Available online at www.worldscientificnews.com

World Scientific News

An International Scientific Journal

WSN 109 (2018) 143-154 EISSN 2392-2192

Selected personal protective equipment for applications in a hot work environment

Pamela Miśkiewicz

Institute of Architecture of Textiles, Faculty of Material Technologies and Textile Design, Lodz University of Technology, Lodz, Poland

E-mail address: pamela_miskiewicz@wp.pl

ABSTRACT

At present, many thousands of people work in Poland in the conditions of a hot microclimate. Currently there are and will continue to exist in the future, and what is related to the job positions on which it will not be possible to reduce or eliminate the activities of dangerous factors of the hot environment. Therefore, people working in "hot" work stations should be equipped with individual protection measures appropriate for a specific workplace. Currently, researchers strive to produce such clothing and its components to ensure the user's safety. However, protective clothing intended for use in a hot work environment most often to fulfill its functions is made of aluminized materials that do not let water vapor. The article presents and characterizes the currently used protective clothing and its individual elements used in the hot microclimate.

***Keywords*:** personal protective equipment, hot environment, protective clothing, working conditions protective gloves

1. INTRODUCTION

1. 1. Thermal comfort

The function of clothing is mainly to protect the human body from adverse external factors. Depending on the type and purpose of the used clothing, it can protect the human body from overheating and from significant heat loss. The task of clothing is primarily to

(Received 14 August 2018; Accepted 02 September 2018; Date of Publication 03 September 2018)

perform many protective functions, but it is also an important element affecting the thermoregulation of the human body. Man is a warm-blooded organism and maintains a constant internal temperature of the body in the range of 37 ±0.4 °C. Thermal comfort is a basic condition affecting the comfort of using clothing. The term "comfort" is related to the human's perception of harmony between the environment and psychophysical experiences, and additionally the thermal balance achieved by the human body during this time [1-3].

The impact of clothing on the user's thermal comfort experience:

- Clothing helps the human body to give warmth to the environment in a hot environment,
- Clothing helps the human body to keep warm in a cold environment [1].

The physical and chemical changes taking place in this laminar layer determine the human's feeling of heat or cold. Changes caused by the ambient temperature cause temperature changes on the surface of the skin [4].

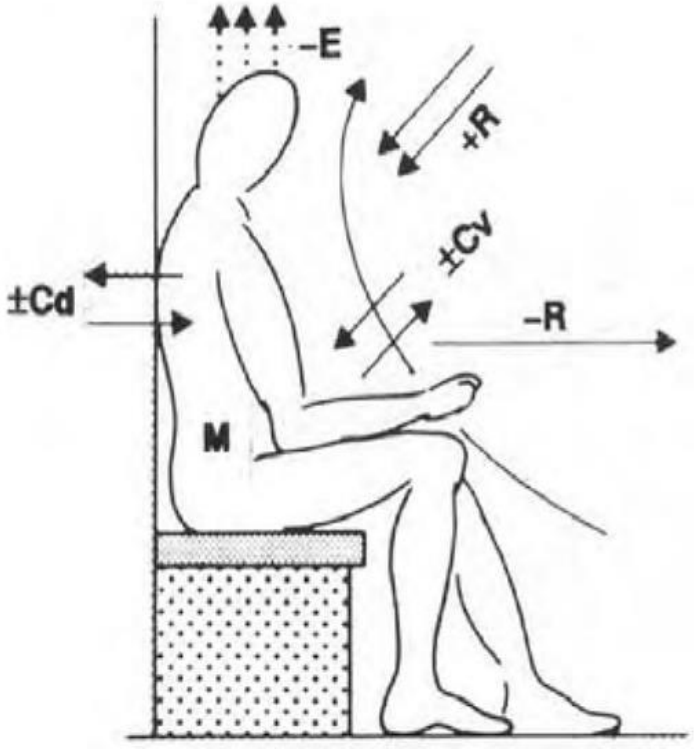

Fig. 1. Heat exchanges of the human body [8]

The mechanism of thermoregulation of the human body is responsible for maintaining the internal temperature that is optimal for the human body. During the use of clothing, there is rarely a situation in which the amount of thermo-production of the human body is equal to the amount of heat that the body gives to the environment. When, when there is a situation in which too much heat is taken from the body, there is a phenomenon of heat deficit. In the case when a certain amount of heat produced by the body is not delivered to the environment, heat

is accumulated. The cases described above may cause or cause thermal discomfort, which may cause overheating or cooling of the human body [3-6].

