Thermal Manikin Simulation Using Experimental Correlations and Clothing Independent Comfort Zone Diagrams

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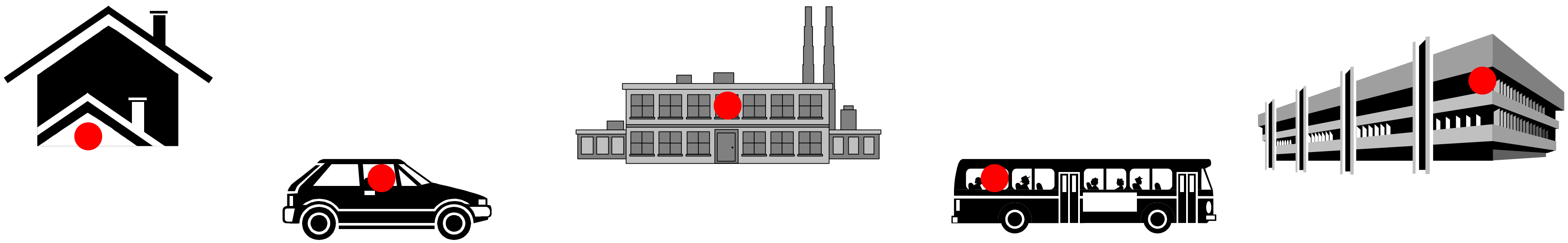
“Research from technology to man"

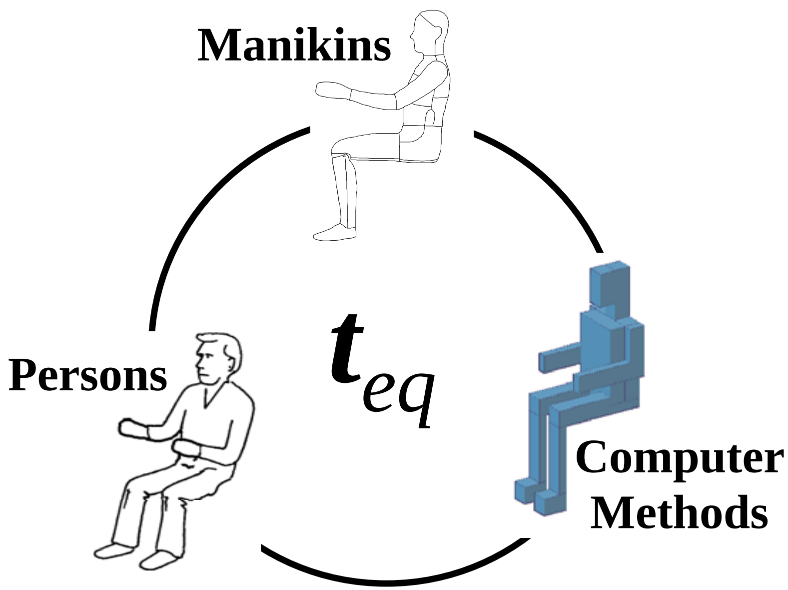
Local evaluation of thermal environments

The purpose of this work is to develop methods to visualise, analyse, and evaluate ***local*** thermal climate in homes, working places and different types of vehicles.



