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ТЕПЛОФИЗИКА И ТЕОРЕТИЧЕСКАЯ ТЕПЛОТЕХНИКА

THERMOPHYSICS AND THEORETICAL THERMOENGINEERING

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Electrovacuum heating elements

Improving the efficiency of heat supply systems for buildings and structures in the current trends in the global development of energy saving cannot be fully realized without the introduction of high-tech and low-energy-intensive electrical equipment. The heat supply of remote objects for various purposes is accompanied by significant losses, since the coolant has to cover considerable distances, in some cases the connection of the object to the heating plant is impossible due to technical problems or considerable material costs for the installation of pipelines. One solution could be the introduction of a low-pressure steam electric heater. This is a new generation electric heater with a fundamentally new design of the heating element. It combines the efficiency of an electric spiral and the comfortable warmth of a traditional heating radiator.

Keywords: radiator, electric heater, energy saving, heating system, heating device, heating.

Throughout the developmental stages of his development, man sought ways to heat his home. It all started with a fire, then the stoves and fireplaces were invented. With the development of technology, previous methods were replaced by autonomous heating systems with boilers operating on various types of fuel and thermal power plants capable of heating cities. But despite the presence of a centralized heating system, a person is not always satisfied with the ambient air temperature in a residential area, such a situation may occur during the interseasonal heating time when the outdoor temperature is still cool and the central heating system is not functioning or has already ceased to function due to the end your season work. A similar situation arises in the southern countries, where there is practically no cold winter and snow, but there are small periods of time when a heat source is needed to heat the dwelling. To solve this problem, you can use a solid fuel and gas stove, but it is not always acceptable for urban conditions besides the fire hazard of a heat source with open fire, it also produces harmful emissions of exhaust gases in the course of its work, which harm the environment of the city and create local areas of concentration of flue gas. The search for the most ecologically clean source of heat prompted engineers to use electric current and create an electric heater, a kind of autonomously working heat source connected to the electrical network. Compact thermal device is capable of producing enough warm to heat a home. In the 30s of the last century in Geneva, the French engineer Jacques Noir [1] developed and launched into production an electric heater, the basis of its design was an electric spiral, which was blown by the air flow created by a fan. Subsequently, he created his own company «Noir». At the same time, oil radiators were developed, the heating element was immersed in oil, placed in a sealed metal case from which heat is transferred to the surrounding air. In the process of heating, the oil transfers the resulting heat to the environment. Each type of heat equipment has certain disadvantages and advantages that have already been described many times in the literature, as well as electric heaters have come a long way to improve and modernize their design [2]. In 1972, the company «Noir» products came to the market with electric heaters equipped with a thermostat, it was possible to regulate the temperature of the supplied air. In 1988, the company «Noir» created

a convector, which was later taken as a basis by many manufacturers. The production of a convection-type heater has opened up new possibilities for heating devices: safety, operation of the device without noise, energy saving. In 2000, a new type of heater called the «Kalida», equipped with a climate control system, entered the market. Currently in the world there are a huge number of different types of heaters and manufacturers of this electrical equipment. The analysis of world production of electric heaters is very significant and is presented by various companies in Europe, Asia and America, for example: De'Longhi, General Climate, Polaris, EWT, Hansa, Timberk, Supra Wika, Fluke, Noir, Hyundai, Resanta, NOVEL, ZASS, Kaiser, Ballu, Siemens, EVUB [3]. Electrical oil with a spiral heating element, convectors, split-systems, as well as infrared heaters are produced. At the moment, the export of electric heaters in Kazakhstan is 100 %, the vast majority is collected in factories in China. Our task is to develop a new generation electric heater equipped with all modern electronic monitoring and control systems, which will make it possible to achieve maximum comfort of use and efficiency of the thermal device.

We have developed a low-pressure energy-saving steam electric heater (LSEH), which can be a substitute for a traditional oil cooler, as well as to compete with existing electric heaters. LSEH combines the advantages of electric spiral, converters and oily electric heaters into a single whole. For example, oily electric heater contains oil that is dangerous in the fire relationship, it heats up for a long time, the metal body heats up strongly, and the oil is subject to degradation. In addition to the thermostat, more expensive branded models have a timer and protection that turns it off from the network when tipping to the floor, which makes its use more convenient and safer. Heaters with an electric helix also have several disadvantages, for example, emit unpleasant odors when burning dust and create noise during their work. There is also an analogue of LSEH developed by VEST, but which has a number of serious differences, its cost is several times higher than the electric heater proposed by us, so it cannot be considered in future as a competitor in the market [4].

