Purdue University
Purdue e-Pubs

International Refrigeration and Air Conditioning Conference | School of Mechanical Engineering

1996

Practical Experience in the Use of R-407C in Small Chillers and Heat Pumps in Sweden

K. Berglof
AKA Kyla AB

J. Morley
DuPont Fluoroproducts

Follow this and additional works at: http://docs.lib.purdue.edu/iracc

Berglof, K. and Morley, J., "Practical Experience in the Use of R-407C in Small Chillers and Heat Pumps in Sweden" (1996). *International Refrigeration and Air Conditioning Conference.* Paper 293.
http://docs.lib.purdue.edu/iracc/293

This document has been made available through Purdue e-Pubs, a service of the Purdue University Libraries. Please contact epubs@purdue.edu for additional information.
Complete proceedings may be acquired in print and on CD-ROM directly from the Ray W. Herrick Laboratories at https://engineering.purdue.edu/Herrick/Events/orderlit.html

Practical Experience in the Use of R-407C in Small Chillers and Heat Pumps in Sweden

by
Klas Berglof
AKA Kyla AB
Sweden

John Morley
DuPont Fluoroproducts
U.K.

ABSTRACT:

Environmental regulations in Sweden have been directed at phasing out Chlorine containing refrigerants as rapidly as is technically possible, and also at reducing total refrigerant system charges and emissions of permitted refrigerants. These measures have lead to an early phase-out of HCFC fluids (the "service tail" ends in Sweden in 2002 for R-22).

Development work has accelerated in Sweden in the application of HFC fluids in low charge systems as alternative refrigerants for both CFCs and R-22.

This paper presents some results of obtained from the developmental testing of R-407C as a working fluid for use as a substitute for R-22, and discusses the subsequent development of small, energy efficient, low charge chiller systems, now in commercial production, using R-407C.

INTRODUCTION:

Sweden has for many years been strongly associated with environmental concern. This has impacted Sweden's domestic way of life - Sweden has pioneered the use of lowest environmental impact technologies wherever possible, including, for example, the use of district heating systems in urban areas using large (5 - 20 MW (1.5 - 6 kton)) heat pumps, as well as the application of efficient ground source heat pumps for ambient heating in the home, and in communal buildings. This concern also influences the way Sweden acts on global environmental issues. It comes as no surprise that Sweden has been a prime mover in the development of international legislation on the global environmental issue of Ozone Depletion. Sweden has led this effort by example: the Swedish legislation for the phase out of ODSs has enforced a timetable that is more strict than any other nation. There are use bans on both CFCs (service use ban from 12/31/97) and HCFCs (the servicing of refrigeration cycle systems with HCFCs is not permitted after 2002).

Because of the potential contribution to Global Warming of HFC fluids, Swedish legislation limits the charge size in refrigeraton systems of these substances (with the objective of minimizing total emissions). Charge size of HFC refrigerants are restricted to 20kg in direct systems and 50kg in semi-indirect systems. These changes have spurred the development of refrigeration systems to use the new non-chlorine containing fluids that are becoming available. Much of this development work has been encouraged and partially funded by the Swedish government.

DEVELOPMENTAL TESTING OF R-22 ALTERNATIVES

There are very many domestic and small commercial chillers and heat pumps installed in Sweden which use R-22 as a working fluid. These systems often have refrigerant charges in the range 1 - 50 kg and provide trouble-free, silent and energy efficient operation in compact units. Many corporate purchasers of such systems are already specifying chlorine free working fluids, which is, in effect, resulting in an earlier phase out of HCFCs for new systems.

With the realization that R-407C is a fluid that best meets the necessary criteria for a replacement for R-22 in many applications, several test programmes were instituted to determine the performance characteristics of R-407C. The data we present here were developed using a test instalation set up at AKA Kyla AB's test centre near Stockholm.

The test unit is an instrumented conventional vapour compression refrigeration circuit, using a reciprocating compressor, with measured heat loads (provided by temperature controlled, metered brine feeds to the service sides of the evaporator and condenser). The evaporator and condenser were specified from the start as plate heat exchangers as this is a technology which showed promise in leading to reduced refrigerant charge systems. System performance parameters were logged by a proprietary data logger (ETM 2000) developed specifically to monitor refrigeration systems. The ETM 2000 data logger is preprogrammed with the refrigerant fluid's thermo properties and, and is thus able to convert pressure mesurements directly to saturation temperatures, and to calculate, online, degrees of superheat and subcooling, and system operating performance parameters (capacity, COP, and compressor isentropic efficiency). A typical output data set is shown in table 1.

