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HEATING CABLE AS A CAUSE OF FIRE DURING OPERATION OF THE DUST SUPPRESSION SYSTEM OF THE PRODUCTION AND RELOADING COMPLEX

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Abstract. The article is devoted to the study of the occurrence of a fire from a heating cable during the operation of the technological process of the dust suppression system of the production and handling complex. The results of a metallographic study of a heating cable subjected to melting during ignition of an electric multi-wire core of a dust suppression system are presented. Recommendations are given to prevent fire hazardous emergency modes of operation of electrical equipment.

Keywords: electric current, cause of fire, heating cable, expert study of a fire at work

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Electric energy is currently of great importance both in industry and in the everyday life of people. Any technological processes associated with this type of energy, and the need for it is constantly growing.

At the same time, the use of electrical equipment is associated with the possibility of fires or explosions due to accidents or improper operation of electrical equipment.

According to statistics, annually in Russia more than 20 % of fires occur due to violation of the rules for the operation of electrical installations [1]. Most fires in electrical installations occur due to emergency operation of wires and cables:

– insulation breakdown by increased voltage;

– breakdown of insulation at the site of microcrack formation due to a manufacturing defect;

– breakdown of insulation at the site of mechanical damage during operation;

– breakdown of insulation from aging;

– breakdown of insulation in the place of local external or internal overheating;

– breakdown of insulation in the place of local increase in humidity or aggressiveness of the environment;

– accidental or intentional connection of the conductive cores of cables and wires to each other or when the conductive cores come into contact with the ground [2].

Analysis of the study of the causes of fires in electrical conductors is of scientific and practical interest, and will contribute to the ability to avoid the occurrence of a fire that causes material damage and a threat to human lives.

The article gives an example of the occurrence of a fire due to the emergency operation of the heating cable in the energy chain of the dust suppression system on the territory of the production and handling complex.

To establish the electrical cause of a fire in the source zone, specialists needed to find a conductor with signs of melting and establish reliable information about the presence of a fire hazardous process characteristic of the emergency operation of electrical equipment (the smell of burnt insulation, sparking, the occurrence of an electric arc, etc.) and combustible materials that can ignite from a nearby ignition source [3].

During the inspection of the fire object by a specialist of forensic institution of the federal fire service fire testing laboratory in Primorsky krai, it was established that the fire object was the cable circuit of the dust suppression system of the production and handling complex «Staker».

The dust suppression system is a unit installed on the territory of the production and transshipment complex located in the port of Primorsky krai, which includes a low pressure line, a dust suppression system container, a high pressure line located in a metal tray and in a cable chain, a line installed directly on «Staker».

The production and handling complex «Staker» is a reloading machine that receives coal from a stationary belt conveyor through a receiving hopper to the boom conveyor «Staker» with further unloading of the coal located on the boom conveyor into a pile (fig. 1). A metal tray is installed along the trajectory of the Stacker, in which a high-pressure line is located.

Fig. 1. **General view of the handling machine «Staker»**

According to the design documentation, the year-round dust suppression system for the Staker during the cold period of operation, at temperatures below +2 °C, provides for automatic activation of heating cables for high-pressure lines.

The high-pressure line system is laid in a closed metal tray up to the middle connection point, then the line is laid in the Kabelschlepp cable chain, which is attached directly to the Stacker through the cable chain connection unit. Schematic representation of the «Staker» and the high-pressure line in the tray and the cable chain «Kabelschlepp» – (fig. 2), the cable chain assembly that allows the reciprocating movements of the «Staker» along the working area of the coal storage – (fig. 3).

In the metal tray and in the cable chain there is a high-pressure line with a heating system that feeds the cable and control cables.

