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Innovative fire-fighting technologies: patentological prospects

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Introduction. Currently, there are increasing threats of wildfires that destroy landscapes, economic objects and human lives.

Problem Statement. The purpose of this study was to compare some innovative technologies for extinguishing wildfires and study the prospects for research in this direction.

Theoretical Part. Technologies for extinguishing wildfires are being developed in several empirical directions. We use aerosols of metal-containing compounds and dispersed liquids with gas, as well as unmanned remotely controlled aircraft for extinguishing forest fires. For crown forest fires, a fire barrier is used. To extinguish peat fires in hard-to-reach places, a helicopter equipped with fire-fighting missiles is used. Peat fires are also extinguished by creating a vertical curtain using fast-hardening foam based on a solution of carbamide-formaldehyde resin. According to the concept of patentology, technology is considered as a set of functionally related technical objects and methods protected by patents, based on their innovative significance. System-forming elements in this case are concepts based on the characteristics of both technical objects and technologies, and patent objects.

Conclusion. It is advisable to build long-term plans for creating patent objects in the field of extinguishing natural fires. It is necessary to consider the scope of the patent results and outcomes of patentological analysis in accordance with the basic criteria of achieving a technical result of design technology, degree of innovation and empirical orientation.

Keywords:innovative technologies, patent, patentology, firefighting, natural fires, patentologicalresearch prospects.

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Introduction. Forests cover 1179 million hectares on the territory of the Russian Federation, or about a third of the world's forest area. Forest fires have a negative impact on the natural environment, including the condition of forest ecosystems. Forest areas are decreasing, and carbon monoxide and pyrolysis products are released into the atmosphere [1, 2]. At the same time, we are aware of increasing threats of wildfires that destroy forests, other natural landscapes, economic objects, and sometimes human lives. Peat fires are also very dangerous, which are often accompanied by the release of highly toxic smoke. Long-term smoke in cities and localities often leads to the development of diseases with severe dysfunction of pulmonary and cardiovascular systems. Issues of large cross-border fires are already being discussed at the international level [3]. Fires lead to the death of forests in large areas [4], and global climate change can worsen this situation, increase the area of their distribution and increase the degradation of forest conditions, i.e. it will become a global biosphere problem [5].

In recent years, the development of new technologies aimed at preventing and extinguishing forest fires has been updated in the world [6]. In favor of this argument, data from I.R. Shegelman and L.V. Shchegoleva [7] show that out of 14 Russian inventions for protection from forest fires, only six were devoted to methods for determining the location of fire localization and fire hazard control, while eight were devoted to extinguishing technologies. Some researchers have purposefully studied new technical solutions for detecting, preventing and extinguishing forest fires [8]. From the authors' point of view, the problem of extinguishing natural fires is relevant not only for forests, but also for peatlands. Thus, the analysis of some existing innovative technologies for extinguishing wildfires and the study of patentological aspects in this direction are quite relevant.

Basic means and methods of natural fires extinguishing. Currently, many innovative high-performance technologies and tools have been developed and are being used to extinguish wildfires. Modern classification of technical means of natural (forest) fires extinguishing [9] includes:

- tools for monitoring the occurrence and localization of forest fires;
- specialized equipment for transporting fire-fighting equipment and firefighters to the place of extinguishing;
- completely new driverless vehicles;
- means of protection of members of fire brigades.

A.G. Shmakov and co-authors [10] proposed to use a mobile generator of controlled dispersion for fire extinguishing, which can be used to suppress flaming or smoldering. The proposed fire extinguishing method using fine aerosols reduces tenfold the flow rate of the process fluid. Metal-containing compounds are promising for use as flame-arresters [11]. It is also believed that chemical compounds can be highly effective inhibitors such as K3[Fe(CN) [Fe (CN) [Fe (CN)6] (potassium ferricyanide) and K4[Fe(CN) [Fe(CN) 6] (potassium ferrocyanide). In this regard, the use of finely dispersed aerosols of potassium compounds and dispersed liquid with gas [12] leads to effective extinguishing of flame foci.

