AIR MOVEMENT & VENTILATION CONTROL WITHIN BUILDINGS

12th AIVC Conference, Ottawa, Canada
24-27 September, 1991

POSTER 52

USING THERMOFOIL HEATERS FOR THE EXPERIMENTAL DETERMINATION OF THE AIR FLOW PATTERNS IN A ROOM.

G. Cannistraro*, C. Giaconia*, G. Rizzo#

* Dipartimento di Energetica ed Applicazioni di Fisica, Università di Palermo, Viale delle Scienze, 90128 Palermo, Italy.

\# Istituto di Ingegneria Civile ed Energetica, Facoltà di Ingegneria, Università di Reggio Calabria, Italy.

USING THERMOFOIL HEATERS FOR THE EXPERIMENTAL DETERMINATION OF THE AIR FLOW PATTERNS IN A ROOM

Synopsis

A new simple method is here proposed for the experimental singling out of the air flow patterns in a room. It is based on the use of a series of thermofoil probes, arranged in a lattice, that can be suspended at the ceiling of the room under test.

1. Guidelines

Relative air velocity is notoriously a fundamental parameter when analyzing thermal comfort conditions inside confined environments. It is necessary for the computation of convective heat exchanges from the human body to the surroundings as well as the value of the clothing temperature. Recently researchers have found a strong dependence of the thermal conditions from the draughts induced by the turbulence of the air flowing in a room.
Usually, precise air flow measurements are performed using hot wires anemometers that, as it is well known, are high precision, high cost instruments. Moreover the stochastic characteristics of the involved physical phenomena, makes a very high instantaneous precision a less significant effort. Starting from these considerations a new simple technique is here proposed.
It is based on the use of a series of rows of thermofoil heaters, suspended at the ceiling of the room. Each probe is easily built-up by means of some inexpensive Pt-100 thermal ribbons: it should enable the evaluation of both air velocity and direction. The thermal behaviour of the probes has been tested in a little wind tunnel facility in the aim of establishing suitable relationships between the air direction and velocity in the nearby space of the probe and its heat losses. As a matter of fact, our measurements concern the electrical resistance of the probe using the four-wire method.
Through the paper some preliminary measures are presented, especially regarding the relationships between the air velocity and the temperature difference between the opposite layers of the probe, in parallel flow. Moreover, the influence of varying the incidence angle, at constant air velocity, has been also investigated.

2. Experimental facilities description

Figure 1 depicts the structure of the probe here used, along with the electrical connections. It contains four low-cost, non-matched PT-100 thermal ribbons. Each of them represents a thermofoil, that is a thin, flexible heating element, with its surface homogeneously heated. The real advantage of this feature is that two out four thermofoils can be used at the same time as a heater element and temperature sensor, when they are driven by a constant current, slightly higher than this one normally employed in the standard measurements.
This current, determining an increase in the foil surface temperature, produces also an easily measurable temperature difference between the heated elements and the elements subjected to the standard current value.
By means of the measure of this temperature, when a well known air flow is superimposed, it is possible to establish a relationship between the above cited temperature difference and the relative air velocity. The air flow can be, of course, produced by means of a suitable fan or simply generated by the natural convection movement existing in the room.
The peculiar arrangement of the probe, as illustrated in the section A-A of Figure 1, creates a strong thermal asymmetry due to the small insulation layers applied on the opposite sides of the probe in correspondence of the heated elements.
This allows the probe to have a different behaviour with respect to the air flow direction.
In order to increase the measuring precision, all the elements (heated or not), even belonging to different probes, should be connected in series, within the voltage supply capability of the current generator.

