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Селина Н.Г., Прохоров В.Т., Дмитриенко Н.А., Рева Д.В. Исследование и анализ возможностей отечественных производителей по обеспечению военнослужащих Арктики востребованной продукцией (сообщение 2)

Selina N.G., Prokhorov V.T., Dmitrienko N.A., Reva D.V.
Research and analysis capabilities of domestic manufacturers to
provide military products demanded Arctic (2 message)

В сообщении 2 проведены исследования по созданию костюма для защиты от холода военнослужащего, находящегося в условиях Арктики. В основу создания теплозащитной одежды для эксплуатации в условиях Арктики должен быть положен научный принцип, учитывающий теплозащитные характеристики утепляющих и подкладочных материалов. При производстве одежды используются утепляющие материалы, способные снизить тепловые потери через одежду. Эти материалы различны по своей структуре, волокнистому составу, толщине, поверхностной плотности и по назначению. Выбор таких материалов производится согласно свойствам основного материала и зависит от условий эксплуатации одежды и ее назначения

Ключевые слова: костюм, военнослужащий, в условиях Арктики, холод, холодовой стресс, охлаждение, теплозащитная одежда, материал, утеплитель, волокно

Селина Надежда Геннадьевна
Аспирант
Донской государственный технический университет
г. Шахты-500, ул. Шевченко, 147

Прохоров Владимир Тимофеевич
Доктор технических наук, профессор
Донской государственный технический университет
г. Шахты-500, ул. Шевченко, 147

The report 2 studied to create a suit for protection from the cold soldiers in Arctic conditions. The basis of creation of heat-shielding clothes for operation in Arctic conditions must be put to a scientific principle, taking into account the heat-shielding characteristics of insulation and lining materials. In the production of clothing used for insulating materials that can reduce heat loss through the clothes. These materials are different in structure, fiber composition, thickness, surface density, and for other purposes. The selection of such materials is made according to the properties of the base material, depending on the operating conditions of clothing and its destination

Key words: a suit, the serviceman, in the conditions of the Arctic, cold, Holodova a stress, cooling, heat-shielding clothes, material, heater, fiber

Selina Nadezhda Gennadevna
Graduate
Don state technical university
Shakhty-500, Shevchenko st., 147

Prohorov Vladimir Timofeevich
Doctor of Engineering Sciences, Professor
Don state technical university
Shakhty-500, Shevchenko st., 147

Дмитриенко Надежда Алексеевна
Кандидат педагогических наук, доцент
Донской государственной технической
университет
г. Шахты-500, ул. Шевченко, 147

Dmitrienko Nadezhda Alekseevna
Candidate of Pedagogic Sciences, Associate Professor
Don state technical university
Shakhty-500, Shevchenko st., 147

Рева Дарья Валерьевна
Аспирант
Донской государственной технической
университет
г. Шахты-500, ул. Шевченко, 147

Reva Daria Valerievna
Graduate
Don state technical university
Shakhty-500, Shevchenko st., 147

More than 1 450 objects of military infrastructure were introduced in 2015. It was pointed out by General Mikhail Mizintsev.

The process of constructing infrastructure of the Arctic zone, the development of aero network, wharfage and construction missile systems are priority tasks for further development of the region.

There are 21 thousand people in the Far North today. This year, we need to manufacture clothes for the protection.

This year the Russian military prepared latest strategic missiles "Yury Dolgoruky", "Alexander Nevsky" and "Vladimir Monomakh". On an ongoing basis over the seas of the Arctic Ocean are patrols anti-aircraft naval aviation of the Northern Fleet. Every year in the Arctic comes from the layers control our warships and support vessels. The great attention is paid to ammunition, clothes for men to action in arctic conditions.

The range of materials are used for the manufacturing heat-shielding clothes, made of raw material, production methods, purpose and can be combined in the following groups:

- Basic are the fibrous tissue of different composition uppers and lining, laminated fabrics, films, fabrics with film, windproof and rubber coatings, etc.;
- Insulating materials are batting, cotton, foam rubber, natural and artificial fur, non-woven insulation and others.
- Materials for connecting parts are sewing thread, glue and thermoplastic materials, welds, etc.;
- Hardware are buttons, hooks, loops, buckles, fasteners and others.