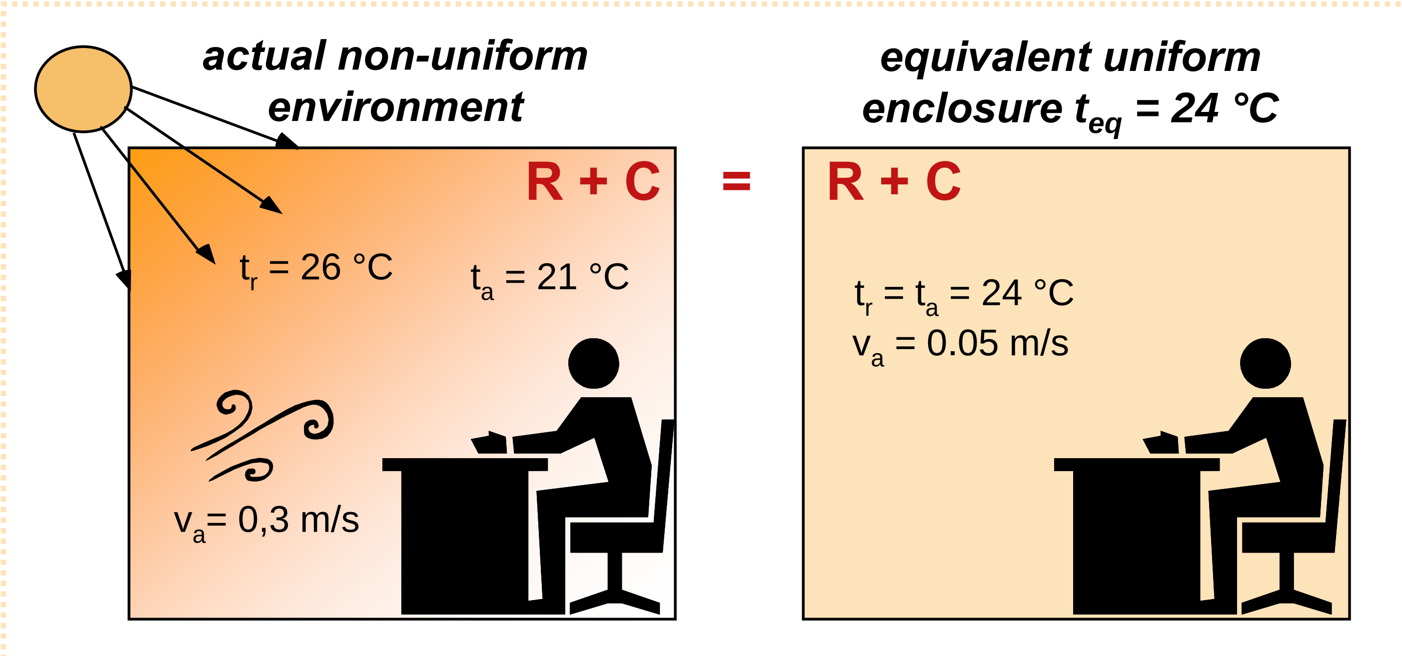
The presentation deals with thermal comfort requirements related to ***all*** parts of the human body.

Visualise, analyse and evaluate



- More than 500 experiments are used to develop new evaluation methods and a virtual manikin positioned in a CFD simulated environment.
- Heat fluxes from full-scale thermal manikins have been determined for different climatic conditions.
- Correlated with thermal sensation votes from persons exposed to the same conditions.

