SLOVENSKI STANDARD
SIST-TP CEN/TR 17608:2022

01-junij-2022

Stanje tehnike na področju uporabe vnetljivih nadomestnih hladilnih sredstev, zlasti iz razreda A3, v opremi za hlajenje, klimatizacijo in toplotnih črpalkah

State of the art on the use of flammable refrigerant alternatives, in particular from class A3, in refrigeration, air conditioning and heat pump equipment

Stand der Technik über die Verwendung von brennbaren Kältemitteln, insbesondere der Klasse A3, als Alternativen in Kälte-, Klima- und Wärmepumpenanlagen

État de l'art sur l'utilisation de fluides frigorigènes inflammables de substitution, en particulier de la classe A3, dans les équipements de réfrigération, de climatisation et de pompes à chaleur

Ta slovenski standard je istoveten z: **CEN/TR 17608:2022**

ICS:

71.100.45	Hladiva in antifrizi	Refrigerants and antifreezes

SIST-TP CEN/TR 17608:2022 **en,fr,de**

TECHNICAL REPORT

RAPPORT TECHNIQUE

TECHNISCHER BERICHT

CEN/TR 17608

April 2022

ICS 71.100.45

English Version

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This Technical Report was approved by CEN on 20 March 2022. It has been drawn up by the Technical Committee CEN/TC 182.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Ref. No. CEN/TR 17608:2022 E

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European foreword

This document (CEN/TR 17608:2022) has been prepared by Technical Committee CEN/TC 182 "Refrigerating systems, safety and environmental requirements", the secretariat of which is held by DIN.

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Introduction

CEN and CENELEC implemented standardisation request M/555 - IMPLEMENTING DECISION of 14 November 2017 on a standardisation request to the European Committee for Standardisation and to the European Committee for Electrotechnical Standardisation as regards use of flammable refrigerants in refrigeration, air conditioning and heat pump equipment. CEN/TC 182 took the lead and established a liaison with CENELEC/TC 61.

The two European Standardization Organizations CEN and CENELEC have responded positively to standardisation request M/555 regarding use of flammable refrigerants in refrigeration, air conditioning and heat pump equipment.

CEN/TC 182 and CENELEC/TC 61 were tasked to address the standardisation request. A new working group (WG12) was set up under CEN/TC 182 with active participation of experts nominated by CENELEC/TC 61.

The technical information was gathered by six ad hoc groups two of which were led by CENELEC/TC 61 experts. The ad hoc groups analysed the current status of risk assessment in general, commercial refrigeration, transport refrigeration, industrial refrigeration, air conditioning and heat pumps, and chillers. Each of the groups finalized their summary with conclusions about existing barriers and recommendations for additional options.

The Technical Committee reviewed guidance for the risk assessment in general and for refrigeration appliances in particular. This includes reviews of guidance and standards that apply for flammable gases in general. Also, the risk assessment was reviewed of global organisations like the risk approach of the Organisation for Economic Co-operation, Development and United Nations Development Programme and United Nations Environment Programme.

The requirements of the Standardisation Request M/555 were reviewed carefully. Having reviewed the documentation, the working group agree that, responding to the standardisation request, the following deliverables were to be prepared:

1) A Technical Specification for the installation of refrigeration, air conditioning and heat pump equipment containing flammable refrigerants, complementing existing standards.
2) A Technical Specification for the operation, servicing, maintenance, repair and decommissioning of refrigeration, air conditioning and heat pump equipment containing flammable refrigerants, complementing existing standards.

The recommendations about transport refrigeration are beyond the standardisation request M/555. CEN/TC 413 will develop of a specific EN standard dedicated to transport refrigeration risk assessment.

1 Scope

This document provides the results of a comprehensive assessment of the state of the art on the use of flammable refrigerants, in particular from class A3.

Refrigerants from class B (toxic) are excluded from this scope.

