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TECHNICAL BULLETIN

TB/033: WORKING WITH LOWER FLAMMABILITY REFRIGERANTS

1: OBJECTIVE

The objective of this technical bulletin is to advise on the changes to working practices required when working with the new generation of A2L refrigerants replacing the higher GWP HFC gases that are currently the industry norm. A2L is a new safety classification from ASHRAE denoting lower flammability, sometimes referred to as "mildly flammable". They generally have a much lower GWP (Global Warming Potential) than current common HFC gases.

2: BACKGROUND

Refrigerant	GWP	Applications
R32	675	Small and light commercial AC split systems; next generation hybrid VRF possibility. Performance similar to R410A - average 5% efficiency improvements on like for like is reported.
R1234ze	7	Chillers and integral units. Capacity is lower than with R134a - not a "drop in" retrospective replacement gas.
R1234yf	4	Automotive AC replacement for R134a
Solstice L40X (R455A), Solstice L41y (R452B)	146 675	Honeywell replacements for R404A and R410A respectively.
XL20(R454C)/XL40(R454A), XL41(R454B)/XL55(R452B)	<700	Chemours replacements for R404A and R410A respectively.

Table 1

The fluorinated greenhouse gases regulation (EC517/2014), commonly referred to as the F Gas Regulation, has introduced a phase down of high GWP gases by limiting the amount of gas that can be placed on the market – that limit being expressed in terms of CO_2 tonnes equivalent. Table 1[1] gives an overview of the current A2L alternatives in use or under discussion with an indication of what sector of the market they are applied to.

The downside to lowering the GWP of a gas tends to be the increasing of flammability levels or other safety related issues. Many of the replacements for current standard HFCs are mildly flammable and have resulted in the new ASHRAE classification A2L – meaning that the gas is flammable but of a lower flammability level than a class 2 gas. In particular the lower flammability tend to be hard to ignite, and have a slow burning velocity of $\leq$ 10 cm/s under test conditions. As such, they are considered to be safe for use in approved systems and can be considered safe for general handling with certain provisos.

1 Adapted from table provided by Cool Concerns to A2L article in the ACR Journal September 2015

3: BEST PRACTICE

3.1 Installation

As long as standard good installation practice is observed then there should be no additional risks involved. "RAC80 Design Specification for DX Air Conditioning & Heat Pump Equipment" should be referred to, as well as earlier Technical Bulletin TB012: Jointing Methods which describe best practice to be observed while brazing copper pipes together.

The use of the inert OFN[2] when brazing not only prevents oxidization of the internal surface of the copper, it also displaces any residual refrigerant gas that may be in the pipework. In the case of an installation this should not be an issue, however best practice will guard against any inadvertent release of gas via a faulty or weeping stop valve allowing flammable gas to enter the pipe under test.

3.2 Service, maintenance and repair work

This is where more care needs to be taken when working with A2L systems. Refer to Technical Bulletins TB016: Safe de-brazing and TB023: Refrigerant Recovery for more information.

In particular, when recovering any A2L gas it is essential that a recovery machine marked as being suitable for A2L gases is used. Although the gases are rated "lower flammability" by ASHRAE standards, and are hard to ignite as we have discussed, they remain rated "flammable" under H&SE DSEAR[3] and the ADR[4] transport regulations guidelines for the UK. As such they are subject to more intrusive work planning and method requirements as well as for storing and transportation of the gas in bottles. Storage and transportation requirements are in line with what is required currently with acetylene and MAPP gas bottles[5].

Similarly, it is essential that only leak detectors and other electrical and electronic equipment that is rated as safe for use with A2L refrigerants are used where A2L gases are present. It is essential when attending a site for any repair work, or for routine servicing, that the technician ensures they are aware of what gas is in the system and treats the system as they would for a flammable gas, even if the system label does not state that a flammable gas has been used. As the availability of A2Ls becomes wider and the use more common, there is a chance that an A2L may be used even where it has not been identified.

