Faculty of Mechanical Engineering

Department of Environmental and Building Engineering

Impact of Ventilating and Asymmetrical Radiation on Human Beings in Hot Environment.

Ph.D. Thesis

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1. Introduction

In tropical countries such as Libya, there are two basic problems with thermal comfort.

a. High indoor temperatures in both traditional and modern buildings.

b. Unfavourable asymmetrical radiation of some of the external boundary walls
heated up by the fierce sunshine.

Aware of these two problems I became interested as an Msc student at the Budapest University of Technology and Economics (BME) in comfort theory whose topics include research projects such as these. I applied for the PhD topic announced by Dr. László Bánhidi, Professor Emeritus at BME and was accepted by the PhD school of BME in 2003 Until 2007, my topic leader was Dr. László Bánhidi and during that time I carried out in-situ measurements in Libya and laboratory measurements with manikins in the BME Laboratory.

In 2007 the situation changed at BME (a merger of departments) so in agreement with BME I applied and was accepted at the PhD School of Szent István University. My topic leader is Professor Dr. István Barótfi. I passed my PhD exams and finished my dissertation here.

During my PhD studies I participated at several recognized international conferences and gave ten speeches. The number of my publications (as shown by the references) complies with the requirements.

2. Antecedents to the Scientific Activity

In modern norms (CR 1752, ISO 7700) Fanger's heat balance and comfort theory provide the basis for thermal comfort dimensioning. This is based on the following:

a. human thermal comfort is influenced by 6 parameters: t_a, t_{mrt}, φ, v_r, I_{cl}, $M/_{FDu}$,

b. human subjective thermal comfort is adequate and optimal if the metabolic heat developed in the human body and the heat transmitted by the body are balanced

c. the heat balance equation was developed to be the basis of this theory

$$H - Ed - Esw - Ere - L = K = R + C$$

Substituting the factors with the equations the detailed heat balance equation is achieved.

$$\frac{M}{A_{Du}}(1-\eta)-0.35\left[43-0.061\frac{M}{A_{Du}}(1-\eta)-p_a\right]-0.42\left[\frac{M}{A_{Du}}(1-\eta)-50\right]-0.0023\frac{M}{A_{Du}}(44-p_a)-$$

$$0.0014\frac{M}{A_{Du}}(34-t_a)=3.4\times10^{-8}f_{cl}\left[(t_{cl}+273)^4-(t_{mrt}+273)^4\right]+f_{cl}h_c(t_{cl}-t_a)$$

$$t_{cl}=35.7-0.032\frac{M}{A_{Du}}(1-\eta)-$$

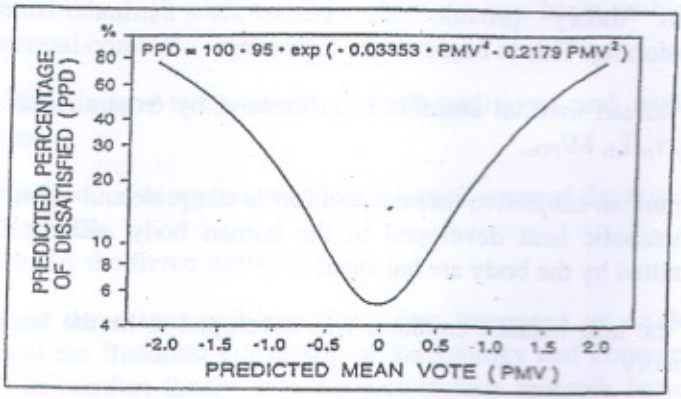
$$0.181_{cl}\frac{M}{A_{Du}}(1-\eta)-0.35\left[43-0.061\frac{M}{A_{Du}}(1-\eta)-p_a\right]-0.42\left[\frac{M}{A_{Du}}(1-\eta)-50\right]-0.0023\frac{M}{A_{Du}}$$

$$(44-p_a)-0.0014\frac{M}{A_{Du}}(34-t_a)=3.4\times10^{-8}f_{cl}\left[(t_{cl}+273)^4-(t_{mrt}+273)^4\right]+f_{cl}h_c(t_{cl}-t_a)$$

d) to define the subjective thermal sensation the PMV-PPD theory was developed where

- PMV - Predicted Mean Vote,
- PPD - Predicted Percentage of Dissatisfied,

The result of this theory is the PMV-PPD index.

