



Position Paper

# Light Commercial Refrigeration

Refrigerants Outlook for Europe  
**2021**

## Introduction

With the Kigali Amendment to the Montreal Protocol, the global community made another important step towards preserving our planet for the future generations by reducing CO<sub>2</sub> 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 been made in integrating propane (R290) into light commercial plug-in systems as a natural alternative to R404A, as well as in the use of carbon dioxide in supermarket sector.

EU F-gas regulations impose a ban on high global warming potential (GWP) refrigerants in several categories of commercial applications over the next few years to gradually reduce direct impact due to HFC refrigerants. 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 biggest difficulty was found in trying to replace R404A.

This paper will summarize current testing for R404A and R134a replacements, with a focus on 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 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.

# EU F-Gas Regulation

**The European Union's F-gas regulations (517/2014) limit the use of refrigerants with high GWP values.**

**The EU deadlines for use of refrigerant substances for different refrigeration segments are:**

## **From January 1st, 2020**

- Hermetically sealed systems that contains HFCs with GWP of 2500 or more (e.g. R404A, R507A) are 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 designed to cool products to temperatures below -50°C) are banned.

## **From January 1st, 2022**

- Hermetically sealed systems that contains HFCs with GWP of 150 or more (e.g. R134a R407F, R407C, R410A, R448A, R449A, R452A) will be banned in refrigerators and freezers used for storage, display or distribution of products in retail and food service (**commercial use**).

Questions on the interpretation of this new regulation can be addressed directly thru the European Commission (DG Clima) website or to major industry associations (e.g. ASERCOM, EPEE, AREA), and/or by contacting the national authority in charge of EU F-gas regulations.

## **EXISTING SYSTEMS MAINTENANCE**

**From January 1, 2020** the use of F-gases with GWP of 2500 or more in refrigeration equipment with gas charge size exceeding 40TCO<sub>2</sub>equiv (e.g., more than 10,2 kg of R404A) was banned. This does not include reclaimed or recycled refrigerants, which will be allowed until January 1, 2030.

For systems impacted by these service and maintenance bans there are two options: retrofit with gases with GWP lower than 2500 or replace them with new equipment that uses a lower GWP refrigerant.

**QUOTA SYSTEM**

EU F-gas regulations (517/2014) limit the sale and distribution of high-GWP gases under a quota allocation system (see Figure 1), leading to a declining supply and a significant increase in HFC prices (see Figure 2). The amounts of HFC gases available for all applications are limited based on GWP value (as of 2018, a reduction of 49% from 2015 usage - 87MTCO<sub>2</sub><sup>equiv</sup>) and industry has been forced to switch quickly to low-GWP alternatives.

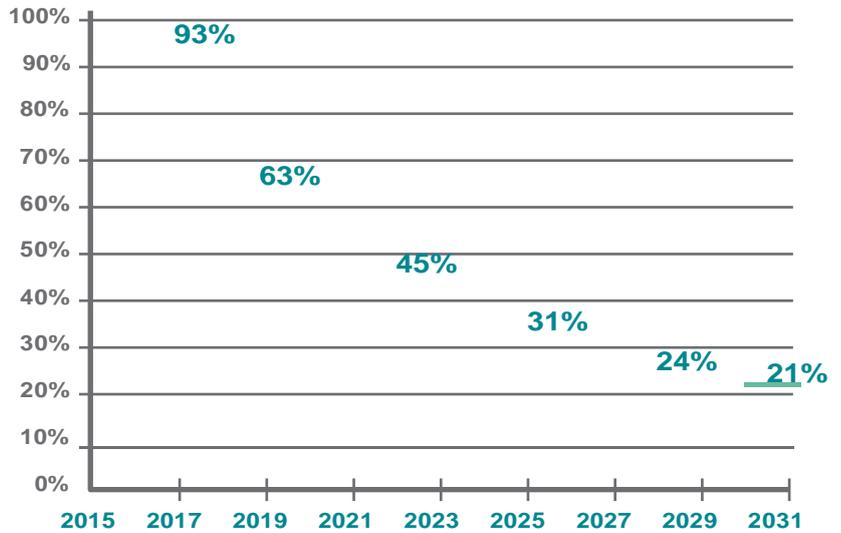


Fig.1 HFC Phase Down Schedule (EU regulation 517/2014)

