HEAT PUMP WITH HIGH OUTLET TEMPERATURES

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ABSTRACT

For house heating applications heat-pumps have a lower primary energy demand than many other heating technologies like oil boilers. In several European countries the heat-pumps have a good market share in new buildings. But the big potential of the retrofit market in Europe was not accessible due to some restrictions: The older heating systems require an outlet temperature of 65°C to 70°C. The heat source for a retrofit HP should be ambient air. So the requirement is a high COP and a temperature lift from –15°C ambient air to 65°C outlet temperature. And the HP should be interesting from an economical point of view which excludes multistage HP and other solutions.

Together with Copeland the German heating system manufacturer Viessmann developed a HP with an Economiser Cycle and hot gas injection in the compressor. The function of the cycle and measurement results from field tests and laboratory will be presented. The results show an interesting behaviour of the cycle for a COP and temperature optimisation.

Key Words: ***retrofit heat pump, scroll-compressor, enhanced vapour injection***

1 INTRODUCTION

Private households represent an important factor in the energy balance in central and northern Europe. In Germany they use about 30 % of the total energy demand. A major part (75 %) of this energy is required for heating.

One possibility to lower the energy consumption is a better thermal insulation of the house. For new houses the legislation gives upper limits for the heating demand, a good insulation is required (see Fig. 1). But the average life of a house is 100 years, a major part are older than 10 years. These houses have a high heating demand and placing a thermal insulation is quite difficult.

The other option is to look at the heating system. Heat pumps may supply heating energy with a good COP. Compared to oil or gas boilers they may reduce the primary energy demand even if the power for the electric driven heat pump is produced with a low efficiency (average efficiency of power stations approx. 1/3 in Germany).

2 RETROFIT HEAT PUMP

In Germany there are about 16.8 million residential buildings (data from 2001). More than 13 million of these houses are one- or two family houses. The heating demand of theses houses is about 200 kWh/(m²a), the maximum heating power is in the range of 20 kW (see Fig. 1).

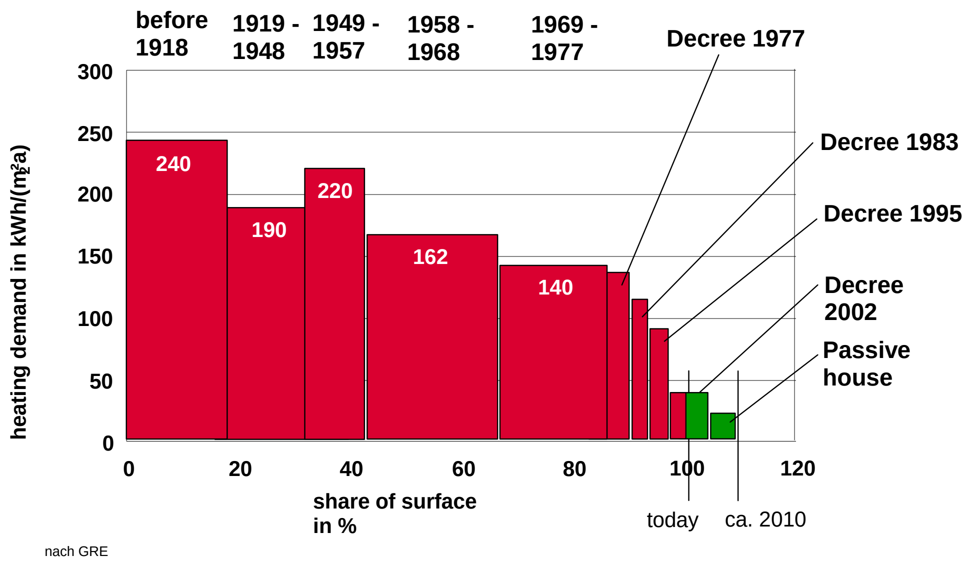

Fig. 1. Heating demand of buildings in Germany (GRE 2001)

Usually a heating system is exchanged every 20 years. So the market for retrofitting is substantially larger than the one for new buildings. But efforts have to be taken to overcome restrictions, specially an inappropriate heat output characteristic and a restricted temperature range:

1. Conventional heat pump cycles are limited in condensing temperature and difference between evaporation and condensing temperature. A standard heating system in an older building requires a maximum temperature between 65°C and 70°C.
2. The heat source for a retrofit heat pump must be easy to install in an existing building. The only source which is always available is ambient air. The problem is that maximum power and outlet temperature of the heating system is required at lowest ambient temperatures.

