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Varovalna obleka za gasilce - Fiziološki vpliv - 1. del: Merjenje skupnega prenosa toplote in potu med potenjem trupa (ISO/DIS 18640-1:2016)

Protective clothing for fire-fighters- physiological impact - Part 1: Measurement of coupled heat and mass transfer with the sweating TORSO (ISO/DIS 18640-1:2016)

Schutzkleidung für die Feuerwehr - Physiologische Wärmebelastung - Teil 1: Messung von gekoppelter Wärme und Stoffaustausch mit dem Schwitztorso (ISO/DIS 18640-1:2016)

Vêtements de protection pour sapeurs-pompiers - Effet physiologique - Partie 1: Mesurage du transfert couplé de chaleur et de masse à l'aide du torse transpirant (ISO/DIS 18640-1:2016)

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ICS:

13.220.10	Gašenje požara	Fire-fighting
13.340.10	Varovalna obleka	Protective clothing

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Protective clothing for fire-fighters- physiological impact —

Part 1:
Measurement of coupled heat and mass transfer with the sweating TORSO

Titre manque

ICS: 13.340.10

ISO/CEN PARALLEL PROCESSING

This draft has been developed within the International Organization for Standardization (ISO), and processed under the **ISO lead** mode of collaboration as defined in the Vienna Agreement.

This draft is hereby submitted to the ISO member bodies and to the CEN member bodies for a parallel five month enquiry.

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Foreword

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ISO 18640-1 was prepared by Technical Committee ISO/TC 94, *Personal safety*, Subcommittee SC 14, *Firefighters PPE*.

ISO 18640 consists of the following parts, under the general title *Protective clothing for fire-fighters — Physiological impact*:

Part 1: Measurement of coupled heat and mass transfer with the sweating TORSO

Part 2: Determination of physiological heat load caused by protective clothing worn by fire-fighters

Introduction

The main functions of clothing are protection of health and maintenance of comfort for the wearer. Furthermore, protective clothing against heat and flame prevents the wearer from health or even life threatening heat stress even in extreme environmental conditions. Today's standards provide requirements for protective properties of protective clothing against heat and flame. However, the better the protective properties of such clothing, the less the heat originating from the human body is dissipated. Fire fighters reach metabolic rates above 500 W/m^2 during their work (Homér 2006, Homér and Gavhed 2007). Thereof 75-80% is released as heat (Gaesser and Brooks 1975), which has to be dissipated from the human body by thermo-regulative processes to avoid an increase in body core temperature. If heat dissipation is not restricted, the human body is able to maintain its temperature in the range of 36.5 – 37.5 °C (normothermia; Mahmood and Zweifler 2007). However, in harsh environmental conditions and/or restricted heat dissipation due to protective clothing the body suffers from heat stress. As a consequence, body core temperature rises. Above 37.5 °C, the human body becomes hyperthermic and working performance is reduced. The state can become even life threatening for any further increases in body core temperature.

To reduce the risk of heat stress during high intensity physical activities, protective clothing against heat and flame should additionally be assessed with regard to its impact on human thermoregulation and heat stress. The fatality statistics of the U.S. Department of Homeland Security (2012) shows the dramatic consequences of heat stress in combination with intensive physical work on the human body. In the year 2011, 50 fire fighters died as a result of stress or overexertion. These incidences represent 60 % of all fatalities in 2011 happened due to heart attacks (48 fire fighters), cerebrovascular accident or from heat exhaustion. Therefore, knowledge on thermo-physiological impact of protective clothing and efforts to reduce this impact helps to reduce the risk from suffering stress from overexertion.