Manufacturing clothes we use insulating materials that can reduce heat loss. These materials are different in structure, have fiber composition, thickness, surface density, and for other purposes. The selection of such materials is made according to the properties of the base material, depending on the operating conditions of clothing and its destination.

The main requirements for insulated materials are:

- Heat-shielding;
- Low air permeability;
- Good hygroscopic properties;
- Ease;
- Softness;
- Little thickness, and others.

Insulated, sealing and lining materials are widely used in manufacturing package winter clothing. This design is constructed as follows: the main (coating) material, waterproof gasket, insulated lining (insulation) and the lining. Each layer of the package performs a certain function, and the materials made up the package, must meet certain requirements.

The basic material must be strong, beautiful, lightweight, durable, small crease and different water absorption, the material for windproof lining is thin, light, and soft, has slight air permeability. If the base material has an air permeability of not more than $6-10 \text{ dm}^3 / (\text{m}^2 \cdot \text{s})$, windproof lining cannot be used.

Insulation is a basic layer that provides thermal protective function of clothes. The materials of this layer should be light, porous and characterized by low thermal conductivity and high elasticity under compression. Using a windproof lining to provide the desired breathability package heat-shielding clothes, breathability warming layer should not be critical. Heaters for clothing are made of fur, wool, wadding, bonded fabrics and foam volume.

The lining should be thin, smooth, have low density, have high abrasion and wrinkle resistance, low shrinkage.

As to the thermal insulation properties of insulation pads we should determine the influenced of the density and thickness of the spacer, technology its manufacturing and duration of wearing clothes.

There are batting knitted, sewed, and needle, as well as non-woven insulated material. Knitted batting is produced by warp knitting machines, raschel weave tights with weft yarn. The base consists of cotton yarn linear density of 29-25. The weft yarn may be woolen (not less than 75% wool) or half-wool (not less than 30% wool).

For the manufacturing of insulation pads cotton wool, much less – wool are used.

The raw material for woolen cotton linters are sheep, camel and goat wool, woolen waste production is used for the patch and wool rags.

Special textiles with a special texture is required to protect against hypothermia when the air temperature is below 30°C . Combined with the strong wind, rain, such low temperature can lead to death [1].

The most effective method of hypothermia is to reduce conductive heat loss. The package materials for heat protective clothing should be layered. The inner layer (body) cannot absorb the heat insulating middle layer if it is not air-permeable but with moisture outlet, the outer layer is wind and water resistant.

Currently, there are a lot of heaters based on synthetic fibers. Insulation is a basic layer providing thermal protective function of clothes. It is designed mainly to create clothes relative to a stationary layer of air, which is known, as a poor conductor of heat. The materials of this layer should be light, porous and characterized by low thermal conductivity and high elasticity under compression.

The best material is considered by many producers and consumers, it is recognized as fluff. However, down, soaking up the moisture, and thereby losing heat-insulating properties the procen of need to be pointed out clothes with the filler is difficult to erase since part of it can come out to outside.

As to the heat-shielding characteristics we can call natural wool. It is well "breathes" material, creating thermal comfort. However, it has significant drawbacks:

when wet – it becomes very heavy need a long time drying, it is completely ceases warming. And also it is a very prickly. Products of this type of insulation should be best to take to the cleaners, because they deform when washing. Using natural wool as insulation significantly increases the cost of the finished product.

Here are the most well-known non-woven insulation imported.

Thinsulate is considered as one of the best insulation at the moment for its properties are thermo feathers []. It consists of very fine fibers hundreds of times thinner than a human fur. Because of its texture keeps wonderfully warm jackets of tinsuleyte are light, thin and warm. A heater has compose 65 % of polyether and 35% of polyester fibers.

Hollofayber, fayberskin, Fibertech, polifayber, izosoft. Synthetic insulation is made from polyester fibers having the form of balls, springs, etc. Able to withstand low temperatures below -25 °.

Holspring is a modern, high-tech insulation that retains heat very well, it is lightweight, hypoallergenic and absolutely no shrinks to wear and washing.

