Tech Guide
A2L Refrigerants:
Concept and Application Guide for Refrigeration Systems in the Scope of EN 378

July 2021
Version 2

Contents

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This handbook must not be distributed outside your company.

Introduction

This Guide covers the application of A2L refrigerants in refrigeration systems which are within the scope of EN 378[1]. It does not cover air conditioning and heat pump systems and it does not cover small (integral) systems which are within the scope of a product standard. It is not a complete design guide. The Guide takes a risk assessment based approach – the hazards of A2L refrigerants are identified and the methods of mitigating these hazards are covered, in this case by following the appropriate standard (EN 378).

There are two key considerations to ensure flammable refrigerant systems are safe in the event of a leak:

- Sources of ignition on or close to the refrigeration system cannot ignite leaked refrigerant. Leak simulation tests (area classification) are carried out to determine the extent of a flammable concentration in the event of a leak and whether measures such as ventilation or the use of non sparking electrical devices are required;

- Refrigerant which leaks into a room cannot build up and pose an explosion risk. Charge size is limited to meet this requirement.

Both considerations are covered in this Guide.

A2L refrigerants can be used in new systems which previously would have used HFCs such as R404A. Charge size is limited and for commercial refrigeration this generally means:

- Cold rooms cannot be run off packs or large condensing units but small, close coupled condensing units or sealed systems such as mono blocks can be used;

- Remote cabinets can be run from central plant but the charge size is typically limited to between 55 and 85 kg (dependent on the refrigerant). There are not usually any construction requirements or additional safety measures for larger shop floors, but there are for smaller shop floors and areas through which pipe work runs such as warehouses. This could be avoided if pipe work was routed outside, so location of plant should be carefully considered. For lower charge sizes (for example in condensing unit systems) there is less likelihood that additional measures are required but this should always be calculated for each application.

The LFL (lower flammability level) of the refrigerant determines the charge restriction so applying refrigerants with a higher LFL allows more refrigerant to be used. R455A has a significantly higher LFL than other A2L refrigerants, but it has a very high temperature glide (13K) so its application should be carefully considered.

Signposts are used in the right-hand margin of the Guide to point to the part of the relevant standard to which you should refer for full information

EN XXX
Part X
Clause X

[1] EN 378 Refrigerating systems and heat pumps. Safety and environmental requirements.

1 A2L Lower Flammability Classification

Refrigerants are classified within refrigeration standards according to their toxicity and flammability. The table below (Table 1, Safety classification) shows this classification:

Table 1, Safety classification

	Lower toxicity	**Higher toxicity**
Higher flammability	A3	B3
Flammable	A2	B2
Lower flammability	A2L	B2L
No flame propagation	A1	B1

The factors which determine the degree of flammability are shown below (Table 2, Flammability):

Table 2, Flammability

Safety classification	**LFL [a], % in air by volume**	**Heat of combustion, J/kg**	**Flame propagation**
3 **Higher flammability**	≤ 3.5	> 19,000	Exhibit flame propagation when tested at 60°C and 101.3 kPa
2L **Lower flammability**	> 3.5	≤ 19,000	Exhibit flame propagation when tested at 60°C and 101.3 kPa and have a maximum burning velocity of ≤ 10 cm/s when tested at 23°C and 101.3 kPa
1	No flame propagation when tested at 60°C and 101.3 kPa		

a: LFL is lower flammability level, see Appendix 3 for values.

Compared to A3 refrigerants such as hydrocarbons, A2L refrigerants require a greater concentration in air to be potentially flammable, as shown in Figure 1, Flammable range below, where the red area is the flammable range.

Figure 1, Flammable range

A2L refrigerants need more energy to ignite – a naked flame is a source of ignition, but it is unlikely (although not impossible) that an unsealed electrical switching device would be an ignition source.

A2L refrigerants are HFCs (see section 2 for more information) so if they are ignited hydrogen fluoride is produced. This forms hydrofluoric acid in contact with moisture and is extremely hazardous.

Legislation and non refrigeration standards

Degrees of flammability are differentiated in refrigeration standards but not in other standards and legislation. The differentiation in refrigeration standards allows maximum charge sizes for A2Ls to be greater than for highly flammable refrigerants. Other standards and regulations classify the A2L refrigerants as highly flammable and do not differentiate between these and A3 refrigerants such as R290 (propane). Therefore A2L refrigerants should be handled, stored and transported as other flammable substances such as hydrocarbons and acetylene.

ATEX 95[2] applies to the design of flammable refrigerant systems.

ATEX 137[3] / DSEAR[4] applies to the handling of flammable refrigerants. See Appendix 2 for more information.

The PED fluid group for most A2L refrigerants is 1, i.e. dangerous.

EN 378
Part 1
Annex E

[2] ATEX 95 equipment directive 94/9/EC, Equipment and protective systems intended for use in potentially explosive atmospheres

[3] ATEX 137 workplace directive 99/92/EC, Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres

[4] The Dangerous Substances and Explosive Atmospheres Regulations is the UK's implementation of the ATEX directive

2 A2L Refrigerants

The currently available A2L refrigerants are HFCs (hydro fluoro carbons), HFOs (hydro fluoro olefins) or blends which include these refrigerant types. The most commonly used are listed below (Table 3, A2L key information) with key information.

Table 3, A2L key information

Refrigerant	Type	GWP	BP at 0 bar g	Applications
R32	HFC	675	$-52^{O}C$	Current: split air conditioning Potential: VRV, VRF, refrigeration
R1234ze	HFO	7	$-19^{O}C$	Integral cabinets and chillers
R1234yf	HFO	4	$-26^{O}C$	Current: vehicle air conditioning Potential: all refrigeration
R454A (XL40)	HFC / HFO blend	238	$-48^{O}C$ to $-42^{O}C$	Cold rooms and small central plant
R454B (XL41)	HFC / HFO blend	466	$-51^{O}C$ to $-50^{O}C$	Air conditioning
R454C (XL20)	HFC / HFO blend	148	$-46^{O}C$ to $-38^{O}C$	Cold rooms and small central plant
R455A (L40X)	CO_2 / HFC / HFO blend	148	$-52^{O}C$ to $-39^{O}C$	Cold rooms and small central plant

Flammability data is provided in Appendix 2.

R32 is currently used in new split air conditioning systems instead of R410A. Its performance and operating conditions are similar to R410A.

HFOs are HFCs with a double carbon bond which has the effect of reducing the GWP but increasing the flammability. Because of their very low GWP they are exempt from most of the requirements of the F Gas regulation.

R1234ze is classed as non-flammable for transport and PED fluid classification but has flammable characteristics under certain conditions.

The blends listed have performance and operating conditions which are similar to R404A and are therefore used in similar systems, although the charge size is limited due to flammability as explained in later sections.

None of the A2L refrigerants can be used to replace non flammable refrigerants in existing systems.

3 Standards

Standards cover the design, application, installation and operation of RAC systems. Product or vertical standards apply to a specific product type (e.g. appliances or split AC systems). System or horizontal standards are general and can apply to a range of system types. Where there is a product standard for the system then this is the standard which should be followed, and the scope of all standards should be studied carefully to ensure the correct standard is applied. The standards which cover the application of A2L refrigerants are shown in the table below (Table 4, Standards). Always refer to the standard for full information.

