMDG Code) contains the Emergency Schedules (EmS) section, which details the emergency response procedures for ships carrying dangerous goods [1] [1].

5.2.1 Operating instructions

Each container shall have a flow sheet permanently displayed adjacent to the operating valves. This shall clearly identify the designation and function of each valve.

6 Preparation for shipment

The consignor should provide a written document (checklist) indicating the conditions that should normally apply during transportation. An example of a typical document for a portable tank is shown in Appendix B.

When preparing a checklist consideration should be given to the type of container design and product, for example, nitrogen shield, fire abatement systems, etc.

The consignor and/or operator should complete the pre-trip section of the checklist. This checklist should accompany the container throughout its journey. It is also necessary to carry out operations/checks as described in 6.1 through 6.7.

Shore-based personnel engaged in the transport of dangerous goods by sea shall receive training commensurate with their responsibilities.

6.1 Periodic tests

Ensure that the container is approved for the required mode of transport and that the approval period will not expire before the anticipated completion of the journey.

6.2 Placarding

Ensure that placarding is in compliance with the relevant marking and labelling requirements.

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

6.3 Marking/data plates

Every portable tank and MEGC shall be fitted with a corrosion resistant metal data plate attached to the container in a conspicuous place readily accessible for inspection. Data plate marking shall be in compliance with the relevant regulations and shall include the date and type of the most recent periodic test, the last International Convention for Safe Containers (CSC) test, and the due date of the next CSC test. The MEGC will also have tube or cylinder retest information on the data plate.

6.4 Emergency contacts

An emergency telephone number shall be clearly displayed on the portable tank or MEGC and shall also be available on the ship.

6.5 Leak test

Ensure that after filling, all valves (except pressure gauge and level gauge isolation valves) are securely closed and that blanking caps or secondary closures are fitted to all fill/discharge couplings with the exception of all PRDs.

Particular attention should be paid to internal leakage across valves, for example, vaporiser supply valve, by checking for frost formation.

6.6 Holding time

Ensure that the pressure of the contents of the portable tank is reduced to a level so the anticipated pressure rise for the duration of the trip will not exceed the set pressure of the vessel PRDs. Based on the actual values of the density and the pressure, the actual holding time shall be calculated for the journey and marked on the portable tank. An example of a calculation to determine the holding time is given in Appendix C.

If the actual holding time is shorter than the expected duration of the journey, the container shall not be transported and the gases industry or their designated operators shall be contacted.

Where venting of product is required, this should be carried out in a safe, well ventilated area, and in a controlled manner under the supervision of a trained operator.

Guidance on methods to prevent the premature activation of relief devices on transport tanks is given in EIGA Doc 184, *Methods to prevent the premature activation of relief devices on transport tanks* [2].

6.7 Insulation shields

Where a nitrogen shield is fitted, ensure the liquid nitrogen level is adequate for the planned trip and the liquid nitrogen pressure is within specified limits as detailed in the checklist.

There shall be a mark on the portable tank adjacent to the nitrogen vent indicating that nitrogen can vent during normal operation. For example, "Nitrogen venting during normal operation".

6.8 Visual checks

The container shall be inspected for in transit damage with particular attention to:

- structural damage to the frame and support members;
- damage that could lead to loss of vacuum;
- damage to twist locks or corner castings and/or tie down points;
- damage to cabinet that could prevent opening of doors or operation of control components;

- damage to control valves, pipework, vaporisers, etc., that could lead to product spillage; and
- damage, loss, or illegibility of data plate.

7 Stowage on board ship

The IMDG Code specifies the requirements that have to be met for on board stowage [1]. However, some advice from the owner or agent should be given to reinforce IMDG requirements or aspects that are not obvious. The following are examples and not a complete list of advice that could be given to the shipping company:

- Stow in a well-ventilated area on deck;
- Stow at a level where instruments can be viewed;
- Arrange lashing so cabinet doors can be opened in an emergency;
- Do not terminate vents near human occupied spaces or structural parts of a ship or near other cargo that can be affected by any release; and
- Stow portable tanks containing refrigerated liquefied gases on deck. This precaution is to prevent the possibility of asphyxiation due to a release of contents within a confined space (below deck).

8 Transport of empty containers or containers with residual product

Containers with residual product are not considered empty and shall meet the same rules for transport unless specific agreements exist with the relevant competent authorities. For shipping purposes, a container is only considered empty if it has been completely purged of any hazardous product and it is less than 2 bar at 20 °C (29 psi at 68 °F) this only applies to gases of Class 2.2 other than refrigerated liquefied gases and meets any applicable regulatory requirements for an empty container.

