**MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE**
**KYIV NATIONAL UNIVERSITY OF TECHNOLOGIES AND DESIGN**

# FASHION DESIGN IN A MULTICULTURAL SPACE

**Monograph**

***To the 90th anniversary of Kyiv National University of Technologies and Design***

**A series of monographs of the Faculty of Design**

**Košice 2020**

**UDC 7.012:687.1.016**

**Recommended for publication by the Academic Board of Kyiv National University of Technologies and Design (Protocol № 3, dated 23.10.2019**)

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**FASHION DESIGN IN A MULTICULTURAL SPACE: MONOGRAPH** / M. V. Kolosnichenko, K. L. Pashkevich, T. F. Krotova et al. – Kyiv: KNUTD, 2020. – Publisched by Academic Society of Michal Baludansky, Košice, Slovakia, 2020 - 258 p. - Printed by UK Technical University of Košice, Slovakia. Printing 300 pcs.

The collective monograph contains the results of the synthesis of theoretical materials, as well as the authors` applied research developments on the design of the clothes of different assortment and purpose, made from different materials considering the modern scientific methods.

**ISBN 978-60-973703-0-5**

**CONTENT**

## 2.2. TECHNOLOGY AS A FACTOR IN THE DEVELOPMENT OF SPECIAL CLOTHES

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***Abstract.*** *The paper is devoted to the scientific and technical solutions of an actual problem of developing protective clothes for aviation staff involved in emergency and rescue operations by improving its design-projecting. The professional and qualification activities of rescuers have been analyzed; the nomenclature of dangerous and harmful factors has been developed and the topography of their influence has been identified; the requirements for protective clothes and materials used for their production have been determined. Based on the conducted theoretical and experimental researches, the assortment range of protective clothes has been formed, and design and technology concepts of overalls with different levels of protection for localization and elimination of emergencies and their consequences have been developed.*

***Keywords:*** *protective clothes, design-projecting, rescuer`s overalls, emergency and rescue operations.*

**Introduction.** The work in aviation necessitates special attention both to the safety of personnel and the protection of passengers. One of the main reasons for the injuries among the rescuers is the lack of efficient and modern personal protective equipment, which includes protective clothes. The basis of the study is the general theoretical works of L.I. Tretyakova, M.V. Kolosnichenko, N.V. Ostapenko, A.R. Horrok, J. Alongi, F. Bosco, and other scientists.

In case of an emergency, specially trained and equipped teams promptly arrive at the scene and begin search and emergency and rescue operations aimed at localization, elimination of accidents, disasters, and their consequences. During the accidents at aviation facilities, the most dangerous for workers and passengers are increased gas contamination, fragments of the metal structure, increased thermal radiation, contact with heated surfaces, rapid movement of heat flows, increased electric current, spills of fuel and lubricants, and so on. Localization and elimination of the consequences of accidents require immediate rescuers` response and appropriate decisions.

Thus, emergency and rescue operations are accompanied by a lot of dangerous and harmful factors and necessitate the efficient organization of the rescuer`s protection system, including by the design-projecting of new types of modern protective clothes with increased reliability and ergonomic indicators.

Protective clothes for emergency and rescue operations of Ukrainian and foreign production that already exist in the consumer market do not provide adequate protection of workers from all dangers and do not fully meet the specified requirements, especially regarding the ergonomics of the design. Also, it does not always protect against specific environmental conditions during aviation events. It is found that the existing clothes for emergency and rescue operations do not withstand the useful lifetime guaranteed by the manufacturer and regulated by standardized documents, which leads to an increase in the number of injuries and deaths of the rescuers. Therefore, the development of modern and effective protective clothes of Ukrainian production with predicted indicators of reliability, ergonomics, and aesthetics for aviation staff involved in emergency and rescue operations is a relevant scientific and technical task.

**Statement of the problem.** The purpose of the work is to develop modern and effective protective clothes with predicted indicators of reliability, ergonomics, and aesthetics for aviation staff involved in emergency and rescue operations.

To achieve this objective, the following tasks are formulated: to analyze the protective clothes` operating conditions, the types of existing sets of protective clothing and other personal protective equipment; to determine the nomenclature of dangerous and harmful factors and provide the topography of their impact on workers; to formulate requirements for protective clothes for emergency and rescue operations and requirements for the materials for their manufacture, and on this basis determine the value indicators of quality by conducting an expert assessment; to generalize and systematize the information base of the components of protective clothes depending on the types of hazards and operating conditions; to offer an assortment range of protective clothes with different levels of protection, in particular overalls for localization, elimination of accidents and their consequences, to develop artistic and design, structural and technological solutions of products for aviation staff, to perform design development using the system of computer-aided design (CAD), to make experimental samples.

**Results of the research and their discussion.** The main purpose of protective clothes is to provide reliable protection of a person from adverse factors and to ensure performance efficiency and normal functional state of the body [1]. In protective clothes, it is also important to combine the maximum level of protection with the ergonomics of the design.

The design of such type of protective clothes considers the specific climatic conditions of the area, seasonality of works, types, intensity, and recurrence of dangerous and harmful factors and topography of their influence, size of the working area, time of workers` continuous stay under the influence of dangerous factors, duration of working hours and breaks, professional and qualification operations, the possibility to use technical

equipment and personal protective equipment, types of characteristic movements and poses, conditions of comfort and maintenance of comfortable conditions during work, etc. [2].

It is known [3] that the rescuer`s equipment consists of special protective clothes, boots, helmet with inner liner, leather gloves, mask, breathing apparatus, and respirator for breathing protection [4, 5]. The systematization of the types of personal protective equipment for rescuers is shown in Fig. 1.

The main component of the process of designing new types of protective clothes for emergency and rescue operations is the development of design and technological solutions. The maximum level of protection of the clothes is achieved, among other things, due to the ergonomics of a product. The design of the clothes and their elements, materials, and technology of production must prevent the penetration of such hazardous substances like dust, gas, steam, surface-active agents, etc. into the underclothing space [6].

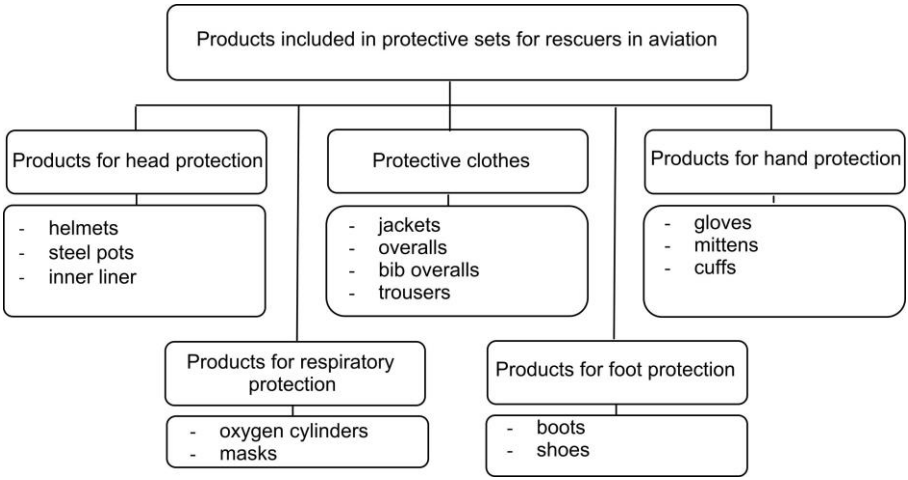


**Fig. 1. Types of protective items for workers in aviation**

Nowadays, there are a lot of protective clothes for rescuers and most often they consist of jacket and trousers (Fig. 2, a-d) or bib overalls (Fig. 2, e-h), overalls (Fig. 3). The jacket should cover the trousers at least 30 cm below the starting line of the trousers. The products mush have knee pads and be able to be dressed in protective footwear. The number, shape, and size of overlays, pockets, and other elements must be justified. To ensure the ease of use, as a rule, the structure should be of a straight silhouette [7-9].

