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ARTICLE

STUDIES WITH THE HEAT PUMP COMPRESSOR AUTO REFRIGERATED

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ABSTRACT

The paper proposed to change the principle of linking the basic elements of TN, replace traditional expensive, overall and metal-plate heat exchanger evaporator and condenser on flexible tubular heat exchangers, compressor placed inside stacked in a circle around the flexible evaporator coils. Ensure thus self-regulated compressor cooling and heat absorption is released from the surface of the compressor during operation. Was made model sample of a new heat pump, conducted his experimental research. Measures the temperature of the compressor modes, evaporator, condenser, and heating and cooling. We studied three options: first, when the compressor is located in the center of the evaporator; Second, when the compressor is located off center, closer to the wall of the evaporator and the third when the compressor is located at the center of the evaporator, but was excluded from the evaporator heat radiation by installing cutoff walls of the cylindrical partition. Experiments have shown that the surface temperature of the walls of the evaporator was 120C, the air around the compressor being located inside the evaporator coil was about 200C. Moreover, with the increase of the compressor temperature, evaporator surface temperature and air temperature around the compressor is reduced. Such a regime confirms compressor cooling effect of the evaporator and a partial absorption of the evaporator heat generated by the compressor.

KEY WORDS
Heat pump, compressor, condenser, evaporator, control

INTRODUCTION

Contamination of the environment, climate change has become a real threat to the planet. The Kyoto Protocol of 1997 and the final of the 21st UN Conference in Paris in 2015 [1] set a goal - to accelerate the transition to a society and economy, consuming little carbon technologies by changing the energy policy and the existing infrastructure. The only way is the gradual replacement of traditional systems with new technologies involving energy balance of renewable energy sources (RES). Kazakhstan actively participates in international programs, organized by the World Exhibition EXPO 2017 on "green" energy [2]. According to forecasts by the year 2030 can be increased to 30% renewable energy share of the world, where one of the leading seats for heat pump technology and heat pumps (HP) [3]. With enormous energy-saving potential, the technology has become a rapidly developing field. Spending 1 kilowatt of electricity to pump drive, get 3-4 kW of heat energy. Annual sales volume VT in the world reached $ 125 billion. The main area of application energy use low-grade energy sources (LGES). The technology does not cause environmental damage, and the potential is huge and LGES renew. These include: solar energy, heat dissipation, which is contained in the ambient air, earth, water. VT are most effective when there is a simultaneous cooling and storage products, air-conditioning air space with the disposal of excess heat cooled products, residential and industrial premises.

Based on this principle of integration of solar energy technology, other LGES [4], [5], [6]. The article suggests the technical and technological solution HP increases technical and economic indicators. In the solution in contrast to known analogs made self-regulating cooling compressor, maintaining its temperature with the heat released from the absorption surface of the compressor during its operation [7]. New technical solutions and internal communications led the study laws HP, which previously no one investigated.

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Currently, the intensity of CO_2 emissions from electricity generation is 0.507 kg CO_2 / kW • h. According to the International Energy Agency (IEA), the figure for 2050 could be reduced to 0.067 kg CO_2 / kW • h due to the rapid growth of renewable energy and improve power generation technologies. It is also known that conventional energy prices are rising and will continue to grow due to the exhaustion of resources [8].

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The only economically and environmentally acceptable alternative must be HP[9]. For comparison, traditional energy give less thermal energy units per unit of energy expended. Heat pumps, on average per year, capable of kWh of electricity consumed to provide up to six kilowatt-hours of thermal energy. This indicator is called the average annual efficiency factor (SPF) [10], [11], [12], [13]. The modular form allows for power to hundreds of MW, with high reliability. Known mega-project - the Stockholm heat pump station with a capacity of 520 MW, which heats 63% of consumers of the capital of Sweden, and the heat source is seawater with an average annual temperature of about + 50° C [14].

Analysis IEA studied the effectiveness of primary energy consumption in the production of electric energy, its influence on the selection using CO2 heat pump as compared with the gas heating[15].

Table1: Comparative indicators of the use of heat pumps and the traditional system with a gas boiler [15].