9 What to do in the case of release of product

9.1 Release of gas

Initially, the leaking gas should be identified. The potential hazards can then be established from the appropriate hazard communication information (for example, EmS, Properties and Observations, safety data sheet (SDS), instructions in writing, portable tank marking, shipping document, etc.). If the name of the gas cannot be readily identified by the person at the scene, it is recommended that the container is observed from a safe distance for other possible identifying marks or labels.

Persons not wearing self-contained or supply air breathing apparatus and other personal protective equipment should not approach the leaking container unless than content of the container is known and necessary precautions are taken. If it is not possible to identify the leaking gas, then it is recommended that it should be assumed to be toxic and flammable.

The severity of the leak should be established, for example, whether the leak is audible, if it is fuming and if so, how much.

All gases except air and oxygen represent a potential asphyxiation hazard if leaking into a confined or poorly ventilated area. See AIGA 008, *Hazards of inert gases and oxygen depletion* [3].

Oxygen enrichment of the atmosphere can lead to a fire because most materials burn fiercely in oxygen. As the oxygen concentration in air increases the potential fire risk increases. Areas where there is a risk of oxygen enrichment of the atmosphere shall be well ventilated. See AIGA 005, *Fire hazards of oxygen and oxygen enriched atmospheres* [4].

If the leaking gas is toxic, then people should be kept away, preferably upwind. The toxic gas leak shall not be approached by unprotected people.

If the leaking gas is flammable, then efforts should be made to ensure the area remains well ventilated and to eliminate ignition sources from the vicinity.

In addition to the previous items, a Multimodal Dangerous Goods Form should list emergency schedules contained in the IMDG Code supplement (for example, fire and spillage schedules).

9.2 Release of vapour from portable tanks containing refrigerated liquefied gases

PRDs on portable tank are sized for adequate pressure release even under fire engulfment conditions. Thus, they are suitably sized for any other increase in heat inleak, for example, pressure increase caused by loss of vacuum.

While the operation of PRDs can be accompanied by a lot of noise, it does not necessarily indicate an emergency situation.

Controlled venting of gas via the vent system can stop operation of the PRDs. Only trained personnel should perform this procedure. Without manual venting, intermittent operation of the PRDs can be expected.

Secondary hazards of vapour release should also be considered (for example, asphyxiation or oxygen enrichment in the case of a confined space). Portable tanks containing refrigerated liquefied gases shall be stowed on deck. This precaution is to prevent the possibility of asphyxiation due to a release of contents within a confined space (below deck).

Precautions shall be taken to prevent cold vapour releases from impinging on the container, the ISO frame, or structural members of the ship because this can lead to material embrittlement and failure in certain conditions.

9.3 Release of refrigerated liquid

Avoid contact with the skin as refrigerated liquids cause cold burns. See also Section 5.

Low temperatures of steel structures can cause embrittlement and subsequent cracking.

The primary objective is to avoid embrittlement of important steel structures either by diversion of cold liquid flow or by maintaining the temperature of the steel, for example, applying large amounts of water.

10 Security

Security is an integral part of the compressed gas industry culture. Safety and security measures protect facilities, employees, and the community by reducing the risk of a wide range of vulnerabilities and mitigating the effects of incidents such as vandalism, sabotage, workplace violence, theft/misuse of product, and terrorism.

The potential theft and diversion of compressed gases is an ongoing concern. Compressed gases have been obtained for illegal drug use, for the manufacture of illegal drugs, and for potential terrorist activities. Compressed gas containers should be properly secured to prevent theft for illegal activity.

Security incidents such as successful or attempted theft or diversion (misuse of package or product) of product or equipment should be immediately reported to local management and, if warranted, to local law enforcement authorities.

11 References

[1] *International Maritime Dangerous Goods Code,* International Maritime Organization. www.imo.org

[2] EIGA Doc 184, *Methods to Prevent the Premature Activation of Relief Devices on Transport Trucks,* European Industrial Gases Association. www.eiga.eu

[3] AIGA 008, *Hazards of Oxygen-Deficient Atmospheres,* Asia Industrial Gases Association. www.asiaiga.org

NOTE This publication is part of an international harmonization program for industry standards. The technical content of each regional document is identical, except for regional regulatory requirements. See the referenced document preface for a list of harmonized regional references.

[4] AIGA 005, *Fire Hazards of Oxygen and Oxygen Enriched Atmospheres,* Asia Industrial Gases Association. www.asiaiga.org

NOTE This publication is part of an international harmonization program for industry standards. The technical content of each regional document is identical, except for regional regulatory requirements. See the referenced document preface for a list of harmonized regional references.

