The problem of fire fighting during the hours of darkness

V A Savchenkova¹², N A Korshunov¹, A V Perminov¹ and S A Voinash³

¹All-Russian Research Institute of Forestry and Forestry Mechanization, 15 Institutional, Pushkino 141200, Moscow Region, Russian Federation,
²Mytischi Branch of Bauman Moscow State Technical University, 1st Institutskaya-1, Mytishchi, Moscow region, Russian Federation
³Polzunov Altai State Technical University, Traktornaya st., 2/6, Rubtsovsk, 658207, Altai Krai, Russian Federation

E-mail: v9651658826@yandex.ru

Abstract. The article presents the results of the first stage of investigation, aimed at improving the efficiency of the system for forest protection from fire by improving the organization and work to extinguish forest fires due to the optimal use of the dark conditions, increasing the safety of workers of forest fire groups in difficult conditions. The possibility of increasing the impact degree on the border of an existing forest fire with available forces and tools on the first day is equivalent to gaining an increase in the amount of labor hours spent within one operational period. It is comparable to the positive effect of using additional forces for a short period of time.

In the course of the analysis, domestic and foreign experience of extinguishing forest fires at dark conditions was considered. A field research program for the next phase has been organized.

1. Introduction
Cases of behavior in extinguishing a forest fire at dark conditions occur regularly, for example in the aviation forest protection system, where manual labor of paratrooper firefighters predominates [1, 2]. Often, forest firefighters arrive to extinguish a forest fire in the afternoon and the aggressive period is extinguished (the progress of the fire stopping in critical directions, localization) is carried out in the daytime and evening, often in twilight until the very time of darkness. Cases when it is necessary to work until 1–2 a.m. are not rare, especially in the northern latitudes of the country, where the hours of darkness come quickly. The subsequent stages of full extinguishing and guarding are conducted again in the morning. In each separate case, firefighting team leaders are forced to estimate situations independently and weigh the risks that arise for firefighters. According to experts, the main reason, which restrains decision-making by leaders is the complexity of visual control of dangerous factors in
the fire such as loss of personnel and equipment, falling trees, haze pollution of the working area, difficulty in predicting dynamically changing fire behavior and weather conditions (primarily wind), compliance with security requirements labor and personnel safety [3,4].

2. Statement of the problem
The purpose of the work is to increase the efficiency of the organization and work conducting to extinguish forest fires during the hours of darkness by improving methodological support in terms of production process technology and labor protection. The research objectives at the current stage are defined as follows:

- an analytical review of the extinguishing forest fires practice at dark conditions, peculiarities of work associated with difficult conditions formed by the influence of various factors such as forest conditions, orography, weather, applied machinery and equipment, etc.;
- estimation of remuneration for work conditions for extinguishing forest fires at dark conditions;
- analytical review of foreign practice for extinguishing forest fires;
- analysis of court practice on research and regulatory support;
- estimation of the problem of the labor protection during extinguishing forest fires at night.

The possibility of increasing the impact degree on the border of the forest fire with available forces and tools on the first day is equivalent to obtaining an increase in the number of labor hours spent within one operational period, which is comparable to the positive effect of attracting an additional number of forces for a short period of time. In this study, a shortage of firefighting forces and equipment was noted. The necessity of accounting for the time period has been established: ascending air flows in the daytime and descending air flows at night.

3. Research results and discussion
The analysis of the industrial practice of extinguishing forest fires showed that a leader always tries to take quick and effective actions, especially in the most dangerous areas of the fire spread, in order to prevent the fire spread, based on the availability of human resources and fire fighting tools. According to experts, it is advisable to carry out the work both during the daytime and at night, if night is more efficient. It ought to be together with the fire spread control and extinguishing.

The relationship of forest fire burning with forest conditions and climatic processes was studied [5]. The relative humidity is greatest at night, when the temperature drops. But at noon the opposite phenomenon, i.e., a decrease in humidity and an increase in temperature occurs (figure 1).
Figure 1. Changes in indicators of temperate climate in summer: (a) – relative humidity, (b) – daily air temperature.

