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Možnosti novega merjenja toplotne izmenjave človeškega telesa: Umetni človek

Possible New Measurements of Heat Transfer of the Human Body: Artificial Person – Manikin

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Prispevek obravnava sodoben in nov prijem pri meritvah notranje mikroklima in natančno merjenje toplotne izmenjave z umetnim človekom.

Po eni strani se iz članka vidijo zasnova, natančnost in kompleksnost meritev na podlagi toplotne izmenjave človeškega telesa, po drugi pa sestava, uporaba in področja uporabnosti instrumenta, imenovanega umetni človek. Pokaže se, da presegajo njegova uporabnost zahteve gradbeništva in strojništva in pomaga pri ugotavljanju ljudem koristnih parametrov.

An advanced new approach to the measurement of indoor micro climate and accurate measurements of heat exchange by use of a thermal manikin are described.

The design, accuracy and complexity of measurements based on the heat exchange of the human body are given, as well as the structure, use and applications of the instrument called a thermal manikin. It follows that its applicability exceeds the requirements of the construction industry and mechanical engineering, and that it allows the establishment of parameters that are useful to people.

0. UVOD

Človek, ki se zadržuje na prostem ali v zaprtem prostoru, skuša poiskati taka mesta, ki so zanj toplotno objektivno in subjektivno najugodnejša. Če takih možnosti ni, si sam prizadeva ustvariti ugodnejše okolje. Prva možnost velja predvsem za bivanje na prostem, druga pa za zaprte prostore.

V inženirski praksi se srečujemo predvsem z nalogami druge vrste, npr. pri načrtovanju mikroklimatskih razmer v zaprtih prostorih. Vendar ne moremo povsem izvzeti nalog, ko je treba manjše površine na prostem preurediti tako, da postanejo človeku objektivno in subjektivno ugodne ali vsaj znosne.

Zaprti prostori imajo posebej pomembno vlogo za civiliziranega človeka, saj prebije v njih 70 do 80 odstotkov svojega življenja, v skrajnih primerih celo 90 do 95 odstotkov.

V zaprtem prostoru zaznava človek mnogo vplivov okolja: zvočni, optični in barvni, aromatski, temperaturni, higieniški in druge.

Po teh vplivih se izoblikuje človekovo subjektivno počutje. Najbolj znana in inženirska uporabna definicija tega pojma je Bedfordova: »*Ugodno počutje je subjektivni občutek, ki se v človeku izoblikuje na podlagi kompleksnih zunanjih vplivov*«.

Med najpomembnejše dejavnike človekovega počutja v zaprtem prostoru spada ugodno toplotno počutje [1]:

0. INTRODUCTION

Whether a human being is outdoors or indoors, he tries to locate places that are subjectively and objectively most agreeable, and if there is no such possibility, he tries to create a more comfortable environment. The first option mostly refers to outdoor conditions, and the second to indoor conditions.

In engineering practice, we deal predominantly with problems of the second kind for instance in the creating of indoor climatic conditions. We should not, however, neglect specific demands for the modification of smaller outdoor areas in order to create objectively and subjectively agreeable, or at least tolerable, conditions.

Indoor conditions are particularly important for civilised man, since he spends 70 to 80 %, sometimes even 90 to 95 %, of his time indoors.

Indoors man perceives several environmental influences: acoustic, optical and colour, odour, temperture, hygienic influences, and other.

The sum of these influences represents subjective human comfort. The best known, and from the engineering standpoint the most applicable, definition of this notion is Bedford's: »*Comfort is the subjective feeling formed in man under complex external influences*«.

Thermal comfort is among the most influential factors of human comfort indoors [1]:

»Ugodno toplotno počutje je stanje človekove zavesti, ki izraža zadovoljstvo s toplotnimi razmerami v okolju.«

Na človekovo toplotno počutje po Fangerjevih raziskavah [2] odločilno vpliva naslednjih šest dejavnikov:

- temperatura zraka, njena prostorska in časovna porazdelitev in spreminjaњe,
- srednja sevalna temperatura obdajajočih ploskev,
- relativna vlaga zraka,
- hitrost zraka,
- sproščanje in oddajanje toplote telesa,
- toplotna upornost obleke.

