Safety standards relevant to Refrigeration, Air-Conditioning and Heat Pump equipment

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1. Introduction

This briefing note has been prepared by the Ozone Secretariat as background material for the workshop on safety standards relevant to the safe use of low global-warming-potential (GWP) alternatives to be held in Bangkok on 10th July 2017. Briefing note 1 covers the safety standards that are relevant to refrigeration, air-conditioning and heat pump (RACHP) equipment. The briefing note:

- provides general background to the organisations that produce standards;
- describes the different types of standards that are applicable to RACHP;
- highlights the standards of greatest importance to the selection of refrigerants.

The information presented here is intended only as background information for the parties. It is not meant to be exhaustive nor in any way prescriptive.

2. General background to safety standards

There is a complex landscape of different standards that are applicable to RACHP systems. Main points of background information are:

- **Levels at which standards are set:** Important “core” standards are set at international level. The core standards are often used to produce national or regional standards. They are usually consistent with the international standards but they are often adapted to suit national or regional circumstances.

There are many safety standards bodies which operate at international, regional and national levels. There are over one hundred national and regional standards organisations.

The main international bodies are the International Organisation for Standardisation (ISO) and the International Electrotechnical Commission (IEC). ISO and IEC publish RACHP safety standards. Within almost all countries, at the national level, ISO and IEC are represented by national bodies, i.e., administrative organisations in the countries that are a member of ISO or IEC. ISO has a total of 163 members and IEC 83 members and 87 affiliate members.

1 See https://en.wikipedia.org/wiki/List_of_technical_standard_organisations for an extensive list of standardisation organisations.
Other main standard bodies include the European Committee for Standardisation (CEN) and the European Committee for Electrotechnical Standardisation (CENELEC); the American National Standards Institute (ANSI), Underwriters Laboratories (UL) and the American Society for Heating, Refrigeration and Air-conditioning Engineers (ASHRAE). UL and ASHRAE are accredited by ANSI for standards development. ASHRAE also publishes guidelines relating to the designation and classification of refrigerants which are used globally.

There are also many other developed countries that are very active in the development of RACHP standards.

- **Coordination between standards bodies:** ISO and IEC are independent non-governmental standards organisations. They have a formal agreement between them to avoid development of conflicting standards and to collaborate on the development of standards that fall under the remit of both organisations. To avoid duplication of work, CEN and CENELEC have formal agreements with ISO and IEC whereby international standards can be adopted at European level or European standards can be adopted at international level.

There are other regional standards organisations, such as the Pan American Standards Commission (COPANT), Pacific Area Standards Congress (PASC), African Organisation for Standardisation (ARSO) and Euro-Asian Council for Standardisation, Metrology and Certification (EASC) which also have coordination agreements with ISO and IEC.

- **Types of standards:** There are two main types of standards that apply specifically to RACHP systems:
  
  i. **Group standards** (also referred to as generic or horizontal standards): These provide rules that can be applied to most parts of the RACHP market;
  
  ii. **Product standards** (or vertical standards): These only cover specific types of equipment within a sector or sub-sector of the RACHP market, e.g. domestic refrigerators.

In addition to these RACHP standards, there are numerous supplementary standards that may be applicable to the RACHP market or sector, in addition to the group and product standards. For example, standards related to pressurised systems apply to many different types of products including RACHP equipment.

- **Requirements within standards:** The safety requirements specified within standards can be characterised in terms of the way that they ensure a certain criterion is satisfied. They can be:
  
  i. prescriptive; or
  
  ii. performance-based.
Often a given standard may comprise some requirements that are prescriptive and some that are performance-based. An example of a prescriptive requirement is a maximum refrigerant charge limit, which is specified on the assumption that it is sufficiently small to minimise the risk that a flammable concentration will arise on a room floor in the event of a leak. Conversely, a performance-based requirement would be to specify that a flammable concentration on a room floor shall not arise in the event of a refrigerant leak and it is then up to the manufacturer to test and evaluate what quantity of refrigerant or other mitigation strategies can be used without exceeding that criterion.

- **Legal applicability of safety standards**: Standards are usually developed by independent bodies drawing on technical expertise and are not automatically legally binding for companies by themselves. Standards can become mandatory if certain national or subnational government establishes certain laws or regulations that specifically mandate compliance with the RACHP safety standards. In other countries, in the absence of specific laws or regulations, they may be entirely voluntary. In some countries, the standards are not mandatory but are considered as one of the ways by which conformity to national regulations is achieved.