This document includes the following elements:

- A segmentation of the refrigeration, air conditioning and heat pump market, making use of existing studies and research, including an assessment of safety-related barriers to the uptake of flammable refrigerants in particular from class A3 across all relevant applications;
- An assessment of the way risk assessments is used in existing standards for refrigeration, air conditioning and heat pump equipment and in other standards and a review of available risk assessment research to be taken into account including identification of potential needs for additional research;
- Analysis of:
  - the relationship between risk and increased charge;
  - the acceptability of increased risk compared to the risk presented by other technologies;
  - the options for additional mitigation methods if the risk increase is unacceptable;
- Review of existing standards and work programmes and identification of standards that should be further updated under existing or future standardisation requests based on relevant product safety legislation, in particular with regard to allowable charge sizes of flammable refrigerants, taking into account available technology as well as emerging research and development;
- Identification of options for performance based requirements that result from risk assessments to enable the use of all flammable substances;
- Identification of options for risk minimisation and for offering flexibility in application of mitigation measures.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

4 Segmentation of the Industry Sector

4.1 General

The refrigeration industry produces a wide range of products and applications. Commercial and professional refrigeration, industrial refrigeration, chillers and air conditioning, transport refrigeration, and heat pumps were investigated. The main results are reflected in this clause. The complete result of the review is provided in Annex B.

4.2 Commercial applications

4.2.1 Commercial Refrigeration

Commercial refrigerated cabinets are used for storage, display, production, or sales of foodstuff. Some of these products are fixed and movable appliances.

Commercial refrigerated cabinets are cooled by a refrigerating system which enables chilled and frozen foodstuffs placed therein for display to be maintained within prescribed temperature limits. Commercial refrigerators and freezers cover a large variety of products; and they are used in diverse environments such as supermarkets, grocery stores, service stations, restaurants, hotels, pubs, and cafés. Commercial Service Cabinets are mainly horizontal refrigerated display cabinets which requires that a person serve the customer with fresh-cut or packed foodstuffs; and the appliance have one or more side facing the customer for display of fresh cut of food in a supermarket. As a sub-category some of these cabinets are also available as Self Service version.

Commercial refrigeration equipment can take many forms and combinations:

- 'self-contained (or plug-in or integral) appliance' means a factory made assembly of refrigerating components that are an integral part of the refrigerated equipment and consists of a storage space, one or more refrigerant compressors, refrigerant evaporators, condensers and expansion devices, eventually accompanied with additional heat exchangers, fans, motors and factory supplied accessories;

- remote display cabinets work with a remote refrigerating unit which is not an integral part of the display cabinet (e.g. condensing units, cooling packs);
- semi plug-in cabinets are cabinets with an integral condensing unit, where the heat is rejected with a secondary water or brine loop;
- refrigerating system with secondary fluid (e.g. chillers).

4.2.2 Professional Refrigerated Products

Professional refrigeration equipment can take many forms and combinations, very similar to those for commercial use. Professional service cabinets are designed for dispensing or storage, but not the sale, of chilled and frozen foodstuff like professional storage cabinets, blast chillers, cold rooms, ice cream makers, etc. A professional service cabinet is a refrigerated enclosure containing goods which are accessible via one or more doors and/or drawers. The sizes of the products are typically based on the standard tray and are used in a commercial environment. They are largely used in foodservice establishments, such as restaurants, hotels, and cafeterias. A very small fraction of "professional" service cabinets contain glass in their doors, drawers, or lids (as opposed to "commercial" service cabinets that display food and hence frequently incorporate glass).

Blast cabinets use a blast of cold air to bring down the temperature of hot food rapidly so it can be stored safely avoiding bacteria growth, and can be chilled or frozen. Blast cabinets are similar in construction to service cabinets. However, they rely on relatively larger refrigeration systems in comparison to service cabinets, some even using up to two compressors per cabinet. Blast cabinets also contain additional fans which blast cold air over food to cool it rapidly.

