ABSTRACT

for the dissertation work of a PhD student

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for the degree of Doctor of Philosophy (PhD) in the specialty

6D072400 – Technological machines and equipment

"IMPROVING THE EFFICIENCY OF THE REFRIGERATION SYSTEM BY USING RADIATION ENERGY INTO THE CELESTIAL SPHERE"

The aim of the work is to increase energy efficiency, stability of the refrigeration system by radiating thermal energy into the atmosphere and reducing condensation pressure during a hot period of time

Based on the conducted literary analysis and in accordance with the purpose, the following tasks were solved:

Tasks of the work:

1. Analysis of methods for cooling condensers and schematic diagrams for reducing the condensation pressure of a refrigerating machine.
2. Computational and theoretical analysis of the energy efficiency of a refrigeration machine when reducing condensation pressure by removing thermal energy by radiation into the atmosphere, depending on climatic conditions.
3. Calculation, development and manufacture of an experimental refrigeration system with an additional liquid condenser, with the removal of thermal radiation into the atmosphere to reduce the condensation pressure of the refrigeration machine.
4. Conducting experimental studies of a refrigeration system with an air-cooled condenser and an additional liquid condenser in various meteorological conditions.
5. Development of a computer model of a refrigeration system with heat removal from an additional liquid condenser, thermal radiation into the atmosphere.
6. Conducting an economic analysis of the efficiency of a refrigeration system with an air-cooled condenser and an additional liquid condenser, with heat removal by radiation into the atmosphere.

Scientific novelty:

- a method has been developed for determining the main characteristics and daily energy consumption of refrigeration systems with a combined node, where condensation heat is removed due to thermal radiation into the atmosphere on hot summer days;
- an algorithm for the thermal balance model of the combined node and a computer model for calculating a refrigeration system with an additional liquid condenser, with the removal of thermal radiation energy into the atmosphere, taking into account the climatic conditions of the region, have been developed;
- formulas have been obtained for calculating the minimum volume of the cold

storage battery, the minimum radiator area, the energy consumption of the compressor while using FGM and CVO, and formulas for determining the amount of electricity consumed by the refrigeration system.

The practical value of the work:

- a calculation method and a computer model have been developed that make it possible to design installations for cooling a condenser using thermal radiation into the atmosphere (Appendix B).

- the results of evaluating the area of effective use of the condenser cooling unit are proposed, due to the location of the cooling facility (Appendix A).

- rational designs have been developed: an installation for cooling food products using sequential capacitors and thermal radiation (patent for a utility model using thermal radiation No. 4408 dated 04/05/2019 "Milk cooling unit" Appendix B)

The object of research:

A steam compression refrigerating machine with combined condensers, in which the heat of condensation of the refrigerant is discharged as thermal radiation into the atmosphere.

The subject of the research work is the process of reducing the condensation pressure, cooling the coolant in the radiator and their impact on the energy efficiency and efficiency of the refrigeration system.

Approbation of practical results. The main results of the dissertation work were presented at international scientific and practical conferences held in Kazakhstan and abroad, discussed at an expanded meeting of the Department of "Machines and devices of production processes" of ATU. The main part of theoretical and experimental research and practical developments was carried out at the Almaty Technological University and at the Odessa National Academy of Food Products during the doctoral student's internship.

The materials of the dissertation work are used in the educational process of the Almaty Technological University in the preparation of bachelors and masters in the fields of "Machines and devices of production processes", "Refrigerating machines and air conditioning systems" (Appendix E).

The developed recommendations, methodology and model are used in Teniz LLP in the development of refrigeration systems with thermal radiation into the atmosphere. The act on the implementation of the results of the dissertation research is presented in the appendix (Appendix D). And the same results of the work were used in the development of an industrial experimental installation in the AR09258901/GF project for 2021-2023 “Research and development of combined refrigeration systems with radiation cooling for industrial refrigeration and air conditioning” (Appendix D).

Scientific statements submitted for protection:

- a theory of the effective application of thermal radiation into the atmosphere for cooling a liquid condenser is proposed;

- an effective method proving the possibility of reducing the condensation pressure using a cooled coolant by thermal radiation into the atmosphere, taking into

account the climatic conditions of the region and an additional liquid condenser;

- a system of equations for the elements of the refrigeration system that allows you to determine energy consumption and an experimental model describing the dependence of specific energy costs when cooling with sequentially arranged capacitors

The relevance of the topic:

With the growth of technological progress, renewable energy sources are especially relevant, since traditional energy sources - coal, gas, oil - are not endless, due to their depletion, as well as their impact on the ecological balance of the planet, on the health and safety of mankind.