This is equivalent temperature, t_{eq}

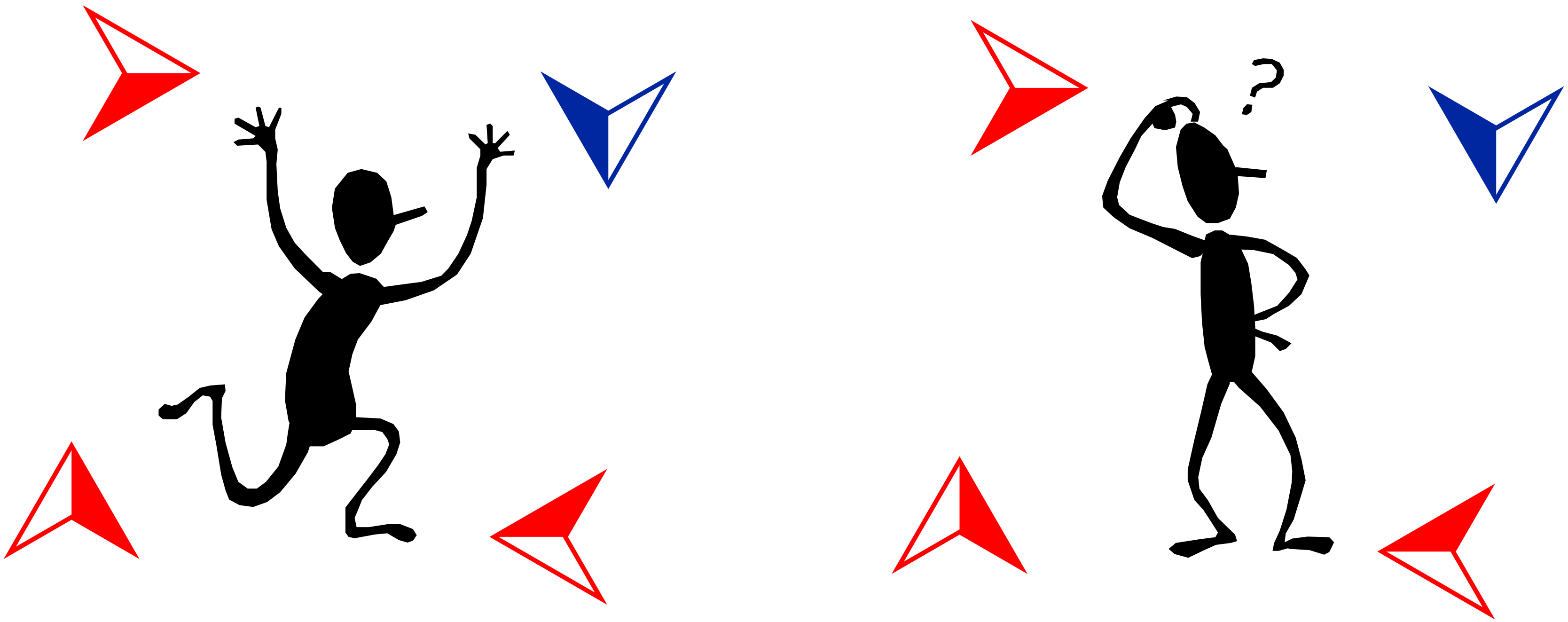


The definition is based on:

- A human body exposed to two environments creating the same radiative and convective heat loss
- The same posture, activity and clothing in both environments.

Local comfort requirements compared to whole body requirements

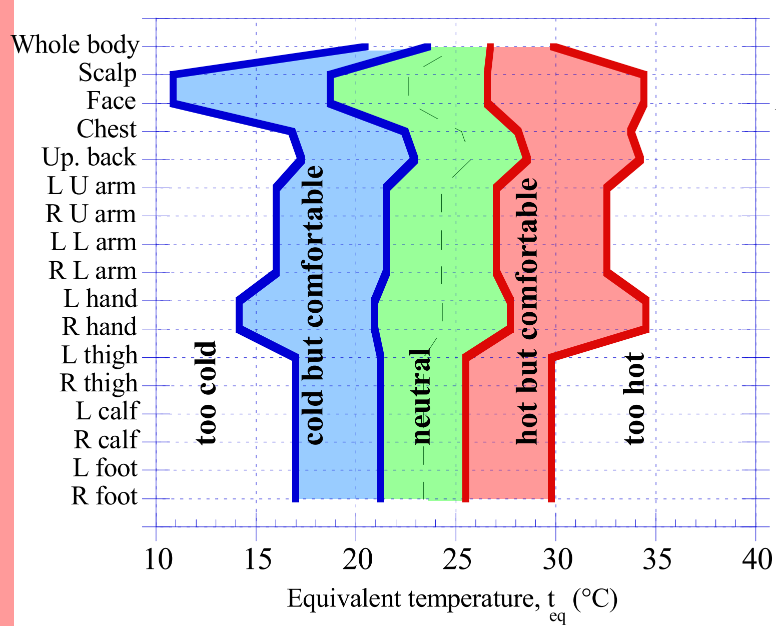
Most real life climate situations contains different asymmetries in the thermal environment generated by ventilation methods, heat transfer from and to surfaces, variations of air temperature and air movements etc.



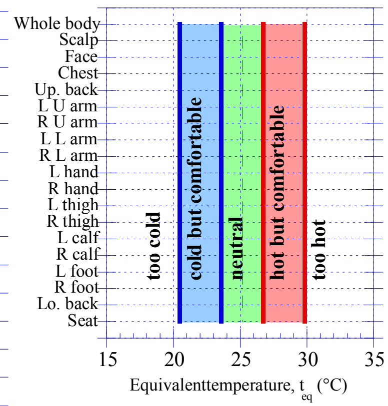
New Comfort Zone Diagrams

A general profile usable with different manikins in different situations with different clothing.

