latitudinal extent and physical and geographical heterogeneity of the republic. Anomalies of average annual and seasonal air temperatures in summer in Almaty, Zhambyl, Turkestan, Kyzylorda, Atyrau and Mangistau regions have always been higher than averaged in other regions of the country. The sharply continental conditions of the listed regions determine the instability of meteorological values, which affects many sectors of the economy, especially agriculture. Therefore, knowledge of the trends of their changes allows choosing the optimal strategy for operational work and reducing losses associated with dangerous temperature changes, and in some cases making a tangible profit.

Key words*:* summer temperature anomalies, hydrometeorological stations, atmospheric air temperature rhythms, variations and deviations of distributions from normal, primary statistical characteristics of air, processing of statistical temperature parameters, patterns of change in average monthly air temperature.

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HEAT PUMP SYSTEM OF AUTONOMOUS HEAT SUPPLY FOR HEATING LOW-POTENTIAL COOLANT

Abstract

Heat supply using a heat pump belongs to the field of energy-saving, environmentally friendly technologies and is becoming increasingly widespread in the world. This technology, according to the conclusion of a number of authoritative international organizations, along with other energy-saving technologies (use of solar, wind energy, ocean energy, etc.), belongs to the technologies of the 21st century. The main heat costs for household needs in buildings during the cold season are heating costs. This is explained by the operating conditions of buildings during the cold season, when heat loss through the building envelope significantly exceeds internal heat release. Therefore, to maintain the required internal air temperature, buildings are equipped with heating units. During the cold season, to create and maintain thermal comfort in buildings, technically advanced and reliable heating installations are required.

The use of the proposed heat pump system will improve the efficiency of autonomous heat supply to decentralized and remote residential and industrial facilities, service enterprises. In addition, the proposed combination of heat pump units and renewable energy sources expands the resource base of the heat pump heating supply system, making it less dependent on fluctuations in ambient temperature, which is very important for increasing the level of reliability of heat pumps.

Key words: *heat pump, heat pump system, heat pump system of autonomous heating supply, heat pump installation, low-grade heat source, renewable energy sources*

Introduction

Currently, approximately up to 800 million HP of various capacities are installed and operated in the world: from several kilowatts to megawatts. Moreover, more than 60% of them are in heating and hot water supply and air conditioning systems of residential buildings and industrial buildings. Hundreds of thousands of private houses, cottages, hotels, recreation centers and other facilities in

America, Europe and Asia are connected to a heat pump, which provides them not only with comfortable conditions, but also with significant energy savings.

Every year, the heat pump fleet is replenished by approximately 1 million units. The thermal power of the world's current fleet of heat pumps of various types is estimated at 250 GW with an annual heat production of 1.0 billion Gcal, which corresponds to the replacement of fossil fuels in the amount of up to 80 million tons of fuel equivalent / year. According to forecasts from the World Energy Council (World Energy Council - WEC), by 2020. the use of HP for heating and hot water supply in developed countries will reach approximately 75% [1].

A distinctive feature of agricultural facilities in Kazakhstan is their relatively small unit capacity and significant dispersion over a vast territory, which creates certain difficulties in building effective centralized heating and hot water supply systems. The energy sector of the agricultural sector is mainly based on imported fuel. Within the republic, remote decentralized consumers located in the interior regions of the regions are allocated to a special category, the delivery of organic fuel to which is fraught with great difficulties.

The main objects of rational implementation of heat pump installations in the coming years in Kazakhstan may be:

- local heating systems for housing and communal services (heating residential buildings, dispersed facilities in rural areas, administrative and social facilities such as schools, hospitals, hotels, boarding houses, etc.);
- heating systems for tourism and recreation facilities, service points and services along major highways;
- hot water supply systems;
- systems for creating an optimal microclimate at public places (sports complexes, cinema and concert halls, shopping and entertainment centers, swimming pools, etc.);
- industrial technological processes (drying, distillation and separation of mixtures, evaporation, heating of raw materials, etc.);
- objects of the agro-industrial complex with waste heat recovery of low potential (livestock farms, poultry houses, greenhouses, grain storage facilities, etc.);
- district heating systems (heating of new high-density buildings, heating of make-up water at heat and power centers, direct heating of network water, etc.).

