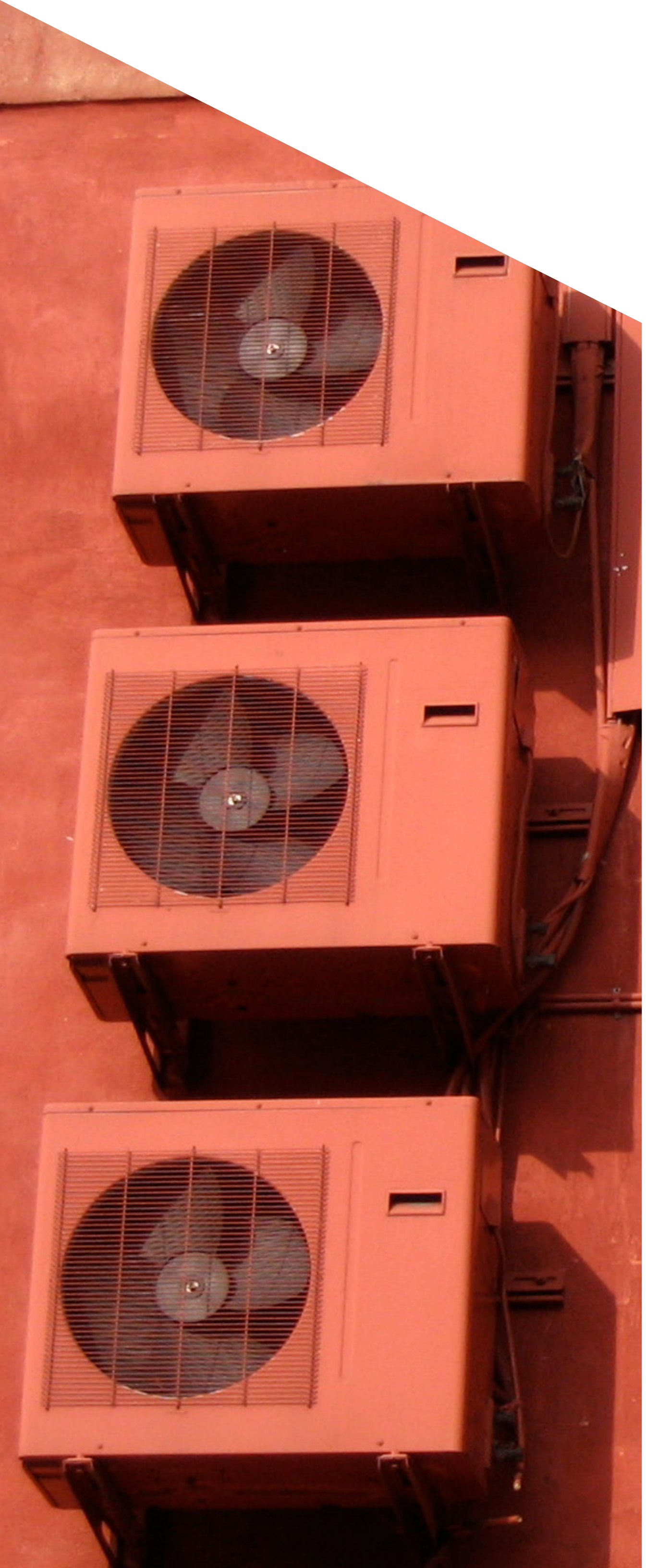
Safety considerations and charge size guidance when using low GWP A2L HFO blends

Introduction

As has been well documented over the last 30 years, many regulations have been implemented globally focusing on the environmental impact of refrigerants and equipment. This ever changing legislative landscape has driven a transition from chlorofluorocarbons (CFCs) to hydrochlorofluorocarbons (HCFCs); to hydrofluorocarbons (HFCs); and, now due to regulations such as EU 517/2014[1] (F-Gas) in the European Union and future regulations that will result from the Kigali Amendment[2] there is a need to change again to lower global warming potential (GWP) products, such as Opteon™ hydrofluoroolefin (HFO)-based products.

Compared to R-507A (GWP 3985), the lower GWP HFO-based alternatives range from 45 to 96% reduction in GWP. However, most of the refrigerants with a GWP <500 have a degree of flammability, which adds complexity to the path forward to achieve the necessary transition required to comply with the F-Gas regulation phase-down. In many cases, a two-step approach will be required to replace high GWP products, such as R-404A and R-507A. Initially, nonflammable alternatives such as Opteon™ XP40 can be used for retrofit and new equipment; but, to stay compliant with the phase-down schedule, there will be a need to use the low GWP mildly flammable alternatives such as Opteon™ XL20 in new equipment—taking into account the necessary safety guidance provided in standards and regulations.

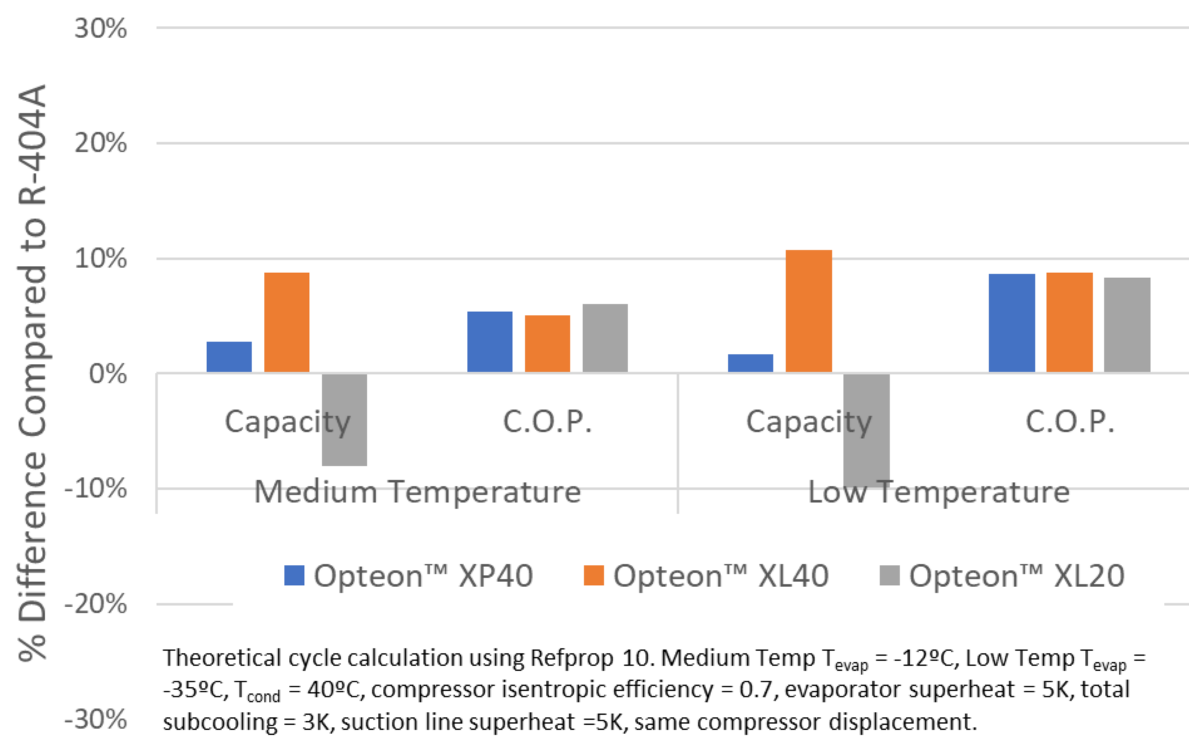


So, what's the plan?