Holspring is a trademark of one of the varieties syntepon, but with high consumer qualities. It has many analogs with similar performance (termofayber, hollafan). Holspring has a high heat-shielding properties, environmentally friendly (the material is safe even for infants), it has a high dimensional stability easy the recover shape and has springy fiber structure. Holspring has a low density and light weight. Holspring completely absorb moisture and excellent "breathing" material.

Hollofan is made from hollow primary polyester fiber. The name comes from the English hollow (hollow) and the first letters of the company's products "Fanema." It has a springy structure that forms interlacing spiral hollow fibers. Products from this heater well their restore shape after deformation. It does not absorb moisture, odors, hypo-allergenic. Producing process is the same but with the addition some wool (30%). This insulation prevents the growth of bacteria.

Halcon is it made from helically crimped partially siliconized polyester fibers securely attached to one another thermally. Currently Halcon has no analogues. Halcon density ranges from 2500 to 3000 g / m².

PrimaLoft® is produced by the American company Albany International. These are a modern series of heaters from ultra – thin polyester fibers. Due to the fact that these fibers are very soft and thin, they have special hollow structure, PrimaLoft® provides excellent thermal insulation properties for a long time.

Thermolite is a synthetic fiber based on polyester, developed and patented by the US company INVISTA (a subsidiary of the corporation DuPont). This material as well as PrimaLoft® has a hollow structure, so that has a high thermal insulation characteristics even in a humid environment and has a good moisture resistance, almost without absorbing it.

Primaloft is synthetic material that has high heat-shielding properties. Created by Albny Interional. Based on the study of the structure and properties of goose down this material was created by Primaloft.

Advantages of imported heaters are obvious but has great to sanctions and restriction of supply disruptions.

National Russian market of polyester insulation is only beginning to emerge. Sintepon does no longer satisfy the requirements of most manufacturers, and European and American heaters, despite their quality, are expensive, so the cost of the final product with their use greatly increased, based on over two decades of experience in the light industry, the company "RadugaTekstil" offers a way to solve the problem and the solution by introducing the newest nonwoven insulation "Seabury" [2].

At this point, "Seabury" produces three products: "Seabury Classic", "Sieber Micro" and "Seabury corduroy."

"Seabury Classics" is a high-quality universal heater it has selected formula that makes insulation more practical, increasing its strength as a part of microfiber material makes it warm and easy.

"Seabury Classic" is perfect for the insulation for any heat-shielding clothes.

"Seabury Micro" is a domestic insulation, material consisting entirely of microfibers. Clothing with "Seabury Micro" is not only very warm, but also light and thin, which makes the heater to be an indispensable material in the manufacturing of insulated model or professional sportswear and all kinds of tourist equipment.

"Seabury Velvet" is a fluffy microfiber insulation with the addition of crimped hollow fibers.

Termofinn from "Termoreal" is made only from the hollow viscose fiber. So is environmentally friendly. This fact is confirmed by certificate quality certificate Quality Standards for Oeko-Tex Standard 100 of the first category.

Termofinn [2] is a heater produced by finish technology that retains its shape after washing is effective at low temperatures.

Termoflnn Plus is a classic insulation Termofinn with the surface, which ultimately reduces the migration of fibers and facilitates cutting.

In 2011, specially for Russian market a unique brand has developed new production of the product – insulation Alpolux, which perfectly combines the heat properties of STI and microfiber [2].

Alpolux is the premium insulation produced according to Austrian technology, genuine STI Merino, lightweight insulation with the highest thermal insulation properties.

Termofinn Micro is made from ultra-fine microfiber, the same world-renowned luxury fiber insulation.

Termofinn Micro is unusually soft warmer light, with very good retention heat of the day recommended I – III, and in the IV and special climatic zones.

Russia stretches over a vast territory. In winter, most of the regions in this country are covered with snow, remaining 220-260 days a year. The average temperature of the coldest month varies from west to east of the country from -20 to -40 ° C, and in Yakutia, reaches -68 ° C. Therefore, the urgent role of warm clothes of domestic production, is great, and shielding property, and should exceed the best foreign analogues.

