INTERNATIONAL STANDARD

ISO 20854

First edition
2019-10

Thermal containers — Safety standard for refrigerating systems using flammable refrigerants — Requirements for design and operation

Conteneurs thermiques — Norme de sécurité pour les systèmes réfrigérants utilisant des fluides frigorigènes inflammables — Exigences de conception et de fonctionnement

Reference number
ISO 20854:2019(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 104, *Freight containers*, SC 2, *Specific purpose containers*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document has been developed to enable the use of flammable refrigerants in refrigerated thermal containers. This document enables container owners and operators to understand and validate the risks associated with operating refrigerating equipment using previously non-acceptable flammable refrigerants. The goal is to achieve an acceptable level of safety for container refrigerating systems using flammable refrigerants as for container refrigerating systems using non-flammable refrigerants.

The background for initiating the development of this document was the foreseeable impact of global and national regulations on hydrofluorocarbons (HFCs) currently used in thermal containers. Hydrofluorocarbons are listed in the Kigali Amendment to the Montreal Protocol from 2016 due to the high global warming potential (GWP) of HFCs and a phase down in the use and availability of R134a, R404A and, for low temperature, R23, is expected in intermodal transport refrigeration.

This document is intended to complement ISO 1496-2 but not to replace existing standards such as the ISO 5149 series. It provides minimum requirements for the design of a refrigerating system and follows a risk-based approach to reduce, but not eliminate, the risks to persons, assets and the environment.

The working group, which developed this document consisted of representatives from refrigerating system manufacturers, refrigerated container box manufacturers, shipping lines, classification societies, equipment owners and other interested industry experts.

Thermal containers — Safety standard for refrigerating systems using flammable refrigerants — Requirements for design and operation

1 Scope

This document describes the design of the mechanical refrigeration unit (MRU) and operation of container refrigerating systems in all anticipated operational modes and locations.

It describes the industry's best practices for the safe operation of flammable refrigerants in refrigerating systems used in thermal freight containers operated on board ships, in terminals, on road, on rail and on land.

This document addresses the use of flammable refrigerants with classifications defined in ISO 817, defined as 2L, 2 and 3, except R717 (Ammonia).

This document describes an operational mode risk assessment (OMRA) which uses methods such as HAZOP (Hazard and operability analysis), FMEA (Failure mode and effects analysis), or FTA (Fault tree analysis) or combination of methods.

This document specifies requirements for the validation and consideration of possible safety concepts and protective devices within the OMRA process, including charge release tests, simulation, and function tests of the associated protective equipment. It defines test requirements for shock, impact, and vibration. A validation procedure is given to demonstrate that risks from hazardous events are investigated and their severity and frequency are meaningfully reduced, with the aim of achieving tolerable risk values.

The obligations of the manufacturer, the container owner as well as the responsible operator are described, as well as how stakeholders can investigate and mitigate risks associated with the use of flammable refrigerants.

Finally, this document describes the requirements of service and maintenance when working with flammable refrigerants.

This document is restricted to refrigerating systems integrated with or mounted on ISO thermal containers according to ISO 1496-2. It provides minimum requirements for reducing the risk associated with the use of flammable refrigerants.

The scope is limited to container refrigerating systems operated in conjunction with the carriage of refrigerated cargo as operating reefer (OR) or when used as a non-operating reefer (NOR) or when empty for positioning — while in intermodal transit. Static land-based continuous operations are excluded.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 817, *Refrigerants — Designation system*

ISO 1496-2, *Freight containers — Specification and testing — Thermal containers*

ISO 5149 (all parts), *Refrigerating systems and heat pumps — Safety and environmental requirements*

ISO 14903, *Refrigerating systems and heat pumps — Qualification of tightness of components and joints*

IEC 60068-2-6, *Environmental testing — Part 2-6: Tests — Test Fc: Vibration (sinusoidal)*

IEC 60068-2-75, *Environmental testing — Part 2-75: Tests — Test Eh: Hammer tests*

IEC 60079-10-1, *Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres*

IEC 60079-14, *Explosive atmospheres — Part 14: Electrical installations, design, selection and erection*

IEC 60079-15, *Explosive atmospheres — Part 15: Equipment protection by type of equipment "n"*

IEC 60335-2-40, *Household and similar electrical appliances — Safety — Part 2-40: Particular requirements for electrical heat pump, air-conditioners and dehumidifiers*

EN 1127-1, *Explosive atmospheres — Explosion prevention and protection — Part 1: Basic concepts and methodology*

EN 14624, *Performance of portable leak detectors and of room monitors for halogenated refrigerants*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
alarm system
system constituting all electrical and electronic parts of the refrigerating system which monitor the correct function of the protective device(s) and/or give a warning in case of malfunctioning or refrigerant leakage

3.2
hazardous area
area in which a flammable or toxic atmosphere is present, or may be expected to be present, in quantities such as to require special precautions for construction, installation or use of apparatus

[SOURCE: IEC-60079-10-1:2015, 3.3.1, modified — In the definition, the word "explosive" has been replaced with "flammable and toxic".]

3.2.1
non-hazardous area
area in which a flammable or toxic atmosphere is not expected to be present in quantities such as to require special precautions for construction, installation and use of equipment

[SOURCE: IEC-60079-10-1:2015, 3.3.2, modified — In the definition, the word "explosive" has been replaced with "flammable and toxic".]

3.2.2
temporary hazardous area
area which can be defined as a hazardous area for a short period of time as a consequence of an abnormal or accidental type leak

3.3
authorized service facility
service facility that is authorized by the manufacturer to repair and to maintain the container refrigerating system

3.4
condenser section
space of the container where all outside parts of the refrigeration circuit including condenser fan are located

Note 1 to entry: The condenser section is not a confined space.

Note 2 to entry: The condenser section corresponds to control volume II (see Annex A).

3.5
container refrigerating system
mechanically refrigerated container with a vapour compression refrigeration cycle using refrigerant as a working fluid

3.6
control volume
theoretical volume representing the space in which a flammable atmosphere can occur as a consequence of a refrigerant leak

Note 1 to entry: It can be delimited by the internal or external space of a container, and/or by specific component compartments.

Note 2 to entry: A description of control volumes is included in Annex A.

3.7
durably technically tight
sealed equipment with enhanced tightness which is equal or less than that of fugitive emissions accomplished by enhanced maintenance and supervision

Note 1 to entry: Clauses 8, 9 and especially Clause 10 provide information on design aspects and operational aspects to maintain tightness, permanently ensured by means of enhanced maintenance and supervision.

Note 2 to entry: Additional information can be found in EN 1127:2011, Annex B.

Note 3 to entry: ISO 5149-2 provides information on “sealed systems” and IEC 60335-2-40 on “enhanced tightness”.

3.8
evaporator space
space inside the container containing the evaporator and air ducts

Note 1 to entry: The evaporator space corresponds to control volume III (see Annex A).

3.9
flammable atmosphere
mixture with air, under atmospheric conditions, of flammable substances in the form of gas or vapour, which after ignition, permits self-sustained flame propagation

Note 1 to entry: For example, a mixture of flammable refrigerant fluid with air under atmospheric conditions.

[SOURCE: IEC 60079-10-1:2015, 3.2]

3.10 flammable limit/explosive limit[1)]

3.10.1
LFL
lower flammable limit
minimum concentration of the refrigerant that is capable of propagating a flame through a homogeneous mixture of the refrigerant and air under the specified test conditions at 23,0 °C and 101,3 kPa

[SOURCE: ISO 817:2018, 3.1.24, modified — Notes 1 and 2 have been omitted.]

3.10.2
UFL
upper flammable limit
concentration of flammable gas or vapour in air, above which the gas atmosphere is not flammable

[SOURCE: IEC-60079-10-1:2015, 3.6.13, modified — In the definition, the words "or mist" have been removed after "vapour". Also, at the end, after "above which", "an explosive gas atmosphere will not be formed" has been changed to " the gas atmosphere is not flammable".]

3.11
flammable refrigerant
refrigerant with a classification of class 2L, 2 or 3 in compliance with ISO 817 classification, refrigerants excluding ammonia

3.11.1
AIT
auto-ignition temperature
lowest temperature of a substance at or above which a chemical can spontaneously ignite in a normal test atmosphere, without an external source of ignition, such as a flame or spark

Note 1 to entry: Refer to the manufacturer's safety data sheet (SDS) of the chemical used.

[SOURCE: ISO 5149-1:2014, 3.7.7, modified — Note 1 to entry has been added.]

3.11.2
RTT
reaction threshold temperature
lowest temperature of a substance at or above which a chemical can be decomposed spontaneously in a normal atmosphere, in the presence of an external source of ignition, such as an open flame, hot surface or spark

Note 1 to entry: As an estimation, the following values may be used: RTT_{est} = AIT – 100 °C.

3.12
flammable substance
substance in the form of gas, vapour, liquid, or mixtures of these, able to propagate a flame from an ignition source

3.13
fresh air exchange mechanism
mechanism that opens the fresh air ducting to allow ventilation

1) The flammability limits are function of temperature and humidity. For refrigerants flammability, ISO 817:2014 defines test conditions of 50 % relative humidity at 23,0 °C and 101,3 kPa for burning velocity and LFL/UFL measurements. The effect of a reduced lower flammable limit and an increased upper flammable limit at higher operational humidity and temperature levels can be taken into account in the operational mode risk assessment.

3.14
fugitive emission
small release of refrigerant from pressurized equipment which does not result in malfunction of the cooling process in its typical operation time

Note 1 to entry: Fugitive emissions result from corrosion or shortcoming of components or joints which are durably technically tight during intermodal operation and do not result to a malfunction and/or need for repair on the refrigerating system in a period of months to years.

Note 2 to entry: Annex C gives information on leak type, size, frequencies and leak rates.

Note 3 to entry: For additional information, see IEC 60079-10-1:2015, C.4.6.

3.15
inside component
component of the refrigerating system which is located inside the internal dimensional envelope of the container

3.16
intended use
use in accordance with information provided with the container refrigerating system, or, in the absence of such information, by generally understood patterns of usage

Note 1 to entry: Intended use of a container refrigerating system is the carriage of cargo under temperature control and when the unit is not operating i.e. used as NOR (non-operating reefer) or waiting empty for loading and/or repositioning — while in intermodal transit.

[SOURCE: ISO Guide 51, 3.6, modified — The words "a product or system" have been replaced with " the container refrigerating system" and Note 1 to entry has been added.]

3.16.1
normal operation
condition where the equipment is operating within its design parameters

Note 1 to entry: Failures (such as the breakdown of components or ruptures) which involve shut-down and urgent repair are not considered to be part of normal operation.

Note 2 to entry: Normal operation includes start-up and shut-down conditions.

Note 3 to entry: Normal operation can include occurrence of fugitive emissions. Normal operation does not include larger leaks. Normal operation of the container refrigerating system requires a certain minimum refrigerant charge. Larger leaks result in system failure.

[SOURCE: IEC 60079-10-1:2015, 3.7.1]

3.16.2
special use
use of a container refrigerating system for cooling and storage of goods in stationary and temporary land operation — not permanently imported

Note 1 to entry: Local regulations and guidelines can apply to the use of a container refrigerating system as permanent storage place of cargo.

3.16.3
reasonably foreseeable misuse
use of the container or container refrigerating system in a way not intended by the supplier, but which can result from readily predictable human behaviour

[SOURCE: ISO Guide 51:2017, 3.7, modified — The words "a product or system" have been replaced with "the container or container refrigerating system" and Notes 1 and 2 to entry have been omitted.]

3.17
non-occupied space
space inside the container which is not occupied for a significant period of time by person(s)

Note 1 to entry: For unpacking and packing of goods, the container doors are open, see 9.5.

3.18
operating site
site or location of operation in which a container refrigerating system can be operated, repaired, or stored during the intended use

3.19
operational mode
combination of type of operation (such as transport mode and storage location) and state of operation (such normal operation, power ON, power OFF, empty container, packed container) in a container refrigerating system

EXAMPLE The container is located in a terminal, on a truck and with power on and empty.

3.20
operational mode risk assessment
OMRA
overall process comprising a risk analysis and risk evaluation of a container refrigerating system in different operational modes

3.21
outside part
component of the refrigerating system which is located outside the insulated walls and inside the external dimensional envelope

3.22
packing
stuffing
action of filling cargo/goods into the container within designed capacity

Note 1 to entry: After packing, the container is loaded with goods.

3.23
PTI
pre-trip inspection
inspection and testing of a container refrigerating system including checking for structural damage and assurance that the refrigerating system is operating according to the specifications

Note 1 to entry: A PTI can be carried out before a container is released for a new trip or after a repair.

