Technical requirements and test methods of elements of equipment-specialized security remedies firefighters in incident critical infrastructure

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Abstract: *A report and examined the technical requirements and test methods for components of the equipment -specialized protective equipment to protect personnel - firefighters , for neutralization and elimination of threats and consequence of these incidents at sites of critical infrastructure*
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1. Introduction

The modern development of technologies predetermines the use of various substances and materials. Defiles small part of them according to their physico-chemical properties are flammable, explosive and toxic. These properties, in turn, determines the item requirements to specialized protective means (SPM) for the protection of firefighters involved in accidents and neutralizing the effects of them.

2. Technical requirements for protective equipment

Protective clothing, for firefighters is specialized personal protective means (SPPM) providing protect the torso, neck, arms and legs fireman. [1]

An additionalspecialized personal protective equipment (ASPPE) is for protect the head, face, wrists and feet.

Although the role of the firefighter is to put out fires, he has many other activities where thermal protection is not required.

Therefore, finding a balance between thermal protection, comfort and other requirements is crucial. Determining the danger s gives an opportunity for the fire department, after a risk assessment to make choices consistent of risks assessment.

Specialized protective means (SPM) is the sum of SPPM and ASPPE with suitable protection of the respiratory tract , where necessary degree.

The use of inappropriate SPM may affect h and reduced productivity and perception and has a paradoxical effect in the daily activities of firefighters.

It is essential that the fire and rescue service at critical infrastructure sites carry out a risk assessment. To verify compatibility th and ergonomics so all parts of ASPPE (respirators, gloves, boots, etc.) And meet at Ziska Regulation (EU) 2016/425 on personal protective equipment. To ensure protection from nuisance is necessary firefighters and staff in maintenance to is familiar with the selection, use, care and maintenance of all personal protective equipment. [2] There is an increased focus on the contamination of firefighters and / or their SPM by smoke, particles and gases, as well as all decontamination processes.

In order to achieve a certain level of protection and comfort of SPPM with assessment of the probable risks, the requirements to SPM and ASPPE are determined.

The requirements for protective clothing, cover design and comfort and, visibility so,of heat a and flame of m echanical and and chemical and materials.

In er h on an assessment of risk, and the specificity of the medium in which they are used SPM levels of protection are divided into two levels of performance:

- **Level 1**: defines the minimum requirements for firefighting clothing when working with fire outdoors and their ancillary activities taking into account the environmental conditions of expected operational scenarios such fire protection activities.

Level it is not applicable for protection against risks arising from firefighting or rescue from firefighting activities in buildings, unless they are combined with level 2 or another and specialized and PPE.

- **Level 2:** defines the minimum requirements for fire fighting clothing risks encountered etc. and firefighting and rescue of fire in structures (buildings).

The distinction between Level 1 and Level 2 clothing is limited to the requirements for protection against heat (X1) and flame (X2). These levels of protection can be achieved through a single garment or a combination of individual clothing.

A security enes are pairs is degrees of protection against ingress of water with identification marks (Y) and resistance to water vapor with (Z).

At the high level of efficiency - Level 2 of SZS is aimed at specialized firefighting with a large amount of radiant heat, operations dealing with hazardous chemicals and others. dangers.

2.1 Requirement to SPM - comfort and design

2.1.1 Black

The levels of protection of the SPM are achieved by clothing, which may contain multilayer materials or combinations of materials. The elements of which composition eno clothing must meet the specified requirement, and should be tested together. To ensure a certain level of protection, they must be worn together. [3,4,5].

In protections ene and from two-piece suit must have overlapping jacket and pants while. The overlap must be maintained when both hands move over the head and when not bending from a vertical position until the fingertips reach the ground. The wrists and ankles should remain covered in an upright position.

Verification of the fulfillment of this requirement shall be visually. [1]

In anshniya t material from which made clothing to misses harmful substances to the inner layer and from there to the skin of the person wearing it. [6,7,8,9,10,11,12]

Protective clothing should be designed so that the design there are no sharp edges, bumps or protrusions, the reason yavashti injury to the user.

