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A.A. Blagorodov
Institute of Service Sector and Entrepreneurship (f) DSTU
Shakhty, Rostov region

D.O. Bordukh
Institute of Service Sector and Entrepreneurship (f) DSTU
Shakhty, Rostov region

V.S. Belysheva
Institute of Service Sector and Entrepreneurship (f) DSTU
Shakhty, Rostov region

V.T. Prokhorov
Institute of Service Sector and Entrepreneurship (f) DSTU
Shakhty, Rostov region

G.Yu. Volkova
FGBU «Federal Bureau of Medical and Social Expertise»
Moscow

ABOUT THE CRITERIA FOR THE JUSTIFIED USE OF MATERIALS FOR THE PRODUCTION OF THE SUIT FOR THE MILITARY SERVICES OF THE ARCTIC

***Abstract**: In the article, research has been carried out on the creation of a jacket for protection from the cold of a serviceman in the Arctic. The basis for the creation of thermal protective clothing for operation should be based on a scientific principle that takes into account the physiology of heat exchange between humans and the environment.When developing thermal protective clothing, the requirements for thermal insulation of all areas of the body should be met. The packages of materials were selected in accordance with the requirements for thermal protective clothing and the materials used for its manufacture.*

***Key words**: suit, serviceman, Arctic, heat-protective jacket, package of materials, physical-mechanical and thermophysical characteristics of materials, criteria for a reasonable choice of materials.*

***Language**: English*

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Introduction

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Criteria for a reasonable choice of a package of materials for the production of a suit for servicemen in the Arctic were chosen as the object of the study. At the same time, preferences will be clarified that would guarantee them comfortable conditions in the performance of their official duties.

Main part

When choosing packages of materials for research, we took into account the physical and mechanical, thermophysical characteristics of materials, information about the specifics of the operation of this clothing, which were obtained by us from open literature sources.

A feature of the reasonable choice of packages of materials for a suit for servicemen in the Arctic is the fact that they must provide him not only with a comfortable state due to a guaranteed temperature regime of the clothing space of at least 340C, but also meet all the requirements for the manufacture of heat-protective clothing.

For the study, packages of both imported polymeric materials for the production of jackets and packages of domestic polymeric materials were considered, which were evaluated for their satisfaction with the requirements for heat-protective clothing when military personnel are in climatic zones with temperatures from -200C to -400C.

The results of previous studies using a software product developed by the authors for a reasonable choice of a package of materials in the manufacture of a suit for servicemen in the Arctic showed that at the initial weighted average surface temperature of a soldier of + 360C for all packages of materials using both domestic polymer materials and imported polymer materials, a sharp drop in body temperature is observed at an air temperature from -200C to -400C, provoking a feeling of discomfort within the first hour of their stay in these conditions, which involves the search for new materials that would guarantee them a comfortable state for at least two hours. Table 1 shows the characteristics of the package of imported polymer materials for the production of jackets, and Table 2 shows the characteristics of the package of domestic polymer materials. The packages of materials were selected in accordance with the requirements for thermal protective clothing and the materials used for its manufacture. When compiling the packages, the purpose of each layer and the thermophysical characteristics of the materials were taken into account.

Domestic hot-melt interlining materials (TKPM), the characteristics of which are given in Tables 1 and 2, will find the greatest application in the manufacture of a suit for servicemen in the Arctic.

Table 1 - Characteristics of a package of imported polymeric materials for the production of a jacket

Model	Package materials	Thickness, mm	Coefficient of thermal conductivity λ, W / m ºC
Model 1	Synthetic fabric (100% PE)	1.6	0.042
	Insulation Promaloft (main) Gasket materials: 1. TKPM "Picardy" 1242 \ 17 2. TKPM "Kufner" R171G57 3. TKPM "Kufner" B141N77 4. TKPM AKR-622 \ AKR218	12.0 1,2 1,3 2.1 3.5	0.034 0.041 0.031 0.021 0.009
	Lining fabric	0.76	0.039
Model 2	Synthetic fabric (100% PE)	1.6	0.042
	Insulation "Hollofan" 2 layers basic Gasket materials: 1. TKPM "Picardy" 1242 \ 17 2. TKPM "Kufner" R171G57 3. TKPM "Kufner" B141N77 3. TKPM AKR-622 \ AKR218	12.0 1,2 1,3 2.1 3.5	0.036 0.041 0.031 0.021 0.009
	Lining fabric	0.76	0.039
Model 3	Synthetic fabric (100% PE)	1.6	0.042
	Insulation "Kombisherst" "250 + 150" basic Gasket materials: 1. TKPM "Picardy" 1242 \ 17 2. TKPM "Kufner" R171G57 3. TKPM "Kufner" B141N77 3. TKPM AKR-622 \ AKR218	12.0 1,2 1,3 2.1 3.5	0.33 0.041 0.031 0.021 0.009
	Lining fabric	0.76	0.039

Each material from the compiled bags meets the requirements for the manufacture of thermal protective clothing.