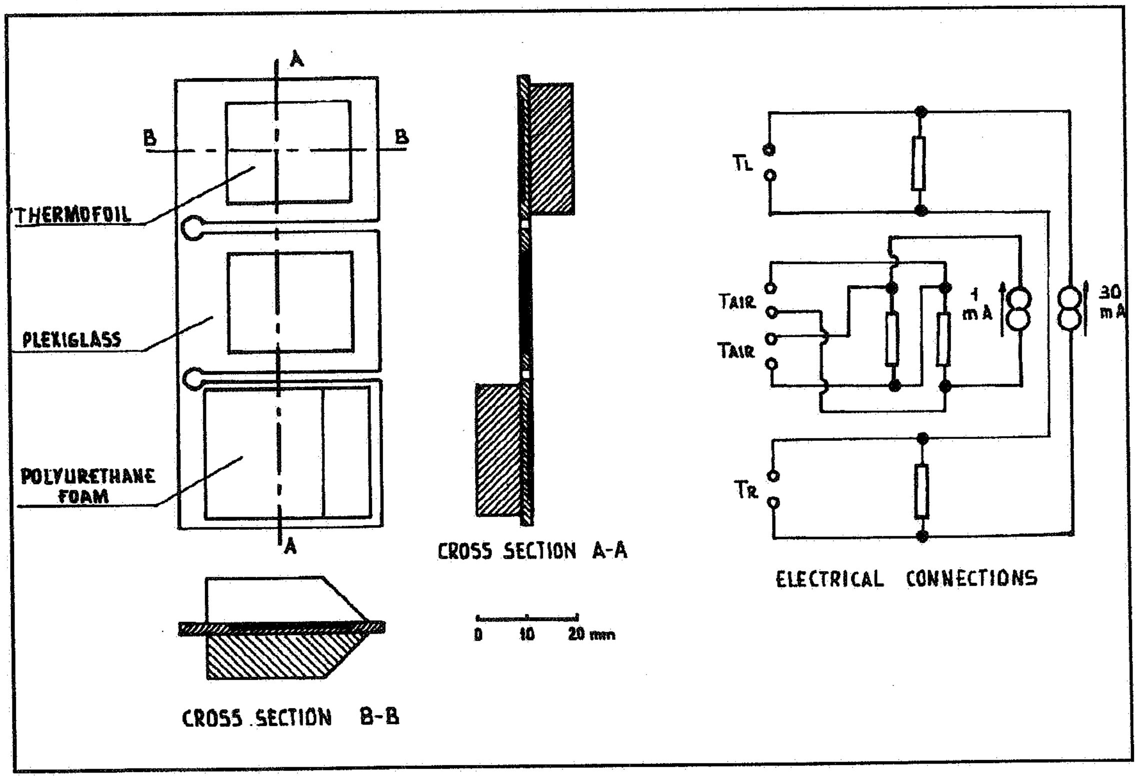

Figure 1. The sketch of the probe with the electrical connections.

As all the resistance share the same current, this turns out in the evident advantage of reducing the causes of error in the four-wire measurement.

3. Measurement methods and summary of the results.

Tests have been carried out in a wind tunnel facility where comparative measures of the air velocity have been performed using a high precision, low-response-time, laser calibrated TSI Anemometer Mod 8450/20M. Two kinds of measures have been accomplished: the first one has been conducted for several values of the air velocity, in steady-state conditions, in order to establish the relationship between the air velocity and the temperature difference between the hot and cold thermofoils, for each side of the probe.
The second has been carried out maintaining at a given value the air velocity and rotating the probe in order to vary the angle between air flux and the normal to the probe surface. This measure has been performed in the aim of finding the relationship between the direction of the air flux and the deviation between the "left" and "right" temperature difference. Because of the complexity of the probe geometry any theoretical prediction would be affected by the poor knowledge of the involved physical phenomena (local turbulence, sharp or blunt edge of the probe, heat transfer coefficients of the materials).
As a consequence we have tried to use a general formula for the heat transfer from a plate in parallel flow valid for Prandtl numbers above 0.6 and supposing that no transition occurs through the plate ($Re_{fluid} << 5 \cdot 10^5$). That is:

$$Nu = 0.664 \cdot Re_{fluid}^{1/2} \cdot Pr^{1/3} \qquad (1)$$

The logical procedure for the measurements has been the following: starting from the knowledge of each electrical resistance value, R(T), we calculate the electrical power dissipated by the heated element; moreover, by means of a trivial regression, we are able to determine the element temperature and, then, using the geometrical characteristics of the probe, we calculate the overall heat transfer coefficients and, the Nusselt number. Finally, Reynolds and Prandtl numbers are computed as a function of the thermophysical characteristics of the fluid.