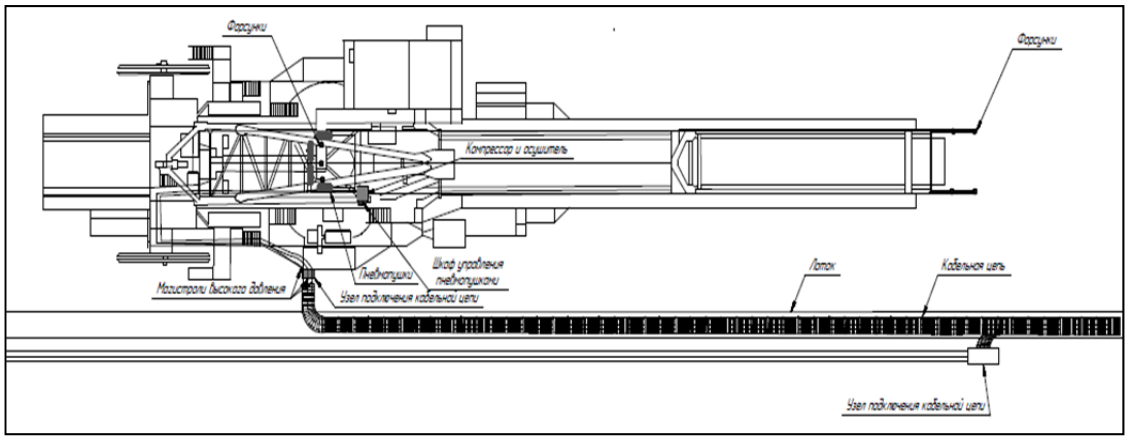

Fig. 2. **Schematic representation of the «Stacker» and the high-pressure line in the tray and cable chain «Kabelschlepp»**

Fig. 3. **A cable chain assembly that allows you to carry out reciprocating movements «Staker» along the working area of the coal warehouse**

Circumstances of the incident

The following entries were recorded in the error log of the control panel for the «Staker» dust suppression system:

– 20.09.2022 at 23:01:47 heating of the high-pressure lines of the dust suppression system was turned on;

– 21.09.2022 at 10:49:24 the boom conveyor was launched;

– 21.09.2022 at 11:57:17 a malfunction of the KM 10, 11, 12 contactor (heating) check of automatic machines, heating cable;

– 21.09.2022 at 12:00:17 there is no connection with the control panel of the «Staker» (PUO);

– 21.09.2022 heating failure of the mains in the circuit (check the RCD);

– 21.09.2022 at 12:36 pm, the docker mechanic discovered smoke in the cable chain, measures were taken to extinguish the fire.

В ходе осмотра места пожара установлено, что в результате горения на участке пикет 32–33, на протяжении около 10 м произошло выгорание горючих материалов (изоляция проводников, тепловая изоляция, пластиковые элементы цепи) в двух уровнях кабельной цепи «Kabelschlepp», рукавов высокого давления, силового, управляющих и греющих кабелей. При возгорании отмечены участки с полным выгоранием горючих элементов кабельной цепи, расположенной сверху (второй от основания металлического лотка). Также изоляция проводников (силового, греющего и управляющих кабелей) на протяжении 10 м полностью выгорела (fig. 4).

Fig. 4. **Thermal damage to the section of the cable chain of the system dust suppression «Stacker»**

At the site closer to picket 33 in the upper level of the cable chain, a break in the power cable was found, a thinning of the metal sheath of high-pressure hoses, further towards the attachment point of the main to the «Staker» there is a section of the heating cable rupture, at the ends of the metal current-carrying conductors of which signs of a fire hazardous emergency operation of electrical equipment in the form of local melting were found (fig. 5, object under the number 3). This area with reflow is located in the most remote part from the power supply of the electrical circuit.

There are fragmented sections of electrical conductors, both heating and power, in the area of cable circuit burnout. This circumstance is due to the effect of dissolution of metal in metal when metal fragments (made of aluminum) melted during combustion get on the conductors of the Kabelschlepp cable chain structure.

