U-3ARC
TRAINING WEBINAR
No. 30

FLAMMABLE REFRIGERATING FLUIDS (PART 1)

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Summary

OBJECTIVES

❖Provide RAC stakeholders with a quick reference to the main safety classifications and safe handling techniques for flammable refrigerants available in the market.

❖ All flammable refrigerants should be handled with care and in accordance with national and international regulations

❖ Reduce damage and analyze risks

Overview of security risks

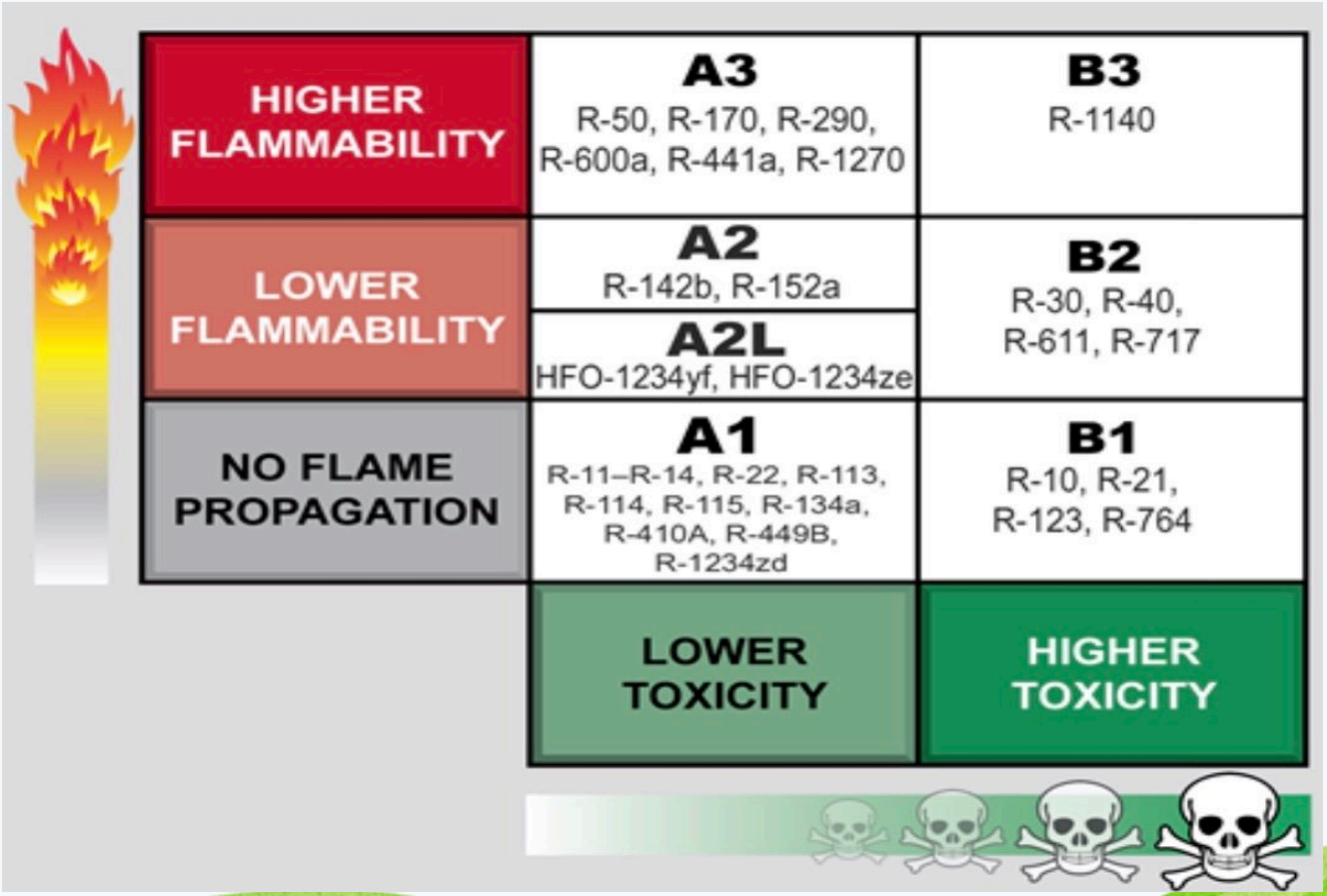
All alternative refrigerants pose additional risks compared to traditional HFC refrigerants.