TB016 highlights the dangers of de-brazing pipe joints and components without using an inert gas such as OFN. The inert gas not only prevents oxidization of the internal surface of the copper, it also purges any residual gas embedded in the refrigerant oil that will boil off when heated, creating a pressure rise that can be ejected at high pressure as the weld is melted. This can cause the oil and/or the gas to be ignited as they leave the joint being de-brazed causing injury to operatives and/or equipment.

2 Oxygen Free, or "dry", Nitrogen
3 Dangerous Substances and Explosive Atmosphere Regulations 2002, Health and Safety Executive www.hse.gov.uk
4 International Carriage of Dangerous Goods by Road
5 The exception to this is HFO1234ze(E) which is classed as non-flammable at 20°C

4: Planning – EN378 and Risk Assessment Method Statements (RAMS)

A number of additional considerations need to be taken when dealing with an installation or work involving an A2L refrigerant due to the H&SE DSEAR non recognition of A2L as a safety classification.

In particular, for a new installation, there needs to be a risk assessment carried out which reviews the application, refrigerant charge, location of components, and occupancy of any room containing refrigerant holding components. BSEN378 -2016: "Refrigerating Systems and heat pumps - Safety and environmental requirements" contains design information crucial to this risk assessment and management process and should always be referred to in the planning stage of an A2L installation. The standard is used for calculating the maximum permissible refrigerant charge in a system based on both toxicity and flammability. Whereas the earlier version of EN378 was fairly straight forward in dealing with flammable or non-flammable, there is now a more complicated design methodology to go through to calculate what maximum charge can be applied to a system if an A2L is used.

Room Size	R32 maximum charge (kgs)	
	Ceiling mounted	Wall mounted
3m by 3m	3.78	3.09
5m by 5m	6.30	5.15
10m by 10m	11.97	10.30

Table 2

Table 2 is a basic rule of thumb calculation based on an R32 ceiling or wall mounted system showing the maximum charge that can be applied in the system, including where only the refrigerant containing pipework passes through the area, if installed in an openly accessible area. Note that floor mounted, window, wall and ceiling mounted systems have different multiplying factors and the figures in the table will be different for other styles of indoor unit. The maximum charge permissible in the case of the larger room has been capped at 11.97kgs for the ceiling mounted system after calculating the various methodologies applicable and taking into account the capped amount of 11.97 rather than the calculated 12.6 kgs. Whereas with the wall mounted system the maximum permissible charge for that room calculates to 10.3 kgs – lower than the capped value, so the calculated amount applies.

More detail of this methodology can be found in the attached Appendix A – Practical Advice on using A1 and A2L refrigerants in Air Conditioning, Heat Pump and Refrigeration applications using EN378:2016 reproduced by kind permission of FETA[6].

This capped amount of charge is currently limiting the use of R32 to split systems as no VRF/VRV is able to work with such a small total charge at the moment. Some manufacturers are currently looking at options for using A2L refrigerants in VRF for the future including developing "hybrid" systems that incorporate low GWP HFCs in a primary flow circuit limited to the multi control box heat exchanger, with the branches to indoor units being served by water circuits for heating or cooling thereby removing the actual refrigerant from the occupied space and removing the barriers to use under EN378.

For service work there also needs to be a full risk assessment carried out. RAMS produced for any work involving an A2L should include specific reference to the nature of the gas involved and additional measures being carried out to reduce any risks involved in the work.

Lower flammability A2L refrigerants should never be retrofitted into a standard HFC system without full safety risk assessment being considered and the full extent of EN378 taken into account. Installations which may pass the requirements of EN378 for R410A, for example, will very possibly not meet the requirements for R32.