Heat loss is caused by the body (Figure 1):

- Radiation of about 44-45%,
- Convection about 30%,
- Pairing around 23%,
- Heating up 1.5% of food,
- Thermal losses with 0.7% excretion,
- Air heating in the lungs 1.30% [7].

Figure no. 2 apart from the factors described above, it contains an exact division of important elements included in particular groups of factors that influence the heat exchange between the human body and the environment.

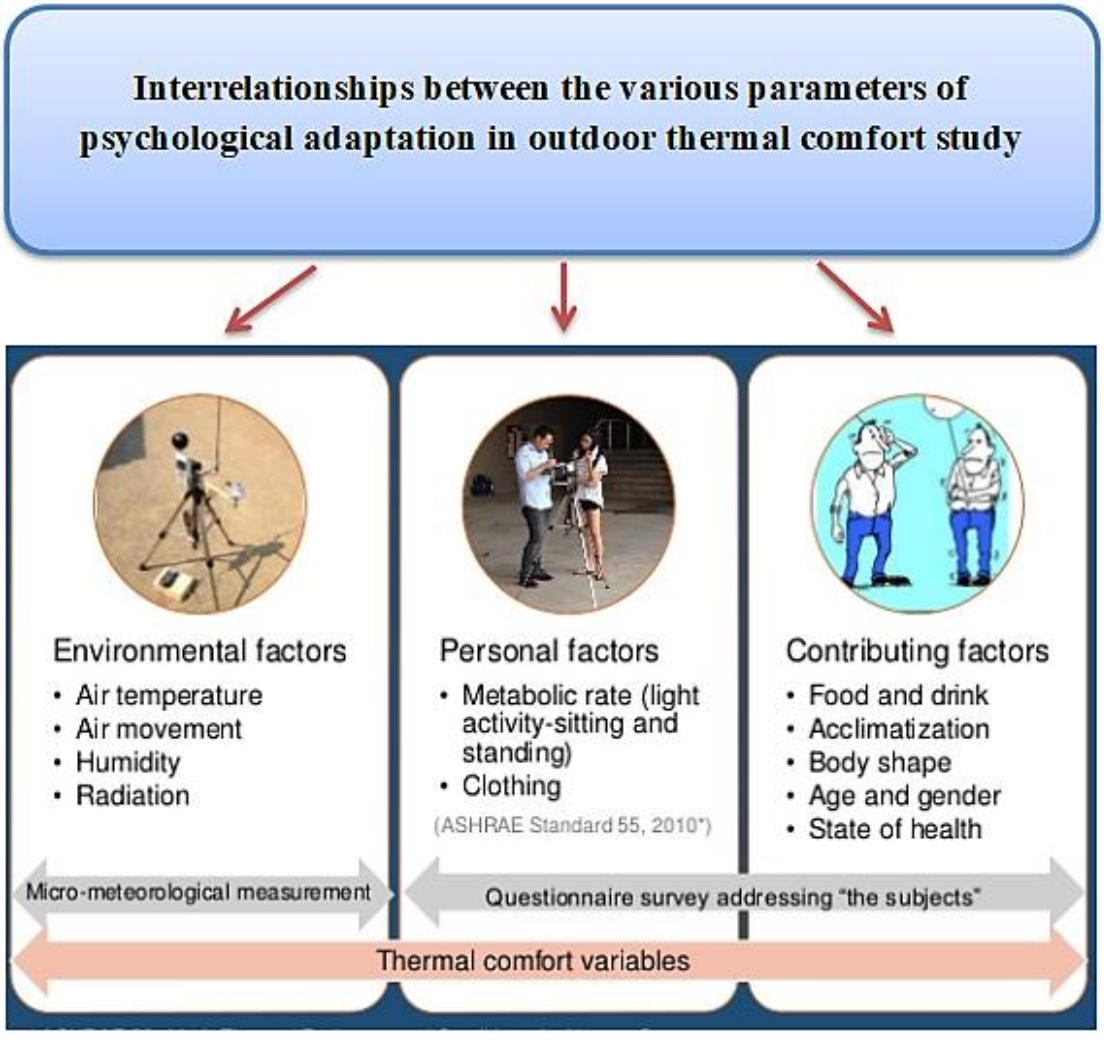

Fig. 2. Interrelationships between the various parameters of psychological adaptation in outdoor thermal comfort study [9]

1. 2. Mechanism of sweat separation

During physical work performed by man, the rate of heat generation by the body increases due to the increase in the metabolism of working muscles. At rest, the temperature of the muscles is 36 °C, but with the start of the effort may increase to 38-42 °C, it is also dependent on the intensity of the effort. Excess