Evaluation of Thermal Comfort in Vehicles - a Unique Solution

Application Note

The Problem

As many people spend several hours a day in cars, buses or trains, it is important to provide a good thermal environment, which gives comfort and optimises performance for both drivers and passengers.

The interaction of convective, radiative, and conductive heat exchange in a vehicle cabin is very complex. The varying radiation from the sun and the influence of inhomogeneous air temperature and air velocity from the vehicle's ventilation, or air conditioning system, creates a climate that may vary considerably in space and time. Furthermore, neither the driver nor the passengers are able to change their positions very much to make up for these asymmetric climate conditions.

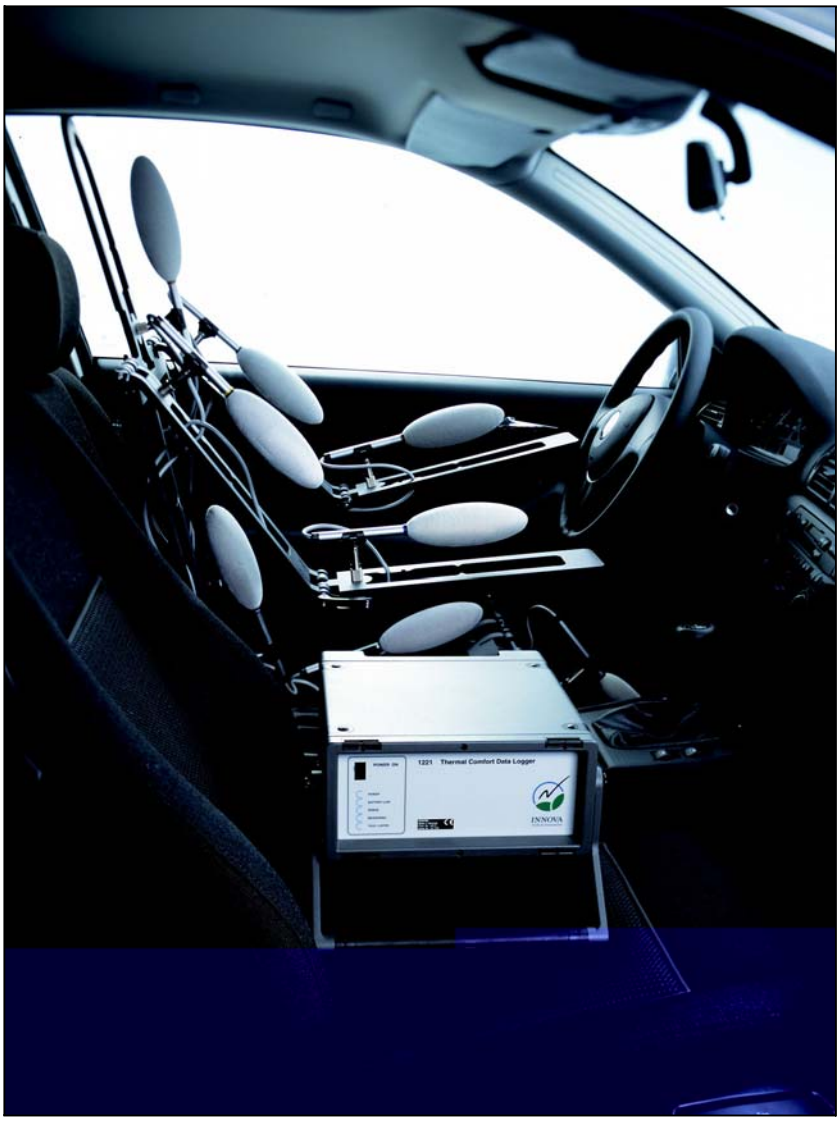

Fig.1 Flatman and the Thermal Comfort Data Logger 1221

Thermal Comfort

The degree of thermal comfort for a person is influenced by six parameters:

- activity level
- clothing
- air temperature
- air velocity
- air humidity
- mean radiant temperature

According to ISO 7730, the combined effect of these six parameters determines the degree of general thermal comfort, and is expressed by the Predicted Mean Vote, the PMV index. It is recommended that the PMV index is between -0.5 and +0.5, which means that less than 10% will find the thermal environment unacceptable. ISO 7730 describes the use of the PMV index in moderate thermal environments.

It is, therefore, very important that the evaluation of thermal comfort takes into consideration all the parameters affecting the overall thermal sensation in the vehicle. A number of standards are under preparation for the evaluation of the thermal environment in vehicles. ISO/NP 14505 defines the Equivalent Temperature as an integrated physical measurement of the thermal climate in the vehicle and presents methods for its determination.

INNOVA's Solution

The Thermal Comfort Data Logger 1221 (Fig.2) enables you to measure all the physical parameters necessary to evaluate thermal comfort according to ISO 7730 and ISO 7726/ EN27726. This instrument has a modular construction, allowing installation of up to four input modules - each of which supports a different type of transducer. For evaluating thermal comfort in vehicles, a total of 8 Dry Heat Loss Transducers can be connected by using 4 modules (UA1278).

