Clothing adjustment value (CAV) as an element of employee protection against excessive exposure to hot environment

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WORKSHOP BAuA-CIOP-PIB
Session 3 Physical Agents
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NE-3 Laboratory of thermal load

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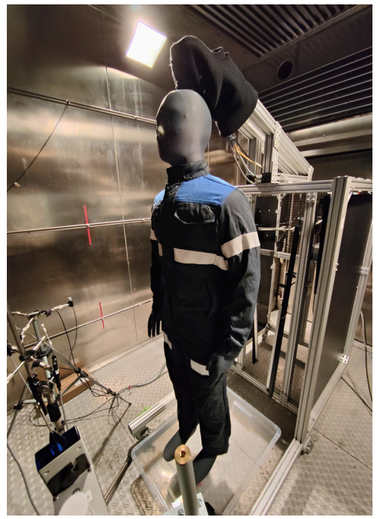
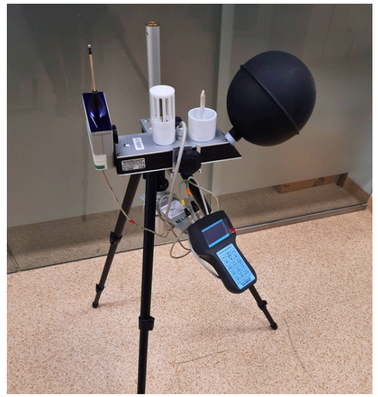
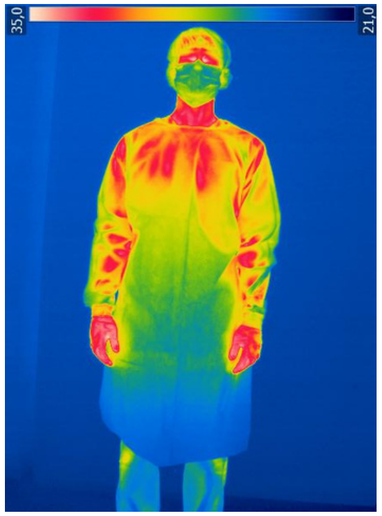
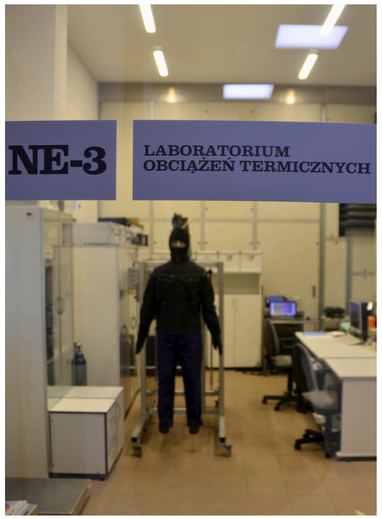
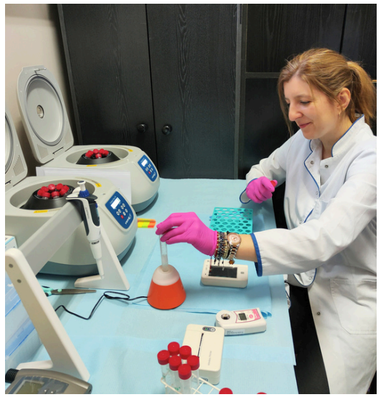
Pracownia Obciążeń Termicznych











Agenda

01 Background of the study

02 Polish OSH regulations

03 Problem Statement

04 Methodology

05 Results

06 Next step

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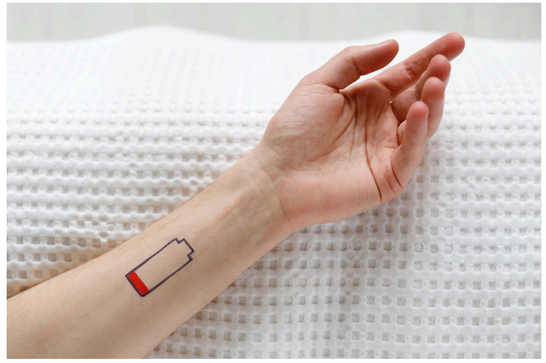
01

Background of the Study

The negative health effects of working in a hot environment



- Heat stroke
- Heat fainting
- Heat exhaustion
- Heat cramps
- Heat rashes
- Dehydration

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01

Background of the Study

High temperature as factor hazard

HOT environment

- ironworks
- foundries
- bakeries,
- mining, etc.

climate change

- indoor worker (inside buildings; offices; etc.)
- outdoor worker (i.a.: construction workers; farmers)

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01

Background of the Study

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WBGT

Wet-Bulb Globe Temperature

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01

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WBGT

Wet-Bulb Globe Temperature

???

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01

CLIMATE CHANGE

"**A 'staggering' number of workers**, amounting to more than **70% of the global workforce**, are likely **to be exposed to climate-change-related health hazards**, and existing occupational safety and health (OSH) protections are struggling to keep up with the resulting risks, according to a new report by the International Labour Organization (ILO)".

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International Labour Organization

General climate-related OSH hazards

- Excessive heat
- Ultraviolet (UV) radiation
- Exreme weather events
- Air polution
- Vector-borne diseases
- Agrochemicals

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International Labour Organization

General climate-related OSH hazards

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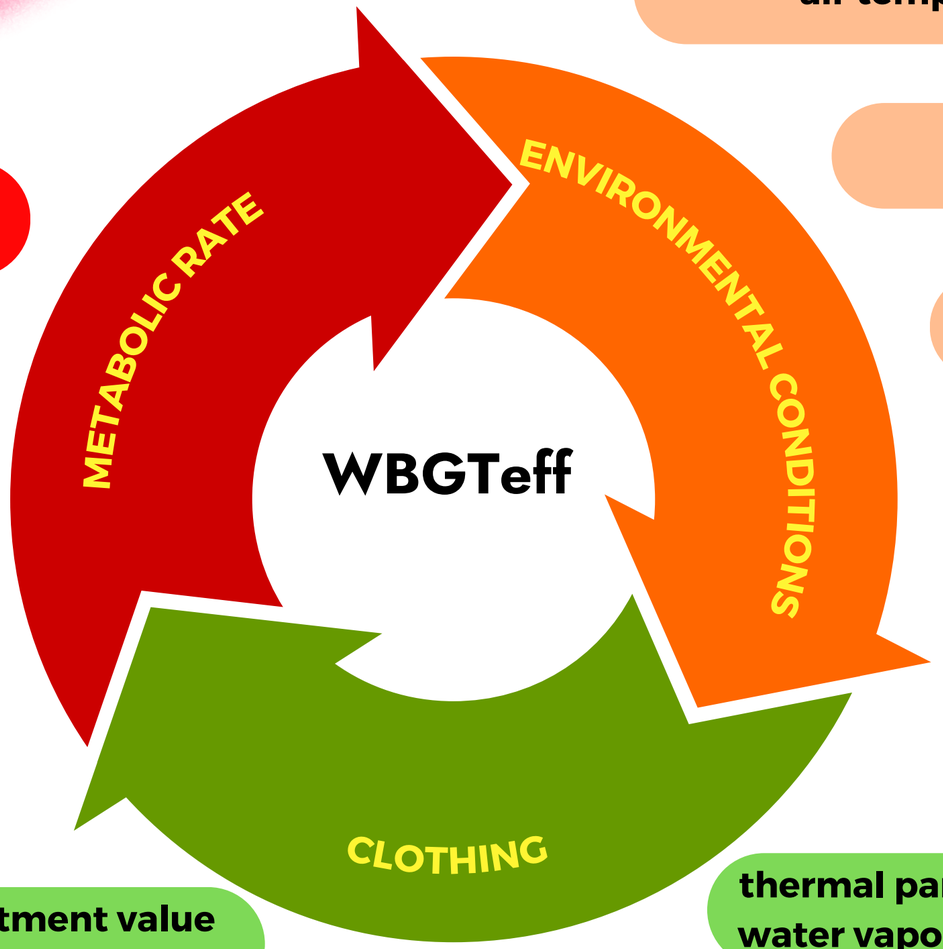
Polish OSH regulations

Wet-Bulb Globe Temperature



metabolic rate class

air temperature

relative humidity

air velocity

radiation temperature

Clothing adjustment value (CAV)

thermal parameters (thermal insulation, water vapor resistance, air permeability)

Polish OSH regulations

Wet-Bulb Globe Temperature

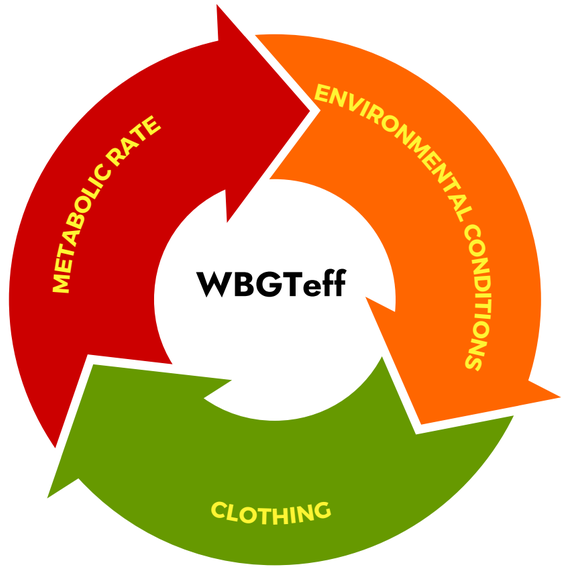
Journal of Laws 2021 item 325:

