



Position Paper

Light Commercial Refrigeration

Refrigerants Outlook for United States and Canada
2020

Introduction

With the Kigali Amendment to Montreal Protocol, the global community made another important step towards preserving our planet for future generations by reducing CO₂ emissions due to human activities. The global phase-down of HFCs in the refrigeration sector represents an important contribution to international climate change mitigation efforts. For many years, Embraco has been actively investing in this direction by developing and promoting hermetic compressors for use with low-atmospheric impact refrigerants on all continents. In addition to isobutane (R600a) in household appliances, significant progress has also been made integrating propane (R290) into light commercial plug-in systems as well in the use of carbon dioxide in the supermarket sector. In the US, even though EPA rules on the subject have been suspended by the US courts for the time being, California and two other states have recently adopted HFC regulations limiting high global warming potential (GWP) substances in air conditioning and commercial refrigeration. All these developments point in a similar direction: the need to lower the

GWP of the refrigerants in use without compromising the indirect CO₂ emissions during the lifetime of the equipment. Canada is headed in the same direction with recently published new HFC rules imposing bans on high-GWP refrigerants for specific applications. In Europe F-gas regulations have imposed progressive bans on certain high-GWP refrigerants for common refrigeration applications, as well as a "quota system" to gradually reduce direct impact due to HFC refrigerants. In addition to the natural refrigerants mentioned before, several alternative synthetic refrigerants have been developed by the chemical industry and more are coming. Embraco has performed extensive tests to assess the capacity of these alternatives to replace high-GWP refrigerants presently in use. The most difficulty was found in trying to replace R404A. This paper will summarize current testing for R404A and R134a replacements, with a focus reliability and performances as well as the evolution of related safety legislation.

Embraco Policy Statement

- Embraco will encourage the use of low GWP refrigerants to support global effort to mitigate climate change.
- Embraco will continue to provide solutions to improve the energy efficiency of refrigeration equipment with low-GWP refrigerants.
- Embraco will support the proactive use of natural refrigerants without compromising appliance safety.
- Embraco will continue to develop products for both natural and synthetic low-GWP refrigerants that exceed present and future energy efficiency standards in order to assure the competitiveness of our products and expectations of our end users.
- Embraco will continue to work with international legislative bodies on the safe use of low-GWP refrigerant options.

Canada HFC Rules

On October 18, 2017, the Canadian government announced amendments to its existing Ozone-depleting Substances and Halocarbon Alternatives Regulations. The changes include a phase-down in bulk HFCs as well as prohibitions on HFCs in certain types of equipment as shown in Table 1.

Table 1 Canada HFC Rules and Effective Dates

	GWP LIMIT	DATE
REFRIGERATION – CENTRALIZED SYSTEMS (MT/LT RACKS)	2200	2020
REFRIGERATION – CONDENSING UNITS	2200	2020
REFRIGERATION – LT STAND-ALONE	1500	2020
REFRIGERATION – MT STAND-ALONE	1400	2020
MOBILE REFRIGERATION	2200	2025
CHILLERS	750	2025

California HFC Rules

California is driving aggressive regulation at a state level by adopting vacated EPA Rules 20 and 21 and delisting high-GWP refrigerants with a bill approved in August 2018 (Table 2). Several other states in the US Climate Alliance (24 states representing 50% of the US population and 57% of the country’s GDP) have either already adopted (Washington and Vermont) or are expected to adopt similar legislation very soon (New York, Maryland, Connecticut).

Table 2 California Delisted Refrigerants

DELISTED REFRIGERANT	APPLICATION	EFFECTIVE DATE
R404A* UNACCEPTABLE	Supermarket Systems	January 1, 2019
	Remote Condensing Units	January 1, 2019
	Stand-alone Retail Units Low Temp	January 1, 2020
	Refrigerated Food Processing and Dispensing Equipment	January 1, 2021
BOTH R404A* AND R134a UNACCEPTABLE	Stand-alone Retail Units Medium Temp <2200 BTU/h**	January 1, 2019
	Stand-alone Retail Units Medium Temp ≥2200 BTU/h	January 1, 2020
	Vending Machines	January 1, 2019

CALIFORNIA – NEW CARB PROPOSAL

California aims to cut the state’s HFC emissions (now at about 20 million metric tons of CO2e), by 50% as of 2030. To accomplish that, the state is using a multi-pronged approach. Regulations adopted by the California Air Resources Board (CARB) in 2018 incorporate former EPA rules and other programs. CARB is now proposing stricter regulations, including a 150-GWP cap for refrigeration systems with more than 50 lb of refrigerant; a 1500-GWP cap for those below 50 lb of refrigerant; and a ban on sales of virgin refrigerants with a GWP above a threshold of 1,500 by January 1, 2022, and a 750-GWP cap for stationary air conditioners by Jan 1, 2023.