Due to limited visibility, the presence of reflective and fluorescent materials with a width of at least 0.02 m is a mandatory requirement. The total surface area of reflective materials must be not less than 0.2 $m^2$, on the sleeves – 0.12 $m^2$, on the back and chest – not less than 0.08 $m^2$. The signal stripes on trousers and bib overalls should be placed at the lower part of the products; the surface area is not less than 0.05 $m^2$ [10, 11].

Protective clothes for rescuers must be designed to allow moisture to drain from the surface of the clothes and not be retained. Therefore, all external pockets must have flaps. For the constant coordination, the clothes should have one or more pockets for a portable radio set. The cut of the sleeve is sewn to ensure the high level of dynamism. The ventilation of the undergarment space must be provided via special holes in the areas of the greatest sweating [12-14]. Protective clothes must have a stand-up collar with a high of at least 100 mm.

Reliability indicators ensure overlays in the areas of abrasion, punctures, cuts (elbow, knee, shoulder overlays, etc.). Shoulder straps, half-belts, self-belts, etc. are used to ensure the fitting of the rescuers` clothes. To prevent hitching with moving mechanisms, the details of the clothes should not extend beyond the garment [14].

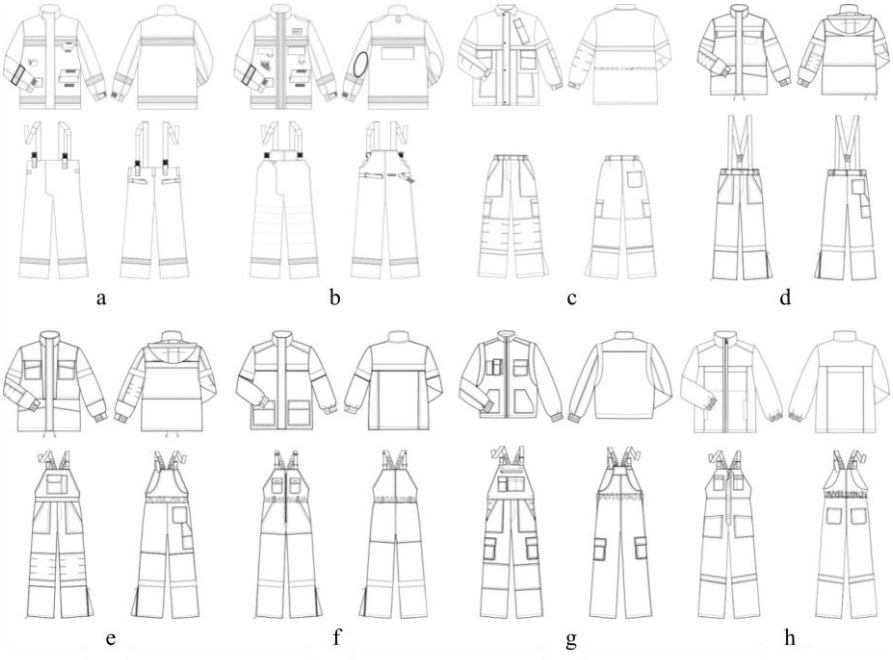


**Fig. 2. The appearance of existing types of rescuers` protective suits**

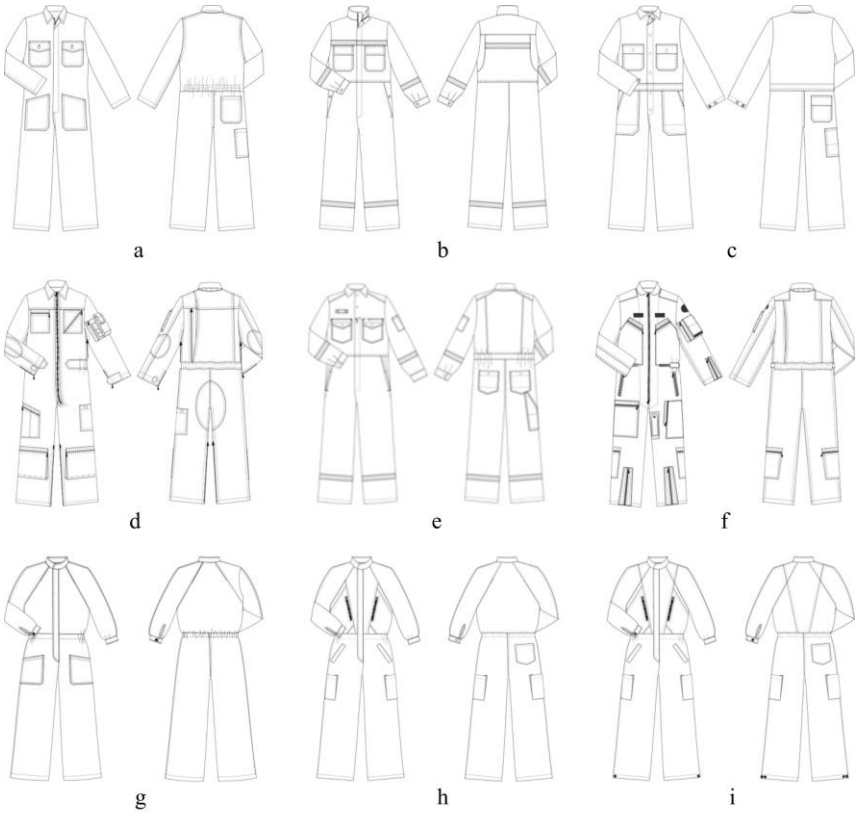


**Fig. 3. The appearance of existing types of rescuer`s protective overalls**

At present, the design of protective clothes is made on a basic-modular basis, i.e. a basic product with specified properties is created. The design is performed on the basic design of this type of clothing of the same group, with the subsequent unification, modification of details and components.

The reliability of the design of protective clothes is ensured, among other things, by the reliability of its elements. That is why the theoretically grounded selection of structural elements, their sizes, and shapes ensures the compliance of the proposed clothes with the requirements.

The clothes should insulate a person from negative external factors as much as possible. For the convenience of use of clothes according to characteristic movements and poses, it is necessary to use an anatomical cut, to compensate dynamic outsizes by designing additional tucks, gores,

and considering the properties of the materials, etc. Depending on the works performed, the clothes must have necessary and enough pockets and other structural and decorative elements. For some types of works, special pockets are designed, such as a pocket for tools, a telephone or a portable radio set, a knife, etc.