Regulation on the maximum permissible concentrations and intensities of harmful health factors in the work environment

European Standard:

PN-EN ISO 7246 Ergonomics of the thermal environment - Assessment of heat stress using the WBGT (wet bulb globe temperature) index

Metabolic rate class	Metabolic rate	**Reference values of WBGTeff**	
	W	acclimatized person [°C]	non-acclimatized person [°C]
0 (resting)	115 (100-125)	33	32
1 (low metabolic rate)	180 (125-235)	30	29
2 (moderate metabolic rate)	300 (235-360)	28	26
3 (high metabolic rate)	415 (360-465)	26	23
4 (very high metabolic rate)	520 (>465)	25	20



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Polish OSH regulations

NOTICE of the minister of health of 6 February 2023 (...) **on tests and measurements of factors harmful to health in the work environment** (Journal of Laws 2023 item 419):

In the case of a hot environment, tests and measurements of microclimate indicators are performed once a year.

REGULATION of the Council of Ministers of 12 June 2019 (...) **on preventive meals and drinks** (Journal of Laws of 2019, item 1160):

The employer provides **MEALS** to employees performing heavy work and Wet-Bulb Globe Temperature (WBGT) above 25 °C.

The employer provides **DRINKS** to employees performing work:

- in hot environment with WBGT above 25 °C
- outdoor working when air temperature is above 25 °C
- at work stations, where the temperature caused by weather conditions, exceeds 28°C.

Polish OSH regulations

Wet-Bulb Globe Temperature

<u>without solar radiation</u>

WBGT=0,7tnw+0,3tg

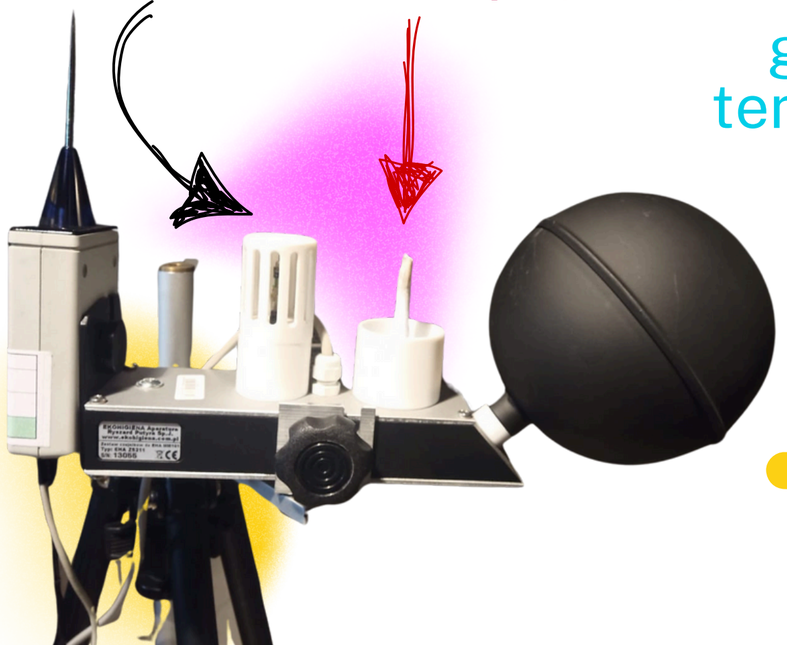
<u>with solar radiation</u>

WBGT=0,7tnw+0,2tg + 0,1ta

relative humidity (RH) and air temp. (ta)

natural wet-bulb temp. (tnw)

globe temp. (tg)



<u>WBGT effective (**with clothing factor**)</u>

WBGTeff = WBGT + CAV

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03

Problem Statement

(CAV) clothing adjustment value

Set of clothing	Thermal insulation of a set of clothing, clo	**CAV, in WBGT, °C**
Standard working clothes made of fabric (reference set)	0,6	**0**
Overall made of treated cotton fabric (or light polyester)	NDA	**0**
Cotton overall	1,0	**2**
Clothing made of a double layer of fabric – often overalls intended to be worn on top of work clothes	NDA	**3**
Single layer overall with a hood and with a vapour barrier (e.g. protective overalls, chemical protection overalls	NDA	**11**

NDA – no data available

PN-EN ISO 7243; Parsons 2003; Schmoldt 2018; ACGIH 2017
Młynarczyk, M. et al., DOI: 10.5604/01.3001.0014.8148

the higher CAV:

- water vapor resistance (Ret) ↑
- air permeability (im) ↓

other clothes ???

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03

Problem Statement

RESEARCH QUESTIONS:

1. What is the correct value of CAV ?

2. Do “thermal comfort parameters” of clothes change depending on washing cycles (state zero vs. state after 50 cycles) ?

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04 Methodology

Clothing ensembles

- selection of 15 sets of clothing for a hot environment
- themal manikin’s test (PN-EN ISO 15831, PN-EN 342; ASTM F2370):
  - thermal insulation,
  - water-vapour resistance
- state zero vs. state after 50 cycles

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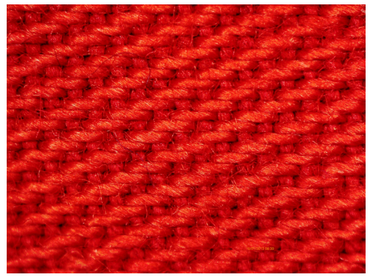
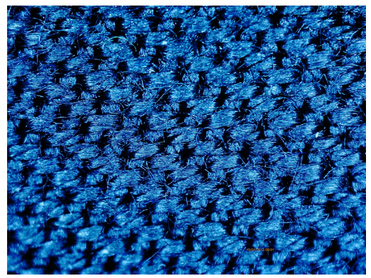
04 Methodology

Material samples

- material samples from selection clothes
- sweating guarded-hotplate test (PN-EN ISO 11092):
  - thermal resistance
  - water-vapour resistance
- material thickness, surface mass, air permeability
- state zero vs. state after 50 cycles





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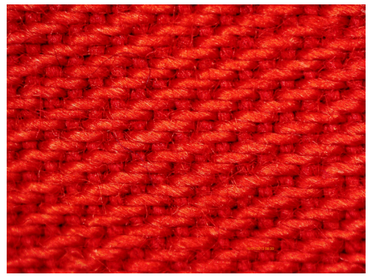
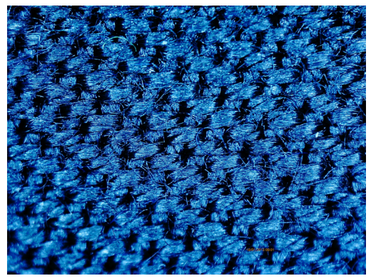
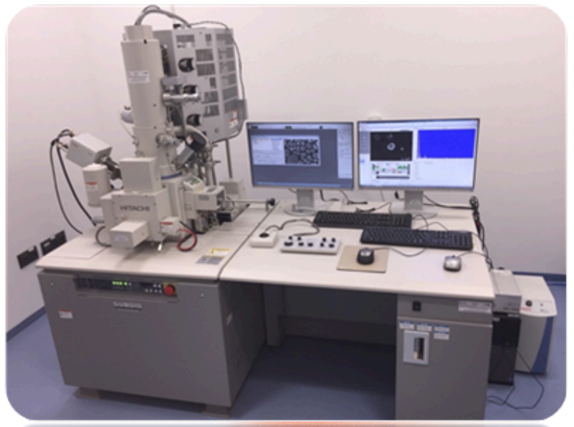
04 Methodology

Material samples

- material samples from selection clothes
- scanning electron microscopy (SEM):
  - image of changes
  - length and width of weft and warp
- state zero vs. state after 50 cycles







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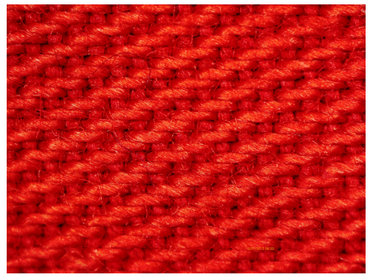
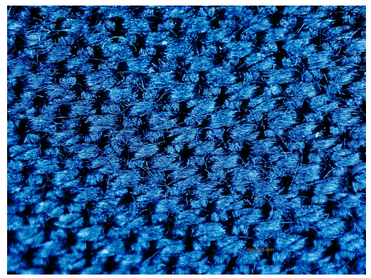
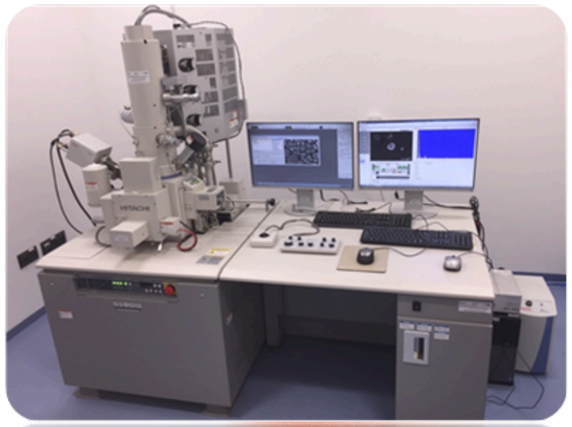




