Experimental Experiences with Evaporator Defrosting of Heat Pumps to DIN 8900

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EXPERIMENTAL EXPERIENCES WITH EVAPORATOR DEFROSTING OF HEAT PUMPS CORRESPONDING TO DIN 8900

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1. INTRODUCTION

Evaporators of air/water-heat pumps must be defrosted at about 5 - 7°C (40 - 45°F) outside air temperature. Corresponding heating capacity and Coefficient of Performance (COP) decrease. Hereafter, only electric driven air/water-heat pumps are described in the range from 5 - 20 kW (1.4 - 5.7 tons) heating capacity and air volume flow rates through the evaporator from 1.5 - 5 m^3/hr. (50 - 200 cu.ft./hr.)

2. THE TWO MOSTLY USED DEFROST SYSTEMS IN ELECTRICAL HEAT PUMPS IN WEST-GERMANY: REVERSE CYCLE AND HOT GAS DEFROSTING

Fig. 1 shows both widely used defrost systems for heat pumps in West-Germany; left: reverse cycle, right: hot gas defrosting.

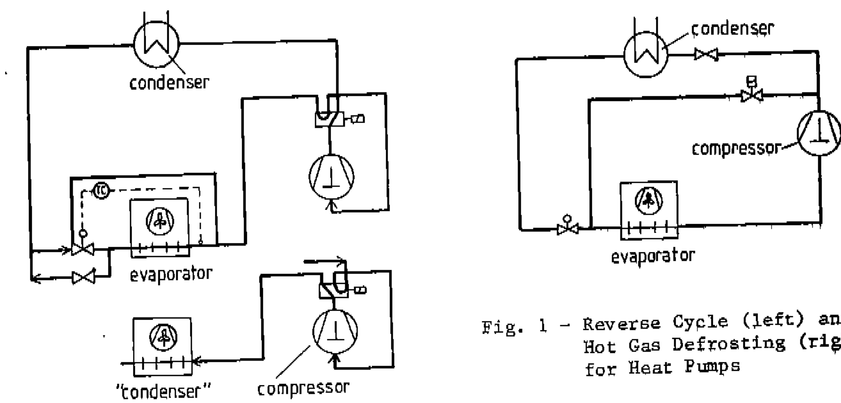

Fig. 1 - Reverse Cycle (left) and Hot Gas Defrosting (right) for Heat Pumps

At the introduction (before 1980) about 75% of the heat pumps had reverse cycles. Since then, more and more heat pumps have been equipped with hot gas defrosting, now about 75%. The most rapid defrost system is the reverse cycle. The disadvantages of reverse cycle defrosting are:

- Energy must be taken from the warm water heating system.
- The condenser can freeze, if it works as an evaporator and this has occurred frequently.
- To avoid freezing of the condenser a buffer must be installed.
- With reversing cycle,materials are heavily loaded (temperature and pressure).
- The reversing valve is relativly sensitive (for example to dirt) and has leaks from the discharge to the suction side.
- Furthermore, the valve works like a heat exchanger between hot gas and suction gas.

The principal disadvantage of hot gas defrosting: In some cases it takes too long to defrost the evaporator (a special case: DIN-Test /1/ cannot be passed).

3. DIN 8900 (GERMAN INDUSTRIAL STANDARD) FOR ELECTRIC DRIVEN HEAT PUMPS /1/

3.1 Test Conditions

Air/water-heat pumps are to be measured at the following test conditions:

- Leaving heat pump water temperature: 35 and 55°C (95 and 131°F)
- Entering evaporator air temperature: +7, +2 and down to -15°C(45, 36 and 5°F)
- Relative humidity about : 85%

3.2 Relative Defrost Time

To get the "DIN-Test-Certificate" the relative defrost time must be less than 15%. It is defined by

$$\tau_{rel} = \frac{\tau_A}{\tau_g} \; 100\% \qquad (1)$$

τ_A = Defrost time(s) during the total operation time of the heat pump (hr.)

τ_g = Total defrost time(s) (hr.)

