International Safety Standards in Air Conditioning, Refrigeration & Heat Pump

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→ Abstract

In order to achieve the obligations of the Kigali Amendment under the Montreal Protocol, countries must adopt refrigerants with a low global warming potential (GWP). Natural refrigerants such as hydrocarbons, carbon dioxide and ammonia are excellent options, but present additional safety hazards compared to conventional HCFC and HFC refrigerants, which is why there is a heightened need to introduce appropriate safety standards. Some current international safety standards for Refrigeration, Air Conditioning and Heat Pump (RACHP) systems can pose substantive barriers to the implementation of natural refrigerants, primarily by means of obstructive refrigerant charge size limits.

There is a relationship between system thermal capacity, efficiency and the required refrigerant charge. Therefore, to enable larger and greater efficiency systems with certain natural refrigerants, there is an explicit need to modify and improve international safety standards to allow larger refrigerant charge sizes while maintaining a minimal level of risk. In order to offset the increased flammability risk associated with a greater charge, additional safety measures to mitigate the risk can be introduced to RACHP equipment. These include improving leak tightness of the system, assuring sufficient airflow, adopting special equipment housing designs and the inclusion of shut-off valves.

It is crucial that any changes to existing safety standards or requirements of entirely new safety standards should initially remain voluntary, as requirements are onerous by nature. After a trial period with a voluntary status, standards can subsequently, if necessary, be established as mandatory requirements. Based on experience, it is estimated that it will take five to ten years for new or revised standards to be developed, approved and published. Such timelines are inconsistent with the needs of the industry in many regions to implement low GWP alternatives in time to comply with obligations under the Montreal Protocol and Kigali Amendment.

This paper has been drafted under the Green Cooling Initiative (GCI), which is financed by the International Climate Initiative of the German Federal Ministry of the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV). It is intended to provide policy makers, standard authorities and private sector representatives with an overview and orientation on international safety standards for RACHP systems, in particular addressing developing countries that endeavour to widen the use of environmentally friendly refrigerants in a safe way. The document identifies what is currently feasible with existing safety standard requirements, and what possibilities exist to ease the barriers and improve safety standards for the future. In particular, the following aspects are addressed:

- The key safety standards applicable to RACHP systems;
- How those safety standards can be applied;
- Technical obligations arising from the various safety standards;
- Options and opportunities to improve safety standards internationally and/or nationally.

This publication is an update of the 2018 version, to reflect the revision of some of the standards. In particular, IEC 60335-2-89 for commercial refrigeration appliances has been revised to increase the maximum refrigerant charge from 150 g to about 500 g of hydrocarbon. Although the upper refrigerant charge limit in IEC 60335-2-40 remains the same, the allowable charge (per unit area of room size) has been increased considerably, thereby permitting much more hydrocarbon refrigerant to satisfy the required cooling capacity.

→ Abbreviations

RACHP	Refrigeration, Air Conditioning and Heat Pump
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardization
GCI	Green Cooling Initiative
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GWP	Global Warming Potential
HC	Hydrocarbons
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
IEC	International Electrotechnical Commission
ISO	International Standardisation Organisation
LFL	Lower Flammability Limit
UNEP	United Nations Environment Programme

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1

INTRODUCTION

1. Introduction

There is a significant trend towards applying natural refrigerants as low global warming potential (GWP) alternatives to ozone depleting substances (ODSs) such as chloroflouorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) and conventional high and medium GWP hydrofluorocarbons (HFCs). Since the adoption of the Kigali Amendment of the Montreal Protocol on the phase down of HFCs on 15th October, 2016, over three-quarters of countries have already ratified it. The Amendment entered into force on 1st January 2019.

Low GWP alternative refrigerants include both synthetic and natural refrigerants. The synthetic alternatives typically include certain saturated HFCs, unsaturated HFCs (known as hydrofluoroolefins, HFOs) and unsaturated hydrochlorofluorocarbons (known as hydrochlorofluoroolefins, HCFOs) and mixtures thereof; whilst these have some desirable characteristics, many exhibit relatively poor thermo-physical properties thus infer greater investment required to achieve certain system efficiency. Moreover, most unsaturated HFCs and HCFCs have fairly low saturated vapour pressures and therefore require larger system components in order to match cooling or heating performance of many of the existing refrigerants – the comparatively high cost of these unsaturated fluorocarbons is therefore exaggerated due to greater material costs and a corresponding larger refrigerant charge. These problems can be overcome to a certain extent by mixing with existing HFCs, but in many cases it results in refrigerant blends with an undesirably high GWP and/or temperature glide. In addition, the future of some HFCs and HFOs is increasingly questionable given growing concerns over and efforts to restrict per- and polyfluoroalkyl substances (PFAS).

Natural refrigerants, including hydrocarbons (HCs) such as propane (R290) and isobutane (R600a), carbon dioxide (R744), and ammonia (R717) have excellent thermo-physical properties, corresponding to high potential system efficiency as well as being relatively cheap. They have negligible GWP ($\leq$ 1) and emissions associated with production and supply are substantially less than with any fluorinated refrigerant. On the other hand, HCs, R744 and R717 present additional safety hazards compared with conventional HCFC and HFC refrigerants. As such, there is a heightened need to employ safety standards. However, it is recognised that some current international safety standards for refrigeration, air conditioning and heat pump (RACHP) applications pose constraints, mostly in terms of limits on the quantity of refrigerant permitted in systems.

Safety standards have a particular relevance with regard to the use and use restrictions of refrigerants in RACHP systems. This was identified as one of the main obstacles to the uptake of environmentally friendly refrigerants in a United Nations Environment Programme (UNEP) study on barriers for low GWP alternatives in Article 5 countries and a subsequent UNEP report on safety standards (Colbourne, 2010; UNEP, 2016), although this equally applies to non-Article 5 countries, too. Reasons for these limitations are largely due to the historical dominance of non-flammable, lower toxicity refrigerants, the inertia associated with changing safety standards (and the views of stakeholders), and also the desire of stakeholders with commercial interests in competing technologies.

This document is intended to introduce the topic of international safety standards for RACHP systems, in particular addressing developing countries that intend to widen the use of environmentally friendly refrigerants in a safe way. It identifies what is currently feasible with existing safety standard requirements, and which possibilities exist to ease the barriers and improve safety standards for the future. In particular, the following aspects are addressed:

- The key safety standards applicable to RACHP systems;
- How those safety standards can be applied;
- Technical obligations arising from the various safety standards;
- Options and opportunities to improve safety standards internationally and/or nationally.

It must be noted that most countries also have national safety regulations, which take precedence over safety standards and, as a matter of priority, stakeholders should always ensure that these are complied with first.

→ OVERVIEW AND CHOICE OF RELEVANT RACHP SAFETY STANDARDS

2. Overview and choice of relevant RACHP safety standards

Within the context of the RACHP sector, there are two international standardisation organisations that publish relevant safety standards: the International Standardisation Organisation (ISO) and the International Electrotechnical Commission (IEC). Similarly, at European (regional) level there are equivalent organisations – the European Committee for Standardisation (CEN) and the European Committee for Electrotechnical Standardization (CENELEC) – which publish comparable standards that broadly cover the same scope and requirements to those of ISO and IEC.[1]

Table 1 provides a summary of the key international and regional standards and their scope of application. Those listed are categorised as "vertical" or product standards and as "horizontal" or group standards. Broadly speaking, vertical standards take precedence over horizontal standards, as they are developed specifically for particular product types and thus have requirements that are more refined for particular cases. Thus, horizontal standards are assumed to cover everything that is not handled by the vertical standards. That is, they include more generic and overarching requirements based on common characteristics and practices of any RACHP equipment, installations and technician activities.

