INVESTIGATION THE PARAMETERS OF REVERSIBLE LABORATORY HEAT PUMP INSTALLATION IN "COOLING" WORKING REGIME

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The purpose of this work is to investigate the influence of the velocity of airflow wrapping the outer surface of the convector's heat exchange apparatus on some of the parameters of laboratory reversible heat pump installation working in "cooling" regime. For this purpose the average values of the heat convection coefficients, heat transfer coefficient, convector's heat flow, coefficient of performance, duration of heat pump work, have been determined at the different values of airflow velocity. When the installation works in "cooling" regime, the heat pump heat exchanger in the outer circle is a condenser, and that the inner circle is an evaporator. In the evaporator the refrigerant takes heat energy from the cold water, circulating in the inner circle, and in the condenser the refrigerant gives heat energy to the hot water, circulating in the outer circle. The convector takes heat energy from the ambient air in the room and decreases its temperature. In "cooling" working regime the water in the buffer represents the low temperature heat source, to which the installation gives heat energy by the heat pump condenser, required to the heat pump work. In order the laboratory installation works for a long time without increasing considerably the temperature of the buffer water (the laboratory installation simulates work of a heat pump installation, giving heat energy to an underground water source), it is necessary to achieve a stratification of the water in the buffer. Nowadays, improving the quality of life requires thermal comfort and air quality accommodation, regardless of external conditions. To achieve these goals using heat pump air conditioning systems.

Keywords: *"cooling" working regime, airflow velocity, heat convection coefficients, heat transfer coefficient, convector's heat flow, coefficient of performance, duration of working heat pump.*

ИССЛЕДОВАНИЕ ПАРАМЕТРОВ ВОЗВРАТНО-ПОСТУПАТЕЛЬНОЙ ЛАБОРАТОРНОЙ УСТАНОВКИ ТЕПЛОВОГО НАСОСА, РАБОТАЮЩЕЙ В РЕЖИМЕ «ОХЛАЖДЕНИЕ»

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Цель данной работы является изучение влияния скорости потока воздуха обертывания наружной поверхности теплообменных аппаратов конвектора, на некоторые параметры возвратно-поступательной лабораторной установки теплового насоса, работающей в режиме "охлаждение". Для этого, средние значения коэффициента тепловой конвекции, коэффициента теплопередачи, поток теплообмена между воздухом и окружающей средой конвектора, коэффициент трансформации, продолжительности работы теплового насоса, были определены на различных значениях скорости воздушного потока. При эксплуатации установки в режиме "охлаждение", теплообменник теплового насоса во внешнем круге представляет конденсатор, внутренний круг – испаритель. В испаритель, хладагент принимает тепло от циркулирующей во внутренний круге холодной воды, в то время как хладагент конденсатор дает приготовление горячей воды, циркулирующей во внешний круге. Конвектор берет тепло из воздуха в комнате и уменьшается его температуру. При работе установки в режиме "охлаждение", вода является источником тепла, который дается при работе теплового насоса. В лабораторной установке для того, чтобы работать в течение длительного времени без значительного повышения температуры воды в буферной (моделируемой эксплуатации установки теплового насоса, что дает тепло с источника подземных вод), это необходимо для достижения стратификацию воды в буфере. В настоящее время, улучшение качества жизни требует теплового комфорта и качества воздуха, независимо от внешних условий. Для достижения этих целей с помощью систем кондиционирования воздуха с системами тепловым насосом.

Ключевые слова: *режим "охлаждение", скорость потока воздуха, коэффициент тепловой конвекции, коэффициент теплопередачи, тепловой поток теплообмена между воздухом и окружающей средой конвектора, коэффициент трансформации, продолжительность работы теплового насоса.*

Introduction

In this article the influence of the set operating parameters of water-air convector in laboratory reversible heat pump installation, working in "cooling" regime, on some of the installation parameters has been investigated. For this purpose, the next parameters have been determined at different values of the airflow velocity, generated by the convector's fan: the average values of the heat convection coefficients of the convector; average value of the heat transfer coefficient of the convector; average value of the heat flow, exchanged between the ambient air and the convector; average value of the heat pump coefficient of performance; average value of the heat pump work duration.