These risks are:

- flammability
- toxicity
- High pressures

Security classification

- The safety classifications below are defined in ISO817 and are also used in EN378-1. The classification consists of two parts: A or B followed by 1, 2L, 2 or 3.



2/ Physical characteristics of alternative flammable refrigerants to HFCs

The main alternatives have low or no GWP, but it is important not to choose a refrigerant based solely on its low GWP; other characteristics should be taken into account, such as:

- Operating pressures;
- Performance – capacity and efficiency;
- Material compatibility, including compressor lubricant;
- Safety, including flammability and toxicity;
- Temperature slide;
- The ease of use and the skill level of design engineers and technicians responsible for installing, servicing and maintaining the equipment.

Basic Properties of Flammable Refrigerants Alternatives to HFCs

Refrigerant	Type	Security class	GWP	Temperature of Saturation °C	Glide °C
R717	NH3	B2L	0	-33.32	--
R32	HFC	A2L	675	-51.65	--
R452B	HFC/HFO	A2L	698	-50.67	0.86
R454A	HFC/HFO	A2L	239	-47.84	5.69
R454B	HFC/HFO	A2L	467	-50.49	1
R454C	HFC/HFO	A2L	148	-45.56	7.81
R455A	HFC/HFO	A2L	148	-52	12.9
R1234ze	HFO	A2L	7	-19	--
R1234yf	HFO	A2L	4	-29.49	--
R436A	HC	A3	3	-34.26	8.15
R1270	HC	A3	2	-47.62	---
R290	HC	A3	3	-42.11	---
R600a	HC	A3	3	-11.75	---

Applications of flammable refrigerants alternatives to HFCs

Sectors	Technical solution	Usual fluids	Alternative flammable fluids on the market
Residential	Air-to-air heat pump, Split air conditioners	R410A	R32 R290
	Water-to-water heat pump	R410A R407C	R32 R290
	Air-water heat pump	R410A	R32 R454C R290
Réfrigération commerciale	Condensing unit (positive cold)	R410A R407C R134a	R454A R454C R455A R1234ze R1234yf R 290 R1270
	Condensing unit (negative cold)	R410A R407C R744	R454A R454C R455A
	Accommodated groups	R134a	R290/R600a

Applications of flammable refrigerants alternatives to HFCs

Sectors	Technical solution	Usual fluids	Alternative flammable fluids on the market
Tertiary And industrial	air-air heat pump	R410A	R32
	VRV system, Multi split	R410A R407C	R32 R452B R454B
	Roof top	R410A	R32
	GEG/PAC (small and medium power, spiro-orbital compressor) Roof top	R410A	R32 R454B R454C R455A
	GEG/PAC (high power, positive displacement screw compressor)	R410A R407C R134a	R1234ze R452B
	GEG/PAC (high power, Centrifugal compressor)	R134a	R1234ze

FLAMMABILITY PROPERTIES OF REFRIGERANTS

LOWER FLAMMABILITY LIMIT (LFL/LII): The minimum concentration of refrigerant capable of propagating a flame

UPPER FLAMMABILITY LIMIT (UFL/LSI): The maximum concentration of refrigerant that is capable of propagating a flame.

AUTOIGNITION TEMPERATURE: The lowest temperature at which a refrigerant will spontaneously ignite in a normal atmosphere without an external ignition source (flame or spark).

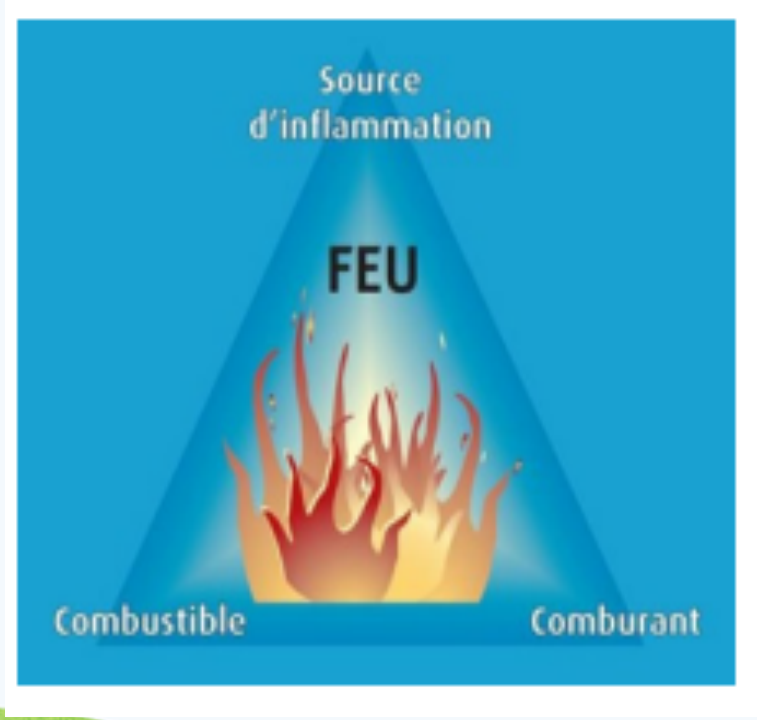
Since a flame can propagate in the range between LFL-UFL, it must be avoided that the concentration of refrigerant in the working area does not reach the LFL and the temperature of the refrigerant does not reach the temperature d self-ignition.