4.2.3 Commercial versus professional cabinets

Both **commercial** and **professional** cabinets rely on compression technology (more than 90%): i.e. all components supporting the refrigeration cycle are included in the cabinet.

The main difference between commercial and professional is not related to installation environment, but to the user: a "commercial" refrigerator is used by a customer (shopper), and will display products, while a "professional" refrigerator is used by trained staff, and will store the products before use. Frequently existing definitions refer to "commercial" service cabinets, when in fact "professional" use of the products is done one side of the appliance, while the other side is for display or collection of product from the shopper that could access a side of the appliance. Therefore, it is noted that terminology varies for identical products.

4.3 Industrial applications

Industrial systems are characterized primarily by the size of the equipment, both physical size and heat transfer capability, and the temperature range covered by the sector. In addition to Industrial Refrigeration, this sector includes Industrial Heat Pumps (heating systems similar in scale and application to Industrial Refrigeration systems) and Industrial Air Conditioning (systems for controlling air temperature in production factories, computer centres and other process areas). Other sectors mainly focus on comfort and food, the industrial sector also includes refrigerating systems for process related activities, example temperature controls in in chemical processes.

Industrial Refrigeration systems are characterized by heat extraction rates in the range 100 kW to 10 MW, typically at evaporating temperatures from − 50 °C to + 20 °C. There is some overlap at the lower end of the capacity scale with commercial refrigeration for shops, restaurants, and institutions. Industrial systems in this sub-sector are characterized by the complexity of the design and the nature of the installation. Systems at lower temperatures, typically down to − 120 °C, and in capacity ranges from 1 kW to 200 kW are a specialized sub-sector including laboratory equipment for pharmaceutical, chemical, and medical applications and test stands for automotive, aerospace and space development facilities. These ultra-low temperature systems are often also required to operate at high temperatures up to + 250 °C to provide a complete temperature test cycle.

Industrial Heat Pump systems have heat delivery rates from 100 kW to over 100 MW, with the heat source usually at ambient temperature or the waste heat temperature of an industrial process. These systems are usually required to deliver higher temperatures than domestic or commercial heat pumps used for space or water heating. Typical temperatures are in the range 60 °C to 90 °C, although if the recovered heat is to be used for steam raising then it needs to be at least 120 °C. Heat recovered from large industrial systems is usually transferred to water or a heat transfer fluid and used for process heating or for supply to district heating systems.

Industrial Air Conditioning systems cannot be differentiated from commercial systems on size alone, as many commercial office buildings have large cooling loads. In addition to size of installation the distinguishing traits of Industrial Air Conditioning systems are that the cooling is not purely for human comfort, the load is not primarily seasonal, and the operation of the facility would be jeopardized by failure of the cooling equipment. Such systems are sometimes called "Mission Critical" and have special design requirements, including the need for uninterrupted service, which are not typically provided by traditional heating, ventilation, and air conditioning practices. In some cases, the mission-critical part of a total cooling load may be supplied in conjunction with a comfort cooling system, configured so that, in the event of partial failure of the system, the mission-critical cooling is maintained at the expense of the comfort of the occupants of the rest of the building. Other Industrial Air Conditioning systems are primarily required to maintain acceptable processing conditions for equipment such as computer servers in data centres.

4.4 Chillers and heat pumps with water heat sink, indirect systems

Chillers and heat pumps with water heat sink are used in domestic, commercial, professional, and industrial applications. Chillers and heat pumps with water heat sink include units with a refrigerant to water heat exchanger on the use side. Capacity range is from about 1 kW up to 2 000 kW.

The units are air to water heat pumps self-contained, water to water heat pumps self-contained, brine to water heat pumps self-contained, air to water heat pumps split, chillers and domestic hot water heat pumps.

The products are used in all market segments. The overall market is 800 000 units per year.