heat produced by the human body during physical exertion is removed by evaporation of sweat [10]. Sweat glands and the process of sweating should be started by the body as soon as possible, so as not to lead to the danger of excessive increase of the body's internal temperature.

The most sensitive to temperature changes is the brain, and the increase of its temperature to 41,5 °C and above leads to irreversible damage. During the day the internal temperature of the human body undergoes changes, in the early morning hours it gets the lowest values, while it is the highest in hours from 8 to 12 and between 18 and 21. During significant physical activity, and depending on the warm or cold environment, on the surface human body temperature changes in certain places, which is shown in the figure. 3 [11-13].

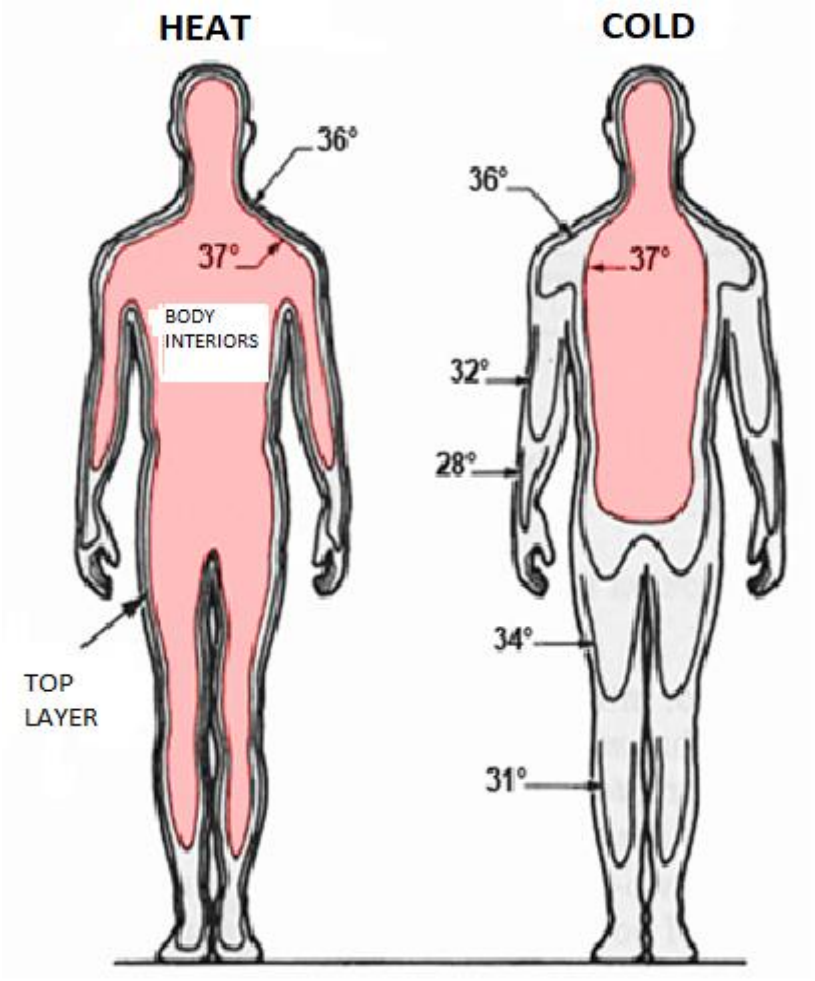

Fig. 3. Changes in the temperature of the human body surface in a warm and cold environment [13].