Technical Equipment		Heat pump SPF=4	Heat pump SPF=6	Gasfired heater
Load (kWh)		100		
Efficiency (a)		4.00	6.00	0.95
Secondary energy use, (kWh)		25	17	105
Primary energy use (kWh) for different power generation efficiency (%) (b)	20%	125	83	105
	30%	83	56	105
	40%	63	42	105
	50%	50	33	105
	60%	42	28	105
CO2 emissions (kg) for different CO2 intensity, (c, d, e) in (kg/kWh)	0.507 (c)	12.7	8.5	—
	0.459 (d)	11.5	7.7	—
	0.067 (e)	1.7	1.1	—
Kr CO_2/m^3	0.208 (f)	—	—	17.1
Heat from ren. energy (kWh)		75	83	—

a) SPF for heat pumps and COP for gas-fired heaters
b) Power generation efficiency including transmission losses
c) CO2 intensity of electricity generation in 2007
d) CO2 intensity of electricity generation in 2050 (IEA ETP 2010 Base)
e) CO2 intensity of electricity generation in 2050 (IEA ETP 2010 Blue)
f) CO2 intensity of liquid natural gas (LNG) in Japan

Two variants were studied heat pump - with CPE to 4 and 6 and with the efficiency of the gas heater 0.95.
The condition of the problem is to provide the consumer 100 conditional units of energy. At the same time, gas heater will consume 105 units of primary energy as 5 units lost.
Heat pumps for these purposes, 25 and 17 consume power units (secondary power), respectively. A necessary amount of primary energy (coal gas) depends on the power generation efficiency (%). For example, if the efficiency of 20% of primary energy consumption of heat pumps with 4 and 6, taking into account the losses in transmission and distribution of electricity, are respectively 125 and 83 units. Gas heater consumes 105. That is, its performance is higher than the first HP, but lower than the second HP. When the efficiency of 30%, both the heat pump, with the indicators 83 and 56 units, superior gas heater. Later, until 2050, it is projected to bring the efficiency of primary energy use to 60%. Then the corresponding primary energy consumption of heat pumps will be reduced to 42 and 28 units[16].

When conditions are predicted taken a corresponding reduction in CO_2 emissions intensity for electricity generation and emissions from the use of a gas heater (table 1, position a, d, e, f). By 2050 projected emissions reduction to 0.459 $kgCO_2$ / kW • h. At the same time for heat pumps, they constitute 11.5 and 7.7 kg. When optimistic forecast $kgCO_2$ 0,067 / kW • h for heat pumps emissions amount to 1.7 and 1.1 kg. While the gas boiler for 17.1 kg.
As can be seen, from an environmental point of view, with all assumptions, heat pumps offer significant advantages. The projected decline over time carbon intensity of electricity production by boilers of new generation further increase the benefits of heat pumps [16]

MATERIALS AND METHODS

The compressors are one of the most important parts of the refrigeration cycle. The compressor compresses the refrigerant that flows into the condenser where it is cooled. It then passes to the expansion valve, evaporates, and finally sucked into the compressor again. Power conditioning refrigeration or air completely depends on the power of the compressor [17].
In the 90s of the last century to drive the compressor, instead of asynchronous motors, brushless DC motors have been used where the permanent magnets are installed around the perimeter of the rotor. Thus, the problem of flexible regulation and control of the engine speed has been solved. Subsequently, their characteristics have been improved by the use of special magnets based on rare earth materials [18][21,22].

The new system of automatic control and management modes of compressors, fans and heat exchangers, depending on the air temperature inside and outside the premises, served as a new impulse for the further development of heat pumps. The most significant results were obtained through the use of scroll compressors

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and inverter control refrigerant flow (VFR variable flow refrigerant) [19], [20].

With this in mind, we proposed a new structural and technological solution that takes into account the shortcomings of the known analogues. Driving the new solution is shown in [Fig. 1].

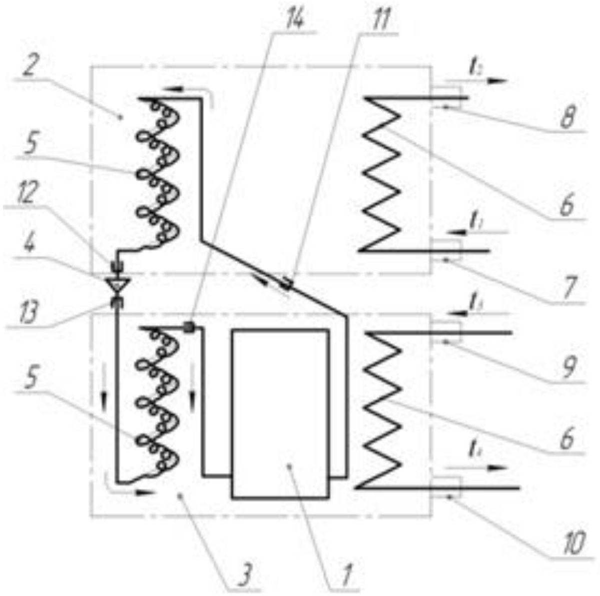

Fig.1: Scheme of structural unit of the new HP.

