NOTE eNOTE IIR Information

36th Informatory Note on Refrigeration Technologies / December 2017

Flammable refrigerants

The IIR publishes Informatory Notes designed to meet the needs of decision-makers worldwide, on a regular basis. These notes summarize knowledge in key refrigeration-technology and refrigeration-application domains. Each note puts forward future priority developmental axes and provides IIR recommendations in this context.

With the phase-out of ozone depleting substances there has been growing interest in the application of flammable refrigerants. Following the Kigali Amendment under the Montreal Protocol concerning the phase-down of hydrofluorocarbons, it is highly likely that flammable refrigerants will comprise the majority of refrigerants in the medium to long term. Flammability hazards arising from the use and application of these refrigerants have hitherto been of limited concern to domestic and commercial sectors. Thus, it is essential that stakeholders understand and become familiar with the relevant considerations for handling the flammability hazards that affect their application. These include flammability characteristics, classifications, governing rules such as safety standards and regulations covering the entire lifetime of systems and equipment including transportation, system design and construction and service, maintenance and other refrigerant handling activities. This Informatory Note aims to provide an introduction to these matters.

This Informatory Note was prepared by Daniel Colbourne, and was reviewed by several experts from the IIR network.

International Institute of Refrigeration
Institut International du Froid

www.iifiir.org | iif-iir@iifiir.org | in | #refrigeration

177, boulevard Malesherbes, 75017 PARIS – France
T: 33 (0) 1 42 27 32 35 – F: 33 (0) 1 47 63 17 98

Introduction

Critical to the general selection of refrigerants is the issue of their environmental impact. Since the beginning of the phase-out of ozone depleting substances (ODS), certain flammable refrigerants – primarily ammonia (R717) and hydrocarbons (e.g., R290, R600a, R1270) – have been of interest as alternative refrigerants. This is because of their zero ozone depletion potential (ODP), negligible global warming potential (GWP), potentially good efficiency and low refrigerant cost.

In parallel with the development and introduction of the first European Regulation on certain fluorinated greenhouse gases (EU F-gas regulation, 2006), the European Directive on emissions from air conditioning systems in motor vehicles (EU MAC directive), more recently the second European Regulation on fluorinated greenhouse gases (EU F-gas regulation, 2014) and eventually the Kigali Amendment to the Montreal Protocol [1], interest in the adoption of low GWP refrigerants has become increasingly significant. A deeper treatment of the topic is provided in other IIR Informatory Notes, such as "Overview of Regulations Restricting HFC Use - Focus on the EU F-Gas Regulation" and "Current long-term alternative refrigerants and their possible applications".

Considering all of the zero ODP refrigerants currently with R-number designation in the 2014 edition of the international standard on refrigerant numbering and safety classification, ISO 817, there are almost 60 with a GWP < 1000. Of these, 47 are flammable. Of the 46 with a GWP < 500, only five are non-flammable (R744, R1233zd(E), R1336mzz(Z), R514A and R515A). Furthermore, a recent screening study on potential new refrigerants indicated that any further additional low GWP refrigerants likely to be adopted for common use are also flammable [2]. The implication is that the majority of refrigerants that will be necessary for countries to comply with their obligations under the 2nd EU F-gas regulation or Kigali Amendment will be flammable.

The purpose of this Informatory Note is to provide an insight into the important implications for industry stakeholders.

Current and historical use of flammable refrigerants

Prior to the implementation of the Montreal Protocol, the most widely used flammable refrigerant was R717, mainly in industrial, cold storage and process applications. Since the implementation of the Montreal Protocol it has become more widely used. Additionally, isobutane (R600a) was introduced for use in domestic refrigerators, primarily in Europe. Today, flammable refrigerants are being used to some extent in almost all refrigeration, air conditioning and heat pump (RACHP) sectors [3]:

- domestic refrigeration (R600a);
- small commercial refrigeration (R600a, R290, R1234yf);
- indirect/secondary retail refrigeration (R290, R1270, R717);
- small air conditioning (R32, R290);
- chillers (R1234yf, R1234ze(E), R290, R1270, R717, R32).