4.5 Air to air air conditioning and heat pumps

Domestic air conditioning products and domestic heat pumps are used in households and similar locations for cooling and heating applying air conditioners and heat pumps. This application category also includes similar applications like care homes, retirement homes and other facilities with nursing services.

Air conditioners generally fall into several distinct categories, based primarily on capacity or application: small self-contained air conditioners, such as window-mounted and through-the-wall air conditioners; non-ducted split residential and commercial air conditioners; ducted, split residential air conditioners; and ducted commercial split, multi-split including variable refrigerant flow, and packaged air conditioners. In each of these categories, the term “air conditioner” includes systems that directly cool or heat the conditioned air, for instance, “air-to-air”, “water-to-air” and “ground-to-air” systems. This category does not include systems that heat or cool water or other heat transferring liquids.

NOTE For example, through the wall; whilst these products represent a small portion of the market they have nevertheless been included since they are still available and have certain construction characteristics of interest. Packaged terminal air conditioner are not usually used in Europe.

Table 1 summarizes the typical physical and installation characteristics of the different types of air conditioners.

Table 1 — Typical configurations of air conditioner types

Type		Primary configuration	System layout	Capacity range (kW)	R-410A charge range (kg)
Hermetically-sealed unit	double duct	Small self-contained	Self-contained	1 – 10	0.3 – 3
	single duct [a]	Small self-contained	Self-contained	1 – 10	0.3 – 3
Duct free split		Ducted free split	Remote	2 – 20	0.5 – 6
Multi-split		Multi-split including variable refrigerant flow	Remote	4 – 300	1 – 80
Ducted split		Residential/small cap	Remote	4 – 20	1 – 6
		Commercial/large cap	Remote	10 – 150	3 – 45
Packaged rooftop [b]		Ducted commercial	Self-contained	7 – 350	2 – 100
Exhaust air-to-air heat pump		Inside / outside	Self-contained	5 – 150	1.5 – 45

[a] Single duct is used to refer to portable air conditioners.

[b] Generally these products are designed with 2 circuits. That is to say 100 kg for the complete unit 350 kW will give 50 kg per circuit.

4.6 Transport applications

The transport applications market distinguishes between human comfort and transport of refrigerated goods. Transport applications includes mobile air conditioning systems in vehicles, railways, buses, vans, mobile homes and caravans for human comfort; and, for the transport of refrigerated goods refrigerated trucks, trailers and reefer containers land-based operation.

Transport applications have specific challenges such as shock, vibration, corrosion, and extreme operating ambient conditions. This leads to design choices different from other refrigeration applications.

Transport of refrigerated goods is typically a non-occupied area with limited access, with periodic, or non-frequent access by humans. The refrigeration units are factory built and typically mounted onto the actual vehicles, casing, or chassis.

Some systems use open type compressors with shaft seals and are driven by the main engine, for example car bus air conditioning with combustion engines. Other systems operate with hermetic or semi-hermetic compressors and electric power supply.

The United Nations Environment Programme Refrigeration and Air Conditioning Technical Options Committee (RTOC) 2018 report stated: “Light duty vehicles use from 0,3 kg to 1,4 kg refrigerant charge, while for buses the charge could be from 8 kg up to 16 kg as a function of the vehicle category (e.g. simple bus, articulated bus). Currently there are approximately 1 000 kt of refrigerant in vehicles considering that there are about 1,3 billion of road vehicles circulating[1]. Assuming that 75 % of circulating vehicles is equipped with mobile air conditioning systems, and assuming a yearly renewal rate of 8 % e.g. 100 million units), the refrigerant demand (excluding service) is about 75 kt/year.”