3.24
power supply
condition where a connection to the three-phase power supply is present

3.25
refrigerant leak detection mechanism
mechanism which can recognize a refrigerant leakage or charge losses of the container refrigerating system

3.26
refrigerating system repair operation
service or maintenance of a refrigerating system in which the container refrigeration system pipework or components is or will be opened

3.27
repair shop
place in a terminal or service facility where container refrigerating systems are serviced and repaired

3.28
responsible operator
MRU operator
person or entity that has operational control of the container including the MRU at any particular time including, but not limited to, repair and storage depots, terminals, transport operators, shippers and consignees

3.29
safety principle
set of provisions which, together, ensure safe design and safe operation of a container refrigerating system

3.30
shut-off device
normally closed device separating parts of the refrigerating system to reduce the maximum amount of refrigerant that can be leaked into a control volume

3.31
service access point
connection used to service the refrigerating system, that enables the refrigerant circuit to be charged, discharged, evacuated and pressure checked

3.32
service facility
building or installation where maintenance and repair of container refrigerating systems is carried out

3.33
smallest inside free volume
remaining inside volume when the cargo compartment is packed to the maximum allowed volume

Note 1 to entry: This volume includes the T-floor space.

3.34
T-floor
specially designed floor with longitudinal channels to allow air to pass underneath the cargo

3.35
terminal
intermodal facility that allows the transport and transfer of containers between different transport modes

Note 1 to entry: In a terminal, intermodal containers are also loaded/unloaded, stored, operated, maintained, packed/unpacked.

3.36
toxic atmosphere
mixture of air, under atmospheric conditions, with toxic substances in the form of gas or vapour which can be harmful or lethal to humans

Note 1 to entry: For example, a mixture of toxic refrigerant fluid or decomposition products with air under atmospheric conditions.

Note 2 to entry: A toxic substance is understood to be a substance in the form of gas, vapour, liquid, or mixtures of these, which can be harmful or lethal, or can impair a person's ability to escape due to acute or chronic exposure by contact, inhalation, or ingestion.

3.37
unit end
front end where the refrigerating system is placed

3.38
unpacking
unstuffing
action of emptying the container

Note 1 to entry: After unpacking, the container is empty.

3.39
ventilation environment
environment capable of diluting releases of hazardous substances in normal operation to a non-hazardous concentration

3.39.1
open air
any unenclosed space, possibly but not necessarily roofed with, as a minimum, natural ventilation

Note 1 to entry: The ventilation environment “open air” refers to or represents areas or operating sites such as PTI, inspection, roofed repair areas, on vessel deck, truck and rail.

[SOURCE: ISO 5149-1:2014, 3.2.7, modified — The words "with, as a minimum, natural ventilation" and Note 1 to entry have been added.]

3.39.2
well-ventilated
area which is naturally or mechanically ventilated

Note 1 to entry: The ventilation environment “well-ventilated” refers or represent areas or operating sites such as vessel cargo hold, workshops, system repair areas.

3.39.3
non-well-ventilated
area other than open air or well-ventilated

Note 1 to entry: The ventilation environment “non-well-ventilated” should be considered if an artificial or forced ventilation system is not in operation (due to power failures or other type of malfunction).

Note 2 to entry: For release rate and accumulation time of hazardous substances in non-well-ventilated areas or operating sites see Annex C.

3.40
ventilation mechanism
means which promotes the replacement of an air volume

3.41
ventilation
movement of air and its replacement with fresh air, i.e. without dangerous substances

3.41.1
natural ventilation
movement of air and its replacement with fresh air due to effects of natural mixing, air movement, or temperature gradients

Note 1 to entry: For open air ventilation is normally based on an assumed minimum wind speed of 0,15 m/s for obstructed areas and 0,3 m/s for unobstructed areas, which will be present virtually continuously (see IEC 60079-10-1:2015, Table C.1).

3.41.2
artificial ventilation
forced ventilation
movement of air and its replacement with fresh air provided by artificial means

3.42
zone
hazardous area classification based upon the frequency of the occurrence and duration of an explosive atmosphere

[SOURCE: IEC-60079-10-1:2015, 3.3.2]

3.42.1
zone 2
area in which an explosive gas atmosphere is not likely to occur but, if it does occur, for example as a result of accidental type release of refrigerant, it can be defined as a temporary hazardous area

[SOURCE: IEC-60079-10-1:2015, 3.3.6, modified — The words "in normal operation" have been removed; the end part after "if it does occur" has been changed; and Note 1 to entry has been omitted.]

3.42.2
extent of zone
distance in any direction from the source of release to where a gas/air mixture will be diluted by air to a concentration below the lower flammable limit

[SOURCE: IEC-60079-10-1:2015, 3.3.7]

4 Symbols and abbreviated terms

FEU	Forty-foot equivalent unit
MRU	Mechanical refrigeration unit (the terms "MRU" and "unit" are considered to be synonymous at this document)
SOI	Source of ignition
SDS	Safety datasheet for chemicals

5 Safety requirements for the design of container refrigerating systems

5.1 General

The safety requirements described in this clause cover the whole assembly of a container refrigerating system using flammable refrigerants: the refrigerating system and the container box and as well as the various operational modes.

5.2 Significant hazards of the refrigerating system

A container refrigerating system shall be designed to achieve the level of tightness as specified in ISO 5149-2 for sealed systems. ISO 14903 shall apply as it specifies qualification of tightness of components and joints for refrigerating systems and heat pumps.

In addition, the MRU design shall be such that a high degree of tightness can be maintained throughout its life with correct maintenance. According to EN 1127, a refrigerating system is classified as a durably technically tight system or as a sealed system with enhanced tightness accomplished by leak tight design and manufacturing procedures for components, joints and connections, implemented service procedures for maintenance and operation including inspection and monitoring of leak tightness.

An MRU is regarded as durably technically tight system or as a sealed system with enhanced tightness, if:

— it is constructed such that it remains technically tight due to its design, as described in this clause and Clause 6; and

— its technical tightness is permanently ensured by means of maintenance and supervision, as described in Clauses 8 and 10.

An MRU with a durably technically tight or sealed system construction with enhanced tightness does not create any hazardous areas in its surroundings while in normal operation.

For the purpose of risk evaluation, refrigerant leaks are to be taken into account.

Therefore, this document addresses the hazards associated with:

— fugitive emissions during normal operation; and

— releases due to failure of joints or components, accident, improper handling and improper service.

The main hazards associated with the leakage of flammable refrigerants resulting to a temporary hazardous area include:

— fire and flame propagation: ignited leaking refrigerant;

— explosion: accumulation of leaked refrigerant leading to a flammable concentration and ignition in a confined space;

— toxicity as described in ISO 817;

— toxicity deriving from decomposition products in case of refrigerant reaction or combustion creating toxic atmosphere.

NOTE Potential hazards related to common refrigerating systems are described in ISO 5149-1:2014, Annex C.

5.3 Safety concept for container refrigerating systems

5.3.1 General

This clause describes the safety principles for flammable refrigerants which cover both the design and the operation of the MRU based on risk reduction by component design and control strategies as well as by processes improvements for operation.

The safety principles are based on the following:

— eliminate hazards or reduce risks as much as reasonably practicable;

— apply appropriate protection measures against hazards which cannot be eliminated;

— inform users about residual hazards and indicate whether specific measures should be taken to reduce the associated risks, where relevant.

5.3.2 Operational mode risk assessment

5.3.2.1 General

The operation of a container refrigerating system is complex as it involves various modes of operation, operators with different responsibilities, diverse ownership of the equipment and multiple intended uses.

An operational mode risk assessment (OMRA) shall be carried out by the MRU manufacturer to analyse the risks related to the operation of a container refrigerating system, involving the refrigerating system manufacturer and the box manufacturer, as well as customers and professional users. The OMRA shall include, but not be limited to, risks associated with maintenance, recycling or dismantling, reuse after the service life of the refrigerating system, including the second-hand market.

The OMRA shall include the intended use, reasonably foreseeable misuse, and special use.

NOTE ISO/IEC Guide 51 gives additional information for evaluation.

The OMRA shall consider at least the following operational modes, taking into account both power ON and power OFF situations, and consider, where relevant:

— transport:
  — ship transport including handling at harbour and terminals;
  — road transport including interim parking or storage anywhere;
  — all rail transport;
  — passing through a tunnel;
  — loading and unloading;
— storage: industrial areas; public space; cold space or cold rooms;
— service and repair: maintenance at professional workshops, functionality testing and quality of repair;
— reasonably foreseeable misuse, such as improper repair and maintenance, continuous charging in the event of a leak, use of wrong or improper tools or parts;
— packing and unpacking: factory or professional packing/unpacking, non-professional packing/unpacking by untrained persons;
— external events: accidents, crash, fire, vibration, corrosion, mechanical damage, unauthorized intervention;
— inspections: customs, veterinarian, port health, such as terminal workers, cargo quality inspection;
— end-of-life and disposal of equipment.

The OMRA shall be carried out using one or more of the following methods or other equivalent methods as applicable to safety aspect under consideration:

— Hazard and operability analysis (HAZOP) according to IEC 61882 or equivalent;
— Failure mode and effects analysis (FMEA) according to IEC 60812 or equivalent;
— Fault tree analysis (FTA) according to IEC 61025 or equivalent.

The MRU manufacturer should provide the necessary results of the OMRA to:

— the installer of the MRU;
— the container box manufacturer;
— the responsible operators of different operating sites for evaluation.

Any required design modifications shall be jointly discussed and incorporated.

The OMRA shall include a risk assessment for flammable refrigerants as a basic part. Results shall be evaluated for all operational modes, where relevant.

The OMRA shall be approved by a classification society.

5.3.2.2 Risk assessment for flammable refrigerants

The risk assessment shall include the following elements:

— determination of the likelihood of occurrence of a flammable atmosphere and the amount of refrigerant involved;
— determination of the probability of the presence and efficiency of sources of ignition;

— assessment of the possible effects of fire, flame propagation, explosion, refrigerant decomposition and toxic atmosphere, chemical reaction of refrigerant with dangerous cargo, fumigation, scrubber or other commonly used substances;

— evaluation of the risks and consequences;

— identification of measures for the reduction of risks.

The risk assessment shall be supported by tests and simulations.

The risk assessment shall use the refrigerant properties specified in ISO 817 or the SDS, the most conservative values shall be used.

NOTE If different SDS for the flammable refrigerant exist, the most conservative values can be used for the OMRA.

The flammable concentration (and thus the LFL and UFL) are function of the concentration of flammable refrigerant in air, the operational temperature and the local humidity[13]. At higher humidity (>80 % R.H.) and temperature (>50 °C), the LFL in air can decrease and the UFL can increase. This effect shall be taken into account for such operations and in the risk assessment. It should also be considered in the estimations for the evaluation of dilution of refrigerant in air (see Annex D).

5.3.3 Tolerable risk

5.3.3.1 General

The tolerable risk value is defined according to:

— applicable regulations and relevant international standards, employable for intermodal operated refrigerated container; and

— the manufacturer's policy for determining criteria for tolerable risk level.

It shall take into account information such as the generally accepted state of the art as well as the current values of tolerable risk of relevant stakeholders or involved parties.

5.3.3.2 Risk reduction

When risk reduction is required, a risk reduction process shall be carried out iteratively until a tolerable risk level is achieved. A process of risk reduction is described in ISO/IEC Guide 51.

A "three-step method" shall be used for risk reduction at the design phase and additional measures at the use phase at all operational modes.

1) inherently safe design;

2) guards and protective devices;

3) information for the responsible operators, instruction and information for consideration at operating sites and for end users.

Taking inherently safe design measures is the first and most important step in the risk reduction process. Guards and protective devices shall be used whenever an inherently safe design measure does not reasonably make it possible to remove hazards or sufficiently reduce risks. The responsible operator has a decisive influence and responsibility in the risk reduction procedure by complying with the information provided by the OMRA from the MRU manufacturer, and described in 9.8 and Clause 10.

5.3.3.3 Tolerable risk criteria

According to ISO Guide 51, risk is defined as the combination of the probability of occurrence of harm, and the severity of that harm.

The tolerable risk area (acceptance criteria) is described as L (low risk) in the Table 1 using a two-dimensional criteria (probability and severity).

The residual risk after the risk reduction process has been carried out, shall be the L (low risk) - area.

If the level of the severity of the event, or harm, is not clearly identified during the risk reduction stage, it is recommended to consider an ignition event as catastrophic.

