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MARZENA RACHWAŁ, PHD, ASSOCIATE PROFESSOR
The Main School of Fire Service
e-mail: mrachwal@sgsp.edu.pl
ORCID 0000-0003-0845-6144

COL. MAŁGORZATA MAJDER-ŁOPATKA, PHD ENG.
The Main School of Fire Service
e-mail: mmajder@sgsp.edu.pl
ORCID 0000-0002-0226-710x

SR CAPT. TOMASZ WĘSIERSKI, PHD ENG.
The Main School of Fire Service
e-mail: twesierski@sgsp.edu.pl
ORCID 0000-0002-9849-6539

COL. ARTUR ANKOWSKI, PHD ENG.
The Main School of Fire Service
e-mail: aankowski@sgsp.edu.pl
ORCID 0000-0002-5052-2195

MAGDALENA MŁYNARCZYK
Central Institute for Labour Protection – National Research Institute
e-mail: m.mlynarczyk@ciop.pll
ORCID 0000-0002-9218-9781

SR. CAPT. ADRIAN BRALEWSKI, PHD ENG.
The Main School of Fire Service
e-mail: abralewski@sgsp.edu.pl
ORCID 0000-0001-9411-8736

ALEKSANDRA SPŁAWSKA
Military Institute of Chemistry and Radiometry
e-mail: a.splawska@wichir.waw.pl
ORCID 0000-0002-1308-3007

COL. ROBERT PIEC, PHD ENG.
The Main School of Fire Service
e-mail: rpiec@sgsp.edu.pl
ORCID 0000-0002-5234-5639

THERMAL PROPERTIES OF SPECIAL NEW GENERATION PERSONAL PROTECTIVE CLOTHING FOR FIREFIGHTERS-RESCUERS

ABSTRACT

Every day, firefighters put their health and life at risk by saving people and their property not only during fires, but by being always ready during all kinds of unfortunate events. Therefore, they need special personal protective equipment, including protective clothing. The purpose of the study was to compare thermal properties of new (PROTON and SYRIUSZ) and old (US-03) personal protective clothing for firefighters. Measurements of thermal insulation (total, effective and local) were carried out using a full body shape thermal manikin Newton consisting of 34 segments, in which temperature and heat flux were controlled independently. Results of the total thermal insulation of the entire clothing reveal differences between all three models. The lowest values were noticed for the model PROTON with light and shorter jacket and the highest values of thermal insulation for the new model SYRIUSZ, indicating that this model protect the user against heat most effectively. New models of personal protective clothing for firefighters should be recommended for use in everyday work, because they are characterized by better parameters than the previous type of protective clothing, both in terms of thermal protection and mobility.

KEYWORDS

firefighters, total thermal insulation, effective thermal insulation, thermal protection, multilayer structure, thermal manikin, personal protective clothing

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WŁAŚCIWOŚCI TERMICZNE SPECJALNEJ ODZIEŻY OCHRONNEJ NOWEJ GENERACJI DLA STRAŻAKÓW-RATOWNIKÓW

ABSTRAKT

Codziennie strażacy narażają swoje zdrowie i życie, ratując ludzi i ich mienie nie tylko podczas pożarów, ale będąc zawsze w gotowości podczas wszelkiego rodzaju nieszczęśliwych zdarzeń. Dlatego też potrzebują oni specjalnych środków ochrony osobistej, w tym odzieży ochronnej. Celem pracy było porównanie właściwości termicznych nowej (PROTON i SYRIUSZ) i starej (US-03) odzieży ochronnej dla strażaków. Pomiary izolacyjności cieplnej (całkowitej, efektywnej i miejscowej) przeprowadzono przy użyciu manekina termicznego Newton o pełnym kształcie ciała, składającego się z 34 segmentów, w którym niezależnie kontrolowano temperaturę i strumień ciepła. Wyniki dotyczące całkowitej izolacji cieplnej całej odzieży wykazują różnice pomiędzy wszystkimi trzema modelami. Najniższe wartości odnotowano dla modelu PROTON z lekką i krótszą kurtką, a najwyższe dla nowego modelu SYRIUSZ, co wskazuje, że ten model najskuteczniej chroni użytkownika przed gorącem. Nowe modele odzieży ochronnej dla strażaków powinny być rekomendowane do stosowania w codziennej pracy, gdyż charakteryzują się lepszymi parametrami niż dotychczasowy typ odzieży ochronnej, zarówno pod względem ochrony termicznej, jak i mobilności.

