

Unilever Ice Cream Cabinets: Conversion to Natural Refrigerants

By Unilever Foods

Background: Unilever's Ice Cream Business

Unilever owns the largest ice cream business in the world, familiar to many through brands like Magnum, Cornetto, Ben & Jerry's and Good Humor, among others. A large proportion of our ice cream is sold through small outlets, where the ice cream is stored and displayed at -18°C using an ice cream cabinet. Unilever owns about 2 million of these cabinets worldwide and replaces a significant number of the older/broken cabinets each year.

Ice Cream Cabinets

Ice cream cabinets use small hermetically sealed compressors with swept volumes of around 5 to 13 cc. Cooling capacities are typically between 170 and 520 W (measured under ASHRAE conditions at -23°C). The condenser and evaporators are simple pipes mounted on the outer and inner vertical surfaces of the cabinet. Often a simple tubular pre-condenser (desuperheater) is fitted in the compressor compartment. Hydrofluorocarbons

(HFCs) are the most commonly used refrigerant for ice cream cabinets worldwide. Only small amounts of refrigerant are used, with charges of around 200 g per circuit for HFCs. The cabinet's principal environmental impact is its power usage throughout its life. However, any leak of refrigerant from the refrigeration circuit, may also add to its impact if the refrigerant has an Ozone Depleting Potential (ODP) or Global Warming Potential (GWP).



in small outlets

Leaks may occur from the refrigeration circuit during operation and storage, predominantly from pin (very small) holes in soldered joints. The refrigerant escapes from these holes at a very slow flow rate and the cabinet may continue to

run for many months before a reduced performance is noticed. Higher flow rate leaks may occur during servicing or disposal if incorrect procedures are used. There are also some instances of damage occurring to the circuit during transport to customers.

Some foam blowing agents, used to produce the voids in the insulation foam, may also have significant ODP and GWP. As this gas escapes it will also contribute to the cabinet's environmental impact.

Refrigerants in Unilever's Ice Cream Cabinets

Unilever has actively supported changes to ice cream cabinets for environmental reasons over the last 15 years. Unilever recognised that it could not influence all parts of the cold chain sector, but its relative size in the market and large purchasing requirements for cabinets allow it to accelerate the pace of change when required, providing leadership for the rest of the industry (see Figure 2).

In 1994, Unilever stopped buying cabinets with CFC and HCFC refrigerants (R-11, R-12, R-22, R-141), replacing them with zero ODP HFC refrigerants (R-134, R-404a). At the same time, Unilever also began buying ice cream cabinets with cyclopentane as the blowing gas in the insulation. Cyclopentane has zero ODP and a comparatively low GWP of ~ 11 .

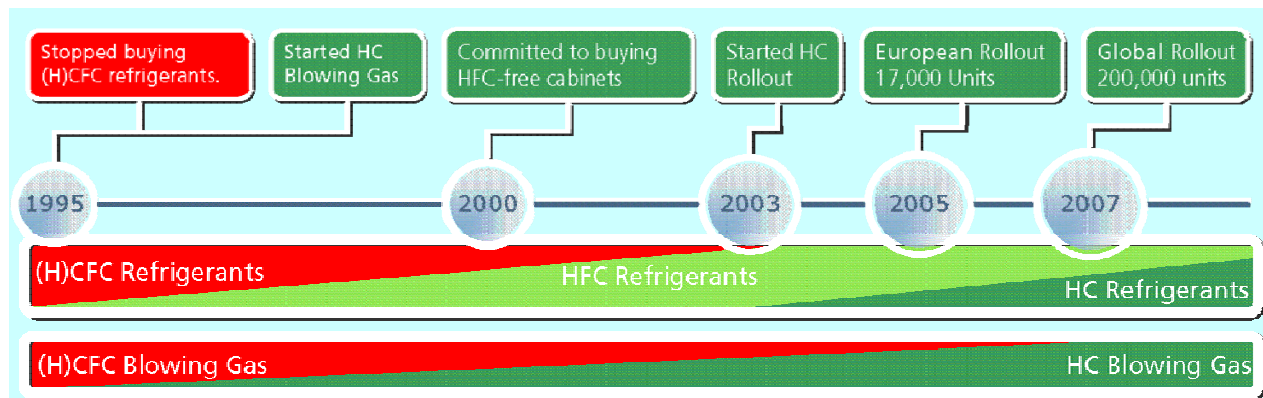


Figure 2 – Schematic overview of refrigerant and blowing gas used in Unilever’s Ice Cream Cabinets

