



HAL
open science

MEASURING AIR TEMPERATURE IN PROXIMITY TO THE HUMAN BODY

Françoise Thellier, Françoise Monchoux, Sabine Piniec

► **To cite this version:**

Françoise Thellier, Françoise Monchoux, Sabine Piniec. MEASURING AIR TEMPERATURE IN PROXIMITY TO THE HUMAN BODY. Moving Thermal Comfort Standards into the 21st Century, Apr 2001, Cumberland Lodge, Windsor „, United Kingdom. hal-02175347

HAL Id: hal-02175347

<https://hal.science/hal-02175347>

Submitted on 5 Jul 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

MEASURING AIR TEMPERATURE IN CLOSE PROXIMITY TO THE HUMAN BODY

Françoise THELLIER, Françoise MONCHOUX, Sabine PINIEC

L.E.S.E.T.H – Laboratoire Etude des Systèmes et de l'Environnement Thermique de l'Homme
Université Paul Sabatier, 118, route de Narbonne, 31062 TOULOUSE Cedex 4 - FRANCE
thellier@sphinx.ups-tlse.fr

ABSTRACT

To analyse and improve a human being's local thermal comfort through simulation and/or experiments, a good description of the thermal environment is needed. Many local physical data are indispensable to calculate body heat exchanged during transient conditions in a non-homogeneous environment. Special problems appeared for air temperature near the body, it has to be measured very close to the surface, but the person needs to move, so the probes have to be fixed on him.

The ISO recommends protecting the probe against radiation by a low-emissivity protective screen and increasing air velocity so the probe's temperature is close to that of the air. In our case, air velocity cannot be increased because it will then changed convective and evaporative exchanges on the skin surface itself. These problems appear when extremely non-homogeneous thermal conditions, e.g. in cars, are studied.

The purpose of this paper is to show that when the air is cold and surfaces are hot, the air temperature measured close to the body is overestimated.

Experiments were performed to understand the influence of the protective screen. A regulated plate was used to represent the skin. It was equipped with different types of probes and a variety of thermal conditions were created. The temperature of the probe was strongly influenced by the screen, which was warmed up partly by radiation coming from the environmental surfaces and partly by conduction. There were also problems with the aerodynamic flow in and around the screen.

In this communication we try to quantify the phenomenon of heat transfer and separate the different modes. The discussion may lead to other recommendations about how to measure air temperature close to surfaces that have temperatures different from that of the air.

Keywords : Air temperature measurements Thermocouples Heat balance

1. INTRODUCTION

To analyse the effects of a given thermal environment on a human being's thermal comfort, we have for many years been using a multi-node human thermoregulation model [Thellier 1994, Stolwijk 1970] which needs a precise description of the surroundings [Leduc 2001]. Local heat balances of each body segment are calculated from the local heat exchanged on skin surfaces i.e. all physical thermal parameters are needed: temperatures of the surrounding surfaces, air temperatures, humidities and velocities. These data have to be known as close as possible to the human's surface

(skin or clothing). They can come from environmental models or be measured during experiments.

We encountered special problems in cars where the environment is highly heterogeneous and the space is enclosed. For example during summer, surfaces are very hot (40 to 60°C), the air blown by the air conditioner is quite cold (5 to 15°C) and the skin is at about 33°C. To measure air temperature close to the body in this situation, we used probes composed of a thermocouple protected against radiation by a low emissivity protection as recommended by International Standards [ISO 1985]. It seemed that this measuring method was very sensitive to the temperature of the surrounding surfaces and also to air flow around the probe. In our case, we wanted to measure air temperature, but the thermocouple indicated only its own temperature, i.e. the result of the heat balance of the thermocouple junction itself. We performed laboratory experiments to evaluate the measuring errors and to analyse the influence of the protective screen when surface temperatures were very different from that of the air. To understand the heat balance of the probes we have also developed models to quantify each component [Pinić 1999].

2. MATERIAL AND METHOD

The experimental device was designed to represent the real measuring conditions, used during experiments in cars. This measuring method had been used for years by the experimental teams we worked with.

▪ Probes for air temperature measurements

The probes were those generally used during experiments with a human body. They were composed of a thermocouple, type-K (Chromel /Alumel) isolated with Teflon, fixed in a protective radiative screen made of aluminium. The screen was cylindrical (1.5 cm high, 1.5 cm in diameter). The “foot” was also made of aluminium and was used to rigidify the probe and to fix it on to the surface (*figure 1*).

