RIGA TECHNICAL UNIVERSITY

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ENHANCEMENT OF COMBAT INDIVIDUAL PROTECTION SYSTEM

Summary of Doctoral Thesis

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RIGA TECHNICAL UNIVERSITY
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"Clothing and Textile Technology"

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THE DOCTORAL THESIS
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DECLARATION

I declare that I have elaborated the present doctoral theses submitted to the Riga Technical University for conferment of a doctor's degree in engineering. The present doctoral thesis has not been presented to any other university for conferment of a science degree.

Igors Šitvjenkins______________________

Date: 30th June 2014.

The doctoral theses has been elaborated in Latvian and comprises an introduction, 3 chapters, conclusions, bibliography, 34 annexes, 92 figures, 47 tables and 189 pages of the basic text. The bibliography comprises 162 entries.

TABLE OF CONTENT

INTRODUCTION

A permanent task of the Latvian Defence system and National Armed Forces (NAF) is to ensure operational readiness and preparedness to eliminate situations of threat to the state including participation in the collective security and defence activities as well as render assistance to state civil institutions. For that reason it is necessary to continue development of NAF as a standardized national defence asset, professionally prepared, able to adapt to combat and different security operations, equipped according to operational demands and interoperable with NATO military formations.[1]

Today the tasks of military uniforms are to provide protection against environmental threats and threats created by man, to provide comfort and preserve a soldier's ability to work and his/her life over a prolonged time period. The main trends in elaboration of uniforms are physiological monitoring, protection against heat and cold, visual and infrared surveillance masking, olfaction and hearing detection, chemical and biological protection monitoring, protection against fire hazards and environment threats and protection against different types of weapons.

The NAF armed forces security system includes equipment for soldier performing special reconnaissance operations, sniper operations as well as special operations. Such operations are carried out on the territory of the Republic of Latvia and also during international military operations. Special tasks operations are characterized by enormous risk to the soldiers due to artificial and natural threats and due to great physical load consisting chiefly of the amount of materials and equipment, which it is necessary to carry, and their location on the body, the strict demands regarding speed of movement and the severe requirements of masking over a wide electromagnetic spectrum as the tasks may often be carried out in deep rear of enemy, detached from allied forces. On a world scale threats of terrorism and separatism have increased, and it generates additional demand for special tasks in the sphere of interior security, materials and equipment used for the latter and their carrying systems for hidden and open carrying. Soldiers carrying out special tasks shall overcome not only the weather changes, but also the relief specifics and shall

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[1] http://www.mod.gov.lv/Par_aizsardzibas_nozari/Politikas_planosana.aspx[1]

be psychologically stable to be able to fulfil the task. Untimely detection and identification of the soldier may cause his/her perish that may also influence political decisions in the interests of the state. Therefore enhanced safety requirements should be posed for the soldier gear.

Substantiation of the doctoral thesis:

The theme of the present doctoral thesis answers the topicality in the sphere of designing, testing and provision of military uniforms and load bearing equipment; until now NAF combat individual protection system has not been studied applying integrated approach taking into account specific conditions of carrying out military operations and a soldiers' physiological parameters.

Topicality of the doctoral thesis theme:

In order to protect a soldier's health and life while performing his/her duties it is necessary to predict the properties of the clothing set. Adequate gear protects the soldier during combat or rescue missions. The structural design of clothing and load bearing system influences the soldier's ability of fulfilling combat tasks quickly and efficiently. Upon introduction of new elements in the system it is necessary to verify their functionality and compliance to NAF requirements as well compatibility with the existing elements of the protection system. Collection of a set of uniforms, and materials and equipment (MTL) corresponding to the anticipatory soldier's tasks, prediction and ensuring of the collected set's protection properties in the specific climatic and environment conditions mitigates the risk of overheating (hypothermia) of the soldier's body and allows to avoid irreversible brain damage or body frostbites. Likewise important are the camouflage properties of uniform – visual camouflage in the environment of the operation to be carried out by means of the print pattern and colour and heat radiance masking from detection by night vision equipment. Participation in NATO missions operations for settling mass riots demonstrated the need to impart flame resistance to the soldier's gear. Systemic and targeted enhancement of the combat individual protection system requires elaboration of scientifically grounded methods for testing and evaluation of individual elements and complete sets.

Aim of the doctoral theses:

To enhance the Latvian National Army combat individual protection system, by elaborating scientifically grounded recommendations for testing of clothing and equipment and collection of a gear set according to the anticipated environment of usage and threat level.

Tasks of the doctoral thesis:

1. Selection and ranging of the primary indices of combat individual protection system
2. Antropometric study of NAF personnel
3. Research into the properties of the uniform fabrics and layering
4. Prognostication of MTL load and energy consumed
5. Elaboration of methods for evaluation of load bearing armour system
6. Improvement of CIPS MTL camouflage properties
7. Evaluation of flame resistance properties of uniforms
8. Prognostication of heat stroke

Practical importance of the doctoral thesis:

- CIPS architecture has been elaborated, based on which it is possible to test and make complete sets of clothing with load bearing equipment elements for specific working environment and tasks
- MTL properties have been determined and test methods have been selected/elaborated to improve NAF procurement technical specifications or provide grounds for exclusive procurement status
- NAF personnel anthropometric parameters have been determined, which may be used to define procurement of clothing size assortment
- Maximum time limit for wearing duration of uniform ensembles at a time has been established that allows to prevent soldier hypothermia
- Prediction of heat stroke has been made allowing to plan the intensity and duration of the tasks carried out under specific conditions by soldiers wearing the most characteristic uniform sets preventing hyperthermia
- Recommendations have been elaborated for improvement of the CIPS camouflage properties.
- Recommendations have been elaborated to integrate flame resistant materials into CIPS
- Introduction of the system complex in NAF will improve soldier safety and fighting capacity

Research methods used for the doctoral thesis:

Carrying out the doctoral thesis research both standardized and original research methods were used: expert surveys, apriori ranging of combat individual protection system (CIPS) parameters, documentation analysis, comparative evaluation of materials and equipment (MTL), a complex method for determination of defects, evaluation by field experiment and surveys, conformity test of a developed new MTL, EUROFIT test and step-ergometry HARVARD STEPtest, MTL load influence on the consumed energy level, clothing layers thermal resistance, water vapour resistance, water vapour permeability index, air permeability, wind endurance, mass and volume, calculated thermal protection time, determination of a complete CIPS and sleeping-bag set thermal insulation, heat stroke prediction method, determination of burning properties, flame resistance manikin test, protection against UV radiation, CIPS camouflage properties tests have been conducted. The study has been carried out with RTU DTI Textile Materials Science laboratory equipment, on an instrumented manikin in Lund University (Sweden), at *Ādaži* firing ground and in the LSPA laboratory.

Scientific innovation of the Doctoral thesis:

- CIPS structure with ranged system parameters has been elaborated
- Evaluation methods for load bearing armour system have been elaborated
- EUROFIT tests and Harward step test have been adapted for evaluation of conformity of complete clothing and equipment sets
- Method for evaluation of camouflage pattern efficiency has been elaborated
- Method for evaluation of uniform and load bearing equipment thermal radiation masking has been elaborated
- Mathematical model has been elaborated for determination of clothing layering heat insulation

Approbation of the Doctoral thesis:

The main results of the Doctoral thesis have been presented at thirteen international scientific **conferences**:

1. Sitvjenkins, I., Viļumsone, A., Torbicka, H. Small Arms Bullets in Body Armour Testing. In: Baltic Defence Research and Technology 2009 Conference, Latvia, Riga, September 10-11, 2009.
2. Sitvjenkins, I., Vilumsone, A., Baltina, I., Zarina, U. Fabric Selection for the Field Uniforms. In: 5th International Textile Clothing and Design

Conference "Magic World of Textiles" (ITC&DC), Croatia, Dubrovnik, 3.-6. October, 2010.