Upoštevajoč teh šest dejavnikov je Fanger izdelal novo meritno metodo, zasnovano na toplotnem ravnovesju človeškega telesa in okolice. Metoda pomeni temeljit preobrat pri meritvah in načrtovanju mikroklima zaprtih prostorov, saj so tradicionalni postopki upoštevali največ dva parametra (temperaturo zraka in toplotno sevanje). Spremenila sta se tudi zahtevnost meritev in nadzor meritnih razmer.

V nadaljevanju prikazujemo povsem novo mersko metodo: meritve na toplotnem umetnem človeku, možnosti in meje uporabnosti te metode in nekaj praktičnih zgledov, ki ponazarjajo novost, pomen in natančnost metode.

1. DEJAVNIKI LOKALNEGA NEUGODJA

V minulih letih se je pokazalo, da ugotavljamo tudi v prostorih, ki so načrtovani na podlagi izsledkov Fangerjevih raziskav, diskrette točke, kjer se ljudje slabo počutijo. Glede na to, da se neugodje pojavlja le na določenih mestih zaprtega prostora, govorimo o lokalnih dejavnikih neugodja. S tem razumemo tiste parametre, ki:

- se uveljavljajo samo v določenih točkah zaprtega prostora,
- ne delujejo na vse telo, ampak le na nekatere dele telesa.

Z vidika toplotne izmenjave telesa in subjektivnega toplotnega počutja sta pomembna dva lokalna dejavnika neugodja: nesimetrično sevanje in prepih.

1.1 Nesimetrično sevanje

Pod pojmom nesimetrično sevanje razumemo sevanje, ki se pojavi med deli človeškega telesa, kadar imajo različno temperaturo, ali pa med telom in stenami, če se po temperaturi razlikujejo. Tako utegnejo nekateri deli telesa prejemati, drugi pa oddajati toploto.

Iz tega splošnega izražanja je razvidno, da gre za vrsto vprašanj, ki vključujejo vse: od izmenjave toplote med različno ogretimi stenami, do rešitev ogrevanja s sevanjem. Izmed mnogih nalog s tega področja so nekateri posebni primeri natančno rešeni, pri drugih pa so narejeni začetki in nakazane poti k nadaljnemu razreševanju [3], [4].

»Thermal comfort is a state of human consciousness that expresses contentedness with the thermal conditions in the environment.«

According to Fanger's studies [2] thermal comfort is crucially affected by the following six factors:

- air temperature, its spatial and time distribution and variability,
- mean radiation temperature of surrounding surfaces,
- relative air humidity,
- air velocity,
- metabolic heat production of the human body,
- heat isolation of garments (clo value).

Considering these six factors, Fanger developed a new measuring method which is based on the heat balance of the human body and the environment. This method is a radical innovation in the measurement and design of an indoor climate because conventional procedures take into account two parameters at most, i.e. air and mean radiant temperature. In addition, the complexity of measurement and the control of measuring conditions were changed.

Below is presented a completely new measuring method: measurements on a thermal manikin. Included will be the limits of this method, some practical cases that illustrate the novelty, as well as the importance and the accuracy, of the method.

1. FACTORS OF LOCAL DISCOMFORT

In recent years, it has been established that even in rooms that have been planned on the basis of Fanger's findings, discrete locations can be found where people do not feel comfortable. Since discomfort occurs only at certain places (in rooms) we speak of local factors of discomfort, which implies parameters that

- prevail only in certain points (locations) indoors, and
- do not affect the entire body, but only some of its parts.

In relation to the heat exchange of the body and the subjective thermal comfort, two local factors of discomfort are important: asymmetric radiation, and draught.

1.1 Asymmetric radiation

By asymmetric radiation, we understand radiation that occurs between parts of the human body when these parts have different temperatures, or between the body and the walls if they differ in temperature. Thus, some parts of the body receive heat and others emit it.

