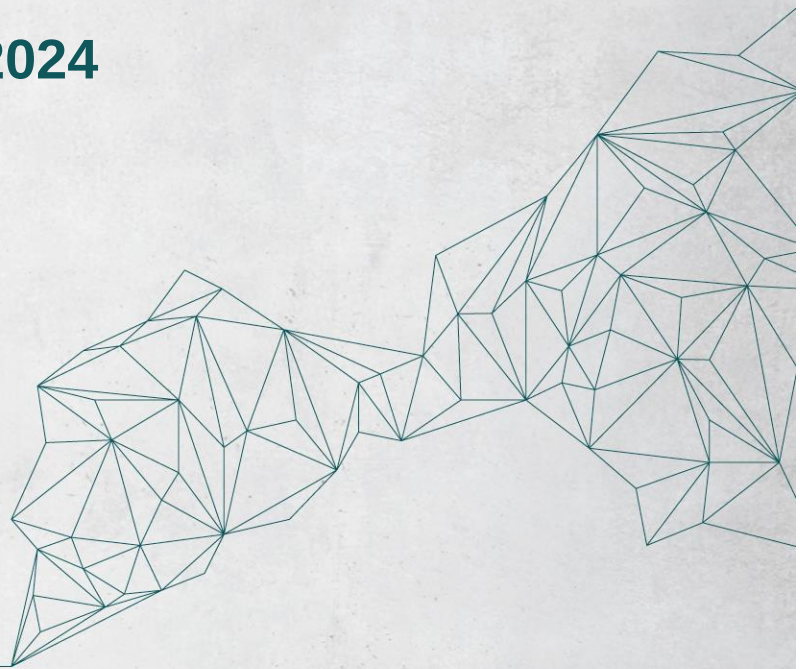
Chillventa Specialist Forums 2024
Chillventa Fachforen 2024

CONNECTING EXPERTS.



A2L refrigerants in different industry sectors: R-454C and its wide operating envelope

SHORT DESCRIPTION

Evaluating charge limitations and safety measures in accordance with EN378 and national legislation considering the flammability of A2L refrigerants. The impact of system, - design, control and complexity.

DETAILED DESCRIPTION

R-454C is a mildly flammable (A2L), non-ozone depleting, low-GWP (148) refrigerant for low, medium and high temperature applications in system installations that is compliant with the latest EU F-Gas regulation and Eco-design Directive. It represents a future-proof long-term solution in commercial refrigeration applications that provides high performance, energy efficiency and sustainability.

Moving away from common medium and high GWP legacy refrigerants to low-GWP refrigerants requires certain changes and a different approach. No matter using an A1 refrigerant such as R-744 a very high-pressure fluid, a mildly flammable A2L refrigerant like R-454C or a highly flammable A3 alternative like R-290, charge limitations, safety and risk considerations are key elements. Due to its unique characteristics, the system architectures/designs and controls and installation and handling procedures must be adjusted accordingly. These parameters increase the overall system and project complexity.

This presentation provides an overview of multiple real-life installations and concrete assessments where R-454C has been chosen as the preferred refrigerant. Showing the impact of flammability, charge restrictions and system design in different industry sectors while benefitting from the advantages of having lower flammability compared to A3 alternatives and lower system complexity compared to A1 solutions. Demonstrating that A2L refrigerants can be used in various applications while being a safe and sustainable alternative.

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Agenda

- Introduction
- Phase Down / F-gas Regulation (EU) 2024/573
- Low GWP Solutions: Safety & Complexity
- Technical Comparison
- Conclusion
- Outlook

Introduction

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Montreal Protocol — 1987

Kyoto Protocol — 1997

EU F-Gas Regulation 2014/517 — 2014

Kigali Amendment to the Montreal Protocol — 2016

EU F-Gas Revision 2024/573 — 2024

The F-gas Regulation paved the way for the adoption of lower-emissions alternatives to R-404A, R-449A, R-134a & R-513a in refrigeration systems.

F-gas Regulation (EU) 2024/573 – GWP Limits – New Systems

150	150	750
Air Conditioning & Heat Pump > 12kW	Commercial Refrigeration	Chiller > 12kW
Opteon™ XL 20	**Opteon™ XL 20**	**Opteon™ XL 41**
R-454C	R-454C	R-454B

< 150 GWP Solutions

Name	ASHRAE GWP	Potential for recovery	Category	Burning velocity (m/s)	Practical limit (kg/m³)	LFL (kg/m³)	Operating Pressure (Tair=35°C)	Boiling Point	Critical Temp.
Opteon XL20	R-454C 148	YES	A2L	1,6	0,059	0,293	~ 17 bar	-45,6°C	+85,7°C
Propane	R-290 3	NO	A3	46,0	0,008	0,038	~ 14 bar	+42,1°C	+96,7°C
Carbon Dioxide	R-744 1	NO	A1	-	0,1	-	~ 100 bar	-78,46°C	+31°C