However, the boundaries between vertical and horizontal standards are not rigid and ultimately designers, manufacturers, installers and contractors must decide which standard is most appropriate for their respective situation[2]. It may be that the most suitable requirements to follow are a combination of those within different sections of the horizontal and vertical standards, particularly if the latter predates the former. Furthermore, requirements within either standard may be deficient in certain measures (perhaps due to their outmoded approach), and it may be apparent that improved guidance from elsewhere should take priority. Indeed, it is inappropriate to regard national or international safety standards as definitive. In the event of third-party certification for equipment, this may be based on one core standard. Ultimately, the objective is to achieve the highest level of safety with the best cost-effectiveness.

Table 1: Scope of different international and regional safety standards for RACHP systems

Sector	Vertical (product) standards				Horizontal (group) standards
International	IEC 60335-2-24	IEC 60335-2-40	IEC 60335-2-89	ISO 20854	ISO5149-1, -2, -3, -4
Regional (examples)	EN 60335-2-24	EN 60335-2-40	EN 60335-2-89	EN 17893	EN 378-1, -2, -3, -4
Domestic refrigeration	×				×
Commercial refrigeration			×		×
Industrial systems					×
Transport refrigeration				×	×
Transport air conditioning					×
Air conditioners, heat pumps		×			×
Water heating heat pumps		×			×
Chillers		×			×

1 The Vienna Agreement and Frankfurt Agreement confirm the objective to coordinate CEN and ISO standards development and CENELEC and IEC standards development, respectively. Apart from helping to harmonise international and regional standards, it also minimises repetition of technical work.

2 If a particular standard has been mandated by national legislation, the choice is curtailed.

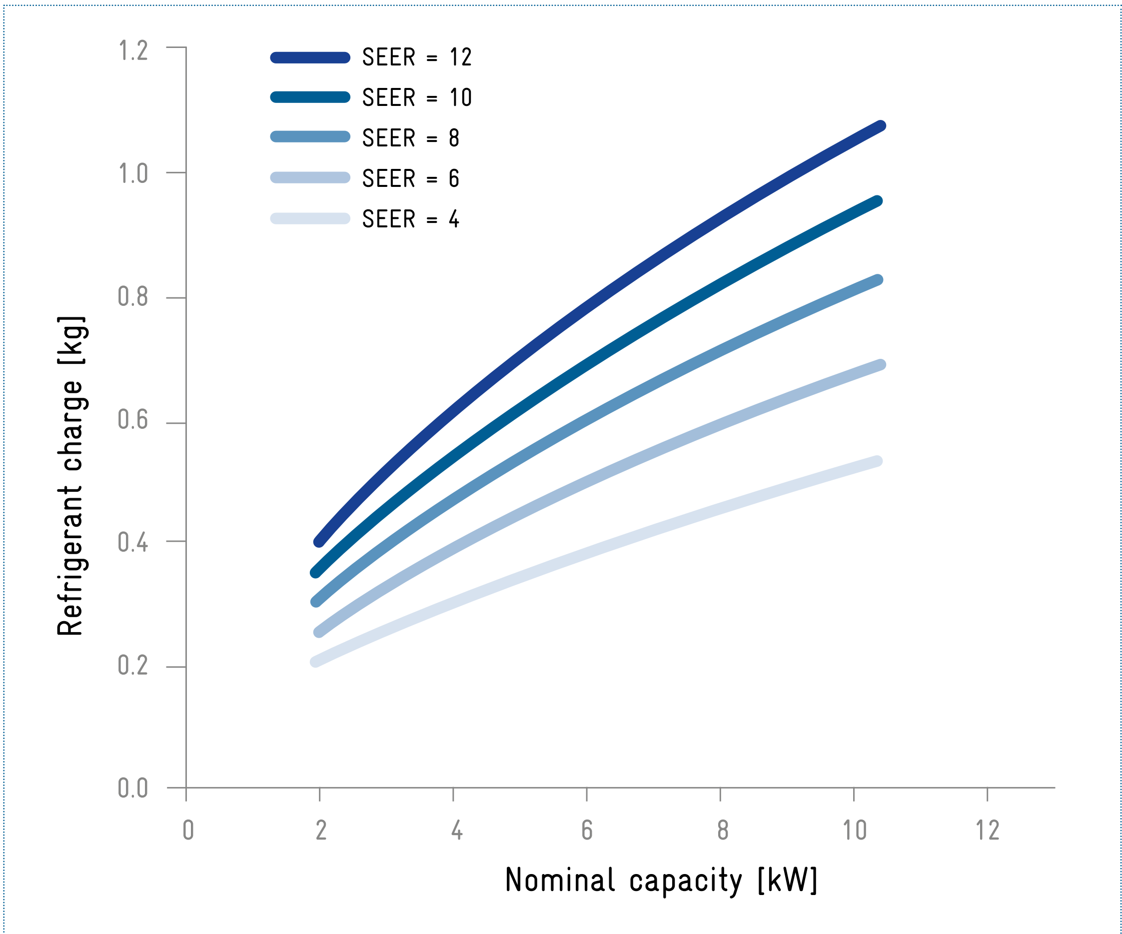
In many cases, countries will adopt the ISO and IEC standards as national standards, which are then essentially a "copy and paste" of the international standards, although it is also common for countries to adopt the international standards but with national modifications. In other countries, safety standards have been developed independently of the international standards, and thus contain requirements that sometimes differ substantially. Industry often prefers to avoid, or at least to minimise, such divergence as a common approach for all regions in design, construction and handling of equipment is more cost-effective.

Although the safety standards listed in Table 1 are specifically applicable to RACHP systems, they can seldom be used in isolation. There are a variety of other standards that address safety matters related to equipment, components and methods that may apply generically across different end uses and industries. Such standards may be invoked by RACHP safety standards to address issues such as safety devices, flammability safety, pressure vessels, electrical safety, controls and so on.

Amongst the numerous types of requirements addressed within the RACHP safety standards, one of the most important aspects to the application of flammable low GWP alternatives is that of refrigerant charge size limits; this is critical when related to the use of HCs. In particular, charge size of systems with flammable refrigerants need to be optimised in order to improve levels of safety while ensuring high energy efficiency. Figure 1 provides an illustration of how the cooling capacity of an air conditioner is related to the refrigerant charge for a range of different seasonal energy efficiency ratios (SEER). A higher SEER requires a higher charge size, as does a larger cooling capacity.

The introduction of energy efficient technologies with low GWP refrigerants requires a suite of technical standards which adequately address both flammability/charge size and energy efficiency.

Figure 1: Example of the relationship between refrigerant charge and cooling capacity as a function of seasonal efficiency of an air conditioner (SEER) with R290



In addition to the RACHP safety standards identified above, there is an array of other safety standards for RACHP equipment and also general concepts that are generally applicable and affect RACHP equipment. Both international and regional standards address:

- General safety of compressors and pumps (e.g., IEC 60225-2-34, EN 809, IEC 60204-1, EN 1012, EN 12693)
- Pressure safety of system vessels and components (e.g., ISO 4126, EN 1736, EN 12178, EN 12263, EN 12284, EN 13136, EN 13445, EN 14276)
- Tightness of components and connections (e.g., ISO 14903, EN 16084)
- Competence of personnel (e.g., ISO 22712)
- Electromagnetic compatibility (e.g., EN 61000-series)
- General safety of machinery (e.g., ISO 12100, ISO 13849-1)
- Risk assessment of equipment using flammable gases (e.g., EN 1127-1)
- Safety characteristics of refrigerants (e.g., ISO 817, IEC 60079-20-1)
- Gas detection (e.g., EN 14624, IEC 60079-29-series, EN 50402)
- Classification of hazardous areas (e.g., EN 60079-10-1)
- Electrical equipment for use in potentially flammable areas (e.g., IEC 60079-0, IEC 60079-1, IEC 60079-2, IEC 60079-5, IEC 60079-6, IEC 60079-7, IEC 60079-11, IEC 60079-13, IEC 60079-14, IEC 60079-15, IEC 60079-17, IEC 60079-18, IEC 60079-19, IEC 60079-25, IEC 60079-26, IEC 60079-32, IEC 60079-33)

Many of these standards can influence the ease and cost of operation when applied to RACHP systems using low GWP alternatives.

