Camouflage Quality Evaluation of the Combat Individual Protection System in the Thermal Infrared Spectrum

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***Abstract* - On the modern battlefield, protection from the enemy surveillance is vital for the survivability of the force. The beginning of the XXI century has made surveillance by means of thermal devices an advanced solution to the searching, identification and recognition of heat sources, including even people.**

The research has been made in order to define the protection level of the Combat Individual Protection System (CIPS) of the Latvian Army from the thermal infrared (TIR) detectors. Eleven different CIPS combinations have been used in the weather conditions of the experiment. The methodology of the field evaluation has been established, and special design clothing system for the sniper and recon units as well as for the camouflage in the snowy terrain has been identified based on the best TIR protection quality. Implementation of the CIPS-Mod1-SNIPER/RECON-system into CIPS has been suggested. The developed field trial methodology of the TIR protection quality definition can be applied to further research on the visual (VIS) and near infrared (NIR) quality of the combat clothing systems.

***Keywords* – CIPS, camouflage, protection, thermal infrared, IR, TIR, combat clothing, electromagnetic spectrum**

I. INTRODUCTION

Research has been conducted on the evaluation of the thermal infrared (TIR) camouflage protection quality of the combat individual protection system (CIPS) in order to define the actual level of the TIR protection of the CIPS, as well as suggest clothing system solutions to increase the actual level of the TIR protection. CIPS is developed according to the State Defence concept of the Republic of Latvia [1].

II. MATERIALS AND METHODS

For the evaluation, general methodology has been applied according to STANAG 2138 PCS "Troop Trial Principles and Procedures – Combat Clothing and Personal Equipment" [2]. Eleven combinations have been evaluated at different distances (30 m, 130 m, 276 m and 426 m) and in conjunction with sleeping bags – 5 m. Weather conditions of Adazi military camp training outdoor area, Echo sector – cloudy, rainy and wet snow, air temperature +2ºC to +4ºC, northwest wind 7-14 m/sec.

TIR reflectance has been measured by Dual Channel Day/Night Thermal Binocular with Geo-location Recon B2-FO. Level of the TIR protection quality has been calculated by using newly developed method of the calculation areas of the different colour rectangles representing the actual level of the TIR reflectance.

III. RESULTS

To assess TIR protection quality, the first combination of CIPS MTL [1] (Fig. 1) includes the combat hat (Garrison), combat underwear (Level 2), Gore-Tex jacket, combat gloves (cold weather) for the upper body; and combat underwear (Level 1), combat underwear (Level 2), combat trousers and M9-combat boots for the lower body. During the experiment, the face has not been covered by any of the MTL included in CIPS; thus, on the TIR image the face is shown as a white area in a corresponding polarization. In the first combination of CIPS MTL, the most shielded part of the body is below the waist to the Gore-Tex jacket bottom edge that covers the lumbar region. The qualitative shielding of this area is associated with additional Gore-Tex membrane fabric strips in pockets and pocket flaps, as well as with the layering of CIPS MTL forming the upper and lower body in this area. Long sleeve shirt of combat underwear (Level 2) overlaps the boxer shorts of combat underwear (Level 1) and the pants of combat underwear (Level 2); Gore-Tex jacket overlaps the combat trousers. A similar layering mechanism is seen in the areas of the body, where certain MTLs of CIPS, which do not overlap, form overlapping by "free fall" in one MTL. For example, such areas are calf areas above the boots as well as the forearms above the palms. Contrary to the above-mentioned areas, where there is no layering, and there is only the small number of layers and layers fit close to the body, the TIR shielding is worse, thus the TIR protection is worse. For example, on the TIR image Gore-Tex jacket pull cord is clearly visible on the waist, which tightens the jacket and presses it to the combat underwear (Level 2), so that the heat is transferred to the pull cord, which is presented by a thermal observation device. A similar mechanism has also been observed in the palm area, shielded only by combat gloves (cold weather), combat hat (garrison), where there is a close contact with the head, M9-combat boots, where the laces press the side of the boot to the foot surface.

To assess TIR protection quality, the second combination of CIPS MTL includes the combat hat (a beret, garrison), combat underwear (Level 3), Gore-Tex combat jacket, SNOW-combat jacket, combat gloves (cold weather) for the upper body; and combat underwear (Level 1), combat underwear (Level 3), combat trousers, SNOW-combat pants and M9-combat boots for the lower body. During the experiment, the face has not been covered by any of the MTL included in CIPS; thus, on the TIR image the face is shown as a white area in a corresponding polarization. In the second combination of CIPS MTL, virtually the whole body is relatively high-quality shielded, except for the area under the SNOW-combat jacket

[1] MTL – material (separately garment)

bottom edge. As noted in the case of the first combination of MTL CIPS, similar layering in the hip area forms better TIR shielding also for the second combination of CIPS MTL. SNOW-combat jacket and SNOW-combat trousers are designed as "free-falling" CIPS MTL, which similar to the first combination of CIPS MTL provide better shielding and better TIR protection. In the palm area, shielded only by the combat gloves (cold weather), TIR protection is of low quality. Similarly, the reduced quality of TIR protection has been detected in the combat hat (beret, garrison), where there is a close contact with the head, in M9-combat boots, where the laces press the side of the boot to the foot surface.

To assess TIR protection quality, the third combination of CIPS MTL includes the combat cap (cold weather), combat underwear (Level 2), combat underwear (Level 3), Gore-Tex jacket, combat gloves (cold weather) for the upper body; and combat underwear (Level 1), combat underwear (Level 2), Gore-Tex-combat trousers and M9-combat boots for the lower body. During the experiment, the face has not been covered by any of the MTL included in CIPS; thus, on the TIR image the face is shown as a white area in a corresponding polarization. Combat underwear (Level 3) of the third combination increases the quality of protection of the upper body compared to the combination, where non-combat underwear (Level 3) is used, see. Fig. 1. Similar to the previous combination, in the palm area, shielded only by the combat gloves (cold weather), TIR protection is of low quality. Similarly, the reduced quality of TIR protection has been detected in the combat hat (cold weather) and M9-combat boots, where the laces press the side of the boot to the foot surface.