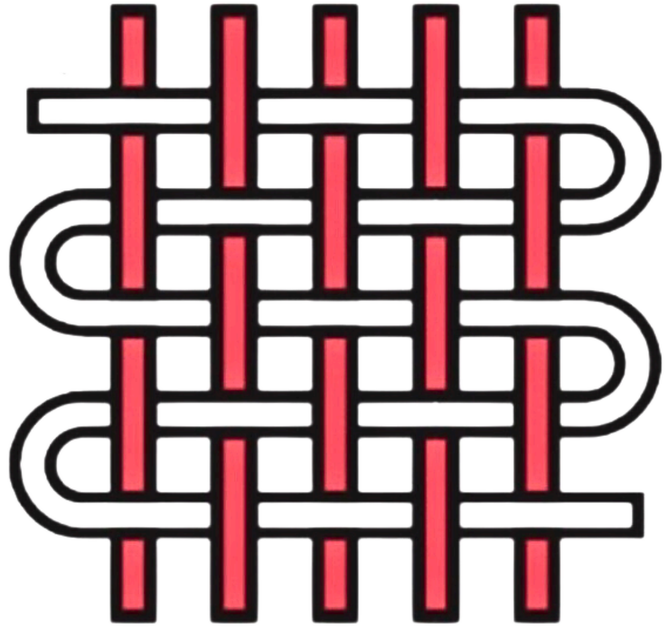


WARP

along direction

WEFT

transverse direction



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05

Results

Clothing ensemble

protective clothing against thermal hazards caused by electric arc:

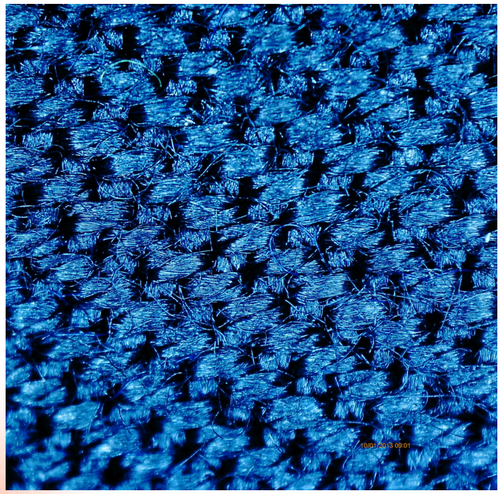
MS CHEM ARC PARKA (jacket)

MS CHEM ARC BIB PANTS (dungarees)

Material samples

MOR2 - 93 % Nomex, 5 % Kevlar, 2 % Anti-static fibres;

260 g/m^2 (surface mass)



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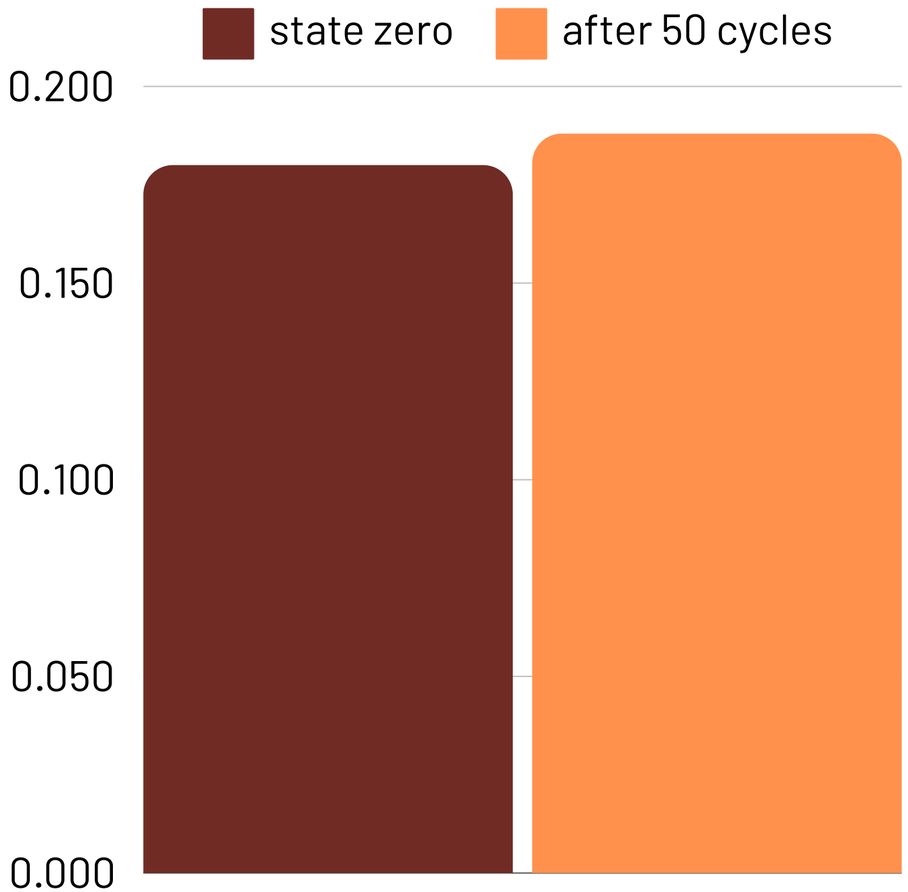
05