First of all, there must be products available that not only have a lower GWP, but that also at least maintain the performance of the products they replace, with energy efficiency being particularly important—as increased indirect emissions from increased power consumption will greatly reduce any net gain of lowering the refrigerant GWP.

The Opteon™ range of refrigerants offer low GWP options for R-404A, R-410A, R-407C, and R-134a, meeting the necessary performance criteria (*Figure 1*).

Figure 1: Performance Comparison of Low GWP Opteon™ Refrigerants Against R-404A



Having experience from the previous phase-outs of CFCs and HCFCs, it is often thought that the F-Gas regulation HFC phase-down will follow a similar pathway. However, the way F-Gas is written, with maximum product GWP end use bans and a rapid reduction in terms of carbon dioxide equivalent (CO_2eq using IPCC[3] data) of HFCs placed on the market, the need to transition to lower GWP alternatives is at an accelerated rate compared to the rate of change under the previous regulations. Ideally, once the F-Gas regulation was introduced in 2015, systems using high GWP refrigerants, such as R-404A (GWP 3922) or R-507A, should have been retrofitted *(Figure 2)* to a lower GWP option, e.g., Opteon™ XP40 (R-449A, GWP 1397); but, the retrofit "wave" did not occur to any significant extent in 2015 and 2016, as R-404A was still readily available (probably due to the significant pre-buy in 2014, as can be seen in the European Environment Agency (EEA) fluorinated greenhouse gases report[4]).

This had the effect of compressing the available time scale when the availability of R-404A did become restricted, provoking a rapid increase in retrofit activity and high market prices[5] for R-404A. This pattern is likely to be repeated as the next phase-down step approaches at the end of 2020, unless the retrofit programmes continue and there is a marked increase in the use of the GWP (<650) refrigerant options available. As seen in *Table 1*, there are a number of options available, but the majority of GWP options are classified as A2L (mildly flammable).

Figure 2: Ideal transition strategy to reduce average refrigerant GWP in line with the phase-down

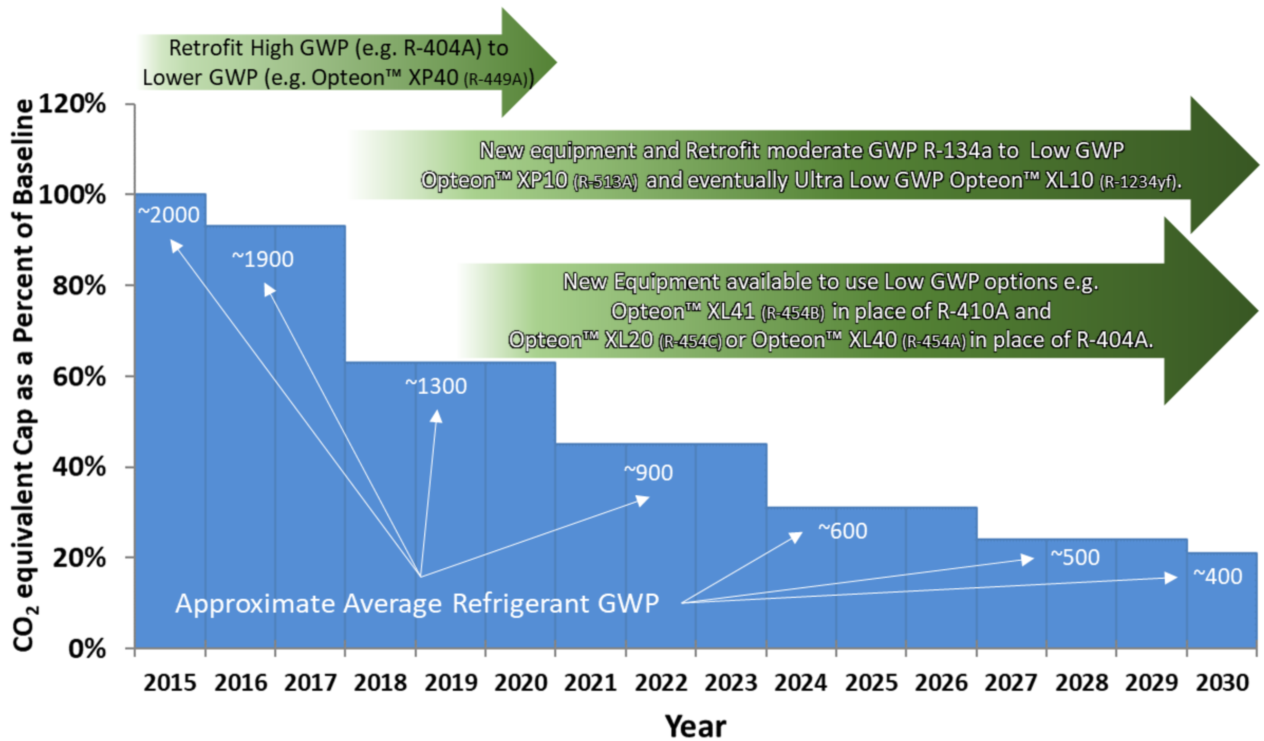


Table 1: Low GWP Refrigerant Options

Low GWP Refrigerant	GWP[3]	ASHRAE #	ISO 817 Classification	Replaces
Opteon™ XP10	631	R-513A	A1	R-134a
Opteon™ XL10	4	R-1234yf	A2L	R-134a
Opteon™ XL20	148	R-454C	A2L	R-407C/R-404A
Opteon™ XL40	238	R-454A	A2L	R-404A/R-507A
Opteon™ XL41	466	R-454B	A2L	R-410A

Until 2010, there were three flammability classes recognised, i.e., 1: no flame propagation (e.g., R-134a), 2: flammable (e.g., R-152a), and 3: highly flammable (e.g., Propane). With the need to move to lower GWP refrigerants, it was realised that although many of the low GWP candidates were flammable, a number presented a lower safety risk than R-152a or propane, and, therefore, research was performed to study what the relative flammability risks were and how a sensible boundary may be drawn between categories.

