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USE OF COMPOSITE ELECTRIC HEATERS IN ANTI-FREEZE SYSTEMS

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Abstract- There has been realized an analysis of existing cable anti-freezing systems, revealed their advantages and defaults. The tasks of research work for broad use of laminar and voluminous multi-electrode composite electric heaters on the base of butyl-rubber in anti-freezing systems have been set. The reasonability of use of composite electric heaters in anti-freezing systems and the possibility of their long-term exploitation in humid and hostile environment have been proved.

Keywords: Anti-Freezing System, Multi-Electrode Composite Electric Heater, Humid and Hostile Environment.

I. INTRODUCTION

The glaze ice formed in gutters, ducts, hoppers and other places of roof surface, chutes and water drains after strong snowfalls represents a serious threat. The traditional practice of snow and ice removal is not effective, since it often leads to damage of the construction of the roof itself, water drains get broken, and down falling masses can injure people. This way, for fighting the consequences of natural phenomena, they create various anti-freezing systems, which originally eliminate ice formation and snow flurries upon roof surface, chutes and water drains.

The anti-freezing systems of buildings and installations that have appeared relatively recently, have shown their efficiency and are being used for constructional production all over the world. The use of such systems allows to exclude the formation of glaze ice in gutters, ducts, hoppers and other places of its most probable appearance. The formation of glaze ice leads to reduction (until full termination) of water outflow through water draining ducts and tubes, which represents serious danger for life and health of people and can lead to considerable material damage.

The heating sections destined to transform the current flowing through them into thermal energy are the basic element of the anti-freezing system. Therefore, their most important electro-, thermos-physical parameters are the power per unity of length (heat liberation), and also the surface of the heating element.

The modern anti-freezing systems are based upon four types of cables: resistive, armored, areal and self-regulating, which in the Russian market are represented by the following manufacturing firms "Special Systems and Technologies" or SST (Russia), Thermo, Kima Heating Cable (Sweden), Ceilhit (Spain), Ensto, Tash (Finland), Nexans (Norway), Alcatel (Norway/France), Devi (Denmark) [1-3].

The realized analysis of the cable heating systems (Table 1), has revealed the following defaults:
- equal heat liberation all over the length of the cable, which leads to overheating of the cable in some sections, while in others, heat generated by it can be insufficient for providing satisfactory functioning of system;
- minor surface of heat liberation of the cable, which requires use of considerable power for successful work of the system;
- loss of efficiency all over the length of the cable in case of default of the heating wire or damaged insulation.

The most efficient are self-regulating cables, which, as distinct from resistive ones, automatically change power over the length of the section depending on factual heat loss: at temperature raise, their heat radiation decreases, which creates an effect of self-regulation. However, the considerable cost of self-regulating cables limits their broad use. Due to this, actual is the research of surface distributing heating of places, exposed to formation of glaze ice, on the base of composite electric heaters (CEH) of laminar and voluminous forms [4-5]. The necessity to improve the functioning of anti-freezing systems determines the following tasks of research work:
- development of constructions on the base of energy efficient surface distributing method of heating with use of laminar and voluminous CEH and justification of their technical economical reasonability;
- execution of complex experimental research of electro-, thermos-physical characteristics of composite electric heaters with the purpose of determination of necessary parameters of composition and construction of heater;
- development of devices of anti-freezing systems of water drains of roofs and drives-up of buildings on the base of composite electric heaters with consideration of special requirements applicable for them: high solidity of electric insulation; low current loss; sufficient heat delivery; resistance against effect of humidity, sun radiation; work in broad variety of temperatures; low energy consumption etc.

Table 1. Technical and cost characteristics of cables for anti-freezing systems

Name	Cable type	Specific power (Watt/m)	Cable diameter (mm)	Standard length (m)	Power (Watt)	Manufacturer	Price, Euro
Electrolux ETC 2-17-200	Resistive twin-wire	17	4.5	11.8	200	Sweden	3100
CH-18-171	Resistive twin-wire	18	4	9.5	171	Russia	1600
TXLP 2-400-17	Resistive single-core	17	4	23.5	400	Norway	5500
HMG 80-2 CR	Self-regulating	5-80	15	80	-	South Korea	410 for lineal m
AKO-52341	Areal	30	9	60	-	Spain	220 for lineal m
SMS 80-2 CR	Self-regulating	5-80	19	80	-	South Korea	450 for lineal m

II. RESULTS AND THEIR DISCUSSIONS

There is provided a heating system on the base of multi-electrode composite electric heaters [2, 3] (Figure 1). Electro insulating layer 3 represents a composition on the base of butyl-rubber with expressed electro-insulating properties and improved physical-mechanical indicators; electro insulating layer 4 is produced on the base of butyl-rubber with technical carbon of marks N-330, N-220. Electrodes 2 and current leads 1 are produced of copper flexible wire with section 1.5 mm^2.