Results

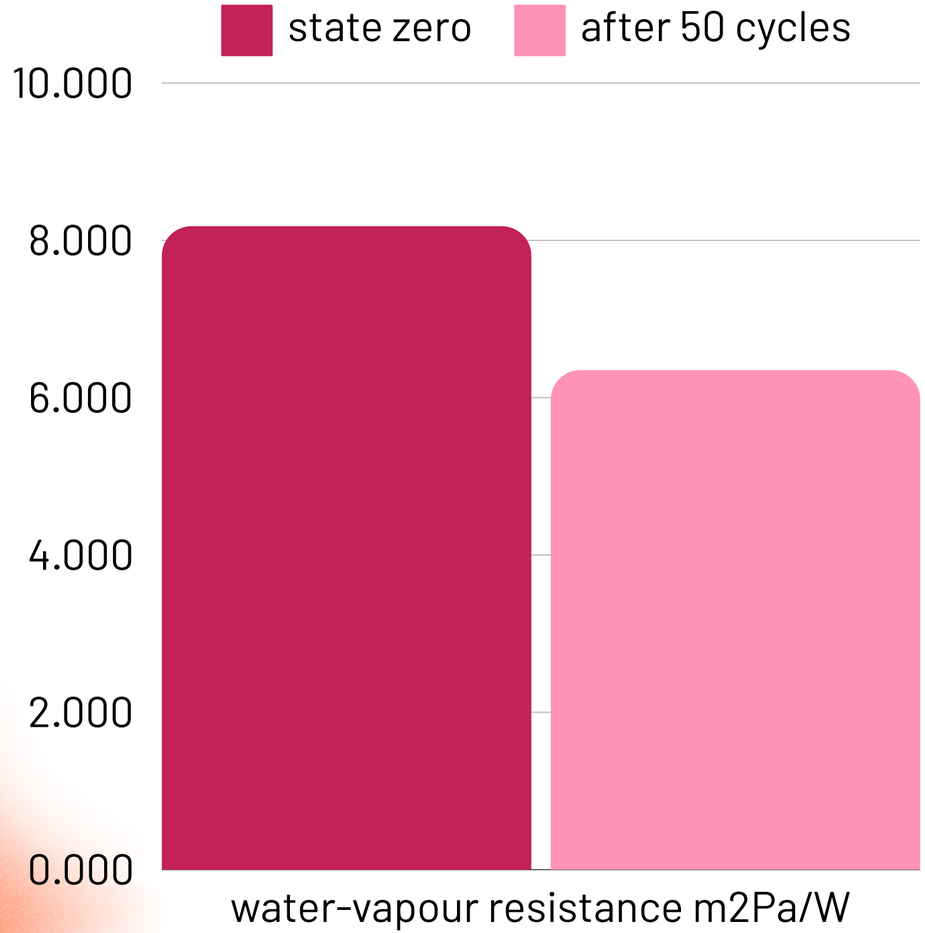
Clothing ensemble

MS CHEM ARC PARKA; MS CHEM ARC BIB PANTS

Δ 4 %



Δ 22%



CIOP PIB

05

Results

Material samples

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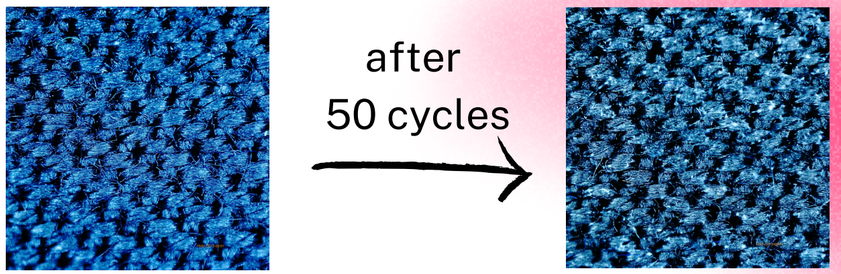
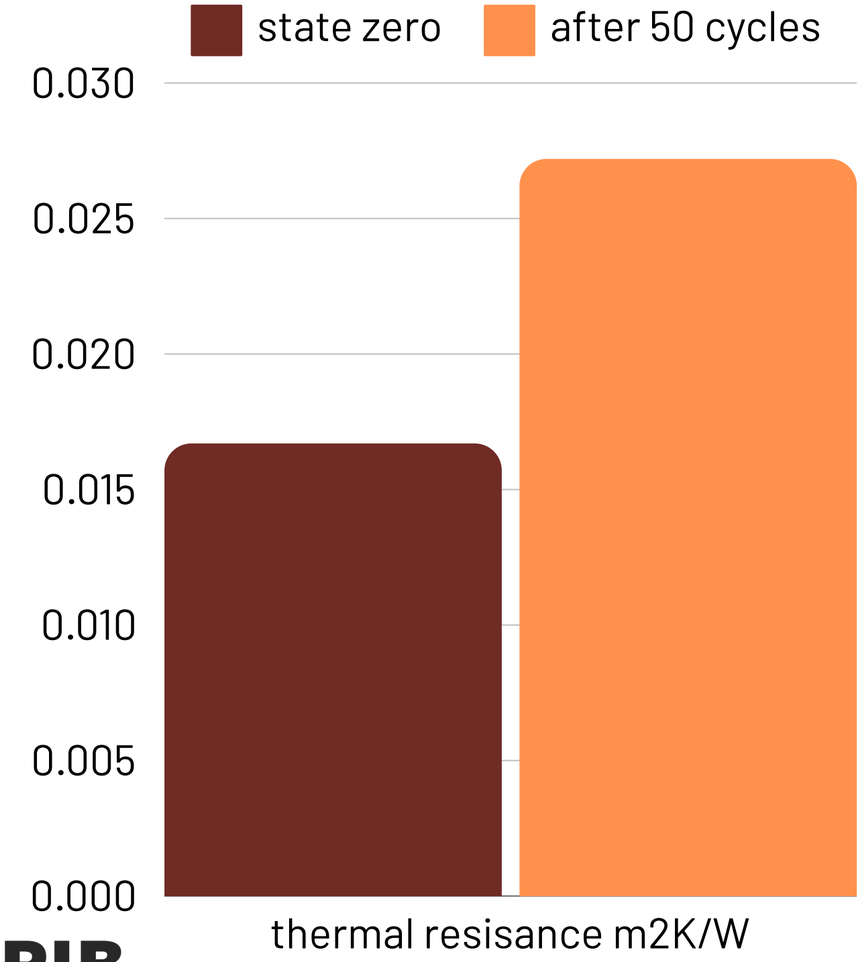
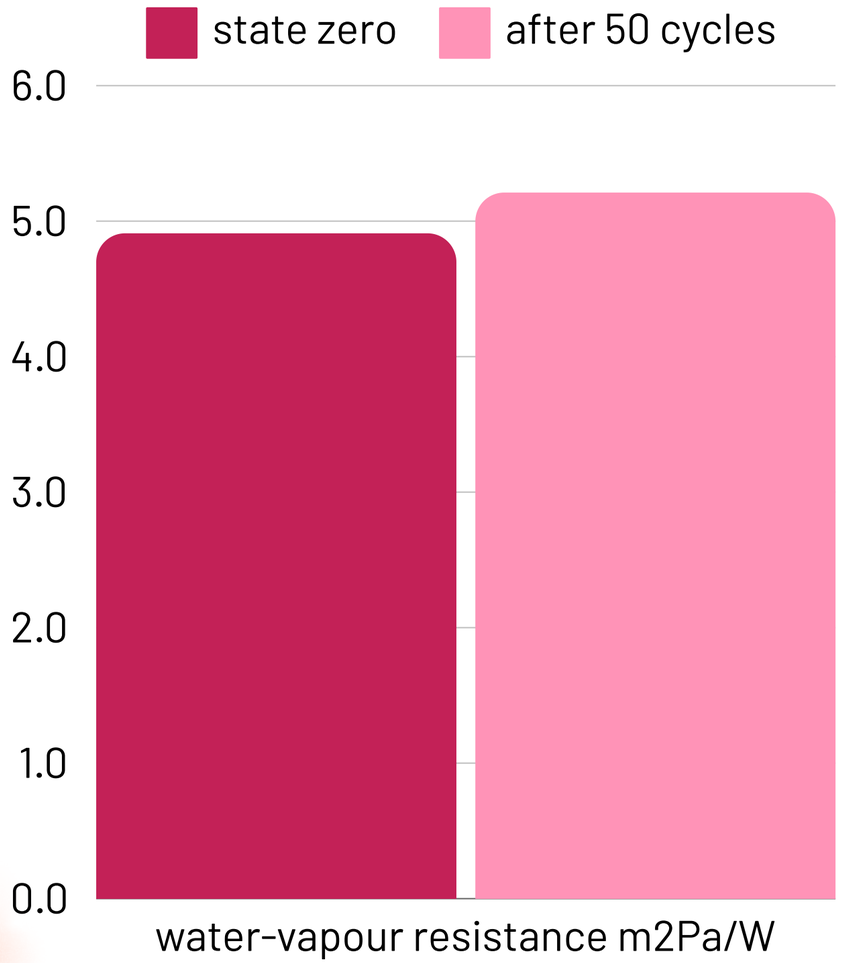


Δ 39 %



Δ 6%



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05

Results

Material samples

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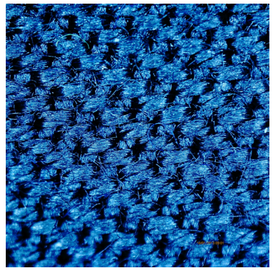
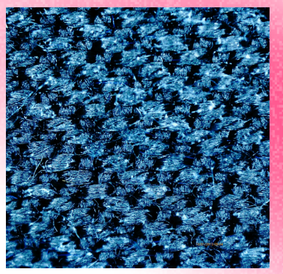
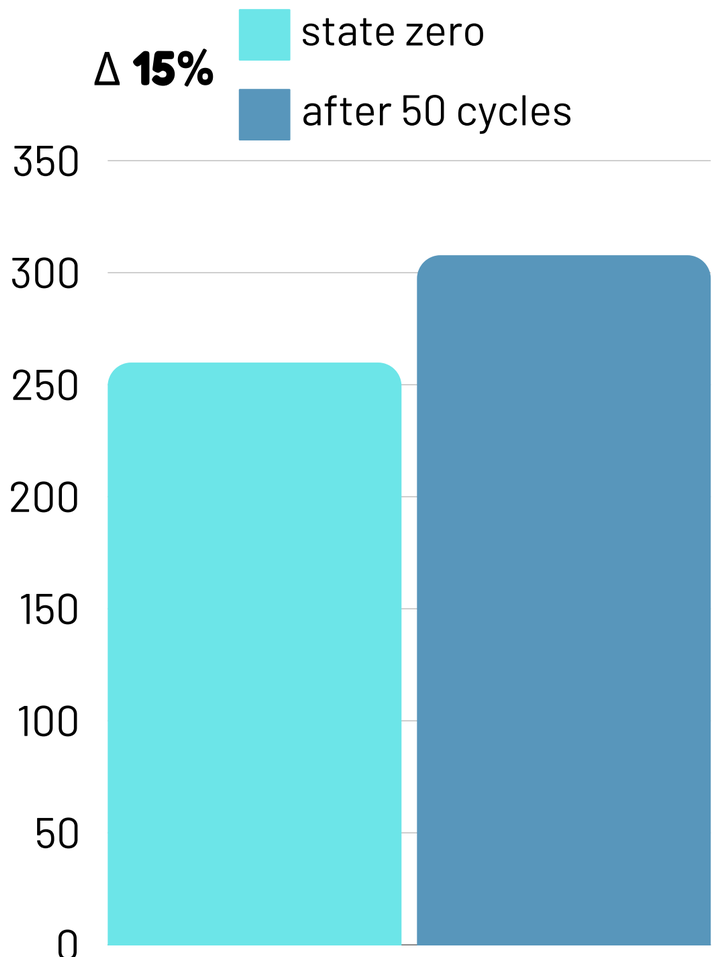
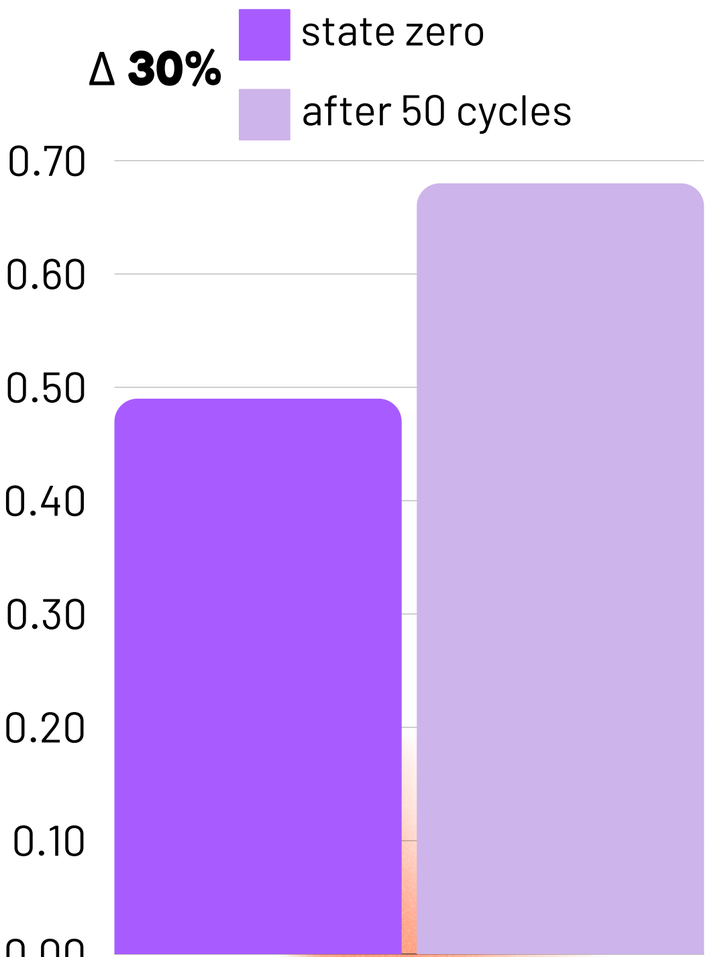
(surface mass)