SŁOWA KLUCZOWE

strażacy, pełna izolacja termiczna, skuteczna izolacja termiczna, ochrona termiczna, struktura wielowarstwowa, manekin termiczny, odzież ochrony osobistej

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1. INTRODUCTION

The fire and rescue service is extremely demanding and frequently entails grave dangers, involving the risk of health and life, as well as work in difficult conditions. The working environment of firefighters-rescuers is highly diverse, as it not only involves putting out fires and working in high temperatures, but also providing help to people in road traffic collisions, all kinds of unpredictable environmental factors such as floods and storms, as well unforeseen events such as oil spills and the growing threat of terrorism. For the sake of human life and property, firefighters must be on standby at all times, regardless of the time of day, season and weather conditions. Thermal exposure resulting from heat conduction, convection and radiation, hot liquid and steam are the main heat hazards aside from open flame. Therefore, providing the fire services with appropriate protective clothing is a matter of importance. The role of protective clothing and other personal protective equipment (PPE) is fundamental for firefighters' safety. In basic firefighting operations, the clothing should protect the user against possible flame impingement, high air temperatures, radiant heat and accidental contact with chemicals, and simultaneously it should also provide water resistance or repellency and some level of mechanical protection [1]. For the firefighter's protective clothing, thermal protection is of vital, but thermal comfort and heat strain of the firefighters are also of great importance and should be taken into account at the same time, especially due to the huge variety of rescue services activities. However, these two contradictory requirements cause great difficulty in selecting suitable fabrics for uniforms [2]. Current firefighter protective ensembles consist typically of multiple layers: non-flammable outer fabric, waterproof membrane, heat-insulating layer and lining [3]. However, this multilayer system increases the weight and bulkiness of the clothing, unfortunately reducing the ease of movement and the thermal comfort by a decrease of vapour permeability [4]. The main problem with firefighters' protective clothing is overheating during rescue and firefighting operations [5,6]. Firefighters frequently find that overheating, weight and the design of the clothing often limit their freedom of movement. This can lead to a decrease in the efficiency and quality of the firefighter's work in the danger zone. The reduced thermal and movement comfort generates an increased oxygen consumption, which translates into a reduction in the effective working time of the rescuer [7–10]. Therefore, developing high-quality protective clothing enhancing protection, safety, and comfort of firefighters is a huge challenge. Many efforts have been made to improve the protective and operational parameters of personal protective clothing [5, 7, 11, 12].

Thermal insulation, water-vapour resistance and air permeability are highly important properties of fabrics and clothing from the point of view of the user's thermal comfort as well as clothing protective efficiency against low or high temperature [13–15]. The thermal insulation value represents a quantitative evaluation of how good thermal barrier the clothing provides the user and is often used by clothing manufacturers for labelling of their products in order to boost sales [16].

In the Main School of Fire Service, a study was carried out of innovative materials, construction and functional solutions concerning protective clothing during implementation of the project entitled "Modern personal protection of National Rescue and Firefighting System rescue services based on the needs of end users". As a result technical and technological documentation was devised, enabling low-serial production of clothes with the possibility of adapting the technology to production in larger series.

The main objective of the study was comparison of the newly manufactured models (PROTON and SYRIUSZ) with the old model (US-03) of special firefighters' personal protective clothing in terms of their weight, materials used for their production and their thermal properties, mainly thermal insulation.

2. MATERIALS AND METHODS

2.1. Tested clothes

Three sets of special personal protective clothing for firefighters have been chosen for investigation of their thermal properties:

1) US-03 (long jacket US-03 with pants US-03)
2) Model PROTON (light jacket PROTON-S with pants SYRIUSZ-X)
3) Model SYRIUSZ (jacket SYRIUSZ-X with pants SYRIUSZ-X).

The model US-03 was the old one, while PROTON and SYRIUSZ models were new generation clothing. PROTON and SYRIUSZ are consistent with new applicable normative provisions of PN-EN 469 and PN-EN 15614, respectively being in force since 4.06.2018 [17, 18]. Different materials used for the production of each model were presented in Table 1.

Tab. 1. Composition of fabrics used in the tested clothing. The following numbers refer to the subsequent layers of clothing, from external layer, through membrane to thermal insulation layer joined with lining

Model	Composition of materials
US-03	1–99% aramid fibres 1% antistatic fibres; 2–65% Kevlar 35% PE (PU laminate); 3–50% aramid fibre 50% viscose
PROTON	1–98% aramid 2% antistatic
SYRIUSZ	1–98% meta-aramid 2% antistatic; 2–250% meta-aramid 25% para-aramid 25% PTFE laminate; 3 – felt 85% meta-aramid 15% para-aramid; 4–50% aramid 50% viscose

Source:

The multilayer structure of the special clothing commonly used by rescue units is as follows:

1) outer layer – protecting primarily against the penetration of flames and mechanical damage,
2) waterproof and vapour-permeable membrane – protecting against the penetration of moisture inside the clothes and water vapour permeating from the inside of the clothes,
3) thermal insulation layer – protecting against the penetration of heat into the the clothes,
4) lining – securing the other layers from the inside.

The PROTON, as a light weighted version of protective clothing, is made of only one layer of fabrics characterized by high mechanical resistance, multilayer models: US-03 has three layers (layers 3 and 4 are integrated with each other), and SYRIUSZ – four layers of fabrics. The surface density of the jackets used in the tests, in the places where there were no pockets, was 650 gm^{-2}, 450 gm^{-2}, 230 gm^{-2} for the US-03, SYRIUSZ and PROTON, respectively. As a consequence, these clothes vary in weight (Table 2).