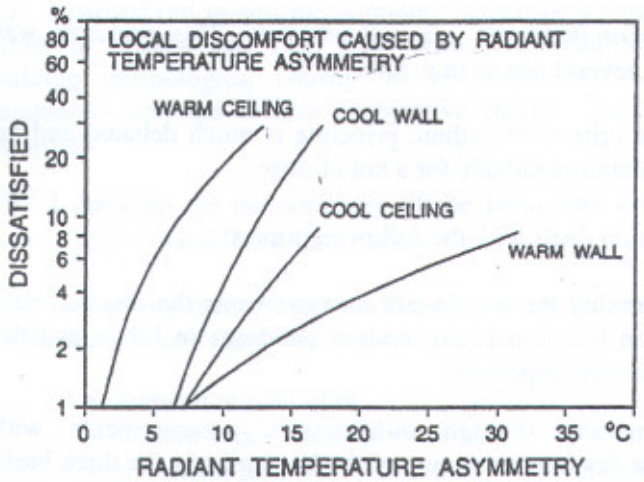


One of the key points of this index is the fact that it is impossible to ensure a thermal environment where everyone is satisfied, 5% of people either find the theoretically optimal parameters too high or too low.

e. Finally, another basic statement of the theory is that parameters determined by the comfort theory apply to everyone irrespective of age, gender or ethnicity.
This statement was later modified therefore the equation (and the derived comfort diagrams) only apply to people living in a temperate climate and does not cover people living in topical climates.

f. The topic of my paper is the impact of asymmetrical radiation.

CR 1752 contains one dimensioning diagram.



This diagram was developed for four cases:

- warm walls,
- warm ceiling,
- cold walls,
- cold ceiling.

The adequacy of these diagrams is highly doubted and there is ongoing research at several research institutes to work out more accurate data.

g. Finally, more and more attention is paid to the investigation of combined impacts when two local discomfort factors e.g. asymmetrical radiation and air flow have a joint impact.

3. Objectives of the Research

According to Fanger's theory (thermal balance equations, comfort diagrams, PMV – PPD) the thermal sensation of humans is

independent of their age, sex and ethnicity. This principle was recorded by several norms (e.g. CR1752).

Out of these criteria the ethnic principle is much debated and no convincing data is available for a hot climate.

My dissertation deals with the following topics:

3.1. Determining through in-situ measurements the microclimate parameters in traditional and modern buildings in Libya and the related subjective responses.

3.2. Determining through in-laboratory measurements with manikins the dry heat exchange of the human body for three basic cases in the given microclimate parameters:

- in ambient temperatures,
- if there is one external warm wall,
- if air inflow is used to set off the impact of the external warm wall.

3.3. For some combinations of parameters the subjective thermal sensation of asymmetrical radiation was also checked through measurements with live subjects from hot environment.

4. Methods Used in the Scientific Project

My activities during the scientific project can be summarized as follows.

4.1. In-depth analysis of the international and Hungarian literature.

4.2. I worked out the measurement methodology for the Libyan locations.

4.3. I carried out in-situ measurement series for several weeks in Libya in houses and flats built with traditional and modern building technologies. During the measurements the physical parameters and the tenants' subjective thermal sensation were recorded.

4.4. I drew up the methodology of the laboratory measurement series using a manikin for three cases:

4.5. Laboratory measurements were carried out for several weeks for the three above mentioned cases:

- ambient temperature,
- if there is one external warm wall,
- if vertical air inflow is used to set off the impact of the external warm wall.

4.6. Laboratory measurements were carried out with live subjects to check the impact of the given asymmetrical radiation.

4.7. I wrote a PhD dissertation about the results, presenting the new scientific findings.

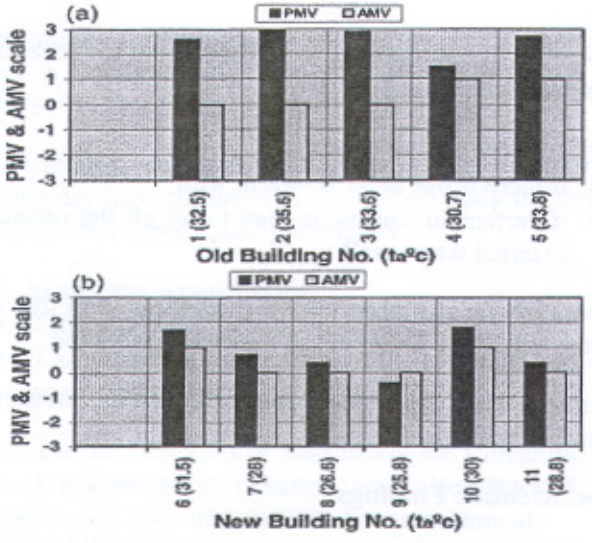
5. New Scientific Findings

5.1. I carried out in-situ measurements in 51 buildings and 237 subjects. Using their results I determined the internal physical parameters of traditional Libyan buildings and the occupants' subjective thermal sensation. These data will provide an important starting point for:

- the increasingly extensive modernization of traditional buildings (e.g. local cooling, energy use) in terms of the relevant designing parameters,

- the impact of physical parameters influencing the anticipated subjective thermal sensation of users and occupants.

