LIFE05 ENV/DK/000158

Development and demonstration of a prototype transcritical CO2 refrigeration system

CO2REF

ENGLISH SUMMARY

History of refrigerants

CO_2 is a so-called new, old refrigerant. From 1850 to the 1930s, CO_2 was widely used in all kinds of refrigeration systems together with other refrigerants such as hydrocarbons and ammonia. They are all good refrigerants with very good properties, but during the 1930s they were forced out of the market by the CFC and HCFC gases because they had low toxicity, were non flammable and worked at lower pressures.

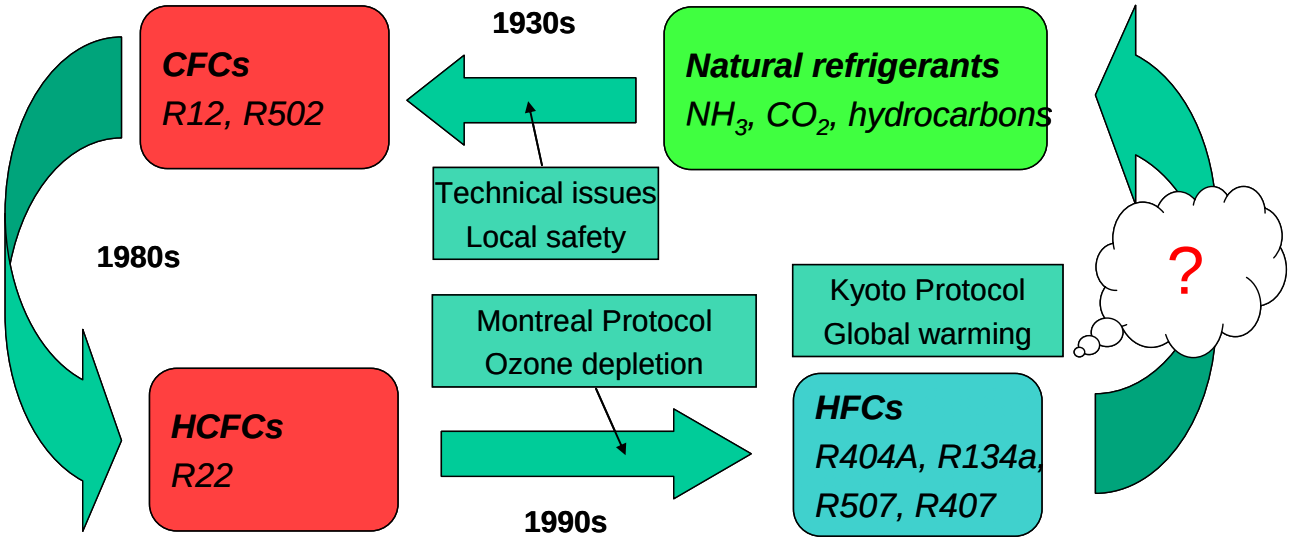

Figure 1: Refrigerant cycle.

In 1956, an ozone hole was discovered for the first time and in 1974 Rowland and Molina linked the CFC gases to the ozone hole. That was the beginning of the Montreal protocol which was signed in 1987 and came into force on 1st January 1989. CFC gases have been banned and HCFC gases will be banned from 2010 for new systems and a total ban will be implemented in the EU countries from 2015.

The substitute for the CFC and HCFC gasses has been believed to be the HFC gases that do not contain chlorine which is responsible for the hole in the ozone layer, but they contain fluorine instead. The HFC's entered the market during the 1990's. In that period, the global warming began to be a hot topic and in 1997 the Kyoto protocol opened for signatures and came into force in 2005. The aim of the Kyoto protocol is to control the emissions of CO_2 and other substances with a global warming potential.