3

→ RELATIONSHIP BETWEEN SAFETY STANDARDS AND NATIONAL REGULATIONS

3. Relationship between safety standards and national regulations

The form, significance and status of safety standards can differ widely amongst countries. Consequentially, stakeholders' opinions of the importance of standards are equally as diverse. Globally, the following variations apply:

- **For safety standards, countries**

  – Develop their own safety standards independently;
  – Adopt international (or regional) standards as national standards "as is";
  – Adopt international (or regional) standards as national standards with modifications;
  – Do not have national standards but instead use other countries' standards.

- **Status of safety standards are either**

  – Entirely voluntary;
  – Mandated by national legislation;
  – Deemed as a means of complying with certain legislation;
  – Broadly voluntary except by contractual agreements by two or more parties.

- **Compliance with safety standards may be**

  – By self-certification;
  – By a third-party certification body only;
  – Overseen by market surveillance systems;
  – Confirmed by at least one governmental institution.

Evidently, it is not straightforward to illustrate typical situations or draw generalisations on how safety standards are treated across most countries.

Many countries do, however, employ broadly applicable safety regulations that handle generic subjects such as pressure safety, toxicity, electrical safety, flammability, explosion protection and general safety of machinery and building safety, amongst others. Implications of these also vary: regulations may invoke safety standards to deal with or clarify certain matters, they may effectively rely on safety standards to formulate the safety concept, or in some cases they may directly conflict with safety standards.

Generally, product liability is enshrined by applicable health and safety legislation in a given country and so any product placed on the market must comply with such legislation. Infrequently, national legislation may invoke safety standards explicitly, although generally, safety standards offer optional interpretation of satisfying the requirements of national legislation. Provided that any new safety standard does not conflict with national legislation that governs the use, application and handling of flammable gases, it should not in principle lead to product liability issues. Such legislation often states that equipment and installations must be "safe" and it is thus left to the user to carry out the requisite risk assessments and to demonstrate that a sufficient level of safety has been attained. The same approach also applies to the use of safety standards; since no standard can comprehensively address each and every single set of circumstances and characteristic of RACHP equipment and installations, the manufacturer and installer have an obligation to take account of all the relevant peculiarities that may not be suitably addressed with the standard. Needless to say, this applies to all the different hazards – electrical, pressure, mechanical, toxicity, etc. – that are applicable to the equipment. In carrying out a risk assessment, the stakeholder should seek out the most reliable and relevant empirical data and along with the appropriate tools and techniques to analyse the risk associated with equipment / installation to help gauge whether the proposed design and construction meets some reference safety level. This is irrespective of any requirements specified within the applicable safety standards.

Concerning possible barriers to trade, the WTO's Technical Barriers to Trade Agreement (TBT) tries to ensure that regulations, standards, testing and certification procedures do not create unnecessary obstacles. Provided that a given country does not publish (a mandatory) safety standard that is more stringent or restrictive than, say, an international standard then a relaxation of requirements, such as charge size limits (that may be offset with appropriate countermeasures) would most likely not conflict with the TBT.

4

→ CURRENT REQUIREMENTS FOR SYSTEMS USING FLAMMABLE REFRIGERANTS

4. Current requirements for systems using flammable refrigerants

RACHP safety standards address a wide range of hazards associated with RACHP systems and equipment. Notably, these safety standards do not only focus on refrigerant safety aspects, but also on many other issues. Aspects related to refrigerant safety represent a proportion of these hazards and the associated design, construction and handling requirements. Table 2 provides a summary of the important topics handled by RACHP safety standards that are affected by the choice of refrigerant.

Table 2: General inclusion of technical requirements within safety standards for RACHP equipment

Category	IEC 60335-2-24	IEC 60335-2-89	IEC 60335-2-40	ISO 20854	ISO 5149-1, -2, -3, -4
	EN 60335-2-24	EN 60335-2-89	EN 60335-2-40	EN 17893	EN 378-1, -2, -3, -4
Scope	Domestic refrigerators, freezers and ice makers	Plug-in commercial appliances and cabinets with a condensing unit and single compressor	Factory-made whole air conditioners, heat pumps, dehumidifiers and partial units	Refrigerated reefer containers, refrigerated road transport	All commercial and industrial refrigeration, air conditioning and heat pump systems
Limits on refrigerant charge amount.	150 g flammable refrigerant, no limits for R744, R717 out of scope	Approx. 500 g of HC, no limits for R744, R717 out of scope	Approx. 1 kg of HC in system inside, 5 kg outside or in enclosure, no limits for R744, R717 out of scope	None; determined by risk assessment	Various, depending upon the circumstances
Ventilation and airflow	No	Yes, optional	Yes, optional	Yes, optional	No (Yes, optional)
Limited releasable charge	No	No (Yes, optional)	Yes, optional	Yes, optional	No (Yes, optional)
Surrounding concentration test	No	Yes	No	Yes, optional	No (Yes, optional)
Leak detection	n/a	Yes, optional	May be used to initiate mitigation measures. May be applicable to systems using flammable refrigerants in machinery rooms or systems in occupied spaces		
Marking	Requires flammability and/or high-pressure warning symbols, as appropriate				
Strength pressure	Specifies pressure tests for systems and components (where applicable)				
Electrical equipment	Specifies design, construction and test requirements			Refers to appropriate standards	
System tightness	No	Systems generally have to be constructed as "sealed" or "hermetically sealed" systems if they are to use flammable refrigerants indoors (e.g., no or limited number of reusable mechanical connections or fittings)			
Secondary/ indirect systems	n/a	Additional components for secondary or indirect circuits (such as those using water or brine) are required to vent a leak that has occurred from the evaporator into the secondary circuit if the primary refrigerant circuit exceeds a certain charge size			
Construction of machinery rooms or ventilated enclosure	n/a		Machinery rooms or special enclosures may have certain requirements if flammable refrigerants are used, such as number and opening of doors, fire resistance of walls, tightness and minimum airflow rates, etc.		
Sources of ignition	Describes what to consider and how to avoid a potential source of ignition, including a test method option (except ISO 5149)				
Information and instructions	Details concerning the installation, use, service, maintenance, and disposal of the equipment so that users, operators and technicians are aware of how to handle flammability hazards				
Pressure limiting/ relief devices	The need for additional devices to limit or relieve excess pressure may apply to smaller systems if flammable refrigerants are used				

* Items in parentheses refer to current draft version of the standard.

As seen in Table 2, design and construction aspects are affected by refrigerant type and certain mitigation measures can be optional. Such measures can potentially influence the cost of systems and the convenience for manufacturers and installers. However, refrigerant charge size limits are ultimately the most pivotal requirements within safety standards in terms of viability for application of natural refrigerants. This is particularly the case for HCs. Table 3 summarises the charge size limits for HCs across current safety standards.

