

## 1.6. Development of design project decision for protecting clothing for the emergency-rescue works in aviation

When designing clothing for emergency and rescue work on aviation facilities, many factors must be considered, including thermal radiation, contact with heated surfaces, rapid flow of heat flows, static current, etc. The ergonomics of the design is important, clothing must not restrict movements, have ventilation openings for heat and steam removal, provide speed, convenience of dressing and removing, bear signs and be combined with other personal protective equipment. The design of the garment must be compatible with the protective equipment that the rescuer uses during his work.

The choice of the optimal version of a reliable, ergonomic and compositionally-completed project design of protective clothing is complicated by the versatility of the requirements.

The main purpose of protective clothing is to provide reliable protection of the worker from various factors of the environment while maintaining a normal functional state and working capacity. In addition, protective clothing should provide the necessary hygienic conditions during work, normal temperature regulation of the body, be comfortable, easy, do not restrict movements, be subject to moisture and chemical purification from contamination. The protective, operational and hygienic properties of clothing are primarily dependent on the materials from which they are made, as well as on the design.<sup>36</sup>

Different types of clothes are used for conducting emergency rescue work: jackets, trousers, overalls and overalls. On the basis of the survey of rescuers, it was found that the most fully formulated requirements are precisely the overalls. This is explained by the fact that spending less time on his dressing, and also taking into account the ergonomic component, is more convenient than a costume.<sup>37</sup>

Characteristics of emergency and rescue clothing are shown in Fig. 1

Although this product is not comfortable with operation, it provides greater protection due to the closeness of the body of the rescuer.

The mandatory condition for designing protective clothing is to take into account all the requirements for clothing. It is known that utilitarian functions are the main ones for protective clothing, so the most attention is paid to them. Fig. 2 shows a list of elements, parts, knot nodes for basic functions, which will result in the introduction of protective, ergonomic, aesthetic and reliability indicators. It is worth remembering that when designing protective clothing, every element of it should be expedient.

For the rescuer's clothing, aesthetic perception is very important. This is explained by the fact that during his professional qualification he, including, has to contact people who are in an unstable psycho-emotional state as a result of an accident. Therefore, the appearance of protective clothing should not worsen this condition and not increase the psychological trauma. An important harmonic color combination, which at the same time should have bright elements for the recognition of the rescuer in conditions of poor visibility, is important.

During the performance of professional qualification, the rescuer has to work in conditions of limited visibility, for example, high smear. Therefore, the protective overalls should contain signal and reflective elements.

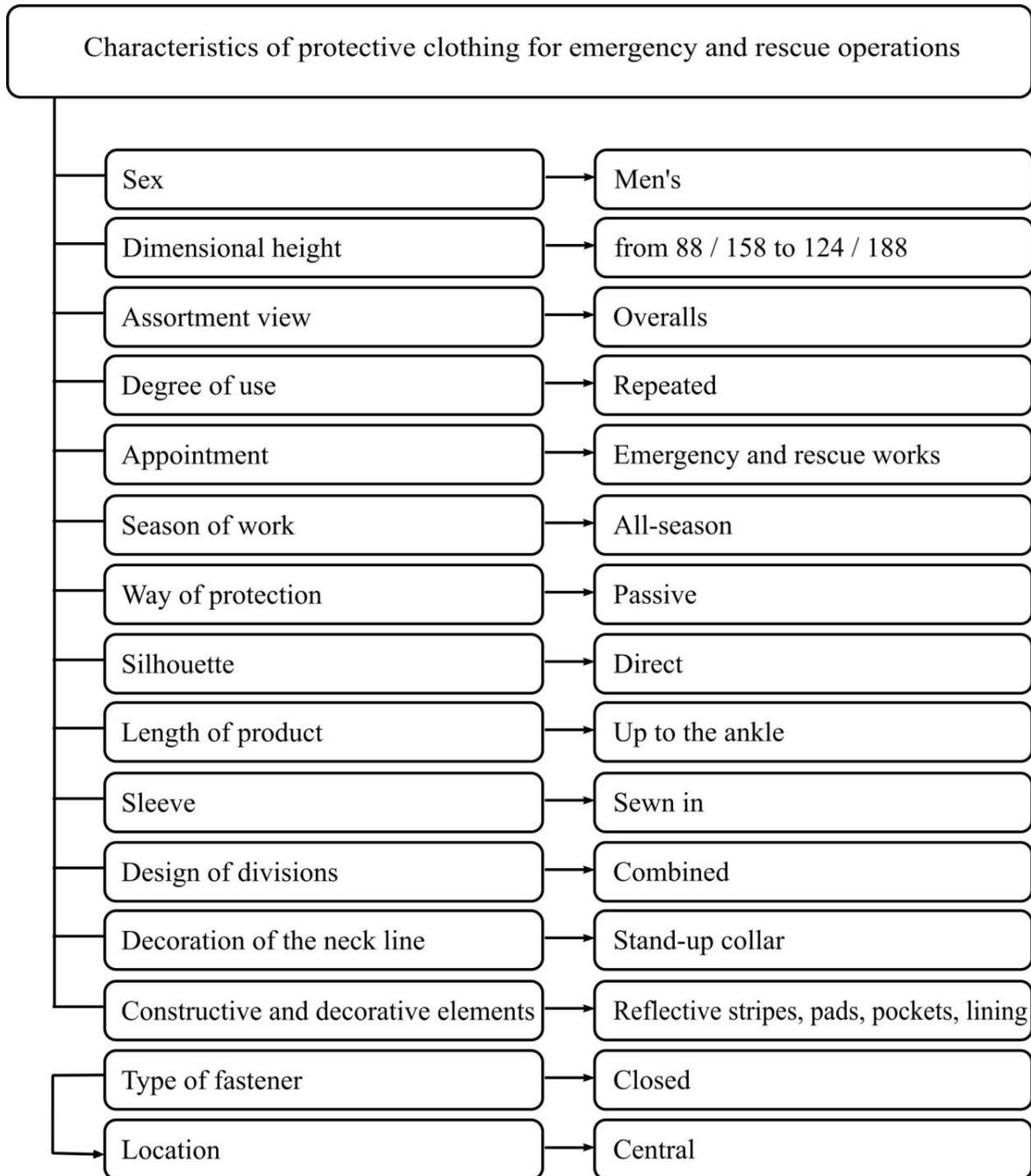
An important aspect in designing protective clothing for a lifeguard is to provide a normal microclimate in the work area. It is known that during overheating of the body, the mechanisms of

