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Investigation the refrigeration cycle of heat pump “water-water”

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Investigation the refrigeration cycle of heat pump “water-water”: *In this work the refrigeration cycle of an existing laboratory heat pump installation "water-water" has been investigated. By measuring the thermodynamic parameters of the refrigerant the real work cycle of heat pump has been built in different regimes of operation. The refrigeration power, condenser power and coefficient of performance have been calculated.*

Key words: *Refrigeration cycle, heat pump “water-water”, refrigeration power, condenser power, coefficient of performance.*

INTRODUCTION

The laboratory installation simulates the work of heat pump system for heating and cooling buildings by the heat pump works with a heat source - water from an underground water source (well or river) [1, 2, 5, 6, 7]. When the installation works in "heating" regime, the heat pump heat exchanger in the outer circle is an evaporator, and that the inner circle is a condenser. In the evaporator the refrigerant takes heat energy from the cold water, circulating in the outer circle, and in the condenser the refrigerant gives heat energy to the hot water, circulating in the inner circle. The convector gives heat energy to the ambient air in the room and increases its temperature. In “heating” working regime the water in the buffer represents the heat source, from which the installation draws the heat energy, required to the heat pump work. In order the laboratory installation works for a long time without reducing considerably the temperature of the buffer water (the laboratory installation simulates work of a heat pump installation, drawing heat energy from an underground water source), it is necessary to achieve a stratification of the water in the buffer. Since, as the laboratory in which is located the installation has a relatively large volume, and because, that experiments haven’t been very long, it has been assumed that the ambient temperature remains constant within the respective experiment [1, 5, 6].

One of the ways to determination of the heat pump parameters is by its refrigeration cycle.

The purpose of the work is building of the real work refrigeration cycle of the heat pump in different regimes of operation by measuring the thermodynamic parameters of the refrigerant, and determination of the basic heat pump parameters on the base of the refrigeration cycle.

PROCEDURE

<u>1. Principal scheme and description of the laboratory heat pump installation</u>

The principal scheme of the laboratory installation is shown on Figure 1.

The laboratory installation allows carry out a number of laboratory and investigation activities. The installation simulates the work of heat pump system for heating and cooling buildings by the heat pump works with a heat source - water from an underground water source (well or river) [1, 2, 3, 7].

The heat pump is water-water type, brand CEAT, model Aurea 20 and works with refrigerant R407C.

For measure the temperatures of the regrigerant in the refrigeration heat pump cycle a digital thermoelectric thermometer "Thermologger K204" has been used. For continuous monitoring of the measured temperatures in a certain interval of time, graphical and tabular visualization of obtained results, the computer program "TestLink SE-309" has been used.

For measure the pressures of evaporation and condensation of the refrigerant a pressure measuring block with two manometers has been used.

For build the refrigeration heat pump cycle in "lgp-h" diagram the software COOL PACK has been used.