3. Sitvjenkins, I., Vilumsone, A., Baltina, I., Zarina, U., Pinke, K. Degradation of the Camouflage Pattern and Textile of the Field Uniforms. In: 11th World Textile Conference (AUTEX 2011), France, Mulhouse, June 8-10, 2011.
4. Sitvjenkins, I., Vilumsone, A., Larins, V., Abele, I., Torbicka, H., Pavare, Z. Quality Evalutation of the Combat Individual Protection System by Eurofit Physical Fitness Testing. In: Starptautiskā zinātniskā conference sporta zinātnē, Latvia, Riga, 26.04.2012.
5. Sitvjenkins, I., Vilumsone, A., Baltina, I., Torbicka, H., Zarina, U., Abele, I. Heat Transfer and Physiological Evaluation of the Flame Retard Combat Individual Protection System. In: Innovative Textile for High Future Demands: 12th World Textile Conference AUTEX, Croatia, Zadar, June 13-15, 2012.
6. Vilumsone, A., Blums, J., Valisevskis, A., Baltina, I., Krievins, I., Ziemele, I., Sitvjenkins, I., Terlecka, G., Parkova, I., Sahta, I., Abele, I., Daboliņa, I., Grecka, M. Mart Clothing for People Safety and Health. In: Apvienotais pasaules latviešu zinātnieku III kongress un Letonikas IV kongress "Zinātne, sabiedrība un nacionālā identitāte", Latvia, Riga, October 24-27, 2011.
7. Sitvjenkins, I., Abele, I., Vilumsone, A., Torbicka, H. Camouflage Protection Quality of the Combat Individual Protection System within Electromagnetic Spectral Band Range of 3 μm to 12 μm TIR (thermo infra-red). In: Riga Technical University 53rd International Scientific Conference: Dedicated to the 150th Anniversary and the 1st Congress of World Engineers and Riga Polytechnical Institute, Latvia, Riga, October 11-12, 2012.
8. Torbicka, H., Šitvjenkins, I., Viļumsone, A. Quality of the Procurement Models and Supplying Norms of the Combat Individual Protection System. In: Riga Technical University 53rd International Scientific Conference: Dedicated to the 150th Anniversary and the 1st Congress of World Engineers and Riga Polytechnical Institute, Latvia, Riga, October 11-12, 2012.
9. Ābele, I., Viļumsone, A., Šitvjenkins, I. Selection Criteria of Sleeping Bags. In: Abstracts of Riga Technical University 54th International Scientific Conference : Section: Material Science and Applied Chemistry: Riga Technical University 54th International Scientific Conference, Latvia, Riga, October 14-16, 2013
10. Igors Sitvjenkins, Kalev Kuklane, Ausma Vilumsone, Iveta Abele. Development of the combat sleeping bag system of the Latvian National

Armed Forces. In: Conference, 6th European Conference on Protective Clothing and NOKOBETEF 11, Belgium, Bruges, May 14-16, 2014.

11. Igors Sitvjenkins, Iveta Abele, Kalev Kuklane, Ausma Vilumsone. Estimation of combat sleeping bag system of Latvian National Armed Forces. In: Conference abstract, 13th International Conference on Global Research and Education, Latvia, Riga, 10,-12 September, 2014.
12. Igors Sitvjenkins, Inese Ziemle, Iveta Abele, Inese Pazane, Ausma Vilumsone. Evaluation of camouflage. IN: Conference abstract, 13th International Conference on Global Research and Education, Latvia, Riga, 10,-12 September, 2014.
13. Iveta Abele, Igors Sitvjenkins, Ausma Vilumsone. The property of militaryt sleeping bags . In: Conference abstract, 13th International Conference on Global Research and Education, Latvia, Riga, 10,-12 September, 2014.

Implementation of the thesis is taking place in the National Armed Forces of the Latvian Republic and the structural divisions of the Ministry of Interior – State Police, State Border Guard, the State Fire-fighting and Rescue Service. A project is in the stage of coordination regarding introduction of common structure of uniforms and equipment, provision and logistics for all (six) militarized institutions of the Republic of Latvia.

The author of the doctoral thesis has participated as a researcher within the **scientific project** supported by the European Social Fund "Establishment of interdisciplinary research groups for a new functional properties of smart textiles development and integrating in innovative products". Agreement No. 2009/0198/1DP/1.1.1.2.0./09/APIA/VIAA/148 s.

The author of the doctoral thesis is also the author of 17 **scientific research publications**. The results of the research conducted within the framework of the doctoral thesis have been presented in international and other scientific publications recognized by the Latvian Council of Science.

List of publications:

1. Sitvjenkins, I. Karavīra individuālā aizsardzības sistēma. Riga: VA Tēvijas sargs, 2008. 160 pp.
2. Sitvjenkins, I., Vilumsone, A. National armed forces Republic of Latvia soldier individual protection system concept. Material Science. Textile and Clothing Technology. Vol.4, 2009, pp. 68.-76. ISSN 1691-3132.
3. Sitvjenkins, I., Vilumsone, A., Torbicka, H. Small Arms Bullets in Body Armour Testing. In: Baltic Defence Research and Technology 2009,

Latvia, Riga, September 10-11, 2009. Riga, Ministry of Defence Republic of Latvia, 2009, pp.1-13.
4. Sitvjenkins, I., Vilumsone, A., Baltina, I., Zarina, U. Fabric Selection for the Field Uniforms. In: 5th International Textile Clothing and Design Conference "Magic World of Textiles" (ITC&DC), Book of Proceedings. Croatia, Dubrovnik, 3.-6. October, 2010. Zagreb: University of Zagreb, 2010, pp. 717-722.
5. Sitvjenkins, I., Vilumsone, A., Torbicka, H. Small Arms Bullets in Body Armour Testing. Military Review. Scientific Journal for Security and Defence, 2009, vol. 3/4 (132/133), pp.96.-106. ISSN 1407-1746
6. Sitvjenkins, I., Vilumsone, A., Ziemele, I., Zarina, U., Pinke, K. Aprior ranking of flame retardance functional reply factors for Soldier Individual Protection System. Material Science. Textile and Clothing Technology. Vol.5, 2010, pp. 47-55. ISSN 1691-3132.
7. Sitvjenkins, I., Vilumsone, A., Abele, I., Pinke, K., Torbicka, H. Defects analysis of load bearing armor systems. Material Science. Textile and Clothing Technology. Vol.5, 2010, pp. 56-63. ISSN 1691-3132.
8. Sitvjenkins, I., Vilumsone, A., Ziemele, I., Zarina, U., Pinke, K. Soldier Individual Protection System Aprior Ranking of Functional Replies. Material Science. Textile and Clothing Technology. Vol.5, 2010, pp. 64-71. ISSN 1691-3132.
9. Sitvjenkins, I., Vilumsone, A., Baltina, I., Zarina, U., Pinke, K. Degradation of the Camouflage Pattern and Textile of the Field Uniforms. In: 11th World Textile Conference (AUTEX 2011): Book of Proceedings, 11th World Textile Conference (AUTEX 2011), France, Mulhouse, June 8-10, 2011. Mulhouse: Organizing Committee Autex 2011, pp. 1083-1087. ISBN 9782746628588.
10. Kreslins, K., Sitvjenkins, I., Vilumsone, A. Karavīra individuālās aizsardzības sistēmas funkcija sprādziena pārspiediena iedarbības mazināšanā. Militārā zinātne, 2011, vol.2, pp. 130-144.
11. Sitvjenkins I., Steinbergs G. Karavīra modulāras mugursomas sistēma. Rīga: NBS Nodrošinājuma pavēlniecība un NBS Mācību Vadības pavēlniecība, 2011, pp. 12.
12. Sitvjenkins, I., Vilumsone, A., Zarina, U., Abele, I. Combat Individual Protection System Evaluation of Functional Replay Thermal Resistance Rct, Water Vapour Resistance Ret and Water Vapour Permeability Index im. Material Science. Textile and Clothing Technology. Vol.6, 2011, pp. 81-91. ISSN 1691-3132.
13. Sitvjenkins, I., Abele, I., Vilumsone, A., Torbicka, H. Camouflage Quality Evaluation of the Combat Individual Protection System in the Thermal Infrared Spectrum. Material Science. Textile and Clothing

