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A LOW-PRESSURE STEAM ELECTRIC HEATER AS THE BASIS OF A NEW
GENERATION AUTONOMOUS HEATING SYSTEM

Abstract. The article is dealing with studying an electric vacuum heater and a low-pressure steam electric heater developed on its basis. A low-pressure steam electric heater can be the basis of a new generation autonomous heating system. Prototypes of a low-pressure steam electric heater with an automatic control system for its operation modes have been developed. The prototype power is 600, 800, 1000 W. Reliability of the electric vacuum heater has been tested empirically. A low-pressure steam electric heater combines the efficiency of an electric coil and the comfort of heat from a traditional central heating radiator without the drawbacks of oil-filled electric radiators and is a reliable, fireproof electric heater.

Keywords. Heating radiator, electric heater, heat supply system, energy efficiency.

Introduction.

A low-pressure steam electric heater (LPSEH) is a thermal device designed to build autonomous heat supply systems of a new generation with an automated control system for operating modes. The heating device is controlled manually using an automatic room temperature control system or remotely with the use of a smartphone. LPSEH can be used to build completely autonomous electrical heating systems, in which pipelines will be completely absent.

In the last century, the Nuaro Company [1] developed and launched the mass production of spiral EHs. It turned out to be a fairly reliable and efficient design. About 90 years ago, an oil EH was developed in Europe, in which a spiral tubular electric heater was placed in oil in a sealed housing. A little later, the first infrared heaters were developed that were used both in everyday life and in production. Each of them has its own advantages and disadvantages that have already been described earlier [2].

In Kazakhstan, EHs are not practically produced, they are mostly exported from China. Taking into account the significant experience in the production and development of EHs, an own design of the EH was developed that was different from the existing analogues. It combines a number of advantages of spiral EHs and heating radiators of central heating systems. A LPSEH is capable of operating in the mode of convective, radiant-convective or radiant heat transfer, which expands the scope of its use.

In this connection, research is needed on providing of developing a new generation EH. The object can be a low-pressure electric steam heater (LPSEH). This EH combines the advantages of electric spiral, convector and oil electric heaters into a single whole [3]. The work basis of the proposed LPSEH is the capillary effect used in modern heat pipes. LPSEH is highly efficient and develops comfortable heat for a person. The LPSEH developed based on the materials presented in [4]. The LPSEH is fully automated. It is possible to combine it with the Smart Home system [3]. Adjustment of operating modes is possible using a remote control or a smartphone. Using the previously obtained results of studying heat pipes [5, 6], the design of the LPSEH electric vacuum heater has been developed that was presented earlier and described in detail in [7]. The heating temperature of its surfaces was selected taking into account
recommendations [8]. Analyzing the trends of developing energy saving systems for heat supply of buildings and small settlements [9, 10], the trends of developing and using LPSEHs have been formulated. The article contains well-known theoretical information in the field of heat engineering and heat transfer [5, 6]. When forming the concept of using LPSEHs in tubeless heating systems, the accumulated materials in the field of operation of heat networks and updated autonomous energy-saving heating systems based on a vapor-drop heater [11] have been used.

**Materials and methods.**

The object of study is a LPSEH section weighing 346 and 434 grams. The sections are made identical in design and differ only in the length of the body [11, 12]. The sections are in the vertical position. The diagram of the experiments is shown in Figure 1.

An adjustable power supply was used in the experiments. The source is connected to AC 220V. A heating element is used to heat the coolant. The heat source for heating the coolant is an electric nichrome spiral. Distilled water has been used as a heat carrier. The electric current, passing in a spiral, heats the coolant, which turns from a liquid state into steam. The heat carrier moves from the lower part of the heat tube body rises to the upper part. In this case, the walls of the tube are heated, in the upper part the steam condenses and flows down the walls of the tube, where it heats up again and evaporates again. The process of phase transition and operation of the known heat pipe is described in [11,12]. The electric spiral of the heating element is located in a completely hermetic housing made of copper tube and does not come into contact with the coolant. Before the experiments, air is pumped out of the tube and a vacuum is created in the range from 9 to 10 kPa (0.09–0.1 Atm), then an insignificant volume of coolant is placed inside in the range of 10-15 ml. A tube and a valve are used to pump out the air. A vane pump DUO
6/M has been used to evacuate air and to produce vacuum. The temperature has been controlled using two temperature sensors connected to a 4-channel digital thermometer HT-9815 (Xintest, China).

**Results and discussion.**

Taking into account the shortcomings of the above electric heaters, a fundamentally new EH design has been developed that is distinguished by high reliability and safety (Figure 2). The fundamental difference between the LPSEH and the traditional oil electric heater is the use of an independent electric vacuum tube with fins, inside which a nichrome spiral electric heater is placed that does not come into contact with air and internal coolant [2, 3].

