Training Course
Hydrocarbon Refrigerants (HC)
Refrigeration & Air- Conditioning
Installation and commissioning

Statement

Hydrocarbon refrigerants are an excellent alternative to HCFCs. Hydrocarbons are used safely in all walks of life from hairspray and cooking gas to fuels for cars and airplanes. Hydrocarbon based technologies have to be designed to operate safely, and they are indeed safe."

Citation: Dr. Volkmar Hasse

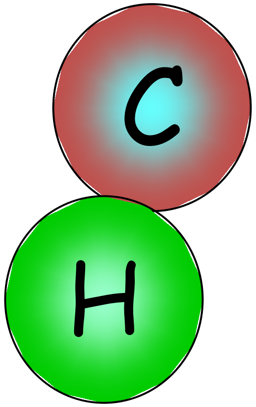
Overview: Modules and Sections

Hydrocarbon Refrigerant Issues

- Potentials application of Hydrocarbon refrigerants
- European standards and regulations
- Design approaches and considerations on safety
- How to practically deal with HC refrigerant flammability
- Electrical circuit and components requirements
- Risk assessment
- Basic personal protection
- Tools and servicing equipment
- HC refrigerant recovery and venting
- The importance of Oxygen Free and Dry Nitrogen (OFDN)
- Deep vacuum procedures for refrigeration system commissioning
- Methods of gas detection (leak finding) in the field
- Other useful hints

Hydrocarbon Refrigerant Issues

HC Pros and Cons



- ☺ Very good refrigerants, good capacity – efficiency
- ☺ Very low environmental impact
- ☺ Compatible with copper and mineral oils
- ☺ Cleanness procedures similar used with R12/R22
- ☺ Service procedures remain largely the same except safety considerations
- ☹ Flammable / Explosive
- 😐 Availability in refrigeration quality min. 99,5...%
- 😐 Systems must be designed so that leak is no danger
- 😐 Appropriate equipment for servicing with HCs
- 😐 Service technicians must be trained for safe handling

Hydrocarbon Refrigerant Issues

Many hydrocarbon gases have successfully been used as refrigerants in industrial, commercial and domestic applications

Examples:

R1270, Propylene, C_3H_6

R290 , Propane C_3H_8

R600a, Isobutane, C_4H_{10}

Blends of the above Gases

Hydrocarbon Refrigerant Issues

Commonly used HC Refrigerants

Refrigerant	**Name**	**Normal boiling point**
R-600a	iso-butane	-11°C
R600a/R290 (50%/50%)	iso-butane/propane mix	-31°C
R-290	propane	-42°C
R-1270	propylene	-48°C
R290/R170 (94%/6%)	propane/ethane mix	-49°C

and in contrast

HCFC R22	*Chlorodifluoromethane*	*-40,8 °C*
HFC R404A	*R125/R143a/134a*	*-46,4 °C*

HC R290 Air-Conditioner EER

Generally 10 to 15 % higher Energy Efficiency Ratio (EER) than R22

Refrigerants and lubricants

Why do we need lubricants:

- lubrication of the compressor
- Sealing and cooling for the oil-filled types

Table: Lubricants and indication of suitability for refrigerant

Refrigerant type	Mineral Oil (MO)	Alkyl-benzene (AB)	MO + AB	Polyoleste r (POE)	Polyalpha olelfin	Polyalkelene-glycol (PAG)
CFCs & HCFCs	✓	✓	✓	(✓)	(✓)	x
HCFC Blends	(✓)	✓	✓	(✓)	x	x
HFCs and HFC Blends	✓	(✓)	✓	✓	✓	(✓)
Hydrocarbons	**✓**	**(✓)**	**(✓)**	**✓**	**✓**	**(✓)**
Ammonia (NH_3)	✓	(✓)	(✓)	x	✓	(✓)
CO_2	(✓)	(✓)	x	✓	✓	✓

✓ – Good suitability (✓) – applicable with limitations x – not suitable

Lubricants for use with hydrocarbon refrigerants

- Most common refrigeration oils are compatible with HCs
  - But: high solubility with certain mineral and POE oils.
  - Various lubricant manufacturers provide refrigeration oils specifically for HC refrigerants.

- Polyolester (POE) oils are specified as suitable for hydrocarbons
  - But: higher viscosity class demand for hydrocarbon raw materials in comparison with those used for HFCs.

Oil Type	**Compatibility**	**Solubility**
Mineral Oil (MO)	Good	High
Alkyl benzene (AB)	Good	Medium
Polyol Ester (POE)	Good	High
Polyol alpha olefin (PAO)	Good	High
Poly alkyl glycol (PAG)	Good	Medium

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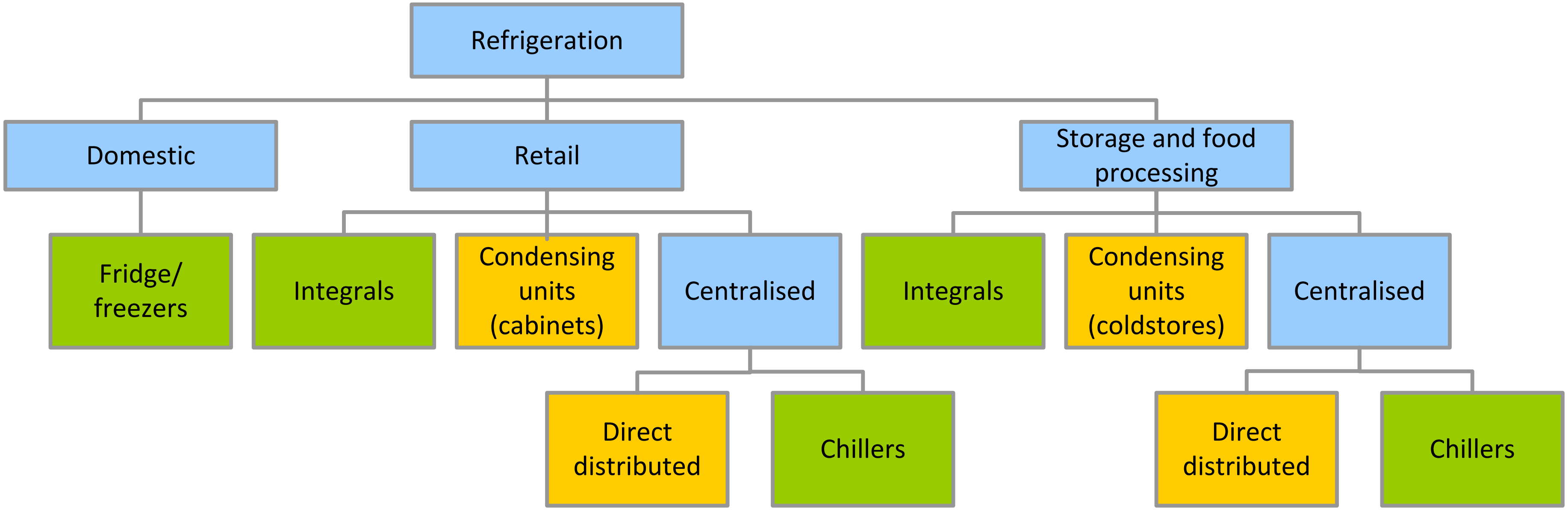
Ease of application of natural refrigerants



Refrigeration

Domestic

Retail

Storage and food processing

Fridge/ freezers

Integrals

Condensing units (cabinets)

Centralised

Integrals

Condensing units (coldstores)

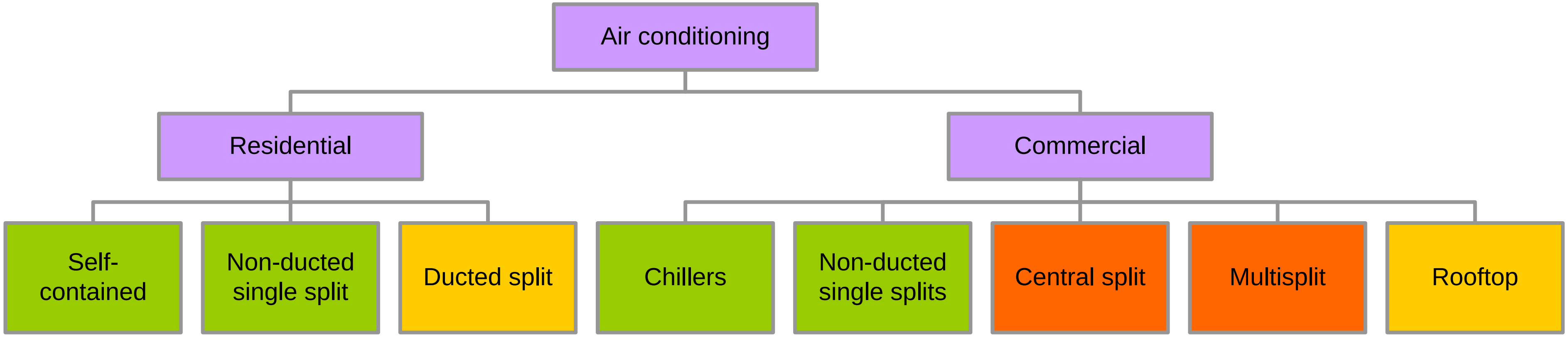
Centralised

Direct distributed

Chillers

Direct distributed

Chillers



Air conditioning

Residential

Commercial

Self-contained

Non-ducted single split

Ducted split

Chillers

Non-ducted single splits

Central split

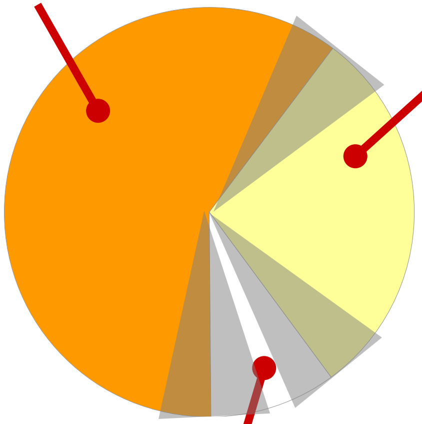
Multisplit

Rooftop

Potential application of HC application

Viable currently/in short-term

Viable if obstructive standards are remedied



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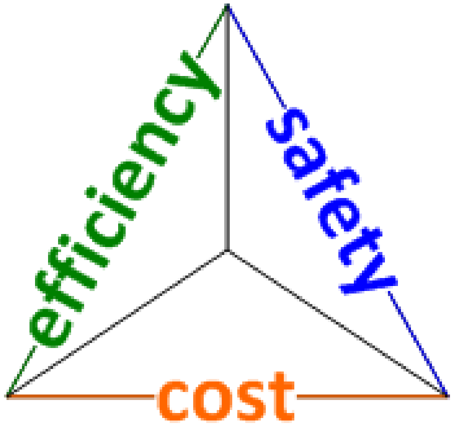


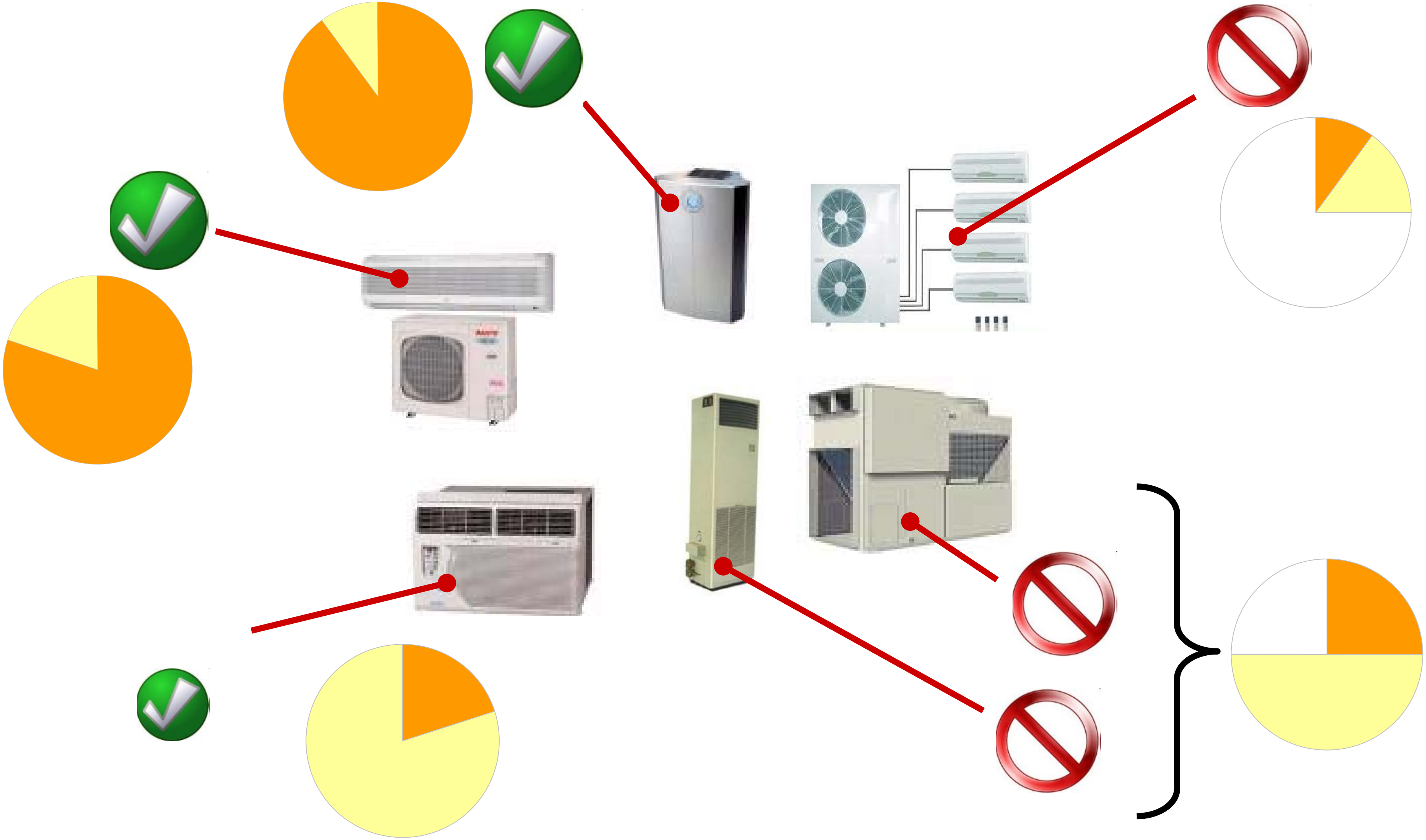
system and application characteristics }

Not viable due to cost, safety or performance limitations

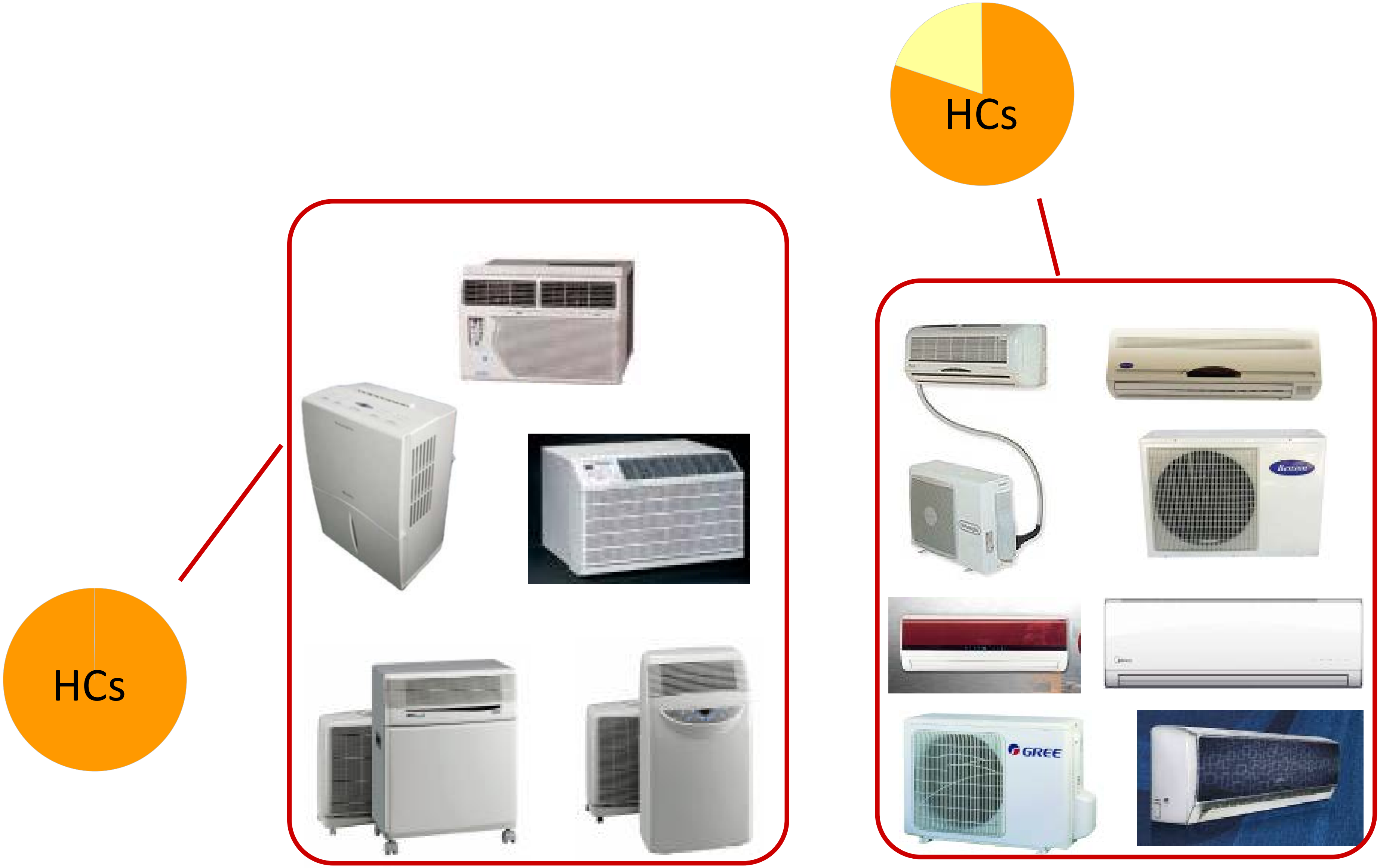
(Often, gap can be closed if alternatives system concepts are used, e.g., chiller instead of piped refrigerant)

NOTE: Viability proportions are approximate; they will always be subject to engineering interpretation

Viable application in air conditioners



Viable application in small air conditioners



Air conditioners – factory sealed

- De’Longhi
  - Portable type air conditioners
- Safety aspects
  - Designed to EN 60335-2-40
  - Charge size up to 400 g of R290
- Cost of R290 systems same as HFC products
- Energy consumption
  - R290 gives 5-10% higher efficiency than HFC options

Air conditioners – split type

- Several manufacturers in Europe, China, India, Australia primarily using R290
- Charge sizes up to 1 kg/7 kW cooling capacity
  - Very high efficiency
- Reversible systems available
- Major shift to R290 underway in China
  - Availability will improve over time

Air conditioners – split type

GREE products

- Several models developed
- Split, window, portable
- Reversible and cooling only
- Products have safety system integrated to reduce leak amount
- Lower cost than equivalent R22, R410A models

Capacity (kW)	EER (W/W)	Charge (g)	Max noise ID/OD (dB)	Dimensions (mm)
2.7	3.55	265	38/52	Indoor 830×284×205 Outdoor 760×257×541
3.5	3.52	330	41/52	

Air conditioners – split type

MIDEA products

- Currently several sizes developed
- Most reversible
- Other products developed
- Safety systems under development

Model	Indoor unit (mm)	Outdoor unit (mm)	Cooling capacity	EER	Heating capacity	COP	R290 charge
KFR-26GW/N7Y-Y(C4)	850 × 275 × 160	780 × 540 × 250	2.6 kW	3.4	2.8 kW	3.6	290 g
KFR-35GW/N7Y-Y(C4)	900 × 285 × 160	780 × 540 × 250	3.5 kW	3.4	3.7 kW	3.6	350 g

Air conditioners – split type

GODREJ products

- Currently two sizes developed
- Each has four models, corresponding to different Indian efficiency star rating categories
- Data for "five star" products

Model Name	R290-12K	R290-18K
Operating Mode	Cooling	Cooling
Cooling Capacity	3400 W	4900 W
Rated Power Input	914 W	1318 W
Rated Input Current	4 A	6 A
EER	3.72	3.72
Refrigerant	R 290	R 290
Refrigerant Charge	0.290 kg	0.340 kg

High efficiency

Very low specific refrigerant charge (<80 g/kW)

Also includes leak safety mechanism to leak safe

Air conditioners – split type

BENSON (Australia) air conditioning

- Single cooling-only, reversible and heat-recovery splits

- Safety aspects
  - Designed to AS/NZS 1677 (similar to EN 378)
  - Charge size up to 1000 g of R290

- Cost of R290 systems less than R410A
- Efficiency (cooling and heating) better than competing R410A and R22 products

		BENHC 24 R / RC	BENHC 34 R / RC	BENHC 50 R / RC	BENHC 65 R / RC	BENHC 85 / RC
Cooling Capacity	Watts	2310	3400	5100	6300	8200
Heating Capacity	Watts	2600	3400	5600	6600	8400
Energy Efficiency Cooling	EER (W / W)	3.12	3.17	2.91	2.9	2.96
Energy Efficiency Heating	COP (W / W)	3.71	3.57	3.07	3.3	2.91

Ducted with HCs

- AICOOL, Indonesia
  - Rooftop ducted and ducted split systems developed to use R290
- Safety aspects
  - Designed to EN 378; up to 2.5 kg of R290 per refrigerant circuit
  - Cost slightly higher than R22 systems

Chillers

HC chillers

- Several manufacturers using HCs
  - Benson, Bright, Earthcare, Frigadon, Futron, Klima-therm, Weatherite, York/JCI, others…
- All produce chillers using HC and other refrigerants (HFC, HCFC, ammonia, etc)
- Used for both refrigeration as well as air conditioning applications

HC chillers

- FRIGADON
  - Air-cooled chillers
- Safety aspects
  - Designed to EN 378
  - Charge size up to 15 kg of R1270
- Cost of R1270 systems marginally more than HFC products
- Energy consumption
  - R1270 gives higher efficiency

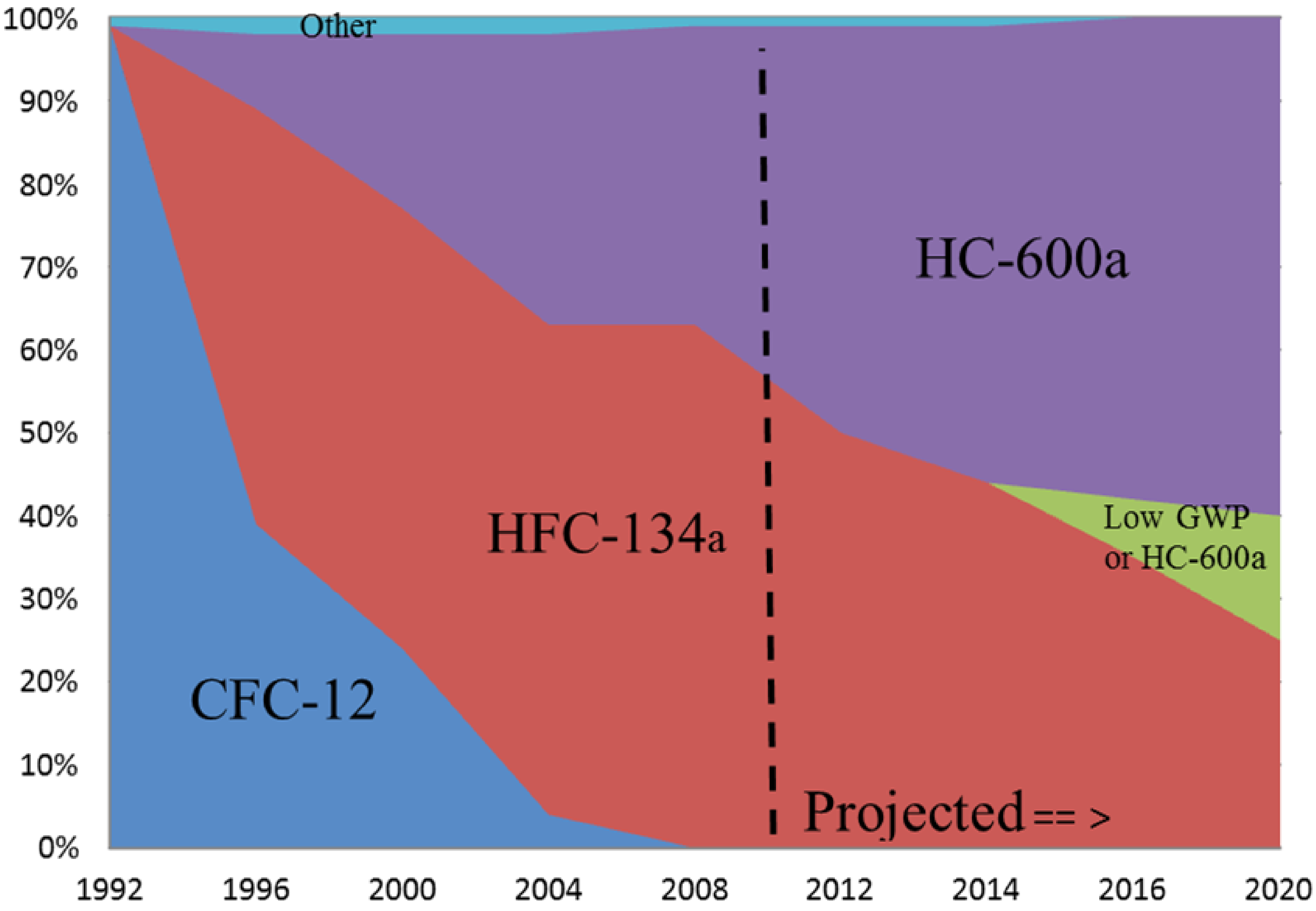
Cooling capacities/ flow rates	Cooling capacity* Brine temp return/flow			
Unit	+22/+17°C	+12/+7°C	0/-4°C	-4/-8°C
FWC-15	1,8	1,3	0,8	0,7
FWC-25	3	2,2	1,4	1,1
FWC-35	4,3	3,1	1,9	1,6
FWC-50	5,9	4,1	2,3	1,9
FWC-80	9,2	6,7	4,1	3,3
FWC-110	13,3	9,7	6	4,8
FWC-130-MT	-	-	7,6	6,2
FWC-130	18,3	13	7,6	6,2
FWC-170	22,5	16,3	10	8,1
FWC-220	-	20,7	12,8	10,5
FWC-220-S(1)	-	-	14,7	12
FWC-220-S(2)	-	-	-	15
FWC-300	36,7	28,2	20	15,2
FWC-400-MT	-	-	27	21,1
FWC-400	50	39,4	27	21,1
FWC-500	-	45,4	31,5	24,3
FWC-500-S(3)	-	54,2	34,3	28,6
FWC-500-S(4)	-	-	42,8	35,6
FWC-500-S(5)	-	-	52	43,8
FWC-650	79,9	59,4	39,5	32,8
FWC-720	93,5	69,9	45,9	38,1
FWC-870	-	86,5	56,1	47,2
FWC-870-S(5)	-	-	66,4	55,9
FWC-870-S(6)	-	-	78,7	66,1
FWC-870-S(7)	-	-	86,4	72,5
FWC-870-S(8)	-	-	95,1	80
FWC-870-S(9)	-	-	-	88,8

Viable application in domestic refrigerators

Domestic refrigerators

- More than 60% of new domestic fridge/freezers on HCs (R600a)
  - Total production > 700 m
  - All European manufacturers using R600a in majority of production
  - Large proportion from Korea, Japan, China
  - Introduction in South America and now North America
- Charge size up to 150g
- Highest efficiency models

Domestic refrigeration refrigerant trends



Source: UNEP RTOC

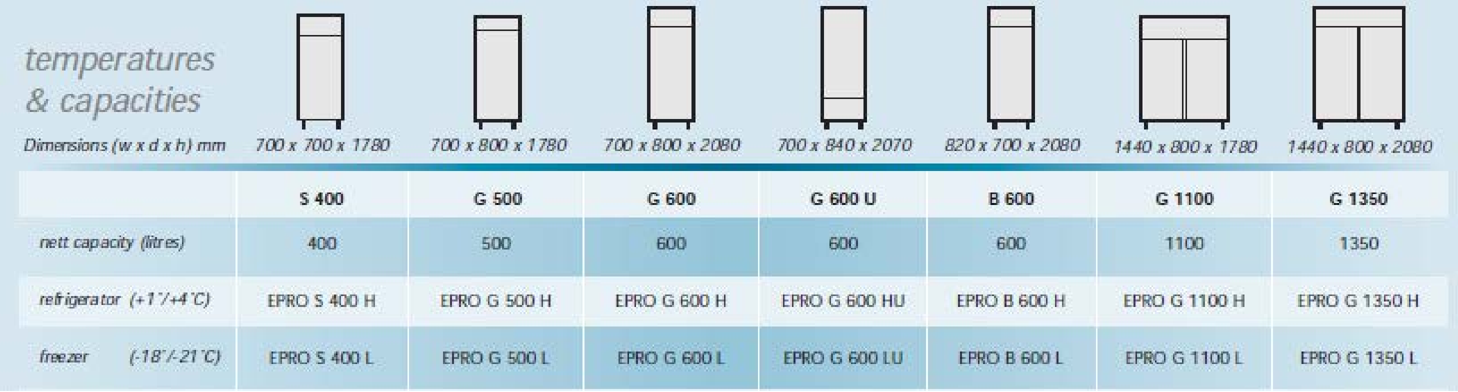
Viable application in commercial refrigerat.