From this general statement, it follows that we are concerned with a number of questions, ranging from heat exchange between differently heated walls to heating with radiators. Some particular problems resulting from these questions are precisely solved, while other solutions are only indicated [3], [4].

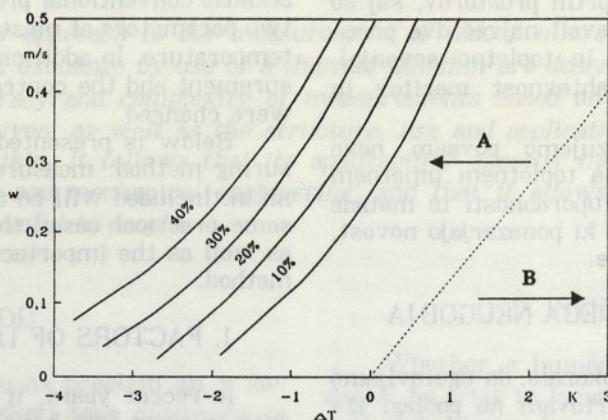
1.2 Vpliv prepiha

Lokalnega neugodnega počutja, ki ga povzroča prepih v zaprtem prostoru, ne gre podrobneje razlagati, saj ga pozna vsakdo iz lastnih izkušenj. Zato so se zgodaj pojavila prizadevanja, kako odpraviti prepih; rezultate ustreznih raziskav so zajeli v nekaj preprostih diagramih.

Novejša raziskovanja so usmerjena v dve vprašanji:

- Kateri deli človeškega telesa so posebno občutljivi za prepih?
- Ali in kako je občutek prepiha odvisen od narave zračnih tokov?

Na prvo vprašanje je odgovor znan: vrat in gleženj sta najbolj občutljiva na prepih (sl. 1, 2, [5]).

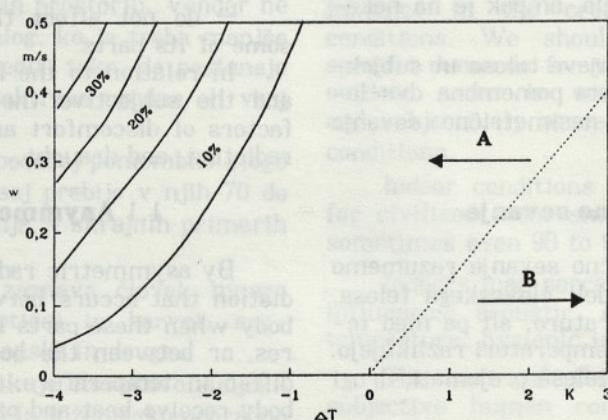


Sl. 1. Občutek prepiha na vratu v odvisnosti od hitrosti zraka in temperaturne razlike zraka (IHVE-Guide, London 1970).

A—občutek hлада, B—občutek toplotе

Fig. 1. The sensation of draft on the neck depending on the air velocity and the air temperature difference (IHVE-Guide, London 1970).

A—sensation of coolness B—sensation of warmth



Sl. 2. Občutek prepiha na gležnju v odvisnosti od hitrosti zraka in temperaturne razlike zraka (IHVE-Guide, London 1970).

A—občutek hлада, B—občutek toplotе

Fig. 2. The sensation of draft on the ankle depending on air velocity and air temperature difference (IHVE-Guide, London 1970).

A—sensation of coolness B—sensation of warmth

1.2 The influence of draught

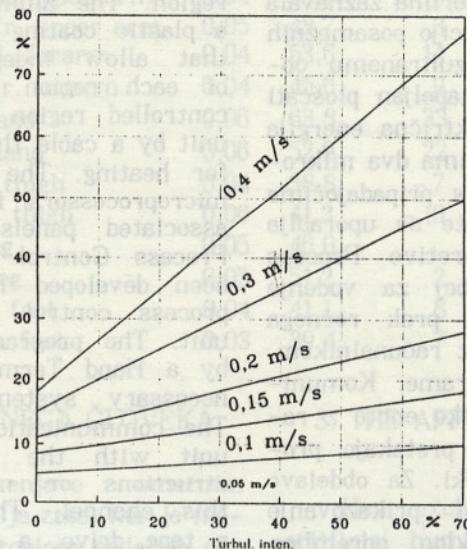
Local discomfort caused by indoor draughts need not be discussed in detail, since we all know it well from our own experience. Consequently, attempts to eliminate draught have long been made. Results of investigations have been given in some simple diagrams.