The results from the comparative tests showed that R-407C performance was very similar to that of R-22, under the service conditons typical of an air conditioning application. Figure 1[1] shows the refrigeration capacities of R-407C compared with R-22 at different evaporating and condensing conditions. Fig 2[1] shows Carnot Efficiencies[2] (η_c) compared for R-22 and R-407C for the refrigerant fluids and for the system (Total Carnot Efficiency[3]).

The Carnot Efficiency (η_c) is given as[2,3]:

$$(\eta_c) = COP/COP_c, \text{ where:} \qquad (eq.1)$$

COP is the measured refrigeration cycle efficiency; and
COP_c is the Carnot Cycle efficiency given by:

$$COP_c = T_{evap}/(T_{cond} - T_{evap}) \qquad (eq. 2)$$

(T_{evap} and T_{cond} are the mean Evaporating and Condensing temperatures, respectively. The relation (T_{cond} - T_{evap}) is often denoted as the Temperature Lift)

The "Total Carnot Efficiency" basis calculation is based on mean temperatures of the service media[3] in the evaporator and condenser, rather than the conventional refrigerant working fluid temperatures, and incorporates system heat transfer effects. Fig 2 shows that the Carnot efficiencies (for both bases of calculation), of R-407C and R-22 are similar.

The "Total Efficiency" data for R-407C highlighted opportunities for minor design changes to be made (vs conventional R-22 design criteria) to enhance the evaporator and, principally, the condenser performance when used in refrigeration systems with R-407C as the working fluid.

COMMERCIAL APPLICATIONS

As a result of the favorable test results obtained, several climate control systems have been developed using R-407C as the working fluid, and are in commercial production.

These systems include ground source heat pumps: One commercially available system, a direct evaporation system, is of particular interest as its evaporator consists of one single pass of 60m (200 ft.) of copper tube and is delivered already charged with refrigerant. The heat source tube (evaporator) is shipped as a coil and is either buried or inserted into a bore hole on site. This configuration had been supplied using R-22 or R-134a as the working fluid in the past, and required careful design and selection of the control instrumentation due to the potential for operating instabilities arising from the long time constant feed back of the superheat signal to the expansion control device. One immediate difference noted after the change to R-407C was a step-change in ease of setting up of the system. The observed apparent dampening of the TXV response is probably an effect of the glide of R-407C. (This is consistent with experience in other systems using R-407C.)

Another Swedish manufacturer is producing a range of secondary heat pumps using R-407C as the working fluid and a glycol-water brine as the heat transfer medium to the evaporator and to the condenser, both of these being plate heat exchangers. These units are delivered to the site pre-charged with refrigerant and already performance tested, requiring only electrical and hydraulic connection.

Currently some 1500 heat pump units are in operation in Sweden using R-407C as the working fluid.

A similar system (configured as a brine chiller) is being manufactured as an "add on" to commercial air handling units to provide an easy "air cooling upgrade" for building installations, in response to an increased demand for air conditioning. This unit was designed in cooperation with the air handling unit manufacturer who specified the use of a chlorine-free refrigeration fluid. Different configurations of this unit are manufactured as stand alone chillers designed to provide brines in the temperature range of -5°C to +10°C. Typical refrigerant charge sizes for systems with this configuration are in the range of 0.10 - 0.12 kg /kW. Several hundreds of these chillers are in use, today, in Sweden.

CONCLUSIONS

R-407C has shown itself to be a viable substitute for R-22 in direct expansion systems (chillers and heat pumps) designed for comfort applications. It is being widely used in Sweden in commercial systems.

ACKNOWLEGEMENTS

The authors would like thank Gustav Hammerberg and Hans Nyman for permission to reproduce Figures 1 and 2.

REFERENCES

1) Hammerberg G. & Nyman H., M.Sc. Thesis, Royal Institute of Technology, Stockholm, 1994.

2) Ekroth I., Granryd E., Thermodynamics and Refrigeration, KTH, Stockholm, 1991.

3) Lundqvist P., ASME Proceedings: International Mechanical Engineering Conf., San Francisco, 1995.