EU F-Gas Regulation

The European Union was the pioneer in F-gas phase-down with the introduction of regulations (517/2014) limiting the use of refrigerants with high GWP values. Current EU deadlines for refrigerant use in new equipment include:

From January 1, 2020

- Hermetically sealed systems that contain HFCs with GWP of 2500 or more (e.g. R404A, R507A) will be banned in refrigerators and freezers used for storage, display or distribution of products in retail and food service **(commercial use)**.

- Stationary refrigeration equipment that contains, or that relies upon for its functioning, HFCs with GWP of 2500 or more (except equipment intended for application design to cool products to temperatures below -50°C) will be banned.

From January 1, 2022

- Hermetically sealed systems that contains HFCs with GWP of 150 or more (e.g. R134a R407F, R407C, R410A) will be banned in refrigerators and freezers used for storage, display or distribution of products in retail and food service **(commercial use)**.

Alternative Refrigerants for Commercial Refrigeration

Embraco offers products for the light commercial refrigeration segment that comply with present and future F-gas regulations, focusing mainly on products that meet final target limit (<150 GWP) with natural and with synthetic refrigerants, as well as compressors for transition refrigerants (150<GWP<2500),

that should allow the industry to convert their products portfolio into low-GWP alternatives in the future. For the time being, only hydrocarbons can be considered a future-proof solution in self-contained systems.

The use of larger charge systems, both with hydrocarbons and low-GWP synthetic refrigerants, will

have to wait until current safety standards and codes (under development) have been updated. Every appliance producer has a choice to make: go natural within the present charge limitations or wait for new safety legislation. Table 3 lists the main criteria that should be taken in consideration when making this decision.

Table 3 Alternative Refrigerants for Commercial Refrigeration

	High GWP HFC's	HC's	Low GWP HFC's
SAFETY CLASS	A1 Not Flammable	A3 Highly Flammable	A2L Slightly Flammable
ENVIRONMENTAL IMPACT	Very High	Ultra Low	Low
REFRIGERANT COST	Ref	Lower	Very High
COMPRESSOR THERMAL REGIME	Ref	Lower	Higher
INVESTMENTS FOR SAFETY	Ref	Yes	Yes
SYSTEM EFFICIENCY	Ref	Much Higher	Higher
CHARGE LIMIT (UL471)	No	5,3oz	17,7oz

Hydrocarbons

PROPANE (R290)

Embraco offers a full product line of HC compressors that conform to the final limits set by current F-gas regulations. R290 is already widely used in several commercial applications and most of existing light commercial applications can be converted to use those refrigerants. In the case of larger applications, due to the general charge limit of 5.3 oz., multi-circuit configuration is a feasible option and already applied in some systems. An important step will be modifying safety standards to allow wider use of A3 class refrigerants. Present EPA SNAP listings allow for 5.3 oz (150 g) of R290 or R600a charge for hermetically sealed applications in light commercial refrigeration.

At a global level, the new IEC standard (IEC60335-2-89), published in June 2019 allows up to 500 g (17.7 oz) of propane charge and 1.2 kg (2.64 lb) of A2L class refrigerants for self-contained commercial applications such as ice makers, with specific additional mitigation measures to maintain the same risk level as per the 150 g limit.

In most of the world, this new standard can already be applied (e.g., Brazil) but in the US and Europe it must be firstly adopted by region/country as part of existing safety standards and codes. Though activity is in progress, the conclusions and the timing are still unclear.