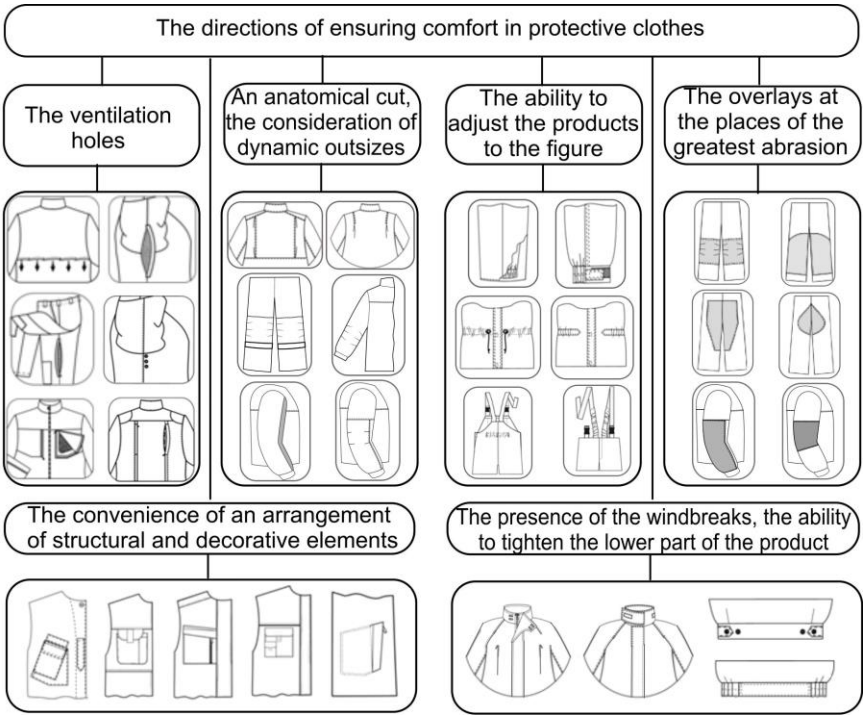


**Fig. 4. The main directions of ensuring the comfort of the workers in protective clothes**

The design of the clothes must ensure their simplest and most correct dressing and removal. The fitting of protective clothes is ensured by various details with the means of size adjustment. To improve the heat exchange in the back, torso areas, etc., the ventilation holes are designed. To increase the useful lifetime, the overlays in the places of the greatest abrasion are designed. To improve the thermal insulation properties, the windbreaks and ruffles that are adjustable at the cuff and lower parts are used in the design of protective clothes. Fig. 4 presents the systematization of the elements of protective clothes by the areas that ensure a comfortable stay of workers in protective clothes under the influence of various hazards [15].

When designing protective clothes, it is important to choose a rational design and technological solutions to ensure the basic functions of protective clothes.

The designing of protective clothing for emergency and rescue operations that will meet the imposed but often contradictory requirements is a complex and responsible task. The staff involved in fire-fighting operations and eliminating their consequences on an aircraft must be provided with protective clothes and other personal protective equipment [16-21].

The prerequisite for the design-projecting of protective clothes for rescuers is a methodological approach to its information support, based on the study of dangerous and harmful factors and the topography of their influence, the climatic conditions of the working environment, the completeness of products, the features of professional and qualification activities (Fig. 5).

In case of an emergency, the rescuers must use the entire set of clothing and personal protective equipment within a limited timeframe. Some products and their elements are worn during the entire work shift period.

Protective clothes are a complete or partial barrier between a person and an aggressive environment, so their design-projecting is performed only after the careful study of the working conditions, depending on which the type, completeness and seasonality are chosen, as well as a reasonable selection of materials, the properties of which must meet the protective, operational, and hygienic requirements. The clothes must meet a set of developed strict and contradictory requirements due to their functional purpose.

Protective clothes for rescuers must be all-season, consist of sufficient and necessary number of products of the set, each of which must have an ergonomic and aesthetic design and technological solutions: to provide a comfortable microclimate in an underclothing space, the maximum possible level of comfort; not to create difficulties in the performance of official duties; not to restrict movements, working positions or sensorial perception; not to cause movements dangerous for the crew or passengers; to ensure proper fitting and remain in the correct position during the whole period of use, regardless of the environment, movements and positions of the rescuer; to be serviceable with the possibility of replacing separate details; to have a design that ensures its fast and correct dressing.

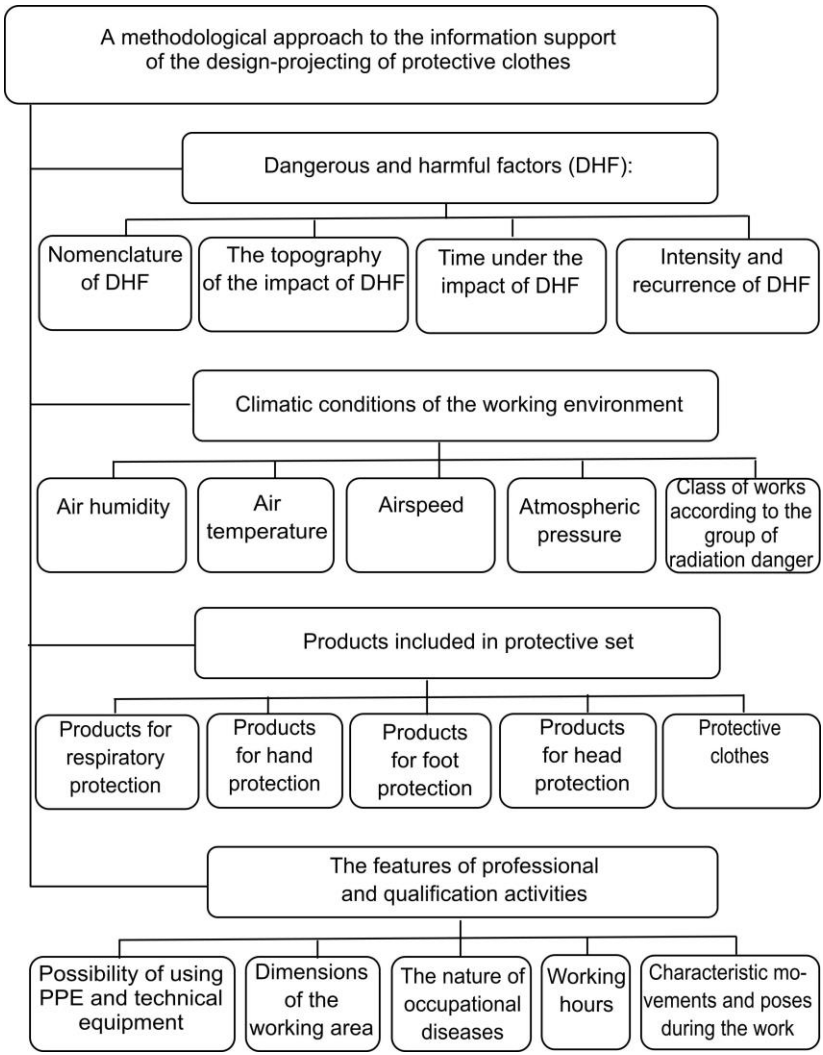


**Fig. 5. The components of the methodological approach to the design-projecting of protective clothes for emergency and rescue operations**

The quality of protective clothes depends on the properties of the package of materials that can meet the rescuers` specific needs in accordance with their purpose. Protective clothes for rescuers must meet

the indicators of protection, heat exchange, reliability, ergonomics, aesthetics, and be economically feasible.

The main component of design-projecting of new types of protective clothes for emergency and rescue operations is a development of design and technological solutions and a reasonable selection of materials with subsequent manufacture of the products [22-24].

The design and technological solutions of protective clothes, the materials from which they are made, as well as the components and accessories used for their manufacture must meet the requirements of current regulations. Protective clothes, the upper material, the inner liner of the helmet, as well as the rescuer`s underwear are subject to mandatory certification and must have a sanitary-epidemiological conclusion on their compliance with applicable regulations. Therefore, the rescuers` clothes must have an ergonomic design to ensure the maximum possible dynamic compliance and be made for two levels of protection – for localization of emergencies and elimination of their consequences.

