ANNOTATION

of the dissertation work
of the doctorate PhD by the specialty 6D071700 - "Heat Power Engineering"
A.S. Rasmukhametova on the topic:
«Exploring ways to increase the efficiency of using heat pumps»

The relevance of research. The transition to market mechanisms in the energy sector of Kazakhstan raises the question of the competitiveness of the existing systems of centralized and decentralized heating. The need to preserve the district heating system in the power engineering industry of Kazakhstan makes priorities in the development of energy science related to the reduction in the cost of supplied heat and electrical energy when they are produced together. At the same time, the financial policy of the owners of energy companies makes it necessary to find low-cost methods to improve the efficiency of the equipment. The large-scale use of heat pumps (HP) can be the basis of the energy-saving policy of Kazakhstan. From the experience of most foreign countries, it is obvious that an increase in the number of implemented heat pumps in the heating systems of the residential and industrial sector contributes to the successful solution economic, environmental and social problems associated with a reduction in the volume of combustible fuel, pollution of the environment, reduction in utility tariffs and the creation of comfortable living and working conditions of people.

The primary issue in the formation of technological schemes of heating is the choice of the type of heat pump in relation to the conditions of a particular object.

The practical use of the heat pump systems (HPS), their testing at existing heating facilities under the conditions of interfacing with traditional heat sources requires the justification and development of typical schemes using advanced thermodynamic cycles. For the regions of Kazakhstan with a very cold climate, some schemes for the local application of the vapour compression heat pump (VCHP) have been tested by professor Alimgazin A.Sh. However, the dissemination of this experience requires the solution of many administrative barriers that occur during the modernization of existing heating systems.

Supplying an isolated consumer with thermal energy for heating purposes is being a specific task. The specificity lies in the fact that the isolated consumer is, as a rule, excommunicated from a centralized supply of primary energy. The case when the isolated consumer has access to electrical energy is considered. One of the widely available sources of the primary energy is the heat of the soil, and in some cases, bodies of water. The heat pump is one of the technologies that allow the use of this type of primary energy.

However, each consumer has own requirements for the use of a heat pump. The energy and economic efficiency of the heat pump depending on the desired temperature level of the heated water. It is known that single-stage heat pumps, as a rule, have a limitation on the temperature of produced hot water. The transition to a multi-stage compression of the working substance or to another cycle in the heat

pump makes it possible to remove this restriction to a certain extent. The temperature of the heated water, in this case, can reach 100 C. Obviously, in this case, the cost of the unit increases significantly. But on the other hand, the higher the temperature of the water used, the more compact the heater becomes. Respectively, the heating system of the building becomes cheaper. In this regard, the "Study of ways to improve the efficiency of the use of heat pumps" becomes very relevant.

The solution of the listed current scientific and technical problems of a thermodynamic, thermophysical, and thermo-technical descriptions determine, in general, the complex task of this dissertation research.

The purpose of the thesis is to optimize the parameters of the heating system of isolated consumers using the heat pumps; Improving the energy efficiency of heat and power equipment based on the use of the heat pumps.

To achieve the goal, it is necessary to solve the following **tasks:**

- Analysis of the results of research on the operation of the heat pumps with single-stage and multi-stage compression in the Carnot cycle;

- Comparative analysis of the effectiveness of the use of traditional heating systems and heat supply with using the heat pumps;

- Determination of the effect of the used refrigerant on the thermodynamic efficiency of the heat pump;

- Comparative analysis of the efficiency of real thermodynamic cycles of the heat pump under single-stage and multi-stage compression using different refrigerants;

- Development of the most efficient thermal circuits for heat supply systems of the isolated consumer with heat pumps for various climatic regions of the Republic of Kazakhstan;

- Conducting a comparative analysis of the energy and economic indexes of heat supply systems with heat pumps;

- Development of a mathematical model of the heat pump operation with stepwise compression in the composition of heat and power equipment.

The main idea and the internal unity of the work.

