Tecumseh

Safeguarding goods and people.

A2L fluid charge with a remote condensing unit.

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1. Purpose of the recommendation guide

This guide is designed to help order to ensure the safety of goods and people and to explain under what context the use of direct expansion refrigeration units is possible.

The practical examples illustrate the different cases set out in the standard EN378.

It is not a substitute for the product installation instructions, nor the standards, nor the national and European regulations in force.

It is organised based on the principles set out in the EN378 series of standards and is not a substitute for mandatory risk analyses for all phases of life of the refrigeration system, especially at the time of installation of the refrigeration units.

2. Flammable refrigerants

2.1. Safety groups and classification criteria for refrigerants according to ISO 817 and ~~the~~ ASHRAE:

Safety groups

Flammability			
Highly flammable	A3	B3	
Moderately flammable	A2	B2	
Slightly flammable	A2L	B2L	
Non-flammable	A1	B1	
	Low toxicity	High toxicity	
			Toxicity

Flammability criteria

A3	Flame propagation in air at 60°C- 101.3 kPa LFL < 0.1 kg/m3 Combustion heat > 19000 kJ/kg
A2	Flame propagation in air at 60°C- 101.3 kPa LFL < 0.1 kg/m3 Combustion heat < 19000 kJ/kg
A2L	A2 criteria AND speed of flame propagation <= 10cm/s
A1	No flame propagation in air at 60°C- 101.3 kPa

Fig 1.

2.2. Classification:

Refrigerants	R454C	R455A	R1234yf
ASHRAE classification	A2L		

2.3. Refrigerant safety data

Refrigerants	R454C	R455A	R1234yf
PED safety group EN378-1 version 2016	1	1	1
Lower flammability limit (LFL) – (kg/m3) EN378-1 version 2016 + A1 2019	0.293	0.431	0.289
Practical limit (kg/m3) EN378-1 version 2016 + A1 2019	0.059	0.086	0.058
Upper flammability limit (UFL) – (kg/m3)	n/a	0.462	n/a
Lower flammability limit (LFL) (%=vol/vol) – ISO 817	6.2	11.8	6.2
Upper flammability limit (%=vol/vol)	<15*	12.9	12.3
Auto-ignition temperature (°C/°F) According to EN378-1 version 2016	n/a	473-477°C 883 - 891°F	405 / 761°C
ODL (kg/m3) EN378-1 version 2016 + A1 2019	0.445	0.313	0.47
Acute toxicity exposure limit (ATEL) ppm/volume ISO 817	120000	120000	100000

*Source MSDS Chemours 25-04-2018

2.4. Risk limitation via use of type A2L fluids:

Flammability ranges:

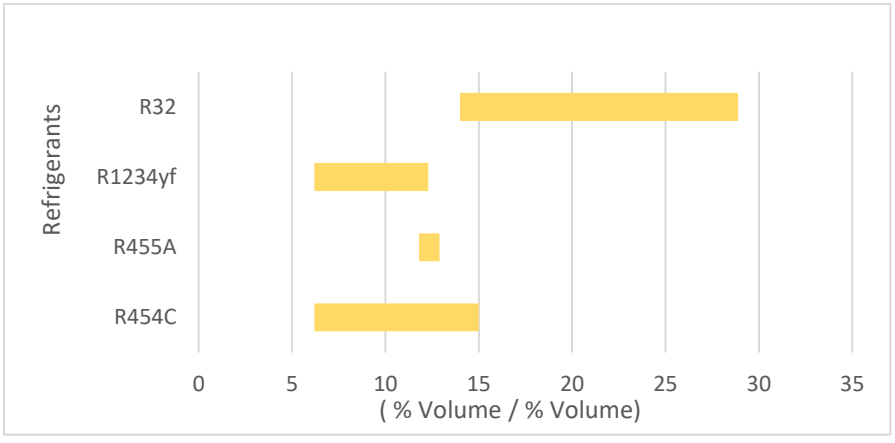


Fig 2.

➔ The flammability ranges of the refrigerants R1234yf, R454C and R455A are among the narrowest of the A2L category fluids.

Impact on the ignition energy, combustion heat and flame speed of the refrigerants R455A, R454C and R1234yf in comparison with R290:

MIE ➔ Their Minimum Ignition Energy is 1200 to 20000 times more energy than R290 to ignite them.

Combustion heat ➔ Their combustion heat is 4.3 times lower than that of R290.

Flame propagation ➔ Their flame propagation speed is 28 times lower than that of R290.

The basic capping of charge limits is increased by a factor of 1.5 to account for the lower combustion speeds of these fluids, which reduces the probability and consequences of ignition.

The multiplication factors 4, 26 and 130 correspond to an R290 charge of 150g, 1kg and 5kg respectively.
m_1: $4m^3$ * LFL
m_2: $26m^3$ * LFL
m_3: $130m^3$ * LFL

Summary table:

	A2L				**A3**
	R454C	**R455A**	**R1234yf**	R32	**R290**
PED group	1	1	1	1	1
Minimum ignition energy (MIE) mJ , at 20°C, 1 atm	n/a	317-331	5000-10000	30-100	0.25
Combustion heat MJ/kg According to Ashrae 34	n/a	10.2	10.7	9.4	46.3
Flame propagation speed (cm/s - in/s) According to ISO817	1.6 - 0.63	1.5 - 0.59	1.5 - 0.59	6.7	46
Flammability range (%=vol/vol)	6.2 to 15	11.8 to 11.9	6.2 to 12.3	14 to 33	1.7 to 7.9

3. Risk and safety associated with the product

3.1. Definition and consequences of a risk

This is defined in the standard EN ISO12100.
A risk is a combination of an occurrence and a severity.
The occurrence of the risk is a measure of the probability that harm will result. The severity of the risk is a measure of the significance of the harm.

Risk = *probability of presence of refrigerant* * *probability of ignition by a component*

3.2. Controlling safety

The tightness of the refrigeration system is controlled by observing good refrigeration practices and choosing wisely with respect to the location of the condensing unit and impact protection for example.

Qualification of the electrical components according to their use and location.