Modern innovative technologies for forest fires extinguishing. The study of the current state and use of innovative technologies for forest fires extinguishing was conducted by N.A. Korshunov and co-authors [13]. The experts selected promising criteria for these solutions: novelty, effectiveness, and positive experience. In particular, it is assumed that a promising technological solution must be confirmed by its practical use in fires extinction, i.e. the declared or actual effectiveness of the technological solution must be proven in practice. The maximum possible readiness of the proposed solution for its potential mass implementation is highly appreciated. At the current stage the novelty of research is shown in the choice of directions for the development and implementation of the most effective promising solutions in the practice of fire extinguishing, which determine the patterns of practical use of optimal methods and technologies not only for extinguishing, but also for fire detection. For example, an important area was the study of the use of unmanned remotely controlled helicopter-type aircrafts equipped with video cameras for fire reconnaissance. These devices can help reduce the risk of injury and death of firefighters, and timely detection of areas with the resumption of peat smoldering can significantly reduce the economic and environmental damage from such fires. The original direction in firefighting is individual small-scale mechanization of a forest firefighter due to the motorization of hand tools (the use of a knapsack forest fire extinguisher and personal exoskeletons). There are interesting and promising proposals for the creation of aviation fire barriers in the form of protective strips using fast-hardening foam compositions. Currently, this technology is at the stage of experimental research.

M.A. Sheshukov and co-authors suggested that to protect localities from forest fires, they should be bordered by firebelts with firelines of poplar seedlings planted in a line (up to 40 rows in a line) [14]. B.N. Borisov and his co-authors developed a barrier for fighting top-level forest fires. It includes a protective cloth made of fireproof material, fixed on vertical rods [15].

As a result of a brief patent and information search for technical solutions in the field of forest fire extinguishing, N.S. Kovalek and M.V. Ivashnev [16] considered the prospect of using the method of soil throwing. Researchers offer technical solutions:

- prevention of the release of the top of the forest cover in the area of the edge of the fire;
- moving the soil with thrower-cutters and guide-plates at an angle to the edge of the fire;
- concentration of soil directly in the zone of a moving fire.

In their research, the authors used an original methodology for the synthesis of patentable intellectual property objects, based on functional and technological analysis of engineering creativity, generalization of analysis and

synthesis of technical systems, taking into account the natural specificity of the functioning of modified technologies [17].

New technologies for using aviation to extinguish forest fires. The use of the VSU–5A helicopter spillway device with the supply of wetting agents and foaming agents is highly effective. However, the air-mechanical foam used in this case when laying protective fire lanes, protects only briefly in the process of fire extinguishing [18]. Currently, a new technology for forming chemical foam using a pump and compressor system has been developed. The technology is based on injecting a dosed amount of foaming agent and a fire-resistant chemical agent, followed by injecting air into this mixture in certain proportions. The formation of a composition for extinguishing fires, creation of a support and control lines occurs in the mixing chamber. Depending on the content of compressed air in the foam, "wet" or "dry" foam is obtained. The latter is more adhesive and can be held on vertical planes for a relatively long time. "Wet" foam has greater mobility, and therefore is suitable for the suppression of burning edges. NPO SOPOT and ITMO University (Saint Petersburg) modified the foam mixing technology to create fire-resistant fast-hardening foam from structured silica gel nanoparticles that repeat the morphology of air bubbles dispersed in solution [19].

New firefighting technologies are also being developed to localize and extinguish fires in remote areas, in case of high-altitude forest and steppe fires. To implement this technology, a helicopter with fire-fighting missiles equipped with a dispersing charge, a sensor for the selected parameter, and a fire extinguishing agent is required. Such a missile is triggered on the ground. In this case, the package with the foaming agent breaks, which, mixing with water, fills the barrel. The reagents form fire-extinguishing foam covering the combustion center [20]. In 2016, S.I. Zhiltsov and P.N. Petukhov proposed a technologically new device based on amphibious hydro-aeroplanes to extinguish forest fires from the air with a fire-extinguishing liquid [21].

