Verification method of strength of refractory slings for positioning and holding after exposure to a heated metal rod

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Abstract. In the introduction of this work, three types of safety systems are considered when working at height. Hazardous factors have been identified that affect the safety of the user, depending on the components of the safety systems and their resistance to high temperatures. The purpose of this work is to improve safety in hazardous sectors of industry, construction and other types of work where increased protection of PPE components from sources of elevated temperatures is required, when working with gas and electric welding, as well as the resistance of materials to sparks from mechanical power tools. In the main part of the article, a new test methodology for refractory slings for positioning and holding was introduced, tests were carried out and the method was adjusted. The experience of the fire sector was borrowed, and in particular, the method in clause 9.8 from GOST R 53268-2009 Firefighting equipment General technical requirements. Test methods was transferred and adapted. Fire rescue belts General technical requirements. Test methods .. The conclusions of adaptation and application of this method to other components of personal protective equipment are made.

1. Introduction
Working at height is an integral part of technological processes at a construction site, in production, in the maintenance of high-rise buildings, antenna mast structures and other high-rise structures where high-rise access is required.

To ensure safety when working at height \([1-5]\), various safety systems are used:
- Collective security systems;
- Stationary security systems;
- Mobile security systems.

The most effective systems are collective systems, their work lies in the passive safety of users, regardless of their qualifications.

These systems include:
- Stationary and temporary fences - used along the perimeter of buildings, structures, stairs and potentially hazardous areas in production and construction;
- Protective and trapping nets – used in the construction of monolithic and monolithic-brick buildings for various purposes with a height of up to 100 m in order to provide additional protection for workers in the event of a fall from a height, as well as to catch falling construction waste (formwork elements and building materials);
- Signal warning guards – signal strips, plates and other signaling signs warning of the danger zone at a height.
The second solution on construction sites or in production, where it is necessary to perform periodic maintenance of equipment, or perform other work, can be called stationary security systems. These systems are specialized rigid vertical and horizontal anchor lines, or anchor points, providing safety [6-11] directly in potential hazardous locations associated with height and stopping a fall if necessary. For such work, the user's qualifications are required, corresponding to the nature of the work performed, it is necessary to consider the hazardous factors that may affect the operation of protective equipment against falls from a height: the fall factor, climatic conditions, electrical conductivity, chemical reagents, etc.

Systems of fixed anchor lines or anchor points can be subdivided according to the methods of ensuring safety at the height used when performing work at height:
- Rigid vertical and horizontal lines – it is a steel cable or a metal profile or rail. The provision of insurance is carried out by moving the mobile anchor point along the horizontal anchor line and by moving the slider-type device along the vertical anchor line;
- Anchor points – it is a variety of different anchor points that are installed in the structure of walls, roofs, steel structures and allow the user to work safely during the area of the anchor point.

In places where it is impossible to install passive safety systems, as well as it is impossible or impractical to install stationary systems, the third type of systems is used. Mobile safety systems when working at height. Such systems represent and include:
- Positioning system – used in the maintenance of metal structures, power line supports; antenna-mast structures, and other structures, where ease of use is achieved by positioning the user directly on the structure;
- Restraint system – it is used where maintenance, installation or dismantling work can be performed safely, and in case of a fall or loss of control, the user did not fall into the area of possible free fall;
- Safety system - it is used where maintenance, installation or dismantling work, when carrying out welding work, cannot be performed in a safe area of work and there is a risk of the user falling down and then holding him;
- Rope access system - it is used where maintenance, installation or dismantling, inspection and other work cannot be performed in a safe work area, and work must be performed in a support-free space.

All these types of safety systems, except for passive protection against falls from a height, consist of components that, in a single complex, are directly involved in ensuring the safety of the user performing work at height. General work at height refers to the inspection, installation, maintenance of equipment or other systems and other work. In the high-altitude field of work, where it is necessary to carry out work in potentially hazardous areas, near sources of elevated temperatures, using gas welding equipment and mechanical power tools, where in the process of work there is a question of ensuring intrinsic safety, resistance to high temperatures of safety system components at height. The problem concerns many industries and construction sites. A standard set of safety components cannot provide protection against open flames, glowing metal, or sparks from a power tool.

System components: harnesses, low stretch ropes, shock absorbers, holding and positioning slings, textile mobile anchor lines and other safety system components [12-14], made of materials that do not interfere with the above hazards.

The purpose of this work: Improving safety when working at height in potentially hazardous sectors of industry, construction and other types of work where increased protection of safety components [15-18] from sources of elevated temperatures is required, when working with gas and electric welding, as well as resistance of materials to sparks from means of mechanical power tools.

