Refrigerant Column

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Comparison between Propane and Isobutane as Refrigerants

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Background

Among the hydrocarbons used as refrigerants, **isobutane** is by far the most common in terms of number of units. Since the ban of R12, it has been the dominant refrigerant in household refrigerators in Europe.

Now, as the heat pump market shifts toward natural refrigerants, the focus has so far been almost exclusively on **propane**.

The **EcoPack project**, carried out at KTH under the leadership of Viktor Ölén (SKVP) and with the participation of Klas Andersson (long-time consultant for Electrolux), Jan-Erik Nowacki, and the undersigned, set out to explore whether isobutane could also be suitable for use in heat pumps.

Project Concept and Rationale

The original idea, proposed by Professor Eric Granryd, was to use a smaller isobutane heat pump to improve the performance of a larger heat pump. By utilizing the **subcooling heat** from the larger unit as the heat source for the smaller one, both the **capacity** and the **coefficient of performance (COP)** could be higher than with the larger heat pump alone.

Since the smaller heat pump would operate at higher than typical temperatures, **isobutane** was chosen over propane, due to its **lower pressures at a given temperature**, making it particularly well suited for high-temperature heat pumps.

Within the project, we demonstrated that a heat pump with up to **12 kW capacity** can be built with as little as **120 g of isobutane charge**.

Safety and Flammability

Both isobutane and propane are highly flammable. However, their **lower flammability limits (LFL)** differ slightly:

- Propane: 38 g/m³

- Isobutane: 43 g/m³

This matters for how much refrigerant can be allowed indoors without special safety measures. According to **IEC 60335-2-40** (and EN378), the charge limit is **4 × LFL**:

- 152 g for propane
- 172 g for isobutane

While the difference is small, it may be decisive for the design of low-charge systems. For charges above 4 × LFL, the allowed quantity depends on **room size**, as well as whether the system is extra tight or if a **fan** ensures mixing of room air (Figure 1).

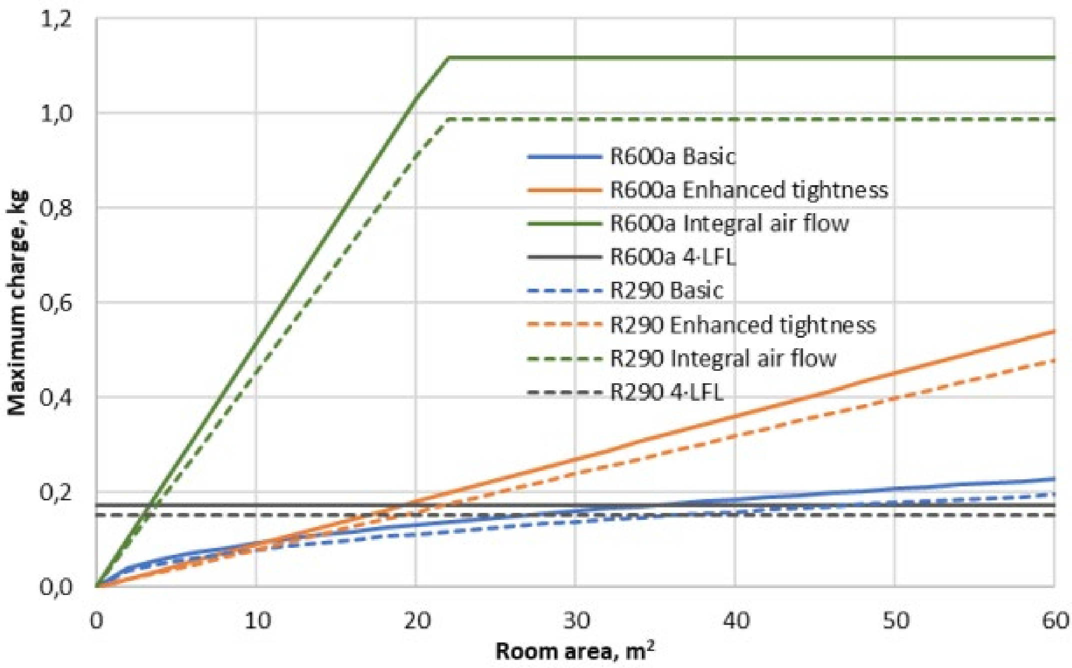

Figure 1. Maximum allowable refrigerant charge as a function of room size (ceiling height 2.4 m) for isobutane and propane. See [1] for assumptions.