Tab. 2. The weight (kg) of individual items of clothing

Model	Jacket	Pants
US-03	2.367	1.332
PROTON	1.297	1.611
SYRIUSZ	2.105	1.611

Source:

2.2. EQUIPMENT

The study was performed in the Central Institute for Labour Protection – National Research Institute (Warsaw), and involved the use of a full-body shape Newton thermal manikin consisting of 34 segments, in which temperature and heat flux could be controlled independently (Figure 1). The outer shell of Newton is made of carbon-epoxy thermal conductive materials. The construction of the manikin enables making analyses of the thermal insulation of the clothing in the context of the entire manikin or only of its individual segments. The Newton thermal manikin system is controlled by ThermDAC software [19].

Tests were carried out in a type WK23'/40-70 (Weiss Technik GmbH, Reiskirchen, Germany) climatic chamber and thermal comfort datalogger Innova 1221 (Innova AirTech Instruments A/S, Ballerup, Denmark) was used for measuring and recording the environmental parameters such as air temperature, relative humidity and air velocity during the measurement.

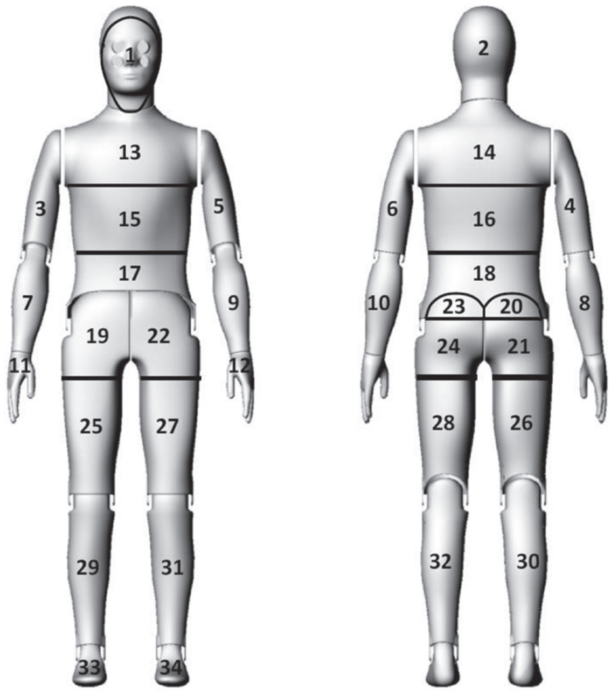


Fig. 1. Segmentation of the Newton thermal manikin: 1 Face; 2 Head; 3 R Up Arm Fr; 4 R Up Arm Bk; 5 L Up Arm Fr; 6 L Up Arm Bk; 7 R Forearm Fr; 8 R Forearm Bk; 9 L Forearm Fr; 10 L Forearm Bk; 11 R Hand; 12 L Hand; 13 Upper Chest; 14 Shoulders; 15 Stomach; 16 Mid Back; 17 Waist; 18 Lower Back; 19 R Up Thigh Fr; 21 R Up Thigh Bk; 22 L Up Thigh Fr; 24 L Up Thigh Bk; 25 R Lwr Thigh Fr; 26 R Lwr Thigh Bk; 27 L Lwr Thigh Fr; 28 L Lwr Thigh Bk; 29 R Calf Fr; 30 R Calf Bk; 31 L Calf Fr; 32 L Calf Bk; 33 R Foot; 34 L Foot [20]

2.3. METHODOLOGY

Measurements and calculations of thermal insulation of a clothing ensemble were carried out according to the standards: PN-EN ISO 15831:2006 Clothing – Physiological effects – Measurement of thermal insulation by means of a thermal manikin (ISO 15831:2004) [21] and PN-EN ISO 9920:2009 Ergonomics of the thermal environment – Estimation of thermal insulation and water vapour resistance of a clothing ensemble [22], with small modification. The clothing ensembles were put on directly on the manikin, without reference underwear.

The thermal insulation of all three clothing models was measured in the context of the entire manikin as well as of its individual segments. The assumed manikin's surface temperature was 34°C (according to [21,23]).

The total thermal insulation (I_T) was a calculation of the parallel method according to the equation:

$$I_T = \frac{(t_s - t_a) \times A}{H_c} \ (\mathrm{m^2\ °CW^{-1}})$$

where:
t_s – mean temperature of manikin's surface (°C), t_a – air temperature inside the climatic chamber (°C), A – total area of the manikin (m^2), H_c – total heat loss from the manikin (W).

While effective thermal insulation (I_{CLE}) was calculated by subtracting the boundary air layer insulation (I_A) from the total insulation (I_T):

$$I_{CLE} = I_T - I_A \ (\mathrm{m^2\ °CW^{-1}}).$$

The boundary air layer insulation (I_A) was measured on a nude thermal manikin.

The thermal insulation unit is *clo* and 1 clo equals 0.155 m^2 $°CW^{-1}$ [24].

The thermal insulations of particular segments (I_{seg}) were calculated according to the following formula:

$$I_{seg} = \frac{(t_{si} - t_a) \times A_i}{H_{si}} \ (\mathrm{m^2\ °CW^{-1}})$$

where:
t_{si} – temperature on the surface of *i*-segment of the manikin (°C); H_{si} – sensible heat loss from *i*-segment of the manikin (W); A_i – surface area of *i*-segment of the manikin (m^2) [24].

Measurements of thermal insulation should be carried out in a steady state in terms of microclimate conditions and thermal manikin as well [21,25].

