Low-GWP Alternatives in Commercial Refrigeration:
Propane, CO₂ and HFO Case Studies
CASE STUDY

Verdemar Commercial Refrigeration

Name of the Store/facility:
Supermercado Verdemar – Nova Lima Store

Location:
Belo Horizonte, Brazil

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Type of Facility:
Gourmet supermarket, Store Area = 1,800 m²,
Small chain fine food and wine retailer.

Refrigerant Used:
CO₂ cascade system with HFC (R-134a) refrigerant as the high side fluid. The new installation uses a cascade system composed of a twin primary system using 75 kg of R-134a (GWP=1430), and a secondary system using 100 kg of CO₂

Project Background:
The Supermercado Verdemar – Nova Lima Store was opened in 2010, at Nova Lima, Brazil, 10 kilometers from Belo Horizonte, at an altitude of 1,350 meters above sea level. The building has 1,800 m² of store floor and 500 m² of kitchens and cold chambers. Fig. 1 shows a photo of the external view of the store.

Alexandre Poni, Executive Director of supermarket chain Verdemar highlighted the leading role that company executives must take in driving sustainability to the retail sector, during his presentation in a conference “Sustainability as a competitive advantage” held in São Paulo. Towards that vision, Verdemar adopted a CO₂ cascade system after undertaking studies on energy efficiency, environmental impact, installation cost reduction and maintenance cost optimisation.

After two years of research the final project design and installation took 30 days and 60 days, respectively. The main challenges were importing special high technology parts and components and ensuring that the relevant personnel were properly trained to operate the system. Fig. 2 shows a photo of refrigerated cases inside the store.

New System/Installation:
The approach is to use CO₂ as one of the fluids in a cascade system along with an HFC refrigerant (R-134a) as the high temperature fluid. R-134a, is an HFC haloalkane refrigerant with GWP of 1,430. Such systems may have a much lower HFC refrigerant charge, and the global warming potential is reduced compared to a baseline system using only HFC refrigerant.

TECHNICAL DATA:
• Cascade system built inside a large rack that holds most of the working components.
• The Primary dual circuit system is based on R-134a with a load of 136 kg of gas, industrially mounted and piped inside the cooling unit rack in the main rack, using a small volume of gas. This system has zero history of leaks and approximately one-third the amount of GWP as compared to a system using only R-404A or R-507.
The Secondary system is based on R-744 (CO\textsubscript{2}), developed with special high technology parts and components, working on Direct Expansion (DX) or in liquid fluid subsystems.

The CO\textsubscript{2} subcritical scheme was specially fine-tuned by lowering the condensing temperature of the R-134a primary system to 40° C and raising the evaporation temperature to -8° C, resulting in 71% less energy consumption with a payback period of 19 months. This is achieved by a special patented adiabatic cooling system at the primary condensation circuit allowing a very efficient heat exchange.

The use of Electronic Expansion Valves were mandatory for better control of the large expansion capacity of CO\textsubscript{2} and to prevent return of liquid to the compressor, as well as keeping stable temperatures at refrigerated points, shorter response time to changes, shorter operation of compressors and lower power consumption.

Low cost, low power iQ motors (70% energy savings) at the secondary liquid fluid systems, with special larger area evaporators developed by Arneg. The savings are compared to traditional DX HCFC showcases used in the past. It is important to mention that this solution avoids the need for defrosting, hence additional energy savings is achieved.

High efficiency, progressively activated fans at the condenser, with Electronically Controlled (EC) variable speed DC motors; working on a high-efficiency moist hives adiabatic cooling system, patented by Plotter-Racks Brazilian contractors.

High-efficiency fans with dual speed ESM\textsuperscript{2} DC motors in evaporation grids, especially at the production sectors, with energy savings of 36% and a payback period of 14 months, and better ergonomic comfort work conditions.

Frequency regulated pumps, with energy savings of 19% and a payback period of 21 months.

Frequency regulated Bitzer compressors, with energy savings of 8% compared to conventional compressors without frequency regulation and a payback period of 23 months.

Low condensing pressure (30 bar).

This profile installation was then deployed in the two stores opened in 2010 and 2011 and at the main Warehouse in 2012, and has since been adopted as a standard for the chain.

So far, the company operates on CO\textsubscript{2} in three out of its eight stores. There are also two new stores in 2013, and plans are in place to convert the older stores to CO\textsubscript{2}.

**AMBIENT CONDITIONS:**
- Maximum expected temperature: 38° C
- Wet bulb temperature: 24° C

**REFRIGERATION LINES CAPACITY:**
- Medium temperature (without condensation): 204 kW
- Low temperature: 35 kW

**MEDIUM TEMPERATURE SYSTEM**
- Medium temperature chiller with secondary fluid
- Primary Fluid: R-134a
- Secondary Fluid: Propylene Glycol
- Evaporation temperature: -8° C
- Maximum condensation temperature: + 40° C
- Total unit capacity: 249 kW

**LOW TEMPERATURE SYSTEM**
- Direct Expansion rack for frozen products
- Primary fluid: R-134a
- Secondary fluid: R-744 (CO\textsubscript{2})
- Evaporation temperature: -29° C
- Maximum condensation temperature: -4° C
- Total unit capacity: 36 kW

Figures 3 and 4 show diagrams for the medium and low temperature systems respectively.

The main lesson learned was that, after personnel training and the construction of a good system with a solid design, the new installation became as easy.

\textsuperscript{2}Energy saving motor
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Medium temperature system diagram

Fig. 3 Medium temperature system diagram
Low temperature system diagram

Fig.4 Low temperature system diagram
to maintain and operate as any other conventional refrigeration system.

**Performance:**
The overall achievement of this installation was a result of investment in training, equipment development and component research. The chosen components behaved as expected, allowing the optimal functioning of technologies to obtain the desired efficiency.

The resulting energy efficiency was 30% better, compared with the previous HCFC conventional systems. The main characteristics of the new CO₂ system are the adaptation of several high technology components in the global assembly such as:

- Intelligent two-speed ESM motors evaporation fans in refrigerated chambers and preparation areas, contributing also to a better ergonomic comfort.
- Progressively activated, variable speed EC motors in special aerodynamic designed ventilators in the condensing unit.
- iQ motors in liquid fluid evaporation grids, with very low energy consumption

The company acknowledges that at present while there is better availability of parts and components in the local market, facilitation of import of special parts and components from official authorities can be an important issue for the adoption of these new technologies. The main items required are R-744 compressors, intermediate heat exchangers, electronic valves and controllers. Fig. 5 shows a photo of the refrigeration system.

As R-744 is odourless, and its presence at levels greater than 10% is a serious health and safety issue, the company uses sensors and detectors in closed rooms and double release valves located in exterior locations as additional safety measures.

**Cost and Economic Considerations:**
Comparing the cost of the new system with conventional installations in the older stores, the company estimates a capital cost increase of 20%, taking into consideration the rack assembling, compressors, condensers, chillers, heat exchangers, evaporators, valves, piping, electric materials, command and control panels, hand work, start up and operation tests. However, this is offset by the reduced maintenance, operating and energy costs of the new system.

Comparison with older systems:
The payback of this system is less than 30 months. The maintenance cost was reduced by 40%. Energy savings are 30%.

One important aspect is that the energy reduction will be continuous, lowering costs and contributing to environmental benefits.

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