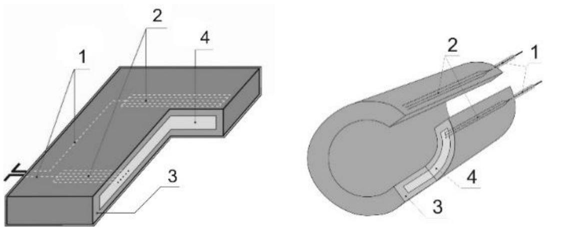
The realized research work [4, 5] of various rubber mixtures has proved that articles of butyl-rubber possess a number of distinguishing qualities, sufficient and necessary for creating electric heaters, working in anti-freezing systems. Butyl-rubber based rubbers possess high resistance to thermal seasoning, are resistant to effect of nitrogen, humidity, acids and alkalis, and also have high electro-insulating properties in broad variety of temperatures [6].

For insulating layer of CEH, there were obtained dependences of specific voluminous resistance (ρ_v), tangent of angle of dielectric losses ($\tan\delta$) and electric solidity ($U_{пр}$) on the time of effect of humidity (full immersion of article into water) at normal temperature conditions (T = 20 ±5 °C) (Figure 2). The research has been realized according to GOST [7] with use of capacitometer and $\tan\delta$ E8-4 and installation of high tension PUS-4 [8].

For determination of indicators of physical mechanical solidity (PhMS), characterizing the seasoning of rubbers in hostile environment, and, consequently, exploitation of the insulating layer of CEH, there were realized research works in the Central Plant Laboratory of OJSC «Altai Tire Plant» (ATP) in accordance with the applicable methods according to GOST [9, 10].

Table 2 shows the values of physical mechanical indicators corresponding to production norms according to GOST, and obtained average values for four samples of rubber mixtures used for insulating layer of CEH.

The methods of testing of CEH for resistance to hostile environments are determined according to GOST [10]. The essence of the method is to submit samples in stress-free state to effect of environments at given temperature and duration and determine their resistance to the indicated effect, by the change of mass, volume or dimensions.



(a) (b)

Figure 1. Schematic image of CEH: (a) laminar, (b) voluminous

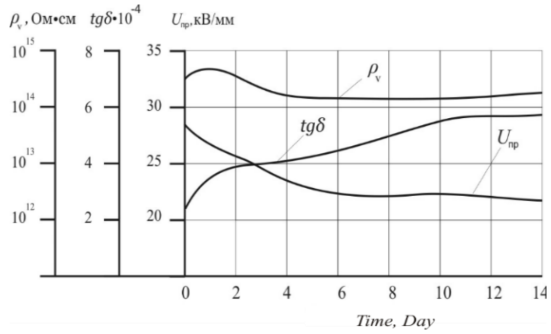


Figure 2. Dependence ρ_v, $\tan\delta$ and $U_{пр}$ on time of effect of humidity

The following chemical agents are used in research as hostile environment: 5% solution of ammonia; 10 and 20% solution of sulfuric acid; 10 and 20% solutions of sodium hydroxide; water. Time of swelling in hostile environment - 24 h.

The values of physical mechanical indicators after effect of hostile environment are shown in Table 2, where ΔP, % is the change of plasticity of the sample.

The analysis of Table 2 shows that rubber mixture under normal conditions corresponding to requirements, applied for the given type of rubbers, after effect of hostile environment subtly loses its solidity and has a small percentage of swelling.

Table 2. Values of Physical Mechanical Indicators of samples of rubber mixture after effect of hostile environment

Type of hostile environment	f_p, MPa	ε_p, %	Θ, %	ΔP, %
NH_4OH, 5 %	11.1	530	21	3.85
H_2SO_4, 10 %	11.5	570	22	1.30
H_2SO_4, 20 %	11.5	550	19	2.60
NaOH, 10 %	10.4	550	20	2.52
NaOH, 20 %	8.4	560	23	7.41
H_2O	12.3	540	16	0.51

Taking into account the specificity of exploitation and functioning of anti-freezing systems, of all the variety of the designed constructions of MECEH, two types are chosen as basic ones: laminar with dimension 200×135×10 mm, and voluminous of cylindrical type with dimension: interior Ø 24 and exterior Ø 44×200 mm [11]. The first type can be exploited on perches, roof valleys, hoppers and casings, the second - in gutters.

For organizing of the anti-freezing system of the main building of the ASTU, it is necessary, first of all, to determine the zones of installation of electric heaters MECEH. The considered district has prevailing south-west winds. Figure 3 shows the mutual disposition of the vectors of wind flow respectively to the main building of the ASTU.

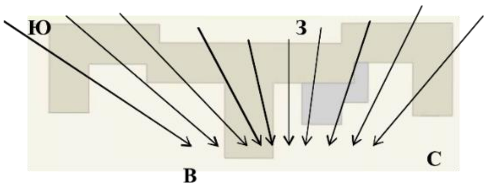


Figure 3. Prevailing directions of wind flow

The major part of snow flurries and glaze ice get formed beyond the wind impediment due to whirls of air masses, consequently, it is necessary to increase the heating power on the north-east part of the building because of the high probability of formation of large snow flurries and glaze ice (Figure 4).

