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TO THE STUDY OF THE POSSIBILITY OF APPLICATION OF PERSPECTIVE SECURITY PROTECTORS FOR IMPROVEMENT OF LABOR PROTECTION AT WORK AT HEIGHT

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The article determines the relevance of the problem of rising injuries in the country. The article presents an algorithm for choosing the means of protecting workers from falling from a height. An innovative safety system for working at heights virtually eliminates the possibility of violating the rules of safety requirements, which can ensure human safety in a rapidly developing technogenic digital society.

Keywords: working conditions, protective equipment against human fall, technogenic digital society, hazard criteria, digital technologies

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ИССЛЕДОВАНИЕ ВОЗМОЖНОСТИ ПРИМЕНЕНИЯ ПЕРСПЕКТИВНЫХ СРЕДСТВ ЗАЩИТЫ ПЕРСОНАЛА ДЛЯ СОВЕРШЕНСТВОВАНИЯ ОХРАНЫ ТРУДА ПРИ РАБОТЕ НА ВЫСОТЕ

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Рассматривается проблема роста травматизма в стране. Представлен алгоритм выбора средств защиты работников от падения с высоты. Предложенная авторами инновационная система безопасности работ на высоте практически исключает возможность нарушения соответствующих требований и может обеспечить безопасность человека в быстроразвивающемся техногенном обществе.

Ключевые слова: условия труда, защитные средства от падения человека, техногенное общество, критерии возникновения опасности, цифровые технологии.

Introduction. The priority of life and health of citizens is one of the defining directions of state policy. To ensure this thesis, the normative document "GOST R 54934-2012 Occupational safety and health management systems" is introduced in the Russian Federation. At the same time, statistics provide figures on the growth of occupational diseases of workers in various sectors of the economy. Studies have shown that the proportion of severe and fatal cases has not decreased in a quarter of a century, and the main causes are poor-quality and dangerous working conditions [1, 2]. The share of such cases in production with difficult working conditions in our country reaches 8 %, which is significantly higher than in developed countries. This situation testifies to the relevance of comprehensive study of injuries in production and planning of optimal measures and technical solutions that increase the safety of personnel [3].

Technical solutions for injury prevention. In modern conditions, scientific and technological progress and labor protection can be considered as a single vector that increases the efficiency of production while reducing and eliminating occupational diseases and injuries of workers. This is facilitated by the developments in the field of improving special high-altitude equipment. In the process of such developments, it is necessary to consider a multiple selection of technical proposals, inventions and patents presented in scientific and technical sources of the Federal Institute of industrial property (in the structure of Rospatent), as well as to classify them. In particular, this applies to equipment for the prevention of injuries of power engineers [4, 5].

The existing and currently being developed methods and devices to protect power engineers from injuries during high-rise works are differentiated according to Fig. 1. Such classification allows you to choose the most rational means of protection [4, 6].