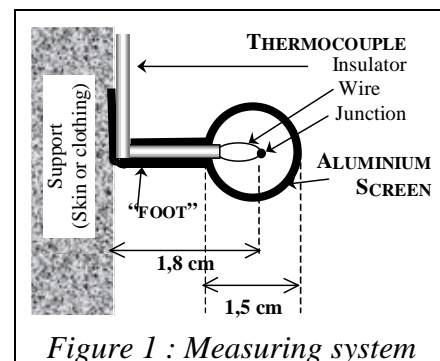


Figure 1 : Measuring system

▪ Experimental system

The system was placed in a regulated room. It was composed of the following elements (*figure 2*) :

- A regulated flat heat exchanger representing the skin. The regulation was provided by temperature-controlled water flowing through the plate. The flow rate was sufficient to enable the water temperature to be varied from 5 to 25°C in 5 min. Strong transients could thus be represented.
- 1 thermocouple fixed on to the surface of the plate to measure its temperature.
- 6 thermocouples embedded in the plate, under its surface, to be sure that it was isothermal. The differences observed over the plate were close to the measurement accuracy of $\pm 0.1^\circ\text{C}$, even during strong transients.

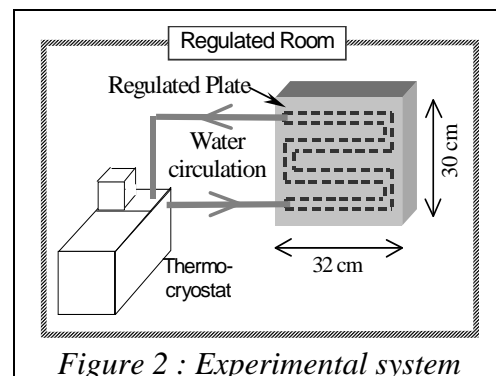


Figure 2 : Experimental system

▪ Temperature measurements

Measurements were made by different types of probes (*Table 1*). Two wire diameters were used, thin - 0.1mm - and thick - 0.2mm. The junction diameter was about five to six times the wire thickness.

- 2 thermocouples (n°7 & 7') were far from the plate to measure the reference air temperature T_{∞} ,
- 5 probes were fixed on the plate, at the same distance (1.8 cm), around its centre to be sure that they were in the same thermal conditions. Some of the protective cylindrical screens were vertical (n°8), others were horizontal (n°9 and 9'), and one of the probes did not have a screen (n°10)
- 2 other probes were fixed on a plastic tube and maintained at the same distance from the plate.

*Table 1: Recapitulation of all probes
(X' same position as the X, but for different wire thicknesses)*

n°	Wire	Sup	characteristics	measured
7	thick	Far	1 m from plate	Refer $T_7 = T_{\infty}$
7'	thin	Far	1 m from plate	Air $T_{7'}$
8	thin	Plate	Vertic. cylinder	Air T_8
9	thin	Plate	Horiz. cylinder	Air T_9
9'	thick	Plate	Horiz. cylinder	Air $T_{9'}$
10	thin	Plate	No screen	Air T_{10}
10'	thick	Plate	No screen	Air $T_{10'}$
11	thin	Plate	No screen	Plate surface T_{11}
12	thin	Tube	Horiz. cylinder	Air T_{12}
13	thin	Tube	No screen	Air T_{13}

We consider that the real air temperature was T_{∞} and the measured one was $T_{mes(x)}$. Our aim was to analyse the measuring errors $Er_{(x)}=(T_{mes(x)}-T_{\infty})$ as a function of the temperature difference between air temperature (T_{∞}) and plate temperature (T_{plate}). We therefore needed to vary $\Delta T=(T_{plate}-T_{\infty})$.

Throughout the experiments, the set point of the air conditioner regulator was fixed to 20°C, as the room capacitance was high. To vary ΔT , we varied the plate temperature (T_{plate}). Data were recorded every 2 s. Twenty thermal conditions were studied: ΔT positive or negative, varying or not, and with or without the air-conditioning. We present the results of only one of the experiments, but the conclusions that are drawn are based on all of them.

3. RESULTS

First, we used Real Time Holographic Interferometry to check that all the junctions were outside the plate's boundary layer. Figure 3 shows an example of an interferometer picture for steady state conditions at $\Delta T=15^\circ\text{C}$. This measuring system has the advantages of not disturbing the observed phenomenon. The optical index of air is related to its temperature. So it is quite easy to go from the interference fringes to the temperature (the iso-colour represents the iso-index and thus the isotherms). The ambient temperature (T_∞) is reached at about 1 cm from the plate. On the figure, it is obvious that the probes n° 8, 9 and 10 are outside the natural convective boundary layer.