The difficulty in compiling the package was the lack of information on a number of materials. Therefore, packages of materials for models No. 1-No. 3 are made up of the most famous imported materials, and packages No. 1 * - No. 3 * are made up of materials of domestic production.

The difficulty in choosing a package of materials also lies in the fact that when choosing the materials used for a specific product, it is necessary to take into account the region in which these products will be used, since specific products will be subjected to different operating conditions in relation to climatic zones. This is especially true for heat-protective clothing used in the Arctic.

Table 2 - Characteristics of a package of domestic polymeric materials for the production of jackets.

Model	Package materials	Thickness, mm	Coefficient of thermal conductivity λ, W / m °C
1	2	3	4
Model 1	Membrane fabric	3.5	0.06
	Sintepon (100% PE) basic Gasket materials: 1. TKPM "Picardy" 1242 \ 17 2. TKPM "Kufner" R171G57 3. TKPM "Kufner" B141N77 4. TKPM AKR-622 \ AKR218	15 1,2 1,3 2.1 3.5	0.035 0.041 0.031 0.021 0.009
	Fleece	1,2	0.039
Model 2	PE fabric (art. 06617-kv)	2.1	0.040
	Insulation Termofinn Micro basic Gasket materials: 1. TKPM "Picardy" 1242 \ 17 2. TKPM "Kufner" R171G57 3. TKPM "Kufner" B141N77 4. TKPM AKR-622 \ AKR218	15 1,2 1,3 2.1 3.5	0.036 0.041 0.031 0.021 0.009
	Viscose-complex lining fabric	0.6	0.044
Model 3	Blended fabric (67% PE + 33% CL)	1.8	0.041
	Wool stitched fabric 2 layers (80% PE + 20% wool) main Gasket materials: 1. TKPM "Picardy" 1242 \ 17 2. TKPM "Kufner" R171G57 3. TKPM "Kufner" B141N77 4. TKPM AKR-622 \ AKR218	twenty 1,2 1,3 2.1 3.5	0.038 0.041 0.031 0.021 0.009
	Lining fabric art. 32013	0.69	0.049

Let us repeat and name the main criteria for the comfort of clothes: the temperature of the skin, which should not be lower than 33.3 ° C, and the temperature of the underwear space should be at least 34 ° C, that is, the microclimate of the underwear space is an indicator of its comfort, including when exposed to low temperatures. For a person, it is not indifferent which part of the body is cooled more while maintaining the total heat transfer, for example, strong cooling of the legs cannot be fully compensated by heating another part of the body without disturbing the person's sense of comfort. Therefore, it was so important to develop a mathematical model to justify the choice of a package of materials in order to create comfort for a serviceman, taking into account the duration of exposure to low temperatures.

The concept of the mathematical model is based on the representation of clothing as a set of multilayer packages of materials of various shapes and compositions.

To calculate the temperature distribution, the authors used the Maple mathematical packages.

The solution to the problem was reduced to finding such a combination of materials for the package, which would realize a minimum of heat flux from its surface while limiting the volume of the package. Thus, we can conclude that using the proposed mathematical model, it is possible to optimize the choice of materials for the manufacture of a heat-protective suit.

Consider the temperature distribution problem $T_i i$ - th layer in the details of the suit, which is a cylindrical multilayer surface. The ambient temperature is kept constant, equal to T_0 ... The heat flux of density comes from the body to the inner surface of the garment q ... On the outer surface of clothing, heat exchange with the environment occurs according to Newton's law with a heat transfer coefficient α.