3.3 Heat Pump Capacity-, Power Input- and COP-Diagram According to DIN 8900

Every heat pump producer who wants to get the "DIN-Test-Certificate" must present a diagram according to Fig. 2. The influence of the defrost procedure is recognizable at 5 - 7°C. At 35°C leaving water temperature the bend caused by defrosting begins at higher air temperatures than at 55°C. The reason is the compressor capacity (volumetric efficiency); it is higher at lower pressure ratios, therefore, the evaporating temperature is lower.

At -15°C outside air temperature the curve closes to the dotted line "Without Defrosting" because of low absolute air humidity at lower temperatures.

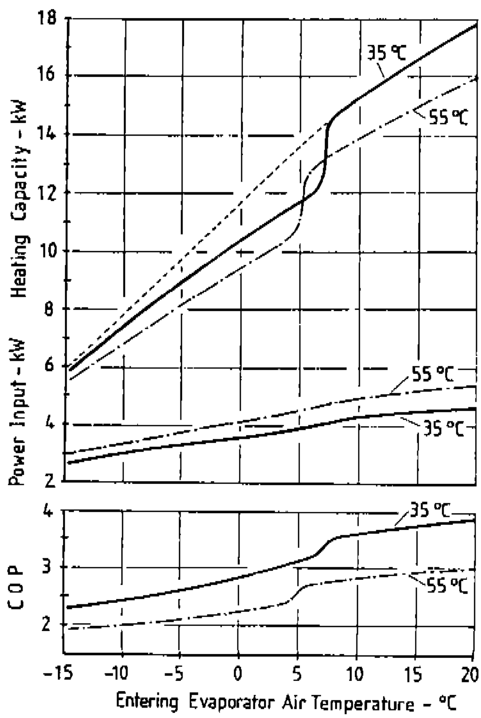

Fig. 2 - Heat Pump Capacity-, Power Input- and COP-Diagram for a Heat Pump According to DIN 8900

4. EVAPORATOR DEFROST BEHAVIOR WITH SOME EXAMPLES

Fig.3 through 5 illustrate the results of some measurements: heating capacity versus compressor running time.

Fig. 3: At Air +7/Water 55°C defrosting is not required. However, at Air +7/Water 35°C heating capacity decreases because of frost formation within 1 hr. from 14.5 to 12.5 kW. In the second heating cycle the slope is more significant.

Fig. 4: Already after 30 minutes the capacity decreases from 4.4 to 3.9 kW ≙ 12%. During the second cycle the capacity is distinctly lower. Reason: The evaporator was not sufficiently defrosted.

Fig. 5: First, the capacity increases at the first as well as the second heating cycle. After 1½ hour the capacity changes from 3.8/3.9 to 3.2/3.4 kW. The capacity decrease during the second cycle is faster.

4.1 Simplified Capacity Behavior During Frost Formation for Various Heat Pump Evaporators

In these diagrams, Fig. 6, are shown the simplified behavior of six measured heat pumps. After that, the behavior of evaporators can be very different at the same conditions. For example "Air +7/Water 35°C", see

- Heat pump B: The capacity decreases after 1½ hours from 15 to 12 kW; no decrease at "Water 55°C".

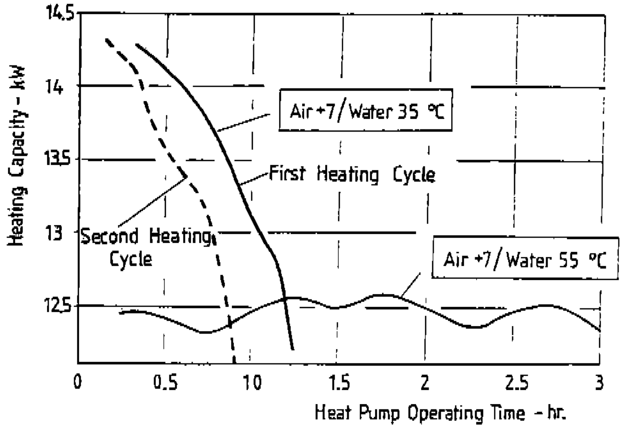

Figure 3

Decrease in Heating Capacity During First and Second Heating Cycles;