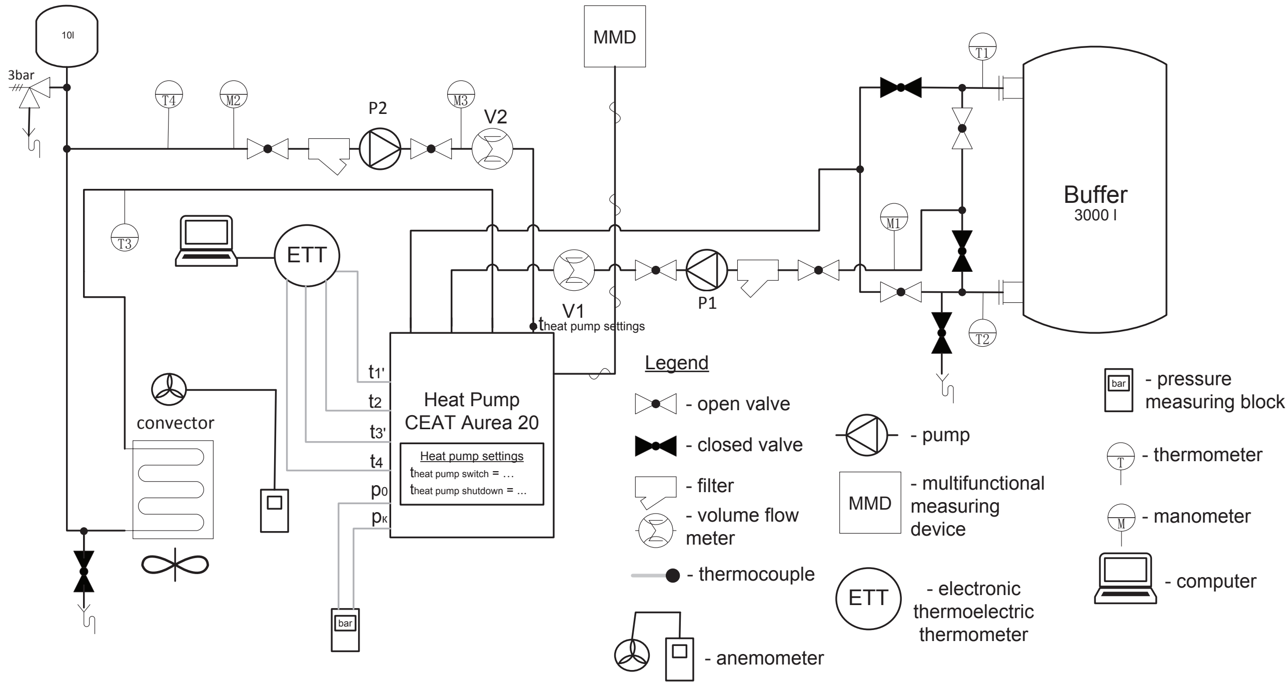


Fig.1. Principal scheme of the laboratory installation

2. Theoretical refrigeration heat pump cycle

The theoretical refrigeration heat pump cycle in "lgp-h" diagram of the respective refrigerant is shown on Figure 2 [4].

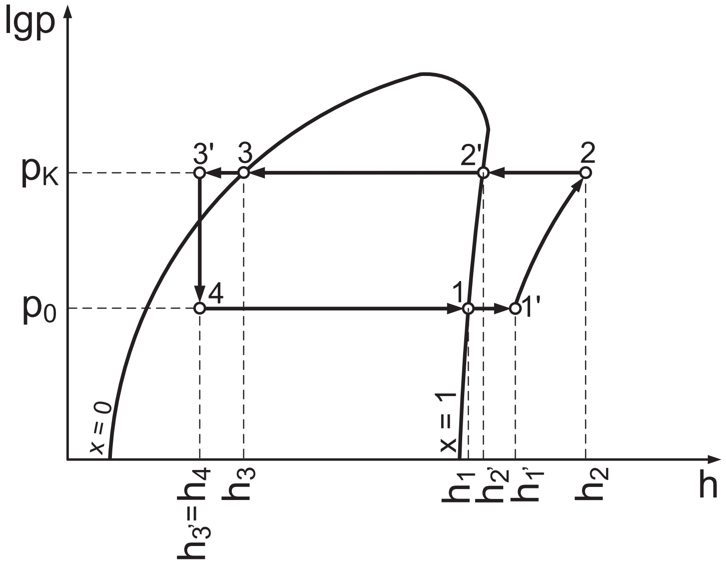


Fig.2. Theoretical refrigeration heat pump cycle

The evaporation pressure is p_0 and the condensation pressure is p_k.

The processes in the cycle are as follows:

$1\text{-}1'$ – isobaric process of preheating of the refrigerant vapor in the regenerative heat exchanger;

$1'\text{-}2$ – adiabatic (isoentropy) process of compression of the refrigerant vapor in the compressor;

2-2' – isobaric process of cooling of the refrigerant vapor in the condenser;

2'-3 – isobaric-isothermal process of condensation of the refrigerant in the condenser;

3-3' - isobaric process of precooling of the refrigerant liquid in the regenerative heat exchanger;

3'-4 - isoenthalpy process of throttling of the refrigerant in the throttling valve;

4-1 - isobaric-isothermal process of evaporation of the refrigerant in the evaporator.