The degree of thermal damage to the cable chain and combustible materials of the cables indicates the spread of combustion from the 33rd picket towards the 31st picket.

During the inspection of the cable chain, from the burnt section towards the return loop (that is, from the place of combustion towards the power source), sections with damaged insulation of both the heating cable and the section of power conductors coming from the power cable were found in the upper level of the cable chain to the connecting sleeves of the heating cable, the degree of damage of which indicates the thermal impact from the current-carrying cores.

The indicated place coincides with the zone of the greatest thermal damage, which additionally indicates that the fire was located precisely in the upper level of the cable chain of the Staker dust suppression system in the area closer to picket 33.

Visual examination of the presented objects

The visual study of the presented objects was carried out according to the existing methodology [4–7] by external examination with subsequent photofixation according to the rules of forensic photography [8, 9].

Three electrotechnical objects were received for the study (fig. 5).

The object under the number 1 is a fragment of a heating self-regulating cable 177 mm long. A fragment of the conductor consists of: the outer layer of insulation is gray, then white insulation, then a semi-conductive self-regulating matrix of black color, then two white multi-wire cores with seven wires per core, the diameter of one wire is 0,5 mm. Two wires of one core were sintered in a local melting and three wires of the other core were also sintered in a local melting (fig. 5–9).

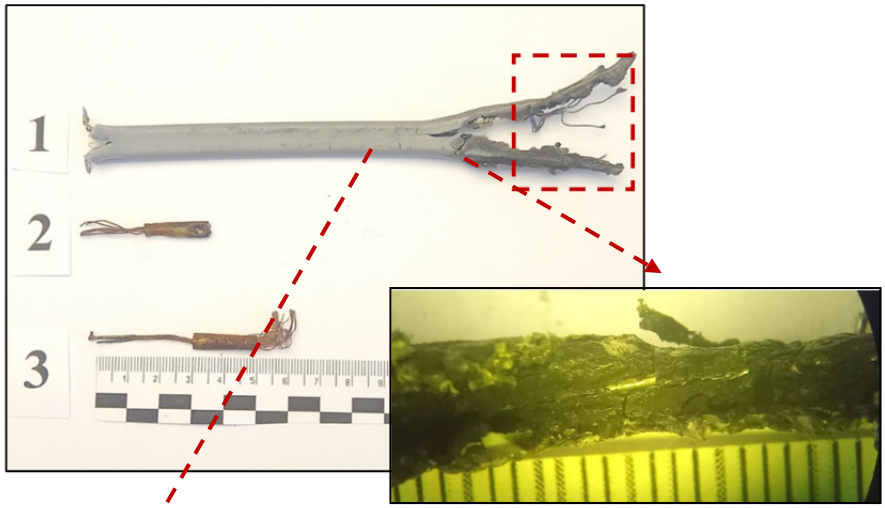

Fig. 5, 6. **In the frame: 1 – a fragment of a heating cable with thermal damage insulation (matrix) from the side of the conductors; 2 – a burnt fragment of the connection of the heating and power conductor; 3 – a fragment of the connection of the heating and power conductor, local melting on the copper wires of the heating cable core (signs of a short circuit)**

