Polyspast - personal fall protection equipment. Features of certification and certification tests

Kirill Zherdev, Olga Korolchenko and Ragim Gadzhiyev
Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia

E-mail: ppe_mgsu@mail.ru

Abstract. In the paper there was considered polyspast system as a means of personal protective equipment against falling from height. The structural place of these products in the classification of protective equipment, their functional purpose in ensuring the safety of work at height is analysed. The issue of statistics of accidents at work at height is touched upon. The relevance of the issue of continuous work on safety in this sector of work is shown. There are similarities in the need for safety and rescue operations in both the sports and industrial sectors. The purpose of this work is to form competent recommendations on various aspects of certification and certification tests of polyspast to improve the safety of users, athletes (including children) and rescuers when performing various tasks and work at height. Within the framework of this work, the procedures for forming technical requirements for certified products, the totality of interaction of the main technical requirements of the technical regulations with the lists of standards specified in the Appendix to the technical regulations are considered. The analysis of two examples of polyspast, certified in the market of the Eurasian Customs Union. The weak points of their certification due to the problems of the normative and technical state of the main documents in this area are shown. The conclusions provide a brief analysis of the problems of certification and certification testing of polyspast systems. Recommendations of both structural and local nature are formulated to improve the safety of certified products.

1. Introduction
The term "personal protective equipment" (hereinafter referred to as PPE) has firmly entered the everyday life of citizens of the Russian Federation as a result of preventive measures related to counteracting the spread of COVID-19. This term refers to various medical and other masks, gloves, dressing gowns, and other items of clothing. At the same time, the above-mentioned equipment that performs functions to contain the spread of viral infection is not PPE, although a number of functions and tasks are similar to PPE. On the territory of the Eurasian Customs Union (EACU), PPE is regulated by TR CU 019/2011. They are divided into protection groups and ensure the safety of a person when exposed to harmful (dangerous) factors in the course of their work. PPE (components of PPE) are classified according to their intended purpose, depending on the protective properties in accordance with Annex N 2 to the technical regulations of the Customs Union specified above:
- against mechanical influences;
- against chemical factors;
- against biological factors;
- against radiation factors;
- against high (low) temperatures, sparks and splashes of molten metal;
- against thermal risks of electric arc, non-ionizing radiation, electric shock, static electricity;
- special high visibility alarm clothing;
- comprehensive PPE;
- dermatological PPE.

As can be seen from the main groups listed above, PPE covers a wide range of issues and areas in the field of human protection from dangerous factors, and can also really overlap in their functional purposes in the field of application with the means of protection that are indicated at the beginning of work. In this work, we analyze PPE against falling from a height, in particular, polyspast systems that belong to the group of protection against mechanical factors.

The sector of work at height, with its apparent simplicity and obvious hazards, is quite complex and widespread in terms of safety [1-3]. Various sources show that a third of all accidents are caused by falling from a height. In the Russian Federation, the statistics of occupational injuries by the number of accidents during work at height is in the first place [4-12]. This type of injury accounts for 30% of all severe and "lethal" statistics, and if we consider cases with a fatal outcome, the percentage will be over 35%.

PPE against falling from a height, in turn, as components and subsystems are combined into the following personal fall protection systems:
- retention systems;
- positioning systems in the workplace;
- rope access systems;
- safety systems;
- rescue systems (rescue and evacuation systems).

The subject of this article are the polyspasts, which more often are a part of rescue systems. Their main task is to optimize efforts and reduce the time of rescue operations at height in case of emergency situations [13]. At the same time, it is important to note that rescue operations and systems used during rescue are used not only in the sector of industrial work at height, but also in sports disciplines such as mountaineering, caving, sports tourism, and so on. In figure 1 it shows the implementation of works using systems and methods of rope access in training center of the Institute for Integrated Safety in Construction (hereinafter referred to as IKBS) of National Research Moscow State University of Civil Engineering, as well as an example of mass competitions in “sports tourism”, in which a huge number of children of different ages take part. A comparative visual analysis shows that from the point of view of performing rescue operations, it does not make sense to divide the industrial and sports sectors, the possibility of carrying out rescue operations should be provided everywhere [14-15].