Technology. Vol.7, 2012, pp. 97-106. ISSN 1691-3132. e-ISSN 2255-8888.
14. Sitvjenkins, I., Vilumsone, A., Larins, V., Abele, I., Torbicka, H., Pavare, Z. Quality Evalutation of the Combat Individual Protection System by Eurofit Physical Fitness Testing. LASE Journal of Sport Science, 2012, Vol.3, No.1, pp. 31-46. e-ISSN 1691-9912. ISSN 1691-7669.
15. Sitvjenkins, I., Vilumsone, A., Baltina, I., Torbicka, H., Zarina, U., Abele, I. Heat Transfer and Physiological Evaluation of the Flame Retard Combat Individual Protection System. In: Innovative Textile for High Future Demands: 12th World Textile Conference AUTEX, Croatia, Zadar, June 13-15, 2012, pp. 1073-1078. ISBN 9789537105440.
16. Sitvjenkins, I., Vilumsone, A., Kreslins, K. KIAS-Mod1-LATPAT maskēšanas apdrukas transformācija KIAS-Mod11-LATPAT (EUROPE) maskēšanas apdrukā. 1. posms - izslēgšanas eksperiments. Militārā zinātne, vol.2(6), 2012, pp. 80-89. ISSN 1691-9300.
17. Igors Sitvjenkins, Kalev Kuklane, Ausma Vilumsone, Iveta Abele. Development of the combat sleeping bag system of the Latvian National Armed Forces. In: Conference abstract, 6th European Conference on Protective Clothing and NOKOBETEF 11, 2014.

The main directions of research of the doctoral thesis are: selection of the Combat individual protection system (CIPS) quality indices and ranging, study of the uniform fabrics and clothing layering, prediction of soldiers' performance and physiological state depending on the climatic conditions, work intensity and duration.

The doctoral thesis has three chapters of body text, an introduction and results and conclusions; it includes a glossary of explanations and abbreviations as well as a list of figures and tables.

Introduction provides a glimpse into problems of the work, grounding of the topicality of research being carried out, formulation of the aim, and tasks of the thesis and its approbation is characterised.

In part one of the present doctoral thesis the National Armed Forces (NAF) of LR political tasks consistent with the State defence concept are reviewed, the condition of combat individual protection system at the initial stage of modernization is characterized and problems for the doctoral thesis research are defined.

In part two the study methods used are summarized: standardized tests and original test methods are described, the validity testing of the obtained results is characterized.

In part three of the doctoral thesis test results are given, their influence on the uniform and equipment properties as well as on soldiers' performance and safety is described.

In the final part the results and conclusions of the doctoral thesis are summarized.

1. COMBAT INDIVIDUAL PROTECTION SYSTEM

On 19th June 2008 by the *Saeima* (the Parliament) of the Republic of Latvia the State Defence concept was adopted [113], according to which under paragraph 24.3.6 the Latvian National Armed Forces (NAF) in a medium term must ensure the ability to deploy and permanently sustain one platoon level unit in an area of operations 15 000 kilometres from Latvian border, one company-level unit at a distance 5000 km, two company-level units at a distance of 3000 km (Fig. 1.1). The soldier protection is formed according to the principle of priority body parts protection principle. In the National Armed Forces a Combat Individual protection System is formed (CIPS) based on a body of several technical, political and economic requirements corresponding to the current world geopolitical situation.

During military operations warriors are subjected to natural and artificial threats. Insufficient prediction of threats may result in errors in the soldiers' provision and diminishing of their fighting ability. In turn, exaggerated threat and erroneous conclusions may lead to the formation of a superfluous number of protective layers and unjustified demand of financial resources. During fulfilment of a particular task artificial and natural threats may exist simultaneously thus causing manifold increase of the threats.

An important task of optimization of individual equipment always is diminishing of the total weight while preserving the fighting ability necessary for survival and fulfilment of the task. The mass of the load to be carried is determined depending on the task and the soldier's weight. A too heavy load will reduce the soldier's fighting ability, increase the internal body temperature and pose a threat to life.

Upon performing the straight duty, characteristic body heat production is in the range from 40 W/m² to 400 W/m², which in accordance with ISO 11079 and ISO 8996 standards corresponds to the states from "at rest" to "doing very hard job" (limited to 1–2 h); in some cases – up to 600 W/m² exceeding by far the maximum permissible limits, which in accordance with ISO 11079 and ISO 8996 are defined as 400 W/m² over a two hour period.

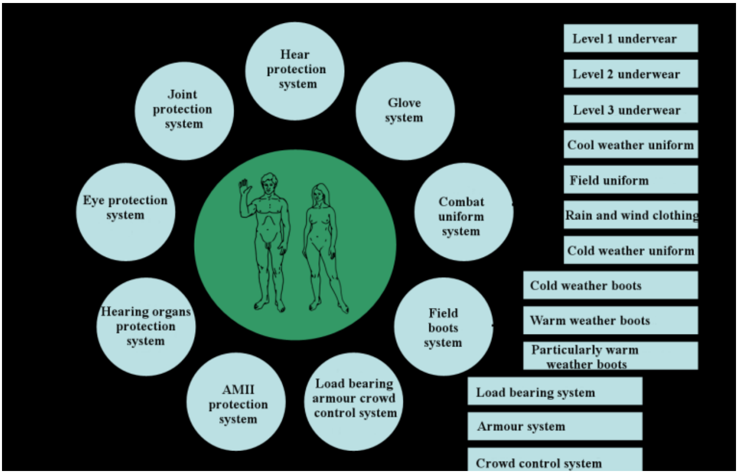

Fig. 1.1. Soldier individual protection system [the author's diagram]

Taking into account the climatic conditions in the Republic of Latvia and heat production ranges, the uniform's basic set conformity to physiological quality basic indices shall be ensured as follows:

- maximum thermal insulation of the set no less than Icl = 4.23 clo (0.606 m^2W/K);
- water vapor resistance not more than Ret = 86.7 m^2Pa/W;
- water vapor permeability index no less than i_m = 0.76 in accordance with ISO15831, and ASTM F 2370 experiments on an instrumented manikin.

Camouflage pattern plays an essential role in the visual recognition of the armed forces of a certain country and individual protection of the soldiers. Modernization of the camouflage pattern is continued in line with the task to develop a camouflage pattern for the region up to 3000 km distance from the territory of the Republic of Latvia, the region of Europe and fighting in densely built-up places (A3 – intermediate climatic regions according NATO AECTP-230).

In the latest years the surveillance equipment operating in the 3 – 5 µm and 8 – 12 µm wave length or infrared (thermal) range and envisaged for identification of heat sources at different distances is becoming common. Therefore it is necessary to assess the camouflaging ability of CIPS at various distances by thermal surveillance equipment.

During combat operations and mass riots CIPS ability to protect against fire threat is also of essential importance. Threat may be basically of three types – thermal threat of open flame, secondary threat and unintentional threat. Thermal threat of open flame is generated by intentional action of relevant type weapons – flamethrowers, napalm, incendiary liquids during riots and other. Secondary threat is generated after the action of weapons and ammunition, for example, ammunition explosions when burns are inflicted by incendiary substances and oils, which are set on fire as well as by burning materials and equipment (MTL), among them MTL included in CIPS. Indirect threat is posed by contact with hot surfaces, for example weapon parts, machine parts etc., and causing burns [6]. Burns are usually subdivided into three levels. First-degree burns are characterised by redness and slight swelling, in case of second-degree burns affect also the underlying levels of skin and cause blistering and third-degree burns affect deeper skin layers and body tissues [24, 51, 109, 110, 112, 114, 115, 122, 133, 135, 136, 139, 140, 141, 142, 147].