Frost Formation at 35°C Leaving Heat Pump Water Temperature and 7°C Entering Evaporator Air Temperature

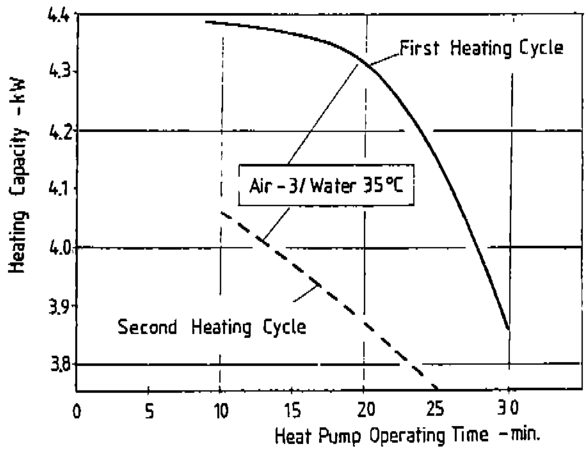

Figure 4

Decrease in Heating Capacity During First and Second Heating Cycles;

Frost Formation at 35°C Leaving Heat Pump Water Temperature and -3°C Entering Evaporator Air Temperature

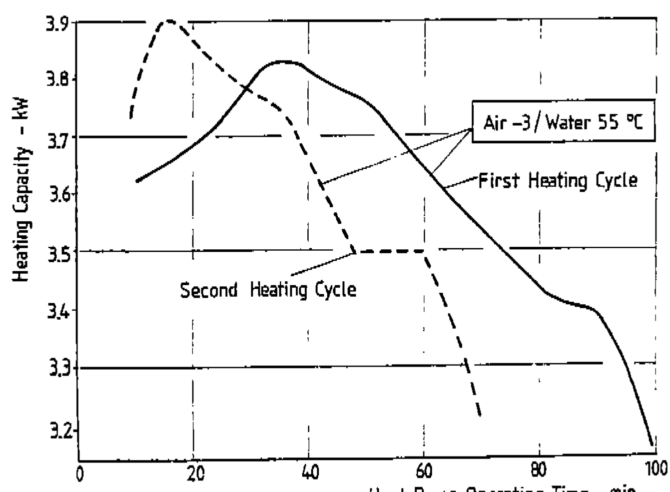

Figure 5

Decrease in Heating Capacity during First and Second Heating Cycles;

Frost Formation at 55°C Leaving Heat Pump Water Temperature and -3°C Entering Evaporator Air Temperature

- Heat pump D: After every hour the evaporator must be defrosted but the capacity drops only a short time before defrosting.
- Heat pump E: Defrosting is necessary after 2 hours, whereby the capacity during the first part of heating cycle increases and than gradually decreases.
- Heat pump F: Defrosting is not necessary.

Concerning heat pump C it is interesting to see how the capacity after every defrost cycle goes down step by step. The defrost procedure is not satisfactory.

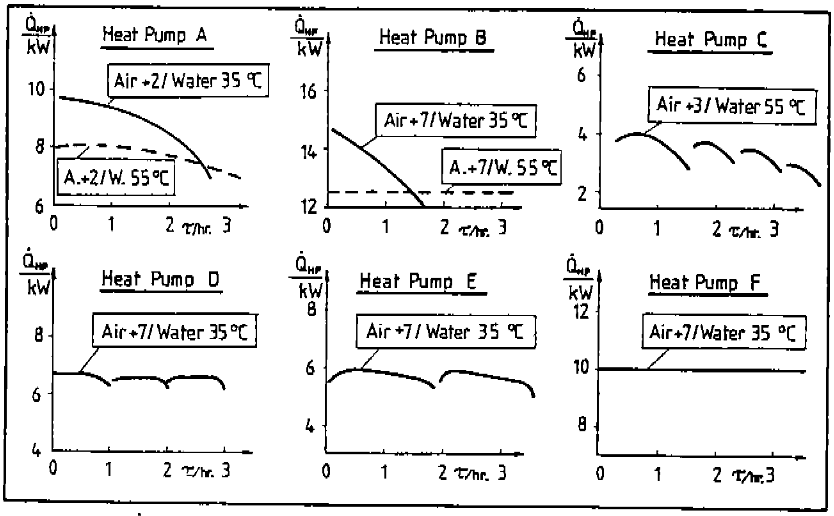

Fig. 6 - Simplified capacity behavior during frost formation for various heat pump evaporators