Table 1
Data Logger Output

Date:	22/03/96
Serial No.	40229
Type:	KA-G4
Refrigerant	R-407C
Charge:	2.4kg

Time	Evap. Temp.	Cond. Temp	Comp.Disch. Temp	Super Heat	Sub-cool	COP	Power Input	T4	T5	T6	T7	Comp. Efficiency	Capacity
	°C	°C	°C	°C	°C		kW	°C	°C	°C	°C		kW
10.21.5	2.2	45.9	74.4	4.5	5.3	3.6	6.4	12.	40.5	32.8	6.9	0.8	23.3
10.21.5	2.	46.2	74.4	4.6	5.6	3.7	6.5	12.	40.5	33.	7.0	0.8	23.6
10.22.0	2.	46.0	74.4	4.6	5.4	3.6	6.5	12.	40.5	32.9	7.0	0.8	23.4

Note: Points T4, T5, T6 and T7 are the service fliud inlet and exit temperatures at the condenser and evaporator.

Fig. 1

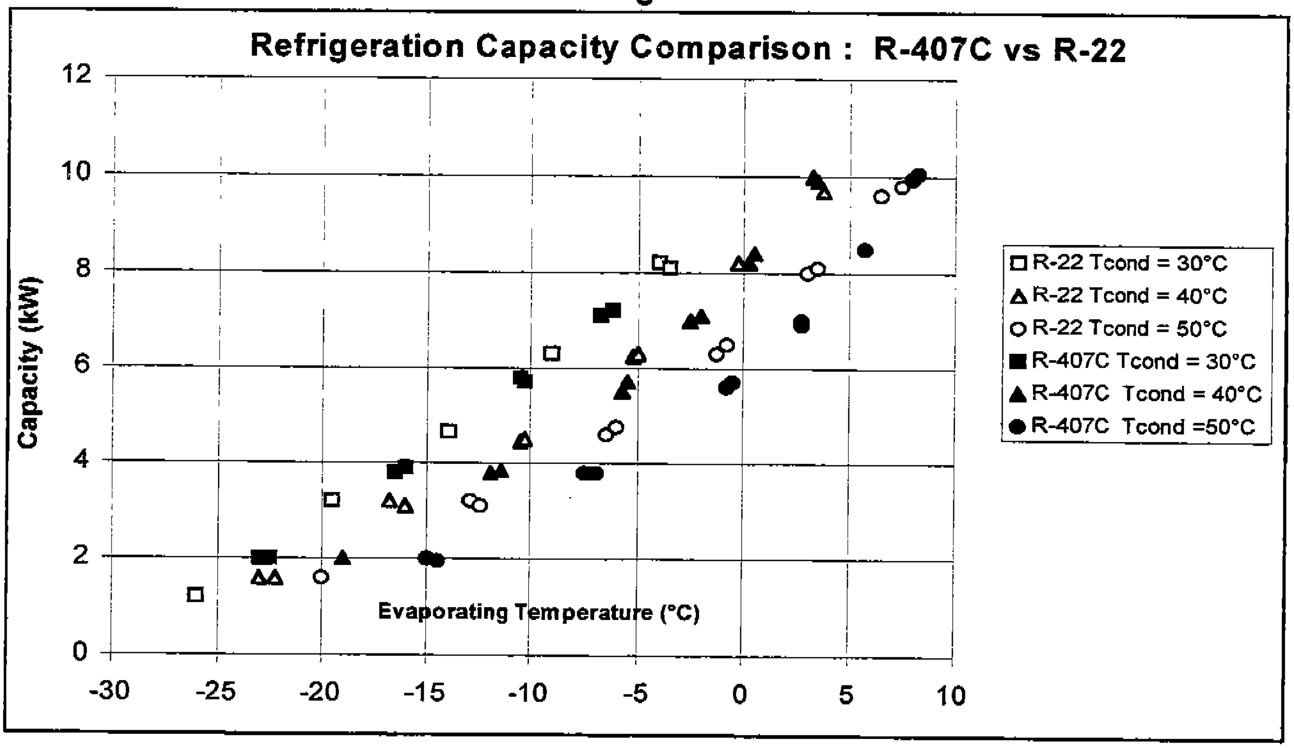

Fig. 2

Carnot Efficiency: R-22 vs R-407C

(Upper Data Set: Refrigerant; Lower Data Set : Total Carnot Efficiency)