Recent research activities are focused on two questions:

- Which parts of the human body are particularly sensitive to draught?
- Does the sensation of draught depend on the nature of the air currents?

The answer to the first question is known: the neck and the ankle are most sensitive to draught (Fig. 1, 2, [5]).

V zvezi z drugim vprašanjem sta Fanger in Pedersen [6] pokazala, da so ljudje bolj občutljivi na turbulentne zračne tokove in sta o tem tudi uvedla merske veličine in izdelala diagrame. Slika 3 prikazuje, kako je odstotek nezadovoljnih odvisen od jakosti turbulence in srednje hitrosti zračnega toka, pri temperaturi 23°C , ki je sicer za toplotno počutje najugodnejša.



Sl. 3. Razmerje nezadovoljnih na podlagi modela v odvisnosti od turbulence in hitrosti zraka pri temperaturi 23°C .

Fig. 3. The degree of discomfort as a function of turbulence intensity and air velocity at 23°C .

Po tem uvodu si oglejmo, s katerimi nalogami se srečujemo, če bi hoteli po Fangerjevi metodi opraviti meritve, in kako jih lahko simuliramo na umetnem človeku.

2. UMETNI ČLOVEK

Umetni človek je pomemben in sodoben pripomoček pri merjenju in načrtovanju mikroklima v zaprtih prostorih. Uporabljam ga v najrazličnejše namene: poleg navedenega še za raziskavo toplotnih razmer v vozilih, za ocenjevanje izolacijske zmožnosti oblaci ali drugih tekstilnih izdelkov, npr. spalnih vreč.

Umetni človek druge generacije, imenovan ETI-MAN, je sestavljen iz merilnega telesa, iz dvoprocесorske upravljalске in pomnilne enote in iz računalnika, ki vodi merilni proces in obdeluje zbrane podatke.

Merilno telo je plastična lutka iz poliestra, ojačenega s steklenimi vlakni, oblikovana po merah povprečnega odraslega človeka. V notranjosti telesa so razmeščeni elementi, ki skrbijo za mehanično držo lutke, in cevi, po katerih so napeljani kabli v posamezne dele telesa. Iz toplotnih in mehanskih razlogov je notranjost izpolnjena s poliuretansko

In relation to the second question, Franger and Pederson [6] have shown that people are more sensitive to turbulent air currents. They also introduced units of measurement and produced diagrams. Figure 3 shows how the percentage of dissatisfied people depends on the intensity of the turbulence and on the air current velocity at 23°C , which is the most suitable temperature for thermal comfort.

Let us now see what problems arise if we perform measurements according to Fanger and how we simulate them on a thermal manikin.

2. THERMAL MANIKIN

A thermal manikin is a very important tool for measuring and planning an indoor micro climate. It is used for various purposes: in addition to the mentioned measurement and design of an indoor micro climate it is also used for the study of thermal conditions in vehicles, for assessing the insulation capacity of garments and other textile products, such as sleeping bags, etc.

We use a thermal manikin of the second generation, called ETI-MAN, which consists of a measuring body, a biprocessor control and memory unit, and a computer that controls the measuring process and processes the acquired data.