This is also one of the reasons that burning intensifies at noon, and subsides by the evening. Studies show that a decrease in air humidity of up to 30–25% often causes the transition of grassroots fire to crowns. Emphasizing the close relationship of temperature with the magnitude of the fire danger in the forest, it should be taken into account that that negative values of temperature in a snowless period are not an indicator of the absence of a fire danger. The study found the influence of weather conditions, which are crucial for the fire spread, since rains and high humidity limit and stop burning. [6, 7, 8]. In the practice, the main factors taken into account that affect the spread of the fire are wind, humidity, forest combustible materials and their supply, air temperature and topography [6, 7, 8]. At the same time, it was established that temperature inversions are not an exception, but one of the constant properties of weather and climate. In different seasons and in different places, they were registered in 75–98% of all observations. Haze pollution is pressed to the ground as a result of temperature inversion in the evening hours. This effect influences the transparency of the air in the surface layer, and in twilight or dark conditions it can affect the efficiency of artificial lighting of the working area [8].

The significance of the wind influence on fires spread and development is noted. At night, the wind is weak and relatively constant in speed and direction. In the morning it intensifies and reaches its maximum by 3–4 p.m. Then the wind gradually subsides and by 10–11 p.m. the speed of the wind drops to the minimum [6, 8]. On the basis of these conditions, scientists of the Siberian state university of science and technologies argue that a period most favorable for firefighting will be from 10 p.m.7 a.m., and a wind regime is minimal in most cases.

The conceptual bases and terms "night time" and "hours of darkness" are studied. During the first stage of the study, the problem of the remuneration for work, which is traditionally significant, was studied. According to the Constitution of the Russian Federation, everyone has the right to remuneration for work without any discrimination. Taking into account the particularly difficult working conditions in forest fires fighting and especially at night, associated with a threat to the life and health of personnel, the problem of the size of payments for night work is important to include into the draft order on the approval of methodological recommendations on the procedure for the formation and accounting of forest fire fighting costs at the expense of subventions provided from the federal budget of the constituent entities of the Russian Federation for the implementation by authorized bodies of state power of the constituent subjects of the Russian Federation in the field of forest relations. One shouldn’t put...
The Federal Forestry Agency sent to the Ministry of Natural Resources of Russia proposals to the draft order on the approval of methodological recommendations on the procedure for the formation and accounting of the costs for forest fires extinguishing at the expense of subventions provided from the federal budget of the constituent entities of the Russian Federation for the exercise by authorized bodies of the state power of the constituent entities of the Russian Federation of transferred powers in the field of forestry relations. According to these proposals, the labor cost for workers involved in extinguishing forest fires includes payments for night work.

At the first stage of the study, the practice of the forest fires extinguishing abroad was studied. Scientists of the United States of America and Canada believe that extinguishing at night can be more effective, since winds usually subside, relative humidity rises, and temperature decreases. It leads to a lower intensity and speed of fire propagation.

The round-the-clock fire extinguishing in more efficient is the primary goal of the aviation extinguishing research community (AFF). A lot of AFF contractors and agencies are looking for more innovative solutions to deal with these disasters.

The USA, Canada, South Korea, China have a practice of forest and natural fires extinguishing by mobile teams at dark conditions. In the USA, in the practice of ground-based forest fires extinguishing at night, the use of special technology “Coyote Tactics”, described in training materials from the mid 90s of the last century, was marked.

In foreign practice, unmanned systems used by the US military are widely introduced. So the unmanned aerial system MQ-1 Predator (now replaced by the MQ-9 Reaper) was used to support fire fighting round-the-clock. Infrared reconnaissance, provided by a small unmanned aerial vehicle, can register the intensity of the fire and its distribution, automatically develop a map of the area with the drawing of the borders of the fire and its contour.

Experimental studies on the integrated use of night vision devices and infrared technology and laser target designation as a guide for extinguishing forest fires using aircraft are of the particular interest.

Innovative policy is the policy of companies aimed at the constant desire to increase the time period for fire extinguishing. The use of special technique “Coyote Tactics” is able to implement the conceptual approach of companies.