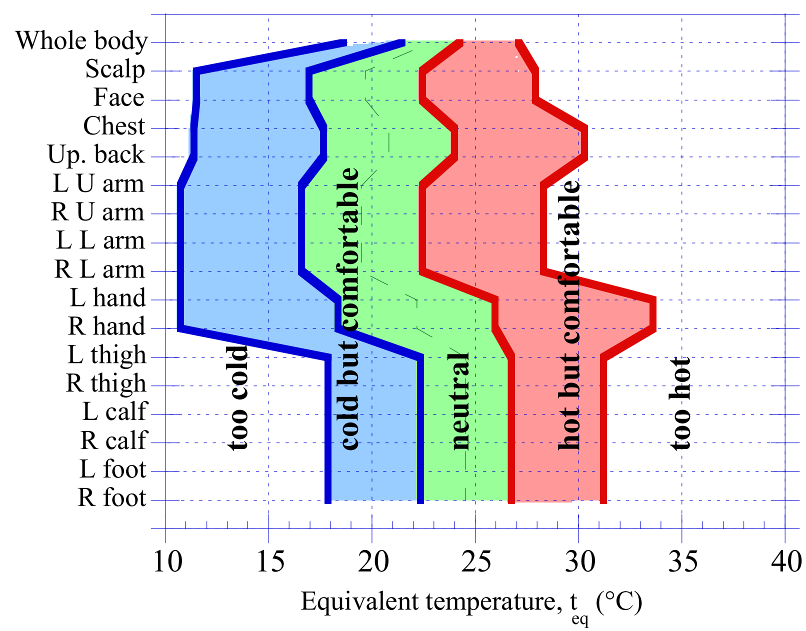
Summer Comfort Zones



"WHOLE BODY" COMFORT ZONES

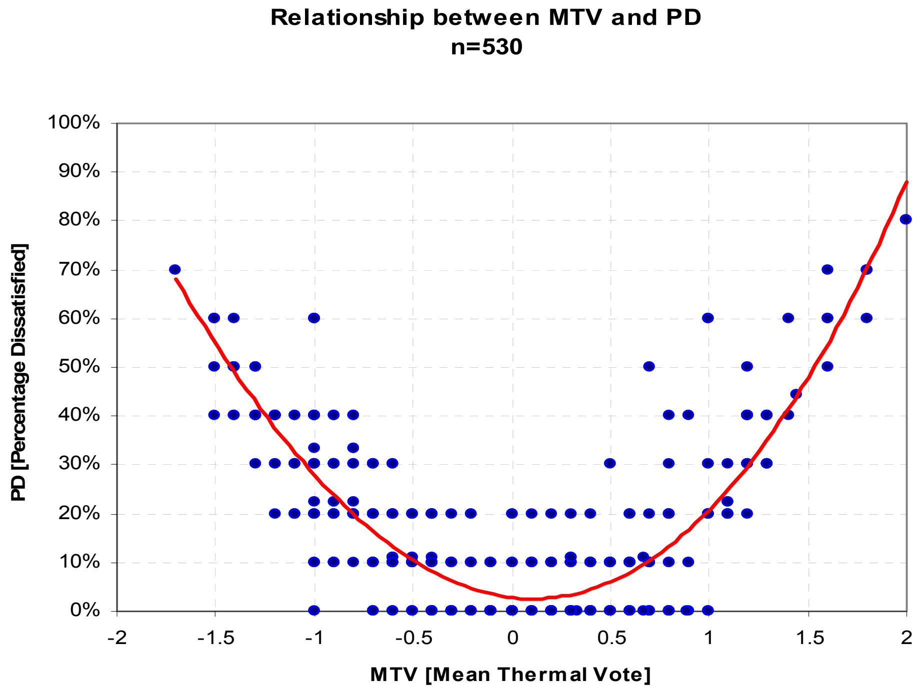


Winter Comfort Zones



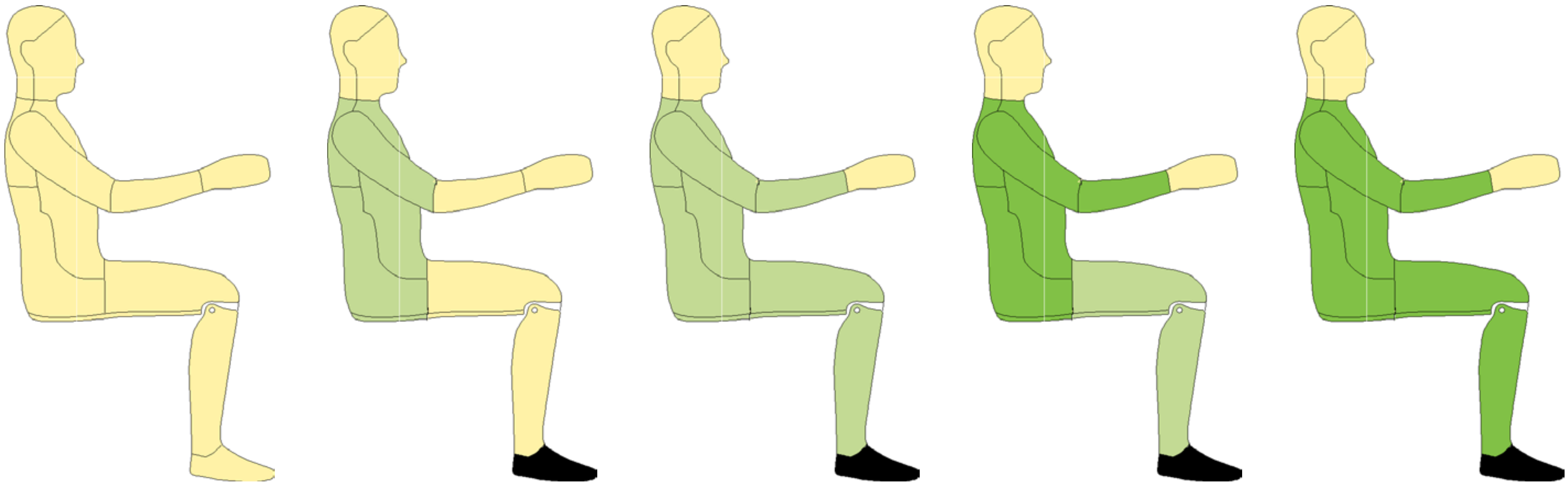
Percentage Dissatisfied

The persons that experience the climate as “too cold” or “too warm” at some part of the body, can be expressed as the Percentage Dissatisfied (PD).