Table 4, Standards

System type	Applicable standard
Cold room + condensing unit	EN 378
Central plant	EN 378
Chiller	EN 378
Split / multi split / VRV / VRF type systems	IEC 60335-2-40[5] which will be transposed into an EN standard (EN 60335-2-40)
Appliance	IEC 60335-2-89[6]. Revised to increase the charge size of A3s and include A2Ls. EN 378 for larger charge sizes.

[5] IEC 60335-2-40 Household and similar electrical appliances. Safety. Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers

[6] EN 60335-2-89 Household and similar electrical appliances. Safety. Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor

4 System Design and Charge Size Limitations

EN 378 covers systems which are not covered by product standards. Systems such as cold rooms and remote cabinets on condensing units or central plant are within the scope of EN 378.

System Design to Avoid Ignition

Flammable refrigerant systems should be designed and built so that leaked refrigerant cannot be ignited. This is achieved by one or more of the following methods:

EN 378 Part 2 Clause 6.2.14

- Ventilation to disperse leaking refrigerant so that the concentration at sources of ignition does not exceed 50% LFL;
- Removal of sources of ignition to outside the potentially flammable zone;
- Use of electrical devices which are not sources of ignition.

Leak simulation testing (area classification) is carried out to determine the extent of the potentially flammable zone in the event of a leak.

EN 378 Part 2 Annex I

Where ventilation is used as a method of avoiding ignition it must always be available at the required level or must be activated by a detector.

Electrical devices which comply with EN 60079-15 or EN 60079-7[7] are not sources of ignition. In addition, IEC 60335-2-40[8] Annex JJ provides information on allowable openings for relays and similar components to prevent ignition of A2L refrigerants. This standard's scope is air conditioning and heat pump systems, but the information in this Annex is relevant for other A2L systems. Appendix 7 provides further information.

EN 60335-2-40 Annex JJ

Components with a surface temperature of more than 100K below the auto ignition temperature of the refrigerant are not sources of ignition.

Appendix 4 provides further information about leak simulation testing.

Charge Size Restriction

Charge size is restricted so that, in the event of a leak, the concentration of A2L refrigerant in air is not dangerous. When calculating the maximum charge size all rooms through which refrigerant pipe work passes must be considered, not just the rooms where the evaporators and condensing unit / pack are.

Charge sizes are restricted for many applications, dependent on access and plant location. Some common examples are in Appendix 6. Larger charges are allowed compared to the

[7] EN 60079:15 Equipment protection by type of protection "n" & EN 60079:7 Equipment protection by increased safety "e"

[8] IEC 60335-2-40:2018 Household and similar electrical appliances – Safety – Part 2-40: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers

highly flammable hydrocarbon (A3) refrigerants, but in most applications charge sizes are lower than for non flammable (A1) refrigerants.

Note that the density of the A2L refrigerants varies, so compared to R404A the charge size will differ. Data for liquid density is included in Appendix 3.

The maximum charge size depends on various factors, including those listed in the table below (Table 5, Access and equipment location categories):

Table 5, Access and equipment location categories

Application	Access	Equipment location
Human comfort or Other applications	a. General b. Supervised c. Authorised	I All equipment in occupied space II Compressor and receiver in machine room or outside III All equipment in machine room or outside IV All equipment in ventilated enclosure

EN 378 Part 1 Clause 5

Refrigeration equipment in open air must be located to avoid leaked refrigerant flowing into a building or otherwise endangering people and property. If leaked refrigerant could stagnate, gas detection and ventilation is required. It may be necessary to carry out testing to determine the extent of a potentially flammable zone in the event of a leak.

EN 378 Part 3 Clause 4.2

Where refrigeration equipment is located in a machinery room, the room must meet the requirements for machinery rooms.

EN 378 Part 3 Clause 5

For A2L refrigerants Table C.2 in EN 278 part 1 specifies the charge limitation. It is summarised below (Table 6, Summary of EN 378-1, Table C.2). This table does not include the comfort cooling / heating applications, only the refrigeration applications (called “other applications” in the standard). It applies to all A2L systems except for sealed A2L systems with a charge size less than:

EN 378 Part 1 Annex C

m_1 x 1.5 kg = 4 x LFL x 1.5 kg (typically between 1.7 and 2.6 kg)

Sealed systems below this threshold can be located in any location without restriction. The definition of a sealed system is included in Appendix 1.

Values of m_1 for various A2L refrigerants are given in Appendix 3.

Table 6, Summary of EN 378-1, Table C.2

<table>
<tr><th rowspan="2">Access</th><th rowspan="2">Application</th><th colspan="4">Location</th></tr>
<tr><th>I</th><th>II</th><th>III</th><th>IV</th></tr>
<tr><td>a</td><td>Other applications</td><td colspan="2">20% x LFL x room volume
and
not more than m_2 x 1.5 kg
Or
Risk management
and
not more than m_3 x 1.5 kg</td><td rowspan="4">No charge restriction [b]</td><td rowspan="4">Not more than m_3 x 1.5</td></tr>
<tr><td>b</td><td>Other applications</td><td>As access category a</td><td>20% x LFL x room volume
and
not more 25 kg
Or
Risk management
and
not more than m_3 x 1.5 kg</td></tr>
<tr><td rowspan="2">c</td><td>Other applications</td><td>As access category a</td><td>As access category b</td></tr>
<tr><td>< 1 person per $10m^2$</td><td>20% x LFL x room volume
and
not more 50 kg
Or
Risk management
and
not more than m_3 x 1.5 kg</td><td>No charge restriction [b]</td></tr>
</table>

m_2 = 26 x LFL; m_2 x 1.5 is typically between 11 and 17 kg
m_3 = 130 x LFL; m_3 x 1.5 is typically between 54 and 84 kg

Values of m_2 and m_3 for various A2L refrigerants are given in Appendix 3.

a. Risk management allows the use of alternative provisions dependent on RCL (refrigerant concentration limit), QLMV (quantity limit with minimum ventilation) and QLAV (quantity limit with additional ventilation) values. See Appendix 1 for the full definitions of QLMV and QLAV and Appendix 3 for values. An outline of these provisions is included below, for full details refer to the standard.
b. Other restrictions apply for open air and machine room locations such as requirements for fixed leak detection in some applications. See the standard for full details.

Risk Management

EN 378
Part 1
Clause C.3

Risk management can only be used if the system meets the following construction requirements:

- The charge does not exceed 1.5 x m_3 (typically between 54 and 84 kg);
- Design, sizing and selection of field installed pipe and components are in accordance with the instructions of the manufacturer of the indoor units;
- The system location is class II, i.e. the compressor and receiver are outside or in a machinery room;
- The indoor unit heat exchanger and control of the system are designed to prevent damage due to ice formation;
- The indoor unit heat exchanger is protected from damage due to fan breakage;
- All joints within the cooled space are permanent except for site made joints to the indoor unit;
- The pipework inside the occupied space is protected from accidental damage;
- All doors to an occupied space are not tight fitting;
- Effect of flow down is mitigated (lower floor levels and basements).