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<sup>36</sup> Avetisyan V. G. Organization of emergency rescue work on aviation transport: training. / V. G. Avetisyan, Yu. M. Senchikin, D. V. Oraevsky – Kh.: Urgent printing, 2012. – 108 p.

<sup>37</sup> Kolenov O. M. Primary training of the fireman and rescuer: educator. manual / O. M. Kolenov, O. E. Bezkulov, V. M. Ischuk – Kh.: NUTZU, Communist Party "Urban Press", 2013. – 455 p.

thermoregulation contribute to increased heat transfer, which is carried out through the blood circulation system by sweating. Therefore, ventilation openings are provided to ensure the removal of excess heat and moisture from the work area. The greatest volatility occurs in the area of the submerged basins, therefore the most effective is the placement of ventilation openings in this zone. In the sleeve-side shaft there is a vent hole 20 cm in length, closed with a zipper and a solid zinc-plated sheath. When opening a zip fastener, the hole is closed with a textile net.



*Fig. 1. Characteristics of protective emergency and rescue clothing*

The peculiarity of the work of the rescuer is that the dressing of the complete set of equipment is given no more than 40 seconds, so the question of quick and comfortable dressing is acute. It should be noted that dressing the coveralls must be performed without removing shoes. It was found that the central placement of the zip fastener is uncomfortable and ineffective,

therefore a new type of fastener is proposed that contains two symmetrically located zippers that reach the hips line. Thanks to this, the overalls are completely open and do not restrict movement during dressing. For the convenience of dressing the overalls in shoes, the width of the bottom of the pants is increased and the presence of a puff in the side seams of the pants on the zip fastener is provided. Sheets are made of orange-colored fabric for visual inspection of the closure of the fastener.