Let us introduce the following notation for the basic criteria:

t - time; $T_i(r,t)$- temperature i-th layer; λ_i - coefficient of thermal conductivity i-th layer; α_i - coefficient of thermal diffusivity i-th layer; $R_{i\text{-}1}, R_i$ - inner and outer radii i-th layer; $i = 1,2...n.$

Now consider n-layered hollow cylinder and boundary value problem

$$\frac{\partial T_i}{\partial t} = a_i \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T_i}{\partial r}\right), \; R_{i\text{-}1} < r < R_i \quad i = 1,2...n. \; (1)$$

With boundary conditions:

$$\lambda_1 \frac{\partial T_1}{\partial r}(R_0,t) + q = 0;$$

$$\lambda_n \frac{\partial T_n}{\partial r}(R_n,t) + \alpha(T_n(R_n,t) - T_0) = 0; \; (2)$$

Ideal contact is assumed between the layers:

$$T_{i\text{-}1}(R_{i\text{-}1},t) = T_i(R_{i\text{-}1},t);$$

$$\lambda_{i\text{-}1}\frac{\partial T_{i\text{-}1}}{\partial r}(R_{i\text{-}1},t) = \lambda_i \frac{\partial T_i}{\partial r}(R_{i\text{-}1},t), \; i = 2,..,n. \; (3)$$

Initial conditions

$$T_i(r,0) = \phi_i(r), i = 1,..,n. \; (4)$$

Solving the problem, it is possible to find the temperature distribution in the layers of the suit and, in particular, the change in the temperature of the underwear space depending on time.

The passage of heat through a multilayer spherical wall is described by a system of heat conduction equations:

$$\frac{\partial T_i(r_i,t)}{\partial t} = a_i \frac{1}{r_i}\frac{\partial^2(r_i T_i(r_i,t))}{\partial r_i^2}, \; (5)$$

$R_{i\ 1} \le r_i \le R_i$, Where $R_{i\text{-}1}, R_i$ - inner and outer radii i-th layer,

t-time, a_i-thermal diffusivity i-th layer, $(i = 1,..,n)$.

The heat flux of density arrives on the inner surface of the ball segment from the foot q:

$$\lambda_1 \frac{\partial T_1}{\partial r_1}(R_0,t) + q = 0. \; (6)$$

On the outer surface of the body, heat exchange with the environment occurs according to Newton's law with the heat transfer coefficient α:

$$\lambda_n \frac{\partial T_n}{\partial r_n}(R_n,t) + \alpha(T_n(R_n,t) \quad T_c) = 0. \; (7)$$

We will assume that there is an ideal contact between the layers, which is expressed by the following relations:

$$T_{i\ 1}(R_{i\text{-}1},t) = T_i(R_{i\text{-}1},t),$$
$$\lambda_{i\text{-}1}\frac{\partial T_{i\text{-}1}}{\partial r_{i\text{-}1}}(R_{i\text{-}1},t) = \lambda_i \frac{\partial T_i}{\partial r_i}(R_{i\text{-}1},t), \; (8)$$

$i = 2,..,n.$ At the initial moment of time, the temperature is set

$$T_i(r_i,0) = \phi_i(r_i), \; (9)$$

$$i = 1,...,n...$$

Thus, the process of heat passage through the spherical segment from the body to the outer surface is described by the boundary value problem with the initial conditions given above.

When calculating, we took into account the following criteria:

- the thickness of the layers of materials in the package;
- coefficient of thermal conductivity and thermal diffusivity of package materials;
- the density of the heat flow coming from the body;
- ambient temperature;
- initial temperature of the package of materials;
- coefficient of heat transfer from the outer surface of the package to the environment;
- the presence of an additional layer in the form of thermal underwear and a woolen sweater.

When calculating, it was also taken into account that a person has guaranteed thermal protection of legs, arms and head, that is, he is dressed in accordance with climatic conditions.

