The main approaches to the system of fire extinguishing and elimination of consequences of accidents of electric vehicles

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Abstract. The authors raise the issue of studying the features of fire extinguishing and accident response in vehicles with hybrid and electric power plants. The article discusses the trends in the development of the electric car fleet in Russia and the world. The main problems related to the elimination of fires and accidents of electric vehicles, both from the technical side and from the environmental safety side, are presented. The article summarizes the international experience in the elimination of fires and accidents of electric vehicles. The need to improve the technology of extinguishing such fires and the main directions for reducing harm to the environment are identified. The main provisions of the Concept of ensuring the safety of the development and operation of the fleet of electric vehicles are proposed. Practical significance will be realized in the development of special fire extinguishing agents and compositions that reduce environmental damage, as well as mobile fire extinguishing equipment.

1. Introduction

New environmental standards and requirements dictate the trends of rapid development and introduction of modern cars with electric and hybrid power plants on the consumer market.

Analyzing the Russian market, already in 2005 the first hybrid appeared, at the end of 2014 the number of sold vehicles of this kind in Russia was 14,917 copies, and by the end of 2019 their number was more than 17 thousand units [1].

The number of electric vehicles has also increased dramatically in recent years. To date, only the volume of sales of American Tesla cars in the world is growing rapidly (Figure 1) [2, 3, 4].

The second impetus for the development of the electric car market was the creation and introduction of passenger transport with electric power units. One of the main advantages of electric buses compared to buses is higher performance, energy efficiency, and comfort for passengers. They are practically silent and easy to operate [5].
Figure 1. Dynamics of sales of Tesla cars from 2012 to 2020.

The development of serial production of electric buses on the basis of the Likinsky Bus Plant near Moscow makes it possible to speak about the systematic equipping of the passenger transport fleet of megalopolises. According to Mosgortrans, it is planned to commission more than 500 by the end of 2020, and by the end of 2021 to double the number of units of such equipment. More than 100,000 passengers are transported by electric buses in Moscow every day [6].

2. Results

Despite the use of modern technologies for creating vehicles with electric power plants and their obvious advantages, accidents and fires with their participation entail more serious consequences. This is primarily due to the technical characteristics of power sources. In case of an emergency, the risk of electric shock increases, both for participants in extinguishing the fire and for passengers.

It is worth noting that the most fire hazardous is the process of charging an electric vehicle, since at this moment up to 600 kW of electricity is consumed, a chemical reaction occurs in the batteries and they get very hot. So during charging, there is a risk of fire not only for the rolling stock, but also for the stationary communications of the charging station. An example is the fire that occurred on March 14, 2019 in the Spanish city Heros during the second pre-season test. At night, while charging in the building, class E motorcycles caught fire, after which the hangar completely burned out, 18 motorcycles and athletes’ equipment burned down (Figure 2). [7]

The total damage is estimated at over $ 25 million. Due to the risk of electric shock to firefighters and the likelihood of poisoning by combustion products, they did not even start extinguishing the fire.

The process of extinguishing fires and eliminating accidents involving electric vehicles is quite complicated and requires compliance with a number of conditions, the main one being the safety of personnel and passengers.

When extinguishing fires with electric vehicles, the risk of electric shock to personnel increases. This happens as a result of the following factors:

1) touching the high-voltage systems of the vehicle;
2) damage to storage batteries and subsequent exposure to the voltage of a person’s step;
3) the occurrence of an electric leakage current along a stream of fire extinguishing substances

When extinguishing a fire of electrical equipment under voltage, the third factor is most common (the passage of an electric current through a stream of extinguishing agent). The reason is the failure to comply with the safe conditions for the supply of fire extinguishing agents, the main of which is water. The basis of these conditions is the observance of safe distances from the barrel to the power source (Figure 3) [8].
Figure 2. Fire in the charging building for class E motorcycles in Heros.

Figure 3. Dependence of the leakage current along the stream from the distance to the electrical equipment under voltage for some fire nozzles [6].
In addition to supplying water for extinguishing fires of electrical equipment, the following types of fire extinguishers can be used: 1) freon fire extinguishers at voltages up to 380 V, 2) powder fire extinguishers up to 1000 V, 3) carbon dioxide up to 10,000 V. However, in open areas (when used to extinguish electric vehicles), the first and the third type is ineffective, and powder types require a special composition for extinguishing alkali metals.

The issue of human footstep being affected by battery damage in electric vehicles is practically unexplored. As for international experience in extinguishing fires of electric vehicles, it involves a large number of firefighting units, so, for example, in the European Union countries send at least 5 fire trucks with 35 firefighters in respiratory protection (Figure 4) [9].

![Figure 4. Elimination of a Tesla car fire in Austria.](image)

The most dangerous part of electric cars is the lithium-ion batteries. When they burn, they emit large amounts of heat and toxic substances, and when extinguished with water or foam, combustion intensifies with a possible explosion. There is also the danger that the subsequent spontaneous combustion of electric vehicles may occur even after several days of extinguishing.

In the same Austria, an electric car that has had an accident is placed in a special fire container and filled with water. In such a container, a car can be in a special parking lot for more than a month (Figure 5) [10].

![Figure 5. Loading the vehicle into a container and filling with water.](image)

Unfortunately, to date, the technology for dealing with such emergencies with electric vehicles in Russia has been little studied. Therefore, it is very urgent, timely and relevant to elaborate the Concept of development and rules of operation of electric vehicle fleet in Russia, as well as to solve safety issues.
This Concept should be based on the following tasks:
1) the creation of joint working groups of departmental units and research organizations, including with the involvement of interested manufacturers, to discuss issues and search for solutions in the field of ensuring the safety of the electric vehicle fleet;
2) conducting joint research, development and applied work on the study of the peculiarities of fires on electric vehicles and the creation of new technical means of extinguishing such fires;
3) development of guideline and normative and technical documents in the field of actions of employees of fire and rescue units during elimination of consequences of road accidents and fires with electric vehicles;
4) elaboration of issues of placing specialized sites for storage of electric cars after road accidents;
5) creation, together with the manufacturers of electric cars, of training grounds and training programs for practicing the actions of employees of fire and rescue units when eliminating the consequences of road accidents and fires with electric cars.

3. Conclusion
The creation and implementation of this Concept will at the initial stage help form the main ways of development of the electric vehicle safety system in Russia, develop basic approaches to the technology of eliminating fires and accidents of electric cars with the involvement of the operational units of the Russian Ministry of Emergency Situations. Joint development work will make it possible to develop special fire extinguishing agents and compositions, as well as create highly effective mobile fire extinguishing equipment for electric vehicles.

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