OTHER HYDROCARBONS: ISOBUTANE (R600a)

R600a - isobutane - represents a valid alternative solution for small appliances. It offers benefits in terms of efficiency but has significant limitations in terms of cooling capacity. Due to its low specific cooling capacity, it requires bigger compressor displacement compared to other refrigerants and consequently, a larger and heavier compressor frame. Isobutane's properties can also limit the evaporating temperature range.

Embraco's catalog features a full range of products utilizing isobutane for LBP and HBP applications, including small chest freezers, bottle coolers and wine coolers.

Next Generation HFCs

R404A ALTERNATIVES

In the long term, the industry under the AHRI’s AREP (Alternative Refrigerant Evaluation Program) has tested a series of new mixtures with GWP of less than 150. All these candidates are slightly flammable and belong to the A2/A2L classification with temperature glide

up to 22R. Tables 4 and 5 list some long-term alternatives to R404A that Embraco is testing for the light commercial segment. It is important for the refrigeration industry to avoid refrigerant proliferation. Hopefully market forces will help speed the adoption of a global standard.

One important step toward allowing wider use of A2L class refrigerants is the safety standards updates (the same applies to A3 safety class mentioned before).

Table 4 Alternative Blends Physical Data

	R 404A	R455A	R454C
TYPE	HFC blend	HFC blend	HFC blend
SAFETY CLASS	A1	A2L	A2L
BOILING TEMP @ 1atm	-53°F	-51°F	-49°F
CRITICAL TEMP	162°F	181°F	180°F
BUBBLE-DEW @14.5 PSIA	1.4R	22.3R	14.7R

Table 5 Embraco Evaluation Summary

	R 404A	R455A	R454C
GWP	3920	148	148
CAPACITY	Ref	Same	Lower
EFFICIENCY	Ref	Better	Better
RELIABILITY	Ref	NA	NA
LUBRICANT	POE	POE	POE
MOTOR TEMP	Ref	Higher	Higher
DISCHARGE TEMP	Ref	Higher	Higher

(* due to safety requirements for electrical components, UD under development, NA not available

Next Generation HFCs

R134a ALTERNATIVES

R1234yf is a valid alternative for commercial systems because of its low specific cooling capacity. Its use would require a completely new product line that, at this stage, does not seem to be a solution for this market segment.

R1234ze is not considered a valid alternative to R134a for light commercial systems because of its low specific cooling capacity. Its use would require a completely new product line that, at this stage, does not seem to be a solution for this market segment.

Table 6 Alternative Blends Physical Data

	R 134a	R1234yf	R1234ze (E)
TYPE	HFC	HFC	HFC
SAFETY CLASS	A1	A2L	A2L
BOILING TEMP @ 1atm	-15°F	-22°F	-2.2°F
CRITICAL TEMP	214°F	203°F	230°F
BUBBLE-DEW @14.5 PSIA	OR	OR	OR

Table 7 Embraco Evaluation Summary

	R 134a	R1234yf	R1234ze (E)
GWP	1430	Below 1	Below 1
CAPACITY	Ref	Slightly lower	Much Lower
EFFICIENCY	Ref	Lower	Lower
RELIABILITY	Ref	Same	NA
LUBRICANT	POE	POE	NA
MOTOR TEMP	Ref	Same	NA
DISCHARGE TEMP	Ref	Same	NA

(*) due to safety requirements for electrical components, UD under development, NA not available

HFC Transitional Solutions

R404A REPLACEMENT

To ease the transition to refrigerants that comply with target final GWP limits, the chemical industry offers several alternatives to existing high-GWP HFC refrigerant blends. The most notable intermediate refrigerant candidates are HFC blends like **R448A, R449A and R452A.**

They are all in safety class A1 (non-toxic, non-flammable) and are all characterized by considerably higher temperature glide than R404A. Tables 8 and 9 outline Embraco’s evaluation of the main physical proprieties of these blends.