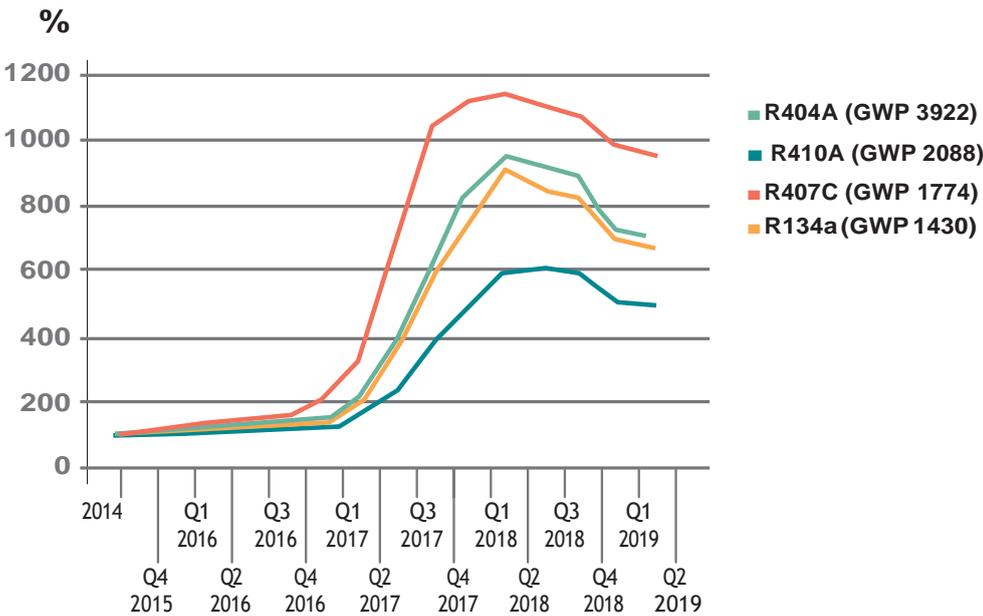


Fig.2 HFC Price Increases in the EU (2014 = 100%)

# Alternative Refrigerants for Commercial Refrigeration

Embraco offers products for the light commercial refrigeration segment that comply with both phases of EU F-gas regulations.

This means products that meet the 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 product portfolio into final low-GWP refrigerants by 2022.

We recommend, if possible, going directly to the final refrigerants. Every appliance producer has to make a choice: go natural or use one of the new synthetic blends presently available. Table 1 lists the main criteria that should be taken in consideration when making this decision:

Table 1 Alternative Refrigerant Options

|                                                                      | High GWP HFCs       | HCs                    | Low GWP HFCs              |
|----------------------------------------------------------------------|---------------------|------------------------|---------------------------|
| SAFETY CLASS                                                         | A1<br>Not Flammable | A3<br>Highly Flammable | A2L<br>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 FOR SELF-CONTAINED HERMETICALLY SEALED SYSTEMS (IEC/EN) | No                  | IEC 13*LFL<br>EN 150g  | IEC 1,2kg<br>EN 150 g     |

# Hydrocarbons

## PROPANE (R290)

Embraco offers full product line of HC compressors as a final solution to meet EU F-gases regulation (up to 38 cc). Propane (R290) is already widely used on several commercial and air conditioning applications. Most of the existing light commercial application can be adapted for use of HC refrigerants.

In 2019 IEC standard used for hermetically sealed applications (IEC60335-2-89) was updated, raising the charge limit to approximately 500 g for propane or 1,2 kg for A2L safety class flammablerefrigerants.

This makes the transition to low-GWP refrigerants much easier than under the previous 150 g limit. This new edition of the standard defines a series of specific additional measures needed to allow higher charge levels without increasing risk as set by the previous standard.

The IEC standard is directly applicable in most of the world countries, but in some countries/regions it has to be integrated into local standardization system. In Europe EN version of IEC standard is expected to be published in 2021.

Until when EU authorities will adopt recently approved new IEC global standard charge limit, it remains still at 150 g per circuit. In case of larger applications multi-circuit configuration is a feasible option. For systems not in the scope of EN 60335-2-89, the general standard EN 378-1 applies, with charge limits in function of system configuration, access category and room volume.

## 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 evaporating

temperature range is also limited. The Embraco catalogue features a full range of products for both LBP and HBP applications, including small chest freezers, bottle coolers and wine coolers.