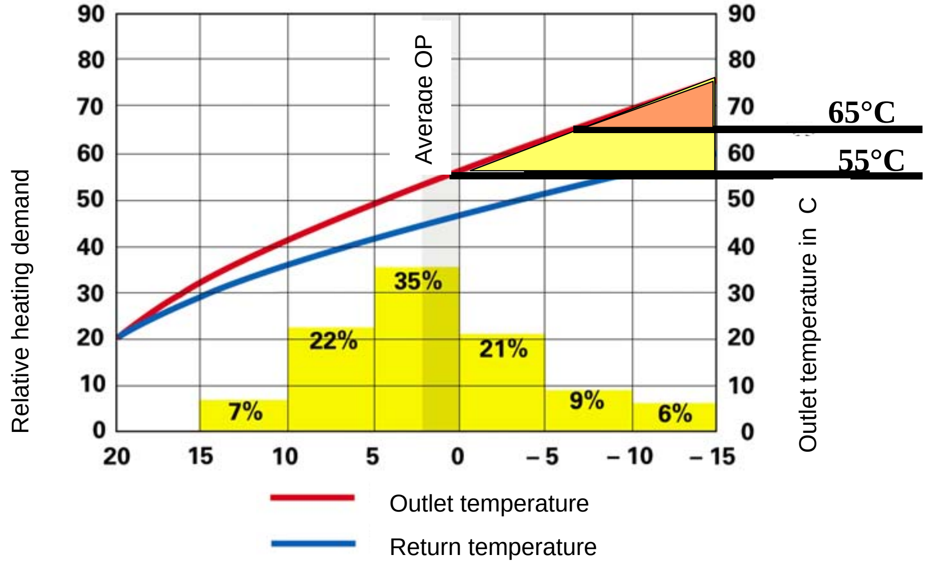

Fig. 2. Heating demand and outlet temperature over ambient temperature.

Figure 2 shows the repartition of the heating demand over ambient temperature and the required outlet temperature for a standard heating system in an older building. A heat pump with a maximum outlet temperature of 55°C covers about 65 % of the annual heating demand. The rest has to be covered by a backup-heating system. At 65°C outlet temperature of the heat pump the fraction of the backup heater is less than 15 %.

3 HEAT PUMP WITH ENHANCED VAPOUR INJECTION

The large temperature lift for a retrofit heat pump and high-pressure ratio will result in unfavourable operating conditions of a one-stage compression cycle, for example in high discharge temperatures and high throttling losses. An alternative is to use a compressor with an intermediate injection of refrigerant during the compression. Two types of this technique exist: The vapour injection (“Economiser Cycle”) improves the capacity using the same pumped volume of the compressor. The liquid injection is used for decreasing high discharge refrigerant temperature of the compressor, assuring a reliable operation and preventing degradation of the oil.

In the retrofit heat pump with R407c the vapour injection is used with a scroll compressor equipped with an intermediate injection port. The scheme is called Enhanced Vapour Injection EVI (see Fig. 3). A small amount of refrigerant is removed after the condenser and is evaporated on one side of the heat exchanger (process 6-10-12 in Fig. 4). This vapour is injected into the scroll compressor (process 2-3). The amount of refrigerant injected is determined by the pressure difference between the condenser and the scroll pocket. The remaining refrigerant from the condenser circulates through the other side of the heat exchanger before being expanded and entering the evaporator (process 6-7-8). Due to the cooling with the saturated vapour (process 2-3) the compressor is able to produce an outlet temperature of 65°C at an evaporation temperature of –25°C. For many applications this is sufficient for a mono-energetic system (electric heater as backup).