5.2. Through the measurements I conducted in Libya I proved that the PMV method did not give us the appropriate values – instead AMV should be defined .



5.3. I compared the data recorded in the previous section with the data of people using Libyan apartments and houses built with a modern technology and equipped with local cooling. This is the first time such quantitative and subjective comparison has been made in Libya, considerably facilitating the work of planners.

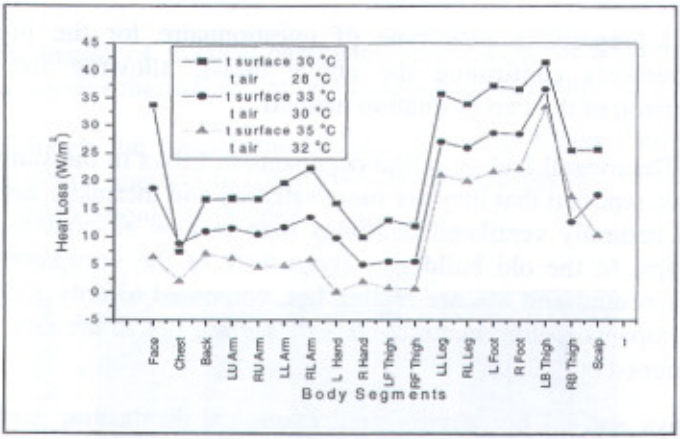
All these promote the definition of minimal thermal comfort parameters in Libya.

5.4. I prepared a new type of questionnaire for the in-situ measurements confirming the above thesis, allowing for the comparison of the two evaluation method.

5.5. The overall feeling of the occupants in Libya in the summer seasons, reported that they are more satisfied and thermally neutral in old naturally ventilated buildings than in new air-conditioned buildings. In the old buildings, about 54% of the occupants are feeling neutral and 8% are feeling hot, compared to only 15% of the occupants feeling neutral and 33% feeling hot in the new air-conditioned buildings.

In Libya and all hot environment countries, the heating and air conditioning systems, in case they exist, are not used continuously. Thus, the indoor temperature is fluctuating. The thermal sensation of the building occupants is the only controller of the ventilation, the heating or the cooling of the building.
Unlike the conventional thermal regulations, which are based on energy consumption, the special feature of the future Libya thermal regulation is related to the fact that it must ensure a minimum level of thermal comfort when the building is free running without any heating or cooling system.

5.6. By laboratory measurements were used to investigate the impact of the most frequent discomfort factor (asymmetrical radiation of warm walls) with a thermal manikin. I determined the temperatures of the various body parts, their heat intake and heat transmission in static air in office spaces where there is a combination of 26, 28 and 30°C air temperatures and a warm wall of 33° and 35C.

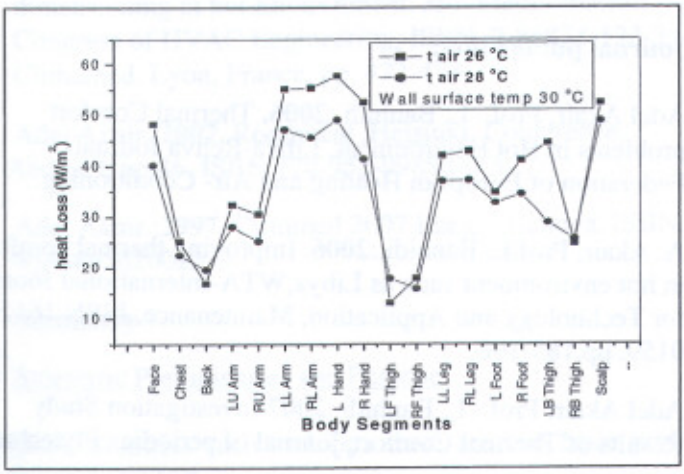


Heat loss with difference surface temperature and air room temperature without ventilation

5.7. Using the poor subjective values obtained during the in-situ measurements and the laboratory data I investigated the heat transmission values for the various body parts in a vertical air flow.