5. AN IMPROVED DEFROST ARRANGEMENT FOR HEAT PUMPS IN MIDDLE EUROPE

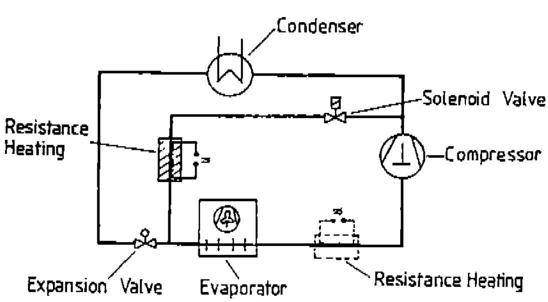

Fig. 7 - An Inproved Defrost Arrangement for Heat Pumps in Middle Europe with Additional Electrical Resistance heating

In Germany for example, only heating is needed and cooling is not necessary. Therefore the reversing cycle must not be the only solution to defrosting evaporators in heat pumps.

An additional electrical resistance heater will be suggested either in the hot gas bypass line or in the suction line, see Fig. 7, to avoid a long defrosting time with the hot gas bypass system.

5.1 Compressor Power Input During Defrost Cycle: Reverse Cycle and Hot Gas Defrost

Fig. 8 shows the result with both mentioned defrost systems. The hot gas defrosting power input changes from 2.5 (heating cycle) to 1.5 kW and then goes up to 3.0 kW (τ_{RC} = 2.5 min.) During the heating cycle the power input is approximatly the "normal" power input of about 2.5 kW. At hot gas defrosting the power input reaches only 2.25 kW. The defrost time (τ_{HG}) is 3 times longer: 8.5 minutes.

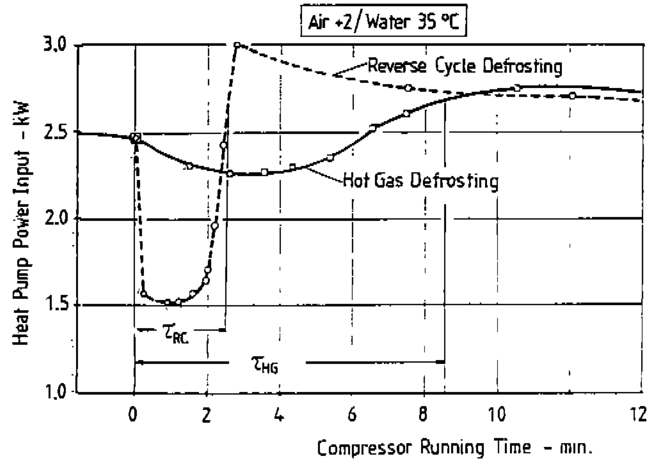

Figure 8

Power Input During Defrost Cycle with Hot Gas and Reverse Cycle Defrosting

5.2 Power Input: Compressor, Resistance Heating and Total

The defrost time depends on the resistance heating capacity. With a 2000 Watt heater the defrost time is 5.5 minutes. In this case, the part of resitance heating is 180 Wh, the compressor 220 Wh, totaling 440 Wh. The defrost time is 7.5 minutes with a 500 Watt heater; the part of the resistance heating is 63 Wh, the compressor 290 Wh. Defrost time is 8.5 minutes without additional resistance heating, the defrost capacity comes only from the compressor and/or motor, see Fig. 9.