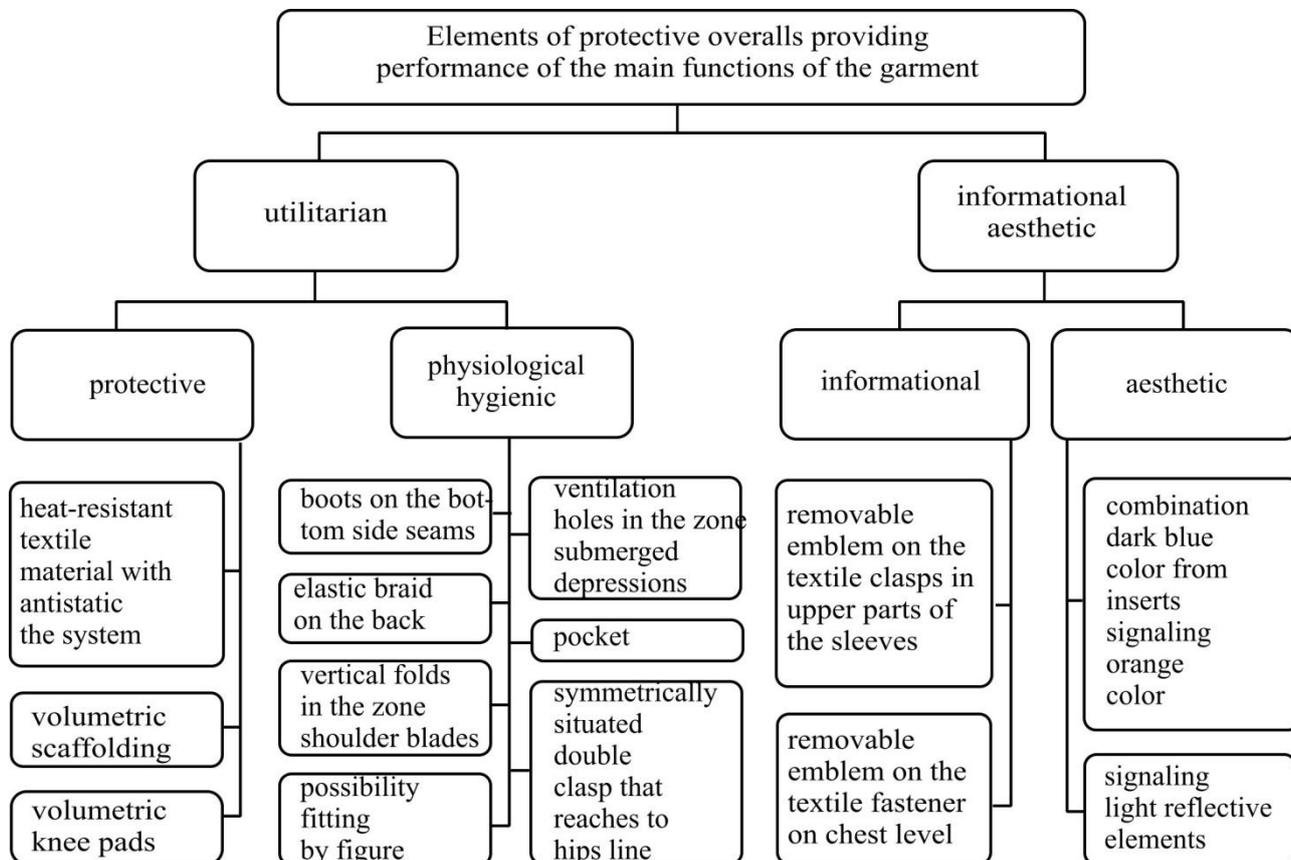


Fig. 2. List of elements of protective overalls to provide basic functions

The ergonomics of the overalls provide additional volume in the area of the elbow and knee joints. Volume pads on the specified areas are more convenient, because they take into account the dynamic increase in the movement of hands and feet and less pressure on the joints. When manufactured, the volume is achieved by introducing strands and folds. Also in the overalls an additional layer of fabric was applied in the elbow and knee zone to extend the life of the operation. When designing a overalls, it is very important to provide ergonomics with the torso of the trunk forward. To do this, you need to take into account the dynamic gain to the length of the back, which is 6-9 cm. To compensate for this increase, a new design of the backrest of the overalls containing the vertically placed elastic braid has been developed. The back has a removable jacket, sewn in a stitching stitch with an elastic bar width of 250 mm, the lower edge of which is sewn to the upper part of the back half with the possibility of a simplified replacement of the elastic braid after reducing its deformation characteristics. For the convenience of performing movements of hands in the area of the blades, there are two vertical folds<sup>38</sup>.

<sup>38</sup> Experimental researches on determination of reliability of heat-protective of heat-protective materials / A. I. Rubanka, N. V. Ostapenko, M. M. Rubanka, O. V. Kolosnichenko, K. L. Pashkevich // *Vlakna a Textile*. – Bratislava. – 2017. – № 4. – P. 3-8.

Provided that protective clothing is manufactured in an industrial way on a conditional-shaped figure, it is important to adapt the clothes to the morphological features of the worker. Therefore, in the protective overalls of the lifeguard there are several ways of adjusting the width or length and so on. Firstly, along the waist, there are clamps and a spire on the back for the possibility of pulling the belt, including a special belt of the firefighter. Secondly, the bottom of the sleeve is decorated with a cuff with an elastic braid and a strap for adjusting the width of the cuff. Thirdly, the bottom of the trousers has slats for adjusting the width of the leg down.

On the basis of the analysis of operating conditions and assortment of protective clothing for rescue operations, the study of professional qualifications, a new design ergonomic solution for the protective overalls was developed. The various constructive elements, which meet the requirements for protective clothing, are substantiated. The attention is focused on new solutions of individual parts and units for the sake of greater convenience when rescuers perform their duties.

On the basis of analysis of all the initial data to the design of protective clothing, an assortment of products for emergency and rescue works, namely single-layer and multi-layer overalls with different levels of protection, was proposed<sup>39, 40</sup>.

*1. Single-layer overalls for the elimination of the consequences of emergencies.* The choice of design-technological solution is based on the requirements put forward for protective clothing and must take into account the operating conditions. It has been established that for rescuers in aviation the most effective use is the use of an overalls. Based on the professional qualification of the rescuers, it is rational to choose a direct silhouette and a sewing sleeve. The ergonomics of the overalls is achieved by additional overlays on the knee and elbow joints, ventilation openings, elastic braid on the back, a double central fastener, a strap and an elastic strap on the bottom of the sleeves, a push down the bottom of the pants and a riser collar.

The construction of the structure takes into account the analysis of information on accidents and disasters, the intensity, the topography of dangerous and harmful factors and the requirements put forward for protective clothing for rescuers. It is equally important to take into account the properties of the material when constructing the structure, for which experimental research has been carried out.

The construction of the base design of the overalls was made using the CAD program "Julivi" (ARM Design, Designer)/

The design of the overalls should take into account the requirement for the minimum dressing time. Taking into account that the central clasp in the overalls is not ergonomic, two symmetrically arranged zip fasteners designed to the length of the hips are designed.<sup>41</sup> Also, for ease of dressing and preventing the entry of foreign matter into the clothing space, an elastic bracelet is placed at the bottom of the sleeves, and the width of the bottom of the pants is increased and the presence of a pouf on the zip fastener is provided. At constant torso of the torso it is mandatory to take into account the dynamic increase to the length of the back. It is found that it is about 6-9 cm, thus designing a new back structure with the use of elastic braid.

Note that varieties of constructive elements to increase the functionality of the overalls are numerous, so you should choose their optimal amount, because it significantly affects both the weight of the overalls and their cost. Do not overload the overalls with such additional elements as

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<sup>39</sup> Thermal stability and flame resistance of cotton fabrics treated with whey proteins / F. Bosco, R. A. Carletto, J. Alongi, L. Marmo, A. Di Blasio, G. Malucelli. // Carbohydrate Polymers, Volume 94, Issue 1, 15 April 2013, Pages 372-377.

<sup>40</sup> Kolosnichenko O. V. Design of concordant forms of modern clothes on the basis of proportional correlations of sacred geometry / O. V. Kolosnichenko, I. O. Prykhodko-Kononenko // Vlákna a textil. – 2017. – № 3. – P. 10-14.

<sup>41</sup> Ezhova O. V. Comparative analysis of foreign models of fashion education / Ezhova O. V., Pashkevich K. L., // Revista Romaneasca pentru Educatie Multidimensionala – 2018. – Vol 10, No 2. – P. 88-101.

pockets, pads, etc. It is established that during the performance of their official duties, rescuers use mainly one pocket - for the storage of protective gloves.

The design and technological solution of the protective overalls includes:

- elastic braid, which is placed along the length of the back and folds in the area of the shoulder blades to increase ergonomics;
- Two symmetrically located zippers for easy wearing and removing;
- lining in the zone of knee and elbow joints to increase wear resistance;
- ventilation openings in the underarctic area for a comfortable microclimate;
- Double seam joints for increased durability of the structure;
- elastic bracelet and downholstered sleeve legs for compatibility with leggings;
- extended trousers, boots and pads at the bottom of the pants for the convenience of dressing up an overalls in shoes;
- a patch pocket for the storage of gloves;
- clamps on the waist for fastening the belt to adapt to the morphological features of the lifeguard.