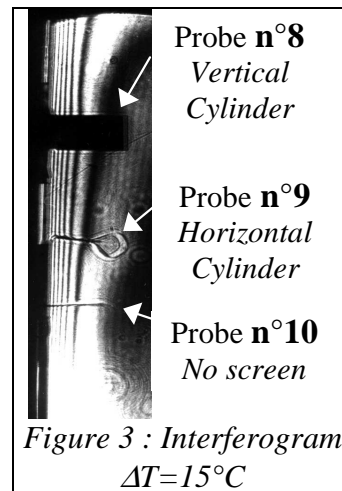
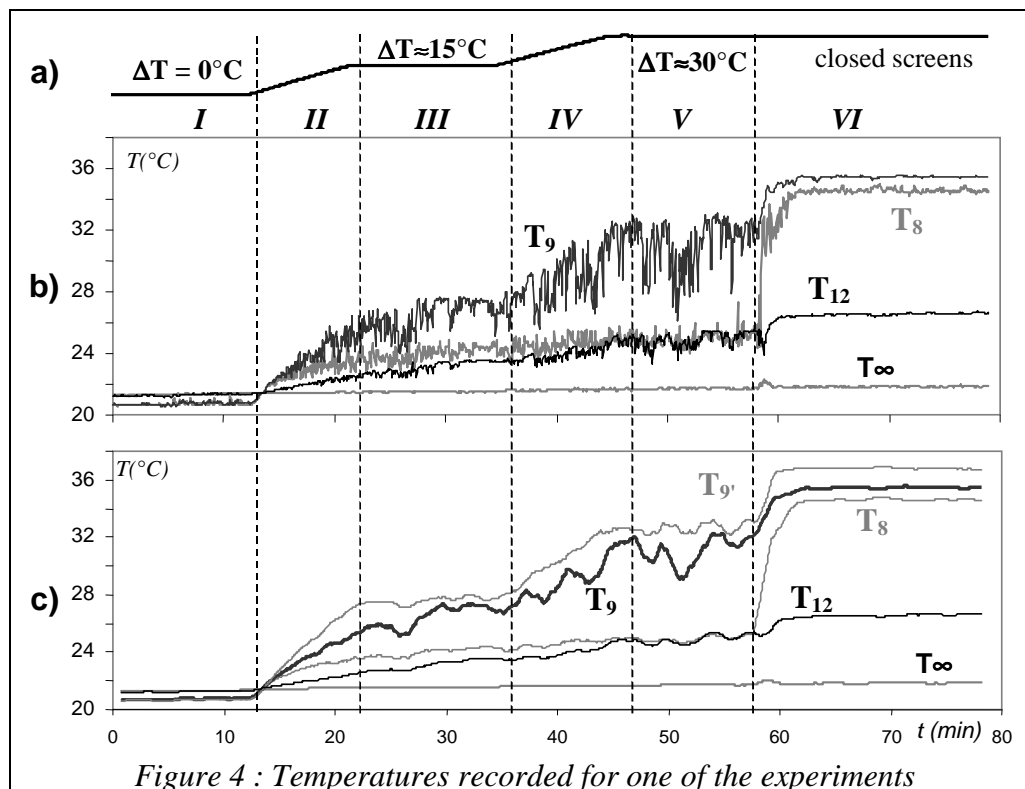


Figure 4 gives an example of the results obtained for one of the conditions. The air conditioning system had to be stopped because it disturbed the general airflow in the room. Thus the room temperature rose slowly by about 1°C during the exposure.

The monitored conditions are shown in figure 4.a. This test was composed of six phases: during phases II and IV the plate temperature rose, and during the other phases it stayed stable at different ΔT (0, 15, 30 $^\circ\text{C}$). During the last phase, monitored conditions were stable but the screens were closed.

The temperatures recorded by some of the probes are shown in figure 4.b. When $\Delta T=0^\circ\text{C}$, all the thermocouples give nearly the same temperature as the reference one T_∞ . Then when ΔT increases, two features become noticeable which are very dependent on ΔT and on the type of probe :

- a large difference between measured and reference temperatures
- oscillations with different amplitudes and frequencies,



The oscillation frequency is not related to the acquisition frequency; one acquisition point does not correspond to one fluctuation. For example, during 12 s. there are 5 acquisition points and the recorded temperature increases continuously by almost 2°C. We can also confirm that it is not an electronic or electrical problem as the frequency of the oscillations is different. We performed a Fourier analysis, in which no characteristic frequency appeared. One question was whether these oscillations were related to the time constant, it seems that the thickest thermocouples showed the fewest oscillations.

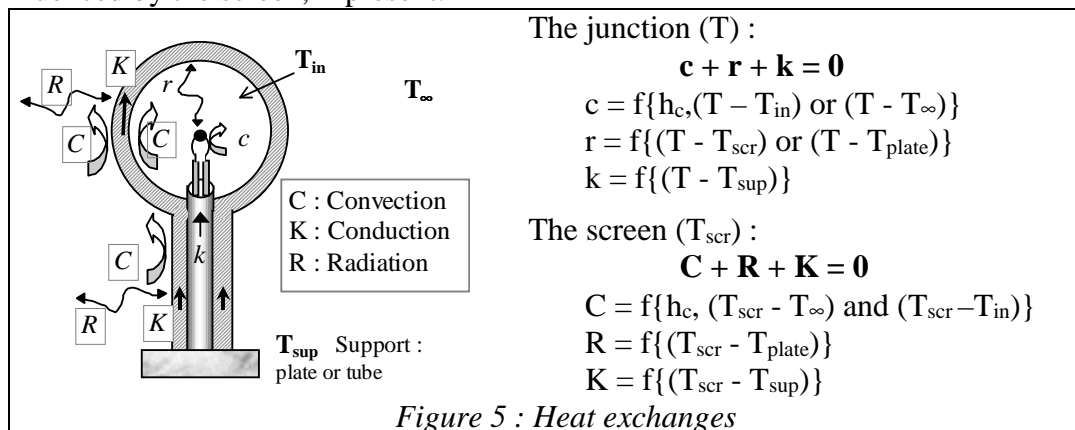
The recorded data were difficult to analyse because two phenomena were superimposed, the fluctuations were strong and masked the temperature differences. We therefore decided to smooth the curves in simple manner. Several tests were carried out so as to sufficiently smooth the curves without losing too much information. Each value was then replaced by the mean of the 15 surrounding ones. The result of the smoothed curves is plotted in figure 4.c. For each probe, the average temperature was calculated on the last 10 minutes of the phases where ΔT remained constant. Table 2 gives a summary of the errors, $Er_{(x)}$, for the various ΔT .