The end of the sleeves, the lower part of the jacket and the end of the trouser legs (overalls) should be made of material that does not allow loosening. Also can stand stably and tightly to the body, in order not to miss the entry of water and harmful substances.

On the clothing are stitched claimed reflective, fluorescent signs, tapes or Combin ation for them to provide no visibility unto them from afar.

D pockets

All pockets of the garment must be designed in such a way as to prevent the entry of heat, flames or hot and gases and material.

The pockets are external and internal made under the following requirements:

(a) an outer pocket made of a separate piece of material such as the outer main sewn on the outside without piercing the outermost layer of the garment.

b) outer - built-in pocket sewn for the inner material of the garment without piercing the outer layer of the garment.

Increasing the number of pockets can lead to additional weight and insulation of the garment, which can increase the physiological impact on the user.

Hood

It is very important to determine in what operations to use a garment with a hood. When the garment is designed with a hood, it can have a negative effect on the accumulation of heat or the perception of the user (reduction of hearing and perception).

Breathable material

In order to allow passage of moisture from the garment from the inside out the material from which is made the garment should be "breathable". This fabric is suitable for slaves because it does not allow the body to be steamed.

And inspection

The clothing is made with holes and nspektsi her in order to provide not possible to verify the protective layers or coatings and different seams.

Closing system

The area of the closing systems must provide the same level of protection as the rest of the garment.

The distance between the broken closing system (eg holes or fasteners) must not lead to unprotected openings in the garment. When using zippers, the sliding clasp shall be designed to lock until fully closed, including when using a zipper with a quick release mechanism. The closing system must not be opened accidentally. The verification of the fulfillment of this requirement is performed visually and with a manual test. [13]

3. Test methods

3.1 Heat and flame

3.1.1 Flame propagation test

All materials and structural seams are tested before and after pre-treatment. Results are evaluated when samples are included in the test framework.

The prefabricated component of the outer garment shall be tested by applying the test flame to the surface of the outer material and to the surface of the innermost lining of individual specimens. [14,15,16]

Clothing type "bulb ", the outer garment and the innermost lining should be tested in addition to separately and together . The sutures are tested with three samples and they must not be opened. In the test Obrazetsa item must be oriented so that the seam to walk the middle line of the test specimen so that the flame of the burner to hit directly on the seam.

The material used for the cuffs of the sleeves and legs and the end of the jacket shall be tested separately, with the flame directed at the outer surface of the material.

Tags, badges, reflective materials, and the like., K oito is applied on the outermost surface of the garment is tested so only after pretreatment in combination with the outer layer to make possible the taking of samples. [17].

3.2. Contact heat test on garments marked X2

For level 2, three samples of component a or clothing must be tested before and after pre-treatment . The tests are performed at a temperature of 250 ° C [18] . In the net test, each sample must have a minimum residence time of 10 s.

K lasifi cation is based on the lowest single result of three they separate values and rounded to the nearest whole second count for the result obtained.

3.3. Heat transfer test of garments marked X1/X2 at:

- Flame - The test is performed with at least three specimens from the set of samples before and after preliminary preparation - cleaning of the garment according to the manufacturer's instructions [19,20]. The classification is according to the lowest single result of the three separate values and rounded to the nearest whole second is considered for the obtained result (Table 1) ;

Tabl. №1

Heat transfer index	Level of implementation 1	Level of implementation 2
HTI_{24}	≥ 9,0	≥ 13,0
$HTI_{24} – RHTI_{12}$	≥ 3,0	≥ 4,0

HTI_{12} – time in seconds, expressed to one decimal place to achieve an increase in the temperature of the caliper of (12 ± 0,1)) ^{0} C.