Different approaches exist for the assessment of thermo-physiological impact. On the one hand, established standard parameters as water vapour resistance (R_{ET}) and thermal insulation (R_{CT}) of fabric samples are considered with regard to thermo-regulative impact. However, these parameters do not fully reflect the real impact of protective clothing as for example, moisture management properties and the combined effect of heat and mass transfer are not considered. On the other hand, human subject trials reveal real thermo-physiological responses for a specific environmental condition and protective clothing ensemble. However, the outcome of this methodology does not only refer to the intrinsic properties of fabric samples but takes into account the cut of the clothing and corresponding trapped air layers within the clothing as well. Furthermore, human subject trials are very time consuming and expensive, constricted by ethical guidelines and provide findings related to the collective of participants included. Thus, reproducibility between laboratories might be limited. The use of thermal manikins overcomes the limitations for human subject trials. As for human subject trials, full body manikins provide findings on ready-made protective garments including cut and fit. The attribution to intrinsic fabric properties remains difficult.

A methodology referring to intrinsic fabric properties and taking into account combined heat and mass transfer is the Sweating Torso (Zimmerli and Weder 1997,[3] Keiser et al. 2008[6]). Sweating Torso device is an upright standing heated cylinder, representing the surface of a human trunk, with the ability for perspiration (Annaheim et al.[5]). The protective fabric sample to be investigated is wrapped tightly around the sweating Torso. Three phases are run to assess dry thermal insulation, dry and wet heat transfer and drying properties. Findings from sweating Torso have been validated with standard methodologies, as sweating guarded hotplate, and were shown to be highly reproducible (Annaheim et al.[6]). Furthermore, validation studies have been conducted to relay sweating Torso findings on thermo-physiological responses for realistic environmental conditions and activities of fire fighters. Based on this knowledge, guidelines are provided for intrinsic textile properties based on thermo-physiological responses.

Protective clothing for fire-fighters- physiological impact —

Part 1:
Measurement of coupled heat and mass transfer with the sweating TORSO

1 Scope

This international standard provides the general principles of a test method for evaluating the physiological impact of complete garments or protective clothing ensembles in a series of simulated activities (phases) under defined ambient conditions. This test method characterizes the essential garment properties for thermo-physiological assessment:

— Dry thermal insulation

— Measures for cooling properties during average metabolic activity and moisture management

— Drying behaviour

This International Standard is intended to be used to measure and describe the behaviour of complete garments or protective clothing ensembles in response to a simulated series of activities under controlled laboratory conditions, with the results used to optimize garment combinations and designs. Furthermore, this International Standard is intended to be used to describe the thermo-physiological impact of protective clothing but not the risk for heat stress under actual fire conditions. The results of this test can be used as elements of a risk assessment with respect to heat stress or cardiovascular load.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6330, *Textiles — Domestic washing and drying procedures for textile testing*

ISO 11092, *Textiles — Physiological effects — Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test)*

ISO 139, *Textiles — Standard atmospheres for conditioning and testing*

ISO 3696, *Water for analytical laboratory use — Specification and test methods*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 CD: cooling delay

Time delay (and temperature rise) until the effect of evaporation cooling will be detected in a experimental phase with simulated activity (elevated heating power) and sweating.

3.2 Evaporated sweat water

Fraction of supplied sweat water which evaporated in active phase with sweating. Difference between supplied sweat water and weight difference of Torso (condensed moisture/stored sweat water).

3.3 Experimental phase

An experimental phase consists of defined sweat rate and surface temperature or heating power. An experiment can consist of multiple phases

Note: Each phase simulates a specific situation with defined temperature or heating power and sweat rate settings. A standard experiment consists of three phases.

3.4 IC: initial cooling

Time (and temperature) at which initial cooling ends in a experimental phase simulating activity with sweating.

3.5 Moisture uptake

Moisture stored in clothing system derived from weight course of Torso during an experiment.

3.6 PC: post cooling

End of post cooling period in an experimental phase without sweating and heating power corresponding to a human being at rest following a simulated activity. The evaporation of stored moisture will extract energy from the sweating Torso which can be detected in a decrease of the surface temperature.

3.7 Phase profile

Series of experimental phases which define the experiment.