Figure 1. Visual comparison of positioning in space: a) in rope access systems; b) in "sports tourism".
A polyspast is a lifting device consisting of several movable and fixed pulleys that are bounded by a rope or cable, which allows lifting loads with a force several times less than the weight of the load being lifted. Any polyspast gives a certain gain in effort to lift the load. At the same time, it is important to understand that in any mobile system consisting of a rope and pulleys, friction losses are inevitable. Figure 2 shows the testing of polyspasts in an accredited testing laboratory of the IKBS [16], which shows the basic concept of these systems.

One of the mechanisms for ensuring the safety of polyspasts as PPE against falling from a height is the process of mandatory certification of these products on the territory of the EACU, which also includes procedures for forming technical requirements for the product and their verification at certification tests in a laboratory accredited by the federal accreditation service.

The main components of polyspasts are pulleys, a rope with a low-tension core, a clip that does not allow the rope to move in one direction and a protective cover for convenient operation.

Pulleys that are part of products at the moment cannot be legitimately certified under TR CU 019/2011 due to the lack of requirements for them [17], as well as the absence of state standard with regulatory requirements and test methods for these products. At the same time, as separate products, they are widely used in the sector of works at height and in sports. The effectiveness and safety of the polyspast largely depends on their strength and functional characteristics.

The purpose of this work is to form competent recommendations on various aspects of certification and certification tests of polyspasts to improve the safety of users, athletes (including children) and rescuers when performing various tasks and work at height, which is directly correlated with the decree of the President of the Russian Federation on the national development goals of Russia until 2030, in particular with paragraph 1 subparagraph a: about preservation of the population, health and well-being of people.

To achieve this goal, the following tasks are formulated:
- consideration of the procedure for forming technical requirements for certified products, the totality of interaction of the main technical requirements of the technical regulations with the lists of standards specified in the Annex to the regulations;
- review and analysis of two examples of polyspasts, certified in the market of the EACU. Identification of weak points in their certification due to problems with the regulatory and technical state of the main documents in this area;
- forming a brief conclusion with recommendations for certification and certification tests of the above products.

2. Analytical part

2.1. Procedure for forming technical requirements for products

At the stage of forming a referral to the testing laboratory, the expert of the certification body, based on the operational documentation of the certified product, forms technical requirements and methods of their verification in accordance with regulatory and technical documents. The basic requirements are taken from the text of technical regulations, as well as the list of international and regional (interstate) standards, and in case of their absence - national (state) standards, the result of which, on a voluntary basis, compliance with technical regulations of the Customs Union "About safety of means of individual protection" (hereinafter list No. 1), methods of testing the technical requirements are taken from the list of international and regional (interstate) standards, and in case of their absence - national (state) standards containing rules and methods of research (testing) and measurement, including rules for sampling, necessary for the application and implementation of the requirements of the technical regulations of the Customs Union "About the safety of personal protective equipment" (TR CU 019/2011) and the implementation of conformity assessment of objects of technical regulation (hereinafter list No. 2). List No. 1 includes items and sections of national and interstate standards, list No. 2 includes items and sections describing test methods. Figure 3 shows the scheme of forming technical requirements for the product in the direction from the certification body to the testing laboratory.

Figure 3. Scheme of formation of technical requirements for the product in the direction from the certification body to the testing laboratory.
The main problems are as follows:
- List No. 1 and No. 2 often include a small part of the standard, that is, a number of technical requirements and test methods are not included in the lists.
- Most of the requirements of the technical regulations for PPE against falling from a height cannot be confirmed by methods from the list No. 2.

Table 1 shows in detail a number of typical problems described above.