Refrigerant Characteristics

	A3	A2L	A1
PED Fluid Group	PED Fluid Group I	PED Fluid Group I	PED Fluid Group II
Component classification	In accordance with PED Fluid Group		
Service equipment	Mechanical: Anti-static Electrical: A3 certified	Mechanical: Standard Electrical: A2L certified	Standard
Risk analysis	Standard + Flammability	Standard + Flammability	Standard
Temperatures	AIT (280 bis 530 °C – 100K)	HSIT (>800°C – 100K)	-
Minimum ignition energy	MIE (<1mJ)	MIE (100 bis >5000mJ)	-
ATEX zone	Zone 0 bis 2 (ø meter)	Maximal Zone 2 (ø decimeter)	-

< 150 GWP Solutions Impact on safety

Regulations

EN-378 part 1-4

ISO-5149 part 1-4

60335-2-89

60335-2-40

Risk

A risk assessment is mandatory by European law -> Machine directive 2023/1230/EG

Valid for all refrigerant classifications A1, A2L, A3, B2L, …

Safety

Gas detector

Safety shut off valve

Acoustic and visual alarm

Ventilation

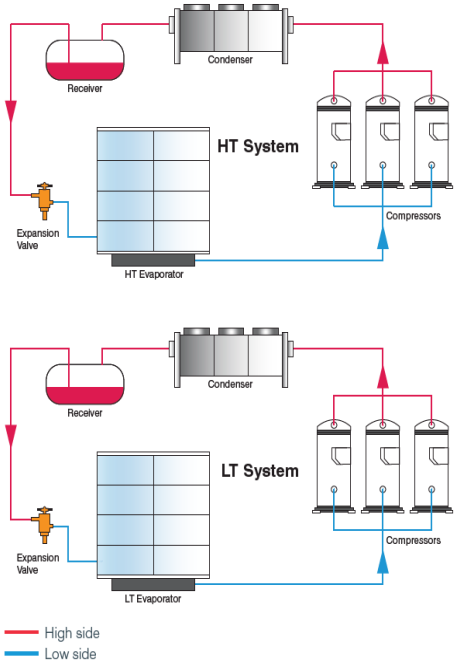
Power supply

PPE

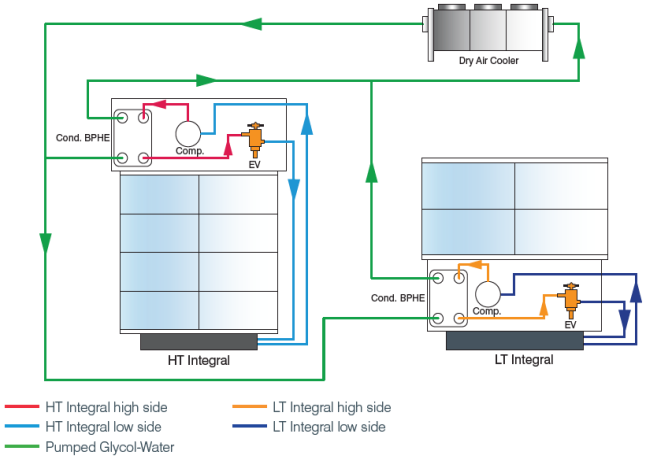
Risk assessment = Risk analysis + Risk evaluation

< 150 GWP Solutions Example Com Ref

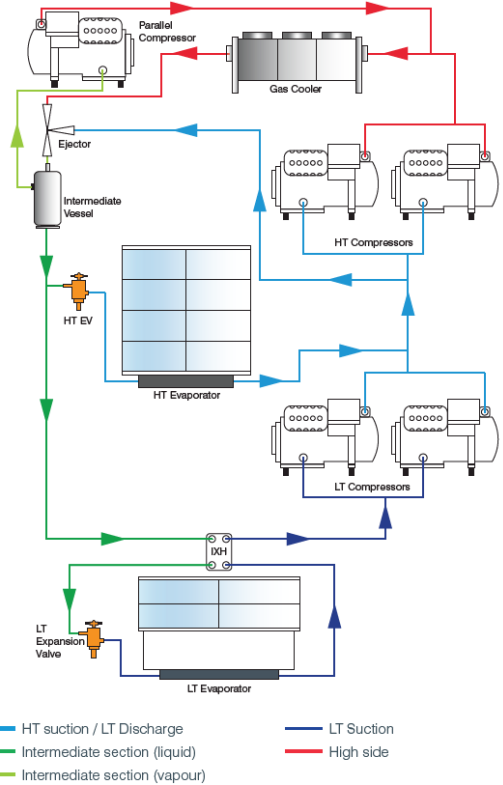
A1 / A2L Basic



R-290 secondary loop



R-744 Booster



Alternative solutions require higher system complexity to cope with safety and efficiency!