## OTHER HYDROCARBONS: PROPYLENE (R1270)

Propylene has very similar properties to propane. Although slightly less efficient, it has the advantage of a higher specific cooling capacity.

Therefore, propylene use must be limited to very specific situations. Its use can be approved in ad-hoc solutions for specific situations under the supervision of Embraco technical support.

# Next Generation HFCs

## R404A ALTERNATIVES

A series of new mixtures with GWP below than 150 are already available on European market. All these candidates are mildly flammable and belong to the A2L classification with temperature glide up to 12 K. Tables 5 and 6 list some long-term alternatives to R404A that Embraco is testing for the light commercial segment.

**Table 2** Alternative Blends Physical Data

It is important for the refrigeration industry to avoid refrigerant proliferation. An important step toward allowing the wider use of A2L class refrigerants is the revision of safety standards. Adoption of new IEC charge limits in the EU is crucial because with only 150 grams of charge it's almost impossible today to design any type of refrigeration system falling under the scope of the -89 product standard using A2L

class refrigerants. However, Embraco is ready to address any specific customer requests for compressor for use with A2L refrigerants.

Hopefully market forces will help speed up the adoption of a global standard. (the same applies to A3 safety class mentioned before).

|                                | R 404A           | R455A            | R454C            |
|--------------------------------|------------------|------------------|------------------|
| <b>TYPE</b>                    | <b>HFC blend</b> | <b>HFC blend</b> | <b>HFC blend</b> |
| <b>SAFETY CLASS</b>            | <b>A1</b>        | <b>A2L</b>       | <b>A2L</b>       |
| <b>BOILING TEMP @ 1atm</b>     | <b>-47°C</b>     | <b>-52°C</b>     | <b>-46°C</b>     |
| <b>CRITICAL TEMP</b>           | <b>72°C</b>      | <b>83°C</b>      | <b>82°C</b>      |
| <b>BUBBLE-DEW @1 bar (ABS)</b> | <b>0,8K</b>      | <b>12,4K</b>     | <b>8,2K</b>      |

**Table 3** Embraco Evaluation Summary

|                          | R 404A       | R455A         | R454C         |
|--------------------------|--------------|---------------|---------------|
| <b>GWP</b>               | <b>3920</b>  | <b>148</b>    | <b>148</b>    |
| <b>APPLICATION FIELD</b> | <b>L/MBP</b> | <b>L/MBP</b>  | <b>L/MBP</b>  |
| <b>CAPACITY</b>          | <b>Ref</b>   | <b>Same</b>   | <b>Lower</b>  |
| <b>EFFICIENCY</b>        | <b>Ref</b>   | <b>Better</b> | <b>Better</b> |
| <b>RELIABILITY</b>       | <b>Ref</b>   | <b>NA</b>     | <b>NA</b>     |
| <b>LUBRICANT</b>         | <b>POE</b>   | <b>POE</b>    | <b>POE</b>    |
| <b>MOTOR TEMP</b>        | <b>Ref</b>   | <b>Higher</b> | <b>Higher</b> |
| <b>DISCHARGE TEMP</b>    | <b>Ref</b>   | <b>Higher</b> | <b>Higher</b> |

NA - not available

# Next Generation HFCs

## R134a ALTERNATIVES

R1234yf is a valid alternative to replace R134a, Embraco offers some compressor models for this refrigerant in its catalogue, but nowadays its use is limited to very specific applications. R1234ze is not considered as 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 not be a solution for this market segment.

**Table 4** Alternative Blends Physical Data

|                                | R 134a | R1234yf | R1234ze (E) |
|--------------------------------|--------|---------|-------------|
| <b>TYPE</b>                    | HFC    | HFC     | HFC         |
| <b>SAFETY CLASS</b>            | A1     | A2L     | A2L         |
| <b>BOILING TEMP @ 1atm</b>     | -26°C  | -30°C   | -19°C       |
| <b>CRITICAL TEMP</b>           | 101°C  | 95°C    | 110°C       |
| <b>BUBBLE-DEW @1 bar (ABS)</b> | 0K     | 0K      | 0K          |

**Table 5** Embraco Evaluation Summary

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

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 refrigerants. The most notable intermediate refrigerant candidates are HFC blends like **R407F, R407A, R448A, R449A** and **R452A**.

They are all in safety class A1 (non-toxic, non-flammable) and are characterized by considerably higher temperature glide than R404A. Tables 6 and 7 outline Embraco's evaluation of the main physical proprieties of these blends.