The US military researchers have evaluated the quality adequacy of clothing combined of multiple layers to fire threat on an instrumented manikin. Heat flow of 2.0 cal cm for 2sec was accepted as the threat level, which is characteristic of the possible fire threat heat flow during field operations permitting survival provided the action time is short. Time in seconds was chosen as a quality index parameter during which the body suffers 20 % second-degree burns 5 % third-degree burns of total body surface. Apart from relation of the quality index parameter to the total body surface, information sources provide additional criteria for evaluation of burns for the purpose of hospitalization. As the basic external layer fire-resistant garment has been selected and every additional clothing layer ensures better thermal insulation and better fire-resistance accordingly. In the US Army research it was concluded that introduction of a jump suit for fire protection of infantry is necessary.

Under equal conditions protection against fire threat depends mainly on the external layer of clothing. Materials with greater surface density provide for a better protection against fire threat. A jumpsuit provides better protection as compared with clothing consisting of a jacket and trousers.

In the doctoral theses the properties of CIPS components, their protection qualities and conformity to the defined requirements have been evaluated

2. METHODS OF RESEARCH

Various research methods have been used in the doctoral thesis, which allowed for ranking and grouping of the CIPS quality indices, determination of the values of individual CIPS quality indices and the ways of their improvement.

The expert survey method was used for the selection of the researched CIPS primary indices, the evaluation of the load bearing armour systems, the comparative evaluation of armour panels, the evaluation of the patterns LATPAT (EUROPE) and for the improvement of CIPS flame resistance properties. The following requirements were set for the selection of experts – military service, including the combat experience and career length in the National Armed Forces and duty performance in the territory of Latvia, foreign missions in the territories of Afghanistan and Iraq. The experience in the terrain surveillance and camouflage skills were established as additional selection criteria for the LATPAT (EUROPE) evaluation.

The indices **ranking method** was used for the selection of the CIPS primary parametrs, the evaluation of the load bearing armour systems, the comparative evaluation of armour panels, LATPAT transformation into LATPAT (EUROPE) and for the improvement of the CIPS flame resistance properties [132]. The Spearman's rank correlation coefficient was applied to check the adequacy of the survey results; Kendall's coefficient of concordance was used to assess the consistency of the experts' opinions.

The method of official document analysis was used for the selection of the CIPS primary quality indices, the evaluation of ballistic threat and its adequacy to the testing methods, the evaluation of the load bearing armour system, **the comparative evaluation** of armour panels, the evaluation of LATPAT (EUROPE) and for the improvement of the CIPS flame resistance properties. Valid legal NATO Standardization Agreements (STANAG), normative documents of the National Armed Forces and military research documents of other allied countries are used for the official **document analysis.**

The method of comparative analysis was used to choose armour panels. The evaluation methods were developed on the basis of ranking results. The quality criteria of the load bearing armour systems are ranked according to their importance. **The defect detection method** is based on the method of observation in the real environment and in the storage place of items. For the observation purpose the items were investigated and compared with a brand new product, and a defect record card was developed, which showed the type of the defect and the product number. Each type of the product was attributed its own card.

A factory testing of **newly developed MTL** was conducted for the system JSF-Mod1-BUG of the load bearing amour rescue system, designed by the company "NFM Group AS". [40, 41, 53, 111]. The testing procedure is based on NATO STANAG 2138 "Troop trials principles and procedures – combat clothing and personal equipment" [91]. The test commission consisted of 7 members selected from NAF, one of whom was appointed the head of the commission. The commission included representatives of all services related to the introduction and use of the armour vest: the Logistics Command, flotillas of the Naval Forces, the Air Force aircraft squadrons, the Defence Science Research Centre. As the test object was an armour vest the Naval Forces flotilla base in Riga was chosen as a testing place to bring the testing conditions as close as possible to realistic rescue conditions. The vest was tested in *Buļļupe* on board the Naval Forces patrol vessel P-05. The testing methods, program and the process were recorded in the test report.

The **Eurofit** and **Harvard** test methods were used for the analysis of CIPS influence at various loads on the physical condition in the course of time. The complex of the EUROFIT physical fitness test includes anthropometric, cardiorespiratory capability and physical fitness tests. Six NAF soldiers were involved in the experiment. Two soldiers from the NAF Joint Headquarters battalion and four soldiers from the NAF Special Tasks Unit.

The **thermal resistance** test was carried out according to the standard LVS EN 31092:2002 "Textiles – Determination of physiological properties – Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded – hotplate test)" [84], which is identical to the EU standard EN 31092:1993 "Textiles – Determination of physiological properties – Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded – hotplate test) [50] (ISO 11092:1993). The experiment was conducted using the non-destructive thermal and water-vapour resistance testing equipment "Permetest" and the program "Permetest Data Evaluation V2.3" developed by the company "Sensora Instruments & Consulting". The device measures the thermal permeability in the range from 1 to 50 W/m^2K, the thermal resistance – in the range from 0.02 to 1 m^2K/W and the simulated temperature of human skin – 35 ^{o}C [38]. Initial thermal resistance indices comply with the standard ISO 11092:1993 as they are calculated according to the formulas provided in the standard [41].

Layer combinations of the CIPS materials and equipment were tested for different parts of the body – the head – in three combinations, the neck – in four combinations, the upper body (without gloves) – in ten combinations, the lower body (without footwear) – in twelve combinations. **The water-vapour resistance** and **the water-vapour permeability** index were determined by the same procedure.

Air permeability was determined according to the standard LVS EN ISO 9237:2000 "Textiles – Determination of the permeability of fabrics to air" by the Material Science Laboratory of the Design Technologies Institute (DTI).

Heat stroke is influenced by the following factors: natural threat of the operational field: increased air temperature and humidity, a soldier's high physical exertion during the task fulfilment caused by a soldier's own physical movement in different types of the terrain; the weight of the gear carried by a soldier, individual protection equipment, weapons, munitions, communications equipment, survival and existence systems and combat uniform; limited heat exchange with the environment via the combat uniform and gear. According to the NATO normative acts, the model of calculation of the rectal temperature (Tref) is used for the prediction of heat stroke; in addition, NAF use the PHS2 calculation model developed by the Lund University. The reason for the use of the PHS2 calculation model elaborated by the Lund University is limitations present in other calculation models with respect to the amount of the protection systems on the body, which is limited by the thermal insulation of 1 clo (0.155 m^2K/W) for a specific combination of the clothing system.

To determine **the flame resistance** requirements for CIPS MTL, a test is carried out according to the standard LVS EN 367:1992 "Protective clothing – Protection against heat and fire – Method of determination of heat transmission on exposure to flame". Twenty fabric samples are tested to determine the heat transfer index. Upon determining CIPS MTL burning behaviour, a test by ignition at the surface and at the edge is conducted pursuant to the standard LVS EN ISO 6940:2000 "Textile fabrics – Burning behaviour – Determination of ease of ignition of vertically oriented specimens". Twenty fabric samples are tested to determine the heat transfer index. **The flame resistant manikin test** is carried out according to the standard ISO 13506 "Protective clothing against heat and flame – Test method for complete garments – Prediction of burn injury using an instrumented manikin". The test provides the possibility to evaluate the predicted degree of a skin burn injury in all areas of the body excluding feet, palms and the upper part of the head. The degrees of skin burn injuries in the areas of the body were evaluated according to the following scale: no burns, pain, first-degree burn, second-degree burn, third-degree burn. Nineteen tests are carried out by using individual protection systems.