To assess TIR protection quality, the fourth combination of CIPS MTL (see Fig. 1) includes the combat cap (cold weather), combat underwear (Level 2), combat jacket (cold weather), combat gloves (cold weather) for the upper body; and combat underwear (Level 1), combat underwear (Level 2), combat trousers and M9-combat boots for the lower body. During the experiment, the face has not been covered by any of the MTL included in CIPS; thus, on the TIR image the face is shown as a white area in a corresponding polarization. In the fourth combination of CIPS MTL, the most shielded part of the body is below the waist to the combat jacket (cold weather) bottom edge that covers the lumbar region. The qualitative shielding of this area is associated with the layering of CIPS MTL forming the upper and lower body in this area. Long sleeve shirt of combat underwear (Level 2) overlaps the boxer shorts of combat underwear (Level 1) and the trousers of combat underwear (Level 2); the combat jacket (cold weather) overlaps the combat trousers. In addition, the combat jacket (cold weather) in this area of the body is close to the body. In a similar way, the combat trousers overlap in the ankle area achieving the qualitative TIR protection. Similar to the previous combination, in the palm area, shielded by the combat fitting gloves (cold weather), TIR protection is of low quality. Similarly, the reduced quality of TIR protection has been detected in the combat hat (cold weather) and M9-combat boots, where the laces press the side of the boot to the foot surface.

To assess TIR protection quality, the fifth combination of CIPS MTL (see Fig. 1) includes the combat cap (cold weather), combat underwear (Level 2), combat underwear (Level 3), SNUGPAK-combat jacket, combat gloves (cold weather) for the upper body; and combat underwear (Level 1), combat underwear (Level 2), combat trousers and M9-combat boots for the lower body. During the experiment, the face has not been covered by any of the MTL included in CIPS, but the soldier has had corrective eye glasses shown on the TIR image as the dark area in the eye area. Thus, it has been concluded that the glasses can provide TIR shielding. On the TIR image, the face is shown as the white area in the polarization. In the fifth combination of CIPS MTL, the most shielded part of the body is below the waist to the SNUGPAK-combat jacket bottom edge that covers the lumbar region The qualitative shielding of this area is associated with the layering of CIPS MTL forming the upper and lower body in this area. Long sleeve shirt of combat underwear (Level 3) overlaps the boxer shorts of combat underwear (Level 1) and the trousers of combat underwear (Level 2); the SNUGPAK-combat jacket overlaps the combat trousers. In addition, more than 4 mm thick SNUGPAK-combat jacket is a qualitative addition to the TIR shielding, except for the zipper area; this is also confirmed by the TIR image: a blue vertical line on the other dark blue background. SNUGPAK-combat jacket zipper structure covers the strip of fabric that makes the outer surface of the jacket without an insulation layer, as in the jacket. Thus, it is possible to assume that there is some correlation between MTL CIPS forming fabric package thickness and TIR shielding effectiveness. Similar to the previous combination, in the palm area, shielded only by the combat fitting gloves (cold weather), TIR protection is of low quality. Similarly, the reduced quality of TIR protection has been detected by the combat hat (cold weather) and M9-combat boots, where the laces press Institute of Textile Materials Technologies and Design the side of the boot to the foot surface. Similar to the fifth combination, the sixth combination of CIPS is just updated with the battle jacket (cold weather) and combat underwear (Level 3) for the lower body. It should be mentioned that it is possible to shield the palms by combat gloves (cold weather) with SNUGPAK combat jacket sleeve bottom edge, where the hole is made for the thumb.

To assess TIR protection quality, the seventh combination of CIPS MTL (see Fig. 1) includes the combat cap (cold weather), combat underwear (Level 1), combat underwear (Level 3), CBRN-combat jacket, combat gloves (cold weather) for the upper body; and combat underwear (Level 1), combat underwear (Level 2), combat trousers, CBRN-combat trousers and M9-combat boots for the lower body. CBRN-gas mask is shown on the TIR image as a dark area in the facial area. Thus, it is concluded that the CBRN-contained breathing apparatus may provide TIR shielding. In general, the seventh combination, which includes the CBRN-combat jacket and CBRN-combat trousers, provides low-quality TIR shielding. Similar to the previous combination, in the palm area, shielded by the combat gloves (cold weather), TIR protection is of low quality. Similarly, the reduced quality of TIR protection has been detected in the combat hat (cold weather) and M9-combat boots, where the laces press the side of the boot to the foot surface.

To assess TIR protection quality, the eighth combination of CIPS MTL (see Fig. 1) includes the combat cap (cold weather), the combat shemagh scarf, combat underwear (Level 3), combat jacket (cold weather), combat jacket, combat gloves (cold weather) for the upper body; and combat underwear (Level 1), combat trousers and M9-combat boots for the lower body.