- **Rules of precedence**: As a general rule, if a product standard is available, it should be used in preference to a group standard. This is because the requirements in a product standard are specifically tuned to the characteristics of a sub-sector of the RACHP market. However, unless national law mandates a particular product standard, the choice is still voluntary. In many cases, it may be appropriate to use group standards, for instance, where:

  1. the requirements of the group standard are more mature or developed;
  2. the scope of the product standard excludes particular characteristics that are applicable to the product or equipment under consideration;
  3. the requirements of the group standard are better suited to the specific application of the product or equipment.

It is possible to use one standard and adopt clauses or requirements from another one provided there is no conflict with that standard. Unless required by domestic law or regulation, there is no overarching authority that specifies which standard must be used in a given set of circumstances; the most important aspect is that a robust technical justification is provided.

- **Implementation of safety standards**: International standards are seldom used directly. In the case of national adoption, the name and number of the standard may be retained or changed to match the national numbering system. Significantly, many countries will include national modifications or deviations, for example where requirements of the international standard conflicts with national legislation. On a regional basis – such as within the European Union – the international standard may be modified before it is adopted and then further modified at national level in the case of conflicts with specific national laws.
Some countries have their own nationally-developed RACHP safety standards, which may be similar or substantially different from the international standards in terms of technical requirements and/or structure and approach. Since many enterprises operate internationally, there is a preference amongst various stakeholders to encourage requirements within RACHP safety standards to be as similar and consistent as possible (also called “harmonised”) so that national variations are kept to the minimum.

3. Overview of the main international RACHP safety standards

There are five international RACHP safety standards that are of key importance. Four are product standards and one is a group standard. These standards are widely used as a basis for national or regional standards, often using a similar nomenclature. For example, IEC 60335-2-40 covers the same product grouping as EN 60335-2-40. These two standards are not identical – they are harmonised as much as possible but may include different requirements. The five international standards are listed in table 1.

<table>
<thead>
<tr>
<th>TABLE 1: APPLICABILITY OF KEY INTERNATIONAL RACHP SAFETY STANDARDS</th>
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<tbody>
<tr>
<td><strong>STANDARD TYPE</strong></td>
</tr>
<tr>
<td>Domestic refrigeration</td>
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<tr>
<td>Commercial refrigeration</td>
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<tr>
<td>Industrial systems</td>
</tr>
<tr>
<td>Transport refrigeration</td>
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<tr>
<td>Air-to-air air conditioners and heat pumps</td>
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<tr>
<td>Water heating heat pumps</td>
</tr>
<tr>
<td>Chillers</td>
</tr>
<tr>
<td>Vehicle air conditioning</td>
</tr>
<tr>
<td>Examples of equivalent national or regional standards</td>
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<tr>
<td>ASHRAE 15</td>
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<td>ASHRAE 15</td>
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</tbody>
</table>

3 ISO 5149 series: Standards on refrigerating systems and heat pumps
4 IEC 60335-2 series: Household and similar electric appliances
5 ISO 13043: Refrigerant systems used in mobile air-conditioning
6 EN 378: Refrigerating systems and heat pumps
7 ASHRAE 15: Safety standard for refrigeration systems
8 UL 250: Household refrigerators and freezers
9 UL 484: Room air-conditioners
10 UL 471: Commercial refrigerators and freezers
11 SAE J2773: Refrigerant risk analysis for mobile air-conditioning systems
Annex I provides a list of the safety standards that relate directly to RACHP systems. In addition to the main standards, there are supplementary standards that often apply (see Annex II). These cover specific issues that must be addressed by equipment manufacturers, e.g. the safe operation of pressurised systems. Many supplementary standards are invoked directly by a main standard. Some are mandated under national legislation. A non-exhaustive list is provided in table 2.