In 2000, Unilever made a commitment to “implement by 2005 a non-HFC purchasing policy for ice cream freezer cabinets in all countries where commercially viable alternatives can be legally used.”

Lesson Learned

Focus on one area with the highest impact and where there is the most leverage to ensure successful implementation.

Alternatives to HFCs as Refrigerants in Ice Cream Cabinets

Prior to 2000, Unilever undertook a full study to ascertain what alternatives to HFCs were currently available or may become available in the near future. The only available HFC replacements at the time were hydrocarbons (HCs), already in use in the domestic refrigeration industry in the form of isobutane (R-600a) but also available as propane (R-290). Propane (R-290), with its higher cooling capacity, was the most appropriate choice of hydrocarbon to meet the high load demands of ice cream cabinets.

Small compressors using carbon dioxide (CO₂) were also becoming available for trial in 2000. Unilever concluded that it was unlikely that CO₂ would be a fully developed alternative at competitive cost in the medium term (5 to 10 years), and that development of new equipment and suppliers would compromise the target for a 2005 implementation of an HFC-free buying policy. This conclusion has proven to be correct for ice cream cabinets. A similar conclusion was reached for Stirling cycle coolers. A more far reaching modification to the cabinet design would have also been required.

Unilever’s American based ice cream company, Ben & Jerry’s, sponsored some research into thermoacoustic cooling at Penn State University, which resulted in a working model publicly demonstrated in a number of venues. But once again, cost and timing were not likely to meet Unilever’s requirements.

In short, by choosing to use propane, both the timing and cost elements of the project could be met with minimum disruption to our suppliers.

Lesson Learned

Reach agreement on the targets to meet (such as cost, time and performance) and be realistic when screening the potential solutions.

Implementation of HFC Alternatives

Following the decision to use propane as the replacement refrigerant for HFCs, a comprehensive programme of testing and approval was started. Unilever had already had some experience with HC refrigerants: in Denmark, as part of a syndicate exploring technologies to increase the efficiency of ice cream freezers; and in India, where some trials had taken place with a view to moving directly from CFCs and HCFCs to HCs without going to HFCs (this trial subsequently stopped due to legislative difficulties in India, not any technical difficulties).

Important components in the testing and approval phase for HC refrigerants were to:

- Establish an implementation team
- Simplify the range of equipment to be switched before implementing the changeover
- Assess safety, liability and legislative barriers
- Initial short term and long term testing in the field
- Maintain close communication with suppliers over future plans
- Prepare training material for service technicians
- Engage stakeholders

Each of these points is described further below.

Implementation Team

Unilever appointed a single person with responsibility for the implementation of the commitment to move all cabinets out of HFC refrigerants. As a global business with many potential stakeholders internally and externally, a single point of contact simplified communications and provided a mechanism to follow the progress of the project. Core team members included experts in refrigeration, public affairs/communication, cabinet buying, safety, and cabinet management (maintenance and disposal). Internal and external stakeholders and industry experts were identified at an early stage.

Equipment Range

Unilever benefited from a relatively small number of equipment models and suppliers and a global buying structure. Unilever was able to focus on just a few models whilst still being able to cover a large proportion of the cabinet fleet and most potential suppliers. This reduced the resource load and sped up implementation. Companies attempting similar changeovers with more complex equipment ranges and supplier relationships would find the implementation much more difficult.

Lesson Learned

Reduce equipment models and suppliers to assist in managing the complexity of the changeover. Identify the key models and suppliers and focus on them to maximise the impact of the change.