LT Application – theoretical comparison

Condenser=40ºC, Evaporator=-30ºC, Subcool amount=2K, Total Superheat= 11K (8K useful), Compressor Efficiency =0.7

Calculation based on Refprop 10 database

		Freon™ 404A	Opteon™ XP40	**Opteon™ XL20**
		R-404A	R-449A	**R-454C**
GWP (AR4)		3922	1397	**148**
Mean Evaporating Temperature	ºC	-30.00	-30.01	**-30.04**
Evaporating Pressure	bar.g	1.03	0.73	**0.57**
Compressor Suction Temperature	ºC	-18.78	-17.27	**-16.77**
Compressor Discharge Temperature	ºC	76.38	96.30	**87.77**
Mean Condensing Temperature	ºC	40.00	40.01	**40.03**
Condensing Pressure	bar.g	17.21	16.57	**14.90**
Evaporator Cooling Capacity	kW	1.95	1.99	**1.76**
Evaporator Cooling Capacity rel.	%	1.00	1.02	**0.90**
Compressor Power	kW	1.31	1.23	**1.10**
C.O.P.		1.49	1.62	**1.60**
C.O.P. rel.	%	1.00	1.08	**1.08**

MT Application – theoretical comparison

Condenser=40ºC, Evaporator=-10ºC, Subcool amount=2K, Total Superheat= 11K (8K useful), Compressor Efficiency =0.7

Calculation based on Refprop 10 database

		Freon™ 404A	Opteon™ XP40	**Opteon™ XL20**
		R-404A	R-449A	**R-454C**
GWP (AR4)		3922	1397	**148**
Mean Evaporating Temperature	ºC	-10.00	-10.01	**-10.05**
Evaporating Pressure	bar.g	3.32	2.86	**2.50**
Compressor Suction Temperature	ºC	1.20	2.89	**3.62**
Compressor Discharge Temperature	ºC	66.67	79.98	**74.95**
Mean Condensing Temperature	ºC	40.00	40.01	**40.03**
Condensing Pressure	bar.g	17.21	16.57	**14.90**
Evaporator Cooling Capacity	kW	4.00	4.12	**3.68**
Evaporator Cooling Capacity rel.	%	1.00	1.03	**0.92**
Compressor Power	kW	1.56	1.52	**1.36**
C.O.P.		2.57	2.72	**2.71**
C.O.P. rel.	%	1.00	1.06	**1.06**

HT Application – theoretical comparison

Condenser=50ºC, Evaporator=5ºC, Subcool amount=2K, Total Superheat= 8K, Compressor Efficiency =0.7

Calculation based on Refprop 10 database

		Freon™ 407C	Freon™ 410A	**Opteon™ XL20**
		R-407C	R-410A	**R-454C**
GWP (AR5)		1624	1920	**146**
Mean Evaporating Temperature	ºC	4.98	5.00	**4.95**
Evaporating Pressure	bar.g	4.85	8.33	**4.79**
Compressor Suction Temperature	ºC	15.09	13.04	**15.56**
Compressor Discharge Temperature	ºC	83.91	88.15	**77.14**
Mean Condensing Temperature	ºC	49.99	50.00	**50.00**
Condensing Pressure	bar.g	20.01	29.65	**19.16**
Liquid Line Temperature	ºC	45.71	47.95	**44.84**
Condenser Capacity	kW	8.98	13.15	**8.50**
Condenser Capacity rel.	%	100%	146%	**95%**
C.O.P. Heating		4.19	4.08	**4.19**
C.O.P. Heating rel.	%	100%	97%	**100%**

Valmarket supermarket - ComRef

Opteon™ XL20
R-454C

FACTS:

Supermarket sales area: 700m²

MT - serving 3 cold-rooms and 33 m of counters:	LT - serving 12 m of counters:
Cooling capacity: 40 kW	Cooling capacity: 13.5 kW
Evaporation temperature: -10 °C	Evaporating temperature: -30 °C
Condensing temperature: +42 °C	Condensation temperature: +42°C

Component supplier: Pastorfrigor; Italia Refrigerazione; Bitzer; Frigomec; Copeland; Antonio Seveso

"This refrigerant allows us to offer supermarket and local shop owners an effective solution. It has allowed Valmarket to maintain a simple and easy-to-manage system which has made our work more effective and has fully satisfied the customer."