At the start of the operation the valve to the vapour injection port is closed and the heat pump works in a one-stage cycle. At a certain discharge temperature the valve opens the injection.

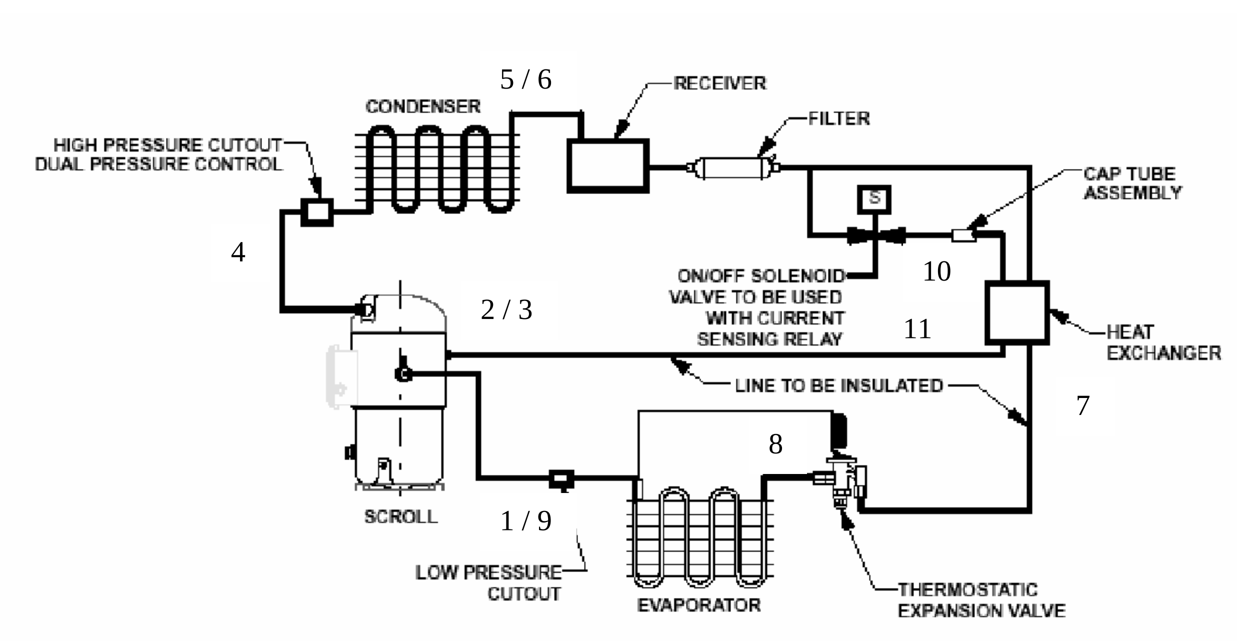

Fig. 3. Scheme with the intermediate vapour injection (Copeland 2003).