Height level measuring	max air speed velocity	Med air speed velocity	min air speed velocity
	Air room temperature = 28 °C		
Inlet velocity	0.4	0.8	0.04
1.5 m velocity	0.08	0.08	0.1
0.5 m velocity	0.02	0.05	0.07
	Air room temperature = 26 °C		
Inlet velocity	0.6	0.6	0.3
1.5 m velocity	0.1	0.1	0.1
0.5 m velocity	0.04	0.05	0.02

Air velocity with difference air speed and height levels for 30 °C surface temperatures and 28 and 26 air room temperature



Heat loss with difference air room temperature and ventilation

5.8. I compared the experiments conducted at the Singapore University with manikins and live subjects to the findings of measurements I carried out in the measuring room of TUB. I chose this solution because at TUB it was not possible to study subjects adapted to a hot climate.

I found that the air inflow was a better solution in terms of the heat transmission of the human body (in particular the head and the upper part of the body) if there is asymmetrical radiation near a warm wall.

The results of the measurements I conducted for various air temperatures and warm walls can be well compared with the Singaporean findings and are complementary.

6. Published papers:

6.1. Journal publication:

1. Adel Akair, Prof. L. Banhidi.:**2006.** Thermal Comfort problems in Hot Environment, Libya-Rehva Journal-Federation of European Heating and Air- Conditioning.

2. A. Akair, Prof.L. Banhidi.:**2006.** Improving thermal comfort in hot environment such as Libya,WTA-International Journal for Technology and Application, Maintenance, ISSN 1612-0159. pp.185-196.

3. Adel Akair, Prof. L. Banhidi.:**2007**.Investigation Study Results of Thermal Comfort, journal of periodica Plytechnica

4. S-R.A. Adel – E.Stevensné- Szádday – R. Goda.:**2005.** Possibility to into account the joint impact of draught and asymmetrical radiation, In Dimensioning thermal comfort in a hot environment.Instalatii pentru constructii, confortul ambiental, proceeding pp. 204-211.

5. A. Akair, L. Banhidi.:**2006.**3rd Mediterranean Congress of HVAC Engineering, ISBN. 2-86834-123-3. Climamed, Lyon, France, pp. 525-531.

5. S-R.A. Adel – E.Stevensné Szádday – R. Goda.:**2005.** Comfort impact of solar radiation in closed spaces. Proceeding pp. 89-91.

6. A. Akair, Prof. L. Banhidi.:**2006**. Asymmetrical Radiation problems in Hot Environment, Healthy Buildings , proceeding, ISBN 978-989- 95067-1-8, pp.177-180.

7. A. Akair, ILona Frohner.:**2006.** Comfort range as a mean of dimensioning in hot Environment. 3rd Mediterranean Congress of HVAC Engineering, ISBN. 2-86834-123-3. Climamed. Lyon, France, pp. 473-478.

9. Adel Akair.:**2007.** Roomvent ,Helsinki Conference, Abstract, pp 86, ISBN 978-952-99898-0-5

8. Adel Akair.:**2997.** Climmed 2007.Enegy, Genova, ISBN, 9788895620022.

7. Summary

7.1 Scientific Preliminaries and Purpose

In tropical countries such as Libya there are two basic problems with thermal comfort.

- High indoor temperature in both traditional and modern buildings.
- Unfavorable asymmetrical radiation of some of the external boundary walls heated up by the fierce sunshine.

My dissertation with the following topics:

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- If air inflow is used to set off the impact of the external warm wall.

3. For some combinations of parameters the subjective thermal sensation of asymmetrical radiation was also checked through measurements with manikin and live subjects.

7.2. Applied Methods

My activities during the scientific project can be summarized as follows.

1. In-depth analysis of the international and Hungarian literature.

2. I worked out the measurement metrology for the Libya locations.

3. I carried out in-situ measurement series for several weeks in Libya in houses and flats built with traditional and modern building technologies. During the measurements the physical parameters and the tenants' subjective thermal sensation were recorded.

4. I drew up the methodology of the laboratory measurements series using a mankin for three cases:

   - Ambient temperature,
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   - If vertical air inflow is used to set off the impact of the external warm wall.

5. Laboratory measurements were carried out for several weeks for the three above mentioned cases.

6. Laboratory measurements were carried out with live subjects to check the impact of the given asymmetrical radiation.

7. I wrote a PhD dissertation about the results, presenting the new scientific findings.

7.3. New Scientific Results

The PMV model in the form of CR 1552 and ISO 7730 can not be used, without modifications, for predicting the overall thermal comfort of the occupants in old naturally ventilated buildings. However, the ISO 7730 standard can be used to measure human thermal comfort in new air-conditioned buildings without modifications.

The overall feeling of the occupants in Libya in the summer seasons, reported that they are more satisfied and thermally neutral in old naturally ventilated buildings than in new air-conditioned buildings. In the old buildings, about 54% of the occupants are feeling neutral and 8% are feeling hot, compared to only 15% of the occupants feeling neutral and 33% feeling hot in the new air-conditioned buildings.

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