The measuring body is a plastic dummy made of polyester, reinforced with glass fibre. It is the size of an average grown-up man. The elements inside the body that are in charge of the mechanical posture of the dummy are connected to the parts of the body by cables. The dummy is filled with polyurethane foam for

peno. Površje telesa je v sedeči drži razdeljeno na 18, v stoječi drži pa na 16 območij. V vsakem območju je v lupino vdelana električna ogrevalna mreža, ki jo je mogoče elektronsko vklapljati ali odklapljati. Na površje lutke je napršena poprečno 0,4 mm debela plast aluminija, da se temperatura na območju enakomerno porazdeli. Plast aluminija je prekrita s plastjo plastike. Na njej so nalepljena uporovna merilna zaznavala za neodvisno temperaturno regulacijo posameznih področij. K vsakemu, ločeno reguliranemu območju je iz upravljaljske enote napeljan ploščati kabel, po katerem se dovaja električna energija za ogrevanje. Upravljaljska enota ima dva mikroprocesorja za vodenje procesov s pripadajočima paneloma. Za programiranje enote se uporablja programski jezik IPCL (Interpretative Process Control Language), razvit posebej za vodenje procesov. Programiramo ga ali prek ročnega terminala (Hand - Terminal) ali z računalnikom, če ima potrebne sistemski programe. Komunikacijski kabel povezuje upravljaljsko enoto z računalnikom. Po tem kanalu se pretakajo programska navodila oziroma izmerki. Za obdelavo podatkov, vodenje meritev in prikazovanje rezultatov skrbi računalniški sklop, opremljen s tračno enoto, dvojnim disketnim pogonom, matričnim 80-znakovnim pisalnikom in risalnikom.

Meritve potekajo tako, da na izbranem območju umetnega telesa vzdržujemo predpisano temperaturo in merimo električni tok, s tem pa tudi količino potrebne toplotne. Za zgled bomo navedli in pojasnili nekatere podatke iz preglednice 1:

- V stolpcu Del. t. so imena telesnih delov.
- Stolpec DT prikazuje odstopanja dejanske temperature od zaželene.
- Pod W/m^2 je gostota toplotnega toka.
- V stolpcu DW so pomožni podatki, koristni za korekcije meritev.
- Stolpec Clo vsebuje podatke o izolacijskih lastnostih obleke, ki loči del telesa od okolja. Uporablja se merska enota »Clo«. Vedeti je treba, da ima tudi pri golem telesu mejna plast zraka, ki se izoblikuje na površju, neko toplotno upornost in jo moramo zato vračunati v Clo obleke.
- V stolpcu EHT so zapisane trenutne temperature okolja, kakor jih občutijo posamezni deli telesa (pri tem štejeta k okolju obleka in tudi lasje).

Iz opisa je razvidno, da je z umetnim človekom druge generacije mogoče zelo natančno meriti, koliko toplotne oddaje telo na suhi način, tj. s sevanjem in konvekcijo.

mechanical and thermal reasons. The surface of the body is divided into 18 regions in a sitting posture and into 16 regions in a standing posture. An electric heating wire is installed on each region. It can be turned on and off electronically. The surface of the body is sprayed with aluminium, which results in a coating approximately 0.4 mm thick. It serves to distribute the temperature evenly over the region. The aluminium coating is covered by a plastic coating on which resistance sensors that allow independent temperature control of each region are placed. Each separately controlled region is connected to the control unit by a cable that supplies the electric power for heating. The control unit comprises two microprocessors for process control, and the associated panels. The IPCL (Interpretative Process Control Language) language that has been developed for the particular needs of process control is used to programme the unit. The programming is carried out either by a Hand Terminal or by computer, if the necessary systems programs are available. The communication cable connects the control unit with the computer. Programming instructions or measured values travel via this channel. The computer, equipped with a tape drive, a double diskette drive, and a matrix 80-character printer and plotter, is used for data processing, measurement control and the display of results.

The prescribed temperature is maintained in a chosen region and the electrical current is measured, and consequently the quantity of the necessary heat. As an illustrative example we shall give and comment some data from table 1:

- In column Del. t, the names of the parts of the body are given.
- In column DT, deviations of the actual temperature from the desired one are given.
- The density of the heat flow is given in column W/m^2 .
- In column DW, auxiliary data for the correction of measurements are given.
- Column Clo includes data about the insulating properties of garments that separate parts of the body from the environment. The measuring unit »Clo« is used. It should be noted that even the external layer of air formed on the surface of a naked body has a certain heat resistance which should be incorporated into the »Clo« of the garment.
- In column EHT, the actual temperatures of the environment, as felt by individual parts of the body, are given (the garment and the air are considered as the environment).
- It is evident from the above that the second generation artificial human body allows very accurate measurements of the heat output of the body by radiation and convection.