Table 8 Alternative Blends Physical Data

	R 404A	R448A	R449A	R452A
TYPE	HFC blend	HFC blend	HFC blend	HFC blend
SAFETY CLASS	A1	A1	A1	A1
BOILING TEMP @ 1atm	-53°F	-49°F	-51°F	-53°F
CRITICAL TEMP	162°F	183°F	180 °F	167°F
BUBBLE-DEW @14.5 PSIA	1.4R	11.3R	11R	6.8R

Table 9 Embraco Evaluation Summary

	R 404A	R448A	R449A	R452A
GWP	3920	1386	1397	2140
CAPACITY	Ref	Better	Better	Same
EFFICIENCY	Ref	Better	Better	Same
RELIABILITY	Ref	Lower	Lower	Same
LUBRICANT	POE	POE	POE	POE
MOTOR TEMP	Ref	Higher	Higher	Same
DISCHARGE TEMP	Ref	Higher	Higher	Same

HFC Transitional Solutions

Both R448A and R449A were approved as an alternative refrigerant to R404A for the NE/NT/NJ compressor series (ECN R449A 2018 and ECN R448A 2019), but with a more restricted operating envelope than R404A due to the higher internal thermal level of the compressor. The restricted envelope for R448A/R449A is presented in Figure 1.

If an application is using an Embraco R404A compressor outside of this above mentioned restricted envelope, please contact Technical Support for further instructions on how to adjust the thermal level of the compressor **eg.by reducing return gas temperature.**

R452A presented the same or lower thermal profile when compared with R404A. R452A can be considered as an alternative for the Embraco R404A product line (ECN R452A 2016) with same operating envelope of R404A, but because of EPA SNAP listings, its use in the US is limited to remote systems and refrigerated transport.

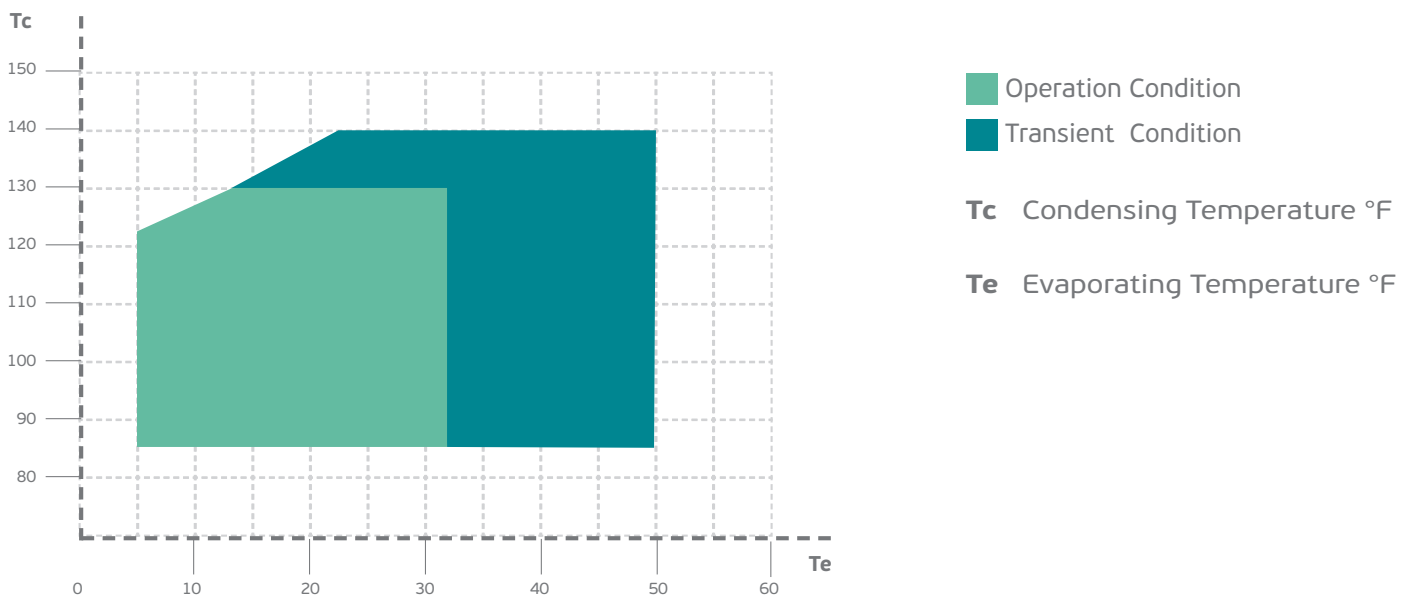


Fig.1 Restricted R448A/R449A Envelope (max. return 68°F)

In addition, customers always have the option of converting systems from R404A to R134a during the transition period just

by changing compressor models and relative system design adjustment.