Further measures are required dependent on the concentration of refrigerant in air in the event of a total refrigerant leak. This is found as follows:

$$Conc = \frac{m}{Vol}$$

m: refrigerant charge, kg
Vol: room volume, m^3

The refrigerant charge is the largest individual charge. The room volume is the volume of any room which refrigerant could leak into, e.g. cold room, shop floor, warehouse. If the floor area exceeds $250m^2$ then $250m^2$ should be used as the floor area. Calculations would need to be carried out for each separate room.

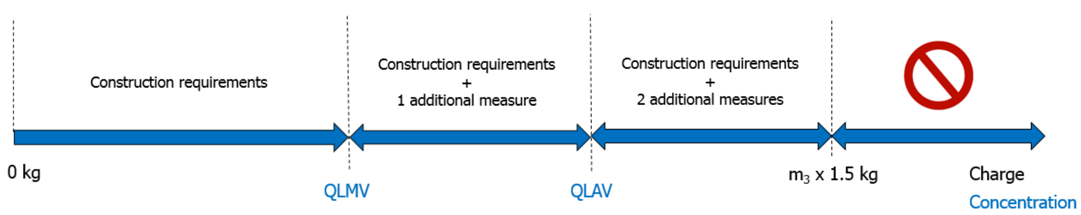

Figure 2, Requirement for additional measures

- If Conc ≤ QLMV no further measures are necessary.
- If Conc is between QLMV and QLAV one additional measure is required.
- If Conc > QLAV two additional measures are required.

QLMV is the quantity limit with minimal ventilation and QLAV is the quantity limit with additional ventilation. Further information is in Appendix 5 and values for a range of A2L refrigerants are in Appendix 3.
The additional measures are:

- Natural ventilation;
- Mechanical ventilation activated by a detector;
- Safety shut off valves activated by a detector;
- Alarm activated by a detector (not suitable as the sole measure if occupants are restricted in their movement).

Further information on these measures is provided in Appendix 5.

Below ground areas

The above applies to systems which are not on the lowest underground floor of the building. For systems on the lowest underground floor the concentration must not exceed QLAV and:

- If Conc ≤ QLMV one further measure is necessary.
- If Conc is between QLMV and QLAV two additional measures are required.

The measures are as above except that safety shut off valves are not an acceptable measure.

Flow down

Even if there is no refrigeration system on the lowest floor, mechanical ventilation is required if:

$$\frac{Largest\ refrigerant\ charge}{Total\ lowest\ floor\ volume} > QLMV$$

See Appendix 5 for information about the mechanical ventilation required.

Flow charts

Flow charts are included for some common applications for which the maximum charge size calculations and the requirement for additional measures can be a challenge to work out.

Before starting you need to know:

- Floor area, m^2, and height, m, of all rooms the pipe work routes through
- Refrigerant type
- Refrigerant LFL, kg/m^3
- Refrigerant charge, kg (remember that density effects the charge weight and that some of the A2L refrigerants have a different density to traditional refrigerants);
- Access category, typically a (general) or b (supervised)

- Equipment location, typically I (all equipment in occupied space) or II (compressor and machine room in machine room or outside).

Charge limit flow chart: small cold rooms

The flow chart below (Figure 3, Flow chart - cold rooms) is for small cold rooms (e.g. those used in retail outlets including supermarkets, convenience stores, pubs etc).

The flow chart should be followed for each cold room and any other room the pipe work routes through and for the relevant refrigerant charge size (or the greatest individual charge if there is more than one system).

It is possible that sealed systems are used for cold rooms (and indeed for small cold rooms this would enable a greater charge to be used). The definition of a sealed system is provided in Appendix 1. Some mono block type systems would be classified as sealed systems.

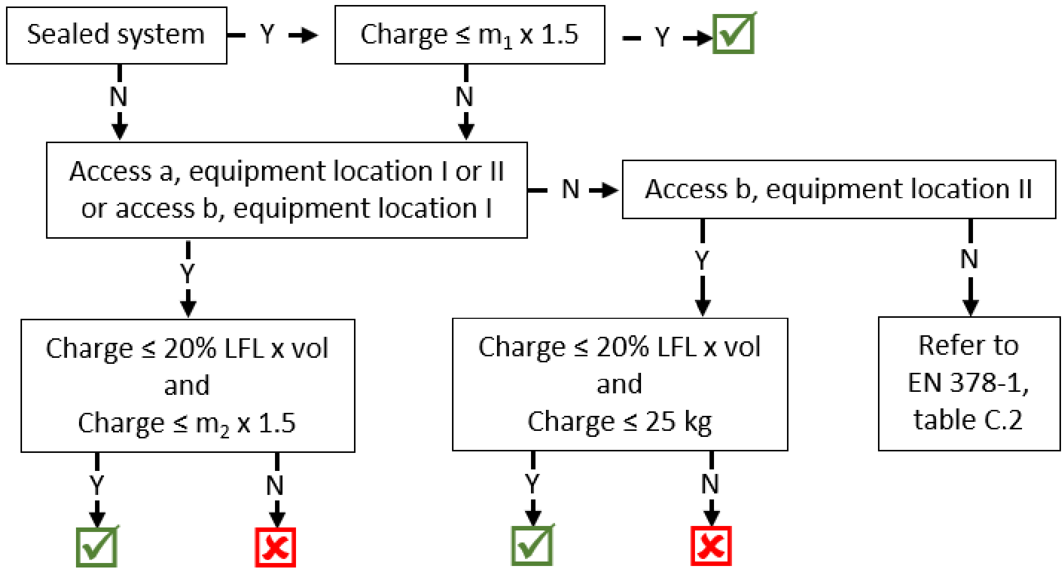

Figure 3, Flow chart - cold rooms

In the flow chart above the option of using risk management to enable larger charge sizes has not been included because for most cold rooms this is not practical (e.g. one of the measures is that doors must not be tight fitting).

Charge limit flow chart: retail system with cabinets and remote plant

The flow charts in Figure 4, Flow chart, DX remote refrigeration systems and Figure 5, Flow chart lowest underground floor are for retail systems which use remote DX plant - condensing units or central plant. It is assumed these are not sealed systems with a charge size less than m_1 x 1.5 kg.

You will also need to calculate the concentration in the event of a leak into an individual room:

$$\text{Conc} = \frac{\text{m}}{\text{Vol}}$$

Conc: concentration, kg/m^3
m: refrigerant charge, kg
Vol: volume of the room, m^3

The flow chart should be followed for each room and the relevant refrigerant charge size (or the greatest individual charge if more than one system provides cooling).