The samples of CIPS MTL raw materials were tested for **protection against exposure to the ultraviolet radiation** according to the standard LVS EN 13758-1:2002 "Textiles. Solar UV protective properties – Part 1: Method of test for apparel fabrics" Twenty samples of CIPS materials were completed for testing of protection against exposure to the ultraviolet radiation [9].

Protection against detection of the thermal radiation by means of night vision equipment cannot be measured using standardized tests. Therefore, a special evaluation procedure was developed on the basis of the STANAG 2138 PPS guidelines. With the purpose of evaluation of the CIPS MTL camouflage properties over a wide electromagnetic spectrum in 3-5 µm and 8-12 µm wavelength bands, a controllable field trial was conducted: the location – NAF *Ādaži* military firing ground, sector E, cloudy, rainy and wet snow, northwest wind 7-14 m/sec, air temperature from + 2 to + 4 ^{o}C, daylight hours (Fig.2.1). The experiment envolved evaluation of the camouflage quality at four distances (30 m, 130 m, 276 m and 426 m) and at a special distance for the evaluation in sleeping bags (5 m). Eleven CIPS MTL combinations satisfying the above mentioned weather conditions were completed for use in the experiment. The thermal surveillance device B2-FO designed by the USA company "FLIR Systems Inc." was used for the surveillance purposes.

Fig. 2.1. Soldiers preparing for the experiment, the image in TIR range [the author's image]

The TIR protection quality was evaluated using the obtained image coloured areas, subdividing them into themost typical typical reactangles, and measuring their area. Coloured areas of the TIR image were evaluated as follows: purple, dark blue colour – excellent TIR protection, light blue and green – good, green – satisfactory, yellow and red colour – unsatisfactory; uncovered areas of the body (the face) were listed separately. The total TIR protection area is formed by the sum of all coloured areas, including uncovered areas of the body. The coloured areas, which received excellent, good and satisfactory evaluation, were considered to be an adequate TIR protection.

3 TEST RESULTS AND THEIR ANALYSIS

The selection of the CIPS primary quality indices is based on NATO Standardization Agreements (STANAG), the normative documents of the National Armed Forces and military research of other allied countries according to the specification of the works to be carried out and the types of threats, civil standards, as well as taking into account technical and economic indices [3, 4, .43, 44, 45, 46, 47, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 86, 108, 151, 152, 154, 156, 157, 158, 159, 161, 162]. Fourteen representatives of the Republic of Latvia National Armed Forces were invited as experts. The expert survey was conducted by means of the questionnaire method, delivering a questionnaire with the first 28 quality indices to each expert individually. The quality indices are listed at random.

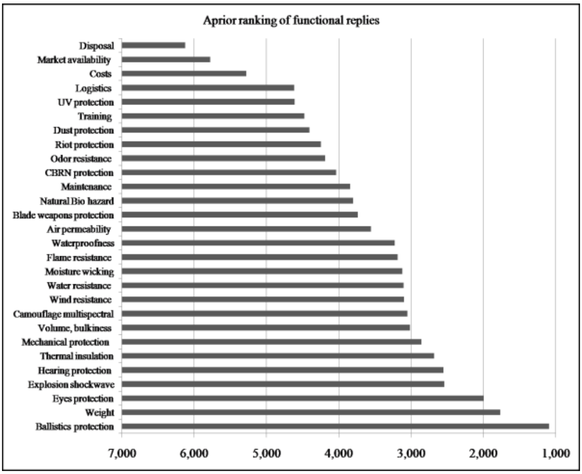

Fig.3.1. Grouping the CIPS quality indices

As a result of **grouping of the CIPS primary quality indices**, a selection of 28 CIPS primary quality indices was obtained, which can be grouped into six basic CIPS quality groups including protection properties, properties influencing soldier ability to fight and technical and economic indices (Fig.3.1). It can be deemed that the grouping of the parameters into sub-groups was performed properly as in all the cases the calculated Link and Volles criterion is lower than its tabulated value.

The NAF **anthropometric research** was conducted using the data of combat units. The average statistical data of a NAF soldier according to the measurements of the focus group are as follows: height 179 cm (measurements of 3 360 soldiers), chest girth 106 cm (measurements of 3 351 soldiers), waist girth 94 cm (measurements of 3 351 soldiers), head girth 57 cm (measurements of 3 358 soldiers), the size of boots 43 (measurements of 3 363 soldiers), hip girth 105 cm (measurements of 3 350 soldiers). The correlation coefficient of soldiers' chest and waist girths is $r = 0.91$; the correlation coefficient for chest and hip girths is $r = 0.74$; the correlation coefficient for waist and hip girths is $r = 0.71$; the height and the size of boots are correlated by applying the coefficient $r = 0.80$. The body surface area $S = 2.02\ m^2$, according to the Du Bois formula ISO 8996 "Ergonomics of the thermal environment – Determination of metabolic rate" [67], the average weight of a soldier is 84 kg.

A research on the physical and mechanical properties of all individual textiles included in the CIPS seven-layer basic set was conducted as a part of the doctoral thesis (table 3.1).

Table 3.1
Clothing combinations for the upper body

Clothingcombination No.	Level 2	Level 3	Cool weather jacket	GoreTex jacket	Snugpak jacket-hooded	Layering thickness ,mm	Surface density, g/m²
1.	x					0.7	115
2.	x	x				2.8	345
3.	x	x	x			7.1	708
4.	x	x	x		x	11.1	963
5.	x	x	x	x		7.5	898
6.	x			x		1.2	305
7.	x	x			x	6.9	600
8.	x	x		x		3.3	535
9.	x		x		x	9.1	733
10.	x		x	x		5.5	668

As the clothing layers are interchangeable depending on specific conditions and tasks, the most typical clothing sets were made for the upper body (included in the summary), lower body, neck and headwear with a purpose of studying the thermal insulation, air and water-vapour permeability properties of the clothing layering.

It was concluded that the CIPS thermal insulation level is insufficient for the cold climate zones C2 – C4, which according to ISO 11079 shall have the thermal insulation from 3 to 4.5 clo. The research determined that in similar conditions membrane laminates reduce thermal insulation (fig.3.2).

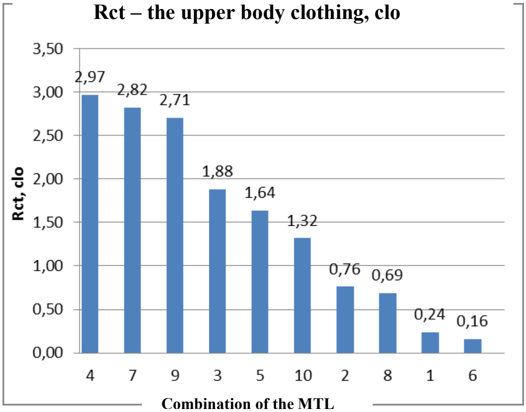

Fig. 3.2. Thermal insulation R_{ct} – the upper body clothing

The CIPS thermal insulation mathematical model is developed with the purpose of predicting thermal protection properties of different MTL combinations. To develop a mathematical model for prediction of the thermal insulation function, three possible factors were selected as variables in the experiment: the number of layers, the density of the layers surface and the thickness of layers. The correlation analysis demonstrated the relationship of the factors "the density of the layers surface" and "the thickness of the layers" R2 = 0.8086.

According to the results of the factor correlation analysis, further in the experiments two factors remained – the number of layers in the garment layering and the total thickness of the layers, between which the correlation analysis did not demonstrate any relationship.

The reliability of the group correlation coefficient R2 = 0.5071 was assessed using the Fisher criterion.

Based on the results of the experiment

$$F_{\exp} = \frac{R^2(m - \mathrm{k} - 1)}{(1 - R^2)k} \qquad (3.1)$$

where m – the number of tests, 11;

k – the number of indications (parameters), independent variables, 2.