It should be noted that “Coyote Tactics” is similar to the technology for forest fires extinguishing in Russia. It confirms the expediency and effectiveness of the system for protecting forests from fires in our country. However, in Russia there is no documented method for forest fires extinguishing at dark conditions.

In order to develop objective methodological recommendations, we made the analysis of the existed problem of organizing the forest fires extinguishing during the hours of darkness, legal and technological estimation of the prospects and risks of implementing the proposed solutions.

The work of people involved in forest fires extinguishing has a risk to their health and life. In real conditions, they have to deal with an uncontrolled fall of trees, a sharp outbreak of fire, exposure to combustion products and other dangerous factors that contribute to bodily harm, injury and death. In this regard, the discussion of the topic of forest fires extinguishing during the hours of darkness is relevant and requires special attention and detailed study.

Normative legal acts determine the possibility of forest fires extinguishing, but with the availability of artificial lighting. However, there are no any criteria established for normalizing such artificial lighting. In the case when a worker, engaged in a forest fire fighting during the hours, was getting injured, a situation is created that does not allow a clear and unbiased understanding of the causes of the incident. How, then, to understand correctly who is to blame for injuring a worker and what needs to be done to prevent accidents?

Forest fires extinguishing due to the optimal use hours of darkness increases the efficiency of the forest protection system from fires. But the court decisions examined during the study on the obligation to extinguish at dark conditions based on the availability of artificial lighting are illegal.

Analyzing the practice of arbitration courts in dealing with cases of extinguishing forest fires during the hours of darkness, attention is drawn to the decision of the Khabarovsk Regional Court. It recognized
the submission of the Khabarovsk Interdistrict Environmental Prosecutor on charges of unlawful inaction in terms of not extinguishing forest fires at dark conditions against the Regional State Specialized Autonomous Institution “The Far Eastern Aviation Forest Protection Base” is illegal.

The illegality of the requirements set out in court decisions is proved not only by the requirements of forest legislation, provided for direct management of forest fire extinguishing, carried out by the leader of the forest fire extinguishing, which, who controls all forces and tools to extinguish forest fires. This is proved by the requirements of regulatory legal acts on labor protection. Therefore, a leader of the forest fire extinguishing is responsible not only for the task fulfillment, but also for the safety of those involved in extinguishing forest fires. A leader’s instructions for the forest fire extinguishing are obligatory for all officials and citizens in the territory where the actions to extinguish the forest fire are carried out. No one has the right to intervene in the actions of the leader of the forest fire extinguishing or to cancel his orders at extinguishing forest fires.

According to article 37 of the Constitution of the Russian Federation, everyone has the right to work in conditions that meet the requirements of safety and hygiene., the amendment to the wording of paragraph 73 in the order of the Ministry of Natural Resources of Russia dated 08.07.2014 No. 313 “On Approving the Rules for Extinguishing Forest Fires” is actual: “At dark conditions, extinguishing forest fires is a subject to the availability of artificial lighting that provides safe working conditions, based on the decision of the leader of the forest fire extinguishing”[13]. According to the requirements of paragraph 73, a head of the forest fire extinguishing has the right to carry out extinguishing during the hours of darkness; but it is not the obligation.

There are no standards that determine the lighting of the working area when extinguishing a forest fire in the dark.

The paper examined the problem of labor protection during extinguishing forest fires along with the considered problems.

The possibility of increasing the impact degree on the border of the existing forest fire with the available forces and tools on the first 24 hours will give a tangible positive effect from the continuous extinguishing process.

The daily humidity variation of combustible materials in the forest indicates the fact that forest fires significantly reduce their intensity at night, making it easier to extinguish. At the same time, work during the hours of darkness is associated with increased danger, since it is difficult to minimize the influence of dangerous factors for humans.