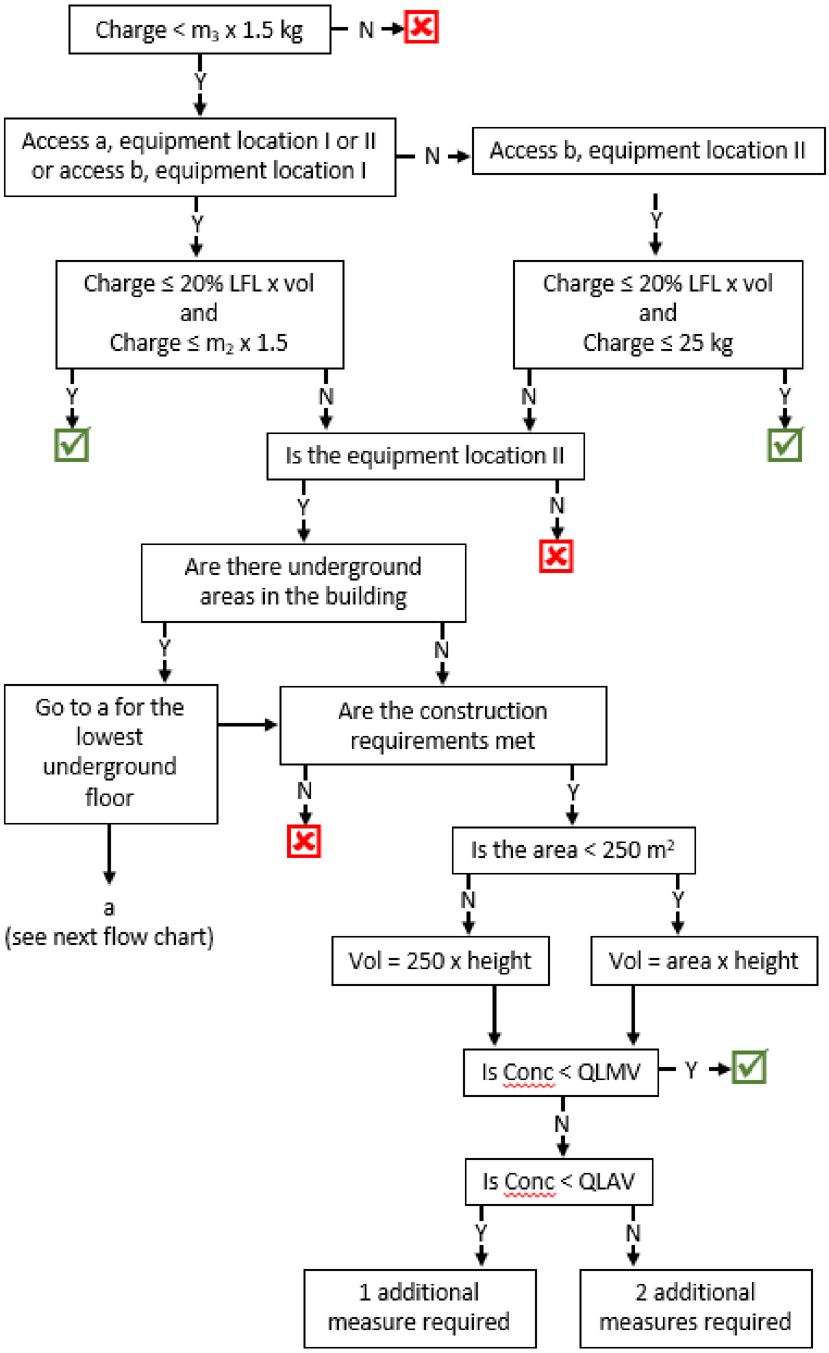

Figure 4, Flow chart, DX remote refrigeration systems

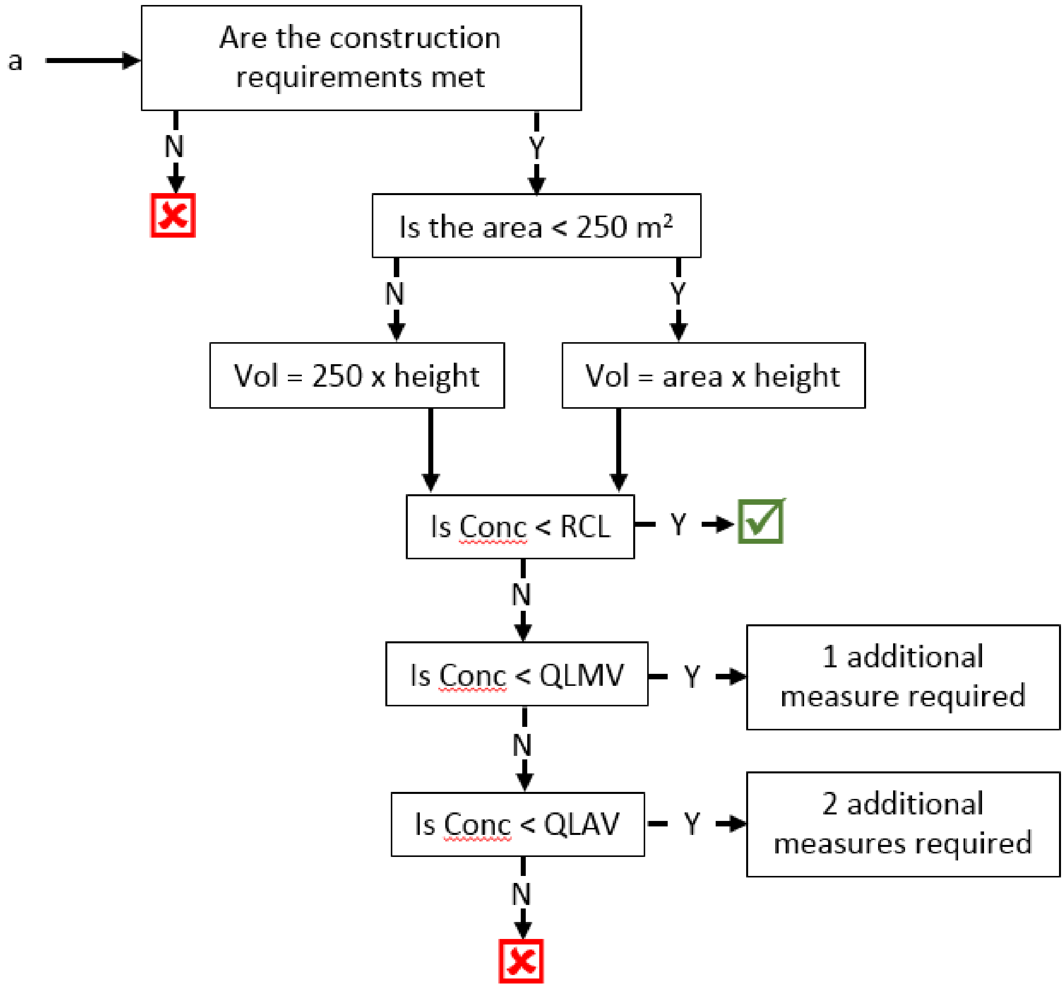

Figure 5, Flow chart lowest underground floor

Flow down - even if there is no refrigerating system on the lowest floor, mechanical ventilation should be provided if:

$$\frac{m}{Vol} > QLMV$$

m: largest individual system charge, kg
Vol: total volume of the lowest floor, m^3
QLMV: quantity limit with minimum ventilation, see Appendix 3 for values.

The ventilation should be as described in Appendix 5.

Appendix 1, Key Definitions

The definitions below are from EN 378 part 1.