[5] ISO 21014, *Cryogenic vessels—Cryogenic insulation performance*, International Organization for Standardisation. www.iso.org

[6] European Agreement concerning the International Carriage of Dangerous Good by Road (ADR), www.unece.org

[7] Lemmon, E.W. and Span, R., *Short Fundamental Equations of State for 20 Industrial Fluids,* Journal of Chemical and Engineering Data, 51:785-850, 2006. www.pubs.acs.org

Appendix A—Examples of portable tanks and multiple element gas containers

Figure A-1—Portable tank for refrigerated liquefied gas (20 ft cryogenic vacuum insulated container)

Figure A-2—Portable tank for refrigerated liquefied gas (40 ft cryogenic vacuum insulated container for helium with a nitrogen shield)

Figure A-3—Portable tank for refrigerated liquefied gas (20 ft thermally insulated container for carbon dioxide)

Figure A-4—Portable tank for liquefied gas (20 ft non-insulated container with sunshield)

Figure A-5—MEGC (20 ft for compressed and liquefied compressed gas)

Figure A-6—MEGC (40 ft for compressed and liquefied compressed gas)

Appendix B—Example of a checklist

TRANSPORT OF VACUUM INSULATED TANK CONTAINERS BY SEA

Nitrogen shield tank container check list

Portable Tank Number:		Contents:	
Route from:		To:	
Estimated Duration in days:			

If any action is required, consult the product supply company or their operator.
Normal condition column and responsibility box shall be filled in in prior to departure from the filling location

		NORMAL CONDITION		ACTUAL CONDITION	
1.	**Product filling**	Date:	Responsibility:	Executed by:	
1.1	Check vessel arrival pressure	bar g		bar g	
1.2	Check container condition and any damage	OK		OK	Not OK
1.3	Weight of product	kg		kg	
1.4	Check vessel pressure	bar g		bar g	
1.5	Check nitrogen shield pressure	bar g		bar g	
1.6	Check product contents level				
1.7	Check nitrogen shield contents level				
1.8	Set any "in transit" valves	open / closed		open / closed	
1.9	Check blanks fitted, required valves and cabinet door closed	OK		OK	Not OK
2	**Shipboard loading**	Date:	Responsibility:	Executed by:	
2.1	Check vessel pressure	bar g		bar g	
2.2	Check nitrogen shield pressure	bar g		bar g	
2.3	Check valves for leakage and cabinet door closed	OK		OK	Not OK
2.4	Check nitrogen shield contents level				
3	**Landing**	Date:	Responsibility:	Executed by:	
3.1	Check vessel pressure on arrival	bar g		bar g	
3.2	Check nitrogen shield pressure	bar g		bar g	
3.3	Check nitrogen shield contents level				
3.4	Check valves for leakage and cabinet door closed	OK		OK	Not OK
4	**Onward journey**	Date:	Responsibility:	Executed by:	
4.1	Check vessel pressure on arrival	bar g		bar g	
4.2	Check nitrogen shield pressure	bar g		bar g	
4.3	Check nitrogen shield contents level				
4.4	Check valves for leakage and cabinet door closed	OK		OK	Not OK
5	**Product offloading**	Date:	Responsibility:	Executed by:	
5.1	Check satisfactory operation	OK		OK	Not OK
5.2	Check produt contents level				
5.3	Check nitrogen shield contents level				
5.4	Blow down if required and check vessel pressure	bar g		bar g	
5.5	Set any "in transit" valves	open / closed		open / closed	
5.6	Check blanks fitted, required valves and cabinet door closed	OK		OK	Not OK

Appendix C—Example to determine the actual holding time of a vacuum insulated tank

The following data has to be available to determine the actual holding time:

- Water capacity (*V*) of the tank in litres from the tank plate;
- Maximum allowable working pressure (MAWP) of the tank in bar (generally equal to the set pressure of the PRD) from the tank plate;
- Gas vapour pressure in the tank in bar after establishing a thermodynamic equilibrium of the gas and liquid phase after filling from the filler or carrier; and
- Heat leak performance of the tank in in kilojoule per second (kilowatt) based on the expected average ambient air temperature. This value may be delivered by the manufacturer of the tank or may be calculated taking into account the heat leak by the insulation of the tank, the support system of the tank and the pipelines to the inner vessel.

C1 Calculation of the holding time for filled and discharged tanks

Normally, the tank container manufacturer will supply details of the hold time capability of the tank container for various fill ratios and products. This relies on the vacuum and insulation being well maintained. If these data are not supplied, ISO 21014 C*ryogenic vessels—Cryogenic insulation performance* provides a method that may be used [5].

This calculation is idealized, assuming a homogenous liquid that is not stratified.

Transportation of the full container promotes sloshing of the liquid inside the tank to prevent stratification and to condense vapor as the liquid volume increases with saturation temperature.

Sloshing of the liquid inside a discharged tank does not always prevent stratification of the gas or liquid phase. The stratification within the container reduces the holding time and may lead to venting earlier than anticipated.