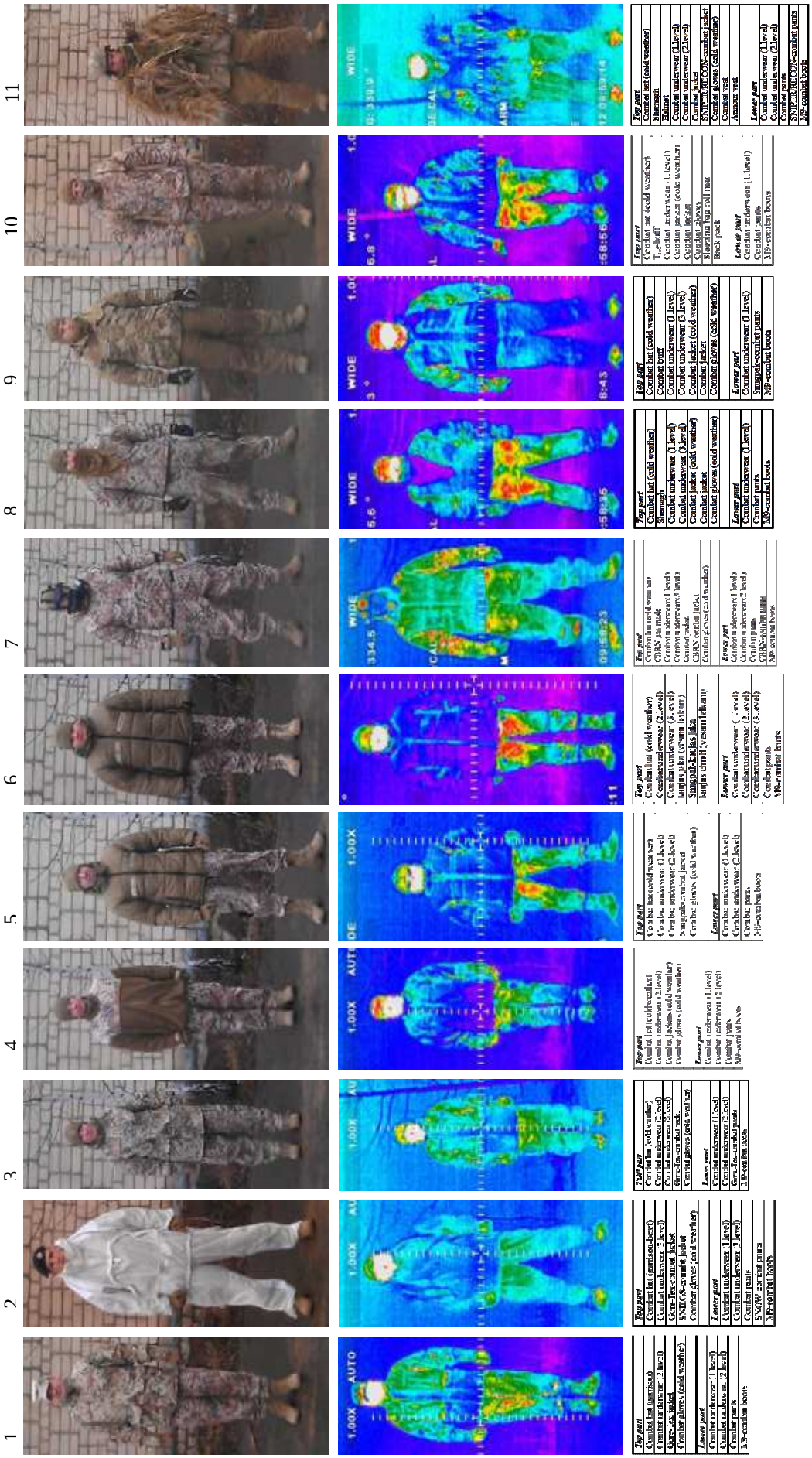

Fig. 1. CIPS combinations (VIS and TIR images)

Attention is drawn to the combat shemagh scarf as effective shielding. TIR image clearly shows that only the combat shemagh has the contrast colour from light blue to dark blue in comparison with the same contrast colour of several layers of CIPS MTL, as well as differs from the contrast colour of the combat hat (cold weather). Besides, the combat scarf overlaps other CIPS MTL layers in the chest area; the TIR image shows that the contrast colour coincides with the contrast colour of ambient background, which indicates the high quality of the TIR protection.

Similar to the previous combination, in the palmgloves (cold weather), the quality of TIR protection shielded by the combat is low. Similarly, the reduced quality of TIR protection has been detected in the combat hat (cold weather) and M9-combat boots, where the laces press the side of the boot to the foot surface. Similar to the previous cases, TIR qualitative shielding has been detected in the combat jacket bottom edge, where CIPS MTL constituent layers from the upper and lower body overlap. A similar mechanism of TIR qualitative shielding has been found in the shin area.

To assess TIR protection quality, the ninth combination of CIPS MTL (see Fig. 1) includes the combat cap (cold weather), combat full face mask, combat underwear (Level 3), combat jacket (cold weather), SMOCK-combat jacket, combat gloves (cold weather) for the upper body; and combat underwear (Level 1), combat underwear (Level 2), combat trousers, SNUGPAK-combat semi-overalls and M9-combat boots for the lower body. SNUGPAK-combat semi-overalls provide effective shielding in TIR CIPS MTL. TIR image clearly shows that the contrast colour is light blue to dark blue just the same as SNUGPAK-combat overalls, compared to the same contrast colours of several layers of CIPS MTL. Similar to the previous combination, in the palm area shielded by the combat gloves (cold weather), the quality of TIR protection is low. Similarly, the reduced quality of TIR protection has been detected in the combat hat (cold weather) and combat full face bandage, because the shemagh fits close to the neck and jaw areas. In M9-combat boots, where the boot laces press against the side of the foot, the TIR surface quality is poor. Similar to the previous cases, TIR qualitative shielding has been detected in the combat jacket bottom edge, where CIPS MTL constituent layers from the upper and lower body overlap. A similar mechanism of TIR qualitative shielding has been found in the shin area. TIR image clearly shows jacket structural elements, such as four external pockets, which provide additional TIR shielding.

To assess TIR protection quality, the tenth combination of CIPS MTL (see Fig. 1) includes the combat cap (cold weather), Tref-combat hat full face buff, combat underwear (Level 1), combat jacket (cold weather), combat jacket, combat gloves (cold weather) and sleeping bag pad for the upper body; and combat underwear (Level 1), combat underwear (Level 2), combat trousers and M9-combat boots for the lower body. Attention is drawn to the low quality of the TIR shielding for Tref-combat hat full face buff. TIR image clearly shows that the bandage keeps the contrast white colour, similar to the uncovered face. TIR image clearly shows that the bandage keeps the contrast white colour, the same as the uncovered face. On the TIR image, the contrast colour of a sleeping bag pad, hold by a soldier, coincides with the contrast colour of the environment, which indicates the high quality of the TIR protection. Similar to the previous combinations, the reduced TIR quality protection is detected for the combat hat (cold weather).

In M9-combat boots, where the boot laces press against the side of the foot, the quality of TIR protection is low, and the quality of the TIR combat gloves is low. Similar to the previous cases, TIR qualitative shielding has been detected in the combat jacket bottom edge, where CIPS MTL constituent layers from the upper and lower body overlap. A similar mechanism of TIR qualitative shielding has been found in the shin area.

To assess TIR protection quality, the eleventh combination of CIPS MTL (see Fig. 1) includes the combat cap (cold weather), combat helmet, combat shemagh, shawl, combat underwear (Level 1), combat underwear (Level 1), combat jacket, RECON/SNIPER-combat jacket, bulletproof vest, combat harness vest, combat gloves (cold weather) for the upper body; and combat underwear (Level 1), combat trousers, RECON/SNIPER-combat trousers and M9-combat boots for the lower body. Besides, CIPS MTL combination has been masked by the soil and vegetation components characteristic of the area; the TIR image shows a high quality level of TIR protection. The parts of the body uncovered by soil and vegetation components have a sufficient quality level of TIR protection. RECON/SNIPER combat trousers increase the quality of the TIR protection for the lower body. Attention has to be drawn to the high TIR shielding quality of the combat helmet; the head, which is not covered by the helmet, is marked as a white area on the TIR image. Combat shemagh represents the necessary quality level of TIR protection. In M9-combat boots, where the boot laces press against the side of the foot, the TIR surface quality is poor. Similar to the previous cases, TIR qualitative shielding has been detected in RECON/SNIPER combat jacket bottom edge, where CIPS MTL constituent layers from the upper and lower body overlap. A similar mechanism of TIR qualitative shielding has been found in the shin area.