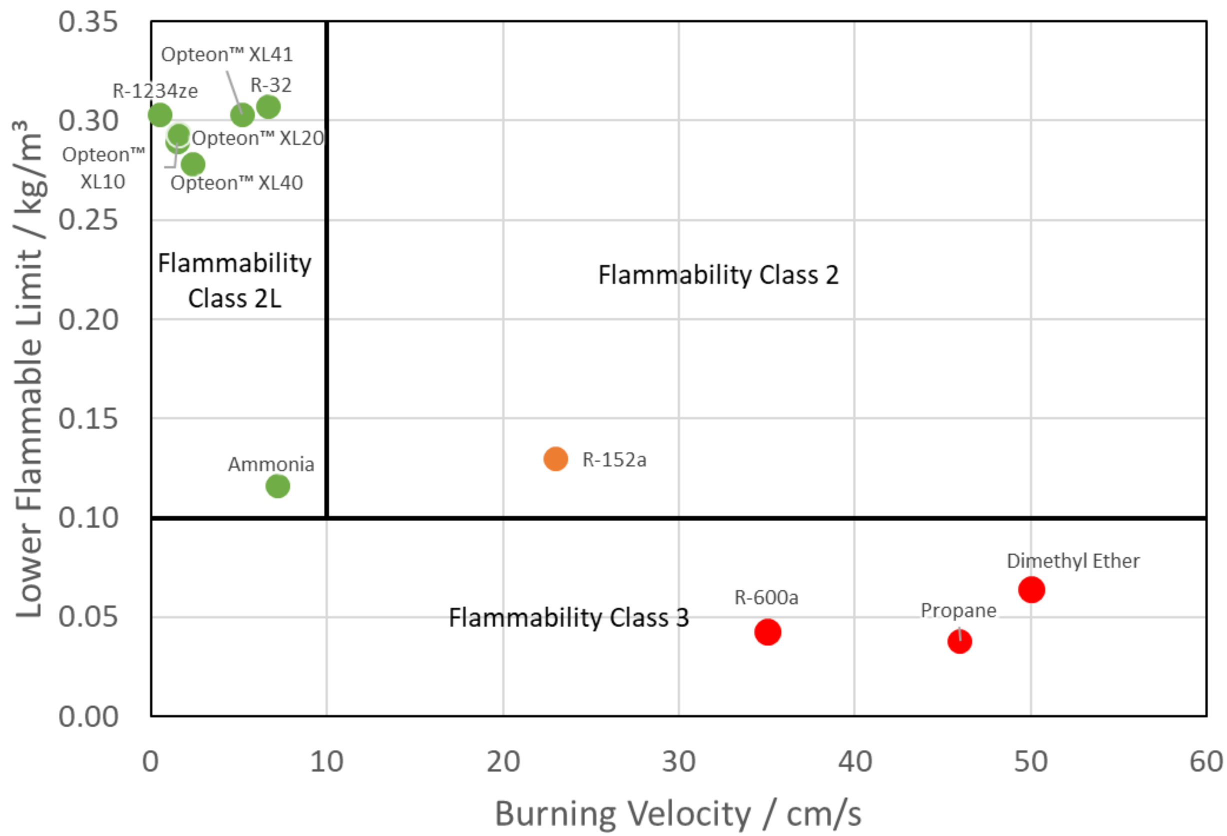
The conclusions of the studies presented a proposal to add a subdivision to the 2 classification, where in addition to the heat of combustion (HOC) <19,000 kJ/kg and a lower flammability limit (LFL) of >0.1 kg/m^3 requirements, refrigerants with a burning velocity (BV) <10 cm/s would be classified as 2L (*Figure 3*).

While the use of flammable refrigerants is well known, e.g., virtually all domestic refrigerators in Europe use R-600a, all the standards and

regulations on the use of flammable refrigerants had been developed based on the flammability classes 2 and 3, which required more stringent safety precautions than the new 2L classified refrigerants. As can be seen in *Table 2*, the flammability properties of the A2L refrigerants present a significantly lower risk. For example, in addition to the lower burning velocity and heat of combustion, A2L refrigerants require a larger quantity of refrigerant to reach the LFL, the range of flammability is reduced, and the minimum ignition energy (MIE) required is orders of magnitude larger than needed to ignite an A3 product.

After formal adoption of the 2L class by ASHRAE Standard 34 (2010) and ISO 817 (2014) standards, the classification was recognised by ASHRAE Standard 15 "Safety Code for Mechanical Refrigeration" (US) and ISO 5149 "Refrigerating Systems and Heat Pumps—Safety and Environmental Requirements" and eventually incorporated into

Figure 3: Refrigerant Flammability Classification Based on Burning Velocity and Lower Flammability Limit



the European standard EN 378:2016. Although there are other equipment-specific standards that will take precedence over EN 378 (e.g., IEC 60335-2-40 heat pumps and AC, IEC 60335-2-89 commercial refrigerating appliances), many of these are still in the process of being updated to recognise the 2L classification. For many applications that fall outside of these specific equipment standards, EN 378:2016 will be the basis for assessing what is required for the safe use of A2L refrigerants. Part 1 of the standard is of particular interest, as it details the maximum charge sizes that are allowed within the guidance of this standard. It should be noted that compliance with EN 378 does not remove the need for risk assessments to be performed at the design, installation, use, and maintenance phases, and that equipment components used with A2L must conform to the Pressure Equipment Directive (PED, 2014/68/EU).

Table 2: Comparison of Flammability Properties of Typical A3, A2 and A2L Refrigerants

Parameter	Propane	R-152a	Opteon™ XL10	Opteon™ XL20
Safety Classification	A3	A2	A2L	A2L
Lower Flammability Limit (LFL) (vol. %) [kg/m^3]	2.2 [0.038]	3.9 [0.130]	6.2 [0.289]	7.7 [0.293]
Upper Flammability Limit (UFL) (vol. %) [kg/m^3]	10.0 [0.192]	16.9 [0.563]	12.3 [0.573]	15.0 [0.569]
UFL – LFL (vol. % - range)	7.8	13.0	6.1	7.3
Minimum Ignition Energy (MIE) (mJ)	0.25	0.38	>5,000	300-1,000
Burning Velocity (Sμ) (cm/s)	46	23	1.5	1.6
Heat of Combustion (HOC) (MJ/g)	46.3	16.5	10.7	10.5

Maximum Charge Size Calculations Under EN 378-1:2016

Annex C of EN 378-1:2016 sets out the criteria for determining the maximum allowable refrigerant charge. When using A2L refrigerants in hermetic refrigeration systems (Other Applications) and fixed Human Comfort systems, there is a minimum charge, 1.5 x m_1 (where m_1 = 4 m^3 x LFL kg/m^3), which can always be used without additional safety precautions and independent of the room size. There is also a minimum charge for non-fixed, factory sealed, single AC systems or heat pumps beyond which additional safety precautions are not required and also independent of the room size. Examples of these minimum charge sizes are shown in *Table 3*.