With today's prices for energy resources and the expected growth in gas prices compared to the increase in electricity tariffs, dispersed facilities in the agricultural sector are becoming preferable for the implementation of a heat pump. The advantages of heat pump technologies in the energy system of the agro-industrial complex are their competitiveness with heat generators burning fossil fuels. The competitiveness of heat pump installations depends on their functional purpose, environmental impact on the environment and on a number of factors of a thermodynamic, design, and economic nature.

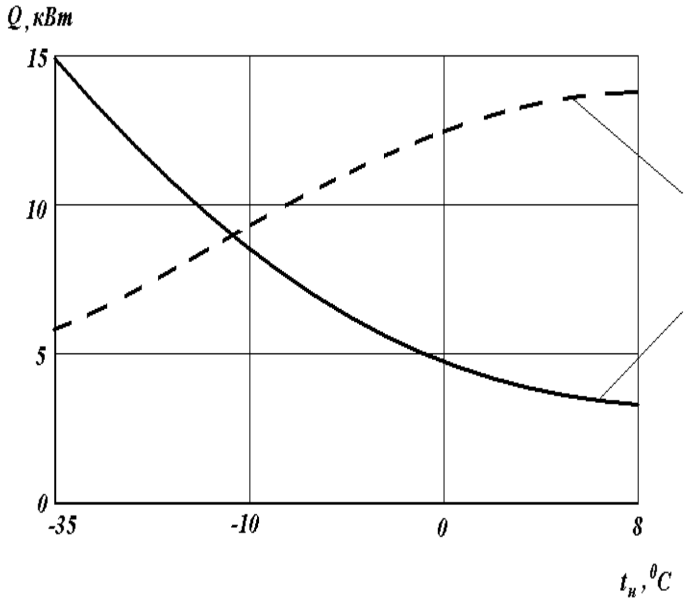
Materials and methods

In recent years, due to worsening environmental problems and the perceived need for energy conservation, all over the world more and more attention is being paid to the use of renewable energy sources, such as solar, wind, geothermal, biogas, etc. to produce heat. Heating installations are being developed that are based not on the combustion of traditional types of organic fuel, but on the use of renewable heat sources, such as heat pumps. A heat pump heat supply system, as a rule, consists of a low-grade heat collection system, heat pumps themselves and traditional sources of thermal energy (heat generators), and serves to cover peak loads.

In the warmer climatic conditions of the southern and western regions of Kazakhstan, the duration of the heating period is 168 days (with an average air temperature ≤ 8 ^{o}C) per year and an average temperature of -1.6 ^{o}C , it is preferable to use low-grade heat from atmospheric air. In this case, air-to-water heat pumps (AHVHV) are more economical in terms of capital investments. Heat pumps of this type have COP = 3.5…4.0 at outside air temperature t=2 ^{o}C [2].

This type of heat pump is widespread, which is due to the relative ease of installation, as well as the lowest cost among all other types of heat pumps. The weakness of TNVHV is the decrease in thermal power when the outside air temperature drops below - 15 ^{o}C.

Figure 1 shows the dependence of heat output and heat load on air temperature [3].



