EMERGENCY RISKS IN POWER GRIDS DUE TO DE-ICING

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ABSTRACT

The article proves the direct link between the use of chloride anti-icing agents and the possibility of abnormal and emergency situations. The occurrence of hazardous situations leads to emergency risks on railway networks. In order to identify such risks in passenger transportation and cargo transportation, the influence of chloride reagents on various objects of rail transport was identified. In the course of the experiments, the negative effect of chloride deicing substances on the materials of the main elements of the railroad contact overhead power lines and infrastructure was established.

Keywords: *railways, emergency risks, cargo transportation, passenger transportation, chloride anti-icing agents, electrification overhead lines, safety, emergency situations.*

Background. *Transportation of cargo and passengers by Russian railway transport is carried out over long distances and year-round. The climate of the country is very diverse, its territory occupies about 1/3 of the area of Eurasia and 1/9 of the earth's land. The length of our lands from north to south exceeds 4000 km, from west to east it approaches 10000 km. Because of the huge area Russia can be considered a country of natural contrasts.*

Objective. *The objective of the authors is to consider emergency risks in power grids connected with the use of de-icing reagents.*

Methods. *The authors use general scientific and engineering methods, experiments, comparative analysis.*

Results.

I.

After analyzing the average temperatures of various regions of the Russian Federation, one can see that the temperature of the warmest month ranges from +1˚C in the Far North to +25˚C in the Caspian lowland and +40˚C in south-western Siberia; the coldest month is from +6˚C on the Black Sea coast to -50˚C in northeastern Siberia [3].

The most characteristic factors, under the influence of which the climate of the Russian Federation was formed [1]:

• remoteness of many areas from the sea (for the most part – not less than 400 km, and some places are at 2400 km) caused the predominance of the continental climate;

• location of the main lands in the northern latitudes determined the dominance of a cold climate (only the south of the European part of Russia, some parts of southern Siberia and Primorye are below 50˚ N, with more than half of the territory lying north of 60˚ N);

• mountain ranges in the south of the country impede the flow of warm air masses from the Indian Ocean, and the Ural ridge does not allow either full air exchange. The flat character of the territory in the west and north does not interfere with the Arctic and Atlantic influences, which make the climate even colder.

All these factors lead to the fact that in a significant part of the territory of the Russian Federation only two distinct seasons can be distinguished – winter and summer; spring and autumn are short periods of change of extremely low temperatures with extremely high. The coldest month is January (on the coast of the seas – February), the warmest month is usually July.

Russia is located in four climatic zones – arctic, subarctic, moderate and subtropical; the largest of them is moderate.

Hence the inevitable conclusion for transport: climate conditions comprising ice and snowfall require the use of various anti-icing means on the roads in order to reduce injuries to the population, prevent accidents on motorways, prevent aircraft icing, etc. [1].

In the case of cargo transportation in accordance with the technical conditions for placing and securing cargoes on open rolling stock [2], it is necessary to carry out the correct loading of goods, as well as their securing. Loading and unloading can be either mechanized or carried out manually. Cargo transportation is carried out year-round, during the winter season too. The human resources involved should be provided with safe working conditions. These include reduced slippery in cold and winter periods.

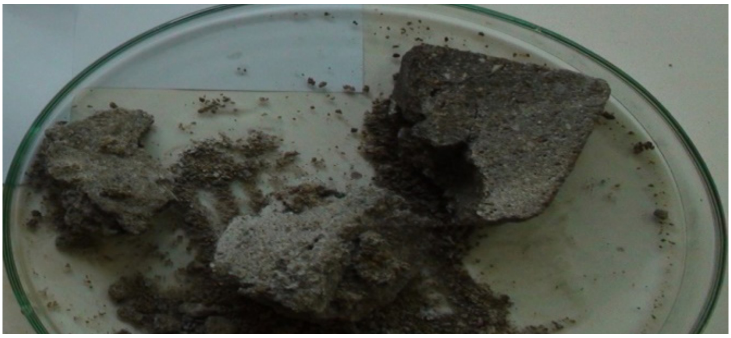
To ensure safety of passenger transportation in the same periods in question, ice should also be fought.

