

COLD CHAIN TECHNOLOGY BRIEF

- REFRIGERATION IN FOOD
PRODUCTION AND PROCESSING

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For most of us, the food cold chain is associated to visible tip of the iceberg

- Controlled temperature transport
- Retail and refrigerated display cabinets
- Household refrigerators.

But refrigeration in food production and processing is also

- Industrial cooling and freezing of raw materials and processed food
- Specific processes (crystallization of fat, cryoconcentration, cryoseparation, freeze drying, ...)
- Storage in large refrigerated warehouses.



A typical industrial machinery room with liquid / vapor separation receiver (on the left) and screw compressors (on the right)

An industrial ammonia freezer



Compared to other sectors, Industrial refrigeration presents some specificities :

- A quite low leakage rate (5-12% per year)
- A quite high refrigeration capacity per unit
15-20 kW_{ref} could be considered as a « small unit », 200-500 kW_{ref} is a « standard » and 1 – 5 MW_{ref} (possibly more) could be considered as « big » facilities
- A quite high energy bill
(800 MWh – 4 GWh / year is common, it is 60 k€ - 350 k€ / year)

=> The energetic performance (architecture of the refrigeration loop and choice of the primary refrigerant) has to be a major concern.

- The organization (architecture) of the refrigeration equipment used in this sectors depends on :
 - The required temperature (cooling, freezing)
 - The nature of the processed product
(fruit & vegetables, meat products, eggs and dairy products, raw materials and processed foods)
 - The size of the industrial site (some kg h⁻¹ up to some tons h⁻¹)

=> *A wide variety of configurations making generalization difficult*



For « small facilities »

At present :

Classical DX systems (possibly with compound compressors for low temperatures) with piston / reciprocating compressors are often used. with R134a (for high temperatures) or R404A (for low temperatures)

No more ozone concerns with these HFCs, but a real global warming concern, especially with R404A (GWP = 3 920 kg eq. CO₂)



R134a condensing unit for the process of a vegetable work area (cycle -3 / +32 °C)



R404A compound compression unit of a blast freezer for meat products (cycle -36 / +32 °C)



For « small facilities »

Potential alternative :

Use of low GWP refrigerants / blends of HFCs or HFCs/HFOs, and possibly CO₂ or HC (only for low refrigerant charges, less than 1.5 kg in France)

The glide of these blends has to be taken into account for drop-in, retrofit and/or conception of the installation. It could be bearable for DX systems.

A specific care has to be taken on the global impact on climate change :

- Using a low GWP refrigerant
- Presenting a low energy efficiency
- With an energy presenting an high carbon impact
- Should result in negative Total Equivalent Warming Impact (and OPEX)

$$\text{TEWI} = \text{GWP} (\approx 15\%) + \text{Indirect effect} (\approx 85\%)$$

Nevertheless, first approaches indicate that the use of R404A is one of the worst choice regarding TEWI.



For « large facilities »

At present :

Flooded systems with liquid / vapor separation receivers are often used (with piston / reciprocating or screw compressors).

Present refrigerants :

R134a or R717 for high temperature (above -10 / -15°C)

R507, R404A or R717 for low temperature (below -25 / -30 °C)

Despite its specificities (toxicity and low flammability), R717 is common in large facilities (excellent energetic performances)



R404A screw compressor and separation receiver for a large -25°C warehouse (cycle -35 / +32 °C)



Ice water production (-7 / -2°C) with plate heat exchangers fed by thermosiphon on a R717 separation receiver (cycle -15 / +32 °C)



For « large facilities »

Potential alternative :

For ammonia, no problem : keep it !

For installation working with HFCs:

- the management of the glide in the separation receivers is a real problem (sometimes insuperable)
- the price of alternative refrigerants is prohibitive as well ...

Changing the installation for a new one is often the best choice (but not the cheapest).

R717, or cascade CO₂ / R717 or CO₂ / low GWP blend

Even if it is an interesting alternative candidate, a full CO₂ transcritical cycle appears to be the least interesting regarding the TEWI (except if heat recovery is valued somewhere else in the process).



Challenges :

1- develop high energetic performance architectures

Industrial refrigeration in food production and processing is energy intensive

⇒ Energy consumption has to be one of the major concern for this sector

⇒ Work on smart cycles (desurperheaters, variable pressures, IHX, cascades, valorization of expansion work, heat recovery, ...)

2- learn to manage the glide of low GWP blends, especially for “small” facilities

3- trust on the sustainability of natural refrigerants, and especially of ammonia for “large” facilities.

3- keep open mind, and observe the re-engineering of “old” solution which shown their advantages and limits (absorption – adsorption), or the development of new technologies (magnetic cooling, electric field cooling, thermoelastic cooling, ...), but according to the present development of these technologies, their implementation in food production and processing is not for tomorrow ...



Conclusion :

Thanks to their performance, compactness and reliability, compression–expansion systems with phase-change refrigerants have been used for more than a century, and they will probably continue to be used for a long time.

For “small” industrial units, alternative refrigerant could be low GWP blend of HFCs or HFCs-HFOs, and possibly HC for very low refrigerant charge (less than 1.5 kg, that remains exceptional for industrial refrigeration).

For HFOs, the concern of their low flammability and of their long term environmental impact has to be serenely studied (and not eluded).

For “large” industrial units, ammonia remains the best choice, despite safety concerns (which can be managed with a certain rigor)

CO₂ appears as an interesting alternative, as far as heat recovery is envisaged and valued somewhere else in the process (otherwise, it is difficult to justify).



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Thanks for your Attention!!

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