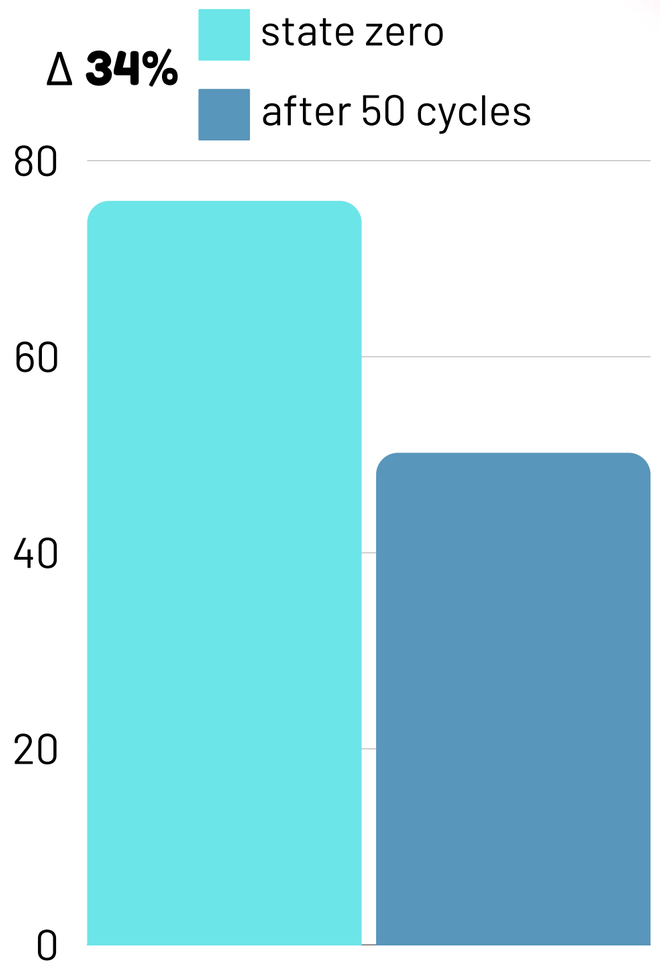


after
50 cycles









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05

Results

Material samples

MOR2 - 93 % Nomex, 5 % Kevlar, 2 % Anti-static fibres; 260 g/m^2 (surface mass)

SCANNING ELECTRON MICROSCOPY

FIBER DIMENSIONS

after
50 cycles

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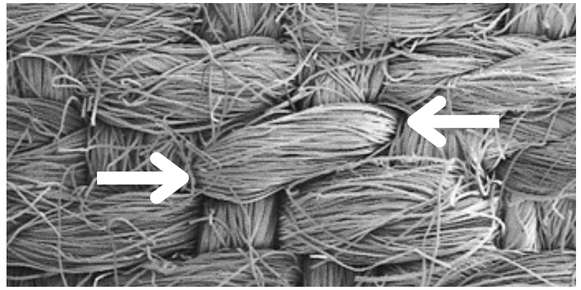
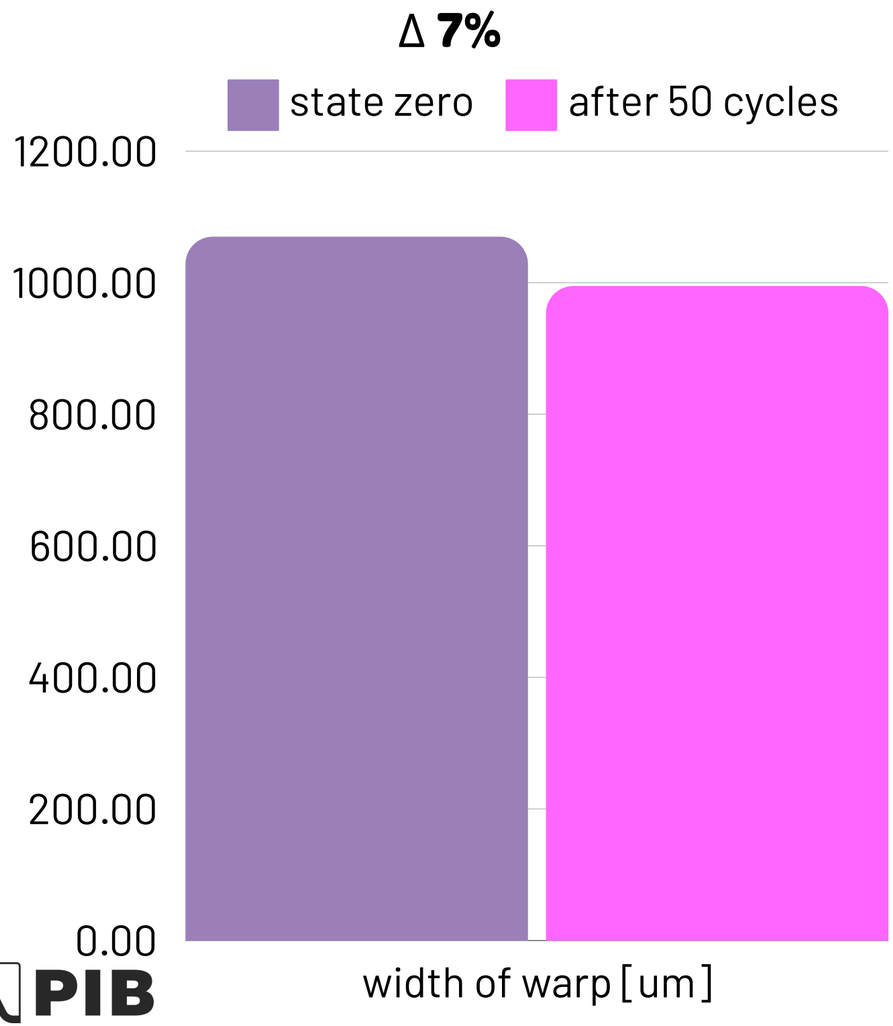
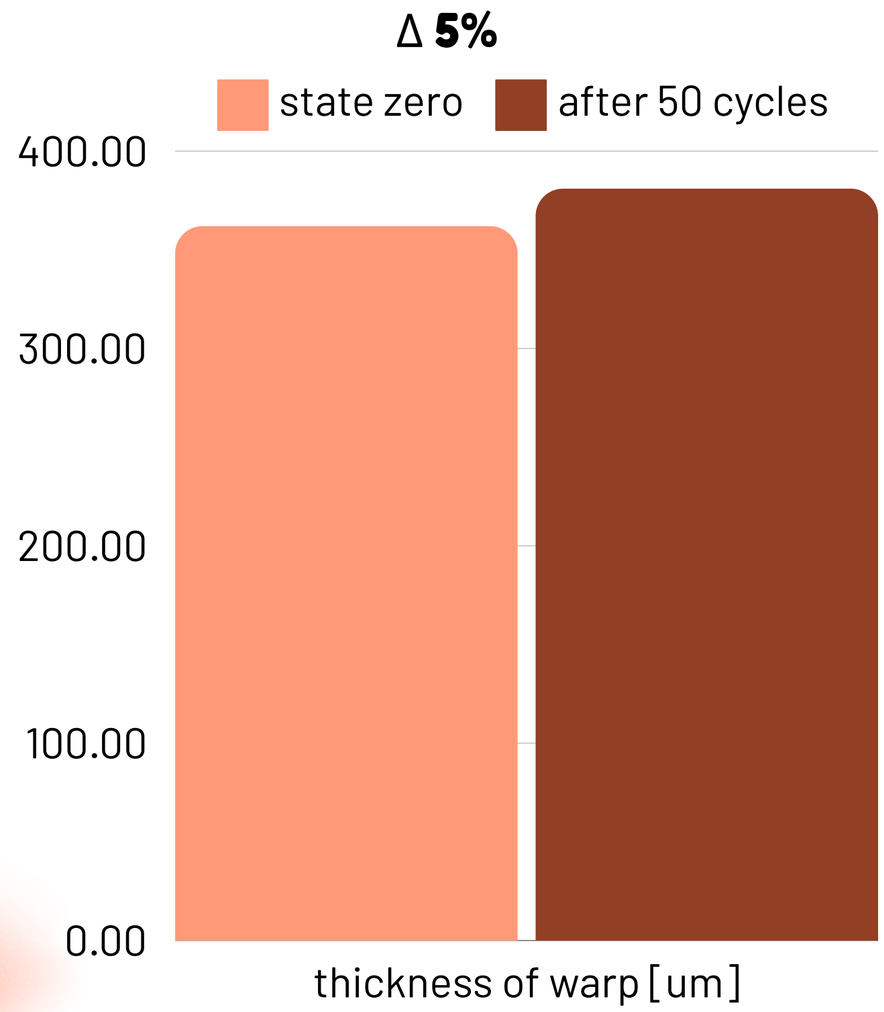
05