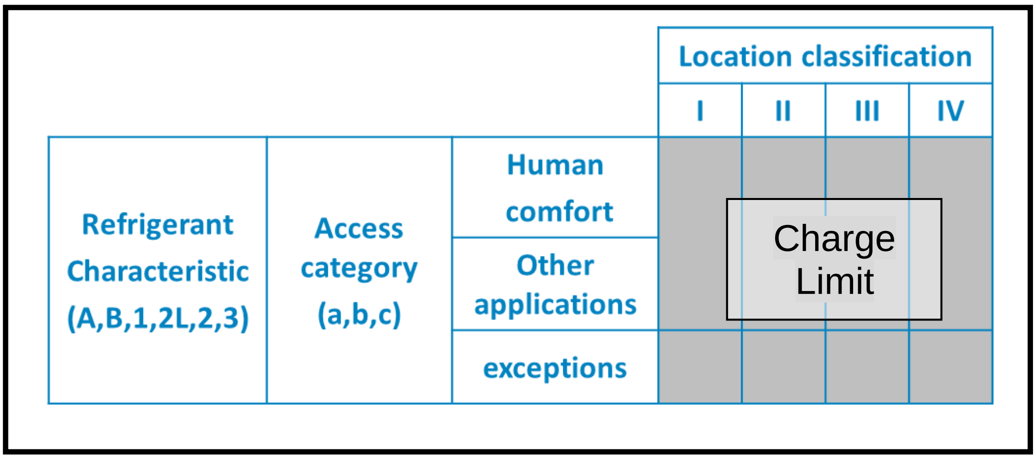
6 Federation of Environmental Trade Associations Ltd.

Appendix A - Practical Advice on using A1 and A2L refrigerants in Air Conditioning, Heat Pump and Refrigeration applications using EN378:2016

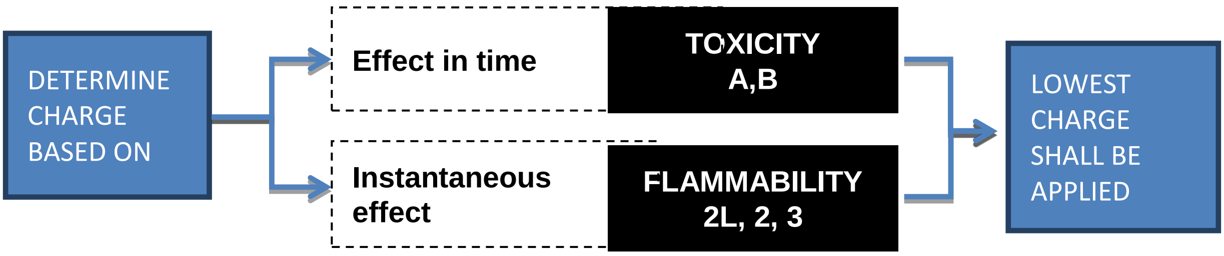
As mentioned previously, EN378:2016, now recognises the use of A2L refrigerants, and also changes the methodology for calculating charge limits based on three characteristics:

- Refrigerant properties
- Access categories
- Location classification

The table below gives an overview of the process.



It should be noted that Class 1 and 2 have charge limits, whereas Class 3 systems in general have no charge limitations except for refrigerants in flammability class 3. Machinery room requirements apply at all times. The process can be defined as in the diagram below:



Examples of this are:

Examples	Toxicity limit	Flammability limit*
R-717 (Ammonia)	0,00035 kg/m³	0,023 kg/m³
R-32	0,3 kg/m³	0,061 kg/m³

Charges are defined by
➔ Toxicity
➔ Flammability

EN378 also allows for the provision of leak detection and ventilation that are **Requirements for alternative provisions. This** brings into play the following terms; QMLV, QLAV, and RCL

QLMV: Quantity Limit with Minimum Ventilation in kg/m³
QLAV: Quantity Limit with Additional Ventilation in kg/m³
RCL: Refrigerant Concentration Limit in kg/m³

The standard now accepts that the maximum leakage into an occupied space is assumed to be not greater than a pinhole leak, and the maximum charge is calculated on that basis. This has enabled the allowable refrigerant charges to be calculated. The full methodology is stated in the standard so that the QLAV and QLMV can be calculated for all refrigerants. The table below states the figures for the most popular gases in use today.