Leakage Behavior

Isobutane has a **lower vapor pressure** than propane. In the event of a leak through a small hole, the **mass flow rate** of the escaping refrigerant will therefore be **much higher with propane** than with isobutane (Figure 2).

As a result, the concentration of propane at floor level (where heavier-than-air refrigerants accumulate) becomes significantly higher unless mixing fans are used. Recent **KTH simulations** confirm that isobutane is **safer in this respect** [2].

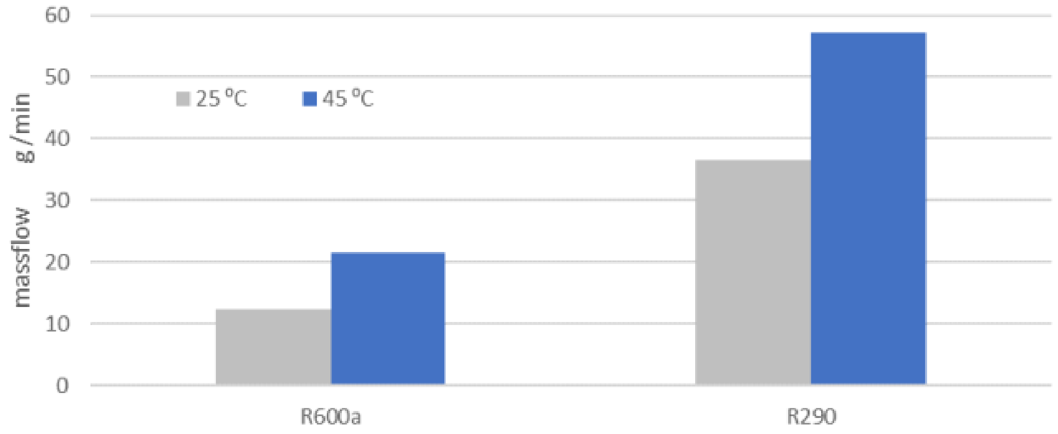

Figure 2. Outflow of isobutane and propane through a 0.5 mm² hole at two temperatures. Calculated according to EN60079-10-1:2015 [1].

Refrigerant Charge and System Design

An analysis was also carried out to estimate which refrigerant requires a greater charge. While lower pressure (isobutane) results in lower gas density, which in turn demands larger pipe dimensions, a **system-wide component analysis** showed that isobutane requires **slightly less charge** than propane for the same capacity.

Conversely, a given refrigerant mass can provide a **higher heating effect** if isobutane is used with appropriately selected components. In addition, as noted earlier, the **maximum allowable charge indoors** is higher for isobutane than for propane.

Compressor Technology

Isobutane's lower pressure also results in **lower leakage** through seals and joints, opening the possibility of using **semi-hermetic compressors**. This paves the way for applying compressors already used in **electric vehicles** for stationary cooling and heating applications.

Some manufacturers are developing such compressors for hydrocarbon use. Their advantages include:

- **Small internal volume** → low refrigerant charge
- **Very little oil** → less refrigerant absorbed in oil
- **Wide speed range** → capacity can be adjusted year-round to demand

The remaining challenge is to ensure **service life** comparable to conventional hermetic compressors.

Conclusions

The findings indicate that isobutane has several advantages as a refrigerant not only for **refrigerators** but also for **heat pumps**:

- Higher allowable charge indoors
- Lower leakage risks due to lower pressure
- Potential for smaller, more flexible compressor solutions
- Comparable or even reduced charge requirement compared to propane

Isobutane therefore represents a **viable and promising alternative** to propane in heat pump applications.

References

[1] Ölén, V., Palm, B., Andersson, K., Nowacki, J-E., 2024. *Low-charge isobutane heat pump for medium and high-temperature applications*. Proc. 16th IIR Gustav Lorentzen Conference on Natural Refrigerants, College Park, Maryland, USA, 2024. DOI: 10.18462/iir.gl2024.1251

[2] Esmaeelian, J., Khodabandeh, R., Palm, B., Ignatowicz, M., 2024. *Impact of hydrocarbon refrigerants type on leakage rate and resulting flammability risk*. Proc. IIR Compressors, Slovakia, 9–11 Sept. 2024. DOI: 10.18462/iir.compr.2024.0694