This evaluation can be done for the entire body experience and **for individual body parts**. For example 23% dissatisfied with the climate at feet level etc.

Different clothing levels



(NC:0.9 clo)

Air layer around the body in sitting position.

(LS:1.1 clo)

Shorts and shirt with short sleeves boxer briefs, shoes and socks.

(S:1.3 clo)

Shirt with long sleeves and trousers with long legs boxer briefs, shoes and socks.

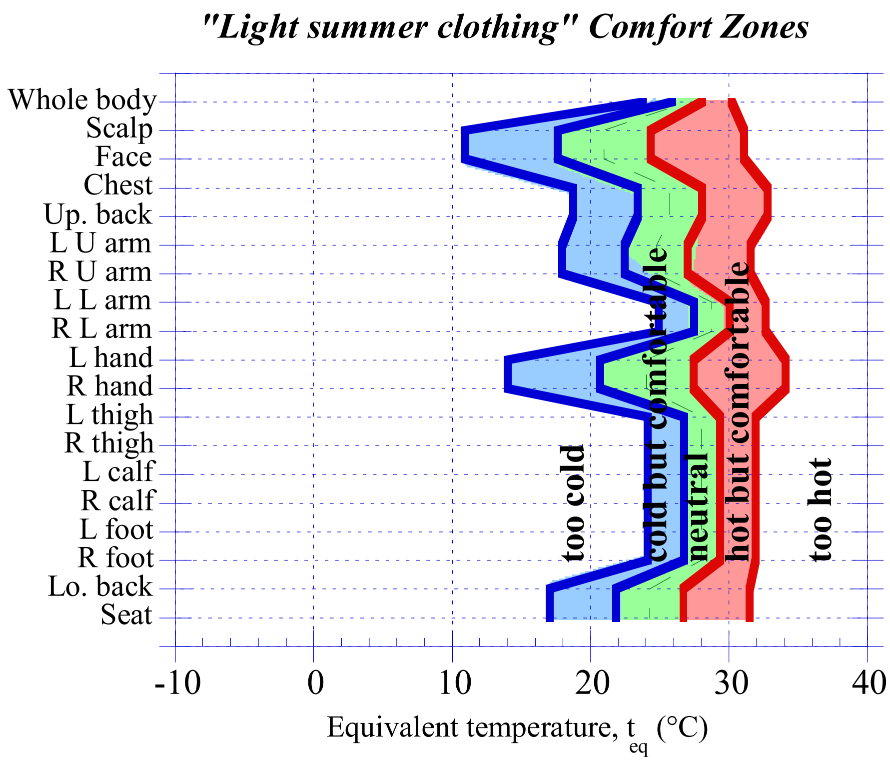
(W:1.6 clo)