Refrigerant	Allowable concentration (kg/m³) RCL	QLMV (kg/m³)	QLAV (kg/m³)
R-22	0.21	0.28	0.50 a
R-134a	0.21	0.28	0.58 a
R-407C	0.27	0.44	0.49 a
R-410A	0.39	0.42	0.42 a
R-744	0.072	0.074	0.18 b
R-32	0.061	0.063	0.15 c
R-1234yf	0.058	0.060	0.14 c
R-1234ze	0.061	0.063	0.15 c
a Based on ODL b Based on a volume fraction of 10 % c Based on 50 % LFL			

The table above is used where additional measures are required, for example when an indoor unit or piping passes through an occupied space and the whole gas charge was to escape into the space.

There are also further stipulations that take precedence:

- If the indoor unit is below 1.8 metres high a fan or ventilation system must be activated to prevent stagnation of the gas in the space, this can be started by a leak detection system. Pipe work must be securely mounted to prevent accidental damage occurring
- Ventilation and dilution transfer openings must have sufficient volume to prevent the QLMV limit from being exceeded. Extract fans must have a grille no higher than 0.2 metres above the floor level and can be continuously operated or switched on by a leak detection system. Transfer grills must be used at high and low levels and can be divided into more than one grille. Safety shut off valves may also be used but must be located to prevent an ingress of gas that would exceed the QLMV, which generally means close to the indoor unit or pipe work that is running through the enclosed area.
- Safety alarms must provide a visual and audible warning with the latter being at least 15 dB(A) louder than the ambient sound level.

<u>SYSTEM EXAMPLE</u>

A VRF/VRV system using R-410A in a hotel with bedrooms of 5m x 3m x 2.2m

As the refrigerant is designated A1, this example would use Table C.1 in EN378

Table C.1 — Charge limit requirements for refrigerating systems based on toxicity

Toxicity class	Access category		Location classification			
			I	II	III	IV
A	a		Toxicity limit × Room volume or see C.3		No charge restriction [a]	The charge requirements based on toxicity shall be assessed according to location I, II or III, depending on the location of the ventilated enclosure
	b	Upper floors without emergency exits or Below ground floor level	Toxicity limit × Room volume or see C.3	No charge restriction [a]		
		Other	No charge restriction [a]			
	c	Upper floors without emergency exits or Below ground floor level	Toxicity limit × Room volume or see C.3			
		Other	No charge restriction [a]			

Hotel rooms are designated as general access (a) and the location classification is designated as II. Hence, the maximum charge would be calculated as follows:

Room size = 5m x 3m x 2.2m

Room volume = 33m^3

RCL =0.39
QLAV =0.42
QLMV =0.42

Maximum charge at RCL = $33m^3$ x 0.39 kg/m^3 = 12.87 kg
Maximum charge at QLAV = $33m^3$ x 0.42 kg/m^3 = 13.86 kg
Maximum charge at QLMV = $33m^3$ x 0.42 kg/m^3 = 13.86 kg

[Note QLAV and QLMV for R-410A are the same]

If part of the system is below ground, the RCL room volume has to be used, and if any of the room volumes are exceeded, a leak detection system must be used.
It should be noted that for all other occupancy types b & c there are no charge restrictions unless the office space is below ground level

The calculations for A2L refrigerants are more complex, as there are more limitations due to the mild flammability properties of these gasses. The same process regarding charge limits is used, but there are differing limits depending on the location of indoor unit and access category as can be seen in the table below.