Table 2 : Recapitulation of the Errors for each probe (°C)

Phase	ΔT	T_{plate}	T_{∞}	$Er_{(x)} = T_{mes(x)} - T_{\infty}$						
				10	10'	13	8	9	9'	12
III	13.3	34.9	21.6	1.6	1.6	1.3	2.4	4.8	6.0	1.5
V	28.3	50.0	21.7	2.6	2.8	2.3	3.2	9.3	10.9	3.1
VI	28.0	49.9	21.9	-	-	-	12.7	13.6	14.9	4.7

4. DISCUSSION

Errors increase with ΔT and are more significant when the probes are fixed on the plate. The temperature measured is that of the junction and is of course influenced by the plate's temperature, through different modes of heat transfer. If we look at very simplified thermal heat balances of the thermocouple junction and of the protective screen, in steady state (figure 5), it is obvious that the junction temperature is influenced by the screen, if present.



Aluminium has a low emissivity (polished; $\epsilon=0.04$) but a high thermal conductivity (200 W/m.K). When the screen is fixed on the warm plate, conductive transfer (K) is induced through the base to the screen. The cylindrical part of the screen is also warmed up by radiation (R) even if it does not touch the plate. Convective exchanges (C and c) depend on air temperature, thus T_{∞} on the outside of the screen, but in the inside of the cylinders they depend on T_{in} , which seems to be very different from T_{∞}

in some configurations because the airflow inside depends on the general airflow in the room. This airflow also has an effect on the convective coefficient h_c .

The junction temperature will be close to T_∞ if conduction (k) and radiation (r) are low. In an ideal system, we should have $T_{scr}=T_\infty$. In fact we do not get this, because radiation (R) and conduction (K) are high when the screen is close or even fixed to the plate. By comparing the different probe configurations, we can have an idea of each phenomenon and try to separate them.

4.1 Conduction in the wires

The conduction in the wires (c) can be estimated. For the thermocouples without a screen, n°10 (on plate) and n°13 (on tube), we observe that $T_{10}-T_{13} = 0.3^\circ\text{C}$ for $\Delta T \approx 28^\circ\text{C}$, which is about the measuring accuracy. This difference is a little higher for the thicker wires $T_{10}-T_{13}=0.5^\circ\text{C}$. In this case the conduction in the wires between the plate and the junction is weak compared to other exchanges.

For the probes with the screen fixed on the plate, n°9 (thin) and 9' (thick), a difference of up to 2°C appears between the two probes. In this case the conduction in the wires itself is greater over a smaller length.

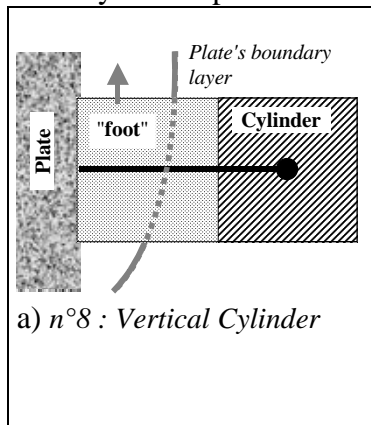
4.2 Radiation

For probe n°13, the tube is in thermal equilibrium with environment ($T_{sup} \approx T_\infty$) and, consequently, conduction (c) is nearly zero. $Er_{(13)} = 2.3^\circ\text{C}$ for $\Delta T \approx 28^\circ\text{C}$ and this is due only to the radiation (r) between the junction and the plate.

If we compare probes n°13 and n°12, both on the tube, the warmer is n°12, for which the screen is heated by radiation and then radiates on to the junction. Radiative exchanges (r) seem to be more larger with the screen in place even if its emissivity is low. The comparison between the thermocouples with horizontal screens, n°12 (on tube) and n°9 (on plate), reveals differences that are more significant. For n°12, the screen is fixed on the tube and therefore heated only by radiation, unlike n°9 that obviously has a very hot screen because of conduction. But other effects have to be taken into account as n°8 and n°9 are very different.