FLAMMABILITY PROPERTIES OF REFRIGERANTS

In the event of a refrigerant leak, two dangerous phenomena can occur:

- Fire hazard
- Risk of explosion

Fire is a chemical reaction of oxidation of a fuel by an oxidant (combustion) requiring a source of energy to initiate this reaction; **This phenomenon is schematized by the "fire triangle".**



FLAMMABILITY PROPERTIES OF REFRIGERANTS

An explosion is the release into the atmosphere of a flammable product which, after mixing with the oxygen in the ambient air to form an flammable mixture, encounters an ignition source of sufficient energy.

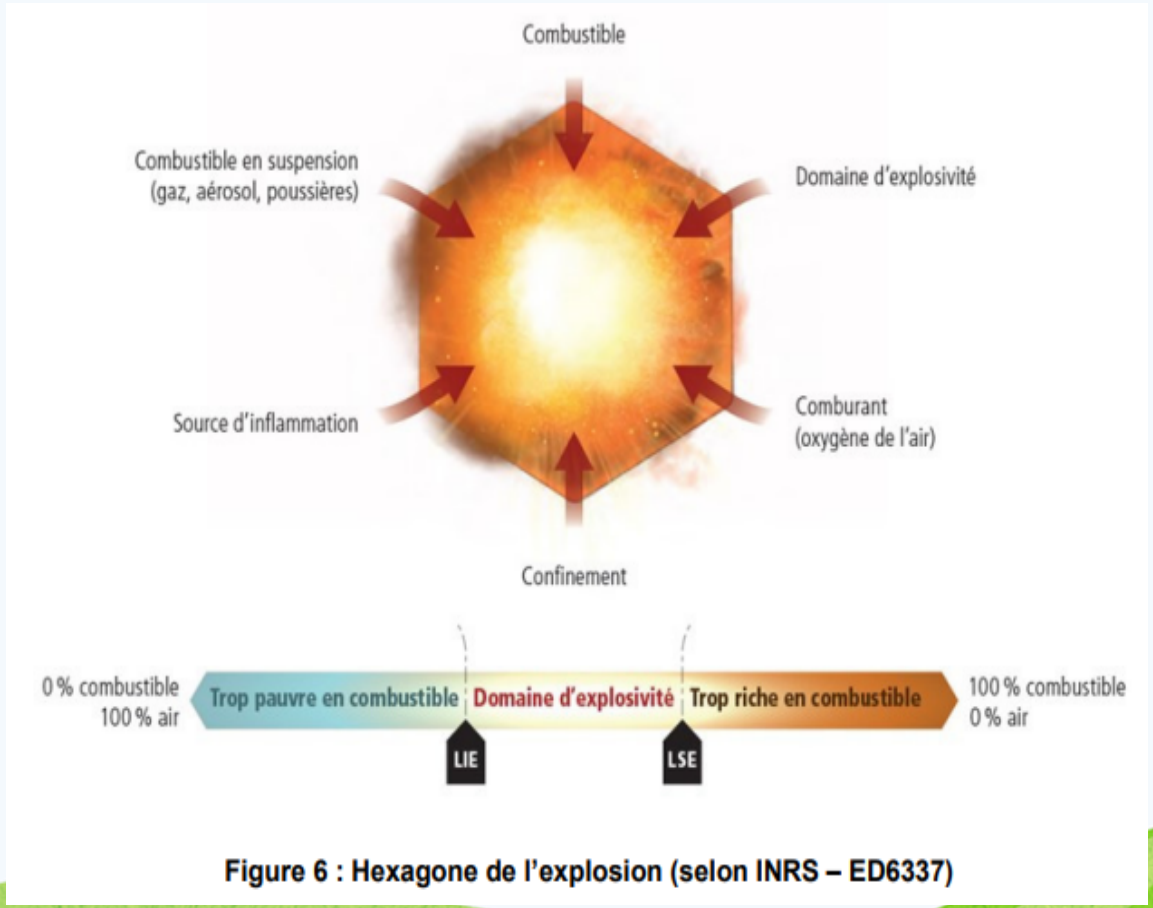


Figure 6 : Hexagone de l'explosion (selon INRS – ED6337)

