Flooring modules based on mica ceramic electric heating in construction industry

T I Shishelova 1, V G Zhitov 1

1Irkutsk National Research Technical University, Department of Physics, 664074, Russian Federation, Irkutsk, Lermontov Street, 83.

Abstract. There are various systems of heating facilities for agricultural purposes. As for young-stock breeding, flooring heating systems are mainly used. In most cases, they are presented by hot water heating or a heating device embedded in concrete. But their structures contribute to significant heat waste and high water absorption capacity. The problem: the development of productive flooring heating structures is relevant. Effective heating systems employed in facilities for agricultural purposes are those based on mica ceramic electric heating. Research aim: To develop flooring heating panels based on mica ceramic electric heating to be used in facilities for agricultural purposes. Research target: A flooring heating panel is a special modular structure with mica ceramic heating elements. Research methods: a number of advanced techniques of physical-chemical studies of composite materials (X-ray diffraction analysis, thermal analysis, and IR spectroscopy) and standardized methods to comply with the All Union State Standard. Research results: The flooring modular heating panel for resistive heating systems used in facilities for agricultural purposes and personnel facilities based on mica ceramic electric heating has been developed and introduced. The technology of manufacturing original mica ceramic electric heating elements (mica ceramic electric heating) with high performance specifications has been developed. The technology is used in the flooring heating model. The physical and chemical processes occurring when producing mica ceramic electric heating have been pointed out. The formula of the load for manufacturing new composite materials has been recommended.

In Irkutsk Region, as well as in other northern parts of regions of the Russian Federation, there is an urgent problem of young-stock breeding in livestock buildings and poultry enterprises. Currently there are various heating systems of buildings and structures for agricultural purposes. An example would be electric heating flooring and floors made mainly of polyvinylchloride wire embedded in concrete. This structure has a high water absorption capacity. In addition, a significant drawback of electric heaters of this type is the rapid deterioration of the polyvinylchloride isolation and the thick layer of concrete foundation. The lamps of ultra-red, ultraviolet radiation (URUV) used in reproduction facilities have a short working life and high energy consumption. The heating by such lamps is based on the top-down flow of light. As a result, there is a significant differential temperature, and the heat is consumed only partially as intended.

New heating systems for agricultural facilities have been offered. Special module structures based on mica ceramic heating elements have been developed (heating panel) (mica ceramic electric heating). These heating elements made it possible to eliminate all the disadvantages due to their high electrical and mechanical properties, chemical resistance in corrosive environments and low water absorption capacity [1-3].
Research aim: To develop flooring heating panels based on mica ceramic electric heating to be used in facilities for agricultural purposes. To develop new formulae of the load to improve the electrical and physical characteristics.

Research target: Flooring heating panel is a special module structure based on mica-ceramic heating elements; mica-ceramic electric heating element is designed for technological and general heating of industrial facilities under high humidity conditions, as well as for residential, industrial and other units of construction industry. Since the core element of the flooring heating model is mica ceramic electric heating, it is advisable to consider the physical and chemical processes occurring in its manufacturing.

Research methods: a group of advanced techniques of physical-chemical studies (X-ray diffraction analysis, thermal analysis, and IR spectroscopy). Electro physical and mechanical characteristics of composites and starting materials were determined by the standardized methods to comply with the All Union State Standard.

Moreover, studying and optimizing the main parameters of the technological process of manufacturing mica ceramic electric heating is important for improving its electro physical characteristics.

Research results: The method of manufacturing mica-ceramic heating elements consists of several steps. The heating nichrome element is placed in a mixture of finely ground mica and fusible glass according to a certain percentage. The method of cold pressing is employed to make the brick. There is a certain regime to heat the brick, it is hot-pressed and annealed in a thermostatic oven then. The heating elements produced in this way have high mechanical strength (cross-breaking strength is not less than 80 MPa), and high chemical resistance. In addition, the heating devices are characterized by high electrical reliability (electrical strength E, MV/m - 10-20, electrical resistivity $10^{10}$-$10^{12}$ Ohm-m), have a low electric energy consumption. They are non-metal-intensive. [3,4]

Physical and chemical phenomena occurring in the manufacturing process of electric heating elements have been studied. [3,5] The issues of their durability and mechanical strength, which largely depend on the results of the interaction of nichrome with the components of fusible glass are of particular practical interest. Microscopic, spectral, x-ray and thermogravimetric methods (differential thermal analysis (DTA)) were used to solve these problems [4,6,7]. X-ray diffraction analysis and thermogravimetric analysis proved that during heat-treating of the powder of nichrome and glass there appear a new phase. The exo-effects in the temperature range of 620-840°C (on the DTA curve of the mixture) indicate an intense interaction of fusible glass and nichrome.[8] Up to the temperature of 820°, the effects of increasing the mass are connected with the formation of low metal oxides (nickel and chromium) on the surface of the nichrome wire. In this temperature range, the technology of manufacturing heating elements takes place. The small degree of oxidation of nichrome wire and as a result the increase in mass that is not higher than one-tenth percent guarantee the operational reliability of the heating device.