Table 3: Refrigerant charge size limits for HCs according to current safety standards for RACHP systems

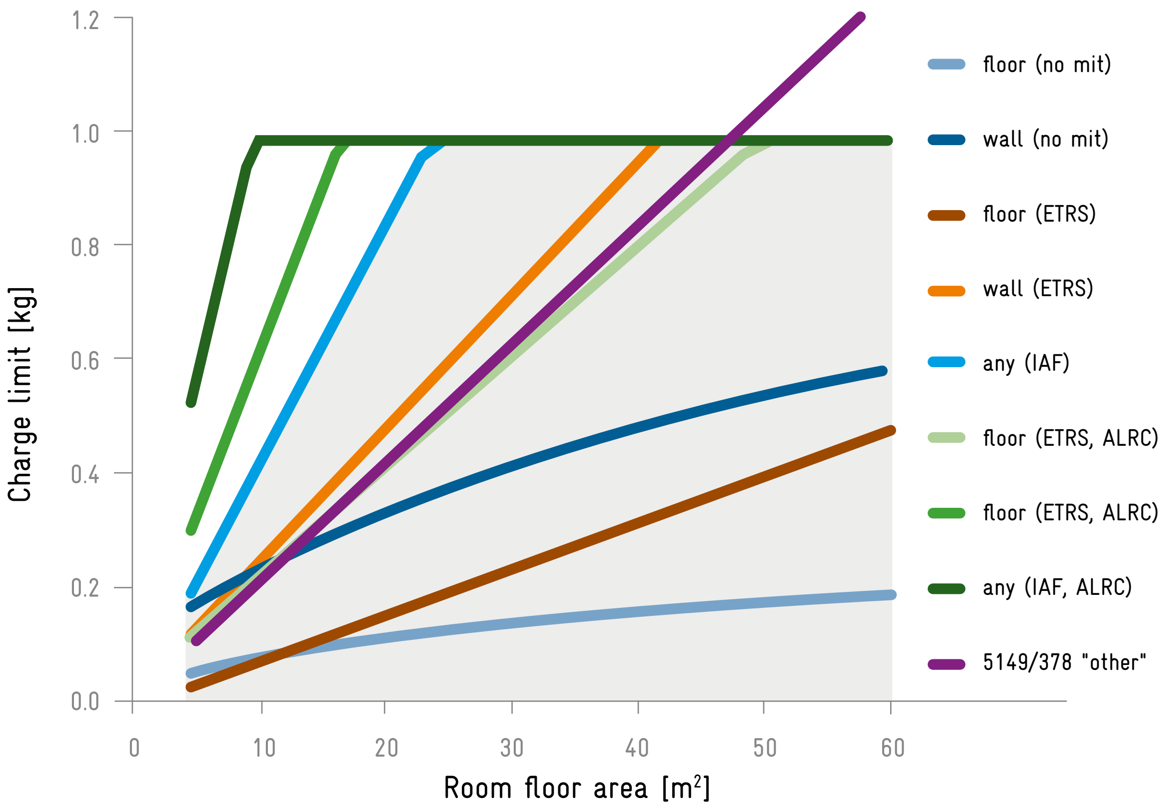
<table>
<tr><th>Equipment/ application</th><th colspan="2">Vertical (IEC 60335-2-24, -40, -89; ISO 13043, ISO 20854, EN 17893)</th><th colspan="2">Horizontal (ISO 5149-1, EN 378-1)</th></tr>
<tr><td></td><td>Upper charge</td><td>Allowable charge</td><td>Upper charge</td><td>Allowable charge</td></tr>
<tr><td>Domestic refrigeration</td><td>0.15 kg</td><td>0.15 kg</td><td>n/a</td><td>n/a</td></tr>
<tr><td colspan="5">Commercial refrigeration</td></tr>
<tr><td>• Stand alone</td><td>0.15 kg</td><td>0.15 kg</td><td>1.5 kg</td><td>$0.008\times V_{rm}$</td></tr>
<tr><td>• Condensing units</td><td>0.15 kg</td><td>0.15 kg</td><td>1.5 kg</td><td>$0.008\times V_{rm}$</td></tr>
<tr><td>• Centralised systems</td><td></td><td></td><td>1.5 kg</td><td>$0.008\times V_{rm}$</td></tr>
<tr><td>Transport refrigeration</td><td>No limit</td><td>No limit</td><td>1.5 kg; 2.5 kg</td><td>1.5 kg; 2.5 kg</td></tr>
<tr><td>Large size refrigeration</td><td>n/a</td><td>n/a</td><td>2.5, 10, 25 kg, no limit</td><td>$0.008\times V_{rm}$</td></tr>
<tr><td colspan="5">Air conditioner & heat pumps</td></tr>
<tr><td>• Small self-contained</td><td>0.3 kg</td><td rowspan="5">Various, depending upon selected measures (see Table 2 and INFO BOX)</td><td>0.3 kg</td><td>$0.01\times V_{rm}$</td></tr>
<tr><td>• Mini-split</td><td rowspan="2">1 kg</td><td rowspan="2">1.5 kg</td><td rowspan="4">$0.04\times h\times A_{rm}^{0.5}$ (Various, e.g., as in Table 2 and INFO BOX)</td></tr>
<tr><td>• Multi-split, ducted split</td></tr>
<tr><td>• Hot water heating heat pumps</td><td>1 kg, 5 kg</td><td rowspan="2">1.5 kg, 5 kg, 10 kg, 25 kg, no limit</td></tr>
<tr><td>• Space heating heat pumps</td><td>1 kg, 5 kg</td></tr>
<tr><td colspan="5">Chillers</td></tr>
<tr><td>• Positive displacement</td><td>1 kg, 5 kg</td><td>1 kg, 5 kg</td><td>1.5 kg, 5 kg, 10 kg, 25 kg, no limit</td><td>n/a</td></tr>
<tr><td>• Centrifugal</td><td>n/a</td><td>n/a</td><td>1.5 kg, 5 kg, 10 kg, 25 kg, no limit</td><td>n/a</td></tr>
</table>

where: V_{rm} = room volume (in m³); A_{rm} = room area (in m²) and h = unit installation height (in m)

As indicated above, current safety standards tend to rely on two types of constraints for refrigerant charge amounts: (i) the maximum or upper charge limit (UCL) being an overall cap according to the application and location of the system, and (ii) an allowable charge limit (ACL) as a function of room size and in some cases the installation height of the equipment.

An example is illustrated in Figure 2, based on air conditioners and heat pumps. With an R290 mass below 0.15 kg, there is no dependency on room size. Above 0.15 kg the ACL is a function of room size, until the UCL of 1.0 kg is reached, after which increasing the room size does not permit any more R290.

Figure 2: Example of the relationship between room size and refrigerant charge limits using different risk mitigation methods. For example, with integrated airflow (IAF), any charge for the room size within the shaded area is permissible.



The UCLs (e.g., 1.0 kg in the above example) are broadly arbitrary values assigned to ensure the quantities used in systems do not extend to uncontrolled amounts. In practice, the UCLs seldom create a significant barrier to the selection and application of HCs in some RACHP sub-sectors. For instance, the vast majority of stand-alone, plug-in commercial refrigeration cabinets and room air conditioners require much less than 1.5 kg of R290 and heat pumps rarely need more than 5 kg. Conversely, for some types of systems such as remote and centralised commercial refrigeration systems, commercial heat pumps in ventilated enclosures and larger multi-split, ducted split and “rooftop” type air conditioning systems the UCL is highly restrictive.

Based on the charge size limits indicated in Table 3, and accounting for typical refrigerant needs to achieve a certain thermal capacity at various temperature levels and associated heat loads, an approximation of RACHP system capacity ranges is provided in Table 4. It can be seen that there are effectively no charge limit restrictions for R744, the restrictions for R717 indoor occupied spaces are almost universal due to toxicity limits, whilst those for HCs they are somewhat arbitrary and could be improved.