Table 7, Definitions

Term	Definition
LFL **Lower Flammability Level**	Minimum concentration of refrigerant that is capable of propagating a flame within a homogenous mixture of refrigerant and air. Measured in kg/m^3.
RCL **Refrigerant Concentration Limit**	Maximum concentration of refrigerant, in air, in accordance with specified in C.3 of EN 378:2016-1 and established to reduce the risks of acute toxicity, asphyxiation and flammability hazards. Measured in kg/m^3.
QLMV **Quantity Limit with Minimum Ventilation**	Charge density of refrigerant that would result in a concentration equal to the RCL in a room of non air tight construction with a moderately severe refrigerant leak. Measured in kg/m^3.
QLAV **Quantity Limit with Additional Ventilation**	Charge density of refrigerant that when exceeded creates an instantaneous dangerous situation if the total charge leaked within the occupied space. Measured in kg/m^3.
Occupied space	Space in a building which is bounded by walls, floors and ceilings and which is occupied by persons for a significant period.
Machinery room	Enclosed room or space, with mechanical ventilation, sealed from public areas and not accessible to the public, which is intended to contain components of the refrigeration system.
Flow down	Flow of refrigerant down in a building to lower floors.
Sealed refrigeration system	System with all brazed or welded joints (or similar). Capped valves or service are allowed but must have a leak rate of less than 3 g / year at a pressure of at least 25% PS.

Appendix 2, Guidance on A2L Refrigerants and the Pressure Equipment (Safety) Regulation SI 2015-1105 (PE(S)R)

This guide covers the implications of using an A2L refrigerant on the PE(S)R category of a system. There is a short explanation at the end of this document of the PE(S)R terms used. See Cool Stuff 23 for more information about PE(S)R and the Pressure equipment Directive (PED).

A2L refrigerants are classed as group 1 (dangerous) fluids because of their flammability. A1 refrigerants (non-flammable) are classed as non-dangerous ("other") for the PE(S)R. This means that, compared to a system of the same size and with the same PS running on a non-flammable (A1) refrigerant, an A2L system could have a higher hazard category.

One of the implications of this is that condensing unit systems which are PE(S)R category I with an A1 refrigerant are now likely to be PE(S)R category II or higher with an A2L refrigerant. A category I system can be self-certified but a category II system (or above) must be assessed by an Approved Body.

Example of PE(S)R Hazard Classification

The example in the table below compares a condensing unit system operating on R448A, an A1 refrigerant, with the same system running on R454C, an A2L refrigerant. The system has a 3 litre liquid receiver.

Refrigerant	Safety class	PS, bar g (at 55^{o}C)	PE(S)R category of 1 1/8" liquid line	PE(S)R category of a 7 litre receiver	PE(S)R category of whole system	Compliance with PE(S)R
R448A	A1	25.5	SEP	I	I	Self certification and UKCA marking is required
R454C	A2L	23.1	I	II	II	Approved body is required to check design and technical information and witness a proportion of strength pressure tests

In the example above for the A2L (R454C) system brazers would need an industry standard brazer qualification. However, it is possible on some larger A2L systems that pipe joints will fall into PE(S)R category II or higher, in which case brazers would need to be approved by an approved body.

Explanation of Terms

PE(S)R (hazard) category

The PE(S)R category of a system usually depends on:

- Receiver size or in some case the hermetic compressor free volume;
- PS;
- Fluid group (toxicity and / or flammability of the refrigerant).

There are five categories – SEP to cat IV. SEP and cat I systems are certificated by the manufacturer / installer, cat II, III and IV system must be assessed by an approved body. The requirements for compliance are similar for all categories although the involvement of the approved body increases with PE(S)R category. Note – SEP is sound engineering practice.

PS

System design pressure, also called the maximum allowable pressure – see CS21 for an explanation of PS.

Approved body

An approved body is a third party independent organisation that is accredited by the UK Accreditation Service, UKAS (in the UK) to carry out conformity assessments, in this case for the PE(S)R.

Appendix 3, LFL and Related Information

Table 8, LFL and related information

Refrig.	LFL kg/m^3	m_1 kg/m^3	m_2 kg/m^3	m_3 kg/m^3	RCL kg/m^3	QLMV kg/m^3	QLAV kg/m^3	Auto ignition temp	Burning velocity cm/s
R32	0.307	1.228	7.982	39.91	0.061	0.063	0.15	648^{O}C	6.7
R1234ze	0.303	1.212	7.878	39.39	0.061	0.063	0.14	368^{O}C	0
R1234yf	0.289	1.156	7.514	37.57	0.058	0.060	0.14	405^{O}C	1.5
R454A [a] (XL40)	0.278	1.112	7.228	36.14	0.056	0.058	0.14	457^{O}C	2.4
R454B [a] (XL41)	0.297	1.188	7.722	38.61	0.059	0.061	0.15	ND	5.2
R454C [a] (XL20)	0.293	1.172	7.618	38.09	0.059	0.061	0.15	444^{O}C	1.6
R455A [a] (L40X)	0.431	1.724	11.206	56.03	0.086	0.092	0.22	473-477	<1.5

ND: not determined.

m_1 = 4 x LFL
m_2 = 26 x LFL
m_3 = 130 x LFL

a, LFL values are from a provisional update to EN 378, QLMV and QLAV values are estimated from LFL, RCL and molecular mass.

The RCL value is the same as the practical limit listed in EN 378 and is approximately 20% LFL. The QLAV is approximately 50% LFL.

Table 9, Liquid density

Refrig.	Liquid density compared to R404A
R32	90%
R1234ze	120%
R1234yf	105%
R454A	95%
R454B	93%
R454C	95%
R455A	105%

The density figures are from multiple sources and are approximate. They should be used as a guide only. For example, the R454A charge weight would be approximately 95% that of R404A in the same size of system.

Appendix 4, Leak Simulation Testing

Introduction

When a compression type appliance / system which uses a flammable refrigerant is designed and constructed it should be done so considering accumulation and stagnation of refrigerant leaking from the system. Where possible the appliance should be designed to minimise these risks by:

1. Using components with minimum leak potential – EN 16084[9];
2. Using as few joints as possible;
3. Removing all non-permanent joints where possible;
4. Removing all sources of ignition where possible;
5. Using electrical components conforming to EN 60079-15[10] where possible;
6. Ensuring good natural ventilation;
7. Ensuring adequate mechanical ventilation.

If the finished design has any potential for refrigerant to accumulate or stagnate in areas where there are potential sources of ignition present, compliance with the standards is checked using a simulated leak and measuring the peak concentration in terms of a % of LFL at sources of ignition identified.

Procedure for leak simulation of A3 refrigerants according to: EN 378-2:2016[11] Annex I (informative). The procedure documented below applies to area classification of potentially flammable zones e.g. around the condensing unit.

Equipment Required

The equipment listed below by type is not prescriptive but is recommended:

- Refrigerant representative of appliance design e.g. R290 Propane;
- Calibrated refrigerant detector capable of displaying % LFL with a T_{90} sensor response time of less than 20 seconds;
- Method of regulating prescribed refrigerant release to point of leakage e.g. hydraulic needle valve or capillary tube;
- Accurate scales ± 1g resolution;
- Stop watch;
- Results recording sheets.