TIR protection quality has been evaluated using the obtained contrast coloured areas, which are divided into more typical rectangular areas. Coloured regions of the TIR image have been evaluated as follows: purple, dark blue colour – perfect TIR protection, blue and green – good TIR protection, green – TIR satisfactorily protection, yellow and red – unsatisfactorily, uncovered areas of the body (face) – listed separately. TIR common defence area is formed by the sum of of contrast coloured areas, including uncovered parts of the body. The TIR adequate protection is considered to be the colour regions, which have obtained excellent, good and satisfactory evaluation of the sum of their areas. The indicator of the final analysis is the ratio of appropriate TIR protection colour area to the sum of all areas (Fig. 2). An important role in the TIR protection is played by CIPS MTL constructive solutions. The second and eleventh combinations have a high level of TIR protection since they are specially designed to provide shielding against the electromagnetic spectrum. The second combination is composed of snow combat jacket and snow combat trousers. The eleventh combination is based on the RECON/SNIPER combat jackets and RECON/SNIPER combat trousers. Both combinations are based on the clothing specially designed for the purposes of the camouflage in the visual spectrum of the electromagnetic field. The second combination is specially designed to provide camouflage in the snow-covered terrain. The results of TIR protection are provided in Fig. 3.

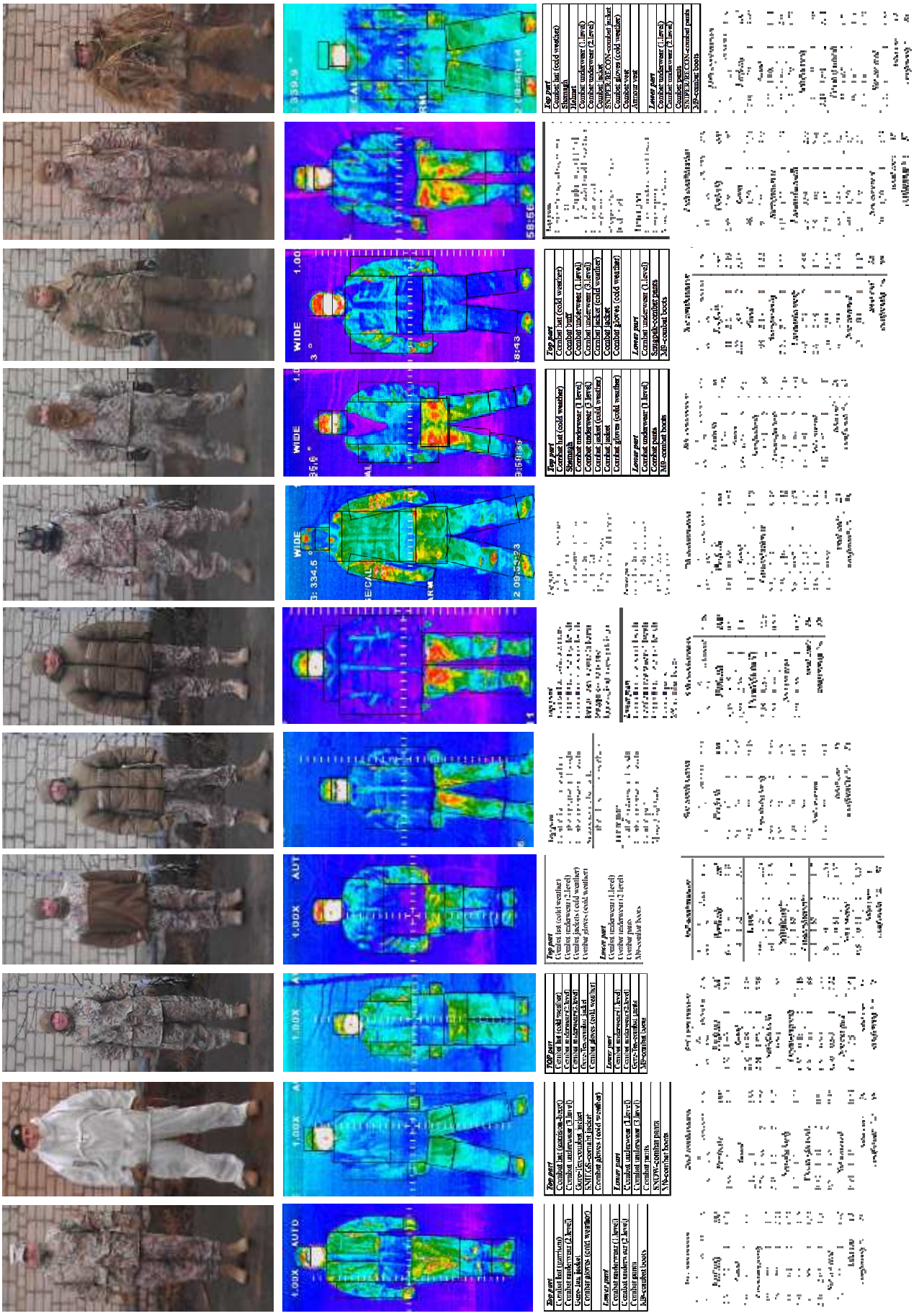

Fig. 2. TIR protection evaluation by the area of colour rectangles

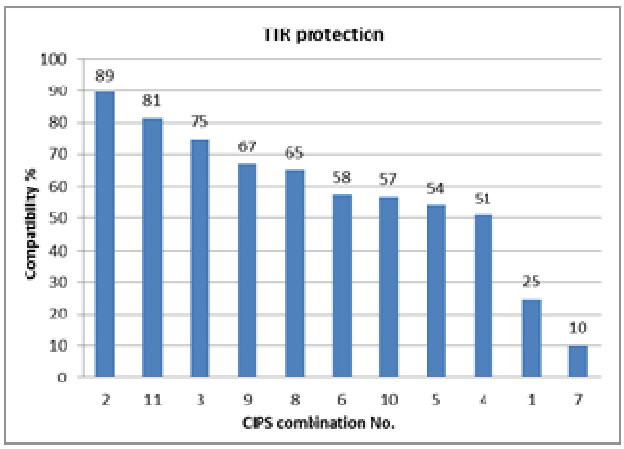

Fig. 3. TIR protection quality evaluation

Combination No.11 is combat jacket and pants or the snipers and reconnaissance personnel. However, there is not any integrated solution to a decrease in the TIR reflectance level. Shemagh is evaluated as CIPS element, which provides high-quality TIR protection. All combinations in conjunction with sleeping bags have high-quality TIR protection.