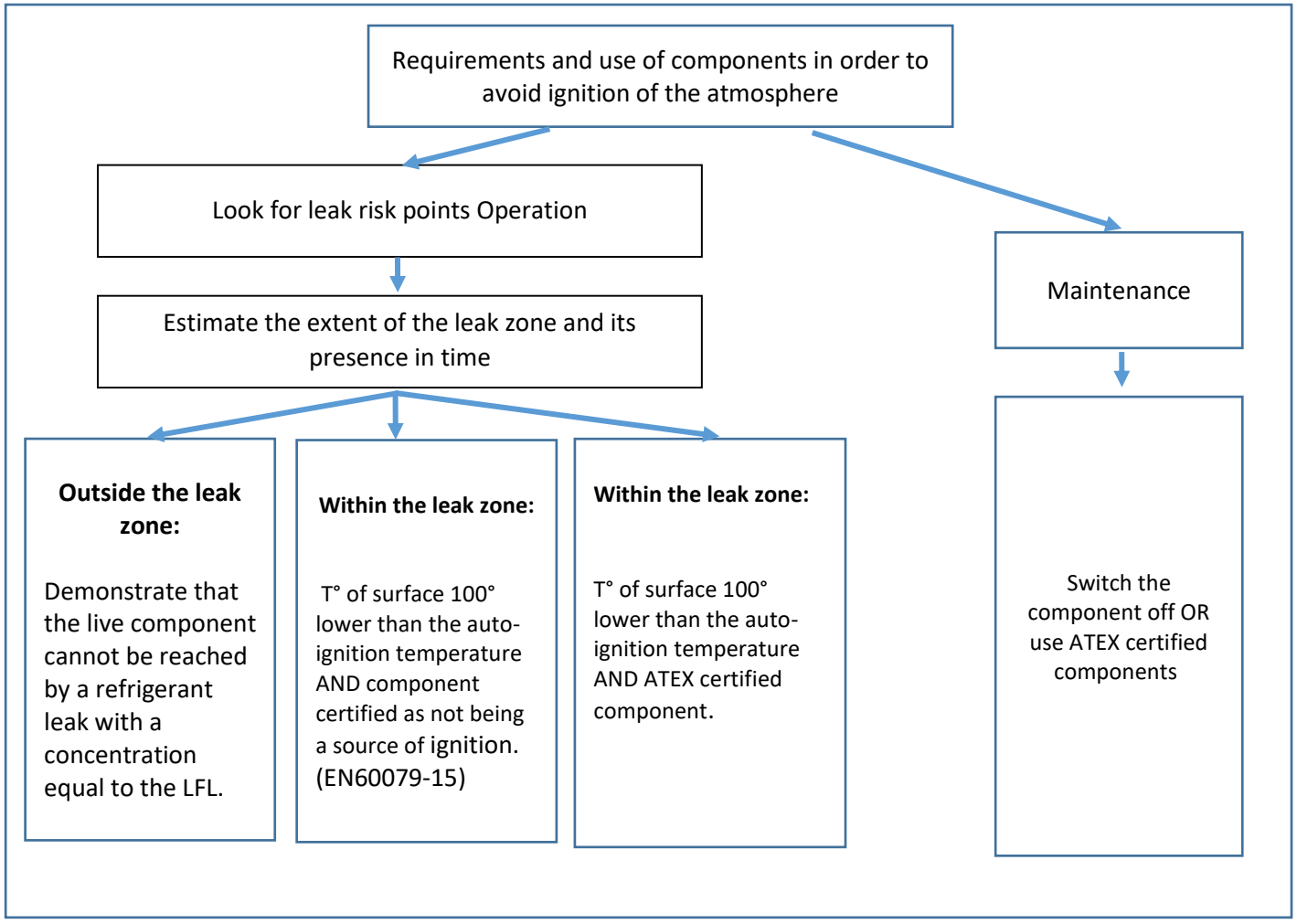


Fig 3.

A risk analysis is carried out according to the charge quantity available and the sources of ignition installed in the area under consideration.

Study the potential refrigerant propagation zone and place the 'at risk' components outside of this zone. Non-stagnation, etc.
(The standard EN 378 Part 2, Annex I describes the type of leak to be considered).

It is strictly prohibited to convert a refrigeration system initially operating with non-flammable HFC fluids into one with flammable fluids.

4. Safety applied to the product:

The phases of life, which are installation, operation, maintenance and recovery/disposal, must take into account of the products environment.

4.1. The design stage

Design of the condensing units:
The fact that the condensing unit is deemed, via the CE mark, to meet the requirements of the European standards and directives gives reason to believe the risks of ignition (by hot surface, spark, etc.) are under control. The Tecumseh refrigeration unit is considered to be a sealed sub-assembly within the meaning of the standard EN378 Part 1.

Choice of location for the condensing unit:
Observe the minimum distances specified in the installation instructions. They take into account the recirculation of the air and the hypothetically flammable area in the event of a refrigerant leak defined by the standard EN378 Part 2 Annex I version 2016. The standard EN60079 Part 10-1 may also be used. The minimum distances to be observed between the SILENSYS ADVANCED unit and the buildings air vents should also take into account the air intake zones around the air intake grilles for building.

The SILENSYS ADVANCED condensing unit and its connections must be protected from impact.

Information about protecting the pipes of the refrigeration systems:
The risk of total rupture of the pipes will be made less likely by physical protection against all accidental damage (capping, false ceiling, etc.) and by the choice of installation location. Example: Installation more than 2.2m off the floor within the premises, etc.

Refrigeration connections:
The different elements of the circuit will preferably be connected using brazed or soldered joints.

Pipes with removable joints prone to disconnection must not be used in areas with human traffic.
Connections with any risk of leaking must be installed in an area where refrigerant accumulation is impossible.

According to the standard EN378 version 2016, a refrigeration system is deemed sealed when all the elements containing refrigerant are rendered tight by welding, soldering or similar permanent connection. The leak rate must be less than 3gr a year. A joint based on mechanical forces, which is prevented from being misused by the need for a special tool is considered a similar permanent connection.

4.2. The installation and maintenance phase

The operator must ensure that access is only authorised for personnel capable of carrying out the necessary maintenance operations.