FLAMMABILITY PROPERTIES OF REFRIGERANTS

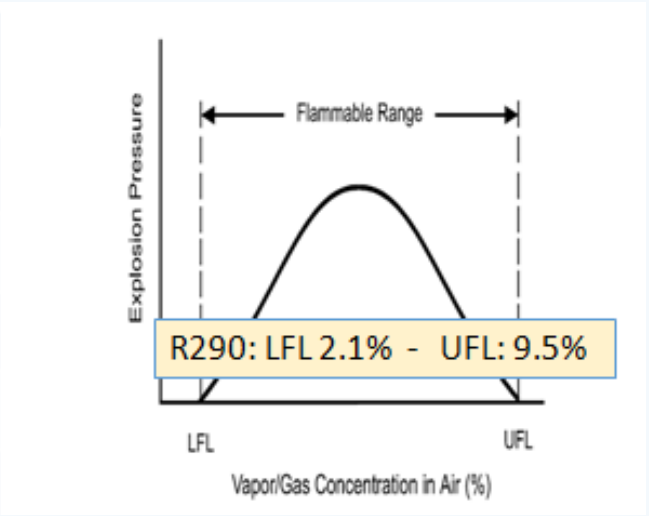
For flammable refrigerants, the practical limit is approximately 20% of the LFL

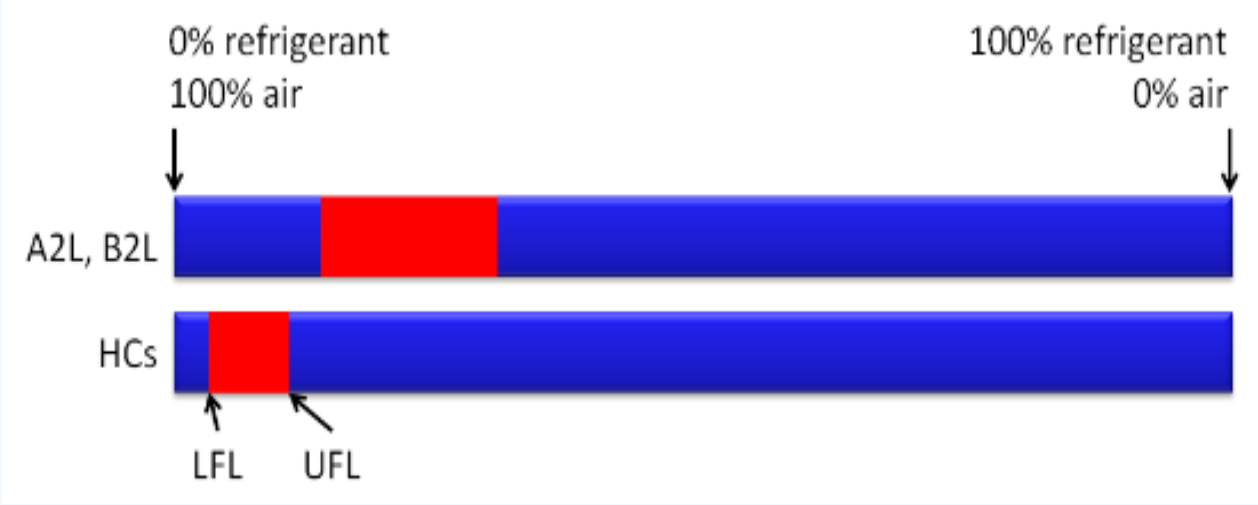
Fluide frigorigène	Classe de sécurité	Limite inferieur d'inflammabilité à 23°C et 50% HR kg/m3	Température d'auto-allumage °C	Limite pratique Kg/m3	Vitesse de combustion à 23°C (cm/s)
R717	B2L	0.116	630	0.00035	----
R32	A2L	0.307	648	0.061	6.7
R452B	A2L	0.310	509	0.062	4.2
R454A	A2L	0.278	457	0.056	2.4
R454B	A2L	0.303	496	0.061	3.7
R454C	A2L	0.293	444	0.059	1.6
R455A	A2L	0.431	---	0.086	<1.5
R1234ze	A2L	0.303	368	0.061	1.2
R1234yf	A2L	0.289	405	0.058	1.5
R436A	A3	0.032	---	0.006	---
R1270	A3	0.046	455	0.008	46
R290	A3	0.038	470	0.008	46
R600a	A3	0.043	460	0.009	46