*Table 6 Alternative Blends Physical Data*

|                                 | R 404A    | R407F     | R407A     | R448A     | R449A     | R452A     |
|---------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
| <b>TYPE</b>                     | HFC blend |
| <b>SAFETY CLASS</b>             | A1        | A1        | A1        | A1        | A1        | A1        |
| <b>BOILING TEMP @ 1atm</b>      | -47°C     | -46°C     | -45°C     | -45°C     | -46°C     | -47°C     |
| <b>CRITICAL TEMP</b>            | 72°C      | 83°C      | 82°C      | 84°C      | 82 °C     | 75°C      |
| <b>BUBBLE-DEW @ 1 bar (ABS)</b> | 0,8K      | 6,4K      | 6,4K      | 6,3K      | 6,1K      | 3,8K      |

*Table 7 Embraco Evaluation Summary*

|                       | R 404A      | R407F       | R407A       | R448A       | R449A       | R452A       |
|-----------------------|-------------|-------------|-------------|-------------|-------------|-------------|
| <b>GWP</b>            | <b>3920</b> | <b>1820</b> | <b>2100</b> | <b>1386</b> | <b>1397</b> | <b>2140</b> |
| <b>CAPACITY</b>       | Ref         | Same        | Same        | Better      | Better      | Same        |
| <b>EFFICIENCY</b>     | Ref         | Lower       | Lower       | Better      | Better      | Same        |
| <b>RELIABILITY</b>    | Ref         | Much Lower  | Much Lower  | Lower       | Lower       | Same        |
| <b>LUBRICANT</b>      | POE         | POE         | POE         | POE         | POE         | POE         |
| <b>MOTOR TEMP</b>     | Ref         | Much Higher | Much Higher | Higher      | Higher      | Same        |
| <b>DISCHARGE TEMP</b> | Ref         | Much Higher | Much Higher | Higher      | Higher      | Same        |

# HFC Transitional Solutions

Compressor temperatures tend to increase significantly with R407F and R407A. A slightly lower temperature increase was observed when testing R448A and R449A. Increased temperatures can lead to motors overheating and/or overload protectors being tripped. This leads to a reduction in reliability and life expectancy (see conclusion notes for their eventual use).

R452A presents the same or lower thermal profile than R404A. R452A can be considered as an alternative for Embraco's R404A product line (ECN R452A 2016) with the same operating envelope of R404A in LBP and MBP applications. Both R448A and R449A were approved as an alternative refrigerants to R404A for NE/NT/NJ compressor series (ECN R449A 2018, and ECN R448A 2019 and ECN R448A/R449A LBP 2020), but only with a more

restricted operating envelope than R404A due to the higher internal compressor thermal level. The restricted envelope for MBP R448A/ R449A is presented in Figure 3 and LBP R448A/R449A in Figure 4. If an application is using an Embraco R404A compressor outside of this 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.