At high external heat loads, the inner surface of protective clothes and the underclothing space overheat first. During the long-term works with a high load, the human body can overheat, but the temperature in the underclothing space should not exceed a critical value of 45 ºC.

During the development of the new type of protective clothes, the range of ambient temperatures is taken from minus 20 ºC (during the works in winter) to 400 ºC in the immediate accident area. The principle of local protection is offered considering the specificity of the influence of various harmful production factors on the separate area of the rescuer`s body. The surface of the human body is divided into zones taking into account the most vulnerable organs and tissues, and spatial orientation during the fire-fighting operations, which makes it possible to justify the requirements for zonal protection of the organism. The results of the analysis have shown that the extreme temperature in the underclothing space (around 50...55 ºC) is reached most rapidly in the head, groin, and chest areas. Based on the results of field and laboratory tests, the four areas of the firefighter`s body are identified: head, torso (back, chest), feet, and hands, which require a priority level of protection.

Therefore, protective clothes for rescuers must have a regulated period of use and storage, be constantly checked for suitability and repair, or refusal to use if necessary.

In the design process, the most important function of the clothes is a protective one. The development of protective clothes for rescuers should consider the changing parameters of the environment, the nature of the works, the worker`s anthropometric parameters, the properties of the materials used, the peculiarities of forming a package of the clothing materials under a given influence of the set of factors, etc.

The main purpose of protective clothes is to ensure the proper degree of protection of the human body from various environmental factors while keeping a normal functional state and performance efficiency.

One of the conditions for the creation of modern protective clothes of high quality that will meet the consumers` demands is to improve the quality of its design. Insufficient consideration of human morphological features (anthropometric and biomechanical characteristics, power capabilities, the sensitivity of analyzers, features of heat and moisture exchange with the environment, etc.) when designing protective clothes can lead to the creation of products with non-ergonomic, irrational design, the use of which will increase the loss of physical, thermal, nervous and emotional energy [25-28].

Therefore, a lot of requirements are based on the methodological approach to the designing of protective clothes for rescuers; such requirements consider the analysis of the working conditions, specifics of climatic conditions of the working area, features of accidents and catastrophes and works on their localization and elimination, recurrence of dangerous harmful factors and topography of their impact on the clothes (Fig. 6).

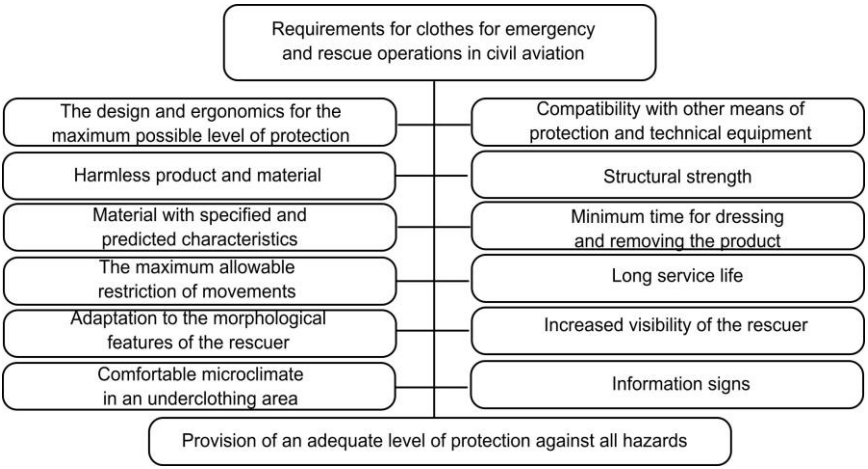


**Fig. 6. The classification of the basic requirements for protective clothes for emergency and rescue operations in aviation**

The convenience and time necessary to put on protective clothes are important for the design, as the work requires the rescuer to put on a complete set of equipment in 40 seconds or faster.

To ensure the maximum possible level of protection, the clothes for emergency and rescue operations must have an ergonomic design. The

conformity of the design of the clothes for emergency and rescue operations with the shape and size of the rescuer`s body is also important, provided that it is manufactured for a conditionally typical figure.

The comfortable microclimate of the underclothing space in the clothes for emergency and rescue operations should be ensured with the ventilation holes, which are in the areas of greatest sweating (in armpits, in step seams, in the seams of the back yoke, etc.). To reduce the sweating while ensuring a normal microclimate in the underclothing space, protective clothes should, if possible, be adequately ventilated.

The extension of the useful lifetime of a product is provided by the additional overlays in the places of the greatest abrasion (for example, elbow, shoulder, knee overlays).

The information about the profession and position of the rescuer in protective clothes is placed on the shoulder straps, emblems, and other elements that are located on the shoulders, sleeves, fronts, and back, etc.

Signal and reflective elements can provide the ability to find the worker quickly in the conditions of limited visibility (smoke, poor lighting, etc.), as well as a good aesthetic perception.

The materials from which protective clothes are made should not ignite spontaneously, flare, support the combustion, or melt; they should not have through holes.

It is also important to consider the aesthetics of protective clothes, namely the color combination and proportionality since the rescuers work with passengers who are in an unstable psychoemotional state due to the emergency.

The fulfillment of all the requirements for the design, technology, and materials will contribute to the creation of modern and effective protective clothes for emergency and rescue operations.

Therefore, the basic requirements for protective clothes and the materials are formulated, which is a prerequisite for the development of nomenclature of mandatory and recommended quality indicators.

The rescuers are provided with protective clothes made from fire-resistant materials for 48 months in accordance with the allowances for clothing and personal protective equipment for aviation workers [16]. However, in accordance with international mandatory norms (ICAO requirements), the use of unusable clothes is not allowed; so, it is repaired when it is appropriate, or replaced by a new set of clothes. The workers inspect the clothes by themselves before every shift, and every 12 months this is done by a special commission. It is allowed to use the clothes, the shelf life of which does not exceed 10 years from the date of manufacture.

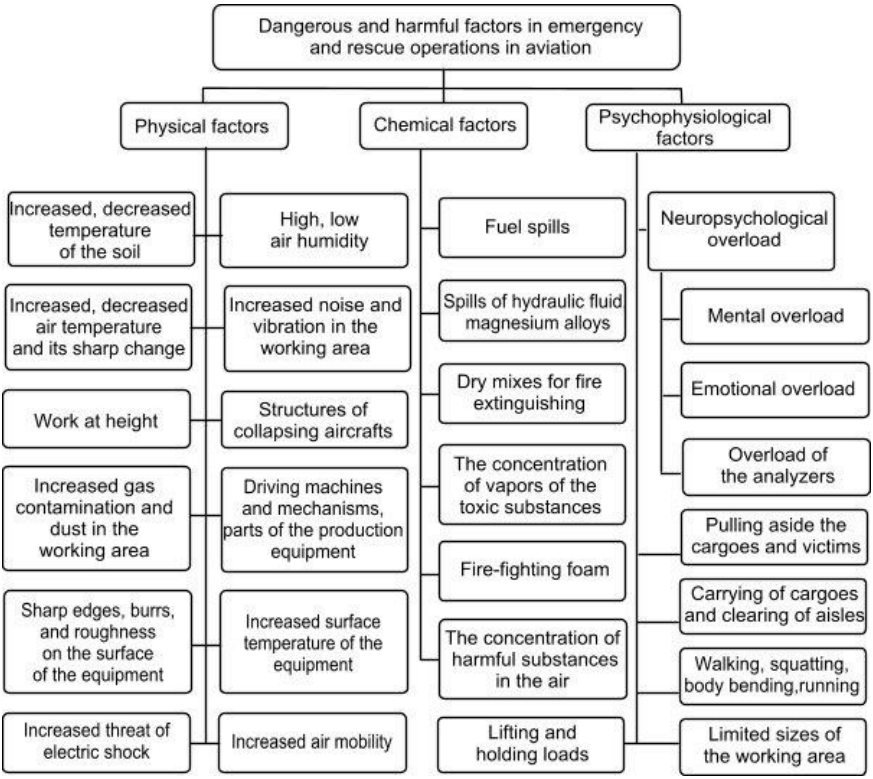


**Fig. 7. The nomenclature of dangerous and harmful factors affecting the rescuers in aviation**

Protective clothes for rescuers differ significantly from the uniform of the firefighters; such clothes are used throughout the firefighting process, as well as during the training. They are designed to protect rescuers from heat radiation, fire, injuries, etc. There are a lot of strict requirements for the rescuers` protective clothes, both for the materials from which it is made and for the design solution.