The heat pump includes: a compressor 1, a condenser 2, an evaporator 3, a throttle device 4, which made structurally a like as coil heat exchangers of the condenser and the evaporator "pipe in pipe", comprise an inner pipe 5 through which circulates the coolant and the external conduit 6 which, namely the annulus, circulates coolant bathing the conduit 5. In this case, the inner pipe 5 is arranged in a spiral pattern to create a helical channel for circulating the coolant in the annulus. External piping equipped with condenser and evaporator entry spigots 7, 8, 9 and the output 10 of coolant, with the proviso that the nozzles are arranged to enter the refrigerant outlet side, and output from the refrigerant inlet. Structurally, the condenser and evaporator piping heat exchanger coils stacked one above the other, along a helical path with the same average diameter and pitch of turns, forming a cylindrical shape, with the placement of the condenser above the evaporator and the compressor within the evaporator. Sequential connection compressor to the condenser, a throttling device with condenser, throttling device and an evaporator with an evaporator to a compressor formed respectively by means of choke connectors 11, 12, 13 and 14

In operation, the refrigerant circulating in a closed circuit from the compressor 1 travels through the inner tube 6 of the heat exchanger of the condenser 2, expansion device 4, the inner pipe of the evaporator 3 and is returned to the compressor in the vapor state. In the process of passing through the condenser coil heated refrigerant gives up its heat to the heat carrier, and the condensed. Passing through the evaporator conduit absorbs heat from the coolant flowing from the low temperature source. Then, the refrigerant is fed back into the condenser and the cycle is repeated.

[Fig. 2] shows a diagram of the experimental stand where HP (1) is set in the middle. As NPIE source for HP used milk cooler (2), as well as a consumer of energy storage vessel (3). The circulation of the coolant in the cooling circuits of milk and provide a buffer tank circulation pumps.

Milk cooler is filled to a predetermined volume of water is heated to a temperature of fresh milk (35 ... 360^{0}C). The initial temperature of the water in the buffer tank is maintained at a level of 200 ^{0}C. After establishing the required temperature distributions when temperature variations do not exceed ± 0,1°C for 10 min, the work turns HP which begins to cool the milk and heat the water in the buffer tank.

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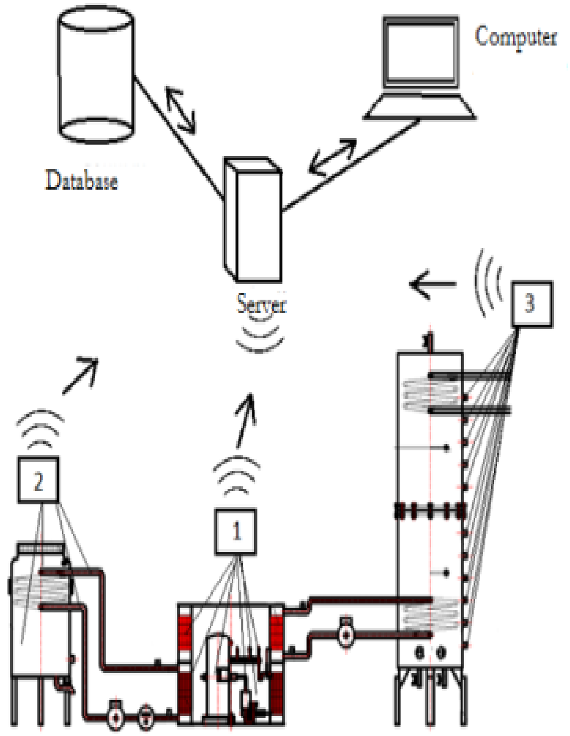

Fig. 2: Process monitoring system.