1 – thermal load; 2 – heating capacity

Figure 1 – Dependence of heat output and heat load on outside air temperature

The dependences presented in Figure 1 are explained by the fact that as tn decreases , the temperature difference in the evaporator decreases, i.e. temperature difference between atmospheric air and boiling refrigerant (t_{exp}) . As a result, at constant values of the heat exchange surface area in the evaporator (F_{isp}) and the heat transfer coefficient (k_{and}), the heat supply from the outside air to the working fluid of the HPI (Q_{isp}), the intensity of vaporization, the compressor performance (L_{comp}) and the heat output of the HPI (Q_{cond}). Since with decreasing tn the value of Q_{isp} decreases much faster than the compressor power L_{comp} , this leads to a decrease in the COP coefficient, as can be seen from the following simple relationships:

$$Q_{tnu} = Q_o + L,\ Q_o = k_{and} \cdot F_{isp} (t_o - t_n),\ COP = (L + Q_o)/ L = 1+ Q_o / L \qquad (1)$$

In the limit, at $t_o = t_n$ we have $Q_o = 0$, $Q_{tnu} = L$, COP = 1 and the heat pump unit essentially turns into an electric heater.

In this regard, if only outside air is used as a coolant, there is no need to talk about reliable heat supply to the consumer. The outside air temperature is never constant and can vary over a very wide range.

Therefore, when creating autonomous heat supply systems, it is more appropriate to use renewable energy sources comprehensively. The advantage of such systems is the constant flow of energy at the exit of the system and its consumption as needed, the continuity of the processes of energy production and consumption, the ease of combining systems, the ability to work with a single storage system, and the ability to optimize such systems according to various parameters.

Therefore, one of the problems in using a heat pump for autonomous heat supply of residential and industrial buildings is the problem of the optimal choice of a combination of heat pumps and renewable energy sources. The choice of a combination of joint operation of a heat pump and renewable energy sources should be made on the basis of a low-grade heat collection system, which consists of various heat exchangers that utilize renewable energy sources and are included in a single circuit with the HP evaporator.

In addition, for the design and creation of autonomous power supply systems, as well as individual power plants based on the use of renewable energy sources, reliable values of the potential of renewable energy resources in the area under consideration are required. This potential can be roughly assessed on the basis of existing data accumulated over several years of observations and published in hydrometeorological reference books and atlases [4, 5], or using modern computer databases [6].

Let's consider the minimum heat configurations of a low-grade coolant with renewable energy sources. According to [7, 8], it is more preferable to use solar energy to reheat the outside air entering the air-to-water HP evaporator circuit. This gives a significant reduction in the consumption of electrical energy expended by the heat pump installation from 25 to 15% of the total output.

In contrast to the energy potential of atmospheric air at a given specific period of time, the solar energy potential, although not constant, is largely predictable and close to average statistical data obtained through long-term observations.

Regardless of the geographical location of the republic, solar energy resources in the country are stable and acceptable, thanks to favorable dry climatic conditions. The number of hours of sunshine in the southern, south-eastern and western regions of the country is 2200-3000 hours per year, and solar radiation energy is 1300-1800 kW per meter per year. Total daytime radiation is 3.8-5.2 kWh / ^{m2} .

Figure 2 shows, as an example, a graph of changes in the average monthly total solar radiation during the year on a horizontal surface for a geographic latitude of 43 ^{o} 16 $^{'}$ (Almaty region, Zhambyl district).