However, the amount of flammable refrigerants currently used still represents a fraction of total refrigerant consumption.

As indicated previously, there are another 30 – 40 flammable refrigerants that are under consideration for use in a variety of different RACHP systems. It is likely that a substantial number of these will begin to be implemented, especially within those regions where there are impending HFC phase-down schedules.

With the introduction of flammable refrigerants, a host of new considerations related to fire and explosion safety are necessary for all stakeholders in the industry. Such considerations were never previously applicable to the design, construction, installation, testing, servicing and decommissioning of most RACHP systems. Due to these implications, use of flammable refrigerants is a contentious topic amongst some stakeholders. Nevertheless, all stakeholders need to be aware of and understand refrigerant flammability and identify where and how designs, procedures, practices and information need to be modified in order to account for it.

Flammability characteristics and their implications

The significant characteristic of flammable refrigerants is that with ignition they can sustain a flame, which is effectively a propagating chemical reaction that consumes the unburned reactants (refrigerant and air) whilst giving off heat at a very high temperature. The likelihood, duration and intensity of this process depend upon a number of flammability characteristics:

- lower flammability limit (LFL) and upper flammability limit (UFL);
- stoichiometric concentration (SC);
- auto-ignition temperature (AIT);
- minimum ignition energy (MIE);
- minimum ignition current (MIC);
- adiabatic flame temperature (AFT);
- laminar burning velocity (LBV);
- heat of combustion (HoC);
- maximum explosion pressure and rate of pressure rise;
- maximum experimental safe gap (MESG).

Data for these characteristics for many of the flammable refrigerants can be found in textbooks and safety standards. However most sources only report some of these parameters so compiling a comprehensive summary for all refrigerants is difficult. These characteristics are determined according to defined test methods and these test methods differ amongst standards and other publications; published values vary sometimes quite widely throughout the literature.

The combustion of halogenated flammable (and non-flammable) refrigerants creates hazardous decomposition products, which must also be considered in the assessment of risk.

There are three main areas where flammability influences the use of refrigerants and associated equipment: determination of the “safe” quantity of refrigerant, avoidance of potential sources of ignition and limiting the consequences of ignition.

In the event of a release of flammable refrigerant, a concentration gradient establishes itself between pure refrigerant and the air. Somewhere between these two boundaries the mixture exists between the LFL and the UFL. Although sensitive to host of different conditions, a refrigerant possessing a lower LFL and higher UFL therefore potentially may yield a greater volume of material that is flammable. A larger flammable volume produces a greater likelihood that the mixture may encounter ignition sources, as well as a greater volume of gas susceptible to burning. One means of limiting the size and extent of a flammable volume is to minimise the stored quantities of the substance.

Potential sources of ignition (SOI) may include flames, hot surfaces, electrical arcs and electrostatic discharges. Lower AIT and MIE/MIC mean that a flammable mixture is more vulnerable to being ignited by such SOIs and therefore greater attention is required for avoiding items that could potentially ignite a release. Substances with a smaller MESG require electrical equipment to have less porous enclosures to ensure against outwards flame propagation (although this cannot be taken in isolation as a safety measure).

If a flammable mixture is ignited then the severity by which it burns is influenced by the amount of stored energy and the rate at which the flame front moves. Thus a higher AFT, LBV and HoC generally imply more severe deflagrations leading to higher overpressures or greater thermal radiation. Accordingly, such refrigerants ordinarily demand more attention to minimisation of these primary consequences, although a lower LBV also results in a longer burning duration which potentially increases the likelihood of a secondary fire. Secondary consequences are strongly influenced by the surrounding conditions (such as degree of confinement of the space, construction materials, proximity of persons and combustible matter). In addition, refrigerants that contain fluorine tend to produce highly toxic compounds such as hydrogen fluoride and carbonyl fluoride from the combustion process that introduces a further primary consequence.

Appropriate warnings, signage and instructions are essential to provide information concerning these characteristics.

Flammability classifications

Arising from the different fields that handle flammable substances, different classification schemes exist.

There are three classification systems mentioned here. Each system has significance in different contexts.