3. RESULTS AND DISCUSSION

The thermal insulation of clothing, being a factor that affects the heat exchange between humans and the environment, represents a quantitative evaluation of how good thermal barrier the clothing provides the user [16].

3.1. Thermal insulation of the entire clothing

The tests for multi-layer models were carried out in the same controlled condition (air temperature ca. 10°C). Detailed information on the microclimate parameters in the climatic chamber were presented in Table 3.

Tab. 3. Conditions for testing the total thermal insulation of clothing

Model	**Physical parameter of the air surrounding the thermal manikin under steady-state conditions**	**Mean values (from 20 minutes) and standard deviation of the air parameter**
US-03	air temperature, °C	10.3 ± 0.1
	relative humidity, %	31.3 ± 1.0
	air velocity, m/s	0.49 ± 0.05
PROTON	air temperature, °C	10.5 ± 0.1
	relative humidity, %	35.8 ± 1.0
	air velocity, m/s	0.51 ± 0.05
SYRIUSZ	air temperature, °C	10.4 ± 0.1
	relative humidity, %	32.2 ± 1.0
	air velocity, m/s	0.49 ± 0.05

Source: own study

Results of the total thermal insulation of the entire clothing (Table 4) reveal differences between all three models. The lowest values were recorded for the model PROTON with a light and shorter jacket, and the highest values of I_T for the new model SYRIUSZ, indicating that this model most effectively protects the user against heat radiation from the fire. The clothing insulation differences depend on many factors, i.e. number of layers, different thicknesses of particular layers of fabrics as well as air layers, which were often designed in clothing to increase the thermal insulation capability and improve the thermal protection performance of firefighter protective clothing [26]. Song [27] indicates the fineness and geometry of the fibre, bulk density of the fabric and its surface properties as the significant factors that affect the thermal properties of fabrics and clothing. Additionally, the clothing fit (tight or loose fitting) is such a significant factor which can change the volume of the clothing micro-environment (air insulation) [28]. To sum up, obtained results concerning the PROTON model were not surprising because this model is assigned primarily for operations other than firefighting and consists of a single layer of fabrics. This is in line with the assumptions of the Headquarters of State Fire Safety in Poland, which, after analysing the needs of rescuers, commissioned the development of ultra-light clothes intended for activities in open spaces involving local hazards, which are not expected to be exposed to large heat fluxes that may arise from a fire [29]. Incidents of this type (e.g. car accidents) currently account for the highest percentage of interventions by rescue units [30].

Values of I_T for both heavier models, especially model SYRIUSZ (0.263–0.264 m^2 °CW^{-1}) were consistent with other studies concerning personal protective clothing for firefighters [31,32] with results varying within the range from 0.262 to 0.273 m^2 °CW^{-1}. The values obtained for the US-03 model show a lower insulation than in the case of SYRIUSZ, despite the higher surface density. The presence of a larger interlayer air space in the SYRIUSZ model could be the reason for it. The application of splines prevents the layers from adhering closely. The effect is achieved thanks to the low thermal conductivity of air and lightweight of this structure. Such a solution that facilitates the breathing of clothes significantly reduces the load on the rescuer. Tests carried out on the START 2000M ergospirometer by Węsierski and Kowalczyk [7] indicate that the oxygen consumption of a loaded firefighter is 5% higher in the US-03 type clothing than in the SYRIUSZ model. On the other hand, the ultra-light construction of the PROTON showed as much as 12.2% difference in oxygen consumption compared to US-03 [7].

Table 4. The values of thermal insulation: total (I_T) and effective (I_{CLE}) of the entire manikin (m^2 °CW^{-1} and clo) and total heat loss from manikin surface in the steady-state conditions (Wm^{-2}).

Model	Test number	I_T (m^2 °CW^{-1})	I_T (clo)	I_{CLE} (m^2 °CW^{-1})	I_{CLE} (clo)	Total heat loss from manikin surface in the steady-state conditions
US-03	1	0.247	1.594	0.166	1.071	95.88 ± 0.21
	2	0.245	1.581			96.57 ± 0.24

cont. Table 4.

Model	Test number	I_T (m^2 °CW^{-1})	I_T (clo)	I_{CLE} (m^2 °CW^{-1})	I_{CLE} (clo)	Total heat loss from manikin surface in the steady-state conditions
PROTON	1	0.220	1.419	0.139	0.897	84.96 ± 0.22
	2	0.219	1.413			85.20 ± 0.14
SYRIUSZ	1	0.264	1.703	0.183	1.181	89.65 ± 0.17
	2	0.263	1.697			89.90 ± 0.18

Source: own study

3.2. Local values of thermal insulation

Local values of total thermal insulation of individual segments of clothing were presented in Table 5. In some segments significant differences between investigated models have been noted, especially in the case of the lower part of the body (Figure 2 and 3). The biggest differences were ascertained for the PROTON model, which, for obvious reasons, varies in terms of thermal insulation values from other clothes. As previously mentioned, the PROTON is designed and intended for outdoor or indoor rescue operations, but not related to exposure to fire and high temperatures. Its use is to improve the work comfort of firefighters, increase their mobility and efficiency in activities other than suppression of fires. Therefore, this model has not been included in the comparison. Although results concerning US-03 and SYRIUSZ models reveal significant disproportions in some body segments, but in case of right upper frontal arm, left forearm and upper frontal thigh they are quite similar.