At present, there is no enough warm clothing for harsh winter conditions than the traditional costume is made of reindeer fur. However, deer fur is not suitable for the modern man, as It has a large mass (1.8 kg / sq m) and thickness (up to 53mm). This creates problems, making the movement hard. Besides fur coat, make up the bulk sheet, are quickly broken down during operation and pollute the environment.

The most warm and suitable raw material is a reindeer, natural eco-friendly material [3].

Deer fur has a hollow structure containing inert air in it provides $0.150 \dots 0.806$ ($\text{m} \cdot ^\circ\text{C}$) / W, depending on the height of the fur. In operation, in spite of the temperature and humidity of environmental factors and physical activity, the insulating properties of reindeer will be preserved. Russian manufacturers have mastered the production of insulation basis of reindeer fur [3].

Deer jacket with fur allows you to be outdoors in the winter in spite of at temperatures below to -68°C , and of physical activity [3].

The total thermal resistance of the package materials suits the intermediate 0.196 ($\text{m} \cdot ^\circ\text{C}$) / W for costume – $0.312 \dots 0.343$ ($\text{m} \cdot ^\circ\text{C}$) / W, depending on the mode of socks. The thickness of the intermediate suit is 1 cm, the upper costume – 2-2.5 cm., And hygroscopicity – not less than 16%.

Products with reindeer fur are very warm and suit for the harsh Russian winter.

As a thermal insulation properties of reindeer fur suit wild and for to three times greater than the well-known modern heaters like wool batting, sherstipon, Thinsulate, hollofayber, padding polyester, etc..

Products with deer fur have a small mass and thickness, keep freedom of movement, comfortable.

Due to the high hygroscopicity of reindeer fur, layers of clothing have thermal stability, and are self-contained of micro-climatic zones. This suit remains dry to the touch. This ensures the maintenance of high thermal insulation properties in spite of changes in ambient climatic conditions.

Products made of reindeer fur can be worn both in Arctic tundra, in Siberian taiga, in the mountainous rock climbing, as well as in urban areas.

Table 1 provides a range of modern insulation materials for the manufacture of heat-shielding clothes for the military in Arctic.

Table 1. The range of contemporary heaters for the production of heat protective clothing for soldiers

Type of material	Imported material	Domestic materials
Insulation	PrimaLoft, thermolite, Thinsulate, hollofayber, fayberskin, Fibertech, poli-fayber, izosoft	Termofinn, termoflenn plus, alpolux, termofinn micro, deer fur, Seabury classic corduroy Seabury

The advantage of domestic fabrics is that they guarantee the stability of supply, they do not affect the exchange rate and import logistics, they fully adopt it to the specific requirements of the Russian consumer.

Currently, a main material for producing heat protective clothing has adopted membrane tissue.

Membrane fabric looks like a fine mesh fabric on the reverse. Knitted mesh from the inside protects the membrane from contamination and mechanical damage. It's very light has maximum functionality with a small amount of tissues.

By the structure of membrane fabric is [4]:

Pore – membranes operate on the following principle – water drops from outside can't pass through the membrane pores because the pores are too small. The molecules of steam are formed on the inside of the membrane fabric freely go out through the pores, but they are quite quickly lose their properties as clogged pores and reduces breathability.

Operating on the following principle of evaporation, it passes into the interior portion of the membrane deposited thereon and diffusion is transferred to the outer layer. Advantages it is very durable, requires careful maintenance work properly at a great temperature range.

Disadvantages: lower air permeability due to the porous membrane.

Combined – top fabrics are coated on the inner side of the porous membrane on top of it thin having a coating of polyurethane membrane they are as steam less film.

Classification of membrane tissue in design. Three-layer – cloth top + driver + lining are glued into one structure using a special technology – lamination. It looks like a fine mesh fabric on the reverse. Knitted mesh from the inside protects the membrane from contamination and mechanical damage. We need not lining as the result it is very light, has maximum functionality with a small volume of tissue.

Double layer – top fabric coated with a membrane. Used with lining protects the material from contamination and mechanical damage.