Table C.2 — Charge limit requirements for refrigerating systems based on flammability

Flammability class	Access category		Location classification I	II	III	IV
2L	a	Human comfort	According to C.2 and not more than m_2 [a] × 1,5 or According to C.3 and not more than m_3 [b] × 1,5			
		Other applications	20 % x LFL × Room volume and not more than m_2 [a] × 1,5 or According to C.3 and not more than m_3 [b] × 1,5			
	b	Human comfort	According to C.2 and not more than m_2 [a] × 1,5 or According to C.3 and not more than m_3 [b] × 1,5			
		Other applications	20 % × LFL × Room volume and not more than m_2 [a] × 1,5 or according to C.3 and not more than m_3 [b] × 1,5	20 % × LFL × Room volume and not more than 25 kg [c] or according to C.3 and not more than m_3 [b] × 1,5	No charge restriction [c]	Refrigerant charge not more than m_3 [b] × 1,5
	c	Human comfort	According to C.2 and not more than m_2 [a] × 1,5 or According to C.3 and not more than m_3 [b] × 1,5			
		Other applications	20 % × LFL × Room volume and not more than m_2 [a] × 1,5 or according to C.3 and not more than m_3 [b] × 1,5	20 % × LFL × Room volume and not more than 25 kg [c] or according to C.3 and not more than m_3 [b] × 1,5		
		< 1 person per 10 m^2	20 % × LFL × Room volume and not more than 50 kg [a] or according to C.3 and not	No charge restriction [c]		

The procedure for calculating the charge limit are broken down into 3 cap factors m_1,m_2, and m_3 these equate to

— m1 = 4 m^3 × LFL
— m2 = 26 m^3 × LFL
— m3 = 130 m^3 × LFL
Calculate formula C1 (A2L)

C1 - mmax= 2.5 × LFL 5/4 × h0 × A1/2

Mmax is the allowable maximum charge in a room in kg;
m is the refrigerant charge amount in the system in kg;
Amin is the required minimum room area in m^2;
A is the room area in m^2;
LFL is the Lower Flammable Limit in kg/m3, as defined in Annex E;
h0 is the height factor of the appliance:
— 0.6 for floor location;
— 1.8 for wall mounted;
— 1.0 for window mounted;
— 2.2 for ceiling mounted,
Where the LFL is in kg/m^3 from Annex E and the molecular mass of the refrigerant is greater than 42 g/mol.

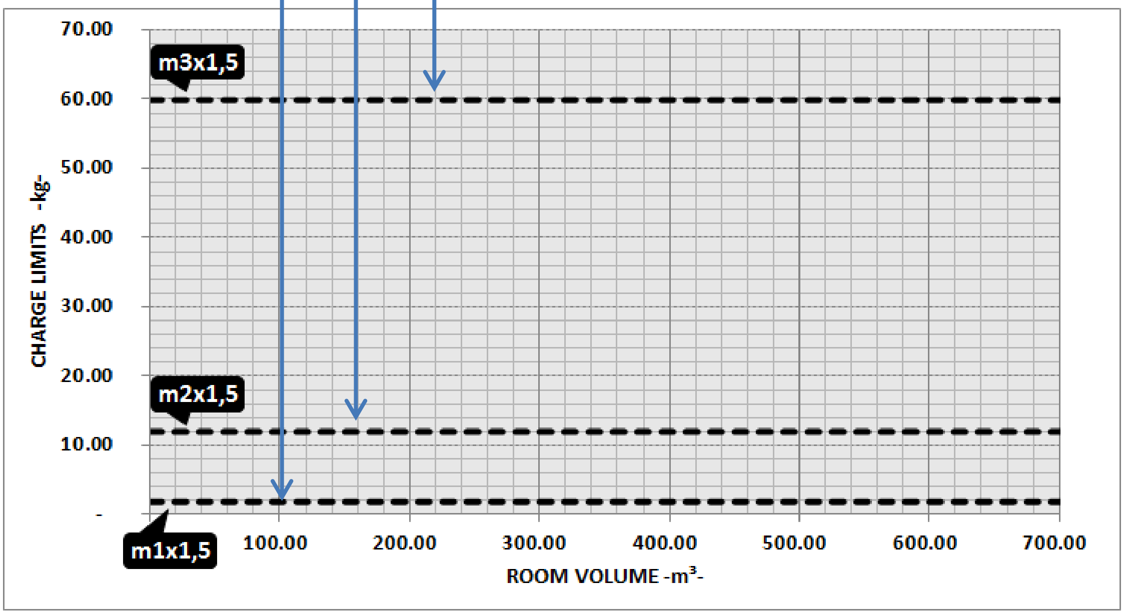
Procedure for calculating A2L charge limit