**Table 1.** Noncompliance with the requirements of TR CU 019/2011 and test methods from state standards included in the list No 2.

| №   | The object of certification | Requirement of TR CU 019/2011, paragraph 4.3 subparagraph 21 | Problem of correlation with test methods |
|-----|------------------------------|-------------------------------------------------------------|------------------------------------------|
| 1   | Positioning devices on type B ropes | Components and connectors of safety and restraint systems must withstand a static load of at least 15 kN, and slings made of synthetic materials-at least 22 kN; Components of safety systems that have a retractor type device with a wire sling or with a built-in device for shock absorption, as well as devices for lifting and lowering and rescue devices, with the exception of individual rescue devices, must withstand a static load of at least 12 kN | Test methods for positioning devices on type B ropes include static strength testing only with a load of $4\pm0.1$ kN. The application of large forces is not allowed due to the design features of these devices and their interaction with a rope with a low-tension core. |
| 2   | Anchor devices | PPE against falling from a height must withstand the dynamic load that occurs when a mass weighing 100 kg falls from a height equal to 4 m, 2 m and 1 m, and belt for work positioning - from a height equal to two maximum lengths of the sling; | The dynamic strength test method involves dropping a load from a height of 2.5 meters, which does not allow you to check any of the requirements of this paragraph. |
| 3   | Anchor devices | | The dynamic strength test method assumes that the load falls from a height of 0.6 meters, which does not allow you to check more than one of the requirements of this paragraph. The distance may be slightly longer due to the geometric parameters of the carbine and shock absorber in most cases, the drop height remains less than 1.0 m. |
| 4   | Retractable type fall arresters | | |

The combination of the problems described in table 1 and the lack of complete standards in list No 1 makes the certification testing process partially unworkable, and the necessary minimum safety criteria that were laid down when forming the mandatory certification procedure are not achieved.

From a legal point of view, an accredited laboratory does not have the right to deviate from the test methods set out in state standards for any parameter. An incomplete description of the standards in list No 1 can be shown by the example of such devices as:
- guided type fall arresters including a rigid anchor line, in Appendix 1 only subparagraphs 4.2.2, 4.3.2 and paragraph 4.4 GOST R 58193-2018/EN 353-1:2014 are displayed. The full standard sets requirements for these devices according to paragraphs 4.1-4.5 taking into account all the subparagraphs.
- rescue lifting devices, only paragraphs 4.3, 4.5 and 4.7 of GOST EN 1496-2014 are shown in Appendix 1. The full standard sets requirements for paragraphs 4.1 - 4.7 taking into account all the subparagraphs.

An important additional problem in certification is the exclusion of requirements for operational documentation and marking from the list No 1 standards and the implementation of only the requirements of the technical regulations in this area. It is the state standards that contain the requirements for the necessary specialized information for each product based on its specifics.

2.2. The analysis of examples of technical requirements for a certified polyspasts

In this article, we will consider two examples of the technical requirements to the polyspasts, which have successfully passed the certification. In this material, we will operate with encrypted designations: product No 1 and product No 2. Table 2 shows the technical requirements for which products entered the market in different years.

| №  | The name of the product | Technical requirements for certification tests                                                                 |
|----|------------------------|------------------------------------------------------------------------------------------------------------|
| 1  | product No 1           | TR CU 019/2011 "About the safety of personal protective equipment" (paragraph 4.3, subparagraphs 21-22; paragraphs 4.10-4.13); GOST EN 1496-2014 (paragraphs 4.3 and 4.5-4.7). Taking into account the purpose of the product and, therefore, the inapplicability of the requirements of clause 4.5 of GOST EN 1496-2014, conduct tests of the product for dynamic strength in accordance with the requirements of subparagraph 4.3.2 of GOST EN 795 |
| 2  | product No 2           | TR CU 019/2011 "About the safety of personal protective equipment" (paragraph 4.2, subparagraphs 1, 5-7, 10; paragraph 4.3, subparagraphs 21, 22; paragraphs 4.10-4.13); GOST EN 1496-2014 "Occupational safety standards system. Personal protective equipment against falling from a height. Rescue lifting devices. General technical requirements. Test methods" (paragraphs 4.3, 4.5-4.7) |

Both devices under consideration, in accordance with the design scheme, operational documentation and definitions set out in GOST EN 1496-2014, belong to class A. A rescue lifting device of class A is a component or subsystem of a rescue system by which a person is lifted by a lifeguard or lifts himself from a lower position to a higher place. It is not possible to define these systems to class B, since they do not have an additional function of lowering with manual control, designed for lowering a person to a distance of 2 m.