Two-a-half layer – a two-layer membrane with an additional application of foam protective layer (a pimple). Jacket as is lightweight, needs no lining.

Single-layer – free membrane is located between the outer layer and the lining. It is used as accessories and shoes.

Microporous membrane tissue. Microporous membrane tissue has a microporous structure. The pore has of a size many times larger than the water molecule and is many times smaller than the smallest water drop. Firms producing it is not easy to implement. High performance of the membrane depends on the quality and chemical composition of the polymer, the special technological developments and sufficient experience in manufacturing [4].

Membrane fabric Gore-Tex® (gorteks) is one of the most wear-resistant water-repellent windproof breathable fabrics. The fabric is composed of two components. The first – the membrane is PTFE (polytetrafluoroethylene), does not miss the water, it contains 9 billion pores per square inch (2.54 square cm). Each pore 000 is less than 20 drops of water, but 700 times more than the vapor molecules. As a result, liquid water can not penetrate through the fabric, but the vapor discharged from the body, extends freely outwardly.

Gore-Tex®XCR- last modified membrane Gore-Tex. It is more durable, has a complex multilayer structure. Gore-Tex®XCR Stretch is stretching membrane combined with streytchevym riding for the best customized fit, does not restrict movement.

Gore-Tex®Wind Stopper® is waterproof fabric – a fabric with a welded membrane Gore-Tex®. It provides full protection from the wind with a strong effect of breathing. In cold windy weather Wind Stopper® products provide heat retention 1.5 – 2 times better than conventional fleece fabrics. Wind Stopper® allows you to use fewer layers of clothing to keep warm, and as a result, greater freedom of movement.

eVENT (event) is an "active" membrane. The German company, and the American manufacturers comment together and of water-repellent microporous membrane material that provides good breathability. The membrane works without difference between outside temperature and the inside of the garment.

TransActive absorbs and removes the moisture out through the fabric. The air permeability of it is more than 20,000 g /m² per day, water resistance is 70,000 mm.

The above mentioned materials are currently used for the manufacturing of insulated clothing produced by companies in Russia.

In the design and manufacture of insulated clothing we should take into account the properties of the materials to be able to make a choice of materials according to the model.

The choice of materials would be justified if the main fabric products will meet the intended purpose, and the other components of the materials will correspond to the properties of the base material.

The correct choice of materials heat-shielding clothes operated in Arctic may depend state of life or health.

The choice of materials for producing heat protective clothing can be divided into four stages:

Stage 1. Drawing up the general characteristics of the product, identifying the design features, the definition of the product and environmental factors.

Requirements for heat-protective clothing, and its main properties are determined on purpose.

Stage 2. Determination of properties of materials, according to which the choice is made to manufacture the necessary heat protective clothing fabrics.

The necessary properties to the material will be manufactured can be determined with the requirements for materials.

Material requirements are divided into the following groups:

- functional;
- operational (reliability requirements);
- ergonomic;
- esthetic and constructive – they must provide appropriate clothing to modern fashion trends, the integrity of the composite solutions, product appearance and others.

Functional indicators characterize the function of clothing, that is, its appointment. In accordance with the functional requirements of the material we should provide freedom of movement and comfort, warmth, anallergic, etc., depending on the purpose.

The requirements in reliability (performance) are characterized by the ability of the product to maintain its appearance and durability. According to the demand of reliability, the material should maintain appearance, have a wear resistance, dry cleaning, laundry.

Ergonomic requirements provide the ease of using of clothing. Ergonomics is hygroscopic, steam and air, dust holding capacity, electrify, drape. Those properties should provide comfort.

The aesthetic and design requirements must ensure the direction of contemporary fashion apparel, the integrity of the composite solutions, product appearance, and others. These requirements influence the choice of design for future models and methods of processing the product.

Shrinkage materials depend on the value of the allowance. This property tissues must be considered when selecting the core, lining and gasket materials. The material to selected uniform based on standards in shrinkage.

The thickness of the material affects the number of blades in the stack when cutting, selection of needles and sewing thread. The magnitude of the effect allowances shopping tissues.

To design and technological requirements are also drape cut, toughness, ability to shaping.