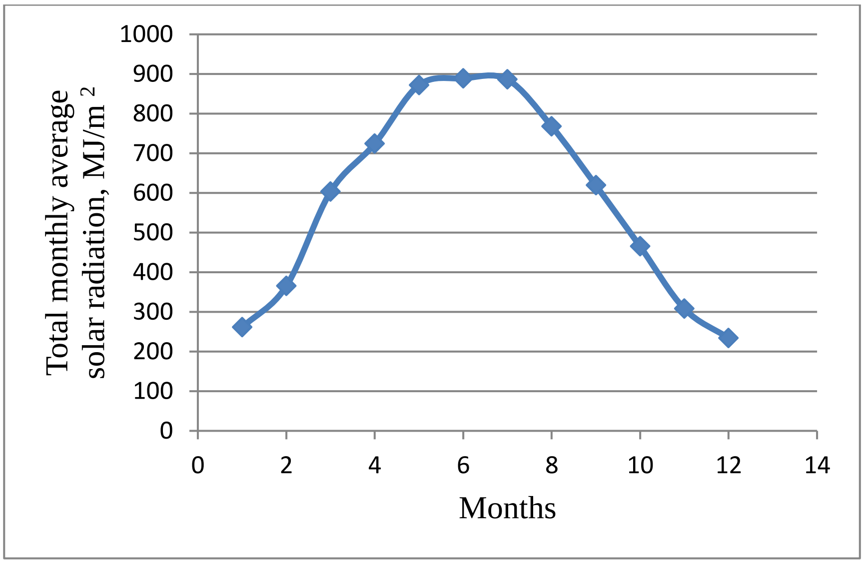


Figure 2 – Graph of changes in the average monthly total solar radiation during the year on a horizontal surface for a geographical latitude of 43 ^{o} 16 $^{'}$

Common devices for converting solar energy into heat are concentrating and directly absorbing solar flow - solar collectors and absorbers or panels. Solar collectors are solar systems, which include a transparent roof with a metal plate with a wavy profile installed underneath , the outer side of which is painted with a selective absorbing coating.

To increase the efficiency of using solar radiation, the solar system can be equipped with a heat-storage structure that accumulates the heat of solar energy. The use of batteries charged during the period of minimum energy consumption and discharged during the period of maximum demand significantly increases the reliability and efficiency of TST operation. Energy storage has a number of advantages:

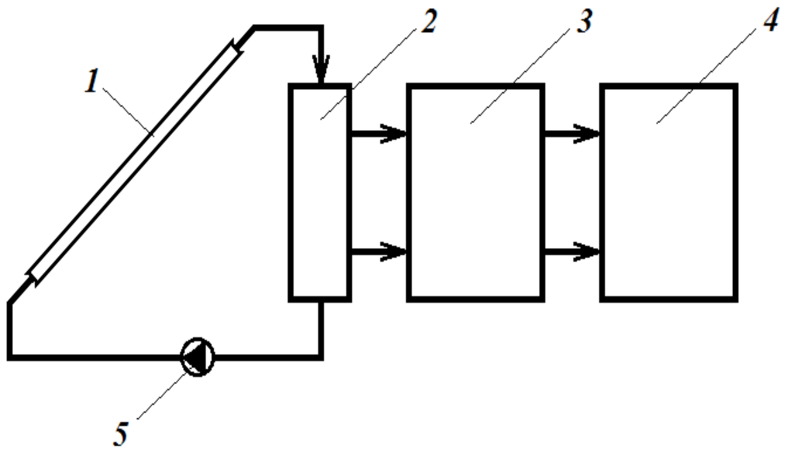
- the need for energy consumption is satisfied to a large extent, when the consumer becomes largely independent of the intermittent operation of the energy source (solar, air);

- due to the battery, it is possible to cover part of the peak loads and reduce the required power and, therefore, the cost of energy sources.

With the help of such a solar system, the temperature of the coolant in the primary circuit of the solar absorbers and in the evaporator circuit of the heat pump in winter can be increased to 3...7 ^{o}C in relation to the outside air temperature.

The solar heat pump system can operate in two modes – summer and winter. In the summer (April-October), the hot water supply of a residential building is completely covered by the heat received from solar collectors. The heat pump, as an additional energy source, is turned on only on cloudy days. In winter, the heat load for heating a residential building is covered by a heat pump unit, which uses the heat of outside air heated by solar absorbers and a heat storage structure as a source of low-potential energy.

The connection diagram of a solar collector with a heat accumulator for autonomous heating and hot water supply of a rural house is shown in Figure 3.



1 – solar panels; 2 – heat accumulator; 3 – heat pump; 4 – heat consumer; 5-circulation pump.

Figure 3 – Scheme of interfacing the solar collector with a heat accumulator

However, using only the heat of the surrounding air and solar energy as the only sources of low-grade heat sources in combination with a heat pump is ineffective. This is primarily due to seasonal and daily fluctuations in outside air temperature, changes in the intensity of solar radiation depending on specific soil and climatic conditions, which entails fluctuations in the operating modes of the heat pump, reducing its efficiency. In addition, at night, solar insolation is practically zero and heating the coolant is not possible.