Preglednica 1: Izmerki na umetnem človeku.

Table 1: The results of measurements on the thermal manikin.

Del. t.	DT	W/m ²	DW	Clo	EHT (°C)
obraz/face	0,05	86,8	34	0,69	23,5
prsní koš/thorax	0,06	37,0	- 16	1,81	28,9
hrbet/back	0,05	43,0	- 15	1,55	28,7
l. nadlaket/l. upper arm	0,04	56,1	9	1,07	25,7
d. nadlaket/r. upper arm	0,05	48,7	3	1,24	26,4
l. podlaket/l. forearm	0,04	53,6	14	0,98	24,8
d. podlaket/r. forearm	0,04	45,6	9	1,18	25,7
l. roka/l. hand	0,06	63,8	33	0,74	23,1
d. roka/r. hand	0,06	52,9	22	0,90	24,5
l. stegno/l. thigh	0,04	38,8	- 7	1,55	27,7
d. stegno/r. thigh	0,06	41,3	- 10	1,46	28,0
l. noga/l. leg	0,05	46,0		1,17	26,7
d. noga/r. leg	0,05	51,2	2	1,05	26,5
l. stopalo/l. foot	0,04	41,1	8	1,15	25,9
d. stopalo/r. foot	0,03	39,4	7	1,20	26,1

3. O UPORABNOSTI UMETNEGA ČLOVEKA

Modeliranje toplotne izmenjave z umetnim človekom se vedno bolj uporablja zato, ker je mogoče natančno meriti, koliko toplotne oddajajo posamezni deli telesa. To pa je pomemben podatek za mnoga strokovna področja, npr. v industriji: vozil, tekstilnih izdelkov in gradbeništву.

S prvim se ne bomo ukvarjali, medtem ko je drugo področje že pomembno tudi za gradbeno industrijo, saj se izolacijske zmožnosti pojavljajo kot eden od parametrov 6-parametričnih merilnih metod [7], [8] v zaprtih prostorih.

V tekstilni industriji se umetni človek vse več uporablja zato, ker s tradicionalnimi postopki ni mogoče natančno meriti izolacijskih lastnosti obleke. Iz znanih vrednosti toplotne prevodnosti posameznih tkanin namreč ne moremo sklepati na prevodnost večplastne obleke, ker ne poznamo vplivov vmesnih zračnih plasti niti v stacionarnem primeru, ko človek miruje, še manj pa tedaj, ko je človek v gibanju ali, ko dela. Natančni podatki o tem pa niso pomembni le z vidika toplotnega ugodja, temveč mnogo bolj pri izdelavi delovnih oblačil s toplotno zaščito.

Pri meritvah toplotnih razmer v zaprtih prostorih, torej na področju gradbene industrije, upravičujejo uporabo umetnega človeka naslednji razlogi:

— Da bi v zaprtem prostoru našli toplotno ugodnejša ozira na najmanj ugodna mesta, je merjenje z umetnim človekom dosti cenejše in hitrejše od meritev na živih ljudeh. Meritve z umetnim človekom ne nadomeščajo, temveč dopolnjujejo meritve na živih ljudeh in skrajšujejo čas meritev.

3. THE APPLICABILITY OF THE THERMAL MANIKIN

Heat exchange modelling by means of the artificial human body is used more and more frequently because it allows accurate measurements of the heat emitted by individual parts of the body. This is important information for many fields, for instance in: the car industry, textile products, civil engineering and industry.

We shall not discuss the automobile industry, but textile products are also important for the civil industry, since the insulating properties occur as one of the six parameters of indoor measuring methods [7], [8].