CIPS combinations with a large area of the trapped air in the layering as well as with multiple layers have a high level of TIR protection quality.

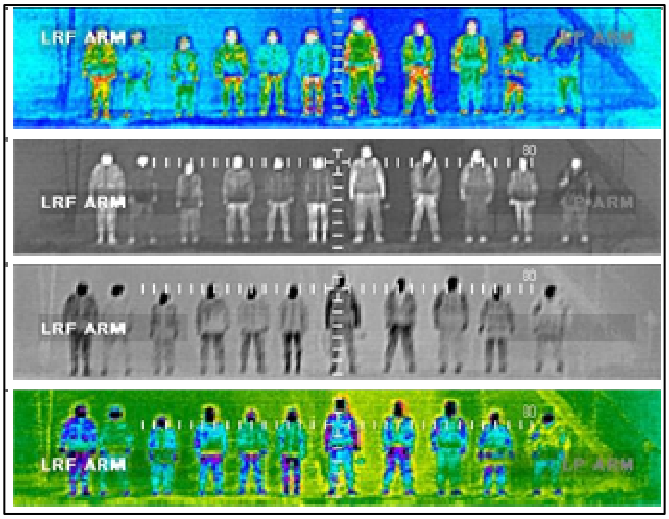

Fig. 4. TIR protection evaluation (distance 30 m)

At a distance of 30 m, TIR quality assessment is the same for each combination (see. Fig. 4) in case of different polarization. In general, TIR adequate protection quality is provided by the second, third and eleventh combination for the upper and lower body, except for feet, face and hands. TIR protection quality of the fifth and sixth combinations is provided by the CIPS MTL, which shields the upper body. TIR protection quality of the ninth combination is appropriate for the CIPS MTL, which shields the lower body. TIR protection quality of the eighth combination is ensured by a combat shemagh, which can be clearly identified.

At a distance of 130 m, TIR quality assessment is the same for each combination (see. Fig. 5) in case of different polarization, as well as the results are the same at a distance of 30 m. On the TIR image, unshielded faces can be identified, as well as CIPS MTL of low-quality TIR protection, which shields the upper body for the first, fourth, sixth, seventh, eighth, tenth combinations. At a distance of 130 m, feet are additionally shielded by soil and vegetation, therefore at this distance footprints cannot be identified on the TIR image.

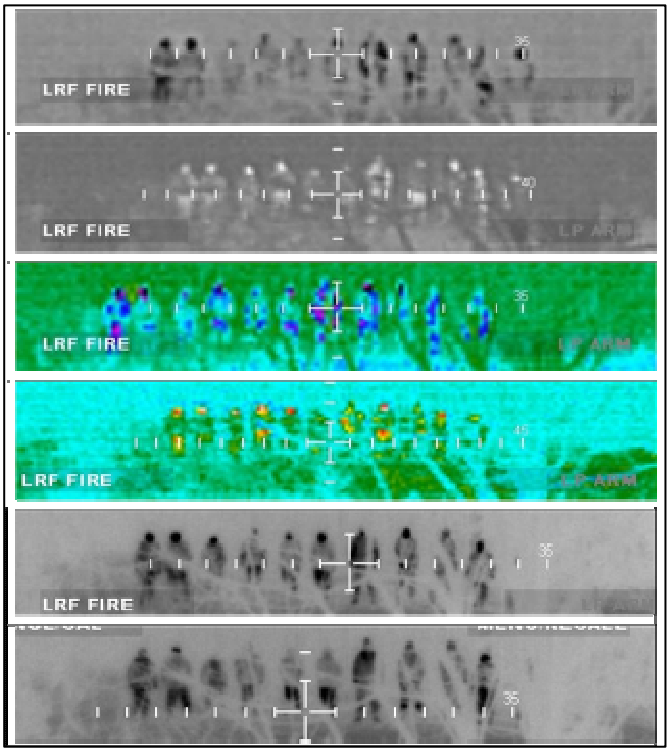

Fig. 5. TIR protection evaluation (distance 130 m)

In addition, the palms cannot be identified; thus, it is possible to evaluate TIR protection quality at different distances and in this particular case, the TIR protection quality for the palms is high at a distance of 130 m and in a given environment. It should be emphasized that the environment affects the TIR shielding; as shown on the TIR image surveillance is conducted under conditions where the vegetation increases the TIR shielding. Thus, inappropriate TIR protection quality provided by CIPS MTL has to be increased choosing natural shields on unit movement paths, as well as individual camouflage uniform with the vegetation to avoid the possibility of detecting the unit by the opposing side. Certain structural elements of CIPS and MTL are properly used, for example, hoods (see the last line in Fig. 5).

At a distance of 276 m, TIR quality assessment is the same for each combination (see Fig. 6) in case of different polarization, as well as the results do not change at distances of 30 m and 130 m. The unshielded face can be identified on the TIR image, as well as low-quality TIR protection is characteristic of the lower body for the first, fourth, sixth, seventh, eighth, tenth combinations. At a distance of 276 m, the soil and vegetation do not provide additional shielding

since soldiers are lined up on the sand hill. Despite the fact that under such conditions on the TIR image footprints shielded by combat boots cannot be identified, as well as the palms shielded by combat gloves (cold weather) and combat gloves of the tenth combination cannot be identified, which allows evaluating the TIR protection quality at different distances, and in this particular case the TIR protection for the palms is qualitative at a distance of 276 m and under the given environmental conditions.

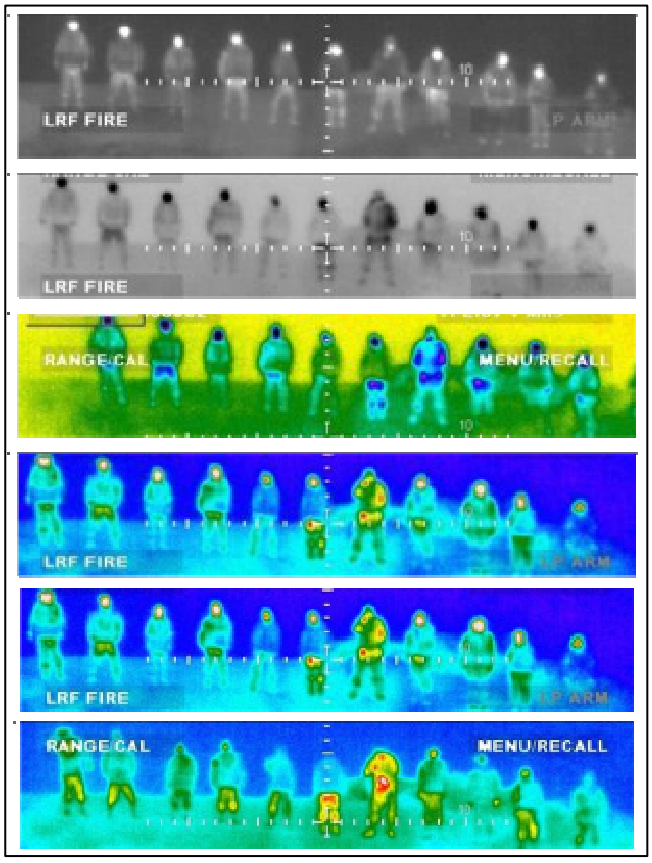

Fig. 6. TIR protection evaluation (distance 276 m)