After analyzing the sources [5], we developed a LSEH, which does not have the above disadvantages of the above-mentioned electric heaters, has high efficiency and creates comfortable heat. This is a fully automated electric heater with the «Climate Control» system and the possibility of coordination with the «Smart Home» system; it is controlled by using a remote control or a smartphone. The achieved technical indicators of the electric heater make it possible to ensure its service life for more than 20 years with a constant efficiency of 90 %.

We have developed and created an experimental laboratory sample of LSEH, consisting of separate sections with a capacity of from 50 to 100 watts. The block-modular layout of the electric heater allows the owner to change its power, if it is necessary, independently, without resorting to the services of skilled workers. Sections are connected in parallel using electrical connections. The LSEH section is made of duralumin alloy, inside which is placed a vacuum electric heater. One section can effectively heat up to 3 m² of living space at a ceiling height of 2.5 meters. The appearance of the prototype laboratory sample and the device of the electrovacuum heater is shown in Figure 1. The LSEH can be floor mounted or mounted on the wall, like a classic radiator, only instead of pipes you need to connect an electrical wire to it, which simplifies its installation [6].



Figure 1. The appearance of the experimental laboratory sample and the device of the electrovacuum heater LSEH

The basis of the LSEH is an electrovacuum heater, which operates as follows: an electric spiral heater 1 provides for rapid heating of the heat-transfer fluid 2 (distilled water); electric current is supplied to the coil by means of electrical wires 3. When the heat-carrier evaporates, the steam reaches the upper part of the body 4, where it gives off heat received from the heater. Cooling off steam condenses and flows along the walls of the body to the bottom again heats up and evaporates. The principle of its operation is based on the well-known effect of the phase transition of a heat pipe. The electric heating element is placed in the housing 5 and does not come into contact with the coolant [7]. The recommended pressure inside the electrovacuum heater should be within 4.053 kPa (0.04 bar). Heat particles move inside the body at the speed of sound due to which the LSEH section weighing about 230 grams is heated to 700 °C in less than 5 minutes, unlike the traditional oily electric heater more than 5 times faster. But there is one problem in the design that had to be solved in order to achieve reliable performance of the LSEH, this is to ensure high tightness of the body of the electrovacuum heating element, since when the pressure rises above 0.1 Atm, the effect of high-grade heating is lost, there were also problems with the set of the required temperature. The principle of operation is discussed in detail in the source [8], and also the novelty of the electrovacuum heating element is given.

During the work on the design of LSEH, we have developed a 3D model (Fig. 2). 3D model allows to execute drawings for its production, as well as to learn more about the device electric heater [9].



Figure 2. 3D model of LSEH

In the process of creating LSEH, we carried out a series of laboratory experiments aimed at improving the design of an electrovacuum heater, which were made in the form of copper tubes with diameter of 20, 28, 32, weight from 270 to 530 grams, length from 250 to 450 mm, heater power — 60, 80 and 100 watts. The pressure inside the tube is 4–10 kPa (0.04–0.1 atm). Temperature is 0 °C. In total, we manufactured and tested 40 electric vacuum heaters. Some results are presented in the dependency graphs in Figures 4 and 5. Temperature was measured using a Fluke 51 contact thermometer with laboratory accuracy (0.05 % + 0.3 °C) and a measurement limit of up to 900 °C (1600° F). Vacuum pump DUO 6/M SERIES PFEIFFER VACUUM with an integrated vacuum meter was used to create the vacuum [10].

The required number of repetitions of experiments [11] is determined on the basis of the coefficient K_{var} and the required degree of accuracy.

The value of the coefficient of variation is determined by the formula:

$$K_{var} = \frac{100 \cdot \delta}{\chi}, \%, \quad (1)$$

where δ — mean square deviation;

χ — arithmetic average.

The value of the mean square deviation is calculated by the formula:

$$\delta = \sqrt{\frac{\sum \delta_i^2}{N - n}}, \quad (2)$$

where δ_i — deviations of individual results from group means;

N — the total number of experiments;

n — the number of experimental groups [12].

To establish the required number of experiments a valid value of K_{add} in percent is given. Knowing the coefficient of variation K_{var} for a given test method, it is possible with a reliability of 0.95 to determine the required number of experiments. According to the results of numerous experimental data, $K_{add} = 12\%$ is taken ($K_{var} = 11.5\%$). This coefficient corresponds to (with a confidence probability of 0.95) the required number of experiments equal to 4. During the processing of the exertional data, data processing using the means of the Microsoft Excel spreadsheet processor, quadratic interpolation of the function (solid line) and the rms (root mean square) approximation (dashed line) were used, as well as performed regression analysis.