If mmax = less than M_1 = No restrictions
If mmax = more than M_1 but less than M_2
Then one additional measure is required plus leak detection

If mmax = more than M_2 but less than M_3
Two additional measures are required plus leak detection

If mmax = more than M_3 the system is not allowed

Charge limits example for 2L refrigerants: human comfort and other applications

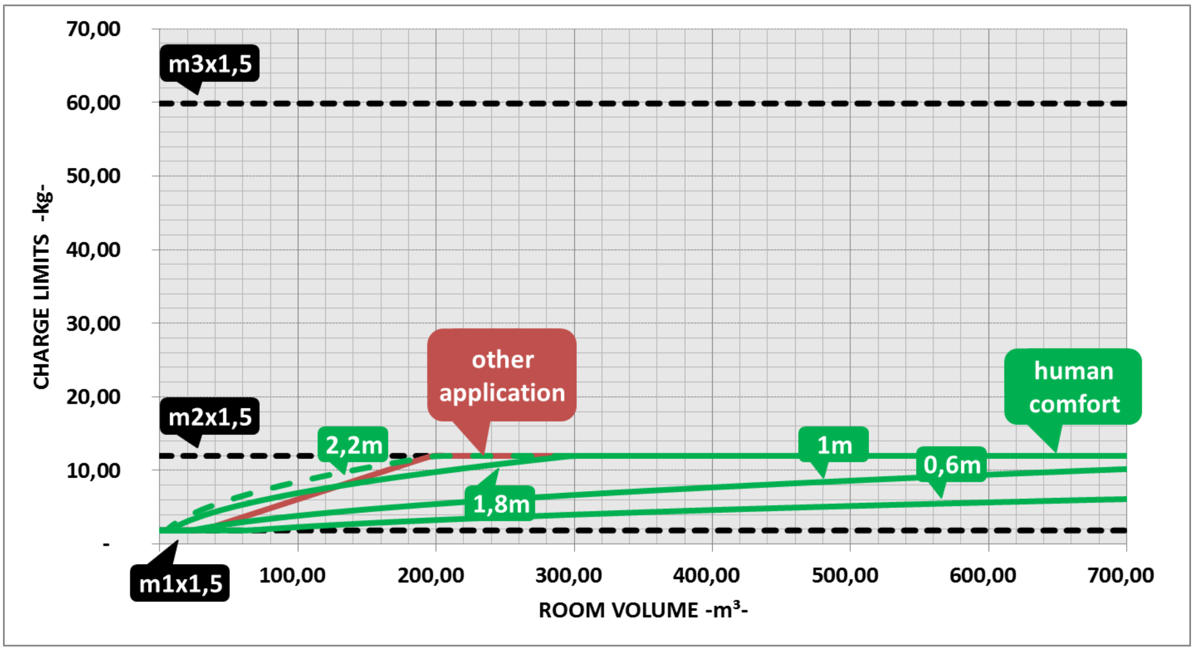


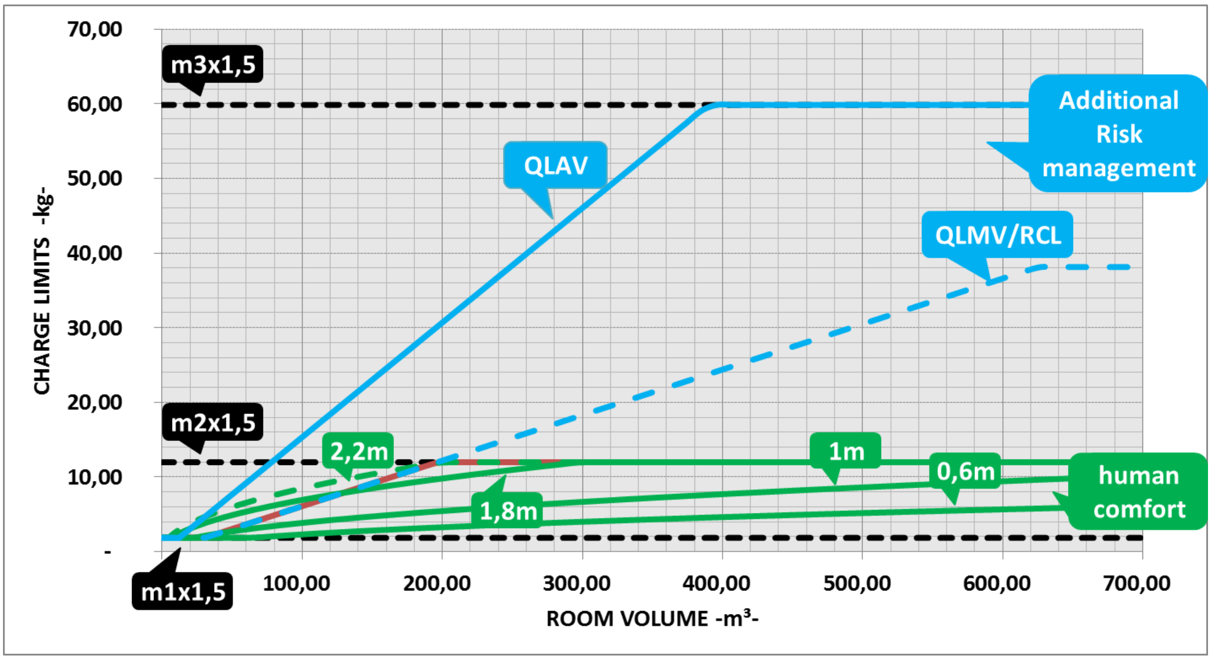
Calculation based on R1234yf and R32.

Addition measures =

1. Leak detection system
2. Ventilation to meet section C3 QLAV
3. Isolation valves are required

The calculation will vary depending on the unit location so to clarify the graph below gives an indication of charge limits that will one additional measure and the second graph uses the same calculation with two additional measures





To clarify the additional measures, we can use the following diagram to explain the different types of additional measures used across the standard

Occupied space requirements for indoor units:

- Below 1,8 m → fan circulation or mechanical ventilation, transfer opening
- General occupancy
- Secure & guard pipes against accidental rupture by moving furniture

Ventilation:

- To a place with sufficient room volume
- Do not consider natural ventilation to outside

Dilution transfer opening (natural ventilation)

- On high and low level.
- Shall have minimum opening area
- Lower level at least 0,2m above floor level

Mechanical ventilation:

- Required airflow
- Mechanical ventilation openings

Safety shut off valves

- Appropriate position
- Amount released shall be below QLMV (RCL for lowest underground level)
- Manufacturer to provide necessary data

Alarms

- Separate power supply
- Audibly, visibly
- Also warn at supervised location;

+ detectors

For other cooling systems such as chillers, the standard remains the same and there no restrictions other than chillers that are using A3 refrigerants and the limitations are as follows: -

Refrigerant class 3	System class III
a general occupancy	5kg (except below ground = 1kg)
b supervised occupancy	10kg (except below ground = 1kg)
c authorised occupancy	No restrictions (except below ground = 1kg)