The overalls are waisted, the upper part of the cuff has horizontal divisions, a back with a cut jacket and vertical divisions, in the central part of the back is an elastic braid 250 mm wide, and two folds in the shoulder blades. The lower part of the overalls consists of the front and back halves of the trousers with lining in the area of the knee joints. At the bottom of the trousers are puffs and stairs. On the right half at the level of the hips – a patch pocket with a valve. Combination with sewing sleeves, the bottom of which is decorated with elastic braid and patams. In the area of the elbow joints are overlays. Fastening overalls to two center-positioned zip fasteners, length to the hips line. The neck is decorated with a riser collar. Belts for belts are located on the waist. Textile fasteners for fastening information elements (chevrons) are placed on the front halves and on the upper part of the sleeve. At the front half below the line of prome, on the back along the shoulder blades and along the waistline, 50 mm wide reflector tapes are placed on the sleeves above the elbow and at the bottom of the trousers.

The design-ergonomic solution, photo-made samples, is presented in Fig. 3,4. Designed and proposed design ergonomic solution for a protective overalls for emergency rescue operations in aviation, meeting all the requirements, is presented in Fig. 5.



*Fig. 3. A general view of the protective overalls for rescuers on the figure:  
a – the front view; b – the rear view*



*Fig. 4. A photo of a protective overalls for the elimination of the consequences of emergency situations in aviation*

The product is made from the recommended fabric of blue and orange. The connection of the parts of the product is made of heat-resistant threads, which do not change their linear dimensions during operation. Two zippers for central locking are used for making a overalls, two for vent holes in the underarm area, two for the bottom of the legs; elastic braid for cuffs at the bottom of the sleeves, elastic braid 250 mm wide for an ergonomic insert on the back; textile fasteners for the bottom of the sleeves and the bottom of the pants and a reflective tape 50 mm wide.



*Fig. 5. General view of the protective overalls for the elimination of the consequences of emergency situations in aviation, a – the front view, b – the rear view*

Thus, the proposed thermal protection kit differs from the existing analogs by the fact that the anterior half is cut off along the waist and knee line, and is additionally equipped with a vertical insert extending in the center of the anterior half to the knees and connected to it by means of two lightning bolts, the rear half is cut off along the waist and line of blades, has an

outboard back, which is sewn to the rear halves along the shoulder blades and contains two vertical compartments, made with an opening of 50 mm, and an elastic t an occiput sewn on the cut edges of the rear halves. The novelty of the proposed solution is confirmed by the Ukrainian patent on utility model number 102935.

2. *Multi-layer protective overalls for localization and liquidation of emergency situations in aviation.* A new design ergonomic solution for a protective multi-layer overalls for rescue operations in aviation has been developed and proposed (Fig. 6-8).



*Fig. 6. A general view of the protective overalls for rescuers in the figure:  
a – the front view; b – the rear view*

The rescue kit is made of gray and red fabric, a thermal insulation layer, a lining fabric and a colored net, a union for the treatment of the bottom of the sleeves and trousers, and the membrane. To connect the parts of the overalls, they are resistant to burning, the effect of the high temperature of the thread. In the manufacture of overalls, heat-resistant zippers are used. The fastening of the information chevrons on the top of the sleeves and the line of the breast, for the pat and the bottom of the pants and sleeves is made with a fireproof textile fastener. For rescue operations in conditions with limited visibility, retro-reflecting strips are provided with a width of 50 mm<sup>42</sup>.

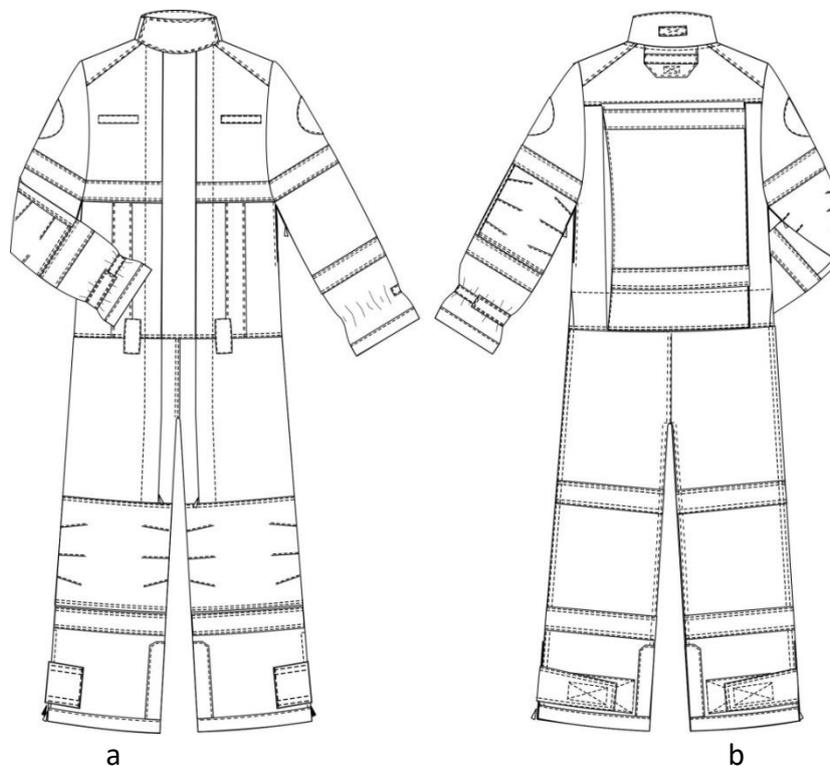
Combination thermal protection with evacuation loop containing sleeves and riser collar, anterior half detachable along the waistline and knee line, additionally equipped with a vertical insert passing through the center of the forelimbs to the knees and connected to it with two lightning bolts, the rear half detachable along the waist and line of blades, with a fly back, which is connected to the rear halves along the shoulder blades, and contains two vertical compartments, made with a possibility of opening by 50 mm, and an elastic braid sewn on the cut lines a rear half that differs from that of the heat-insulating and substrate layers, a safety valve along the back of the neck, an evacuation loop system consisting of the upper and lower loops located between the heat-insulating layer and the top material.