Plug-in chillers and freezers

- Many commercial cabinets with R290, R1270, R600a
    - End users report 5 – 15% lower energy use
- Numerous manufacturers within Europe, Japan, Central America, Southern Africa, China, SE Asia, etc
- Two general categories
    - Movable type appliances with charges up to 150 g
    - Fixed appliances charges up to 1.5 kg

Plug-in catering

- Foster Refrigerator
  - Commercial stand-alone cabinets
- Safety aspects
  - Designed to EN 60335-2-89
  - Charge size up to 150 g of R290
- Cost of R290 systems same as HFC products
- Energy consumption
  - R290 gives 15% lower kWh/24h than R134a/R404A option



temperatures & capacities

Dimensions (w x d x h) mm	*700 x 700 x 1780*	*700 x 800 x 1780*	*700 x 800 x 2080*	*700 x 840 x 2070*	*820 x 700 x 2080*	*1440 x 800 x 1780*	*1440 x 800 x 2080*
	S 400	**G 500**	**G 600**	**G 600 U**	**B 600**	**G 1100**	**G 1350**
nett capacity (litres)	400	500	600	600	600	1100	1350
refrigerator (+1˚/+4˚C)	EPRO S 400 H	EPRO G 500 H	EPRO G 600 H	EPRO G 600 HU	EPRO B 600 H	EPRO G 1100 H	EPRO G 1350 H
freezer (-18˚/-21˚C)	EPRO S 400 L	EPRO G 500 L	EPRO G 600 L	EPRO G 600 LU	EPRO B 600 L	EPRO G 1100 L	EPRO G 1350 L

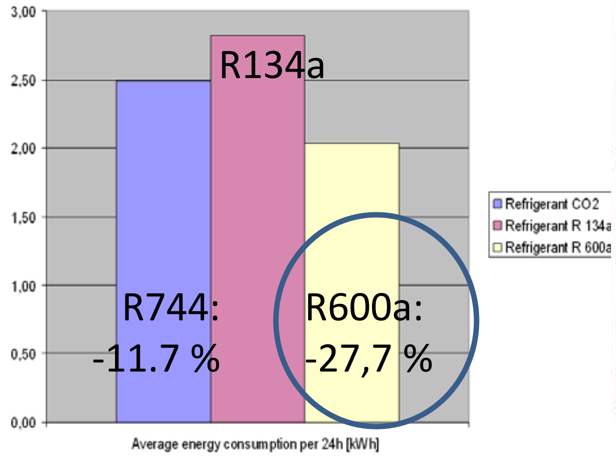
Other appliances

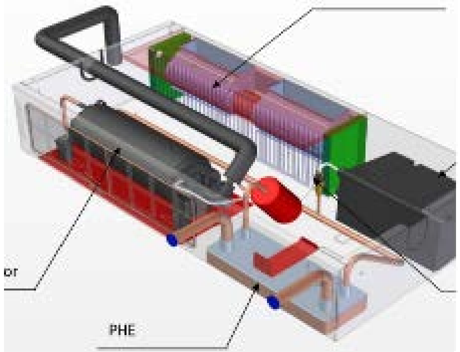
- Professional food and drinks preparation equipment
  - Shake sundae machine
  - Post-mix beverage machine
  - Juice dispenser
- Ice makers
- Cold storage
  - Meat freezers and chilled produce rooms

Plug-in chillers and freezers – efficiency

Examples of data for chiller & freezer cabinets

Source: Pedersen, 2008

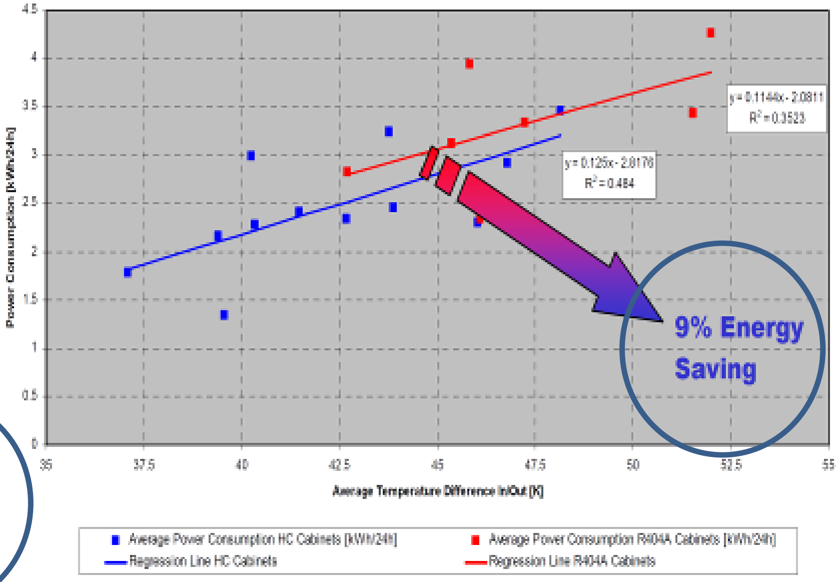




R404a v R1270 Comparison Data

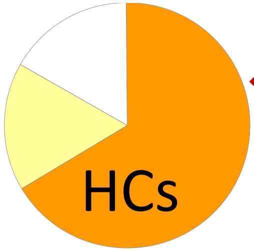
			R404a	R1270	% Saving
Case Type	Model	Length	DEC (watts)	DEC (watts)	
FHC	IC	2.50m	1424	1196	-16%
HGD	GD	2.50m	1514	1272	-16%

Source: King et al, 2011



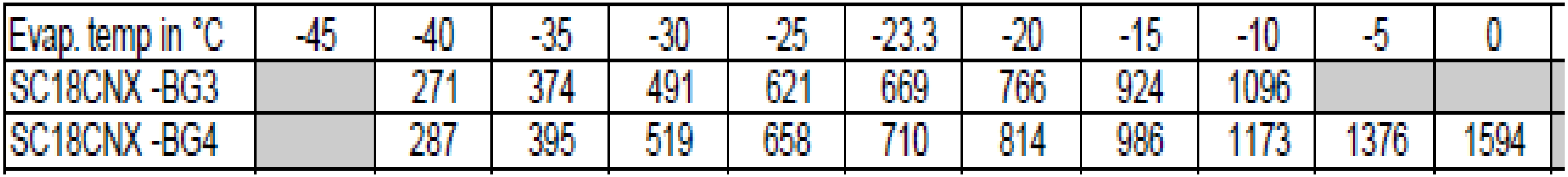
Source: van Gerwen et al, 2008

Viable application in condensing units

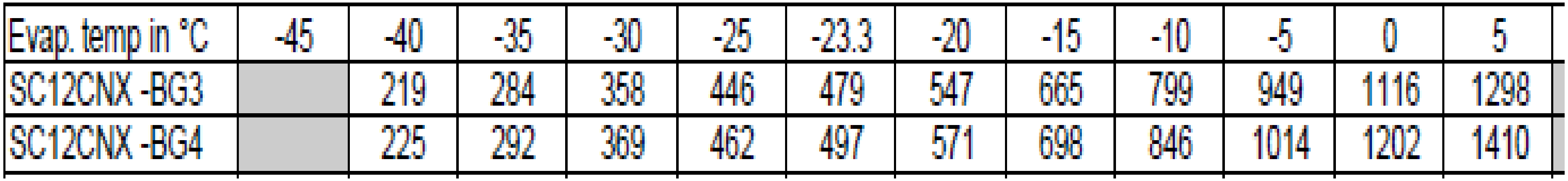


Small HC condensing units

- Danfoss
  - Range of R290 condensing units
  - Smaller capacity range
- Safety aspects
  - Designed to EN 378/EN 6035-2-89
- High efficiency

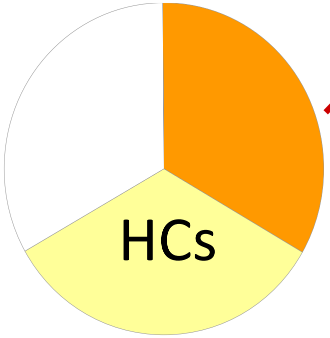


Evap. temp in °C	-45	-40	-35	-30	-25	-23.3	-20	-15	-10	-5	0
SC18CNX -BG3		271	374	491	621	669	766	924	1096		
SC18CNX -BG4		287	395	519	658	710	814	986	1173	1376	1594

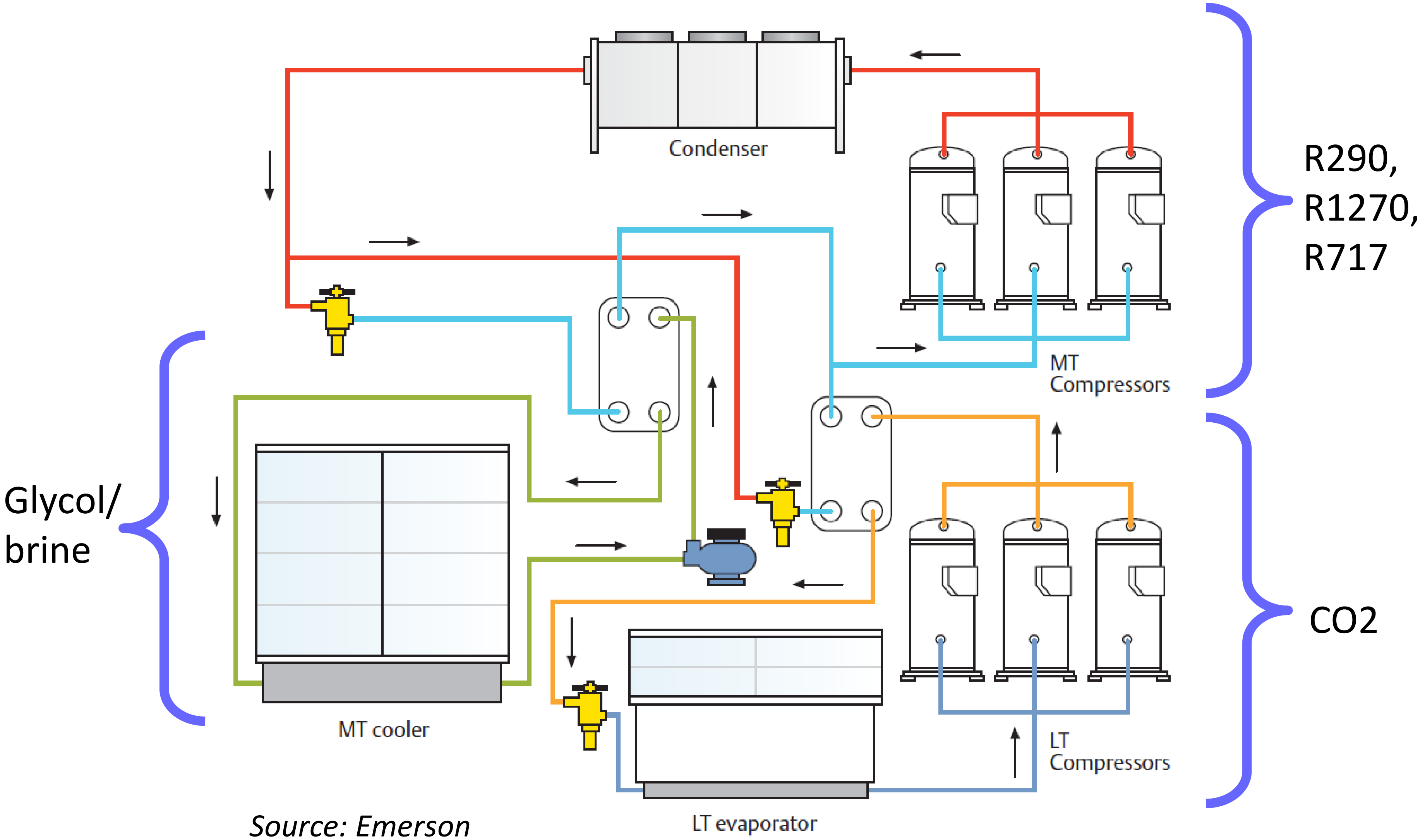


Evap. temp in °C	-45	-40	-35	-30	-25	-23.3	-20	-15	-10	-5	0	5
SC12CNX -BG3		219	284	358	446	479	547	665	799	949	1116	1298
SC12CNX -BG4		225	292	369	462	497	571	698	846	1014	1202	1410

Viable application in larger coldstores



Indirect/cascade

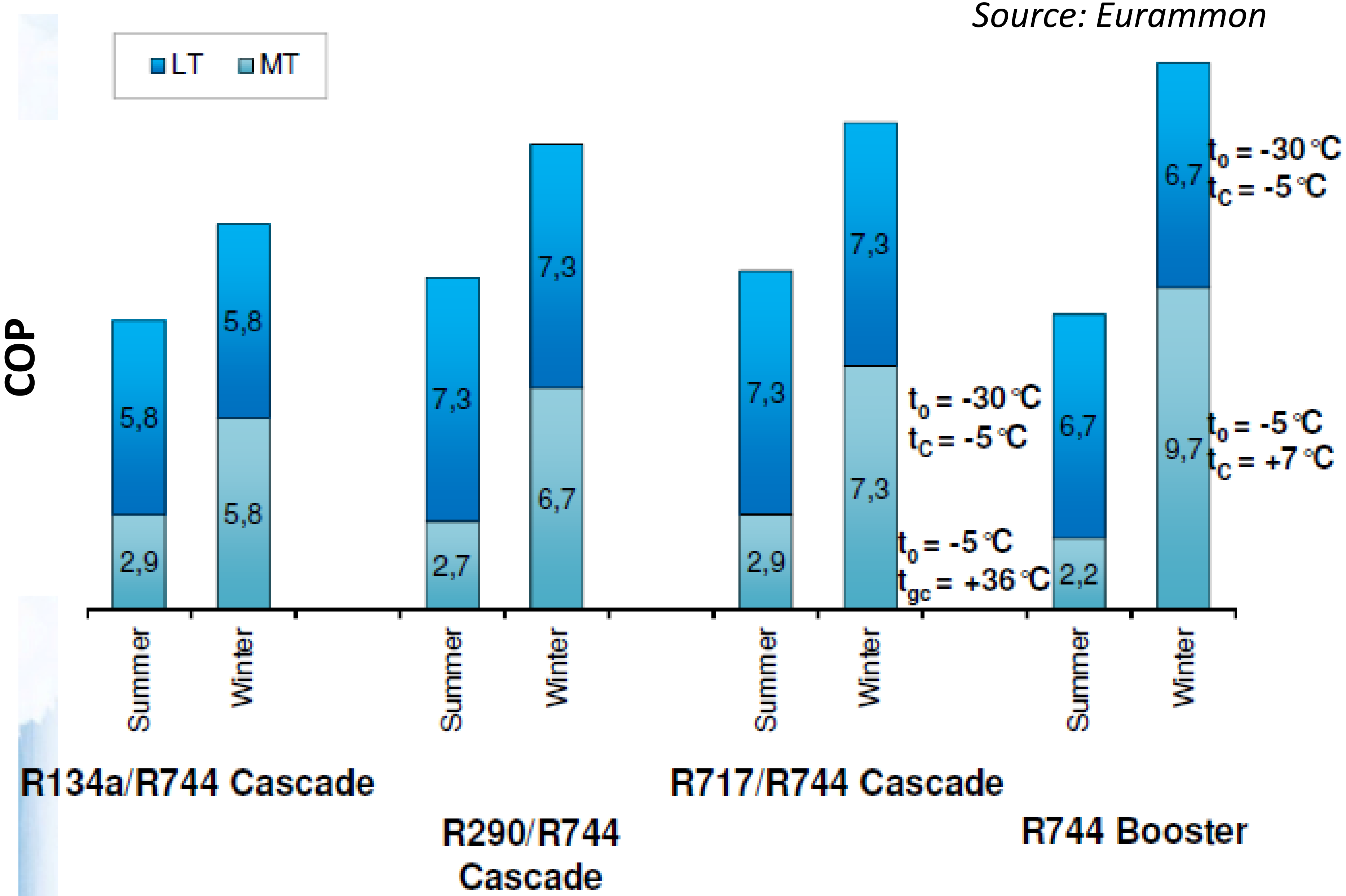


Source: Emerson

Examples of indirect systems using HCs

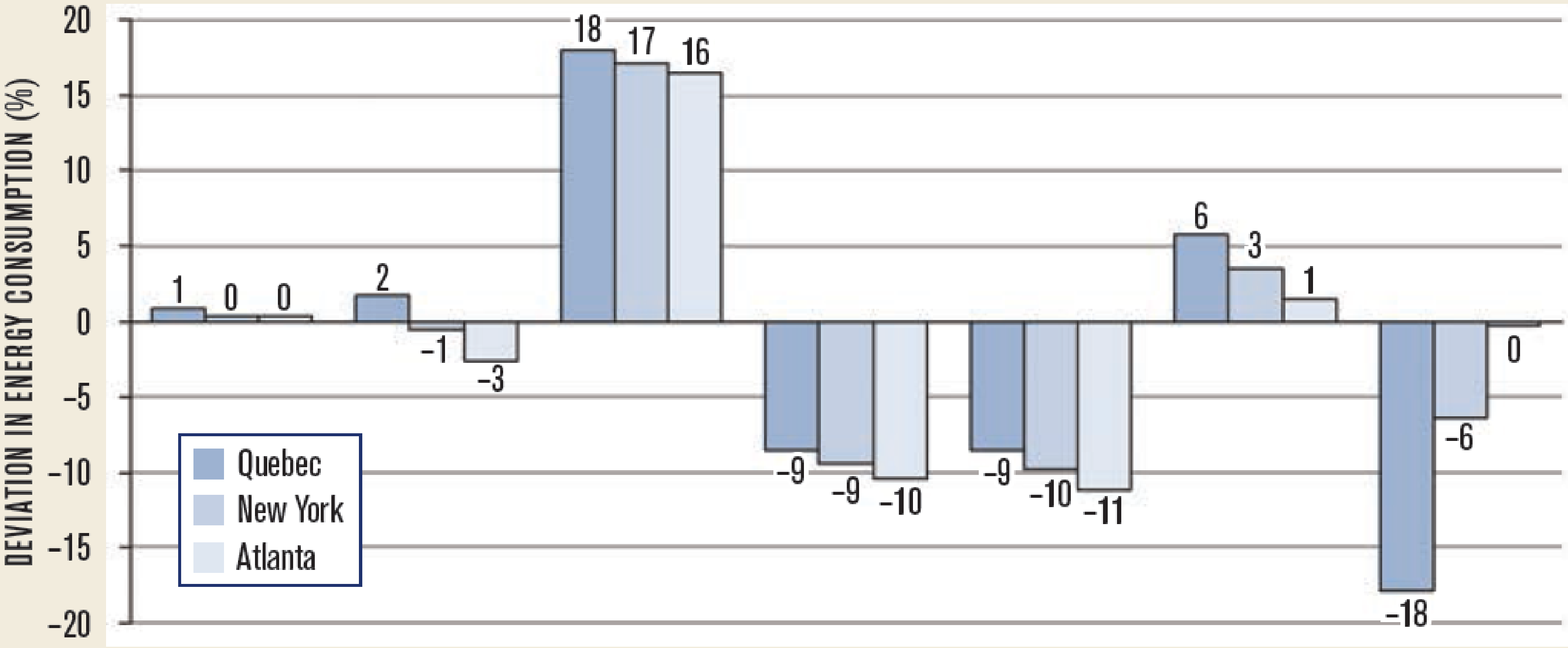
Comparison of certain options

Source: Eurammon



Comparison of energy consumption

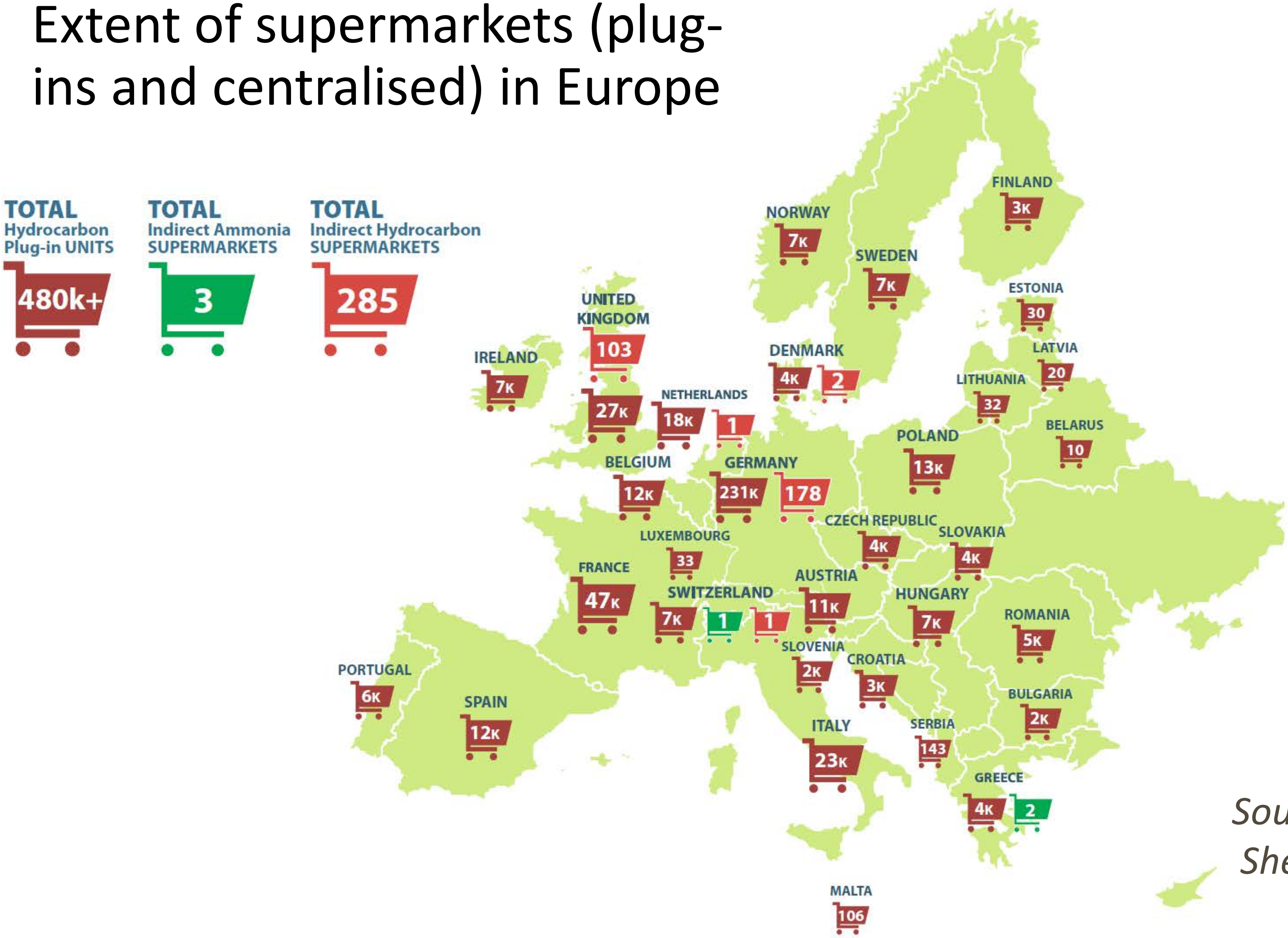
Source: Danfoss



Alternative System	(1) R-404A/ CO_2 Cascade	(1) R-134a/ CO_2 Cascade	(2) R-404A Chiller	(3) Propane Chiller	(3) Ammonia Chiller	(3) R-134a Chiller	(4) Transcritical CO_2 Booster
MT	R-404A DX	R-134a DX	Prop. Glycol	Pumped CO_2	Pumped CO_2	Pumped CO_2	CO_2 DX
LT	CO_2 DX	CO_2 DX	CO_2 DX	CO_2 DX	CO_2 DX	CO_2 DX	CO_2 DX

Penetration of HC systems in 2013

- Extent of supermarkets (plug-ins and centralised) in Europe



Source: Shecco

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General – safety rules for natural refrigerants

Main topics within RAC safety standards:

- Classification of refrigerants, occupancy, systems
- Refrigerant charge size limits
- Safe design and testing of components and pipes
- Safe design and testing of assemblies (systems)
- Electrical safety, sources of ignition
- Installation areas, positioning, pipework, mechanical ventilation, gas detection
- Instructions, manuals, data plates
- Refrigerant handling

Classification of refrigerants: flammability and toxicity

Refrigerants are classified according to their flammability and toxicity.

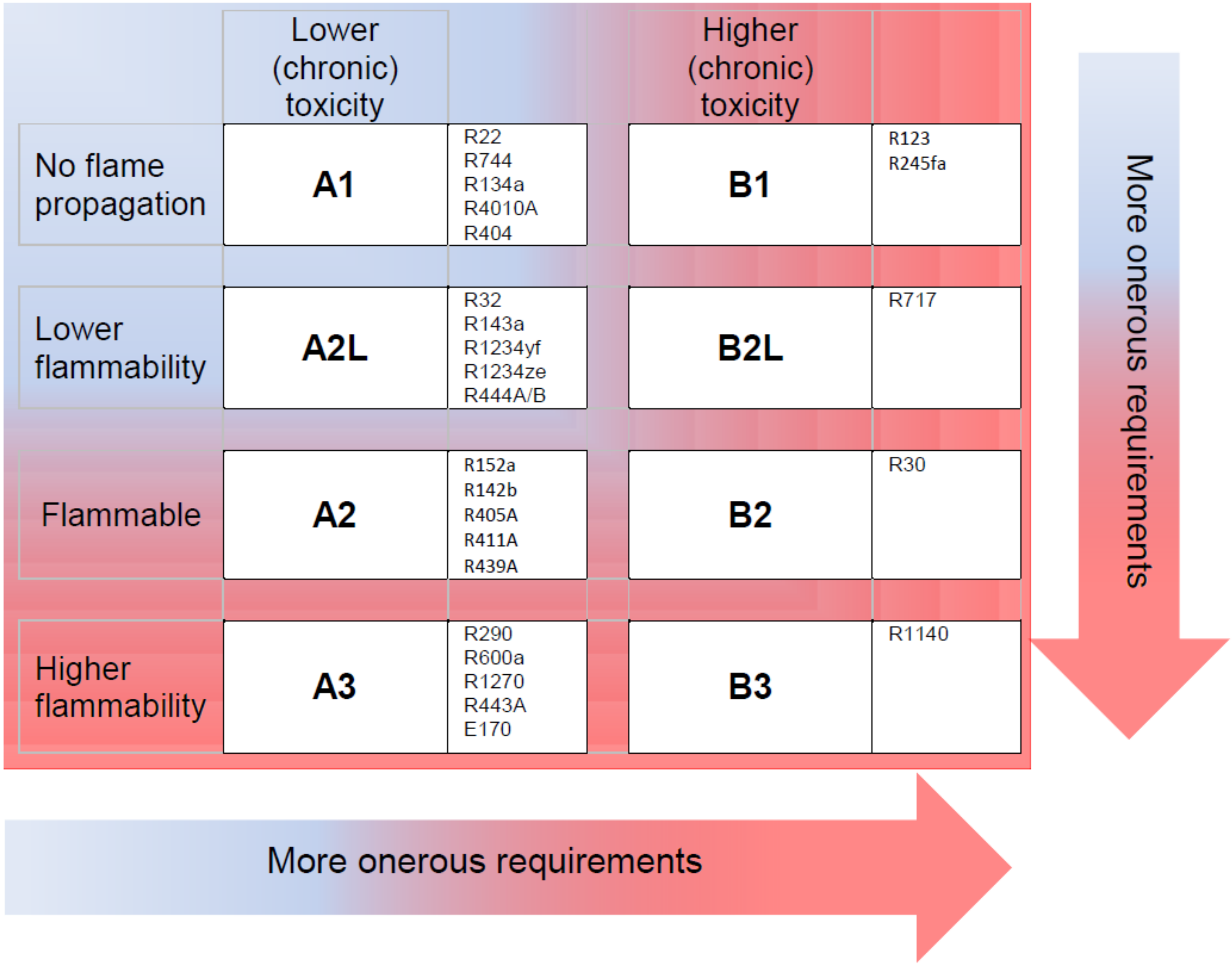
The safety classifications are defined in ISO817:2009 and are also used in EN378-1:2017-03

After years of standards revisions A2L safety classification are included now in EN 378, ISO 817, ISO 5149 and ASHRAE standards (American Society of Heating, Refrigeration and Air Conditioning Engineers).

Classification of refrigerants

A “higher” classification (i.e. toxicity class B instead of class A, and flammability class 3 instead of class 1) means:

- the refrigerating system has more demanding design requirements,
- in order to handle the higher risk represented by the refrigerant.



	Lower (chronic) toxicity		Higher (chronic) toxicity	
No flame propagation	**A1**	R22 R744 R134a R4010A R404	**B1**	R123 R245fa
Lower flammability	**A2L**	R32 R143a R1234yf R1234ze R444A/B	**B2L**	R717
Flammable	**A2**	R152a R142b R405A R411A R439A	**B2**	R30
Higher flammability	**A3**	R290 R600a R1270 R443A E170	**B3**	R1140

More onerous requirements

More onerous requirements

Note: In contrast to the previous version of EN378:2008/2012, A2L safety classification is included with the revisions of EN378:2017-3, ISO817 and ISO5149.

Flammability Classification ASHRAE and for EN 378 and ISO 817: flammability rating

Safety classification	Lower Flammability level, % in air by volume	Heat of combustion, J/kg	Flame propagation
A1	No flame propagation when tested at 60^{o}C and 101.3 kPa		
A2, lower flammability	> 3.5	< 19,000	Exhibit flame propagation when tested at 60^{o}C and 101.3 kPa
A2L, lower flammability, proposed sub classification	> 3.5	< 19,000	Exhibit flame propagation when tested at 60^{o}C and 101.3 kPa and have a maximum burning velocity of ≤ 10 cm/s when tested at 23^{o}C and 101.3 kPa
A3, higher flammability	≤ 3.5	≥ 19,000	Exhibit flame propagation when tested at 60^{o}C and 101.3 kPa

Classification of refrigerants: practical concentration limit

There is an additional measure for the application of refrigerants, the Practical Limit (PL). This is, in principle, the lowest “dangerous” concentration of a refrigerant, with a safety factor applied.

PL concentration is used for simplified calculation to determine the maximum acceptable amount of refrigerant in an occupied space.