### Table 2: Examples of ISO and IEC Supplementary Standards Related to Safe Application of Refrigerants

<table>
<thead>
<tr>
<th>Subject</th>
<th>Examples (Not Comprehensive List)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerant classification and characteristics(^{12})</td>
<td>ISO 817, ISO/IEC 60079-20-1</td>
</tr>
<tr>
<td>Components, tightness of components</td>
<td>ISO 14903</td>
</tr>
<tr>
<td>Flexible piping</td>
<td>ISO 13971</td>
</tr>
<tr>
<td>Pressure safety devices</td>
<td>ISO 4126-1, ISO 4126-2</td>
</tr>
<tr>
<td>Safety of compressors</td>
<td>IEC 60335-2-34</td>
</tr>
<tr>
<td>Gas sensors/detection</td>
<td>IEC 60079-29-1, IEC 60079-29-2, IEC 60079-29-3, IEC 60079-29-4</td>
</tr>
<tr>
<td>Classification of potentially flammable areas</td>
<td>IEC 60079-10-1</td>
</tr>
<tr>
<td>Protection of electrical or other types of equipment within potentially flammable areas(^{13})</td>
<td>IEC 60079-0, IEC 60079-14, IEC 60079-15, IEC 60079-18, IEC 60079-33</td>
</tr>
<tr>
<td>Handling refrigerant</td>
<td>IEC 60335-2-104</td>
</tr>
</tbody>
</table>

Safety is not the only criterion that determines refrigerant selection, but here the impact of safety standard requirements is analysed.

Refrigerants that have additional safety hazards associated with them are required to be applied with the appropriate safety measures. The form of these measures differs, depending upon the hazard of:

- **flammability**: stricter limits on the quantity of refrigerant in occupied spaces; use of gas detection, alarms and emergency ventilation; prohibition of items that could act as sources of ignition; warnings/signage;

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\(^{12}\) ASHRAE 34 also classifies and designates refrigerants.

\(^{13}\) The number of standards applicable here is lengthy so a few examples are provided. The bibliography includes a more exhaustive list.
pressure: thicker materials; higher pressure rating for pipes and components; additional use of pressure relief devices and/or pressure limiting devices; higher competencies for workers involved in construction of components and assemblies;

toxicity: stricter limits on the quantity of refrigerant in occupied spaces; limited use in more densely populated areas; use of gas detection, alarms and emergency ventilation; provision of personal protective equipment.

Safety standards include a number of requirements that are intended to address these hazards. Table 3 provides a non-exhaustive list of requirements in the standards summarised in table 1, with an indication of the potential impact on refrigerant choice. The impact can vary by standard, by refrigerant, and by the size, type and location of the system. The content of table 3 is intended to be indicative and individual standards should be referred to, to understand the implications on a case-by-case basis.

### TABLE 3: MAIN ISSUES WITHIN SAFETY STANDARDS THAT AFFECT REFRIGERANT CHOICE

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>DESCRIPTION</th>
<th>IMPACT ON REFRIGERANT CHOICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limits on refrigerant charge amount*</td>
<td>An absolute value which is a function of the application, refrigerant type, location and/or equipment type. Alternatively, a variable value that also takes into account the size of the room and/or the characteristics of the refrigerant (e.g., the lower flammability limit). Charge limits normally apply per refrigerant circuit, but can apply to an entire appliance. Further limits or additional measures may apply for systems that are located below ground level.</td>
<td>Highly significant – charge limits dictate if and when a particular refrigerant can be used.</td>
</tr>
<tr>
<td>Electrical components and components with hot surfaces*</td>
<td>Equipment, components, housings and/or positioning must be such that there is no risk of igniting a leak of refrigerant. Confirmation is required by leak simulation tests or by the use of components or equipment intentionally designed and certified for use with flammable atmospheres (&quot;ex-type&quot; components(^\text{16})).</td>
<td>Can potentially be prohibitive due to cost implications if &quot;ex-type&quot; components are needed.</td>
</tr>
<tr>
<td>Pressure limiting/relief devices*</td>
<td>The need for additional devices to limit or relieve excess pressure may apply to smaller systems if flammable refrigerants are used.</td>
<td>Slight cost impact for certain systems.</td>
</tr>
<tr>
<td>Gas sensors**</td>
<td>Gas sensors may be required to initiate mitigation measures such as ventilation, alarms, terminating electrical supplies, etc. These may be applicable to systems using flammable refrigerants in machinery rooms or even for systems in occupied spaces;</td>
<td>Potentially some cost impact for certain systems and long-term service obligations.</td>
</tr>
<tr>
<td>Construction of machinery rooms**</td>
<td>Machinery rooms may have certain requirements if flammable refrigerants are used, such as number of doors, fire resistance of walls, ventilation equipment, etc.</td>
<td>Potentially significant cost implications depending upon machinery room arrangement.</td>
</tr>
<tr>
<td>Airflow rate**</td>
<td>Minimum airflow rates specified either as a means of permitting greater refrigerant charge or for emergency ventilation.</td>
<td>Minor capital cost impact; possible operating cost implications.</td>
</tr>
</tbody>
</table>