Table 1 — Risk matrix and acceptance criteria, values to be evaluated according to IEC 61025 or equivalent

Probability of occurrence of harm per container per year				Severity of harm				
				0	I	II	III	IV
				No damage	Negligible (smoke from product)	Marginal (products on fire and burned)	Critical (serious injuries, hospitalization and fire)	Catastrophic (death, fire and burned)
Probability	5	Frequent	$\geq 10^{-3}$	L	H	S	S	S
	4	Probable	$<10^{-3}$ and $\geq 10^{-4}$	L	M	H	S	S
	3	Occasional	$<10^{-4}$ and $\geq 10^{-5}$	L	M	M	H	S
	2	Remote	$<10^{-5}$ and $\geq 10^{-6}$	L	L	M	M	H
	1	Improbable	$<10^{-6}$ and $\geq 10^{-7}$	L	L	L	M1	M
	0	Incredible	$<10^{-7}$	L	L	L	L	L
L low risk; tolerable risk area M medium risk H high risk S serious risk; the intolerable risk area								

If serious risk is identified during operation, including recognized accidents or misuse, countermeasures should be taken immediately.

The reduction and elimination of hazards in container refrigerating systems in case of leaks or release of flammable refrigerants should be made by the MRU manufacturer (or nominated party) and it should be described in a risk analysis (see 5.3.2).

The reduction and elimination of hazards shall be made by the MRU manufacturer and the results shall be described in the OMRA (see 5.3.2).

5.3.4 Flammable refrigerants

The safety principles recommended in this document provide both general and specific guidelines for the prevention of the build-up of flammable atmospheres, protection by design and construction of equipment, installation of protective systems and components.

The safety principles should include provisions for the following elements as applicable and according to results of the risk assessment for leak prevention:

— refrigerating system tightness (see ISO 14903);

— refrigerant charge optimization through optimum dimensioning of the components;

— separation of the evaporator: low mass of refrigerant in the components located inside the container at power OFF (see Figure B.1 in B.2).

— leak detection and ventilation (see B.4 and B.3):

  — inside leak detection;

  — alarms system;

  — ventilation of the inside/outside atmosphere.

— reduction of source of ignition:

  — inside container electrical components;

  — outside container electrical components;

  — other external sources.

During intended use and normal operation of the MRU the safety principles shall ensure that the outside and the inside of the container are non-hazardous areas in terms of flammability (see 5.2).

NOTE 1 Examples of hazardous area classification are given in IEC 60079-10-1:2015 Annex E. Examples of calculations to ascertain the degree of ventilation and time of persistence of a flammable atmosphere are given in IEC 60079-10-1:2015 Annex C.

In case of refrigerant release larger than fugitive, the build-up of a flammable atmosphere in proximity of the outside unit end of the container (control volume I, see Annex A) should be prevented following:

— the recommendations in 9.8,

— the safety principles described in 5.3,

— validated by testing described in 6.8,

— the operation requirements described in 9.4 and

— the mechanism to reduce risk as described in Annex B.

5.3.5 Protection against hazards

5.3.5.1 Protection against explosion hazards

5.3.5.1.1 General

The protection against explosion hazards should include different measures for prevention of refrigerant leakage, prevention of build-up of flammable atmospheres and elimination of SOI. The detection of a hazardous amount of leaked refrigerant requires protective actions and the initiation of an alarm.

As described in 5.3.2 the OMRA shall be performed for all intended and special uses including packing and unpacking, and foreseeable misuse.

While performing the OMRA, all operational modes shall be classified according to the following types of ventilation:

— natural ventilation: occurring in places such as open air, in tunnels, during transport, on deck of vessels, repair area as examples;

— forced ventilation: occurring in places such as cargo holds (for heat removal), enclosed spaces in buildings, underground parking, repair shop or area, loading and unloading as examples.

NOTE 1 Accidental type rupture leak, for example on the condenser section, can generate a temporary hazardous atmosphere (control volume II, condenser section) above LFL for a short period of time.

Clause 9 provides further requirements concerning the operational sites.

The degree of dilution outside the container should be considered as "high" with "fair" to "good" availability. In normal operation the control volumes I and II, which are located outside the container, should be considered as non-hazardous areas (see Annex A).

NOTE 2 The definition of ventilation degree and ventilation rate is provided in IEC 60079-10-1.

The air leakage rate of a container to exchange air from inside to outside is sufficient to dilute fugitive emissions when not operating or used as NOR. However, this situation shall be taken into account in the OMRA.

5.3.5.2 Protection against excessive internal system pressure

The refrigerating system shall be designed according to the existing norms that specify the pressure requirements of ISO 5149-2:2014, 5.2.2.

5.3.6 Validation of safety concept and protective devices

To validate the risk reduction by the safety concepts and protective devices intended to achieve the tolerable risk value, charge release tests or simulations shall be carried out.

To support this validation process, a zone assessment shall be carried out according to IEC 60079-10-1. In addition, a SOI analysis according to EN 1127-1 shall be done.

The testing or simulation of the charge release shall be carried out in order to evaluate the maximum concentration, the zone extent and persistence time that can be reached if the refrigerant is leaking inside and/or outside of the container according to the principles of IEC 60079-10-1. The leak types, as specified in Annex C, shall be used for these tests and considered for worst case testing.

The tests or simulations shall be carried out by the MRU manufacturer and results verified by a classification society. The purpose is to demonstrate that risks from hazardous events are investigated and their severity and frequency are meaningfully reduced by the safety measures, with the aim of achieving the tolerable risk values.

6 Design and construction of the refrigerating system

6.1 General

All components and pipework should be capable of withstanding the mechanical, chemical and thermal loads to which they can reasonably be expected to be exposed during normal operation including all operational modes within reasonable design limits and material properties.

NOTE Container handling involves movements by special equipment that can cause direct contact between the handling equipment (such as straddle carriers, cranes, lifters, trailers, cell guides) and the container refrigerating system. This can cause damage to the components of the refrigerating system.

When feasible, the components of the MRU containing refrigerant should be:

— protected against direct impact that can cause functional damage;

— designed to withstand high pressure combined with vibrations and shock energy as described in 6.3. For the testing procedure, see 6.8.3.

The design of the MRU shall take into account the results of a risk assessment (see 5.3.2) with regard to maintenance, normal repair and service. The owner and/or operator shall be responsible for ensuring the repair, service and maintenance employees are knowledgeable of the correct methodologies to

work on the unit and have the required certifications (see Clause 10). Requirements for training are described in 10.2.

All electrical installations, including software, shall be designed to support the responsible operator in identifying and installing approved spare parts only. Certified parts, including software, can be coded and marked that replacement with improper parts is inhibited.

In support of this, where possible, the unit shall be designed to minimize the impact of improper repair.

6.2 Components and piping of refrigerating systems with flammable refrigerant

6.2.1 General

The components and piping of the refrigerating system shall comply with the requirements of ISO 5149-2 and of this document.

6.2.2 Components

During normal operation, the outside (condenser space in control volume II, see Annex A) of the container is considered a non-hazardous area according to IEC 60079-10-1. However, for design evaluations for the outside components located in the condenser space, an assessment, as part of the OMRA, shall be carried out. To support this assessment an ignition source analysis shall be done. The conditions for operation at operating sites shall be considered according to requirements in Clause 9.

NOTE Based on experience and simulations[5], a flammable atmosphere cannot be formed outside the footprint of the container with fugitive emission rates in normal operation as classified in Annex C.

6.2.3 External fire relief device

In case of external fire, uncontrolled rupture or failure of braze joints or pipes occurs depending on where the highest fire temperatures and heat impacts are.

At a temperature at which a brazed joint (or brazed joints) can begin to part, uncontrolled rupture occurs, caused by uncontrolled release of refrigerant in any direction due to the result of an external fire/thermal incident.

An appropriate device (or appropriate devices) shall be installed to facilitate a controlled release of refrigerant.

The refrigerant release shall be in such a way that it does not cause further unsafe conditions to personnel or emergency services.

6.3 Assemblies

6.3.1 General

Unless otherwise stated in this document, the refrigerating system assemblies shall comply with the requirements of ISO 5149-2: 2014, Clause 5.

The supporting elements of the refrigerating system shall have sufficient strength to withstand the forces under loading and other intermodal movements of the container.

Provisions shall be taken to withstand normal vibration during normal operation and handling, such as those resulting from ship, truck and railway operations.

The ability of the MRU to withstand stresses deriving from cargo loading and/or accelerations to which the container can be subjected during service should be assessed independently from the assessment of stresses on the container box.

6.3.2 Components and joints

Refrigerant piping shall be protected to avoid damage during normal operation and handling of the container.

6.4 Interior of the thermal container

6.4.1 General

The installation shall be constructed according to requirements in ISO 5149-2:2014.

6.4.2 Ventilation inside the container

The ventilation system may be considered as an integral part of the safety features. In that case, and in a failure situation of the ventilation system, the refrigerating system should be turned off and, if applicable, the shut off devices should be closed.

Clause B.3 describes this optional protective device.

NOTE 1 IEC 60079-13 would permit failure of a ventilation system for zone 2 areas to generate an alarm and would not require shut down of associated electrical systems. However, this assumes the alarm would be suitably acknowledged and actioned. For thermal containers it is assumed that such an alarm response would be handled by the alarm system described in 6.7. Otherwise, the alarm response is not valid and shutdown is required.

NOTE 2 IEC 60079-13 requires that air flow for ventilation system is monitored as the true measure of system function which can then detect numerous possible causes of ventilation failure.

For thermal containers, mechanical air flow sensors should be avoided since the sensor can become faulty, e.g. due to seizure of moving parts in corrosive conditions which would then need to be considered in the OMRA.

6.4.3 Refrigerant detectors

If refrigerant detectors are used, they should meet the requirements given in ISO 5149-3:2014, Clause 9.

The reliability of the gas detector, including the possibility of detector impairment due to the operating conditions and exposure to other chemicals, should be considered in the OMRA. Further guidance for the selection and application of gas detectors can be found in IEC 60079-29-2.

Clause B.4 describes this optional refrigerant detection device.

6.4.4 Protection against hot surfaces

The maximum temperature of hot surfaces during normal operation shall be below the reaction threshold temperature (RTT) of the used refrigerant. If RTT is unknown, then the estimated RTT_{est} shall be used.

NOTE 1 Information of these values can be found in the refrigerant SDS, ISO 5149-1. The most conservative value should be used.

NOTE 2 According to thermal decomposition and flammability characteristic of R1234yf as a function of humidity, a different value can be used (see [13]).

Hot surface temperatures higher than the reaction threshold temperature (RTT) can result in hazardous situations in case of refrigerant releases, including fugitive emissions (see 5.2). The OMRA shall take such possible hazardous situations into account.

6.4.5 Electrical components

The inside of the container is defined as non-occupied space in which no flammable atmosphere can be accumulated in normal operation and by fugitive refrigerant leaks due to design related container air-leakage.

To avoid over- or under-pressure inside the container due to ambient temperature variations, such as day and night temperatures, a container shall not be airtight (see ISO 1496-2).

However, to mitigate risks related to accidental type of refrigerant releases, the inside of the container is further defined as a zone in which no SOI shall be present.

Therefore, the inside of the thermal container shall be considered as a temporary hazardous area, a zone 2 in accordance with IEC 60079-10-1. The selection and installation of electrical equipment inside the thermal container shall be suitable for at least EPL Gc in accordance with IEC 60079-14.

IEC 60079-14 allows for various types of equipment to be used in EPL Gc applications. Some types of equipment have higher maintenance requirements to ensure ongoing explosion protection ratings than other types, therefore the maintenance factors should be considered in the OMRA.

For refrigerants classified type 2L the requirements for electrical SOIs described in IEC 60335-2-40:2018 shall be followed.

For components surface that can be exposed to leaked flammable refrigerants, the temperature limit shall comply with 6.4.4.

6.5 Outside electrical cabinet

The location of the outside electrical cabinet should be chosen so that the leaking refrigerant does not flow or accumulate into the outside electrical cabinet in normal operation or in the event of a leak. This shall be demonstrated by leak simulation or testing according to 5.3.6.

If this cannot be tested or proven by simulations, the following shall apply:

— the requirement of IEC 60079-15:2010, Clause 20 for restricted breathing enclosures; or

— the flame arrest enclosure verification test described on IEC 60335-2-40 for 2L refrigerants.

NOTE 1 Components and apparatus complying with IEC 60079-15:2010, Clauses 16 to 22 or an applicable standard that makes electrical components suitable for use in Zone 2 as defined IEC 60079-14 are not considered as a source of ignition.