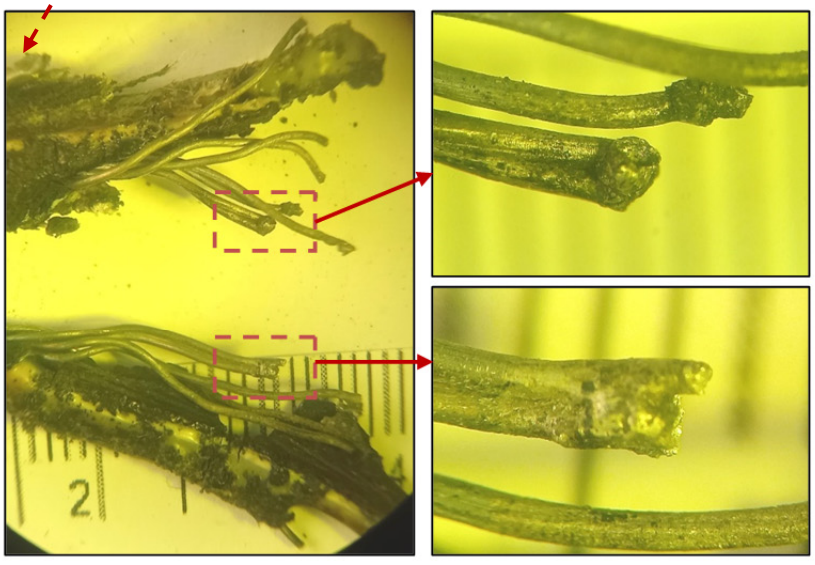

Fig. 7–9. **Enlarged image of a fragment of a heating cable with melting on the core wires**

T Thus, in the course of a visual study of a fragment of a heating cable, signs of emergency operation of electrical equipment were found, which are characteristic of the occurrence of a short circuit current and overcurrent overload as a result of an electric arc.

The object under the number 2 is a fragment of a metal sleeve of a cylindrical shape 20 mm long, 5 mm in diameter, on one side a copper stranded conductor 19 mm long departs from the sleeve, six wires in the conductor with a diameter of 0,46 mm each, on the other end a fragment of a stranded copper conductor is observed , the diameter of one wire is 0,27 mm, the wires are broken.

The object under the number 3 is a fragment of a cylindrical metal sleeve 20 mm long, 5 mm in diameter, on one side of the sleeve a multi-wire copper core 32,7 mm long departs from the sleeve, six wires in the core with a diameter of 0,46 mm each, four wires were sintered in local melting dimensions 2,5x3,7x2,5 mm. From the other end of the sleeve, a copper stranded conductor 21 mm long departs, 33 wires in the conductor, the diameter of one wire is 0,27 mm, five wires are sintered in local melting (fig. 5, 10, 11).

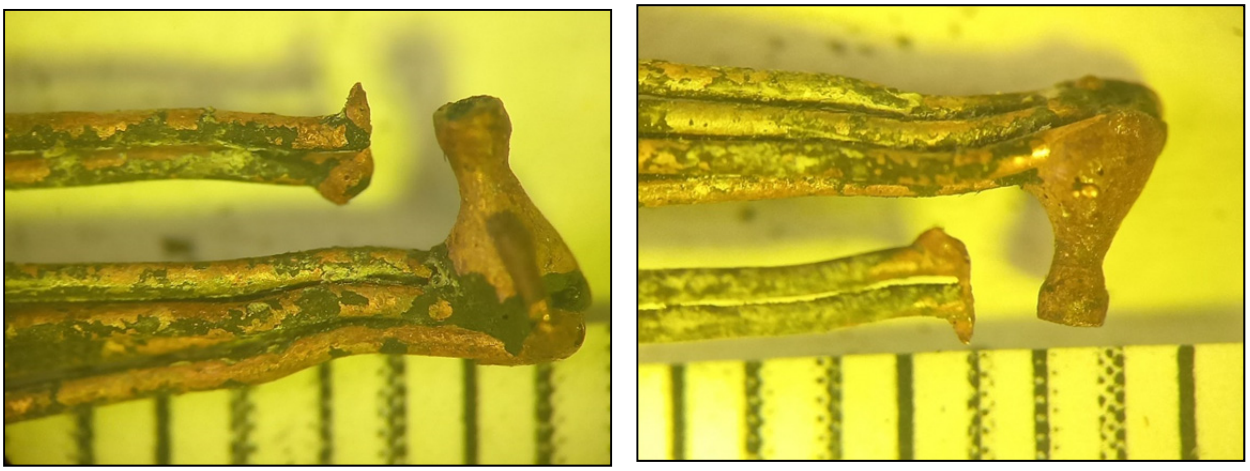

Fig. 10, 11. **Enlarged image of melting on the copper wires of the heating cable № 3**

Thus, during the visual examination of object № 3 – a fragment of a copper conductor (a metal sleeve with fragments of copper conductors of a heating and power cable), signs of emergency operation of electrical equipment were found on the copper conductor of the heating cable, characteristic of a short circuit as a result of an electric arc current.

