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THE DEVELOPMENT OF EXTREME COLD WEATHER CLOTHING SYSTEM FOR WARFIGHTERS OF THE ARMED FORCES OF UKRAINE

Purpose *is to develop, research, test and adjust the production of windproof, waterproof winter suits with improved tactical, technical and physical characteristics for a dismounted soldier of the Armed Forces of Ukraine.*

Scientific novelty. *The obtained results are to develop theoretical and practical bases of the interaction of separate materials (packages of materials), considered as promising for the manufacture of windproof, waterproof winter suits for a dismounted soldier of the Armed Forces of Ukraine.*

Practical value. *The development, testing and production of new elements of the extreme cold weather clothing system, which can be put into service in the Armed Forces of Ukraine in the period from 2020 to 2025. This kind of scientific work is being conducted for the first time in the history of the Armed Forces of Ukraine after the proclamation of Independence and is one of the elements of the transition of the Armed Forces to NATO standards.*

Keywords: *development, extreme cold weather clothing system, windproof and waterproof winter suits, Armed Forces of Ukraine, NATO standards, ePTFE membrane, synthetic fabrics.*

Objectives. The Armed Forces of Ukraine have a big experience of the participation of dismounted soldiers in various types of military conflicts and The Ministry of Defence of Ukraine try to use approaches of the NATO in R&D process of the Combat Clothing, Individual Equipment and Protection. The main reason is to make a soldier's safety andmore capableof a new type of military conflict. We have a new time when the enemy widespread use of special-purpose units (reconnaissance and sabotage units), sniper pairs and a broad network of agents and it give us necessary to maximize unification of combat uniforms and equipment of soldiers and officer of different units and troops. But from the Soviet Union collapse Ukraine doesn't have any R&D project of it and no one department in The Ministry of Defence don't have an objective task to work in Combat

Clothing, Individual Equipment and Protection direction and all R&D offices of Soviet Union Armed Forces were in Russia. The Ministry of Defence of Ukraine created The Main Department for research and support of the material supply of the Armed Forces of Ukraine in 2015 and this Department started to change in the uniform direction. But the small period of time and low level of technology of some Ukrainian manufactures facilities got us to start for scientific strategy without real NATO standards staff for our soldiers.Since 2017 The Main Department for research and support of the material supply of the Armed Forces of Ukraine and Kyiv National University of Technologies and Design with some Ukrainian, German, Austrian, Croatian and Slovakian companies started the new project of the development of extreme cold weather clothing system for warfighters of the Armed Forces of Ukraine. Windproof, waterproof winter suits should be one of the elements from the new generation of the extreme cold weather clothing system for the Armed Forces of Ukraine. The basic idea of the new type of windproof, waterproof winter suits grounded on basic principles of the suites which Ukrainian soldiers used nowbut new suites will be produced with new and modern types of materials.

Methodology. Objects of research are the general disadvantages of winter suits which soldier used now; weather conditions in which winter suits planned to use; main types of activities of servicemen during which winter suits; the general ergonomic properties of winter suits; the influence of foreign economic and political factors on the provision of the Armed Forces of Ukraine with elements of combat clothing, personal equipment and protection. The main focus of the work is to create the optimal model for the elimination of problem issues revealed during the research of the above objects. The basis for the formation of research was the experience of the previous project of previous generation of the wintersuits and analysis of its application in real combat conditions, as well as the requirements of a number of NATO standards, in particular, STANAG 2138, STANAG 2333, STANAG 2895, STANAG 4364, ACCP-1and others. For the development process are used lab tests results, control troop tests results and will use field troop trials results (planned to start December 2019).

Research results.The analyst of soldier's experience use of the previous generation of the winter suits gives the main criteria for the layout of these suits, and separate some element like a windproof insulation layerand waterproof layer of the suite. This type of layering system gives us the possibility to call this suit like system "3 in 1". The system "3 in 1" give us wider diapason for use, batter ergonomic and comfort for soldiers for a different type of winter weather, battle conditions and activity of the soldiers. Any low-level commander has own independence to prepare his soldier for the best reason of use windproof insulation layer and a waterproof layer or combine them (see Table 1.)

Table 1 – **Weather conditions and layers, which can be used**

Weather conditions	Layers
Windy, Wet, Low Cold	WTL
Windy, Wet, MiD Cold	IWDL
Windy, Wet, Hi Cold	WTL + IWDL

1WTL - Waterproof layer;
2IWDL - Insulation and windproof layer.

Analysis of the previous generation suits use to give us some main disadvantages as critical low level of waterproofness of WTL; low level of windproofness of IWDL; big water absorption properties of the insulation material of IWDL; low level of water, oil, gas repellence; big difference of properties for tear and straight density of out layer fabrics for IWDL and WTL; big difference of colour properties of out layer fabrics for IWDL and WTL; bad characteristic of out layer fabrics for IWDL and WTL in NIR; small period of life IWDL and WTL and other.