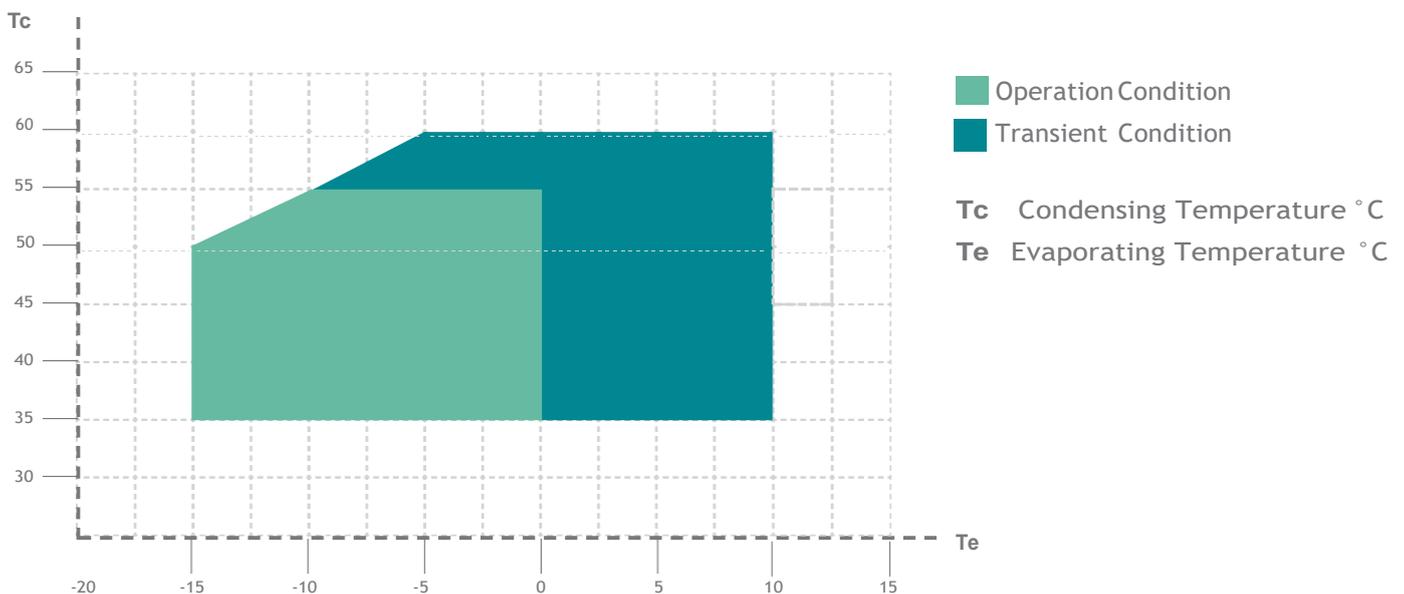
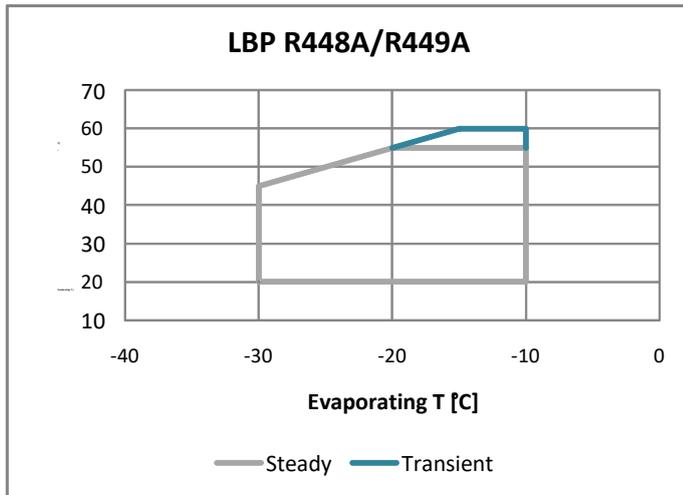


Fig.3 Restricted R448A/R449A MBP Envelope (max. return 20 °C)



**Fig.4** Restricted R448A/R449A  
LBP Envelope (max. superheat  
10K)

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

The only reason to use the below mentioned R134a alternative blends during the transition period is because of their lower GWP allowing greater quantities under quota limitations.

Both R513A and R450A are approved for NB/NE/NT/NJ series (ECN R513A R450A 2017 and ECN CR/2966/en/18/10) as alternative refrigerant for Embraco R134a models.

*Table 8 Alternative Blends Physical Data*

|                                 | R134a | R450A     | R513A     |
|---------------------------------|-------|-----------|-----------|
| <b>TYPE</b>                     | HFC   | HFC blend | HFC blend |
| <b>SAFETY CLASS</b>             | A1    | A1        | A1        |
| <b>BOILING TEMP @ 1atm</b>      | -26°C | -24°C     | -29°C     |
| <b>CRITICAL TEMP</b>            | 101°C | 106°C     | 98°C      |
| <b>BUBBLE-DEW @ 1 bar (ABS)</b> | 0K    | 0,8K      | 0,8K      |

*Table 9 Embraco Evaluation Summary*

|                       | R134a | R450A | R513A |
|-----------------------|-------|-------|-------|
| <b>GWP</b>            | 1430  | 605   | 631   |
| <b>CAPACITY</b>       | Ref   | Lower | Same  |
| <b>EFFICIENCY</b>     | Ref   | Same  | Same  |
| <b>RELIABILITY</b>    | Ref   | Same  | Same  |
| <b>LUBRICANT</b>      | POE   | POE   | POE   |
| <b>MOTOR TEMP</b>     | Ref   | Same  | Same  |
| <b>DISCHARGE TEMP</b> | Ref   | Same  | Same  |

## **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 for more accurate estimation of the performance in the application. Guidelines on how to define mid-point temperature are stated in standard EN 13215:2016+A1:2020 in Annex B, where linear and thermodynamic interpolations are described.