NOTE 2 For 2L refrigerants, electric components of switching device and allowable opening of relays and similar components complying with IEC 60335-2-40 are not considered an ignition source.

In case of leak simulation test, the test shall include the scenario in which the selected mechanisms to reduce risk as described in Annex B are activated if these mechanisms had been applied.

NOTE 3 In case of accidental type leaks inside the container and operating ventilation mechanism according to B.3, the air flow from the outlet channel can contain high concentrations of flammable refrigerant.

6.6 Refrigerant charge

The refrigerant charge within the refrigeration cycle shall be specified by the manufacturer and included on the name plate, operation and service manuals.

6.7 Alarm system

6.7.1 General

An alarm system shall be in place, which generates an alarm in case of refrigerant losses or leakage potentially causing a hazardous situation.

The alarm system shall be evaluated during the risk assessment process for efficient risk reduction below the tolerable risk. It shall include a refrigerant leak detection mechanism which may process different types of analyses, measurements or detection techniques, and shall indicate refrigerant leak.

The alarm system shall also alert an authorized person by audible and visual indication to take appropriate action according to the results of the risk assessment. The alarm should be able to be incorporated in the general alarm system and meet the requirements of the operator, transmitted for example through any remote communications device. Additional information and instructions shall be available on the operator panel (display) indicating the procedures to be adopted in event of an alarm.

The monitoring of signals from the alarm system may have the functionality to detect charge losses over longer operation time caused by fugitive or small leaks and call for preventive maintenance.

Detailed information and instructions concerning the alarm system including the leak-detection mechanism shall be provided in the operation and service manual.

The audible and visual alarm system specifications shall be sufficient to meet the owner's requirements.

Clause B.5 gives additional information.

6.7.2 Alarm system power

The power source of the alarm system shall be part of the general power supply of the refrigeration machinery.

If power is applied to the container refrigerating system, the alarm system shall start automatically.

Backup power for the alarm system for the detection of leaks when the MRU is off power shall be provided. The nominal capacity of the backup power shall be sufficient to meet the owner's requirements.

6.8 Testing

6.8.1 General

Tests shall be conducted prior to utilization of the unit as an MRU.

Type testing is required to ensure compliance with this document.

Strength/pressure test for components and system tightness test shall be carried out in accordance with ISO 5149-2:2014, 4.4.2 and 4.4.3.

If a mechanism to reduce risk presented in Annex B is used, the correct functioning during use, including NOR operation until end of life, should be tested according to the principles described in Annex B. These shall be certified and approved by an accredited third party or classification society.

6.8.2 Protective device test

All devices shall be tested in order to verify their functionality.

6.8.3 Vibration type-test

The vibration test shall demonstrate that, under the influence of internally and externally initiated vibration, no damage is caused to the parts containing the refrigerant.

The complete container refrigerating system shall be carried out according to IEC 60068-2-6 with the severity for ship, rail and truck transportation (see Table 2).

Table 2 — Recommended values for testing

Frequency	Displacement/Acceleration	Sweep rate
$2(^{+3}_{-0})$ Hz to 13,2 Hz	±1 mm	Maximum 1 octave/minute
13,2 Hz to 100 Hz	0,7 g	Maximum 1 octave/minute

The duration of the test in case of no resonance condition is 90 minutes at 30 Hz.

The duration of the test at each resonance frequency is 90 minutes.

The pass criterion for the test is that the refrigerant shall not leak from the system and the system tightness is not affected.

6.8.4 Shock and impact type test

The outside and inside components of the refrigerating system containing refrigerant shall be protected against, or withstand, impacts that can cause functional damage and lead to refrigerant leakage. The testing procedure shall be carried out according to IEC 60068-2-75. The impact test should include acceleration of at least 2 g in the x, y and z directions.

NOTE Impact tests are aimed at determining the ability of a specimen to withstand specified severities of impact. They consist in the application to the specimen of a prescribed number of impacts defined by their impact energy and applied in the prescribed directions.

In case of tests concerning outside components containing refrigerant, the manufacturer should prescribe the attitudes or behaviour of the specimen and the locations on the specimen where the impacts should be applied, corresponding to where damage is most likely to occur in practice. Unless otherwise specified, the blows shall be applied perpendicularly to the tested surface.

The inside components containing refrigerant shall be protected by an end wall able to withstand the cargo loading and/or the forces or static equivalents of accelerations identified in the end-wall strength test as specified in ISO 1496-2.

The test is passed if no refrigerant leakage is detected and the leak tightness of the refrigerating system is unaffected.

6.8.5 Production test

The refrigerating system shall undergo the following final factory tests of the whole system:

— leak tightness and pressure tests according to ISO 5149-2;

— all devices used as required by the results of the safety concept shall be tested;

— compliance with this document.

The manufacturer shall be aware of applicable local requirements, laws and regulations in the production and emission values for refrigerants.

6.9 Marking and documentation

6.9.1 General

The manufacturer of the refrigerating system shall provide all necessary information according to existing standards, in particular ISO 5149-2.

The marking of container refrigerating systems shall follow the recommendations of 6.9.2. Additional requirements are described in Clause 7.

It is the manufacturer's responsibility to ensure the marking(s) and location(s) have been reviewed by a recognized classification society.

6.9.2 Marking

The approval reference number shall be marked on a permanently fixed plate near the serial number.

Warning symbols shall be placed on the container refrigerating system. Warning symbols should inform on the presence of:

— potentially flammable atmosphere;

— flammable refrigerants.

Symbols regarding prohibition of smoking and presence of uncontrolled naked flames shall be presented at the door end and the unit end of the container refrigerating system. Warning notices shall be placed on the outside of the container doors to inform that unauthorized persons should not enter. Additionally, warning notices shall be displayed near the operator panel prohibiting unauthorized operation of the system.

Warning notices and relevant symbol(s) shall be affixed, as a minimum, on visible location(s), such as:

— safety signs;

— on the compressor(s), on refrigerant service connections, on frequently replaced spare parts containing flammable refrigerant;

— warning notices: on the back panel inside the container, at the container doors.

Figure 1 — Graphical symbol ISO 7010-W021, Combustible and flammable materials

Service access points to equipment or components shall be marked with the flame symbol shown in Figure 1.

6.9.3 Manuals and documentation

6.9.3.1 General

The manufacturer shall specify the necessary operations for the safe use and handling of equipment using flammable refrigerants.

The documentation should give additional information on risks identified by the OMRA. Examples should be presented in the manual and safety instructions. The examples should describe the correct and incorrect operation and use. The description should be simple and understandable and include pictures and sketches.

6.9.3.2 Documentation

The documentation shall include the results of the protective device(s) tests as described in 6.8 and the results of the risk assessment as described in 5.3.2.

6.9.3.3 Operation and service manual

The manufacturer should supply adequate operation and service manual, including leaflets, and safety instructions in the main business languages.

The operation and service manual should at least contain the following information:

— purpose;

— description of the container refrigerating system and equipment;

— refrigerant type and charge amount;

— refrigerating system schematic diagram and electrical circuit diagram;

— list of specified parts;

— instructions concerning starting, stopping, standstill and inspection before trip;

— precautions to be taken when lifting or transporting;

— information displayed on display of the unit, the information for marking system;

— maintenance instructions;

— actions to be taken in case of alarm;

— procedure for maintenance and repair after indicated alarm or malfunctions;

— description of repair and maintenance procedures, including refrigerant removal and recovery;

— list of suitable tools and equipment for repair and maintenance;

— information for handling, installation, cleaning, servicing;

— instruction that refrigerant pipe work shall not be damaged during any repair on the box;

— all ventilation equipment or air ducts of the container refrigerating system shall not be obstructed;

— instruction on how to create a well-ventilated area for a refrigerating system repair operation;

— specific information about the required qualification of the working personnel for maintenance, service and repair operations;

— other information for the operation of the container in different operating sites which have been identified as essential in the risk assessment;

— other information for the operation of and requirements for equipment inside the container, such as temperature reading devices, lighting;

— accident prevention procedures.

6.9.3.4 Drawings

A piping and instrumentation diagram (PID) of the refrigerating system shall be displayed identifying the shut-off and control devices.

The PID should be located in the electrical cabinet.

6.10 Certification

The requirements described in 6.2 to 6.9 and the applied protective device(s) should be reviewed/certified for flammable refrigerants as relevant.

The certificate for the MRU shall be issued by a classification society or another equivalent accredited organization.

7 Design related requirements of the MRU manufacturer for safe service, maintenance, repair

Requirements for execution of service, maintenance, repair and recovery are described in Clause 10. In contrast to Clause 10, Clause 7 describes the safety-related requirements for the design process for the MRU manufacturer.

The design of the MRU shall be such that the requirements for service, maintenance, and repair of ISO 5149-4:2014, EN378-4:2016, Annex E and the latest version of IEC 60335-2-40 can be met.

Additional requirements are described in the following:

— the passing on of instructions for use, maintenance, and repair;

— ensuring access and traceability of safety-related repairs;

— ensuring that testing of protective device(s) can be made;

— the specification of the required level of competence of personnel;

— the constructive consideration of the repair process with regard to error prevention and of all kinds of components.

The requirements for operation at operating sites in Clause 9 shall be considered in the design process as well.

The risks associated with container repair operations (such as welding and painting) and refrigerating system repair operations (such as pipework repair, component maintenance and refrigerant charging) shall be investigated in an OMRA according to 5.3.2. The repair procedures, in terms of best practice using flammable refrigerants, should be developed on the basis of the results of the OMRA. These procedures, where relevant, should be made available by the manufacturer in the operation and service manual.

In addition, the manual shall include information to enable the responsible operator to ensure proper procedures are in place at each depot and service centre to handle units with flammable refrigerants including information about applicable local regulations.

7.1 Education and training

Personnel who can use, repair and/or maintain the MRU should be properly trained. Training should ensure that each type of refrigerating system is well known and all safety measures are understood.

To support this quality process, education and training procedures should be provided by the manufacturer for authorized service facilities.

NOTE 1 Owners and operators need to be aware of their local requirements for handling flammable refrigerants (see details in Clause 8).

NOTE 2 If certifications are required for local maintenance and operation, those certifications need to be in place before working with the units (see details in 10.2).

7.2 Safety instructions

The relevant safety instructions shall be provided for all alarm events described in 6.7 and 9.7.

The following safety instructions for operation shall be provided by the MRU manufacturer:

— explanations relating to warning alarms and symbols (for example on the source of hazards) and examples of best practice to prevent hazards and failures;

— causes of the potential defects and measures to be taken, such as instructions concerning leakage testing and leakage detection;

— reference to protective measures, first aid provisions and procedures under emergency conditions (such as in the event of leakage, decomposition of fluorinated refrigerants and creation of toxic atmosphere, fire and explosion);

— explanations and actions to be taken in case of alarm;

— contacts to competent maintenance technicians in the event of leakage or breakdown;

— functioning and maintenance of protective device(s);

— charging and recovery of refrigerant;

— handling of refrigerant and associated hazards;

— disposal of the flammable refrigerants;

— disposal of the flammable liquid oil mixtures.

7.3 Testing before operation

The manufacturer shall provide a self-check by design that is carried out automatically after power up in accordance with the safety concept. The purpose of the self-check is to verify that the relevant protective device(s), control and measurement devices and alarm systems are functioning.

The self-check shall include a check on refrigerant charge loss.

The test should ensure that an alarm with further instruction is activated if a failure is detected in components.

7.4 Maintenance and repair

The manufacturer shall:

— specify that maintenance and repair should be carried out by qualified and trained personnel only;

NOTE It is the owner's and operator's responsibility to ensure the personnel are qualified and trained to work on the MRU, utilizing manufacturer or third-party training. See Clause 10 for detailed information.

— indicate that local occupational safety and health rules and regulations can apply;

— instruct that following tasks are performed during maintenance and after repair:

  — all control and measurement devices especially protective device(s) and alarm systems are checked to verify their correct operation;

  — leak tests are carried out at the relevant parts of the MRU.

The manufacturer shall specify that only OEM-approved components, including controller software, should be used in case of replacement. Component changes and or/modifications of the refrigerating system should not be permitted unless authorized by the OEM.

All electrical installations, including software, shall be designed to support the responsible operator in identifying and installing approved spare parts only. Certified parts, including software, can be coded and marked that replacement with improper parts is inhibited.

8 General recommendations at operating sites

Refrigerating systems are addressed by IMO rules on transport of dangerous goods on a global basis and by local restrictions, including container refrigerating systems.