The measured temperatures are: $t_{1'}$, t_2, $t_{3'}$ and t_4. Also the pressures p_0 and $p_к$ have been measured.

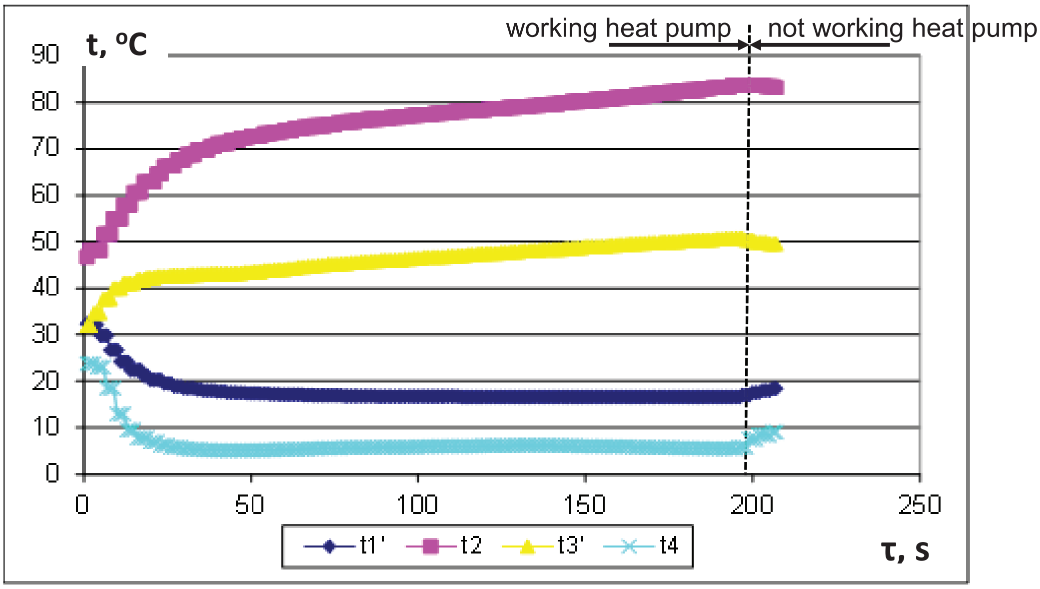
3. Experimental results

The input parameters of the installation of the investigated regimes are shown in Table 1, where w_2 is the velocity of the airflow in the narrowest section of the outer surface of the convector.

Table 1. Input parameters in the investigated regimes

Regime	Settings of the heat pump		Setting of the convector's fan	Volume water flow in the inner installation circle	Volume water flow in the outer installation circle	Temperature of the ambient air
	Temperature of heat pump switch	Temperature of heat pump shutdown				
A	42 °C	45 °C	degree "HIGH", w_2 = 5.06 m/s	0.41 m³/h	1.48 m³/h	13 °C
B	37 °C	40 °C				
C	32 °C	35 °C				
D	27 °C	30 °C				

Figure 3 shows the change of the measured temperatures within one working cycle of heat pump.



$t_{heat\ pump\ switch}$ = 42 °C $t_{heat\ pump\ swutdown}$ = 45 °C

Fig.3. Change of the measured temperatures in time

It can be seen from Figure 3 that when the heat pump switch there is a period of sharp change in the temperatures. After this period they change more gradually.

The build real heat pump refrigeration cycles in "lgp-h" diagram of R407C using the software COOL PACK are shown on Figure 4. For building of the cycles the values of the measured pressures (p_0 and p_K) and measured temperatures ($t_{1'}$, t_2, $t_{3'}$ and t_4) at the moment of heat pump shutdown have been used.

It can be seen from Figure 4 that with lowering the temperatures of heat pump switch and shutdown the refrigeration cycle moves down.

The reported data from the refrigeration cycles and the calculated parameters of heat pump are shown in Table 2 and Table 3.