The estimation of PL is based on the lowest of the following parameters:

1. Acute-toxicity exposure limit (ATEL), based on mortality and/or cardiac sensitisation, and/or anaesthetic or central nervous system (CNS) effects
2. Oxygen Deprivation Limit (ODL)
3. 20% of the lower flammability limit (LFL)

Practical limit for HC concentration

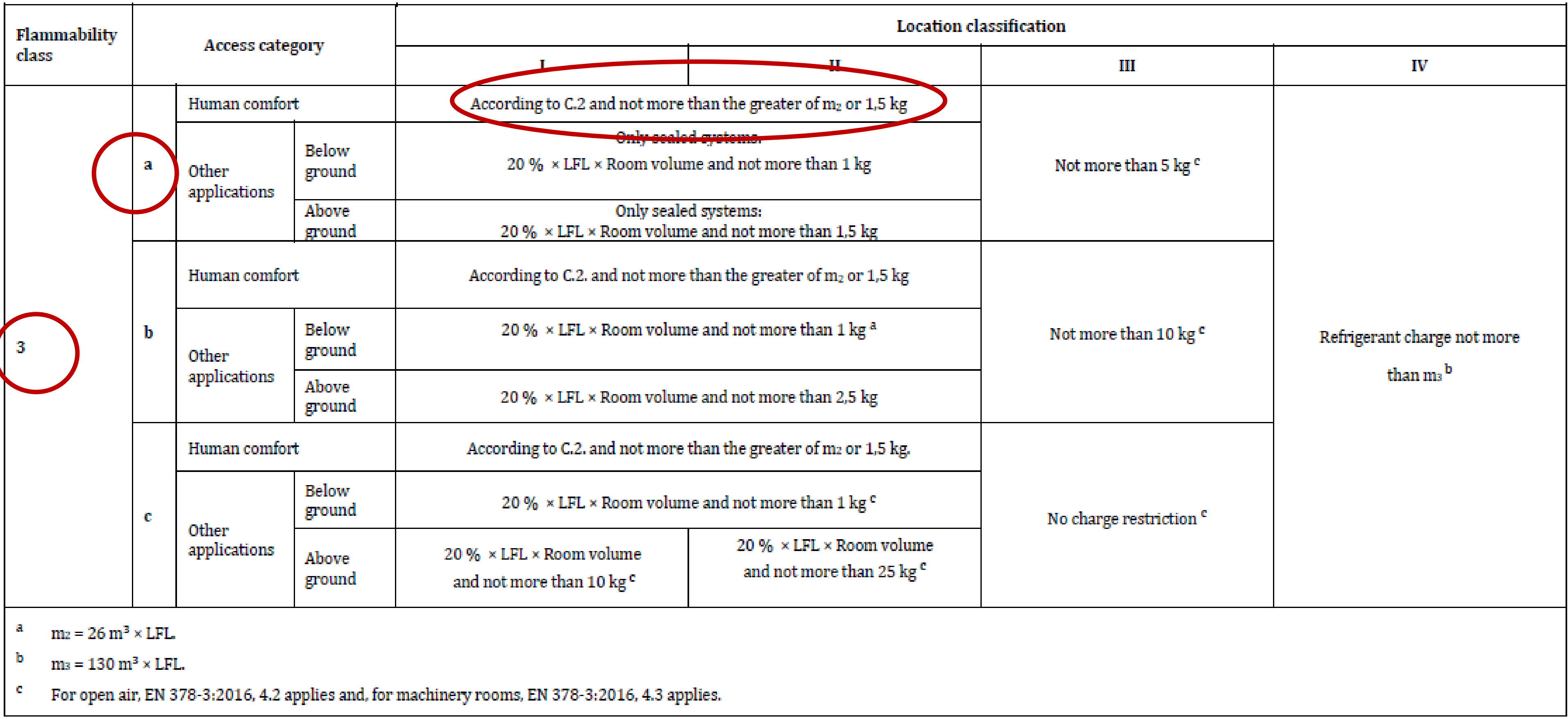
For HC refrigerants, 20% of the LFL represents the lowest concentration of the 3 parameters mentioned before.

- This characteristic is used to determine the practical limit (PL).
- PL is expressed in terms of mass per unit volume.

Refrigerant number	Chemical name	Chemical formula	Safety class	Practical limit d (kg/m3)	ATEL/ODL g (kg/m3)	LFL h (kg/m3)	Autoignition temperature (°C)
R290	Propane	CH3CH2CH3	A3	0,008	0,09	0,038	470
R600a	2-methyl propane (isobutane)	CH(CH3)3	A3	0,011	0,059	0,043	460
R717	Ammonia	NH3	B2L	0,00035	0,00022	0,116	630
R744	Carbon dioxide	CO2	A1	0,1	0,072	NF	ND
R32	Difluoromethane (methylene fluoride)	CH2F2	A2L	0,061	0,3	0,307	648
R22	Chlorodifluoromethane	CHClF2	A1	0,3	0,21	NF	635

NF signifies non-flammable / / ND signifies not determined (EN 378-1 / Table E.1)

Maximum allowable HC charge sizes EN378-1:2017-3



Flammability class	Access category			Location classification			
				I	II	III	IV
3	a	Human comfort		According to C.2 and not more than the greater of m_2 or 1,5 kg		Not more than 5 kg [c]	Refrigerant charge not more than m_3 [b]
		Other applications	Below ground	Only sealed systems: 20 % × LFL × Room volume and not more than 1 kg			
			Above ground	Only sealed systems: 20 % × LFL × Room volume and not more than 1,5 kg			
	b	Human comfort		According to C.2. and not more than the greater of m_2 or 1,5 kg		Not more than 10 kg [c]	
		Other applications	Below ground	20 % × LFL × Room volume and not more than 1 kg [a]			
			Above ground	20 % × LFL × Room volume and not more than 2,5 kg			
	c	Human comfort		According to C.2. and not more than the greater of m_2 or 1,5 kg.		No charge restriction [c]	
		Other applications	Below ground	20 % × LFL × Room volume and not more than 1 kg [c]			
			Above ground	20 % × LFL × Room volume and not more than 10 kg [c]	20 % × LFL × Room volume and not more than 25 kg [c]		

[a] $m_2 = 26\ m^3 \times \text{LFL}$.

[b] $m_3 = 130\ m^3 \times \text{LFL}$.

[c] For open air, EN 378-3:2016, 4.2 applies and, for machinery rooms, EN 378-3:2016, 4.3 applies.

Related standards and personal competency requirements for HC and other refrigerants

Standard	Title	Guidance (among others)
EN378-1:2017	Refrigerating systems and heat pumps – Safety and environmental requirements, Basic requirements, definitions, classification and selection criteria	Practical limit Maximum charge sizes
EN378-2:2017	Refrigerating systems and heat pumps – Safety and environmental requirements, Design, construction, testing, marking and documentation	Pressure test Flared joints tightening torques
EN378-3:2017	Refrigerating systems and heat pumps – Safety and environmental requirements, Installation site and personal protection	Location of outdoor units HC detectors
EN378-4:2017	Refrigerating systems and heat pumps – Safety and environmental requirements, Operation, maintenance, repair and recovery	Repairs to HC systems Competency of personnel working on HC systems

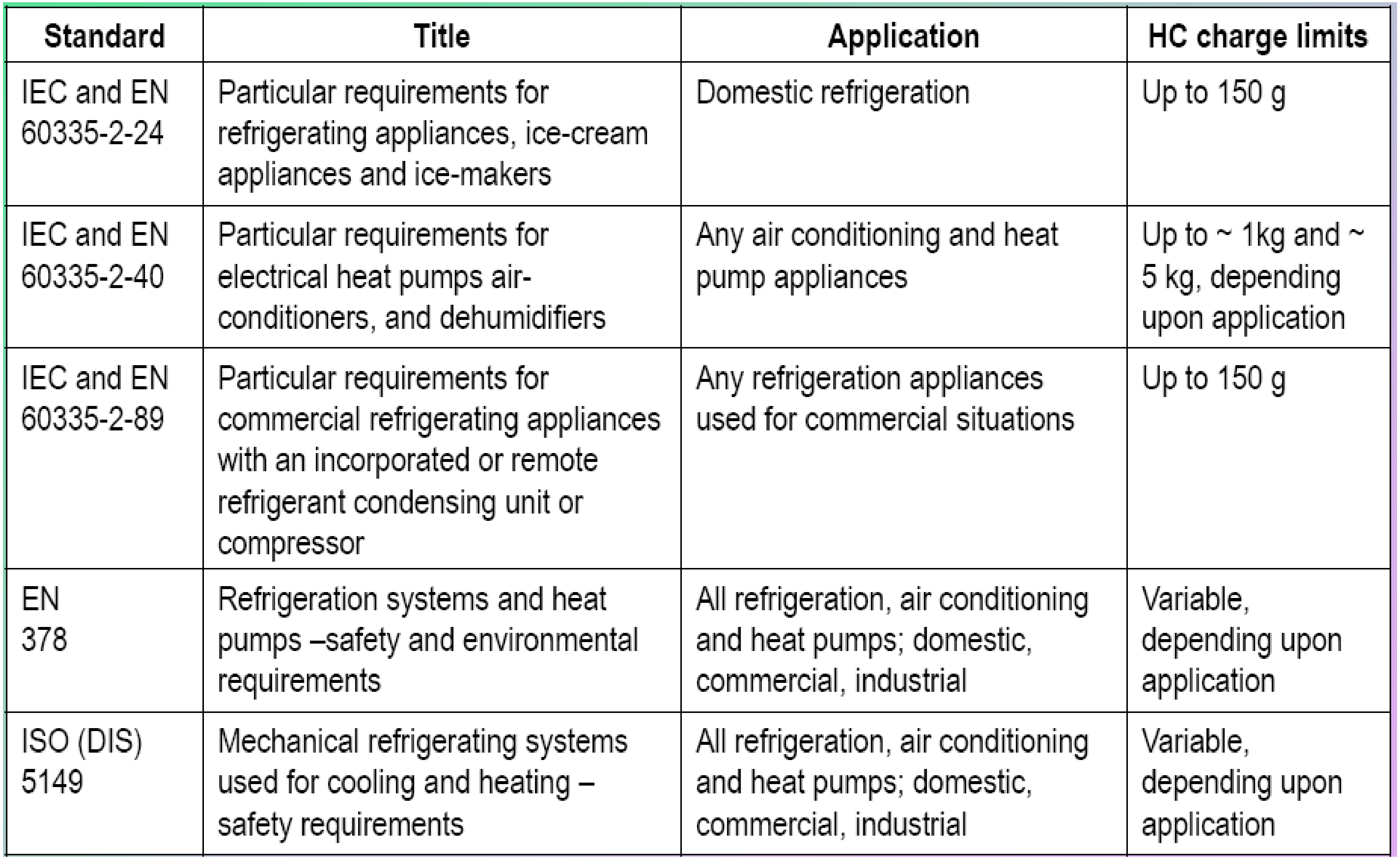
Related standards and personal competency requirements

Standard	Title	Guidance
IEC 60335-2-40	Particular requirements for safety of household appliances, electric air conditioners, heat pumps and dehumidifiers	Electrical safety Inappropriate operation
EN13313	Refrigerating systems and heat pumps - Competency of personnel	Job competencies and core activities
EN 50110	Operation of electrical installations	Job competency
EN ISO/IEC 17024	Conformity assessment - General requirements for bodies operating certification of persons	Competency of certification bodies
ISO 13585-2012	Brazing competencies certification	Examination criteria, inspection procedures and the area of application for a brazing competencies test certificate

Safety rules for alternative refrigerants

Standard	Equipment type	Coverage
EN 378:2017-3	Commercial and industrial	Components, safety devices, system design, location, charge size limits, refrigerant classification, installation site, maintenance
ISO 5149:2014-4	Commercial and industrial	
EN 60335-2-24	Domestic fridges and freezers	Marking, pressure testing, electrical
EN 60335-2-40	Factory built a/c and heat pumps	Marking, pressure testing, maintenance, electrical, charge limits
EN 60335-2-89	Factory built commercial fridges	Marking, pressure testing, electrical

Safety standards and charge sizes



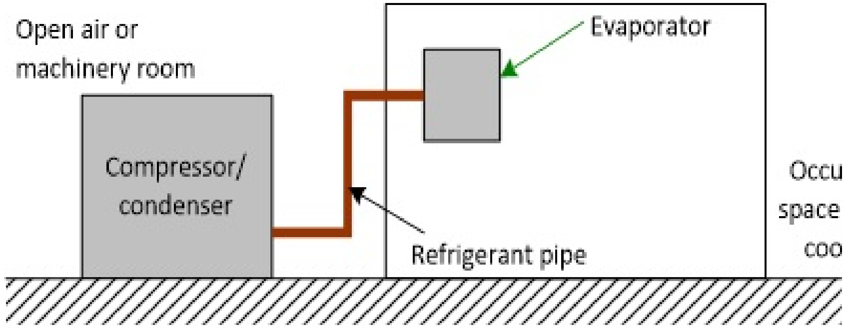
Standard	Title	Application	HC charge limits
IEC and EN 60335-2-24	Particular requirements for refrigerating appliances, ice-cream appliances and ice-makers	Domestic refrigeration	Up to 150 g
IEC and EN 60335-2-40	Particular requirements for electrical heat pumps air-conditioners, and dehumidifiers	Any air conditioning and heat pump appliances	Up to ~ 1kg and ~ 5 kg, depending upon application
IEC and EN 60335-2-89	Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor	Any refrigeration appliances used for commercial situations	Up to 150 g
EN 378	Refrigeration systems and heat pumps –safety and environmental requirements	All refrigeration, air conditioning and heat pumps; domestic, commercial, industrial	Variable, depending upon application
ISO (DIS) 5149	Mechanical refrigerating systems used for cooling and heating – safety requirements	All refrigeration, air conditioning and heat pumps; domestic, commercial, industrial	Variable, depending upon application

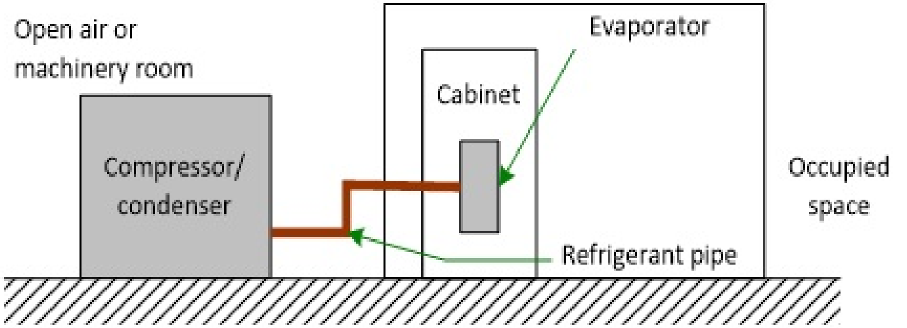
ATEX: introduction

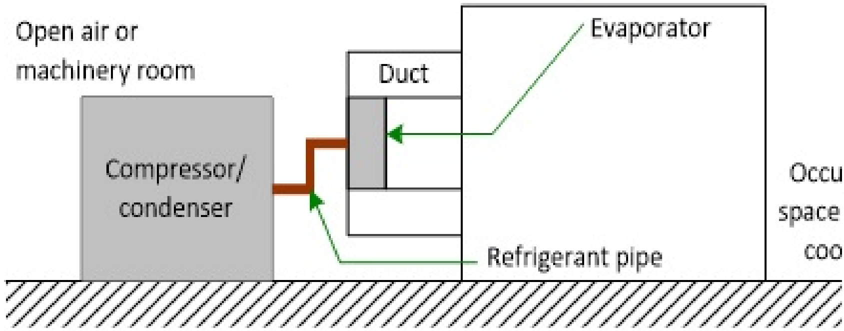
ATEX (Abbreviation: *ATmosphère Explosive*)
is the name commonly given to the legal requirements for controlling explosive atmospheres and the suitability of equipment and protective systems used in them.

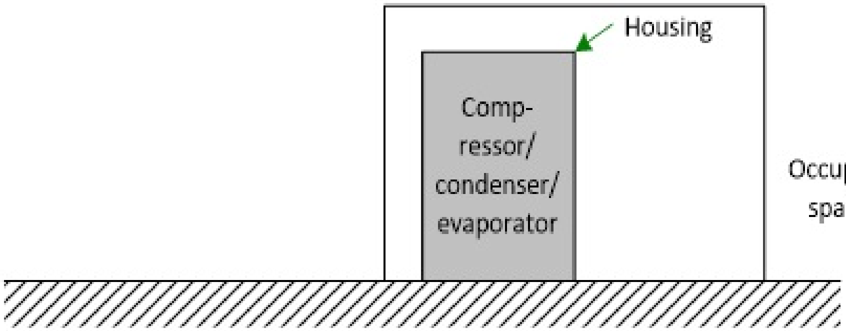
Guidance from EN 60079-10:
Classification of hazardous areas

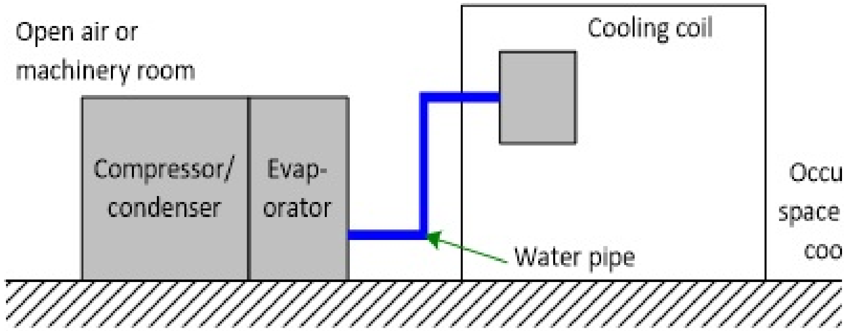
Generic types of RAC systems

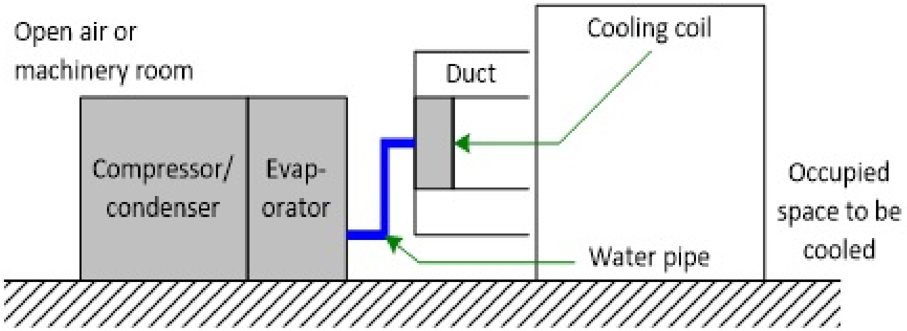












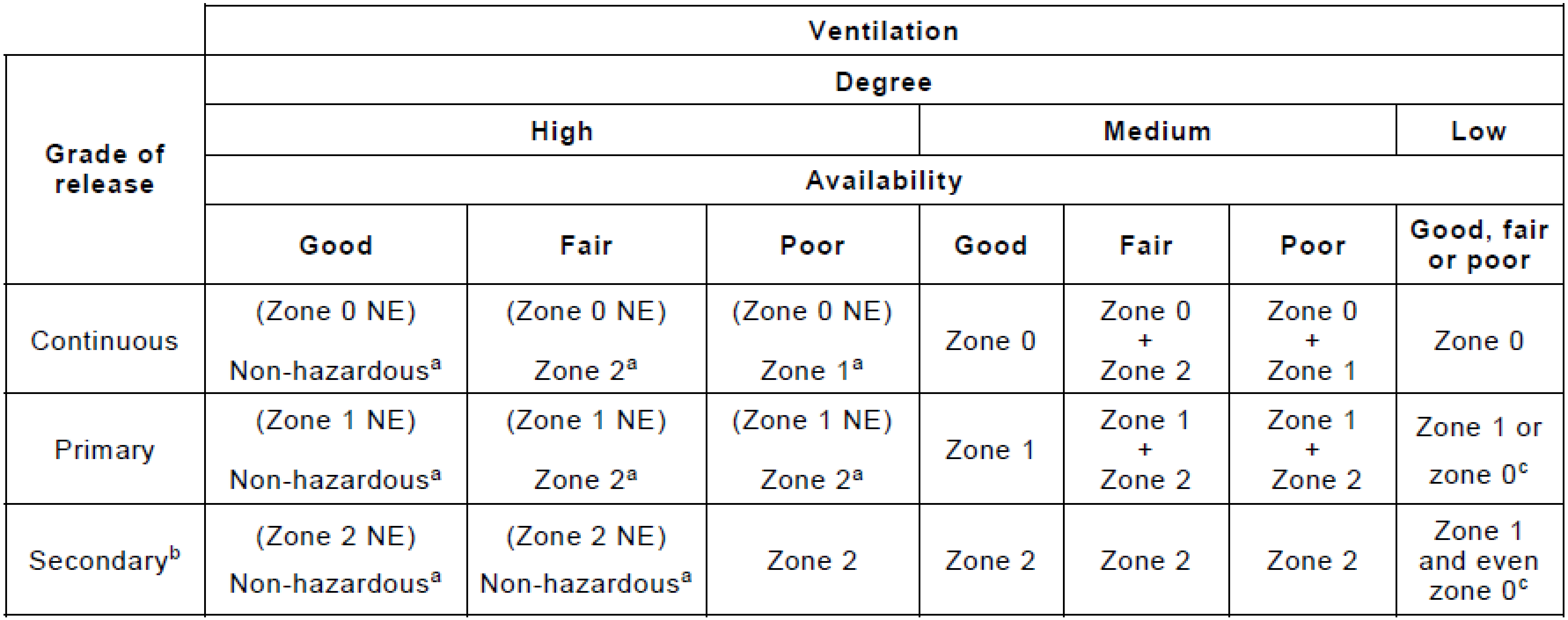
ATEX zone classification

Description	Gas, Vapour, Mist	Dust	Adaptable appliance group
Atmosphere	Mixture of air and flammable gases, vapors or mists	Contained cloud of combustible dust, contained in the air	Gas / Dust
Area, in which a potentially explosive atmosphere are permanent,for longer periods or often, available.	**Zone 0**	**Zone 20**	**II 1 G / II 1 D**
Area in which can occasionally compose a hazardous explosive atmosphere during normal operation	**Zone 1**	**Zone 21**	**II 1 G or II 2G** **/** **II 1 D or II 2 D**
Area where an explosive atmosphere does not normally occur or only temporary during normal operation	**Zone 2**	**Zone 22**	**II 1 G or II 2G or II 3 G** **/** **II 1 D or II 2 D or II 3 D**

ATEX zone classification:

The more the ventilation, the lower the ATEX zone / requirements

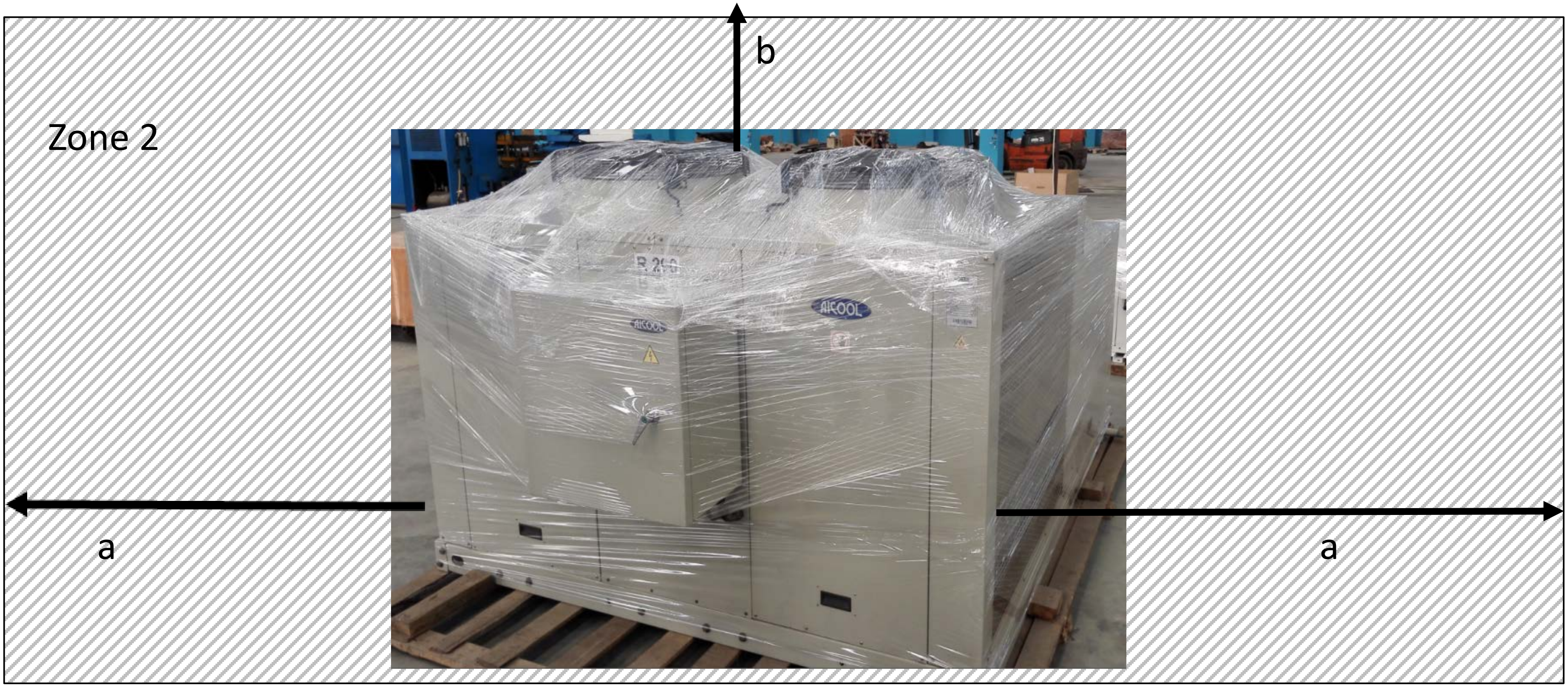
Table B.1 – Influence of independent ventilation on type of zone



Grade of release	Ventilation						
	Degree						
	High			Medium			Low
	Availability						
	Good	Fair	Poor	Good	Fair	Poor	Good, fair or poor
Continuous	(Zone 0 NE) Non-hazardous[a]	(Zone 0 NE) Zone 2[a]	(Zone 0 NE) Zone 1[a]	Zone 0	Zone 0 + Zone 2	Zone 0 + Zone 1	Zone 0
Primary	(Zone 1 NE) Non-hazardous[a]	(Zone 1 NE) Zone 2[a]	(Zone 1 NE) Zone 2[a]	Zone 1	Zone 1 + Zone 2	Zone 1 + Zone 2	Zone 1 or zone 0[c]
Secondary[b]	(Zone 2 NE) Non-hazardous[a]	(Zone 2 NE) Non-hazardous[a]	Zone 2	Zone 2	Zone 2	Zone 2	Zone 1 and even zone 0[c]

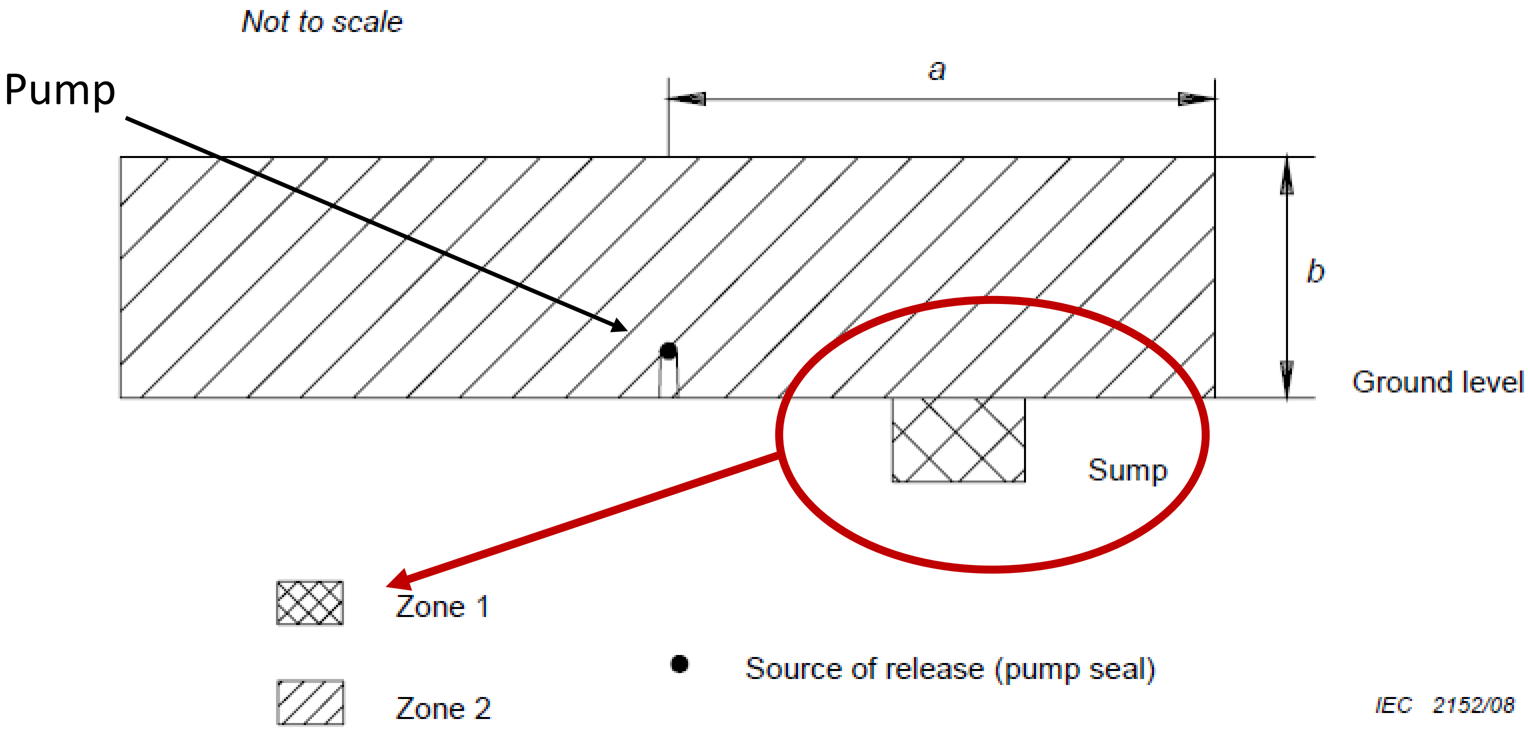
EN 60079-10-1 2009 / Table B.1

ATEX zone classification: example



According to EN 60079-1 Annex C, Example 1:
a = 3 m horizontally from source of release
b = 1 m from ground level and up to 1 m above the source of release.