* Applies to all standards in table 1, ** Applies only to ISO 5149/EN 378 (at present)

14 Most refrigerants operate at "low to moderate" pressure. For example, the peak pressure encountered in most RACHP applications is around 25 bar. R-744 (CO\(_2\)) has a GWP of 1 and is a low GWP refrigerant that is non-flammable. A drawback of R-744 is that it operates at higher pressure which leads to a more complex system architecture than for most other refrigerants.

15 HFCs as well as many low-GWP alternatives have very low toxicity. An exception to this is R-717 (ammonia) which has a GWP of zero but it is toxic.

16 ex- is indicative of devices that are suitable for use in potentially explosive atmospheres.
Stages in product lifecycle

It is important to recognise the range of different circumstances in which safety issues such as flammability need to be considered. These include the following stages in a typical RACHP product lifecycle:

- equipment design;
- equipment manufacture;
- transport of new equipment containing flammable gases;
- installation of new equipment;
- normal operation during equipment life;
- servicing and maintenance;
- decommissioning at end-of-life.

Different safety standards may apply at certain stages of the lifecycle and some of those standards may not necessarily be specific RACHP standards but other group standards aimed at different industries.

Safety problems related to a specific product can vary in severity through the lifecycle. For example, when a flammable refrigerant is used, the risks during normal operation could be very low because it is not likely that there will be a leak in an area with a source of ignition. However, during site installation, maintenance or at end-of-life, a technician might be using tools, which would readily ignite any remaining refrigerant that has leaked out of the equipment. Safety standards working groups take account of the extra risks that could be involved during installation, servicing or decommissioning.

Standards exist for the training of designers, installers and maintenance technicians. For example, European Standard EN 13313 "Refrigerating systems and heat pumps – Competence of personnel" (which is in the process of becoming an ISO EN standard) provides a comprehensive set of guidelines about the training competencies for different personnel working on RACHP systems at different stages of the product lifecycle. This standard applies to all types of refrigerants. Training of personnel on flammability issues is crucial as flammable refrigerants become more widely used. Training standards may need to be reviewed to ensure they comprehensively deal with flammability.

17 Decommissioning includes recycling / recovery and disposal.
18 In many countries, there are other safety related regulations that cover RACHP and may take precedence over safety standards, which is an important consideration if their requirements are more stringent than those in the safety standards. Examples may include regulations which cover flammable gases in manufacturing and process environments, transportation of dangerous goods, workers involved with the handling of flammable substances.
Standards related to retrofit of existing RACHP systems

New equipment can be properly designed to use flammable fluids, taking relevant safety issues and safety standards fully into account. Using a flammable refrigerant to retrofit existing equipment that was designed for a non-flammable fluid can often create significant safety risks and is generally not recommended by RACHP experts. Furthermore, in some countries (e.g. United States), it is also prohibited for certain types of equipment.

Using RACHP standards

RACHP safety standards are normally utilised in various circumstances, including:

- product range concepts and strategies;
- new product design and development;
- modification of existing product design (e.g. to implement alternative refrigerant);
- defining necessary steps within production process;
- format and drafting of marking, instructions and manuals;
- testing of products;
- internal product approvals;
- preparation for and installation of systems;
- check of compliance with safety regulations;
- external / third party approvals and certification of products and installations;
- decommissioning at end-of-life.

19 At a recent meeting of the Multilateral Fund Executive Committee, Decision 72/17 was agreed, which stated: “Anyone engaging in retrofitting HCFC-based refrigeration and air-conditioning equipment to flammable or toxic refrigerants and associated servicing, does so on the understanding that they assume all associated responsibilities and risks.”
Third party testing, inspections, approvals and certification are sometimes necessary or preferred. This depends either upon internal rules of the manufacturer or upon national regulations. In some countries nominated third parties must be used to verify conformity to certain safety standards, whereas in other countries self-declaration of the manufacturer or installer is considered adequate.