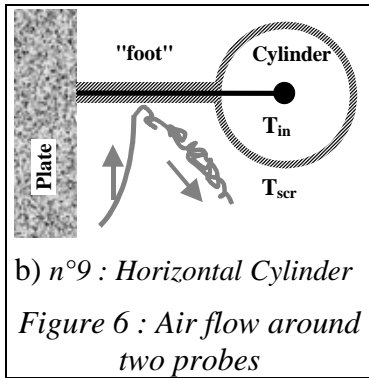
4.2 Convection : Air flow in the screens

4.2.1 Orientation of the cylinders. The presence of a screen fixed on the wall increases the measuring errors. Whatever the orientation of the screen, we can consider that radiative and conductive contributions are almost the same, but convection seems to be very different. If we compare n°8 (vertical screen) and n°9 (horizontal screen), their temperature differences can only be explained by a different air flow inside the cylinder, which depends on its orientation. This confirms that it is an aerodynamics problem.



If we look (*figure 6.a*) at probe n°8 (vertical screen) the “foot” of the screen is in the direction of the vertical ascending airflow of the plate's convective boundary layer. The air temperature around the junction is close to the reference one ($T_{in} \approx T_\infty$). The error is up to $Er_{(8)}=3^\circ\text{C}$.

In the case of probe n°9, the horizontal cylindrical screen and its support are obstacles to the convective airflow along the plate (*figure 6.b*). It is difficult to know what occurs; the airflow becomes three-dimensional. Inside the cylinder, the air



seems to stagnate then to escape by "puffs". When the general airflow is stable, the air seems to remain a "long" time in the cylinder and warms up; the air temperature in the screen T_{in} tends towards T_{scr} . In this case the error can reach $E_{r(9)}=10^{\circ}\text{C}$. When the general flow is turbulent, the puffs are more frequent, the oscillations and the errors are of the same order as for probe n°8.

4.2.2 Closing the screens. The oscillations of the measured temperatures seem to be due to perturbation of the airflow around the junctions. To check this point, we sealed the extremities of the screens with an adhesive in order to be sure of the immobility of the air in the vicinity of the junctions (figure 4, phase VI).

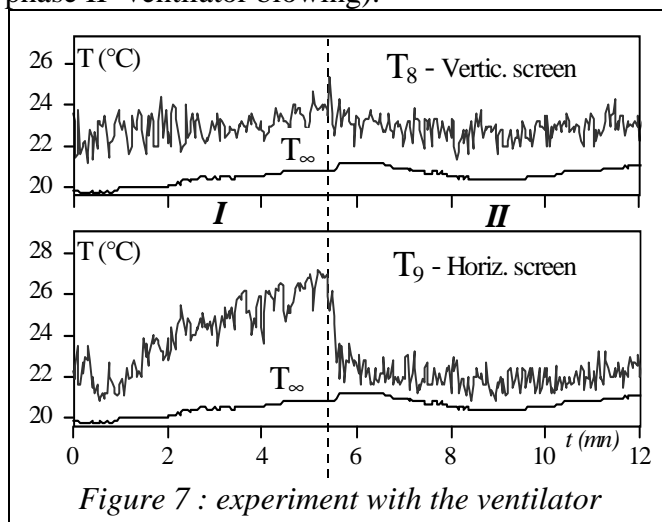
As soon as the screens were sealed, it took a few minutes to reach a new equilibrium, and then the fluctuations disappeared completely. The thermocouples on the plate (n° 8 and 9) gave nearly the same temperatures, which were much higher than for open screens. The junctions were in a small, closed enclosure where the air was confined and was probably at the screen temperature, which was quite warm because of conduction. It seems that for $\Delta T=28^{\circ}\text{C}$ the screens on the plate were at least at 35°C . This effect is highlighted if we compare this result to the one for probe n°12, for which the measured temperature is 26.6°C , and the screen is heated only by radiation.

It can thus be deduced that the screens in contact with the wall are heated mainly by conduction but also partly by radiation. In a very simplified way, if the overestimation of the measured temperature by probe n°12 is due to radiative warming, we can then conclude that the $E_{r(9)}$ is due to conduction in the screen for around 70 % and to radiation for 30 %.

4.2.3 Forced convection. In order to determine the effect of the general airflow, tests were carried out with a ventilator placed perpendicular to the plate at a distance of 1 m.. Air velocities near the plate were quite high for all blowing powers between 0.3 and 1.2 m/s, which corresponds to forced convection. Figure 7 presents the results: phase I - no ventilator, phase II -ventilator blowing).

For probe n°8, the vertical screen was cooled by the air blown horizontally, but hardly any reduction was observed in the error.

The effect was more significant for probe n°9 whose screen was horizontal and parallel to the forced airflow. When the ventilator was blowing, the error was lower, the air temperature inside the screen T_{in} was close to T_{∞} and thus the measured temperature approached T_{∞} .