The objectives of this work: development, approbation and application of the test methodology in relation to the object of research of this work.

2. Materials and methods

2.1. Product technical requirements:
The static breaking load of a refractory sling for holding and positioning, after exposure to it for at least 30 seconds with a metal rod heated to a temperature of (450 ± 10) °C, should be at least 7.5 kN.

2.2. Test Method.

2.2.1. Test object.
- Fire-resistant positioning lanyard with length adjuster (code 001), double fire-resistant lanyard for holding (code 002);
- Minimum static strength - 15 kN;
- The sample is made of aramid material;
- Sling diameter 16 mm.

2.2.2. Sampling
The test is carried out on three specimens of a refractory lanyard for holding and positioning.

2.2.3. Test equipment:
a) thermal oven allowing to maintain the temperature (450 ± 10) °C for at least 20 minutes;
b) a rod made of steel grade St3 in accordance with GOST 380 in accordance with Figure 1-2 with a size of at least (10x10x200) mm;
c) a stopwatch with an error of no more than 1.8 s in 60 minutes;
d) an installation for tensile testing - must ensure the measurement of force with a relative error of not more than 1%, the minimum distance between the clamps is 300 mm. Moving clamp movement speed no more than 200 mm / min;
e) a metal ruler with a graduation of 1 mm.

![Figure 1. Rod made of steel grade St3.](image1)

![Figure 2. Application of a rod to refractory slings for positioning and holding after warming up.](image2)
2.2.4. Preparing for the test
The steel rod is heated at a temperature of $(450 \pm 10) \, ^\circ \text{C}$ for at least 20 minutes.

2.2.5. Testing
The sample is spread over its entire length on a horizontal surface. Not later than 5 s after heating, a rod is applied in the middle of the sample in the transverse direction.

3. Results and discussion
The object of study in this work is refractory retention slings and refractory slings with a length adjuster. Refractory slings most often come into contact by deliberate or accidental negligence with sparks from mechanical and gas welding equipment, are located near sources of open fire or high temperatures. Within the framework of this work, the concept of the methodology from clause 9.8 of GOST R 53268-2009 “Fire fighting equipment. Fire rescue belts. General technical requirements. Test methods”.

After no later than 30 seconds, the rod is removed from the sample.

The procedure is repeated for the remaining samples.

Next, alternate loading of three samples is carried out until their destruction according to the schemes indicated in Figures 3-4.

Figure 3. Schematic of static load testing of a sling with a length adjuster. 1 - length control element; 2 - connecting element; F - static load.

Figure 4. G Schematic of a static load test for a holding sling. 1,3 - end connection of the sling; 2 - free ends of a two-shoulder sling; a - connection points for test 1 (between a and a); b - connection points for test 2 (between b and b); F - static load.

If the rupture occurs at a distance of less than 10 mm from the edge of the clamp, the result is not valid and the test is repeated on another sample (Table 1-2).

The breaking force after tests on the impact of a heated metal rod is for:

| № sample | The breaking force, kN |
|-----------|------------------------|
| 001       |                        |
Correction and approbation of the test method on refractory slings was carried out. Conclusions are made about the application of this method, in checking the refractoriness of slings when exposed to high temperatures, by applying a heated metal rod. The original methodology and requirement can be found in GOST R 53268-2009.

### 4. Summary

Based on the above aspects, within the scope of this article, a big problem is formed, caused by safety when working at height, associated with direct contact of safety system components near sources of elevated temperatures. In particular, the problem arises with personal protective equipment made of synthetic material and used in construction, production, as well as other work at height associated with hazardous factors affecting the structure and integrity of the material. Hazards such as working with gas welding, gas cutting, electric welding, and near sources of high temperatures can directly endanger the life and health of users using conventional personal protective equipment.

In this work, the experience of the fire rescue field is adopted and adapted, where fire rescue belts undergo mandatory tests for the effect of a heated metal rod. A metal rod simulates different situations that may arise when sparks occur during gas welding, electric welding or the operation of a mechanical power tool, as well as short-term contacts of heated parts or surfaces. This method in clause 9.8 of GOST R 53268-2009 is adapted and tested on refractory slings for holding and positioning. This method clearly shows the residual static strength after the application of the metal bar. The presence of such a method indicates its further implementation in the sector of personal protective equipment against falls from a height, and approbation of this method on other components of high-altitude fall safety systems. The complex of measures increases the overall collective safety at height as a whole, which cannot but affect the general culture of work at height.

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