HTI_{24} - times per second, expressed to one decimal place, to achieve a temperature increase in the calorimeter of (24 ± 0,1) ° C

Transmission - The test shall be performed with at least three copies of the sample set before and after preliminary preparation. [21,22] The tests are performed at a heat flux density of 40 kW / m^2. (Table 2)

Tabl. №2

Heat transfer index (radiation)	Level of implementation 1	Level of implementation 2
$RHTI_{24}$	≥ 10,0	≥ 18,0
$RHTI_{24} – RHTI_{12}$	≥ 3,0	≥ 4,0

3.4. Residual tensile strength of the material upon exposure to:

- Radiation- The test is carried out at least in triplicate on sample sets of a base and in the weft of the outermost material after pre-treatment at a density of heat flux of 10 kW /m^2. Each specimen must have a tensile strength ≥ 450 N. [23,24]

- Heat resistance - and zpitvane it is carried out at a temperature of (180±5)°C for a time of 5 minutes. All the material and the used and clothing should not ignite m or top th and does not shrink so more than 5 %. Each layer of material is tested separately. [25]

Closing system devices were tested at a temperature of (180 ± 5) ° C for a time of 5 min., They should retain the function after the test.

- Heat resistance of seam s clothing - test shall be carried at a temperature of (260 ± 5) °C, the seams must not melt.

3.5. Test for resistance to penetration by liquid chemicals - The test is performed with at least three specimens from the set of samples after pretreatment. Proveryavat filaments warp and weft , using the time for -application of 10 s, with liquid chemicals described in Table. 3. [26]

For each sample there must be no penetration to the inner surface and the index of the repulsion to be ≥ 80% classes cation based on average result of test .

Tabl. №3

Chemikal	Mass (%)	Temperature of chemical ± 2 °C
H_2SO_4	30	20
C_8H_{10} (o-xylene)	100	20

3.6. Mechanical examination of the material from which the garment is made

- Tensile strength

P ri testing of in anshniya material after the pretreatment, the threads on the base and weft of fabric with a coating must withstand a tensile strength ≥ 450 N. [27]

The seams of the outer material during the test must have a maximum seam tear strength ≥ 300 N. [20]

Tear strength

When testing the outer material after pre-treatment, its warp and weft threads shall be able to withstand a tear force ≥ 30 N. [27]

3.7. Water penetration of clothing marked with Y1 / Y2

The finished product is tested for resistance to water ingress at a pressure of 0,98 ± 0,05 kPa / min and must achieve one of the following efficiency levels:

- Y1 <20 kPa, for clothing without moisture barrier;
- Y2 ≥ 20 kPa, for clothes with a moisture barrier. [28].

3.8 Resize

Changes and size after cleaning material and n and protective clothing should not exceed ± 3% for woven and ± 5% for trikot Agen material and non-woven fabric

The performance test of the kit is not performed. Each layer of the set must meet the requirements for resizing.

3.9. Area of visibility of the material

The minimum size of reflective material should be no less than 0,13 m ^{2}, and the minimum size of the fluorescent material must not be less than 0,2 m^2.

The minimum area for compound material for execution must be not less than 0.2 m^2.

3.10. Comfort requirement

- Resistance to water vapor with marked Z1 / Z2

The requirements for water vapor resistance (Ret) must be in accordance with one of the following efficiency levels for the following indicators:

- Z1> 30 m 2 Pa / W, but not more than 45 m^2 Pa / W;
- Z2 ≤ 30 m 2 Pa / W.

- Clothing testing

the finished product is tested on a manikin at an exposure: 8 s at 84 kW / m ^{2}.

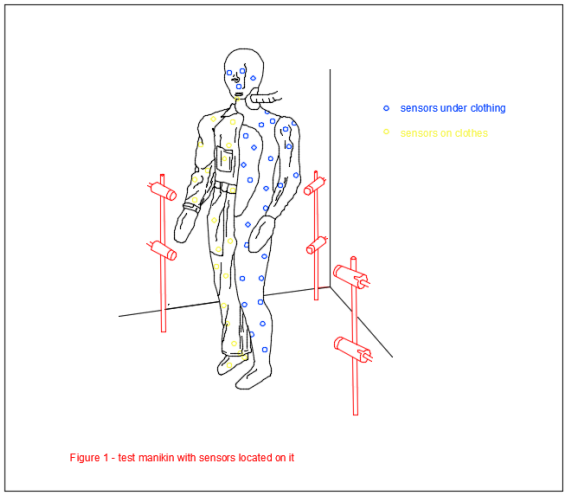
In addition, additional integrated devices must be included to be used with protective clothing testing.

In addition to tests on and clothing Level 2 or prefabricated clothing can be tested and instrumental mannequin with a precondition that the clothes are made from materials tested and have the appropriate size [29].