HFC Transitional Solutions

R134a REPLACEMENT

Both proposed alternative blends mentioned below (R450A and R513A) can be considered at this stage as an acceptable lower GWP replacement refrigerant for R134a systems (see ECN R513A R450A 2017 and ECN CR/2966/en-18/10).

Table 10 Alternative Blends Physical Data

	R134a	R450A	R513A
TYPE	HFC	HFC blend	HFC blend
SAFETY CLASS	A1	A1	A1
BOILING TEMP @ 1atm	-15°F	-11°F	-20°F
CRITICAL TEMP	214°F	223°F	208°F
BUBBLE-DEW @14.5 PSIA	OR	0,9R	1.4R

Table 11 Embraco Evaluation Summary

	R134a	R450A	R513A
GWP	1430	605	631
CAPACITY	Ref	Lower	Same
EFFICIENCY	Ref	Same	Same
RELIABILITY	Ref	Same	Same
LUBRICANT	POE	POE	POE
MOTOR TEMP	Ref	Same	Same
DISCHARGE TEMP	Ref	Same	Same

Warning

Warning Statement About Use of Flammable Refrigerants (A2L, A3) with Embraco Compressors, approved for A1 Safety Class Refrigerants (R134a, R404A, etc.)

Embraco is currently producing hermetic compressors for use with A3 and A2L refrigerants to replace high-GWP HFCs. However, it is important to note that:

1.

Embraco compressors designed and approved for non-flammable refrigerants (A1 class), **cannot be used** with any type of flammable refrigerants, including both A3 and A2L class refrigerants.

2.

Until new charge limits are adopted in the country/region, present regulations allow the use of up to 5.3 oz (150 g) of A3 safety class flammable refrigerant per refrigeration circuit.

3

Given the above-mentioned charge limitations and considering that all flammable refrigerants require the same design, manufacturing, and maintenance precautions, we strongly recommend the use of an HC solutions wherever technically possible.

4.

Embraco offers a full portfolio of compressor models for R290, the refrigerant considered the best option for both systems with a 5.3 oz (150g) charge limit as well as those where new charge limits are already in force.

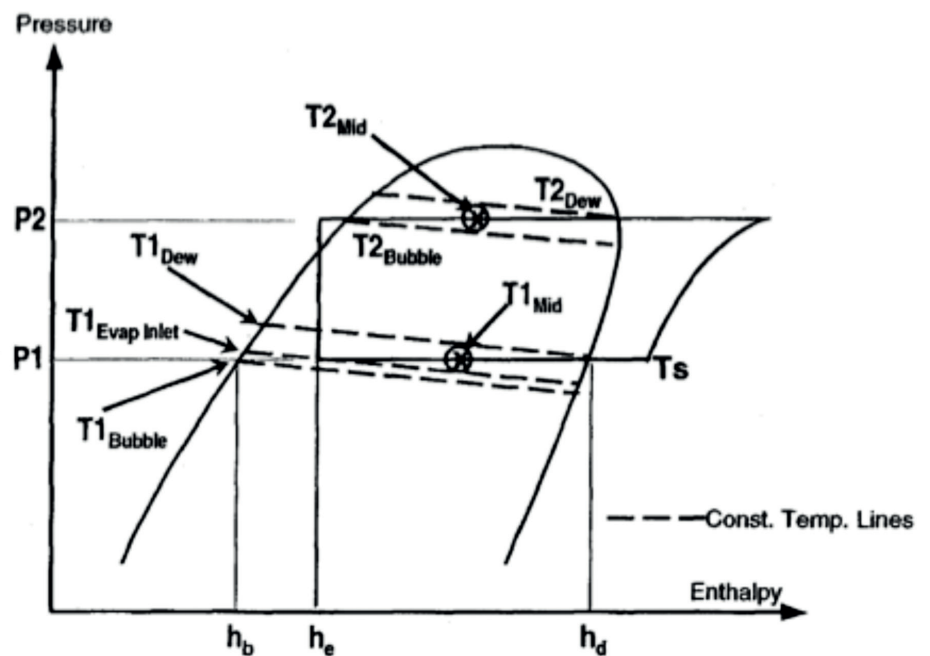
5.