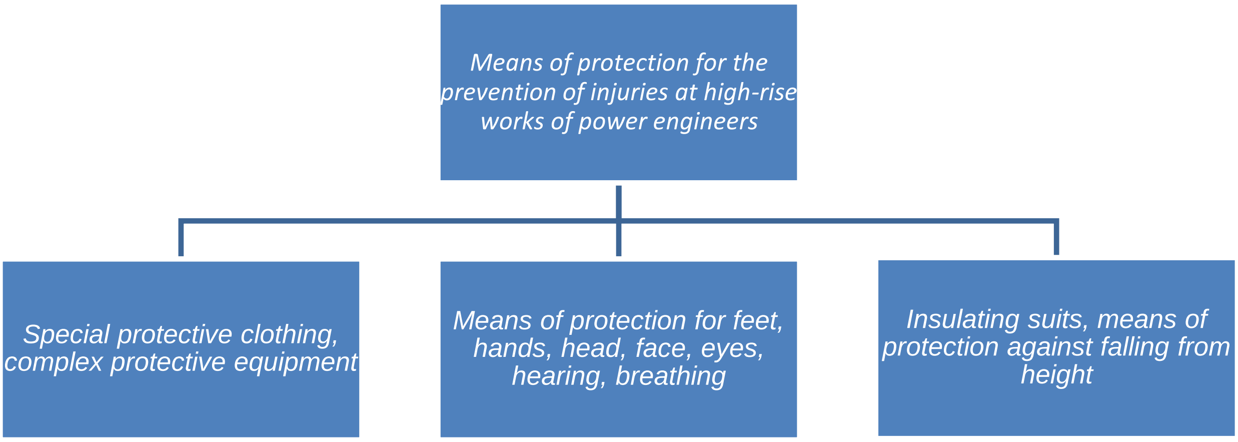

Fig. 1 Classification of technical solutions for injury prevention

In addition, the means of protection against falling from height can be classified according to the following characteristics:

- by the height of work performed;
- by the time of preparation of the protection to work;
- by the convenience of fastening of means of protection on clothes;
- by psychological comfort;
- by complexity of maintenance;
- by cost parameter.

Parameters for assessing the protection of personnel performing work at high-rise facilities. The following are the conditions and criteria for analyzing the quality of specific parameters, means and methods of personnel protection at high-rise facilities:

1. The height of the work ($j = 1$). This is actually the specified height of the possible use of individual personal protective equipment, stated by the manufacturer with technical parameters, characteristics and guarantees. The maximum estimate of this parameter $C_1 = 10$ points, the weight factor $b_1 = 10$.

2. The complexity of the industrial object ($j = 2$). This is the degree of dangerous proximity to the vertical planes of the facade of the building, architectural projections, external ventilation ducts, radio and television antennas, air conditioners. The maximum estimate of this parameter $C_2 = 10$, the weight factor $b_2 = 10$.

3. The time spent on the transfer of the protection from the storage state to the operational state. The maximum estimate of this parameter $C_3 = 10$, the weight factor $b_3 = 50$.

4. Convenience of placement of protection means: portable, easily moved, or stationary, noticeable against the background of other elements. In this case, the location on the overalls or the vertical surface of an industrial object is preferable compared to other considered methods, since work at height usu-

ally does not provide additional time for the preparation of the fixation points of equipment and rescue devices. The maximum estimate of the considered parameter $C_4 = 10$, the weight factor $b_4 = 1$.

5. Applicable type of electric power source. It can be a small portable source or a source of energy at an industrial facility for the operation of equipment and protective equipment. In this case, it is preferable to use free from the energy source means of protection. The maximum estimate of this parameter is $C_5 = 10$, the weight factor is $b_5 = 10$.

6. Participation of personnel (assistants, assistants of the master) in preparation for technical application and control of equipment integrity. The maximum estimate of this parameter $C_6 = 10$, the weight factor $b_6 = 50$.

7. Protection against intense heat. This includes the means (equipment, devices and elements) of protection against exposure to high temperatures, for example, in case of fire. The maximum estimate of this parameter $C_7 = 10$, the weight factor $b_7 = 50$.

8. Restrictions on weather conditions. It is preferable to be independent of weather conditions (wind, rain, snow) at the point of application. The maximum estimate of this parameter is $C_8 = 10$, the weight factor is $b_8 = 1$.

9. Emotional comfort during the operation of the protective equipment in difficult conditions. The maximum estimate of this parameter is $C_9 = 10$, the weight factor is $b_9 = 10$.

10. Operational availability, which means the possibility of using the means of protection by people of different ages and the level of technical qualification. This may be due to the difficulty of securing the device indoors and on the outside of a high-rise object. The maximum estimate of the given parameter $C_{10} = 10$, the weight factor $b_{10} = 50$.

11. The list of equipment by the number of structural elements, parts, assemblies required to equip protective equipment. The maximum estimate of this parameter is $C_{11} = 0$, the weight factor is $b_{11} = 0$.

12. Protection against unauthorized access, interference in the construction, breakage under the influence of various industrial and natural factors, vandal resistance, resistance to breakage when falling from heights allowed by the design. The maximum estimate of this parameter is $C_{12} = 10$, $b_{12} = 1$.