Δ 7%
state zero
after 50 cycles
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
width of warp [um]


Δ 5%
state zero
after 50 cycles
400.00
300.00
200.00
100.00
0.00
thickness of warp [um]

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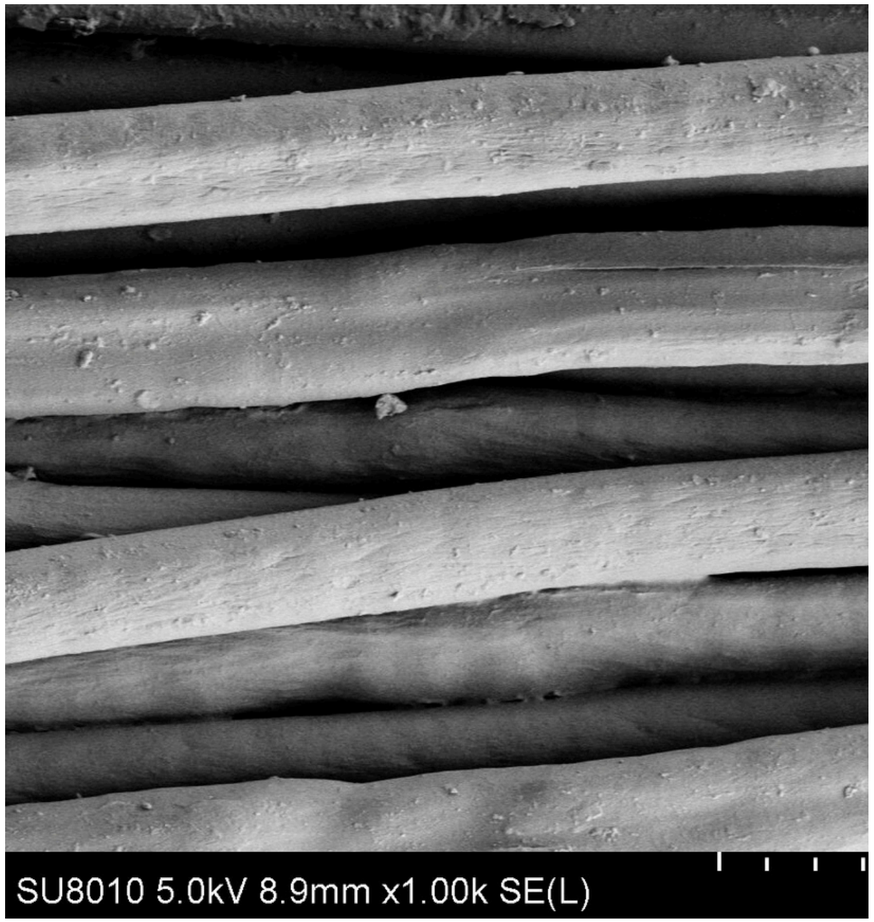
05

Results

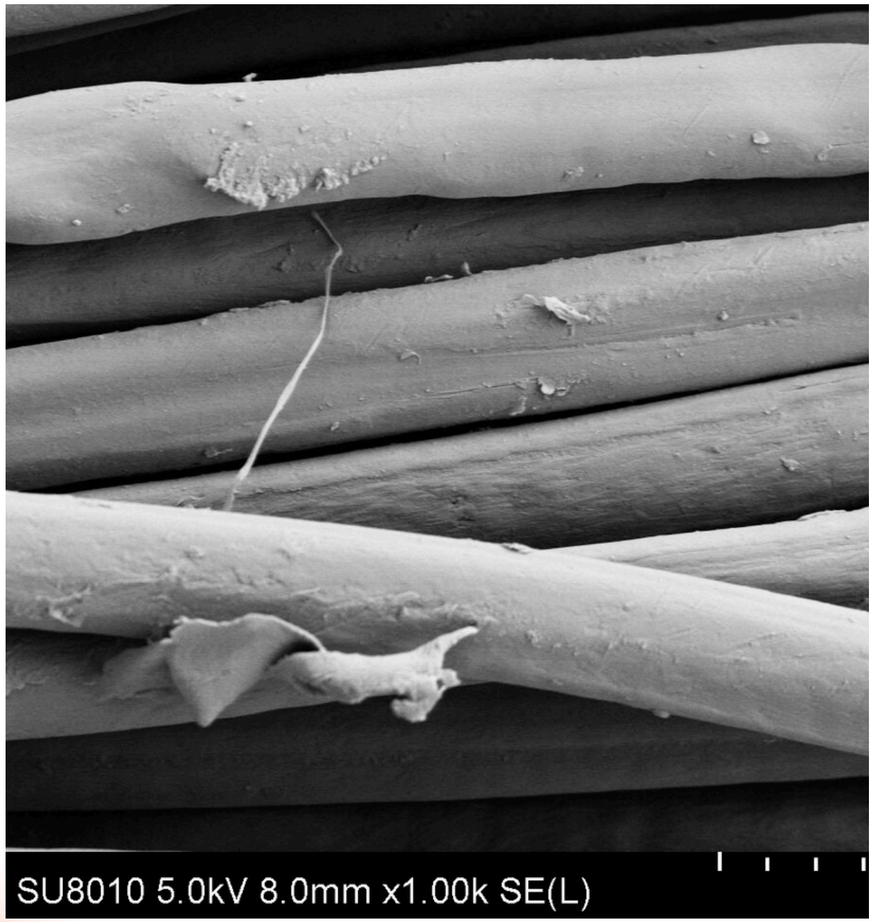
FIBER MORPHOLOGY

Material samples
MOR2 - **93 % Nomex**, 5 % Kevlar,
2 % Anti-static fibres; 260 g/m^2
(surface mass)