1 - Heat pump module, 2 - module cooling milk, 3 - module storing space..

Cooling capacity and thermal recorded heat meters, which are set by the evaporator and condenser fixed microcontroller. According to these parameters is given the value of the integrated cooling capacity and thermal performance over time.

[Fig. 3] schematically displayed the collection, transmission, processing and storage of data in research. The basis of the information system constitute the central unit (server), database, personal computers, software, and data acquisition modules with heat pump (1) Coolers of milk (2) and buffer tank(3). Heat pump module collects data from these sensors 12, temperature sensors (DS18B20 encapsulated) two fluid flow sensors (G1WFM) and two pressure sensors (Wika-R1). milk cooler module is connected to the 4th temperature sensor (DS18B20) and one flow rate sensor (G1WFM). battery module collects data from 15 temperature sensors (DS18B20), successively arranged along the vertical direction. The process of collecting information triggers the central unit by sending a request to each module separately. After receiving the request, each module begins sensors survey and collect data in a single package, which is subsequently sent back to the central unit. Server receives packets with the "raw" data processes them according to the relevant algorithms for easy storage. The server then sends the data to the database for storage. You can view the current values, using special software from the user PC.[Fig. 4] shows a fragment of the experimental studies.

Fig. 3: Detail of experimental studies HP,

Experimental studies conducted HP for 3 variants:
1st variant - the compressor is located in the center of the evaporator.
2nd option - the compressor is off-center, close to the wall of the evaporator.
3rd option - the compressor is located in the center of the evaporator, but ruled out heat exchange by radiation from the walls of the evaporator.
Each experiment is carried out at temperatures corresponding entry points Th. The circuit arrangement of the temperature sensors and the pressure is shown in[Fig. 4].

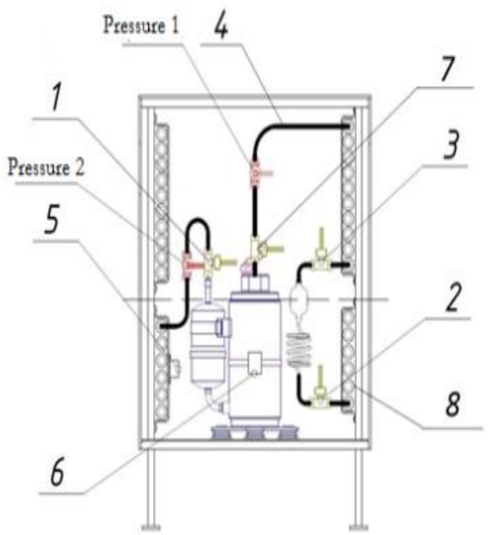

Fig.4: Arrangement of the sensors in HP.

Work evaporator is characterized by four other sensors 1 and 2 and sensors at the inlet and outlet of the evaporator coil [Fig.4]. They also show the temperature of milk in the milk cooler.
Work capacitor characterize four sensors 3 and 4, and sensors at the inlet and outlet of the condenser exchanger [Fig.4]. They also show the water temperature in the accumulating tank.
The temperature of the compressor show mode sensor 6 attached to the side wall and the sensor 7 is attached to the compressor cover. Sensor 6 indirectly indicates the temperature state of the motor, which is located inside the compressor 6. opposite point temperature sensor 7 characterized by a cap which is directly compressing refrigerant. The temperature condition in the space between the compressor and the evaporator show sensors 5 and 8.
Temperature recording schedules, the refrigerant pressure in these points in [Fig. 5], and power characteristics are shown in [Fig. 5 ... 14].

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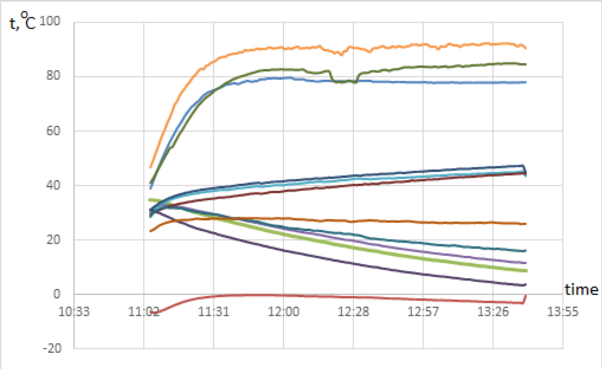