Table 4: Approximate capacity range of different types of applications using HC, R744 or R717

Equipment/application	Approximate maximum capacity with alternative refrigerant (kW)[3]		
	HCs	R744 †	R717 ‡
Domestic refrigeration	No limit	No limit	No limit (sorption)
Commercial refrigeration			
• Stand-alone equipment	up to 15	No limit	Negligible
• Condensing units	up to 10	No limit	Negligible
• Centralised systems	up to 4	No limit	Negligible
Transport refrigeration	up to 15	No limit	n/a
Large size refrigeration	60 to no limit	No limit	No limit
Air conditioner & heat pumps			
• Small self-contained	up to 10	No limit	Negligible
• Mini-split (non-ducted)	up to 10	No limit	Negligible
• Multi-split	up to 6	No limit	Negligible
• Ducted split	up to 20	No limit	Negligible
• Ducted commercial	up to 20	No limit	Negligible
• Space/hot water heat pumps (domestic)	up to 50	No limit	Negligible
• Heat pumps (commercial)	50 to no limit	No limit	No limit
Chillers			
Positive displacement	150 to no limit	No limit	No limit
Centrifugal	25 to no limit	No limit	n/a

† Degradation of capacity and efficiency at moderate to high ambient temperatures must be considered.
‡ "Negligible" means effectively not permitted due to extremely small ACL.

3 The values are based on approximate specific charge sizes per kW of cooling (or heating) for air conditioning, chilled or freezer temperature levels, whether the equipment is located inside or outside, and according to the charge size limits from the cited safety standards. "Not permitted" for R717 means effectively not permitted, due to extremely small ACL.

5

→ RECOMMENDATIONS FOR REVISED SAFETY STANDARDS FOR NATURAL REFRIGERANTS, PARTICULARLY HYDROCARBON REFRIGERANTS

5. Recommendations for revised safety standards for natural refrigerants, particularly hydrocarbon refrigerants

The permitted refrigerant quantities – both ACL and UCL – for HC refrigerants is contentious. In some applications, such as commercial refrigeration, the amount of refrigerant can be constrained due to the size of a shop (e.g., a display cabinet in a convenience store). This can inhibit the applicability of, for example, larger commercial refrigeration system in smaller shops. In air conditioning applications where the desired cooling capacity of an air conditioner is strongly influenced by the size of the conditioned space, some models may require more refrigerant than is allowed (i.e., to provide the desired cooling capacity for that space). In order to help resolve such constraints, additional safety mitigation measures can be applied to the RACHP systems to offset the potentially increased flammability risk ordinarily associated with a greater charge quantity (e.g., per room size). Such mitigation measures include:

- Improving leak tightness of the system, over and above assumed standard practice;
- Adopting equipment housing design to help disperse leaks better than that assumed with conventional housing designs;
- Guaranteeing a sufficient airflow rate within the space, to ensure that leaked refrigerant does not stagnate at the floor and its concentration stays below the lower flammability limit (LFL);
- Inclusion of valves or other components to limit the refrigerant amount released in the event of a leak.

The last two measures may be applied in conjunction with some form of leak indication (e.g., gas sensors, ultrasonic detection or system parameters) so they can be activated on demand.

A detailed discussion of these matters can be found elsewhere (Colbourne et al., 2020). The following provides a practical illustration of how such measures can be applied.

IMPROVED TIGHTNESS

Until recently, ACLs were based on the assumption that the refrigerant leaks out instantaneously and at a very fast rate (a "catastrophic" leak). Since a higher leak rate gives the refrigerant less time to dilute in the surrounding air, higher concentrations within the room may develop and, in order to avoid those concentrations reaching the lower flammability limit (LFL), the refrigerant mass is constrained accordingly.

Safety standards did not proactively impose measures to avoid such fast leaks occurring. Therefore, if "improved tightness" measures are implemented, the likelihood of rapid, "catastrophic" leaks can be effectively disregarded. Accordingly, if a relatively slow leak is assumed, then the refrigerant more easily dilutes with the surrounding air and a greater amount of released refrigerant can be tolerated before a potentially flammable concentration develops.

Although quantifying a direct relationship between certain implemented measures and an expected leak rate is not practical, engineering logic and experience helps to provide some approximations. Thus, if all refrigerant-containing parts of the system that are inside the building are engineered so that the possibility of damage from external mechanical impact is eliminated, internal rubbing and fretting of parts are prevented, configuration of piping is such that potentially deleterious resonances do not occur in piping, cracking due to icing or fan damage is prevented, then large instantaneous leaks have no reason to occur. Indeed, recent research[4] found that in such systems, refrigerant leak hole sizes are mostly very small and occasionally of medium size; large hole sizes only occur rarely and are due to human intervention (Colbourne et al., 2021).

4 http://lifefront.eu

Research has found that under these circumstances, approximately 2 – 3 times as much refrigerant can be leaked than that prescribed by some allowable charge formulas (e.g., Table 3) before LFL is reached (e.g., Cleaver et al., 1994; Li, 2014; Zhang et al., 2013). Accordingly, revised formulae have been proposed for RACHP equipment (Colbourne and Suen, 2021).

EQUIPMENT HOUSING AND ENCLOSURES

Experiments have found that the design of the enclosure that the RACHP systems is housed within can also affect the concentration arising from a refrigerant leak, both within a confined space (such as a room) or surrounding an outdoor unit (Colbourne and Suen, 2016; 2021). Thus, the design of an enclosure can assisst with enabling a higher ACL or even reducing minimum separation distances around installed units.

SYSTEMS WITH INTEGRAL AIRFLOW

Allowable charge sizes are based on the assumption that room air is quiescent, where leaks mix with the air mainly through the momentum of the released refrigerant itself. With most RACHP equipment there is always some (beneficial) airflow occurring in occupied spaces, but since under some circumstances the airflow is minimal, any possible benefit to refrigerant releases had hitherto been ignored.

Since RACHP systems typically use fans to distribute the air that it has cooled or heated away from the equipment and usually widely distributed throughout the space it is installed, this can be exploited. If the airflow can be guaranteed when needed, it can be accounted for in the dilution of leaked refrigerant. The presence of forced airflow – either continuously or initiated by some means of leak detection – dramatically improves dilution of a refrigerant release and thus a much greater quantity of refrigerant can be tolerated before a flammable concentration arises in a given space. Formulae have been developed to determine the minimum airflow rates needed to ensure a leak is suitably mixed within a room (Colbourne and Suen, 2022).

Ultimately, if the airflow provided by the fan within the unit that houses refrigerant-containing parts either operates continuously or is initiated by a sensor such as a gas detector, any leaked refrigerant can be mixed almost homogenously within the room. Accordingly, a greater mass of refrigerant for a given room size can be permitted.

SYSTEM WITH LIMITED RELEASABLE CHARGE

Existing charge size limits assume that the entire amount of refrigerant charged into the system will leak out. However, this is not possible as refrigerant remains in the piping and components at atmospheric pressure and absorbed in compressor oil. Depending upon the size of system, type of oil, refrigerant, etc., this passive retention of charge can equate to around 3% to 15% of the total charge. Additionally, shut off valves may be employed within a system to actively limit the amount of refrigerant that could be released. System architecture, control functionality, operating conditions, leak location, etc. all have an influence, but approximately 30% to 95% of the nominal charge amount can be actively prevented from being released. Whether the situation is passive or active, a rigorous test method is necessary to determine the actual amount of refrigerant that can leak out, considering the various operating modes and conditions.

To determine the minimum room size within which the system can be installed, the actual refrigerant amount released from a system – as determined by some standardised test procedure – may be considered.

REFRIGERANT LEAK DETECTION

There are several mitigation measures that may rely upon detection of a refrigerant leak, such as initiation of airflow or closing of safety shut-off valves.

Leak detection may be in the form of different technologies, for example:

- Gas detection, where a sensor reacts to the presence of the leaked refrigerant within the air (or liquid).
- System parameters, where system operation in the form of pressures, temperatures, etc., are monitored and compared against values that should be present with a full-charge; and deviation indicates the possibility of a refrigerant leak.
- Acoustic sensing, where the noise, such as in the ultrasonic range, associated with the leaking refrigerants is detected by a sensor which is calibrated to that arising from high pressure refrigerant leaking from a system (e.g., Colbourne and Vonsild, 2023).