3.8 SC: sustained cooling

Steady state of cooling in an experimental phase simulating activity with sweating.

3.9 Spacer

A device used to create air space between the Torso surface and a test specimen.

Note: Simulation of air layer in real use. Air layer influence the overall thermal resistance and moisture transport. A spacer may be used to simulate a defined air layer.

3.10 Sweat water

Supply of water used to simulate sweating. Distilled water (grade 2 ISO 3696) or purified water (grade 1 ISO 3696) shall be used.

Note Distilled or purified water shall be used to simulate sweating. Normal water will clog the supply tubes and will lead to build up of a bio film or the growth of algae. Type I water according to NCCLS (1988) proved to be efficient to avoid clogging of the supply tubes.

3.11 Thermal resistance (R_{ct})

Measure for thermal insulation in $m^2.K/W$. R_{ct} is calculated at steady state from the difference between Torso surface and ambient temperature, the surface area of the device and the heating power needed to maintain the temperature difference.

3.11.1 Correction factor for R_{ct} (R_{ct0})

Thermal resistance measurement without a sample on the sweating Torso to determine a system specific correction factor for the thermal resistance R_{ct}.

Note Thermal resistance as defined above depends on the geometry of the apparatus, wind (convective energy exchange and still air layer on surface) and ambient conditions. R_{ct0} is a cumulative measure of this and might differ slightly from device to device and installation to installation. By taking it into account differences in results from different installations can be reduced.

3.12 Torso balance

Device used to measure Torso weight.

3.12.1 Wind shield, cover

The balance to register Torso weight is delicate and wind will increase fluctuations in readings. A wind shield covering the balance and the lower part of the Torso ensures optimal accuracy.

3.13 Torso surface temperature

Average temperature on the surface of the measurement area of the Torso.

Note Temperature is assessed with a thin nickel wire applied to the surface or a similar method allowing measurement of the average surface temperature. There are two wires attached to the Torso surface which allows differentiation between the front and back side of the device (important for experiments with wind)

3.14 Torso weight,

The overall weight of the sweating Torso system (Torso device and test object) during a test

3.15 Total sweat water

Amount of water supplied to Torso surface during active phase with sweating; difference in sweat water tank weight.

3.16 Wind speed

Velocity of air flow on Torso surface in climatic chamber during experiment.

Note To avoid undefined boundary air layers due to random air exchange in the chamber and the temperature difference between Torso surface and climatic chamber a fan system is used. The fan system consists of ventilators to achieve a set wind speed on the Torso surface of 1 m/s (turbulent air flow adjusted with a hot-wire anemometer).

4 Symbols (and abbreviated terms)

R_{ct} Thermal resistance in $m^2 \bullet K/W$ assessed in steady state conditions (phase 1 of experiment)

R_{ct0} Correction factor for R_{ct} based on geometry, wind settings and climatic chamber (phase 1 of experiment)

CD Cooling delay (time in min until cooling effect of perspiration becomes apparent)

IC initial cooling (initial rate of surface temperature reduction in °C/h observable after CD

SC sustained cooling (rate of surface temperature change in °C/h (or min?) resulting from cooling effect of perspiration and wet insulation of the fabric)

PC End time (and temperature) of post cooling, phase 3 of the experiment

5 Apparatus

The sweating Torso is an upright standing cylindrical test apparatus, simulating the human trunk with thermal guards on the upper and lower end (see Figure 2). The apparatus is equipped with heating foils, sweating nozzles, a multi-layer shell (simulation of the skin layers) and electronics to control the valves and sensors.

The whole measurement system (see Figure 1) consists mainly of the sweating Torso (1) on a balance (2) positioned in a climatic chamber and the control system ((3) power supplies, controllers, and computer with data acquisition) placed outside the chamber including a sweat water tank on a second balance (4).