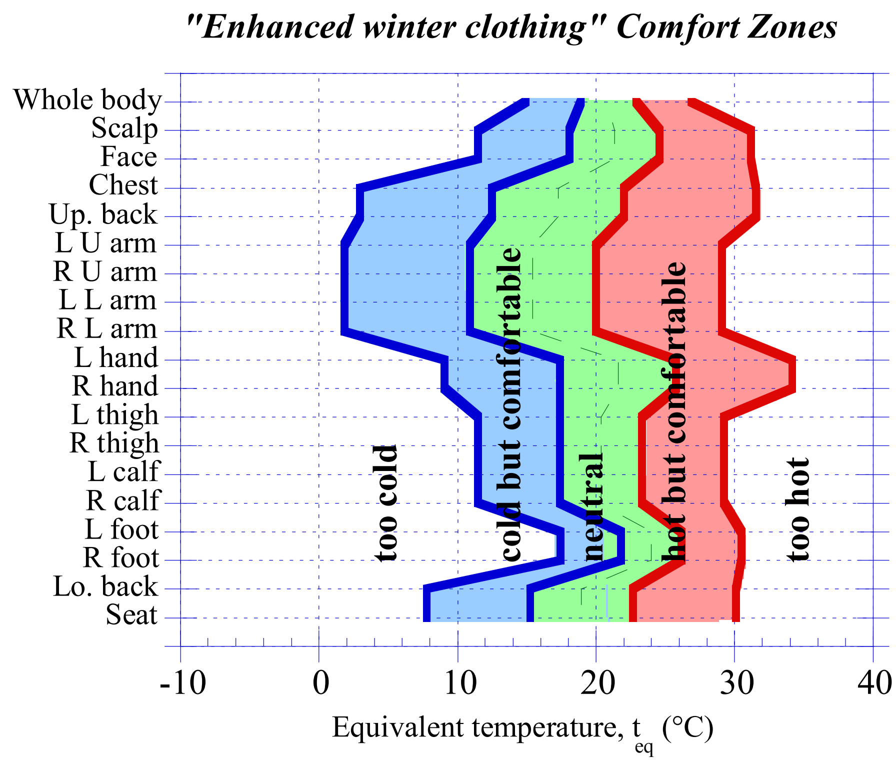
Same as S but with an additional cardigan.

(EW:1.9 clo)

Same as W but with winter underclothes with long sleeves and legs.

Clothing independent evaluation

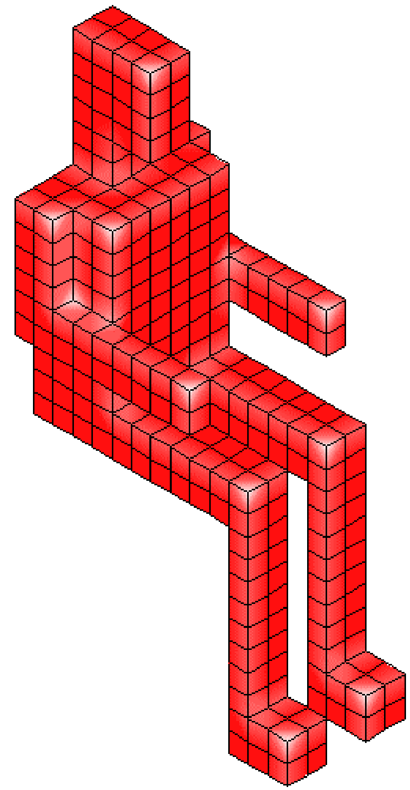




The heat loss corresponding to a certain level of comfort, or discomfort, in the diagram is the same. The shape of the zones does however change with the clothing used.