Embraco declines any responsibility for compressors used without approved refrigerants, and warns that potential reliability issues, such as motor overheating and electrical component malfunction, could occur with the use of unauthorized refrigerants.

Performance Evaluation

It is important to consider that refrigerants with significant glide have to be treated differently than in the past. A dew point pressure approach cannot be used to define actual

system operating conditions; a mid-point approach should be used. How to define mid-point temperature is illustrated Figure 2 below.



$$\frac{T1_{evap\ inlet} - T1_{bubble}}{T1_{dew} - T1_{bubble}} = \frac{h_e - h_b}{h_d - h_b}$$

$$T1_{mid\ point} = mean(T1_{evap\ inlet}; T1_{dew})$$

Fig.2 Mid-point Temperature Chart and Formulas

Conclusions

Hydrocarbons (isobutane-R600a and propane-R290) represent the best long-term solution for both low and medium pressure light commercial self-contained applications. Expected safety legislation changes will remove some of the existing roadblocks related to charge limits for flammable refrigerants.

As for the transition period, R448A and R449A mixtures can be used on specific Embraco R404A series with restricted envelope (see ECN R448A 2019 and ECN R449A 2018). R452A can also be considered as an alternative (see ECN R452A 2016) but only for transport and remote applications in the US.

R513A and R450A are approved as alternatives to R134a for use during the transition period in specific Embraco R134a series (see ECN R513A R450A 2017 and ECN CR/2966/en/18/10). R1234yf is also an acceptable alternative for R134a also for the long term, but due to its flammability, can be used only with specifically designed models.

- Embraco Approved Refrigerant
- Please contact Technical Support
- Not Approved

* different displacement
 **only remote and transport
 ***with restricted envelope

CURRENT REFRIGERANT	TEMPORARY SOLUTION	FINAL SOLUTION
R404A/R507	R452A**	R290*
	R407C	R455A
	R448A***	R454C
	R449A***	R744
	R134a*	
R134a	R134a	R1234yf
	R513A	R600a*
	R450A	R290*
		R744

General Trends

Light Commercial Segment from Embraco's Prospective

		LIGHT COMMERCIAL REFRIGERATION			
		WATT	150 - 5000		
		REGION/YEAR	TODAY	2022	2025
HC	AMERICA		REGULAR USE	MAIN REFRIGERANT	MAIN REFRIGERANT
	EUROPE		REGULAR USE	MAIN REFRIGERANT	MAIN REFRIGERANT
	JAPAN		REGULAR USE	REGULAR USE	REGULAR USE
	CHINA		REGULAR USE	MAIN REFRIGERANT	MAIN REFRIGERANT
	REST OF THE WORLD		REGULAR USE	MAIN REFRIGERANT	MAIN REFRIGERANT
HIGH GWP HFC's	AMERICA		MAIN REFRIGERANT	REGULAR USE	NICHE USE
	EUROPE		REGULAR USE	NICHE USE	NICHE USE
	JAPAN		MAIN REFRIGERANT	REGULAR USE	NICHE USE
	CHINA		MAIN REFRIGERANT	REGULAR USE	NICHE USE
	REST OF THE WORLD		MAIN REFRIGERANT	REGULAR USE	NICHE USE
LOW GWP HFC's	AMERICA		NO CLEAR	REGULAR USE	REGULAR USE
	EUROPE		NO CLEAR	NICHE USE	REGULAR USE
	JAPAN		REGULAR USE	REGULAR USE	MAIN REFRIGERANT
	CHINA		NO CLEAR	NICHE USE	REGULAR USE
	REST OF THE WORLD		NO CLEAR	NICHE USE	REGULAR USE
CO ₂	AMERICA		NICHE USE	REGULAR USE	REGULAR USE
	EUROPE		NICHE USE	REGULAR USE	REGULAR USE
	JAPAN		REGULAR USE	REGULAR USE	REGULAR USE
	CHINA		NICHE USE	REGULAR USE	REGULAR USE
	REST OF THE WORLD		NICHE USE	REGULAR USE	REGULAR USE

- MAIN REFRIGERANT
- REGULAR USE
- NICHE USE
- NO CLEAR