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MANUFACTURE OF HIGH-TEMPERATURE ELECTRIC HEATERS BASED ON SOLAR ENERGY

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Abstract: *This article discusses the role of solar energy as a natural energy source for the synthesis of electric heaters. The work of famous scientists on the development of the field of using energy devices based on solar energy in heat supply systems is presented. As a result of converting solar energy into heat, productivity can be increased by automatically adjusting energy consumption in the manufacture of high-temperature electric heaters using a set of solar energy devices, using these structures to reduce capital costs in the manufacture and operation of high-temperature electric heaters. A distinctive feature of electric heaters is their electrical resistance, maximum and minimum conditions at room temperature, the choice of heaters and their division into groups. The resistance of a high-temperature electric heater is the result of measurements in an open field at a constant temperature of 1000-1500°C in a steady state of the working section. Electric heaters can be used in other rooms as well. Chromite is the least aggressive substance in comparison with lanthanum, gases in the atmosphere at heater temperatures up to 1200°C. When the oxygen reduced pressure is less than 100 Pa, it is possible to operate at 1400°C in this gaseous environment. Convenience, simple and quick replacement, continuous and cyclic operation, heating in an oxidizing atmosphere up to 1800°C, stability of electrical properties during operation (no aging) - the possibility of using old and new electric heaters together, the ability to work in the whole temperature range (from room temperature to the maximum). In addition, lanthanum chromite high temperature electric stirrer types, lanthanum chromite high temperature electric heating elements are made of ceramic material, conductive and resistive heating capabilities directly from room temperature, lanthanum chromite heaters are used in air driven resistance electric furnaces and up to 1700° C °, some provide thermal processes at temperatures up to 1800°C C in boxes. It is stated that the heaters can be used continuously and intermittently with full cooling between cycles.*

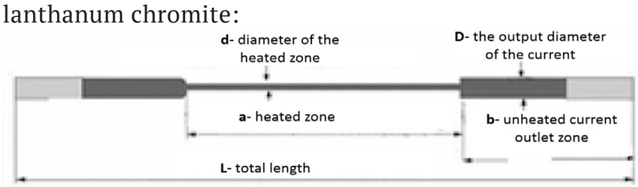
Introduction. Famous scientists Strebkov D.S., Kharchenko V.V., Alekseev V.V., Vissarionov V.I., Kazanyan B.I., Tarnievsky S.N., Andersen B., Beckman U., Duffy J., Klein S., McVeig D., Khrustov B.N. and b., Uzbek scientists Zakhidov R.A., Avezov R.R., Klychev Sh.I., Abbasov E.S., Abdurakhmonov A. Mamatkosimov made a great contribution. In particular, they conducted research on the development of energy-efficient technologies for using solar energy in the production of ceramic materials, improving the temperature and humidity conditions and modeling heat and mass transfer processes for optimal control of technological processes. Although the use of solar energy for ceramic materials is widely used in foreign countries (Russia, Ukraine, etc.). Insufficient attention is paid to solving the complex requirements for the parameters of high-temperature electric heaters using renewable energy sources, especially solar energy. [1-4] By converting solar energy into heat, the use of a set of solar energy devices can increase productivity by up to 50% by automatically adjusting energy consumption in the production of high-temperature electric heaters, as a result of which these designs can reduce capital costs by 60-70%.

Methods and materials. A distinctive feature of electric heaters is their electrical resistance. It is much higher at room temperature, but drops to a minimum as the temperature rises to 800°C. When the temperature limit exceeds 800°C, the resistance of the heater increases by about 5% every 100°C between 1000 and 1500°C. Therefore, by measuring the resistance at room temperature, note that these values do not correspond to resistance values at operating temperature of the same heater. This should be taken into account when choosing heaters and connecting them to groups. The resistance of a high-temperature electric heater is measured in an open field at a constant temperature of 1000-1500°C in a steady state of the working part, and its value is calculated by dividing the supply voltage by the current flowing through the heater.

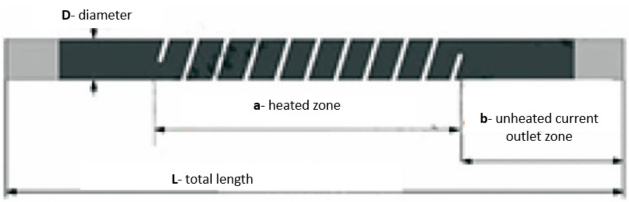
The electric heaters can be used in other rooms as well. The least aggressive substances in relation to lanthanum chromite are inert gases (argon, helium), nitrogen, carbon dioxide at a heater temperature in the atmosphere up to 1200°C. When the oxygen reduced pressure is less than 100 Pa, it is possible to work in this atmosphere at a temperature of 1400°C. [5-6].