Stage 3. The choice of materials for the garment is done according to the requirements to materials and products.

The choice of materials is used on price lists, albums with samples and determination which ones meet the requirements of standards. The absence of indicators of the properties is carried out with laboratory tests.

Stage 4. Clarification of product design, technological modes of manufacturing operations. Modes of processing materials are selected according to their properties. According to the methods of processing and properties of the chosen materials for the future model, there is a need to clarify the structure of the product.

Confectioning materials in the garment bag are made according to the general requirements for the clothes, which are depend on the type of product and destination. When selecting a package, you need to consider the properties of materials, components of it.

The correct choice of materials for package garments ensures high-quality output with predefined properties for soldiers in Arctic.

Table 2. Characteristics of the package polymeric materials imported for the production of jackets

Model	Package Materials	Thickness, mm	total thermal resistance, R_{sum} , $m^2 \cdot ^\circ C / W$	Thermal conductivity, λ , $W / m \cdot ^\circ C$	Coefficient of thermal diffusivity, a ($m^2 / \text{ч}$)
Model 1	Synthetic fabrics (100% PE)	1,6	0,038	0,42	0,00044
	Insulation Promaloft	12,0	0,353	0,034	0,00036
	Lining	0,76	0,0195	0,039	0,00050
Model 2	Synthetic Fabrics (100% PE)	1,6	0,038	0,42	0,00044
	Insulation "Hollofan" layer	12,0	0,33	0,036	0,00034
	Lining	0,76	0,0195	0,039	0,00050
Model 3	Synthetic Fabrics (100% PE)	1,6	0,038	0,42	0,00044
	Insulation "Kombisherst"	12,0	0,364	0,33	0,00033
	Lining	0,76	0,0195	0,039	0,00050

The object of investigation was heat shielding for the average soldier in extreme conditions of Arctic. The design and technology of manufacturing of the product meet

the requirements of GOST 12.4.236-236-2011 OSSS. Clothing for protection at low temperatures. Manufactured in accordance with the fundamentals of uniforms.

When selecting a package material for paper we took into account physical, mechanical, thermal and physical characteristics of the materials, information on the specifics of the operation of the clothes, which were obtained from the open literature.

Table 2 shows the package materials for thermal protection jacket made of polymeric materials are imported.

Packages materials were selected in accordance with the requirements for heat-protective clothes and materials used for its manufacturing. When preparing packages we take into account the purpose of each layer and the thermo-physical properties of materials.

Table 3 shows the packages materials for heat protective jackets made of polymeric materials produced domestically.

Table 3. Characteristics the package of domestic production of polymeric materials for jackets

Model	Package Materials	Thickness, mm	total thermal resistance, R_{sum} , $m^2 \cdot ^\circ C / W$	Thermal conductivity, λ , $W / m \cdot ^\circ C$	Coefficient of thermal diffusivity, a ($m^2 / \text{ч}$)
Model 1	Membrane tissue	3,5	0,570	0,006	0,00030
	Sintepon (100% PE)	15	0,0430	0,035	0,00039
	Fleece	1,2	0,031	0,039	0,00034
Model 2	PE fabric (no. 06 617-square)	2,1	0,057	0,040	0,00044
	Insulation Termofinn Micro	15	0,701	0,036	0,00032
	Lining viscose-integrated	0,6	0,014	0,044	0,00052
Model 3	Blended fabrics (67% Polyester 33% CL)	1,8	0,044	0,041	0,00044
	Cloth piercing "Sherston" layer 2 (80% Polyester 20% shesrsti)	20	0,704	0,038	0,00030
	Lining art. 32013	0,69	0,014	0,049	0,00051

Each material of composed corresponds to the requirements for the production of heat-protective clothing.

The difficulty of drawing up the package is the lack of information about a range of materials (not in press the required thermal characteristics of new materials, there is the necessary equipment in the laboratory of the department, and the determination of thermal characteristics limited the costs). Therefore, packets materials are of the best known imported materials, the packet number 1 * – №3 * composed of materials of domestic production.