The calculated Fexp = 4.115, Ftab = 4.459 is compared with the respective marginal tabulated value with the reliability of 95 %. The number of degrees of freedom v1 = k = 2, v2 = m-k-1 = 11-2-1 = 8.

As Fexp < Ftab, the studied correlation (see Fig. 3.4 b) is insignificant, i. e., the factors are mutually independent. The first degree two factor orthogonal plan was used to develop the mathematical model, see table 3.2.

The variation range for the factors "the number of layers in the clothing layering" ΔX1 = 1 and "the thickness of the clothing layering" – ΔX2 = 4.2. The natural values of the factors have been normalized by using the symmetric coding.

$$x_{ij} = \left(\frac{X_{ij} - \overline{X}_j}{\Delta X_j} \right) \qquad (3.2)$$

where *Xij* – *j*-th factor natural value at *i*–th level;

$\overline{X}_j$ – *j*-th factor natural value at the mean level;

ΔX_j – variation interval/range of *j* –th factor levels.

Respectively, in the coded mode factors x1 = (X1-4)/1 and x2 = (X2-8.4)/4.2. The plan of the experiment, the work schedule, the results and calculations of regression coefficients have been summarized in Table 3.2.

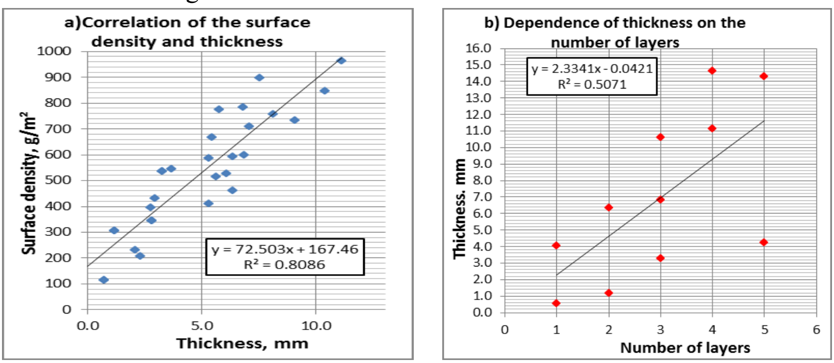

Fig.3.3. Analysis of the factor correlation

Table 3.2
Calculation of regression coefficient

Nr.	Experiment plan matrix			Work matrix		$\overline{Y}_u$, Rct m^2K W	Regression equation coefficients		
	x_0	x_1	x_2	No of layers X_1	Thickness X_2, mm		x_1*y	x_2*y	x_1*x_2*y
1	1	1	1	5	12,6	0.388	0.39	0.39	0.39
2	1	-1	1	3	12,6	0.570	-0.57	0.57	-0.57
3	1	1	-1	5	4,2	0.127	0.13	-0.13	-0.13
4	1	-1	-1	3	4,2	0.266	-0.27	-0.27	0.27
						0.3378	-0.0804	0.1412	-0.0106
						b_0	b_1	b_2	b_{12}

Experiment parameters, number of experiments N = 4, number of observations n = 10, factor number k = 2. The following regression coefficients were obtained – see Tab. 3.2.
For validation of the regression coefficient significance the statement that regression coefficient is significant, if its absolute value outweighs the credibility interval.

$$P(b_i-\Delta b_i \leq \beta_i \leq b_i+\Delta b_i)=\alpha, \qquad (3.3)$$

where

$b_i-\Delta b_i$; $b_i+\Delta b_i$ – regression coefficients credibility intervals;

α – 0.05 credibility probability for the statement that the coefficient $\boldsymbol{b_i}$ value estimated by calculations differs from its true value β_i by value, which does not overweigh the coefficient evaluation error Δb_i.

$$\Delta b_i = \pm\frac{t \cdot s\{y\}}{\sqrt{N \cdot n}} = 0{,}0085, \qquad (3.4)$$

where

t – "Student's" criterion (for probability 95% t=2);

$s\{y\}$ – approximated restoration-recovery error value;

N – number of experiments considered upon determination of regression coefficients (N=4);

n – number of observations in the experiment (n=10).

$$s\{y\} = 2.67\mathrm{E}-04 \text{, as } s^2\{y\} = \frac{s_E}{f_E} = \frac{\sum_1^N \sum_1^n \left(y_{uj} - \bar{y}_u \right)^2}{\sum_1^N (n-1)} = 7.15\mathrm{E}-04, \quad (3.5)$$

where s_E – sum of squared deviations related to restoration variance;

f_E – number of freedom degrees, equal to the difference between the number of all experiment observations N_{kop} and the number of individual observations N, $f_E = N(n-1)$=36;

y_{uj} – reference value in the observation;

$\bar{y}_u$ - arithmetic mean reference value in the experiment.

Validation of regression coefficients significance demonstrated the low significance of coefficient b_{12} with probability 95% (α=0.05), as its value b_{12}= -0.01 is very close to the error value of coefficients $\Delta \boldsymbol{b}_i$=+/-0.0085. Wherewith the coefficient was regarded as equal to zero and excluded from the regression equation.

Thus CIPS heat insulation mathematical model for verification is:
$y = 0.3378-0.0804x_1 + 0.1412x_2$ or deciphered with natural values
$Y=0.3770-0.0804X_1+0.0336X_2$.
To validate adequacy of the mathematical model the value of Fisher criterion was calculated

$$F_{calc} = \frac{s_{ad}^2}{s^2\{y\}} = 6.3$$

and the tabulated value was found
F_{tab} ≈250, considering that $s^2\{y\}$ = 7.15E-04 and variation of adequacy s^2_{ad} =4.47 E-04
at the number of freedom degrees $f_{ad} = N-k-1$=1, where k – number of independent factors.

It is evident that $F_{calc} < F_{tab.}$ It allows to assert that the regression equation obtained or the mathematical model of CIPS heat insulation is adequate.
Adequacy validation data – see Table 3.3.

Table 3.3
Data for finding s^2_{ad}

Work matrix		$\bar{Y}_{exp}$	Y_{progn}	$(\bar{Y}_{exp} - Y_{prog})^2$
Number of layers X1	Thickness X2			
5	12.6	0.388	0.399	0.000112
3	12.6	0.570	0.559	0.000112
5	4.2	0.127	0.116	0.000112
3	4.2	0.266	0,277	0.000112
			s^2_{ad}	0.000447

With a purpose of load bearing armour system enhancement registration and assessment of the used systems defects was performed (fig.3.4). In total 91 vest defects were analysed and recommendations for improvement of the system were elaborated.

In order to evaluate changes in the body ability to work under influence of different clothing sets and gear Eurofit and Harvard tests were carried out: in 5 days of the experiment 5 repeated work performance tests with 5 different protective clothing sets. The first test was conducted with clothing set No. 1 with total weight 1.7 kg, No. 2 with total weight 11.0 kg; Nr. 3 with total weight 20.2 kg, No. 4 with total weight 19.6 kg; No. 5 with total weight 11.8 kg.

Upon establishing the protection level of load bearing armour systems against **threats posed by bullets and fragments** standards were analysed and it was concluded that bullets can be subdivided into three groups. Group one included bullets from cartridges envisaged for shooting with pistols, revolvers and submachine guns. Group two included cartridges of more powerful bullets without body armour penetration capability, envisaged for shooting with rifles, assault rifles and machineguns. Group three – bullets with body armour penetration capability of cartridges envisaged for shooting with rifles, assault rifles and machineguns. Within each group analysis was performed of bullet diameter (mm), weight (g), speed (m/s), energy (J) and ballistic energy density (j/mm2). Within each bullet group there are several types of ammunition, the ballistic energy density of which is greater than the ballistic energy density established in the standards, therefore ballistic protection equipment may not be safe enough against all types of bullets and fragments. Senior officials in state institutions and companies should pay attention to such ammunition as a potential test bullet in ballistic material tests.