It should be emphasized that the environment affects the TIR shielding; as shown on the TIR image surveillance is conducted under conditions where the vegetation increases the TIR shielding at a distance of 130 m. As shown in Fig. 6, the eleventh combination, which includes vegetation and soil, provides protection in these circumstances, so inappropriate TIR protection quality provided by CIPS MTL has to be increased choosing individual camouflage uniform with the vegetation to avoid the possibility of detecting the unit by the opposing side. Certain structural elements of CIPS and MTL are properly used, for example, hoods (see the last line in Fig. 6), as well as other structural elements provide additional TIR protection at a distance of 276 m.

At a distance of 426 m, TIR quality assessment is the same for each combination (see Fig. 7) in case of different polarization, as well as the results do not change at distances of 30 m, 130 m, 276 m. The unshielded face can be identified on the TIR image, as well as low-quality TIR protection is characteristic of the lower body for the first, fourth, sixth, seventh, eighth, tenth combinations. At a distance of 426 m, the soil and vegetation do not provide additional shielding. Despite the fact that under such conditions on the TIR image footprints shielded by combat boots cannot be identified, as well as the palms shielded by combat gloves (cold weather) and combat gloves of the tenth combination cannot be identified, which allows evaluating the TIR protection quality at different distances, and in this particular case the TIR protection for the palms is qualitative at a distance of 426 m and under the given environmental conditions.

It should be emphasized that the environment affects the TIR shielding, as shown on the TIR image surveillance is conducted under conditions where the vegetation increases the TIR shielding at a distance of 130 m. The eleventh combination, which includes vegetation and soil, provides protection in these circumstances, so inappropriate TIR protection quality provided by CIPS MTL has to be increased choosing individual camouflage uniform with the vegetation to avoid the possibility of detecting the unit by the opposing side. Certain structural elements of CIPS and MTL are used properly, for example, hoods (see the last line in Fig. 7), as well as other structural elements provide additional TIR protection at a distance of 426 m.

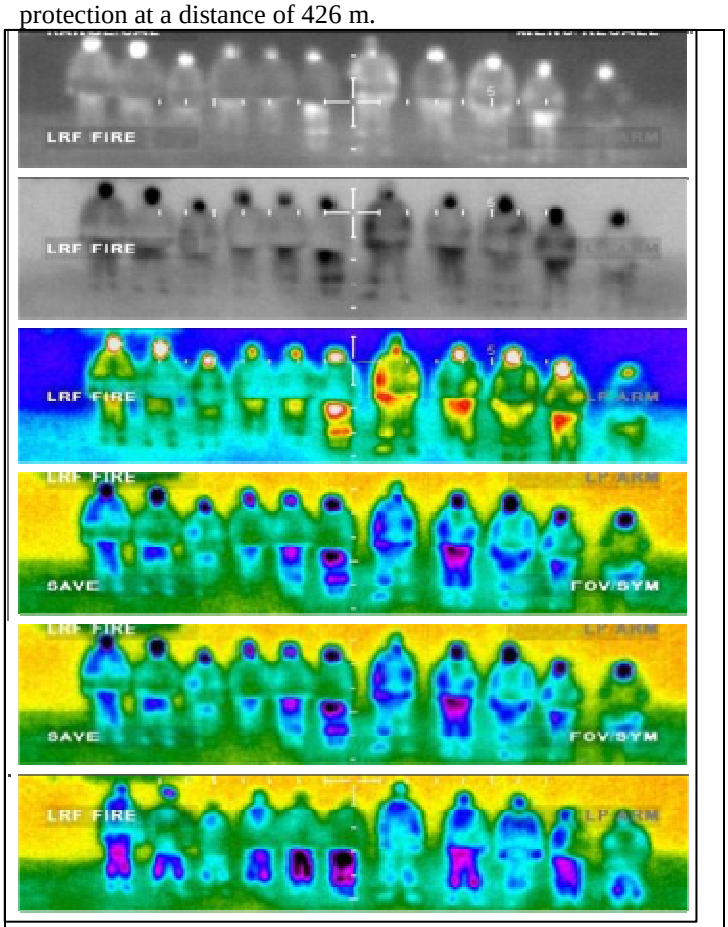

Fig. 7. TIR protection evaluation 426 m

Fig. 7 demonstrates the TIR protection quality of CIPS MTL combinations (426 m) under different polarization. At the top of the TIR image soldiers are lined up facing the thermal observation device, and at the bottom of the TIR image the soldiers are lined up with their backs to the thermal observation device. The fifth and sixth combinations have hoods with combat hats (cold weather); the first and second combinations have combat hats (garrison) and combat berets (garrison); the eleventh combination has a helmet with a combat hat (cold weather); other combinations have combat hats (cold weather). TIR protection quality has increased for CIPS MTL head and neck areas.

CIPS MTL intended to be worn outside as much as possible can be designed as "free-fall", since the constructed MTL TIR provides better shielding and therefore better TIR protection. In addition, the "free-fall" CIPS MTL makes the body silhouette indistinct, which in turn further increases the overall quality of camouflage.