The clothes for emergency and rescue operations are a complex multifunctional object that must consider the working conditions and meet the requirements for reliability, ergonomics, and quality of garments. To perform emergency and rescue operations, it is necessary to use personal protective equipment for organs of sight, hearing and breathing, hands, feet, skin in the creation of a protective system. Even under normal production conditions, the appropriate protective clothes and additional personal protective equipment (for hands, feet, organs of hearing, and

breathing) should always be available to rescuers, providing the necessary short-term protection during emergencies [29].

The characteristics of personal protective equipment used by the rescuers in Ukraine are analyzed, and it is identified that the main reason for non-compliance of protective clothes with the working conditions is the low level of physical, mechanical, and hygienic characteristics of materials used, as well as the components for their manufacture. Such non-conformity is especially evident when protective clothes are affected by high temperatures and concentrated chemicals. The current norms of the provision of emergency and rescue teams [16], in contrast to European practice, do not include the special underwear; rescuers wear protective clothes over the daily standard form labeled “rescuer” on the chest. The form is blue and made of mixed fabric: (60…70) % is polyester and (30…40) % is cotton or wool, respectively.

In addition to the effects of high temperatures, the rescuers are affected by a lot of dangerous and harmful factors (DHF) when performing their duties (Fig. 7). The rescuers` working conditions are determined by a set of factors of working environment that affect human health and the ability to work.

The systematization of the groups of factors (physical, chemical, and psychophysiological) is based on the nature of their impact on humans:

- increased, decreased temperature of the working area – after extinguishing the open flame, the rescuers begin to perform their professional duties, while the temperature in the working area is still high;
- increased, decreased temperature of the soil in the working area, accordingly, remains increased as well;
- high thermal action is a heat that comes out of a damaged aircraft or its wreckage after a fire is extinguished;
- high, low air humidity – the extinguishing the fire by surface-active agents or other extinguishing agents leads to an increase in humidity in the working area (the primary task of extinguishing the fire is to reduce the temperature and density of smoke in the cabin by spraying jets with high-crushing drops; at the same time, it is necessary to ensure quick opening of emergence exits, to extricate the fuselage in the predetermined places to ensure the maximum speed of evacuation of passengers and crew members from the cabin);
- increased gas contamination, dust in the working area, as almost all fires are accompanied by combustion of substances with the release of toxic smoke;
- increased surface temperature of the equipment, including the hull of the aircraft, its parts and wreckage after the crash, personal belongings, and objects in the aircraft, etc. (depending on the location, aircraft fires are divided into: chassis fires, engine unit fires, spilled fuel, cabin fires; chassis fires most often occur when landing and are mainly related to the

combustion of the materials such as hydraulic fluids, rubber, and magnesium alloys; the combustion of hydraulic fluid due to the destruction of chassis hydraulic system is one of the most common fires; getting into the brake drum, heated to a high temperature (300 – 600 °C), the hydraulic fluid breaks into flames that leads to the ignition of tires of wheels; the high temperature of the fire leads to the ignition of magnesium alloys of the drums of the chassis wheels and occurs in 6-8 minutes after the start of the fire; a characteristic feature of the burning of magnesium alloys is the presence of splashes of burning metal, white glow of flame and the appearance of white dense smoke, such a fire leads to an explosion of shock absorbers of the landing gear unit and spreads to the wing or fuselage of the aircraft, depending on the type of chassis; the probability of explosion of tires, armor landing gear units and hydraulic accumulators must be taken into account during the firefighting operations, because the explosion may lead to their scattering for 100-150 m);

- structures of collapsing aircraft;
- increased noise in the working area after the burning and destruction of structures of aircraft or buildings damaged in the plane crash, the screams of people, the sirens of fire engines, ambulances, etc.;
- driving machines and mechanisms (fire engines, ladders on fire engines, fire hoses, etc.);
- moving parts of production equipment, ladders on fire engines, fire hoses, etc.;
- sharp edges, burrs, and roughness on the surface of the equipment, parts of the aircraft structure, its wreckage, fragments of passengers` luggage, other things from the aircraft;
- increased air mobility;
- the threat of electric shock.

Chemical factors include surface-active agents that were onboard or may be the part of the construction, or used in flight operations; fuel spills (up to 50 tons can be onboard), dry mixes, and fire-fighting foam; spills of hydraulic fluid, magnesium alloys, etc. A hard landing is often accompanied by a spill of fuel over a large area around the aircraft. Depending on the aircraft position on the ground, the nature of the destruction of its fuel tanks, and spill of the fuel around the aircraft, the fires are divided into double-type and one-type fires. The double-type fires of spilled fuel are the most dangerous and difficult in extinguishing and rescuing people.

The psychophysiological factors are divided into physical, namely, static, and dynamic overloads and neuropsychological overloads. The static overloads include lifting and holding the load. The dynamic overloads include carrying loads and walking, squatting, body bending, running, etc. The peculiarities of the rescuers` work are the performance of their professional duties and tasks in an aggressive environment together with danger to life and health, under the adverse effects of physical and

chemical factors, high “cost” of their activities, decisions taken, increased responsibility for saving people, material valuables, localization and liquidation of an emergency, in the lack of time for the analysis of information obtained, making the decision and performance of necessary actions, difficult dynamics of changes of functional states, high level of nervous and mental pressure, increased physical activities, possibilities of panic and fuss caused by both victims and strangers, dynamic changes in the environment, emergencies, etc. [16].

Therefore, the working conditions stipulate the increased demands not only on the health and physical training but also on the individual psychological make-up of the rescuers.

Analytical studies of the rescuers` working conditions allow developing the nature and recurrence of dangerous and harmful factors and the topography of their impact on protective clothes during the emergency and rescue operations (Fig. 8) [29].