Recommendations are given by the United Nations[8], the International Maritime Dangerous Goods Code (IMDG-Code)[10], the European Agreement concerning the International Carriage of Dangerous Goods by Road, ADR[9], the U.S. Government, Code of Federal Regulations[11], for the transport of dangerous goods including refrigerating systems with flammable refrigerants. Recommendations UN No. 3358 (REFRIGERATING MACHINES containing flammable, non-toxic, liquefied gas) refer to special provision No. 291:

> *"Flammable liquefied gases shall be contained within refrigerating machine components. These components shall be designed and tested to at least three times the working pressure of the machinery. The refrigerating machines shall be designed and constructed to contain the liquefied gas and preclude the risk of bursting or cracking of the pressure retaining components during normal conditions of transport. Refrigerating machines and refrigerating-machine components are considered not subject to these Regulations if they contain less than 12 kg of gas".*

Consequently, the handling of MRU using flammable refrigerants charged with less than 12 kg at operation sites does not require procedures for dangerous goods.

The responsible operator shall be aware of legal or binding guidelines and requirements concerning the operation of operating sites such as for industrial premises, vessel, railway and road traffic.

The responsible operator shall be aware of local occupational safety and health measures.

With reference to ISO/IEC Guide 51, requirements for the reduction of personnel risks, by means of personal protective equipment (PPE), is not laid down in detail in this document:

> *"These occupational safety and health measures are defined nationally, on the basis of the EC Treaty and the corresponding European Directives, e.g. in state or trade association regulations. The decision as to which specific protective measure to choose in individual cases when applying the test procedure is the responsibility of the employer"*

However, information on PPE is given in 9.1 where important.

Care shall be taken to ensure that the personnel in charge with the operation, maintenance and repair of the container are adequately instructed and competent with respect to their tasks.

Recommendations about operating sites are also documented in the operation and service manual, as described in 6.9.3.3.

Operating sites in which the MRU with flammable refrigerants are handled or stored should be operated and maintained so that any release of flammable refrigerant, and consequently the extent of hazardous areas in case of accidental type release, are kept to a minimum, whether in normal operation or abnormal operation, with regard to frequency, duration and quantity of any release. Subclause 5.3.2 describes the principles of an OMRA, which covers the full container life cycle.

Annex C shows refrigerant release rates as a function of leak type and leak amount, and occurrence (frequencies) of releases from the MRU.

In case of activities other than those of normal operation, e.g. commissioning or non-routine maintenance, including opening of the refrigerating system for repair, an area classification may not be valid. According to IEC 60079-10-1, it is expected that the activities other than those of normal operation are dealt with by a safe system of work. The area classification should take into account any routine maintenance.

9 Safe operation at different operating sites

9.1 General

The responsible operator is the person or entity that has operational control of the container at any particular time including, but not limited to, repair and storage depots, terminals, transport operators, shippers and consignees.

The responsible operator at any operating site shall evaluate the relevant results of the OMRA provided by the MRU manufacturer, which is described in 5.3.2.

The responsible operator shall execute a separate risk assessment, if an operating site or the local situation and operation is not sufficiently covered in the OMRA provided by the MRU manufacturer. The responsible operator shall inform the MRU manufacturer on additional risks information not included in the OMRA.

The following information and recommendations provide assistance for the evaluation, as well as the information given in Annex C.

Non-flammable refrigerants safety guidelines and risk assessments for operation of containers having refrigerating systems can be used as basis. Flammable refrigerant guidelines and risk assessments should also be used.

NOTE 1 During normal operation of the MRU no hazardous areas in terms of flammability can be outside the footprint of the container.

The responsible operator's risk assessment shall include intended use, reasonably foreseeable misuse, and special use if applicable.

Special and additional personal protective equipment (PPE) is not required for normal operation of the MRU as this represents operation in non-hazardous atmosphere. In situations where a danger is suspected or clearly noticeable, the appropriate PPE should be used as a precaution. Examples for such situations are:

— opening of container door without power and back-up power and unknown inside concentrations (see 9.5);

— in case of alarms (see 9.7);

— after an accident (see 9.8.2).

Events such as accidental type, large or small leaks, according to Annex C shall be investigated to identify severity and frequency of hazardous events, which should not result in a higher risk than those described as tolerable in 5.3.3.

Considering the definitions in IEC 60079-10-1:2015, Clauses 1, 3.7.3 and 3.7.4 for MRUs, events of accidental type or large leak rate of refrigerant, according to Annex C, are understood as catastrophic failures or rare malfunctions and do not apply to the concept of abnormality for area classification. Consequently, such events constitute no requirements for additional special facility equipment at operating sites with regard to the use of flammable refrigerants in normal operation (see Note 3). Accordingly, this document contains no requirements for facilities or equipment at operating sites.

Recommendations for operating sites handling the container, including dangerous situations, and/or the container refrigerating system in normal operation address:

— accidental type leaks at the container refrigerating system with action and mitigation procedures (see 9.8);

— fugitive emissions at the container refrigerating system, which can result in accumulation of refrigerant in enclosures, with requirements depending on the ventilation environment (see 9.4);

— intended opening of the refrigerating system for repair (see Clause 10).

The responsible operator of a site shall take refrigerant leaks into account for the risk evaluation, based on their operational processes or conditions. Examples are presented in D.3.

NOTE 2 Accidental type leak events are classified as catastrophic failure according to IEC 60079-10-1:2015, 3.7.4; large leaks are classified as rare malfunction according IEC 60079-10-1:2015, 3.7.3.

NOTE 3 Normal operation can include occurrence of fugitive emissions. Normal operation does not include larger leaks.

NOTE 4 Information on leak types can be found in Annex C.

NOTE 5 Experience has shown that rupture type leaks occur rarely and with acceptable consequences due to ignition of refrigerant release[5].

9.2 Operating sites

Operating sites are classified according to the following location characteristics regarding handling, repositioning or operation of the whole container:

— open air;

— well-ventilated area;

— non-well-ventilated area.

Table 3 shows the combination of operating sites with relevant recommendations depending on ventilation environment. Table 3 is presented as an orientation, ventilation environment shall be determined for each individual case.

The door opening process is described separately in 9.5 but included in Table 3 to combine operating sites with relevant recommendations.

Table 3 — Identification of relevant recommendations for responsible operator for operating sites with respect to ventilation environment

Operating Site	Operation	Responsible operator	Container location and ventilation environment			Relevant clause
			Open air	Well ventilated	Non-well ventilated	
Requirements described in subclause:			9.4.1	9.4.2	9.4.3	
Terminal, depot, shop, repair facility	Box repair	Depot	x	x		10.3
	Cleaning inside	Depot	x	(x)		9.5, 10.1, 10.2
	Inspection	Depot	x	x		9.5, 10.1, 10.2
	Live area (OR, NOR)	Terminal	x			10.1, 10.2
	Load	Terminal	x			9.2, 0
	On rail	Rail Operator	x	x		9.2, 0
	PTI	MRU Contractor	x	x		9.5, 10.2, 10.4
	Service, PTI area	Depot/Terminal	x	x		9.5, 10.2, 10.4
	Stacker	Terminal	x			9.2, 0
	Storage	Depot	x			9.2, 0
	Packing/unpacking	Shipper/Consignee	x	x		9.5
	System repair[a,c]	MRU Contractor	x	x	(x)	9.5, 10.2, 10.4
Vessel	Load	Terminal	x	x	(x)	9.2, 0
	OR, NOR	Vessel Crew	x	x	(x)	9.2, 0
	System repair[c]	Vessel Crew	x	x	(x)	10.4
Truck, Rail	OR[d], NOR[e]	Truck Driver, Train Operator	x	x	(x)	9.2, 0
	Load	Truck Driver, Train Operator	x			9.2, 0
	Inspection[b]	Truck Driver	x	x		9.5, 10.1, 10.2
	Packing/unpacking	Shipper/Consignee	x	x		9.5
	System repair[c]	MRU Contractor	x	x	(x)	9.5, 10.2, 10.4
Repair	System repair[c]	MRU Contractor	x	x	(x)	9.5, 10.2, 10.4
Public Event	Inspection[b]	Owner/User	x	x	(x)	9.5, 10.1, 10.2
	Storage	User	x			9.2, 0
	OR, NOR Operation	Owner/User	x	x		9.2, 0
	Packing/unpacking	User	x	x		9.5
	System repair[c]	MRU Contractor	x	x	(x)	9.5, 10.2, 10.4

[a] Contractor can be called if vessel is alongside.

[b] The operation of a Gen-Set results in the same conditions in normal operation.

[c] Only trained and authorized MRU technicians shall be allowed to repair.

[d] Operating reefer.

[e] Non-operating reefer.

9.3 Significant hazards

Subclause 5.2 describes potential hazards relating to refrigerating systems in general with reference to ISO 5149-1:2014, Annex C. Significant hazards related to the refrigerating system using flammable refrigerants including opening of the refrigerating cycle during service or replacement of components and repair are also described in 5.2.

Hazards related to operating sites or operation at different locations are included.

NOTE Refrigerant releases larger than those from fugitive emissions are not expected in normal operation.

Given that it is unlikely that more than one small or larger leaks occur at any one time, only one release from one container should be considered, according to IEC 60079-10-1.

9.4 Ventilating condition at operating sites

In general, ventilation is the appropriate and sufficient method to prevent flammable atmosphere outside the MRU footprint due to leaks from the container refrigerating system.

Ventilation can be accomplished by different means, such as the movement of air due to the wind and/or by temperature gradients or by artificial means such as fans. Two main types of ventilation are recognized:

a) natural ventilation;

b) artificial or forced ventilation, general (e.g. a whole enclosed space) or local (e.g. extraction near a leak location).

NOTE 1 Applying the method from IEC 60079-10-1:2015 to the outside components of the MRU with fugitive emissions or small leaks in control volume I, II, as defined in Annex A, concludes that no accumulation of leaked refrigerant in well-ventilated area or in open air is possible, and therefore no flammable concentration is formed.

NOTE 2 Requirements and accident prevention in case of refrigerant release larger than fugitive emissions according to Annex C are described in 9.8.

Rules for ventilation requirements at operating sites are for example:

— Rules for classification and construction for ship technology, seagoing ships: Ventilation

— ISO 13779;

— If relevant: international building code and industrial ventilation guidelines and standards such as:

  — CEN CR 1752;

  — ASHRAE 62.

NOTE 3 See also the requirements in 5.3.5.1.1.

9.4.1 Requirements for operation in open air

Open air operations happen at all types of operating sites (e.g. storage or operation at live area, test in PTI area at terminals, storage including stacked containers, on deck, on truck, on rail, on land as well as unobstructed loading and unloading on vessel, rail, truck, and service including repair and maintenance).

An open-air area exists if the area is an unenclosed area, which is possibly roofed, with natural ventilation.

In open air, no additional safety measures are required in normal operation at operating sites.

Natural ventilation is sufficient to ensure dispersal of any flammable refrigerant which arises in the area caused by fugitive emissions or small leaks. Requirements and accident prevention in case of refrigerant release larger than fugitive emissions according to Annex C are described in 9.8.

9.4.2 Requirements for operation in well-ventilated areas

Operation in well-ventilated areas includes cargo hold, operating in normal conditions, repair shops with forced ventilation and other enclosed spaces with good ventilation.

A well-ventilated area exists if the existing ventilation is able to dilute flammable refrigerant release sufficiently in normal operation, and exchange fresh air so that no hazardous area can be created.

A well-ventilated area requires no safety measures in addition to the existing ventilation in normal operation.

Requirements and accident prevention in case of refrigerant release larger than fugitive emissions according to Annex C are described in 9.8.

NOTE 1 The necessary ventilation rate to dilute fugitive emissions can be calculated as shown in Annex D.

NOTE 2 Existing requirements for ventilation are sufficient to ensure condition for well-ventilated areas (for example DNV-GL, Rules part 6, chapter 4, Clause 9 Carriage of refrigerated containers - RCP, 2016). According to 5.3.2, the MRU manufacturer evaluates in the OMRA if the ventilation environment is sufficient to prevent temporary hazardous atmosphere caused by larger leaks.

The existing forced air ventilation at operating sites and especially in cargo holds with water cooled condenser shall be in operation at minimum capacity and remain operational.

NOTE 3 In cargo holds with water cooled condenser, the minimum air flow rate is V_{air} = 500 m^3/h per R-FEU stowage position.

NOTE 4 In cargo holds with air cooled condenser, the minimum air flow rate is V_{air} = 4 200 m^3/h per R-FEU stowage position.