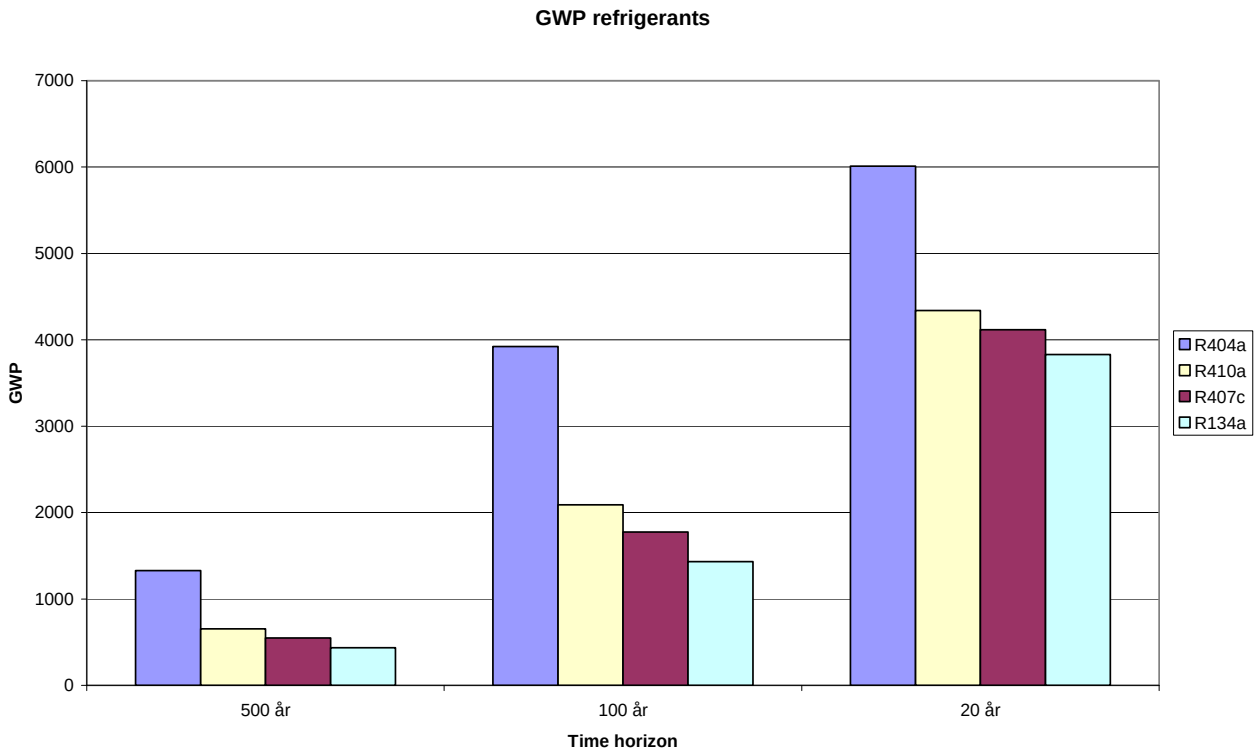

Figure 2: GWP for different refrigerants.

The impact HFC gases over time have on global warming appears from the chart above. Normally, the value of 100 years is used, but the value for 20 years is probably the most interesting value when regarding the world's current situation where we can begin to see the first effects of global warming. On the chart, different common refrigerants have been plotted and R404a is the one that commonly is used in supermarkets. In the course of 20 years, the global warming potential (GWP) of 1 kg of R404a is equal to 6.010[1] kg of CO_2 and in 100 years it equals 3.900 kg of CO_2.

In many countries there is focus on the phasing out of HFC's. In Denmark, there is a general ban on the use of HFC's in new installations and tax is imposed on HFC's. In Norway, there is high tax on HFC's and in Sweden there is a limit on the charge of equipment inside real estate. Germany has also issued their goal of 40% reduced CO_2 emissions in 2020. Also companies like Coca Cola, Tesco, M&S, McDonalds, Nestle, Masterfoods and Unilever are looking in the direction of natural refrigerants.

Many people consider CO_2 to be the best alternative because it is classified as non-flammable and non-toxic while the currently used hydrocarbons are highly flammable and ammonia is toxic as well as flammable.

In this project, focus is placed on developing a refrigeration system for a discount supermarket using CO_2 as the only refrigerant.

[1] Value of GWP can vary depending on the source.
http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-ts.pdf page 33-34

Scope of the project

The system developed in this project should meet the following requirements:

- ✓ CO_2 as the only refrigerant.
- ✓ Same reliability and functionality as a system using conventional refrigerants.
- ✓ Energy consumption has to be at the same level or lower than that for conventional refrigerants.
- ✓ Same need for servicing as conventional systems.

The main obstacles for achieving this are:

- ✓ Only a limited amount of components available and some of them currently only as prototypes.
- ✓ System concept not tested before (Booster).

The system has to be able to substitute an HFC refrigeration system without the supermarket owner or the customer in the supermarket noticing any difference.

Results of the project

The new system has been in operation since 1st March 2007 in the test supermarket. The energy consumption has been measured and has been compared with the energy consumption of similar installations.

Figure 3: Pictures of the supermarket.

Economic and environmental benefits

In reality this means that 1 kg of R404a equals 3920 kg of CO_2 if the effect is measured over 100 years or 6010 kg of CO_2 measured over 20 years. A small supermarket contains app. 100 kg of R404a and a large supermarket contains app. 1.000 kg and the average leak rate is around 10% per year.

To put this into perspective it is commonly known that transportation contributes enormously to CO_2 emissions. In the following, there is a small example showing how many kilometres you can drive in a Skoda Octavia 2,0 TDI and have the same greenhouse effect as one kilogram of the most common HFC refrigerant in supermarket refrigeration (R404a).

Example:

How many kilometres can you drive in a Skoda Octavia 2,0 TDI with equal greenhouse effect as one kilogram of R404a?