Before commencing any maintenance, the technician must secure the work area. He/she will make sure that all local and site regulations regarding the safety of hazardous or flammable substances are observed.
Non-exhaustive list of operations prior to maintenance:

- Wear PPE and make sure you have the appropriate tools for handling flammable fluids.
- Secure the area by putting up the flammable fluid and safety zone maintenance warning sign and make sure there is an extinguisher close by.
- Ventilate the work area with the appropriate equipment, ensuring constant and secure air exchange (think about the low areas).
- It is widely agreed that any sources of heat or ignition should be placed more than 3m from the risk zone.
- Check for the presence or absence of flammable fluid in the work area, check the tightness of the system(s).

Purging the refrigeration system and recovering the refrigerant:
Once the work area has been secured, the following tasks and recommendations are suggested (list not exhaustive):

- Ventilation: the fluids must not be able to migrate to another room in the building. The fan(s) providing air renewal in the area must not cause sparks and their operation must be controlled.
- The refrigerant purge operation requires a vacuum pump and ATEX recovery system designed for the fluids in question.
- Warming up the compressor tank to help degas the oil is recommended. Do not use a blow torch.
- Lock off the power supply and disconnect the other electrical components.
- Do not mix refrigerants in containers.
- Do not use disposable containers.

It is obligatory to purge the system and render it inert before carrying out any ‘hot works’ on the refrigeration circuit.

No naked flames are allowed except for welding, soldering or other similar operations and only on condition that the refrigerant concentration is monitored and that adequate ventilation is provided.

Replacing electrical and refrigeration components:

- Only fit components approved by Tecumseh.
- Each new component must meet the same safety standards as the original component.
- It must bear the same safety markings as the original component.

The refrigeration components must be approved for use with the fluids mentioned on the nameplate. Particular attention must be paid to the PED marking. Equivalence must be verified with respect to:

- The PS: maximum permissible pressure equivalent to other components of the circuit
- The fluid group used: flammable fluids - > group 1

Chemical compatibility:

The fluid used must be directly marked on the component or be part of the chemical family indicated on the component.

Evacuation and charging with refrigerant:

Evacuate with an appropriate ATEX vacuum pump while ventilating and renewing the air in the area. Make sure the vapours are released into a secure area.
Check the vacuum capability of the refrigeration system.
Pre-charge the refrigeration system in liquid phase. The product installation instructions indicate what process to follow.

Then, carry out a leak check, identify the type of fluid and the charge contained in the refrigeration system.

4.3. The operating phase

Ignition control within the environment surrounding the product is the operator's responsibility. It must be guaranteed by the conditions of installation, use and maintenance (for example: no potential source of ignition around the product and no storing flammable materials in close proximity, work on the equipment must be supervised, etc.)

4.4. Recovery/disposal

The same safety precautions and rules apply for refrigerant recovery, dismantling of the refrigeration system and disposal.

5. Characterisation of the zone for calculating the charge.

The SILENSYS refrigeration units are not designed for operation within an ATEX zone. The TECUMSEH products are designed in compliance with the product standards (series EN60335). The leak risk is minimised by the design and installation. Therefore the use of ATEX components is not obligatory.
The EN60335 series product standards and the generic standard EN378 define the use of flammable fluids without imposing compliance with the ATEX directive where the installation is outside an ATEX zone.

The design and installation of a condensing unit according to the product standards implies that it will not create an ATEX zone. Therefore compliance with this standard need not be studied.

5.1. Definition of an ATEX zone

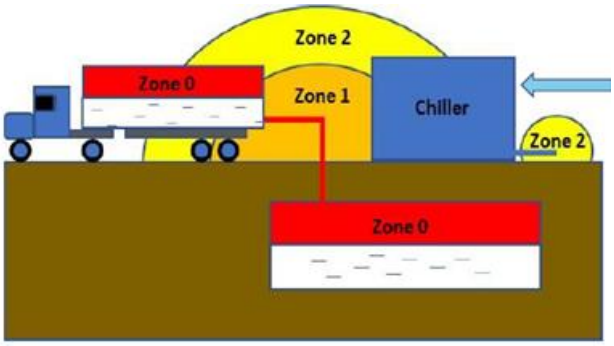
Hazardous areas are classed according to the frequency of occurrence and duration of presence of an explosive atmosphere.

Zone 0: an area in which an explosive gas atmosphere is present continuously or for long periods or frequently.

Zone 1: an area in which an explosive gas atmosphere is likely to occur periodically or occasionally in normal operation.

Zone 2: an area in which an explosive gas atmosphere is not likely to occur in normal operation, but if it does occur, it will only exist for a short time.

Positioning of a chiller
Illustration – source Asercom



The vapour compression system does not cause ATEX zones.

If the system is placed in an ATEX zone, the system manufacturer must ensure ATEX compliance.

However, the requirements do not depend on the type of refrigerant in your installation.

5.2. Fig. 4.EN378, Location categories and Access categories

5.2.1. Location classification

Location class	Location definition	Example
I	Located in an occupied space, i.e. an enclosed space in a building occupied by people for a significant period	
II	Compressor and pressure vessels (HP side) located in a machinery room or in the open air, the other parts in an occupied space	
III	In a machinery room or in the open air	 
IV	In a ventilated enclosure (special industrial design system)	

5.2.2. Access categories

Access category	Illustration	Example
General access ‘a’		Public access buildings: Hospitals, courts, supermarkets, schools, concert halls, hotels, restaurants, etc.
Monitored access ‘b’		Offices and business premises, laboratories, factories, etc.
Restricted access ‘c’		Manufacturing facilities (chemical or food products), storage facilities, non-public areas in supermarkets, etc.