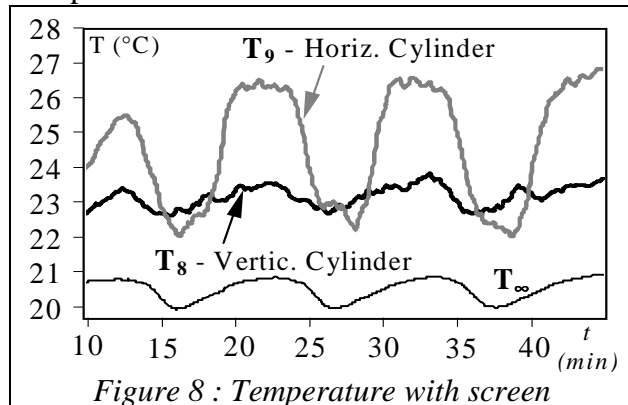


We also noticed, for each thermocouple, a slight attenuation of the amplitude of the fluctuations but the frequencies seemed higher. When the ventilator blowing power was changed, no significant changes were observed.

In forced convection conditions, the radiative transfers were still present but they were no longer predominant, and the screen temperature was close to T_∞ as convection was enhanced. The influence of the radiative screen on the soldering was less significant than in natural convection.

4.2.4 Unknown convective air flow; effect of the air conditioning. It appears that the air conditioner played a very important role on the airflow around the dummy. The air temperature in the room varied by $\pm 0.5^\circ\text{C}$ around the set point temperature of 20°C because of the regulation system, the period being about 12 min. Because of lack of space in the experimental room, the dummy was quite close to the air-conditioning system, which was fixed on the ceiling and blew air horizontally. The ventilator ran continuously. We used a hot wire thermo-anemometer to measure air temperature and velocity in the room. The air velocity was 2.8 m/s at the outlet, 0.5 m/s at 1 m, and lower than 0.1 m/s around the dummy (0.1m/s: lower measuring limit). Figure 8 presents the result of the smoothed temperature curves, showing that there was an amplification of the room temperature variations.

When the refrigerating unit started, i.e. when $T_\infty \geq 21.3^\circ\text{C}$, the output temperature quickly went from 20°C to 15°C . This cold air conferred a significant downward component which modified the natural convective airflow near the dummy. This perturbation lasted a few minutes after the refrigeration stopped.



When the refrigerating unit started, the fluctuation amplitude increased but the error decreased; it seems that the airflow was mixed convection. When it stopped, fluctuations were attenuated and the error increase, the general airflow became more stable, returning to only natural convection.

5. MODELLING

While performing the experiments, we began to develop models to quantify heat exchanges on the junction and the protective screen in the different configurations. When the screen was fixed to the plate its temperature was very close to that of the plate, even when the emissivity was low (if $T_{\text{plate}}=50^\circ\text{C}$ and $T_\infty=20^\circ\text{C}$, $T_{\text{scr}}=49.5^\circ\text{C}$ for $\epsilon=0.3$ and 49.8°C for $\epsilon=1$). However, radiative exchanges on the junction were 5 times as great for $\epsilon=1$ than for low emissivity.

A major problem arises; we do not know the values of the convective coefficients h_c or the air temperature T_{in} inside the screen. Those two parameters have a very important effect on the equilibrium temperature of the screen and thus on radiation on the junction. (for example: $T_{\text{scr}}=49.5^\circ\text{C}$ for a low h_c but about 35°C if h_c is ten times higher [Moffat 1988]). T_{in} and h_c are difficult to quantify because they depend on the airflow that we are having difficulty identifying. Is it laminar or turbulent, with

natural or forced convection ? We have not yet found the answers but we intend to use a C.F.D. code to analyse what could happen in the screens.

6. APPLICATION : correction of the temperature measurements

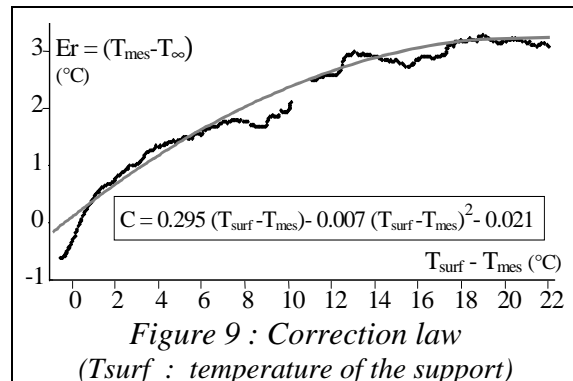
Let us return to the initial problem, i.e. the measurement of local air temperatures needed to calculate convective heat exchanges for the human model. The most significant location is at head level as this temperature is also used to calculate thermal judgements [Piniec 1997]. During experiments in a real car in a wind tunnel, the probe at head level was directly fixed on to the skin surface of the forehead, which was quite warm.

Precise values of these air temperatures are needed and we are now sure that measurement errors should be corrected. The original question was to estimate these errors but, as we have seen, it is at present impossible to obtain a correction law based on physical equations. So we decided to extract an empirical correction law from the experimental results obtained on the plate.