In order to unify approaches to solving a number of problematic issues, was proposed to use one typical uniform cloth for the outer layer of IWDL and WTL. The needed qualities for the outer layers provided by using assynthetic materials like the main raw material; the density of yarn;the type of weaving; the number of fabric treatments and the way of laminating it with different types of laminates with the ePTFE base.

Table 2 - **Shortlist of WTL out layer fabric properties and their comparison**

Properties	Old generation	Availability	New generation	Availability
Lightweight	2 layer, 65% CO, 35%PES, twill 2/1, 228 g/m^2, DWR, PU membrane	-	2 or 3 layers, 100% NY, twill 2/2, 130 or 170 g/m^2, DWR[5], DOR[5], DFR[5], bicomponent membrane based ePTFE	+
Tensile strength wet		-		+
Tear strength wet		-		+
Dimensional stability		+/-[4]		+
Abrasion resistance		-		+
Resistance to water		+/-		+
WVR[1] wet/cold		-/-		+
Durability W/O/F[2]		+/-[4]		+
Colour fastness		+/-[4]		+
NIR proprties[3]		-		+
Lifecycle		-		+

[1]Water vapour resistance;
[2] Water, Oil, Fuel;
[3]Near-infrared;
[4]The option is present but not enough;
[5]Durable Water Repellent, Durable Oil Repellent, Durable Fuel Repellent.

Considering that IWDL can be used as a separate element of the garment, it should have the same main properties with the previous WTL exception of water resistance, but in the old generation of suits, this principle was lost.

Table3 - **Shortlist of IWDL out layer fabric properties and their comparison**

Properties	Old generation	Availability	New generation	Availability
Lightweight	2 layer, 100% PES, twill 2/1, 190 g/m^2, DWR	-	2 layer, 100% NY, twill 2/2, 120 g/m^2, DWR[5], DOR[5], DFR[5], bicomponent membrane based ePTFE	+
Tensile strength wet		+		+
Tear strength wet		+		+
Dimensional stability		+		+
Abrasion resistance		-		+
WVR[1] wet/cold		+		+
Durability W/O/F[2]		+/-[4]		+
Colour fastness		+/-[4]		+
NIR proprties[3]		-		+
Lifecycle		+/-[4]		+

[1]Water vapour resistance;
[2] Water, Oil, Fuel;
[3] Near-infrared;
[4] The option is present but not enough;
[5]Durable Water Repellent, Durable Oil Repellent, Durable Fuel Repellent.

Typical conditions for placement of military personnel in real combat conditions include their prolonged stay in dugouts and underground shelters. For the most part, such conditions of accommodation are characterized by a significant humidity of the air, lack of normal ventilation and high temperature due to the use of air heaters in the winter.Such conditions adversely affect the full functioning of the materials used to make suits of the previous generation.The main problem was the partial accumulation of moistureof the insulation not woven material of old generation IWDL. The second problem of IWDL was a big profile of material package with a low level of compression properties.

Suite design wasdeveloped andbased on the previous generation suite with certain differences (see Fig. 1, 2, 3 and 4).

The design improvement of:

IWDL jacket- intended to provide better comfort to the soldier, expand access to the contents of pockets when soldier using personal protective equipment and reduce heat loss;

IWDL trousers- intended to provide freedom of movement and comfort to the soldierwith take-off (take-on) process and reduce heat loss;

WTL jacket - intended to provide total waterproofness, expand access to the contents of pockets when soldier using personal protective equipment and same ergonomic characteristics with IWDL jacket for "muscle memory" of a soldier;

WTL trousers - intended to provide total waterproofness,freedom of movement and comfort to the soldier with take-off (take-on) process.

Table 4 - **Shortlist of IWDL insulation material properties and their comparison**

Properties	Old generation	Availability	New generation	Availability
Lightweight	Bicomponent fine fibres, 100% PES, primary andregenerated, TBF[1]	+/-[2]	Bicomponent fine and ultra-fine fibres, 100% PES, primary and regenerated, TBF[1], DWR[3]	+
Thickness		+/-		+
Thermal Insulation dry		+		+
Thermal Insulation wet		+/-		+
Compression		-		+
Not water absorption		-		+

[1]Thermal Bonding Fibers used;
[2]The option is present but not enough;
[3]Durable Water Repellent.

Conclusion. In order to meet the requirements of the NATO STANAG 2138, suite testing was arranged in one of the most advanced specialized laboratories of W. L. Gore & Associates, Inc in Germany. The testing was supposed to be the materials planned for the production of suits and suits as well.

The main idea of the first part of the suits tests was to confirm their waterproof properties in the Germany labs and in Ukrainian Carpathians as a control field test.

As a result, WTL jacket and trousers were fully completed according to EN 14360: 2005 -Protective Clothing Against Rain - A Test Method for Ready-made Garments - Impact from Above with High Energy Droplets. Durable Water.