13. Interference functions for personnel. This is the quantity and level parameters of interference to employees of the enterprise, created by the protection means at all intervals of work performed. The maximum estimate of the given parameter $C_{13} = 10$, the weight factor $b_{13} = 1$.

14. Ease of operation of the fastening means of protection for industrial overcoat and equipment. The maximum estimate of this parameter is $C_{14} = 10$, the weight factor is $b_{14} = 1$.

15. Cost estimate of the means of protection. This is the approximate cost of a unit of protection, taking into account the production in specified volumes. The estimate of this parameter is taken $C_{15} = 0$, the weight factor $b_{15} = 0$. Parameter b_{15} has an information orientation.

16. Scheduled maintenance. This parameter corresponds to the cost of all types of repair and maintenance for the planned period established by the manufacturer. The maximum estimate of the parameter $C_{16} = 0$, the weight factor $b_{16} = 0$ — information parameter.

Expert assessment. Means of protection against falling from height possess the individual technical features dictating the correct conditions of application. Table 1 shows the technical parameters p_r^j of each means of protection of the *i-th* series. Technical parameters p_r^j are quantified by experts for the whole range of *i-th* protection means. The definition of a set of important technical criteria becomes the initial stage of comparative expert analysis. The values of each element of the obtained matrix consisting of expert estimates a_r^j and estimates of the considered parameters p_r^j are summed in each row of the *i*-th protection means. Here we take into account the above maximum estimates of this parameter C_j of the considered technical characteristic and the values of their weight significance b_j conditionally averaged for each of the characteristics in the studied interval of comparative expert analysis [5, 7].

The estimated calculations of the parameter a_r^j in the first approximation, taking into account expert estimates, were carried out for all *i*-th means of protection either qualitatively, when the positive a_r^j vector is 10 and the negative vector a_r^j is 0, or by the formula for the weighted average:

$$a_r^j = 10\frac{(p_r^j - p_{\min}^j)}{(p_{\max}^j - p_{\min}^j)},$$

where $p_{\min}{}^j$ and $p_{\max}{}^j$ — the smallest and the largest value of matrix parameters p_r^j from the number of the considered *j*-th characteristics around the *i*-th row of personnel protection means.

For the choice of means of protection against falling from height, the authors carried out the calculation of values of weight factors. If the interval among the main factors is relatively small (the factors do not differ from each other by more than 10 percent), it is possible to use a uniform linear scale. With a relatively large range of changes in the forming factors, the authors used a non-linear (logarithmic) scale.

The choice of means of protection of energy sector employees from falling from height was carried out by the method of optimization of technical parameters using a certain number of expert assessments of basic values. It is difficult to assess the technical parameters in the production process, as well as in the initial research, experimental and design development of the means of protection. With this choice, it is advisable to use a mathematical model, which can be used with several criteria for evaluating possible technical and design solutions. Such solutions take into account both quantitative characteristics (the height of the work, the time of preparation of the equipment for work) and qualitative measures (convenience of fastening the means of protection on the clothes of workers, comfort during operation, the need for maintenance) [6, 7].

The criteria for evaluating A_i are pre-determined significant indicators, the specific values of which determine the assigned weight factors k_i. This dimensionless conditional form fits effectively into the computational procedures for expert matrices, and the evaluation of the target functions of $Ц_{ij}$ in the range from 0 to 10 points on the basis of experimental (expert) data has shown its effectiveness. In this technique, the degree of compliance with the optimal solution depends on the competence of the experts who set the parameters of the values k_i and $Ц_{ij}$. The most accurate calculation is provided by the method of expert assessments involving several competent specialists. The scores of the target function are placed in the upper left corner of the matrix cells, and the product of the parameters k_i and $Ц_{ij}$ -in the lower right. The values of the integral target functions $Ц_j$, obtained according to the adopted method for each solution variant, are in the bottom line.

Table 1 presents an example of the solution to the problem of choosing a means of protection of energy sector employees from injuries of a physical nature in difficult conditions, including falls from high-rise objects, by optimizing the parameters.