EN378-1 safety information table

FLAMMABILITY PROPERTIES OF REFRIGERANTS

Refrigerants	HFC - R410A	HFC-32	HC- 290	HC-600a
LFL/ LII	Non-flammable	14.4% by volume	2.1% by volume	1.7% by volume
UFL/LSI	Non-flammable	33.4% by volume	9.5% by volume	9.7 % by volume
T°C SELF-IGNITION	NA	648	470	460





Usage restrictions - maximum load size

The regulatory and normative context

The regulatory texts that may apply to flammable fluids may be different and complementary depending on the type of building or the flammability class of the fluid.

Good knowledge of the standard and regulations in force is essential to guarantee the safety and lifespan of refrigeration systems and heat pumps.

Depending on the fluids, other texts or standards must also be considered, such as:

- **The F-Gas regulation** (European regulation No. 517/2014 of April 16, 2014): tightness control for certain fluids (pure or mixed HFCs);
- **The ATEX directives** (directive 1999/92/CE of December 16, 1999 and directive 2014/34/CE of February 26, 2014) and the **NF EN 60079-10-1** standard: characteristics of devices according to the zone, determination of the extent of leakage zone, protective devices for workers, protective devices and systems intended for use in explosive atmospheres;
- **The PED directive** (directive 2014/68/EU of May 15, 2014), the decree of November 20, 2017, the Professional Technical Specifications for in-service monitoring of ***pressure refrigeration systems*** of July 23, 2020: group of fluids and associated requirements, followed in service.
- **Standard NF EN 378: 2017 “Refrigeration systems and heat pumps – Safety and environmental requirements”**

The regulatory and normative context

1/ F-Gas regulations

European regulation No. 517/2014 of April 16, 2014 relating to fluorinated greenhouse gases defines 3 main actions:

- Prevention of fluid leaks, in particular by strengthening tightness checks.
- The timetable for reducing quantities of greenhouse gases
- Progressive marketing bans.

The fluids affected by these requirements are hydrofluorocarbons (HFCs):

By definition, hydrofluorocarbons represent HFC fluids as well as mixtures containing any of these substances. The fluids affected by these requirements are A2L fluids.

Persons who perform the installation, servicing, maintenance, repair or commissioning and decommissioning of equipment must be certified for the fluids concerned.

2/ATEX regulations

General requirements

The **regulations** concerning **explosive atmospheres** (known as **"ATEX** regulations) are based on two European directives:

- Directive 1999/92/EC of December 16, 1999 relating to the safety and health protection of workers likely to be exposed to the risk of explosive atmospheres.
- Directive 2014/34/EC of February 26, 2014 concerning devices and protection systems intended for use in explosive atmospheres.

Within the meaning of the directives, an "EXplosive ATMosphere" (ATEX) results from a mixture of air and flammable substances in proportions such that an ignition source of sufficient energy produces its explosion.

Any flammable substance is considered a substance capable of giving rise to the formation of an explosive atmosphere.

2/ATEX regulations

The European **ATEX directive requires** that risk reduction measures cover two aspects:

- **technical measures:**
  - Avoid, if possible, the formation of an ATEX zone.
  - If it is not possible to avoid the formation of an area, the appearance of inflammation in the area must be avoided.
  - If an ignition nevertheless occurs, then it is necessary to immediately stop and/or limit the area affected by the explosion (presence of flames and/or excess pressure) in order to reduce the number of people likely to be in contact with this area.
- **organizational measures:** they relate to various measures including:
  - Training of workers (maintenance, etc.)
  - Implementation of safety instructions.
  - Indicate premises or locations likely to have an ATEX zone via the pictogram

2/ATEX regulations

The classification of places into ATEX zones aims to delimit and prioritize the areas where explosive atmospheres can form. This zoning helps with the choice of equipment and safety devices depending on the type of zone.

Locations where an explosive atmosphere can form are classified into 3 zones depending on the nature, frequency and duration of presence of this ATEX.