NOTE 5 The operation of the condenser fan of the container refrigerating system results in an air flow rate of >2 000 m^3/h.

As a minimum requirement, which can be defined for the smallest service volume of 1,5 m^3 (0,6 m depth × 2,50 m width × 1 m height), an air flow rate, V_{air}, greater than 80 m^3/h is recommended.

NOTE 6 The value of 80 m^3/h is estimated as minimum requirement based on a leak rate of 0,2 g/s and a small service volume of 1,5 m^3 and represent a conservative baseline value. The smallest space for repair is used as volume: see recommendation of classification societies (for example: DNV-GL rule, RCP, part 6, chapter 4, Clause 9, 8.1: Access to container refrigeration units). Ventilation adjustments to safe energy are permitted according to calculation as shown in Tables D.1 and D.2.

Examples for the assessment of ventilation are presented in Annex D.

9.4.3 Requirements for operation in non-well-ventilated areas

Operation in non-well-ventilated areas is atypical for intermodal container operating sites. Inspection, loading, unloading, or system repair is typically performed in open air or in well-ventilated areas.

Potentially non-well-ventilated area may be, for a short period of time, a cargo hold without forced ventilation in case of power failure onboard (during loading/unloading).

As accumulation of leaking refrigerant over time is the relevant hazard in a non-well-ventilated area, the area shall be assessed according to Annex D considering a fugitive emission rate and the relevant period of operation time of the container being present in the non-well-ventilated area to calculate the required ventilation rate to avoid hazardous atmosphere. The calculated ventilation rate shall be multiplied with a safety factor of 4 (k = 0,25).

NOTE 1 Annex C gives information for determination of possibly accumulated leak amount per time. Annex D gives information for the calculation of ventilation requirements.

NOTE 2 Fugitive emissions result to refrigerant amounts from 0,1 g/day to 10 g/day (see Annex C).

No requirements for non-well-ventilated areas exist if it can be ensured that the storage time of the MRU is less than the time to accumulate to concentration of 25 % LFL. Else, the following measures shall be taken:

— transform the non-well-ventilated into a well-ventilated area (see 9.4.2); or

— the container shall be removed, if the space is not larger than release mass divided by 25 % LFL (see 9.4.4).

Requirements and accident prevention in case of refrigerant release larger than fugitive emissions according to Annex C are described in 9.8.

9.4.4 Container operation in non-ventilated areas

A non-ventilated enclosure is a completely closed space with no openings or ventilation and thus no dilution is assumed.

NOTE 1 It is unlikely that a container is operated or stored in a non-ventilated area.

In the case that this situation occurs and a container in placed in such a location, a safety system shall be installed in the area.

NOTE 2 Provisions for machinery rooms can be applied for such locations as specified in ISO 5149-3.

9.5 Requirements for opening of container door and for packing and un-packing of goods

Door opening or packing and unpacking operations are typically performed in open air or well-ventilated areas. The instructions given in the CTU Code[11] (CTU, Cargo transport unit) apply.

Due to the different ambient temperatures during operation, a container shall not be airtight. According to the ideal gas law, an impermissible overpressure (under pressure) would occur in the airtight closed container volume.

NOTE 1 Experiments have shown that closed containers are not airtight An air flow rate of at least 0,155 m^3/h can be assumed for ventilation of possible refrigerant leaks through remaining openings, such as air ducts.

NOTE 2 ISO 1496-2:2018, 8.14, describes a tightness test which can be used for testing of the air leakage rate.

No requirements for door opening, packing and unpacking are mandatory for normal operation.

For cases where damage is suspected, such as shock, accident, pipe rupture, the following measures should be taken:

— check the alarm system for possible warning concerning hazardous atmosphere inside the container and follow the alarm system instructions;

— open the doors if no hazardous atmosphere exists inside the container;

— connect the power cable to the container refrigerating system to active the alarm system if power supply is available;

— for hazardous atmosphere inside the container, without power supply:

  — open flame or other potential SOI shall be prohibited in the vicinity of at least a radius 3 m from the door;

  — open the doors for dilution of possible hazardous atmosphere for a minimum of 10 minutes.

These procedures shall be supported by the alarm system, which is powered by either the general power or back up power.

NOTE 3 Due to possible the accumulation of leaked refrigerant inside the container, a hazardous atmosphere can be created in case of damage, which requires the opening procedures described above.

NOTE 4 Independent from the cargo stuffing procedure, the operation of the evaporator fans supports the dilution of hazardous atmosphere from inside the container through the open door sufficiently.

NOTE 5 If the container doors are open, the inside is considered as open air after the procedure described above.

For packing and unpacking after door opening, the following requirements shall be met, shared with operating personnel and documented in the operation and service manual.

— Procedures should be in place to avoid accidents or damage to the evaporator pipework or pipe connections by forklifts or other loading equipment. Pipe ruptures or damage can cause hazards.

— If accidental damage occurs resulting in leaking refrigerant, do not place sources of ignition near the leak so as to avoid hazardous events (see 9.8 for handling of accidental type of events).

9.6 Electrical installations at operating sites

As long as the ventilation requirements described in 9.4 are met, no additional safety measures are required for electrical installations at operating sites in normal operation.

9.7 Operator instruction for handling of alarms

Required operation instructions on how to handle alarms from the container refrigerating system are addressed in this clause.

In addition, local laws, rules and regulations shall be taken into account, as applicable. The operator shall also ensure that the operating personnel in charge of the operation, supervision and maintenance of the container is adequately instructed and competent to act on alarms from the alarm system. The operator shall develop an operator safety guideline or alarm procedure adjusted to the operating site, document and enforce it.

The alarm procedures shall be based on the instruction described in the operation and service manual of the container refrigerating system. The alarm procedures shall be periodically investigated concerning the correct and safe execution and improved where required.

When the alarm system indicates an alarm, operating personnel shall follow the instructions of the individual alarm procedure for the operating site, the instructions shown on the operator panel (display) and recognize warning labels.

Indicated alarms representing larger leaks (although these situations are typically infrequent) shall be handled with care. Requirements for this situation are in accordance with accidental type situations which are described in 9.8.

Indicated alarms warning for hazardous atmosphere inside the container shall be handled as described in 9.5, according to the operation and service manual of the container, and according to operator safety guidelines.

NOTE 1 The alarm system design of the container refrigerating system is described in 6.7, additional information is given in B.5.

NOTE 2 The monitoring of the alarm system information can have the functionality to detect charge losses over time caused by fugitive emissions or small leaks and call for preventive maintenance.

The operator should investigate the requirement on an individual basis.

Required actions of responsible person(s) who recognize(s) alarm (normal operation):

— Confirm alarm code and inform authorized technician(s).

— If a hazardous atmosphere inside the container is indicated: eliminate ignition and potential ignition sources as described in 9.5.

— Make sure the container refrigerating system is located in ventilating condition as described in 9.4.

Required actions of responsible person(s) who recognize(s) emergency alarm in case of large leaks representing abnormal operation or an accidental type situation, and/or noticeable or detectable danger:

— person(s) shall not enter the vicinity of the container, shall eliminate SOI, and arrange fire extinguishing equipment.

9.8 Accidents

Containers and container refrigerating systems are involved in accidents caused by rough handling, transport crashes, external fires near the MRU, fire by self-igniting cargo, and other incidents.

Accidents can result in damage to the refrigerating system creating high refrigerant leak flow. The released refrigerant amount can generate a hazardous atmosphere in the vicinity of the ruptured component or pipe. The risk evaluation for accidental type releases within the OMRA process shall take large and rupture type leaks into account.

NOTE 1 Annex C give information for values for leak mass flow and release time for large and rupture leaks.

The unintended or improper opening of an MRU is classified as accidental type failure. Hazardous atmosphere in the vicinity of the container refrigerating system can occur in case of inadequate or improper service, such as opening of the pipework under pressure before an evacuation procedure.

In case of fire at the container refrigerating system, brazed connections can release refrigerant in an uncontrolled manner due to high temperature resulting in possible high-pressure refrigerant release with large jets of flame. The operator shall ensure that this danger is known by fire fighters and/or other parties, who can be involved in fire situations. The design to control the refrigerant release is described in 6.2.3.

NOTE Under fire conditions, fluorinated refrigerants generate toxic decomposition products, including hydrogen-fluoride and/or carbonyl-fluoride and can create toxic atmosphere.

The MRU manufacturer shall provide information to the operator of the operating site about results from the OMRA, especially regarding possible consequences of accidental type events. Exchange of information shall be considered good practice in order to understand consequences and prevent accidents.

9.8.1 Measures for accidents prevention

Prevention of accidents through the operator at operating sites with respect to container refrigerating system using flammable refrigerants are listed below:

— Be aware of local rules and safety guidelines for operating sites and take care that personnel strictly observe them.

— Collect and evaluate experiences from operation, accident history, failure history of actual or comparable situations for the development of mitigation measures for accident prevention.

— Information by the operator to his personnel, about the use of flammable refrigerants and possible danger in case of release, in particular also to the strict observance of the safety guidelines; information can include that danger exists due to the formation of a flammable atmosphere, fire jet, and audible noise of flow indicating pipe rupture.

— Avoid uncontrolled refrigerant system openings.

— Systematic analysis can be used to evaluate reasons for human failures and identify methods or measures to improve human reliability and to mitigate such behaviour. An incentive system can be developed in order to prevent such mistakes.

— Appropriate preventive action shall be developed and measures enforced, and continuously improved. Therefore, a continuous improvement process (CIP) can be used to evaluate and improve ongoing processes with respect to accident prevention.

— Relevant rules and standards shall be considered for accident prevention; information can be found in standards such as ISO 12100.

9.8.2 Measures after accidents

Existing procedures for required actions after accidents at operating sites shall be reinvestigated by the responsible operator with respect to the release of flammable refrigerant in accidents.

The vicinity of the damaged parts can be dangerous due to flammable atmosphere and shall be abandoned if possible until the dangerous situation is clarified. Pipe ruptures and large leaks occur combined with (very) loud, (clearly) audible noise of flow.

Toxic decomposition products from burning refrigerants can exist for a period of time and can create toxic atmosphere. The ventilation conditions shall be considered for all kind of installations. Care shall be taken regarding possible physical contact with contaminated surfaces.

Accidental type alarms from the alarm system of the container refrigerating system should lead to the same measures as described below for accidents.

If an emergency alarm indicates large refrigerant leakage, the operator shall eliminate potential ignition sources (such as open flames, operating electric devices) in the vicinity of minimum 3 m and shall not shut down the refrigeration machinery until emergency function is completed or the situation is clarified.

Following an accident involving suspected rupture of the refrigerating system, the following measures shall be taken (example listing):

— follow local accident handling procedures applied to the operating site;

— be aware that a flame jet can be formed, especially if an audible noise indicates a pipe rupture;

— be aware that the MRU alarm system can act automatically;

— in case of large(r) leaks be aware that flammable refrigerant can be accumulated in low lying areas, which can be some distance away;

— use of personal protective equipment (PPE);

— if possible, eliminate SOI in the vicinity of the dangerous situation;

— keep away from the dangerous situation;

— if possible, provide ventilation for dilution of flammable atmosphere.

Ventilation shall be avoided in case of fire.

9.9 Operating instructions, manuals, guidelines at operating sites

Existing instructions, manuals, or guidelines at operating sites shall be revised by the responsible operator to include MRU using flammable refrigerants.

Documents may be revised, with provided information from the MRU manufacturer about results of the OMRA, with respect to the operation, storage, handling or other type of operation as listed in 9.2.

Documents shall, at least, meet the requirements and recommendations in Clause 9.

9.10 Information in the manual related to operating sites

The requirements for the operation and service manual of the MRU are described in 6.9.3. These include information for operating sites.

10 Servicing recommendations and requirements at operating sites

Service, maintenance, and repair should be undertaken as described in the operation and service manual and according the recommendations of ISO 5149-4, EN 378-4:2015, Annex E, and in addition as described as follows.

The owner and/or responsible operator shall be responsible for ensuring the repair, service and maintenance, employees are knowledgeable of the correct methodologies to work on the unit and have the required certifications (see 10.4).

It shall be the owner's and operator's responsibility to ensure the personnel are qualified and trained to work on the units, utilizing manufacturer or third-party training. Requirements for training are described in 10.2.

On a yearly basis, safety training shall be provided as described in 10.4.2.

Inspection and cleaning of the MRU and the container structure shall not include opening of the container refrigerating system, described in subsection 10.4.

