EU F-Gas Regulation Guidance

Target audience for this Information Sheet

This information sheet is aimed at all organisations that need to consider using flammable or mildly flammable fluids in place of non-flammable HFCs.

Information Sheet 27: Flammability Issues

1. Background

This guidance is for organisations affected by the 2014 EU F-Gas Regulation (517/2014). The F-Gas Regulation creates controls on the use and emissions of fluorinated greenhouse gases (F-Gases) including HFCs, PFCs and SF_6. The 2014 EU F-Gas Regulation replaces the 2006 Regulation, strengthening all of the 2006 requirements and introducing a number of important new measures.

A key feature of the 2014 F-Gas Regulation is the introduction of the phase down in the supply of HFCs within the EU market. This will lead to an 80% cut in the amount of HFCs that can be sold in the EU by 2030[1]. To achieve such significant cuts, the users of HFCs will need to start using alternative fluids with much lower global warming potentials (GWPs) than the current HFCs[2]. Many of the low GWP alternatives to HFCs are flammable – this creates potential safety issues and may restrict their usage. This Information Sheet provides guidance on the impact of using flammable HFC alternatives.

A wide range of further guidance is available for other aspects of the EU F-Gas Regulation – see Information Sheet 30 for a full list and a glossary of terms.

2. Non-flammable HFCs

Most HFCs are non-flammable and this is a characteristic that made HFCs a popular choice for many end user applications. Key uses of non-flammable HFCs include:

- Refrigeration, air-conditioning and heat pumps (RACHP)
- Technical and medical aerosols
- Insulation foam
- Fire extinguishing fluids

The non-flammable property of most HFCs makes it relatively easy to manufacture, install and maintain equipment such as RACHP systems. If some non-flammable refrigerant leaks there will be no risk of fire. Similarly, an aerosol using a non-flammable HFC propellant may be safer to use in circumstances where there may be a source of ignition.

One of the reasons that most HFCs are non-flammable is that their molecular structure is very stable. Unfortunately, this property also gives HFCs a very long atmospheric life and a high GWP. Low GWP alternatives usually have less stable molecules – this is good from a GWP perspective, but it results in many alternatives being flammable.

---

[1] See Information Sheet 28 for guidance on the HFC phase down process

[2] See Information Sheet 29 for guidance on low GWP alternatives

3. Flammability is not a simple issue

If there are plenty of non-flammable options available it is easy to apply a simplistic approach to flammability: if a flammable fluid is undesirable, safety codes take a conservative view and state that flammable fluids cannot be used.

This simplistic approach is not ideal when there are fewer non-flammable fluids to choose from. To make more widespread use of low GWP alternatives, it is important to recognise that there are widely varying "levels of flammability". There is a continuous spectrum of flammability which includes:

- **Highly flammable** fluids – these are very easy to ignite and can burn with explosive impacts. The most common examples are hydrocarbons (HCs) such as propane and butane. These have very useful properties for use as refrigerants, aerosol propellants and foam blowing agents. However, they are also used as fuels and they can be ignited very easily.
- **Flammable** fluids – they are more difficult to ignite, but once ignited will continue to burn and could create a significant hazard.
- **Mildly flammable** fluids – these are very difficult to ignite, they burn "gently" and might be extinguished when the source of ignition is removed. Mildly flammable fluids create a smaller fire risk than an equivalent amount of a more flammable fluid.
- **Non-flammable** fluids – these cannot be ignited[3].

Existing safety codes do not properly distinguish between different levels of flammability. For example EN 378 2008 ("Refrigerating systems, safety and environmental requirements") only has 3 categories of flammability which are based on a simplified set of flammability parameters. EN 378 is currently being updated to include a 4th flammability category, although that may still prove to be an over-simplification that restricts the use of mildly flammable fluids.

A problem faced by both the authors of safety codes and users of flammable fluids is that flammability is a complex issue and it is not easy to find a simple way of defining a safe operating envelope for each fluid. Flammability can be measured in a number of ways. The most important parameters include:

1) **LFL, lower flammability limit**. LFL is the minimum concentration of a gas or vapour that is capable of propagating a flame within a homogeneous mixture of that gas or vapour and air.
2) **UFL, upper flammability limit**. UFL is the maximum concentration of a gas or vapour that is capable of propagating a flame within a homogeneous mixture of that gas or vapour and air.
3) **HoC, heat of combustion**. HoC is the energy released as heat when a compound undergoes complete combustion with oxygen under standard conditions.
4) **BV, burning velocity**. The BV is the speed at which a flame propagates.
5) **MIE, minimum ignition energy**. The MIE indicates how much energy must be in an ignition source (e.g. a spark or naked flame) to initiate ignition of a gas or vapour.

---

[3] They cannot be ignited under the test conditions specified in a relevant safety code (often atmospheric pressure at 20°C). Some "non-flammable" fluids can be ignited at higher temperature or pressure.