5 Current practice in the sector

All substances that exist in liquid and vapour states absorb heat during evaporation and can therefore be used as refrigerants. Refrigerants have widely varying properties and impacts and due to the significant environmental and safety impact of certain refrigerant types, can be heavily regulated during manufacture, use and disposal. There are numerous refrigerants either in use today or being proposed as alternatives. Commonly used refrigerants in refrigeration applications are the following:

- HFCs: Hydrofluorocarbons
- HCs: Hydrocarbons
- Unsaturated HFCs (also known as HFOs or Hydrofluoroolefins)
- NH3: Ammonia
- CO2: Carbon dioxide

Table 2 lists the various options that are currently in use or under consideration for air conditioning, along with their global warming potential and ISO 817 safety classification. Also listed are the types of air conditioner system that each refrigerant option is currently used in or is at least being considered for. All options listed are toxicity class A.

[1] https://www.statista.com/statistics/281134/number-of-vehicles-in-use-worldwide/.

Table 2 — Refrigerant options for air conditioning

Refrigerant	GWP (RTOCa 2018)	Flammability class	Subsector currently used in the European Union	Subsector proposed/ anticipated
R-1270	< 1	3		non ducted system
R-290	< 1	3	small self-contained, ducted split, packaged rooftop	ducted commercial split
R-1234yf	< 1	2L	small self-contained	
R-152a	148	2		non ducted system
R-32	704	2L	small self-contained, non ducted system, ducted split, ducted commercial split	multi-split, packaged rooftop
R-452B	710	2L		All
R-454A	250	2L		All
R-454B	490	2L		All
R-459A	480	2L		All

[a] United Nations Environment Programme Refrigeration and Air Conditioning Technical Options Committee.

Currently the majority of commercial plug-in or self-contained refrigeration appliances using flammable refrigerants have charge sizes of no more than 150 g of hydrocarbon (HC) such as R-600a (isobutane) or R-290 (propane) per refrigerant circuit. This is due to the charge size constraint of 150 g of flammable refrigerant within the current IEC 60335-2-89 Ed. 3. There are several millions of such units currently in use.

Horizontal standards such as EN 378 (2016) and ISO 5149 (2014) permit charge sizes of up to 1,5 kg of hydrocarbon per refrigerant circuit. Where the charge exceeds 150 g there are additional requirements for the installation site, such as certain minimum room size in which the system can be placed, a mandatory risk assessment considering the specific installation surroundings due to the potential higher charges released, a plant by plant certification.

Whilst the number of self-contained refrigeration appliances using flammable refrigerants is relatively minor compared to global populations of self-contained refrigeration appliances with non-flammable refrigerants, there is reasonably good level of experience with such self-contained refrigeration appliances and especially with products using up to 150 g per circuit. If there was a fundamental underestimation of the risk posed by the current design requirements for these self-contained refrigeration appliances, then this would become apparent to the direct stakeholders and the industry as a whole. Based on this historical data the use of flammable refrigerants with a maximum charge of 150 g per circuit in self-contained refrigeration appliances can be considered as an acceptable risk.

Recent regional and international legislation such as the European F-gas regulation, the 2016 Kigali Amendment of the Montreal Protocol and minimum efficiency regulations in USA and other countries mean that most common refrigerants used today in self-contained refrigeration appliances will no longer be applicable. Apart from R-744, the only viable refrigerants for the short to medium term are flammable, and even out of the possible options only a small number of hydrocarbons and hydrofluorocarbon/u-hydrofluorocarbon mixtures may be viable.

Based on this historical data the use of flammable refrigerants with a maximum charge of 150 g per circuit in self-contained refrigeration appliances can be considered as an acceptable risk without taking care of surrounding environment using a safety approach based on type tests.

Chillers only connected by a secondary system to the area served the appliance can be positioned outside or be equipped with ventilated enclosure / machinery room that allows to handle even high refrigerant charges safely.