![Figure 1. DTA curves: 1 – glass; 2 – nichrome; 3 – mixture of nichrome and glass.](image)

Technological mode of manufacturing mica-ceramic heater is not dangerous for nichrome wire. Microscopic and spectral methods of the research have shown that the boundary of nichrome in the insulating base of the mixture is fuzzy, blurred and has traces of mutual dissolution. It indicates that
the nichrome interacts with the composite mixture. The data of emission analysis have showed 0.01-0.03% amount of nickel and chromium in the glass when contacting with nichrome. Nickel and chromium oxides found on the surface of the wire interact with the glass components at the stage of high-temperature processing to form the corresponding silicates. These systems provide a good contact between nichrome and the insulating mixture. It helps to reduce heat loss in the interfacial reaction of nichrome-insulating mixture. Finely ground glass during the heat treatment spreads over the surface of the nichrome resistive heater providing the filling of the surface of the nichrome and good adhesion to the substance in the interfacial reaction of the crystallizational coating. This leads to the mechanical hardening of the structure as a whole.

The current heating elements are imposed a number of requirements to. The most important ones are increasing insulation resistance, maintaining mechanical strength at elevated temperatures and high thermal conductivity. [11,12] In order to increase mechanical strength and reduce water absorption capacity, the blending ratio of the composition of the load for the insulating layer of the heater should be the following, mass.%: mica muscovite - 25-35; mica phlogopite - 25-35; fusible aluminum-borosilicate glass - 35-45. Phlogopite added to the electrical insulation mica activates the inter-phase interactions of the components in the process of heating and hot pressing. As a result, a dense monolithic structure is formed. [3,9,10]

When solving practical issues related to the use of mica-ceramic electric heating elements in agriculture, there is a need for simplifying their installation arrangement. Towards this end in view, special module structures of mica ceramic heating elements (heating panel) were developed. Figure 2 shows the panel.

Significant contribution to the strengthening of the structure makes alumomagnesian spinel $\text{Al}_2\text{MgO}_4$. The tensile strength during static bending increases by 40-45%, water absorption capacity is reduced by 5 times. Thus, in the process of manufacturing a resistive heater, a deeper inter-phase interaction in the mica-glass system is provided. It leads to creating a monolithic dense material with high mechanical properties and low water absorption capacity. When adding the modifying agent (5% clinker) to the electric insulation load of the heater, it is also possible to reduce water absorption capacity by 50%, while the volume resistivity increases 10 times [3,4].

Increasing moisture resistance while maintaining the insulation resistance of the heaters during their continuous service in moisture environments is achieved after their annealing. There their surfaces are treated with 3-5% solutions of organic still residue (left after the production processes of methylchlorosilane). Then they are heated at 110 - 150°C.

When solving practical issues related to the use of mica-ceramic electric heating elements in agriculture, there is a need for simplifying their installation arrangement. Towards this end in view, special module structures of mica ceramic heating elements (heating panel) have been developed. It consists of several resistive electric heaters framed with angle section steel and placed on an asphalt concrete base. And the surface of the electric heater from the side of the asphalt concrete base is clad with the tar-bitumen mixture. Figure 2 shows the panel.

![Figure 2. The heating panel: 1 – resistive heaters; 2 – angle section steel; 3 – asphalt concrete base; 4 – bitumen; 5 – contact zones.](image-url)
The main part of the mechanical loads that have an effect on the surface of the heater when in service is taken by the rigid asphalt concrete base. It protects the resistive elements from destruction. The micaceous plastic between the bitumen and mica-ceramic surface of the heater provides high corrosion protection, electrical insulation and good connection between the heater and the asphalt concrete base. All this contributes to the reliability of the panels during their operation.

The aggressive environment in livestock buildings where metal pipes and water radiators are located often leads to corrosion and destruction of concrete. The heating device based on mica-ceramic heating elements is acid-proof. Its being acid-proof is much more advantageous in comparison to other types of the heater. The heating panel is distinct in high sterility. The feature is explained by the high mass content of mica in it. With the use of heaters of this type, there is a real possibility of automatic temperature control, which is energy efficient when consuming electricity. Electric heating by means of such heaters is 1.5-2.0 times more economical than hydronic heating system.

The advantage of this type of heating is that the heating comes from below and creates a favourable microclimate. It has a good effect on the development of animals as they are on the warm surface of the plates, whereas the heating by lamps is aimed mostly at the upper level of the facilities.

Discussions and conclusions

Flooring heating modules based on mica ceramic heating elements have been developed. They are widely used in construction industry.

The technology of producing original mica-ceramic electric heating elements (mica-ceramic electric heating) with high technical characteristics (chemical resistance, thermal conductivity, moisture resistance, efficiency, reliability in operation) has been developed and introduced into the industry.

It is experimentally proved that in manufacturing mica-ceramic electric heating devices both nichrome and mica are dissolved in glass to form products of inter-phase interaction. It leads to mechanical hardening of the mica-ceramic electric heating elements and provides high thermal conductivity in the contact zones.

New load compositions for the insulating layer of mica-ceramic electric heating elements have been developed:

The use of both phlogopite and muscovite in equal amounts in the composition of the load of the heater allows increasing the static bending of the material by 40-50% and reducing its water absorption capacity by 5 times. Adding such a modifying agent as clinker increases the volume resistivity of electrical insulation by 10 times.

The method of manufacturing a flat electric heater for the temperature of 850-1000 °C has been developed. Phlogopite with partially substituted hydroxyl groups by the ion of fluorine is used when manufacturing the heater.

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