Within Annex C, Table C.2 specifically addresses the use of A2L classified refrigerants. The charge calculations are determined by assigning specific access categories, location classifications, and application, which is either "Human Comfort" or "Other Applications."

The access categories are detailed in *Table 4* with category "a" having the least restricted access and category "c" the most restricted access.

There are four location classifications (*Table 5*). Location classes I, II, and III are directly related to the location of the refrigerant-containing parts of the system, e.g., entirely inside, partially inside, or completely outside the occupied space.

The final class IV is for special designs, where even if the system is within the occupied space, it is designed in such a way that any leakage will not enter the occupied space and is vented to an unoccupied, well-ventilated space.

The access categories, application type and location classes are arranged in a matrix, which can be cross-referenced to look up the relevant charge size guidance. The charge size calculations may differ depending on the application, i.e., either Human Comfort or Other Applications, and offer options for scenarios where no additional protective measures are required, or for location class II, additional

Table 3: Minimum Refrigerant Charge Beyond Which Additional Safety Precautions Are Not Required and Also Independent of the Room Size

Application	Propane	Opteon™ XL10	Opteon™ XL20	Opteon™ XL40	Opteon™ XL41
Hermetic other applications and fixed human comfort minimum charge size (kg)	0.15	1.73	1.76	1.67	1.82
Non-fixed, factory sealed, single AC systems or heat pumps minimum charge size (kg)	0.15	1.16	1.17	1.11	1.21

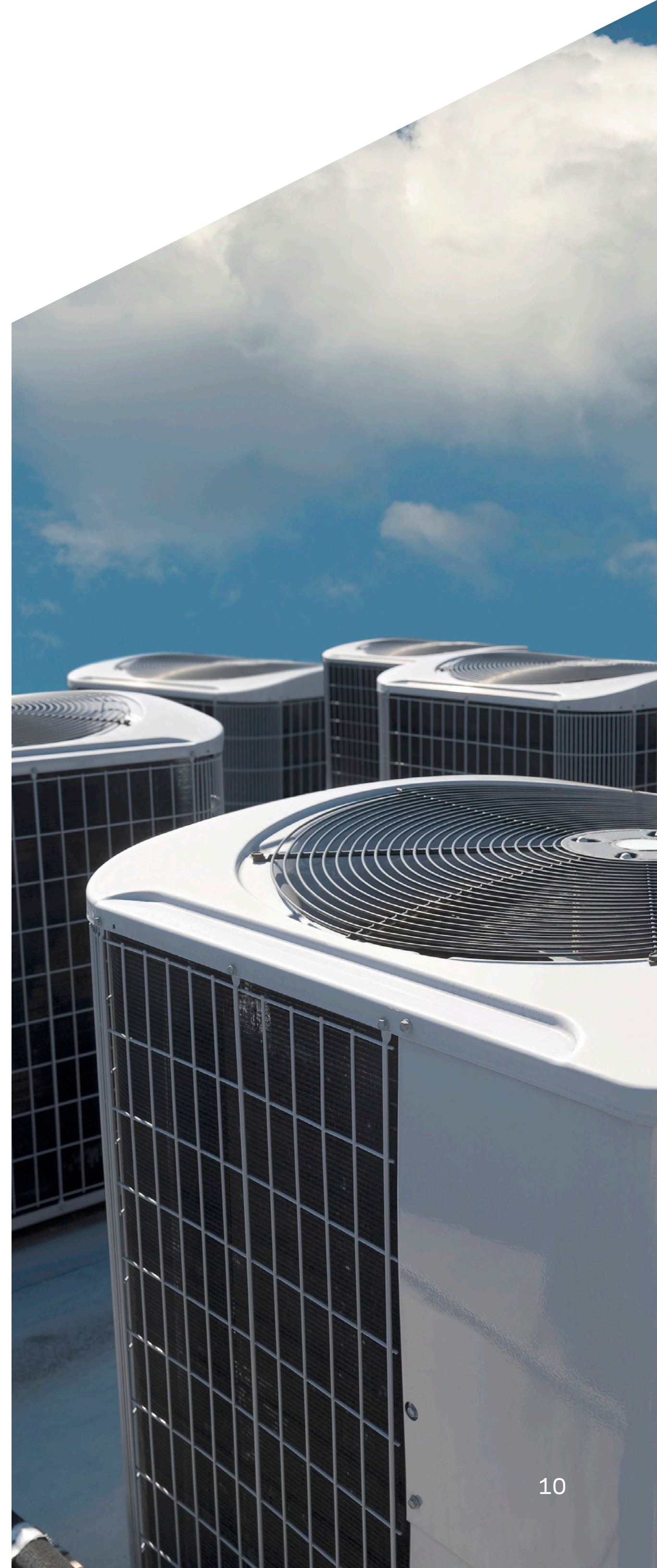
protective measures may be taken to allow an increased refrigerant charge to be used. Location class III has no charge restriction, provided the machinery room design criteria are compliant with EN 378-3:2016 4.2 or 4.3; but, as previously mentioned, a thorough risk assessment will still be required.

Table 4: EN 378:2016 Access Categories

General Occupancy	Supervised Occupancy	Authorised Occupancy
Category a	**Category b**	**Category c**
Rooms, parts of buildings, buildings where: ▪ Sleeping facilities are provided ▪ People are restricted in their movement ▪ Unlimited number of people have access without safety precautions	Rooms, parts of buildings, buildings where: ▪ Only limited number of people have access with some being acquainted with the safety precautions	Rooms, parts of buildings, buildings where: ▪ Only authorised persons have access, who are acquainted with safety precautions ▪ Manufacturing, processing, or storage of products take place
Examples: Hospitals, train stations, shops, hotels, apartments, public buildings	**Examples:** Offices, laboratories, places for general manufacturing	**Examples:** Factories, warehouses, non-public areas in supermarkets

Table 5: EN 378 Location Classifications

Mechanical Equipment within the occupied space	Compressors in machinery room or open air	Machinery room or open air	Ventilated enclosure
Class I	**Class II**	**Class III**	**Class IV**
			
Examples: Cabinets, portable AC, refrigerators…	**Examples:** Condensing units, Split-AC/HP…	**Examples:** Chillers, heat pumps…	**Examples:** Special designs