ISO 817 and ANSI/ASHRAE 34

Within the RACHP industry, the refrigerant safety classification system detailed in ISO 817 and ANSI/ASHRAE 34 are perhaps most widely recognised for refrigerants. In terms of flammability, four ISO 817 classes apply:

- class 1 (no flame propagation): refrigerants that do not exhibit flame propagation in air at 60 °C and 101,3 kPa;
- class 2L (lower flammability): refrigerants that exhibit flame propagation at 60 °C and 101,3 kPa, have a LFL > 3.5% by volume, a heat of combustion < 19,000 kJ/kg and a maximum burning velocity of ≤ 0.10 m/s;
- class 2 (flammable): refrigerants that exhibit flame propagation at 60 °C and 101,3 kPa, have a LFL > 3.5% by volume and a heat of combustion < 19,000 kJ/kg;
- class 3 (higher flammability): refrigerants that exhibit flame propagation at 60 °C and 101,3 kPa and have a LFL ≤ 3.5% by volume or have a heat of combustion that is ≥ 19,000 J/kg.

These classifications mainly have an impact on the determination of refrigerant charge sizes and other design characteristics for RACHP systems and equipment.

IEC 60079-20-1

The international framework standards for prevention of ignition of flammable gases and vapours rely on a classification system according to that detailed within IEC 60079-20-1.[1]

For gases and vapours, different classes are differentiated according to the MESG and/or MIC ratio (relative to methane)[2]:

- group IIA: MESG ≥ 0.9 mm or MIC ratio > 0.9;
- group IIB: 0.55 mm ≤ MESG < 0.9 mm or 0.45 ≤ MIC ratio < 0.8;
- group IIC: MESG < 0.5 mm or MIC ratio < 0.45.

Most flammable refrigerants would be classed as Group IIA. The impact of the different classes is largely related to specific requirements for the various types of protection applied to potential sources of ignition under the IEC 60079 and the ISO/IEC 80079 series of standards, i.e., Ex-type protection.

UN GHS

Under the UN Global Harmonised System (GHS), as well as that for the UN model regulations for the transportation of dangerous goods, there is a relatively simple flammability classification system. This is based on two basic categories (in addition to non-flammable):

- Gases, which at 20 °C and a standard pressure of 101.3 Pa:
  - are ignitable when in a mixture of 13% or less by volume in air;
  - or have a flammable range with air of at least 12 percentage points regardless of the lower flammable limit.
- Gases, other than those of Category 1, which, at 20 °C and a standard pressure of 101.3 kPa, have a flammable range while mixed in air.

The flammability is determined according to the standard ISO 10156: 2010. Under this scheme, almost all flammable refrigerants are class 1. Regarding terminology and warning labels, all vessels and systems containing flammable refrigerants require a “flame” symbol, a signal word “danger” and a hazard statement “extremely flammable gas”. Critically, this classification scheme is the one mandated for use in safety data sheets (SDS) in most countries.

Governing rules

The field of rules and regulations concerning the use and application of flammable of substances, whether or not within RACHP systems and equipment, is complex and inconsistent amongst most countries.

In general, the following different categories apply:

- general regulations that govern the application and handling of flammable substances, broadly irrespective of the end use or industry sector;
- gegulations that address the transportation (and sometimes the storage) of any flammable substance;
- guilding regulations and codes that specifically apply to various situations where flammable substances may be considered for use within buildings, including for RACHP;

---

1 *Currently being revised as ISO/IEC 80079-20-1*

2 *There is a very close correlation between MESG, quenching distance and MIC* [4]

- gafety standards applicable to use of flammable substances in general circumstances;
- gafety standards for general applications (such as any RACHP equipment or installations) or specific products (such as refrigerators or heat pumps);
- industry codes of practice, such as those that apply generally to RACHP equipment or installation or to specific products.

The situation varies widely amongst different countries. Some countries are bereft of any governing rules, except for perhaps brief indicative guidelines from a particular governmental entity or an industry association. Conversely, in some countries all of the above categories of governing rules are present.

Within the context of the different categories of governing rules identified above, due to the variations in countries legal systems, some categories take precedence over others.