SCANNING ELECTRON MICROSCOPY



after
50 cycles



fiber damage

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05

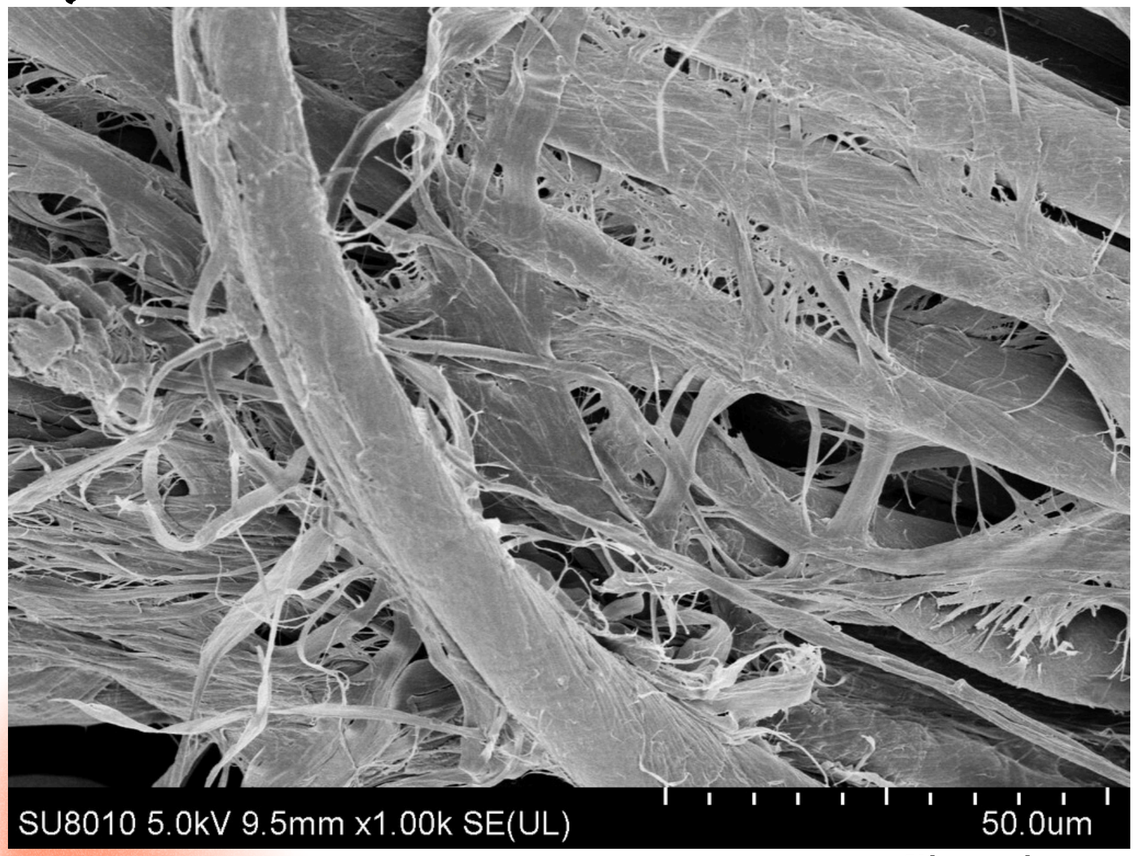
Results

Material samples
100% **Cotton** (350 g/m2)

SCANNING ELECTRON MICROSCOPY

FIBER MORPHOLOGY

after
50 cycles



fiber damage

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05

Results

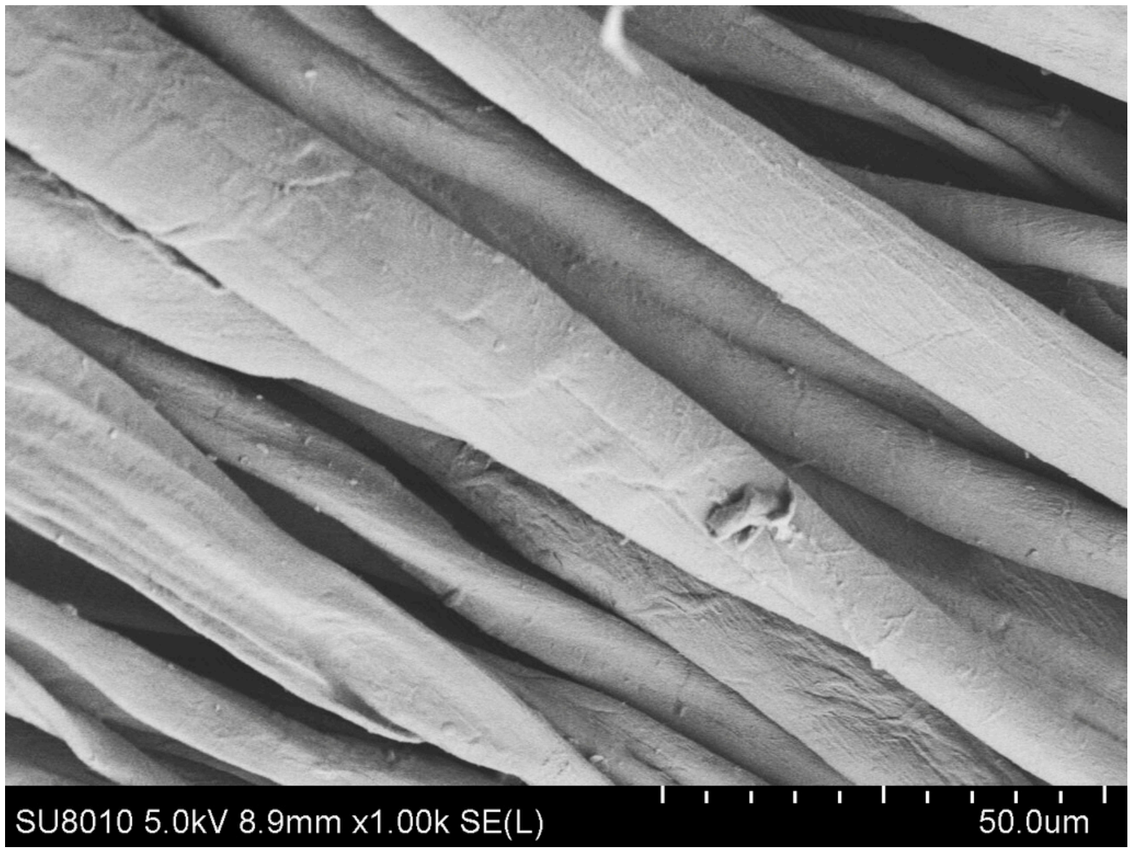
Material samples

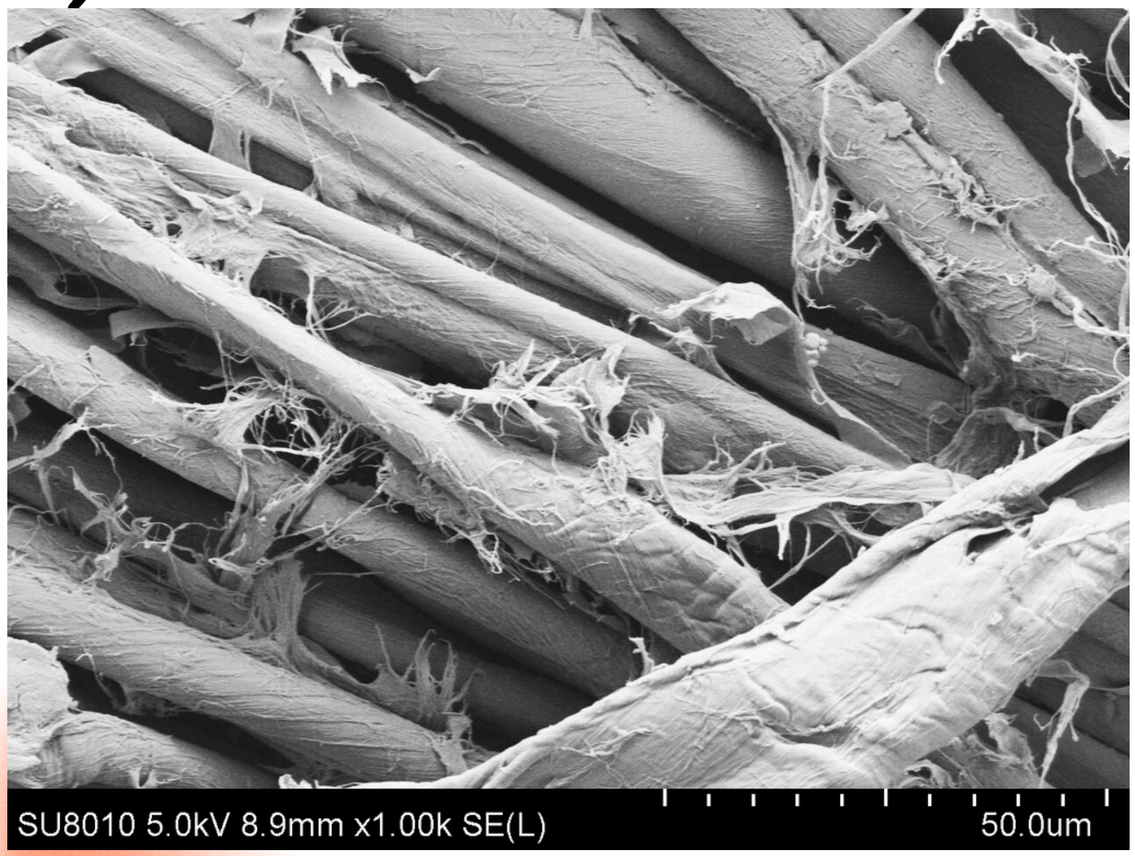
50% **Cotton**/ 39% Modacrylic/ 10% Viscose/
1% Antistatic fibres

SCANNING ELECTRON MICROSCOPY

FIBER MORPHOLOGY

after
50 cycles





fiber damage

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05

Results

summary

Material samples
MOR2 - 93 % Nomex, 5 % Kevlar,
2 % Anti-static fibres; 260 g/m^2
(surface mass)

	It	Ret
zero vs. 50 cycles	⬆ 4%	⬇ 22%

	Rct	Ret	SM*	MT*	AP*
zero vs. 50 cycles	⬆ 39%	⬆ 6%	⬆ 15%	⬆ 30%	⬇ 34%

* SM - surface mass; * MT - material thicknes; * AP - air permeability

	width of warp	thickness of warp
zero vs. 50 cycles	⬇ 7%	⬆ 5%

the higher CAV:

- **water vapor resistance (Ret) ↑**
- **air permeability (im) ↓**

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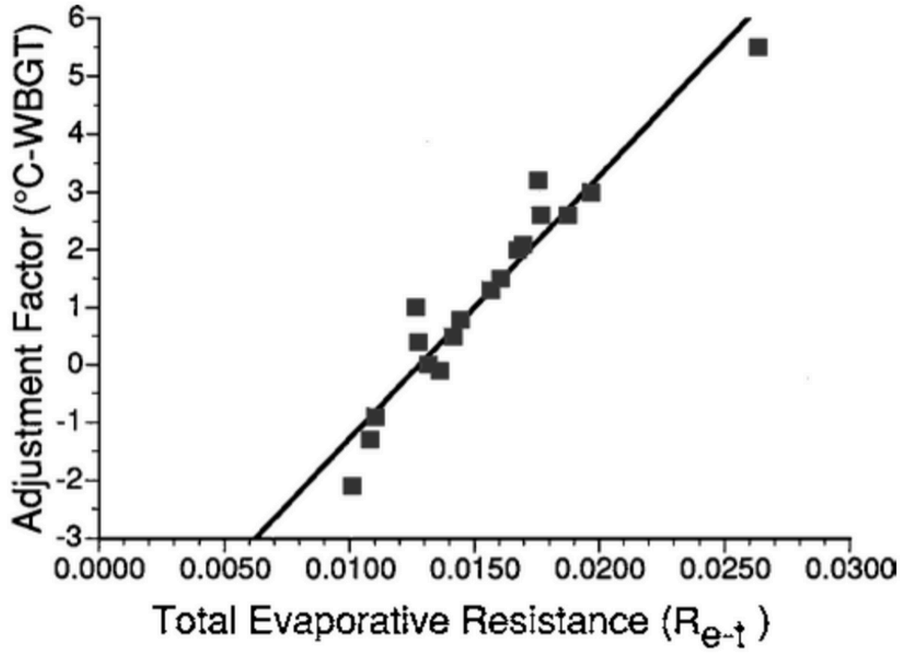
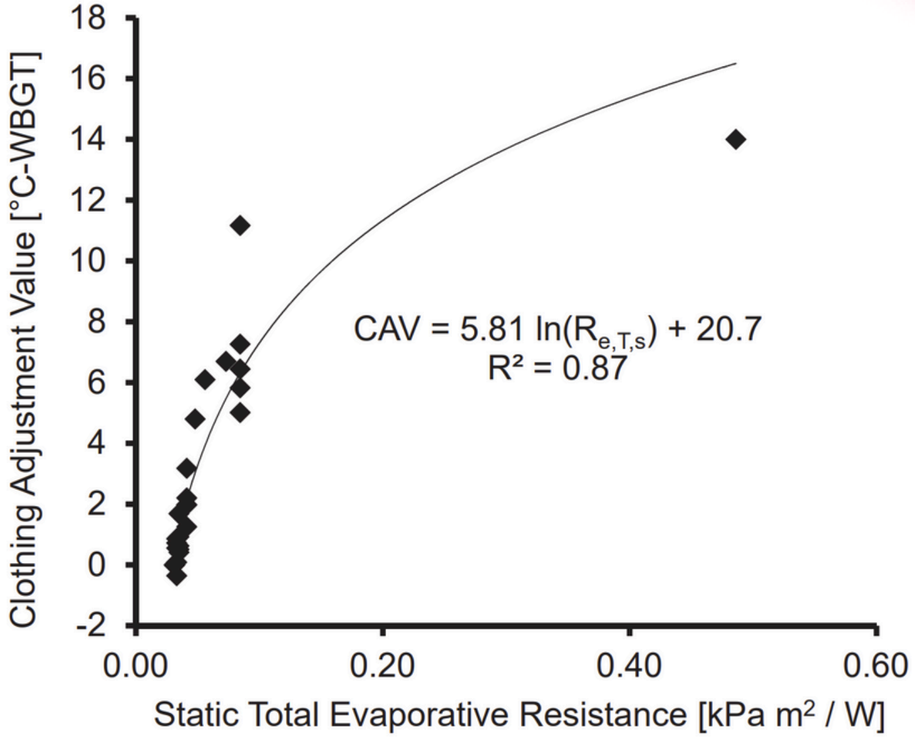
06

Next step



O'Connor D. J. (1999) Continuing the Search for WBGT Clothing Adjustment Factors, Applied Occupational and Environmental Hygiene, 14:2, 119-125



Bernard T., et al. (2017) Prediction of WBGT - based clothing adjustment values from evaporative resistance Industrial Health , 55, 549–554

Based on obtained thermal parameters,
the CAV (for tested clothing) will be calculated

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06 Next step

After analysis of the obtained results, **the database with the Clothing Adjustment Value** (CAV) and **thermal parameters** of protective clothing (**including wash cycles**) will be created.

Based on the database, **an application** that will allow for estimating the Clothing Adjustment Value (CAV) will be created.

The application will allow for **the correct assessment of the heat load in a hot environment (WBGTeff).**

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Research Team

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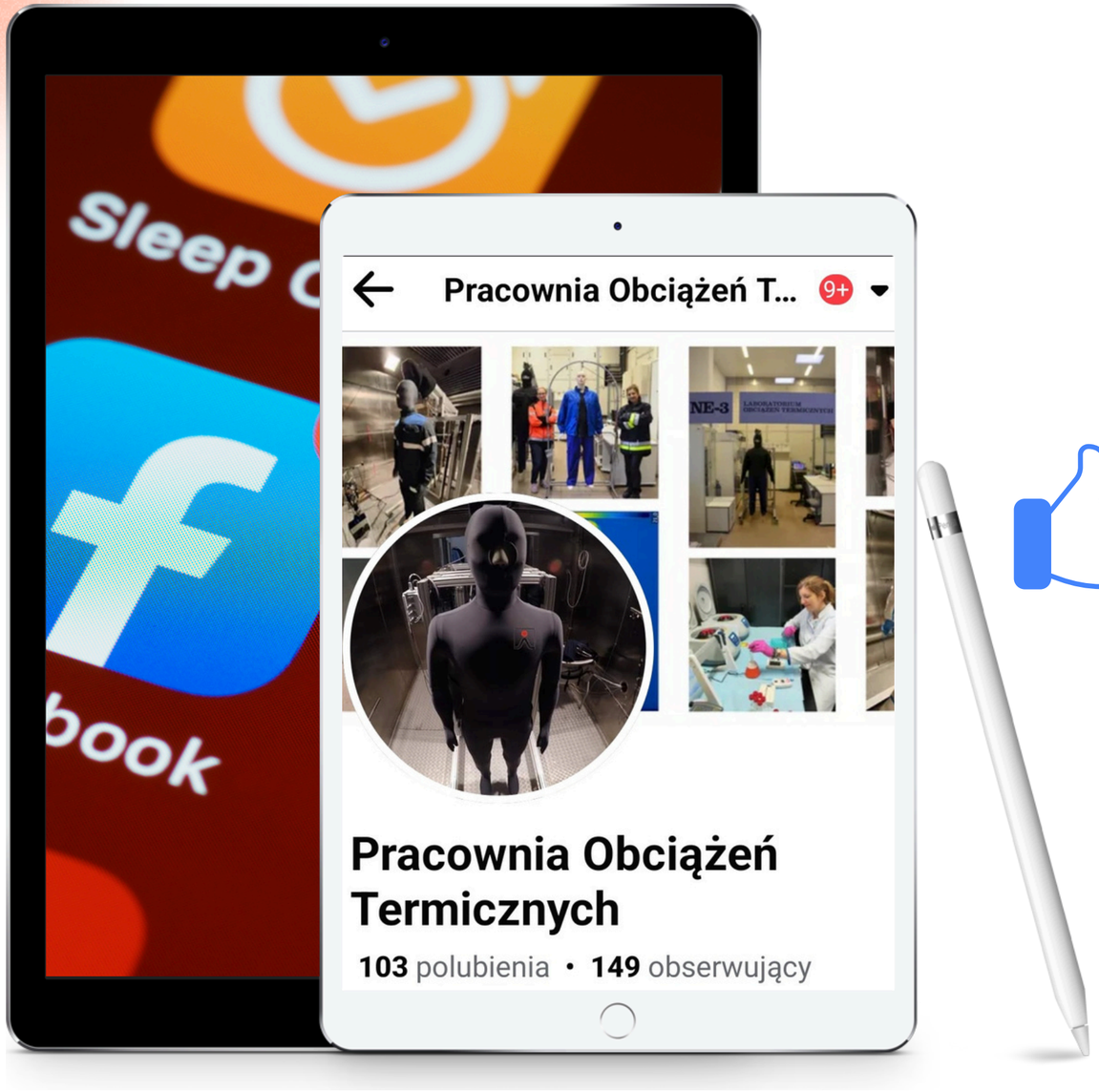

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Thank You

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