Objectives

The purpose of this work is to investigate the influence of the velocity of airflow, wrapping the outer surface of the convector's heat exchange apparatus, on some of the parameters of laboratory reversible heat pump installation, working in "cooling" regime.

Procedure

1. Principal schemes and description of the laboratory heat pump installation in "cooling" working regime

The principal scheme of the laboratory installation is shown on Figure 1 [1, 5, 6].

The heat pump is water-water type, brand CEAT, model Aurea 20.

The convector is brand BUMYANG, model FVC20MLL2.

When the installation works in "cooling" regime, the heat pump heat exchanger in the outer circle is a condenser, and that the inner circle is an evaporator. In the evaporator the refrigerant takes heat energy from the cold water, circulating in the inner circle, and in the condenser the refrigerant gives heat energy to the hot water, circulating in the outer circle. The convector takes heat energy from the ambient air in the room and decreases its temperature [1, 2, 3, 5, 6].

In "cooling" working regime the water in the buffer represents the low temperature heat source, to which the installation gives heat energy by the heat pump condenser, required to the heat pump work. In order the laboratory installation works for a long time without increasing considerably the temperature of the buffer water (the laboratory installation simulates work of a heat pump installation, giving heat energy to an underground water source), it is necessary to achieve a stratification of the water in the buffer. Therefore, in "cooling" working regime the principal scheme shown on Figure 2 has been used.