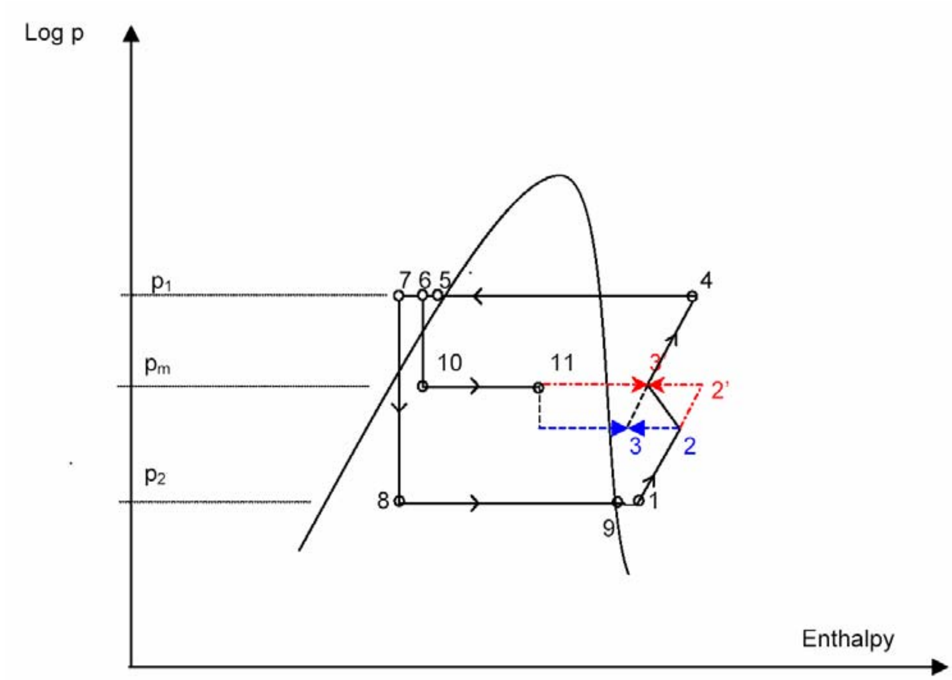

Fig. 4. Thermodynamic cycle of two-stage compression in log p – enthalpy diagram (Kadribegovic 2004)

4 EXPERIMENTAL RESULTS

4.1 General characteristics

The air-water heat pump with a nominal capacity of 10 kW has been tested at the heat pump test center TÖSS in Wintherthur / Switzerland. The data confirm that the heat pump is able to produce an outlet temperature of 65°C even at low ambient temperatures.

Compared to a one-step compression heat pump (see left diagram in Fig. 5) the EVI scheme shows a favourable dependency of the heating power at low ambient temperatures. At 35°C outlet temperature the vapour injection is not activated. At higher outlet temperatures (50°C and 65°C) the EVI acts like a power booster.