## 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.

All Embraco products mentioned in the Declaration of Conformity are compliant with all relevant EU directives.

#### 3.

For refrigeration systems falling under the scope of the harmonized standard EN 60335-2-89, EU regulations allow the use of flammable refrigerants up to 150 g refrigerant charge for each single refrigeration circuit until the new IEC limit is adopted.

#### 4.

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 HC solutions wherever technically possible.

#### 5.

Embraco offers a full portfolio of compressor models for R290, the refrigerant considered the best option for both systems with a 150 g charge limit as well as those with the new IEC charge limit once the harmonized EU standards are approved.

#### 6.

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

## Conclusions

Hydrocarbons (isobutane-R600a and propane-R290) represent the best long-term solution for both low and medium pressure light commercial self-contained applications. Future EU legislation changes are expected to remove some of the existing roadblocks related to charge limits. As for the transition period between now and 2022, R452A can also be considered as an alternative refrigerant (see ECN R452A 2016) for both LBP and MBP but also R448A, and R449A mixtures can be used with specific Embraco R404A series within a restricted operating envelope (see ECN R448A 2019 and ECN R449A 2018 and ECN R448A/R449A LBP 2020). Using the blends mentioned above outside of Embraco approved system conditions, or using other transition blends like R407F or R407A as an alternative refrigerant for systems using

Embraco R404A compressors may require system changes such as a reduction in condensing temperature (larger condenser, improved ventilation) or return gas temperature in order to achieve a similar thermal profile to R404A. To maintain an Embraco warranty, the final application needs to be validated by the Embraco TechnicalSupportTeam on a case-by-case basis. In particular, using these blends in systems operating under high compression ratio conditions should be avoided. R513A and R450A are approved as alternative 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 for the long term, though its flammability must be taken into consideration.

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

\* different displacement  
 \*\*NE/NT/NJ restrict envelope  
 \*\*\*only NE/NT/NJ products

| CURRENT REFRIGERANT | TEMPORARY SOLUTION |          | FINAL SOLUTION |         |
|---------------------|--------------------|----------|----------------|---------|
|                     | LBP                | MBP      | LBP            | MBP     |
| R404A /R507         | R452A              | R452A    | R290*          | R290*   |
|                     | R134a*             | R134a*   | R455A          | R455A   |
|                     | R407C              | R407C    | R454C          | R454C   |
|                     | R448A**            | R448A**  | R1270          | R1270   |
|                     | R449A**            | R449A**  | R744           | R744    |
|                     | R407A              | R407A    |                |         |
|                     | R407F              | R407F    |                |         |
| R134a               | R134a              | R134a    | R1234yf        | R1234yf |
|                     | R513A***           | R513A*** | R600a*         | R600a*  |
|                     | R450A***           | R450A*** | R290*          | R290*   |

# General Trends

## Light Commercial Segment from Embraco's Prospective

|                 |                   | LIGHT COMMERCIAL REFRIGERATION |            |      |      |
|-----------------|-------------------|--------------------------------|------------|------|------|
|                 |                   | WATT                           | 150 - 5000 |      |      |
|                 |                   | REGION/YEAR                    | TODAY      | 2022 | 2025 |
| HC              | AMERICA           |                                |            |      |      |
|                 | EUROPE            |                                |            |      |      |
|                 | JAPAN             |                                |            |      |      |
|                 | CHINA             |                                |            |      |      |
|                 | REST OF THE WORLD |                                |            |      |      |
| HIGH GWP HFC's  | AMERICA           |                                |            |      |      |
|                 | EUROPE            |                                |            |      |      |
|                 | JAPAN             |                                |            |      |      |
|                 | CHINA             |                                |            |      |      |
|                 | REST OF THE WORLD |                                |            |      |      |
| LOW GWP HFC's   | AMERICA           |                                |            |      |      |
|                 | EUROPE            |                                |            |      |      |
|                 | JAPAN             |                                |            |      |      |
|                 | CHINA             |                                |            |      |      |
|                 | REST OF THE WORLD |                                |            |      |      |
| CO <sub>2</sub> | AMERICA           |                                |            |      |      |
|                 | EUROPE            |                                |            |      |      |
|                 | JAPAN             |                                |            |      |      |
|                 | CHINA             |                                |            |      |      |
|                 | REST OF THE WORLD |                                |            |      |      |

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