6. Calculating the maximum charge according to the area

The toxicity and flammability criteria are taken into account to determine the maximum charge (EN378), see diagram below:

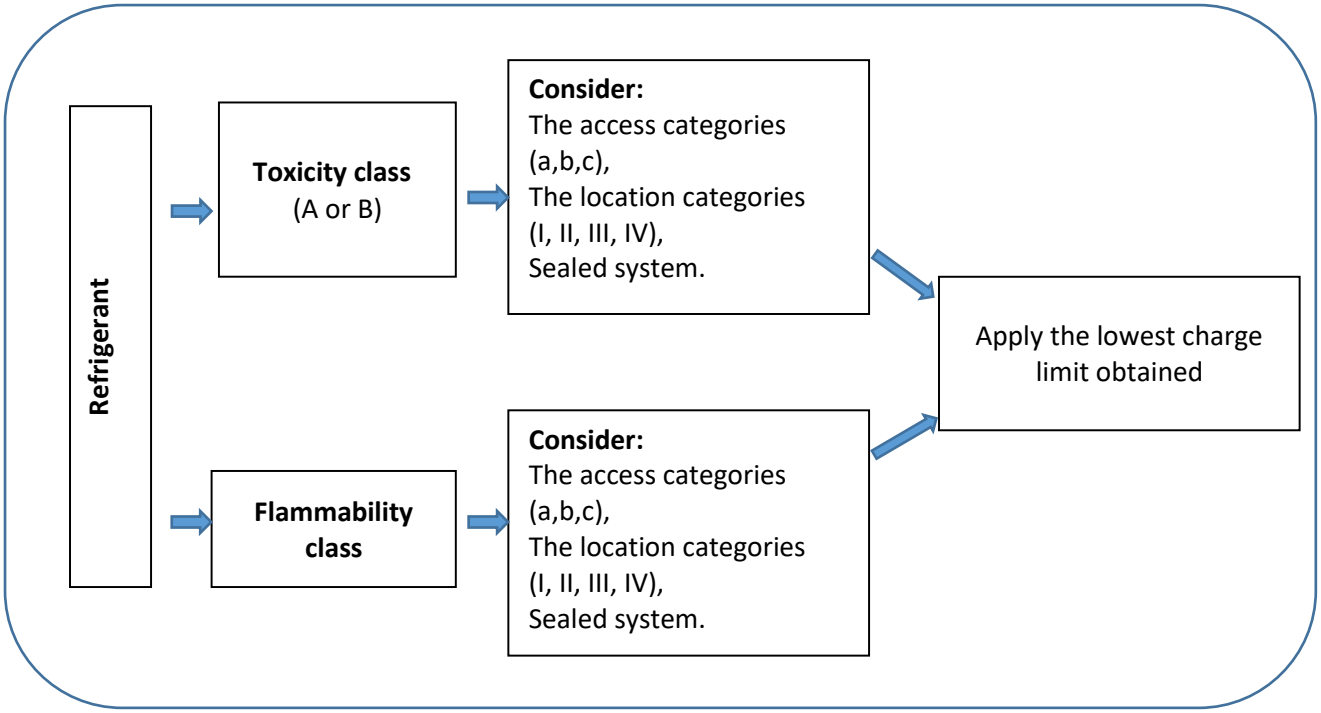


Fig 5

The most restrictive criterion used for the refrigerants R1234yf, R455A and R454C is **flammability**. According to the standard EN378 version 2016. *The charge limits refer to a sealed system.* Different cases are evaluated according to table C2 and paragraph C3.

6.1. Case A: Table C2 / Location class Cat I & II / General access "a"

Charges graph without additional safety device.

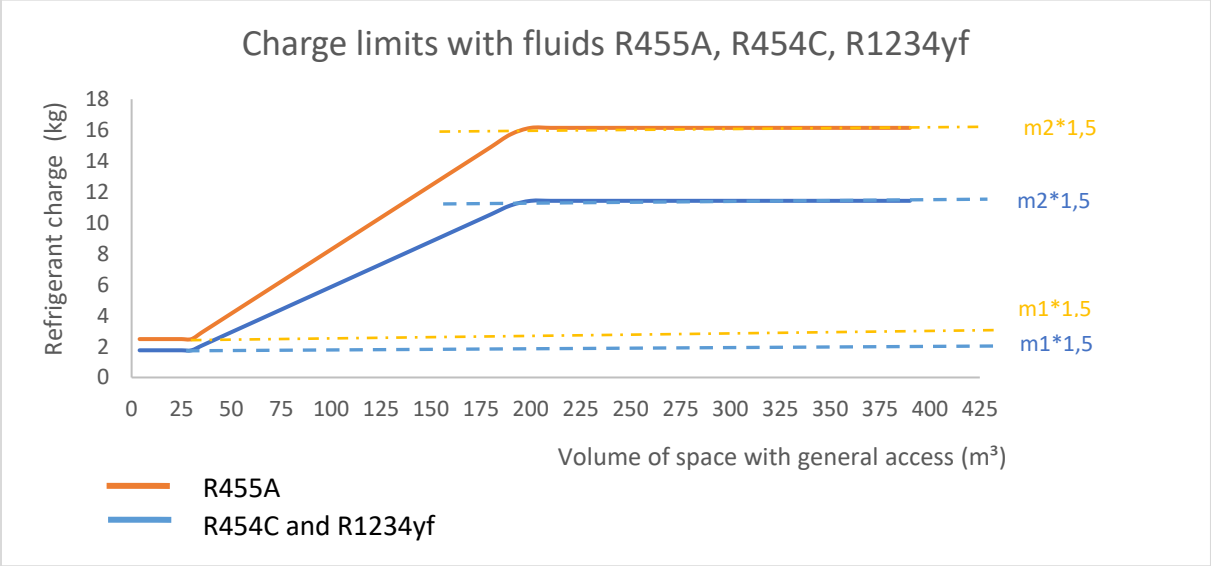


Fig 6.

This graph applies for example:

- To Commercial Refrigeration Cabinets (CRB) directly accessible by the consumer and not affected by the product standard EN 60335-2-89.