ATEX zone classification: example



According to EN 60079-1 Annex C, Example 1:
a = 3 m horizontally from source of release
b = 1 m from ground level and up to 1 m above the source of release.

ATEX zone classification: chiller example

<table>
<tr><td colspan="15">Table C.1 – Hazardous area classification data sheet – Part I: Flammable material list and characteristics EN 60079-10-01 / 2009</td></tr>
<tr><td colspan="14">Plant: **Chiller Example 1**</td><td>Reference drawing:</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td></tr>
<tr><td></td><td colspan="2">Flammable material</td><td></td><td colspan="2">LEL</td><td colspan="3">Volatility (a)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>No</td><td>Name</td><td>Composition</td><td>Flashpoint °C</td><td>kg/m3</td><td>vol. %</td><td>Vapour pressure 20 °C bar</td><td>Melting point °C</td><td>Boiling point °C</td><td>Polytropic index of adiabatic expansion</td><td>Relative density gas/air</td><td>Ignition temp. °C</td><td>Group</td><td>Temp. Class</td><td>Any other relevant information and remarks</td></tr>
<tr><td>1</td><td>Propane</td><td>C3H8</td><td>-104°C</td><td>0.031</td><td>1.7</td><td>8.327</td><td>-187.7°C</td><td>-42.1°C</td><td></td><td>1.55</td><td>450°C</td><td>IIA</td><td>T3</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="15">(a) Normally, the value of vapour pressure is given, but in the absence of that, boiling point can be used (5.4.1d).</td></tr>
</table>

EN 60079-10-1 2009 / Annex C

ATEX zone classification: chiller example

<table>
<tr><td colspan="16">Table C.2 – Hazardous area classification data sheet – Part II: List of sources of release EN 60079-10-01 / 2009</td></tr>
<tr><td colspan="5">Plant: Chiller Example 1</td><td colspan="10">Area: Roof top</td><td>Reference drawing:</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td colspan="2">6</td><td>7</td><td colspan="3">8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
<tr><td></td><td colspan="2">Source of release</td><td></td><td colspan="4">Flammable material</td><td colspan="3">Ventilation</td><td colspan="4">Hazardous area</td><td></td></tr>
<tr><td rowspan="2">No.</td><td rowspan="2">Description</td><td rowspan="2">Location</td><td rowspan="2">Grade of release (.a)</td><td rowspan="2">Reference (.b)</td><td colspan="2">Operating temperature and pressure</td><td rowspan="2">State (.c)</td><td rowspan="2">Type (.d)</td><td rowspan="2">Degree (.e)</td><td rowspan="2">Availability (.e)</td><td rowspan="2">Zone type 0-1-2</td><td colspan="2">Zone extent m</td><td rowspan="2">Reference</td><td rowspan="2">Any other relevant information and remarks</td></tr>
<tr><td>°C</td><td>bar</td><td>Vertical</td><td>Horizontal</td></tr>
<tr><td>1</td><td>Seal of compressor</td><td>Chiller Rack</td><td>P</td><td>1</td><td>59°C</td><td>19.72</td><td>G</td><td>N</td><td>High</td><td>Good</td><td>2</td><td>3</td><td>1</td><td>1</td><td>Semi hermetic compressor</td></tr>
<tr><td>2</td><td>Pipe joint Evaporator</td><td>Chiller Rack</td><td>P</td><td>2</td><td>38°C</td><td>12.11</td><td>G</td><td>N</td><td>High</td><td>Good</td><td>2</td><td>3</td><td>1</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

(.a) C – Continuous; S – Secondary; P – Primary.
(.b) Quote the number of list in Part I.
(.c) G – Gas; L – Liquid; LG – Liquefied gas; S – Solid.
(.d) N – Natural; A – Artificial.
(.e) See IEC 60079-10-1 Annex B.

EN 60079-10-1 2009 / Annex C

Charge size restrictions for HCs

Regulation EN 378-1:2017-03 specifies maximum charge size limitations and practical limits for both refrigeration and comfort cooling/heating applications.

Most commonly applied limits:

- Systems with less than 150 g HC may be located anywhere
- 1 kg charge for systems must be located below ground
- 1.5 kg for systems in public area (e.g. supermarket shop floor)
- 2.5 kg for systems in a supervised area
- No limit for complete systems (e.g. chillers) outside and /or in an authorised access area

Please refer to EN378:2017-03 for full details!

Charge size restrictions for HCs

There are practical limits which apply if the HC refrigerant could leak into an enclosed area.

- For non-comfort cooling / heating applications such as cold rooms this is 8 grams / m^3 (0.008 kg/m^3) for R290.
- For comfort cooling and heating applications the maximum charge in kg is:

$$m_{max} = 2,5 \times LFL^{5/4} \times h_0 \times A^{1/2}$$

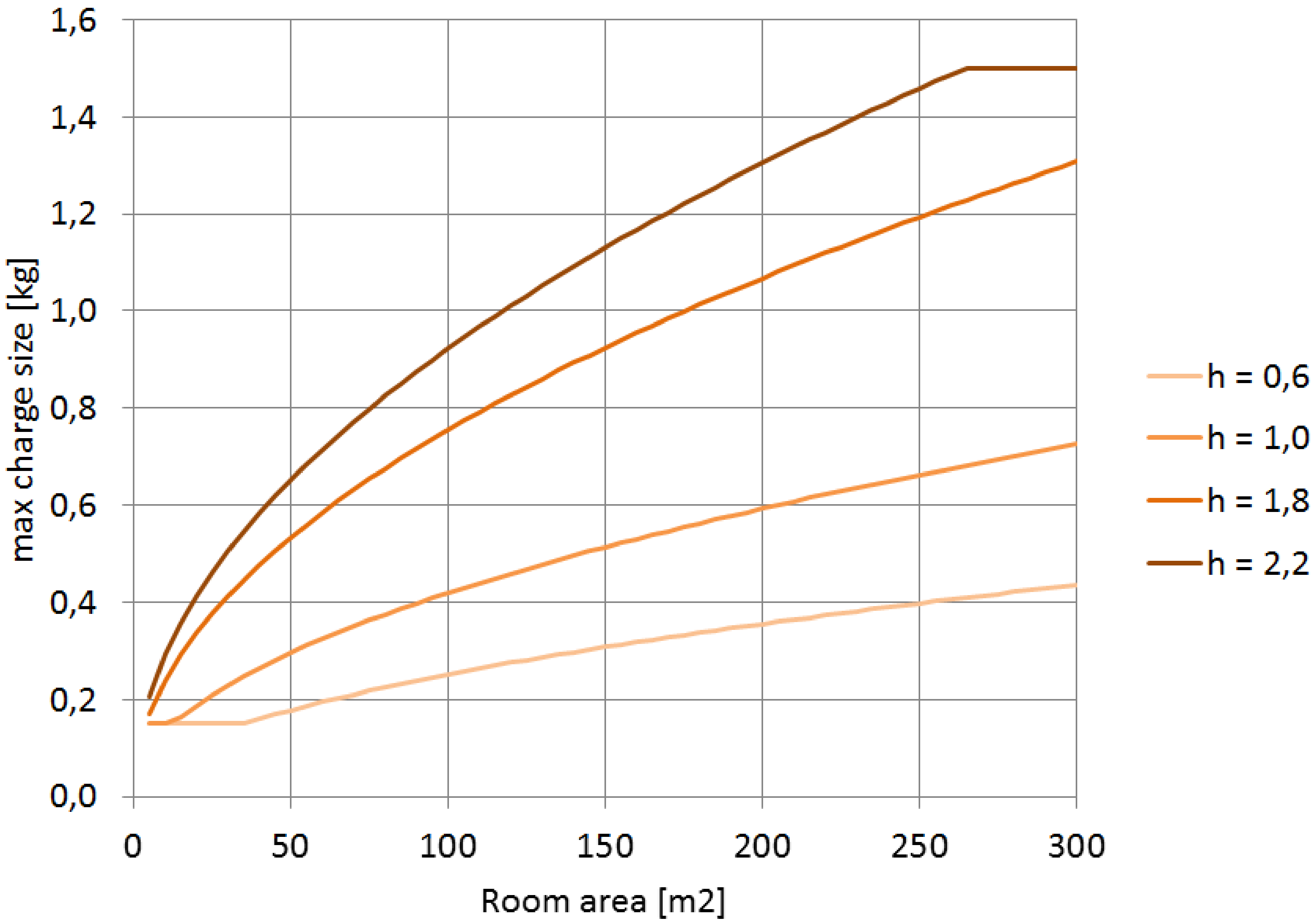
- The minimum room area in m^2 is:

$$Amin = m^2/(2,5 \times LFL^{5/4} \times h_0)^2$$

LFL =	Lower Flammability Level
h_0 =	height of the unit, in m (0.6 m for floor mounted, 1.0 m for window, 1.8 m for wall, 2,2 m for ceiling)
A =	Floor area, in m^2

Reference: EN378-1:2017-03

Maximum allowable charge sizes (R290)



Example: Allowable charge size

Minimum room size for a given refrigerant charge for ACs for human comfort.

SAC : GSC 18 Godrej

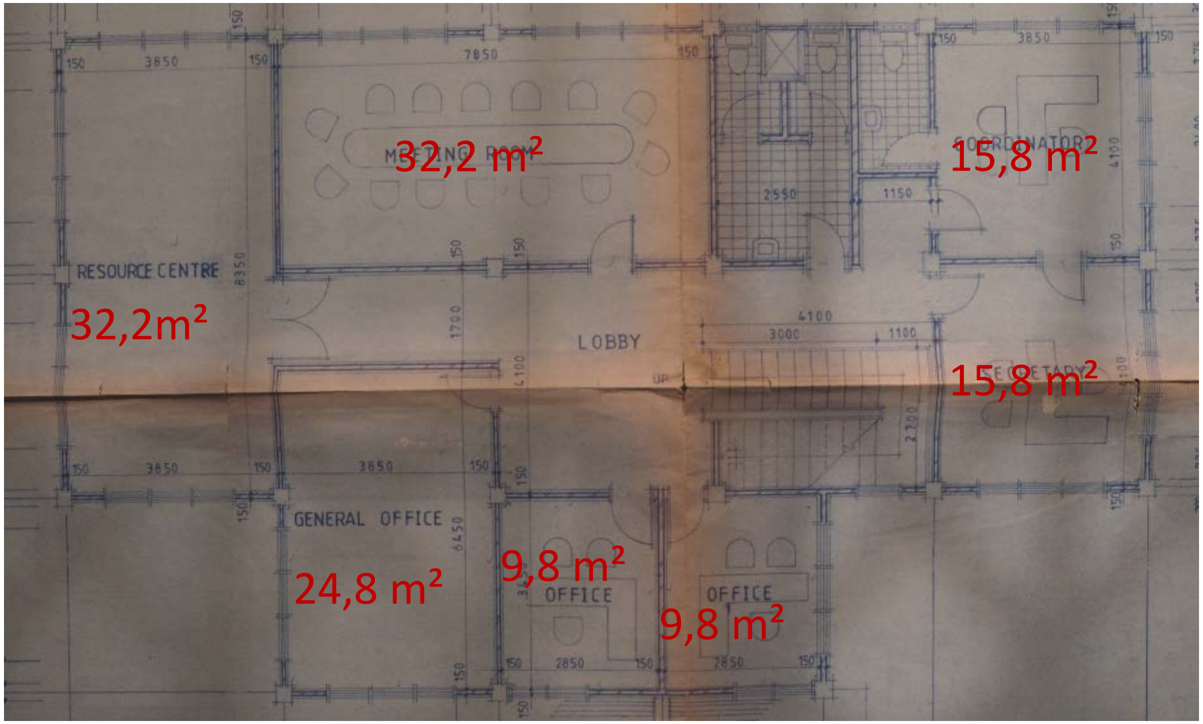
IDU = min. 2,2m height

Charge: 375gr. R290

A min = $m^2/(2{,}5 \times \mathrm{LFL}\ 5/4 \times h0)^2$

A min = $0{,}375kg^2/(2{,}5 \times 0{,}038\ 5/4 \times 3)^2$

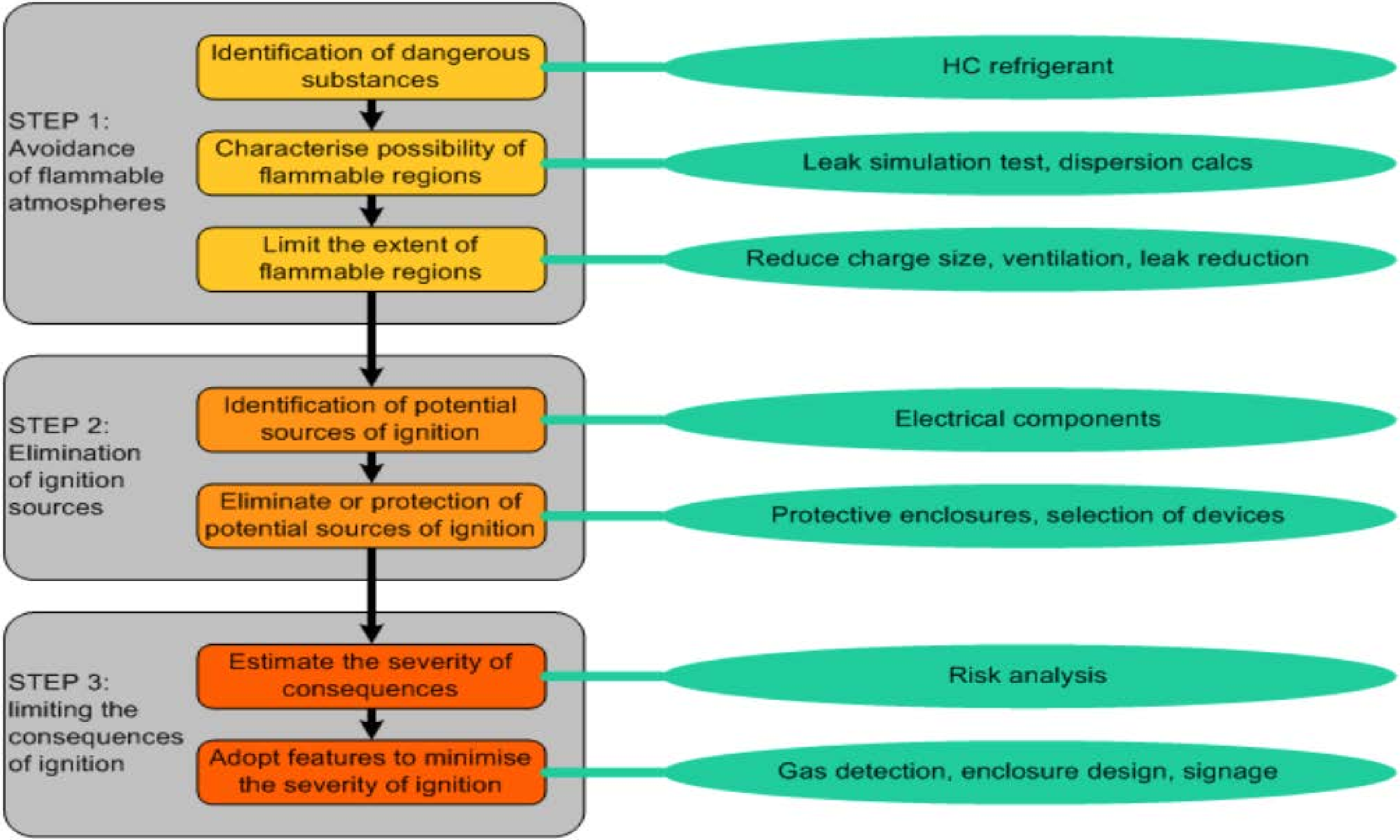
Amin= 16,5m²



Overview: Modules and Sections

- Hydrocarbon Refrigerant Issues
- Potentials application of Hydrocarbon refrigerants
- European standards and regulations
- Design approaches and considerations on safety
- How to practically deal with HC refrigerant flammability
- Electrical circuit and components requirements
- Risk assessment
- Basic personal protection
- Tools and servicing equipment
- HC refrigerant recovery and venting
- The importance of Oxygen Free and Dry Nitrogen (OFDN)
- Deep vacuum procedures for refrigeration system commissioning
- Methods of gas detection (leak finding) in the field
- Other useful hints

Principle design approach for explosion protection



STEP 1: Avoidance of flammable atmospheres

- Identification of dangerous substances — HC refrigerant
- Characterise possibility of flammable regions — Leak simulation test, dispersion calcs
- Limit the extent of flammable regions — Reduce charge size, ventilation, leak reduction

STEP 2: Elimination of ignition sources

- Identification of potential sources of ignition — Electrical components
- Eliminate or protection of potential sources of ignition — Protective enclosures, selection of devices

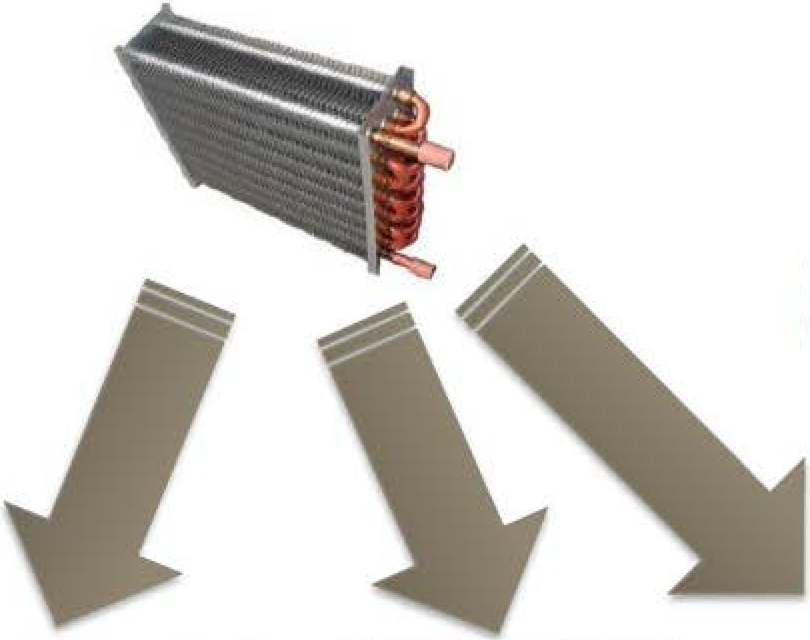
STEP 3: limiting the consequences of ignition

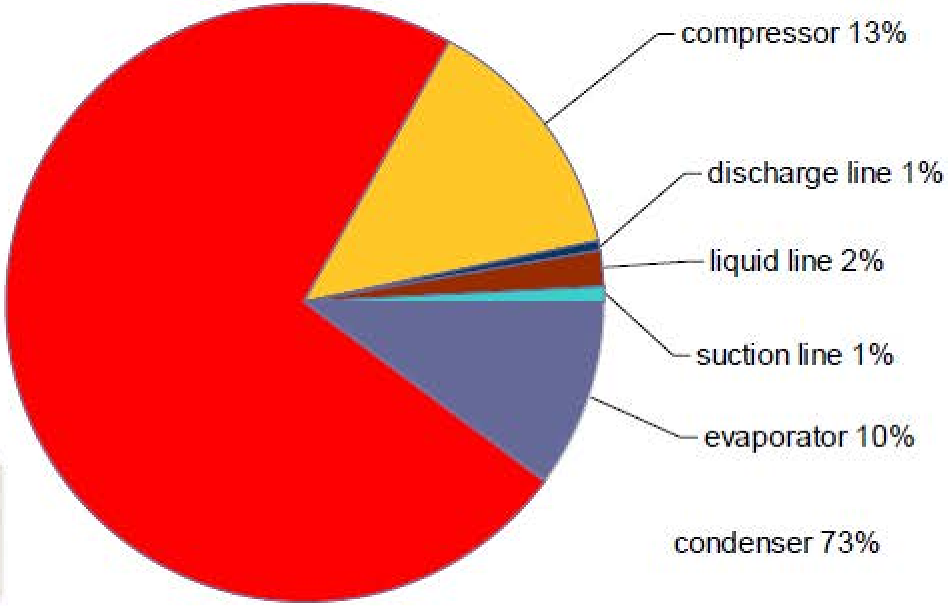
- Estimate the severity of consequences — Risk analysis
- Adopt features to minimise the severity of ignition — Gas detection, enclosure design, signage

Safety – risk analysis approach

Before addressing safety aspects directly, initial task to minimise refrigerant charge

- Primarily target condenser; HX design
- With some effort, can approach <20% of HCFC/HFC charge

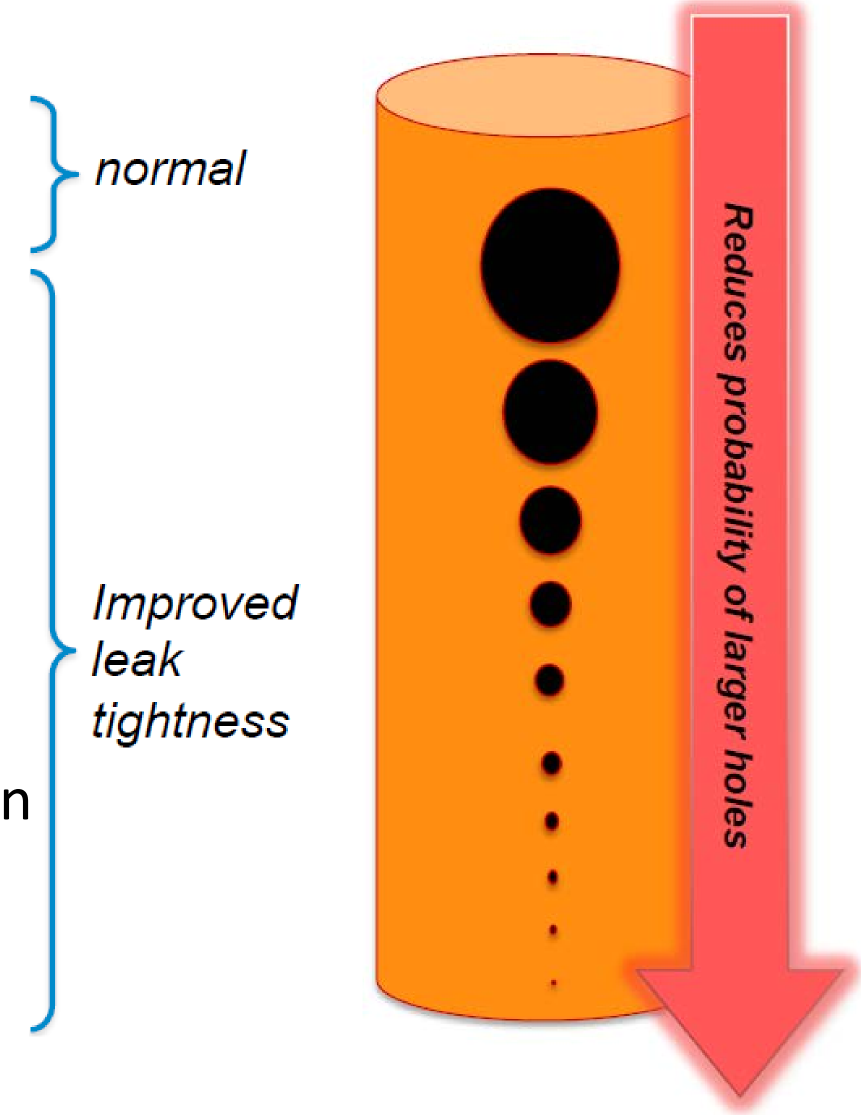




Safety – improved system tightness

Improve system tightness

- ➢ Strength pressure test
- ➢ Leak tightness test
- ➢ Additional tests
  - Mechanical impact, vibration, resonance, cycling, drop, corrosion, long-term run
- ➢ Tightness standard ISO 14903
- ➢ Additional design/ construction
  - Prevention of frost damage, thermal cycling, etc)



Overview: Modules and Sections

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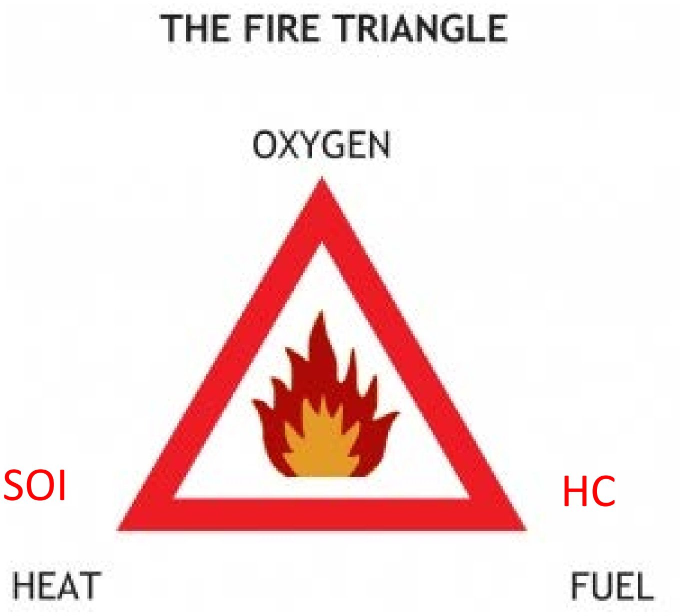
- Other useful hints

Understand the basic concept of flammability

Three ingredients are needed for a fire:

1. Fuel at the right concentration!
2. Supply of oxygen (usually from air)
3. A source of ignition (SOI).

- If these ingredients are **controlled**, e.g. by **eliminating at least one but preferably two** of these, fire can be prevented.
- In order to achieve this, **three general guidelines** should be followed:
  - Sealed system provision;
  - Avoidance of SOI;
  - Use of ventilation.



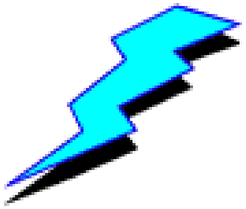
Sources of ignition

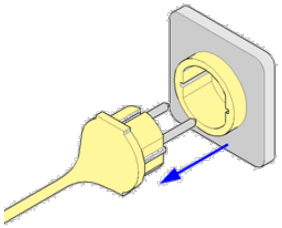
Sources of ignition (SOI):

- electrical apparatus that could arc or spark,
- mechanically generated sparks,
- flames and hot gases that are not suitably enclosed,
- hot surfaces that exceed specified temperature limits,
- static electricity as well as stray electric currents,
- cathodic corrosion protection.

To determine whether a SOI is in a position where leaked refrigerant could flow or stagnate, EN 60079-10-1: 2009 shall be used to estimate the size and extent of a potentially flammable zone.

The leak simulation test according to EN 378-2 meets the requirements of EN60079-10-1.





EN 378-2 and EN 1127-1

Examples of SOI: electrical devices

☹ Light and socket switches

☹ Some relay / overload protectors (klixons)

☹ Contactors and most on / off switches

☹ Light starters (ballasts)

☹ Most pressure switches (HP, LP, oil)

☹ Timers, e.g. for defrosting

☹ Thermostats

☹ Some defrost heaters

Examples of SOI: tools / equipment

- ☹ Brazing equipment
- ☹ Some electronic leak testers
- ☹ Unsealed switches on equipment such as vacuum pumps
- ☹ Generator

Safety – eliminating ignition sources

Identify items/components that could be potential sources of ignition (SOI)

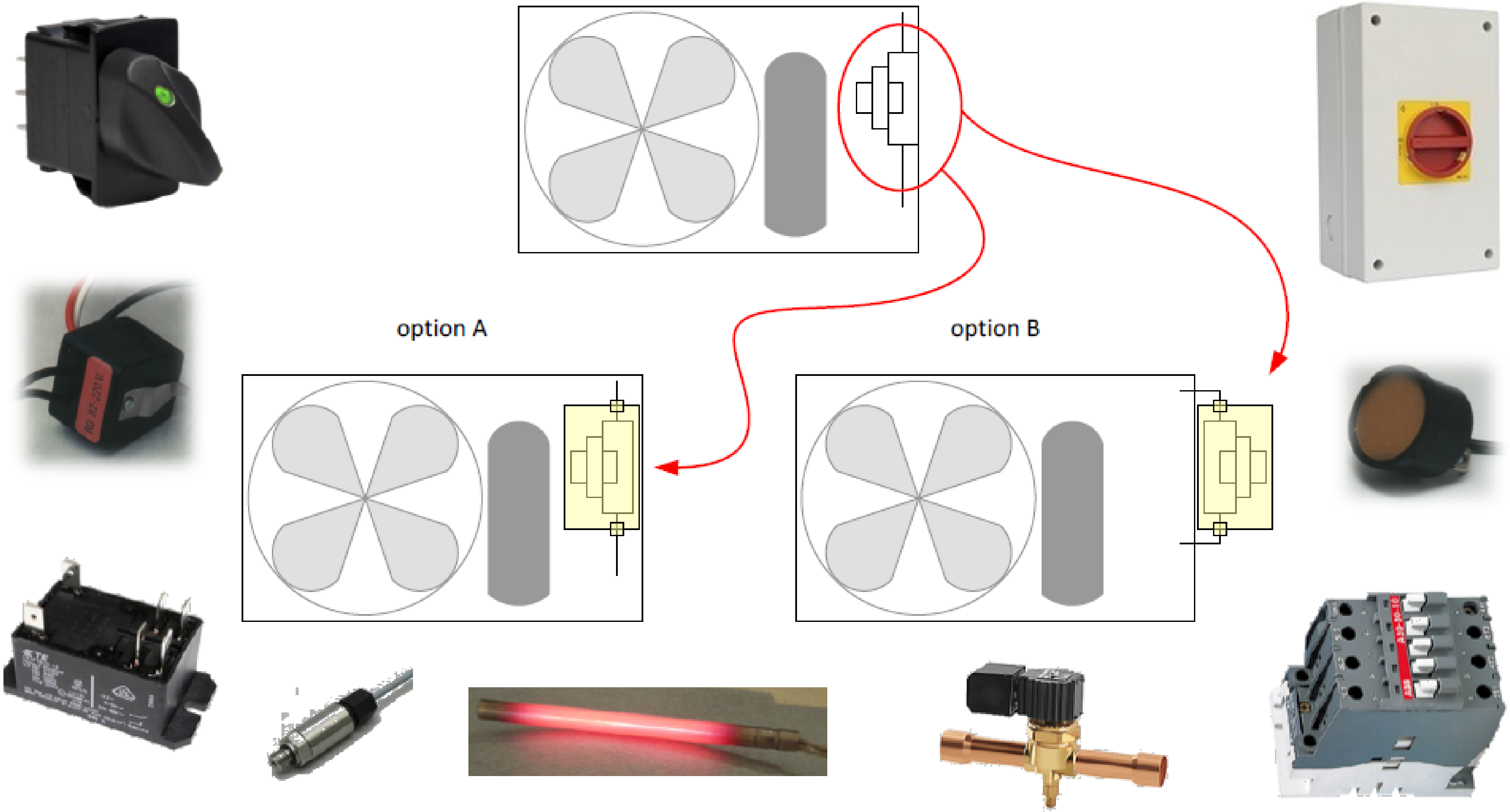
- Using ‘zoning’ approach
- Potential varies by substance

Characteristic		R600a	R290	R1270
Auto-ignition temperature	°C	460	470	455
Minimum ignition energy	mJ	0.25	0.25	0.28
Minimum safe gap	mm	0.95	0.9	0.91

Safety – eliminating ignition sources

Two basic approaches

- Move to a location where leaked refrigerant cannot collect
- Replace component with “protected type”



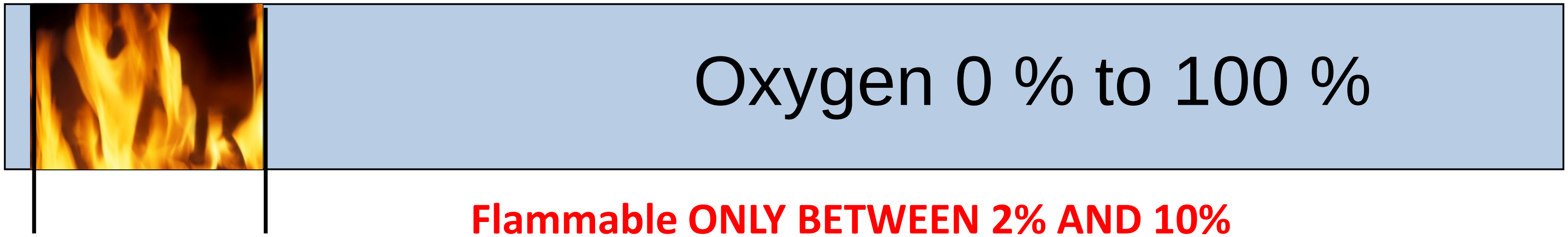
Potentially hazardous situations

☝ **If hydrocarbon refrigerant leaks out of the system, combustion will occur if the correct mixture exists and there is an ignition source.**

Note:

It is very unlikely that combustion will occur inside a system as there is insufficient air.