In sources [11,12] one can get acquainted with the principle of operation of the LPSEH. Distilled water is used as a heat carrier. It has undergone preliminary preparation in a deaerator and a magnetic resonator. Inside the electric vacuum tube, pressure is developed in the range of 0.03-0.01 atm. The higher the rarefaction of the atmosphere in the inner cavity of the tube, the more efficient the operation of the EH. At specified pressure, conditions are provided for obtaining steam at the temperature of lower than 20 °C.

![Figure 2 - The appearance of the LPSEH prototype](image)

When the electric heater is turned on, the work surfaces heat up quickly. Therefore, there are sufficiently high requirements for the tightness of the heat pipe in order to prevent the violation of vacuolization.

The LPSEH section is cast of a duralumin alloy (density 2800 kg/m³ and thermal conductivity 120 W/(m·deg)). The operation of the tube is based on the phase transition of water from the liquid to the gaseous state; in the upper part condensation occurs and the condensate of water vapor returns to the heating zone. The heating element is made of nichrome wire wound in the form of a spiral. Good cooling provides it with a long service life. The maximum working temperature of the LPSEH section does not exceed 70 °C. This temperature complies with the hygienic standards provided by traditional central heating systems, which develops comfortable heat and does not lead to the combustion of dust (it creates an unpleasant smell in the room). The LPSEH consists of separate sections of electrovacuum heaters with the power of 100-300 W that are assembled into one common EH depending on the area of the heated room and the prevailing demand. The electric heater is at the bottom of the tube base. The coolant heats up and turns into steam that rises up to the top, transferring heat from the base to the top. This helps to achieve a rapid heating effect of each tube and the movement of thermal particles at the speed of sound. The LPSEH is equipped with a climate control system that allows operating more efficiently and reducing energy costs. The LPSEH requires an electrical network with voltage of 12 to 380 V of
any kind of current. It can also be connected to the DC network of solar modules [12]. The LPSEH consists of separate sections that are assembled into a single radiator depending on the required power, in the ratio of 1 section (100 W) per 1.2-1.7 m² of the room area. Accordingly, an EH with the power of 1000 W is able to heat an area of 12 m².

A fundamentally new LPSEH design provides zero probability of the flow path wear and the occurrence of leakage, defrosting, airing, corrosion and clogging of the flow path. LPSEH does not have moving and rotating parts, circulation pumps, air locks and process water as in heating radiators. It has a fairly high efficiency of more than 90%, since it is based on an electric spiral. The heating time of the working surface is up to 5 times shorter than that of an oil cooler. LPSEH is up to 1.3-1.4 times more economical than the existing oil electric heaters due to design solutions and the use of an electronic operating mode control system.

Figure 3 shows a sketch of the LPSEH section that helps to understand the design of this EH.

![Figure 3 - A sketch of the LPSEH section](image)

The LPSEH climate control system control unit allows operating more efficiently and reducing energy costs. This unit has been developed based on the existing temperature controller made in China. The body is made using a 3D printer. The power supply is based on a DC12V network adapter. The temperature control step is 0.1 °C, and the control range is from 15 to 30 °C, which makes it possible to adjust to any indoor temperature. The unit has the ability to be connected to a remote or wireless control system. The use of an additional WI-FI range communication module allows coordinating the LPSEH with any mobile devices and computers. For work, a standard utility is used that allows turning your smartphone into a remote control. All the electric heaters can be controlled remotely at the same time. The switching capacity of the control unit is 10 A, while its cost lies in the range of 5-6 US dollars. If needed, there can be used a controller with a switching capacity twice as large. At the same time, its cost will be in the range of 10-12 US dollars. The cost of this system is several times lower than that of analogues sold in the market for controlling the temperature of heaters.
Figure 4 shows a photograph of the LPSEH climate control system control unit. On the front panel there are three eight-segment temperature indicators and control buttons. When the temperature drops below the set value, the EH automatically turns on and the green indicator lights up, which shows the output operation.

![Figure 4 - The LPSEH climate control system control unit](image)

If the temperature in the room rises above the set point, the controller disconnects the electrical load and the red LED lights up, while the control unit does not turn off but is in standby mode. To measure the temperature, a semiconductor sensor is used that is connected to the analog ports of the microcontroller. The sensor is located outside the control unit housing.

To explain the location of the main elements of the control unit, an explanatory diagram is presented in Figure 5.

![Figure 5 - The elements of the LPSEH control unit](image)

1 – mains plug for connection to AC 220 V, 2 – power cord, 3 – control and navigation buttons, 4 – three eight-segment temperature indicators, 5 – load on indicator, 6 – load off indicator, 7 – control unit housing, 8 – temperature sensor, 9 – power cord for EH connection, 10 – network adapter for EH connection.

The Microsoft Excel tools have been used to process the experimental data, the graphs show the limits of measurement errors, a trend line has been built, and equations for approximating dependence curves have been given. A regression analysis has also been performed. For the theoretical study, the mathematical apparatus of the theory of convective heat and mass transfer has been used. Initially, theoretical studies of the process of heat transfer along the tube wall and a liquid-saturated wick have been carried out using the Fourier transform.