Due to the current problems, the leading priority for the modernization of technological equipment is to reduce the energy consumption of refrigerating machines by increasing their energy efficiency.

At a meeting on the establishment of a working group on the development of the electric power industry, President Kassym-Jomart Tokayev instructed to develop a concept for the low-carbon development of Kazakhstan until 2050, including measures for "green growth" and deep decarbonization of the national economy. Decree of the Prime Minister of the Republic of Kazakhstan dated December 29, 2020. The government is also working on a National project for the development of the electric power industry, and the country's energy balance is being prepared until 2035.

The Head of State said: "...Earlier, we set a goal to bring this figure to 10% by 2030. Taking into account the new realities and the current positive dynamics, I set the task to increase the share of renewable energy in electricity generation to 15% by 2030."

At food industry enterprises in regions with a hot summer climate and dry air, a significant increase in temperature and, as a result, an increase in pressure occurs in the air-cooled condenser of the refrigerating machine. This is typical for the continental climate of the Central Asian region, including Kazakhstan. The choice of the direction of the dissertation work on the development of a refrigeration system with a more efficient way of cooling a condenser using a renewable energy source.

To reduce the condensation pressure, it is proposed to use an additional installation with thermal radiation into the atmosphere in conjunction with an air cooling condenser (CVO).

One of the ways to solve this problem is the sequential installation of air and liquid condensers cooled by thermal radiation into the atmosphere and natural convection.

There are many schemes of refrigeration units using RO, the possibility of using which depends on the climatic characteristics of the area of the cooled object, as well as on the required temperature regime. Using the previously developed model, it is proposed to evaluate the possible level of energy saving in the cooling supply system due to the use of RO during its operation in various cities. Similar studies have not been conducted before

In a hot summer climate, there is a problem associated with an increase in

condensation pressure in steam compression refrigerating machines (PCM), which in turn causes a decrease in the refrigeration coefficient and an increase in power consumption by the compressor. For example: In southern regions with a continental climate (for example, in the south of Kazakhstan), the atmospheric air temperature reaches 45 °C on some days. Taking into account the heating of the air by solar radiation, the condensation temperature in the CVO can reach 60 ° C and above.

To increase the efficiency of the PCCM, it is proposed to install a liquid cooling condenser in series with an air cooling condenser.

The dissertation work was carried out within the framework of project 0118RK00535 under the grant of the KN of the Ministry of Internal Affairs of the Republic of Kazakhstan AR5130918/GF "Research and development of scientific and engineering foundations for the use of radiation cooling in refrigeration and air conditioning systems" for 2018-2020, project AR09258901/GF "Research and development of combined refrigeration systems with radiation cooling for industrial refrigeration and air conditioning" on 2021-2023, as well as an individual doctoral student's plan.

Assessment of the current state of the scientific problem being solved.

Along with population growth, industrial development and people's desire for a more comfortable environment, there is a rapid demand for electricity in the refrigeration sector in the 21st century. Modern traditional cooling technology faces the problems of high energy consumption and the greenhouse effect caused by greenhouse gas emissions from electricity generation and leakage of refrigerants into the environment.

The physical phenomenon of cooling objects at night below the temperature of the surface air layer is called Effective radiation of the Earth. The surface of the object, located horizontally under certain weather conditions (the maximum effect is observed on a cloudless night) and in the absence of incoming radiation, is able to emit more thermal energy than it receives back from external sources. As a result, its temperature can be maintained below the ambient temperature. By bringing the coolant to the radiating surface, it can be cooled. This cooling effect used in the work, which will maintain the temperature of the coolant close to the night air, is called radiation cooling (RO).

Radiation cooling due to thermal infrared radiation into the atmosphere is an environmentally friendly, alternative method of producing cold.

Kazakhstan occupies a leading position in the world in terms of greenhouse gas emissions per unit of GDP. Therefore, our republic has actively joined in solving this problem and introduced a system of trading quotas for carbon dioxide emissions. A significant part of hydrocarbon emissions is driven by the energy sector, in turn, refrigerating machines consume about 20% of the world's electricity. Refrigerating machines and air conditioning systems have a significant level of electricity consumption in industrial enterprises, commercial buildings and private homes. At the same time, the prevalence of refrigeration and air conditioning systems is increasing, as well as energy prices are rising.