The choice depends a sanctions. Therefore, Russian government supports the enterprises producing the products from domestic raw materials. Especially when it comes to property and clothing brand clothes of power structures and departments.

Moreover, there are now domestic counterparts, imported raw materials, and as a result, a wide variety of materials used in the manufacture of heat-protective clothing, leads to a number of difficulties when choosing a package of materials for a specific product.

The difficulty of choice materials is used for a specific product; just take into account the region in which these products will be used. Since specific products will have different operating conditions regarding to climate zones. This is actual as heat protective clothing, operated in Arctic.

With the advent of new materials, the possibility of information on the properties of these materials is difficult to find. Therefore it is, urgent to determine the physical and mechanical properties, particular thermal characteristics of new materials. This knowledge will help to optimize the process of manufacturing products (i.e., to choose the best option among many possible).

The main criteria is taken comfort clothes: skin temperature, which should not be lower than $33,3^{\circ}\text{S}$ and underwear temperature shall be not less than 34°S [1], climate underwear space is an indicator of its comfort, including the impact of on lower temperatures. Therefore, it is so important to develop a mathematical model to justify the selection of a package of materials to create a comfort person in view of the magnitude and duration of exposure to low temperatures.

The complexity of the process of heat transfer and the inability take must be into account the diversity of operating factors require the introduction of a number of conditions and restrictions:

- A person is considered to be an integral body, it receives heat from the total heat production;

- Thermal comfort condition is characterized by temperature of underwear space;

- Cooling is considered as the first stage, when the well-being is maintained normal thermoregulatory functions they are not strained, skin temperature is not lower than the critical value, thus maintaining heat generation at a certain average level, independent of physical activity;

- Clothing protecting of the main parts of the body (torso, arms, legs) corresponds to the weather conditions in which there is a person;

- Moisture from the environment is taken into account when selecting the heat transfer coefficient with the surface of the garment to the environment and the choice of thermal conductivity and thermal diffusivity of the outer layers of clothing;

- To wear clothing in the winter evaporation of sweat is not significant in thermoregulation and can be account for a small decrease in heat-shielding properties of the inner garment.

Thermal resistance of clothing is usually regarded as a system consisting of a single material, represents the sum of the thermal resistance of individual layers and layers (outer parts, lining, mezhpodkladka, interlayer technology adhesives, air and so on. D.), And the amount of resistance heat transfer from the one medium to another at the border separating the individual layers.

The main factors affecting the temperature underwear space in constructing a mathematical model are the ambient temperature, heat generation body, the thermo

physical properties of the materials constituting the garment bags, the shape of these packages, and the heat transfer to the outer surface of the garment into the environment.

The concept of a mathematical model on the idea of clothing as a set of multi-layer packet of materials of various shapes and composition [3].

Approximating human body shapes are considered as systems with distributed or lumped. When approximating a cylinder body can speak, only an approximate playback of the thermal regime of man. Rough approximation provides a model in which the thermal conductivity, heat production and heat loss from the body's tissues, assumed to be constant throughout the thickness of the cylinder or layer. Most authors do not take into account the physiological system of human thermoregulation. They see a man in a comfortable environment where the mechanisms of thermoregulation are inactive. In our studies we take into account the system of thermoregulation. Blood flow in the tissues, metabolic heat production and heat losses by evaporation are considered as a function of average body temperature; brain temperature and the average temperature of the skin; temperature marrow, skin and the heat flux from the surface of the skin.

Analysis of existing mathematical models of the thermal state of a person under the influence of environmental factors are expected to determine the shape allows elements of the human body, which can be divided into the following sections: the head – the ball; arms, legs – cylinders; trunk – a set of elliptic cylinders – is roughly [3].

Thus, a person can be represented as a set of geometric shapes.

Developed earlier [4] A mathematical model for the selection of materials for a package of products for the footwear as well based on the presentation of the foot as a set of geometric shapes. Therefore, the question arose about the possibility of using this model in relation to the choice of package materials for clothing. This mathematical model was tested in the calculation of the package materials for heated clothing [3] and received positive results.

The main factors influencing the temperature inward space in the construction of a mathematical model are the ambient temperature, heat generation body, thermal properties of materials, components of the package, the shape of the package and the heat transfer from the outer surface sets suit the environment [3].