Example: flammability risk for R-290



Flammable ONLY BETWEEN 2% AND 10%

2.1 % 9.5 **%**

HC R-290
refrigerant

If the concentration is below the lower flammability level (LFL) of ca. 2% by volume in air, there is **not enough HC for combustion**.

If the concentration is above the upper flammability level (UFL) of ca. 10%, there is **insufficient oxygen for combustion**.

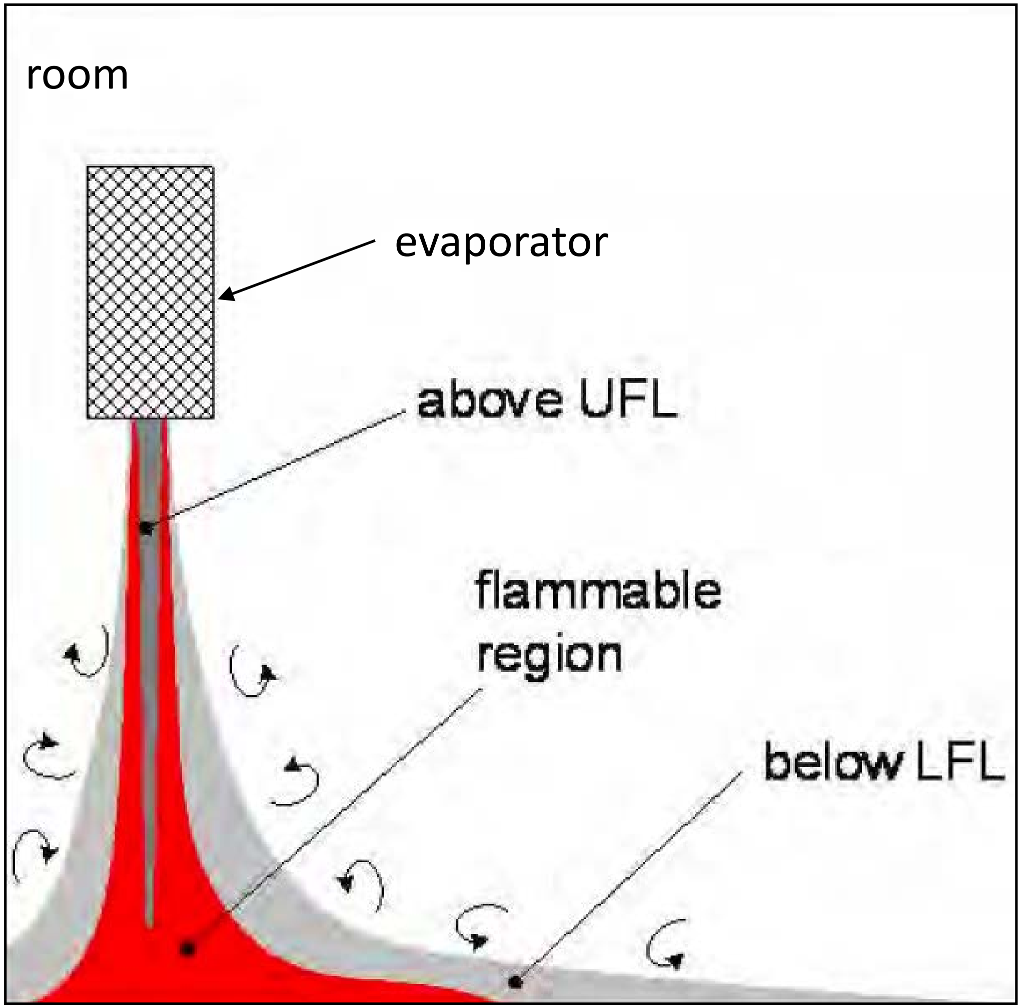
- ➢ **The critical region to ignite R-290 is between both conditions.**

Dispersion of refrigerant leak

Flammability risk in a room

Illustration of the flammable region:

Following a refrigerant leak from an evaporator into a room



Auto-ignition temperatures of refrigerants and lubricant

Approximate auto-ignition temperatures

R22	635 ºC
R12	750 ºC
R134a	743 ºC
R290	470 ºC
R600a	460 ºC
HFC-1234yf	405°C
Oil	**222 °C**

Products of burning refrigerants:

Chemical refrigerants strongly and negatively affect health and the environment

- When HCs burn, they **produce carbon and steam**.
- When chemical refrigerants (such as HFCs and HCFCs) burn, they **ALL** produce toxic fumes.

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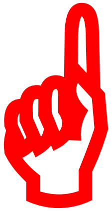
Electrical Design - Overview

Due to their physical properties and **high flammability**, refrigerant systems **using hydrocarbon refrigerants** require **special safety precaution** measures.



- The **electrical design** plays a **central role for safety** and exceeds the requirements for the use of non-flammable refrigerants.
- **Careful consideration of the design and construction** of HC refrigeration systems and their installations is essential to **achieve maximum safety**.

Electrical requirements: relevant standards

In general all system designs of the electrical equipment should comply with:

- product standard of the **EN 60335** series, or
- **EN** 60204-1 (Safety of machinery) and for electronically controlled systems related with **EN ISO 13849-1** and / or **EN 62061** (Safety-related parts of control systems)

Additionally for flammable refrigerants:

EN 378-2:2017-3

6.2.14 Protection against fire and explosion hazards

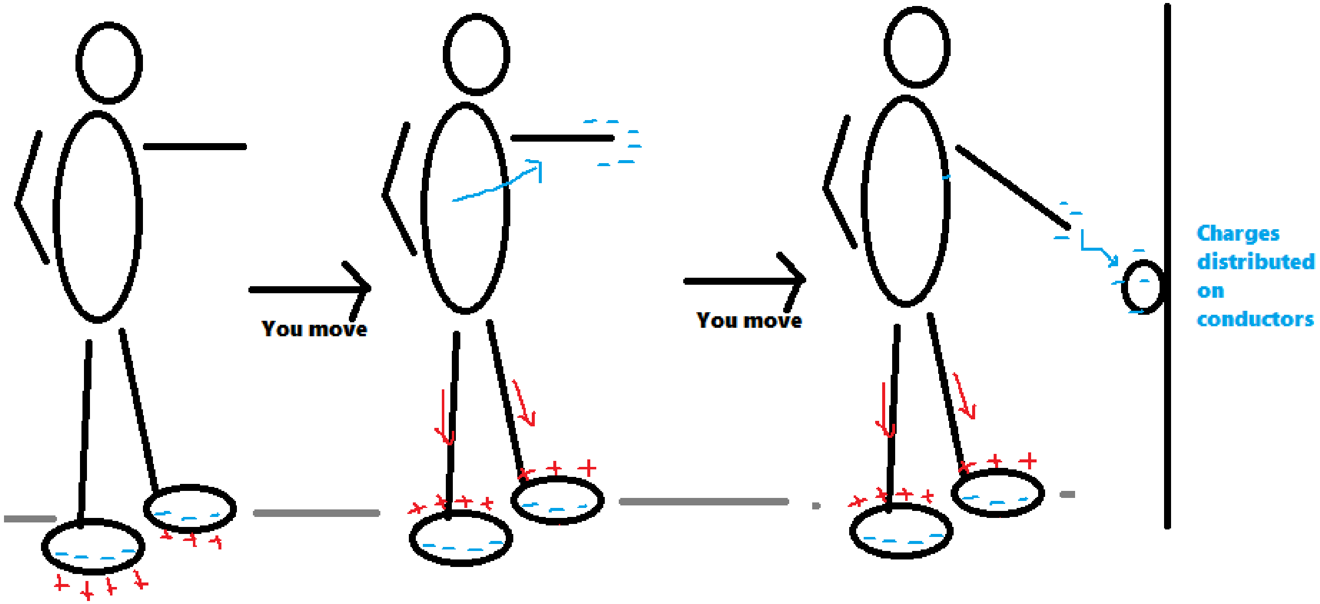
6.2.15 Requirements for ventilated enclosures where applied for A2(L), B2(L), A3 and B3 refrigerants as defined in EN 378-1:2017-3 Annex C1, C2 (charge limits)

Electrical grounding is essential

All HC appliance components must be grounded!

Electrostatic discharge (ESD) is the sudden flow of electricity between two electrically charged objects caused by contact, an electrical short, or dielectric breakdown. A build-up of static electricity can be caused by tribocharging or by electrostatic induction. The ESD occurs when differently-charged objects are brought close together or when the dielectric between them breaks down, often creating a visible spark.

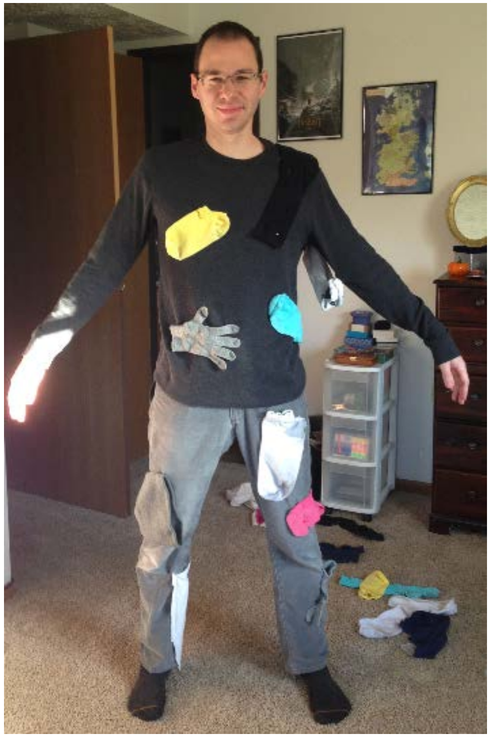
ESD can cause a range of harmful effects of importance in industry, including gas, fuel vapour and coal dust explosions, as well as failure of solid state electronics components such as integrated circuits.



Electrical grounding is essential

All HC appliance components must be grounded!

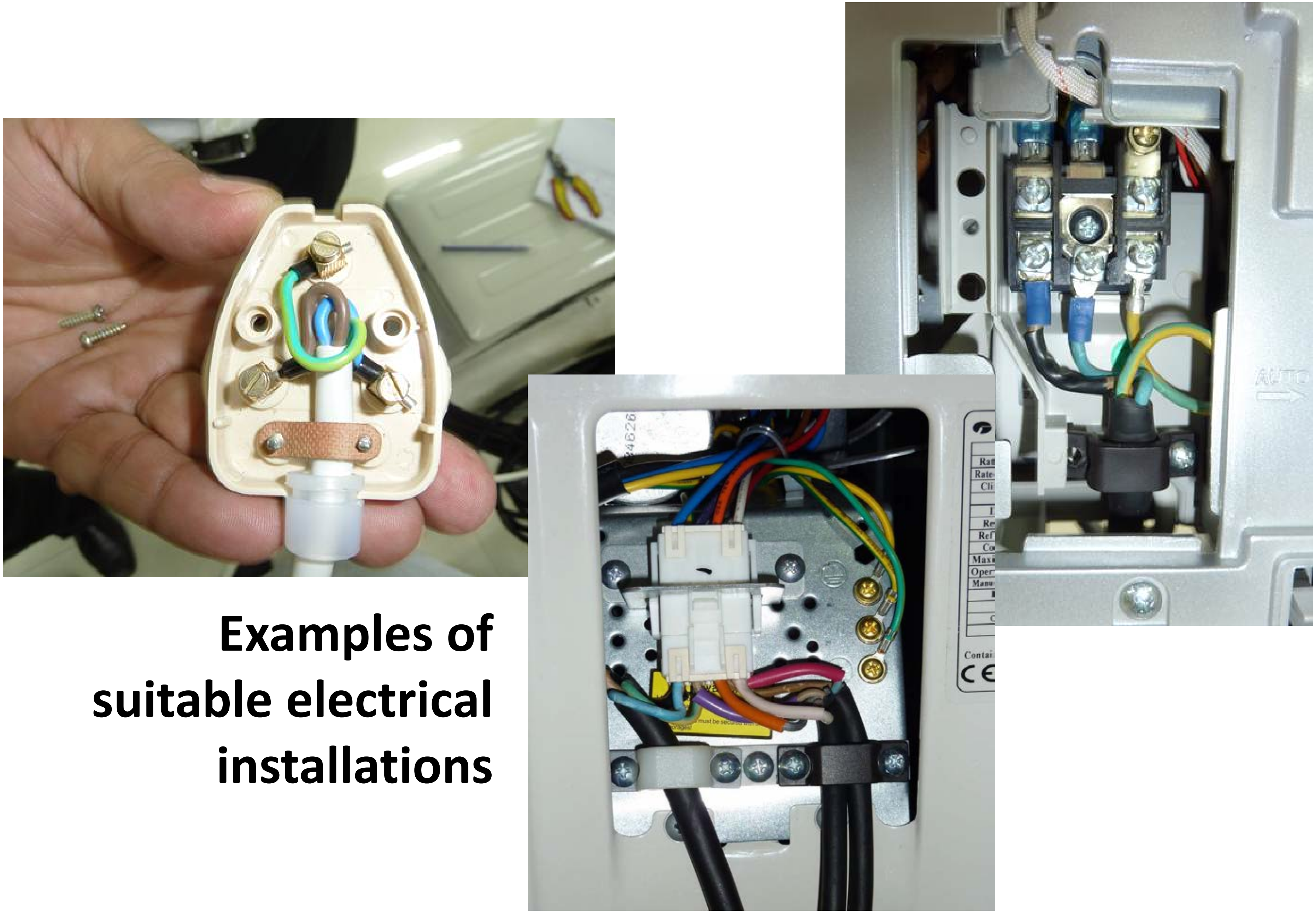
Metal-based material can cause sparks when operating and working on HC appliance. The resulting electrical discharge can cause catastrophic failure in sensitive electrical components and ignite HC refrigerants.



Steps to be taken for elimination of risk:

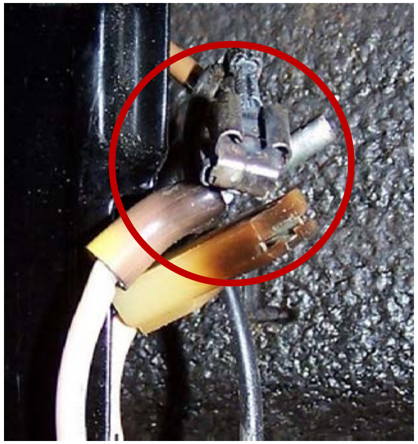
- Touch a grounded metal object once in a while to remove any charge from your body.
- Touching a water tap works extremely well.
- (as does touching a corner of a wall where there is metal stripping under the plaster)
- Use anti static wrist strap equipment to avoid potential differences between you and the appliances serviced
  - But attention: These moulding strips are not always grounded!

Electrical safety

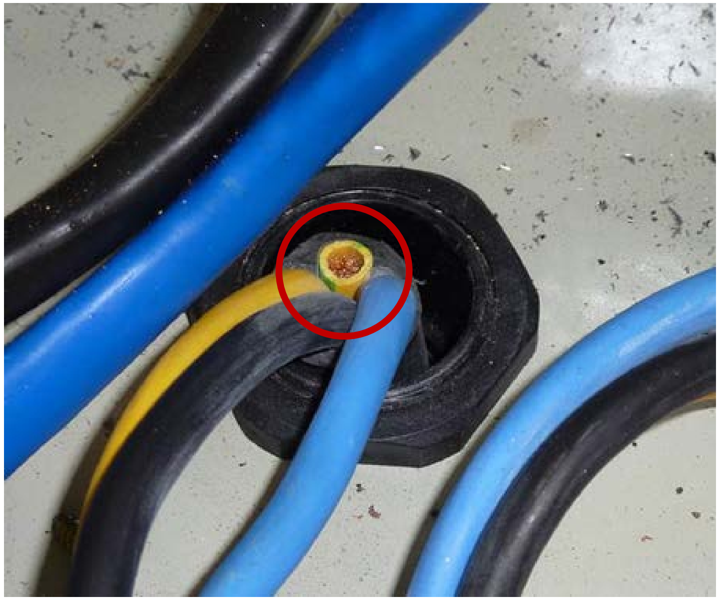


Examples of suitable electrical installations

Electrical safety – Arcing and sparks



These are some no-goes!



Protection of equipment

Refrigerating systems using flammable refrigerants:

- must be **constructed** in a way that **any leaked refrigerant will not flow or stagnate** → avoidance of fire or explosion hazard.
- This applies to areas within the unit where components and equipment could be sources of ignition (SOI) under normal conditions or in the event of a leak.

A leak simulation test

should be according EN378-2 Annex I

EN 378-2:2017-3, clause 6.2.14

Electrical safety: electrical panel design and cabling

Design principles:

- The electrical panel should be positioned externally, i.e. outdoors.
- The electrical panel should be mounted at an elevated position.
- Make sure that refrigerant cannot enter the electrical panel in the event of a leak.
- Make sure that the cable entries are sealed with appropriate grommets/glands.
- The electrical panel doors must seal when closed (use of appropriate gaskets).

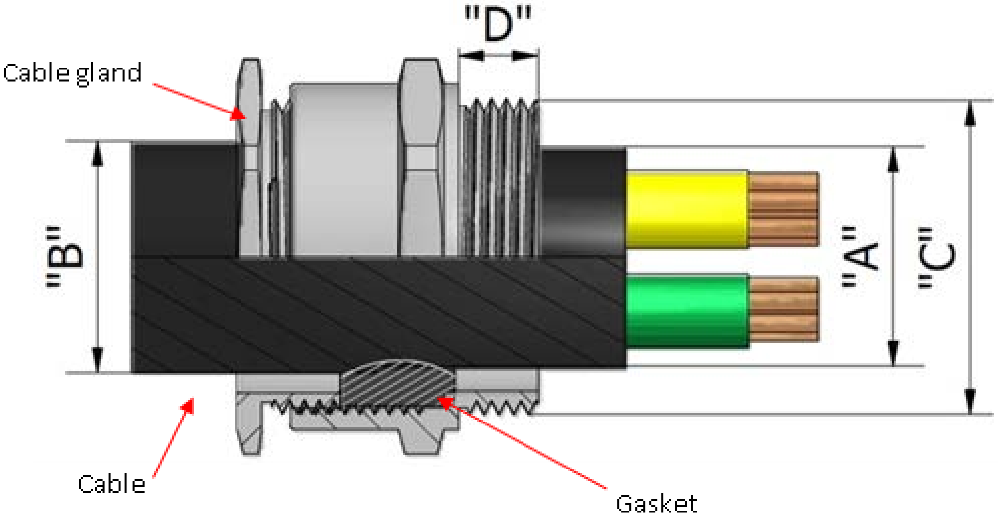
It is necessary to carry out a leak simulation test to ensure that refrigerant cannot enter the electrical panel in the event of a leak (EN 378-2).

Electrical safety: suitable panel design and cabling

Example: compressor housing

Design of electrical panel assembly:

- Must comply with requirements by EN 60079-10.
- Use cable glands to feed electrical cables into the panel.
- Make sure that gland and cable sizes match.
- Tighten the inner gasket after inserting the cable.



Electrical safety: suitable ventilation

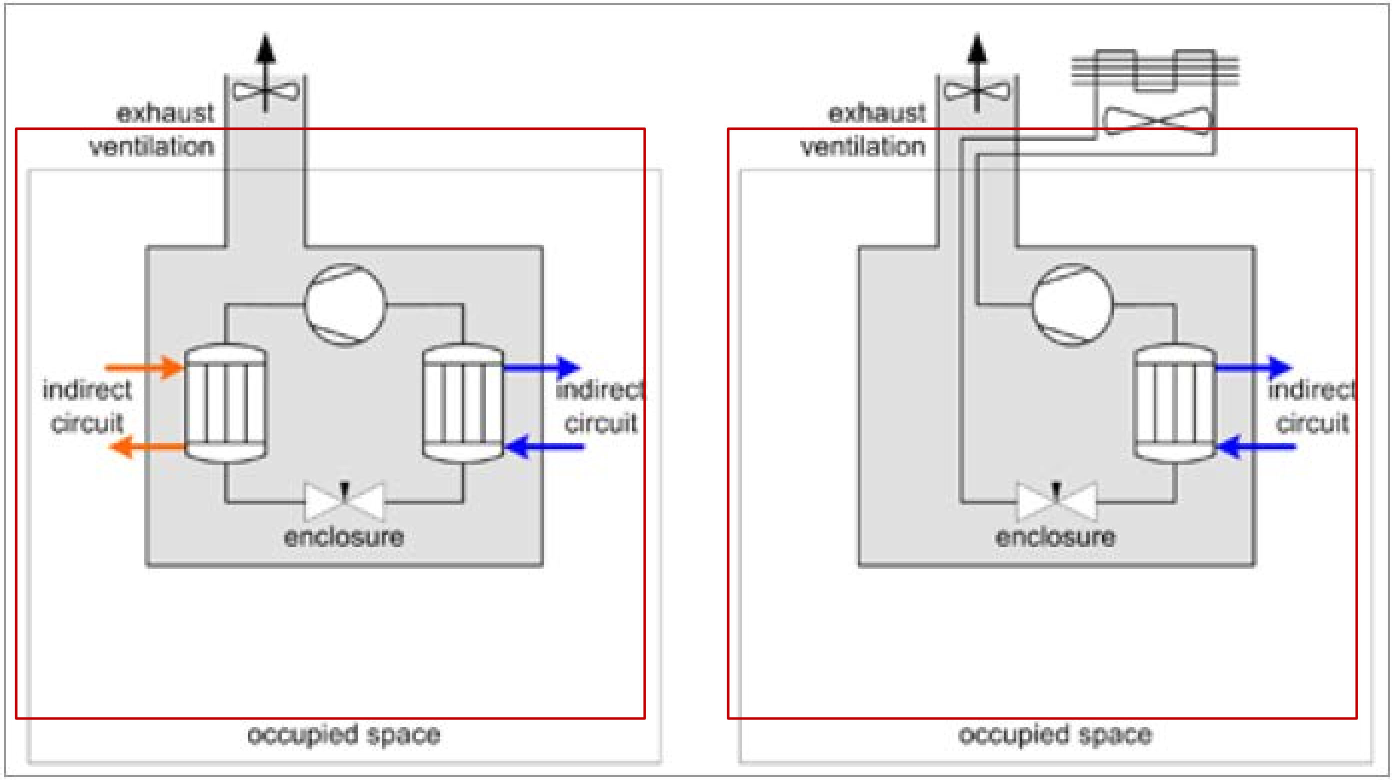
Design principle for ventilation:

- Supply of sufficiently high airflow at the time needed with adequate control mechanisms.

Ventilation design cases:

- Emergency ventilation
- Natural ventilation
- General constant ventilation

Ventilated enclosures: examples



Schematic diagrams of options for ventilated enclosures

- Volume of occupied space min. 10x the volume of the enclosure

Ventilated enclosures: requirements for operation

Requirements for the operation of ventilation systems (either option 1 or 2):

- Option 1:
  - The ventilation system **runs at all times**, with **continuous monitoring of the airflow**.
  - **Switch into a safe mode within 10 seconds** after the **airflow falls below Q_{min}**. The safe mode should be maintained until the airflow is restored.
- Option 2:
  - The ventilation system is **switched on by a refrigerant gas sensor before 25 % of LFL** (Lower Flammability Limit) is reached, as per EN 378-1:2017-03, Annex E.

EN 378-2, clause 6.2.15

Refrigerant gas sensor: turns on before 25 % of LFL

Gas sensor:

- Should switch on ventilation before 25 % of LFL is reached (378-1:2015, Annex E).
- Should be suitably located considering the refrigerant's density. -> max. 30cm above bottom
- The sensor and ventilation function should be checked at regular intervals according to the manufacturer's instructions.
  → see also chapter maintenance
- A failure should be indicated and the system should be switched to a safe mode with the fan switched on until the failure has been resolved.

murco
gas detection solutions
A Bacharach Company

EN 378-2, clause 6.2.15 & 378-4 Annex E

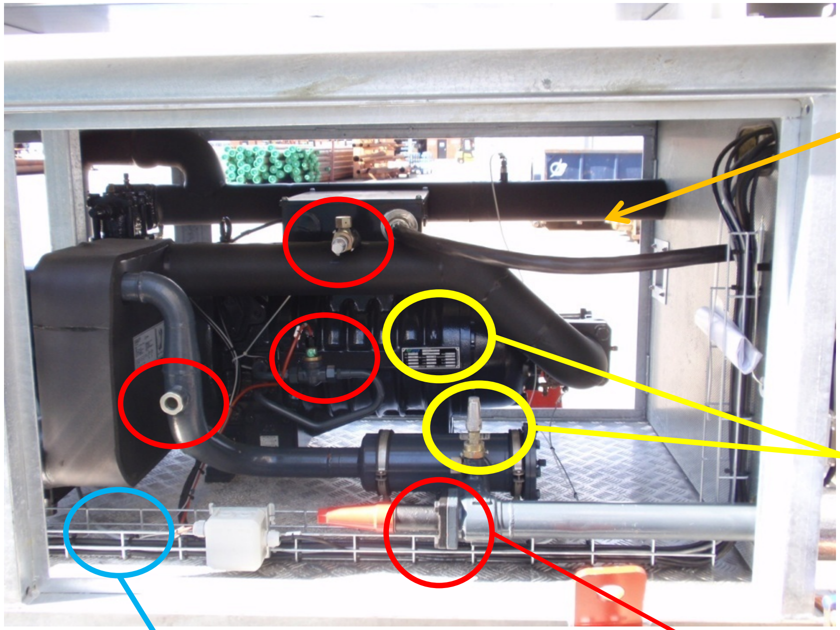
Example: HC chiller model range *Sabroe SAB light*

Machinery room zone classification according to EN60079-10

Sabroe SAB light by Johnson Controls

Product regulatory compliance

Correct application of flammability standards

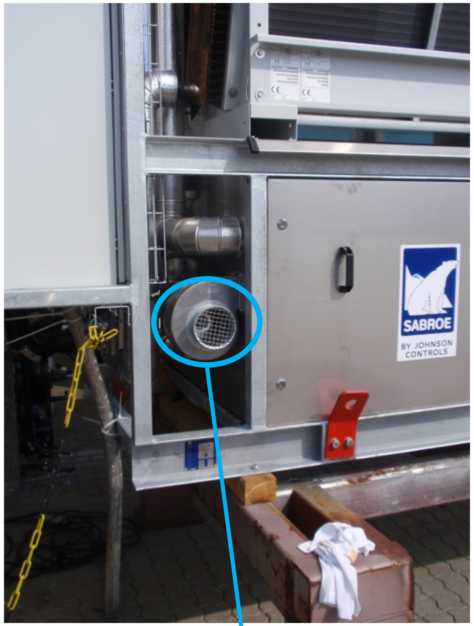


Machinery room zone classification according to EN 60079-10

Distance between el. components and leakage points according to EN 60079-10

Sensor for flammable gas detection according to EN 378-3

Total of 50 pipe joints inside a machinery room. Non-permanent joints are potential leakage points according to EN 60079-10. Leakage rate depending on method of detection according to EN 1779



Emergency ventilation according to EN 378-3 and EN 60079-10

EN 378-3, EN 1779, EN 60079-10

Key take-away's

- ✓ Control the "fire triangle": eliminate at least one, better two ingredients for a fire
- ✓ Know the corresponding safety measures and related design principles.
- ✓ Adhere to the relevant rules & regulations and to the instructions given by the manufacturer/supplier.
- ✓ Any leaked refrigerant is not permitted to flow or stagnate in HC refrigerating systems.
- ✓ Know the potential sources of ignition (SOI) and know how to avoid them.
- ✓ Know the requirements for ventilated enclosures, regarding both their design and operation.
- ✓ Know the requirements for the operation and use of refrigerant gas sensors.
- ✓ Know to evaluate the existing electrical design in with respect to safety

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Risk assessment ?!

Is it useful?

Risk Assessment

Risk Assessment

Risk Assessment

Risk Assessment

Risk Assessment

Risk assessment?

Useful?

Even if work steps are repeated?