All equipment and protection systems (electrical and non-electric) used in these risk areas must meet safety levels appropriate to the area.

Considering the flammable substance in the form of gas or vapor, these three zones (with the category of material adapted to these zones) are:

Definition of the zone according to the frequency and duration of presence of an ATEX	Area (flammable substance in the form of gas, vapor)	Characteristics of devices to be used depending on the area
Location in which an explosive atmosphere is present continuously or for a long period during normal operation: **Permanent risk**	Zone 0	Category 1
Location in which an explosive atmosphere is likely to occur occasionally during normal operation: **Occasional risk**	Zone 1	Category 2 (or 1)
Location in which an explosive atmosphere is not likely to occur normally but if it does, may only exist for a short period of time: **Potential risk**	Zone 2	Category 3 (or 1or2)

The regulatory and normative context

3/ Standard NF EN 378

Aims to reduce the possible dangers of refrigeration systems for people (installers, users and technicians), property and the environnement.

It is broken down into 4 parts:

- NF EN 378-1: Basic requirements, definitions, classification and selection criteria
- NF EN 378-2 (standard harmonized with the Machinery, LV and PED Directives): Design, construction, testing, marking and documentation
- NF EN 378-3: On-site installation and protection of people
- NF EN 378-4: Operation, maintenance, repair and recovery

The EN 378 standard, version 2017, provides additional elements compared to the previous version, in particular concerning the addition of a new fluid category (A2L) or even fluid load limits.

In the event of an incident, the quantity of fluid in a refrigeration system is decisive. That's why ***load restrictions are planned depending in particular on the combination of all the criteria*** mentioned in the following table.

The objective being to avoid an accumulation of concentration which could lead to risks of fire and explosion.