1. 3. Working environment conditions

Working conditions are a very important issue from the point of view of the employer and employee. Correct identification of harmful factors and their impact on working people makes it possible to conduct proper policies and take preventive measures in the area of occupational health and safety. According to the Central Statistical Office, in 2017 in Poland 485,000 people worked in hazardous conditions.

Persons employed in specific work positions are exposed to harmful factors related to the work environment or work nuisance and to mechanical factors in the field of machine operation. With 557,600 people at risk of over 58% were exposed to threats related to the work environment. According to the Central Statistical Office in Poland, in 2017 -262.1 thous. persons counted once in the group of the predominant factor performed their work in hazardous conditions with factors related to the work environment. Figure 4 shows the share of selected hazards related to the work environment [14].

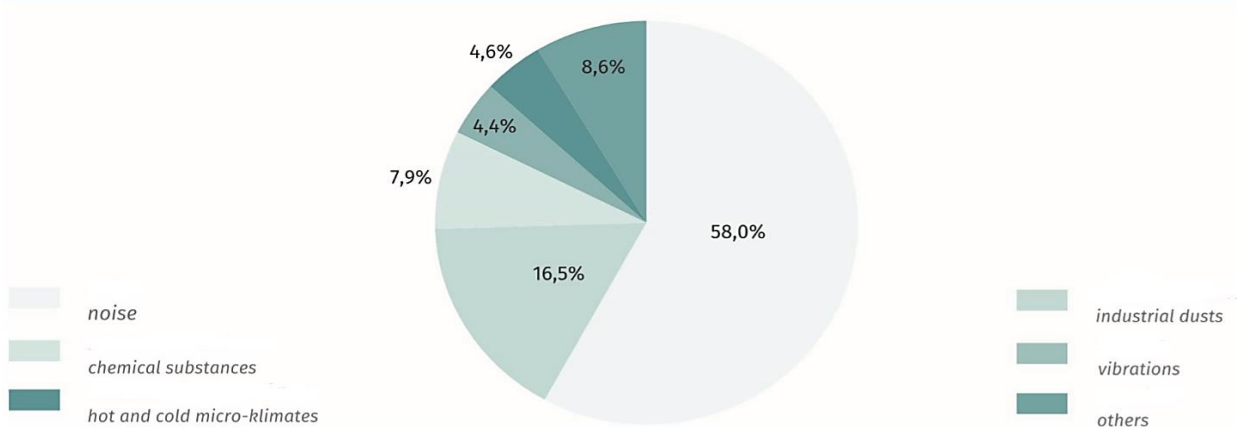

Fig. 4. Percentage share of hazardous factors related to working environment [14]

2. HOT WORKING ENVIRONMENT

Nowadays, we can observe on the textile and clothing market the development of new techniques and technologies related to the production of more and more innovative products. New technologies in the clothing industry are to provide the user with, above all, safety, comfort of use and functionality under certain conditions. A hot working environment occurs when the air temperature is between 25 and 60 °C, and the relative humidity is between 10-80% [15]. The ability to remove heat from the body is significantly affected by clothing [16].

Performing work by an employee in conditions of a hot microclimate is associated with the possibility of exposure to dangerous factors, i.e.

- splashes of molten glass or metals,
- splinters of hot glass, metal and slag,
- contact with the flame,
- contact with various hot items,
- strong thermal radiation that can cause skin and eye danger.

The above-mentioned factors may cause accidents at certain workplaces. The conditions of the hot microclimate occurring at the workplace may cause an employee hypothermia, which may cause disorders of the cardiovascular system, the central nervous system and the digestive tract. In addition, the conditions of the hot microclimate prevailing during work often lead to drainage of employees.