It is important to recognise that the actual text of a safety standard does not necessarily represent absolute requirements. In the introduction to the IEC 60335-series product safety standards, the following is stated:

“An appliance that complies with the text of this standard will not necessarily be considered to comply with the safety principles of the standard if, when examined and tested, it is found to have other features that impair the level of safety covered by these requirements.”

This means that one should not rely on the text within the safety standard to provide sufficient criteria to ensure that the equipment is “safe”. It is the responsibility of the manufacturer and installer to ensure that all aspects have been suitably addressed.

The same standards series also state:

“An appliance employing materials or having forms of construction differing from those detailed in the requirements of this standard may be examined and tested according to the intent of the requirements and, if found to be substantially equivalent, may be considered to comply with the standard.”

In other words, if it is preferred to design the product in a manner that does not literally comply with the text of the standard, but the approach taken does not create a greater risk than if the literal interpretation was applied, then that alternative design can nevertheless be deemed to comply with the standard. This statement is recognition that the safety requirements cannot necessarily reflect all possible ways that a certain level of safety can be achieved in a cost-effective and ergonomic manner. Moreover, it recognises that as technologies develop, other means by which an equivalent level of safety can be achieved will evolve and these should not be excluded.
Annex I

List of safety standards that relate directly to RACHP systems


2. IEC 60335-2-40: 2016, Safety of household and similar electrical appliances — Part 2-40: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers

3. IEC 60335-2-89: 2012, Household and similar electrical appliances — Safety — Part 2-89: Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant unit or compressor

4. ISO 13043: 2011, Road vehicles – Refrigerant systems used in mobile air conditioning systems (MAC) – Safety requirements

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


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


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


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


15. EN 60335-2-40: 2016, Safety of household and similar electrical appliances — Part 2-40: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers

16. EN 60335-2-89: 2012, Household and similar electrical appliances — Safety — Part 2-89: Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant unit or compressor

17. SAE J2773 201702, Standard for Refrigerant Risk Analysis for Mobile Air Conditioning Systems

18. UL 250, 1993, Household Refrigerators and Freezers

19. UL 471, 2010, Standard for Commercial Refrigerators and Freezers

20. UL 484, 2014, Standard for Room Air Conditioners

ANNEX II

List of supplementary standards that apply to RACHP systems

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


3. IEC 60079-10-1:2015, Explosive atmospheres — Part 10-1: Classification of areas — Explosive gas atmospheres


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


8. IEC 60079-17:2013, Explosive atmospheres — Part 17: Electrical installations inspection and maintenance


12. IEC 60079-20-1:2010, Explosive atmospheres – Part 20-1: Material characteristics for gas and vapour classification – Test methods and data


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

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

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


22. IEC 60079-5:2015, Explosive atmospheres – Part 5: Equipment protection by powder filling “q”


24. IEC 60079-7:2015, Explosive atmospheres – Part 7: Equipment protection by increased safety “e”

25. IEC 60204-1, Safety of machinery – Electrical equipment of machines – Part 1: General requirements

26. IEC 60335-2-104:2003, Household and similar electrical appliances – Safety – Part 2-104: Particular requirements for appliances to recover and/or recycle refrigerant from air conditioning and refrigeration equipment


30. IEC TS 60079-40:2015, Explosive atmospheres – Part 40: Requirements for process sealing between flammable process fluids and electrical systems

31. IEC/IEEE 60079-30-1:2015, Explosive atmospheres – Part 30-1: Electrical resistance trace heating – General and testing requirements

32. IEC/IEEE 60079-30-2:2015, Explosive atmospheres – Part 30-2: Electrical resistance trace heating – Application guide for design, installation and maintenance

33. ISO 11650: 1999, Performance of refrigerant recovery and/or recycling equipment

34. ISO 13971: 2012, Refrigeration systems and heat pumps – Flexible pipe elements, vibration isolators, expansion joints and non-metallic tubes – Requirements and classification

35. ISO 14903: 2012, Refrigerating systems and heat pumps – Qualification of tightness of components and joints

36. ISO 4126-1, Safety devices for protection against excessive pressure – Part 1: Safety valves

37. ISO 4126-2, Safety devices for protection against excessive pressure – Part 2: Bursting disc safety devices

38. ISO 7010:2011, Graphical symbols – Safety colours and safety signs – Registered safety signs


40. ISO 817: 2014, Refrigerants – Designation system and safety classification