Convenience: easy and quick replacement; continuous and cyclical operation; heating up to 1800°C in an oxidizing atmosphere; stability of electrical properties during operation (no aging) - old and new heating elements can be used together; the ability to work in the entire temperature range.

Types of high-temperature electric heaters based on lanthanum chromite:



Type - K lanthanum chromite electromagnet - in the form of a dumbbell, a-working area, L- total length, d-diameter of the working part, D-diameter of the contact part, b-part of the cold contact, the maximum operating temperature of type K-type electric heaters reaches 17500 ° C. [7].



The electric submersibles made of lanthanum chromite, type C - are tubular elements with a spiral working part. Due to its geometric properties, the resistance of the central spiral part is much higher than that of the edge - this provides the most efficient redistribution of the generated heat along the length of the element. The working temperature of type-C of the electric stirrers is 1700 ° C.

The working area of the Chromite Lanlan T-type heater is slightly thicker than that of the K-type, so the maximum operating temperature is 1800°C. [8]

Results. High-temperature electric heating elements based on chromite and lanthanum are made of ceramic material, are conductive and allow resistance heating directly from room temperature. Structurally, these heaters made of chromite and lanthanum are made in the form of wires and pipes of various cross-sections and configurations, which have a metal coating at the ends for connecting electrical contacts. Heaters based on chromite and lanthanum are used in air-driven electric resistance furnaces and provide thermal processes at temperatures up to 1700 ° C, in some cases up to 1800 ° C. The heaters can be used continuously and intermittently with full cooling between cycles. Heating elements based on chromite and lanthanum are easy to replace, which reduces production losses.

In the industrial production of this type of heaters, the following technologies are used:

- large and small functions of the ceramic mass are synthesized by the addition of lanthanum and chromium oxide, followed by the addition of calcium. All these chemical elements are brought into the same state;
- then from the prepared fractional mass, ceramic pipes with a flowing wire are formed;
- the pipes are heated in a high-temperature industrial electric furnace, which allows the heater to be one unit.

This product has a length of up to 1500 mm and more. The voltage in the supply network can be used for any network, but mainly 220, 380 volts. The maximum temperature of such elements is up to 1800 degrees. Determination of material density and porosity. The density and porosity of the coated ceramic materials were determined using hydrostatic gravity according to the following expression:

$$\rho = m_{н}\, \rho_{сув.}/(m_{н} - m_{сув.}) \qquad (1)$$

where p - is the density of the sample, kg / m^3; mн is the mass of the sample, kg; $p_{сув}$. - density of the liquid, kg / m^3; $m_{сув}$. is the mass of the sample in liquid, kg.

Pure purity was determined by the following expression:

$$П = (m_{т.\ сув.} - m_{н.})\cdot 100\% /(m_{т.\ сув.} - m_{сув.}) \qquad (2)$$

where П- is the purity of the samples,%; $m_{т.сув.}$. - is the mass of the sample saturated with liquid, kg.

Determination of linear shrinkage. Recovery of samples during synthesis was determined by the following expression:

$$У = ((l_0 - l_1) / l_0)\ 100\ \% \qquad (3)$$

where Δm - is the mass loss of the sample during synthesis,%; m_0- is the mass of the sample before synthesis, kg; m_1 - is the mass of the sample after synthesis, kg.

Determination of the modulus of elasticity. The modulus of elasticity was determined by the resonance method on polished samples 5x5x45 mm using the resonance characteristics of the "ZVUK-230". The resonance frequencies are known, the elasticity of the constant materials is calculated. Measurement error is 1-2%.

Determination of bending and compression pressure of the transverse shell. The pressure in the casing was determined on a Shimadzu AG-300kNX volt-ampere machine on 5x5x45 mm samples according to the following expression:

$$\sigma_{эгилиш} = 3/2\ P\ K / (b\ h^2) \qquad (4)$$

where $\sigma_{эгилиш}$ - is the bending pressure, MPa; P - bending force, H; K - is the coefficient of the test base; b - is the width of the sample, m; h - sample height, m.

Compressive strength was determined on a Shimadzu AG-300kNX machine in 10x10x10 mm samples in accordance with the following expression:

$$\sigma_{сиқиш} = P / (b\ h) \qquad (5)$$

where $\sigma_{сиқиш}$ - is the compression pressure, МПа; P - compressive force, H; b - is the width of the sample, m; h - sample height, m.

