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EFFECT OF PRESSURE LOSS ON ENERGY EFFICIENCY OF STEAM-COMPRESSION HEAT TRANSFORMERS

It is investigated how pressure losses in the equipment elements from the refrigerant side influence on the energy characteristics of the heat transformer. The results of cycle parameters with different refrigerants use are received. It is revealed that the irreversible loss cause negative impact on the regime parameters and should be considered in the design and selection of equipment for the heat transformers.

Introduction. Heat transformer is a complex technical system. The criterion for possible use is energy efficiency, which is influenced by the work of the main equipment and components connecting it to one device. In the calculation methods the role of these elements is often not taken into account. Usually the problem is solved at the empirical level.

Available guidelines [1, 2] regarding limiting the pressure loss of the refrigerant in the evaporator and condenser of heat transformer is not a sufficient condition for the design of the optimal device, because it does not include the impact of specific conditions.

In contrast to the well-known publications [1–3], this paper deals with a numerical study of the quantitative impact of pressure loss in parts of the equipment circuit due to friction and local resistance, on the energy characteristics of the transformer heat.

Subject and methods. It is studied the cooling-heating unit used to cool the fresh milk with further utilization of heat for industrial needs. Fig. 1 shows the scheme.

The device runs in the transient regime which is determined by the evaporator operations. The device is made in the form of displacement stagnant heat exchanger. The evaporator is filled with 1,000 l of refrigerated milk at 35°C. To intensify the process milk is stirred with mixer. Heat rejection from the milk is used in the capacitor to heat water used for industrial needs.

In the installation concerned the capacitor is a single-thread coil pipe heat exchanger with displacer. Pipe coil (18×1.5 mm) is made of steel, coil diameter is 0.242 m, the number of coils – 40, pitch ratio – 1.1. Diagram of flow media in the capacitor is counterflow and transversal. Condensation point is maintained at 50°C. The water temperature at the inlet to the condenser was 5°C. During the operation of the equipment one must be carried out the boundary requirement for milk cooling time – no more than 3 h to a temperature of 4°C. As a working substance refrigerant R22 was used.

An analysis in this paper was carried out using a complex method for calculating vapor-compression heat transformers. This method involves the combined calculation for loop and heat exchanger loop subject to the irreversible losses in the loop. The method of analysis is implemented as a software package in Fortran [4, 5].

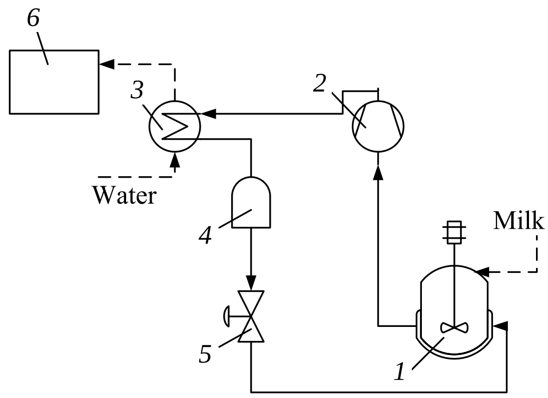

Fig. 1. Refrigerating-heating unit:
1 – evaporator; *2* – compressor; *3* – capacitor;
4 – receiver; *5* – thermostatic expansion valve;
6 – accumulator tank

Results of computational experiment. It was studied the effect of the pressure loss of the refrigerant due to friction and local resistance on the efficiency of the installation. *Ph*-diagrams (Figs. 2, 3) give the parameters of thermodynamic cycles, corresponding to the initial and final operating modes at a specific time 30 and 130 min.