In order to prevent various types of hazards to which an employee working in hot microclimate conditions is exposed, certain personal protection measures are applied, i.e.:

- equipment for face and eye protection,
- protective clothing,
- protective gloves,
- safety shoes [17].

3. PROTECTIVE CLOTHING

Fig. 5. Protective clothing against splashes of molten metal [17]

In many workplaces in various industries, such as metallurgical plants or steel mills and during fire-fighting activities, the working person is exposed to hot factors. It is necessary to use protective clothing whose task is to protect the human body from hot environment factors occurring in one or several forms. The condition of proper selection of protective clothing for a specific hazard occurring at workplaces related to hot environment conditions is the

identification of harmful and dangerous factors that constitute a source of risk, exposed people, circumstances and the intensity of their exposure. Currently, Polish standards, created on the basis of European standards, describe requirements for specific parameters characterizing the properties of protective clothing against the effects of hot factors. Individual requirements are presented in the form of protective classes, which are based on the results obtained from laboratory tests of materials. Effective protection of employees performing work in hot environment conditions can only be ensured if the protective clothing used is properly selected to the level of hazards and the type of work performed for a specific workplace.

Protective properties of clothing dedicated to employees who are exposed to hot factors are obtained by applying single, multilayer or material systems depending on the risk. Special construction requirements are placed on clothing that protects against splashes of molten metals. Such clothing should consist of a sweatshirt long enough and wide enough to cover the top of the trousers, even when the employee bends while the trouser legs should be long enough to overlap the footwear. Any metal fastenings located in the outer part of the clothing product should be covered to counteract the adhesion of molten metal. An example of clothing protecting against splashes of molten metals made of aluminized glass fabric is shown in Figure 5. Requirements for protective clothing intended for firefighters are stricter and more stringent and constitute a separate issue [17].

4. PROTECTIVE GLOVES

Gloves protecting against high temperatures are designed to protect the user's hands from fire or heat. Among many branches of industry to industries in which we meet the threat to workers' hands occurring in the form of heat or fire, we can include: foundry, metallurgy, mechanical, glass and ceramic industry. Gloves whose task is to protect hands against high temperatures are most often made of various materials and their various systems. Knitted fabrics, fabrics and nonwovens made of Twaron, Kevlar, Basofil, Nomex, Preox fibers, as well as non-flammable wool yarn, heat-resistant skins, cotton yarns and fabrics made of aramid, glass or glass fibers are used to make gloves. basalt coated with aluminum.

Gloves with different protective properties can be made depending on the application of the selected type of yarn, number of threads and the weight of the liner. In addition, the different protective properties of the gloves are influenced by the choice of the weave used and the number of layers of materials used to perform the selected glove construction. PN-EN 407: 2007 standard specifies the requirements as well as test methods for gloves whose task is to protect against hot thermal factors. According to the standard, gloves should meet general requirements including in the scope of tearing strength, abrasion resistance and requirements relating to the effectiveness of protection against thermal factors such as resistance to small splashes of molten metal, behavior during smoking, resistance to convective heat, contact, radiation. Depending on the purpose, the gloves should exhibit certain levels of effectiveness in tests for individual requirements. Gloves for the protection of hands intended for metallurgists are most often designed by using in the dorsal part a woven fabric made from aramid fibers, aluminized, or glass fibers. For the palmar side, fabrics made of non-flammable fibers and heat-resistant skins are usually used. Gloves designed for employees of mills are designed with a long cuff that also protects the forearm or shoulder. In the case of clothing

accessories that are gloves, it is difficult to strike a balance between ensuring proper performance and protection. Gloves that have a sufficiently high level of protection with respect to thermal resistance are usually made of several layers of various materials, which limits the user's manual abilities during work. Gloves guaranteeing a sufficiently high level of protection are usually made of several material systems that then affect the construction of the glove.