Therefore, a combination of heat pumps with other sources of renewable energy may be effective, for example, a combination of a ground heat exchanger - a heat pump, where the first device increases the temperature of the coolant, and the second produces deeper energy extraction.

The soil mass is actually a heat accumulator of unlimited capacity, the thermal regime of which is formed under the influence of solar radiation and the flow of radiogenic heat coming from the bowels of the earth. At a relatively small depth from the surface there is a layer of soil, the temperature potential of which in the cold season is much higher than that of the outside air, and in the hot season it is much lower.

Works [7, 9] note that soil at a depth of more than 1.5 m is characterized by low (8-12 ^{o}C), slightly varying temperature and allows us to consider it as an effective source of energy for heat pumps. In this case, ground heat exchangers should be buried 30-40 cm below the soil freezing depth.

Negative properties of ground heat exchangers are considered to be changes in soil temperature in the annual cycle relative to its natural temperature. Correctly accounting for the heat distribution process is fraught with significant difficulties. Meanwhile, the consumption of thermal energy from the soil massif, as indicated [7], causes a decrease in the temperature around the heat exchanger by

2... 4 ^{o} C. Subsequently, the soil temperature fluctuates within 0.5...1.0 ^{o} C , depending on the annual heating load.

Given the requirements for complete autonomy of a rural house, it is necessary to make maximum use of available renewable energy resources. The use of such sources of thermal energy as solar collectors, a ground heat exchanger and heat accumulators in a minimal configuration, including only a heat converter, is not able to provide high-quality and guaranteed constant heat supply to an autonomous consumer.

System reliability can be achieved by combining autonomous heat and power supply with solar water heating installations and solar power plants. In this case, low-grade heat, replacing each other, is consistently supplied from three or more renewable energy sources through the use of an evaporator and a condenser of an air-to-water heat pump.

The use of solar water heating installations ensures uninterrupted hot water supply for domestic needs, and the location of the heat exchanger (boiler-accumulator) next to the HP hydraulic unit, "warm floor" with coolant. The use of photovoltaic modules in an autonomous heat supply system makes it possible to provide the proposed TST with a reliable backup power supply.

Taking into account the information provided, it becomes clear that at the stage of developing a feasibility study for objects with a heat pump heating system, the following issues should be addressed:

- when designing buildings using energy-saving technologies, including the use of heat pumps using heat from renewable energy sources, it is necessary to consider the object as a single whole;
- the design thermal, cooling and electrical loads of the facility are determined, taking into account all internal household and technological heat releases;
- possible measures to reduce energy loads using traditional methods were considered;
- daily and annual schedules of heat and electrical energy consumption were determined;
- the energy potential of available renewable energy sources and the required power to cover the thermal loads of the building have been determined;
- a schematic diagram of a heat supply system using heat pumps was selected and preliminary design study was completed;
- annual operating costs were calculated for the traditional heat supply option and the option with heat pumps.

When selecting a heat pump for an autonomous heating system of a residential building or industrial facilities, it is unprofitable to orient the power indicators of the heat pump to the maximum power requirements (to cover energy costs in the heating circuit in the coldest period of the year). Experience shows that HP should cover 70...75% of the total annual energy demand for heating and hot water supply.

In the climatic conditions of Kazakhstan, heat from the external circuit is still not enough for heating in severe frosts, so during operation it should be possible to connect a heat pump paired with a backup heat generator, for example a gas boiler.

Since there are currently no uniform requirements for heat exchangers based on renewable energy sources, such heat collection systems should be designed taking into account seasonal and daily changes in outside air temperature, the intensity of incident solar radiation, the main soil-forming rocks and their properties depending on natural conditions of this area.

Research results

Connected to the above, a possible solution to this problem in terms of efficiency, cost of implementation, and, accordingly, payback is a combination of systems based on the utilization of heat from solar energy, soil from the surface layers of the Earth and energy from the surrounding air.