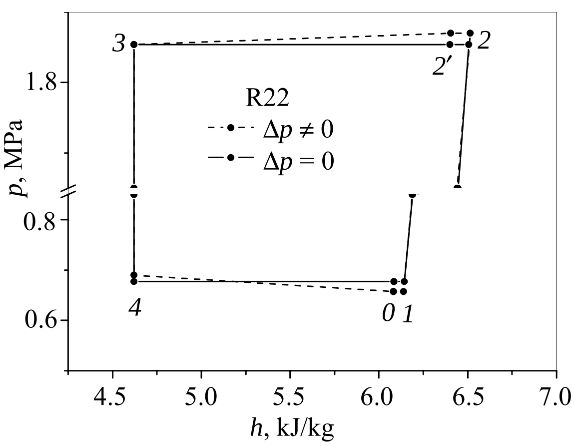

Fig. 2. Cycle parameters at the beginning of installation operation (in 30 min):
1–2 (*2*′) – irreversible (reversible) compression in the compressor; *2–3* – the heat rejection in the condenser; *3–4* – throttling; *4–0–1* – boiling and overheating in the evaporator

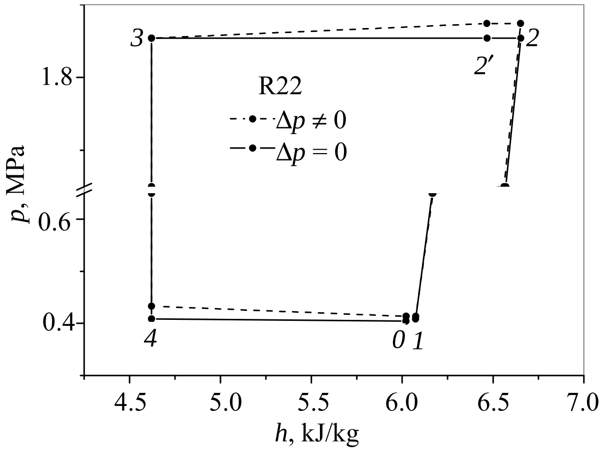

Fig. 3. Cycle parameters at the end of the installation operations (in 130 min). The symbols are the same

The comparison of the cycles shows that as the time of installation operation increases, evaporator pressure decreases; while in the condenser, it remains almost constant. This increases the compression ratio of the compressor $\sigma = p_2 / p_1$, which for the cases above increased from 3.07 to 4.47. Expended specific work on the compressor gear has increased by 1.5 times. This results in the reduction of cooling and heating capacity for any fixed mode.

Fig. 4 shows the change in the refrigerating capacity of the installation. The pressure loss reduces the refrigerating capacity by 5% on average. Two modes of installation operation are also shown. They correspond to 30 and 130 min. The power consumed by the compressor and the value of coefficient of performance are given for them. Apparently that the loss of pressure leads to a reduction of coefficient of performance by 1.02 times. Reduction of the refrigerating capacity results in the decreasing of power on the compressor gear, but the pressure loss has no effect on its change.

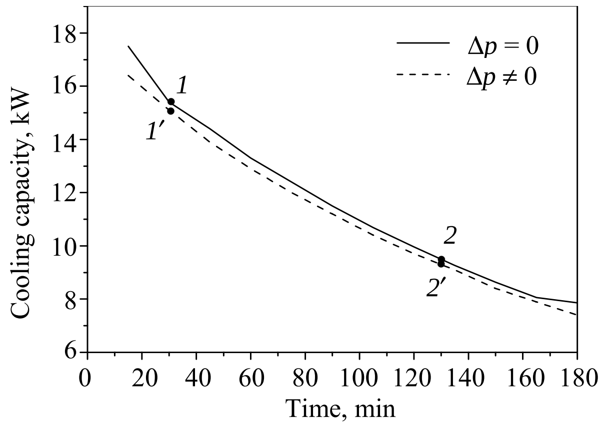

Fig. 4. Changing of the refrigerating capacity of the installation after pressure loss:
$1 - N_{el} = 6.28$ kW, $\varepsilon = 2.5$ (at $\Delta p = 0$);
$1' - N_{el} = 6.19$ kW, $\varepsilon = 2.43$ (at $\Delta p \neq 0$);
$2 - N_{el} = 5.47$ kW, $\varepsilon = 1.74$ (at $\Delta p = 0$);
$2' - N_{el} = 5.43$ kW, $\varepsilon = 1.67$ (at $\Delta p \neq 0$)

In the course of cooling time the temperature of milk reduces (Fig. 5). Under the pressure loss, it has a lower value, which corresponds to the data presented in Fig. 4.