The fundamental idea of the thesis is the study of the energy efficiency of heat supply systems based on the heat pumps. Development of techniques necessary for the effective use of a combined heat supply system with a geothermal heat pump and a gas boiler operating in the programmed heat supply mode, depending on the outdoor temperature. Rationalization of the thermal circuit of the heat pump with effective technical and economic indicators based on the numerical analysis of thermodynamic work cycles. Creating an effective mathematical model of heat supply systems using high-temperature heat pumps as part of heat and power equipment.

The scientific novelty:

- Studies have been performed and the analysis of the efficiency of using heat pumps with different numbers of stages at two different working agents has been carried out.

- A technique of selecting the type of working agents based on an analysis of the effect on the characteristics of the heat pump installation has been developed.

- A method for heat recovery of wastewater of multi-storey buildings using a heat exchange insert to ensure the operation of the heat pump has been developed and protected by a patent.

- The conditions and boundaries of energy-efficient combined use of HPS and traditional heat sources are determined.

- A technique for optimizing the technical and economic indicators of a vapour compression heat pump based on an analysis of the effectiveness of real thermodynamic cycles has been developed.

The scientific significance of the thesis. Substantiation of recommendations on the choice of the thermodynamic cycle of the heat pump in order to improve the energy efficiency of its work.

The reliability of the results of the research. The reliability of the obtained results is ensured by using a complex of modern theoretical research methods and experimental data obtained on high-tech equipment. In order to acquire experimental data are used modern means of measurement and control.

The practical value of the thesis is to develop a combined decentralized heat supply system for a residential building based on a heat pump with software heat release, as well as a software product for

- calculating the choice of the optimal heat source power;
- calculations of optimization of thermal circuit parameters;
- calculations of the optimization of the heat load of the building;
- calculation of energy and economic indicators of the heating system.

As a result of the thesis, the efficiency of using R-134a and R-600a refrigerants in two-stage heat pumps that perform a thermodynamic cycle with condensate subcooling and heat recovery of the working agent steam has been confirmed.

Provisions to be defended:

- the results of experimental studies on the performance of a decentralized heat supply system for a residential building with various heat sources (gas boiler-heat pump, heat pump with stepwise compression) depending on the ambient temperature;

- the results of a comparative calculation of the performance indicators of single-stage and two-stage heat pumps;

- results of research on the dependence of the thermodynamic efficiency of the heat pump on the choice of operating refrigerants;

- mathematical model of the heat pump with stepwise compression in composition with heat and power equipment.

The research methods are theoretical-statistical and experimental research. In the study of thermodynamic problems of increasing the efficiency of using the heat pumps in heating systems, the following methods have been used: thermodynamic calculation of the heat pump cycles and exergy analysis of energy losses in the heat pump systems, engineering calculation of parameters of

autonomous and centralized heat supply systems; graph analytical methods; methods of mathematical modeling.

The object of the research of the thesis is decentralized heat supply systems for residential and public buildings, industrial and heating boiler rooms, CHP (combined heat and power plant) with the heat pump installations included in the equipment.

The personal contribution of the aspirant consists of:

- in the analysis and synthesis of literature data; in conducting numerical simulation;

- in planning, organizing and conducting experimental research, processing and summarizing the results;

- in the development of new technical solutions.

Approbation of the results of the thesis. The results of the thesis have been tested at eight international scientific conferences:

- XVI-International Scientific and Practical Conference "Modern Trends in the Development of Science and Technology", the report "Analysis of the efficiency of the heat pump with a piston compressor." By Abildinova S.K., Rasmukhametova A.S. – Belgorod.

- IV-International Scientific and Practical Conference "Actual problems of transport and energy: ways of their innovative solutions.", the report "Assessment of energy efficiency of the implementation of new technologies in the reconstruction and modernization of thermal power plants." by Rasmukhametova A.S. – Astana, ENU, 2016.

- V-International Scientific and Practical Conference "Actual problems of transport and energy: ways of their innovative solutions.", the report "Low-temperature heating system of food industry facilities" by Abildinova S.K., Rasmukhametova A.S. – Astana, ENU, 2017.