Tab. 5. Local values of the total thermal insulation (m2 °CW^{-1}).

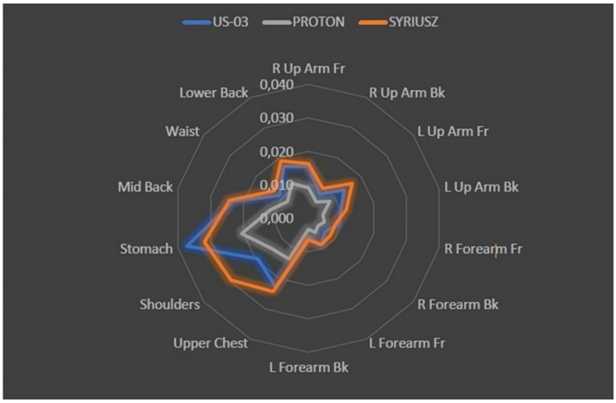
Segment	US-03	PROTON	SYRIUSZ
R Up Arm Fr	0.016	0.009	0.016
R Up Arm Bk	0.008	0.005	0.010
L Up Arm Fr	0.014	0.008	0.017
L Up Arm Bk	0.010	0.004	0.012
R Forearm Fr	0.009	0.005	0.008

cont. Tab. 5.

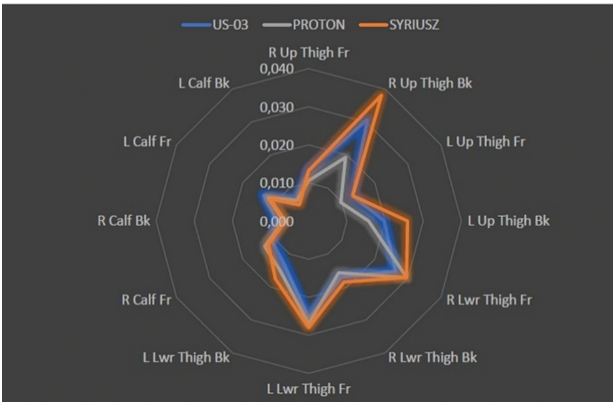
Segment	US-03	PROTON	SYRIUSZ
R Forearm Bk	0.006	0.004	0.008
L Forearm Fr	0.009	0.005	0.009
L Forearm Bk	0.006	0.003	0.006
Upper Chest	0.023	0.014	0.024
Shoulders	0.019	0.014	0.030
Stomach	0.037	0.021	0.032
Mid Back	0.023	0.012	0.024
Waist	0.011	0.008	0.013
Lower Back	0.017	0.012	0.019
R Up Thigh Fr	0.013	0.011	0.013
R Up Thigh Bk	0.031	0.019	0.038
L Up Thigh Fr	0.013	0.010	0.013
L Up Thigh Bk	0.020	0.016	0.026
R Lwr Thigh Fr	0.026	0.030	0.030
R Lwr Thigh Bk	0.017	0.016	0.019
L Lwr Thigh Fr	0.026	0.027	0.028
L Lwr Thigh Bk	0.013	0.015	0.018
R Calf Fr	0.011	0.013	0.012
R Calf Bk	0.008	0.007	0.006
L Calf Fr	0.014	0.012	0.012
L Calf Bk	0.006	0.006	0.005
Mean	0.016	0.012	0.017
Sum	0.406	0.306	0.448
Minimum	0.006	0.003	0.005
Maximum	0.037	0.030	0.038

Source:

The greatest scatter of the local thermal insulation values (Figure 3), in favour of the US-03 model, was visible for the abdominal zone. It was caused by the different cut of the pants in the new models, in which the fragment called “dungarees” has been abandoned. Such a high result for the US-03 was therefore due to an additional layer of material in the stomach area associated with both the dungarees and the arrangement of the pockets. It was difficult to explain why such unfavourable I_{seg} values were obtained for the calf zone. Perhaps it could have been the effect of pant legs being too loose in the new model of protective clothing. Generally, results reveal better thermal properties for the majority of body parts in case of the new clothing model SYRIUSZ.



a)



b)

Fig. 2. Local values of thermal insulation (m^2 °CW^{-1}) of clothing on selected manikin segments: (a) upper part of the body; (b) lower part of the body
Source:

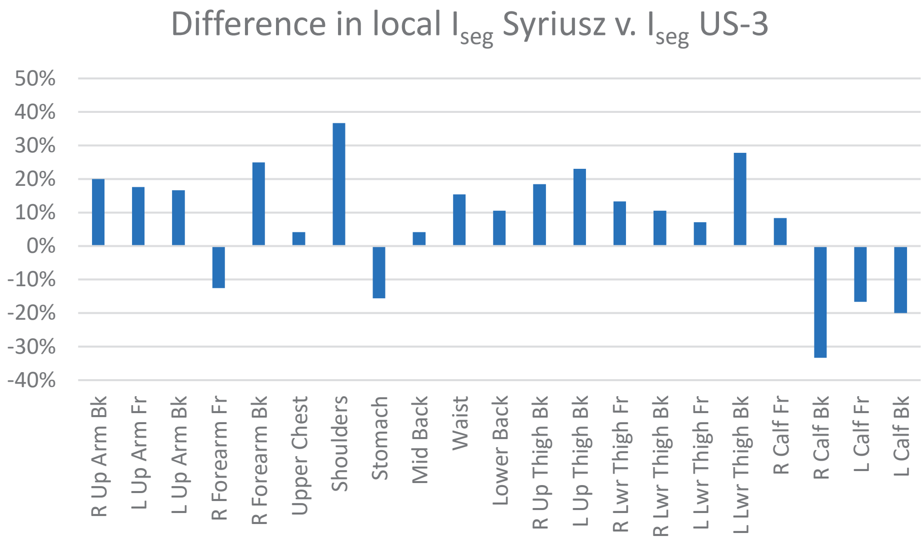


Fig. 3. Differences in local thermal insulation I_{seg} between two models: SYRIUSZ v. US-3
Source:

5. CONCLUSIONS

Results demonstrated a pronounced diversification in term of total, effective and local thermal insulation of the three investigated personal protective models of firefighters' clothing. The role of that specially designed lighter clothing for firefighters is to avoid weighing them down while they perform less dangerous actions. Proof has been gained in tests with the use of a thermal manikin. Values of thermal insulation were much lower for the PROTON model because it was deliberately designed as clothing for activities not related to exposure to fire and high temperatures. In addition, the SYRIUSZ model exhibited better thermal insulation, which also translates into safety – "worse" access of heat from the outside to the body, but with a more ergonomic cut. SYRIUSZ means better protection with less weight, and thus less strain on the body. Additionally, the new lighter models of protective clothing allow reducing the physiological cost and firefighter load during rescue operations and increasing his mobility and productivity. New models of personal protective clothing for firefighters should be recommended for use in everyday work, because they are characterized by better parameters than the previous type of protective clothing, both in terms of thermal protection and mobility. A modern approach to conducting rescue and firefighting operations and understanding the specificity of firefighters' tasks have contributed to the development of lightweight clothing technology intended for operations in open spaces, an example of which is PROTON type clothing. This garment is characterized by worse insulation parameters, however, it allows to significantly increase the work efficiency what shows the spirometer experiments [7].

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MARZENA RACHWAŁ – doktor habilitowany nauk inżynieryjno-technicznych w dyscyplinie inżynieria środowiska, górnictwo i energetyka; zajmuje się badaniem stanu środowiska naturalnego, szczególnie gleby i powietrza atmosferycznego, koncentrując się na właściwościach geochemicznych, magnetycznych i mineralnych zanieczyszczonych gleb i pyłów przemysłowych; innym obszarem jej badań jest ocena wpływu zanieczyszczeń pyłowych na zdrowie ludzi, a także biomonitoring; pełniła funkcję kierownika lub wykonawcy w wielu projektach naukowo-badawczych krajowych i międzynarodowych; jest współautorem licznych publikacji w czasopismach o zasięgu międzynarodowym indeksowanych w bazie JCR i Scopus, kilku rozdziałów w monografiach oraz dwóch monografii naukowych. Od 2000 r. była związana z Instytutem Podstaw Inżynierii Środowiska PAN w Zabrzu, w którym osiągnęła poszczególne stopnie kariery zawodowej, przez wiele lat pełniąc również funkcję Sekretarza Rady Naukowej; obecnie pracuje w Szkole Głównej Służby Pożarniczej w Warszawie jako profesor uczelni.

MARZENA RACHWAŁ – PhD in Engineering and Technology in the discipline of Environmental Engineering, Mining and Power Engineering; she deals with research on the state of the natural environment, especially soil and atmospheric air, focusing on geochemical, magnetic and mineral properties of contaminated soils and industrial dusts; another area of her research is the assessment of the impact of dust pollution on human health, as well as biomonitoring; she was a manager or a contractor in many national and international scientific research projects; co-author of numerous publications in international journals indexed in JCR and Scopus, several chapters in monographs and two scientific monographs. Since 2000, she has been working at the Institute of Fundamentals of Environmental Engineering, the Polish Academy of Sciences in Zabrze, where she successfully proceeded through various steps of the professional career, and for many years also worked as Secretary of Scientific Council; currently she is working at the Main School of Fire Service in Warsaw as a university professor.

MAŁGORZATA MAJDER-ŁOPATKA – inżynier chemii, doktor nauk inżynieryjno-technicznych, funkcjonariusz Państwowej Straży Pożarnej w stopniu brygadiera. Pracownik badawczo-dydaktyczny Szkoły Głównej Służby Pożarniczej. Zainteresowania naukowe: bezpieczeństwo pożarowe i procesowe, identyfikacja gazowych produktów rozkładu termicznego i spalania, innowacyjne metody likwidacji skażeń.

MAŁGORZATA MAJDER-ŁOPATKA – chemical engineer, doctor of engineering and technical sciences, Brigadier of the State Fire Service. Researcher and academic lecturer at the Main School of Fire Service. Research interests: fire and process safety, determination of gaseous products of thermal decomposition and combustion, innovative methods for removal of contaminants.