Safety and Legislative Barriers

Whilst propane has excellent thermodynamic properties, its flammability means that its use needs to be considered carefully. Safety and legislative issues must be fully understood.

The use of hydrocarbons has been widespread in the European domestic refrigeration market since the mid-1990s. Although domestic refrigerators and freezers are very similar in construction and materials used, commercial freezers have a larger cooling load placed on them and are subjected to more severe usage patterns. Thus, whilst the safety data available from the domestic industry is relevant, it could not be used to assess the risk of using HCs in commercial freezers.

For an accurate assessment of risk, cabinet and component failure data is a key requirement. Failure frequency may be specific to the source of the components, cabinet manufacturer, and the severity of use whilst in the field. Unilever uses cabinets all over the world, so was able to take these potential variations into account. Frequency of refrigerant leaks (% cabinets/year) and the leak rate (mass/time) are particularly important data to be collected. In ice cream cabinets, leaks typically occur from ‘pin-holes’ at soldered joints between pipes. Very infrequently, leaks occur from physical damage of the pipe work through mishandling during transport.

In Unilever’s experience, leak frequencies are low. No data on leak rates were available for pin holes, probably because they are very low (grams per year). Models exist to calculate leak rates from physically damaged pipes.

Unilever commissioned an independent entity to conduct Quantitative Risk Assessments (QRAs). The QRAs studied usage scenarios (e.g., cabinet servicing, cabinet operation in a small shop), based on generic equipment types, using published failure data and consequence models. Calculated risks are specific only to that scenario.

A second assessment was undertaken using a computational fluid dynamics model, which allowed risk assessments to be undertaken for more specific situations and usage patterns. Inputs to the model included amongst others: position and number of sources of ignition; ventilation rates; leakage data; size of room; and amount of refrigerant. The risk assessment work also identified those parts of the cabinet that contributed most to the overall risk associated with the use of HC cabinets.

Data from both studies confirmed that risk of ignition with HC refrigerant was very low. Of the scenarios reviewed, servicing had the highest risk.

Fault	Type	% Cabinets
Correct Elect Fault in Cabinet	Electrical	0.58%
Replace Thermostat	Electrical	0.40%
Replace Cabinet Cable	Electrical	0.23%
Replace Condenser Fan Motor	Electrical	0.17%
Replace Incorrect Fuse in Plug	Electrical	0.12%
Replace Timer	Electrical	0.06%
Sum		1.56%
Repair Leak & Add Gas	Refrigerant	0.58%
Recharge Gas Using Scales	Refrigerant	0.35%
Internal Leak	Refrigerant	0.29%
Sum		1.21%
Repair Water Leak	Mechanical	0.40%
Warranty Change Out	Mechanical	0.35%
Repair/ Cure Noise Problem	Mechanical	0.23%
Replace Lids	Mechanical	0.23%
Fit Parts	Mechanical	0.17%
Repair Lids	Mechanical	0.17%
Repair Trims	Mechanical	0.12%
Repair Door	Mechanical	0.12%
Repair Trims	Mechanical	0.12%
Repair Insulation	Mechanical	0.06%
Sum		1.96%
Attended Parts Needed	Other	0.23%
Attended Further Att Req'd	Other	0.17%
Wrong Part Sent	Other	0.12%
Site / Equipment Report	Other	0.06%
Sum		0.58%
Replace Comp/Elect/Drier/Gas	Components	0.12%
Fit Filter Drier	Components	0.12%
Sum		0.23%

Figure 3 – Typical failure data for one country over one year

Lesson Learned

Failure data from a company’s own records will allow for a much more accurate risk assessment. Generic data available in literature may not reflect actual failure rates.