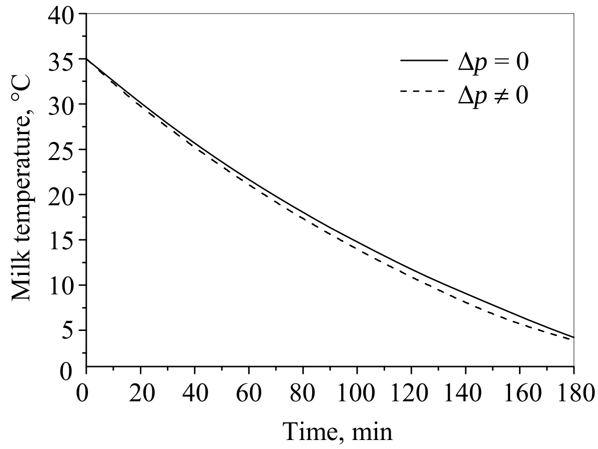

Fig. 5. Changing the temperature of milk because of pressure loss

Changing of the installation refrigerating capacity has a character similar to that shown in Fig. 4 for cooling. Pressure losses lead to lower refrigerating capacity by 3.5–5.0%.

Refrigerants R134a and R134a-R152a (80% R134a and 20% R152a) are considered as alternative working substances for refrigerating heating installation. Thermodynamic cycles for these refrigerants are shown in Fig. 6, 7.

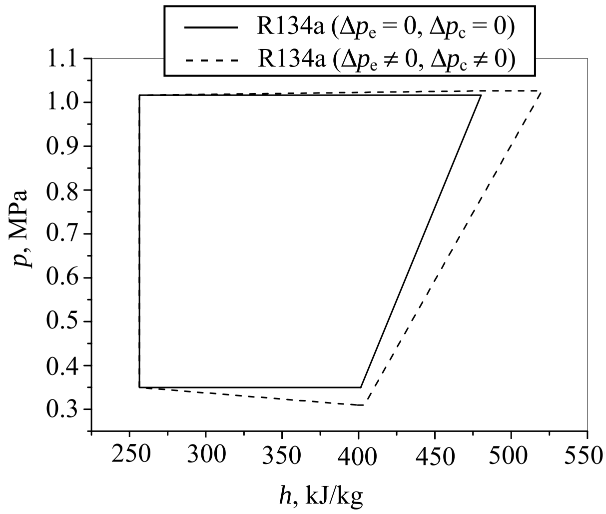

Fig. 6. Cycle parameters of refrigerant R134a

Under the pressure loss, real cycles of working substances considerably differ from ideal, compared with the cycles for the refrigerant R22 (Fig. 2, 3).

There is a considerable pressure loss at the inlet to the compressor and the increase of the specific work. The specific work expended on the refrigerant compression increases by ~1.5. This is due to the properties of these refrigerants, in particular, a lower value of the density.

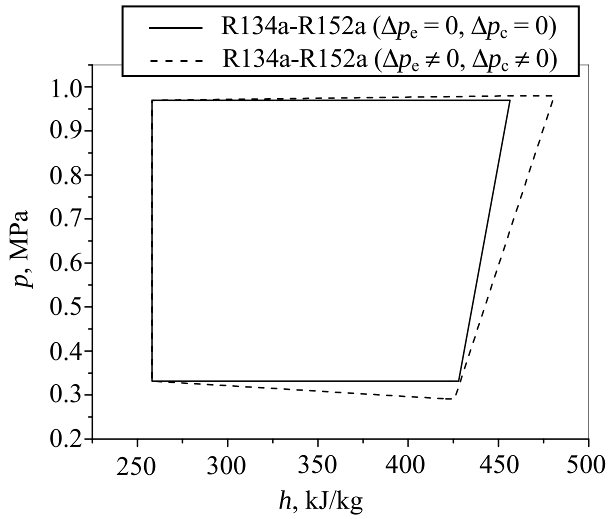

Fig. 7. Cycle parameters of refrigerant R134a-R152a

Conclusion. Thus, the pressure loss leads to increased consumption of energy on the compressor gear and reduction of the installation energy efficiency. Consequently, they must be considered in the design and selection of equipment for heat transformers. Pressure loss saving of the refrigerant in the evaporator and condenser for the considered mode can increase the efficiency of the device up to 5%.

References

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