[9] EN 16084:2011 Refrigerating systems and heat pumps. Qualification of tightness of components and joints

[10] EN 60079-15:2010 Explosive atmospheres. Equipment protection by type of protection "n"

[11] This procedure is taken from EN 378-2:2016 Annex I. A defined leak detector response time has been added

Testing Environment

1. The test is performed in a draught free location.
2. The equipment / system shall be arranged as intended for its installation and according to the installation manual. Where there are various possibilities for the installation, the arrangement that gives the most unfavourable result shall be used.
3. The appliance is switched off or operated normally, whichever gives the most unfavourable results.
4. If the appliance is to be operated during the test, gas injection should start at the same time the unit is switched on.
5. If a part of the system has a minimum room size associated with it according to EN 378 Part 1, the test is carried out in a room of that size within ±20%.
6. Consideration should be given to leaked refrigerant during testing. The test area should be monitored and free from sources of ignition. Following testing or between tests the area should be well ventilated to disperse any leaked refrigerant. A second detector should be used to continually monitor background levels.

Leakage Simulation

1. For joints and components within the scope of EN 16084 the leak rate shall not be less than 1g/s ±5%. For all other cases the mass flow rates shall not be less than 3g/s ±5%. The refrigerant shall be released in the vapour phase and a capillary or needle valve can be used to control the flow.
2. The total mass of the released refrigerant shall not be less than the charge of the refrigeration system or until the concentrations have not increased or changed by more than ±10% of the mean value within three minutes.
3. The refrigerant shall be released at a pressure of at least 0.25 PS of the applicable part of the system and not less than 2 bar.
4. The refrigerant is released in the direction that results in the highest concentration at the source of ignition being tested. Typically the release points would be brazed joints.
5. The concentration of refrigerant in air (% of LFL[12]) should be measured at the electrical components considered to be a source of ignition every 5 seconds.
6. The % LFL shall not exceed 50% at any point during the test. ≥50% LFL represents a potentially flammable environment (Zone) and the potential source of ignition needs to be treated appropriately.
7. The test is performed twice and is repeated a third time if one of the tests gives more than 40% of the LFL

The above leakage simulation should be repeated for all potential sources of ignition and leakage points identified. The orientation of the leak source should not be such to either bias the test results in the positive or negative and should represent a realistic profile of a leak at that point of the system.

[12] LFL – Lower Flammability Level (% of LFL from 0 to 100%) 100% representing the LFL of the refrigerant.

Appendix 5, Additional Measures

This appendix provides more information about the additional measures which are required as outlined in EN 378-1:2016 C.3.2. Key points are listed below, but you should refer to the standard for full information.

A2L Gas Detector

A detector is required to activate the safety measure(s) or to warn if a safety measure such as natural ventilation has failed. The detector must:

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- Be located where refrigerant concentrates in the event of a leak, e.g. under the evaporator in a cold room;
- Continuously monitor;
- Trigger at or below 25% LFL and continue to operate while the concentration exceeds this level;
- Have a response time of 30 s or less at 1.6 x the trigger concentration;
- Alarm in the event it fails;
- Be installed so that it can be checked, repaired and maintained;
- Be protected from damage;
- Be correctly commissioned and have an appropriate maintenance regime.

An oxygen deprivation detector must not be used.

Measures

The additional safety measures allowed are:

- Ventilation;
- Safety shut off valves;
- Alarm.

The key points for each of these measures is listed below.

Ventilation

Ventilation must be to outside, or to an indoor space large enough so that the concentration does not exceed QLMV, assuming equal dispersion in both areas.

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Clause 6.3

Ventilation – natural

Natural ventilation to outside is not considered.

To achieve natural ventilation to an adjacent area, dilution transfer openings are required. The total area should be as follows:

$$A = \frac{0.0032 \; x \; m}{QLMV \; x \; Vol}$$

A: total opening area, m^2
m: refrigerant charge, kg
QLMV: quantity limit with minimum ventilation, kg/m^3, see Appendix 3 for values
Vol: volume of room, m^3

There should be at least two openings, one at ground level and one at high level. The latter is not required if there is a false ceiling with no walls between rooms above ceiling level.

The height of the openings is shown below. They do not need to be adjacent to a door, the door is shown for height reference.

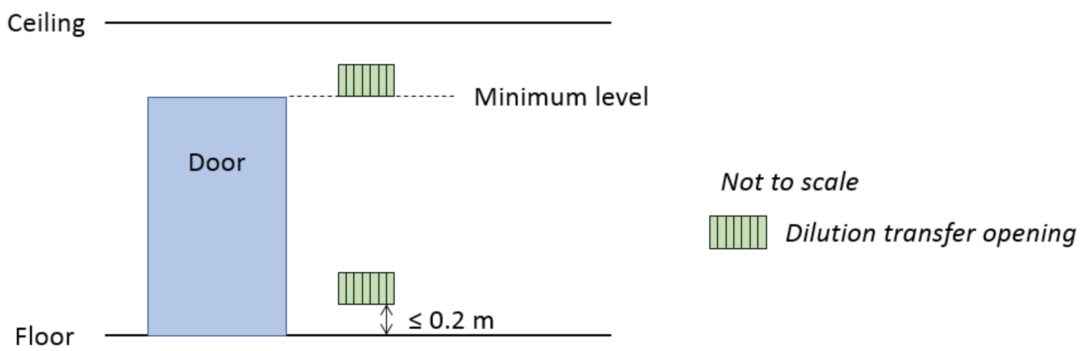

Figure 6, Position of openings

Ventilation – mechanical

The minimum air flow required for mechanical ventilation is as follows:

$$Q = \frac{10}{RCL}$$

Q: minimum required air flow, m^3/h
RCL: Refrigerant concentration limit, kg/m^3, see Appendix 3 for values

The lower edge of the mechanical exhaust ventilation opening should be as shown for the lower opening in Figure 6, Position of openings. In addition to the opening for extract, there should be openings into the room of the same size.

The mechanical ventilation can be operated continuously or activated by the detector.

It is strongly recommended that the openings are located where they cannot be blocked.

Safety shut off valves

EN 378
Part 3
Clause 6.4

Safety vales are used to shut off the flow of refrigerant into pipe work in the occupied space and therefore limit the potential for further leakage into that space.

The safety shut off valve should be positioned in the refrigeration system so it does not allow a leak which would result in a concentration above QLMV (or the RCL for the lowest underground floor). The detector sensor response time should be taken into account when calculating the amount of leakage. The valve should be positioned outside the occupied space.

The valve must close in the event of power failure.

Alarm

EN 378
Part 3
Clause 8

The alarm must:

- Alert an authorised person to take appropriate action;
- Be audible, e.g. a buzzer at least 15 dB(A) above background noise levels;
- Be visible, e.g. a flashing lamp;
- Have a power supply which is independent of mechanical ventilation and the refrigeration systems is it protecting (back up batteries can be used).

For machine rooms the warning should be inside the machine room and outside it in a supervised area.

For occupied spaces the warning should be at least inside the occupied space.

For access category a areas the warning should be inside the occupied space and outside it in a supervised area.

An alarm is not sufficient as the only measure if occupants are restricted in their movement.

Appendix 6, Examples of Charge Limitations

This appendix includes examples of charge limitations for a range of typical applications. You should refer to the standard for full information.

Example 1: Retail cold room

It is assumed that the:

- Access category is a (general access) or b (supervised access);
- Equipment location is I (in the occupied space) or II (compressors and receivers outside or in a machinery room);
- System is not a sealed system (see Appendix 1 for the definition of a sealed system).