In accordance with the problems described in subsection 2.1 of this work, we see that the direction for testing, in accordance with list No 1, does not contain part of the points affecting class A devices, namely paragraph 4.4 GOST EN 1496-2014 "Purpose of a class A rescue lifting device", and in turn does not contain the correct paragraph 4.5 "Dynamic performance and purpose of a class B rescue lifting device" which refers to devices of another class, these requirements refer to the method of paragraph 5.6, which, due to the technical features of these devices and their belonging to another class, cannot be implemented. At the same time, the dynamic strength requirement from the technical regulations, described in item 3 and 4 of table 1, also remains. In this regard, the experts of the certification bodies decided to apply the methodology from another standard, in particular GOST EN 795, which regulates the technical requirements and test methods for anchor devices.

On the one hand, the solution using subparagraph 4.3.2 of GOST EN 795 is good and allows you to check the dynamic strength, however, as was also indicated in clause 3 table 1 the test load is discharged from a height of 2.5 meters, which again does not correlate with the requirement of TR CU.
019/2011. On the other hand, checking the dynamic strength by this method does not take into account the specifics of the operation of this product, its functional purpose, and is an attempt to level the problems in the system of technical regulation and mandatory certification. We can definitely say that the decision according to item 1 table 2 certainly more competent and professional than according to item 2 table 2.

At the same time, it should be noted that paragraph 4.4 of GOST EN 1496-2014, which cannot be included in the testing direction, due to the problems mentioned above, affects the functional characteristics of the product, namely, the etching is determined after lifting, when tested with a control load, which is important when performing rescue operations. Another important aspect that is completely unregulated when testing these products is the lack of verification of the efficiency that this device gives and the stability of the operation of this product within this coefficient. When performing rescue operations, when a lifeguard needs to lift an injured person or a transport bag with equipment, a very important aspect is how easily and predictably he can do this. As mentioned above, the structure of polyspast includes pulleys, so it is necessary to test their performance and resource intensity under load as part of the tests of these products, and despite the fact that at the moment there is no regulatory document regulating their testing, this issue becomes even more relevant, since it directly affects the efficiency factor discussed above [17]. Not affect the clip that does not treat the rope in the opposite direction, and how it affects the rope, because the number of devices possible wear of the rope clip and as a result, may occur treatment, which is not valid when performing rescue operations. It is also important and necessary, given the performance characteristics, to introduce dynamic tests that reflect real operational situations.

Based on the above, we can say that certification of polyspast systems for compliance with the requirements of TR CU 019/2011 is currently possible, but with a number of significant problems that put all market participants in an awkward position. At the same time, it cannot be said that such certification provides the minimum necessary safety standards that are assigned to it. Given that Russian standards in the field of PPE against falling from a height are more harmonized with European standards, which are the minimum threshold criteria for safety in the European Union and are set out in part in the annexes to TR CU 019/2011, we can say that the minimum level of safety in the EACU is not fully provided, not to mention the quality criteria.

3. Conclusion

From the analysis of part of the process of certification of polyspast, as well as their tests, it is clear that technical regulation together with the mandatory certification system does not fulfill its functions to ensure the minimum safety criteria for a number of products. At the same time, the existing gaps in the technical regulations do not allow persons involved in certification to do their work competently, and also put them in a difficult position from the point of view of legal security. The lack of a clear relationship between the technical requirements of TR CU 019/2011 and lists No 1 and No 2 does not facilitate certification at a qualitatively high level, but on the contrary, they are often reduced to formalism.

To increase the level of safety of certified products, and as a result, increase the level of user safety when using these products, you need to perform the following steps:

- To enter standards in full in the list No 1, including requirements for marking and operational documentation. This will allow certification experts to fully form the minimum technical requirements for products in the direction of testing.