<sup>42</sup> J. Schmidt, R. Paul, E. Classen, S. Morlock, J. Beringer. Comfort testing and fit analysis of military textiles // Performance Testing of Textiles Methods, Technology and Applications A volume in Woodhead Publishing Series in Textiles, 2016, pp. 25-37.



*Fig. 7. A photo of a protective overalls for localization of emergency situations in aviation*

The proposed overalls contain an additional heat-insulating layer and a substrate that allows the rescuer to work at high temperatures and near open flames<sup>43, 44</sup>.



*Fig. 8. General view of the emergency rescue overalls for localization of emergency situations, a – the front view, b – the view from behind*

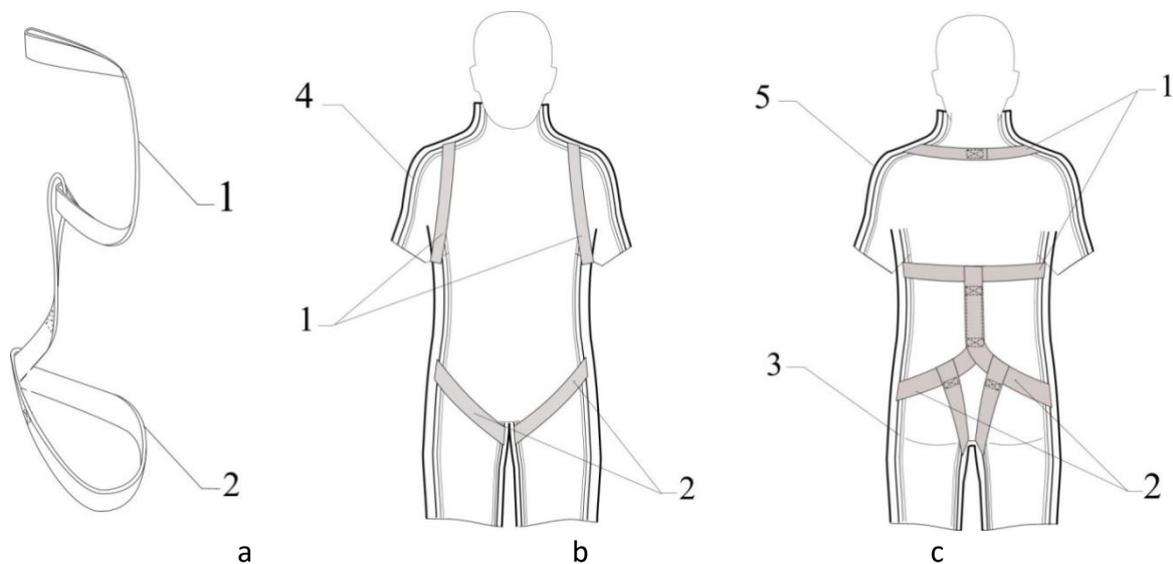
The overalls contain reinforcing shoulder pads. Zones of the knee and elbow joints are reinforced with volumetric knee pads and elbows, at the bottom of the sleeves and legs – reinforcing lining from the union. The front protective valve is located in the chin area. At the back

<sup>43</sup> Zhuravleva N. L. Development of the method of designing a special purpose linen suit for creating a comfortable microclimate: a dis. ... Candidate tech Sciences: 05.19.04 / Zhuravleva Nadezhda Leonidovna; MGUDT. – M., 2015. – 205 p.

<sup>44</sup> Koketkin P.P. Industrial design of special clothing / P. P. Koketkin, Z. S. Chubarova, R. F. Afanasyeva – M.: Light and food industry, 1982. – 184 p.

of the back coat under the neck there is a safety valve for the outer loop, under the valve the internal and external reinforcing overlays from the union are adjusted to increase the strength of the structure in the area of the exit of the evacuation loop outside. In the case of moisture in the underwear space on the bottom of the sleeves and trousers on the inside is a membrane for the unobstructed removal of moisture from the dressing space. The reflective strips are placed on trousers above and below the knee line, on the sleeves above and below the elbow line, the back along the waist line and along the shoulder blades, on the front half along the hinges and along the central part, by means of the safety valve for closing the outer evacuation loop. In the upper part of the sleeves and along the breasts there is a textile buckle for attaching chevrons. On the front of the waist, there are two clamps and on the back of the waist - a waist belt for pulling the belt <sup>45</sup>.

Between the insulation layer and the front and rear halves there is an evacuation loop system that consists of the upper and lower hinges (Fig. 9).



*Fig. 9. Appearance of the evacuation loop system:*

*a – side view; b – front view, c – rear view;*

*1 – upper loop; 2 – lower loop; 3 – internal lining layer; 4 – thermal insulation layer;*

*5 – an external heat-resistant layer*

In the performance of their official duties, the rescuer can suffer damage, including loss of consciousness, therefore the introduction into the design of the evacuation loop system provides an accelerated rescue of the incapacitated rescuer.