Fig. 5 (a): Temperature characteristics of heat pump.
(Option 1 - the compressor is located in the center of the evaporator)

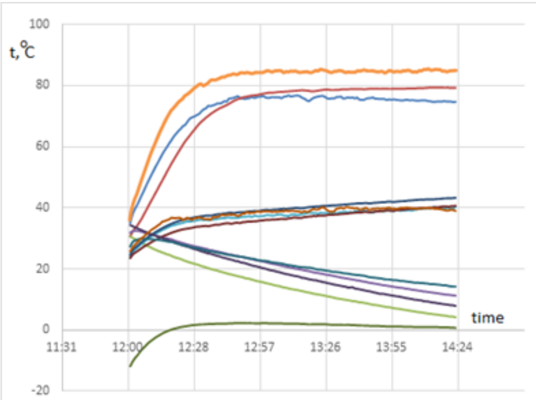

Fig. 5 (b): Temperature characteristics of heat pump.
(Option 2 - the compressor close to the wall of the evaporator)

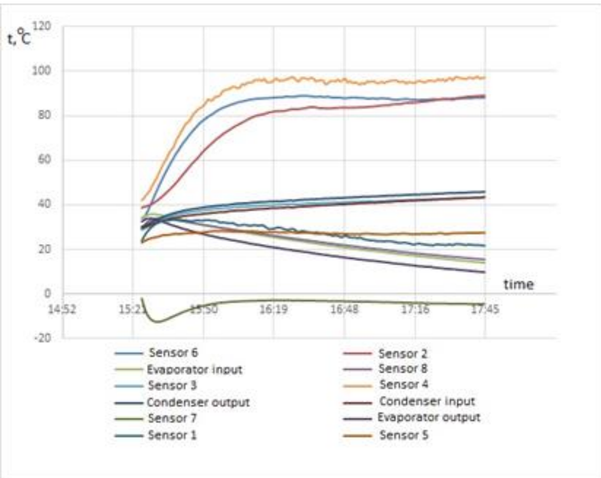

Fig. 5 (c): Temperature characteristics of heat pump (Option 3 - the compressor is isolated from the screen of the evaporator).

Analysis of the graphs of [Fig. 5 (a),(b) and(c)] shows that the temperature characteristics of the heat pump in all 3 variants are within acceptable operating levels.

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the refrigerant temperature at the outlet of the compressor is the highest in the system HP, formed as a result of compression of the refrigerant (sensor 4). It rises to a maximum 950⁰C (option 3), the minimum up to 850 ⁰C (option 2).
With a temperature of the refrigerant supplied to the input capacitor. As a result of passing through the condenser, the refrigerant cools and condenses at the condenser outlet (sensor 3) has 44-450S temperature [Fig. 5]. In the 2nd embodiment, as compared with embodiments 1 and 3, it comes out at a temperature below 50C.

The temperature difference between the inlet and the outlet of the condenser approximately 400 ⁰C (third option) and 460⁰C in the 2nd version. Such differences between input and output is stored over the steady state (90 minutes).

As can be seen, for 43 minutes the temperature of the refrigerant out at steady state. In this case, the in let temperature to the condenser 3 installed on a stabilized value, 85-950⁰C. At the condenser outlet temperature continues to rise linearly from 35-40⁰C to 40-450⁰C. This is explained by an increase in temperature in the heat-sink capacity, respectively, decrease in the intensity of heat transfer agent.

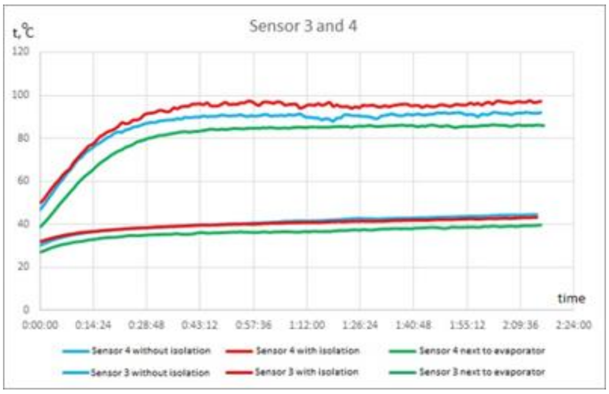

Fig.6: Graphs refrigerant inlet temperature (upper graphs) and the outlet of the condenser, with 3 options.