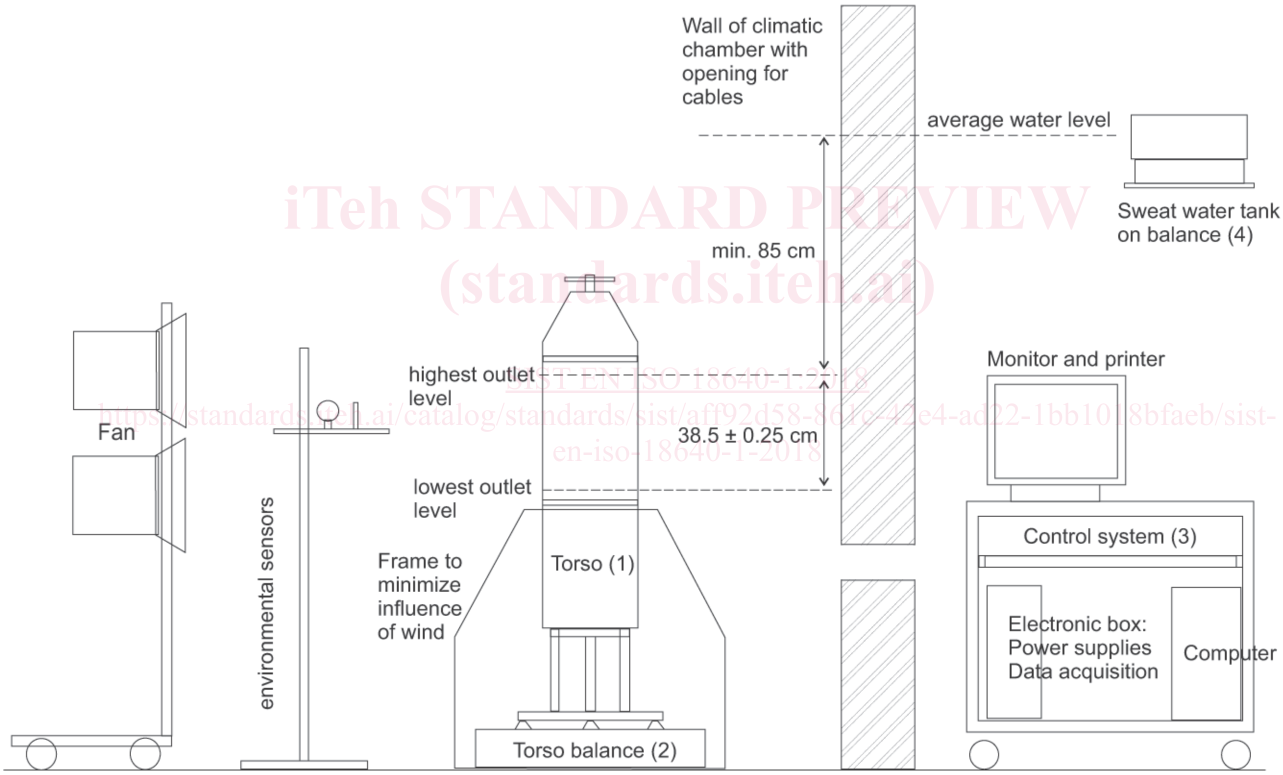

Figure 1 — Overview Torso system

5.1 Sweating Torso

The sweating Torso simulates the human trunk. The cylinder has an outer diameter of 30.0 ± 0.25 cm (circumference of approx. 94.25 cm) and a length of 46 ± 0.25 cm with an aluminium tube and heating foils inside. On the lower and upper end of the upright standing cylinder there are thermal guards with individually controlled heating. There are temperature sensors in the aluminium part (Pt-100 sensors or equivalent) for temperature control as well as on the surface of the measurement cylinder (Ni wires or equivalent).

The electronic components to control the valves for the 54 sweating nozzles are situated in the lower guard. Transducers converting the resistance values of the temperature sensors are also located here.