The analysis of the accidents results in:

- lack of personal protection equipment;
- use of low-quality materials for the special clothes;
- violation of labor protection requirements by personnel and employers;
- lack of a comprehensive operating policy in the field of labor protection.
- The main dangerous factors that pose a threat to human’s life and health are identified:
  - high ambient temperatures and flame radiation;
  - possible mechanical impact on a person by falling trunks and tree branches;
  - rotating parts of machines and mechanisms;
  - thermal effects of sparks and charcoals of burning wood
  - haze pollution, increased concentration of carbon monoxide.

Nowadays, in fact, at forest fires extinguishing, firefighting groups, as a rule, suspend active work during the hours of darkness. Traditionally, there is an operational pause in work for 6-8 hours every day.

The life and health risks of people involved in extinguishing forest fires such as work in the mountains, poisoning, works of full extinguishing and guarding in the dark, haze pollution, limited visibility, lack of coverage of the working area were investigated.
The analysis of dangerous factors associated with the work connected with forest fire extinguishing during the hours of darkness helps to estimate the complexity of this type of activity and the level of responsibility of the leader of the firefighting.

It is necessary to develop scientifically based methodological recommendations for organizing and conducting works to extinguish forest fires at dark conditions. Their usage will allow forest fire groups to increase a degree of active impact on the border of the fire and increase a level of ensuring the safety of firefighting in difficult conditions.

The practical significance of the results of the research at the first stage is the ability to estimate the current state of the practice of extinguishing forest fires at night to make organizational and managerial decisions on tactics and strategies for eliminating fires and stabilizing fire situations.

The scientific novelty is as follows:

- estimation of judicial practice regarding the question of forest fires extinguishing during the hours of darkness in relation to labor protection requirements and current changes in forest legislation;
- analysis of threaten factors associated with the work to extinguish forest fires at dark conditions with a simultaneous estimation of the degree of risk to the human life and health engaged in this work.

The results of the first stage will serve as a basis for the recommendations development at the second stage of the research on the work organization to extinguish forest fires at dark conditions. The methodology for fires extinguishing during the hours of darkness will be developed for the first time.

4. Conclusion
A program for further research is formed on the basis of the investigated problem of extinguishing forest fires estimation during the hours of darkness.

The field research (experiments) will be carried out during the second stage of this research work according to the following program:
1. The selection of typical tasks and technological operations during the forest fire extinguishing during the hours of darkness. They require confirmation of critical parameters (conditions) and obtaining experimental data based on field and practical experiments;
2. Development of a field research program;
3. Selection of sites for field research;
4. Conducting field research (practical experiments).
5. Generalization and analysis of the obtained data.
6. Application (adaptation) of the results to create guidelines for the organization and conduct of the work to forest fires extinguishing during the hours of darkness.

References
[1] Korshunov N A, Savchenkova V A, Perminov A V and Kalinin M S 2019 Assessment of the state of the forest fire system of the country Available from: http://lhi.vniilm.ru/ No 3 Pp 82-93
[2] 1997 Recommendations for the detection and suppression of forest fires, approved by the Deputy Head of the Federal Forestry Service of Russia D.I. Odintsov from 12/17/1997
[3] 2015 Order of the Ministry of Labor and Social Protection of the Russian Federation of 02.112015 No 835n “On approval of the Rules on labor protection in logging, woodworking and forestry operations”
[4] Voynash S A and Voynash A S 2018 Installation for fire extinguishing RF patent No. 183642 for utility model (Moscow: Rospaten) vol 28
[5] Savchenkova V A, Korshunov N A and Runova E M 2018 Estimation of the relationship of forest-growing features of the forest area with the burning of forests Forestry magazine 3 95-107
[6] Schetinsky E A 2003 Satellite of the head of forest fires extinguishing (M: VNIILM) p 80
[7] 2013 *Extinguishing forest fires* Available from: https://aocc.ru/wp-content/uploads/downloads/2013/02/METODICHKA-po-lesnym-pozharam-2013.pdf

[8] Matveev P M and Matveev A M 2011 *Forest Pyrology* (Krasnoyarsk: SibGTU)

[9] Ivanov V A, Korshunov N A and Matveev P M 2004 *Fires from lightning in the forests of the Krasnoyarsk Angara* (Krasnoyarsk: SibGTU) p 132