The instrument can operate with a 12V DC supply, and a power consumption of up to 45W.

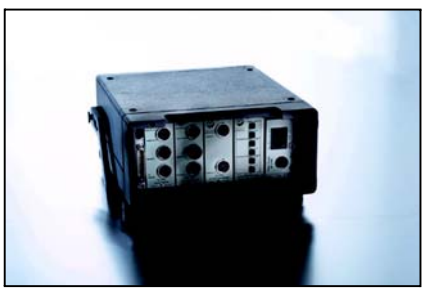

Fig.2 Thermal Comfort Data Logger 1221

The Equivalent Temperature, which integrates the combined effect of air temperature, air velocity and radiation, can be measured with the Dry Heat Loss Transducer MM0057 (Fig.3). The transducer is designed to simulate the human body thermally. It contains a surface temperature sensor and surface-heating element. The power to this element is adjusted automatically to bring the surface to a temperature similar to that of a human, while taking into account the clothing and activity level. The shape is determined by the need to obtain the same angle factor to the individual room enclosure as that of a person. With a number of transducers placed on FLATMAN, a flat, man shaped aluminium rig (Fig.1), each transducer simulates a certain body part, i.e. a certain area of a person. Cuts are made in the rig in order not to disturb the airflow around the transducers.

Fig.3 MM0057

The idea is to measure the equivalent temperature at each position and estimate an equivalent temperature for the whole body based on the area weighted average. Table 1 shows the area of different body parts, examples of positions of sensors and the corresponding weighting factors for estimating the weighted equivalent temperature for the body as a whole.

Body Segment	Skin Area (m^2)	Relative Area (%)
Head	0.180	10.3
Abdomen	0.544	31.1
Right Foot	0.112	6.4
Left Arm	0.112	6.4
Right Thigh	0.200	11.4
Left Thigh	0.200	11.4
Right Foot	0.201	11.5
Left Foot	0.201	11.5

Table 1 Area of individual body parts and related weightings

Measurement Results

Fig. 4 shows the results from measurements in a car during warm-up with 8 Dry Heat Loss Transducers MM0057. The temperature of each transducer is shown and the weighted equivalent temperature is calculated. It can be seen from the graph that the equivalent temperature at the head (yellow line) is considerably lower than that at other positions. This is due to the high air velocity from the vents combined with a low clothing value for the head, i.e. 0 Clo. If these measurements are made with thermocouples, this effect will not be taken into consideration.

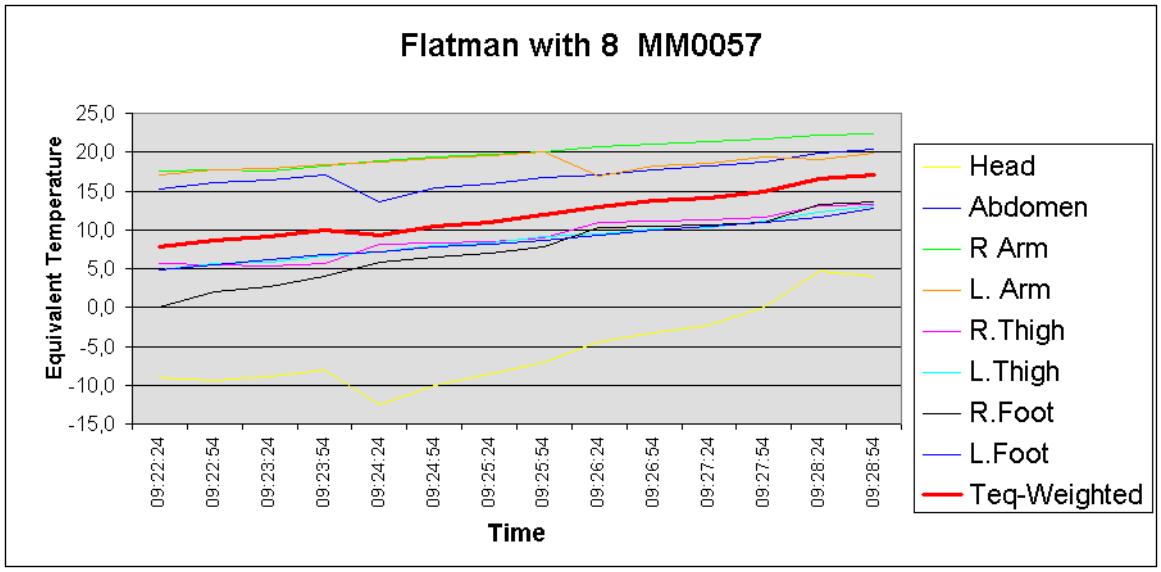

Fig.4 Measurement of Equivalent Temperatures during a warm-up experiment in a vehicle

INNOVA AirTech Instruments

Innova AirTech Instruments A/S
Energivej 30,
DK-2750 Ballerup, Denmark

Tel.: (+45) 44 20 01 00
Fax: (+45) 44 20 01 01

www.innova.dk
E-mail: innova@innova.dk