Functional Specifications

Incorporating the knowledge gained through the QRAs with the more obvious risk mitigation actions, like using spark proof components, Unilever issued its suppliers with functional specifications highlighting areas that suppliers should consider when designing and manufacturing HC cabinets. These were used as a template for subsequent audit work on initial trial samples. In particular, suppliers were expected to ensure that:

- Any potential ignition sources in the equipment had been identified and eliminated at the design stage
- The design and manufacture minimised the possibility of leaks occurring (e.g. minimal joints, attention to corrosion issues)
- Any gas that does leak should be able to dissipate wherever possible
- The cabinets and refrigeration components are clearly labelled for use with propane

Initial Testing

Initial testing of ice cream cabinets took place during the Sydney Olympics in 2000. As Unilever's ice cream business in Australia was a sponsor of the Sydney Olympics, Unilever was challenged by Greenpeace to help make those Olympics the "Green Olympics." Fifty cabinets were specially manufactured to run HC refrigerants and placed on the Olympic site for the five weeks of the Olympics and Paralympics. Cabinets were placed in a variety of positions inside the venues. All cabinets experienced usage patterns much higher than typical. During this trial, the HC cabinets and a representative sample of HFC cabinets were fitted with temperature recorders outside and inside the cabinet, which measured the ambient and storage temperatures. The cabinets were also fitted with power meters. The data reported confirmed that the HC cabinets would be able to maintain the correct temperatures even under severe use conditions.

Following the success of the Olympic trial, the HC and HFC cabinets, still fitted with the monitoring equipment, were placed on the market in either Sydney or Brisbane for a further year. Engineers from the Danish Technological Institute (DTI) assessed the data from the trial and presented their findings at the IIR Gustav Lorentzen conference in Beijing in 2002. In summary, comparing the HC cabinets to their HFC counterparts over the year on the market, the HC cabinets had:

- Used approximately 9% less energy under comparable conditions (difference between ambient and storage temperatures);
- Required no additional maintenance or breakdown; and
- Maintained the ice cream at the correct temperature.

Lesson Learned

A well designed trial, independently run and assessed, provides confidence in the data and will assist in selling the technology change both internally and externally.

Supplier Interaction

Unilever began discussions with its main suppliers of refrigeration cabinets before 2000. By ensuring that suppliers were kept informed, they had sufficient time to consider the implications of any technological change in terms of investment in manufacturing equipment and cabinet design changes. Time was also spent discussing the reasons for the change (in 2000, climate change was not as newsworthy as it is now), building commitment for the change on an emotional as well as commercial level.



Figure 4 – HC cabinet in use at the Sydney Olympics

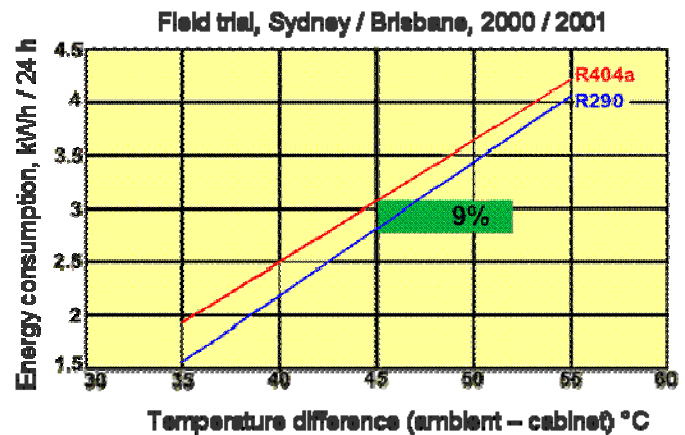


Figure 5 – Graph of energy consumption versus temperature difference between ambient and storage temperatures inside HFC and HC cabinets placed in the field in either Sydney or Melbourne.

Early communication also helped to identify potential pitfalls and barriers. Clear deadlines and unequivocal messages of intention to implement the HFC-free policy ensured that suppliers took the appropriate actions.

Lesson Learned

Engage in early interaction with suppliers to explain what is required and why, helps to reduce the barriers to change and the time to make those changes. Global buying policies must be agreed, communicated, and acted on in a timely manner.