And this struggle is led on a broad front. Railway transport enterprises, subdivisions of JSC Russian Railways, in particular, use chloride anti-icing reagents (AIR). The choice of these types of reagents is determined by relatively low price, safety (according to manufacturers), ease of use. Until now, it was believed that chloride AIR are absolutely safe for people, animals, various materials and the natural environment. However, some studies, including ours, have refuted these misconceptions.

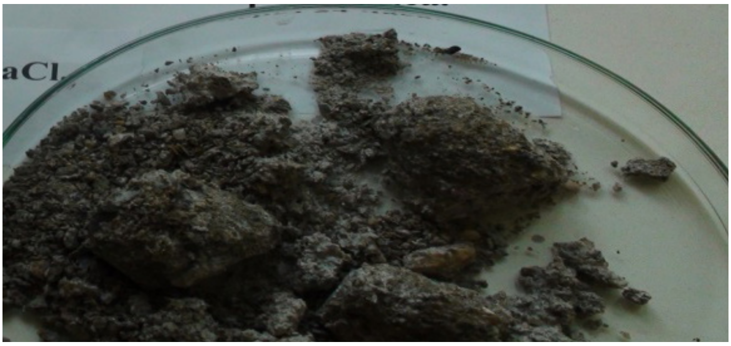
In the doctoral theses of N. K. Rosenthal [3], O. A. Shvagireva [4], as well as the works of the authors of this article [5–11] the results of studies on the negative impact of chloride AIR on materials, objects of the technosphere and the environment are shown. And in

Pic. 1. Initial concrete samples.

Pic. 2. Concrete samples after five cycles of testing, aged in a 3-component model of an anti-icing reagent.



Pic. 3. Concrete samples after 20 cycles of testing, aged in a 3-component model.



Pic. 4. Concrete samples after 25 cycles of testing, aged in a 3-component model.

this case, we will discuss the destruction that can be caused by chloride AIR when the elements of overhead lines of the contact network of electrified railways are exposed to it, and the consequences of such destruction, which can lead to accidents.

II.

As already mentioned, chlorides can destroy such materials as concrete, metal structures, which include iron (Fe), copper products (Cu), first of all – copper wires. Catenary supports of overhead lines (OL), bases for metal supports are made of concrete, iron helps to create cables, supports, copper is not only the main component of electrical wires, but also constitutes part of bimetallic cables.

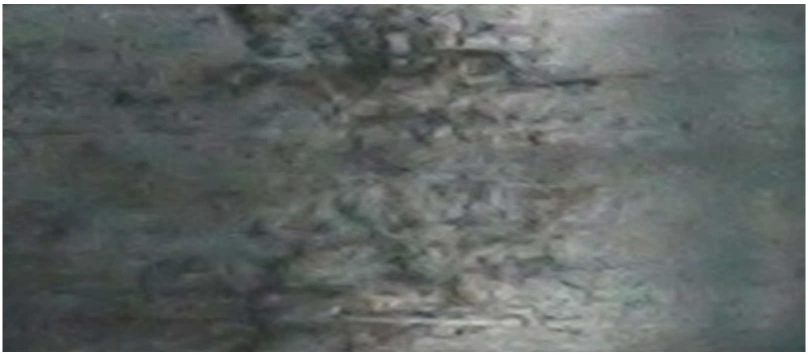
Ways how chloride AIR contacts with overhead lines were studied in [6–10]. When analyzing and conducting a series of experiments, the authors concluded that the bulk reagents appear on the wires of the contact network by means of convective mass transfer.

Following destruction of the materials which are a part of support, wires, cables and other, emergency situations might be expected that can lead to human victims. The fall of the supports, for example, entails not only the failure of the electrification network, mechanical damage to nearby objects and injury to people, but also the destruction of the latter by electric current due to wire breakage.