6.2. Case B: Table C2 / Class Cat II / monitored access (b) or restricted access (c)

Charges graph without additional safety device

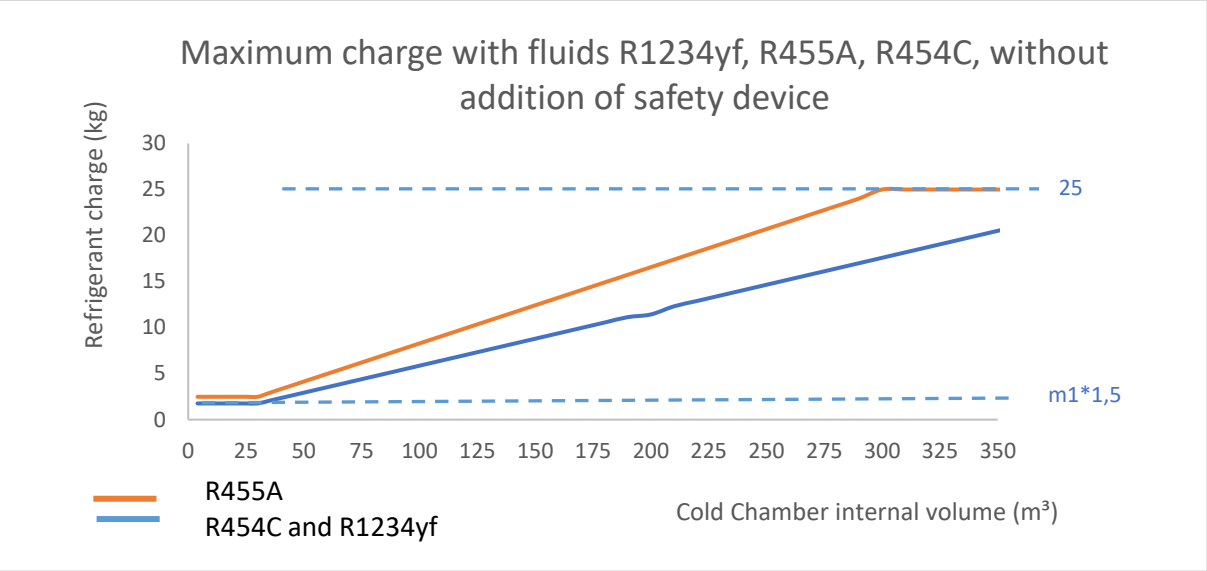


Fig 7.

This graph applies for example:

- To cold rooms and laboratories for food preparation.
- To storage cabinets, not affected by the product standard EN 60335-2-89, located in food preparation laboratories with a remote or encased unit.

6.3. Case C: Table C2 / Class Cat II / Restricted access (c) and staff density < 1 person per 10m² /
Therefore, for areas over 25m3, this case may apply for example:

- To cold rooms,
- To food preparation laboratories

Only authorised personnel informed of general and special safety measures of the establishment are able to enter the area concerned.

No charge restriction (Extract from table C2 of the standard EN378 Part 1 version 2016).

The risk analysis determines whether or not the refrigeration system will need to be installed in a separate machinery room.

Tecumseh recommends that only qualified personnel have access to the condensing unit for installation and maintenance.

6.4. Case D: Paragraph C3 / Charge limit, with additional safety device(s), for a cold room application for example.

According to the standard EN378 – Part 1, paragraph C3.

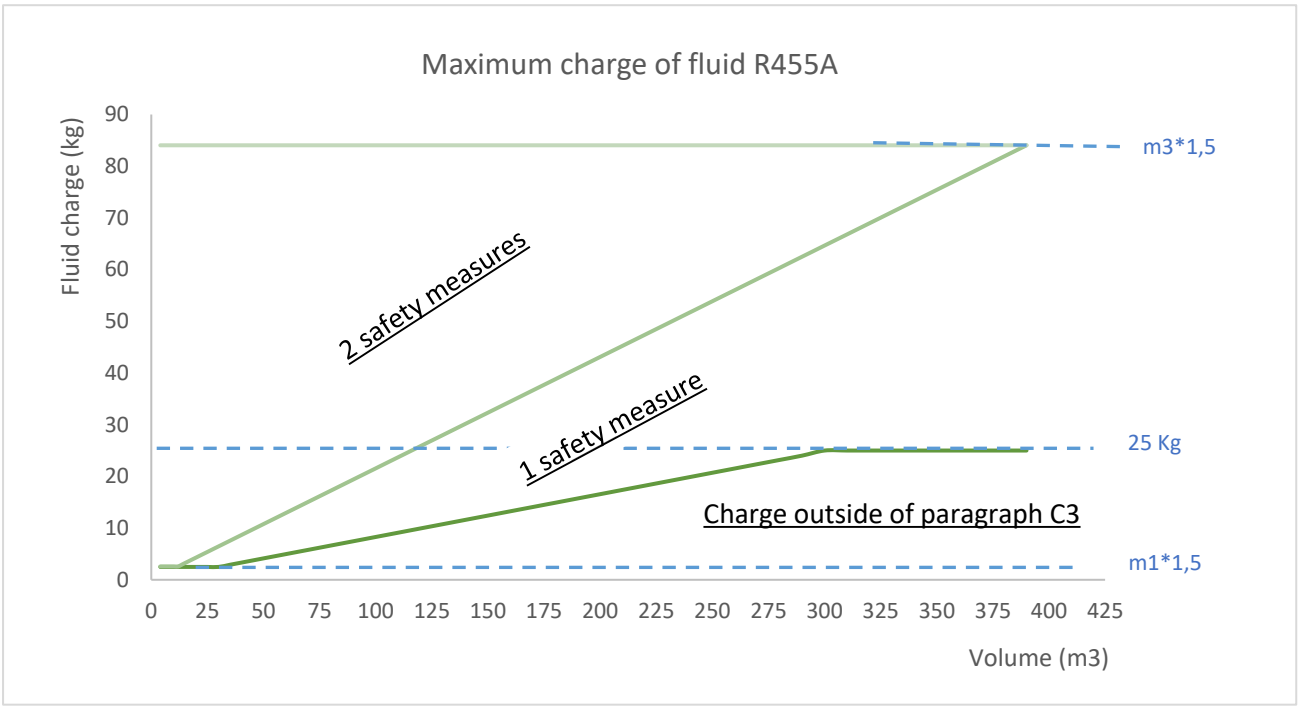


Fig 8.