Figure 3 shows a plot of temperature change versus heating time for tubes with volume of 10 and 15 ml. The tube of the electrovacuum heater with the parameters copper — 28 mm in diameter, weight — 355 g, length — 310 mm, heater power — 80 W was investigated. The volume of coolant is 10 and 15 ml. The pressure inside the tube is 5.066 kPa (0.05 atm).

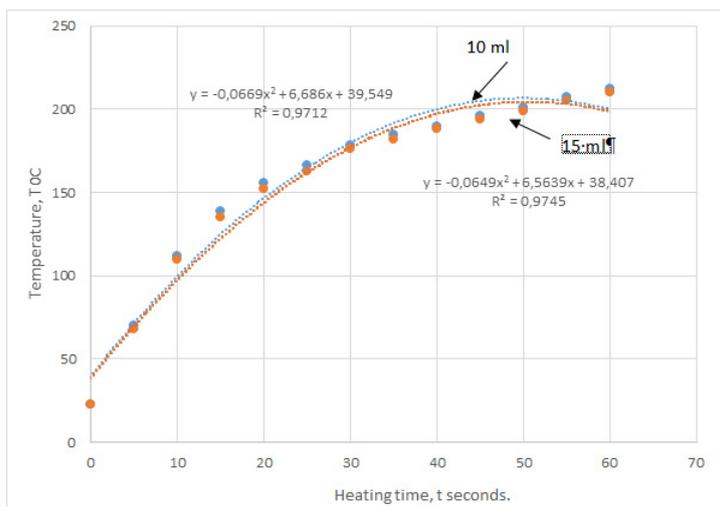


Figure 3. Graph of temperature change versus heating time for tubes with a volume of 10 and 15 ml

Figure 4 shows a plot of temperature versus coolant volume from 5 to 15 ml. The tube of an electrovacuum heater with a tube with parameters copper 20 mm in diameter, weight — 368 g, length — 305 mm, heater power — 80 W was investigated. The volume of coolant is 10 and 15 ml. The pressure inside the tube is 4,053 kPa (0.04 atm). Presumably, in the process of switching to a pressure of 0.01 atm (1.01 kPa), the efficiency of the electrovacuum heater, as well as the heat pipe, can be increased by 15–20 %, because the friction energy losses in a more discharged atmosphere decrease, the transmission rate can reach sound. If the pressure in the heat pipe is lower, then the heat transfer process is more efficient and the efficiency is higher. In the process of increasing the pressure in the internal cavity of an electrovacuum heater (above 0.1 atm), the effect of high-grade heating is completely lost and there are problems with a set of the required temperature.

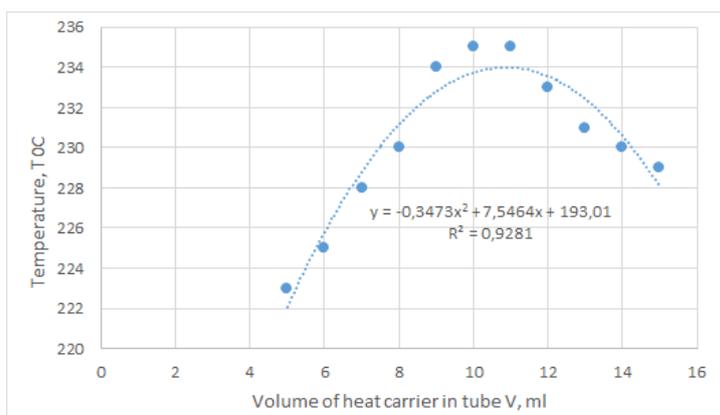


Figure 4. A plot of temperature change versus coolant volume from 5 to 15 ml

We have carried out experiments related to the determination of the mass of an 80W electric vacuum heater. The volume of coolant is 10 and 15 ml. The pressure inside the tube is 5.066 kPa (0.05 atm). As the mass increases, the surface temperature of the heater decreases. The tests were carried out with 5 samples of different mass when heated from 1300 to 2160 with a mass of, respectively, from 230 to 530 grams. The dependence of the temperature change of the surface of the housing of the electrovacuum heater on its mass is established, the graph is shown in Figure 5. The LSEH has automatic power adjustment depending on the ambient temperature in the room, therefore, if necessary, the electrovacuum heater has a significant dynamic range margin for adjustment.