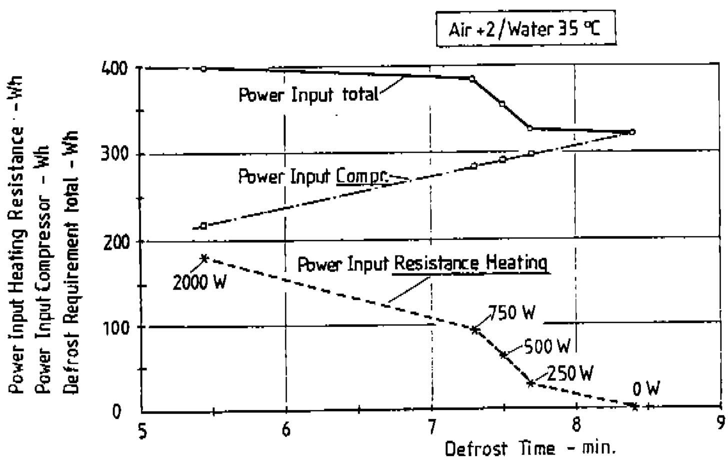

Figure 9

Power Input (Resistance Heating, Compressor and Total) versus Defrost Time

5.3 Comparison of COPs with Both Defrost Systems and with 750 Watt Additional Resistance Heating

COPs were measured at leaving water temperatures of 35 and 55°C and entering air temperatures of +7, +2 and -10°C, see Table I.

Important: "Reverse Cycle" does not consider the heat taken out of the water heating system, only the electric energy. In case of this consideration, COP of hot gas defrosting would be more favourable.

At 35°C: COP is 3 - 9% higher with reverse cycle in comparison to hot gas system.

At 55°C: COP is 3 - 6% higher with hot gas defrosting than with reverse cycle.

The reason is the leakage at higher pressure ratios between the discharge and suction side within the reverse valve.

TABLE I

Coefficient of Performance for Various Defrosting Systems:
Reverse Cycle, Hot Gas and Hot Gas with Resistance Heating

	Coefficient of Performance I Reverse Cycle Defrost. COP	II Hot Gas Defrosting COP	III Hot Gas Defr. with Resistance Heating /COP	COP-Difference in % between Reverse Cycle =100% and Hot Gas Defrost. System II	System III
Air +7 / Water 35°C	3.00	2.85	2.89	-5.0 %	-3.7 %
A. +2 / W. 35°C	2.70	2.47	2.46	-8.5 %	-8.9 %
A. -10 / W. 35°C	2.06	1.99	1.96	-3.4 %	-4.9 %
A. +2 / W. 55°C	1.96	2.03	2.02	+3.6 %	+3.1 %
A. -10 / W. 55°C	1.40	1.48	1.48	+5.7 %	+5.7 %

6. COMPARISON OF RELATIVE DEFROST TIMES FOR EIGHT VARIOUS HEAT PUMPS

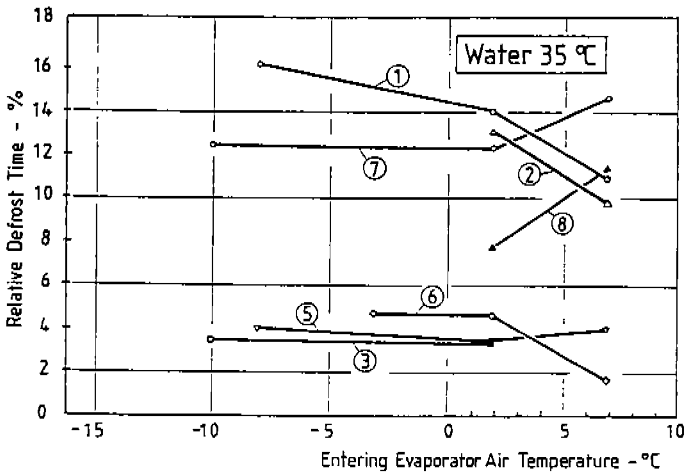

Figure 10

Relative Defrost Time versus Entering Evaporator Air Temperature;