Fig. 6. Examples of different construction of gloves protecting against hot factors [17]

Therefore, construction solutions with one or three fingers are used. When selecting the right gloves to protect the user's hands from heat, perform the following steps:

- proper identification of the type of hazard that occurs at a particular workplace (selection of appropriate specialist gloves used to protect hands against a particular hazard, eg gloves intended for firefighters or gloves for works in metallurgy),
- determining the part of the upper limb, which is exposed to heat or fire (selecting a cuff of a certain length to protect the part exposed to hot factors),

- determination of the intensity of the harmful factor acting (selection of protective gloves with appropriate levels of protection effectiveness for this factor),
- determination of the work performed by the employee and the required manual efficiency during the activities performed, as well as comfort of use (selection of the appropriate construction of protective gloves) [17].

The Central Institute for Labor Protection together with the Lodz University of Technology in its research also used the modification of the basalt fabric by coating in the form of aluminum foil for use in gloves protecting against high temperatures. As a result of the analysis of the tests carried out due to the low resistance to contact heat and cracks at the seams caused by the confectioning process, the modified fabrics did not find application in the palm part of the glove. However, the structure of protective gloves developed during the tests based on the use of aluminized basalt fabrics found application in the upper part of the protective glove (Figure 6) [18-21].

Research related to the subject of the issue was conducted by the Textile Architecture Institute at the Lodz University of Technology, where the surface of the basalt fabric was covered with aluminum foil in order to apply it to clothing protecting against hot factors [22].

5. EYE AND FACE PROTECTION EQUIPMENT

The main task of eye and face protection equipment, which protects against the effects of hot factors, is the protection of the face and eyes against:

- strong thermal radiation,
- splashes of molten metal,
- short-term contact with the flame,
- very hot splashes of glass, slag and metals.

Depending on the purpose and construction, the equipment used to protect the face and eyes from thermal factors can be divided into:

- equipment that is used during firefighting,
- equipment used in metallurgy,
- equipment used during electric welding or plasma jet cutting,
- equipment used during gas welding and related techniques.

Another criterion for the division are differences in the construction of the equipment, according to this criterion we distinguish:

- metallurgical hoods (Fig. 7.a),
- goggles,
- face shields mounted on a protective helmet,
- welding goggles,
- mesh face shields (Figure 7.b),
- welding shields [17].

a)

b)

Fig. 7. a) metallurgical hood, **b)** mesh face shield for the metallurgist [17]

6. SAFETY SHOES

In the case of footwear that protects in a hot work environment, high demands are placed on the protective functions they perform and their performance. Depending on the specifics of a specific workplace, which is related to the protective properties of the footwear, the type of the material and the design of the footwear are selected accordingly. Footwear that performs its tasks in the field of protective and functional functions should demonstrate resistance to incandescence and ignition, high thermal insulation as well as heat resistance. Leathers that are used on the top of the footwear should neither stiff nor shrink due to high

temperatures while the soles should not show abrasion, charring, cracking or melting when in contact with heated ground. Due to the physical effort of employees, footwear should be characterized by lightness and flexibility, so as not to lead to additional energy expenditure by the body.In addition, footwear should exhibit high permeability and absorption of water vapor, as well as pot-life. Footwear intended for use by firefighters, metallurgists and welders is the odious topic of the discussed issue [17].

7. SUMMARY

Working in hot weather conditions leads to employees experiencing heat stress, fatigue, and may also cause disturbances in the functioning of the cardiovascular system, which in turn results in the formation of occupational diseases. The subject of the problem is related to work positions in various branches of the economy despite the fact that the production processes have been automated. In Poland, according to the data taken in the hot environment, many thousands of people work. Therefore, the employer's duty is to conduct organizational and technological activities that could eliminate or at least reduce the occupational hazard caused by the dangerous factor of the work environment. Researchers strive to manufacture clothing or a selected item of clothing, eg protective gloves, which at the same time would limit the heat load of an employee at a particular workplace, guaranteeing safety and ensuring comfort of use.