Regulations concerning flammable substances

There is a broad range of means by which countries legislate (or not) the handling flammable substances and associated equipment. Several countries and regions have adopted framework legislation that governs situations that involve the potential release of flammable gases (and dusts).

In Europe there are two sets of legislation: the European directive on equipment and protective systems intended for use in potentially Explosive Atmospheres ("ATEX equipment") and the European directive on the safety and health protection of workers potentially at risk from explosive atmospheres ("ATEX workplace"). The ATEX equipment directive applies to equipment that is to be used in potentially flammable atmospheres and installations that may come into contact with flammable atmospheres. It requires that a flammability risk assessment is carried out and necessitates reduction of the amount of flammable materials, minimisation of likelihood of releases, application of measures (such as ventilation) to eliminate potentially flammable atmospheres, avoidance of potential sources of ignition and, where necessary, features to lessen the severity of consequences in the event of ignition. It does not impose any practical constraints such as limits on the quantity of flammable substance or situations where it can be used. The ATEX workplace directive follows a similar risk-based approach, but in addition requires that personnel handling flammable substances have been provided with the requisite training and suitable equipment.

Other countries' regulations, such as those of Australia and New Zealand (Health and Safety at Work (Hazardous Substances or dangerous goods) Regulations), the Russian Federation (law On Industrial Safety of Hazardous Industrial Facilities), China (Product Quality Law and the Production Safety Law), Brazil (Portaria 83:2006) and India are comparable to ATEX. In Japan, the situation is covered by the High Pressure Gas Safety Act and supplemented by others (Industrial Safety and Health Act and Constructional Requirements for Electrical Equipment for Explosive Atmospheres).

In USA and Canada there is no national legislation that is comparable to ATEX; instead province, state, county and/or local building codes mandate the use of specific safety standards (see below). Notwithstanding this the regulatory framework and reliance on established codes such as NFPA and UL codes provide a similar safety objective to other Western countries.

Regulations concerning transportation of flammable substances

Almost all countries adhere to the various UN regulations for transportation of dangerous substances.

The primary source is the United Nations Model Regulations for Transport of Dangerous Goods, which generally applies to transport by road and rail. It includes provisions specifically for refrigeration systems with flammable refrigerants (UN3358), whereby refrigeration equipment containing less than 12 kg of flammable refrigerant is exempt from the regulations provided it is protected by design (i.e., complies with applicable safety standards) and for equipment containing over 12 kg, it must be subject to a pressure type-test of at least three times the maximum working pressure and comply with the packaging requirements detailed in these regulations.

For transport of systems by sea, the applicable rules are the International Maritime Dangerous Goods Code, whose requirements follow those of the model regulations.

Differences exist in the rules for transport by air, according to the International Civil Aviation Organisation/ International Air Transport Association, which forbids transport of equipment containing more than 0.1 kg in either passenger or cargo planes (however, if the flammable refrigerant is in cylinders, up to 150 kg is permitted).

Building regulations and codes applicable to flammable substances

Many countries have building regulations (or codes) that impact on the potential use of flammable refrigerants. There are two situations. One is where regulations explicitly prohibit or limit the use of some quantity of flammable refrigerants in certain types of buildings; examples of countries where this is currently the case include France, Italy, Singapore, Spain and Thailand. The second situation is where regulations mandate that any systems or equipment associated with the building must comply with product and/ or installation standards; examples of this include USA and Canada. A large number of countries do not have building regulations that impact on the application of flammable refrigerants.

Safety standards for flammable substances in general circumstances

Closely linked to the framework regulations concerning the safe application of flammable substances, are a series of international standards, which have been adopted nationally by most countries and invoked by those national regulations. These standards are primarily those within the IEC 60079 and ISO/IEC 80079 series. Among these standards are the following:

- IEC 60079-20-1 on classification and properties of flammable substances;
- IEC 60079-10-1 on area classification (zoning) of potentially flammable atmospheres;
- IEC 60079-29 series on gas sensors and detection systems for flammable gases;
- IEC 60079-0, -1, -2, -5, -6, -7, -15, -18, -26, -32, -33, -39 (etc.) on protection of electrical or other types of equipment for use within potentially flammable areas;
- IEC 60079-14 on design, selection and erection of electrical installations for use in potentially flammable atmospheres;
- ISO/IEC 80079-36, -37 and -38 on non-electrical equipment for use within potentially flammable atmospheres;
- IEC 60079-19 on repair, overhaul and reclamation of equipment used in potentially flammable atmospheres.