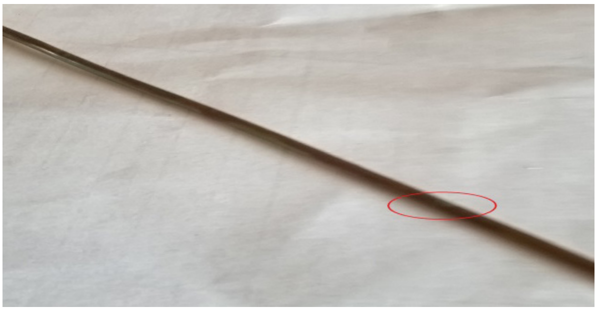
The destruction of concrete supports, which can lead to their fall, is the inevitable outcome of the use of chloride-based AIR at facilities associated with cargo and transport. Chlorides are highly corrosive to concrete. In the authors' works [5–7, 9, 11] this fact was surprisingly proved. Concrete structures when exposed to chloride AIR under conditions of temperature extremes are destroyed almost completely. Moreover, it is quite difficult to notice the sequence of the process. The destruction happens quickly enough and, if we may say so, «suddenly». In their studies, the authors have repeatedly noticed that concrete samples subjected to study in chloride environments during temperature cycles for a long time almost did not change their appearance: only a small amount of gray deposit was observed in the vessels where the samples were tested. Then small chips appeared. And only at some point the finally destroyed sample appeared (Pic. 1–4).

For the tests, two- and three-component solutions of chloride AIR models were used. The two-component

Pic. 5. The test iron plate after immersion in a three-component solution of chloride AIR.

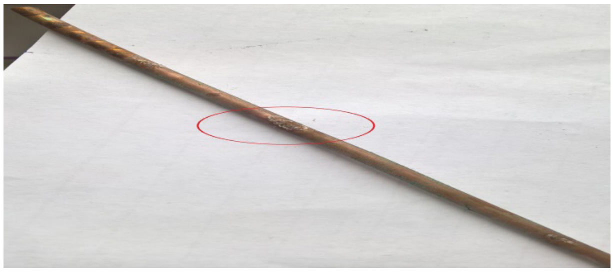


Pic. 6. Plaque on the surface of the plate.



Pic. 7a. View of a sample of copper wire treated with a 4 % solution of a model solution of chloride AIR at 200°C in a laboratory furnace.

Pic. 7b. Fragment of damage to the sample of copper wire.



Pic. 8a. View of a sample of copper wire treated with chloride AIR 16 % of concentration at 200°C.

Pic. 8b. Fragment of damage to the sample of copper wire.

model consists of NaCl and $CaCl_2$, the three-component model consists of NaCl, $CaCl_2$, $MgCl_2$. Concrete samples were taken on one of the platforms near Moscow. Information about the brand of concrete is missing. The tests were carried out for a month (30 days). The temperature regimes corresponded to the temperatures of the cold period of the year of the middle zone of Russia [1], and cyclic tests were conducted (alternating effects of sub-zero temperatures -12°C), and then above-zero temperatures (+5°C)). Total 25 cycles were conducted.

Studies show that in case of influence of chlorides on concretes there is Rehbinder effect. The greatest destruction was shown by samples tested in a three-component reagent model. This fact confirms the assumption that chloride media are active for concrete and cause destruction according to the very exact type of Rehbinder effect.

Such unexpected destruction of concrete is sometimes difficult to be tracked in practice. This makes that option the most dangerous and capable of causing emergency situations.

In determining the influence of chloride AIR on metal structures (for the first time this experiment was conducted in the final student graduate qualifying work of D. I. Duseev, supervised by S. V. Churiukina), which include Fe, cleaned iron plates were immersed in a two- and three-component anti-icing model reagents. The plates were kept in solution for one hour. After removing from solutions, a marker was added to them. After adding it, the solution of the two-component reagent model turned yellow, with a slight greenish tint. The coloring of the three-component model was more intense. Since hexacyanoferrate is a marker indicating presence of Fe^{2+} ions, we can speak about the onset of corrosion. Iron from a neutral state with a zero oxidation state changes to the +2 oxidation state:

$$Fe - 2e \rightarrow Fe^{2+} \quad (1)$$

This is an intermediate state of iron, the oxidation state will be further +3, the metal will be covered with a rusty coating when exposed to atmospheric oxygen. After some time, we shall note a small deposit on the surface of the iron plates (Pic. 5, 6). In our case, the greatest intensity of the process is seen in the variant of the three-component model of AIR.