Execution of the evacuation loop in the form of two interconnected loop belts, one of which covers the shoulders through the submandibular, passing at the level of the line of the blades through the opening of the other, which in turn covers the legs at the level of the hips in the perineum area, provides a safe and quick extraction of the lifeguard. from a danger zone with loss of consciousness or injury (Fig. 10, 11). The bottom loop consists of a folded belt in half, forming a hole, which is fixed by a threaded connection parallel to the line of the backbone. The ends of the loop bend the loop itself, creating holes that are joined by a filamentous method, thereby creating additional loops-holes for dressing on the human face. The holes provide an opportunity to adapt the system to the morphological features of the rescuer and to be comfortable in the process of operation. The upper loop is stretched through the hole of the lower loop and stretched through

<sup>45</sup> Litvinenko G. E. Personal protective equipment: manufacturing and application / G. E. Litvinenko, L. D. Tretiakova. – K.: Libra, 2008. – 317 p.

the holes of the coquette of the back of the combine outside, forming the outer loop. The length of the evacuation hinges is laid out for the operation of the evacuation system itself and comfort in use.

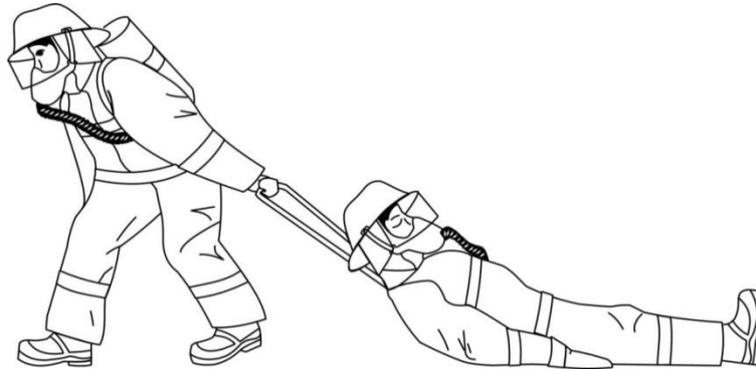


Fig. 10. Evacuation of the rescuer from the danger zone in case of loss of consciousness or injury



Fig. 11. Test of the evacuation loop

By color solution, overalls may be different, but a combination of gray fabric and inserts of a red colored material is proposed. In the places of greatest pollution, which are determined by the topography of the influence of dangerous and harmful factors, black markings and inserts are placed; in areas of abrasion – lining wear-resistant material (union). It is provided textile closures of circular shape with a diameter of 100 mm in the upper part of the sleeves and at the level of the chest with a length of 120 mm for the affixing of information signs.

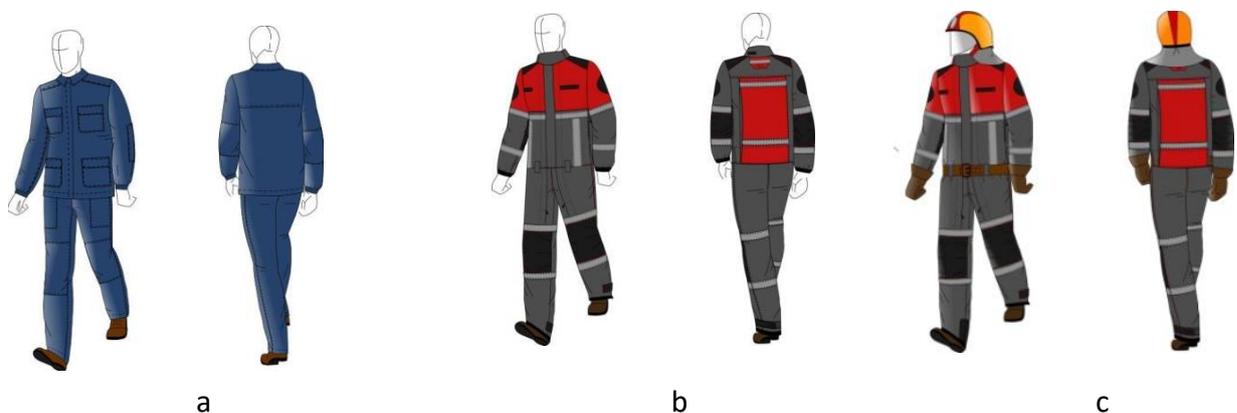


Fig. 12. Sequence of dressing of a set of clothes for conducting of emergency rescue works:

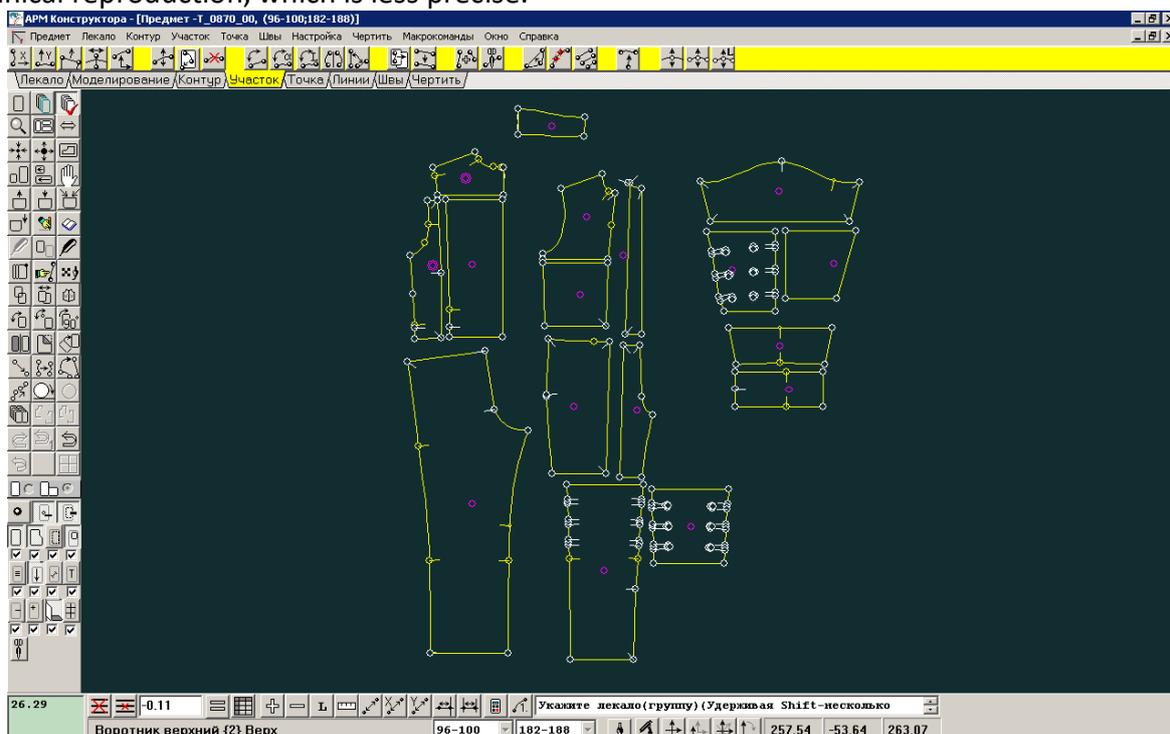
*a – a work suit, b – protective overalls without equipment; c – protective overalls with outfit*