The safety code EN 378 2008 uses LFL and HoC to distinguish between highly flammable, flammable and non-flammable fluids. In the revised code currently being written, it is expected that a new category of “mildly flammable” is to be introduced, based on those fluids that have a low burning velocity. Table 1 summarises the characteristics of flammability used in EN 378.

Table 1: European Safety Code EN 378: Flammability Classes

Flammability Class		**Lower Flammability Limit** **LFL** kg/m3		**Heat of Combustion** **HoC** MJ/kg	**Burning Velocity** **BV** cm/s
3	Highly flammable	<0.1	or	>19	n/a
2	Flammable	>0.1	and	<19	n/a
2L *	Mildly flammable	>0.1	and	<19	<10
1	Non-flammable	Cannot be ignited			

* For EN 378 the 2L category is a proposal that is still under discussion.

However, the 2L category is used in ISO 817:2014 “Refrigerants — Designation and safety classification”

The flammability issue is made even more complicated by various other effects that influence combustion. Three important examples are:

a) The exact geometry of an ignition source can change the MIE – a spark between thin electrodes will ignite a gas with less energy than a spark between thick electrodes (due to the effect of heat removed from the combustion zone, via conduction along the electrodes).

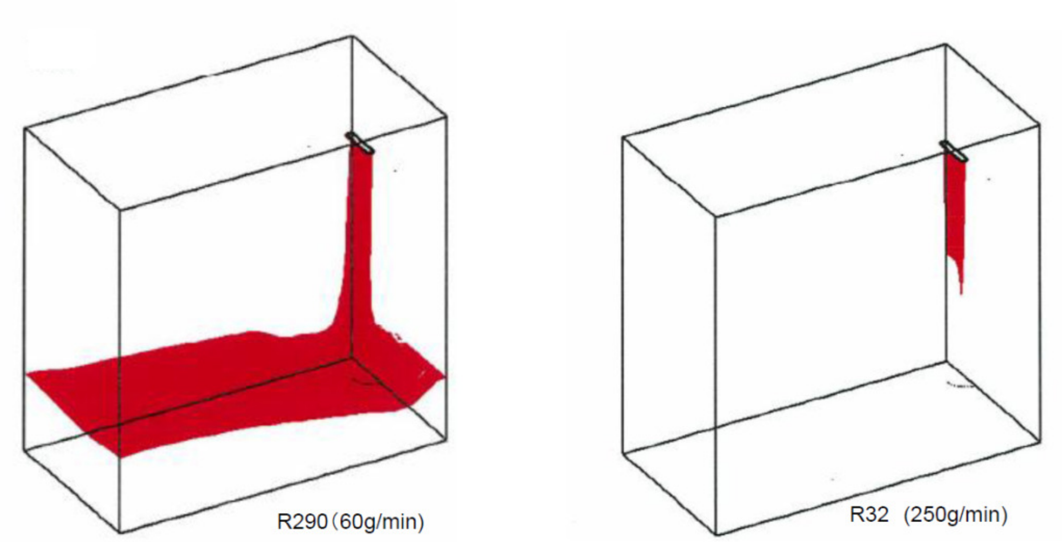
b) High air humidity can increase the burning velocity of some fluids; for example the BV of HFO 1234yf is 1.5 cm/s in dry air, but 5.9 cm/s in very humid air. However, this effect does not occur for all fluids. For example, HFC 32 has a BV of 6 cm/s at all levels of humidity.

c) A dilution effect occurs when a leaking gas mixes with the air around it. For a highly flammable gas, the LFL is low and a lot of dilution must occur before the gas concentration drops to below the LFL. For mildly flammable gases, the LFL is much higher and dilution below the LFL can occur much more quickly. Figure 1 illustrates this effect (which can also be affected by gas density). The highly flammable propane leak rate is only a quarter of the leak rate for mildly flammable HFC 32, but it creates a much greater “ignition risk footprint” (the red area).

These issues have been discussed to illustrate the high complexity of the flammability issue. Safety codes must take a conservative approach in the absence of sufficient technical data.

Figure 1: Modelling of leakage and areas of gas concentration above the LFL[4]

These diagrams illustrate a computer prediction of the extent of the flammable region, when gases of different flammability leak into a room. The scenario shown here relates to leaks of R290 (propane, flammability class 3) and R32 (HFC 32, flammability class 2L) from a wall-mounted RACHP unit. The areas shown in red represents the zone where the gas concentration is between the LFL and the HFL, which means there is a risk of ignition if a sufficiently strong ignition source is present. Note, the R290 leak is 60 g/min, whilst the HFC 32 leak is over 4 times larger at 250 g/min.



4. Likelihood and Severity of Risks

It is important to distinguish between the likelihood of ignition and the severity of the consequences of ignition.

The likelihood of ignition depends significantly on the LFL and the MIE:

- A highly flammable fluid has a low LFL (i.e. there only needs to be a small amount of the gas mixed with air for ignition to be possible) and a low MIE (i.e. a low energy ignition source such as a small spark will cause ignition).
- A mildly flammable fluid has a higher LFL – this means there will be a smaller area in which there is risk of ignition (in most normal circumstances, as illustrated in Figure 1). It also requires a much higher MIE, which means there needs to be a much more powerful ignition source located in the risk of ignition area.