Training

During the initial stages of the project it was clear that servicing of the cabinets was an area where training would be required to ensure safe servicing and repair of the HC cabinets. Some countries already had a pool of trained technicians available but, in many countries, suitable training courses were not available. Unilever commissioned a training package for refrigeration technicians specifically for ice cream cabinets. This training package consisted of a detailed presentation, A4 and pocket sized reminder sheets, and a post-training test sheet. The presentation included detailed notes so that experienced refrigeration technicians could deliver the material if necessary. The presentation highlights to technicians why the change to HCs was being made, the safety hazards, and the specific areas where extra care was required. The training package was professionally illustrated, keeping words to a minimum, facilitating its translation into German, Spanish and French.

Cylinder Storage

Outside - follow local regulations for LPG, if none at least:

- ☺ In a locked cage
- ☺ At ground level
- ☺ Away from air intakes to building
- ☺ Remote from ignition sources
- ☹ No smoking



Figure 7 – Example of Information in Training Presentation

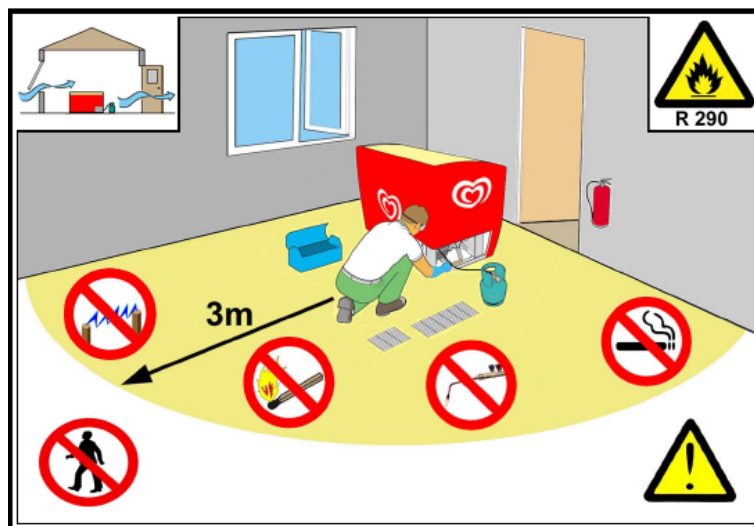


Figure 6 – Pocket sized reminder for technicians after completion of training

Lesson Learned

Servicing was identified as the highest risk in the QRA. Ensure technicians are properly trained by providing excellent training material.

Impacts of Switch to Alternative

Internal Communication

The change to HC refrigerants potentially touched many functions within Unilever: Sales; Cabinet Management; Safety, Health and Environment; Marketing; and Public Affairs. Cabinet managers were a key group, and regional meetings were held so that these groups could share their experiences both before and after the rollout. Familiarity with the impact that the rollout would have in the field allowed a rollout package to be prepared to support the local “champions.” Rapid follow-up on any issues raised ensured that any negative issues did not slow down the rollout.

Awareness of the project was raised among Unilever’s Ice Cream community through articles in internal publications. In addition, one-on-one meetings were held with the affected functions in key countries in each region to allow for more detailed discussions to take place.



Figure 8 – Internal magazine article on HC rollout

Lesson Learned

Targeted internal communications reduced the barriers to implementation of the HC cabinets by ensuring internal stakeholders were informed at an appropriate level of detail. Ensure mechanisms exist for identifying and solving any problems as early as possible.

External Communication

During initial testing and rollout of the HC cabinets, Unilever continued to engage its suppliers and other external stakeholders.

Where appropriate, country-based PR launches were used to inform the outside world about Unilever’s activity. A wide range of stakeholders were invited, including industry groups, the media, and policymakers. The events lasted a couple of hours and followed a consistent pattern:

- Academic presentation to explain the background to climate change
- Company presentation to give specific details of the local rollout of HC cabinets
- Presentation by Greenpeace to highlight their environmental concerns with HFC refrigerants and support the work done by Unilever
- Overview of Unilever global commitment to replacing HFC cabinets



Figure 9 – Presentation in Athens on the rollout of HC cabinets in Greece.