Thus, design ergonomic solutions for protective overalls with different levels of protection have been developed. The components of protective clothing for rescuers in aviation are systematized. In designing constructive solutions, compatibility with personal protective equipment and technical equipment used by the lifeguard in fulfilling their professional qualifications is taken into account (Fig. 12). The novelty of the proposed solution is confirmed by the Ukrainian patent on the utility model No. 115678.

*3. Designing protective overalls using CAD.* The production of modern effective protective clothing requires fundamentally new approaches to its design-design. Due to this, the systems of automated design of clothing are becoming quite common (CAD system (computer aided design)). Their use can significantly reduce the time of development and the tools used for this, while increasing the accuracy of design development, reducing the cost of materials and processing time by optimizing the work with personal computers. The technical support of CAD is based on the use of computer networks and telecommunication technologies, personal computers and workstations. Mathematically, CAD is characterized by the use of computational mathematics, statistics, mathematical programming, discrete mathematics, artificial intelligence.

With the proliferation and availability of personal computers and the general computerization of all manufacturing processes CAD became indispensable in the mass production of clothing. Most CAD includes design programs for developing sketches of the appearance of products, the selection of color gamut; design programs that ensure the implementation of the project in the forms; technological programs that ensure the implementation of layout layouts and design of the process of cutting and sewing products.

The development of templates in CAD begins with the basic design. It can be obtained in several ways: by constructing CAD in an algorithm (by analogue constructing manually) or by inputting patterns from a digitizer. It should be noted that the construction of CAD uses the methods of visual programming and is more logical, since it provides obtaining graduation of the template for a given size-increase. The introduction of forms from digitizer gives the opportunity to get the forms for one or two sizes-increments, and the gradation is obtained by techniques of technical reproduction, which is less precise.



*Fig. 13. Modeling of the overalls in the subsystem Juliani CAD (ARM Designer)*

The construction of the model design is performed using functions based on the simplest geometric commands. In CAD the transfer of loops and their modification, expansion of the product (conical, parallel, parallel-conical), division of details of a certain configuration, cutting of parts into parts and others are performed.

Also, in the manufacture of templates CAD allows you to store them under conditions of use for different materials or colors. It should be noted that the accuracy of the obtained patterns is much higher, since the system allows to measure all relevant segments with an accuracy of millimeter, construction of the approximation of the contours is executed with mathematical accuracy, the assumptions on the seams are constructed on the principle of equidistant and are maximally correct. Particularly simplistic is the acquisition of derivative patterns such as sheathing, heel, padlocks, etc. (Fig. 13). Fig. 14 shows the appearance of the upper protective overalls.