The regulatory and normative context

3/ Standard NF EN 378

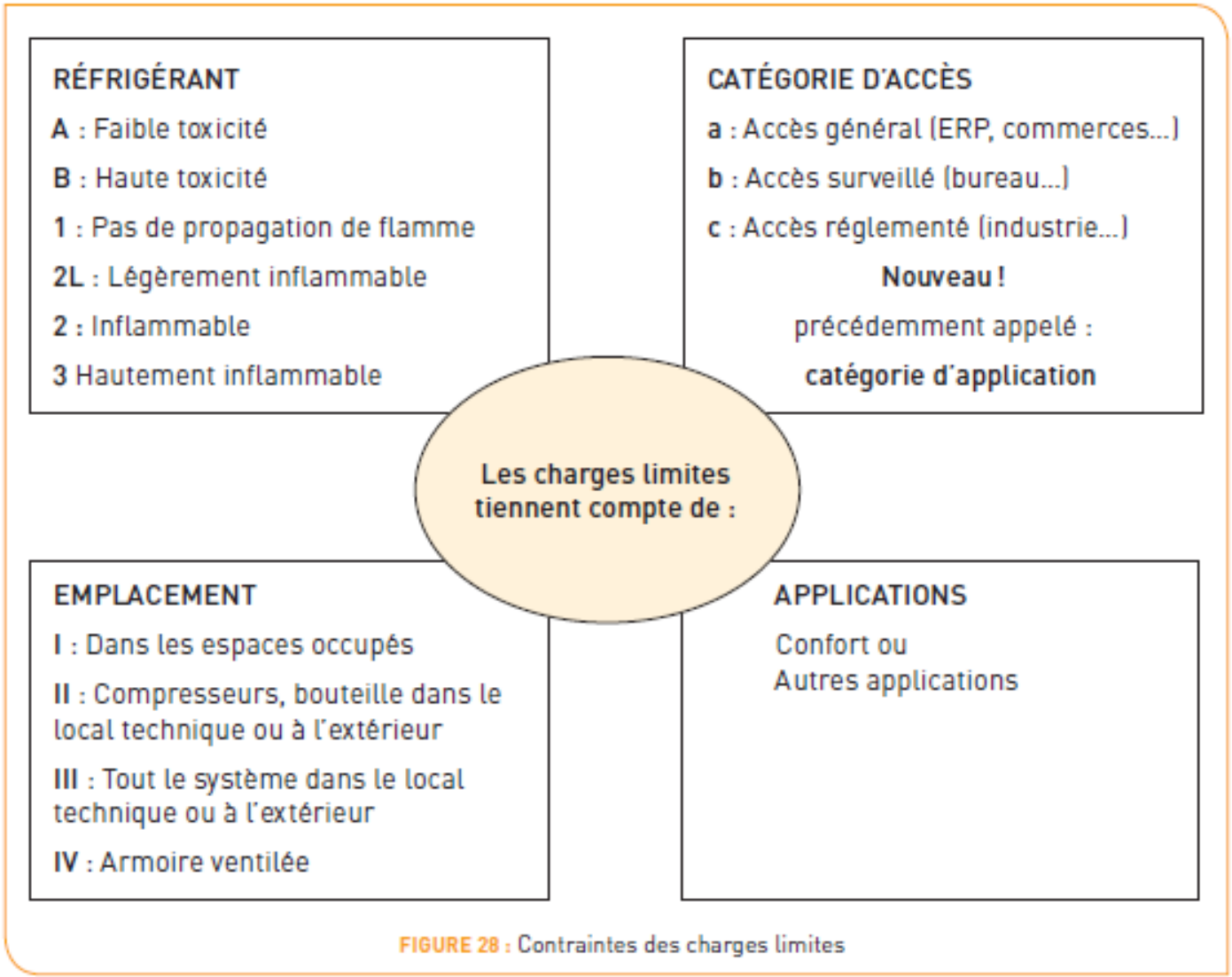


FIGURE 28 : Contraintes des charges limites

Determination of limit loads for flammable refrigerants

Use of flammable refrigerants for "comfort" needs

The **total quantity of flammable fluid « M_{max} »** circulating in an installation is limited in order to avoid any risk of fire in the event of a leak. This quantity is determined according to the following formula, a formula also defined in NF EN 378-1.

$$M_{max} = 2.5 \times LII^{(5/4)} \times h0 \times A^{(1/2)}$$

With :

LII: lower flammability limit of the fluid (kg/m3)

A: surface area of the premises (m2)

h0: coefficient linked to the height of the equipment located lowest in the room, the value of which is equal to:

h0= 0.6 for a ground location

h0= 1.0 for window mounting

h0= 1.8 for wall location

h0= 2.2 for ceiling mounting,

Determination of limit loads for flammable refrigerants

Use of flammable refrigerants for "comfort" needs

Residential Sector - Comfort Direct system (complete system or only indoor unit in occupied space)			
	A2L	**A2**	**A3**
Load calculation	**2.5 x LII(5/4) x h0 x A(1/2)** **And** **< = 39* LII** **1.84 kg < Load R-32 ≤ 11.97 kg** According to quantity limit with breakdown QLMV, QLAV and load <=195*LII. - Measurements (non-removable connection, protection, location II)	**2.5 x LII(5/4) x h0 x A(1/2)** **And** **< = 26* LII**	**2.5 x $LII^{(5/4)}$ x h0 x $A^{(1/2)}$** **et** **< = max (26* LII; 1.5kg)** **0.152 < Charge R-290 ≤ 1.5 kg**
Exceeding the calculated load	Yes (for configuration with QLMV, QLAV)	No	No
Safety measure to increase the load	Ventilation Isolation valves Alarm Leak detector control for a level <= 25% LII		
Fluid charge without requirements	<= 1.5*4*LII Load R-32 <= 1.84 kg	<=4*LII	<=4*LII **Load R-290 ≤ 0.152 kg**

Determination of limit loads for flammable refrigerants

Use of flammable refrigerants for “comfort” needs

Tertiary Sector - Comfort Direct system (complete system or only indoor unit in occupied space)			
	ERP 1-4		
	A2L	A2	A3
Load calculation	**$2.5 \times LII^{(5/4)} \times h0 \times A^{(1/2)}$**		
Exceeding the calculated load	Yes for main application (Multi split, VRV) **No charging restriction if:** **Two safety devices**: Circuit closing valve + ventilation controlled by detection to maintain a leak level in the room <LII		
Exceeding the calculated load in the engine room - (GEG)	***No restrictions in the engine room if:*** *Detection system (with 2 sensors) allowing the shutdown of the refrigeration system (complete shutdown, solenoid valve) + activation of a mechanical air extractor to maintain a level in SDM <LII*		
Safety zone around removable fittings	Outdoor installation: No	Outdoor installation: 2 to 10m depending on liquid pipe diameter	
	Indoor installation: 1 to 4 m depending on liquid pipe diameter		Indoor installation: 2 to 10 m depending on liquid pipe diameter