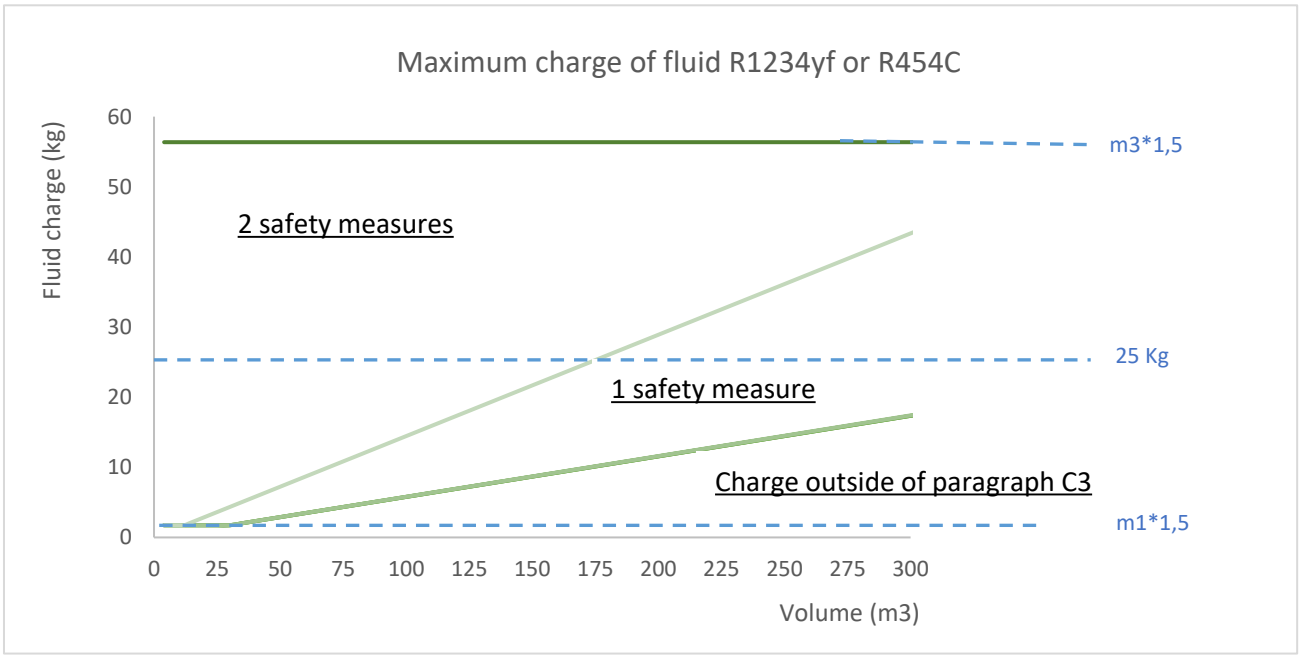


Fig 9.

Appropriate safety measures are:

- Natural or mechanical ventilation
- Shut-off valves and a safety alarm in conjunction with a gas detection device. The valves will stop the flow of refrigerant so that the amount is less than the QLMV value in the occupied space.

The detector trigger threshold will be the practical flammability limit (25% of the LFL).
Definition of charge thresholds:

- Quantity Limit Minimum Ventilation (QLMV)
- Quantity Limit Additional Ventilation (QLAV)
- Refrigerant Concentration Limit (RCL).

If the Charge / Volume > $RCL_{(if\ underground)}$ or Charge / Volume > QLMV
-> One safety measure applies

If the Charge / Volume > QLAV
-> Two safety measures apply

	R455A	R454C	R1234yf
RCL (kg/m3) *Source ISO 817	Fluid charge (kg)24000 ppm/vol *	n/a 12000 ppm /vol *	0.058 0.012000 ppm /vol *
Molar mass (g/mol)	87.5	90.8	114
QLMV (kg/m3) *Based on 20% LFL	0.086*	0.058*	0.06
QLAV (kg/m3) Based on 50% LFL	0.215	0.146	0.14

Knowing that:

- The fluid is A2L,
- The SILENSYS Advanced condensing unit is not a monoblock system within the meaning of the standard since it is not autonomous, not charged and moreover requires the connection of elements that contain refrigerant.
- The cold room is not considered an occupied space because the occupation is not significant. Hence the paragraph “The doors to the occupied space are not tight” does not apply.

Hence personnel will only enter the cold room to store the food.
Under no circumstances will the cold room be used as a food preparation area. The food will be unpacked before entering the cold room.

Thus, if you observe all the paragraphs below, the refrigerant charge limit will be as per the graphs - Fig. 8 and Fig. 9.
(Source: standard EN378 paragraph (C3))

- The charge does not exceed 150kg or 1.5* m_3 with m_3: 130m^3 * LFL

It will therefore be lower than:

R455A	R454C	R1234yf
56 kg	38 kg	37.5 kg

- The SILENSYS Advanced condensing unit will be placed outside, location class II according to the standard.

- The evaporator and control system for the refrigeration system are designed to avoid degradation due to the formation of ice.

- The evaporator fan breaking must not cause a refrigerant leak.

- The joints used on the occupied space are not removable.

For example screw connections are prohibited.
An exception is possible for connections of the indoor unit to the piping.

- In the occupied space, the piping is protected against accidental damage.

Pipes enclosed in ducting for example.

- There is no basement or other level beneath that containing the refrigeration system.

If not, its area must be taken into account to verify that the system's refrigerant charge divided by the volume of the room on the floor below is lower than the Quantity Limit with Minimal Ventilation (QLMV). Safety measures apply.

7. Calculating the charge in a refrigeration system

7.1. Calculating the charge for the condensing unit

Estimated charge of a condensing unit and comparison with the maximum permissible charge in relation to the volume occupied.