The use of a thermal manikin in the textile industry is increasing because it is not possible to measure accurately the insulating properties of garments by conventional procedures, since the conductivity of multi-layer garments cannot be anticipated from the known heat conductivity values of individual textiles, because we do not know the influence of intermediate air layers in a stationary case (when we are still), and even less when we are at work or moving. Detailed data about this are not important only from the standpoint of thermal comfort, but even more for the manufacture of heat protective garments.

The use of a thermal manikin for the measurement of indoor thermal conditions, i.e. in the construction industry, is justified by the following reasons:

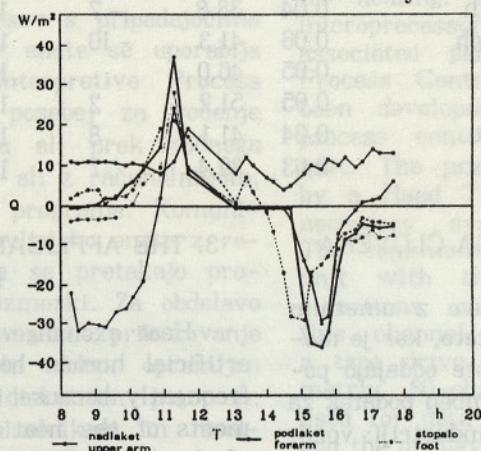
— It is less expensive to use a thermal manikin than to perform measurements on human beings to find the most or least convenient places ar regards indor thermal comfort,

— Včasih ne moremo ali ne smemo eksperimentirati z živimi ljudmi, npr. v zelo hladnem ali zelo vročem okolju, ki je nevarno za zdravje.

— Za odkrivanje lokalnih dejavnikov neugodja.

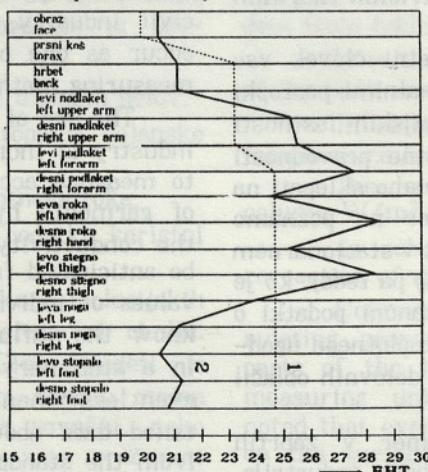
V zvezi z zadnjim primerom navajamo tri zgleda:

— Slika 4 prikazuje izmerke na zastekljeni verandi eksperimentalne solarne hiše, s katerimi je določeno asimetrično sevanje med desno in levo nogo oziroma desno in levo roko v odvisnosti od časa [9]. Slike se vidi, kako dobro in natančno je mogoče z umetnim človekom določiti vplive hladnega ali toplega zunanjega zidu ali okna na toplotno izmenjavo telesa.



Sl. 4. Razlika med oddano toploto desnih in levih delov telesa v primeru asimetričnega sevanja v odvisnosti od časa.

Fig. 4. The difference between the emitted heat of left and right parts of the body in case of time-dependent asymmetric radiation.



Sl. 5. Vrednosti temperature EHT umetnega človeka.

1 — Vrednost EHT pri sedežu v optimalnem zračnem toku, SF:2.3(SCANO 6/10)W/m² 48.4 ETH
(TOTAL) 23.8

2 — Vrednost EHT pri sedežu v neoptimalnem zračnem toku, REF/SF – IP DRAWN W/m² 48.4
ETH(TOTAL) 23.8

Fig. 5. Temperature values EHT of the thermal manikin.

1 — The value of EHT for a seat in an optimal air current, SF:2.3 (SCAN 6/10)W/m² 48.4 ETH
(TOTAL) 23.8

2 — The value of EHT for a seat in a non-optimal air current, REF/SF – IP DRAWN W/m² 48.4
ETH (TOTAL) 23.8

— Sometimes we cannot perform experiments on human beings, for instance in very hot or cold environments that are harmful to people,

— The detection of local factors of discomfort.