The experiments described previously show that the most penalising configuration is the one with the horizontal screen (probe n°9) in natural convective airflow. In this configuration the error can reach 10°C for $\Delta T=30^\circ\text{C}$. Such ΔT can exist in a car. We chose not to base our results on probe n°9 for the following reasons:

- the air velocity in the vehicle is never very low.
- the face is not a flat plate and the flow in the vicinity is surely not so stable; just breathing may modify the airflow.

The correction is based on probe n°8. To obtain the "real temperature" a correction is made to the measured value. $T_{\text{real}}=T_{\text{mes}} - C$ (figure 9). Using this expression, the experimental air temperatures were modified. We now use the corrected experimental data to calculate heat exchanges with our human thermo-regulation model.



7. CONCLUSION

The experimental device that has been set up allows us to point out two things that are superimposed: fluctuations and differences between the reference temperature and measured temperature. In all the thermal conditions studied, we conclude that, for all types of probes, there are a thermal and an aerodynamic problem that are strongly coupled.

The “protective screen” is a source of measurement error. The thermocouples protected by a screen in contact with the hot plate have their screen heated by conduction but also by radiation. Their junction is then heated by conduction through the wire but also by radiation from the hot screen. It has to be underlined that in this case the error is smaller for a thermocouple not protected by a screen and not in contact with the surface, the lowest error being made by probe type n°13.

The measurements are influenced by many parameters related to the type of probe: diameter of the wires, thus conduction in the wires, temperature of the support, presence of a radiative screen, its emissivity and its orientation relative to the

principal air flow.

The experiments carried out and analysed allowed us to qualify the error made on the air temperatures and thus to evaluate a correction law to determine the “real temperature”. This law could be improved by the analysis of other experiments. Errors cannot be avoided, but we hope to quantify each heat transfer, to get an analytical correction law. The major problem is the airflow. There can be different cases :

- Forced convection, high air velocities, then oscillations and errors are low.
- Natural convection, airflow is very stable, oscillations are present but small, and errors depend on the orientation of the screen, the best position being vertical to favour natural convection in the screen.
- Mixed convection, air flow is perturbed, then oscillations are very large and error impossible to determine clearly, especially when the screen is horizontal.

Finally, in our configurations, it seems that protecting the thermocouples from the radiation by a screen as recommended by ISO 7726 is a source of error when the screen is in contact with a support that has a temperature different from T_{∞} . A forced flow will minimise the error but even if this technique is recommended, it cannot be used close the human body.

Many factors can be at the origin of measurement errors. Metrology needs to be studied before starting the experiments. If measuring errors cannot be avoided, they have to be quantified to make a correction to the measured data possible. Thermal comfort will be difficult to estimate if the physical parameters are known with a poor accuracy.

REFERENCES

ISO 7726 International Standards, 1985. Thermal environments. Instruments and methods for measuring physical quantities. NF-EN 27726. ISSN 0335-3931.

LEDUC G., MONCHOUX F., THELLIER F., 2000. Analysis of human's radiative exchange in a complex enclosure. International Conference. Moving comfort standards into the 21st century, Windsor, UK, April 2001.

MOFFAT. R.J., 1988. Experimental methods in heat transfer. Experimental heat Transfer, Fluid Mechanics and Thermodynamics. Eds Elsevier Sciences Publishing Co, pp.13-31.

PINIEC S., 1999. Thermique de l'homme dans une voiture. Modélisation et expérimentation. Analyse de la métrologie. PhD. Dissertation (French), Toulouse n°3453, 176 p.

PINIEC S. , THELLIER F., DUVEAU H., DEFFIEUX J.C., 1997, MA.THER: Model of local thermal sensations of a car driver. Proceedings A.T.A. Congress, pp. 109-117, n° SAE 97A3014, Bologna, Italy, October 1997.

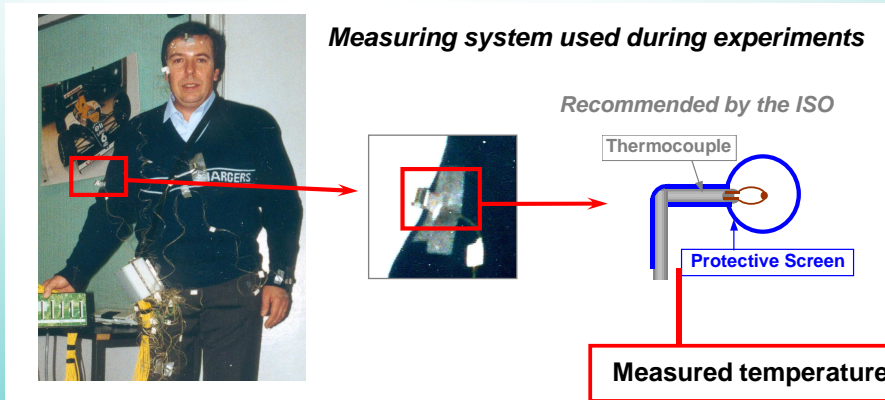
THELLIER F., CORDIER A., MONCHOUX F., 1994. The analysis of comfort requirements through the simulation of an occupied building. Ergonomics, Vol.37, n°5, pp. 817-825. Eds. Taylor & Francis Ltd.