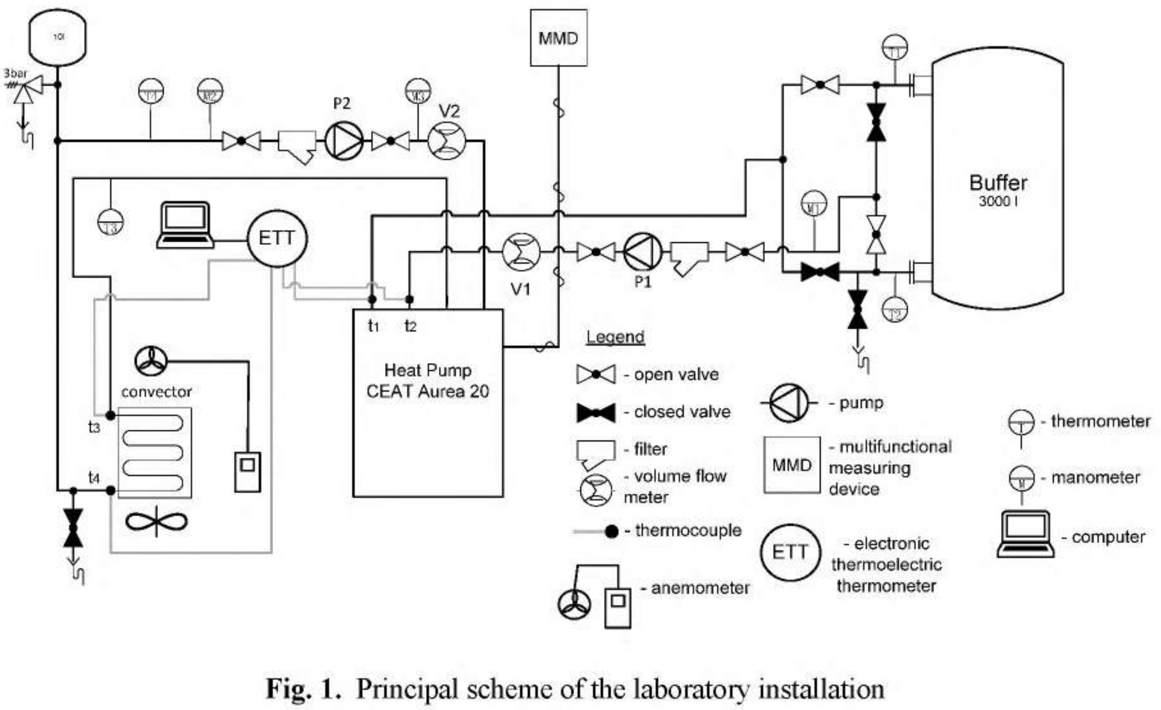

Fig. 1. Principal scheme of the laboratory installation

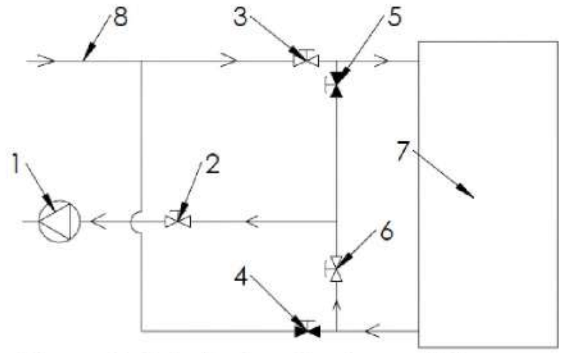

Figure 2. Principal work scheme of the outer installation circle

The positions of the elements on Figure 2 are as follows: 1 - circulation pump; 2, 3 and 6 - open valves; 4 and 5 - closed valves; 7 – water buffer; 8 – from the heat pump.

2. Input parameters of the installation of the investigated "cooling" working regime

Table 1. Input parameters in "cooling" working regime

Setting of the convector's fan	Settings of the heat pump	Setting of the circulating pump in the inner installation circle	Setting of the circulating pump in the outer installation circle	Temperature of the ambient air	Velocity of the airflow in the narrowest section of the outer surface of the heat exchange apparatus
degree "LOW"	temperature of heat pump switch t_4 = 10,7 °C; temperature of heat pump shutdown t_4 = 7,2 °C	$\dot{V}_1 = 0{,}000255\ m^3/s$	$\dot{V}_2 = 0{,}000319\ m^3/s$	$t_{ambient\ air} = 23{,}3\ ^{\circ}C$	$w_2 = 0{,}92\ m/s$
degree "MID"				$t_{ambient\ air} = 23{,}3\ ^{\circ}C$	$w_2 = 2{,}51\ m/s$
degree "HIGH"				$t_{ambient\ air} = 23{,}3\ ^{\circ}C$	$w_2 = 5{,}06\ m/s$

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 $t_{ambient\ air}$ remains constant within the respective experiment.

The average temperature of the water in the buffer remains approximately equal to $t_{ambient\ air}$, within the respective experiment.

Results and discussion

1. Investigation the influence of the airflow velocity w_2 on the heat convection coefficient α_1 between the water in the convector tubes and their inner surface

The heat convection coefficient α_1 has been determined by a criterion equation [1, 4, 5, 6].

The change of the coefficient α_1 when there is a change of the velocity w_2 of the airflow in the narrowest section of the outer surface of the heat exchange apparatus, is shown on Figure 3.

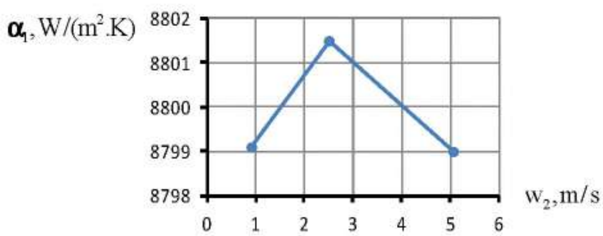

Fig. 3. Graphical dependence between α_1 and w_2

The heat convection coefficient α_1 changes in many small limits. For the change of airflow velocity from 2,51 to 5,06 m/s, it can be made the conclusion that the increase of the heat flow $\dot{Q}_{con}$ and the decrease of the temperature difference between the temperature of the inner tubes surface and the water temperature in the central cross sectional area of tubes, have been compensated. On the other hand, according to the method for determination the heat convection coefficient by a criterion equation, it can be made the conclusion that due to the small change of the average water temperature in the convector tubes, there is a small change of the water physical parameters and hence of the criterions Re and Nu .