This is representative of typical retail cold rooms.

The maximum allowable charge (m) for these cold rooms is summarised below:

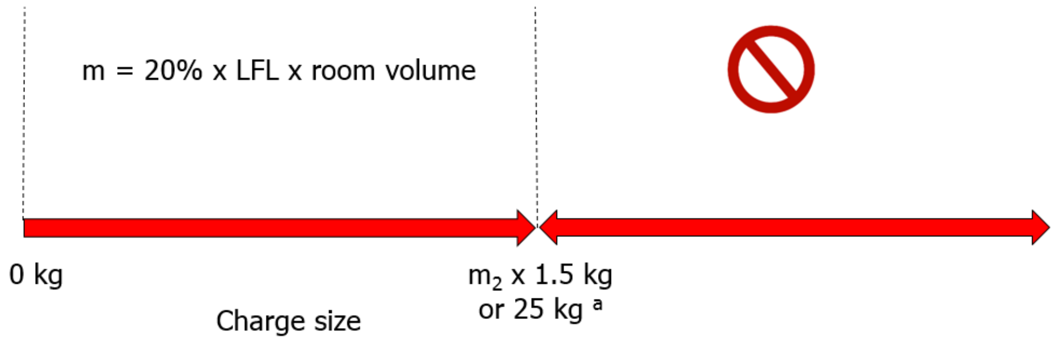

Figure 7, Example, retail cold room

a The cap of 25 kg applies to access category b and equipment location II, otherwise the cap is m_2 x 1.5 kg.

This application cannot use the risk management construction requirements to exceed the threshold m_2 x 1.5 kg or 25 kg because one of the requirements is that all doors to an occupied space must not be tight fitting. This is not viable for a cold room with doors.

Examples of the maximum charge size for a range of typical retail cold room sizes are given below:

Table 10, Maximum charge for a range of retail cold rooms

Cold room, m			Maximum charge, kg (20% LFL x vol)					
Width	Length	Height	R32	R1234ze	R1234yf	R454A	R454C	R455A
1.3	1.7	2.1	0.28	0.28	0.27	0.26	0.27	0.40
3	3	2.1	1.16	1.15	1.09	1.05	1.11	1.63
5	6	2.1	3.87	3.82	3.64	3.50	3.69	5.43

The standard restricts charge size significantly in retail cold rooms to the extent that they cannot be run from a pack. The practical option would be individual close coupled condensing units or monoblock systems. If the condensing unit is located inside, then the volume of the room in which it is located also needs to be checked for maximum charge size (although it is unlikely that this room volume would be small enough to restrict the charge lower than the cold room).

Greater charge sizes may be allowed for cold rooms in non retail applications as these are generally larger and / or fall into other access categories, refer to EN 378 for full information.

Example 2: Retail cold room using a sealed refrigeration system

In this example the assumptions are the same as example 1, but in addition it is assumed this is a sealed refrigeration system (see Appendix 1 for the definition of a sealed system). A mono block system could meet the requirements of a sealed system.

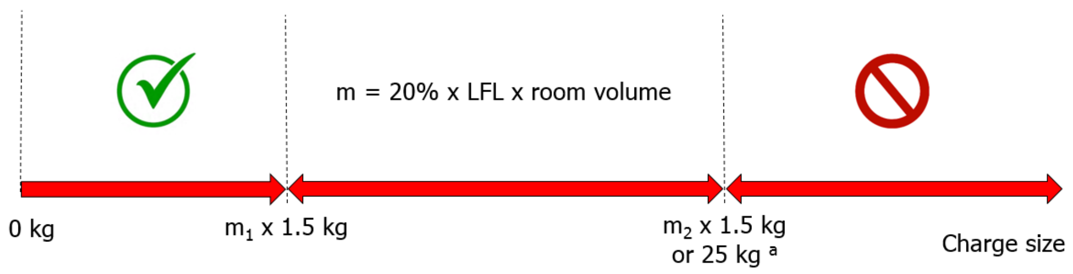

Figure 8, Example, retail cold room with a sealed refrigeration system

Up to a charge size of m_1 x 1.5 kg (e.g. 1.67 kg for R454A) the room volume is not relevant, above that charge size the charge is limited by room volume as in example 1.

As for example 1, this application cannot use the risk management to exceed m_2 x 1.5 kg.

Examples of the maximum charge size for the same range of cold room sizes is given below:

Table 11, Maximum charge for a range of retail cold rooms with a sealed refrigeration system

Cold room, m			Maximum charge, kg (1.5 x m_1)					
Width	Length	Height	R32	R1234ze	R1234yf	R454A	R454C	R455A
1.3	1.7	2.1	1.84	1.82	1.73	1.67	1.76	2.59
3	3	2.1	1.84	1.82	1.73	1.67	1.76	2.59
5	6	2.1	3.87	3.82	3.64	3.50	3.69	5.43

For the smaller two rooms sizes in the table above m_1 x 1.5 kg is the greater for all refrigerants so that is the applicable charge restriction.

Example 3: Remote retail cabinets on a pack or condensing unit

It is assumed that the

- R454A is used (LFL = 0.278 kg/m^3);
- Access category is a (general access)
- Equipment location is II (compressors and receivers outside or in a machinery room) and that there are no below ground areas;
- System is not a sealed system (see Appendix 1 for the definition of a sealed system);
- The pipe work passes through the warehouse;
- Shop floor 275 m^2 x 2.8 m high;
- Warehouse 52 m^2 x 2.8 m high.

For R454A:

m_2 x 1.5 = 26 x 0.278 x 1.5 = 10.8 kg
m_3 x 1.5 = 130 x 0.278 x 1.5 = 54.2 kg

The table below (Table 12, Maximum charge for shop floor and warehouse) shows the maximum charge sizes based on volume for each of the rooms.

Table 12, Maximum charge for shop floor and warehouse

Room	Area, m^2	Height, m	Volume, m^3	Max charge, kg
Shop floor	275	2.8	770	0.2 x 0.278 x 770 = 42.8 kg
Warehouse	52	2.8	145.6	0.2 x 0.278 x 145.6 = 8.1 kg

This example is considered with two different system options - condensing units (which would have a lower individual charge) and a multi compressor pack.

Example 3.1, Condensing units, 10 kg largest individual charge

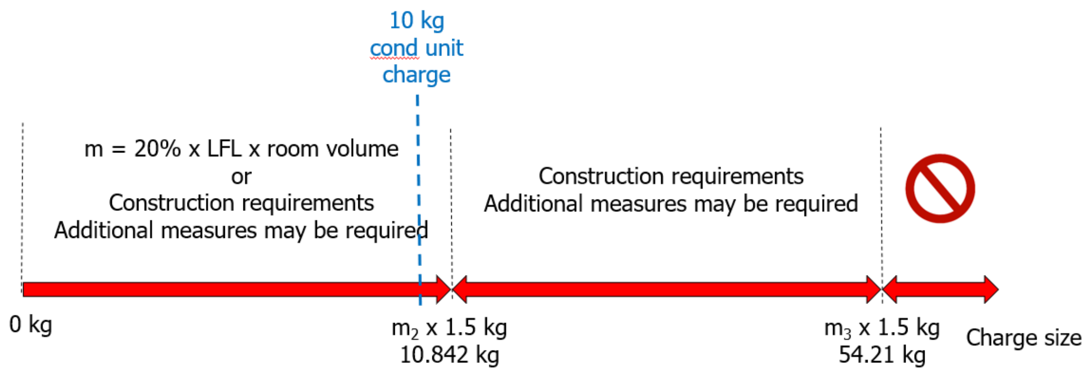

Figure 9, Charge size with threshold values

For the shop floor the charge of 10 kg is below both the maximum allowed by the volume calculation (42.8 kg) and the m_2 x 1.5 threshold (10.8 kg). No construction requirements or additional measures are therefore required on the shop floor.