One or more of these methods may be used to indicate occurrence of a refrigerant leak, thereby enabling selected mitigation methods to be initiated.

CHARGE DETERMINATION BY TEST

ACLs within some current standards are broadly based on limited measurements of "idealised" releases, i.e., where a refrigerant enters the surroundings under conditions that are essentially unfavourable for mixing with air, thereby leading to higher concentrations and thus requiring a constraint on the amount. But as discussed above, in real RACHP equipment there are practical characteristics that lead to deviations from this, where dilution of a leak by up to five or more times greater, compared to an "idealised" case. A correspondingly greater amount of refrigerant can thus be released before the LFL is reached. The influencing factors are complex and so determining resulting refrigerant concentration cannot be easily approximated. Therefore, individual testing may be used.

For a given housing design, leakage conditions, leak detection, use of measures to limit releasable charge and means of airflow/ventilation, releases may be simulated and the refrigerant concentration surrounding the unit are measured and the acceptable charge of refrigerant be determined. Arguably, such a methodology is substantially more reliable than a rudimentary calculation as is used prescribed within safety standards, since it accounts for all the different unique characteristics of the tested RACHP equipment.

ADDRESSING POTENTIAL SOURCES OF IGNITION

Currently, most international safety standards do not fully address the handling of potential sources of ignition in a way that is consistent with the established standards for protection against ignition of flammable gases. This specifically refers to the IEC / EN 60079-series of standards. ISO 5149 effectively neglects the issue and IEC 6035-2-40 and -89 partially address the issue. In this respect, appropriate revisions may be considered for such standards.

Most standards include approaches and methodologies to address the handling of potential sources of ignition, either by inspection, control or by testing.

OVERVIEW

The INFO BOX summarises the various refrigerant charge determination possibilities based on the above concepts within some of the current safety standards. Substantial improvements and flexibility in allowable charge sizes can be achieved through the different approaches described. Options (i), (ii) and (iii) are effectively included in the current IEC 60335-2-40 and IEC 60335-2-89 and it is hoped that they will be within the revised ISO 5149 and EN 378. Option (iv) is already used but typically leads to highly restrictive ACLs.

INFO BOX: DETERMINATION OF ALLOWABLE CHARGE LIMIT

Allowable charge limits (ACLs) vary, depending upon the size of the room, height of the refrigerant-containing parts, whether the equipment has integral airflow and components to limit the releasable amount of refrigerant. In summary:

I) Enhanced tightness refrigeration system (ETRS), where assumed leak rate is much smaller than non-ETRS. In this case, allowable charge limit (ACL) is given by equation (1).

$$m_{ACL} = F \times LFL \times h_0 \times A_{rm} \qquad (1)$$

where the concentration factor, F = 0.35, h_0 is the height of the unit [m] and A_{rm} is the area of the room [m^2].

II) Systems which use integral airflow (IAF), where indoor unit fan operates continuously or in response to leak detection. Systems may be ETRS or non-ETRS; this only affects the required minimum airflow rate required to disperse a leak. The ACL is given by equation (2).

$$m_{ACL} = F \times LFL \times h_{rm} \times A_{rm} \qquad (2)$$

where F = 0.50, h_{rm} is the height of the room [m] and A_{rm} is the area of the room [m^2].

III) Limited releasable charge (m_{RC}), where, if the releasable charge can be determined by test, the resulting mass can be assumed rather than the charged amount (m_C); equation 3. This can be considered to fall into two categories:

- "Passive" limited releasable charge (PLRC), which typically accounts only for the mass retained in refrigerant oil and the system volume at atmospheric pressure, and
- "Active" limited releasable charge (ALRC), which employs features such as safety shut-off valves to hold charge within the outdoor unit in response to leak detection.

$$m_{RC} \cong (1-\vartheta) \times m_C \qquad (3)$$

where the retained charge coefficient, ϑ, may be around 0.8 – 0.9 for PLRC and anywhere from 0.05 to 0.75 for ALRC, based on experiments. For ALRC, the smaller the internal volume of the indoor part of the system (relative to the whole system) and the faster the response time of the leak detection system, the lower ϑ will be. Whichever method is used, m_{RC} cannot exceed m_{ACL}.

IV) The ACL calculation for the basic method with no additional mitigation methods is equation (4).

$$m_{ACL} = 2.5 \times LFL^{1.25} \times h_0 \times \sqrt{(A_{rm})} \qquad (4)$$

6

ADVANCING NATIONAL AND INTERNATIONAL SAFETY STANDARDS

6. Advancing national and international safety standards

To reiterate, in order to achieve national obligations under the Kigali Amendment, it is necessary for RACHP systems to use refrigerants with low GWP. However, safety standards can pose substantive barriers to the implementation of such refrigerants – primarily HCs – by means of obstructive refrigerant charge size limits for certain applications. Therefore, there is an explicit need to revise these safety standards so that larger charge sizes are permitted, along with guidance on how to apply them safely.

Presently, all of the critical safety standards IEC / EN 60335-2-89, IEC / EN 60335-2-40, ISO 5149 and EN 378 are being worked on in order to develop revisions and/or amendments. Some of the stakeholders involved are working towards improving charge size limits. Discussions are in progress and new investigations are emerging all the time.

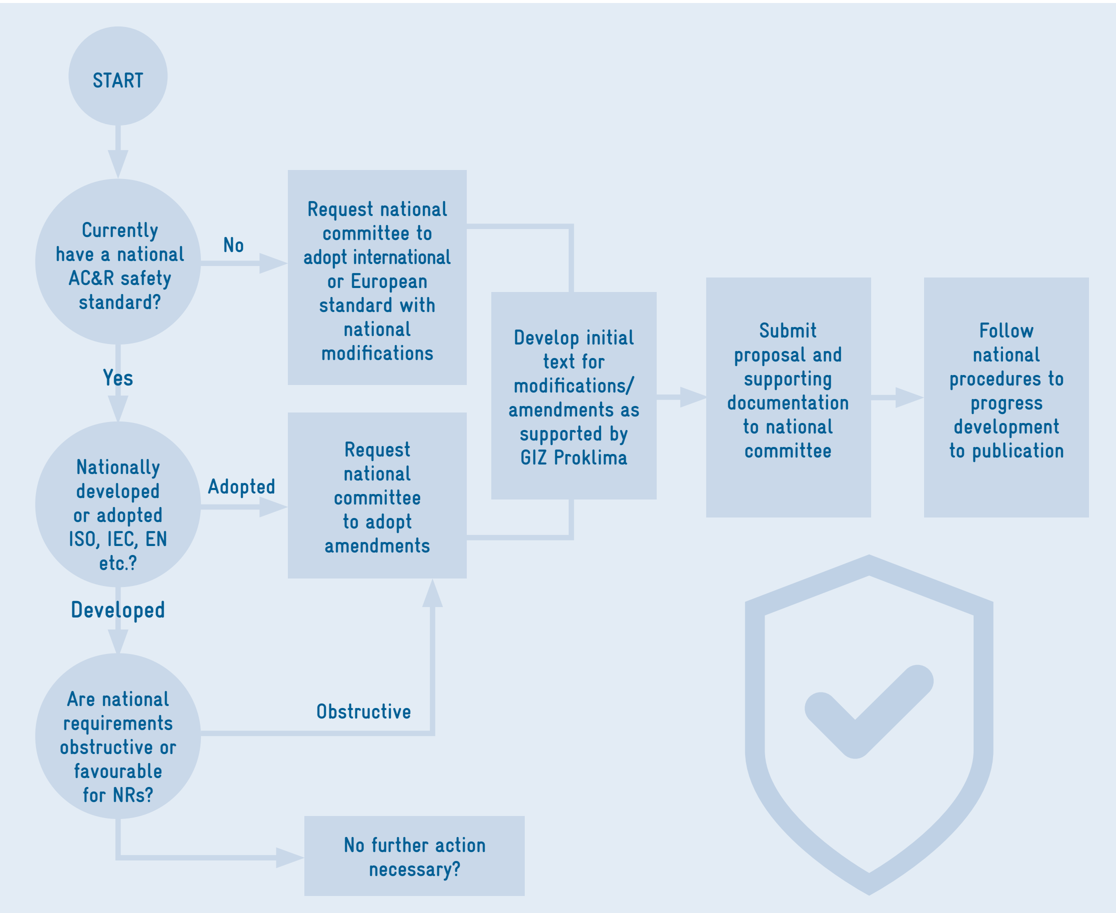
However, such activities are time-consuming and protracted due to established procedures for standards development, as well as to conflicting views amongst stakeholders involved with competing technologies. Predictions about the publication duration of new requirements range from five to ten years; such timelines are inconsistent with the needs of the industry to implement low GWP refrigerants in time to comply with obligations under the Montreal Protocol and Kigali Amendment. Consideration may be given to mechanisms for interested countries to address such barriers nationally and/or regionally. Since local circumstances vary, the appropriate route for resolving the obstructions may vary. Table 4 provides an indication of the types of interventions necessary, depending on the origin of the national safety standard and its legal status.