Determination of the crack resistance coefficient. The fracture toughness coefficient (K_{1C}) was determined by the entrance to the Vickers pyramid. Cracks were detected using a TP-7p-1 optical hardness tester up to 10 μm in length. The K1C values are determined by the following expression:

$$K_{1C} = 0{,}018\ (P/c^{1,5})\ (E_{упр}/HV)^{0,5} \qquad (6)$$

where K_{1C}- crack resistance coefficient, MPa • m$^{1/2}$; c - crack length, m.

The thermal stability of silicon carbide SiC, like all other polycrystalline ceramic materials, extends to brittle materials; therefore, all laws related to the movement of ceramics under the influence of thermal stresses arising from temperature changes can be applied to it. The main properties that determine the resistance of materials to thermal and thermal shock loads are strength, modulus of elasticity, coefficient of thermal expansion, thermal conductivity and heat dissipation. The study of the thermal resistance of many ceramic materials shows that an increase in mechanical strength, a decrease in the elastic modulus, an increase in the coefficient of thermal expansion and an increase in thermal conductivity always contribute to an increase in the thermal resistance of ceramic materials. Silicon carbide is characterized by high thermal conductivity, reaching values in the range of 50-150 W/m° K for products based on SiC, a relatively low coefficient of thermal expansion (4.5-5). 10-6 1/k. These properties mainly determine the high heat resistance of ceramic products made of silicon carbide [9 - 10]. Aluminum oxide - 20-79.5%, silicon carbide - 20-75 and ceramic products with a hardening additive during combustion of the product are characterized by a porosity of 30-40%, flexibility up to 80 MPa and practically unlimited heat resistance. Up to 1200° C. This material was named Tecor [11-13]. Tecor material has been used to make small tube glass bead sintering crucibles that can be used as a water filter at home. When firing crucibles with glass beads, the heating temperature reached 850° C, the heating time was 2 hours, followed by sharp cooling. Crucibles made from the specified material can be stored for up to 1500 cycles. It should be noted that the inclusion of silicon carbide, which is sufficiently resistant to oxidation up to 1500° C, into the composition of charged ceramic products up to ~ 100-200 μm, significantly increases thermal stability. Ceramic products with a SiC content of more than 50% can withstand instant heating up to 1500° C. [14-16].

Thermal conductivity of SiC (silicon carbide).

This property mainly determines the performance of silicon carbide materials at high temperatures. Heat in silicon carbide is transferred mainly by phonons. Thermal conductivity of SiC single crystals is close to the thermal conductivity of diamond, silicon and other covalent crystals. The thermal conductivity of SiC-based ceramics depends on many factors - the amount of porosity, the residual carbon and silicon content, and temperature. Porosity always significantly affects the value of thermal conductivity of all ceramic materials, including SiC materials. Thermal conductivity of dense materials made of SiC has high l products, reaching 120-150 W/m.K. As the porosity increases, the thermal conductivity decreases significantly, but still remains at a porosity level of 20-30% at 40-50 W/m.C.

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In the middle part of the solar oven, the temperature reaches its maximum value (about 2050° C) in about 10 minutes, and then is maintained at 1700-1800° C for 17 minutes after the start of the test (thermocouple № 1). The drop in temperature after 17-17.5 minutes can be explained by the deposition of electric heating material and the corresponding redistribution of heat. The change in the amount of heat supplied to the sample is noticeable, especially in the area adjacent to the electric heater (thermocouple № 1), and practically imperceptible at large distances (thermocouple № 4). At a distance of 200 mm from the sample (furnace center), the temperature (thermocouple № 3) reaches 1250° C in about 9-10 minutes, and at a distance of 300 mm (thermocouple № 4) in about 23 minutes.

Figure 1. Shows time plots of temperature values obtained from the improved models above. In the course of the experiment, the temperature was measured at four points (thermocouples of the chromel-alumel type were used): thermocouples №. 1 and 4 were located at a distance of 20 mm from the sample surface, №. 2. - the ambient temperature was measured at a distance of 180 mm from the sample surface in thermocouple №. 3.

An experiment was carried out in which the temperature was measured at four points (chromel-alumel thermocouples were used): thermocouples № 1 and 4 were located at a distance of 20 mm from the core surface, № 2. - the ambient temperature was measured at a distance of 180 mm from the surface of the core and in thermocouple №. 3. The location of the thermocouples is shown in Figure 2. The dynamics of measurements in Figure 3.