7.1.1. MHBP condensing units, R455A refrigerant

Model	Cooling capacity (watts)	SILENSYS unit charge (kg)	Ext. diam. liquid pipe (inches)	Charge Liquid pipe 10m long (kg)	Max. charge with a safety measure (kg)	Max. charge without safety (kg)	Volume (m3)
SIL AE 4450P	717	0.5	1/4	0.168	2.5	2.5	1
SIL AE 4460P	860	0.5	1/4	0.168	2.5	2.5	5
SIL AE 4470P	995	0.5	1/4	0.168			
SIL AJ 4480P	1140	0.8	3/8	0.47	2.5	2.5	10
SIL AJ 4510P	1339	0.8	3/8	0.47			
SIL AJ 4513P	1688	0.9	3/8	0.47	4.3	2.5	20
SIL AJ 4517P	1842	1.1	3/8	0.47	6.46	2.5	30
SIL AJ 4519P	2367	1.1	3/8	0.47	8.62	3.4	40

This table is not intended for pre-selection of condensing units for cold rooms.

7.1.2. MHBP condensing units, R454C refrigerant

Model	Cooling capacity (watts)	Fluid charge of the unit (kg)	Ext. diam. liquid pipe	Fluid charge of 10m liquid pipe (kg)	Max. charge with a safety measure (kg)	Max. charge R454C (kg)	Volume (m3)
					1.7	1.7	1
SIL AE 4450P	638	0.48	1/4	0.16			
SIL AE 4460P	760	0.48	1/4	0.16	1.7	1.7	5
SIL AE 4470P	884	0.48	1/4	0.16			
SIL AJ 4480P	971	0.76	3/8	0.45			
SIL AJ 4510P	1152	0.76	3/8	0.45	1.7	1.7	10
SIL AJ 4513P	1502	85	3/8	0.45			
SIL AJ 4517P	1697	1.05	3/8	0.45	2.9	1.7	20
					4.39	1.7	30
SIL AJ 4519P	2207	1.05	3/8	0.45			
					5.86	2.34	40

This table is not intended for pre-selection of condensing units for cold rooms.

8. Charge and pipe dimensions

8.1. Dimensions

The diameter of the cooling pipes of the condensing units, specified in the installation instructions and in the technical data sheets, is determined so as to cover the full evaporation range, thus for the maximum refrigerant flow.

The majority of the refrigeration systems intended for food storage work within a reduced evaporation range compared to that offered by the condensing unit.

Example for fresh food storage:
Evaporation range of the Medium and High-Pressure (MHBP) condensing units: -25 to +15°C

Possible evaporation range of the refrigeration system: -10 to +5°C
The maximum fluid flow of the refrigeration circuit will only be 75% of what the condensing unit is able to convey.

The diameter of the liquid pipe can therefore often be reduced while maintaining the maximum speed of 1m/s.

8.2. Calculating the charge for the pipes

The charges are estimated for a reference length of one linear metre.

The diameters and thickness of the tube refer to the standard NF EN 12735 - Part 1: Seamless, round tubes for the air-conditioning and refrigeration. Part 1: tubes for piping systems

Mid/mid operating mode, 10K superheating, zero subcooling.
MHBP application: To/Tc = -10/45°C
LBP applications: To/Tc = -30/40°C

8.2.1. Liquid pipes:

Rating conditions: Liquid T = bubble Tc corresponding to mean Tc =45°C

Ext. diam. (inch - mm)	Int. diam. (mm)	R1234yf charge (gr / linear m)	R454C charge (gr / linear m)	R455A charge (gr / linear m)
1/4 - 6.35	4.75	17.9	16.1	16.8
5/16 - 8	6.4	32.4	29.3	30.6
3/8 - 9.52	7.93	49.8	44.9	47.0
1/2 - 12.7	10.7	90.6	81.8	85.5
5/8 - 15.87	13.87	152.2	137.4	143.7
3/4 - 19.05	17.05	230.0	207.6	217.1
7/8 - 22.2	19.73	308.0	278.0	290.7
1 1/8 - 28.57	25.27	505.2	456.0	476.8
1 3/8 - 34.92	31.62	791.1	714.0	746.6

8.2.2. Suction pipes:

Rating conditions: Gas T = Tdew +10K
Tdew corresponds to mean To =-10°C (with mean Tc =45°C)
Tdew corresponds to mean To =-30°C (with mean Tc =40°C)

		R1234yf charge (gr / linear m)	R454C charge (gr / linear m)		R455A charge (gr / linear m)	
Ext. diam. (inch - mm)	Int. diam. (mm)	Mean To	Mean To		Mean To	
		-10	-10	-30	-10	-30
1/4 - 6.35	4.75	0.2	0.3	0.1	0.3	0.1
5/16 - 8	6.4	0.4	0.5	0.2	0.5	0.2
3/8 - 9.52	7.93	0.6	0.7	0.4	0.8	0.4
1/2 - 12.7	10.7	1.1	1.3	0.6	1.4	0.7
5/8 - 15.87	13.87	1.8	2.3	1.1	2.4	1.2
3/4 - 19.05	17.05	2.7	3.4	1.6	3.6	1.7
7/8 - 22.2	19.73	3.7	4.6	2.2	4.9	2.3
1 1/8 - 28.57	25.27	6.0	7.5	3.6	8	3.8
1 3/8 - 34.92	31.62	9.4	11.8	5.6	12.5	6

8.3. Refrigerant weight distribution

Fluid charge in the components / sub-assemblies:

SILENSYS ADVANCED Sil AJ 4519P: 1.1 kg
Pipe, length 20m: 0.98 kg
Evaporator: 0.3 kg

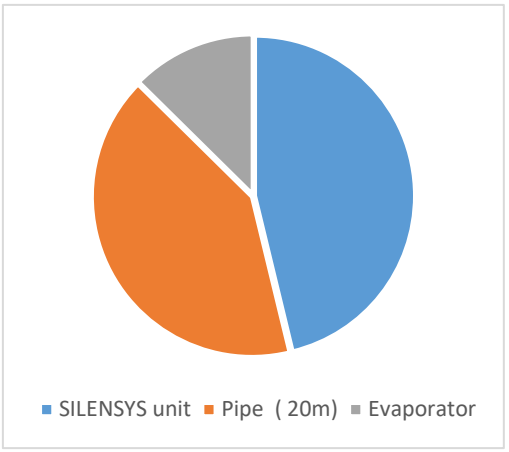


Fig. 10.