Service repair and maintenance activities that involve the opening of the MRU are covered in 10.4, handling of refrigerant is described in 10.5, and the decommissioning of the container refrigerating system is covered in Clause 11.

General failure prevention is described in 10.2.2, in contrast failure prevention during intended opening of the system is described in 10.4.9.

Requirements described below do not apply to accidental type failures with releases larger than small leaks or other infrequent malfunctions which are beyond the concept of abnormality dealt with in this document. Recommendations on how to act in case of accidents are given in 9.8.

Since normal operation does not include repair, procedures for these activities and work area requirements as well as recommendation for repair process improvements are described in this clause to achieve a safe system of work.

For typical work areas which are intended for repairs of the MRU, an area classification is provided and defines the relevant requirements (see 10.4.3).

10.1 Operating sites with service activities

Service and repair are carried out at different operating sites with ventilation environments as listed in Table 3.

In normal operation of the MRU, general services and maintenance do not require any addition of safety procedures at operating sites for repair, except if the container refrigerating system is intended to be opened.

10.2 General

The general requirements in Clause 9 for safe operation at operating sites shall be considered.

Guidance for repair described by the manufacturer in the operation and service manual for the MRU (according to 6.9.3) shall be strictly followed.

The relevant results of the OMRA for service, repair and maintenance shall be taken into account, as provided by the MRU manufacturer.

For operating sites with service, maintenance activities and openings of the container refrigerating system the methods and procedures described for accident prevention can be considered.

Using flammable refrigerants, improper service causes higher risk, compared to MRU with non-flammable refrigerants. Therefore, the responsible operator of the repair site shall take care to implement safe procedures.

For service, maintenance and repair, quality processes for improvements, such as continuous improvement processes (CIP), shall be applied to address known repair situations possibly causing hazardous events in case of release of flammable refrigerants, such as:

— improper power cable repair: improper repair can result in sparking cables connections or cable fire;

— incorrect spare part(s): can result to unintended installation of SOI inside the container;

— improper repair tools and equipment, such as incorrect vacuum pump;

— incorrect release of refrigerant.

10.2.1 Instruction of personnel

Care shall be taken to ensure that the personnel charged with supervision, repair and maintenance of the MRU are adequately instructed and competent with respect to their tasks.

Personnel shall be instructed about the fact that flammable refrigerants are used in the MRU and care shall be taken with work potentially causing damage or rupture on the pipework or components.

It is prohibited to open the container refrigerating system, except when intended opening and repair on the refrigerating system is required.

It is prohibited to use inappropriate tools for, or during opening of, the container refrigerating system.

For a container with closed doors, before starting activities inside the container, follow the requirements in 9.5.

10.2.2 General failure prevention

All electrical installations, including software, shall be designed to support the responsible operator in identifying and installing approved spare parts only. Certified parts, including software, can be coded and marked that replacement with improper parts is inhibited.

10.3 Repair and maintenance on the container structure

Repair and maintenance include procedures such as cleaning, container structure repairs, welding without work on the MRU or opening of the refrigerating system.

In normal operation, no hazardous areas exist around the container.

For outside box repair and maintenance, no requirements.

For inside box repair and maintenance, no requirements, except for door opening procedure see requirements in 9.5.

For tools and equipment, no requirements.

Repairs on the box should be performed in such a way that no opening or damage of the MRU occurs. Care shall be taken with hot works or welding due to the fact that a flammable refrigerant is included in the pipework and components of the refrigerating system.

10.4 Repair and maintenance on the MRU including opening of the refrigerating system

10.4.1 General

Maintenance should ensure that:

— accidents to personnel are prevented;

— damage to goods is prevented;

— refrigerating system components remain in good working order;

— purpose and availability of the system are maintained;

— leakage of refrigerant or oil is identified and remedied.

General requirement for repair and opening of the MRU are described in detail in ISO 5149-4:2014, Clause 5 (especially 5.3).

Guidelines in EN 378-4:2018, Annex E, for repairs of equipment using flammable refrigerants should be considered.

10.4.2 Instruction of personnel

Instructions for operating sites according to 9.9, shall be recognized, in addition to instruction of personnel in 10.2.1.

The competence levels of MRU technicians with respect to the work tasks and activities should be in accordance with EN 13313 or equivalent. It is recommended that skills and competence of technicians be documented by means of appropriate training or proof of work. The responsible operator of the repair site shall ensure that practical competences of personnel comply with the competence level required for flammable refrigerants.

Local certification and training requirements shall be strictly followed, at a minimum it is required that certified technicians have a refrigerant handling qualification or equivalent and have completed a flammable refrigerant safe handling course within the last three years. In addition, technicians shall complete all manufacturers' training for servicing and maintaining for MRUs containing flammable refrigerants.

Repair on the MRU requires safe working procedures to avoid flammable atmosphere. Instructions for safe working procedures at operating sites are:

— be aware of alarms and follow instructions if displayed on the operator panel or as instructed and described in the operation and service manual;

— in the unlikely event of a repair situation that a leakage is detected in the particular moment of repair or if suspected, the technician shall under no circumstances carry SOI into the vicinity of the MRU;

— before opening the system or any hot work, the refrigerant shall be removed completely according to requirements in 10.4.6;

— to ensure that no air is drawn into the container refrigerating system during pump down of refrigerant, a pump down is only permitted if no leakages are suspected or detected in the low-pressure section;

— people carrying out work on a refrigerating system shall not use any sources of ignition in such a way that it can lead to the risk of decomposition of refrigerants, fire or explosion;

— open flames shall be prohibited, except when used for hot work;

— smoking is prohibited outside and inside the container;

— if repair on parts of the MRU inside area are intended, the provisions of 9.5 shall be followed prior to repair work;

— after any repair of protective device(s), the functionality shall be tested according to the operation and service manual.

10.4.3 Work area requirements

Proper repairs with and without intended opening of the container refrigerating system shall be performed in an area that is either open air or well-ventilated, and that this situation is maintained during the period of repair.

NOTE The operation of the condenser fan of the MRU can provide sufficient ventilation in the vicinity.

Safety checks should be performed as described in the operation and service manual before beginning the work.

If any hot work is to be conducted on the MRU or any associated parts, appropriate fire extinguishing equipment shall be available at hand. A suitable fire extinguisher adjacent to the charging is recommended.

10.4.4 Inspection

For general requirements for inspection during operational life of the MRU, see ISO 5149-4:2014, Annex D.

Cables shall be visually inspected and if damaged or improperly repaired, they shall be repaired according the service and repair manual.

Check that cabling will not be subject to wear, corrosion, excessive pressure, vibration or any other adverse environmental effects. The check shall also take into account the effects of aging or continual vibration from sources such as compressors or fans.

Regular leak tests, inspections and checking of the protective device(s) shall be carried out according instruction in the service and repair manual, or for example at PTI. Refrigerant leaks shall be identified and repaired as soon as practicable by a competent person and the system shall only be put into service again when all the leaks have been repaired. Leak testing of the system is to be performed if serious suspicion of leaks is raised, focusing on those parts of the system most likely to leak.

Sources of ignition, such as lighters or open flame shall not be used for the detection of refrigerant leaks. Only detection equipment that is intrinsically safe shall be used, detectors with SOI are prohibited.

Protective device(s) shall be checked at least during PTI, or equivalent, for protective devices, emergency signals and alarm systems. Valves, bursting discs and fusible plugs shall be visually checked.

Visual corrosion inspection should be carried out at PTI on piping, piping supports, components and component supports.

10.4.5 System failures

System failures as recognized by the alarm system and suitable instructions shall be displayed.

Possible system failures combined with unknown alarm information can be:

— controller or display of the alarm system is not functioning, no alarm information;

— other type of electronic components failures: protective device(s) cannot function.

If inside repair is foreseen and system failures occurred, the provisions of 9.5 shall be followed.

For system failure caused by charge losses, or component failure, such as compressor or heat exchanger failure, repair according to 10.4.6 shall be performed.

10.4.6 Actions and procedure for repair and opening of the refrigerating system

10.4.6.1 Removal, evacuation of refrigerant

For removal and evacuation of the refrigerating system for repairs, the conventional procedure shall be used.

In addition to the MRU operation and service manual description, the following procedure shall be adhered to:

— ensure that the parts to be evacuated and repaired are not blocked or closed by valves;

— remove refrigerant with equipment suitable for use with flammable refrigerants to recover and evacuate the system;

— recover refrigerant into a permitted cylinder (the recovery cylinder shall be evacuated to remove air before first use);

— evacuate;

— purge the circuit with inert gas (oxygen-free nitrogen). Compressed air or oxygen shall not be used for purging;

— open the circuit by cutting or brazing;

— ensure that the outlet for the vacuum pump is not close to any ignition sources and that ventilation is available;

— evacuation times as described in the operation and service manual shall be followed to meet the required vacuum.

When cutting or opening, the inert gas pressure shall only be slightly higher than ambient pressure.

It is important that best practice is followed since flammability of the refrigerant or decomposition shall be considered.

10.4.6.2 Draining the oil from a refrigerating system

The oil shall be drained carefully by competent personnel in accordance with the service manual.

When draining oil from compressors (or collectors) by means of a drain plug, the pressure in the compressor (or collector) shall be reduced to atmospheric pressure before removing the plug.

Oil shall not be discharged into sewers, canals, rivers, ground or seawater.

Oil recovery shall be carried out in a responsible manner, refrigerant oil is typically flammable.

10.4.6.3 Change of components

Repairs on components containing the refrigerant shall be carried out according to the MRU operation and service manual, to the requirements for operating sites and in the following order, where relevant:

— releasing for repair;

— instructing the maintenance staff;

— emptying, recovery and evacuating according 10.4.6.1;

— purging (with oxygen free nitrogen);

— disconnecting and safeguarding of the components to be repaired;

— carrying out the repair;

— testing and checking of the repaired component (pressure test, leakage test, functional test);

— evacuating and recharging with refrigerant according 10.4.6.7.

10.4.6.4 Hot works

To safely un-braze joints:

— the refrigerant shall be evacuated from the system;

— the evacuation and recovery procedure shall be performed according to 10.4.6.1;

— the system shall be filled with oxygen-free dry nitrogen to a pressure of 0,1 bar g;

— the system shall be connected to the purge line, which shall be open to atmosphere;

— un-braze the connections.

To safely braze joints, when re-brazing connections, the system shall be purged with dry nitrogen with at least one access point open to atmosphere to eliminate pressure build-up.

NOTE Hot works, brazing requires specific personnel qualifications.

10.4.6.5 Repair of protective device(s)

Repair of protective devices shall be performed according to the operation and service manual supplied by MRU manufacturer. It shall be ensured that parts are installed and meet at least the original specifications. Marking on the equipment should be visible and legible. Markings and signs that are illegible shall be corrected.

NOTE Repair of sealed electrical components and intrinsically safe components are described in IEC 60335-2-40.

Repair and maintenance to electrical components shall include initial safety checks and component inspection procedures. If a fault exists that can compromise safety, then no electrical supply shall be connected to the circuit until it is satisfactorily dealt with.

After any repair of protective device(s), the functionality shall be tested according 7.3 and according to the MRU manual.

10.4.6.6 Leak detection

Leak detection shall be carried out if a leak is suspected (indicated refrigerant losses or alarm from detection mechanism of the MRU) or recorded according to requirements in 10.4.10, and after repairs.

Following leak detection methods can be used:

— electronic leak detector, accuracy up to 10^{-7} mbar l/s;

— leak detection spray or leak detection fluids (such as soap and water bubble method or fluorescent method agents), accuracy up to 10^{-4} mbar l/s (equivalent to 1 bubble in 10 seconds);

— ultrasonic detection. accuracy up to 10^{-3} mbar l/s.

If a portable electronic leak detection is used, the performance shall comply with and tested according to EN 14624 or IEC 60079-29-1.

The bubble method can find leak rates larger than fugitive emission with a high accuracy, representing a leak rate of approx. 150 g/year to 300 g/year.

NOTE 1 Leaks create a noticeable sound even in case of small leaks.

Electronic leak detectors shall be used to detect refrigerant leaks which are suitable for the refrigerant to be detected and shall be calibrated at least once per year or according to the detector manufacturer's manual.

Ensure that the detector is not a potential source of ignition. A halide torch or any other naked flame shall not be used to identify leaks.

NOTE 2 Decomposition products of burning refrigerants are toxic and can create toxic atmosphere or the flame can result to jet flame.

If a leakage of refrigerant is found which requires opening or hot work, the refrigerant shall be removed as described in 10.4.6.1.