Comparison shows the embodiment that the temperature characteristics vary. In the 2nd embodiment, the refrigerant inlet temperature 3-400⁰. Clower than in the first embodiment and 7-80 ⁰C than in the 3rd embodiment. This can be explained by the fact that, in the 3rd embodiment, due to lower cooling temperature of the above compressor. However, the temperature of the refrigerant leaving the condenser in the 2nd embodiment, below 50 ⁰C, than in other embodiments.

RESULTS

The refrigerant temperature at the evaporator inlet is (probe 2) is the lowest in the whole system formed as a result of low-temperature boiling if it enters the vacuum zone. As the sensor 1, passing through the evaporator and absorbs heat milk, it increases.
[Fig.7] shows the temperature characteristics of the comparative "heating" of the refrigerant in the evaporator. As can be seen, at the inlet of the evaporator, the refrigerant flows at a temperature of -50 ⁰C (option 1) to -120 ⁰C (option 2) (lower graph). At the beginning of the process, before entering the operating mode, temperatures are sub-zero values. Then, as the ramp-up, the temperature stabilizes.
During the passage through the evaporator and the "heating" of the refrigerant temperature at the evaporator outlet increases to 280 ⁰C, in the 3rd embodiment, and up to 330 ⁰C in the 2nd embodiment.

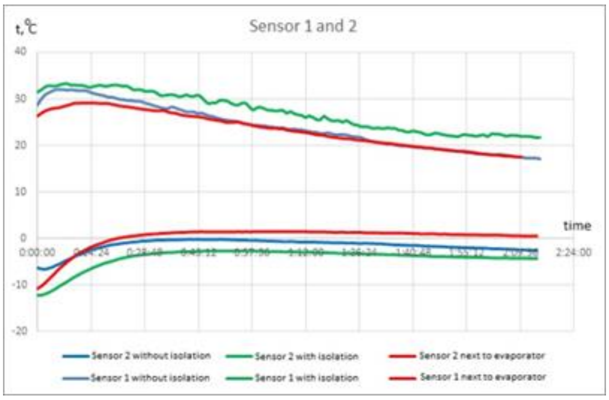

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Fig.7: Graphs refrigerant inlet temperature (upper graphs) and the evaporator outlet at 3 variants.

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Comparison shows the embodiment that the temperature characteristics vary. The lower inlet temperature (sensor 2) has the 2nd option, then 1 and 3rd options. When reaching the steady state, a higher temperature has a second option (220 ^{0}C), 1 and 2 options around 170^{0}C. Accordingly, it is indicative of a higher cooling capacity, which can be observed on the testimony of the thermal energy meter. The temperature of the milk during the experiment is reduced from 35 to 100 ^{0}C.

According to the testimony of the sensor 7 [Fig. 8] of the compressor temperature in the steady state on the surface of the cap is between 800 ^{0}C (option 2) to 880^{0}C (option 3). On the side wall surface (sensor 6) rises to 780^{0}C [Fig.9]. The difference is small (around 20 ^{0}C), indicating a lack of engine overheating. Otherwise, it was possible to observe the sensor temperature exceeded 6, where the motor is installed in
over.

Over

Fig.8: Temperature Charts compressor cap with 3 versions.

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The temperature distribution in the 1 st embodiment is about 850 ^{0}C at the 2nd embodiment at 50 ^{0}C is lower indicating better cooling of the compressor with the 2nd embodiment. Judging by the performance characteristics shown in [Fig. 8], apparently, when the displacement of the compressor to the evaporator, the evaporator absorbs heat better compressor.

The highest temperature of the compressor 3 rd embodiment reaches 900 ^{0}C. However, the permissible temperature of the compressor heating to 1100^{0}C is quite acceptable temperature zone for normal operation of the compressor.

Figure 9 shows the temperature characteristics of the comparative compressor side wall (sensor 6).
As shown, the compressor is heated strongly during the 3rd embodiment, when almost no heat exchange with the evaporator in the form of radiation and deteriorating its cooling. As mentioned above, this has some effect on the heat output of the compressor. The temperature difference between the 1 st and 2 embodiments is practically not observed.