The test is performed with a single cycle of pretreatment e Reha or said fitted kit, which with is combined to obtain a level of protection X 1 or X 2. T substantially the in heat flux of 84 kW / m ^{2} for a duration of 8s. The test must be performed with or without underwear. The average value for the three tested garments is reported.

Any additional integrated devices that will be used with the clothing may be included in this test.

Thermocouples are placed on the manikin, forming separate sections on it, as the optimal number is 130. (Fig. 1 and Fig. 2)



***Fi. 1** Mannequin with sensors*

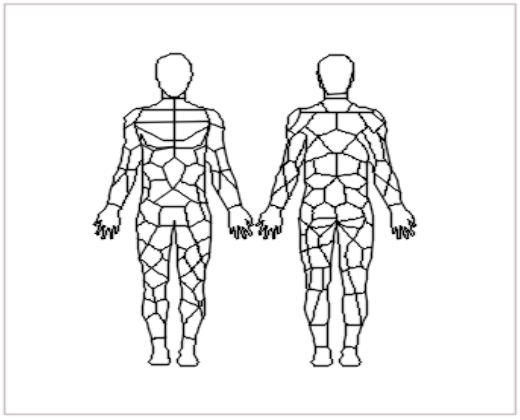


***Fig.2** Zoning*

real test of fire-retardant clothing and the impact on the manikin and the degrees of burns are shown in fig. 3 and fig 4

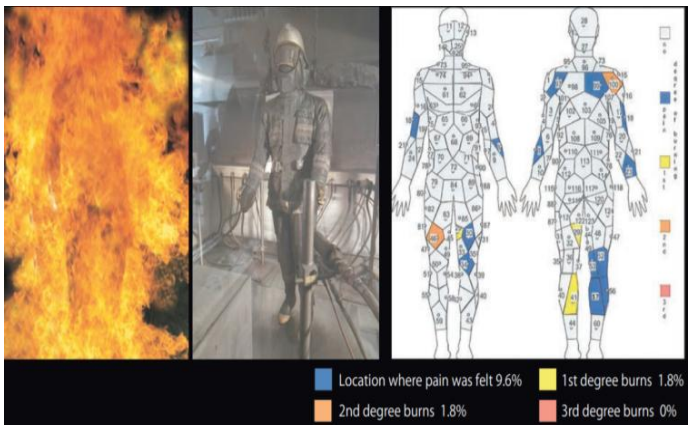


Fig. 3

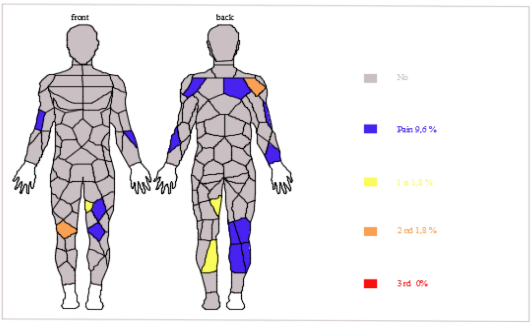


Fig. 4

3. Conclusions

In er n streams passing to the clothes in separate tests in the light of the findings of the risk assessment in real and situations and in case of accidents hazards they have a large effect on the body. for this it is necessary to continue the tests in order to improve the protective qualities of the specialized protective clothing.

According to the risk assessment for the critical infrastructure site with the most likely severe scenarios, we propose to develop a chamber with an integrated version of the test methods in which the amount of oxygen in the chamber, temperature, pressure and flow rate of different gases can be regulated and the combination thereof. The test manikin is wearing a full set of protective clothing and personal protective equipment, with standard equipment - for respiratory protection. The sensors are arranged both on the outer

side of the garment and on the inside by measuring quantities such as temperature, moisture permeable OCT of toxic products, static but electricity, Tamb h Oliri ability.

In conclusion, it can be said that the proposed test model, including the synergy of hazards, will simulate situations as close as possible to the real ones. The conclusions will be drawn for the Grand pm Nittel value of default parameters to which protective agents will be effective, is enabled evaluation of specific protection and against other hazards, for example chemical, biological, radiological and electrical hazards.

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