Thermocouple № 1 showed a sharp rise in temperature, which began after 8.5 hours and did not exceed 1350° C. Thermocouple № 2 showed a maximum temperature of 1200° C. Thermocouple showed the ambient temperature № 3, which by the end of the campaign did not exceed 150° C. Thermocouple № 4 showed that a maximum temperature of 1000° C was reached at the end of the run.

It should be noted that the power consumption shown in the experiment was 103,000 kW/h. According to experimental data, it can be argued that at a distance of 0 ÷ 30 cm.

The process of forming silicon carbide from the core in the industrial furnace continues. The experimental results also suggest that the mode of power supply for heating the furnace has a significant effect on the mass yield of silicon carbide. It should be noted that the process of obtaining silicon carbide is affected by the uneven heating of the core and the deposition of the charge.

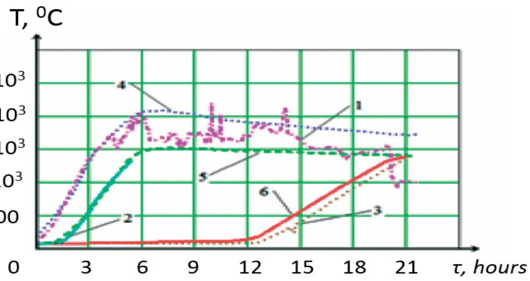

Figure 1. Experimental and calculated values of temperature dependence on time when the oven is running. The numbers from 1 to 6 correspond to the thermocouple numbers.

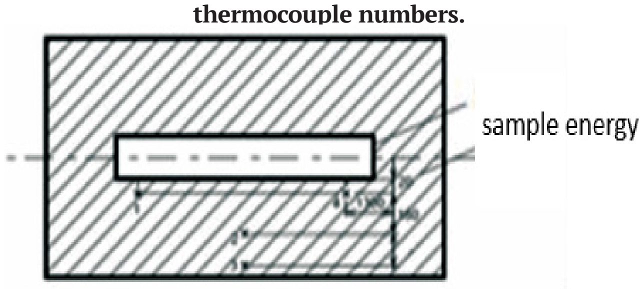

Figure 2. Installation diagram of thermocouples in the cross section of the furnace.

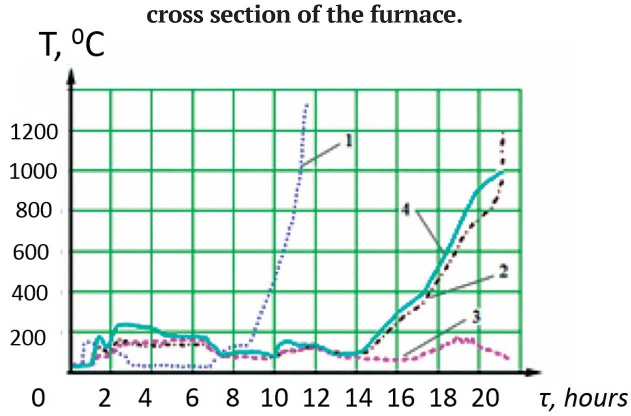

Figure 3. The amount of insurance premiums and insurance coverage collected by companies operating in Russia in 2012-2020[8] (million rubles).

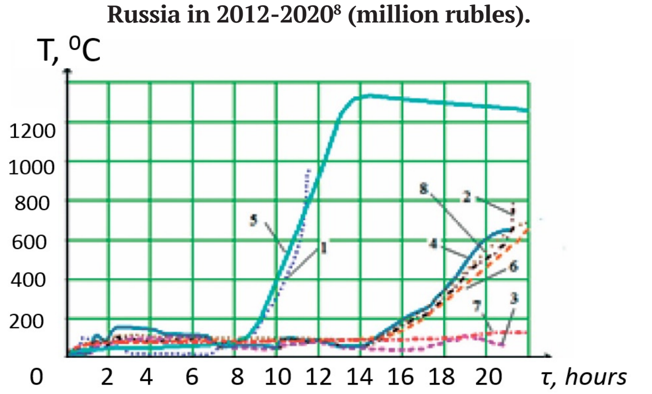

Figure 4. Experimental and calculated values of the time dependence of temperature for the period of operation of the furnace. The numbers 1 through 8 correspond to the thermocouple numbers.

In figure. 4 shows a comparison of the experimental data with the calculated values of temperatures obtained using improved models.

Conclusion. As you can see from the pictures. Figures 1 and 4 are in good agreement between the experimental and calculated data. Taking into account the deposition and condensation of moisture in the material during the filtration process made it possible to better describe the complex technological process of silicon carbide production.

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