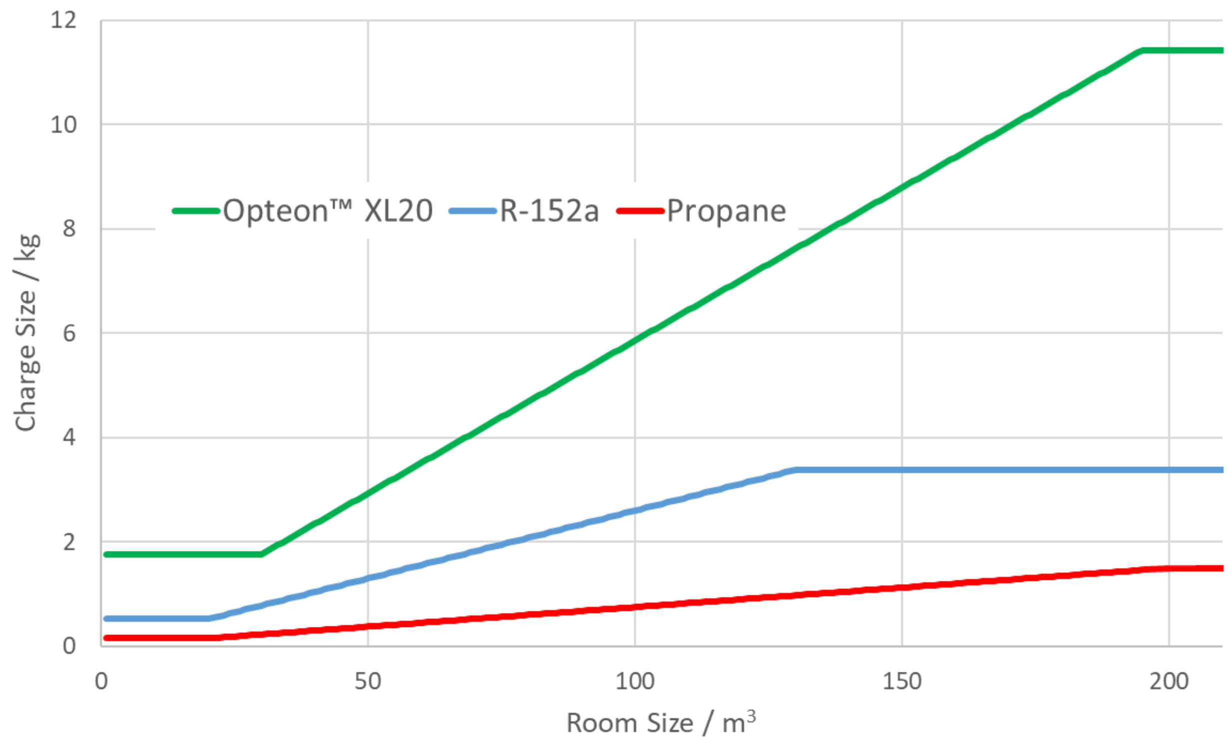


Other Applications Charge Size for Location Classes I and II With No Additional Protective Measures

Location class I and access categories *a*, *b*, and *c* (where the occupancy is >1 person/10 m^2) and location class II access category *a*, with no additional protective measures in place, have a maximum refrigerant charge of 20% of the LFL (kg/m^3) multiplied by the room volume up to a maximum m_2 x 1.5 (where m_2=26 m^3 x LFL kg/m^3). *Figure 4* shows maximum charge sizes for typical A2L, A2, and A3 refrigerants in these classes. Clearly, it can be seen that the charge sizes allowed for A2L refrigerants may be >10 times larger than for A3 refrigerants. As previously mentioned, in sealed (hermetic) systems, there is no requirement to reduce the charge beyond m_1 x 1.5 *(Table 3)*; but, for non-sealed systems, the room volume calculation still applies.

A practical example of a location class I access category *a* would be a food display cabinet in a small shop. If the room was 6 m x 5 m x 3.5 m (105 m^3), then a cabinet using Opteon™ XL20 would be able to use a maximum refrigerant charge of 6.15 kg compared to propane for which the maximum charge would be just 0.788 kg. Multiple systems may be in the same room, as each system is considered in isolation.

Figure 4: Maximum Charge Size Examples for A2L, A2, and A3 Refrigerants for Location Class I, Access Categories a, b, and c and Location Class II Access Category a



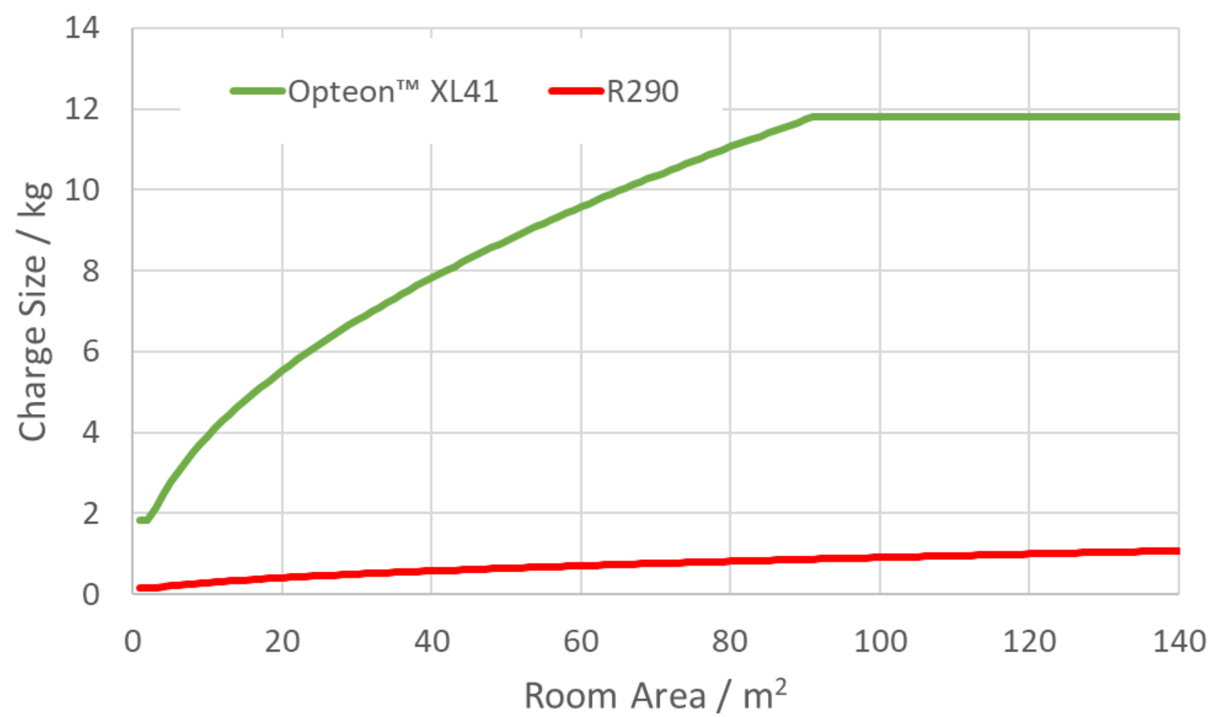
Location class II and access categories *b* and *c* (where the occupancy is >1 person/10 m^2) require the same charge size calculation as access category *a*, but allow an increased maximum charge up to 25 kg. If the access category is *c* and the occupancy level is <1 person/10 m^2, then for location class I, the maximum charge is increased up to 50 kg, and for location class II, there is no charge restriction, provided the machine room design criteria are compliant with EN 378-3:2016 4.2 or 4.3.