Although these are often overlooked when applying flammable refrigerants, since they are closely linked to many countries' safety regulations it is critical that they be considered. As a result of the general application requirements these standards are also applicable to buildings in many countries.

Safety standards for RACHP equipment, installations or products

Most familiar to those within the RACHP industry are the sector-specific safety standards. The most prominent international standards and equivalent European regional standards and national USA standards are listed in Table 1, indicating which sectors they apply to. "Vertical" standards, also known as product standards, tend to apply to specific types of equipment, whereas horizontal standards cover all equipment within a given sector. It is noted that equivalent standards are also published in numerous other countries.

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

Sector		Vertical				Horizontal
	International	IEC 60335-2-24	IEC 60335-2-40	IEC 60335-2-89	ISO 13043	ISO 5149-1, -2, -3, -4
	Regional and industry (exemples)	EN 60335-2-24; UL 250	EN 60335-2-40; UL484	EN 60335-2-89; UL 471	SAE J2773	EN 378-1, -2, -3, -4; ASHRAE-15
Domestic refrigeration	X					
Commercial refrigeration			X			X
Industrial systems						X
Transport refrigeration						X[3]
Air-to-air air conditioners heat pumps		X				X
Water heating heat pumps		X				X
Chillers		X				X
Vehicle air conditioning					X	

These standards address the following topics, which are pivotal to the cost-effective application of flammable refrigerants:

- limits on refrigerant charge amount,
- control of electrical components and components with hot surfaces,
- use of pressure limiting and relief devices,
- use of gas sensors,
- construction of machinery rooms,
- extract ventilation and/or circulation airflow rates.

3 *Not applicable for ASHRAE 15*

Whilst these safety standards are most familiar to practitioners within the RACHP industry, they often have voluntary status (as far as addressing flammability matters) and those related specifically to potentially explosive atmospheres usually take precedence. Whilst some requirements within standards for RACHP systems may enable application-specific interpretation of the IEC 60079-series of standards, critically, there also are numerous inconsistencies both in terms of philosophy and practical measures. It is essential that practitioners do not apply one set of rules in a manner which conflicts with the other.

There is recognition that current safety standards do pose significant barriers to the uptake of flammable refrigerants and that actions should be taken to remedy the situation [5, 6, 7]. Due to the attention on wider use of flammable refrigerants, there are activities underway at regional, national and international level to revise and/or amend these standards to address their wider application and also to better attain consistency with the IEC 60079-series.

RACHP industry codes of practice

Several industry organisations have developed safety codes to help guide practitioners through the myriad rules and regulations associated with the use of flammable refrigerants to help provide a more practical interpretation of what the obligations are. Examples of this include the British Institute of Refrigeration "Safety Code of Practice for Refrigerating Systems utilising A2 & A3 refrigerants" and the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH) "Flammable Refrigerant Safety Guide". In addition to these, many refrigeration system and component manufacturers offer guidelines on the subject.

Considerations for RACHP equipment during its lifetime

Whenever RACHP equipment is developed, worked upon or operated, the use of a flammable refrigerant introduces new considerations throughout the equipment lifetime i.e. from conception to disposal. An overview of the important stages is identified in Figure 1, along with examples of relevant personnel and typical activities. Just as with other issues such as pressure safety and electrical safety, stakeholders need to be aware of the potential hazards and ways of means of mitigating them and retaining integrity. Amongst these various steps where a flammable refrigerant is used, some pose greater flammability risk than others.

For instance, production, storage and transportation tend to create the least flammability risk, partly due to them representing a very short period of time within the equipment's lifetime, but also because they are typically managed by the manufacturer, who can control the situation more easily.

Where it concerns the "in-use" stage, where the equipment is operating without interference the level of risk is largely dependent upon specific design and construction features, which are typically handled appropriately if the applicable regulations and standards are suitably adhered to.