Table 5: Interventions for resolving obstructive safety standards

Origin of national safety standard	Status of safety standards		
	Voluntary standard	Standard is mandated by legislation	Standard offers one means of complying with legislation
Own national standard	Modify standard at national level	Modify national standard under consultation with authority responsible for said legislation	Modify national standard with cross-checks against obligations of said legislation
Copy of international standard	Implement national modifications to international version	Modify standard under consultation with authority responsible for said legislation	Modify standard with cross-checks against obligations of said legislation
International standard with national changes	Implement (further) national modifications to international version	Modify standard under consultation with authority responsible for said legislation	Modify standard with cross-checks against obligations of said legislation
None; use other country standard	Adopt other country's standard nationally and apply national modification	n/a	n/a
Do not currently use standard	Adopt other national or international standard and apply national modifications	n/a	n/a

In case a safety standard lacks sufficient requirements necessary for broad application of natural refrigerants, some degree of intervention will be necessary to, for example, introduce requirements consistent with the recommendations in section 5. Where the existing standard is a nationally developed document, a copy of an international standard or one with nationally determined changes, further modifications can and should be made. In cases where there is currently no national standard, an appropriate international or regional standard may be adopted and, if necessary, modified accordingly. In the event that a national standard is mandated by national legislation, any modifications should be carried out in consultation with the appropriate authorities to ensure that no conflicts with regulations arise. A similar approach applies where a standard is not mandatory but is recognised as one of several legal options of complying with a national regulation. In all these circumstances, the necessary steps are affected by the specific safety standards in use.[5] Ultimately, each country's situation should be addressed on a case-by-case basis. The flow chart in Figure 3 identifies the key decisions and steps to be considered when addressing these issues nationally.

Figure 3: Flow chart identifying the main decisions and steps for addressing national safety standards



5 If countries have adopted certain standards that contain extensive restrictions such as UL 60335-2-40 or ASHRAE-15, which pose considerable obstructions to low GWP natural refrigerants, then further work is required to resolve the obstructions.

In conclusion, countries mandating safety standards must ensure their internal processes enable them to freely change and alter national standards or national adoptions of international safety standards to suit their national needs and circumstances. This is essential with respect to allowing the wider use of potentially flammable low GWP alternatives in order to meet ambitious improvements in energy efficiency, and lower climate and environmental impact of refrigerants (Munzinger et al., 2016).

In line with any modification to the safety standards, it is also appropriate to address these issues within national legislation. In particular, to ensure that:

- National building safety regulations do not conflict with the requirements of modified safety standards;
- Any modifications are consistent with national regulations on pressure, flammability, toxicity, electrical and machinery safety;
- Sufficient knowledge and expertise on the technical subjects addressed therein are readily available for national experts to contemplate.

Critically, any changes to safety standards should at the first stage not be mandatory, since the nature of these requirements tends to be rather onerous. Following an initial trial period of voluntary developed standards, they can subsequently be established as mandatory standards, following refinements and practical trials, etc.

In order to achieve the obligations of the Kigali Amendment under the Montreal Protocol, countries must ensure that safety standards cease to pose barriers to the implementation of natural refrigerants, by means of obstructive refrigerant charge size limits. In order to offset the increased flammability risk associated with a greater allowable charge, additional safety measures to mitigate the risk can be introduced to system design and construction, such as improving leak tightness of the system, assuring sufficient airflow, adopting equipment housing design and inclusion of valves.

7

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Standards [6]

EN 1012-2: 1996+A1:2009 Compressors and vacuum pumps. Safety requirements - Vacuum pumps

EN 1127-1: 2019 Explosive atmospheres. Explosion prevention and protection - Basic concepts and methodology

ISO 12100: 2010 Safety of machinery. General principles for design. Risk assessment and risk reduction

EN 12178: 2016 Refrigerating systems and heat pumps. Liquid level indicating devices. Requirements, testing and marking

EN 12263 :1999 Refrigerating systems and heat pumps. Safety switching devices for limiting the pressure. Requirements and tests

EN 12284: 2003 Refrigerating systems and heat pumps. Valves. Requirements, testing and marking

EN 12693: 2008 Refrigerating systems and heat pumps. Safety and environmental requirements. Positive displacement refrigerant compressors

ISO 13043: 2011 Road vehicles - Refrigerant systems used in mobile air conditioning systems (MAC) - Safety requirements

EN 13136: 2013 Refrigerating systems and heat pumps. Pressure relief devices and their associated piping. Methods for calculation

EN 13445-1: 2014 Unfired pressure vessels - Part 1: General

EN 13445-2: 2014 Unfired pressure vessels - Part 2: Material

EN 13445-4: 2014 Unfired pressure vessels - Part 4: Fabrication

EN 13445-5: 2014 Unfired pressure vessels - Part 5: Inspection and testing

EN 13445-6: 2014 Unfired pressure vessels - Part 6: Requirements for the design and fabrication of pressure vessels and pressure parts constructed from spheroidal graphite cast iron

EN 13445-8: 2014 Unfired pressure vessels - Part 8: Additional requirements for pressure vessels of aluminium and aluminium alloys

ISO 13849-1: 2015 Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design

EN 14276-1: 2020 Pressure equipment for refrigerating systems and heat pumps - Vessels. General requirements

EN 14276-2: 2020 Pressure equipment for refrigerating systems and heat pumps Part 2: Piping - General requirements

EN 14522: 2005 Determination of minimum ignition temperature of gases and vapours

EN 14624: 2020 Performance of portable locating leak detectors and of fixed gas detectors for all refrigerants

6 Latest amendment or corrigenda may not be included in the list

ISO 14903: 2017 Refrigerating systems and heat pumps. Qualification of tightness of components and joints

ISO 14903: 2022 Refrigerating systems and heat pumps - Qualification of tightness of components and joints

EN 14986: 2017 Design of fans working in potentially explosive atmospheres

EN 15198: 2007 Methodology for the risk assessment of non-electrical equipment and components for intended use in potentially explosive atmospheres

EN 15233: 2007 Functional safety assessment explosive atmospheres

EN 1593: 1999 Non-destructive testing. Leak testing. Bubble emission techniques

EN 16084: 2011 Refrigerating systems and heat pumps - Qualification of tightness of components and joints

EN 1736: 2008 Refrigerating systems and heat pumps. Flexible pipe elements, vibration isolators, expansion joints and non-metallic tubes. Requirements, design and installation

PD CEN/TS 17606: 2021 Installation of refrigeration, air conditioning and heat pump equipment containing flammable refrigerants, complementing existing standards