2. Investigation the influence of the airflow velocity w_2 on the heat convection coefficient α_2 between the outer surface of the convector and the airflow

The heat convection coefficient α_2 has been determined by a criterion equation [1, 4, 5, 6].

The change of the coefficient α_2 when there is a change of the airflow velocity w_2, is shown on Figure 4.

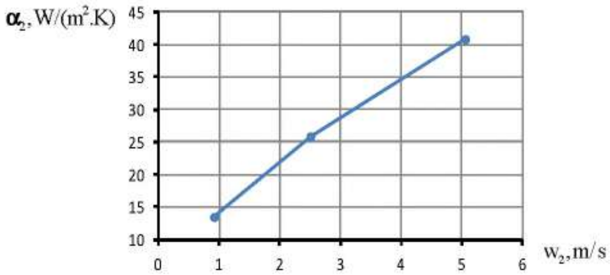

Figure 4. Graphical dependence between α_2 and w_2

The reason for the increase of the heat convection coefficient α_2 is the significant increase of the criterion of Reynolds with the increase of the airflow velocity. On the other hand, the air temperature in the convector increases and its kinematic viscosity increases too, but it has less influence.

3. Investigation the influence of the airflow velocity w_2 on the heat transfer coefficient U between the water in the convector tubes and the airflow, wrapping the convector's outer surface

The heat transfer coefficient U has been determined by the equation for single layer flat wall, ignoring the thermal resistance of the tubes and ribs [1, 4, 5, 6].

The change of the coefficient U when there is a change of the airflow velocity w_2, is shown on Figure 5.

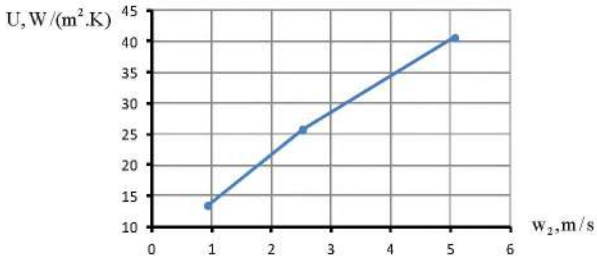

Figure 5. Graphical dependence between U and w_2

A reason for the increase of the heat transfer coefficient U by increasing the airflow velocity w_2 is the increase of the external heat convection coefficient α_2, which has a much greater influence on U than the reducing internal heat transfer coefficient α_1. As can be seen, the values of U have been almost similar to those of α_2 [the differences are of the order of tenths and hundredths of 1 W/(m^2.K)].

4. Investigation the influence of the airflow velocity w_2 on the heat flow $\dot{Q}_{eva}$, exchanged in the inner installation circle (in the heat pump evaporator and by the convector)

The heat flow $\dot{Q}_{eva}$ has been determined by the basic calorimetric equation [1].

The change of the heat flow $\dot{Q}_{eva}$ when there is a change of the airflow velocity w_2, is shown on Figure 6.

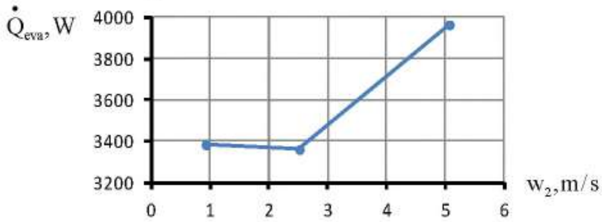

Figure 6. Graphical dependence between $\dot{Q}_{con}$ and w_2

The data for the first two velocities are comparatively close.

For the increase of the airflow velocity from 2,51 to 5,06 m/s, the change of $\dot{Q}_{eva}$ can be explained in the following ways:

► From the perspective of the basic calorimetric equation, the heat flow in the convector has increased by increasing the airflow velocity, because the temperature difference "t_3(convector output) - t_4(convector intput)" increases. On the other hand, the water temperature in the inner circle almost not changes.