Based on the results of research [10], as well as an assessment of the characteristics of meteorological conditions during the heating season in the south-eastern zone of the republic [8], we propose the following hybrid TST, consisting of air and water solar collectors, a ground heat exchanger and a heat accumulator , used for heating and hot water. water supply The thermodynamic diagram of the interface between the low-grade heat collection system and the heat pump is shown in Figure 4.

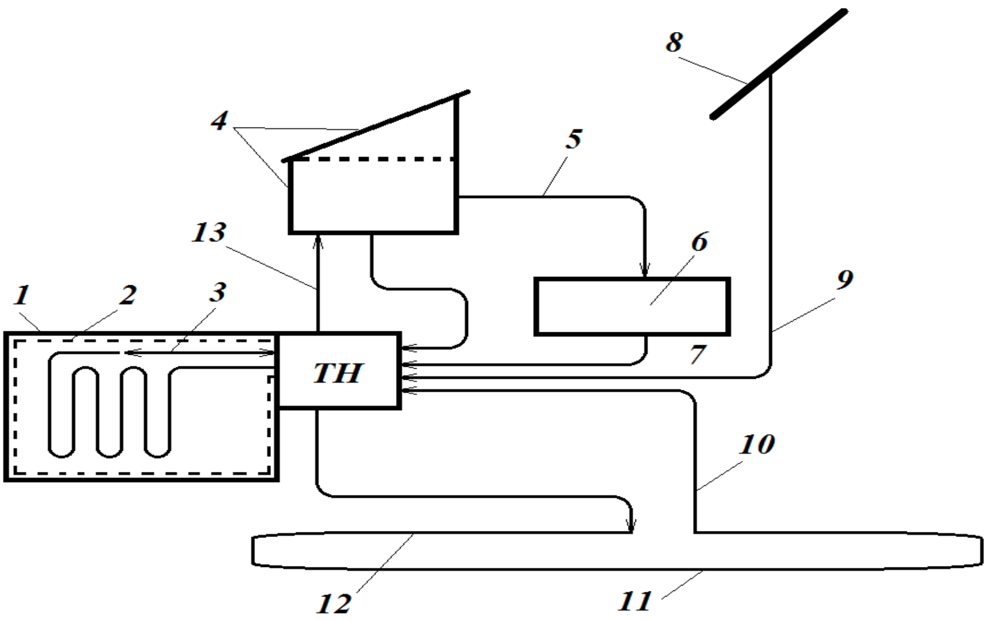
As can be seen from the figure, the evaporator circuit of an air-to-water heat pump is powered from various sources of low-grade heat: the energy of the sun, soil, ambient air and heat accumulated in a heat storage tank .

For the most efficient use of thermal resources of renewable energy sources, the system for collecting low-grade heat from them is located in a room, which is attached to the heated building as a heating point (TS) [11]. This placement minimizes the number of air ducts and reduces heat loss during the transformation of thermal energy. Utility rooms, garages, etc. can serve as a heating point.

A special feature of the heating point is that all elements of the low-grade heat collection system are built into the heating substation room and through it automatic regulation of the consumed heat in heating systems is carried out depending on changes in the outside air temperature.

Horizontal and vertical airborne solar collectors are placed in the roof and southern façade of the transformer substation, consisting of a sealed, thermally insulated metal or wooden frame and a black metal plate that absorbs heat. On top of this frame is covered with a transparent coating: glass or two-layer cellular polycarbonate.

A ground heat exchanger is formed by laying heat exchange pipes in earthen trenches 1.5...2.0 m deep, connecting the branches in series or parallel. As a heat exchanger, you can use two-layer pipes, corrugated on the outside and smooth on the inside, made of high-density polyethylene with a nominal internal diameter of 80...110 mm.