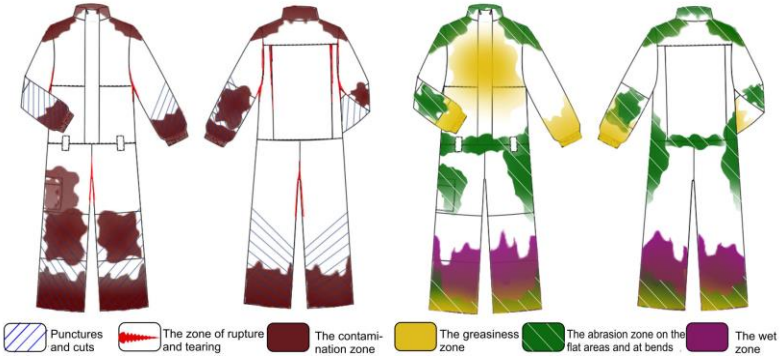


**Fig. 8. The topography of the influence of dangerous and harmful factors during the emergency and rescue operations in aviation:**
a – front view; b – back view

It should be noted that the rescuer in clothes is completely under the influence of the high temperature and dust, thus, it is not indicated on the topography. The topography of the influence of dangerous and harmful factors shows the following areas:

- the zone of punctures and cuts arising from the wreckage of metal and other aircraft structures or sharp objects that are onboard or around it;
- the zone of rupture and tearing, which is most often in the area of shoulder blades, armpits, leg seam, etc.;
- the contamination zone covers the area of the shoulder slope, neck, elbow and knee joints, the lower part of trousers and sleeves, the area around the pocket;

- the abrasion zone on the flat areas and at bends (due to the frictional force in the armpits, on the waist upon contact with special equipment and belts, in the pocket area, around the neck, in contact with the means of head protection, on the shoulder slope and along the lower part of trousers);

- the greasiness zone characterizes possible oiling by spilled substances that are on board or are a part of its design and mechanisms; the areas along the lower part of the sleeves and in front are the areas of the greatest contamination;

- the wet zone is in the shoulder slopes and along the lower part of trousers.

The consideration of the developed topography makes it possible to create the design of protective clothes that will provide maximum protection, ergonomics, and reliability of the product.

When designing clothes for emergency and rescue operations in aviation, it is necessary to consider a lot of factors, including thermal radiation, contact with heated surfaces, rapid heat flow, static current, etc. Ergonomic design is also important, as clothes should not curtail the movement, have ventilation holes for heat and steam, provide speed, ease of dressing and removing, have identification marks, and be combined with other personal protective equipment. The design of the clothes must be compatible with the protective equipment used by the rescuer during the work.

The selection of the optimal version of reliable, ergonomic, and compositionally perfect design of protective clothes is complicated by the variety of requirements.

The main purpose of protective clothes is to ensure reliable protection of the worker from various environmental factors while keeping normal functional condition and performance efficiency. Also, protective clothes must provide the necessary hygienic conditions during the work, normal thermoregulation of the body, be comfortable, light, not curtail the movement, be wet- and chemical-cleaned from dirt. Protective, operational, and hygienic properties of clothes primarily depend on the materials from which they are made, as well as on the design.

Different types of clothes are used in emergency and rescue operations, namely: jackets, trousers, bib overalls and overalls. Based on the survey conducted among the rescuers, it is found that just overalls meet the requirements to a high extend. This is because it takes less time to put it on, and considering the ergonomic component, it is more comfortable than a suit.

Although this product is not convenient in use, it provides greater protection due to the more closed body of the rescuer.

A prerequisite for the design of protective clothes is to consider all the requirements for clothes. It is known that utilitarian functions are the

basic functions of protective clothes, so the greatest attention is paid to them. Fig. 9 lists the elements, details, components of overalls that ensure its basic functions, and due to the introduction of which the protective, ergonomic, aesthetic, and reliability indicators will increase. It is important to remember that when designing protective clothes, each of the elements should be appropriate [30].

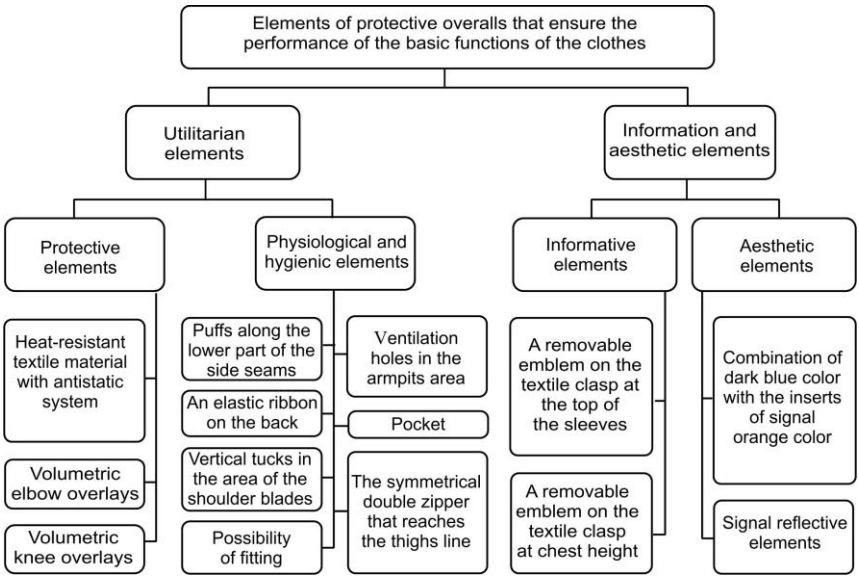


**Fig. 9. The list of the elements of protective overalls designed to provide their basic functions**

Aesthetic perception is also quite important for the rescuer`s clothes. This is because during the performance of his professional activities he, in particular, has to come into contact with people who are in an unstable psycho-emotional state due to a plane crash. That is why the appearance of protective clothes should worsen neither this condition nor psychological trauma. Also, the harmonious color combination is important, which at the same time must include bright elements to recognize the rescuer in poor visibility.

When performing professional and qualification activities, the rescuer has to work in the conditions of limited visibility, for example, in high smoke. That is why protective overalls must have signal and reflective elements.

An important aspect for the design of the rescuer`s protective clothes is to ensure a normal microclimate in the underclothing space. It is known that when the body overheats, the mechanisms of thermoregulation

increase heat transfer, which is carried out through the circulatory system through sweating. Therefore, to ensure the removal of excess heat and moisture from the underclothing space, the ventilation holes are made. The greatest moisture occurs in the armpits, therefore, the most effective is to place ventilation holes there. Also, there is a 20 cm long ventilation hole in the sleeve-side seam, which is closed with a zipper and a strapping that is cut as a one-piece. When opening the zipper, the hole is closed with a textile net.

The peculiarity of the rescuer`s work is that he must put on a complete set of equipment in 40 seconds or faster, so the question of fast and convenient dressing is quite important. It also should be noted that the dressing of the overalls must be done without removing shoes. It is found that the central placement of the zipper is inconvenient and inefficient, that is why a new type of fastener is proposed, which consists of two symmetrically located zippers that reach the thighs line. Due to this, the overalls are fully open and do not restrict movements during dressing. For the convenience of dressing overalls in shoes, the width of the lower part of the trousers is increased and the presence of puffs in the side seams of the trousers on the zipper is provided. The puffs are made of signal orange fabric for visual control whether the fastener is closed or not.

The ergonomics of the overalls provide additional volume in elbow and knee joints. In these areas, volume overlays are more comfortable as they consider the dynamic increase when performing movements of the arms and legs and put less pressure on the joints. In their manufacture, the volume is achieved through the introduction of gores and tucks. The overalls also have an additional layer of fabric in the elbow and knee areas to extend the service life. When designing overalls, it is very important to ensure ergonomics during the forward inclination of the body. For this purpose, it is necessary to consider the dynamic addition to the length of the back, which is 6 – 9 cm. To compensate for this addition, a new design of the back of the overalls is developed, which has a vertically placed elastic ribbon. The back has a cutting yoke, in the stitching seam of which an elastic ribbon 250 mm wide is sewn, the lower edge of which is sewn to the upper part of the back half, with the possibility of simplified replacement of the elastic ribbon after the reduction of its deformation characteristics. For the convenience of the performance of movements by hands, two vertical tucks are placed in the area of the shoulder blades.