Risk Assessment

Risk Assessment

Risk Assessment

Risk Assessment

Risk Assessment

Risk Assessment

Should they all be experts?

Risk Assessment

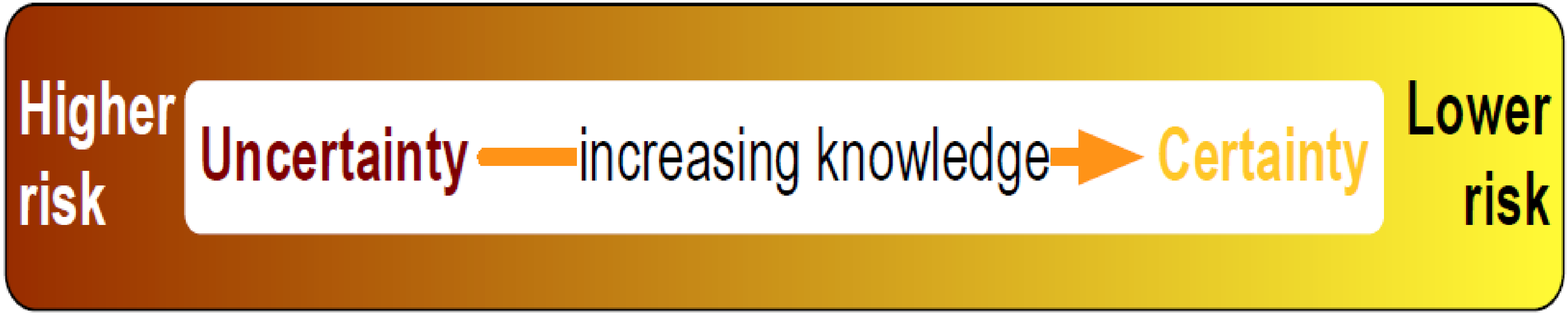
Should they all be experts?

Risk Assessment

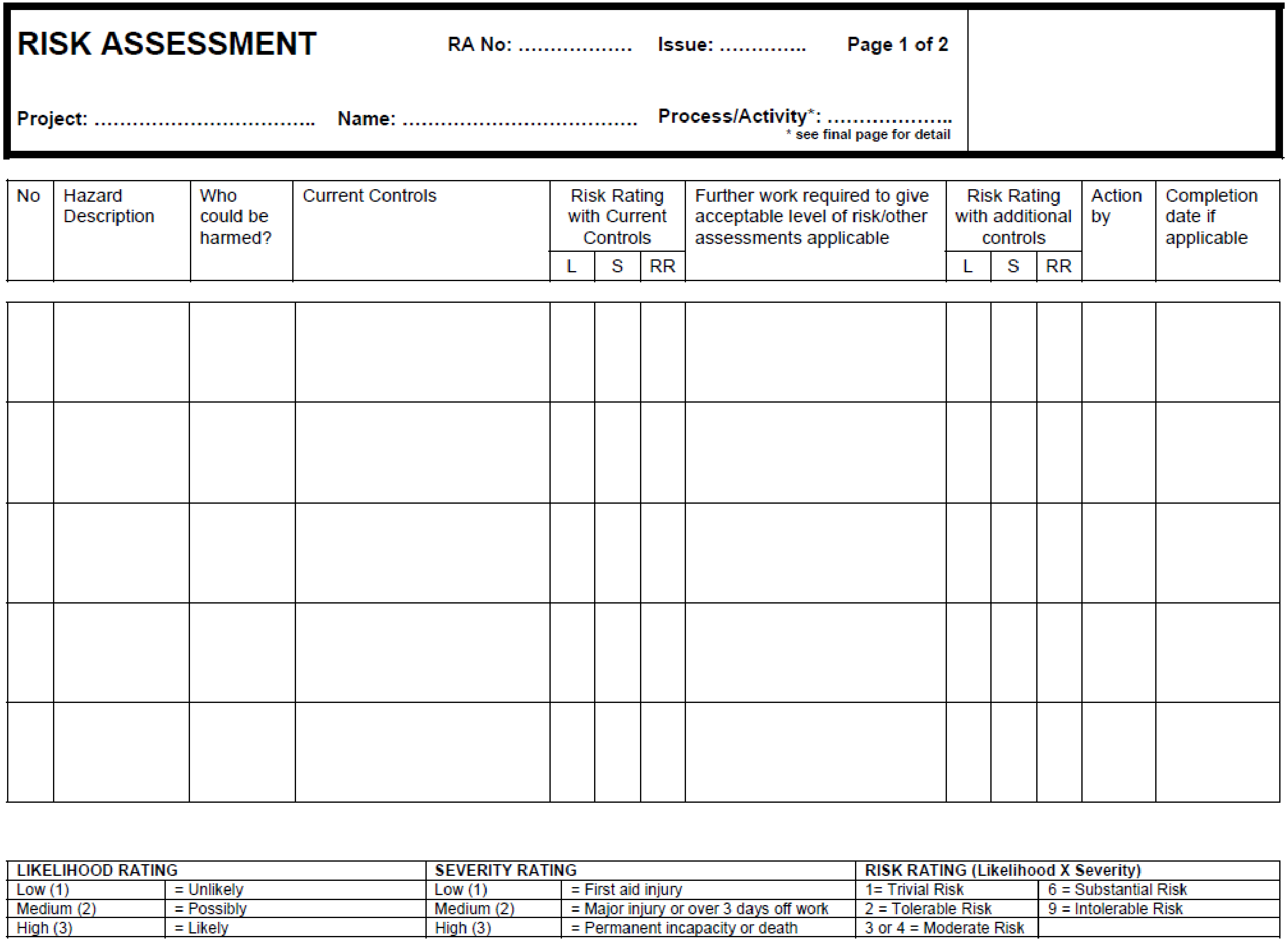
Risk Assessment

Risk analysis (identifying the processes) and risk assessment (characterisation, quantification) is useful for aiding safe application of flammables

- Assists in identifying critical flammability hazards through rational understanding of flammability risks
- Implies thorough evaluation of variables
- Imposes systematic checking of influencing factors
- Highlights areas needing improvement in safe design



Obligatory risk assessment



RISK ASSESSMENT RA No: ……………… Issue: …………. Page 1 of 2

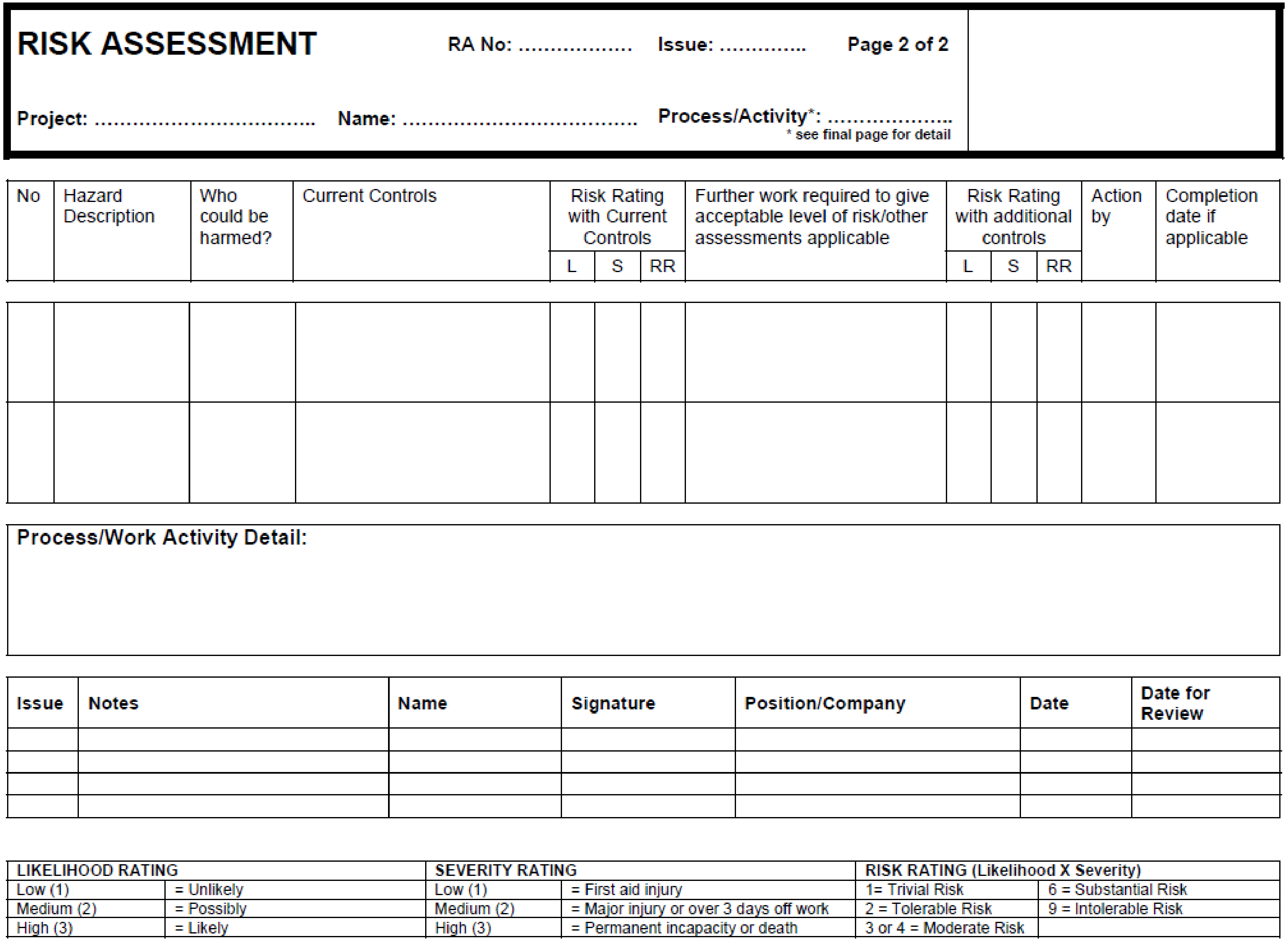
Project: ……………………………. **Name:** ……………………………… **Process/Activity*:** ……………….

* see final page for detail

No	Hazard Description	Who could be harmed?	Current Controls	Risk Rating with Current Controls			Further work required to give acceptable level of risk/other assessments applicable	Risk Rating with additional controls			Action by	Completion date if applicable
				L	S	RR		L	S	RR		

LIKELIHOOD RATING		SEVERITY RATING		RISK RATING (Likelihood X Severity)	
Low (1)	= Unlikely	Low (1)	= First aid injury	1= Trivial Risk	6 = Substantial Risk
Medium (2)	= Possibly	Medium (2)	= Major injury or over 3 days off work	2 = Tolerable Risk	9 = Intolerable Risk
High (3)	= Likely	High (3)	= Permanent incapacity or death	3 or 4 = Moderate Risk	

Obligatory risk assessment



RISK ASSESSMENT

RA No: ……………… **Issue:** …………. **Page 2 of 2**

Project: ……………………………… **Name:** ………………………………. **Process/Activity*:** ……………….

* see final page for detail

No	Hazard Description	Who could be harmed?	Current Controls	Risk Rating with Current Controls			Further work required to give acceptable level of risk/other assessments applicable	Risk Rating with additional controls			Action by	Completion date if applicable
				L	S	RR		L	S	RR		

Process/Work Activity Detail:

Issue	Notes	Name	Signature	Position/Company	Date	Date for Review

LIKELIHOOD RATING		SEVERITY RATING		RISK RATING (Likelihood X Severity)	
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Basic personal protective equipment (PPE)

Wear the adequate PPE for each activity!

Gloves and goggles for protection against freeze burns (as with all refrigerants)

Overall / long sleeves and legs

Safety shoes

Check: All necessary personal protective equipment is available and being used correctly.

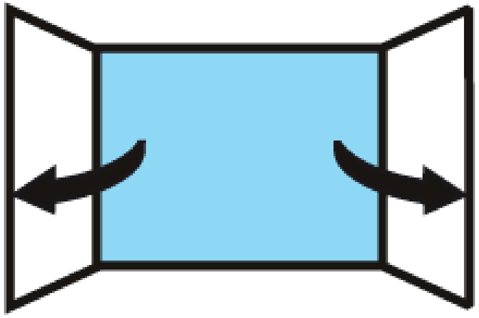
Portable gas sensor: how to use it

While technicians are working on the system, it can be advisable to use a portable gas detector.

- Detector can be clipped to clothing or placed on the floor within the working area.
- It should be switched on for the duration of the work and set to alarm at 15% of the LFL, to alert staff members of imminent flammable concentration.
- For safety reasons, the gas detector should not have a "Zero Background" function.
- Technicians can be alerted whenever an inadvertent release of flammable refrigerant occurs.
- Technicians are capable of immediately acting on the relevant emergency procedures.


Need for background ventilation and instructions

- The work area is to be properly ventilated before working on the refrigerant circuit or before brazing or handling electrics.
- Ventilation should safely disperse any released refrigerant and preferably expel it externally to the outside
- All maintenance staff must be instructed.
- Erect appropriate warning signs, including “no smoking” and “do not enter the area” signs



Ex-proof blower: venting of work area

- Should be used, if gas concentration above 0.25 LFL is to be expected (according EN 378)!

Qualities and abilities of ex-proof blower:

- High output (~1400m^3/h)
- Designed for explosion proof environment
- Potential equalization
- Light weight (easy to handle)

Fire extinguisher

Suitable fire extinguishing equipment must be available within the immediate work area: when servicing, storing or transporting HCs

- Dry powder type (usually identified with a blue flash) or CO2
- 2 kg charge size

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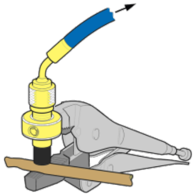
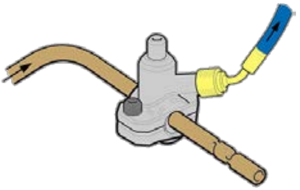
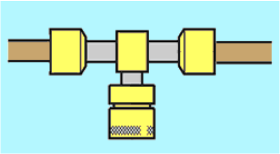
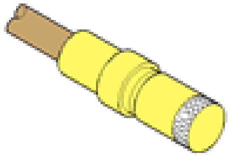
Access tools for HC technology

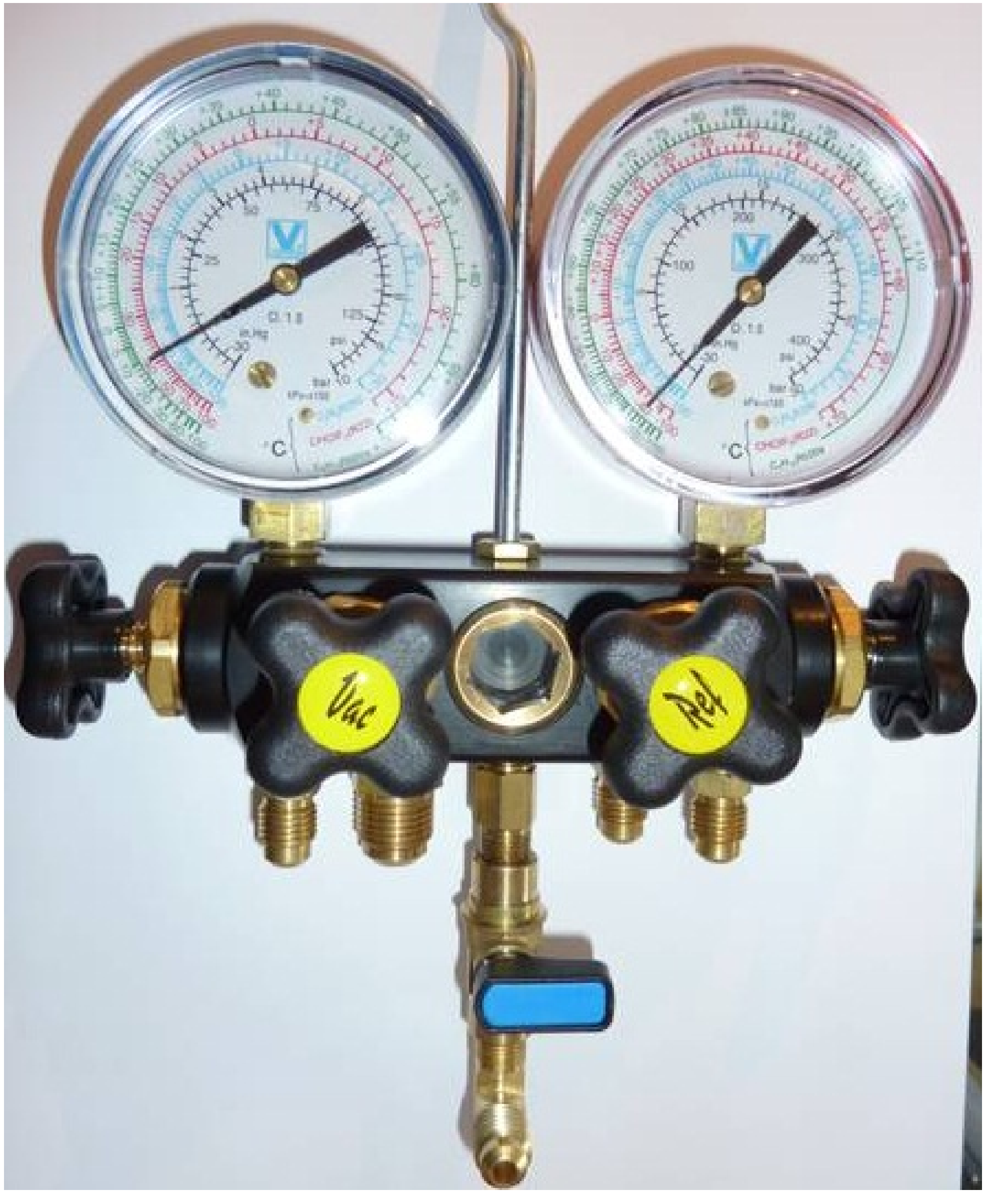
Suitability for different applications:

	Venting	Evacuation	Charging	Sealing
 Piercing pliers	☺	☹	☹	
 Line tap valve	☺	☹	☹	☹
 Lockring		☺	☺	☺
 Schrader		😐	☺	😐

Manifold set (4-Way)

Standard 4 valve manifold gauge set

- R600a
- R290
- R22



Vacuum pump

Standard vacuum pump improvements (electrical connections and sealing)

E.g. remove on/off switch

E.g. switch on/off remote outside 3 m area

Do not use “home-made” vacuum pumps

Exhaust hose for HC venting to the safe environment

Vacuum pump

Vacuum pump for flammable HC gases

two stage, 46 L/min; ultimate vacuum 1x10-2 mbar; Power consumption 120W; Protection classification IP54;

Oil charge 300 cc; CE confirmation and according II3GD nA tD 4T IP55 (zone 2-22 ATEX); 3/8” and ¼” SAE/UNF connection;

Gas ballast valve;

Exhaust port with hose adapter (venting hose)

Oil filter

Exhaust hose for HC venting to the safe environment

Recovery unit

- For use on refrigeration systems utilizing class A3 (non-toxic, flammable)
- Ignition proof ON-OFF switch
- Sealed start relay
- Hardwired

Oxygen free dry nitrogen (OFDN)

Must have for the applications:

- Pressure / strength test
- Equipment flushing
- Inert gas brazing

Cylinder Content (Litre)	Filling Pressure (bar)	Gas Content (m³)	Cylinder gross weight (ca. kg)
5	200	1	9,8
10	200	1.911	15,7
20	200	3.822	37,0
50	200	9,556	77,7
Purity 4.0 OFDN gas is of 99,99 % and a water content of maximum of 30 ppm.			

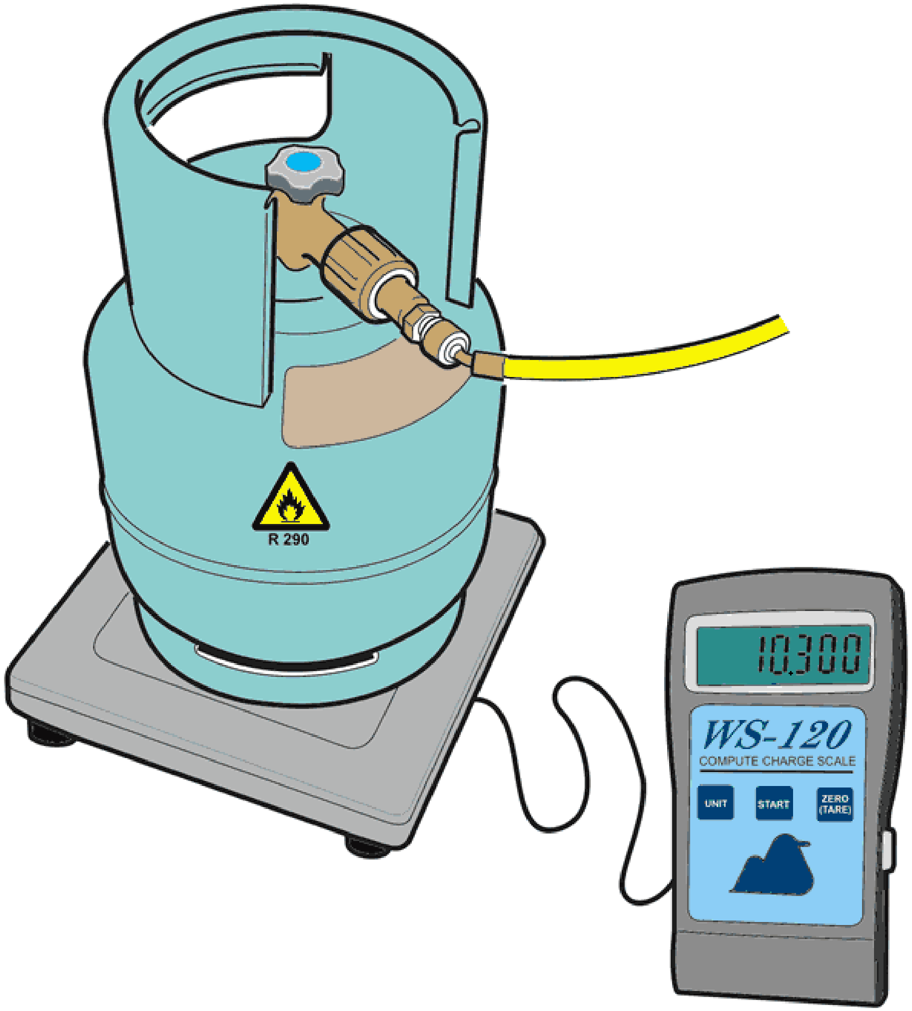
Charging equipment – option 1

For refrigerant charge > 500 g

Measuring range ≤ 100 kg

Accuracy of about +/- 0.5% needed

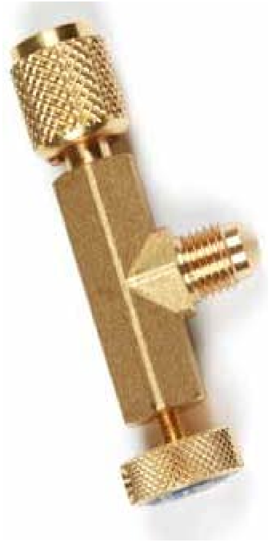
Resolution 2 g



Charging equipment – option 2

For refrigerant charge ≤ 500 g

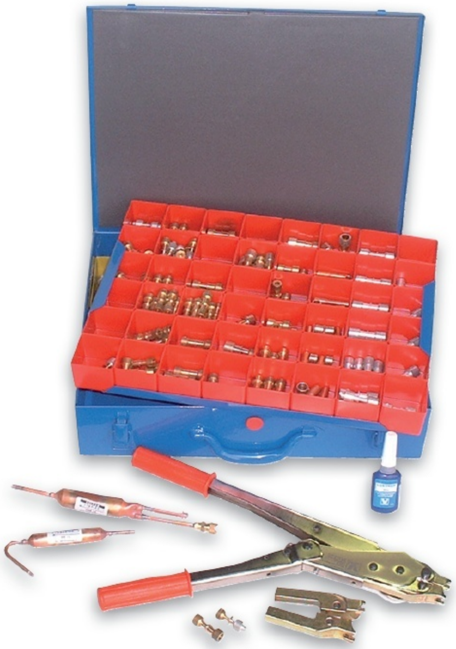
!

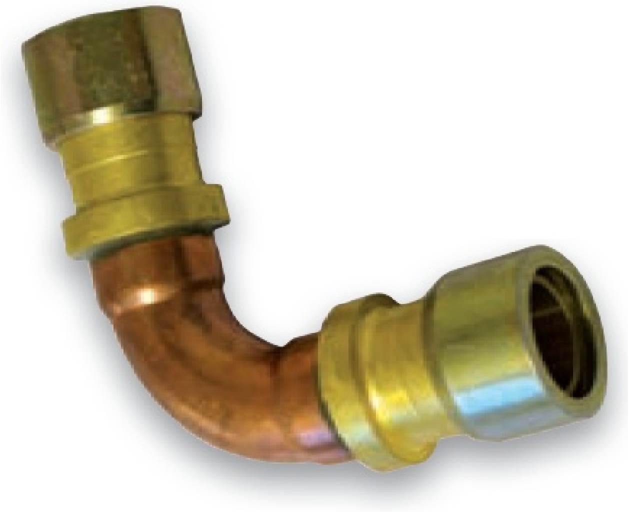


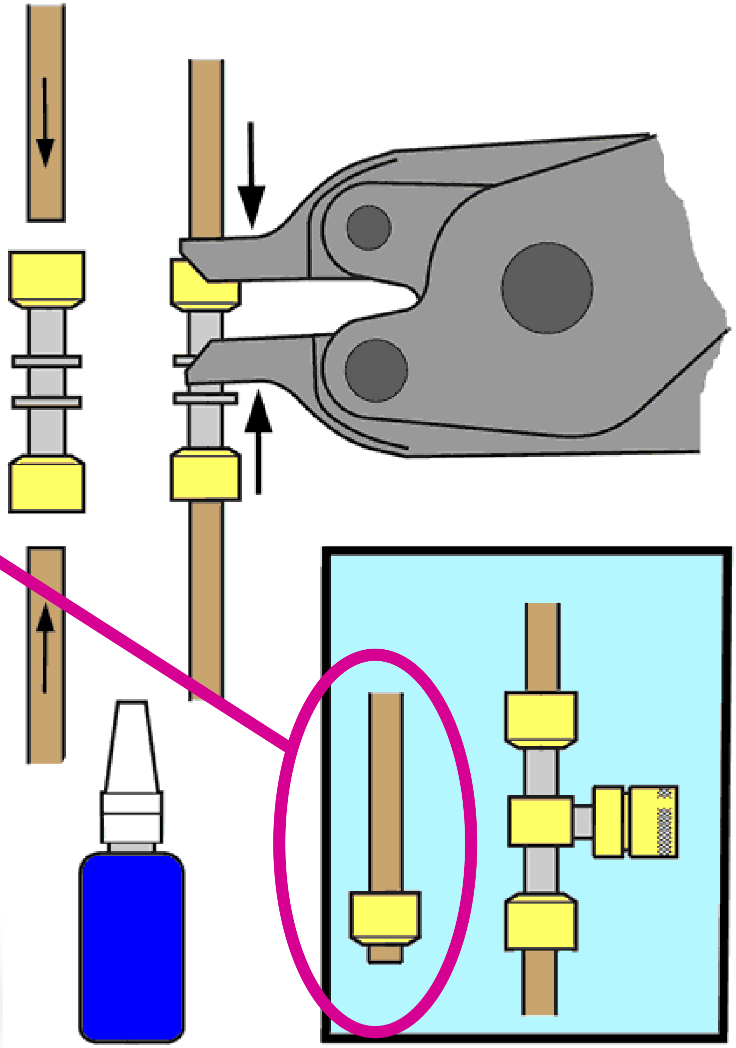
- Measuring range ≤ 5 kg
- Resolution 1 g

Sealing tools – option 1

Lockring **seals without brazing**

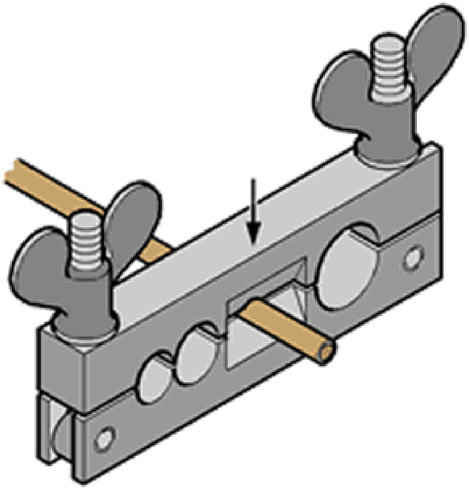




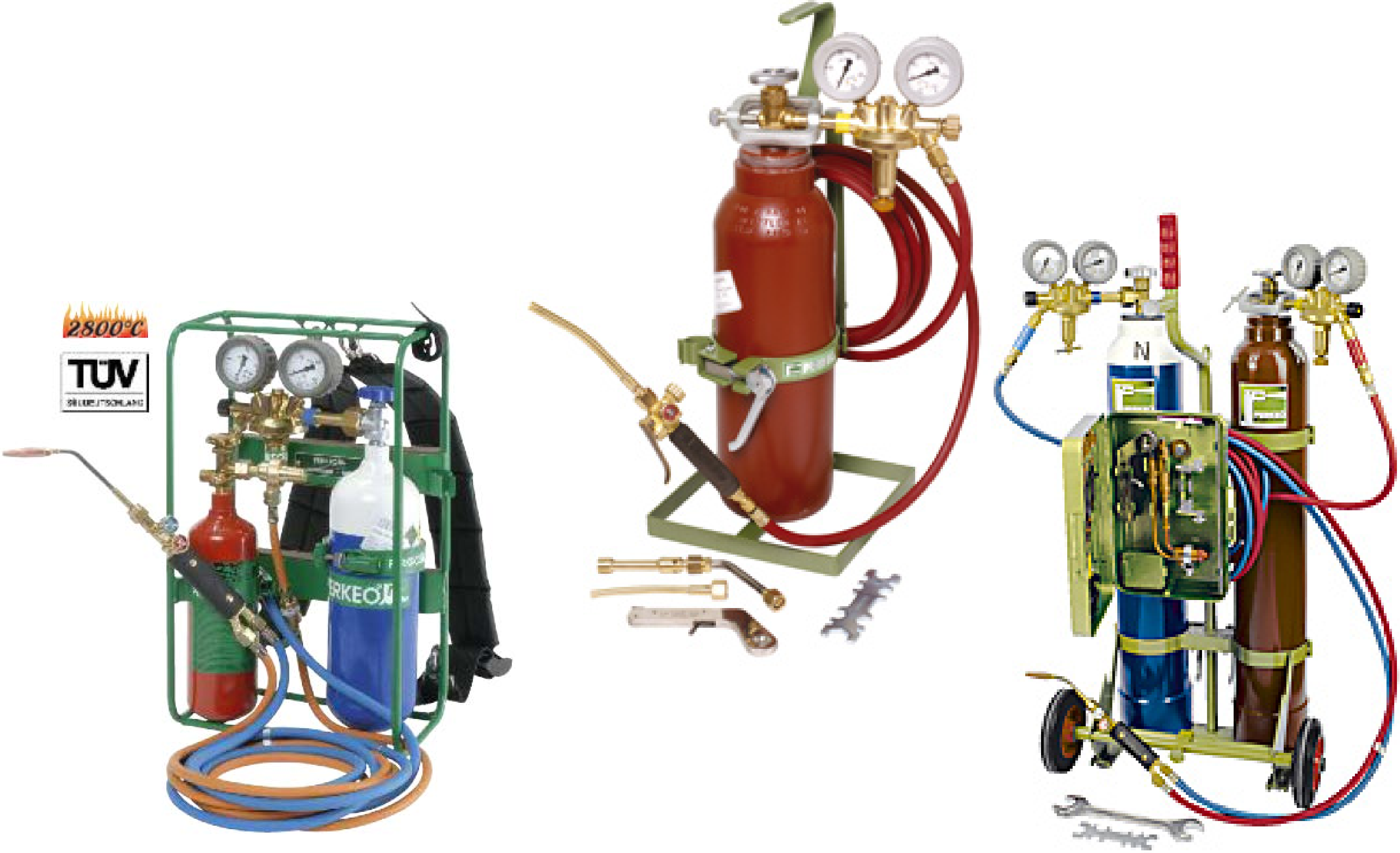


Sealing tools – option 2

- A crimping tool seals before brazing



Brazing equipment



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Refrigerant recovery

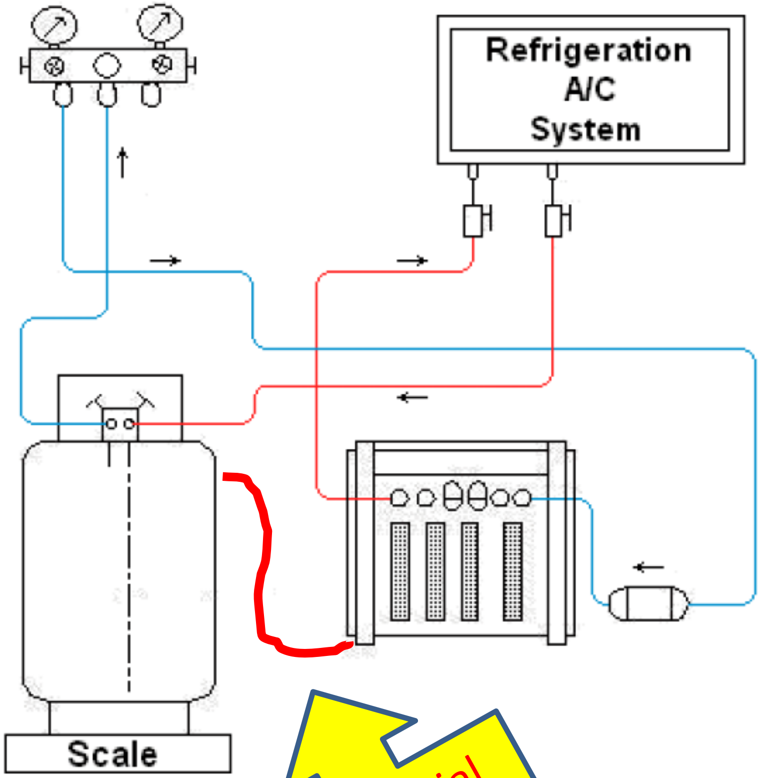
Requirements

<u>Commercial systems:</u>

- Refrigerant must be recovered
  - Recovery unit certified for A3 refrigerants (EN 378)
  - Potential equalisation needed between storage cylinder, recovery (HC refrigerant transferring equipment) unit and technician

Removal of liquid refrigerant is possible!