Three examples of the detection of local factors of discomfort are:

— Figure 4 gives the results of measurements on a glassed-in veranda of an experimental solar family house. These measurements determine the asymmetric time dependent radiation between the left and the right leg or arm [9]. It is clearly seen how well and how precisely the influence of cool or warm walls or windows on the heat exchange of the body is determined by the thermal manikin.

— Slika 5 prikazuje trenutne temperature okolja EHT (gl. razlago k pregl. 1), ki jih zaznava umetni človek na voznikovem sedežu avtobusa v oblačnem vremenu [10]. Pripomnili bi, da je avtobus zaprt prostor, katerega mikroklimo morata rešiti konstrukterja motorja oziroma karoserije. Z umetnim človekom je bilo mogoče raziskati vplive zračnih tokov na ugodno počutje voznika, upoštevajoč topotno izmenjavo telesa.

— Tretji zgled se nanaša na uporabo umetnega človeka na področju energetike:

* Budiaktova [11] je v laboratorijskem okolju raziskovala energetske razmere in ovrednotila topotno izmenjavo pri podnem ogrevanju;

* Banhidi in njegovi sodelavci so primerjali podno gretje, ogrevanje z zidnimi paneli, radiatorji oziroma ploščatimi grelniki glede na topotno izmenjavo človeškega telesa oziroma na asimetrično topotno sevanje [12].

— Figure 5 presents the current environmental temperatures EHT (see note to table 1) experienced by a thermal manikin on the bus driver's seat in cloudy weather [10]. It should be noted, however, that the bus is a closed place, the micro climate of which can be controlled by the designer. The thermal manikin could be used to investigate the influence of air currents on the driver's comfort considering the heat exchange of the body.

— The third example refers to the use of a thermal manikin in the field of energy:

* Budiaktova [11] studied energy conditions in a laboratory and evaluated the heat exchange in floor heating.

* Banhidi and coworkers compared floor heating, panel heating, radiators or plate heaters in relation to the heat exchange of the human body or asymmetric heat radiation, respectively [12].

4. LITERATURA

4. REFERENCES

- [1] ASHRAE Standard 55-66: Thermal Environmental Conditions for Human Occupancy. New York. 1966.
- [2] Fanger, P.O.: Thermal Comfort. Mc Graw Hill, 70.
- [3] McIntyre, D.A.: The Thermal Radiation Field. Buildings Science 9. 247-262, 1974.
- [4] Fanger, O.-Banhidi, L.-Olesen, B.-Langkilde, G.: Discomfort Caused by Overhead Radiation. CLIMA 2000. ETE kiadvány, Budapest, 1980.
- [5] IHVE Guide, London, 1970.
- [6] Fanger, P.O.-Pedersen, C.J.K.: Discomfort due to Air Velocities in Spaces. Proc. of the Meeting of Commission B1, B2, E1 of the IIR, Belgrade, 1977/ 4, p.p. 289-296.
- [7] ASHRAE Standard 55-81: Thermal Environmental Conditions for Human Occupancy. New York. 1981.
- [8] ISO 7730: Moderate Thermal Environments. International Standards Organization. Geneva, 1984.
- [9] Banhidi, L.-Fabo, L.-Juhasz, J.: Testing the Indoor Climate of Passive Solar Houses with the Thermal Manikin Technique. Plea '88. Energy and Buildings for temperate Climates. Pergamon Press, 1988.
- [10] Wyon, D.P. (1988) Thermal Manikin Evaluation of the Microclimate in the Driver's Seat of a City Bus in Summer. Paper to Journée Spécialisée »Comfort Thermique dans les Véhicules de Transport«. INREST, Lyon-Bron. May 19. 1988. (Re-analysis of data preparation of report, participation in meeting.)
- [11] Budiakne Marsal Maria: Padlofutesek energetikai ertekelese műmberes laboratoriumi meresék alapjan. Epületgepeszet XXXVIII. 1989/4, p.p. 152-156.
- [12] Banhidi, L.: Survey of Laboratories Investigation Aspects of Thermal Comfort. CIB Working Paper, Publ. 89. pp 1-34, 1985.

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