To calculate the temperature distribution used mathematical package Maple. Input program

- the thickness of layers of package materials;
- coefficients of thermal conductivity and thermal diffusivity of these materials;
- the density of heat flow from the body to the inner surface of the bag;
- the temperature of the environment;
- the initial temperature of the package of materials forming the suit;
- the coefficient of heat transfer from the outer surface of the package to the environment.

The solution of the problem reduces to finding such a combination of the thickness of the package in some parts of the model that minimizes the flow of heat from its surface while limiting the amount of weight on the package. In the classical approach

is the normalization equation takes into account the weight of insulation thickness of insulation for all geometric image package [3].

Thus, it can be concluded that using the proposed mathematical model it is possible to optimize the choice of materials for producing heat protective clothing.

We consider the temperature distribution in the details of clothing, is a cylindrical multi-layer surface:

$$\frac{\partial T_i}{\partial t} = a_i \left(\frac{\partial^2 T_i}{\partial r_i^2} + \frac{1}{r_i} \frac{\partial T_i}{\partial r_i} \right) + \frac{q_{iv}}{c_i \rho_i}.$$

C boundary conditions:

$$T_1(0, t) \neq \infty; \lambda_n \frac{\partial T_n}{\partial r_n}(R_n, t) + \alpha(T_n(R_n, t) - T_c) = 0;$$

$$T_{i-1}(R_{i-1}, t) = T_i(R_{i-1}, t); \lambda_{i-1} \frac{\partial T_{i-1}}{\partial r_{i-1}}(R_{i-1}, t) = \lambda_i \frac{\partial T_i}{\partial r_i}(R_{i-1}, t).$$

The initial conditions $T_i(r_i, 0) = f_i(r_i)$, where t – the time; T_i – The temperature of the i -th layer; $i = 1 \dots n$; T_c – Ambient; c_i – Coefficient of specific heat of i -layer; a_i – The thermal diffusivity of the i -th layer; ρ_i – Density of i -th layer; λ_i – Thermal conductivity coefficient of the i -th layer; q_{iv} – the bulk density of the heat flow i -th layer; α – coefficient of heat transfer from the skin or the protective layer (fur cap); $f_i(r_i)$ – The initial temperature of the i -th layer.

For example, consider packets materials for thermal protection clothing set forth in Table 1 and 2.

In the calculation took into account the following factors:

- The thickness of the material layers in the package;
- Thermal conductivity and thermal diffusivity of materials packet;
- Density of heat flow from the body;
- Ambient;
- The initial temperature of the package materials;
- Heat transfer coefficient of the outer surface of the bag into the environment;
- The presence of an additional layer in the form of heat-linen and woolen sweaters.

In the calculation we took into account also that the person has the appropriate heat protection of feet, hands and head. It should be dressed according to the weather conditions.

To check the security heatproof jacket can also use another thermo physical characteristics – heat flux density, show the speed of the heat flow per unit area.

The results of calculations are presented in Figures 1 – 3 -for materials imported and Figure 4 – 6 – materials for domestic production. Figure 1 – 6 shows the average skin temperature of the human body on the time the latter at low temperatures (-20°C ; -30°C ; -40°C). From these figures it is clear that the initial average temperature of the skin $+36^\circ\text{C}$ for all packages of materials, a sharp drop in body temperature with air temperature of -20°C , -30°C , -40°C . However, for a number of packages materials 3 and 3, and an air temperature of -20°C , -30°C downward trend in average skin temperature decreases, a man dressed in a heatproof clothes consisting of materials package number 3 and 3 will not feel discomfort for two hours. And at -40°C package number 3 * shows satisfactory results within one hour, and the package number 3 * within two hours.

Figure 1. The results of calculations for a package consisting of imported materials

Figure 2. The results of calculations for a package consisting of materials of domestic production

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Исследование и анализ возможностей отечественных производителей по обеспечению военнослужащих Арктики востребованной продукцией (сообщение 2)

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Research and analysis capabilities of domestic manufacturers to provide military products demanded Arctic (2 message)