It should be noted that modern electric heaters have low maintainability, this leads to the fact that the consumer is not able to perform repairs on his own and is forced to contact specialized organizations that perform repairs, on the one hand it's right that the manufacturer excludes the possibility of self-repair at home, but workshops cannot always help in the repair, a couple just do not have the necessary spare parts. Sections LSEH have a unified design and allow you to repair by yourself.

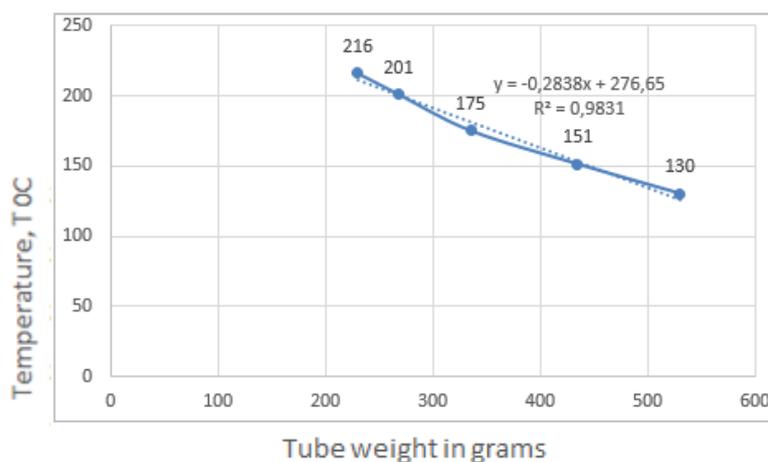


Figure 5. Dependence of the surface temperature of the case of an electrovacuum heater on its mass

A low-pressure energy-saving steam electric heater is an economical replacement for a traditional oil radiator; it can compete with existing electric heaters. The technological advantage is the high efficiency of heat transfer inside the system without loss. The main economic advantage of LSEH is lower power consumption; it is up to 1.3 times less than an oily electric heater, high reliability and a long service life. LSEH is absolutely safe in terms of an explosion or a fire in the event of a leak or falling onto the floor. Water is used in the place of expensive synthetic oil, which significantly reduces the cost and facilitates the design of the electric heater. Low material costs for installation and operation of the heating system are not achievable by competitors, 100 % automation with the possibility of coordination with the «Smart Home» system. The use of LSEH technology can have a multiplier effect for creating heating radiators with a liquid heat carrier; this will allow reducing their metal consumption and cost, without loss of consumer qualities. There is an opportunity to use our technology in systems «warm floor».

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Электрвакуум жылыту элементтері

Ғимараттар мен құрылыстардың жылу мен жабдықтау жүйелерінің энергия үнемдеудің жаһандық дамуының ағымдағы үрдістеріндегі тиімділігін жоғарылату жоғары технологиялық және төменқуатты тұтынатын электржабдықтарын енгізбестен толығымен іске асырыла алмайды. Әртүрлі мақсаттар үшін қашықтағы объектілерді жылумен жабдықтау маңызды шығындармен қатар жүреді, себебі салқындатқыш қашықтықты айтарлықтай қамтуы тиіс, ал кейбір жағдайларда құбырларды орнатуға техникалық қиындықтар немесе елеулі материалдық шығындар салдарынан нысанды жылыту қондырғысы қосылмайды. Бір шешім ретінде төменқысымды буэлектрлі жылытқышты енгізу болып табылады. Бұл қыздыру элементінің түбегейлі жаңа дизайны мен жаңа буын электржылытқышы. Ол электрлік спиралдың тиімділігін және дәстүрлі жылурадиаторының ыңғайлы жылуын біріктіреді.

Кілт сөздер: радиатор, электржылытқышы, энергияүнемдеу, жылыту жүйесі, жылыту құрылғысы, жылыту.

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Электрвакуумные нагревательные элементы

Повышение эффективности систем теплоснабжения зданий и сооружений в современных тенденциях общемирового развития энергосбережения не может быть реализовано в полной мере без внедрения высокотехнологичного и низкоэнергоемкого электрооборудования. Теплоснабжение удаленных объектов различного назначения сопровождается значительными потерями, так как теплоносителю приходится преодолевать значительные расстояния, в некоторых случаях подключение объекта к теплоцентрали невозможно в силу технических проблем или значительных материальных затрат на монтаж трубопроводов. Одним из решений может быть внедрение парового электрообогревателя низкого давления. Это электрообогреватель нового поколения с принципиально новой конструкцией нагревательного элемента. В нем сочетаются эффективность электрической спирали и комфортное тепло традиционного радиатора отопления.

Ключевые слова: радиатор, электрообогреватель, энергосбережение, система теплоснабжения, тепловой прибор, отопление.

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