In accordance with ISO 21014, use the following thermodynamic properties of the gas filled in the tank [5]:

- specific internal energy, liquid (u_{sl}) in kJ/kg at vapour pressure at filling;
- specific internal energy, liquid (u_{fl}) in kJ/kg at vapour pressure of MAWP;
- specific internal energy, gas (u_{sg}) in kJ/kg at vapour pressure at filling;
- specific internal energy, gas (u_{fg}) in kJ/kg at vapour pressure of MAWP;
- heat leak (Q) in kJ/s for the tank;
- mass (m_{sl}) in kg of liquid in the tank after filling;
- mass (m_{fl}) in kg of liquid in the tank at MAWP;
- mass (m_{sg}) in kg of gas in the tank after filling; and
- mass (m_{fg}) in kg of gas in the tank at MAWP.

Calculate the holding time (t_c) in (h) until the PRDs (PRVs) will open:

$$t_c = \frac{(m_{fg} \times u_{fg} + m_{fl} \times u_{fl}) - (m_{sg} \times u_{sg} + m_{sl} \times u_{sl})}{3600 \times Q}$$

The required masses can be calculated according to the following:

$$m_{fg} = \frac{V - (M \times v_{fl})}{(v_{fg} - v_{fl})}$$

$$m_{fl} = \frac{V - (M \times v_{fg})}{(v_{fl} - v_{fg})}$$

$$m_{sg} = \frac{V - (M \times v_{sl})}{(v_{sg} - v_{sl})}$$

$$m_{sl} = \frac{V - (M \times v_{sg})}{(v_{sl} - v_{sg})}$$

Where:

V = container gross volume (m^3)

M = total mass of contents (kg)

v_{sl} = specific volume of liquid at filling condition (m^3/kg)

v_{fl} = specific volume of liquid at MAWP (m^3/kg)

v_{sg} = specific volume of vapour at filling condition (m^3/kg)

v_{fg} = specific volume of vapour at MAWP (m^3/kg)

NOTE As an example, Table C-1 shows the thermodynamic properties of saturated nitrous oxide

If the calculated holding time is smaller than the expected duration of the journey, the vapour pressure of the tank may be reduced, for example, by releasing vapour of the tank. If this is not possible, the duration of the journey has to be reduced, for example, by using an intermediate stop where the tank can have its pressure released.

In addition, it has to be verified that the tank is not completely filled with liquid before the vapour pressure reaches a value that is equal to MAWP of the tank:

Take from Table C-1:

- the density ρ_{sl} in kg/m³ of the liquid at filling related to h_{sl}
- the density ρ_{fl} in kg/m³ of the liquid at MAWP related to h_{fl}

Calculate the maximum allowable degree of filling in % for the expected journey by using the formula:

Degree of filling = (ρ_{fl} / ρ_{sl}) 100

In the case of United Nation (UN) portable tanks, this value is limited to 98% so that the following formula has to be used:

Degree of filling = 0.98 (ρ_{fl} / ρ_{sl}) 100

C2 Example for a nitrous oxide tank container

For a tank container constructed in accordance with the European Agreement concerning the International Carriage of Dangerous Good by Road (ADR) [6] with a MAWP of 20 bar (gauge pressure) that is filled with nitrous oxide (N_2O) with a vapour pressure of 16 bar (15 bar gauge pressure) the degree of filling should be less than:

(975.54 / 1013.7) 100 = 96.53%

For a UN portable tank with MAWP of 20 bar (gauge pressure) that is filled with nitrous oxide (N_2O) with a vapour pressure of 16 bar (15 bar gauge pressure) the degree of filling should be less than:

0.98 * (975.54 / 1013.7) 100 = 94.31%

If the actual degree of filling is greater than the allowable value, the degree of filling has to be reduced, for example, by discharging liquid nitrous oxide.

Table C-1—Thermodynamic properties of saturated nitrous oxide [7]

Vapour pressure	Temperature	Density, liquid	Density, vapour	Internal energy, liquid	Internal energy, vapour
(bar, abs)	(K)	(kg/m³)	(kg/m³)	(kJ/kg)	(kJ/kg)
10	234.95	1068.3	25.918	88.162	358.71
11	237.72	1058.1	28.468	93.229	359.38
12	240.31	1048.5	31.031	97.998	359.95
13	242.74	1039.3	33.611	102.51	360.45
14	245.05	1030.5	36.208	106.80	360.87
15	247.23	1021.9	38.825	110.90	361.24
16	249.31	1013.7	41.462	114.83	361.55
17	251.30	1005.6	44.122	118.61	361.81
18	253.20	997.85	46.805	122.25	362.02
19	255.03	990.25	49.514	125.77	362.19
20	256.79	982.81	52.249	129.18	362.32
21	258.49	975.54	55.011	132.48	362.41
22	260.13	968.40	57.803	135.70	362.47
23	261.71	961.38	60.625	138.83	362.50
24	263.25	954.48	63.479	141.89	362.49