For the warehouse the charge is above the maximum allowed by the volume calculation. It is below the m_3 x 1.5 threshold, so the charge is allowed providing the system meets the construction requirements. To determine if additional measures are required Conc needs to be calculated:

$$Conc = \frac{charge}{volume} = \frac{10}{145.6} = 0.068\ kg/m^3$$

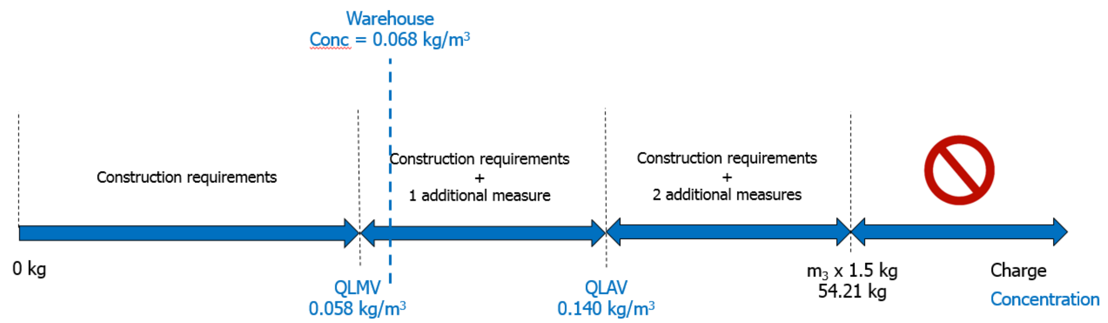

Figure 10, Warehouse additional safety measure requirement

As shown in the diagram above (Figure 10, Warehouse additional safety measure requirement) Conc is between QLMV and QLAV so one additional measure is required in the warehouse. The simplest measure would be a detector and alarm. The alarm must provide a warning (audible and visible) at least inside the warehouse.

Example 3.2, Multi compressor pack with 35 kg charge

In this case the charge is above the threshold of 10.84 kg (see example 3.1) so construction requirements must be applied for both areas. To determine if additional measures are required Conc needs to be calculated for both the shop floor and the warehouse.

Warehouse:

$$Conc = \frac{charge}{volume} = \frac{35}{145.6} = 0.240\ kg/m^3$$

Shop floor, the floor area is greater than 250 m^2 so the volume is calculated assuming the area is 250 m^2:

$$Conc = \frac{charge}{volume} = \frac{35}{250 \times 2.8} = 0.05\ kg/m^3$$

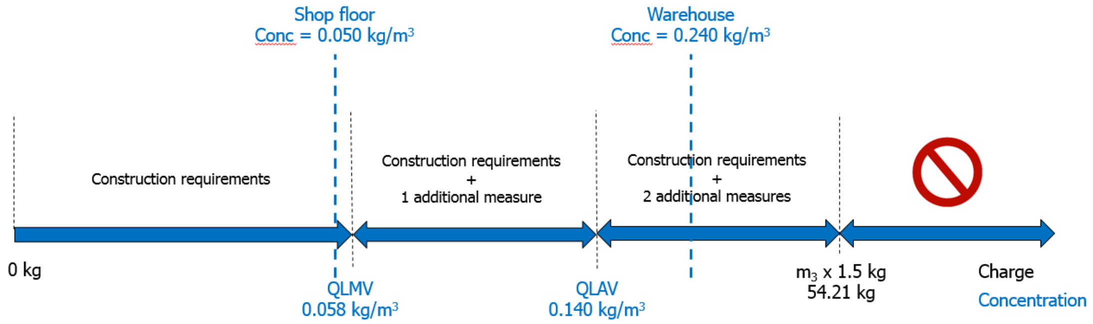

Figure 11, Additional safety measure requirement

As shown in the diagram above (Figure 11, Additional safety measure requirement) Conc is above QLAV so two additional measures are required in the warehouse. The simplest measures would be a detector and alarm plus mechanical ventilation. The alarm must provide a warning (audible and visible) at least inside the warehouse.

Conc is below QLMV on the shop floor so no additional measures are required (construction requirements must be followed). However, the diagram shows that a small increase in charge will increase Conc to above QLMV and at least one additional measure would be needed on the shop floor.

Example 4: Chiller cooling a secondary fluid

This example is for a chiller which is cooling a secondary fluid, for example for process cooling. In this case the equipment location is III (all refrigeration components outside or in a machinery room). The access category is not relevant as there is no charge restriction for any category.

The location of the chiller is important and there are several considerations:

EN 378 Part 3 Clauses 4.2, 4.3

Chillers located outside (a room with at least one of the long walls louvered [13] is considered outside):

- Leaked refrigerant must not be able to flow into a building or other endanger people or property.
- Leaked refrigerant must not be able to flow into any ventilation fresh air opening, doorway, trapdoor or similar;
- Where the chiller is in a shelter it shall have natural or forced ventilation;
- Gas detection is required if the refrigerant could stagnate;
- Area classification must be carried out.

Chillers located in a machinery room:

- The machinery room must meet the requirements in EN 378-3 clauses 5.1 to 5.14.

[13] The louvre must have at least 75% free area and cover at least 80% of the wall area.

Appendix 7, Allowable Opening of Relays and Similar Components

The information is in this appendix is derived from IEC 60335-2-40 Annex JJ. This specifies the maximum size of an opening which would prevent flame propagation in an electrical device which can arc or spark. Openings larger than that specified could allow flame propagation and so should not be used unless type testing is carried out.

You need to know the effective diameter (d_{eff}) of the opening:

For circular openings it is simply the diameter of the circle in mm.

For square opening it is the length of one side in mm.

For rectangular openings it is:

$$effective\ diameter = 4\ x\ \frac{A}{S}$$

A is the cross sectional area, mm
S is the perimeter of the opening, mm

The maximum allowable size of d_{eff} depends on the burning velocity, S_u, of the refrigerant (included in Appendix 3), but it must not exceed 7 mm:

$d_{eff} < 22.3 \times S_u^{-1.09} \leq 7$ mm

Maximum allowable effective diameters are shown below for the common A2L refrigerants.

Table 13 Max allowable effective diameters

Refrig.	**Burning velocity (S_u) cm/s**	**22.3 x $S_u^{-1.09}$**	**Maximum allowable effective diameter, mm**
R32	6.7	2.80	2.80
R1234ze	0	Not defined	N/A
R1234yf	1.5	14.33	7
R454A	2.4	8.59	7
R454C	1.6	13.36	7
R455A	<1.5	14.33	7