References

[1] M. Matusiak M, Heat-protection of clothing fabrics. Monograph, Works of the Textile Institute, Special Edition, Lodz, 2011, pp. 23-28; pp. 35-36, pp. 40-41

[2] N. Djongyang, R. Tchinda, D.Njomo, Thermal comfort: A review paper, *Renewable and Sustainable Energy Reviews*, 14, 2010, pp. 2626-2640

[3] P. Miśkiewicz, A. Cichocka, The impact of garment personalization on the user's thermal comfort Part I. The influence of fitting degree on the thermal insulation of garments. *Textile Review Fiber Leather Clothing*, no. 11, 2017, pp. 34-37

[4] Ł. Buszman, Thermoactive Secrets, *Textile and Textile Spectrum,* 2/2005

[5] A. Bogdan, Skin Temperature Change as Parameter Determining Human Heating Comfort. *District Heating, Heating, Ventilation* (str. 107 nr. 3/2010)

[6] G. Havemith, I. Holmer, K. Parsons, „ Personal factors in thermal comfort assessment: - clothing properties and metabolic heat production", Energy and Buildings, 34, 2002, pp. 581-591

[7] W. Więźlak, J. Elmrych – Bocheńsk , J Zieliński. Clothing. Construction, ownership, production, Łódź, Scientific Publisher of the Institute for Sustainable Technologies - PIB, 2009, pp. 43-44; pp. 54 – 60, pp. 61-63, pp. 66, ISBN 978-83-7204-866-0

[8] S. V. Szokolay, Introduction to Architectural Science: The Basis of Sustainable Design, Elsevier/Architectural Press, 2008, pp. 115-135

[9] M. Srivanit, S. Auttarat, „ Thermal comfort conditions of urban spaces in a hot-humid climate of Chingmai city, Thailand", The 9th International Conference on Urban Climate July 2015

[10] H. Mayer, P. Höppe, „Thermal comfort of man in different urban environments, *Theoretical and Applied Climatology*, 38, 1987, pp. 43-49

[11] P. Miśkiewicz, A. Cichocka, The impact of knitwear structure on the thermophysical properties of thermoactive underwear, *Textile Review Fiber Leather Clothing*, no 7, 2018, pp. 29-34

[12] B. Władyka, Is sweating necessary, *AURA*, 12/2013, pp. 34-35

[13] Edited by W. Traczyka, A. Trzebskiego., Physiology of man with elements of applied and clinical physiology, Warsaw, 2001, PZWL Medical Publishing, pp. 266-268, pp. 274-275, ISBN 83-200-2364-5

[14] Statistics Poland, Working conditions in 2017, Warsaw 2018, poland

[15] G. Bartkowiak, A. Marszałek, A. Dąbrowska, Thermal load of employees in a hot work environment and ways is reduced , *Work Safety*, 10/2012, pp. 28-32

[16] D.D. Pascode, L.A. Shanley, E.W Smith, Clothing and exercise; Biophysics of heat transfer between the individual, clothing and environment, *Sports Medicine*, no. 18, 1994, p. 38-54

[17] K. Majchrzycka, A. Pościk, Selection of personal protective equipment, Warsaw, 2007, pp. 244-250

[18] R. Hrynyk, I. Frydrych, Construction of gloves made of aluminized basalt fabrics that provide protection against thermal factors, Part I: Laboratory tests of protection parameters, *Textile Review*, no. 6, 2015, pp. 28-33

[19] R. Hrynyk, I. Frydrych, Construction of gloves made of aluminized basalt fabrics that provide protection against thermal factors, Part II: Applied research, in industrial conditions, *Textile Review*, no. 9, 2015, pp.34-36

[20] R. Hrynyk, I. Frydrych, Study on textile assemblies with aluminized basalt fabrics destined for protective gloves, International Journal of Clothing Science and Technology, no. 27 (5), 2015, pp. 705-719

[21] R. Hrynyk, I. Frydrych, E. Irzmińska, A. Stefko, Thermal properties of aluminized and non-aluminized basalt fabrics, *Textile Research Journal*, 83 (17), 2012, pp. 1860-1872

[22] P. Gliewicz, A. Cichocka, I. Frydrych, Assessment of thermal insulation of fabrics intended for clothing to protect against high temperature, *Textile Review*, no. 1, pp. 30-34, 2015.