Leaving Heat Pump Water Temperature 35°C

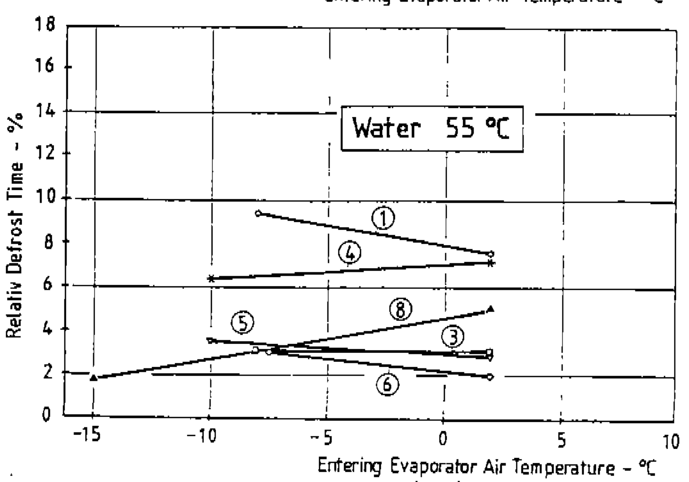

Figure 11

Relative Defrost Time versus Entering Evaporator Air Temperature;

Leaving Heat Pump Water Temperature 55°C

Fig. 10 shows the results of measured relative defrost time at 35°C and Fig.11 at 55°C leaving water temperatures and entering air temperatures at +7 to -15°C with eight various heat pumps. Generally, defrost times at 35°C are longer than at 55°C, partly near the DIN 8900-15% limit /1/: heat pump "1" at -8°C. The average relative defrost time at 35°C is about 9%, at 55°C about 5%.

7. CONCLUSION

Heat pumps in Middle Europe are built only for heating and not for cooling, therefore a reverse cycle is not necessary. To defrost the evaporator, is recommended to use a hot gas bypass system. An additional resistance heater should be used to avoid too long of defrosting time. Some measurement of results have been described.

REFERENCES

/1/ DIN 8900, Teil (part) 4: Prüfung von elektrisch angetriebenen Luft/Wasser-Heizwärmepumpen (Tests of electric driven air/water-heat pumps according: German Industrial Standard 8900), June 1982

/2/ Experimental and theoretical investigations on heat pumps: DIN-tests, measurements in industry commission and examinations paper from A.Barth, H.Gramlich, A.Herzog, B.Kusmitsch a.o.

ACKNOWLEDGMENT

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ABSTRACT

About 30 electric driven heat pumps have been measured by DIN-Test-Institut at Fachhochschule Karlsruhe between 1980 to 1985. Some special investigations of evaporator defrosting have been made, too. Energy consumption,relative defrosting time, coefficient of performance among other things have been compared at different defrosting systems for several heat pumps.

In those countries where heating and cooling is desirable only reverse cycle defrosting is required. In Middle Europe cooling is not necessary, therefore hot gas defrosting can be used instead of reverse cycle. However, defrosting time of larger heat pumps (more than 10 - 20 kW) increases, so that DIN-Test cannot passed. For these heat pumps a more effective defrosting system has been suggested. Measurements with this system have been made and the results compared with other systems.

RESUME

Environ 30 pompes à chaleur électriques ont été testées entre 1980 et 1985 à l'Institut de test-DIN de Fachhochschule Karlsruhe. Des recherches spéciales ont aussi été faites sur le dégivrage des vaporisateurs. La consommation d'énergie le temps de dégivrage et le coefficient de rendement, entre autres choses, ont été comparés sur divers systèmes de dégivrage de plusieurs pompes à chaleur.

Dans les pays où l'on utilise des pompes à chaleur à la fois pour chauffer et pour refroidir, un système de dégivrage par inversion de cycle est suffisant. En Europe Centrale, le refroidissement n'est pas nécessaire, on peut donc utiliser du gaz chaud pour le dégivrage, au liev du systeme d'inversion de cycle. Toutefois, le temps de dégivrage de pompes à chaleur plus grosses (Plus de 10, voire 20 KW) augmente, si bien que de telles pompes ne répondent pas aux critères définis por le test DIN. Pour ces pompes à chaleur, on a pensé à un système de dêgivrage plus efficace. Des mesures ont été faites avec ce système et les résultats comparés avec d'autres systèmes.