Repellentof shell fabric of WTL jacket and trousers are tested after 20 washing cycles according to ISO 4920:2012 - Textile fabrics - Determination of resistance to surface wetting (spray test) with a result between 0-1.

Rain tower test of WTL jacket and trousers according to ISO 811:2018 Preview

Textiles -- Determination of resistance to water penetration -- Hydrostatic pressure test passed with more than 100 kPa (1 bar) for shell fabric and more than 20 kPa (0,2 bar) for cross-seams.

After the mentioned 20 washing/drying cycles and after the rain tower testthe garments are not allowed to show water penetration towards the body and wicking have to be limited as by definition.

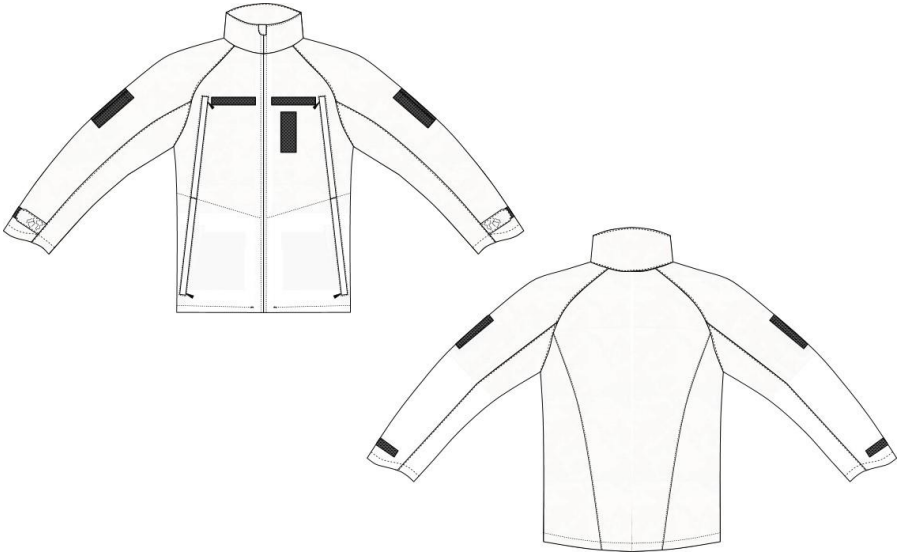

Fig. 1. **IWDL jacket**

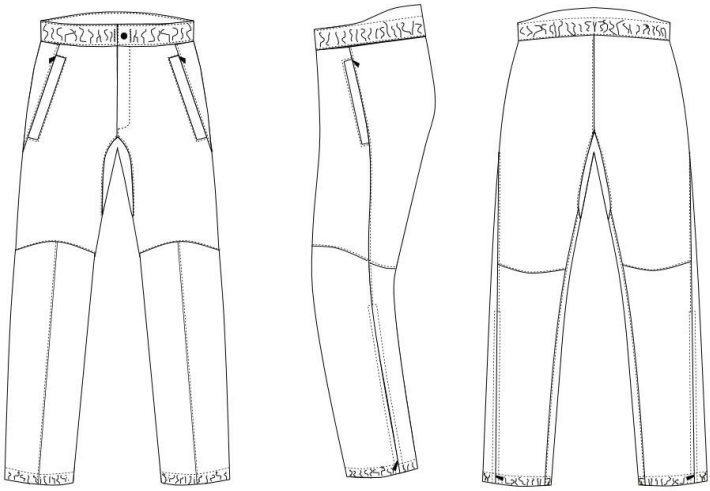

Fig. 2. **IWDL trousers**

Fig. 3. **WTL jacket**

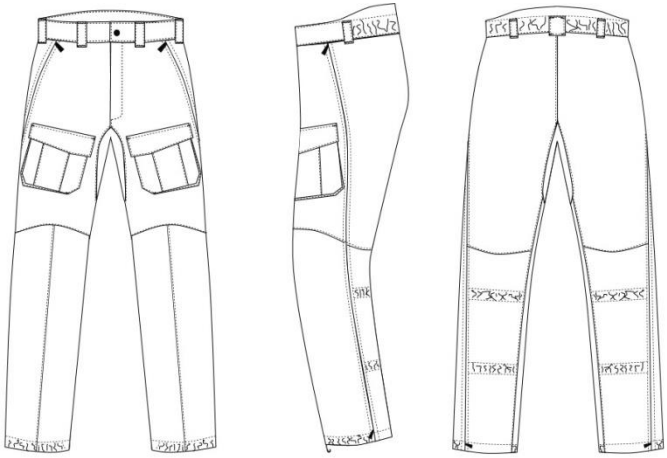

Fig. 4. **WTL trousers**

All previous laboratory tests confirmed during field test 08-11 September 2018 near mountains Petrosand Goverla.

Photo 1. - **EN 14360 lab (Putzbrunn)**

Photo 2.- **Control field test (Goverla)**

References

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8. ISO 811:2018 PreviewTextiles - Determination of resistance to water penetration - Hydrostatic pressure test.