CO_2 emission 149 g/km (Skoda data)
Using the GWP of HCF for 20 years (6010) you can drive 40.335 km and using the GWP for 100 years (3920) you can drive 26.310 km.

Therefore, a reduction in the use of R404a and other synthetic refrigerants would have considerable impact on the greenhouse effect and this project has demonstrated that a sound technical and economical solution is available.

The direct emission from the HFC's is not the only CO_2 emission from the refrigeration systems. The indirect emission from the consumption of electric energy is also part of the emission. The split between the two types of emission is app. 50/50% and therefore removing the refrigerant part is a big contribution. However, the energy consumption still needs to be lower or at the same level as that of conventional systems in order to be attractive.

Monitoring the energy consumption for this system and for a reference system has been part of the project. The results show that the energy consumption of this system is app. 4% lower than for a conventional R404a parallel system.

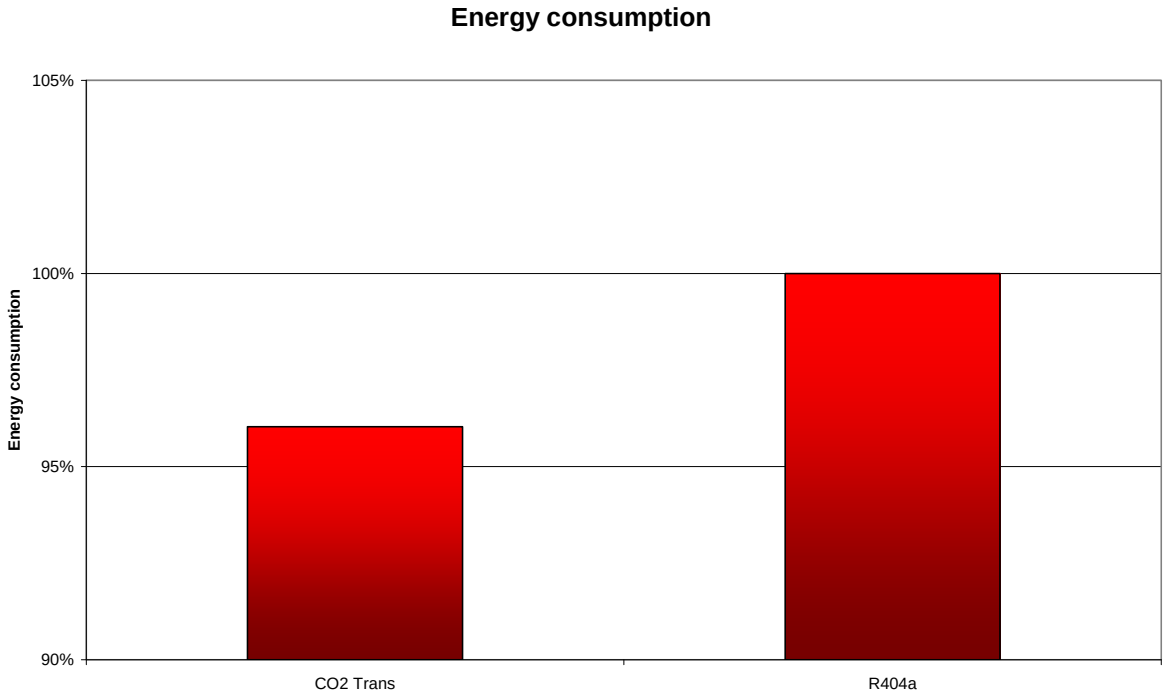

Figure 4: Energy consumption of the transcritical system and the reference system.

The price of this new CO_2 system in Denmark is the same compared to a HFC system or slightly higher depending on the installation due to taxes on HFC refrigerants and smaller pipes needed for the CO_2 installation. Therefore, this new CO_2 is considered to be a cost effective method to reduce the carbon footprint.

As the new system has approximately the same initial procurement price and the energy consumption is at a similar level or lower the life time costs of the system have to be lower than a conventional system. The service costs for the new system have not been monitored because there has been a lot of testing, but on other systems there are indications that the service costs are app. 15% lower - mainly due to the inexpensive refrigerant.

Transferability of the project

The supermarket that was built in this project was relatively small and it was built in Denmark where there is a relatively cold climate. The system is very easy to transfer to bigger systems because component availability is much better and many of the dynamic effects are easier to handle on bigger systems. Regarding the climate the system design is for cold climates, but can easily be redesigned for warmer climates. For warmer climates the energy consumption will be higher.

The first system was installed in Denmark on 1st March 2007 and at the end of 2007 app. 20 systems were in operation in Denmark in sizes from 30 kW to 200 kW total installed capacities. At the end of 2007, the installation rate for this type of system is approximately 1-2 systems a week.

Other companies have already “copied” the design and are also installing the system. Therefore, it is assumed that by 2008 more than 100-150 systems will be installed in Denmark using this technology.

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