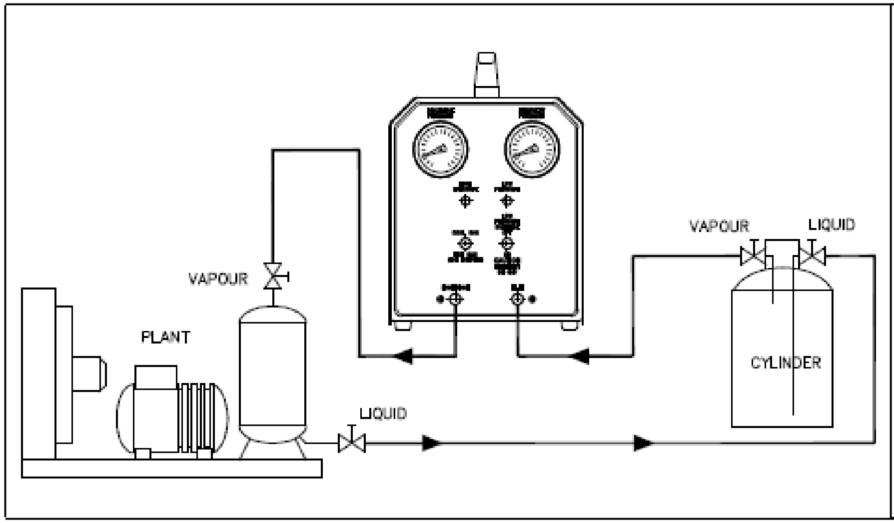
- Receiver
- Expansion valve
- Solenoid valve



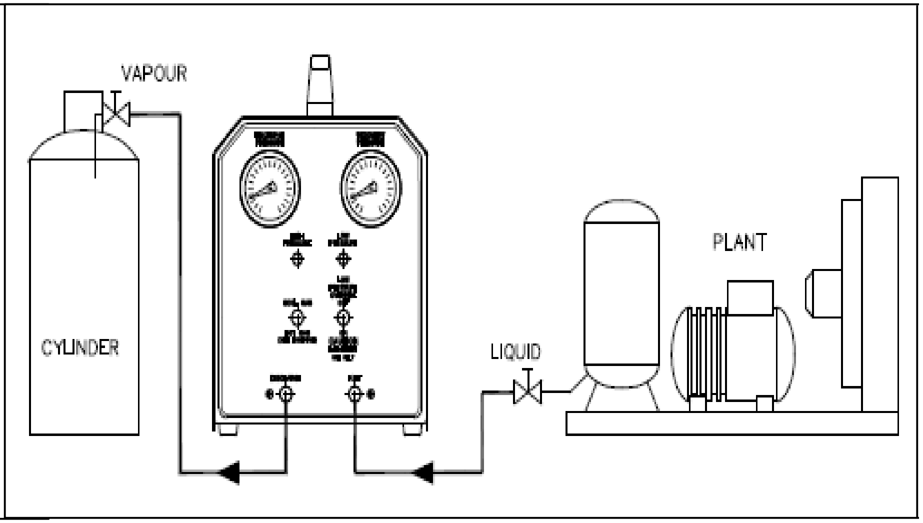
!! Potential equalisation wire !!

Refrigerant recovery

!! Potential equalisation wire !!



Push–pull recovery charge size > to 3kg



Recovery liquid charge size ≤ 3kg

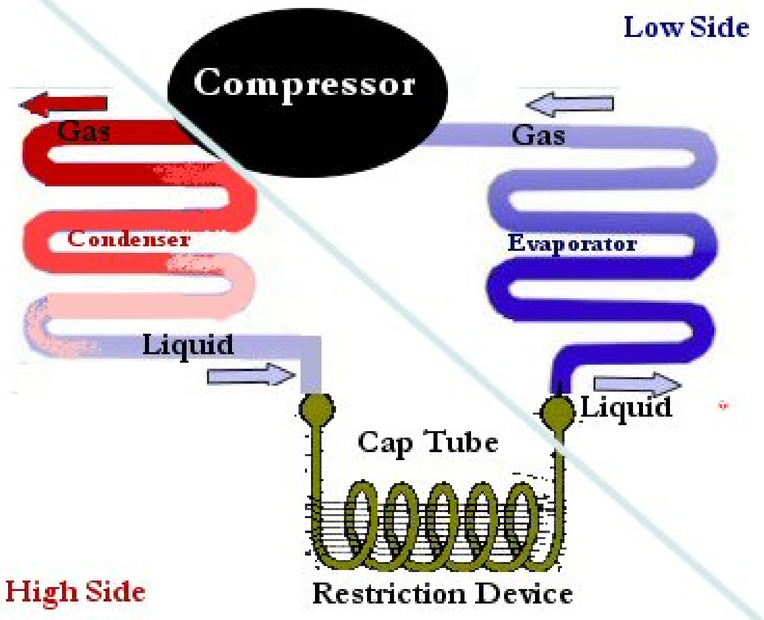
Refrigerant venting instead of recovery:

What must be considered (1)

Normally, venting to a safe place is carried out with systems containing a small quantity of HC refrigerant only and operating with capillary tubes.

- ➢ Use a vent-line and place the end within the outside ambient (end of hose about 1 m height)
- ➢ Ensure low refrigerant flow by metering with manifold, for effective dilution of HC with air!
- ➢ Charge amount max. 500 g!

Venting only in the vapour and gas phase!

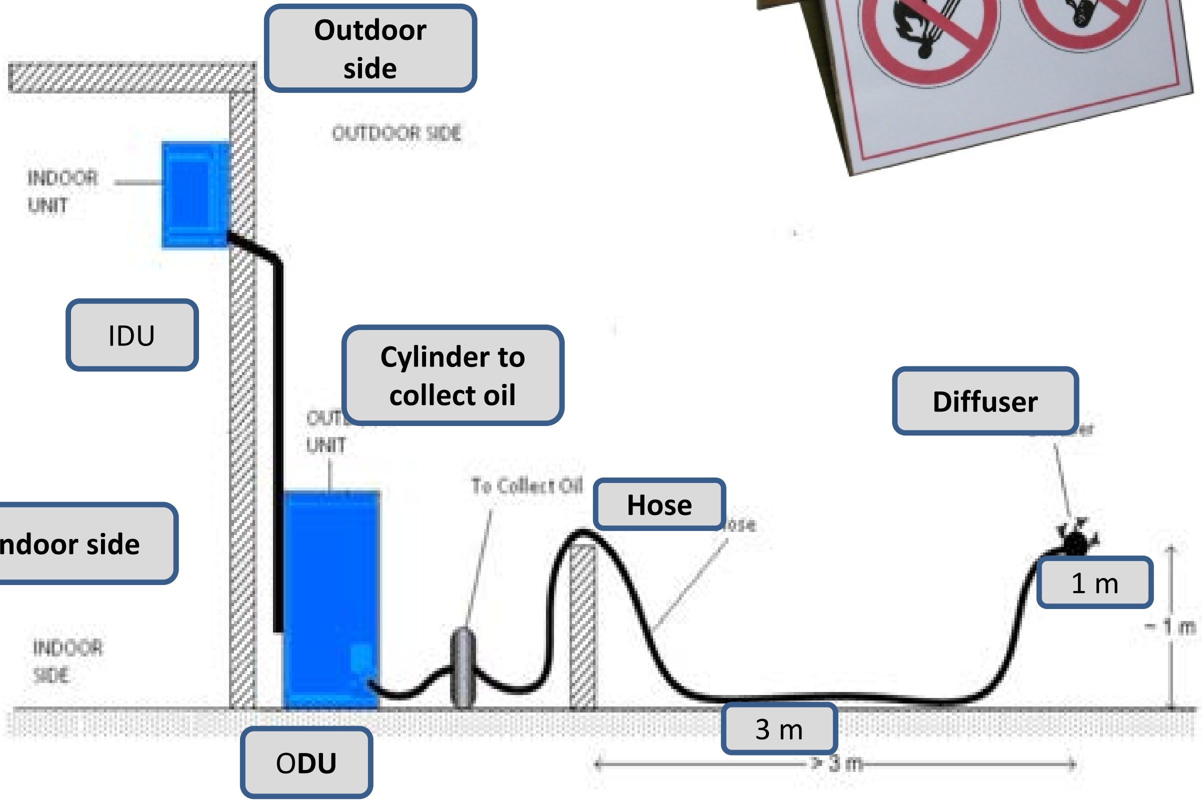


Refrigerant venting instead of recovery:

What must be considered (2)

Charge system
limit for venting in capillary systems <u>≤ 500 g </u>!

While removing the refrigerant from the system, oil should be separated.



Refrigerant venting:

Minimise deflagration risk!

Risk of deflagration!

Make sure that refrigerant does not accumulate.

It always moves to the coldest and deepest point and therefore often accumulates at the following locations:

- in floor ducts
- siphons
- gutters
- air vent at the brine loop

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Inerting with OFDN (oxygen free dry nitrogen)

Why it is needed

After recovering and before opening the RAC system, the system has to be rendered inert.

Only use OFDN!

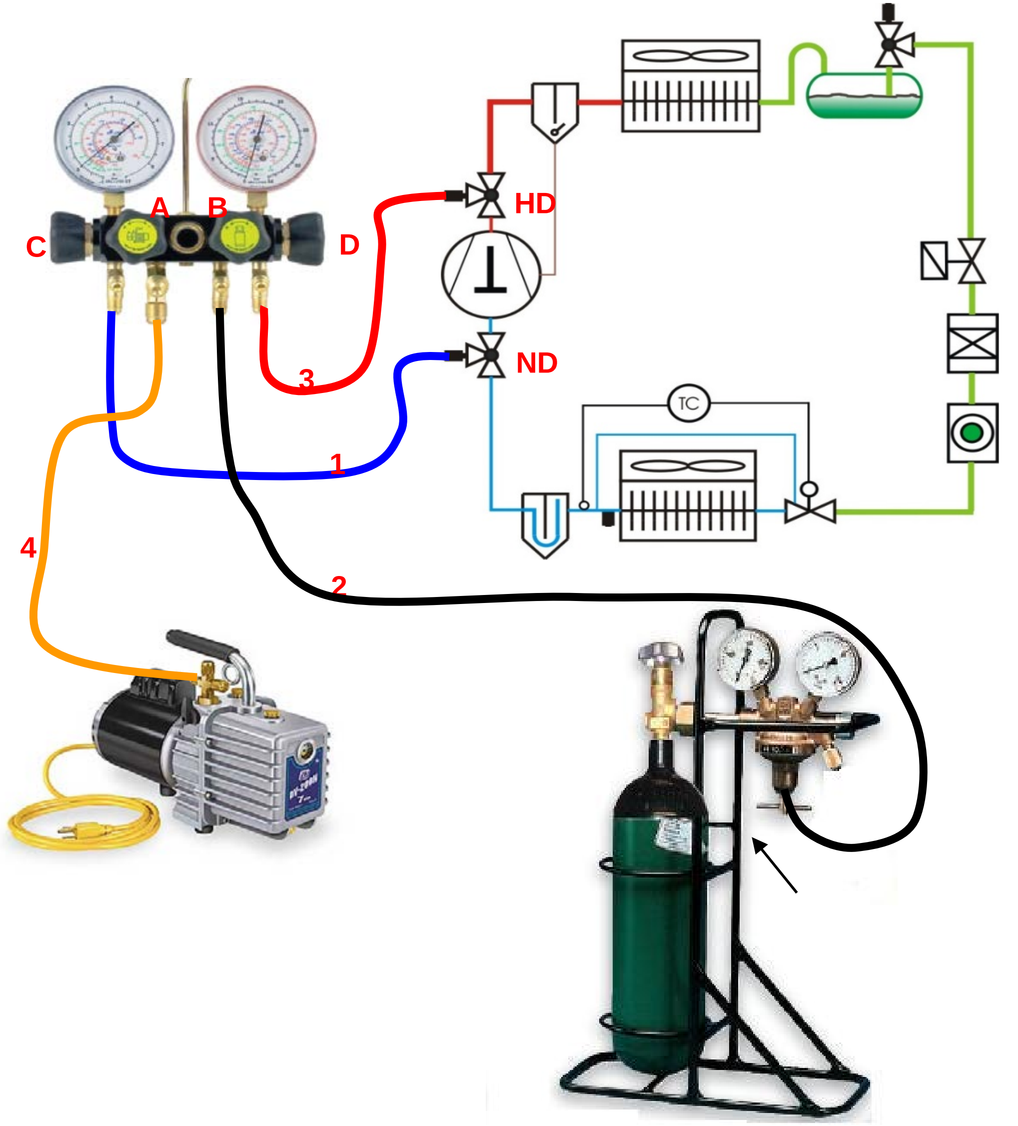
The following procedure should be followed before working on the refrigerant circuit:

- purge circuit with inert gas OFDN
- evacuate to an absolute pressure of 0.4 bar (= 0.04 MPa)
- purge again with inert gas OFDN
- open the circuit.

Inerting with OFDN

(oxygen free dry nitrogen)

- Use oxygen free and dry nitrogen only!



Inerting with OFDN: considerations for brazing

(oxygen free dry nitrogen)

Always apply OFDN to inert the refrigerant circuit (components, tubing) before and during any brazing activity:

- Due to the risk of hidden propane in pipes und accessories (siphons etc.)
- To avoid the creation of tinder

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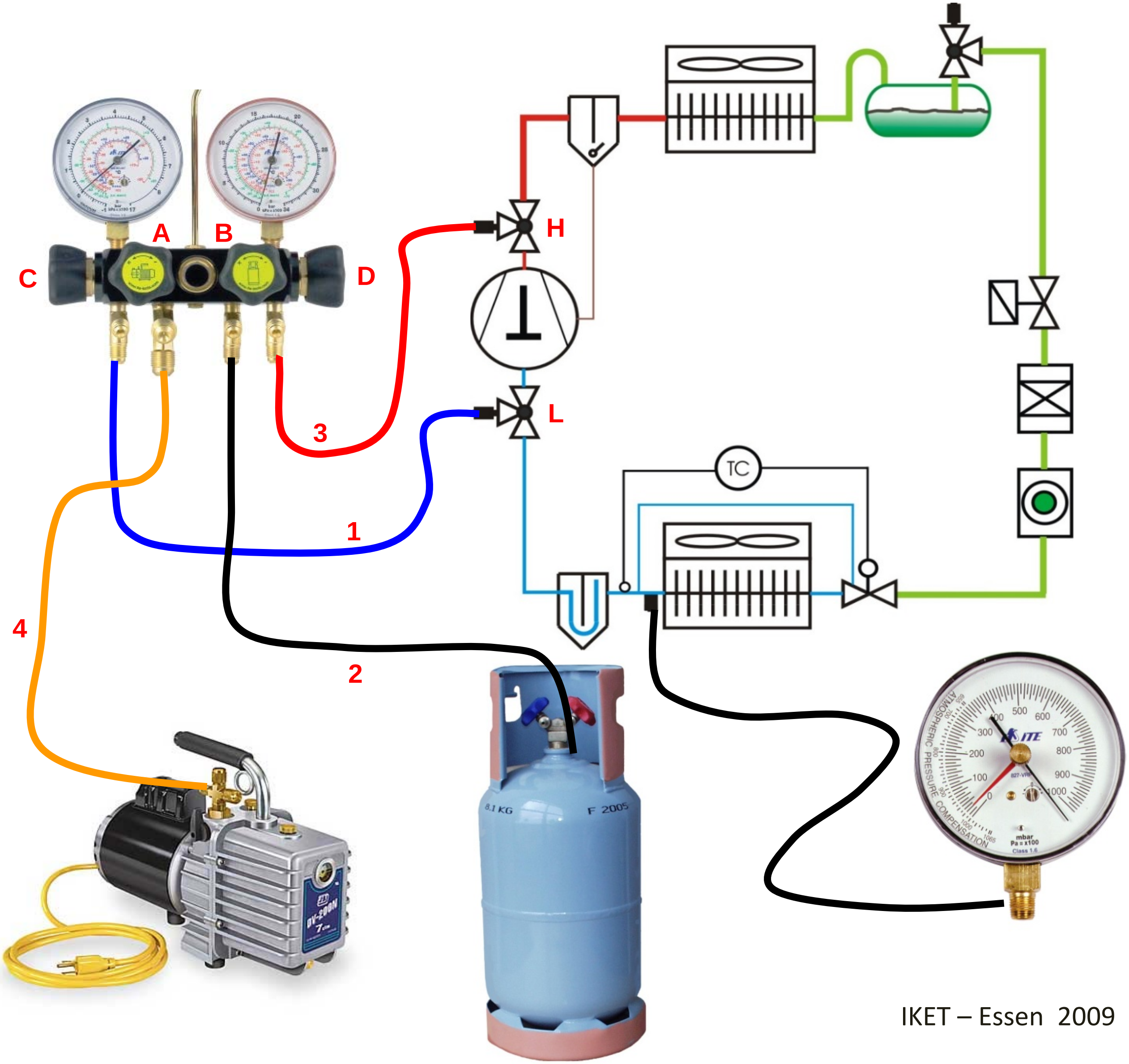
Vacuum: why it is needed

Before charging with refrigerant, the refrigerant circuit must be evacuated in order to remove

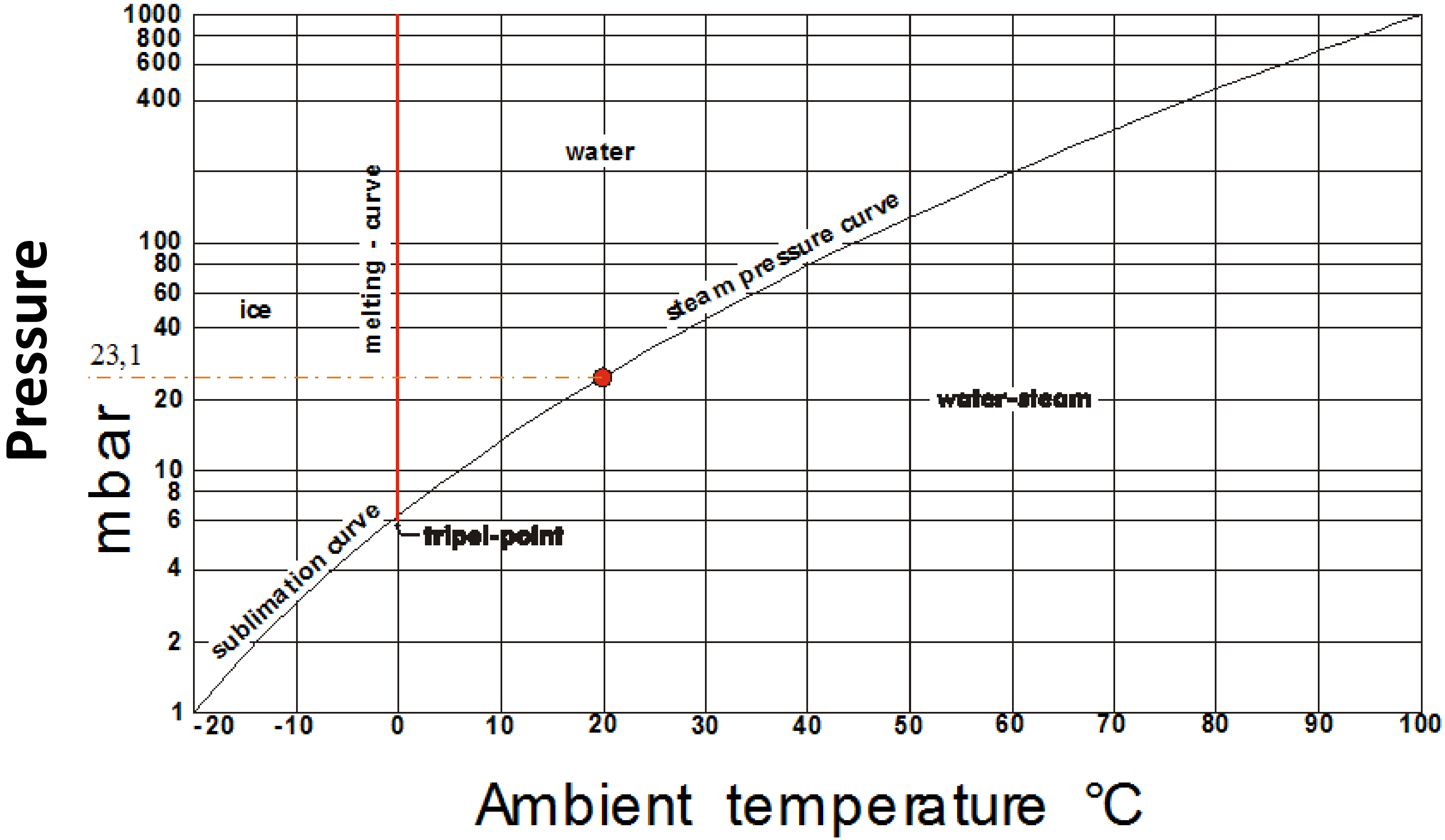
- non-condensable gases (air, N_2 or residual refrigerants),
- humidity.

Commissioning setup



IKET – Essen 2009

Evacuation: pressure/temperature diagram for water



Required pressure range for evacuation

Evaporation H_2O °F	Evaporation H_2O °C	mbar	Microns	PSI	Torr	Inch Mercury (Hg) gauge	% Vacuum
212	100,0	1013,070	759.968,00	14,69800	759,968	0,00	0
205	96,1	713,150	535.000,00	10,34690	535,000	8,86	29,59
194	90,0	700,530	525.526,00	10,16200	525,530	9,23	30,63
176	80,0	473,340	355.092,00	6,86600	355,100	15,94	53,13
158	70,0	311,500	233.680,00	4,51900	233,680	20,72	69,15
140	60,0	199,090	149.352,00	2,88000	149,350	24,04	80,29
122	50,0	123,240	92.456,00	1,78800	92,460	26,28	87,8
104	40,0	73,470	55.118,00	1,06600	55,120	27,75	92,72
86	30,0	42,320	31.750,00	0,61400	31,750	28,67	95,81
80	26,7	33,860	25.400,00	0,49100	25,400	28,92	96,65
76	24,4	30,470	22.860,00	0,44200	22,860	29,02	96,98
72	22,2	27,090	20.320,00	0,39300	20,320	29,09	97,32
69	20,6	23,700	17.780,00	0,34400	17,780	29,12	97,65
64	17,8	20,550	15.420,00	0,29500	15,420	29,31	97,96
59	15,0	16,930	12.700,00	0,24600	12,700	29,42	98,32
53	11,7	13,540	10.160,00	0,19600	10,160	29,55	98,65
45	7,2	10,150	7.620,00	0,14700	7,620	29,62	98,99
32	0,0	6,090	4.572,00	0,08800	4,570	29,82	99,4
21	-6,1	3,390	2.540,00	0,04900	2,540	29,84	99,66
6	-14,4	1,690	1.270,00	0,02450	1,270	29,86	99,83
1,4	-17,0	1,330	1.000,00	0,01934	1,000	29,88	99,87
-4	-20,0	0,990	750,00	0,01450	0,750	29,89	99,9
-9,4	-23,0	0,670	500,00	0,00967	0,500	29,90	99,93
-24	-31,1	0,340	254,00	0,00490	0,254	29,905	99,97
-35	-37,2	0,170	127,00	0,00245	0,127	29,910	99,98
-40	-40,0	0,133	100,00	0,00193	0,100	29,916	99,986
-60	-51,1	0,034	25,40	0,00049	0,025	29,917	99,996
-70	-56,7	0,017	12,70	0,00024	0,013	29,918	99,998
-90	-67,8	0,003	2,50	0,00005	0,002	29,919	99,999
		0,000	0,00	0,00000	0,000	29,920	100

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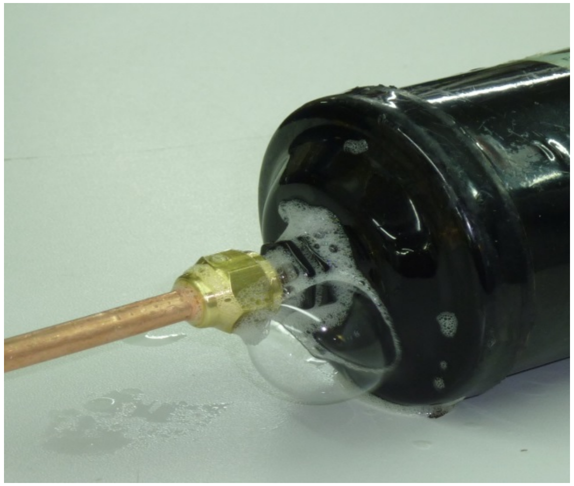
Gas detection technologies

TCD



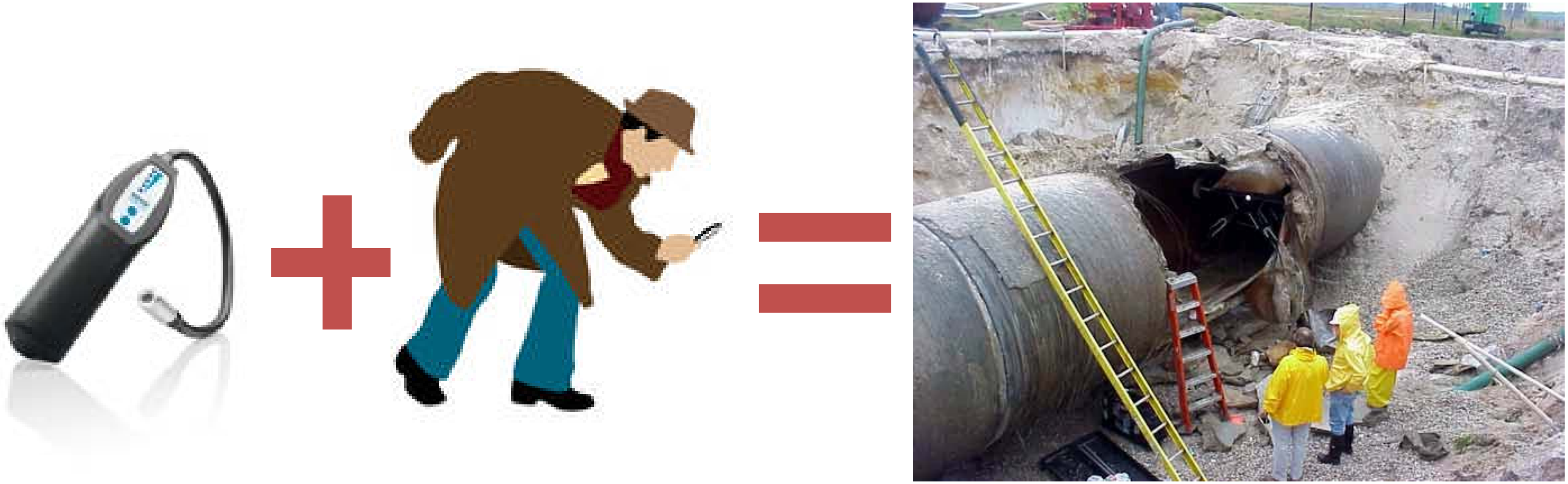
Electronic TCD gas detector (sniffer): requirements

- **Device must be compatible with the refrigerant** that is contained in the system undergoing the leak testing.
- Technicians must **know their leak detector's capabilities** and also what they are not capable of detecting.
- **Carbon monoxide and alcohol can affect the sensitivity** of some electronic gas detectors. Be sure neither is present when trying to detect a leak.