The bubble method and the ultrasonic method can identify leaks using inert gas.

If leaks cannot be found on systems with remaining refrigerant, the remaining charge shall be removed, and the system leak tightness, as specified in this document, shall be tested using nitrogen or nitrogen with a trace of helium or carbon dioxide.

10.4.6.7 Charging procedures

Prior to recharging the system, it shall be pressure-tested with the appropriate purging gas and leak tested.

The refrigerating system shall be recharged with the designed amount of refrigerant according to the product specifications provided by the MRU manufacturer.

In addition to conventional charging procedures, the following requirements shall be met:

— charging procedure as described in the MRU operation and service manual shall be strictly followed, especially with respect to the functionality of the alarm system;

— hoses or lines shall be as short as possible to minimize the amount of refrigerant. If charging lines are not evacuated, they shall be purged carefully (by opening, then closing the cylinder valve for purging);

— cylinders shall be kept in an appropriate position according to the manufacturer's instructions;

— the charge shall be accurately weighed;

— charging shall be monitored and care shall be taken not to overfill the MRU.

During intermodal operation, recharging of leaking systems with leaks larger than fugitive emissions is known in practice. This operation does not represent normal operation and shall result in immediate qualified repair and action as described in the operation and service manual. Otherwise, the MRU can be shut down, provided that the consequences of the shut-down are not dangerous for the rest of the operations of transport, discharging and emptying the MRU, or for the goods transported in order to not provoke an emergency situation.

10.4.7 Tools and equipment

General requirements for tools and equipment can be found in ISO 5149-4.

Requirements for tools and equipment described do not apply to accidental type failures including improper repair with releases larger than small leaks which are beyond the concept of abnormality dealt with in this document.

No additional forced ventilation equipment is required, since repairs shall be done in open air or well-ventilated area.

No portable detection equipment for personnel monitoring is required, since repairs shall be performed in open air or well-ventilated area.

NOTE 1 Proper technician repair, in open air or a well-ventilated area, does not create any hazardous area as no releases larger than small leaks (0,2 g/s peak mass flow) are expected and sufficient dilution occurs.

NOTE 2 In case of accidents or mistakes, larger than small releases in open air or well-ventilated areas will be noticed or recognized by involved technicians with higher perceptibility than a portable detection device (such as a refrigerant cloud, a sound of a large leak etc.).

A suitable vacuum pump, recovery machines, recovery cylinders and manifolds for flammable refrigerants shall be used.

Refrigerant handling equipment for flammable refrigerants shall not be used for non-flammable refrigerant and vice versa.

All equipment for flammable refrigerant handling shall be marked for clear identification.

10.4.8 Testing after repair

Testing after repair shall be done according to ISO 5149-2:2014, 5.3, which includes pressure testing, tightness testing and function testing.

In addition, all safety functions, such as the alarm system including self-test, shall be tested as specified by the MRU manufacturer. The test should ensure that the alarm system is working.

10.4.9 Failure prevention for repair and opening of the refrigerating system

Methods and process improvements for failure prevention are described in this document: general accidents prevention is described in 9.8.1, general failure prevention at service is described in 10.2.2.

Catastrophic failures with rupture type leaks in repair situations include but are not limited to:

— break into MRU pipework without prior emptying of the system, such as the opening of the pipework by an open flame torch creating a ruptured pipe connection and/or ignition resulting to decomposition of refrigerants, creating a toxic atmosphere or a jet of flame, cutting high pressure pipes by grinder;

— uncontrolled release of refrigerant under full system pressure into the work area, resulting in accumulation and possible ignition by SOI in vicinity.

Behaviour related failures in repair situations include but are not limited to:

— ignorance of alarm system information;

— ignorance of guidelines, human errors, missing instructions, repair by uneducated person (e.g. executing improper charging, wrong vacuum pump or recovery unit, wrong spare parts like improper evaporator fan).

These failures should be prevented by organizational actions.

10.4.10 Documentation

Repair activities shall be documented and recorded.

The following information should be stored in the records:

— details of all maintenance and repair work;

— amount of refrigerant charged;

— exchanges and replacement of components of the system;

— results of all tests.

10.5 Handling, recovery, reuse and disposal of refrigerant

General handling, recovery, reuse of the refrigerant should comply with existing standards. Local rules and regulations can also apply.

Recovery, reuse operations should be carried out locally at terminal or in-service facilities. Local regulations can apply to the disposal of used refrigerants.

General requirements for recovery can be found in ISO 5149-4:2014, 6.2.

Transport and storage shall comply with ISO 5149-4:2014, 6.3.

Disposal procedures shall comply with ISO 5149-4:2014, 6.5.

Requirements for documentation shall comply with ISO 5149-4:2014, 6.6.

ISO 5149-4:2014, Annex C, provides information on handling and storage of refrigerants. National rules and regulations as well as rules of certified bodies can apply for the storage of refrigerant cylinders on board of vessel (for example, DNV-GL Rules I-1-2 Machinery installations Section 10. F).

Special requirements for recovery are as follows:

— all flammable refrigerants should be recovered;

— recovery with a suitable recovery machine (a standard recovery machine for halocarbon type refrigerants shall not be used);

— the recovery cylinder shall be evacuated to remove air before it is first used;

— flammable refrigerants shall not be mixed with other types of refrigerant in a recovery cylinder;

— recovery cylinders shall be filled according to the specified safe fill weight;

— the recovery cylinder shall be specified for flammable refrigerants and clearly labelled to show the refrigerant type.

A left-hand thread is required for flammable refrigerant cylinder, an adapter is required to connect a manifold.

11 Decommissioning of the container refrigerating system

Before final disposal, all the fluids (refrigerant and oil) inside the MRU shall be removed according to the description in 10.4.6.1 and 10.4.6.2. The equipment should be purged afterwards with inert gas.

The refrigerating system should be left completely empty.

The decommissioning party shall be aware of applicable national regulations.

Annex A
(informative)

Definition of control volumes

The control volumes are defined as three-dimensional spaces containing gaseous atmosphere. Seven control volumes are defined as given in Figure A.1 as a typical example.

1) Control volume I is the volume behind the container at the MRU, which can be potential flammable atmosphere in case of an accidental type leak at the outside parts of the refrigerating system (dimensions adjusted to operational mode).

2) Control volume II, or compressor and condenser section, represents the volume where all outside parts of the refrigeration circuit, including the condenser fan, are located. The volume is delimited by the structure of the equipment.

3) Control volume III, or evaporator and plenum space, comprises the space occupied by the evaporator and the inside MRU air ducts to the T-floor and from the ceiling.

4) Control volume IV is the air volume in the T-Floor.

5) Control volume V is the cargo compartment/the internal container volume, where cargo can be placed including the space above. It is separated from the outside except for the door which can be opened for packing and unpacking.

6) Control volume VI is the volume behind the open doors (dimensions adjusted to operational mode).

7) Control volume VII is the volume of the ducts used to exchange air between the inside and the outside of the container refrigerating system.

Figure A.1 shows the location of the different control volumes I to VII.

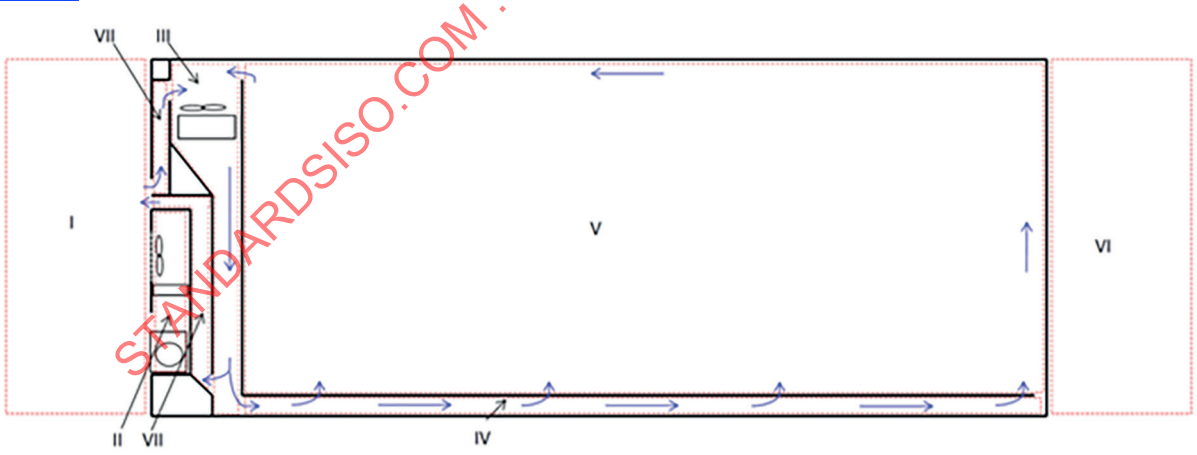


Figure A.1 — Control volumes 1 to 7

Annex B
(informative)

Description of mechanisms to reduce risk

B.1 General

The following mechanisms to reduce risk are described as examples.

B.2 Separation mechanism

As possible part of leak control measure, a separation mechanism limits the amount of refrigerant which can be released in case of leakage and therefore reduces w_g as described in D.2.

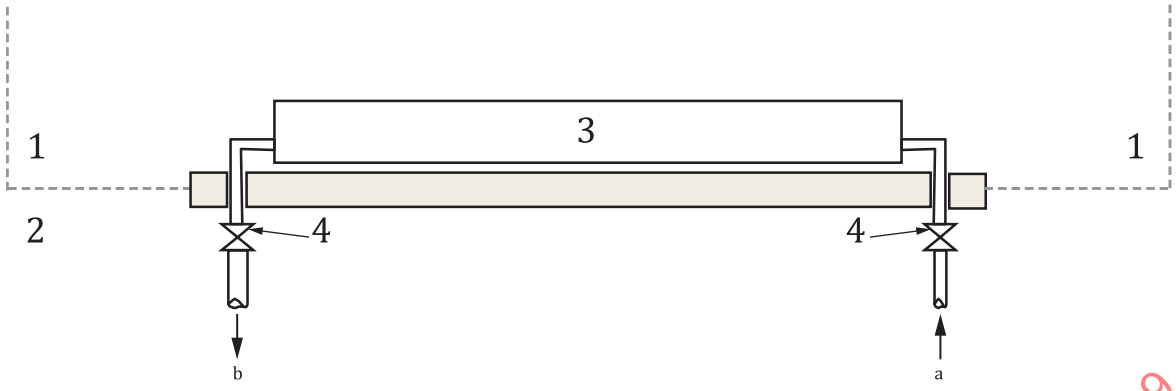
The separation mechanism should divide the refrigerating system into different parts by using shut-off devices.

The shut-off devices should be active in case of power supply OFF situations (the refrigerating system has no energy supply) or long-time standstill situations (the compressor is not operating over a long period of time). This ensures that only limited amounts of refrigerant can leak from the separated parts and components of the system.

The separation mechanism shall ensure that at power OFF situations, a leak of refrigerant from parts located inside the container will result in a release not exceeding the amount that can lead to the presence of a flammable atmosphere inside the container in the smallest inside free volume and the evaporator space.

The shut-off devices shall be placed on the outside of the container.

NOTE An expansion valve can have the function of a separation device and can be used as a component in the separation mechanism.



Key

1 inside container
2 outside container
3 evaporator
4 separation device
a Refrigerant flow in.
b Refrigerant flow out.

Figure B.1 — Example for evaporator separation and location of shut-off devices

Non-detachable or hermetic connections and joints should be used to connect the shut of devices into the piping system.

B.3 Ventilation mechanism

B.3.1 General

The function of the ventilation mechanism is to allow the exchange of air between different control volumes.

The ventilation mechanism should consist of:

— condenser fan(s) and duct(s);

— evaporator fan(s) and duct(s);

— fresh air exchange duct and fresh air exchange mechanism (valves and/or fans);

— T-floor;

— the cargo space.

B.3.2 Outside ventilation mechanism

The exterior unit where parts containing refrigerant are included shall be designed to allow flammable refrigerant to escape under natural ventilation. The leaked refrigerant should not accumulate even when mechanical ventilation is not present.

In power supply ON situations, the ventilation mechanism (condenser fan) shall be activated in case of detection of a refrigerant leakage by a detection mechanism at full speed. The ventilation should limit the persistence time and/or avoid the build-up of flammable atmospheres.

NOTE The condenser section (Control volume II, see Annex A) is at least a naturally ventilated space and the likelihood of the presence of a flammable atmosphere is very low (see the description for natural and forced ventilation in IEC 60079-10-1:2015, C-1 and C-2).