The results of the experiments are shown in Figures 6 and 7. The volume of the coolant has been varied and amounted to 10 ml and 15 ml, the power supplied to the electric coil has been 80 W. The temperature in the room at the time of the experiments has been 24 °C.
Figure 6 - The heating time dependence of the LPSEH section weighing 346 grams with the heat carrier volume of 10 and 15 ml

Figure 7 - The heating time dependence of the LPSEH section weighing 434 grams with the heat carrier volume of 10 and 15 ml

Increasing the weight of the LPSEH section from 346 to 434 grams has led to decreasing the temperature of the working surfaces, and with the section weight of 600 grams, its surface temperature will be about 100 °C, with the heater power of 80 W. The volume of the coolant affects the heating efficiency, the highest performance has been achieved with the volume of 13 ml, but with increasing the volume over 15 ml, a gradual decrease in temperature begins. With the coolant volume of 20 ml, the heating performance will decrease by 4 %. The pressure inside the vacuum tube is important. At the pressure of 5 kPa (0.05 atm) a heat pipe with the input power of 80 W and the mass of 310 grams can heat up to 235 °C. Reducing the pressure inside the tube of the electric vacuum heater will increase its efficiency.
Conclusion.

Four prototypes of LPSEHs with an automatic control system for its operation modes have been developed. The power of the samples has been 600, 800, 1000 W of various configurations. Reliability of the electric vacuum heater has been tested experimentally. One of the 800 W samples has been in the working condition for two years and four months, while all the sections remained operational.

The obtained technical indicators of EO will ensure the effective operation of LPSEH for 20 years at an efficiency of 90%. LPSEH provides two modes of heat exchange – convection-radiant and radiant.

LPSEHs can be attributed to a new generation EH that combines the efficiency of an electric coil and the comfort of heat received from a traditional heating radiator of the central heating system. LPSEH does not have the disadvantages of oil-filled electric radiators, it is a reliable, fireproof EH. It can be integrated into the "Smart Home" system that is gradually entering our lives and will become an integral part of everyday life in the near future.

Using the LPSEH technology, in the future it is possible to transit to pipeless electric heating systems.

Despite the scientific work done, LPSEHs require further comprehensive research in order to find more effective technical solutions, especially in the field of maintaining vacuum inside of the tube, as well as developing its production technology.

REFERENCES

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ЖАҢА БУЫН АВТОНОМДЫ ЖЫЛЫТУ ЖҰЙЕСІНИҢ НЕГІЗІ РЕТІНДЕ ТӨМЕН ҚЫСЫМДЫ БУ ЭЛЕКТР ЖЫЛЫТҚЫШЫ

Аннотация. Макала электр вакуумдық жылытқышты және оның негізінде жасалған томен қысымды бу электр жылытқышын зерттеуге арналған. Томен қысымды бу электр жылытқышы автономды жаның бұған жылу жүйесінің негізі бола алады. Жұмыс режимдерін автоматты басқару жүйесі бар томен қысымды бу электр жылытқышының тәжірибелік үлгілері жасалды. Үлгілердің қуаты 600, 800, 1000 ватт болды. Электр вакуумдық жылытқыштың сенімділігі тәжірибе жүзінде сыналды. Томен қысымды бу электр жылытқышы электрлік спиральдың тиімділігі мен орталық жылу жүйесінің дәстүрлі жылу және қылу жылытқышының кемшіліктерін жайытқышына қосылды. Сонымен қатар май электр радиаторларының кемшіліктері жоқ және сенімді, отқа төзімді электр жылытқышы болып табылады.

Түйінді сөз. Жылу жылытқышы, электр жылытқыш, жылу жүйесі, энергия тиімділігі.

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ПАРОВОЙ ЭЛЕКТРООБОГРЕВАТЕЛЬ НИЗКОГО ДАВЛЕНИЯ КАК ОСНОВА АВТОНОМНОЙ СИСТЕМЫ ОТОПЛЕНИЯ НОВОГО ПОКОЛЕНИЯ

Аннотация. Статья посвящена исследованию электровакуумного нагревателя и созданного на его основе парового электрообогревателя низкого давления. Паровой электрообогреватель низкого давления может быть основой автономной системы отопления нового поколения. Созданы опытные образцы парового электрообогревателя низкого давления с автоматической системой управления режимами его работы. Мощность образцов составила 600, 800, 1000 Вт. Надежность электровакуумного нагревателя была проверена опытным путем. Паровой электрообогреватель низкого давления сочетает в себе эффективность электрической спирали и комфортность тепла, полученного от традиционного радиатора отопления центральной системы теплоснабжения, при этом он не имеет недостатков масляных электрических радиаторов и является надежным, пожаробезопасным электрообогревателем.

Ключевые слова. Радиатор отопления, электрообогреватель, система теплоснабжения, энергоэффективность.

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