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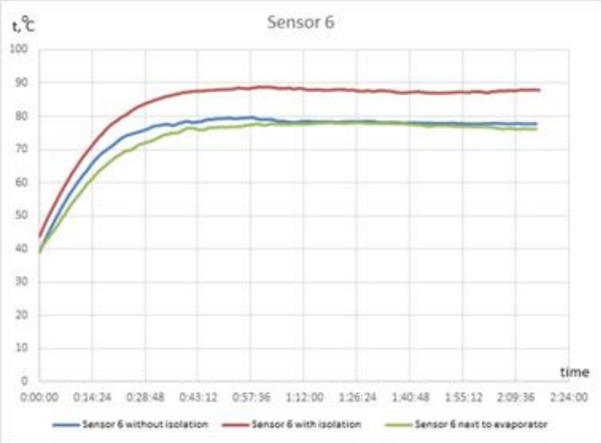

Fig.9: Temperature Charts compressor side wall in 3 versions.

The air temperature around the compressor (sensor 5) is stable at around 200 ° C [Fig. 10]. The surface temperature of the evaporator coil is about 120 ° C [Fig. 11]. Moreover, with the increase of the compressor temperature (sensors 6 and 7), the evaporator surface temperature and air temperature around the compressor is reduced. This mode confirms the effect of cooling the compressor and evaporator partial absorption of the evaporator heat generated by the compressor. favorable regime for the operation of the compressor.

[Fig. 10] shows comparative characteristics of the air temperature in the space between the evaporator and the compressor in 3 variants. Temperature characteristics of 1 and 3rd options are practically identical and equal 25-270 ^{0}C. In the 2nd embodiment, the temperature is in the range 20-230 ^{0}C. Features options indicate that the compressor is in good conditions. However, when the compressor displacement from the center of the air temperature around the compressor 4-50 ^{0}C below. This can be explained by the finding that when the compressor is in the approximate area to the evaporator, it is cooled better, below the surface temperature (sensor 6), and accordingly, it is less heats the surrounding air.

Fig.10: Temperature plots in the space between the evaporator and the compressor in embodiments 3.

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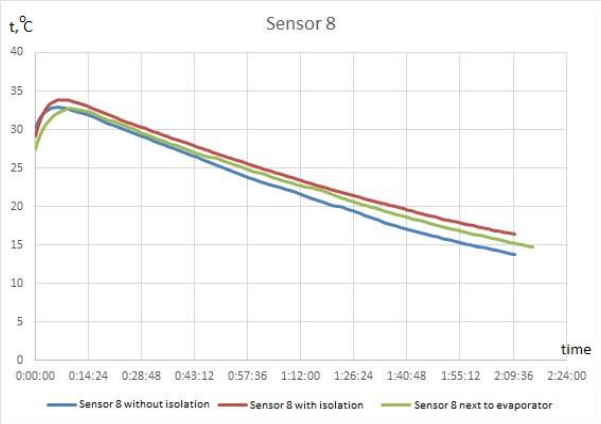

Fig.11: Graphs the surface temperature of the evaporator in embodiments 3.

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A comparative analysis of heat output and power consumption graphs for the study of 3 options [Fig. 12]. To analyze the use area with steady state operation after 30 minutes. operation. Starting the[process is discarded since there is the range of the independent reasons.

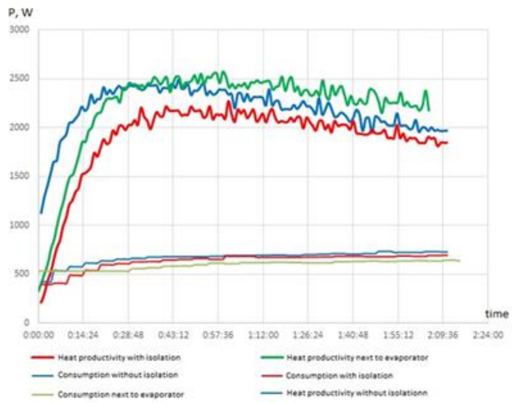

Fig.12: Charts heat output and power consumption under 3 versions.

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As can be seen, the heating capacity options differ. Low rates are observed in the 3rd embodiment where heat output is 1800-2200 Watts. Indicators 1st option range from 2000-2300 Watts. The best performance in the 2nd variant, 2300-2500 Watts. It is 8% higher than that of the 1st embodiment, and 17% higher than that of the third embodiment.