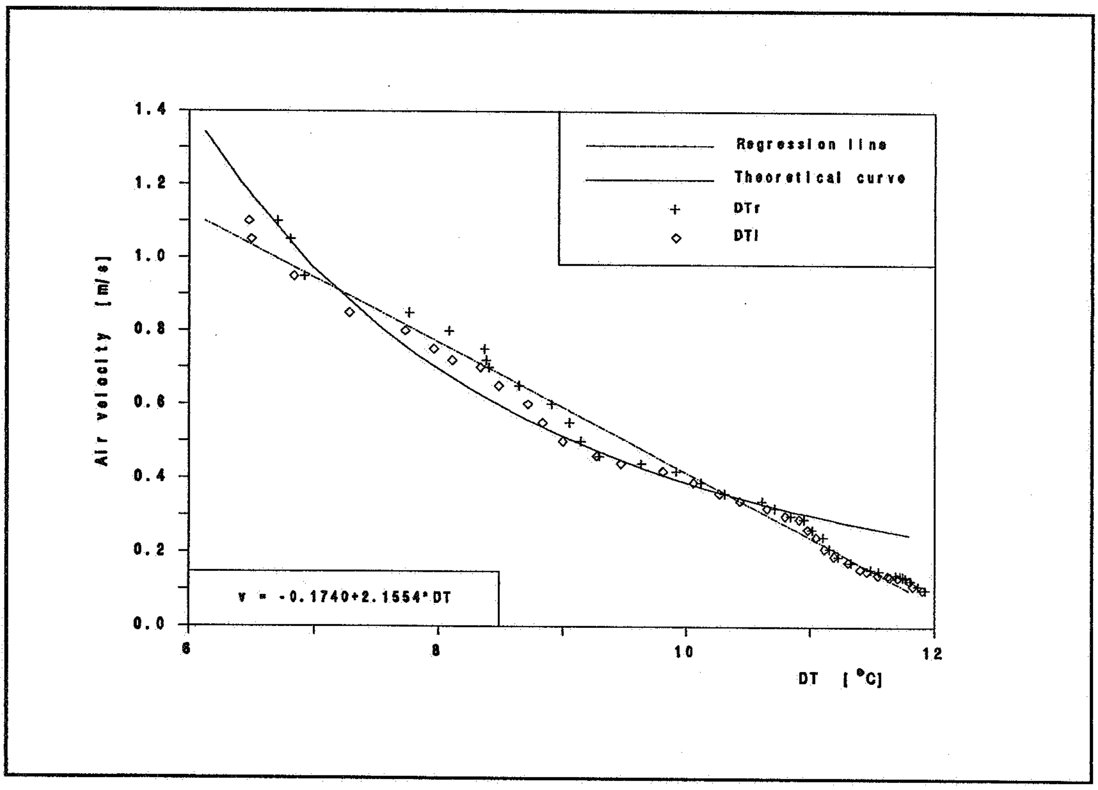

Figure 2. **Relationship between DT and the air velocity (T_{air}=25°C).**

Figure 2 shows the dependence of the temperature difference by the air velocity, both for the "left", DT_l, and "right", DT_r, side of the probe. In the same figure we have reported, in solid line, the equation 1, and, in dashed line, the first-order regression over all the experimental points. It is evident that the empirical relation doesn't apply for lower values of the air velocity, near the field of the natural convection.

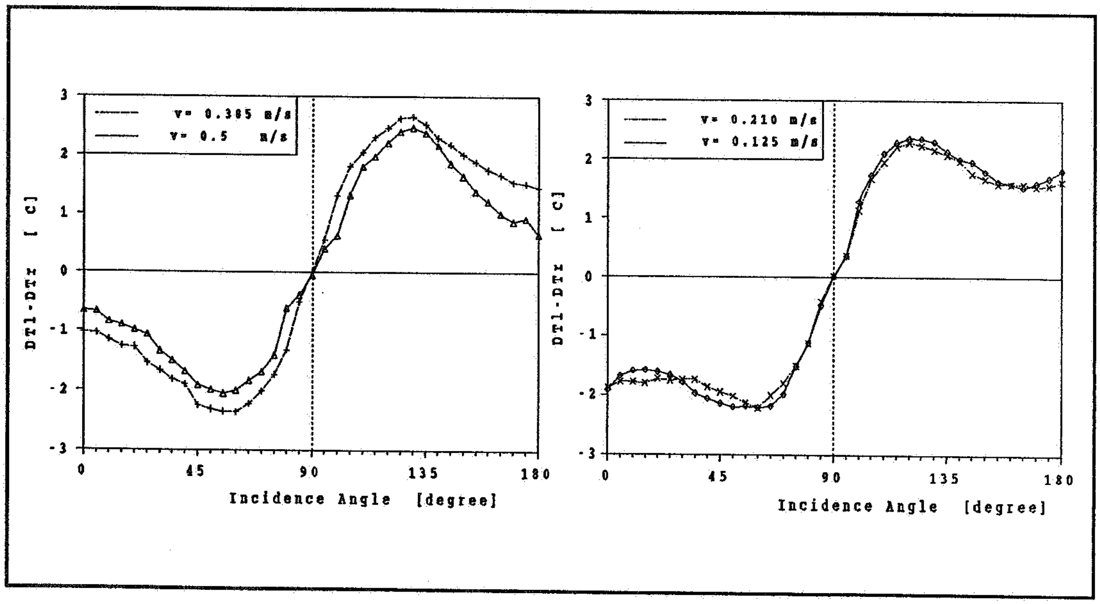

Figure 3. **Relative temperature difference as a function of the incidence angle, for two ranges of air velocity (T_{air}=25°C).**