Frigotecnica Ice machines

Opteon™ XL20
R-454C

FACTS:

Application: Flake Ice maker - up to 4000 kg / day
Cooling equipment:
Compressor: Bitzer
line components: Frigomec & Castel
Controls: Danfoss

Refrigerant	Opteon™ XL20 (R-454C)
Daily output	450/580 kg/24h (992/1212 lbs/24h)
Ice thickness	2/3 mm (0.08/0.12")
Ice temperature	-14 °C/-18 °C (6.8 °F/-0.4 °F)
Water consumption	24 l/hr. (5.28 gph)
Cooling capacity (-30 °C/+40 °C | -22 °F/+104 °F)	2.9 kW
Power absorption (-30 °C/+40 °C | -22 °F/+104 °F)	2.3 kW
Dimensions	75 x 46 x 45 cm (29.5 x 18.1 x 17.7 inches)
Weight	70 kg (154.3 lbs)

"Baldo Mirabile, partner and technical manager at Frigotecnica who has followed the project from its initial stages commented: "Using R-454C was easier than we expected. From the first tests, it was clear that performance would meet the requirements of our customers and that the low GWP would enable us to improve our environmental image, ensuring our long-term vision. We are in the process of extending the use of R-454C into our entire range of machines."

Freezer for an airline caterer

BIRGELS
PRIMA KÄLTE KLIMA

Opteon™ XL20
R-454C

FACTS:

R-454C solution for a freezer system:

System:
4 Bitzer Ecolite condensing units 11kg charge per system

Installation:
Birgels Kälte und Klima Rhein-Main GmbH & Co. KG

"High system reliability thanks to failover“
"Another significant advantage was the cost: the purchase price of the system was 30% lower than that of the alternatively planned CO_2 refrigeration system. In addition, lower costs are expected for service, maintenance and operation. "

Flooded system using Opteon XL20

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R-22 to R-507A to R-454C

clauger GRENCO Ibérica

Opteon™ XL20
R-454C

FACTS:

R-454C used for chlorine liquification

System: Bitzer Screw Compressor
1470 kg of charge

Required changes:
Safety shut off valves and 3-way valves, dehydrator cartridges, oil

Machinery room:
A2L leak detector; EX proofed extractor, emergency shower and eye wash, self-contained breathing apparatus

R-507A (GWP = 3.985)
R-454C (GWP = 148)
Alternating, 3 phases, 400 V 50 Hz
Water condensation
23°C / 26°C
35°C
+5°C / +40°C (ambient temperature)

KIMIKAL GRUPO GAZECHIM

Voice of Customer:
R-454C (Opteon™ XL20), has a low Global Warming Potential (GWP 148) and similar performance to R-507A. It is the ideal refrigerant, for medium and low temperature applications. R-454C allows for high energy-efficiency, as it enables better equipment COP compared to R-507A. From an environmental perspective, this choice significantly reduces the TEWI, which accounts for both direct and indirect CO2 emissions.

Conclusion

Regulatory landscape

Regulations support global HFC phase Down and guide for safe systems & installations

Safety

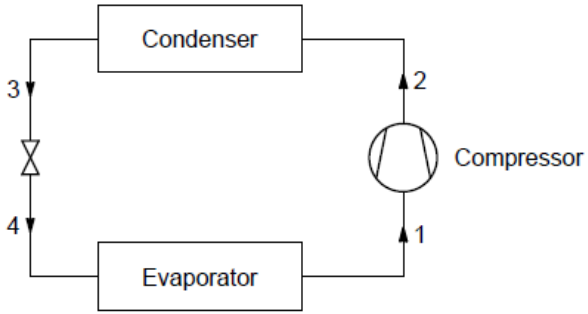
Risk assessment for all refrigerant types

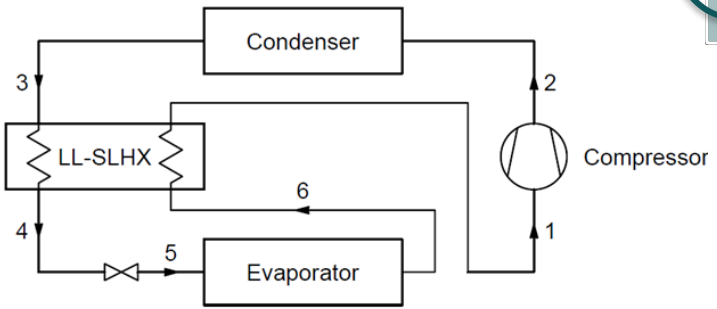
Complexity

A1 & A2L refrigerants allow very close system architectures

R-454C can be used in various applications

Outlook: How to further increase the efficiency and capacity of HFO systems





COOLING IMPROVEMENTS	Modification	COP Improvement (%)	Cooling capacity Improvement (%)
Measure	Compressor	+0 …+6.5	+0 … +4.6
Measure	IHX opt. vs. IHX std.	+4 … +14	+1 … +17
Measure	SH control	+2 … +22	+3 … +25
Measure	**IHX + SH Control**	**+6 ... +36**	**+4 ... +42**

Hardware & Software changes enable tremendous energy savings.
Talk to us! We will be happy to support you!

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