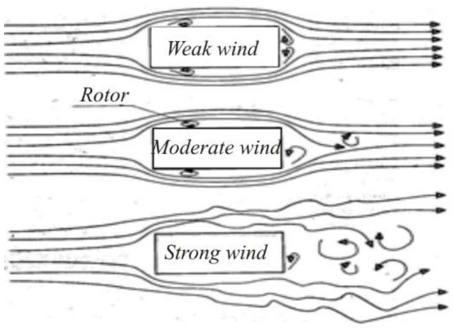


Figure 4. Turbulence of air flows

The perimeter of the roof of the main building is equal to 577 m. The length of the lineament of the south-west part of the roof is equal to 297 m (the front part of the building), and the one of the north-east part - 280 m.

The number of water drains is 33, and their height, with account of heating of the hoppers and points of water discharge is about 22 m, for heating shall we choose the south-west part of the roof and all the water drains. For heating, we choose the north-west part of the roof and all the water drains (Figure 5).

We choose the principal diagram of control with the use of the controller RT-200 (Figure 6). The principle of work of the system consists of the following. If the temperature of ambient air is in operational range (gets installed in manufacture and can be changed by consumer), relay K_1 gets involved, thereby releasing the lock from all the chains of control.

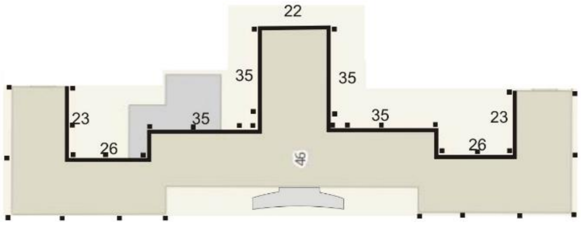


Figure 5. Points of heating of the roof of the Main building of the ASTU with indication of the length of the sections and disposition of water drains

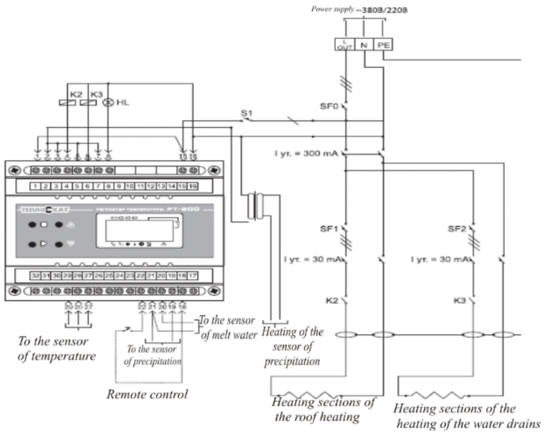


Figure 6. Principal diagram of anti-freezing system on the base of MECEH

If the timer of heat insertion had been previously set on entering the temperature range (gets installed in manufacture and can be changed by consumer), the device will switch on the heating of the whole roof (relay K_2 and K_3) for the time set in the timer (preparation regime). Upon termination of this time, the heating will get switched off, and RT-200 controls the state of the sensors of water and precipitation. At appearance of precipitation, RT-200 switches on the heating of the roof and perch (relay K_2 and K_3 respectively). At absence of precipitation, the device switches off the heating of roof (relay K_2).

The gutters and the perches stay heated until the absence of the signal from the sensor of melt water. After this, the heating shall stay switched on according to the built-in delay timer (gets installed in manufacture and can be changed by consumer, while it depends on the length of the water drains). Upon termination of the delay time, the heating will get switched off. Besides, manual control of the device is possible in form of forced insertion of heating, or emergency shutdown of heating.

III. CONCLUSION

1. The advantages of the designed anti-freezing system on the base of surface distributing laminar and voluminous electric heaters MECEH consist of the following:
- breakdown of several electric heaters does not affect essentially the work of the whole heating section, if non-working heaters are not concentrated upon a small section of length;

- considerable area of heated surface;
- regulation of distribution of power over the length of the section: in places of major ice concentration (for example, at entrances and outputs of water drains) electric heaters of major power get installed.

2. For broad introduction of the proposed construction in anti-freezing system of building and installations, electric heaters MECEH provide the following indicators:
- uniformity of distribution and necessary parameters of temperature field on the surface of the heater;
- conditions of electric and fire safety, reliability, resistance to humidity and chemicals in hostile environment, ecological cleanness;
- thermal durability, high dielectric indicators, heat accumulating properties, considerable run-to-failure;
- reliability of the system of control of electric heating power and fulfilment of conditions of self-regulation and autostability of temperature;
- energy efficiency and economical reasonability of the used technical means of electric heating.

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BIOGRAPHIES

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