Human Comfort Charge Size for Location Classes I and II With No Additional Protective Measures

Within the Human Comfort application category, the maximum charge size calculation for fixed systems is the same for location classes I and II and access categories *a*, *b*, and *c*. This calculation, $m_{max} = 2.5 \times LFL^{5/4} \times h_0 \times A^{1/2}$, takes into account a height factor (h_0), which can be selected from floor location (0.6 m), wall-mounted (1.8 m), window-mounted (1.0 m), or ceiling-mounted (2.2 m) and is based on the room floor area (A). The maximum allowed charge is $1.5 \times m_2$.

Alternatively, the equation may be rearranged to allow the minimum allowable room floor area for a given refrigerant charge, i.e., $A_{min} = m^2/(2.5 \times LFL^{5/4} \times h_0)^2$. An example comparison of the achievable charge sizes for a ceiling-mounted Human Comfort system using typical A2L and A3 refrigerants is shown in *Figure 5*.

Figure 5: Maximum Charge Size Examples for A2L and A3 Refrigerants for "Ceiling-Mounted Human Comfort"



Within the Human Comfort application guidance in EN 378-1:2016 Annex C2.2, there is a special requirement for non-fixed, factory sealed, single package air conditioning systems or heat pumps with a charge greater than 4 x LFL (kg/m^3) but less than or equal to 8 x LFL (kg/m^3). For a refrigerant such as Opteon™ XL41, this would apply to charge sizes above 1.2 kg, up to 2.4 kg and may restrict the use of such systems in rooms with a floor area below 14.55 m^2.

Increased Charge Sizes Implementing Additional Protective Measures—Quantity Limit Minimum Ventilation (QLMV) and Quantity Limit Additional Ventilation (QLAV)

As previously mentioned, there are provisions within EN 378:2016 that will allow larger charge sizes to be used with A2L refrigerants in both Human Comfort and Other Applications, provided additional safety measures are put in place. The provisions are set out in EN 378-1:2016 Annex C.3 and require that:

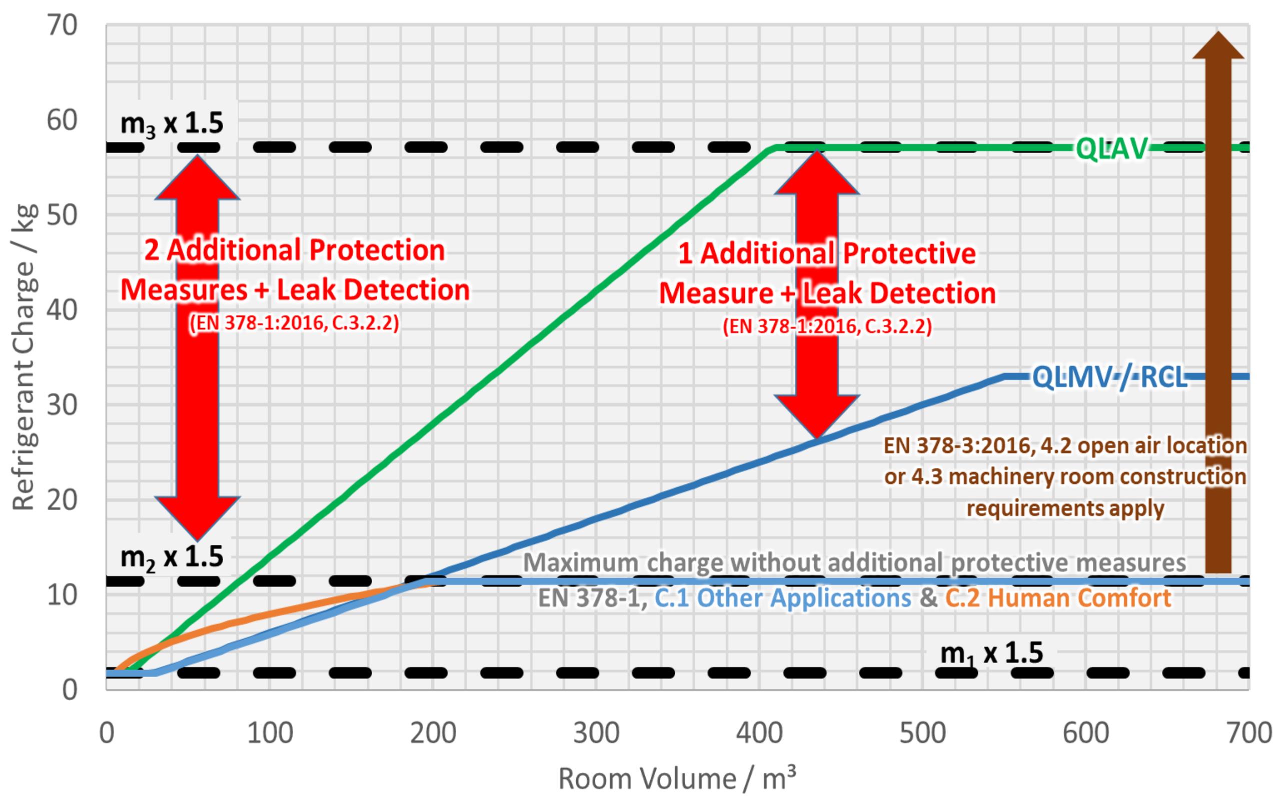
- The system is in location class II,
- The charge does not exceed 150 kg or m_3 x 1.5 (where m_3 = 130 m^3 x LFL kg/m^3),
- Rated cooling (heating) capacity of each of the indoor units is not more than 25% of the total cooling (heating) capacity of the outdoor system,
- Indoor unit has protection against ice damage and fan breakage,
- Only permanent joints are used within the occupied space (except for site-made joints directly connecting the indoor unit to the piping),
- Refrigerant pipes in the occupied space are protected against accidental damage from environmental factors (e.g., water, temperature, debris, etc.) or movement of system components or items around the system (e.g., vibration, moving furniture, etc.),
- Doors of the occupied space are not tight-fitting,
- Effect of flow down (to floors beneath the system) are mitigated with ventilation in those areas.