In addition to local events, opportunities to spread the message were taken by speaking at conferences, contributing to articles, and speaking with the media.

Lesson Learned

A local PR event builds commitment in the local team and ensures sufficient resources are available to push the roll out through.

Joint Initiatives Related to Natural Refrigerants

Unilever has been involved in a joint initiative with several companies equally committed to eliminating HFC refrigerants from their point of sale equipment (e.g., freezers, chillers, HVAC systems). Carlsberg, The Coca-Cola Company, IKEA, McDonald's, PepsiCo and Unilever—supported by Greenpeace and UNEP—have formed an initiative called Refrigerants, Naturally! (<http://www.refrigerantsnaturally.com>). Refrigerants, Naturally! Provides:

- A working group and supportive environment where information is shared to encourage and spread excellence for those committed to eliminating HFCs in point-of-sale refrigeration
- A platform and a critical mass in communicating with the refrigeration technology supply chain, with other users, governmental, political and public institutions about the feasibility and environmental gain of non-HFC-cooling



Members of Refrigerants, Naturally! are committed to:

- The elimination of HFCs in point-of-sale cooling applications
- Developing a timetable for eliminating HFCs
- Making a substantial resource commitment to achieve fluorocarbon elimination, including R&D, testing, financial investment, staff time or political energy
- Sharing information between members, including data and results with other companies, government decision makers, and the public

The initiative was awarded the United States Environmental Protection Agency's Climate Protection Award in 2005 in recognition for leadership in developing innovative ways to combat global warming by promoting the development of environmentally friendly refrigeration technology. Refrigerants, Naturally! is recognised as a "Partnership for Sustainable Development" by the UN Commission on Sustainable Development.

Refrigerants, Naturally! staged a major event in Brussels in 2004. The event brought together suppliers, policy makers, media and our peer group to listen to key note speakers from the EU, UNEP, Greenpeace and showcased the technical developments of the companies.



Figure 10 – Guest and company key note speakers at the 2004 Refrigerants, Naturally! event

Lesson Learned

Industry alliances create extra leverage to accelerate the pace of change. Managing the expectation of external parties is important. By engaging with these groups, explaining business models, and highlighting potential problem areas, this expectation can be managed.

Impacts on Producers

All of Unilever's suppliers had already had considerable experience in handling flammable gases since the introduction of cyclopentane as a blowing agent in 1994. This no doubt made the transition to flammable refrigerants easier, although there was still some investment to be made in containing and monitoring the flammable gases during production. Domestic suppliers had already been using flammable refrigerants since the mid-1990s, so equipment and experience was readily available. This investment, spread over the large numbers of cabinets being produced, had little impact on the production costs.

Impacts on End Users

In Unilever's case, the capital cost for a HC cabinet was virtually cost neutral. Service costs and product quality were identical to the previous HFC refrigerated cabinets. Some small technical issues around the choice of lubricant in the compressors caused some minor problems at the initial stage, but were soon corrected. Operating costs for Unilever's customers were actually reduced due to the lower amount of electricity consumed.

Impacts on Environment

Charge sizes for HC refrigerants are about 50% of that for the HFC equivalents (approximately 100 g for HCs, 200 g for HFCs). Further, HCs have a lower per-kilogramme cost than HFCs in most countries. As previously mentioned, energy savings were monitored in the field over a one-year period and showed an average 9% reduction in power usage for the HC refrigerated cabinets. Tests under laboratory conditions have shown even higher energy savings. Leak rates have not shown any change.

Whilst there is no maximum charge size for HC gases, equipment with more than 150 g in each circuit do have some placement restrictions. However, that still leaves considerable room for implementation in a wide range of commercial equipment, especially if engineering innovations are used to reduce the amount of refrigerant required (e.g., micro-channel evaporators in air cooled devices).

TECHNICAL CONTACT

Alan Gerrard

Unilever Foods R&D

Phone: +44 1234 22 28 13

Email: Alan.Gerrard@unilever.com