New technologies for peat fires extinguishing. The analysis of existing technical solutions designed to extinguish forest fires has shown that their use in the elimination of peat fires is not practical, since the epicenter of peat burning may be located at a depth of a fire. I.D. Badin and co-authors suggested using "A device for extinguishing fires on peatlands" using helicopters [22]. The principle of operation of the device is the depressurisation of the cylinder with carbon dioxide when it hits the ground, decomposition of carbon dioxide into water and carbon dioxide, which under pressure spreads under the surface of the peat to the depth and blocks the access of oxygen to the fire. The device allows you to quickly and effectively eliminate peat fires, including hard-to-reach places.

Another technological approach to fighting peat fires is to create a vertical curtain. In particular, N.P. Kopylov and V.I. Zabegaev developed a method for local firefighting, according to which fast-hardening foam based on water, solution of amino-formaldehyde resin, foaming agent, concentrated sulfuric acid, and target additives containing liquid glass and formamide are used when creating a vertical curtain [23].

The principle of extinguishing a fire by isolating the hearth from oxygen is also discussed in another technological version proposed by the same authors. This is a technology for extinguishing local underground peat fires by flooding with water and capillary imbibition of all reservoir deposits. Next, they determine the boundaries of active local underground peat combustion centers and consistently move a helicopter with a multi-section tank to them. The tank is regularly filled with water in the necessary sections in accordance with the irrigation and fire-fighting map [24].

The original technological approach allows you to use the energy of explosives when extinguishing a fire. This method in arsenals for storing explosive materials increases the effectiveness of extinguishing and reduces the likelihood of uncontrolled explosion of ammunition. The areas where explosives are stored are covered with soil, in which the explosive charges are placed. Their explosions move the soil of the embankment, filling in the fire place. The method can be used for extinguishing forest and underground fires over large areas [25]. For extinguishing peat fires on large areas V.I. Zabegaev and N.P. Kopylov proposed a method, the essence of which consists in laying moles on the lower level of peat formation. They detonate the cord explosive placed in them with the formation of a ditch, at the bottom of which they form a fire-prevention gap from the mineral layer of the earth [26].

Patentological prospects of research in the field of fighting wildfires. Patentological essence of the concept is inextricably linked with the structural-integrative approach. The concept of patentology and its general characteristics were developed by V.M. Evstropov in 2017 [27]. According to this concept, technology is considered as a set of functionally related technical objects and methods that are protected by patents, based on their innovative significance. The system-forming elements are concepts based on the characteristics of both technical objects and technologies (technical characteristics) and patent objects (utility models, devices and methods). Stages of patentological research may include [28]:

- pre-processing of patent arrays for a given topic;
- formation of a thematically restricted locus of patent data;
- patentological analysis of the obtained results;
- analysis of technologies in terms of classification.

The patent locus is positioned as the desired part of the patent cluster — a thematic set of patents linked by functional vertical and horizontal links. Vertical links are provided by the chronological development of the patent and technical object. Horizontal links are understood as links between groups of inventions and utility models that form the patent locus, including the patent objects themselves, as well as their analogues. New patent research based on the patentological approach can optimize the creation of modern patent and technical solutions used for extinguishing forest fires [29].

The patentological approach can optimize the activities of modern innovative engineering [30], for example, when developing methods for using robotics in extinguishing natural fires. At least, currently, the work is under way to create robots (drones) for multi-functional and tactical purposes, including the creation of unmanned aerial vehicles [31]. In addition to the robotization of forest fire extinguishing, the prospects of creating an intelligent system for controlling extinguishing processes by equipping members of forest fire brigades with intelligent devices are discussed [32].

Conclusion.A comparative analysis of some modern technologies and patent directions of forest fire extinguishing is carried out. Based on the analyzed data, we comes to the conclusion about the feasibility of building long-term plans for creating patent objects in the field of extinguishing natural fires, taking into account the loci of patent results and their patentological analysis. These measures should be carried out in accordance with the main criteria for achieving the technical result of the designed technologies, the degree of innovation and empirical orientation (creation of fundamentally new technical means for extinguishing natural fires, etc.).

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V.M. Evstropov — formulation of the main research concept and article structure, literary and patent analysis. S.L. Pushenko — theoretical research, critical analysis, editing.