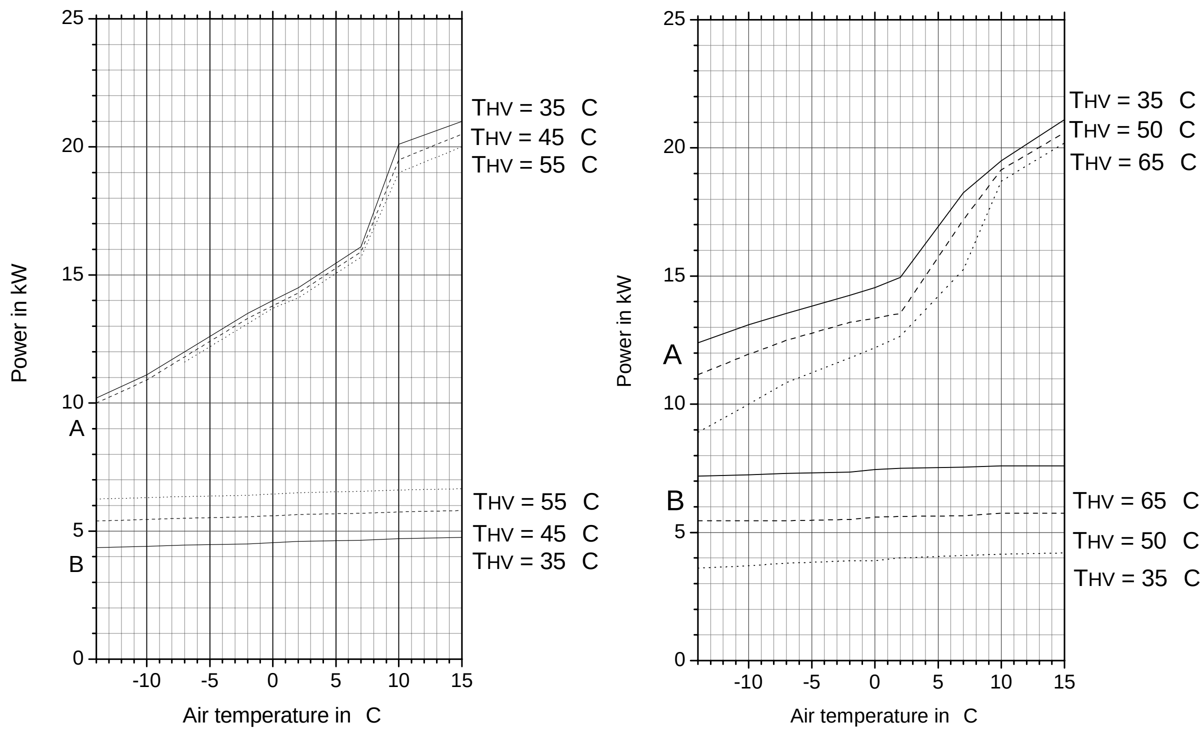

Fig. 5. Heating capacity (A) and electric power consumption (B) for different air and outlet temperatures (T_{HV}) for a one-step compression cycle heat pump on the left side and an EVI cycle heat pump on the right side (Viessmann 2004).

4.2 Characteristics of the EVI cycle

At the Royal Institute of Technology in Stockholm / Sweden the vapour injection cycle has been tested for its suitability for a heat pump. The heat pump was of the brine-water type with a nominal capacity of 13 kW. The following results have been taken form the thesis of Kadribegovic (Kadribegovic 2004). The cycle has been analysed using the ClimaCheck method.

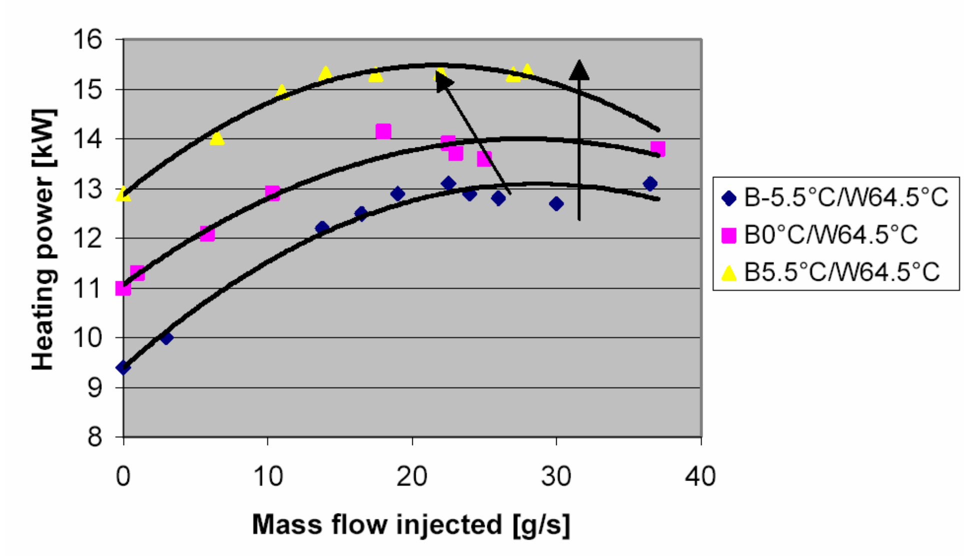

Fig. 6. Heating power at different economiser mass-flow rates (Kadribegovic 2004)

As Fig. 6 shows the heating power reaches a maximum when increasing the mass-flow through the economiser. 20 g/s represent about 10 % of the mass-flow through the evaporator. Further inspections indicate that there is a maximum for every combination of evaporation and condensation temperature.