Metallographic study

From the fragment with melting of object № 3, a section with melting 9 mm long was cut off, from which a microsection was prepared (fig. 12). To do this, a round frame was installed on the glossy surface of the ceramic plate, in which a segment was placed.

With reflow (fig. 13). The frame was filled with self-hardening plastic «Protacryl-M» (hardening time – 60 min).

Surface treatment of microsections was carried out on a unit for the preparation of metallographic sections UPSh-1 on sandpaper № 400, 600, 800, 1000 and 1200. Processing was carried out approximately up to half of the flashing cross section with a supply of running water.

At the final stage of processing, mechanical polishing of sections was carried out on the UPSh-1 installation, on a polishing cloth wheel (wool) with the addition of abrasive polishing paste.

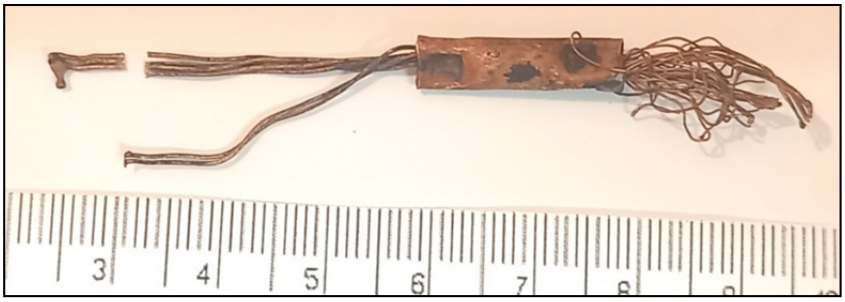

Fig.12. **Section with melting, separated from object № 3 for metallographic examination**

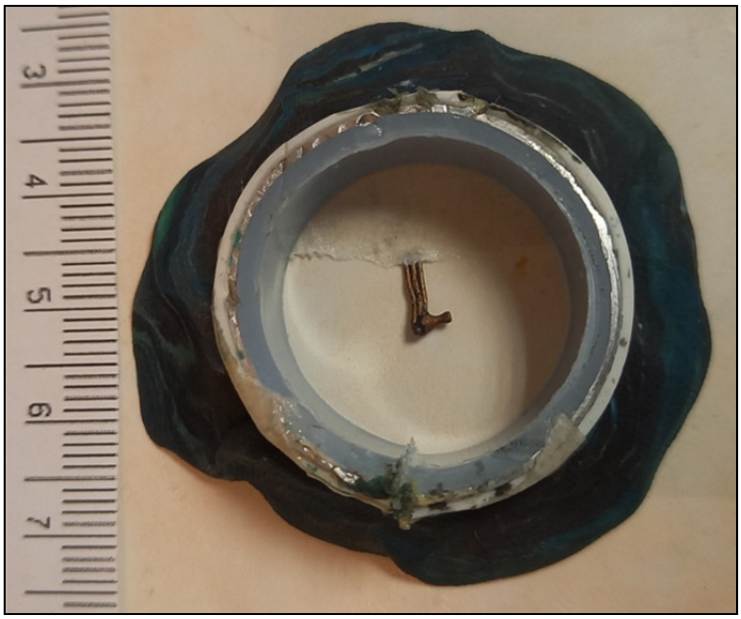

Fig. 13. **Piece with melting in the frame**

After mechanical polishing, the abrasive was removed from the surface of the section by washing under running water.