► In terms of the "Newton – Rikhman" law by the process of heat convection between the inner surface of tubes and the water, larger influence turns the increase of the temperature difference "(average temperature of the inner tubes surface) - (average water temperature in the central section of tubes)" than the change of the internal heat convection coefficient α_1.

► From the perspective of the "Newton – Rikhman" law by the process of heat convection between the airflow and the outer surface of heat exchange apparatus, an influence turns the significant increase of the outer heat convection coefficient α_2.

► In terms of the heat transfer process in the convector, an influence turns the significant increase of the heat transfer coefficient U.

<u>5. Investigation the influence of the airflow velocity w_2 on the average coefficient of performance $COP|_S$, in "cooling" working regime (summer regime)</u>

The coefficient of performance $COP|_S$ has been determined on the base of the heat flow $\dot{Q}_{eva}$, exchanged between the ambient air and the convector, and the consumed by the heat pump electric power [1, 3, 7].

The change of the coefficient of performance $COP|_S$ when there is a change of the airflow velocity w_2, is shown on Figure 7.

The data for the first two velocities are comparatively close.

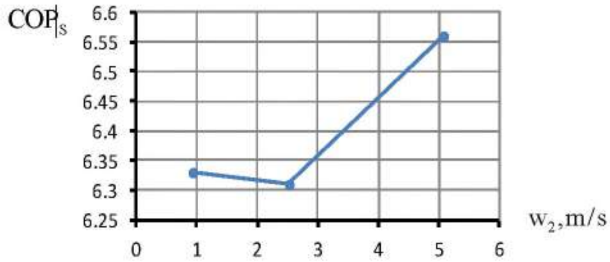

Figure 7. Graphical dependence between $COP|_S$ and w_2

For the increase of the airflow velocity from 2,51 to 5,06 m/s, the coefficient of performance $COP|_S$ increases, because larger influence on it turns the increase of the heat flow through the convector than the change of the average electrical power, consumed by the heat pump.

<u>6. Investigation the influence of the airflow velocity w_2 on the average duration of heat pump work $\tau_{working\ heat\ pump}$</u>

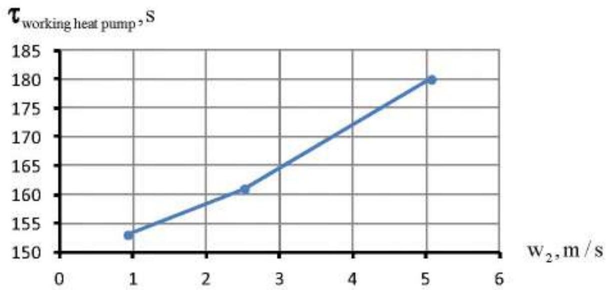

Figure 8. Graphical dependence between $\tau_{working\ heat\ pump}$ and w_2

The data for the first two velocities are comparatively close.

For the increase of the airflow velocity from 2,51 to 5,06 m/s, the average duration of heat pump work increases, because at a bigger airflow velocity, the convector gives a large amount of heat to the water in the tubes (the heat flow $\dot{Q}_{eva}$) and the heat pump requires more time to reach its temperature of shutdown (t_4).

Conclusion

The change of the airflow velocity w_2 in the narrowest section of the outer surface of the convector's heat exchange apparatus, leads to a significant rate of change of the external heat convection coefficient α_2 and respectively of the heat transfer coefficient U, while the internal heat convection coefficient α_1 almost not changes.

A feature of the heat convection process between the convector's outer surface and the wrapped it airflow is that if the temperature of this surface reaches the dew point, there will be obtained a condensation process of a water vapor on the surface. Therefore, when there is a determination of the coefficient of heat convection α_2, it is necessary to take into account the process of heat convection at condensation.

The relatively short periods of work of the heat pump due to lack of a buffer vessel in the inner circle of the installation, as well as the relatively low heat power of the convector, compared with the power of the heat pump.

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