The data obtained confirm: the destruction of metal elements of overhead lines of the catenary through intensive corrosion can lead to emergencies as a result of damage to supports and other metal structures.

The authors of the article studied the effect of chloride AIR on the elements of the overhead lines of the contact network made of copper (wires, bimetallic cables) in conditions close to real. The impact of chlorides on copper occurs at elevated temperatures. According to the Joule–Lenz law (2), when an electric current flows through a conductor, the latter heats up. The average heating temperature of copper wires that do not have insulation is approximately 200°C [12].

$$Q = I^2Rt, \quad (2)$$

where Q – amount of heat released, J;

I – amount of current flow, A;

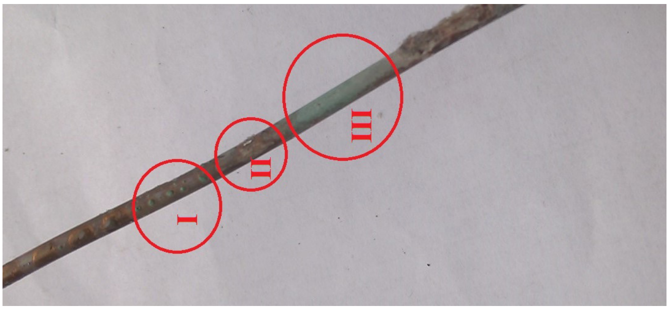
R – conductor resistance, Ohm;

t – work time.

Experiments to determine the effects of chlorides were as follows. The samples of copper wires were treated with solutions of reagents of different concentrations: 2, 4, 8, 16, 20, 33 %. Wires treated with solutions were heated in a laboratory furnace at 200°C for three minutes. It was planned to carry out 25 cycles of such processing, but already in the course of the third, brown and bluish-green spots formed on the surface of all samples to one degree or another, which indicates the reaction of copper with chlorides. As a result of these reactions, copper chlorides $CuCl_2$ (brown spots) appeared on the surface of the wires, and when cooled, the chlorides (II) $CuCl_2 \cdot 2H_2O$ (bluish-green spots) dihydrates (Pic. 7–9) appeared.

With an increase in concentration of model solutions, the nature of the damage becomes more devastating, and their number also increases.

Conclusions. *Describing damage to the contact wire, various sources provide very similar illustrations [13, 14]. Pic. 10a, b show the types of damage to the*

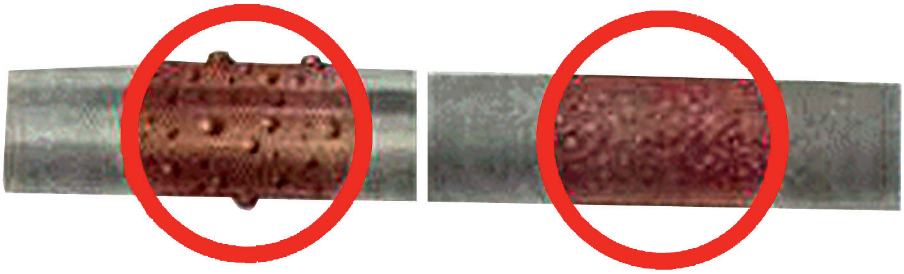


Pic. 9a. View of a sample of copper wire treated with chloride AIR 30 % of concentration at 200°C. The circles in the figures indicate the places (fragments) of damage.

Pic. 9b. Fragment I of damage to the sample of copper wire.

Pic. 9c. Fragment II of damage to the sample of copper wire.

Pic. 9d. Fragment III of damage to the sample of copper wire.



Pic. 10. The main types of damage to the contact wire: a) beads; b) caverns and regulus [14].

contact wire, very close to those obtained when exposed to chloride AIR on copper at high temperatures.

Such damage will cause breakage of the contact wire. A wire breakage, as it is known, leads to emergency risks.

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