Determination of limit loads for flammable refrigerants

Use of flammable refrigerants for “comfort” needs

Tertiary Sector - Comfort Direct system (complete system or only indoor unit in occupied space)			
	ERP 5		
	A2L	**A2**	**A3**
Load calculation	**$2.5 \times LII^{(5/4)} \times h0 \times A^{(1/2)}$** **and** **< = 39* LII**	**$2.5 \times LII^{(5/4)} \times h0 \times A^{(1/2)}$** **and** **< = 26* LII**	**$2.5 \times LII^{(5/4)} \times h0 \times A^{(1/2)}$** **and** **< = max (26* LII; 1.5kg)**
	According to the quantity limit with breakdown QLMV, QLAV and <=195*LII - Measurements (non-removable connection, protection, location II)		
Exceeding the calculated load	Yes (for configuration with QLMV, QLAV) with detection,	No	No
Exceeding the calculated load in the engine room	***No load restriction in the engine room if*** (location III): a mechanical exhaust ventilation system for normal operation and emergency operation controlled by leak detection to maintain a level < 25% LII + alarm		
Safety zone around removable fittings	Protection device against fire and explosion risk in the event of a fluid leak. Identification of ignition source. No contact with potential fluid leaks		
Fluid charge without requirements	<= 1.5*4*LII	<=4*LII	<=4*LII

The exclusion zone: is an area in which all risks of ignition must be avoided.

Radius in m			
Interior diameter D piping circulating the liquid phase (mm)	**Outdoor facilities with A2 or A3 fluids**	**Facilities interior with A2L or A2 fluids**	**Facilities interior with A3 fluids**
D ≤ 10	2	1	2
10 < D ≤ 20	4	2	4
20 < D ≤ 50	10	4	10

Radius of exclusion zones (m) to consider near the fittings depending on the diameter of the piping, the nature of the installation and the fluid

Determination of limit loads for flammable refrigerants

Use of flammable refrigerants
for Refrigeration needs

The **total quantity of flammable fluid « M_{max} »** circulating in an installation is limited in order to avoid any risk of fire in the event of a leak. This quantity is determined according to the following formula, a formula also defined in NF EN 378-1.

Mmax < 20%*LII*volume of the room

Determination of limit loads for flammable refrigerants

Use of flammable refrigerants for Refrigeration needs

Commercial and industrial refrigeration sector Refrigeration appliance (integrated or remote compressor unit or motorcycle) (refrigerated cabinet, sale, storage) (complete system or indoor unit in an occupied space) NF EN 378			
	A2L	**A2**	**A3**
Load calculation	**<=20%* LII* volume of the room** **Or** **Linked (volume, QLMV,QLAV)** **R-32 load ≤ 0.061 x Room volume and ≤ 11.9 kg**	**<=20%* LII* volume of the room**	**<=20%* LII* volume of the room**
Maximum permitted load	➢ **general access:** <= 26*LII ➢ **monitored and restricted access:** <= 25kg	➢ **general and monitored access:** <= 26*LII **R-152a load ≤ 3.38 kg** ➢ **Restricted :** **Ground floor – floors:** <= 25kg- (I) <=10kg - (II) **Basement:** <= 26*LII	❖ **Ground floor – floors** ➢ **general access**--<=1.5 kg ➢ **monitored access**-<=2.5 kg ➢ **Restricted**<=10kg – in occupied space <=25 kg – external compressor **(II)** ❖ **Sous sol** <= 1 kg
Possible exceeding of the calculated load	Yes (for configuration with QLMV, QLAV) with additional measures: detection, ventilation, isolation valve	No	No
Safety zone	Protection device against fire and explosion risk in the event of a fluid leak. Identification of ignition source. No contact with potential fluid leaks		

Commercial and industrial refrigeration sector
A2L fluid

Calculation of fluid load: 20% x LII x cold room volume and ≤ 25 kg

Possible exceeding of the calculated load

(Fluid load/cold room volume)≤ QLMV (25%LII)
No additional requirements

QLMV < (Fluid load/cold room volume) ≤ QLAV (50% LII)
+ 1 security measure
- refrigeration circuit isolation valves linked to a fluid leak detector
Detector configured for concentration < QLMV (< 25% LII)

(Fluid load/cold room volume) > QLAV
+ 2 security measures
- Refrigerant circuit isolation valves
- Alarm (audible and visual) in occupied space
Detector acting on valves and alarm configured for concentration < QLMV (< 25% LII)

PART 2

Risk analysis
AND
prevention measures

THANK YOU FOR YOUR ATTENTION