- In the list No 2, it is also necessary to reflect all existing methods from state standards or other regulatory documents, in cases of their absence, related to the objects of technical regulation. This will allow both experts and laboratories to have a broader set of tools to perform their tasks.

- To elaborate requirements to the text part of the technical regulations, to keep working provisions and requirements, and those that will not succeed to make the text part of the rules of the compact concept of the technical regulations, form from list No 1.
The next step to ensure safety is to develop national or international standards for all types of products. At the moment, for example, in polyspast systems, such positions as pulleys, pulleys combined with clamps, clamps made of repshnur, which are gripping units, are not covered. At the same time, it is worth noting that the number of polyspast systems on the market is not large, so perhaps the most correct solution is to introduce some technical requirements and test methods for these products into existing standards in related areas.

The considered examples of certified products refer to the work of competent and reputable experts. As part of this work, we did not consider cases when only the requirements of TR CU 019/2011 were applied to the product that was eventually certified. Taking into account the problems of the main text part described in section 2 of this work, we can say that there is not security, but formal work under the name "certification".

In the current situation, an important task for experts is to study products in detail and work out various solutions for making product requirements [18-20], taking into account a number of related standards and test methods [21-24], as shown in item 1 table 2. Experts need to work through the issue more deeply, taking into account all the cross-references to the product requirements, and form a more detailed and transparent direction. In the current situation, this will be a correct and professional step towards ensuring the safety of products and preserving people's lives and health [25-30].

Specialists in the field responsible for the safety of work at height, as well as those who purchase PPE against falling from a height, in turn, must objectively understand that only products that are certified for compliance with the requirements of TR CU 019/2011 and have additional control protocols for compliance with all the requirements of the profile state standard can be safe. At the same time, it is also important to understand that the quality criteria are not included in the above algorithm, but are confirmed by additional methods, including standards of organizations aimed specifically at quality parameters, for example, resource intensity or increased corrosion resistance, etc.

References

[1] Stupakov A A, Lelikov G D, Semenov P A and Vasilenko V V 2015 Inspection and restoration of high-rise facilities by the method of industrial high rise works Mechanization of construction 2(848) 48-52
[2] Korolchenko D A and Pham N T 2019 Loads in rope access system when working at heights IOP Conference Series: Materials Science and Engineering 603(5) 052010
[3] Pham N T, Lelikov G and Korolchenko D 2018 Improvement of the safety systems for working at heights on transmission towers IOP Conference Series: Materials Science and Engineering 365(4) 042054
[4] Khamidullina E A, Tolstikhina Yu A, Povetskina P N 2018 System approach to high-rise operations safety XXI century. Technosphere Safety 3(3) 24–35
[5] Rahitov G S, Abdyukova G M 2015 Analysis of occupational injuries at construction sites. Collection of Scientific Articles of Participants of the All-Russian Scientific-Practical Conference with International Participation 2 286
[6] Patrick Manu, Nii Ankrah, David Proverbs and Subashini Suresh 2010 An approach for determining the extent of contribution of construction project features to accident causation Safety Science 48 687-92;
[7] Winge S and Albrechtsen E 2018 Accident types and barrier failures in the construction industry Safety Science 105 158–66;
[8] Nadhim E A, Hon C, Bo Xia, Stewart I and Dongping Fang 2016 Falls from height in the construction industry: A critical review of the scientific literature Int J Environ Res Public Health 13(7) 638;
[9] Muhammad Sh and Muhammad R 2019 An overview of construction occupational accidents in Hong Kong: A recent trend and future perspectives Applied Sciences 9(10) 2069;
[10] Proto A R, Mazzocchi F, Cossio F, Bortolini L, Pascuzzi S, Caruso L, Diano M and Zimbalatti
G 2016 A survey on occupational injuries in works on trees in Italy *Procedia - Social and Behavioral Sciences* 223 435-41;

[11] Lestari R I, Brian H W Guo and Yang Miang Goh 2019 Causes, solutions, and adoption barriers of falls from roofs in the Singapore construction industry *Journal of Construction Engineering and Management* 145;