- ➔ Minimise the length of the liquid pipe as much as possible.
- ➔ Do not oversize the installation
- ➔ The starting liquid pipes can be resized downwards according to the maximum rate of evaporation in order to minimise the quantity of fluid.

9. Examples on typical installations

9.1. Charge calculation on applications

9.1.1. Positive cold room with remote condensing unit outside.

Internal volume = 30m3 	Location category: II Access category: b Permissible R455A refrigerant charge: 2.5 kg Unit installed: SILAJ4519P-TZ Cooling capacity: 2.37 kW Charge in the unit : 1.1 kg Charge in the liquid pipe (10 m): 500gr

Fig 11.

9.1.2. Commercial refrigeration cabinet with remote condensing unit outside

	Location category: II Access category: a Permissible R1234yf refrigerant charge: > 1.7 kg Unit installed: SILAJ4513N-TZ Refrigerant R1234yf Cooling capacity: 1.43 kW Charge in the unit : 0.8 kg Charge in the liquid pipe (10m): 500gr

Fig 12.

9.1.3. Commercial refrigeration cabinet with condensing unit located inside the cabinet.

All parts of the refrigeration system are in the occupied space.

	Location category: I Access category: a Volume of the room containing the commercial refrigeration cabinet: > 4m^3 Permissible R1234yf refrigerant charge: 1.7 kg Unit installed: CAJ4513NH-FZ R1234y refrigeration Cooling capacity: 1.65 kW Estimated charge in the refrigeration system: 0.65 kg

Fig 13.

9.2. Critical points for installation on site (Silensys unit)

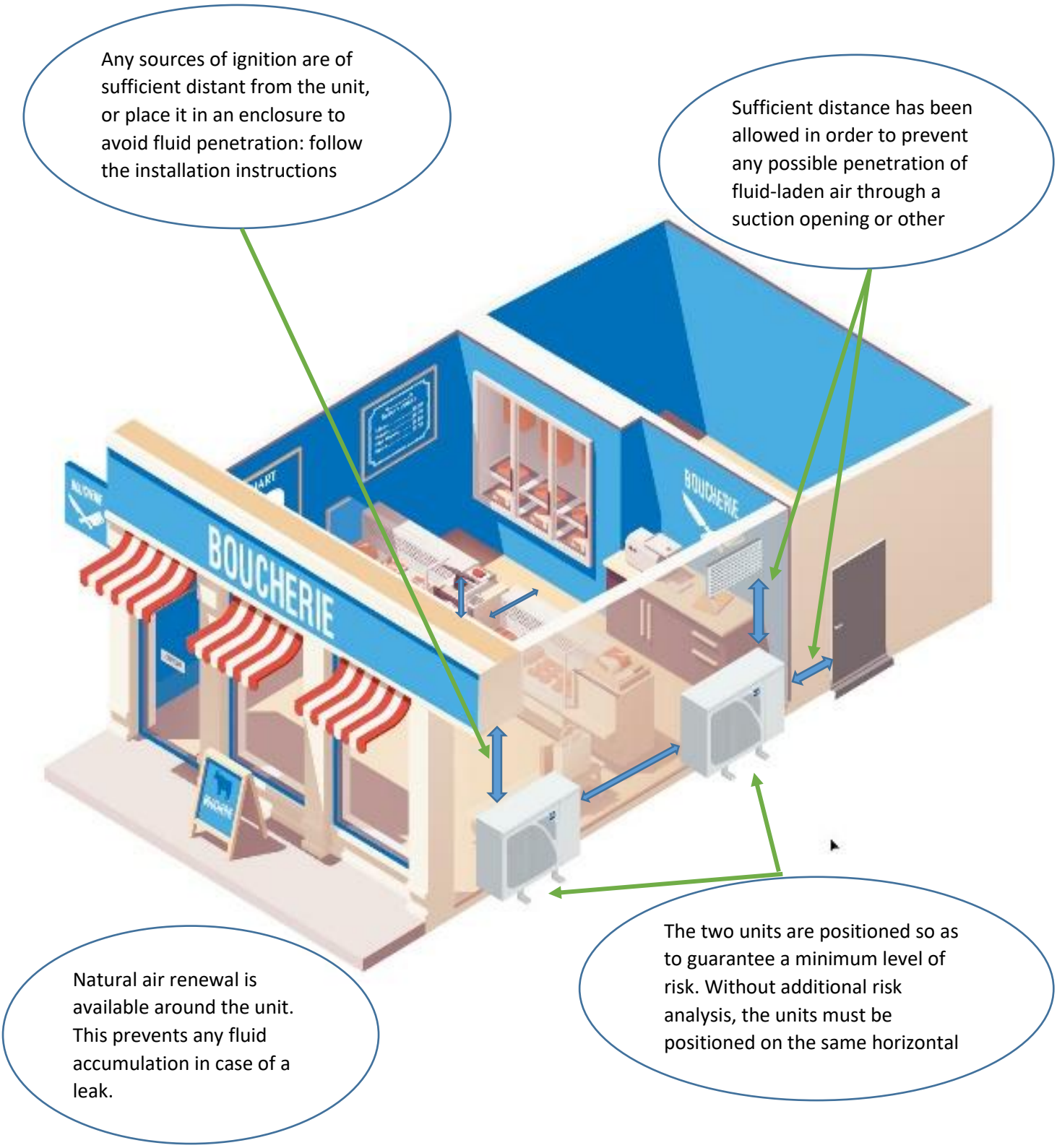


Fig 14.

The pipes are installed along the wall and in a manner that avoids any impact that could cause them to rupture.

10. Bibliographic references

For more information, a set of explanatory documents is available:

- Practical guide relating to fire safety in retail stores and shopping centres, (available in French language only)
- UNICLIMA guide: Standard NF En 378: 2017 for Refrigeration systems and Heat pumps, (available in French language only)
- ASERCOM guide: Safety Standards and Components for flammable refrigerants,
- AFCE guide: Review on the Energy efficiency of the fluids and Low GWP systems available (available in French language only)

https://www.interieur.gouv.fr/content/download/107412/852971/file/GUIDE%20M.pdf
https://www.uniclima.fr/documentation.html
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