Large refrigeration systems often use R-717 (ammonia) as the refrigerant. R-717 is classed as B2L by the ISO 817 safety classification. Where R-717 is considered to be unacceptable the decision is usually based on the hazards posed by toxicity in the specific location, for example if the system is located in a built up area or close to a school or hospital. The most likely alternative until recently would have been a non-flammable, lower toxicity refrigerant such as R-404A or R-507. As these are being phased out due to high global warming potential there is an increased interest in R-744 (carbon dioxide) either in cascade with R-717 or in a transcritical system configuration. There is currently virtually no use of A3 refrigerants in the industrial sector except in specialist niche markets where the flammability of the refrigerant is not an additional concern, for example in a process plant or oil refinery.

6 Design measures for flammable refrigerants

6.1 General

Products placed onto the European single market satisfy the requisite health, safety, and environmental requirements. How this is achieved is laid out in the 'Blue Guide' on the implementation of EU product rules 2016. It is necessary to meet the essential health and safety requirements of the applicable European Directive or Directives in order to place a product on the market. Detailed design measures are given in Annex D.

Following a harmonized standard is an easy way to comply with the requisite essential health and safety requirements. If other routes are used, they may be depending upon the applicable directives and the necessary conformity route. A notified body may have to verify the approach. Figure 1 gives an explanation of the routes that are appropriate for meeting the essential health and safety requirements of Directives. Provided that the essential health and safety requirements of the relevant Directives are satisfied, then following any or no European refrigeration, air conditioning and heat pump safety standards are permitted.

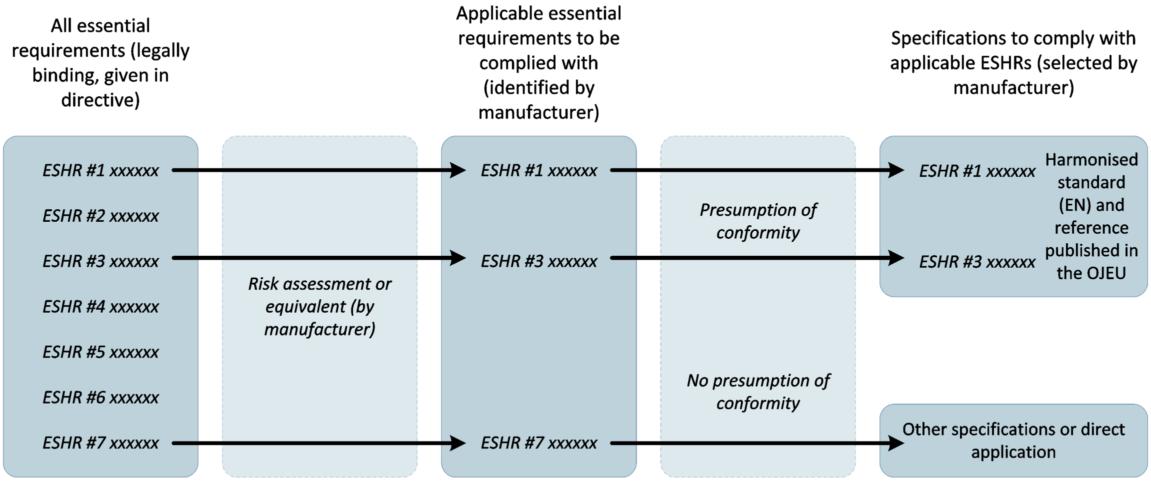

Figure 1 — The role of harmonized standards when complying with applicable essential requirements identified by a manufacturer

Regardless whether harmonized standards are followed to comply with the essential requirements of the regulations, a risk assessment of the product has to be performed as required by the regulations pertaining to safety.

6.2 Design measures

Figure 2 provides an overview of the various levels of intervention that may be applied to refrigeration, air conditioning and heat pumps systems and equipment, along with some examples of how these interventions may be practically applied. Broadly, those at the top of the list can be considered as having a higher level of reliability. As a priority, those measures that avoid the refrigerant entering into the space may be deemed more reliable, whereas those which require intervention of human occupants to initiate some action to reduce the risk may be deemed less reliable. Thus, the approaches towards the top of the list may be considered preferentially, although this can also be affected by specific circumstances and equipment type.