Table 1

The choice of individual means of protection of energy sector employees from injuries of a physical nature in difficult conditions

Criterion for evaluation of protective equipment	Weight factor	Type of the system of individual protective equipment			
		A Local shockproof devices, n_1	B Protective equipment of electrically-insulating type, n_2	C Protection from falling from height, n_3	D Means of protection of respiratory organs, n_4
Height of the operations	0.1	4 0.4	4 0.4	5 0.5	3 0.3
Time of preparation of means of protection	0.2	3 0.6	4 0.8	8 1.6	5 1.0
Operability of fastening of means of protection on clothes	0.2	4 0.8	2 0.4	4 0.8	2 0.4
Participation of assis-tants in the preparation of means of protection	0.1	7 0.7	5 0.5	7 0.7	4 0.4
Psychological comfort	0.1	6 0.6	4 0.4	4 0.4	4 0.4
Maintenance	0.1	4 0.4	6 0.6	6 0.6	5 0.5
Cost parameter	0.2	3 0.6	4 0.8	4 0.8	3 0.6
Target function Ц$_j$	1.0	4.1	3.9	5.4	3.6

Special equipment. Fall protection equipment (n_1) in the form of special equipment with a belt safety system is widely used to prevent injuries. The disadvantages of such means of the first generations are the complexity of interconnection and fixation of the belt safety system [5, 8, 9].

The proposed digital overall for work at height (Fig. 1) is a special clothing made of composite materials with reinforced zipper and safety belts, equipped with a special rope.

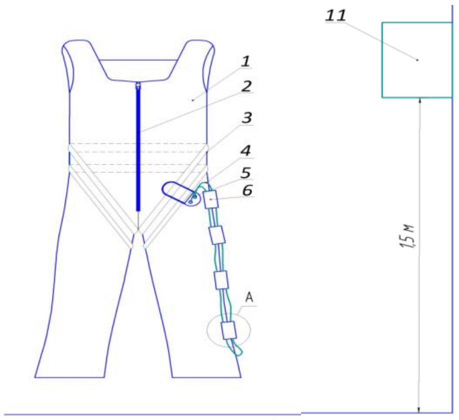

Figure. 1. Innovative overalls: 1 — special overalls; 2 — zipper; 3 — belt safety; 4 — power cable; 5 — digital carabiner; 6 — Velcro fasteners; 11 — control unit

The reinforced cable in the construction of the overall is made of carbon fiber, fiber and nylon. The use of fiber-optic wire together with the control unit in the digital carabiner, the transmitter of light signals-pulses and the receiver of signals-pulses provides constant control of the strength characteristics of the cable [9]. The digital altimeter built into the carabiner is set to a dangerous altitude. It gives the employee a reminding signal (buzzer) about the violation of security requirements and calls to the Central office at the same time. In addition to this information, the computer of the Central office records the periods of time when the employee is not fastened and fastened to the anchorages at a height [9].

The weight of the special protective equipment of the insulating type (n_2) shall ensure the possibility of safe working conditions of workers. Accessories attached to the material of the top of the protective equipment must not come into contact with the inner surface of the thermal insulation lining. The design of special equipment and hand protection equipment should allow the worker to perform all activities efficiently during routine or rescue operations. This equipment shall be used together with a fire helmet, personal respiratory and visual protection equipment, instruments, a radio station and personal protective equipment for the feet of the worker.

According to statistics, more than 560 fires are registered every day in our country, as a result of which about 40 people die every day and about 35 are injured [5, 7]. In case of fire, including electrical installations, a large amount of carbon monoxide, and other harmful and poisonous substances is released, and the oxygen concentration in the atmosphere is reduced to unacceptable values (about 17%). The most effective in such cases are the means of protection of respiratory organs (n4) of the insulating type, in contrast to the filtering means of protection; they allow evacuating with a local decrease in the concentration of oxygen in emergencies, since oxygen is released inside the insulating apparatus.

Conclusion. From the analysis of the obtained integral parameters, it follows that for the selected weight coefficients k_i, the means of protection against falling from height with the value of the target function $Ц_3$ = 5.4 are relevant for further study. This allows us to focus on more detailed studies of the elements of protection against falling from height and to begin the development of new anchor systems.

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