The basis for the development of the topic was the need to eliminate the identified technical shortcomings of technological refrigeration equipment such as

an increase in condensation pressure, an increase in the compression ratio of the compressor, an increase in electricity consumption, a violation of the stability of operation and, as a result, a decrease in the service life of the compressor, a shortage and high cost of fresh water, freezing of water in winter.

The initial data for the work were the results of scientific research, analyses, developments and preliminary design data on improving technological equipment to reduce condensation pressure and reduce compressor power consumption. Known cooling systems in which radiation cooling is used to cool the intermediate coolant, and its further use to lower the temperature of the cooled object, have disadvantages such as the high cost of the system due to the large amount of coolant in the system, low efficiency, large cold storage, etc.

The justification for the need for research work was the lack of knowledge of technological processes and equipment for reducing condensation pressure, cooling the coolant in the radiator and their impact on energy efficiency and efficiency of the refrigeration system, the lack of scientifically sound solutions to increase the productivity and technological efficiency of the equipment.

Information about the planned scientific and technical level of development.

The results of the conducted research will make it possible to create an energy-saving installation consisting of an experimental unit with a RO and a refrigerating machine with air and liquid cooling condensers in series, taking into account the peculiarities of climatic conditions, as well as engineering calculation methods based on the fundamental laws of thermodynamics. This indicates a high scientific and technical level of development and is a new, promising direction for the development of refrigeration technology.

Information about patent research.

A patent search was conducted for refrigeration systems combining the possibility of using a thermal and steam compression refrigerating machine, using databases from Kazakhstan, Russia, the USSR, the USA, and EU countries with a search depth of 50 years. The disadvantage of known refrigeration units is their low efficiency during periods when cold is generated by natural circulation of the refrigerant, that is, with the compressors turned off. The analysis made it possible to conclude that the proposed installation is energy-saving and allows to increase the technological efficiency of the process under consideration. In this work, the development and research of a refrigeration system with a CVO and an additional liquid condenser cooled by heat dissipation of condensation by radiation cooling and natural convection has been carried out.

Information on metrological support of scientific research work. During the research, trusted, calibrated instruments were used. The measurement methods and the accuracy class of the devices comply with the "Law on Ensuring the Uniformity of Measurements".

Personal contribution of the author.

The author analyzes the existing installations using thermal radiation into the atmosphere, substantiates the relevance, develops an experimental installation and conducts research.

The author participated in the development of the calculation methodology and algorithm, in computer modeling and in the development of patented installations.

1. The analysis of methods for cooling condensers and schematic diagrams for reducing the condensation pressure of a refrigerating machine has shown that with the help of sequentially switched on CVS and FGM, the condensation pressure can be reduced, thereby increasing the stability of operation and, as a result, the service life of the compressor increases. The method of developing energy-efficient installations for cooling condensers using alternative energy sources can be considered one of the most promising areas for the development of energy-saving types of technological machines and equipment.

2. A computational and theoretical analysis of the effect of reducing condensation pressure by using natural cold and the energy of thermal radiation into the atmosphere on the efficiency of the refrigerating machine, depending on climatic conditions, was carried out. At the peak time of the load on the condensation unit, the condensation temperature decreases in the liquid heat exchanger by an average value of 〖Δt〗_(k.to.)=10K, and the enthalpy values at points 2, 2', 3, 3' will correspond to a reduced value of the condensation temperature by 10K (according to experimental data), and accordingly a decrease in pressure p_k by 3 105Pa (for R134a). The average temperature when using a liquid condenser is TC=+30℃. The power consumption of the installation in this case is ~ 0.3 kW. When the unit is running for 2 hours, 0.6 kW is consumed.

At 2 hours of maximum temperature per day, energy savings are about 1-0.6 = 0.4 kWh per day.

When using this design with a connected liquid heat exchanger, energy savings are 90×0.4=36 kWh for about 90 days in the summer months.

The experimental setup considered in this study is being developed for use in a sharply continental climate. The study was conducted in Almaty. This city is located at 43° north latitude. The climate of the city is characterized by a significant daily change in air temperature exceeding 10 ° C. Data on atmospheric air temperature were used for calculations (Figure 9)

3. An experimental condenser cooling unit has been developed and manufactured. The experimental installation of XM with a PC includes a standard refrigerating machine with a compressor, and in addition to it, a liquid cooling condenser is connected after the air cooling condenser, which in turn is connected to the cold storage battery. A 40% propylene glycol solution is used as a coolant (pour point -26 °C). It is allowed to use water in the experiment, but it will need to be drained in the cold season.

