EVALUATION OF THE THERMAL ENVIRONMENT IN TRACTOR CABS

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INTRODUCTION

An optimal thermal climate in a vehicle is an important determinant factor for the driver's health, performance and comfort. A poor climate and its effects upon the driver may endanger traffic safety [4]. In the confined space of a tractor cab the thermal environment becomes very complex. Driver sits close to walls and windows. Glass windows are large and poorly insulated. Radiative heat exchange caused by cold or solar load may locally be excessive. HVAC–systems are normally powerful to compensate for poor insulation and considerable temperature gradients may build up. In addition, air velocities may be locally very high. The thermal impact on the driver is not easy to evaluate, Spot measurements are difficult to interprete and most climate indices only account for the average or whole body effect of the thermal load. This is not sufficient, since man may feel thermoneutral but *still* suffer severely from local thermal disturbances and asymmetries. Measurements with a thermal manikin yield a more complete, integrated and detailed picture of thermal effects [3, 6].

The purpose of the present investigation was to compare measurements with a thermal manikin with comfort votes obtained for a panel of subjects.

METHOD

A man-sized, sitting thermal manikin (AIMAN) was positioned in the driver's seat in a tractor cab, placed in a climatic chamber. Heat flow in W/m^2 from 15 different segments of the manikin surface was measured and controlled by a computerized system. Heat flow data were recalculated and expressed as EHT (equivalent homogeneous temperature), which serves as a standardized expression of the thermal load. EHT is the temperature of a room with air temperature=mean radiant temperature and air velocity <0.05 m/s, in which *dry* heat loss is the same as in the given environment HVAC-system of the cab was controlled to provide three levels of internal cabin temperature (corresponding to **40.48** and 56 W/m^2 of whole body *dry* heat **loss** from the manikin) and different types of vertical temperature gradients (wanner at head level, colder at head level and no difference between head and foot level).

Ten male subjects were exposed on consecutive days at random to the different types of climate for sessions of 1 hours duration. Thermal votes according to the Bedford 7-point scale were obtained after 30 and 60 min for the whole body and for the same 19 body segments as the manikin. The mean thermal vote (MTV) was calculated for the ten subjects.

Experiments with subjects and manikin were carried out during winter (-20 °C) and summer conditions (30 °C with solar load and 35 °C without solar load). A total of 20 climatic conditions were investigated.

RESULTS AND DISCUSSION

Linear regression equations were calculated for all segments for MTV as function of EHT. Data for summer and winter conditions were analyzed separately. Correlation coefficients for whole body MTV were 0.92 and 0.91, respectively. Corresponding coefficients for individual segments were high and varied between 0.63–0.98. Usually, the lowest correlations were obtained for segments, that were only marginally affected by thermal factors. This was particularly true for parts of the body in contact with the seat (lumbar back and buttocks). For these segments very small or no differences in EHT and MTV were recorded.

In figure 1 are depicted mean thermal votes of subjects for the different climatic conditions in relation to equivalent homogeneous temperature. (EHT) calculated on the basis of measurements of heat loss with the thermal manikin. Data are given for the whole body during both summer and winter conditions and for the right and left arm during winter conditions, respectively. Regression lines are drawn for the data plots.

Sensitivity to local thermal influences was higher for legs and feet, than for arms and hands. Uncovered parts like face and hands were subjected to great variations in local heat exchange, but were not particularly sensitive. Sensitivity to whole body thermal effects was the same for winter and summer conditions. However, at the same EHT–value subjects voted wanner in the winter due to warmer clothing (higher insulation value).

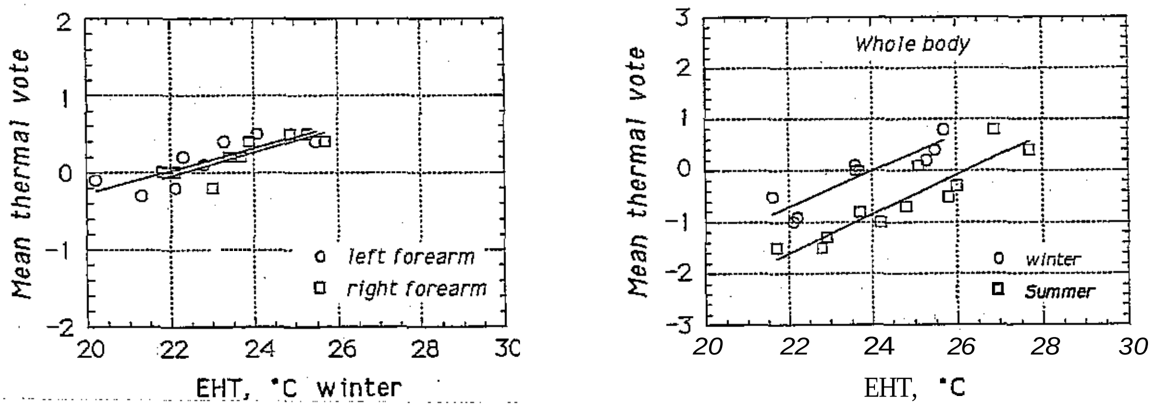

Figure 1. Regression lines for mean *thermal* votes of subjects and the equivalent homogeneous *temperature (EHT)* calculated **on** the basis of manikin *measurements for* whole *body and forearms,* respectively.

On the **basis of** the regression lines obtained and exemplified in Figure 1, it is possible to specify a lowest and a highest EHT–value for each body segment, corresponding to a defined level of acceptance (MTV). **A** MTV–value **between** ±0.5 on *the* 7–point scale **has** been proposed **as** criteria for acceptable ("comfortable") indoor climate conditions [1, 2]. Wyon et al. [5] proposed for the more complex vehicle climate a value of ±0,8 to be more realistic and practical. This value would then correspond to approximately 80% of a group of people being satisfied with the thermal conditions. The set of temperature intervals (EHT–intervals) so obtained may serve **as** a guide-line for the evaluation of vehicle climate and for the development and improvement of HVAC–systems.

CONCLUSIONS

Measurements **of** local climate disturbances with **a** man–sized thermal manikin are well correlated with the thermal sensation experienced by subjects exposed to the Same conditions.

Criteria for acceptable climatic conditions can be defined in terms of quantities measured with the manikin.

The manikin method represent a quick, accurate and reproducible technique for reliable and cost–effective assessment **of** many of the complex details of the climate in a vehicle **and** their integrated effects on humans.

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