PD CEN/TS 17607: 2021 Operation, servicing, maintenance, repair and decommissioning of refrigeration, air conditioning and heat pump equipment containing flammable refrigerants, complementing existing standards

PD CEN/TR 17608: 2022 State of the art on the use of flammable refrigerant alternatives, in particular from class A3, in refrigeration, air conditioning and heat pump equipment

prEN 17893: 2023 Thermal road vehicles - Safety standard for temperature-controlled systems using flammable refrigerants for the transport of goods - Requirements and risk analysis process

ISO 20854: 2019 Thermal containers - Safety standard for refrigerating systems using flammable refrigerants - Requirements for design and operation

ISO 21922: 2021 Refrigerating systems and heat pumps - Valves - Requirements, testing and marking

ISO 22712: 2023 Refrigerating systems and heat pumps - Competence of personnel

EN 31010: 2019 Risk management. Risk assessment techniques

EN 378-1: 2016 Refrigerating systems and heat pumps. Safety and environmental requirements. Basic requirements, definitions, classification and selection criteria

EN 378-2: 2016 Refrigerating systems and heat pumps. Safety and environmental requirements. Design, construction, testing, marking and documentation

EN 378-3: 2016 Refrigerating systems and heat pumps. Safety and environmental requirements. Installation site and personal protection

EN 378-4: 2016 Refrigerating systems and heat pumps. Safety and environmental requirements. Operation, maintenance, repair and recovery

ISO 4126-1: 2013+A2:2019 Safety devices for protection against excessive pressure - Safety valves

ISO 4126-10: 2010 Safety devices for protection against excessive pressure - Sizing of safety valves for gas/liquid two-phase flow

ISO 4126-2: 2019 Safety devices for protection against excessive pressure - Bursting disc safety devices

ISO 4126-3: 2020 Safety devices for protection against excessive pressure - Safety valves and bursting disc safety devices in combination

ISO 4126-4: 2013 Safety devices for protection against excessive pressure - Pilot-operated safety valves

ISO 4126-5: 2013+A1:2016 Safety devices for protection against excessive pressure - Controlled safety pressure relief systems (CSPRS)

ISO 4126-6: 2014 Safety devices for protection against excessive pressure - Application, selection and installation of bursting disc safety devices

ISO 4126-7: 2013+A1:2016 Safety devices for protection against excessive pressure - Common data

ISO 4126-9: 2008 Safety devices for protection against excessive pressure - Application and installation of safety devices excluding stand-alone bursting disc safety devices

EN 50402: 2017 Electrical apparatus for the detection and measurement of combustible or toxic gases or vapours or of oxygen. Requirements on the functional safety of gas detection systems

EN 50676: 2019 Electrical equipment used for detection and concentration measurement of refrigerant gases. Performance requirements and test methods

ISO 5149-1: 2014 Refrigerating systems and heat pumps - Safety and environmental requirements - Part 1: Definitions, classification and selection criteria

ISO 5149-2: 2014 Refrigerating systems and heat pumps - Safety and environmental requirements - Part 2: Design, construction, testing, marking and documentation

ISO 5149-3: 2014 Refrigerating systems and heat pumps - Safety and environmental requirements - Part 3: Installation site

ISO 5149-4: 2014 Refrigerating systems and heat pumps - Safety and environmental requirements - Part 4: Operation, maintenance, repair and recovery

IEC 60079-0: 2011, Explosive atmospheres - Part 0: Equipment - General requirements

IEC 60079-1: 2014, Explosive atmospheres - Part 1: Equipment protection by flameproof enclosures "d"

EN 60079-10-1: 2022 Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres

IEC 60079-11: 2011, Explosive atmospheres - Part 11: Equipment protection by intrinsic safety "i"

IEC 60079-13: 2010, Explosive atmospheres - Part 13: Equipment protection by pressurized room "p"

IEC 60079-14: 2013 Explosive atmospheres - Part 14: Electrical installations design, selection and erection

IEC 60079-15: 2010, Explosive atmospheres - Part 15: Equipment protection by type of protection "n"

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IEC 60079-18: 2014, Explosive atmospheres - Part 18: Equipment protection by encapsulation "m"

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IEC 60079-26: 2014 Explosive atmospheres - Part 26: Equipment with Equipment Protection Level (EPL) Ga

IEC 60079-29-1: 2016 Explosive atmospheres - Part 29-1: Gas detectors - Performance requirements of detectors for flammable gases

IEC 60079-29-2: 2015 Explosive atmospheres - Part 29-2: Gas detectors - Selection, installation, use and maintenance of detectors for flammable gases and oxygen

IEC 60079-29-3: 2014 Explosive atmospheres - Part 29-3: Gas detectors - Guidance on functional safety of fixed gas detection systems

IEC 60079-29-4: 2009 Explosive atmospheres - Part 29-4: Gas detectors - Performance requirements of open path detectors for flammable gases

IEC 60079-32: 2015 Explosive atmospheres - Part 32: Electrostatics hazards

IEC 60079-33: 2012 Explosive atmospheres - Part 33: Equipment protection by special protection 's'

IEC TS 60079-39: 2015 Explosive atmospheres - Part 39: Intrinsically safe systems with electronically controlled spark duration limitation

IEC 60079-5: 2015 Explosive atmospheres - Part 5: Equipment protection by powder filling "q"

IEC 60079-6: 2015 Explosive atmospheres - Part 6: Equipment protection by liquid immersion "o"

IEC 60079-7: 2015 Explosive atmospheres - Part 7: Equipment protection by increased safety "e"

IEC 60204-series Safety of machinery - Electrical equipment of machines

IEC 60335-1: 2020 Household and similar electrical appliances - Safety Part 1: General requirements

IEC 60335-2-104: 2021 Household and similar electrical appliances - Safety - Particular requirements for appliances to recover and/or recycle refrigerant from air conditioning and refrigeration equipment

IEC 60335-2-11: 2022 Household and similar electrical appliances. Safety - Particular requirements for tumble dryers

IEC 60335-2-118: 2019 Household and similar electrical appliances. Safety. Particular requirements for professional ice-cream makers

IEC 60335-2-24: 2020 Household and similar electrical appliances - Safety - Particular requirements for refrigerating appliances, ice-cream appliances and ice makers

IEC 60335-2-34: 2021 Household and similar electrical appliances - Safety - Particular requirements for motor-compressors

IEC 60335-2-40: 2022 Household and similar electrical appliances - Safety - Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers

EN 60335-2-75: 2004+A2:2008 Household and similar electrical appliances. Safety - Particular requirements for commercial dispensing appliances and vending machines

IEC 60335-2-89: 2019 Household and similar electrical appliances - Safety - Particular requirements for commercial refrigerating appliances and ice-makers with an incorporated or remote refrigerant unit or motor-compressor

IEC 62990-1: 2019 Workplace atmospheres - Part 1 Gas detectors - Performance requirements of detectors for toxic gases

ISO/IEC 80079-20-1: 2017 Explosive atmospheres - Part 20-1: Material characteristics for gas and vapour classification - Test methods and data

ISO 80079-36: 2016 Explosive atmospheres - Part 36: Non-electrical equipment for explosive atmospheres - Basic method and requirements

EN 809: 1998 Pumps and pump units for liquids. Common safety requirements

ISO 817: 2014 Refrigerants - Designation and safety classification

Full details of all the standards listed can be found at:

European Committee for Electrotechnical Standardization (CENELEC):
https://www.cenelec.eu/dyn/www/f?p=104:103:0::::FSP_LANG_ID:25

European Committee for Standardization (CEN):
https://standards.cen.eu/dyn/www/f?p=CENWEB:105::RESET

International Electrotechnical Commission (IEC):
http://www.iec.ch/dyn/www/f?p=103:105:0::::FSP_LANG_ID:25

International Organization for Standardization (ISO):
https://www.iso.org/search/x/

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