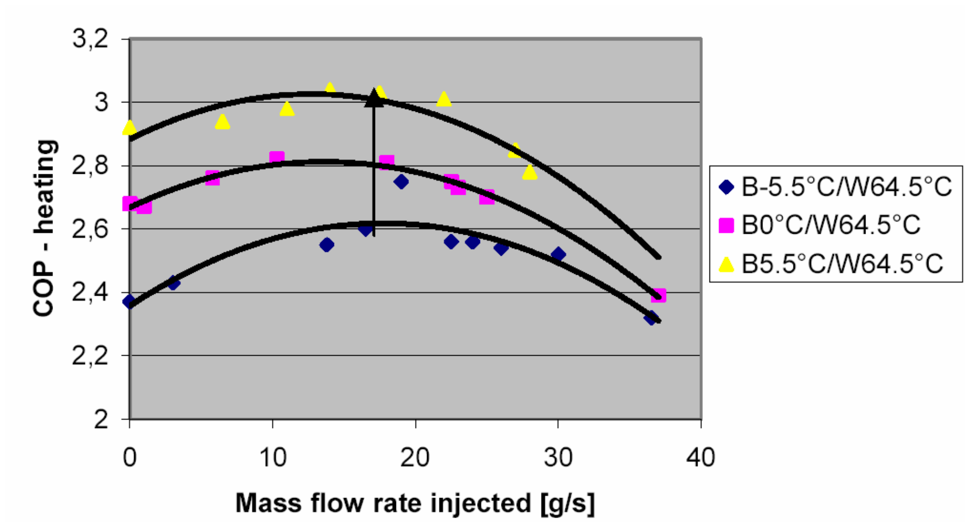

Fig. 7. COP at different economiser mass-flow rates (Kadribegovic 2004)

The coefficient of performance shown in Fig. 7 is based on the heating output and the electrical power to the compressor. It can be seen that for the same conditions as in Fig. 6, the COP has a maximum at slightly lower mass-flow rates than the heating power which makes the choice of the expansion capillary tube somehow difficult.

But when looking at the compressor discharge temperature (Fig. 8) it becomes clear that a mass-flow rate below 20 g/s should be avoided.

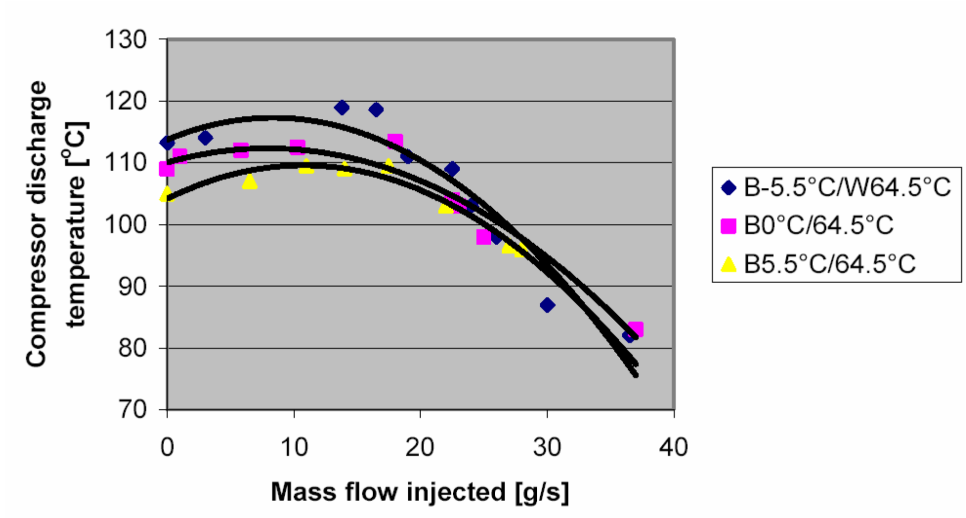

Fig. 8. Compressor discharge temperature at different economiser mass-flow (Kadribegovic 2004)

4.3 Field test

Heat pumps with die EVI concept have been installed at different locations during a research project in Switzerland and France (BFE 2002). In the measured data an the theoretical analysis the EVI cycle reached the best results concerning COP. Compared to a one-step compression cycle the seasonal performance factor (average seasonal COP) improved by 18 %.

5 CONCLUSIONS

The EVI scroll compressor has shown a high potential in a heat pump. The improved temperature and heating power characteristics may help to overcome barriers towards a retrofit system and are also helpful for other applications like domestic hot water production.

Heat pumps with EVI cycle optimised for high condensing temperatures are available on the market. There are further options to use the cycle also as a power booster and for further COP optimisation.

LITERATURE

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