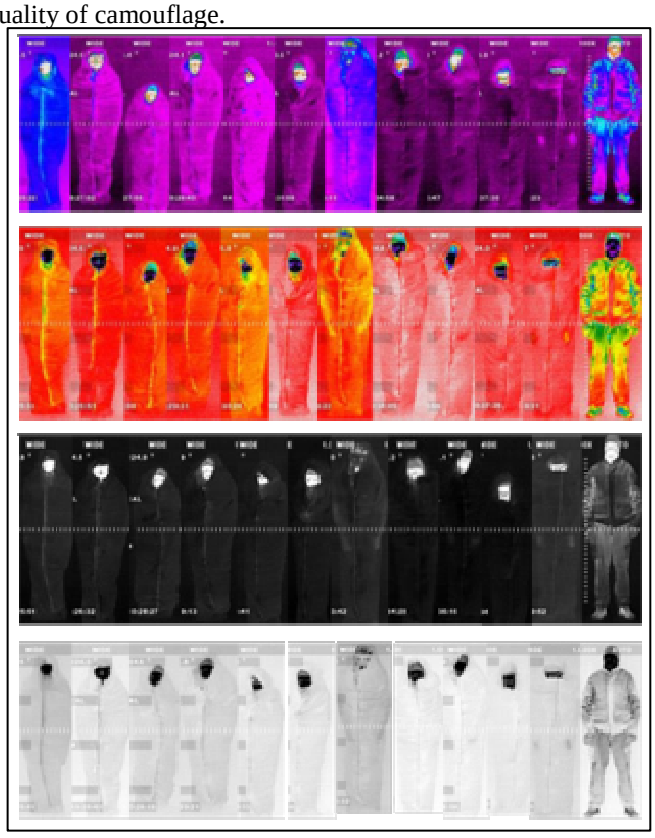

Fig. 8. SNUGPAK-SF-2-sleeping bag (TIR protection)

CIPS MTL with a thickness of 4 mm or more (SNUGPAK) provide better shielding and better TIR protection. Fig.8 shows the experiments with a sleeping bag with a thickness of more than 4 mm, in addition to CIPS MTL layers found on the sleeping bag. Fig. 8 provides the results of TIR protection quality for CIPS MTL combinations topped with SNUGPAK-SF2-sleeping bag. SNUGPAK-SF2-sleeping bag has a thickness of more than 4 mm, No matter what CIPS MTL combination is used, SNUGPAK-SF2-sleeping bag provides TIR protection. For comparison, combat underwear of CIPS MTL combination (Level 2), combat trousers and combat boots-M9 are used. CIPS within MTL multi-layer combinations provides better shielding and thus better TIR protection, which is explained by CIPS MTL layers, as a natural barrier to the effects of the heat wave transmission. CIPS MTL with membrane fabric provides better shielding and better TIR protection.

Combat shemagh is another example of CIPS MTL in "free fall", which provides qualitative TIR protection for the head and neck areas. Besides, the combat shemagh provides multi-layered combination for one MTL included in CIPS, and "breaks" the silhouette of head and neck in the ambient background, which in turn increases the overall quality of the camouflage in the wavelength range of 3–12 μm. Attention is drawn to the combat shemagh and its inclusion in the combat uniform since the measurements of quality insulation, water vapour resistance, air permeability, mechanical protection, fire resistance have confirmed that the shemagh provides multi-functional security, which increases the quality of CIPS. Research shows that at small distances (up to 50 m) the TIR shielding and, as a result, the TIR protection should be increased for boots, where laces press the side of the boot to the foot, because the boots heat from the feet and are detectable on the TIR image at small distances; the same applies to the head and face. Boots are not detected over long distances (130 m, 276 m and 420 m), which is explained by the fact that the soil is a natural barrier to the TIR wave. Head and face are detected at all distances (50 m, 130 m, 276 m and 420 m). Thus, it can be concluded that the TIR foot protection should be ensured for personnel, who should be located at small distances from the possible observation point of the opposing side and whose location should not be prematurely disclosed. The solution could be CIPS-Mod1-SOTACS-system [4], CIPS-Mod1-MKI-system [5], [6], [7], as well as CIPS-Mod1-SNIP/RECON-system [8] with boot covers, boonie hat, veil, hoods [9], which together with the vegetation and soil provide camouflage protection for TIR passing distances (see Fig. 9).

Fig. 9. Boonie hat, veil and hood, boot covers, hood on a jacket

The use of soil and vegetation in CIPS MTL significantly increases the camouflage quality in the TIR range and in the range of 3–12 m, as well as "breaking" the body silhouette at all distances of the experiment. Battle hat (cold weather) is close to the head that makes sufficient thermal insulation, low water vapour resistance and the qualitative index of water vapour permeability. TIR image does not comply with TIR quality level. The solution is to use hoods, which is also confirmed experimentally. In addition, the solution can be to wind scarves around the head and neck. According to the experiment, ballistic protection of CIPS MTL (helmet and

bulletproof vest) and hitch systems (backpacks) provides shielding and hence the TIR protection. In MTL case, ballistic protection can be explained by many layers of organic fibres (exceeding 32), which affect TIR wave absorption and reflection. A similar mechanism occurs in the backpack, along with its contents to exert pressure on the TIR wave absorption and reflection. Thermal monitoring tools cannot be used as an instrument for CIPS MTL psychological assessment, since on the TIR images the same contrast colours of CIPS MTL layers are observed for CIPS MTL with different physiological quality indices. A certain correlation is observed between the contrast colours and CIPS MTL packet thickness or number of layers. Correlation is observed between the contrast and colour tones of CIPS MTL package weight.

IV. Discussion

There is no standardized procedure in NATO relevant documents for the evaluation of TIR reflectance for the individual protection systems representing multiple layering clothing systems. The developed evaluation system by calculating the areas of colour rectangles can be applied to the further evaluation of the different clothing systems under the different climate conditions. Methodology is very cost effective and can be applied by military clothing evaluators and military personnel. CIPS combinations make TIR evaluation closer to the real combat field situation and real use of the garments, taking into consideration not only layering but also design features, compared to textile package evaluation.

V. Conclusions and Future Research

CIPS evaluation has shown the acceptable level of the TIR protection quality, without using specially designed camouflage suits with integrated TIR protection. Design features of the CIPS, increasing camouflage protection in TIR, have been identified, and they should be implemented in operational activities of the military personnel, as well as integrated in the further upgrading of the CIPS. Based on the research, CIPS-Mod1-SNIPER/RECON-system has been established. It is recommended using additional garments to increase TIR protection for certain parts of the body for the personnel of the military reconnaissance and sniper units. The developed methodology of the field trial and calculation of the coloured rectangles should be implemented in the quality evaluation procedures and should be used every time, when any new developed elements are to be integrated into CIPS. The methodology developed for the TIR protection evaluation can be applied also to the evaluation of the newly developed CIPS-Mod11-LATPAT (EUROPE) [10] camouflage pattern in visual (VIS) and near-infrared (NIR) electromagnetic spectrum. However, calculation of the coloured rectangles should be modified to the visual matching of the landscape at different distances.