The basic principles are:

- minimise refrigerant charge;
- Construct refrigerant circuit to minimise leakage;
- Eliminate all potential sources of ignition from equipment;
- Ensure construction cannot result in persistent flammable mixtures;
- Design must minimise the severity of consequences in the event of ignition;

- Integrate mitigation measures where appropriate, such as gas detection, airflow and means to limit amount of refrigerant released;
- Apply markings to warn of flammability hazards;
- Provide instructions related to correct installation, servicing and maintenance.

Nevertheless, despite being deemed to meet the necessary design requirements, the extent to which it has been installed correctly and the integrity of its intended risk reducing features that have been retained are critical to the level of risk during in-use. Disregarding critical installation instructions could render the equipment unsafe (such as installing a large charge system in a very small room, or passing pipework through vulnerable spaces). Further circumstances that can render "safe" equipment "unsafe" can arise from inappropriate servicing. Examples include replacing faulty Ex-type protected electrical equipment with components with the same function but without the requisite ignition protection, over-filling systems beyond the allowable charge, replacing brazed joints with flared ones, failing to maintain gas detection systems or blocking defined ventilation provisions.

However, it is the activities involving refrigerant handling, such as installation, servicing and decommissioning, where the risk is substantially higher. These activities often involve the transfer of quantities of flammable refrigerant and intentional releases (purging lines or venting). The probability of occurrence of flammable atmospheres is high. Similarly, the likelihood of presence of SOIs is also high, whether it is from working on system electrical equipment, use of certain service equipment such as incorrect recovery machines or brazing torches, or simply cigarette lighting. In addition to a high ignition frequency that the technician is usually close to these situations potentially heightens the severity of the consequence (for instance, in terms of thermal dose and contact with decomposition products). Appropriate training, technician competence and possession of the appropriate tools and equipment can lead to substantial reduction in flammability risk during refrigerant handling activities [8].