TN – heat pump; 1 – heated room; 2 – radiator circuit of the heating system; 3 – underfloor heating circuit; 4 – circuit of the air solar collector; 5.7 – heat accumulator channels ; 6 – heat accumulator ; 8 – water solar collector ; 9 – pipelines of the solar water collector ; 10,12 – channels of the ground heat exchanger; 11 – ground heat exchanger; 13 – channel of spent NIE.

Figure 4 – Block diagram of the heat pump system for autonomous heat supply

The heat storage structure is placed in the transformer room in the form of a pit with a volume of at least 5 m^3 . Non-freezing liquids (antifreeze, antifreeze, etc.) or solid materials (magnesite, soapstone , chamotte, etc.) with high heat capacity can be used as a heat-accumulating mass .

A solar system based on solar collectors for heating and hot water supply is formed from vacuum solar panels, a boiler - battery, expansion tank, circulation pump and pipe fittings. To power your home using solar panels, you need solar panels, a charge controller, batteries and an inverter.

The premises of the heating point also house the outdoor unit of an air-to-water heat pump, which uses heat from a recovered system for collecting low-potential renewable energy sources.

The proposed TST works as follows. During the heating period, before entering the TNVHV evaporator, outside air passes through horizontal and vertical air solar collectors, and is accompanied by the selection of heat from solar radiation. The heated coolant is supplied to the evaporator of the outdoor unit TNVHV. Thermal transformation of heat to a higher temperature level occurs by transferring heat from the heated low-potential coolant to the refrigerant circulating in the evaporator circuit. Next, the refrigerant evaporates, the refrigerant vapor is compressed in the heat pump compressor, and its heat is transferred to the heating system water circulating through the heat pump condenser. Water for the heating system is heated in the heat pump to a certain temperature and, using a circulation pump, is supplied to the heating system (to the heated floor or heating devices).

The coolant cooled in the TNVHV evaporator circuit is supplied to the ground heat exchanger using a fan. Passing through corrugated pipes laid in the trench of a ground heat exchanger, the cooled air takes away the heat of the soil at the depth of the non-freezing layer of soil and again returns back to the heating point. This eliminates the possibility of cooling the outside air heated in the solar collector by coolant cooled in the TNVHV evaporator.

In the case of cold weather, when the outside air temperature is lower than the temperature of the coolant exhausted in the TNVHV evaporator, the ground heat exchanger will operate in closed mode. At the same time, the waste coolant is driven through integrated systems of airborne solar collectors and heated instead of outside air. This method of heating a low-potential heat source is much more profitable than heating cold outside air.

To prevent frequent switching on and off of the heat pump due to fluctuations in outside air temperature, a solar water collector is connected to the heating process . Hot water from the storage boiler enters the HP condenser and is then distributed through the floor and radiator heating circuits.

Heat accumulation occurs from solar collectors in a heat storage structure. In a heat-storing structure, heat is transferred to the heat-storing mass. At night, the heat accumulated in the heat-storing structure is transferred to reheat the surrounding air before feeding it into the TNVHV evaporator circuit.

Conclusions

The use of the proposed heat pump system will improve the efficiency of autonomous heat supply to decentralized and remote residential and industrial facilities, service enterprises. In addition, the proposed combination of heat pump installations and RES expands the resource base of TST, making it less dependent on fluctuations in ambient temperature, which is very important for increasing the reliability level of heat pumps.

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ТӨМЕН ПОТЕНЦИАЛДЫ САЛҚЫНДАТҚЫШТЫ ЖЫЛЫТУҒА АРНАЛҒАН АВТОНОМДЫ ЖЫЛУМЕН ЖАБДЫҚТАУДЫҢ ЖЫЛУ СОРҒЫ ЖҮЙЕСІ