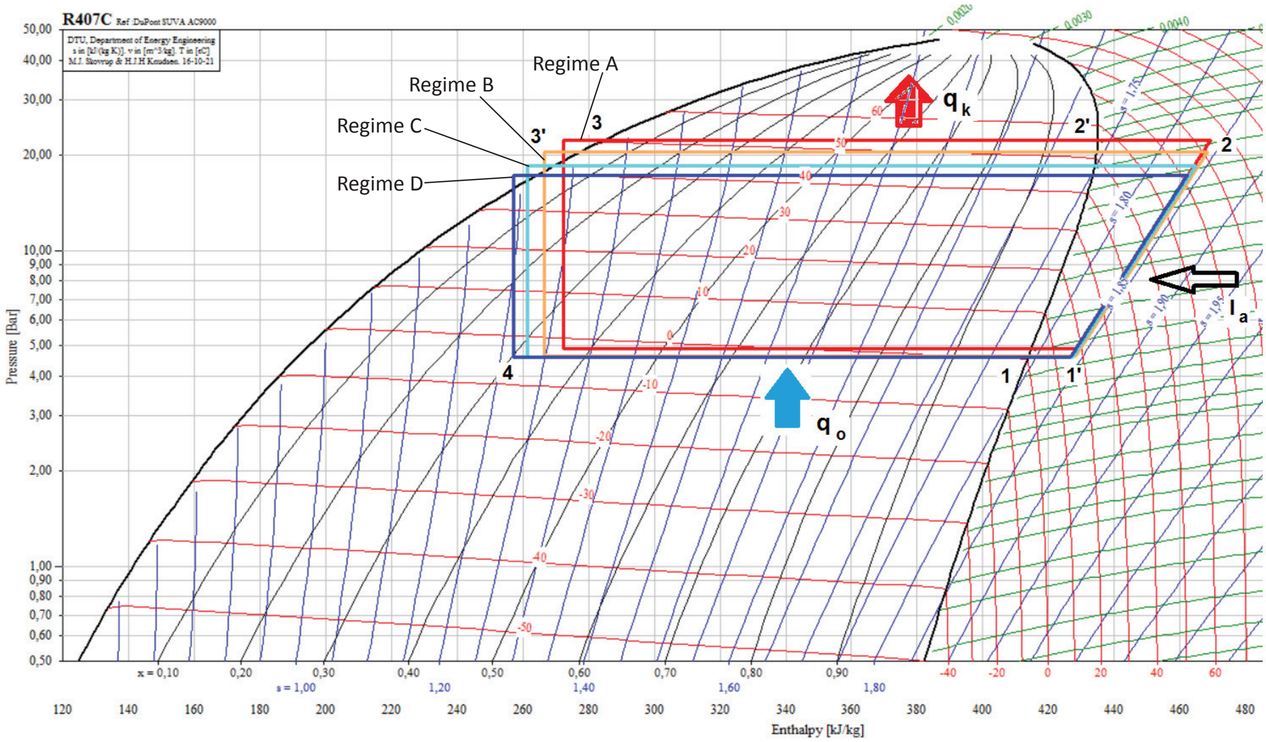


Fig.4. Real heat pump refrigeration cycles

Table 2. Reported pressures and temperatures, calculated temperature differences

$t_{heat\ pump\ shutdown}$	p_0	p_k	t_0	t_k	t_1	$t_{1'}$	t_2	$t_{2'}$	t_3	$t_{3'}$	t_4	$\Delta t_{superheat}$	$\Delta t_{subcooling}$
°C	bar	bar	°C	°C	°C	°C	°C	°C	°C	°C	°C	°K	°K
45	4.9	22.5	2.17	55.4	2	18.4	83.1	55.4	50.7	49.5	9	16.4	5.9
40	4.65	20.6	0.65	51.8	0.73	17.6	81.2	51.4	46.6	46.3	6.5	16.87	5.5
35	4.6	18.6	0.34	47.7	0.62	16.5	76.3	47.7	42.4	43.8	4.3	15.88	3.9
30	4.6	17.4	0.34	45.1	0.62	15.9	70.9	45.3	39.6	39.9	4.1	15.28	5.2