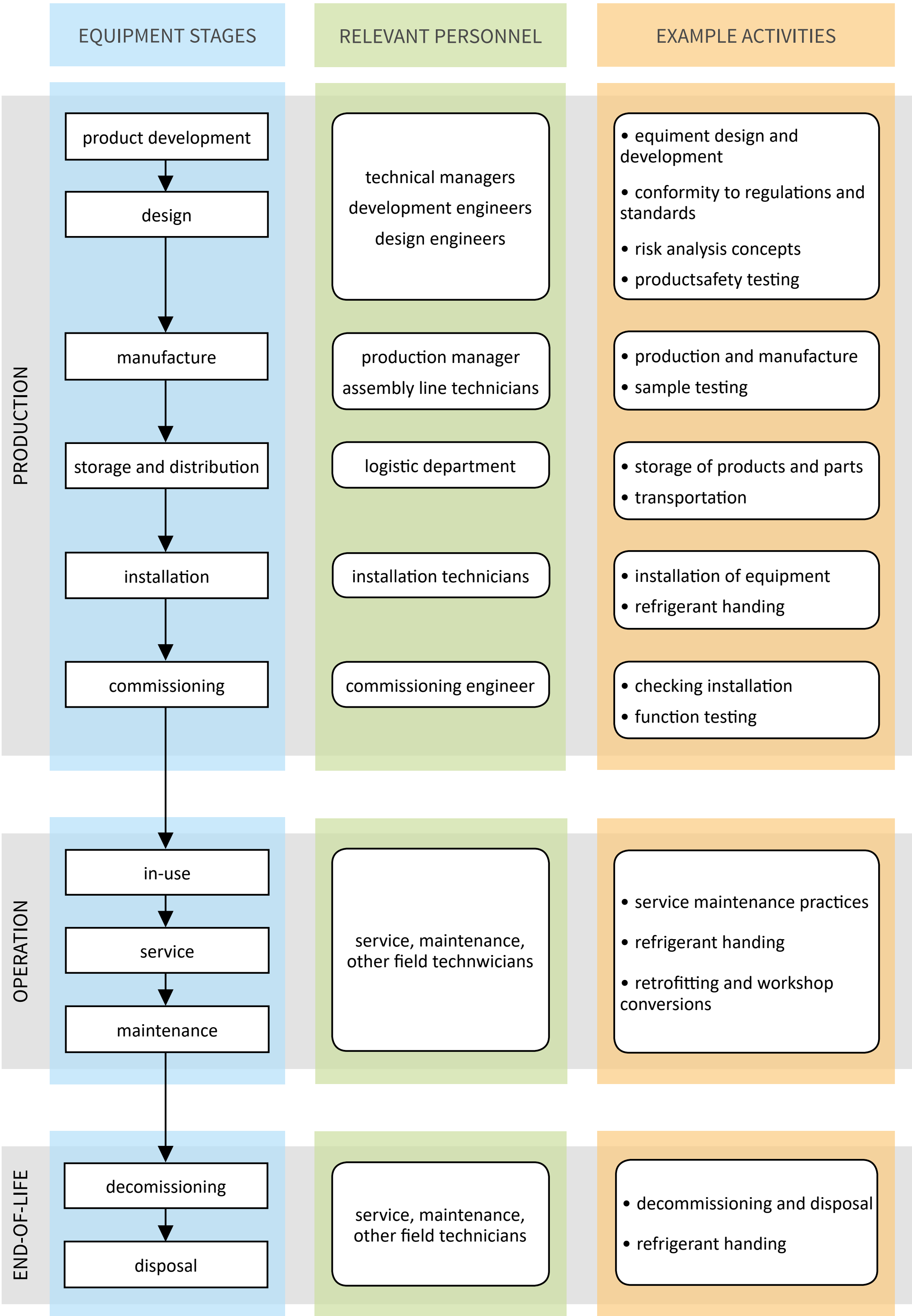

Figure 1: Overview of the stages within the equipment lifetime, the key personnel and the subject groups that may be needed to execute the work [9]

Concluding remarks

The main issues identified throughout this Informatory Note are as follows:

- The RACHP industry, especially within non-Article 5 countries (which are subject to more rapid HFC phase-down schedules), must prepare to handle flammable refrigerants to a greater extent than they have done until now. It is likely that flammable refrigerants will penetrate almost all sub-sectors.
- With the application of flammable refrigerants, there are a variety of technical, regulatory and infrastructural considerations that have to be addressed by a variety of stakeholders. It requires forethought regarding the entire lifetime of RACHP equipment and the obligations of the personnel involved.
- Flammable refrigerants possess a variety of characteristics that affect the likelihood that they are ignited and the type and severity of consequences in the event of ignition. It is appropriate to take these into consideration when designing RACHP equipment and also when carrying out risk assessments.
- According to their flammability characteristics, flammable refrigerants are subject to certain classifications. However, different classification schemes are applied in different technical and legal contexts.
- The number and types of rules and regulations applicable to flammable substances in general and flammable refrigerants in particular is diverse, both within countries and internationally. It is a complex situation that necessitates a broad understanding of the topic. Appreciation of this information is required across many stakeholders, including design engineers, production staff, installation engineers, service and maintenance technicians and those involved with the decommissioning and dismantling of RACHP equipment.
- In many countries, rules and regulations may intentionally or inadvertently pose substantial barriers to the application of flammable refrigerants. Governmental bodies associated with the Montreal Protocol should determine whether such rules – particularly building regulations and safety standards – prohibit or limit the use of flammable refrigerants and attempt to remedy the situation so that such refrigerant options are not prevented from use.
- Experience and also research on the safe application of flammable refrigerants remains relatively limited. There is a significant need for further research activities investigating the numerous aspects associated with flammability risk. All interested stakeholders are encouraged to consider contributing to this objective.
- The issue of flammable refrigerants remains sensitive and discussions are often polarised, particularly regarding “acceptable” types of flammable refrigerants. It is important to be aware of the numerous interests working towards one direction or another.