The installation uses a small piston hermetic compressor Wansheng WQ15HF (China) with a cooling capacity Q0=332.9 W at a boiling point t0 =-23.3 ° C and a condensation temperature tc=+54.4 °C (low-temperature operation according to ASHRAE LT standard). According to all characteristics, this compressor is an exact analogue of the Secop (Danfoss) SC15F compressor.

The Kaideli FNHM 12/4 finned tube heat exchanger (China) with a heat exchange surface area of 4 m2 is used as an air cooling condenser of the KVO. Its

fan consumes 30 watts, and the rated heat output is 1200 watts.

The FGM liquid cooling condenser is a cylindrical metal container with a diameter of 220 mm and a height of 625 mm, made from a receiver model GVN VLR.33b.21.B6.C6.F4 (Turkey). A spiral of copper pipe with an outer diameter of 9.52 mm and a length of 7 m is wound inside the container. The area of the heat exchange surface of the spiral is 0.2 m2. The refrigerant is fed into the spiral from a copper pipe. The coolant fills the space between the container and the spiral.

All elements except the radiator are located indoors. The radiator is located on the street (Figure 15).

Boiling point: -10°C
Condensation temperature: +29°C
Overheating: 10°C;
Hypothermia: 5°C;
Ambient temperature: +25°C;
Atmospheric air temperature peak: +35°C;

In the "CoolPack" program, according to the calculation:
Discharge temperature: +75°C;
Cooling Capacity: 688 W;
Theoretical operation of refrigerant compression: 123 W;
Total compressor efficiency: 65%
Electric power of the compressor motor: 189 W;
Heat of condensation: 811W;
Refrigerant mass consumption: 0.0043 kg/s
Volumetric refrigerant flow rate: 0.000447 m3/s = 1.61 m3/hour

4. During the experiment, it was found that the condensation temperature can be reduced from +35.6 to +31.4 °C due to the inclusion of FGM at a low temperature of the air supplied to the CVO (less than +30°C). At a high temperature of the air supplied to the CVO, the condensation temperature can be reduced from +48.5 to +38.3 ° C due to the inclusion of FGM.

The inclusion of FGM leads to an increase in the electrical power Ne consumed by the installation, since the pump H2 is switched on. A decrease in condensation pressure leads to an increase in the cooling capacity of the compressor Q0, which causes an increase in the refrigeration coefficient of the installation ε.

5. A simulation of a refrigeration unit was carried out with the help of which the parameters of the main elements of the system were determined, as well as a decrease in daily energy consumption by 6.5% compared with ordinary PCCM (from 421 W to 385 W, i.e. by 36 W). A computer model of a refrigeration system with an air-cooled condenser with heat removal from an additional liquid condenser and thermal radiation into the atmosphere has been developed.

6. An economic analysis of the efficiency of a refrigeration system with an air-cooled condenser was carried out when using an additional condenser cooled by thermal radiation into the atmosphere.

In connection with international standards, it is accepted that an acceptable payback period for a solution that increases energy efficiency is acceptable for up to 7 years, in our case, with the total cost of installation, the cost of an additional capacitor and with a cold storage battery is 4,270,044 tenge, which in terms of reduced energy consumption and a payback period of 4.6 years.

The payback period of the installation with an additional liquid condenser and thermal radiation into the atmosphere was 4.6 years.

The installation is safe for the environment, as it does not emit harmful substances into the atmosphere.

Publications. Theoretical and experimental research has been reflected in 20 scientific publications, including 4 articles in journals with zero impact factor included in the Web Of Science and Scopus databases; 2 articles in the journal recommended by the Committee for Quality Assurance in Science and Higher Education of the Republic of Kazakhstan; 14 publications in the materials of international scientific and technical conferences.

The structure and scope of the dissertation. The dissertation work consists of an introduction, a literary review, theoretical calculation, experimental studies, computer modeling and their discussion with conclusions, technical and economic efficiency and conclusion.

The list of sources used includes 101 titles. The work is presented on 115 pages of computer text, contains 23 tables, 34 figures and 6 appendices.