[12] Winge S and Albrechtsen E 2018 Accident types and barrier failures in the construction industry Safety Science 105 158–66;

[13] Stupakov A A and Lelikov G D 2014 Calculation of risks from the use of personal protective equipment against falls from a height *Mechanization of construction* 12(846) 50-54

[14] Parfenenko A P 2010 Problems of evacuation of children and teenagers under fire *Technology of technosphere safety* 5(33)

[15] Kholschevnikov V V and Parfenenko A P 2011 Evacuation of children in buildings of educational institutions *Fire safety in construction* 4 49-61

[16] Stupakov A A, Kapyrin P D, Lelikov G D, Semenov P A and Vasilenko V V 2015 Stands for the study of personal protective equipment against falling from a height *Bulletin of MSUCE* 8 130-39

[17] Pham N T, Vasilenko V and Korolchenko D 2018 Test and certification procedures of pulleys as a part of personal fall arrest system *IOP Conference Series: Materials Science and Engineering* 365(4) 042057

[18] Lelikov G D and Vasilenko V V 2017 Analysis of the use of safety synthetic rope slings as PPE from falling from a height *Construction — the formation of the living environment*. Electronic Resource: Collection of works of the XX International Interuniversity Scientific and Practical Conference of Students, Undergraduates, Postgraduates and Young Scientists 475-77;

[19] Vasilenko V V, Lelikov G D, Ovchinnikova T A and Korolchenko D A 2019 Determination of criteria for assessing the effect of inorganic acids on synthetic ropes in order to improve the safety of high-altitude works *Pozharovzryvobezopasnost/Fire and Explosion Safety* 28(6) 35-51

[20] Vasilenko V V, Lelikov G D and Zherdev K V 2020 Effect of acid solutions on the residual strength of safety and rescue ropes *Occupational Safety in Industry* 2 38-44

[21] Pham N T, Vasilenko V and Korolchenko D A 2017 Actualization of the dynamic test methods to be systemized for temporary edge protection systems *Pozharovzryvobezopasnost/Fire and Explosion Safety* 26(12) 35-44

[22] Vasilenko V V 2017 Actualization of methodology for dynamic testing of shock absorbers as personal protective equipment against falling from a height *Construction — the formation of the living environment*. Electronic Resource: Collection of works of the XX International Interuniversity Scientific and Practical Conference of Students, Undergraduates, Postgraduates and Young Scientists 439-41

[23] Korolchenko D, Vasilenko V and Lelikov G 2018 Problems of the dynamic test method for individual protection equipment (shock absorbers) *MATEC Web of Conferences* 193 05034

[24] Vasilenko V, Korolchenko D and Pham N T 2018 Definition of the inspection criteria for personal protective equipment (for work at heights) on example of full body harnesses *MATEC Web of Conferences* 251 02042

[25] Cherkina V M and Evich A A 2017 Application of BIM technologies in tasks of quality control and labor protection *VII International Scientific Conference “Integration, Partnership and Innovation in Construction Science and Education” (IPICSE–2020)* 382-385

[26] Kazennov V V, Komarov A A, Mishuev A V, Gromov N V 2012 Emergency gas explosions in premises *Educational and methodological guide for bachelors* Moscow

[27] Polandov Iu H, Korolchenko A D and Dobrikov S 2020 On the Nature of the Acoustic Oscillations in Gas Explosions *IOP Conf. Series: Materials Science and Engineering* 869 052039

[28] Gorev V A, Korolchenko A D 2020 Impact of the idle run of a rotating easily dumped structure on pressure in the room *IOP Conf. Series: Materials Science and Engineering* 869 052069
[29] Polandov Iu H and Korolchenko A D 2020 About the Danger of Vibration Combustion in Gas Explosions in the Room *IOP Conf. Series: Journal of Physics: Conf. Series* **1425** 012010

[30] Polandov Iu H, Korolchenko A D and Evich A A Conditions of occurrence of fire in the room with a gas explosion *Pozharovzryvobezopasnost/Fire and Explosion Safety* **29**(1) 9-21