For the QLMV and QLAV calculations, the maximum room floor area that can be used is 250 m^2. If the charge quantity exceeds the QLMV value, then appropriate protective measures, such as additional ventilation (natural or mechanical), safety shut-off valves, or safety alarm in conjunction with a leak detection device, must be employed. In accordance with EN 378-1:2016 Annex C3.2.2, for rooms above ground, if the refrigerant charge is between the QLMV and QLAV values, at least

one of these measures must be implemented. If the charge size is above the QLAV value, at least two of these measures must be applied. As can be seen in *Figure 6*, applying the required additional protective measures results in maximum charges in excess of 50 kg.

In order to simplify the calculation process, a spreadsheet has been developed incorporating all of the various calculations. The calculations for Human Comfort or Other Applications are available on separate worksheets. Once the correct application worksheet is chosen, the user just needs to select the appropriate location class, access category, refrigerant of interest, input the room dimensions (a rectangular room is assumed; for other shapes, the room volume or floor area should be calculated and suitable dimensions input to give the same volume or floor area), and, if known, the estimated refrigerant charge for the installation. The maximum charge without additional protective measures (C.1 or C.2) is then calculated, as well as the QLMV and QLAV values (C.3). If the estimated required charge size is below the calculated maximum charge, the calculated charge will be shaded green; but, if the estimated charge is more than the calculated charge, the calculated charge will be shaded red. An example of a calculation for Other Applications is shown in *Figure 7*.

Figure 6: Example with Opteon™ XL20 Showing Maximum Refrigerant Charge Using QLAV Calculation (EN 378-1:2016, Annex C.3) Compared to No Additional Protective Measures Calculation (EN 378-1:2016, Annex C.1 or C.2)



Use of the calculator spreadsheet allows the appropriate guidance for charge size from EN 378:2016 to be assessed quickly and easily. It is possible to use charge sizes greater than those indicated within the standard, but the system designer/installer/user must be able to prove through the risk assessment process that the use of an increased charge presents an acceptable level of risk.

Figure 7: Example of the Maximum Refrigerant Charge Size Calculator for Other Applications Based on EN 378-1:2016

Opteon™ XL Refrigerant Charge Calculator

Enter the Location, Access Categories and Refrigerant using the drop down list. Type in the room dimensions and estimated refrigerant charge.
(Always refer to the full EN 378:2016 standard to ensure all the necessary requirements are fulfilled)

Location Classification: Class II

> Compressors in machinery room or open air
> If all compressors and pressure vessels are either located in a machinery room or in the open air then the requirements for a class II location shall apply unless the system complies with the requirements of class III. Coils and pipework including valves may be located in an occupied space.

Access Category: c

	Examples:
Rooms, parts of buildings, buildings where only authorized persons have access, who are acquainted with general and special safety precautions of the establishment and where manufacturing, processing or storage of material or products take place	Manufacturing facilities, e.g. for chemicals, food, beverage, ice, ice-cream, refineries, cold stores, dairies, abattoirs, non-public areas in supermarkets

Other Applications or Low Occupancy: Other Applications

Refrigerant: Opteon™ XL20 (R454C, GWP[1] = 148)

Room Dimensions / m

Height:	2.2 m	Length:	10 m
Width:	20 m	Room Volume:	440 m^3

Estimated Required Refrigerant Charge / kg: 25kg

Refrigerant Charge Limits / kg

EN 378 Appendix C1:	25.00kg
EN 378 Appendix C3 (QLMV):	26.40kg
EN 378 Appendix C3 (QLAV):	57.14kg

> Systems where the rated cooling (heating) capacity of the indoor unit is not more than 25 % of the total cooling (heating) capacity of the outdoor unit systems and where pipes serving equipment in the occupied space in question are not oversized relative to the capacity of that equipment, where the heat exchanger in the indoor unit and the control of the system are designed to prevent damage due to ice formation, where the refrigerant-containing parts of the indoor unit are protected against fan breakage or the fan is designed to prevent breakage, systems where only permanent joints are used in the occupied space in question except for site-made joints directly connecting the indoor unit to the piping,where the refrigerant-containing pipes in the occupied space in question are installed in such way that it is protected against accidental damage in accordance with EN 378-2:2016, 6.2.3.3.4 and EN 378-3:2016, 6.2, alternative provisions to ensure safety are provided in accordance with EN 378-1:2016, C.3.2.2 and C.3.2.3, doors of the occupied space are not tight-fitting and the effect of flow down is mitigated in accordance with C.3.2.4.
> If the value exceeds the QLMV, appropriate measures such as ventilation (natural or mechanical), safety shut-off valves and safety alarm, in conjunction with a gas detection device, see in EN 378-3:2016, Clauses 6, 8, 9 and 10. A safety alarm alone shall not be considered as an appropriate measure where occupants are restricted in their movement. (see EN 378-3:2016, 8.1) shall be taken.

1. GWP values are from Intergovernmental Panel for Climate Change (IPCC) Assessment Report 4 as specified in EU 517/2014 legislation.

Note: The information provided is intended only as a guide and should not be taken in isolation. All assessments should be made with reference to the full text contained within the current EN 378:2016 standard. Also the above calculations do not remove the need for a risk assessment before installing or using equipment utilising Opteon™ 2L Flammable refrigerants.

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Risk Assessment—Flammability Considerations

It has already been stated that compliance with EN 378:2016 does not remove the requirement for a risk assessment. Although often overlooked, it has always been a requirement for risk assessments to be performed for any equipment utilising refrigerants, irrelevant of the flammability classification. The use of flammable refrigerants obviously poses potential additional risks, and, therefore any standard risk assessment processes used for A1 rated refrigerants must be reviewed to ensure assessment of risks related to flammability are fully covered.

Within the European Union, the ATEX 137 Workplace Directive (1999/92/EC)[6] is the primary guidance for consideration. This directive will be implemented at a national level in each country and may have a different name, e.g., in the UK, the ATEX 137 Directive exists as the "The Dangerous Substances and Explosive Atmosphere Regulations (DSEAR)." Interestingly, the UK DSEAR Regulation requires a DSEAR (ATEX) risk assessment for any pressurised gas, whether it is flammable or not, which means the risk assessment process when using a mildly flammable refrigerant is fundamentally no different than using a non-flammable refrigerant (although using a mildly flammable refrigerant is likely to add some complexity to the process). It should be noted that in some countries additional national requirements may exist, and users should ensure these are also taken into account.