Table 2. Reported enthalpies and specific volumes, calculated heat pump parameters

$t_{heat\ pump\ shutdown}$	h_1	$h_{1'}$	h_2	$h_{2'}$	h_3	$h_{3'}$	h_4	v_1	$v_{1'}$	v_2	q_o	l_a	q_k	COP
°C	kJ/kg	kJ/kg	kJ/kg	kJ/kg	kJ/kg	kJ/kg	kJ/kg	m^3/kg	m^3/kg	m^3/kg	kJ/kg	kJ/kg	kJ/kg	-
45	414.7	428.6	467.5	434.8	284.9	272.5	272.5	0.0492	0.053	0.0191	142.2	38.9	182.6	4.69
40	414.2	428.3	468.1	434.7	277.5	266.5	266.5	0.0517	0.056	0.0133	147.7	39.8	190.6	4.79
35	413.8	427.4	464.8	434	269.2	261.4	261.4	0.0524	0.0564	0.0147	152.4	37.4	195.6	5.23
30	413.8	426.9	462	433.4	264.2	257.2	257.2	0.0524	0.0561	0.0157	156.6	35.1	197.8	5.64

The graphical dependence between the heat pump coefficient of performance (COP) and heat pump shutdown temperature (the temperature of the cooling water of heat pump condenser) is shown on Figure 5.

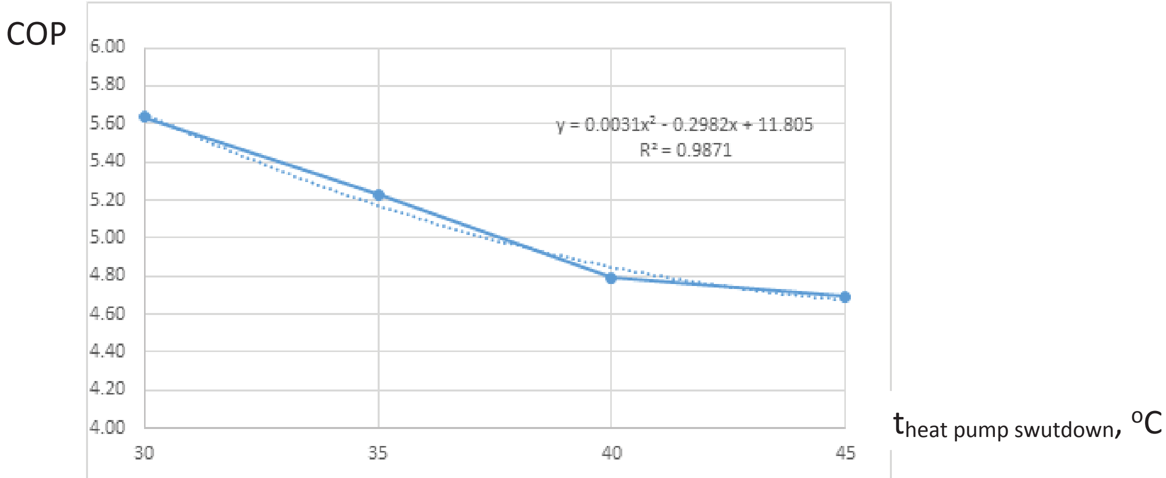


Fig.5. Graphical dependence between the heat pump coefficient of performance and heat pump shutdown temperature

CONCLUSION

Changing the operating regime of heat pump (from regime A to regime D) it has been observed the following change of heat pump parameters:

1. By lowering the operating temperature of heat pump, the specific cold production q_0 increases as a result of shortening the process of throttling, with 11.6 %.

2. Reducing the operating temperature increases the thermal power $q_к$ of the condenser with 15.2 %.

3. It is obvious that by reducing the operating temperature COP increases and it has been found that the increase is approximately 16.7 %.

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This paper has been reviewed.