The results show that the arrangement of the compressor in the evaporator zone of impact to Th. The evaporator absorbs the heat emitted from the surface of the compressor which is added to the main flow. In view of the fact that the temperature difference between the compressor Stack (about 800 ^{0}C) and the evaporator (about 180 ^{0}C) is 600 ^{0}C strand, it suggests that the main flow is radioactive heat transfer between the surfaces. As is known, in the 3rd embodiment, heat radiation is eliminated between the compressor and the evaporator, by setting the screen there between. Accordingly, there has been some decrease in performance. However, even under these conditions the compressor does not overheat because its convective cooling is maintained.
Electricity consumption in all cases practically the same (bottom three depending [Fig.12]).

Energy conversion efficiency (ECE) are between 2.5 and 4.5 units [Fig. 13]. Thus, in the second embodiment, it is higher than the first by about 10% than in the 3rd embodiment, up to 15%.

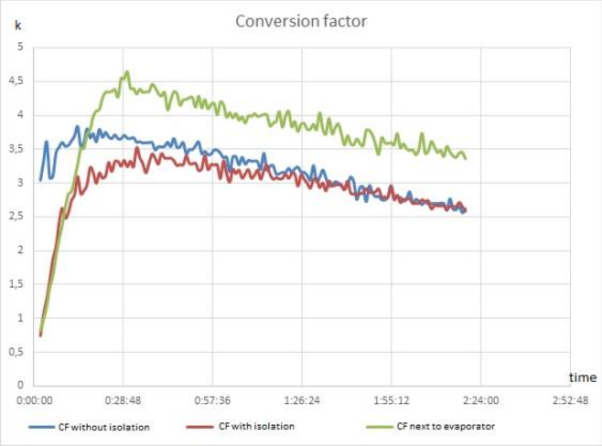

Fig.13: Charts of ECE at 3 versions.

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Graphs cooling options shown in [Fig.14], correlate with the heating performance graphs. Performance of the 1st and 3rd options are practically the same. In the 2nd embodiment, it is above. If the 1st and 3rd embodiments, the end of the process, it is poryadka1200 W in the 2nd embodiment rises up to 1600 Watts. That is, above 25%.

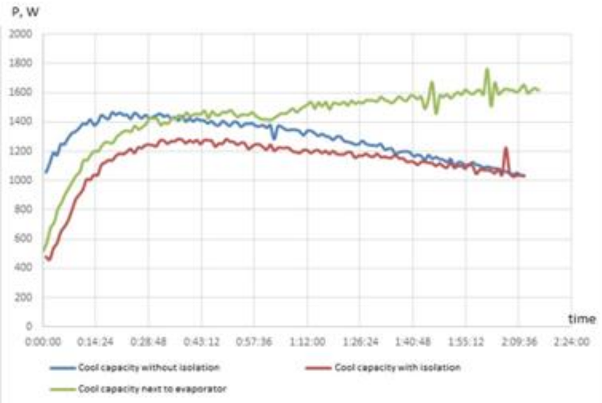

Fig.14: Charts cooling with 3 versions.

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[Fig. 15] shows comparative characteristics of the pressure (bar) Refrigerant inlet (bottom graphs) and at the outlet of the compressor 3 variants.

Fig.15: Graphs pressure (bar) Refrigerant inlet and outlet of the compressor in embodiments 3.

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As can be seen, the pressure at the outlet of the compressor tends to continuously increase from 10 to 17 bar. This is explained by an increase in water temperature in the buffer tank, lowering the temperature of the milk. Maintaining increasing temperature difference between the condenser and the evaporator, increases power consumption and pressure influences.

CONCLUSION

The air temperature around the compressor, the evaporator is located inside the heat exchanger is maintained at a stable level of about 200 ºC. The surface temperature of the evaporator coil is about 120 ºC. Moreover, with the increase of the compressor temperature, evaporator surface temperature and air temperature around the compressor is reduced. Such a regime confirms compressor cooling effect of the evaporator and a partial absorption of the evaporator heat generated by the compressor, favorable regime for the operation of the compressor. However, when the compressor displacement from the center of the air temperature around the compressor 4-50ºC below. This can be explained by the finding that when the compressor is in the approximate area to the evaporator, it is better cooled surface temperature and below, respectively, the less it heats the surrounding air.

CONFLICT OF INTEREST
The authors of the article will not conflict

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