To reveal the microstructure, the section was subjected to chemical etching in a reagent obtained by mixing a weighed portion of ferric chloride weighing 5 g with hydrochloric acid 30 ml and water 100 ml.

The microsection was etched by wiping with a cotton swab soaked in the reagent. After etching, the surface of the sections was washed under running water and dried with filter paper.

The sections prepared according to the above method were examined on an EC METAM RV-21 metallographic microscope at 50, 100, 150, and 200-fold magnification.

Photographing the microstructure of the prepared sample was carried out with a VEC-335 video camera.

Results of a metallographic study of reflow

Object № 3 (fig. 4, 9–11).

A study using a metallographic microscope of the indicated melting has established that in the zone of the conductor part the basis of the microstructure is copper (light areas), small equiaxed grains are observed along the boundaries and inside the copper grains in the form of dark dots – copper oxide I (Cu_2O). In the melting zone, the microstructure of the melting zone is based on medium elongated grains, there is a clear straight boundary between the melting zone and the conductor part (fig. 14).

In the course of the metallographic study of object № 3 – a fragment of the copper conductor of the heating cable, it was found that the microstructure of the conductor part has small equiaxed copper grains, a direct boundary between the microstructures of reflow and the conductor part is observed, the microstructure of reflow has medium elongated copper grains. These signs are typical for a short circuit that occurred before the fire.

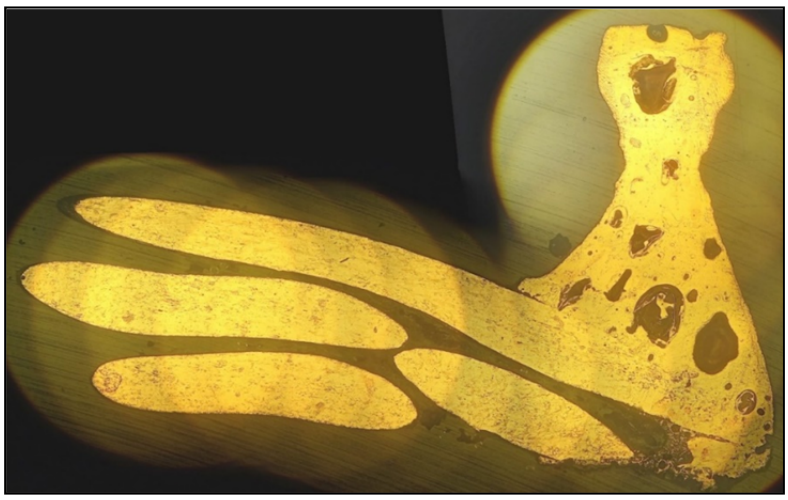

Fig. 14. **Panoramic shot of the microstructure of the reflow of the object № 3, (100^{x})**

Thus, taking into account the studies carried out, taking into account the location of the fire, the cause of the fire was the ignition of combustible materials (wire insulation, thermal insulation) due to fire hazardous emergency operation of electrical equipment – a heating cable system located in the moving part of the cable circuit of the dust suppression system «Stacker».

Violation of the rules for the operation of electrical installations (in our case, a heating cable) remains an urgent issue in the field of safety when using electrical equipment.

The novelty of the study of this problem lies in the ability to solve a wide range of problems in industrial and everyday use in everyday life by the population of an electric heating system. At the same time, many are unfamiliar with the danger of using heating cables, although in the long-term use of the cable it is quite serious.

The article considers and analyzes such a case, which in the future will give the necessary impetus to similar studies related to fire hazardous emergency modes of operation of electrical equipment.

The ignition of the considered object does not occur often, but it can lead to a disruption in the technological process, which can lead to a shutdown of the entire production process and significant material losses.

Therefore, when designing, installing and operating electrical installations, it is necessary to strictly comply with the requirements of regulatory and technical documentation, and the state fire supervision authorities should pay more attention to the problem of violating the rules for their operation in the field of fire safety.

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