Recommendations

The IIR advises stakeholders to take account of the issues raised within this Informatory Note, and in particular:

- In order to comply with regulations controlling the use of HFC refrigerants, those with low GWP will have to be broadly applied, and a greater proportion will be flammable.
- Due to the potential deleterious consequences of igniting flammable refrigerants, their application demands appropriate design and construction measures to ensure requisite levels of safety.
- Countries tend to have generic flammable gas regulations that govern the use and application of any flammable substance. Many adopt safety standards that prescribe how flammable refrigerant may (or may not) be applied. A number of countries have national building regulations, which limit the use of flammable refrigerants. It is critical for countries to assess their national rules and regulations and ensure they do not unnecessarily inhibit the application of suitable refrigerants.
- Ongoing research and development related to the safe application of flammable refrigerants will likely generate more robust and broadly applicable rules for the application of flammable refrigerants. Stakeholders, including those from industry, governmwent and academia should involve themselves in the process to help minimise potentially undesirable outcomes.
- Some RACHP sector safety standards currently pose restrictions to some flammable refrigerants for some applications and these barriers need to be addressed to enable a wider and potentially more cost-effective choice of technical options. Since these RACHP sector safety standards often comprise requirements for flammable refrigerants that are inconsistent with the historical requirements within the generic safety standards flammable substances, it is recommended that closer working relationships are needed between standards groups to help resolve aspects on all sides, including consistency between the IEC 60079-series and the RACHP safety standards.

International Institute of Refrigeration
Institut International du Froid

References

[1] UNEP. The Kigali Amendment (2016): The amendment to the Montreal Protocol agreed by the Twenty-Eighth Meeting of the Parties (Kigali, 10-15 October 2016). In UNEP website [online]. 2017. Available on : <http://ozone.unep.org/en/handbook-montreal-protocol-substances-deplete-ozone-layer/41453> (Accessed 11/20/2017)

[2] MCLINDEN M. O., BROWN J. S., BRIGNOLI, R., et al. Limited options for low-global-warming-potential refrigerants. Nature Communications [online]. 2017, vol.8, 9 p.
Available on: <https://www.nature.com/articles/ncomms14476> (Accessed 11/20/2017)

[3] UNEP. Report of the Technology and Economic Assessment Panel [en ligne]. Decision XXVII/4 task force update report on further information on alternatives to ozone-depleting substances. Nairobi, Kenya: UNEP, 2016, 179 p.
Available on <http://bit.ly/UNEP_TEAP_XXVII_4> (Accessed 11/20/2017)

[4] GROVE J. R. Measurement of quenching diameters and their relation to the flameproof grouping of gases and vapours. I.Chem.E [online] Symposium series n°25, p.51-54.
Available on: <http://bit.ly/Grove1968> (Accessed 11/20/2017)

[5] UNEP. Barriers to the use of low-GWP refrigerants in developing countries and opportunities to overcome these. In UNEP website [online]. 2010.
Available on: <http://bit.ly/UNEPLemmet> (Accessed 11/20/2017)

[6] UNEP. Report of the Technology and Economic Assessment Panel [online] Decision XXVIII/4: Establishment of regular consultations on safety standards. Nairobi, Kenya: UNEP, 2016, 2p.
Available on <http://bit.ly/UNEP_TEAP_XXVIII_4> (Accessed 11/20/2017)

[7] EUROPEAN COMMISSION. Report from the Commission [online]. Barriers posed by codes, standards and legislation to using climate-friendly technologies in the refrigeration, air conditioning, heat pumps and foam sectors. Brussels, Belgium: European Commisison, 2016, 8p.
Available on <http://bit.ly/UECom2016> (Accessed 11/20/2017)

[8] COLBOURNE D. 2011. Risk analysis of flammable refrigerant handling during service and maintenance activities. In : Proceedings of the 23rd IIR International Congress of Refrigeration, August 21-26, 2011, Praha [online]. Paris : IIR, 2011, 9p.
Available on <http://bit.ly/Fridoc-Colbourne-2011> (Accessed 11/20/2017)

[9] COLBOURNE D., HUEHREN R., EDERBERG L. 2010. Guidelines for the safe use of hydrocarbon refrigerants [online] Eschborn, Germany: GIZ Proklima, 2012, 320 p.
Available on <http://bit.ly/ColbourneGIZ> (Accessed 11/20/2017)