- The device should be **checked at least once a year** to ensure reliability and accuracy.
- If possible, **use a "reference leak source"** for calibration.
- Having a „reference leak source" it can be used before any job for gas detection (leak finding)

Warning: Most electronic gas detectors are not recommended to be used in atmospheres that contain flammable or explosive vapours or refrigerants. Sensors may operate at an extremely high temperature. **If the sensor comes in contact with a combustible gas, ignition will occur.**

What is leak detection?

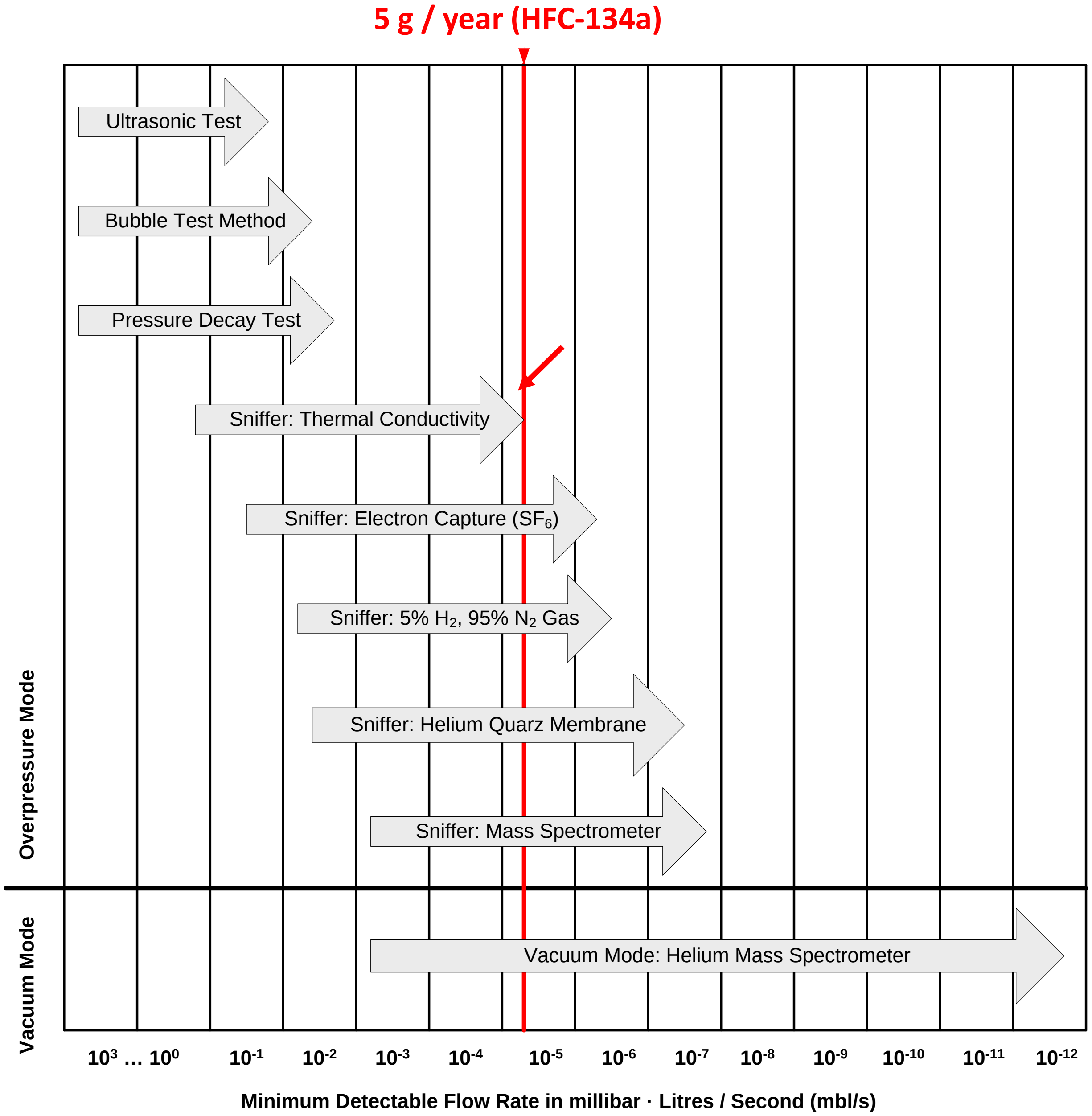


Gas detector + detective work = find leak

Moving the sniffer (TCD) sensor

Move at 0.2 cm per second along the tubes and around spots suspected for a leak!

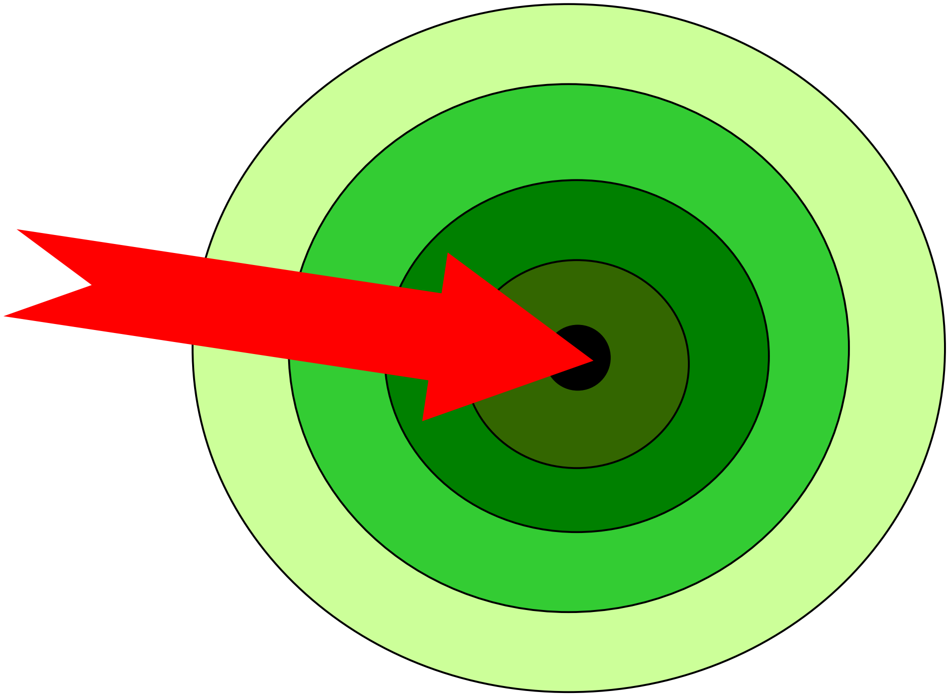
Comparison of leak detection methods



Key take-away's

- ✓ Valid rules and regulations must be followed.
  → HC chillers can be operated safely and energy-efficiently.
- ✓ A risk assessment is obligatory before starting the job.
- ✓ Do not work if it is not completely safe.
- ✓ Always use the right tools and PPE.
- ✓ Always keep the fire triangle in mind.

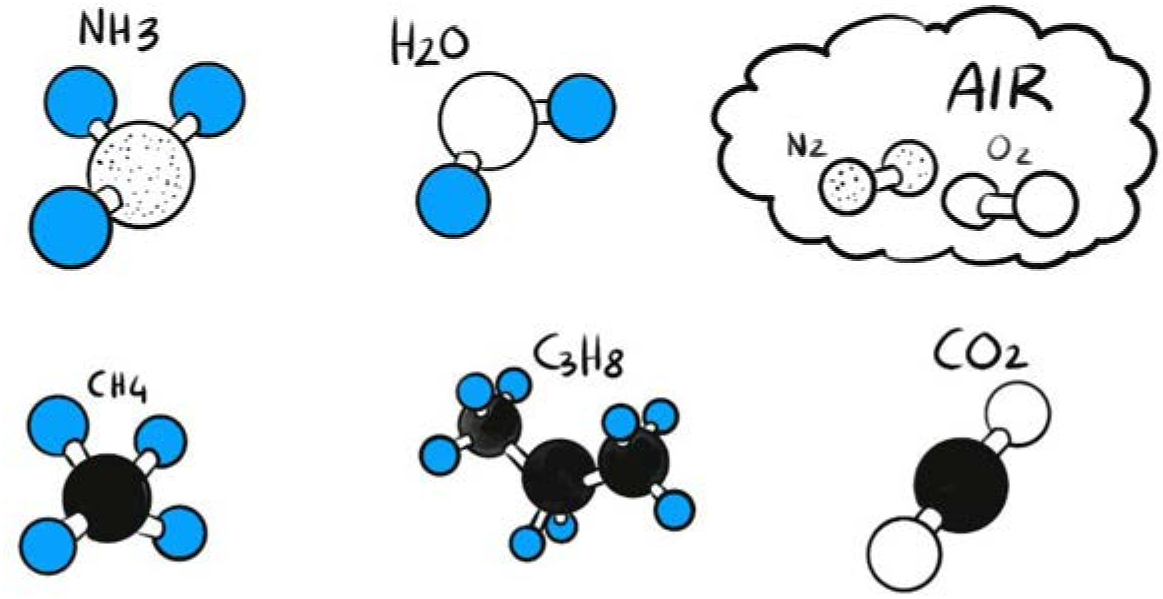
Targets



no Accident

no Environment Pollution

no Health Hazard



Thank You for Your attention!

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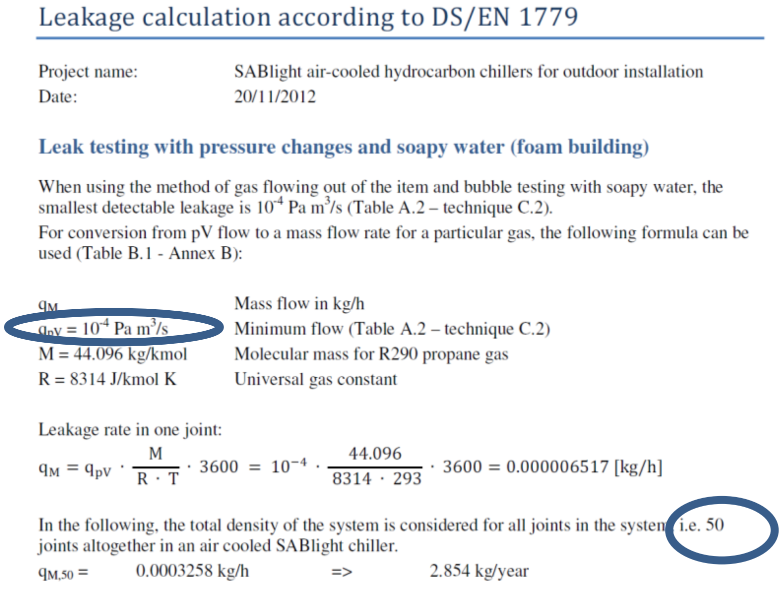
Propane (R290) chiller ODP = 0 & GWP = 3

Product Regulatory Compliance – Flammability Calculation



Leakage calculation according to DS/EN 1779

Project name:	SABlight air-cooled hydrocarbon chillers for outdoor installation
Date:	20/11/2012

Leak testing with pressure changes and soapy water (foam building)

When using the method of gas flowing out of the item and bubble testing with soapy water, the smallest detectable leakage is 10^{-4} Pa m^3/s (Table A.2 – technique C.2).

For conversion from pV flow to a mass flow rate for a particular gas, the following formula can be used (Table B.1 - Annex B):

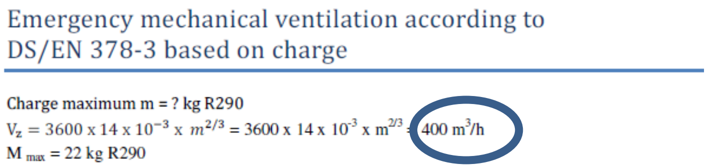
q_M	Mass flow in kg/h
$q_{pV} = 10^{-4}$ Pa m^3/s	Minimum flow (Table A.2 – technique C.2)
M = 44.096 kg/kmol	Molecular mass for R290 propane gas
R = 8314 J/kmol K	Universal gas constant

Leakage rate in one joint:

$$q_M = q_{pV} \cdot \frac{M}{R \cdot T} \cdot 3600 = 10^{-4} \cdot \frac{44.096}{8314 \cdot 293} \cdot 3600 = 0.000006517 \text{ [kg/h]}$$

In the following, the total density of the system is considered for all joints in the system i.e. 50 joints altogether in an air cooled SABlight chiller.

$q_{M,50}$ = 0.0003258 kg/h => 2.854 kg/year



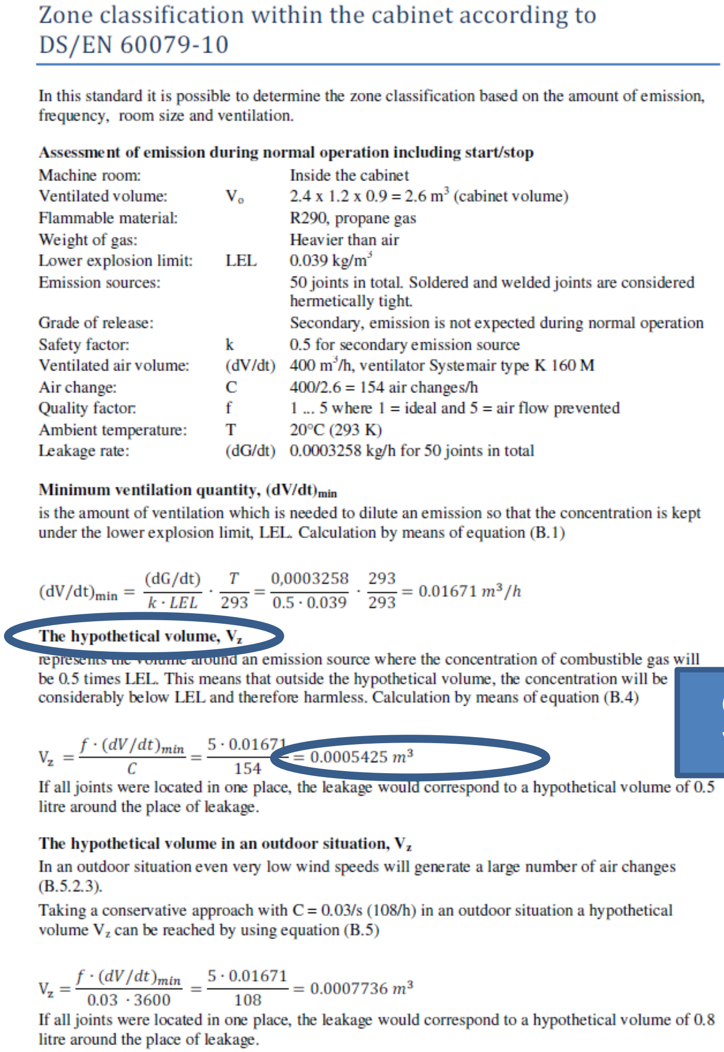
Emergency mechanical ventilation according to DS/EN 378-3 based on charge

Charge maximum m = ? kg R290

$V_z = 3600 \times 14 \times 10^{-3} \times m^{2/3} = 3600 \times 14 \times 10^{-3} \times m^{2/3}$ = 400 m^3/h

M_{max} = 22 kg R290

Possible reduction:
Using 15 air change/hour:
dV/dt = V x 15 = 39 m³/h



Zone classification within the cabinet according to DS/EN 60079-10

In this standard it is possible to determine the zone classification based on the amount of emission, frequency, room size and ventilation.

Assessment of emission during normal operation including start/stop

Machine room:		Inside the cabinet
Ventilated volume:	V_o	2.4 x 1.2 x 0.9 = 2.6 m^3 (cabinet volume)
Flammable material:		R290, propane gas
Weight of gas:		Heavier than air
Lower explosion limit:	LEL	0.039 kg/m^3
Emission sources:		50 joints in total. Soldered and welded joints are considered hermetically tight.
Grade of release:		Secondary, emission is not expected during normal operation
Safety factor:	k	0.5 for secondary emission source
Ventilated air volume:	(dV/dt)	400 m^3/h, ventilator Systemair type K 160 M
Air change:	C	400/2.6 = 154 air changes/h
Quality factor:	f	1 ... 5 where 1 = ideal and 5 = air flow prevented
Ambient temperature:	T	20°C (293 K)
Leakage rate:	(dG/dt)	0.0003258 kg/h for 50 joints in total

Minimum ventilation quantity, $(dV/dt)_{min}$

is the amount of ventilation which is needed to dilute an emission so that the concentration is kept under the lower explosion limit, LEL. Calculation by means of equation (B.1)

$$(dV/dt)_{min} = \frac{(dG/dt)}{k \cdot LEL} \cdot \frac{T}{293} = \frac{0,0003258}{0.5 \cdot 0.039} \cdot \frac{293}{293} = 0.01671\ m^3/h$$

The hypothetical volume, V_z

represents the volume around an emission source where the concentration of combustible gas will be 0.5 times LEL. This means that outside the hypothetical volume, the concentration will be considerably below LEL and therefore harmless. Calculation by means of equation (B.4)

$$V_z = \frac{f \cdot (dV/dt)_{min}}{C} = \frac{5 \cdot 0.01671}{154} = 0.0005425\ m^3$$

If all joints were located in one place, the leakage would correspond to a hypothetical volume of 0.5 litre around the place of leakage.

The hypothetical volume in an outdoor situation, V_z

In an outdoor situation even very low wind speeds will generate a large number of air changes (B.5.2.3).

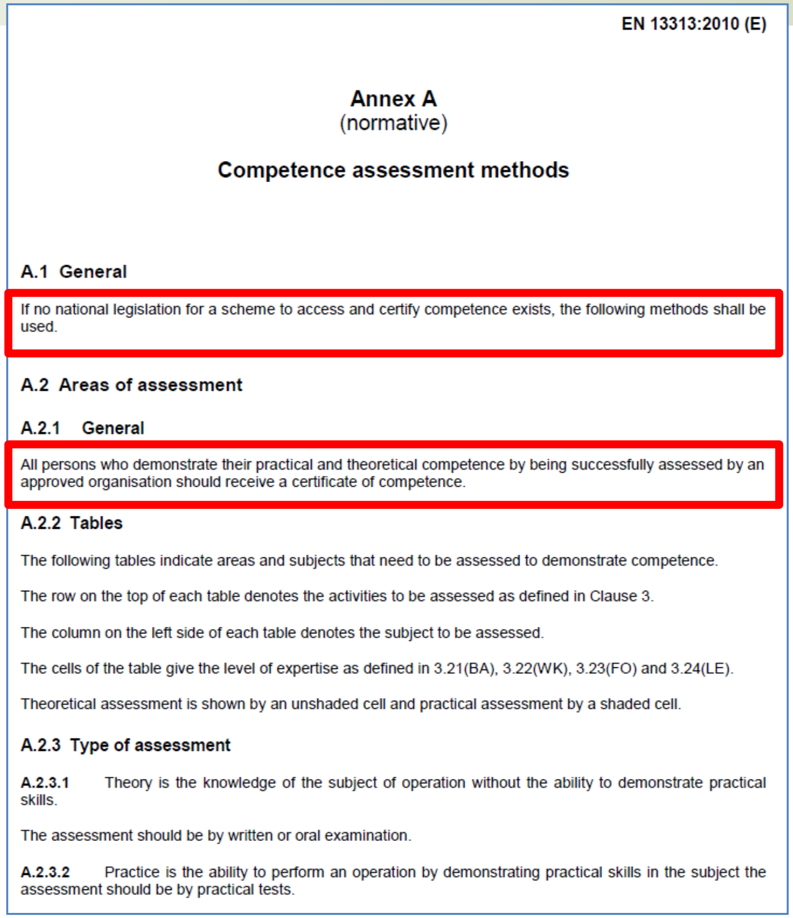
Taking a conservative approach with C = 0.03/s (108/h) in an outdoor situation a hypothetical volume V_z can be reached by using equation (B.5)

$$V_z = \frac{f \cdot (dV/dt)_{min}}{0.03 \cdot 3600} = \frac{5 \cdot 0.01671}{108} = 0.0007736\ m^3$$

If all joints were located in one place, the leakage would correspond to a hypothetical volume of 0.8 litre around the place of leakage.

One leak:
Vz = 0,1 L

Competence: EN 13313



EN 13313:2010 (E)

Annex A
(normative)

Competence assessment methods

A.1 General

If no national legislation for a scheme to access and certify competence exists, the following methods shall be used.

A.2 Areas of assessment

A.2.1 General

All persons who demonstrate their practical and theoretical competence by being successfully assessed by an approved organisation should receive a certificate of competence.

A.2.2 Tables

The following tables indicate areas and subjects that need to be assessed to demonstrate competence.

The row on the top of each table denotes the activities to be assessed as defined in Clause 3.

The column on the left side of each table denotes the subject to be assessed.

The cells of the table give the level of expertise as defined in 3.21(BA), 3.22(WK), 3.23(FO) and 3.24(LE).

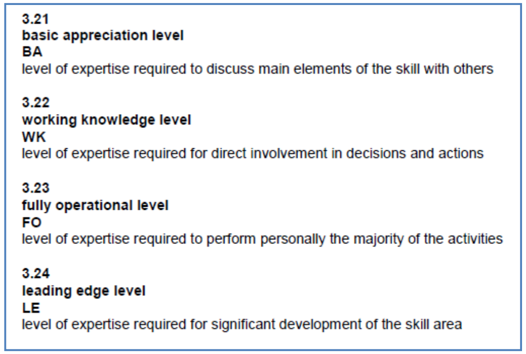
Theoretical assessment is shown by an unshaded cell and practical assessment by a shaded cell.

A.2.3 Type of assessment

A.2.3.1 Theory is the knowledge of the subject of operation without the ability to demonstrate practical skills.

The assessment should be by written or oral examination.

A.2.3.2 Practice is the ability to perform an operation by demonstrating practical skills in the subject the assessment should be by practical tests.



3.21
basic appreciation level
BA
level of expertise required to discuss main elements of the skill with others

3.22
working knowledge level
WK
level of expertise required for direct involvement in decisions and actions

3.23
fully operational level
FO
level of expertise required to perform personally the majority of the activities

3.24
leading edge level
LE
level of expertise required for significant development of the skill area

Included in EN 378 and soon in ISO

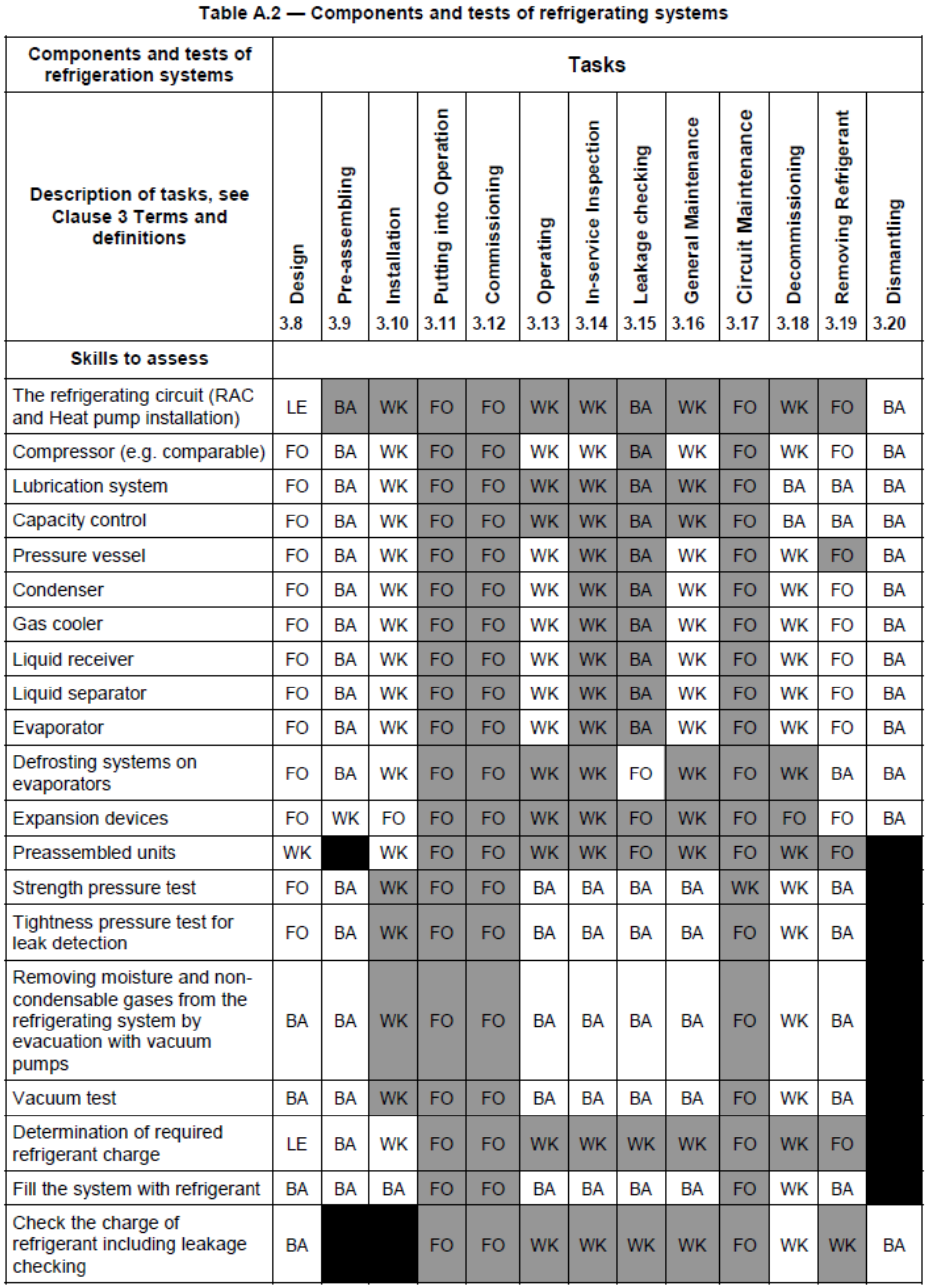


Table A.2 — Components and tests of refrigerating systems

Components and tests of refrigeration systems	Tasks												
Description of tasks, see Clause 3 Terms and definitions	Design 3.8	Pre-assembling 3.9	Installation 3.10	Putting into Operation 3.11	Commissioning 3.12	Operating 3.13	In-service Inspection 3.14	Leakage checking 3.15	General Maintenance 3.16	Circuit Maintenance 3.17	Decommissioning 3.18	Removing Refrigerant 3.19	Dismantling 3.20
Skills to assess													
The refrigerating circuit (RAC and Heat pump installation)	LE	BA	WK	FO	FO	WK	WK	BA	WK	FO	WK	FO	BA
Compressor (e.g. comparable)	FO	BA	WK	FO	FO	WK	WK	BA	WK	FO	WK	FO	BA
Lubrication system	FO	BA	WK	FO	FO	WK	WK	BA	WK	FO	BA	BA	BA
Capacity control	FO	BA	WK	FO	FO	WK	WK	BA	WK	FO	BA	BA	BA
Pressure vessel	FO	BA	WK	FO	FO	WK	WK	BA	WK	FO	WK	FO	BA
Condenser	FO	BA	WK	FO	FO	WK	WK	BA	WK	FO	WK	FO	BA
Gas cooler	FO	BA	WK	FO	FO	WK	WK	BA	WK	FO	WK	FO	BA
Liquid receiver	FO	BA	WK	FO	FO	WK	WK	BA	WK	FO	WK	FO	BA
Liquid separator	FO	BA	WK	FO	FO	WK	WK	BA	WK	FO	WK	FO	BA
Evaporator	FO	BA	WK	FO	FO	WK	WK	BA	WK	FO	WK	FO	BA
Defrosting systems on evaporators	FO	BA	WK	FO	FO	WK	WK	FO	WK	FO	WK	BA	BA
Expansion devices	FO	WK	FO	FO	FO	WK	WK	FO	WK	FO	FO	FO	BA
Preassembled units	WK		WK	FO	FO	WK	WK	FO	WK	FO	WK	FO	
Strength pressure test	FO	BA	WK	FO	FO	BA	BA	BA	BA	WK	WK	BA	
Tightness pressure test for leak detection	FO	BA	WK	FO	FO	BA	BA	BA	BA	FO	WK	BA	
Removing moisture and non-condensable gases from the refrigerating system by evacuation with vacuum pumps	BA	BA	WK	FO	FO	BA	BA	BA	BA	FO	WK	BA	
Vacuum test	BA	BA	WK	FO	FO	BA	BA	BA	BA	FO	WK	BA	
Determination of required refrigerant charge	LE	BA	WK	FO	FO	WK	WK	WK	WK	FO	WK	FO	
Fill the system with refrigerant	BA	BA	BA	FO	FO	BA	BA	BA	BA	FO	WK	BA	
Check the charge of refrigerant including leakage checking	BA			FO	FO	WK	WK	WK	WK	FO	WK	WK	BA

"ISO/TC 86/SC 1 Resolution 6 (Paris 2015-6)
SC 1 agrees to create a new ISO standard based on EN 13313 under the Vienna agreement with CEN lead as proposed by CEN/TC 182.
Resolution 6 was taken by unanimity."