- International scientific practical conference «Trends in science and technology». By the report «Analysis of the efficiency of eco-friendly refrigerants of a new generation in the operation of high temperature heat pumps». «Journal of fundamental and applied sciences A. Sultanguzin, S.K.Abildinova, A.S.Rasmukhametova – Algeria, 2017.

- VI-International scientific-practical conference "Actual problems of transport and energy: the way of innovation resolution", the report "Efficiency of centralized heat supply systems in joint use of heat pumps" by Rassmuhametova AS – Astana, ENU, 2018.

- VI- International scientific-practical conference "Actual problems of transport and energy: the way of innovation resolution" the report on the theme "Improving the Energy Efficiency of a Thermal Pump on the Application of Two-Staged Compression" by Abildinova S.K, Musabekov R.A, Rasmuhametova A.S. – Astana, ENU, 2018.

- International Scientific and Practical Conference: "The role of youth in the development of the knowledge economy" – 2018, with a report on the topic "High-temperature heat pumps, which use environmentally friendly refrigerants of the

new generation." by Musabekov R.A., Abildinova S.K., Rasmukhametova A.S. – Almaty, AUES, 2018.

The publications

The main provisions of the work are presented in 17 publications, including 6 editions recommended by Committee for the control of education and science of the Ministry of education and science of the Republic of Kazakhstan, one article in the journal «NEWS of the national academy of sciences of the Republic of Kazakhstan series of geology and technical sciences» included in the Scopus (Elsevier) database (impact factor - 0.06); 8 articles in collections of materials of international conferences, of which 3 in international conferences held abroad; received one patent for a utility model: №3347 - "Heat transfer insert system for utilization of low-grade heat."

Amount and structure of the work. The thesis contains an introduction, 4 chapters, conclusion, list of references. The dissertation is presented on 122 pages of computer typing, includes 39 figures, 40 formulas, 21 tables, 88 titles in a list of references, 4 appendix.

In the introduction, the relevance of scientific work is disclosed, the researched problem is specified. The main idea, scientific novelty, the reliability of the work, practical value, the provisions submitted for presenting, the personal contribution of the author, as well as approbation of the results and publication are presented.

The first chapter of the thesis presents an overview of the state of the problem of the effective use of vapour compression heat pump installations in heating systems. The technological and economic comparison of various options for heating a decentralized consumer is considered. A decentralized heat supply system has been developed for a residential building with a combination of various heat sources. The effect of changes in ambient air temperature on the characteristics of a combined heat supply system with a heat pump is investigated. The problems of optimizing the load conditions of the combined heat supply system of a residential building are considered. A comparative analysis of the technical and economic indicators of heat sources of a residential building is conducted. According to the goal, the research objectives are formulated.

The second chapter considers the dependence of the thermodynamic efficiency of the heat pump on the choice of working agents. Based on a numerical experiment, the influence of the thermodynamic properties of various working agents (refrigerants) on the characteristics of heat pump installations was analyzed and the most promising refrigerants were selected to ensure high thermodynamic efficiency, safe operation of the heat pump and not having negative effects on the atmospheric ozone layer and global warming.

The third chapter introduces the results of the study of the performance indicators of heat pumps with stepwise compression. The concepts of using the heat pump with a two-stage compression of the working agent are formulated. Experimental studies were carried out on a test bench with an Altal GWHP26N heat pump with a thermal power of 24.2 kW and the results of a comparative

calculation of the performance indicators of single-stage and two-stage heat pumps are presented. Various schemes for the implementation of the thermodynamic cycle for a single-stage and two-stage heat pump are considered. The efficiency of the two-stage heat pumps that implement a thermodynamic cycle with supercooling of condensate and the regeneration of the heat of the working agent steam has been proven.

The fourth chapter discusses the effectiveness of central heating systems in terms of sharing heat pumps. The most efficient thermal circuits of centralized heat supply systems with high-temperature heat pumps for various climatic regions of the Republic of Kazakhstan are presented. An effective mathematical model of a heat supply system with a high-temperature heat pump as part of heat and power equipment has been developed.

The conclusion reflects the main results and conclusions on the thesis.