Provided that protective clothes are manufactured industrially for a conditionally typical figure, it is important to be able to adapt clothes to the morphological characteristics of the worker. Therefore, the rescuer`s overalls provide several ways to adjust their width or length, and so on. Firstly, along the waistline, there are hooks and self-belt on the back, thus, it is possible to run the belt, including a special fire belt. Secondly, the lower part of the sleeve is decorated with a ruffle with an elastic ribbon and a half-

belt to adjust the width of the ruffle. Thirdly, to lower part of the trousers has half-belts to adjust the width of the lower part of the trousers.

Based on the analysis of operating conditions and assortment range of protective clothes for emergency and rescue operations, and the study of professional and qualification activities, a new design and ergonomic solutions of protective overalls is developed. Various structural elements that will meet the requirements for protective clothes are substantiated. Also, attention is paid to the new solutions of individual parts and components used for greater convenience in the performance of the duties by rescuers [6].

Based on the analysis of all initial data on the design-projecting of protective clothes, an assortment range of the products for emergency and rescue operations is presented, namely single-layer and multilayer overalls with different levels of protection.

1. Single-layer overalls for the elimination of the consequences of emergencies

The selection of the design and technological solutions is based on the requirements for protective clothes and must consider the operating conditions. It is found that the use of overalls is the most effective for rescuers in aviation. Considering the professional and qualification activities of rescuers, it is rational to choose a straight silhouette and a sewn-on cut of the sleeve. The ergonomics of the overalls is achieved using additional overlays on the knee and elbow joints, ventilation holes, elastic ribbon on the back, central double fastener, straps, elastic ribbon along the lower part of sleeves, puffs along the lower part of trousers, and stand-up collar.

The design of the structure considers the analysis of information on accidents and catastrophes, intensity, the topography of dangerous and harmful factors, and the requirements for protective clothes for rescuers. It should also consider the properties of the material; for that reason, the experimental studies have been conducted.

The construction of the basic design of the overalls is made using the CAD system “Julivi” (AWS Design, Designer).

The design of the overalls must consider the requirement for minimum time for dressing. Given that the central fastener in the overalls is not ergonomic, two symmetrically located zippers that reach the thighs line are designed. Also, for the convenience of dressing and preventing the ingress of foreign substances into the underclothing space, an elastic ribbon is placed along the lower part of the sleeves, the width of the lower part of the trousers is increased, and the presence of puffs on the zipper is provided. With a constant forward inclination of the body, it is necessary to consider the dynamic addition to the length of the back. It is found that such addition is approximately 6 – 9 cm, therefore, the new design of the back with the use of the elastic ribbon is presented.

We should note that there are a lot of structural elements that can increase the functionality of the overalls, that is why it is advisable to choose the optimal amount of such elements as it significantly affects both the weight and the cost of the overalls. There is no need to add such additional elements as pockets, straps, etc. to the overalls. It is found that in the performance of their professional duties, the rescuers mainly use one pocket to keep protective gloves.

The design and technological solutions of protective overalls provide for:

- elastic ribbon, which is placed along the length of the back, and tucks in the shoulder blades area to increase ergonomics;
- two symmetrical zippers for easy dressing and removing;
- overlays in the knee and elbow joints to increase abrasion resistance;
- ventilation holes in the axillary area for a comfortable underclothing microclimate;
- seams with double grinding off for the increased durability of the design;
- elastic ribbon and straps along the lower part of sleeves for compatibility with gauntlets;
- widened pants, puffs, and straps along the lower part of trousers for the convenience of dressing overalls in shoes;
- patch pocket to keep the gloves;
- hooks along the waist to fasten the belt for adaptation to the rescuer`s morphological features.

The overalls are cut at the waist, the upper part of the front has horizontal divisions, the back has a cutting yoke and vertical divisions; in the central part of the back, there is an elastic ribbon 250 mm wide, and two tucks in the area of the shoulder blades. The lower part of the overalls consists of the front and back halves of the trousers, which have overlays in the knee joints area. Along the lower part of trousers, there are puffs and straps. On the right half, at the level of the thighs, there is a patch pocket with a flap. The overalls are with sewn-on sleeves, the lower part of which is decorated with an elastic ribbon and straps. Overlays are located in the area of elbow joints. The overalls are fastened with two centrally placed zippers that reach the thighs line. The neck is decorated with a stand-up collar. At the waist, the hooks for the belt are located. On the front halves and on the upper part of the sleeve, there are textile clasps for fastening of information elements (chevrons). Also, 50 mm wide reflective strips are placed on the front half below the armhole line, on the back along the shoulder line and at the waistline, on the sleeves above the elbow and along the lower part of the trousers.

The designed and proposed design and ergonomic solutions of protective overalls for emergency and rescue operations in aviation in

compliance with all requirements are presented in Figure 10.

The development of the design of protective overalls is a complex and time-consuming process. The proposed protective clothes for emergency and rescue operations are ergonomic and maximally protect the body of the rescuer; such clothes are compatible with other personal protective equipment. A systematic approach is used to develop protective clothes.

Therefore, the proposed protective heat-resistant overalls differ from existing analogs, because the front half is made as cutting one at the waist and knee line, additionally equipped with a vertical insert that passes through the center of the front half to the knees and connected to it by two zippers, the back half is made as cutting one at the waistline and the line of the shoulder blades with a floating back attached to the back half along the line of the shoulder blades and containing two vertical tucks, made with the possibility of opening at 50 mm, and an elastic ribbon sewn along the cutting lines of the back half. The novelty of the proposed design is confirmed by the patent of Ukraine for a utility model [30].

2. Multi-layer protective overalls for localization and elimination of emergencies in aviation

A new design and ergonomic solutions for protective multi-layered overalls for emergency and rescue operations in aviation are developed and proposed (Fig. 11).

The rescuers` overalls are made of gray and red fabric, a heat-insulating layer, a lining fabric, and a grid, a split leather used for processing of the lower part of sleeves and trousers, and a membrane. Threads that are resistant to burning and high temperatures are used to connect the parts of the overalls. Heat-resistant zippers are used in the manufacture of overalls. The fastening of the information chevrons on the top of the sleeves and along the breast line, to the shoulder straps and along the lower part of trousers and sleeves is carried out using a fire-resistant textile clasp. Also, 50 mm wide reflective strips are provided for emergency and rescue operations in limited visibility. The overalls are thermal protective overalls with an evacuation loop containing sleeves and a stand-up collar, the front half cut along the waist line and the knee line, additionally equipped with a vertical insert passing through the center of the front half to the knees and connected to it by two zippers, the back half cut along the waistline and the line of the shoulder blades, with a floating back attached to the back half along the line of the shoulder blades and containing two vertical tucks, made with the possibility of opening at 50 mm, and an elastic ribbon sewn along the cutting lines of the back half; such overalls have heat-insulating and lining layers, a protective valve along the neckline on the back, the system of evacuation loop consisting of upper and lower loops located between the heat-insulating layer and the top material [31].

a b

**Fig. 10. The general appearance of protective overalls for the elimination of the consequences of accidents in aviation наслідків аварійних ситуацій в авіації:**
a – front view, b – back view

a b

**Fig. 11. The general appearance of the rescue overalls for localization of emergencies:**
a – front view, b – back view

The proposed overalls have an additional thermal insulation layer and lining, which allow the rescuer to work in high temperatures and near

open flames. The overalls also have reinforcing shoulder overlays. The areas of the knee and elbow joints are reinforced with volumetric knee and elbow overlays; along the lower part of the sleeves and trousers, there are reinforcing overlays made of split leather. The front protective valve is in the chin area. At the back, on the yoke under the neck, there is a protective valve for the outer loop; under the valve, there are internal and external reinforcing overlays made of split leather aimed to increase the strength of the structure in the area where the evacuation loop comes out. In case of moisture entering the underclothing space, a membrane is placed along the lower part of the sleeves and trousers for unhampered removal of moisture from the underclothing space.