The fundamental principles of the risk assessment, with regards to formation of possible flammable atmospheres, are outlined in standard EN 60079-10-1:2015, which requires identification of:

- Possible sources of release,
- Rate, frequency, and duration of any release,
- Effectiveness of any ventilation,
- Zone type (flammable atmosphere is present continuously, occasionally, or not during normal operation),
- Extent (size) of the zone.

The primary forms of ignition sources to be considered for refrigeration applications are those producing energy in the form of heat, electricity, mechanical, and chemical, but a full list and description of potential ignition sources can be found in EN 1127-1:2012.

Individual risk assessments will be required at all stages of use, from design and manufacture, to the installation/decommissioning, maintenance, and normal usage stages. It is generally agreed that the highest risk occurs during installation, maintenance, or decommissioning. During these operations, it may be necessary to introduce additional temporary hazard zones and safety measures.

Once the zones have been defined, any ignition sources within the zone will need to be identified and removed or controls put in place to prevent an ignition event occurring should a flammable atmosphere occur.

As shown in *Table 2*, the flammability properties are significantly different from those of A3 refrigerants, such as propane. Many potential ignition sources that would cause an ignition with propane are not ignition sources for many A2L refrigerants. The results from testing[7] performed by the Air Conditioning, Heating & Refrigeration Institute (AHRI) are shown in *Table 6* and clearly show that many domestic electrical appliances and even friction sparks and smouldering cigarettes may not be considered as ignition sources when using A2L refrigerants. In fact, the cigarette was extinguished by the refrigerant within two minutes of being placed within the flammable refrigerant mixture.

Table 6: Results of Ignition Tests Using A2L Refrigerants at the Stoichiometric Mixture With Air (Flammable Atmosphere) from AHRI Report No. 8017

Potential Ignition Source	R-32	Opteon™ XL55	Opteon™ XL10
Hot wire	D	D	D
Safety match	D	D	L
Lighter flame insertion	D	L	L
Leak impinging on candle	L	N	L
Cigarette insertion	N	N	N
Barbecue lighter	N	N	N
Plug and receptacle	N	N	N
Light switch	N	N	N
Hand mixer	N	N	N
Cordless drill	N	N	N
Friction sparks	N	N	N
Hair dryer	N	N	N
Toaster	N	N	N
Hot plate insertion	N	N	N
Space heater insertion	N	N	N

Legend: **D** – Deflagration (flame propagated away from ignition source), **L** – Localised flame (no flame propagation), **N** – No refrigerant combustion

Summary

Since the publication of the first papers in 1974 that revealed the environmental effects of emissions of refrigerants to the atmosphere, the understanding of the effects of these emissions have led to the development of increasingly environmentally sustainable products, with international legislation encouraging users to move away from environmentally harmful products. The latest agreements addressing concerns on the contribution of refrigerant emissions to climate change have led to a pathway from using high GWP products, such as R-404A, to mildly flammable HFO-based long-term sustainable refrigerants, such as the Opteon™ XL Series via lower GWP non-flammable products such as Opteon™ XP40, which will eventually achieve >80% reduction in the CO_2 equivalent direct emissions.

The use of mildly flammable refrigerants is still new to the industry, but regulations and standards are changing and offer guidance on how to use these products safely with charge sizes, which can be in excess of 10 times the charge sizes considered "safe," when using highly flammable hydrocarbons in occupied spaces. This charge size flexibility is creating opportunities for equipment manufacturers and end users to move to sustainable low GWP options safely and cost effectively, while maintaining performance and using the same basic technology they've been used to handling. Applications from air conditioning and heat pumps, to small retail systems and multi-compressor commercial systems, are all being developed to take advantage of the enhanced properties of the Opteon™ XL Series refrigerants, and the Chemours technical team is ready and willing to assist with these developments.

References

1. Regulation (EU) No. 517/2014 of the European Parliament and the Council of 16 April 2014 on fluorinated greenhouse gases.

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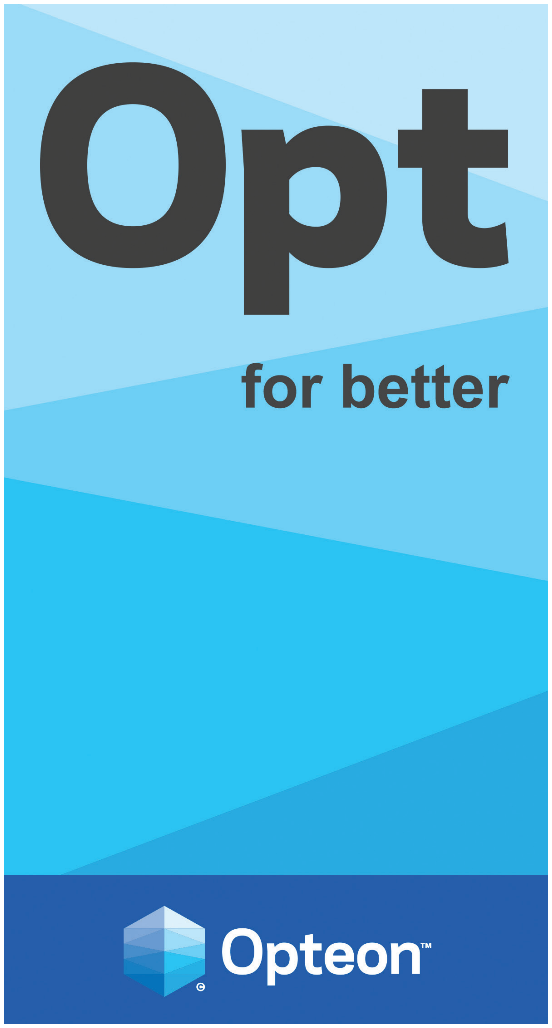
About Opteon™ Refrigerants



The Opteon™ refrigerants portfolio offers the optimal balance of environmental sustainability, performance, safety, and cost to help meet both regulations and business goals.

Specifically, in Europe, the very low GWP Opteon™ XL refrigerant portfolio supports the market transitions required by the F-Gas regulation and enables customers to select their optimal solution—considering performance, safety, sustainability, and total cost of ownership.

Businesses trust Opteon™ refrigerants because they offer:

Low GWP
Up to a 99% reduction compared to previous refrigerant generations.

Zero ODP
The HFO-based refrigerant family is non-ozone depleting.

Ease-of-Conversion
Minimizing conversion costs and downtime.

Excellent Capacity
A near match to many HCFC- and HFC-based technologies.

Energy Efficiency
Reduced energy use creates long-term savings over the system's life.

Long-Term Regulatory Compliance
HFO-based refrigerants can meet or exceed global and local regulatory standards.

Knowledgeable Experts
With more than 85 years of industry experience, Chemours refrigerant experts can help customers achieve both compliance and peak performance.

Visit Opteon.com/regulations for more information on HFC replacements or to contact our experts.

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