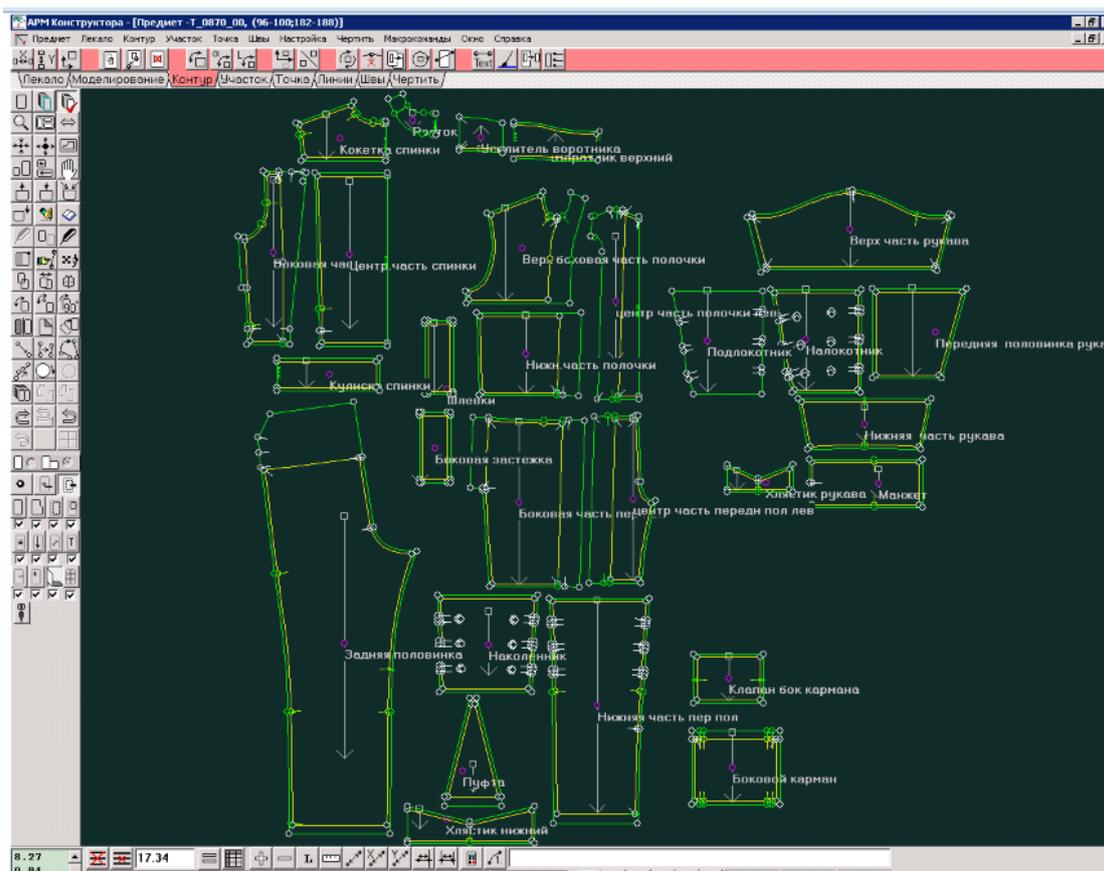


Fig. 14. Design of models of overalls model in CAD subsystem Julivi (ARM Designer)

An important stage in the manufacture of clothing is the optimization of the process of making layouts. The complexity of its solution is to provide the minimum waste of materials, based on such output data as the width of the fabric and the parameters of the pattern. Known two ways of layout of a template in CAD – is mechanized, that is, the decompressor manually sets the width of the material and performs the layout of the patterns, based on their own experience; automated - the expert specifies the parameters of the layout, the permissible deviations from the direction of the thread of the base and the corners of the turns, and then the program automatically selects the most optimal variant with the smallest percentage of intercalate attacks.

In both cases, it is important that the rules for the implementation of the layouts, such as placement of the layouts in accordance with the fringe lines, are strictly adhered to (only a slight deviation is acceptable). The interior parts, such as plumbing, sub-valves and others, are allowed to rotate to the angle of 90°. When performing the layout on a part with napkin, reflection and

pattern, it is not allowed to deploy to 1800. Some parts, for example, a heel, can be cut to optimize the layout (Fig. 15) .

The main task in the implementation of the layout is to reduce the percentage of inter-facial attacks at the expense of the most rigorous placement of patterns, while complying with the rules for the implementation of layouts to prevent defects of products, such as distortions, glare, etc.

It should be noted that the automation of the process of designing and manufacturing protective products is rather expensive, but with the rational introduction and selection of optimal software and special equipment quickly enough to pay off in conditions of average and more power of the enterprise.

Automation of designing and designing protective overalls for emergency and rescue operations with different levels of protection has ensured the high accuracy and quality of the work done.

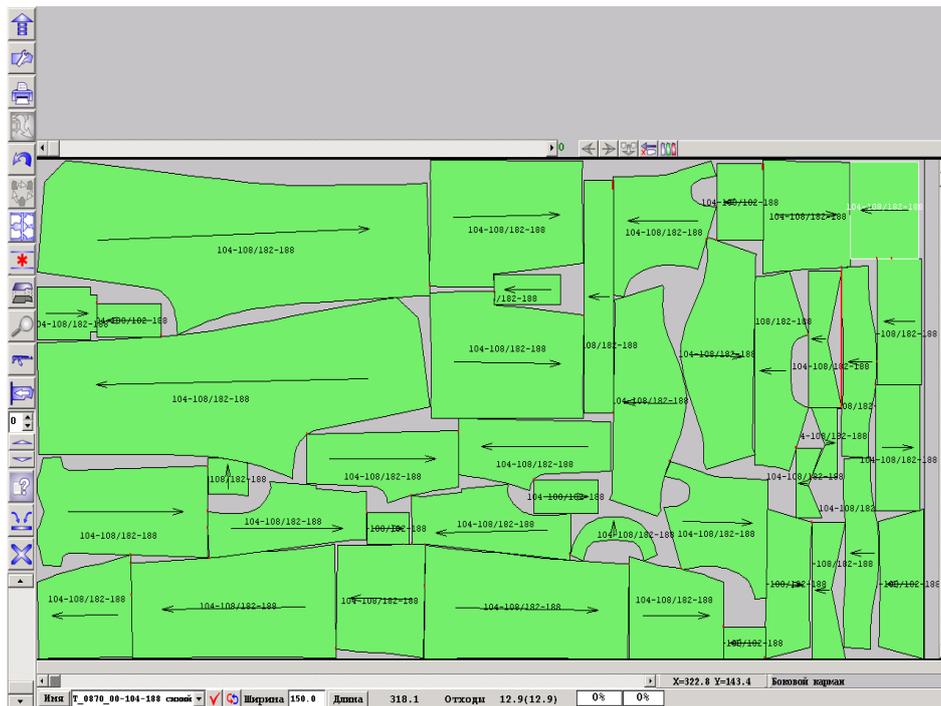


Fig. 15. Working window in the subsystem CAD Julivi (workstation Disintegrator). Layout layout

**Conclusions.** The choice of assortment of protective clothing for conducting emergency rescue works on localization, liquidation of emergency situations in aviation and elimination of their consequences is substantiated. Implemented requirements for this protective clothing. The image of the corresponding constructive elements is given. An art-design, constructive-technological solution of a single-layer protective overalls for the elimination of the consequences of emergency situations, taking into account the peculiarities of the operating conditions and the requirements, has been developed. The design-design solution was characterized, the scheme of technological sequence of manufacturing was developed, the schemes of processing of nodes were given. Multi-layer protective coveralls are proposed for localization and liquidation of emergency situations. In order to provide an adequate level of protection against identified hazards in a multi-layer overalls, heat-insulating and lining materials are provided. Introduced into the design of the evacuation loop system for the possibility of rescuing an incapacitated rescuer. The scheme of technological sequence of manufacture of overalls for conducting of emergency rescue works is developed. The design of overalls is made in the system of automated designing of clothes "Julivi", which provides high precision of design development and convenience of manufacturing in the conditions of mass production.