The reflective strips are placed on the trousers above and below the knee line, on the sleeves above and below the elbow line, on the back at the waistline and the shoulder line, on the front half along the armhole line and along the central part, along the protective valve that closes the outer evacuation loop. At the top of the sleeves and along the chest line, there is a textile clasp for fastening of chevrons. On the front half along the waistline, there are two hooks, and on the back half, there is a self-belt to run the belt.

The evacuation loop system is located between the heat-insulating layer and the front and back sides and consists of the upper and the lower loops (Fig. 12).

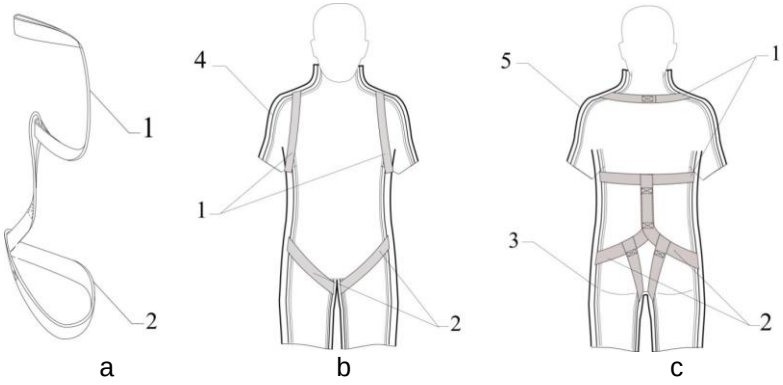


**Fig. 12. The appearance of the evacuation loop system:**
a – side view; b – front view; c – back view; 1 – the upper loop; 2 – the lower loop; 3 – inner lining layer; 4 – heat-insulating layer; 5 – outer heat-resistant layer

During the performance of the duties, the rescuer may suffer injuries, including loss of consciousness, so the introduction of the evacuation loop

into the system provides an accelerated rescue of the incapacitated rescuer.

The execution of the evacuation loop in the form of two interconnected straps-loops, one of which covers the shoulders through the armpits, passing at the level of the shoulder blades through the opening of the other, which in turn covers the legs at the thighs area (in the perineum), provides reliable and fast pulling off the rescuer from the danger zone in case of loss of consciousness or injury (Fig. 13). The lower loop consists of a belt folded in half, forming a hole that is fixed by a threaded connection parallel to the line of the spine. The ends of the loop wrap around the loop itself, creating holes that are threaded together, thus forming additional loopholes to be dressed on the human figure. The holes provide an opportunity to adapt the system to the morphological features of the rescuer and be convenient during operation. The upper loop extends through the hole of the lower loop and extends through the holes of the yoke at the back of the overalls to the outside, thus forming an outer loop. The length of the evacuation loops includes overhangs for the operation of the evacuation system itself and comfort in use.

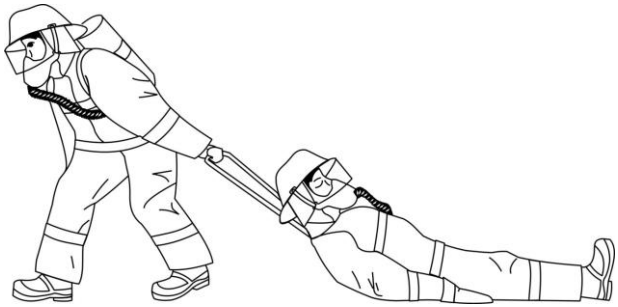

**Fig. 13. The evacuation of the rescuer from the danger zone in case of loss of consciousness or injury**

Therefore, the design and ergonomic solutions for protective overalls with different levels of protection are developed. The components of protective clothes for rescuers in aviation are systematized. The technological schemes of assembly and cross-sections of threaded connections of protective overalls for rescuers are presented. When developing the design solutions, the compatibility with personal protective equipment and technical equipment used by the rescuer during the performance of his professional and qualification duties is considered (Fig. 14).

The production of modern and effective protective clothes requires fundamentally new approaches to its design. In this connection, the

systems of computer-aided design of clothes (CAD Systems) become more and more widespread. Their use allows to significantly reduce the time for the development and the number of tools used, while increasing the accuracy of design, reducing the material costs and processing time by optimizing the work by using personal computers (Fig. 15).

a b c

**Fig. 14. The sequence of dressing a set of clothes for emergency and rescue operations:**

a – working clothes; b – protective overalls without equipment;
c – protective overalls with equipment

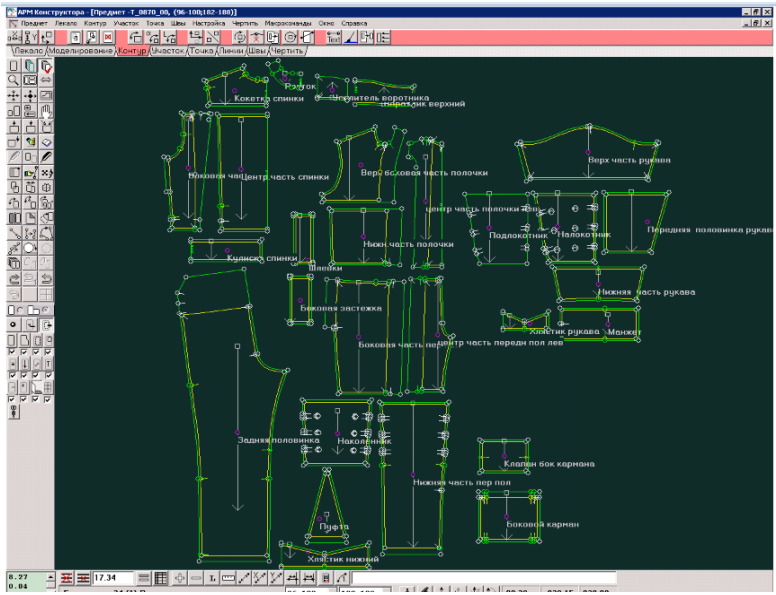


**Fig. 15. The processing of patterns of overalls design in the CAD subsystem “Julivi” (AWS Designer)**

**Conclusions.** The actual scientific and technical task on the creation of effective and modern protective clothes with predicted indicators of reliability, ergonomics, and aesthetics for emergency and rescue operations in aviation based on theoretical and experimental research is solved in the work. The analysis of professional and qualification activities of rescuers gave the basis to define the nomenclature of dangerous and harmful factors and the topography of their impact on the clothes, as well as to develop requirements for the rescuers` protective clothes and to the materials used for their manufacture.

The automation of design-projecting of protective overalls for emergency and rescue operations with different levels of protection has ensured the high accuracy and quality of development.

The varieties of design and decorative decisions for the introduction of the rational elements into the design and technological solutions of protective clothes that would provide a proper degree of the worker`s protection against the certain dangers have been systematized. The design and technological solutions of protective overalls with different levels of protection for localization, elimination of emergencies, and their consequences have been developed. The design of the overalls is made in the CAD subsystem “Julivi”, which provides high accuracy of design and ease of manufacture in terms of mass production. Also, the assortment range of clothes for rescuers with different levels of protection has been developed.

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