As previously stated, we have also carried out several measures at a constant value of the air velocity, in the aim of investigating the influence of the incidence angle variations.
Figure 3 depicts some experimental results for two different velocity ranges. As it is well evident, at lower values of the air velocity the dependence of the relative temperature difference (that is DT_l-DT_r) by the incidence angle, shows a more clear relationship, and a larger zone where an univocal value of the incidence angle could be found.
Figure 4 shows all the experimental points and a tentative regression line valid for incidence angles close to 90 degrees.
Analysis of the heat loss from circular cylinders, has demonstrated that the Nu number is nearly independent of the temperature difference between the heated element and the ambient fluid. This result appears to hold when either the air temperature or the probe temperature is changed.

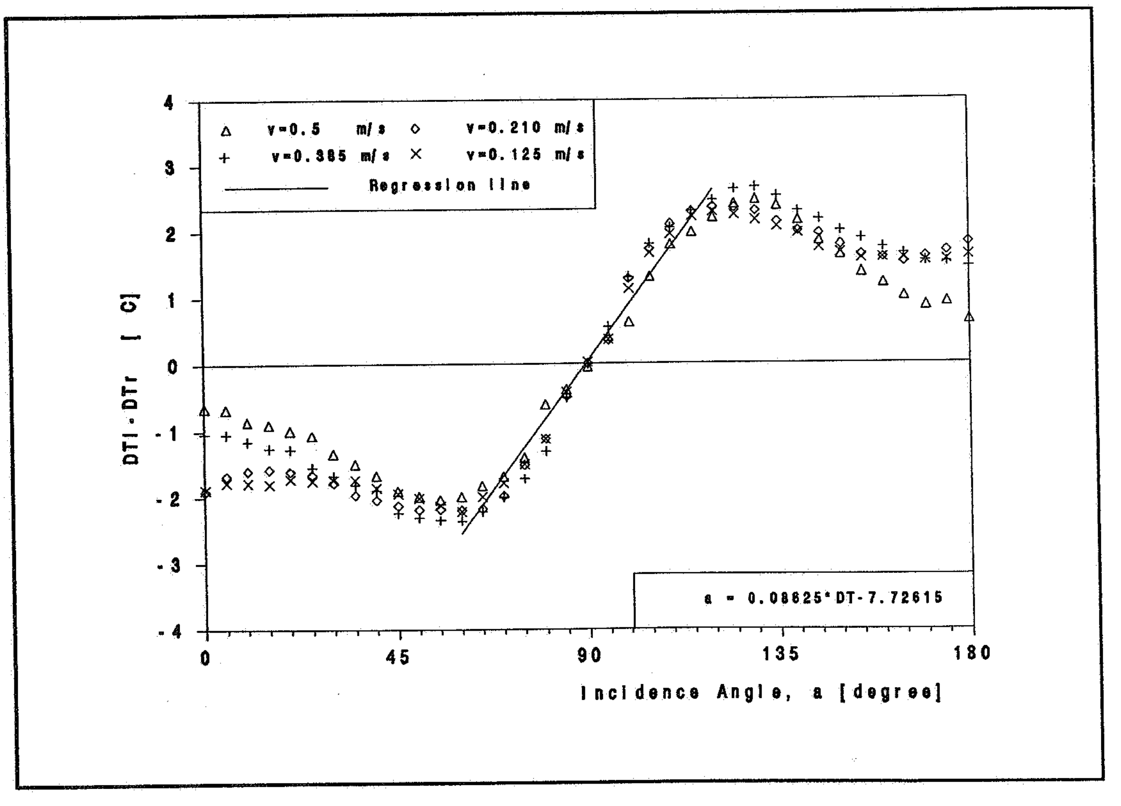

Figure 4. **Sketch of the experimental points with a tentative regression line.**

Some further experiments have demonstrated that this conditions could be applied even in our case.

5. Conclusions

Due to its characteristics, the proposed method candidates itself as a very suitable tool to be employed in rooms, with minor interventions. The only equipments needed are a constant current source, a series of thermofoils, a four-wires resistance meter and a high speed (or sample and hold) data logger.

6. Bibliography

INCROPERA F.P. & De WITT D.P. "Fundamentals of heat and mass transfer". J. Wiley & Sons, New York, 1990

SANDBORN V.A. "Resistance temperature transducers", Metrology Press, 1972.