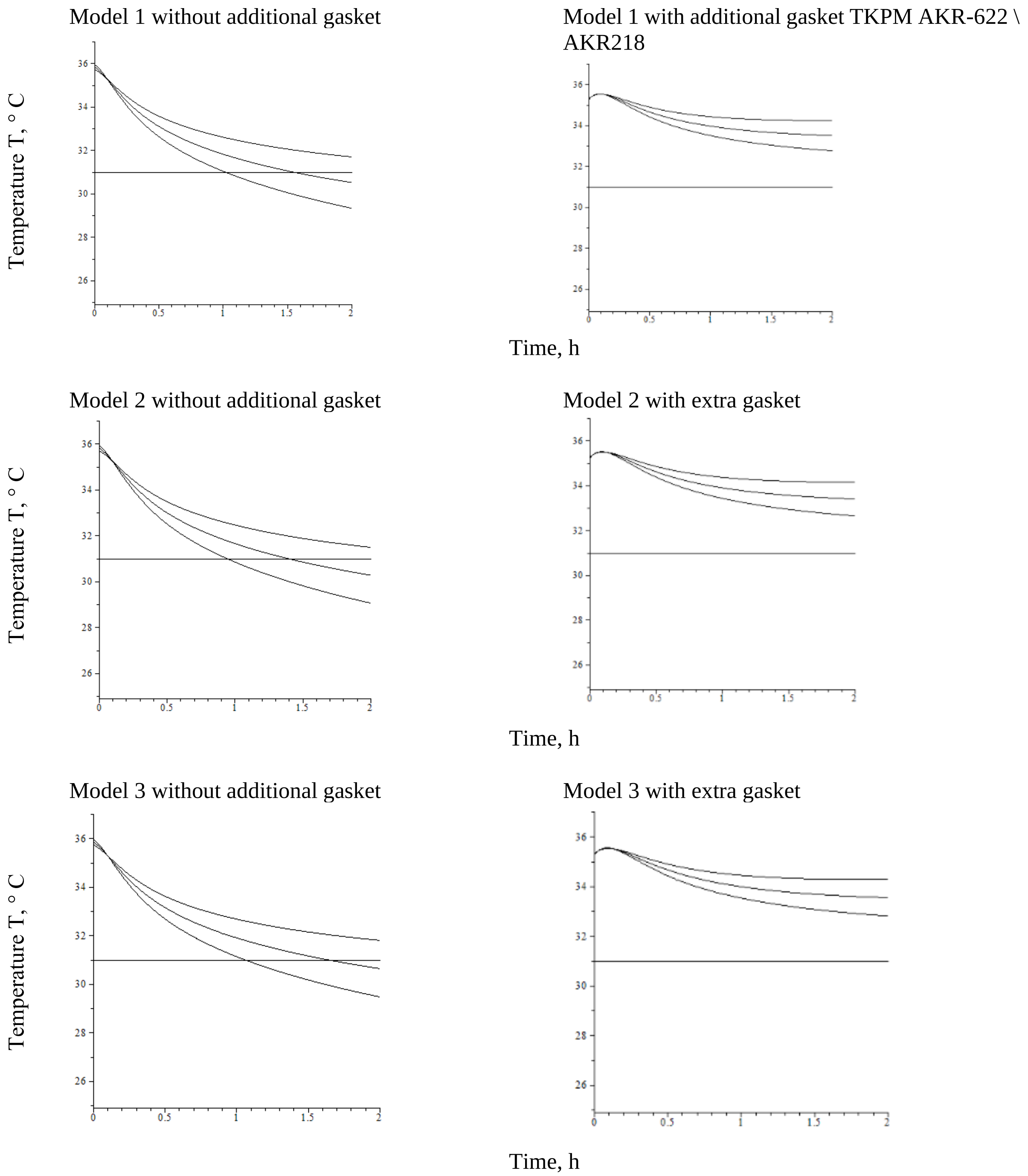
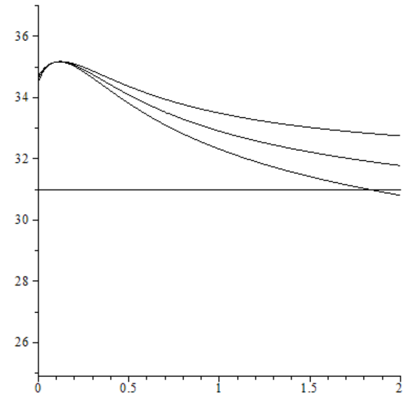
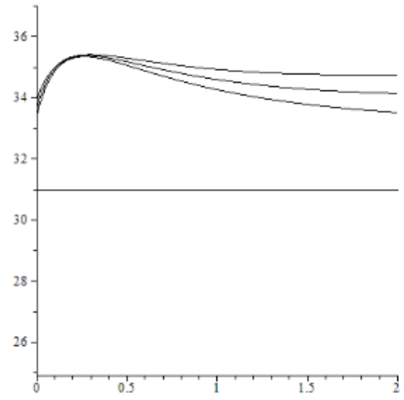


Figure 1 - The results of calculating the weighted average skin temperature for bags consisting of imported materials at ambient temperatures: curve 1 -20 ° C, curve 2 - 30 ° C, curve 3 - 40 ° C.