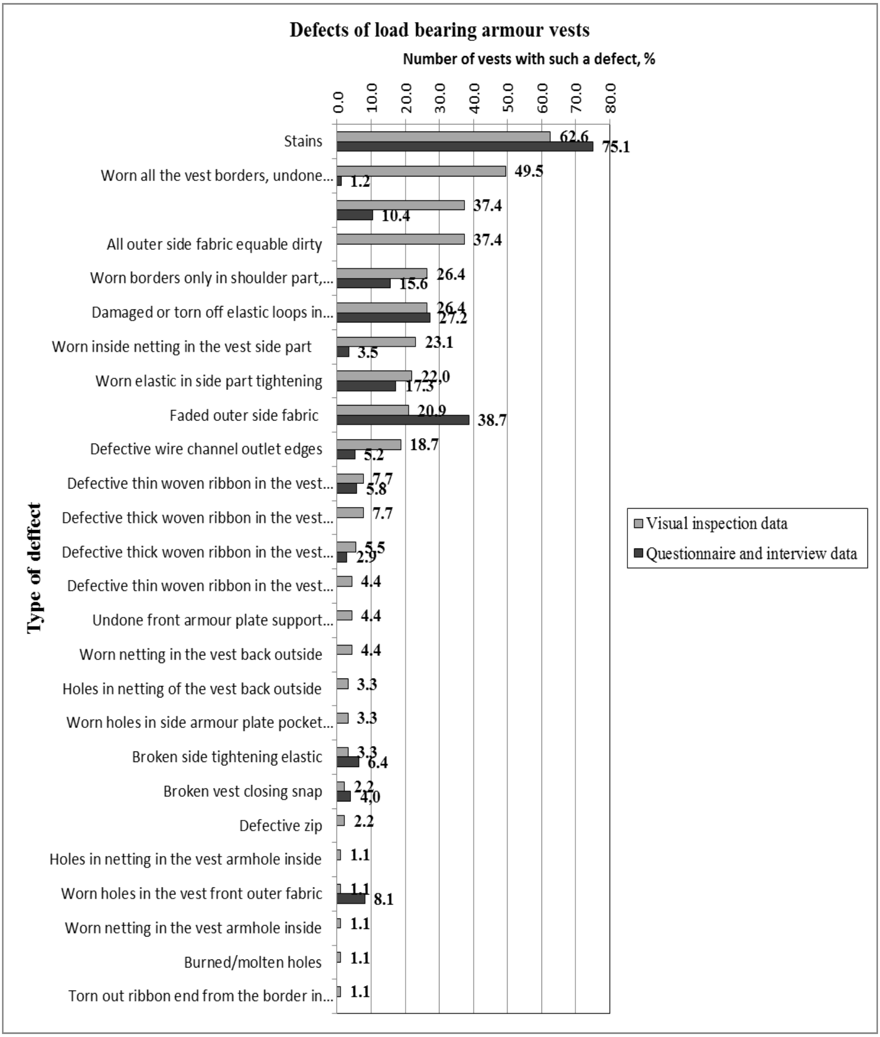

Fig. 3.4. Diagram of load bearing armour vests defects

Physical ability to work evaluated in Harvard STEP-test according to HSTI index value in individual tests with different clothing sets demonstrates no statistically significant differences (P>0.05) in body capacity for work indices. The different protective clothing sets used do not affect the experiment participants' ability to perform physical work in ergometric step test, and accordingly also NAF soldiers' performance, which is an essential index for evaluation of protective clothing efficiency.

In the thesis CIPS garments flame resistance qualities are evaluated and physical and mechanical properties and physiological comfort properties of garments with and without flame resistance have been compared (table 3.4.). As there are no essential differences in the results it provides grounds for introduction of flame resistant materials in all CIPS layers.

Table 3.4
Soldier uniform outerwear properties

NYCO	Latpat Ripstop	USw	Olive	USd	Kermel	BRw	BRd	Latpat
Air permeability coefficient, mm/s								
138.28	66.80	92.85	62.79	106.88	187.04	289.91	750.16	177.02
Wear resistance, cycles (12 kPa)								
190 000	50 000	60 000	60 000	60 000	55 000	30 000	25 000	30 000
Material tear-resistance (weft and warp), N								
38.16	23.43	21.03	29.56	45.64	54.09	45.98	78.03	18.46
44.86	19.49	45.39	34.00	61.96	57.92	53.23	81.47	25.19
Surface density, g/m^2								
217.45	216.11	256.96	222.79	265.60	268.52	203.32	198.41	206.68
Drying rate % /5 hours								
74	65	40	53	36	62	80	51	54
Water absorption, g/hour								
62	68	210	99	199	94	51	125	89
Fabric bending strength (weft and warp), µNm								
12856	67513	44599	34139	36008	46820	14113	14428	42616

NYCO	Latpat Ripstop	USw	Olive	USd	Kermel	BRw	BRd	Latpat
16057	99709	37060	42057	26986	51259	23324	20719	109475
Surface water-repellency, points								
5.00	5.00	2.00	2.00	1.00	5.00	2.00	2.00	5.00
Shrinkage, surface %								
2.41	2.08	2.74	2.32	1.83	1.33	1.83	1.17	3.31
Crease-resistance, points								
3.00	3.00	4.00	2.00	4.00	4.00	4.00	4.00	4.00

To calculate thermal insulation of the clothing layers it is important to determine the **metabolic rate** in order to prevent soldier possible overheating or freezing. During experimental tests in the climate camera the thermal insulation indices of CIPS MTL sets have been established. In actual wear environment there are many variable factors influencing soldiers' performance and comfort. To project **permissible wearing duration** of CIPS ensembles **at a time** , an estimate of the limited duration of usage *Dlim* (table 3.5) has been made in accordance with the standard ISO 1107: 2008 **"**Ergonomics of the thermal environment - Determination and interpretation of cold stress when using required clothing insulation (IREQ) and local cooling effects", modelling different environment conditions and soldier metabolic rates. In the calculations for various clothing sets the metabolic rate M (fig.3.5), environmental temperature T, thermal insulation *clo* were varied. Unvariable parameters are air humidity RH%=85, human body mass 81 kg, height 181 cm, body surface 2.0 m^2.

In the study calculations were made for seven CIPS MTL sets at the temperature range from -50 C^o to +10 C^o and metabolic rate range from 70 W/m^2 to 400 W/m^2.

The duration limit of one-time wearing of CIPS MTL is influenced by a soldier's metabolic rate and environmental temperature. The modelled conditions (table 3.5) demonstrate a higher threat to life at a low metabolic rate in the modelled conditions than at low environmental temperature and a high metabolic rate.

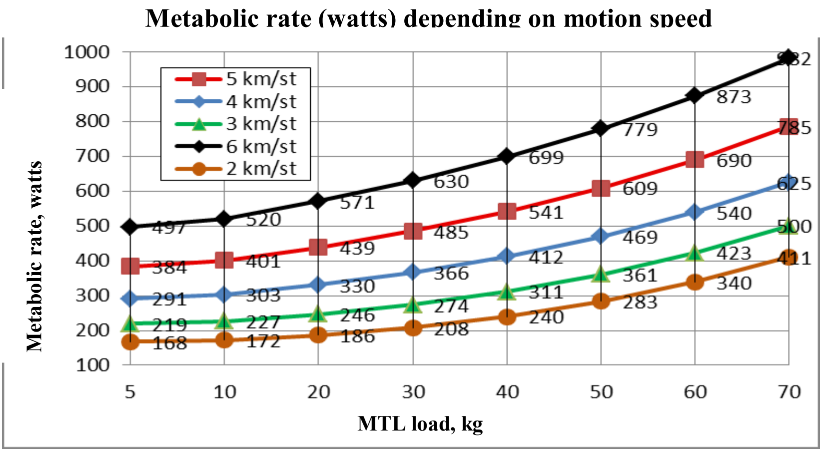

Fig. 3.5. M – metabolic rate, watts

From the results obtained it can be concluded that the sets tested in the experiment have good thermal protection properties and at the relevant metabolic rate they can preserve soldiers' work performance.

