Refrigerants Naturally Conference

Technical overview

I. Introduction

The Coca-Cola Company, Unilever and McDonald's are committed to reducing their impact on the environment. One area of focus has been the potential effect of commercial refrigeration on global warming and the ozone layer.

Two international documents guide the efforts on developing innovative alternatives to commercial refrigeration technologies:

1. The Montreal Protocol:
Aimed at reducing the impact of chemicals on the ozone layer. The impact is measured in terms of the substance's Ozone Depletion Potential (ODP). A total phase out of these substances has been agreed worldwide.

2. The Kyoto Protocol:
Aimed at reducing the effect of chemicals on global warming. The impact is measured in terms of their Global Warming Potential (GWP).

II. Current technology and possible alternatives

Currently, **HydroFluoroCarbons (HFCs)** are widely used in many commercial refrigeration applications. HFCs are the replacement refrigerant for **ChloroFluoroCarbons (CFCs)**, which were the refrigerant of choice for many years, but which are being phased out due to their high ODP characteristics following the Montreal Protocol. As shown in Figure 1 (on page 3), HFCs have zero ODP, but still have a high GWP. Today, the focus is shifting from ODP to global warming, and HFCs have been included in the Kyoto basket of gases whose emissions need to be reduced.

Commercial refrigeration, covering diverse units such as beverage coolers, vending machines, ice cream freezers, open deck coolers and freezers used in supermarkets etc., represents some 25% of the total HFC market – and some 40% of total HFC emissions expressed as CO2-equivalent.

Several companies in the commercial refrigeration industry are looking into innovative alternatives for HFCs in an effort to fight global warming and ozone depletion. Since each of these innovative refrigeration technologies have their own specific characteristics, the evaluation of which type is the best solution mainly depends on the specific needs of the sectors and companies that use them. These needs include external temperatures, humidity levels, charge size, pull-down requirements, operating temperatures and frequency of lid openings among others.

Possible alternative refrigeration technologies include:

- **Hydrocarbons (HCs)**

What are they? Hydrocarbons such as propane, isobutene and cyclopropane are naturally occurring gases that have been identified as one of the possible alternative refrigeration gases for HFCs. HCs have environmentally benign characteristics (zero ODP and negligible GWP) and good technical performance.

Functionality: HCs work on a simple vapour compression cycle (Rankine cycle) in the same way as the current HFCs. Working temperatures and pressures are close to those of HFCs so no substantially different equipment is required.

Availability: HCs have already been used as refrigerants in the EU and Asia for a number of years, but mainly in domestic refrigeration. Hydrocarbons are now being introduced in commercial or industrial refrigeration as a commercially viable alternative for HFCs. HC refrigerants are also a key component of the 'Greenfreeze' programme being run by Greenpeace.

- **Carbon Dioxide (CO_2)**

What is it? Carbon Dioxide is a colourless, odourless, non-combustible gas that occurs naturally in the Earth's atmosphere. It is a natural refrigerant and a possible alternative for HFCs. CO_2 has environmentally benign characteristics (zero ODP and GWP equal to 1) and good technical performance.

Functionality: CO_2 refrigeration systems work in a very similar way to any other conventional Rankine refrigeration system (i.e. all domestic and commercial equipment today in the market). The system consists of a compressor, a gas acting as cooling agent, an evaporator, and an expansion device. The compressor compresses the CO_2 to a high pressure, which also raises its temperature. This hot compressed gas is then cooled by the ambient surroundings (and the heat it loses is rejected to the ambient). This cooling effect converts it to a high pressure liquid phase, provided the ambient temperature is within certain limits (critical point is at 31C - if the temperature is above 31C, a small cooling boost is required to liquefy the gas). This high pressure liquid is then expanded, which turns it to a gas phase again and cools it: this is the cooling effect that is captured in the evaporator and chills the equipment. The gas is then returned to the compressor to repeat the cycle.

Availability: CO_2 is already used in some countries for heat pumps and, provided development hurdles linked to high operating pressures and system efficiencies are tackled, has excellent opportunities to work in commercial refrigeration.

- **Stirling Cycle**

What is it? Stirling is the name of a thermodynamic cycle that can be used to produce cold (or heat). The Stirling Cycle is theoretically able to achieve the maximum efficiency in cooling. While this refrigeration method has been used for a long time for specific applications (namely cryogenics) its use for commercial refrigeration represents a new development. All existing refrigeration systems (whether using HFCs, CFCs or HCs) apply another thermodynamic cycle, the Rankine Cycle. The Stirling Cycle runs on small amount of helium and has zero ODP and zero GWP.

Functionality: Whereas traditional refrigeration is based on vapour compression technology which uses a constant cycle of phase changes (i.e. the gas is converted into a liquid and then again into gas, through a compressor and an evaporator), the Stirling Cycle is an example of a non vapour compression technology. The Free Piston Stirling Engine consists in a hermetically sealed capsule containing a very small amount of helium, which is a naturally occurring gas with zero ODP and zero GWP. The capsule contains only two moving components: a piston and a displacer. The piston, driven by a linear motor, compresses and expands the helium; the displacer brings this gas back and forth from the cold side to the warm side of the cooler. During expansion, heat is absorbed at the cold side, and during compression heat is rejected at the hot side.

Availability: Stirling has been used for particular niche applications (e.g. cryogenics) but recent developments, like the Free Piston Stirling Engine has allowed testing as a viable alternative commercial refrigeration technologies, especially for smaller sizes.

- **Thermoacoustic Cooling**

A thermoacoustic chilling unit is a form of Stirling motor with less moving parts. In basic terms, the thermoacoustic chiller is a closed-pressure vessel that contains a stack of fine-mesh window screens called a 'regenerator,' along with two heat exchangers, and a source of acoustic energy. This source generates high-amplitude sound energy in an environmentally safe inert gas (helium), which is converted into cooling power. To a nearby observer, the sound is barely audible (<60 dB).

- **Solar powered refrigeration technologies**

Solar energy is the direct conversion of the sun's energy into either electricity or heat. Using solar energy to power a refrigeration system offers considerable benefits such as for example the zero or low maintenance requirements, the reduction of carbon dioxide emissions or the reduction of noise or waste.

However, apart from some proto-types that use a combination of solar energy and batteries, further research is still needed to develop a commercially viable refrigeration system that is only powered by solar energy.

Figure 1. Effect on the environment of refrigerants

	Ozone	*Global Warming*	
CFC	***High***	***Very High***	×
HFC	***Zero***	***High***	×
HC	***Zero***	***Negligible***	✓
CO_2	***Zero***	***Negligible***	✓
Stirling Cycle	***Zero***	***Zero***	✓