STOLWIJK J.A.J., 1970. Mathematical Model of thermoregulation. Physical and Behavioural Regulation. Eds J.D. Hardy, A.P. Gagge. Thomas Springfield Publishing. Chap. 48, pp.703-721.

MEASURING AIR TEMPERATURE IN CLOSE PROXIMITY TO THE HUMAN BODY

Françoise THELLIER, Françoise MONCHOUX, Sabine PINIEC

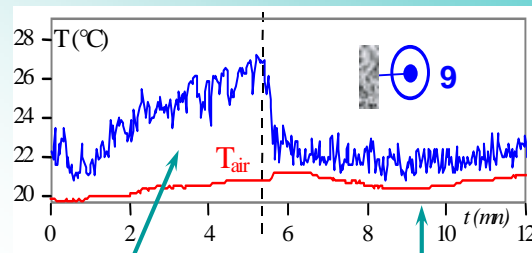
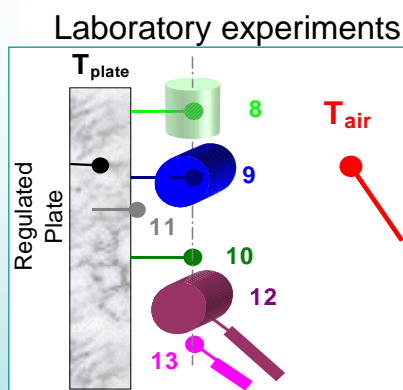
L.E.S.E.T.H - Laboratoire Etude des Systèmes et de l'Environnement Thermique de l'Homme
 Université Paul Sabatier, 118, route de Narbonne, 31062 Toulouse Cedex 4 - France



OBJECTIVES

- ↓ Estimate the measuring errors of the experimental recorded temperatures
- ↓ Analyse the influence of the protective radiative screen

Results & Main Conclusions



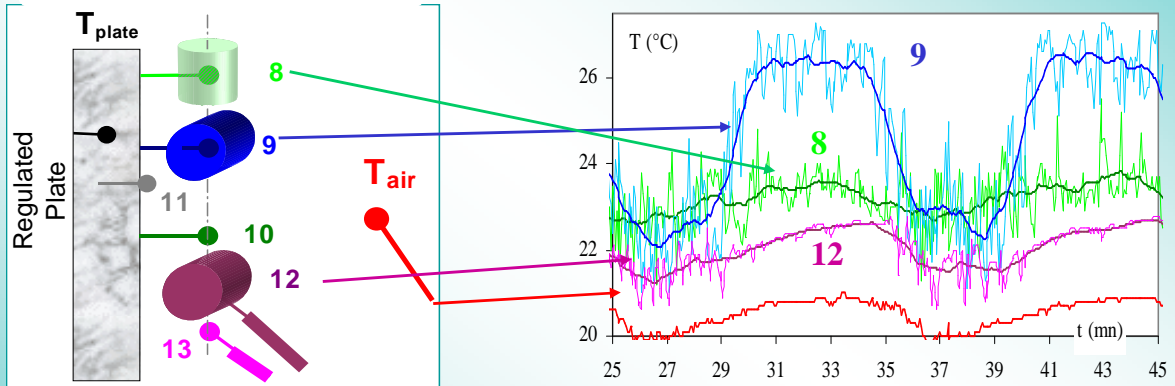
Natural convection
 T_{air} strongly overestimated

Forced convection
 With a ventilator
 lower error
 Impossible to use near to the human body

CONCLUSIONS

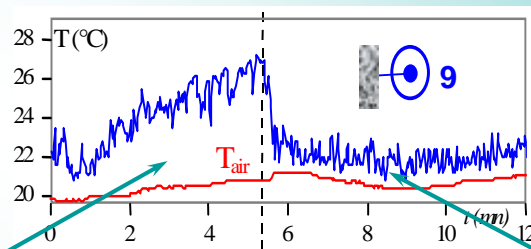
- If the airflow is not known \Rightarrow it is better not to use a screen
- The screen modifies the air flow around the junction
 \Rightarrow If a screen is used the best position is vertical
- Measuring errors cannot be avoided
 \Rightarrow they have to be determined to have the best accuracy on T_{air}

Laboratory experiments



- ⇒ Strong oscillations
- ⇒ Measuring errors depend on a lot of phenomenon

MAIN CONCLUSIONS



Natural convection
 T_{air} strongly overestimated

Forced convection
With a ventilator
lower error
Impossible to use near to the human body

CONCLUSIONS

- If the airflow is not known ⇒ it is better not to use a screen
- The screen modifies the air flow around the junction
⇒ If a screen is used the best position is vertical
- Measuring errors cannot be avoided
⇒ they have to be determined to have the best accuracy on T_{air}