Table 3.5
Wearing duration at a time (example)

Basal not-FR, 4.23clo								
M (W/m²)	70	80	80	100	110	120	110	150
Ta (ºC)	-25	-25	-30	-30	-30	-30	-40	-50
Dlim, h.	1.3 - 1.1	2.0 - 1.5	1.4 - 1.1	4.0 - 2.3	4.8 - 8.0	over 8	2.3 - 1.6	over 8
SOTACS not-FR/FR, 1,7 clo								
M (W/m²)	70	70	300	200	150	150	150	200
Ta (ºC)	0	10	0	0	0	-10	-5	-30
Dlim, h.	0.8 - 0.7	3.1 - 1.6	over 8	over 8	over 8	4.2 - 1.3	8.0 - 3.2	1.2 - 0.7
Basal not-FR/FR, 2,81 clo								
M (W/m²)	70	100	150	70	50	90	70	70
Ta (ºC)	-5	-5	-30	0	0	-3	-10	-7
Dlim, h.	1.4 - 1.1	8.0 - 4.3	3.1 - 1.4	2.6 - 1.7	1.5 - 1.2	8.0 - 3.0	1.0 - 0.8	1.2 - 1.1

Table 3.6
Prediction of heat stroke (example)

Tre, (n=1.1, 81 kg, 181 cm, 2,0 m2) Ta=30°C, RH%=70, 5 km/h, 35 kg								
Tid, min	2	10	20	30	40	50	60	120
Tre(°C)	**36.9**	**37.3**	**37.7**	**37.9**	**38.0**	**38.0**	**38.0**	**38.0**
Tsk (°C)	34.5	35.0	35.2	35.4	35.4	35.5	35.5	35.5
Water loss(g)	3	34	111	216	336	463	594	1390

The data in the table 3.6 are indicative of the fact that for a soldier in the above combat uniform with load bearing equipment and a load up to 35 kg marching at a speed 5 km/h at 30 °C for two hours **heat stroke** is not predicted

.

CONCLUSIONS AND RESULTS

1. As a result of the analysis of the National Defence concept primary operational requirements were established considering the operational zones defined in the concept and the climate categories linked with NATO AECTP-230 “Climatic condition”.
2. As a result of the research a system of 28 CIPS quality functions has been obtained, which may be grouped into three groups – defence, functions influencing combat capability and technical and economic functions. The elaborated system should be used in procurement models selecting the economically most advantageous offer according to the system of several criteria determining CIPS enhancement in the priority directions.
3. Anthropometric study of NAF personnel was conducted to provide senior officials with statistically grounded size charts for future purchase orders of CIPS MTL sizes. In the anthropometric study statistical mean soldier torso measurement data were determined, which are necessary for calculation of work input in the research on clothing sets thermal insulation.
4. In order to improve the ballistic protection ammunition market analysis was carried out as a result of which discrepancy between the bullet types available on the market and the bullets used in the test procedures was found. Bullets having a greater ballistic energy density than the ones included in the test standards are also found in the NAF military equipment. In future research it should be tested, if load bearing armour system quality is adequate for such threat.
5. Ranging of load bearing armour system quality indices has been performed; the method for comparative assessment of load bearing armour system elements has been elaborated. The elaborated system should be used in procurement models selecting economically most advantageous offer according a system of several criteria.
6. The method for determination of defects has been elaborated in order to enhance load bearing armour systems. Pursuant to the implementation of the rearch CIPS-Mod1-BEAR-II system was improved along with changes in the relevant contract obligations. As a result of survey and interviews the quality of CIPS-Mod1-CIRAS system was assessed. The

method may be used to improve the quality of other protection systems of the type in future.

7. Within the research a new method for assessment of new load bearing armour system MTL conformity before their acceptance into NAF use was elaborated and aprobated. The method was used for testing load bearing life-saving armour systems JSF-Mod1-JORMUNGAND destined for the Naval Forces flotilla ship complement. In the experiment with a Naval Forces flotilla ship and the involvement of Air Force Aviation base deficiencies were found in the developed prototype, which the manufacturing factory will eliminate. The method will be used in future to assess the load bearing armour system AES-Mod1-PUMA, destined for Air Force Aviation Base helicopter crew provision.
8. The EUROFIT tests used in sport sector allowed assessing the influence of uniform and load bearing armour systems on soldiers' physiological state. It was concluded that the assessed different ensembles of protective clothing do not influence the experiment participants' physical work performance in ergometric step test and NAF soldiers' performance accordingly.
9. As a part of the study of CIPS physiological quality research was carried out on water vapour resistance and air permeability of the most characteristic clothing materials sets and mathematical models for thermal insulation and water vapour resistance have been elaborated. The results are indicative of CIPS compliance to the climatic categories C0 – C1 in accordance with NATO AECTP-230 "Climatic conditions" external temperature range from -6ºC to -30ºC. As a part of the study of CIPS thermal insulation a controlled field experiment was conducted of specific CIPS combinations with sleeping bags at low temperatures -24ºC with test persons – soldiers who were sleeping in these ensembles for 8 hours. The results of the experiment confirmed the sleeping bag conformity to C0 – C1 climate categories. In further research the system compliance to climate categories C2 – C4 at outside ambient temperature range -37 ºC to -57 ºC should be reached as required by the State Defence concept.
10. The priority direction for enhancement of CIPS functions characteristic of combat operations is flame resistance quality improvement. Within the framework of research CIPS compliance at the following threat levels has been reached: at heat flow 84 kW/m2, in 4 seconds 15 % – second degree

burns, 10 % – third degree burns and 0.8 % – first degree burns. Total area of burns is 25.8 %, which corresponds to survival conditions after fire impact.

11. Using expert methods body zones were determined having priority of protection from fire impact as well as MTL, in which flame resistance properties should be integrated. As during combat operations load bearing armour systems are to be worn not only over combat shirt but also over level 1, 2 or 3 underwear, and the area of uncovered body parts increases using level 1 underwear, the possibility to replace the existing underwear and field uniform materials with fire-resistant materials was evaluated. Structural, physical and mechanical properties of field uniform textiles used in armies of different counties were tested: thickness; density; surface density or 1 m^2 mass; linear density of weft and warp, weave, fibre material content, maximum breaking force using the strip method of tear strength, breaking load/force using fast grip method, breaking load/strength using tearing, rupture strength using 3-D compression, resistance to abrasion, bending endurance, disorientated creasing, air permeability, water permeability using water vaporization method, changes in linear measurements, drying speed. It has been found that the physiological quality of a flame resistant material and a material without flame resistance properties is equal, which provides grounds to start integration of fire resistant materials in CIPS.
12. As a result of the study it is proposed to integrate CIPS-Mod1-SNIPER RECON system into CIPS camouflaging electromagnetic range 3–12 μm, the design of which without any special technology solutions provides quality camouflaging in the electromagnetic wave range 3–12 μm, and additionally provides for location of soil and vegetation in the system structure. Research methodology is based on controlled field experiment using thermal radiance surveillance equipment and evaluation of images by contrasting colour areas.
13. To extend the field uniform camouflaging efficiency to European region an exclusion experiment by expert method was carried out where the experts gradually selected the most adequate one out of the 25 designed camouflage print samples. The sample was named LATPAT (EUROPE) and its study and improvement is continued.

The NAF combat individual protection system reasoned in the Doctoral thesis protects a soldier up to a certain level of artificial and natural threat factors which a soldier may encounter in modern war. The system uses protection layers set, which a soldier can put on or take off depending on the operation task as well as modulate interchangeably to achieve the most effective combination of layers for fulfilment of a specific task while ensuring for him-/herself a certain level of comfort and a sense of security.

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