The severity of the consequences of ignition depends significantly on BV and HoC:

- A highly flammable fluid has a high BV – this can lead to explosive ignition within a cloud of gas that is above the LFL. If the HoC is also high, then the damage caused by the burning gas will be greater.

---

[4] Osami Kataoka, JRAIA, January 2013, "Flammability of 2L Class Refrigerants "

- A mildly flammable fluid has a low BV – in the situation where ignition occurs, the burning takes place slowly. Burning cannot be sustained if the air velocity is higher than the BV and it might not be sustained if the ignition source is removed.

Flammability Class 3 gases (highly flammable) such as propane exhibit both a high likelihood of ignition and a high severity of consequences following ignition.

Flammability Class 2L gases (mildly flammable) such as HFO 1234yf or HFC 32 are relatively difficult to ignite (both in terms of high LFL and high MIE) and their low BV makes the consequences of ignition much less severe.

Table 2 illustrates the variation in some of the key flammability characteristics discussed above,

Table 2: Examples of Key Parameters

Fluid	**Flammability class**	**LFL** kg/m^3	**MIE** [5] mJ	**HoC** MJ/kg	**BV** cm/s
Propane	3	0.038	0.3	46	43
HFC 152a	2	0.130	10	16	23
Ammonia	2L	0.116	100	19	7
HFC 32	2L	0.307	1000	9	6
HFO 1234yf	2L	0.289	5000	9	1.5

The data in Table 2 clearly show that a class 3 fluid is very easy to ignite (very low LFL and MIE) and that the consequences of burning can be severe (high BV and high HoC).

It is interesting to note that ammonia has been widely used in large industrial systems for many years. There are very few cases of fire related to an ammonia leak (due to the difficulty of ignition).

HFC 152a has a higher LFL and lower HoC than ammonia. Based on previous safety codes that would indicate that HFC 152a is "less flammable" than ammonia. However, practical experience indicates that HFC 152a is much more readily flammable than ammonia. This can be explained by the low MIE (making ignition much easier) and the high BV (making the consequences more severe). This shows the importance of avoiding a simplistic way of categorising flammability.

Ultra-low GWP fluids such as HFO 1234yf and moderate GWP fluids like HFC 32 are important alternatives that could help meet the EU HFC phase down targets. The data in Table 2 indicates that these fluids are much more difficult to ignite (much higher MIE and LFL than ammonia) and that consequences of ignition are more limited (low BV and Low HoC). These are encouraging characteristics, although it must be stressed that until safety codes have been revised it is difficult to define the safe "operating envelope" for fluids of this type.

---

[5] These MIE values are only approximate – they can vary considerably depending on test conditions

5. What does this mean for equipment manufacturers and end users?

To achieve a rapid phase down in the use of high GWP HFCs, it is likely that there will need to be a greater use of flammable fluids.

The safe operating envelop for well-established flammable fluids such as propane and ammonia can be established using existing safety codes such as EN 378 2008. In the case of propane and other hydrocarbons (HCs) this severely limits the applicability of these fluids except in very small systems (e.g. sealed refrigeration systems with less than 0.15 kg of refrigerant). For ammonia, the key safety issue is toxicity and this restricts the use of ammonia outside restricted locations such as factories and special plant rooms.

The safe operating envelop for new fluids such as HFO 1234yf and HFC 32 will need to be established over a period of time, based on increasing levels of practical experience and further technical research. This is likely to proceed in 3 stages:

a) Existing codes can be used immediately. Whilst these do not give full credit for the mildly flammable characteristics, they still allow much greater refrigerant charge than for HCs. For example a charge limit might be 1 kg for HCs and 7.8 kg for HFC 32[6]. This allows quite widespread application in small retail refrigeration and small air-conditioning systems.

b) Revised codes are likely to be available by the end of 2015. These will widen the operating envelope for mildly flammable fluids (e.g. the charge limit quoted above would rise from 7.8 kg to 11.7 kg for HFC 32). This will enable a greater range of application than the current codes.

c) Within another few years it is likely that codes will be revised again, to take account of practical experience and new research. These may allow even larger charges to be used, although that clearly depends on the nature of the experience gained.

Gluckman Consulting
specialists in refrigeration and climate change

This Information Sheet has been prepared by Gluckman Consulting

in collaboration with the Defra (UK Department for Environment, Food and Rural Affairs) and Jacobs

This document can be used and distributed for no charge. It contains the best information available to date and will be updated as more or different information is made available. It does not seek to provide a definitive view on the legal requirements; only the courts can provide such a view. If there are uncertainties you should always refer to the text of the Regulation and seek qualified legal advice.

admin@gluckmanconsulting.com www.gluckmanconsulting.com

---

[6] This is the m_2 charge cap in EN 378 based on 26 * LFL. This is only intended as an illustration – the calculation of charge limit should be based on the procedures given in EN 378 2008.