Model 1 * without additional gasket

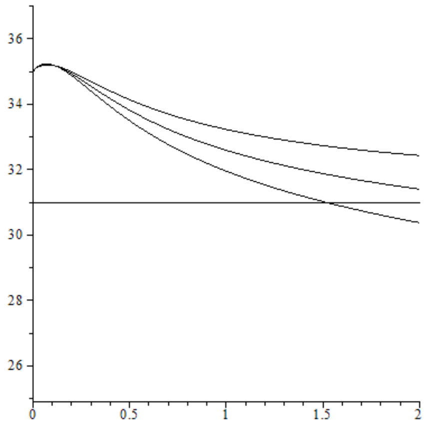


Model 1 with additional gasket

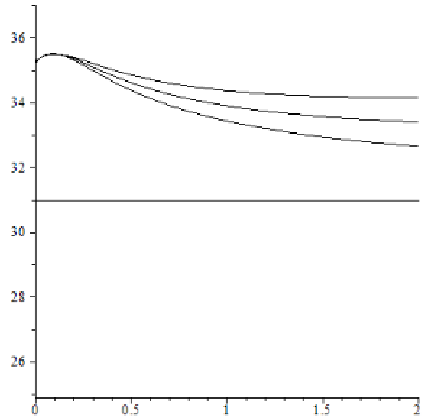


Time, h

Model 2 * without additional gasket

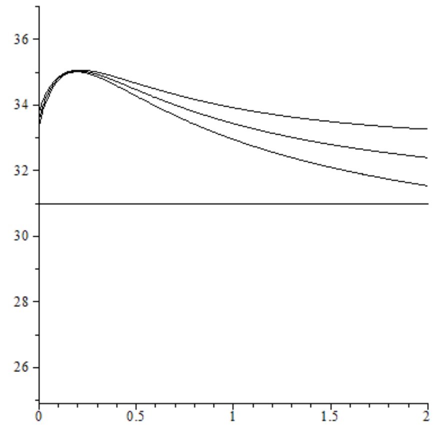


Model 2 with extra gasket

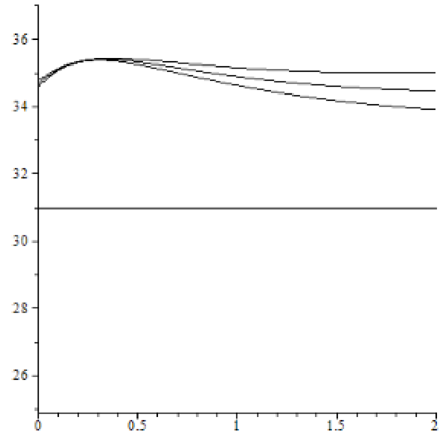


Time, h

Model 3 * without additional gasket



Model 3 with extra gasket



Time, h

Figure 2 - The results of calculating the weighted average skin temperature for bags consisting of domestically produced materials at ambient temperatures: curve 1 -20 ° C, curve 2 - 30 ° C, curve 3 - 40 ° C.

The calculation results are presented in Figure 1 for imported materials and in Figure 2 for domestically produced materials. These figures show the dependence of the weighted average temperature of the human body on the time spent at low temperatures (from -20 ° C to -40 ° C). It can be seen from the above figures that at an initial weighted average skin temperature of 36 ° C for all packages of materials, a sharp drop in body temperature is observed at an air temperature from -20 ° C to -40 ° C.

Conclusion

Analysis of the research results confirmed the justification of using TKPM as cushioning materials in the manufacture of a suit for servicemen of the Arctic, since with all TKPM, the comfort of a serviceman is provided for 2 hours of his stay in climatic zones with an ambient temperature of -20 ° C and -30 ° C, but comfortable conditions when it is in the climatic zone at -40 ° C is provided only with the use of TKPM AKR-622 / AKR218, the thermal conductivity coefficient of which is the smallest, namely λ = 0.009W / m · ° C.

The authors have proved that the main criterion for the comfort of a suit of servicemen in the Arctic when they are in different climatic zones is the thermal conductivity coefficient. The possibility of using a software product to justify the choice of material packages for a suit of servicemen in the Arctic in various climatic zones has been confirmed. A high coincidence of the calculated values of heat loss from the surface of the tested jackets with the experimental data has been achieved, which confirms the legitimacy of using the software product developed by the authors for the justified choice of material packages for the suit of the Arctic military personnel located in different climatic zones.

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