Аңдатпа

Жылу сорғысын қолданатын жылумен жабдықтау энергияны үнемдейтін, экологиялық таза технологиялар саласына жатады және әлемде кең таралуда. Бұл технология, бірқатар беделді халықаралық ұйымдардың қорытындысы бойынша, энергияны үнемдейтін басқа технологиялармен қатар (күн энергиясын, жел энергиясын, Мұхит энергиясын және т.б. пайдалану) 21 ғасырдағы технологияларға жатады. Суық мезгілде ғимараттардағы тұрмыстық қажеттіліктер үшін жылудың негізгі шығындары жылыту шығындары болып табылады. Бұл суық мезгілде ғимараттардың жұмыс жағдайына байланысты, ғимараттың қоршау құрылымдары арқылы жылу шығыны ішкі жылу шығарудан едәуір асып түседі. Сондықтан ішкі ауаның қажетті температурасын ұстап тұру үшін ғимараттар жылыту құрылғыларымен жабдықталады. Суық мезгілде ғимараттарда жылу жайлылығын құру және сақтау үшін техникалық жағынан мінсіз және сенімді жылыту қондырғылары қажет.

Ұсынылып отырған жылу сорғы жүйесін пайдалану орталықтандырылмаған және шалғайдағы тұрғын үй және өнеркәсіптік объектілерді, қызмет көрсету саласындағы кәсіпорындарды дербес жылумен жабдықтау тиімділігін арттыруға мүмкіндік береді. Сонымен қатар, жылу сорғы қондырғылары мен жаңартылатын энергия көздерінің ұсынылатын комбинациясы жылу сорғысының жылу жүйесінің ресурстық базасын кеңейтеді, бұл оны қоршаған орта температурасының ауытқуына аз тәуелді етеді, бұл жылу сорғыларының сенімділік деңгейін жоғарылату үшін өте маңызды.

Кілт сөздер: жылу сорғысы, жылу сорғы жүйесі, жылу сорғысы автономды жылумен жабдықтау жүйесі, жылу сорғы қондырғысы, төмен потенциалды жылу көзі, жаңартылатын энергия көздері

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ТЕПЛОНАСОСНАЯ СИСТЕМА АВТОНОМНОГО ТЕПЛОСНАБЖЕНИЯ ДЛЯ ПОДОГРЕВА НИЗКОПОТЕНЦИАЛЬНОГО ТЕПЛОНОСИТЕЛЯ

Аннотация
Теплоснабжение с использованием теплового насоса относится к области энергосберегающих, экологически чистых технологий и получает все большее распространение в мире. Эта технология, согласно заключению ряда авторитетных международных организаций, наряду с другими энергосберегающими технологиями (использование солнечной энергии, энергии ветра, энергии океана и т.д.), относится к технологиям 21 века. Основными затратами на тепло для бытовых нужд в зданиях в холодное время года являются расходы на отопление. Это объясняется условиями эксплуатации зданий в холодное время года, когда теплопотери через ограждающие конструкции здания значительно превышают внутреннее тепловыделение. Поэтому для поддержания необходимой температуры внутреннего воздуха здания оборудуются отопительными приборами. В холодное время года для создания и поддержания теплового комфорта в зданиях требуются технически совершенные и надежные отопительные установки.

Использование предлагаемой теплонасосной системы позволит повысить эффективность автономного теплоснабжения децентрализованных и удаленных жилых и промышленных объектов, предприятий сферы услуг. Кроме того, предлагаемая комбинация теплонасосных агрегатов и возобновляемых источников энергии расширяет ресурсную базу теплонасосной системы теплоснабжения, делая ее менее зависимой от колебаний температуры окружающей среды, что очень важно для повышения уровня надежности тепловых насосов.

Ключевые слова: тепловой насос, теплонасосная система, теплонасосная система автономного теплоснабжения, теплонасосная установка, низкопотенциальный источник тепла, возобновляемые источники энергии

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ТЕХНОЛОГИЯ И ТЕХНИЧЕСКИЕ СРЕДСТВА СТЕРИЛИЗАЦИИ ПТИЧЬЕГО ПОМЕТА И ПРОИЗВОДСТВА КОМПЛЕКСНОГО ОРГАНИЧЕСКОГО УДОБРЕНИЯ

Аннотация
Приведены результаты анализа методов переработки птичьего помета и производства