TOMASZ WĘSIERSKI – zajmuje się badaniami procesów neutralizacji niekontrolowanych uwolnień substancji niebezpiecznych, w tym wykorzystania kurtyn wodnych w procesie sorpcji. Autor ponad 70 publikacji naukowych oraz branżowych. Adiunkt w Instytucie Inżynierii Bezpieczeństwa SGSP.

TOMASZ WĘSIERSKI – studies processes of neutralisation of uncontrolled releases of hazardous substances, including the use of water curtains in the sorption process. Author of over 70 scientific and industry publications. Assistant Professor at the Institute of Security Engineering of the State Fire Service.

ARTUR ANKOWSKI – jest doktorem nauk technicznych w dyscyplinie inżynieria środowiska, magister inżynier pożarnictwa. Ukończył również studia podyplomowe materiały niebezpieczne i ratownictwo chemiczne w Wojskowej Akademii Technicznej w Warszawie, studia podyplomowe kryminalistyka w procesach karnych w Wyższej Szkole Policji w Szczytnie oraz studia podyplomowe z w zakresie przygotowania pedagogicznego w Akademii Polonijnej w Częstochowie.

Brał m.in. udział w akcjach ratowniczych w ramach kompanii szkolnej Centralnego Odwodu Operacyjnego. Wykładowca, instruktor, autor programów szkoleń specjalistycznych oraz programów nauczania dla strażaków PSP. Jego zainteresowania naukowe związane są z ratownictwem chemicznym i ekologicznym, BSP, wykrywaniem skażeń oraz zagrożeniami CBRNE. Brał udział w projektach w zakresie badań naukowych i prac rozwojowych na rzecz obronności i bezpieczeństwa państwa, kandydat na eksperta w Narodowym Centrum Badań i Rozwoju. Obecnie pracownik badawczo-dydaktyczny na stanowisku adiunkta w Instytucie Inżynierii Bezpieczeństwa w Szkole Głównej Służby Pożarniczej.

ARTUR ANKOWSKI – PhD in technical sciences in the discipline of environmental engineering, with a master's degree in firefighting. He also completed postgraduate studies in hazardous materials and chemical rescue at the Military University of Technology in Warsaw, postgraduate studies in criminology in criminal processes at the Police Academy in Szczytno and postgraduate studies in pedagogical preparation at the Polonia Academy in Częstochowa.

Mr. Ankowski participated, among others, in rescue actions as part of a training company of the Central Operational Support Unit. Lecturer, instructor, author of specialist training programmes and curricula for firefighters in the State Fire Service. His scientific interests are related to chemical and ecological rescue, BSP, contamination detection and CBRNE threats. He has participated in diverse projects in the field of scientific research and development work for national defence and security; an expert candidate at the National Centre for Research and Development. Currently a research and didactic employee holding the position of assistant professor in the Institute of Security Engineering at the Main School of Fire Service in Warsaw.

MAGDALENA MŁYNARCZYK – jest doktorem nauk technicznych w dyscyplinie inżynieria środowiska oraz absolwentką Politechniki Warszawskiej (magister inżynier biotechnologii). Od 2018 r. pełni funkcję kierownika Pracowni Obciążeń Termicznych na stanowisku adiunkta w Centralnym Instytucie Ochrony Pracy – Państwowym Instytucie Badawczym. Jest również członkiem Polskiego Towarzystwa Ergonomicznego (oddział Warszawa), Komitetu Naukowo-Technicznego FSNT-NOT Ergonomii, Ochrony Pracy oraz Techniki w Medycynie oraz członkiem zespołu Grupy Ekspertów ds. Mikroklimatu przy Międzyresortowej Komisji ds. Najwyższych Dopuszczalnych Stężeń i Natężeń Czynników Szkodliwych dla Zdrowia w Środowisku Pracy. W 2021 r. była członkiem roboczego zespołu dotyczącego bezpiecznych i higienicznych warunków pracy pracowników ochrony zdrowia w czasie pandemii COVID-19 Rady Dialogu Społecznego. W swojej pracy zawodowej zajmuje się zagadnieniami dot. wymiany ciepła między człowiekiem a otoczeniem, wpływu parametrów środowiska zewnętrznego na człowieka pod kątem zmian fizjologicznych oraz możliwości odczuwania komfortu cieplnego. Jest autorką wielu publikacji naukowych w czasopismach o zasięgu międzynarodowym, jak i krajowym.

MAGDALENA MŁYNARCZYK – PhD in technical sciences of technical sciences in the discipline of environmental engineering and a graduate of the Warsaw University of Technology (MSc in biotechnology). Since 2018 head of the Laboratory of Thermal Loads as an assistant professor in the Central Institute for Labour Protection – National Research Institute. She is also a member of the Polish Ergonomics Society (Warsaw Branch), the FSNT-NOT Scientific and Technical Committee on Ergonomics, Occupational Protection and Technology in Medicine, and a member of the team of the Group of Experts on Microclimate at the Interministerial Commission for the Highest Admissible Concentrations and Intakes of Factors Detrimental to Health in the Working Environment. In 2021, she was a member of the working team on safe and healthy working conditions for health care workers during the COVID-19 pandemic of the Social Dialogue Council. In her professional work, she deals with issues concerning heat exchange between humans and their surroundings, the influence of external environmental parameters on humans in terms of physiological changes and the possibility of experiencing thermal comfort. She is an author of numerous scientific publications in international and national journals.