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Igors Šitvjenkins, Iveta Ābele, Ausma Viļumsone, Hanna Torbicka. Kaujas individuālās aizsardzības sistēmas maskēšanās līmeņa vērtēšana

Pēdējos gados plaši izplatījušies novērošanas līdzekļi, kas darbojas viļņu diapazonos 3 – 5 µm un 8 – 12 µm jeb tā saucamajā infrasarkanajā (termālajā) diapazonā (turpmāk tekstā – TIR diapazons) un paredzēti siltuma avotu detektēšanai un identificēšanai dažādās distancēs. KIAS ietilpstošo MTL maskēšanās novērtēšanai plašā elektromagnētiskajā spektrā viļņu diapazonos 3 – 5 µm un 8 – 12 µm tika veiks kontrolējams lauka eksperiments ar dažādām KIAS ietilpstošu MTL kombinācijām atbilstošiem šādiem eksperimentā fiksētajiem laika apstākļiem: vieta – NBS Ādažu poligons E-sektors, apmācies, lietus un slapjš sniegs, ziemeļrietumu vējš 7-14 m/s, gaisa temperatūra + 2ºC + 4ºC, diennakts gaišais laiks. Eksperimenta ietvaros tika veikta maskēšanās kvalitātes novērtēšana četrās distancēs (30 m, 130 m, 276 m un 426 m), kas atbilst tieša šāviena attālumiem līdz 400 m un pieskaņoti apvidus iespējām, kā arī atsevišķa distance novērtējumam guļammaisos (5 m). Eksperimentam tika sakomplektētas 11 (vienpadsmit) minētajiem laika apstākļiem atbilstošas KIAS MTL ģērbu kombinācijas, kas tika novērtētas iepriekš minētajos apstākļos. Novērtēšanai eksperimentā ir izmantota ASV kompānijas FLIR Systems Inc. termālās novērošanas ierīce B2-FO. TIR aizsardzības kvalitāte tika novērtēta, izmantojot iegūto TIR attēla kontrasta krāsas apgabalus, dalot tos raksturīgākajos taisnstūros un mērot to laukumu. TIR attēla krāsu apgabaliem tika pieņemts šāds novērtējums: violeta, tumši zila krāsa – teicama TIR aizsardzība; gaiši zila – laba; zaļa – apmierinoša; dzeltena un sarkana krāsa – neapmierinoša aizsardzība; neaizsegtās ķermeņa zonas (seja) – tika uzskaitītas atsevišķi. Kopējais TIR aizsardzības laukums veidojas, summējot katras krāsas apgabalu laukumus, iekļaujot arī neaizsegtās ķermeņa zonas. Par atbilstošu TIR aizsardzību tiek uzskatīti krāsu apgabali, kas ieguvuši teicamu, labu un apmierinošu novērtējumu. Kopējais novērtējuma rādītājs atbilst TIR aizsardzības krāsu apgabalu procentuālajam īpatsvaram no kopējā apgabalu laukumu summas. Nozīmīga loma TIR aizsardzībā ir KIAS MTL konstruktīvajam risinājumam. Lielāko TIR aizsardzības novērtējumu ieguva 2. un 11.kombinācija, kas īpaši veidotas KIAS MTL maskēšanai plašā elektromagnētiskajā spektrā. 2.kombinācija veidota ar maskēšanās tērpu sniegotam apvidum: kaujas jaka SNIEGS un kaujas bikses SNIEGS; 11.kombinācijā ietilpst kaujas jaka SNIPER/RECON un -kaujas bikses SNIPER/RECON.

Игорь Шитвенкин, Ивета Абеле, Аусма Вилюмсоне, Ханна Торбицка. Оценка качества маскировки боевой системы индивидуальной защиты в спектре инфракрасного теплового излучения

В последние годы получили распространение средства наблюдения, действующих в диапазонах длин волн 3-5 мкм и 8-12 мкм, или так называемого инфракрасного теплового диапазона, в английской абревиатуре – TIR (thermal infrared), для обнаружения источников теплового излучения, идентификации и распознавания их на различных расстояниях. Оценка маскировки боевой системы индивидуальной защиты (БСИЗ) в диапазоне волн 3 – 12 µм была проведена путем контролируемого полевого эксперимента с различными комбинациями БСИЗ, подпадающие под следующие погодные условия место – Национальные вооруженные силы Адажский полигон Е-сектор, облачно, дождь, северный ветер 7-14 м/сек., температура +2°C + 4°C, дневное время суток. Эксперимент был проведен с целью оценки качества на четырех расстояния 30 м, 130 м, 276 м, 426 м, что соответствует прямой расстояние выстрела до 400 м. Позиция обьектов наблюдения была изменена в зависимость от возможностей окружающей среды. Также была проведена оценка качества спальных мешков на растоянии до 5 м. В эксперименты были использованы 11 (одиннадцать) комбинации БСИЗ. Оценка качества была проведена с использованием теплового устройства наблюдения B2-FO американской компании FLIR Systems, Inc. Качество защиты оценивали с помощью полученных контрастных изображения инфракрасного теплового излучения (ИТИ) цветных областей. Цветовые области были разделены на прямоугольники и были замерены площади всех цветовых областей. Были приняты следующие оценки ИТИ цветное изображение областей: фиолетовый, темно-синего цвета – отличная защита, светло синий – хорошая защита, зеленый – удовлетворительную защиту, желтый и красный – неудовлетворительную защита, открытые участки тела (лицо) – были перечислены отдельно. Общее защита ИТИ формируется путем суммирования каждой области цветового контраста в областях, в том числе открытые участки тела. ИТИ адекватной защиты считается цветом областей, которые получили отличные, хорошие и удовлетворительные оценки сумма их площадей. Окончательный анализ качества защиты ИТИ является процент соотношение суммы площадей получивших отличные, хорошие и удовлетворительные оценки к общей сумарной площади. Важную роль в ИТИ защите принадлежащего БСИЗ конструктивным решениям. Высоким качеством ИТИ защиты обладают вторая и одинадцатая комбинация специально разработан для БСИЗ маскировки широкого электромагнитного спектра. Вторая комбинация представляет собой костюм для маскировки на снежной местности СНЕГ-боевые брюки и СНЕГ-боевая куртка. Одинадцатая комбинация представляет собой – систему боевой одежды СНАЙПЕР/РАЗВЕДЧИК-боевые брюки и СНАЙПЕР/РАЗВЕДЧИК-боевая куртка для снайперов и разведчиков