ADRIAN BRALEWSKI – pracownik Szkoły Głównej Służby Pożarniczej. Uzyskał tytuł doktora w dziedzinie nauk o bezpieczeństwie obroniony w maju 2019 r. w Akademii Sztuki Wojennej. W 2014 r. ukończone studia magisterskie w zakresie inżynierii bezpieczeństwa pożarowego. Zainteresowania naukowe autora: ocena ryzyka, analiza ryzyka, modelowanie zagrożeń, czynniki systemowe i suplementowe, zarządzanie kryzysowe, ochrona ludności. Uczestnik licznych projektów krajowych i międzynarodowych.

ADRIAN BRALEWSKI – an employee of the Main School of Fire Service. Received a PhD in Security Science, defended in May 2019 at the Academy of Military Arts. Graduated in 2014 with a master's degree in fire safety engineering. Scientific interests of the author: risk assessment, risk analysis, hazard modelling, systemic and supplementary factors, crisis management, civil protection. Participant of numerous national and international projects.

ALEKSANDRA SPŁAWSKA – ukończyła studia na Wydziale Technologii i Inżynierii Chemicznej Politechniki Bydgoskiej w Bydgoszczy w 1999 r. W 2013 r. ukończyła studia podyplomowe Menedżera Innowacji w Kolegium Zarządzania i Finansów Szkoły Głównej Handlowej w Warszawie. W 2018 r. uzyskała stopień doktora w dyscyplinie nauk o bezpieczeństwie w Akademii Sztuki Wojennej w Warszawie na Wydziale Bezpieczeństwa Narodowego. Pracuje od 2002 r. w Laboratorium do Przestrzegania Konwencji o Zakazie Broni Chemicznej w Zakładzie Rozpoznania i Likwidacji Skażeń w Wojskowym Instytucie Chemii i Radiometrii.

Pracuje jako adiunkt oraz pełni obowiązki Kierownika Pracowni analizy wysokotoksycznych substancji organicznych objętych konwencją o zakazie broni chemicznej w Zakładzie Rozpoznania i Likwidacji Skażeń. Bierze udział w pracach badawczo-rozwojowych związanych z wykrywaniem i identyfikacją bojowych środków chemicznych i biologicznych. Posiada praktyczne doświadczenie w tworzeniu mobilnych laboratoriów CBRN oraz mobilnych zestawów do pobierania próbek CBRN (Pobieranie i identyfikacja czynników biologicznych, chemicznych i radiologicznych) oraz aktywnie jest zaangażowana w liczne polskie i międzynarodowe projekty badawcze związane z tematyką CBRNE (EDA, EU).

Aleksandra Spławska – graduated from the Faculty of Technology and Chemical Engineering of the Bydgoszcz University of Technology in Bydgoszcz in 1999. In 2013, she completed postgraduate studies of Innovation Manager at the College of Management and Finance of the Warsaw School of Economics. In 2018, she received her PhD degree in the discipline of security sciences from the Academy of Military Art in Warsaw, Faculty of National Security. She has been working since 2002 at the Laboratory for Compliance with the Chemical Weapons Convention in the Department of Reconnaissance and Contamination Elimination at the Military Institute of Chemistry and Radiometry. She is working as an Assistant Professor and fulfils the duties of the Head of the Laboratory for analyses of highly toxic organic substances covered by the Chemical Weapons Convention in the Department of Reconnaissance and Countermeasures. She participates in research and development work related to the detection and identification of chemical and biological warfare agents. She gained practical experience in setting up mobile CBRN laboratories and mobile CBRN sampling kits (Collection and identification of biological, chemical and radiological agents) and is actively involved in numerous Polish and international research projects related to CBRNE (EDA, EU).

Robert Piec – doktor nauk technicznych w dyscyplinie inżynieria środowiska. Ukończył również studia podyplomowe: zarządzenie w stanach zagrożeń w Szkole Głównej Służby Pożarniczej, bazy danych w Wyższej Szkole Informatyki Stosowanej i Zarządzania oraz seminarium doktoranckie analiza ryzyka w Akademii Finansów. Jest autorem lub współautorem wielu artykułów, rozdziałów monografii oraz referatów prezentowanych na konferencjach krajowych i zagranicznych. Obecnie jest Dyrektorem Instytutu Bezpieczeństwa Wewnętrznego Szkoły Głównej Służby Pożarniczej.

Robert Piec – PhD in Technical Sciences in the discipline of Environmental Engineering. He also completed postgraduate studies in Hazard Management at the Main School of Fire Service, postgraduate studies in Data Bases at the College of Applied Computer Science and Management and postgraduate studies with doctoral seminars at the Academy of Finance in Risk Analysis. He has authored or co-authored numerous articles, monograph chapters and papers presented at national and international conferences. Currently he is the Director of the Institute of Internal Security at the Main School of Fire Service.