New computational manikin with surface temperature regulation

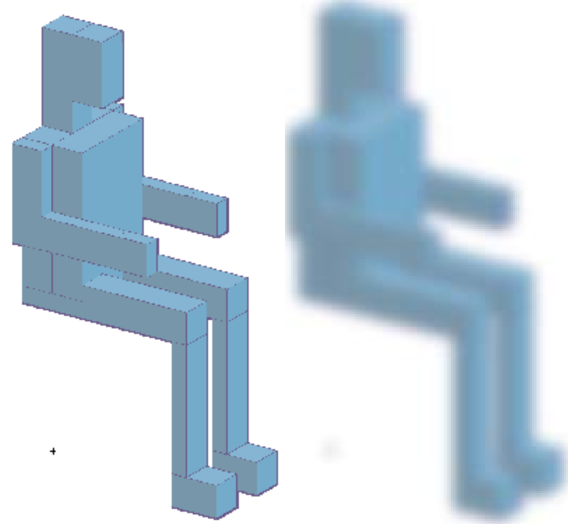
Several CFD codes support continuous modification boundary conditions during the flow and temperature field calculations.



Functions have been designed to regulate the numerical manikin surface temperature and calculate the equivalent temperature.

New user subroutines are written so that the surface temperature data and comfort diagram output are continuously updated for real time monitoring.

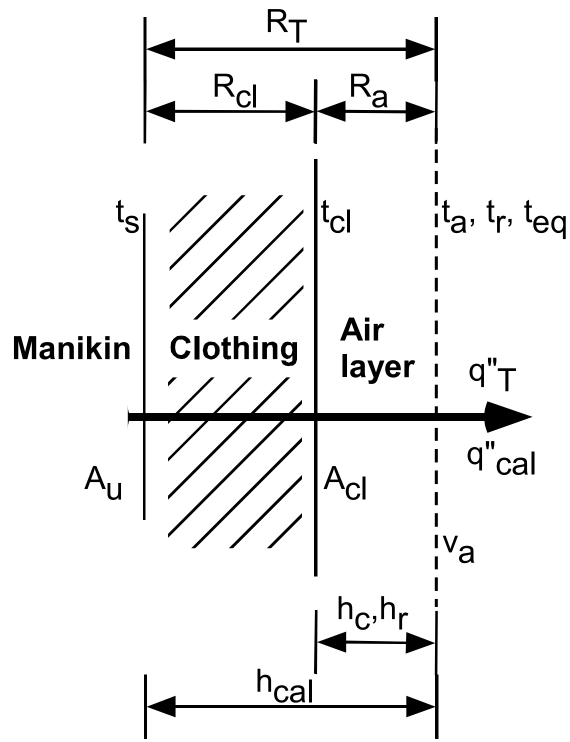
New computational manikin



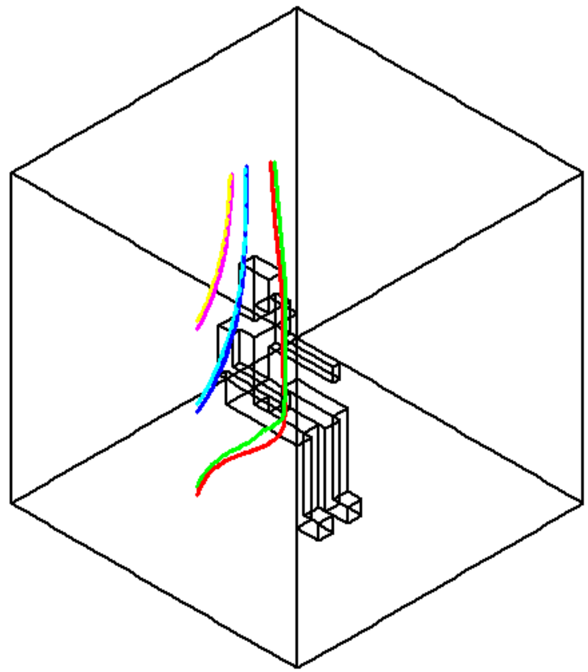
The virtual manikin is built with an active heat flow interface to a CFD code.

The surface temperature of this numerical manikin is regulated during the iteration process, using the adaptive boundary conditions.

This procedure together with a virtual calibration is used in order to even out geometrical differences.



New computational manikin

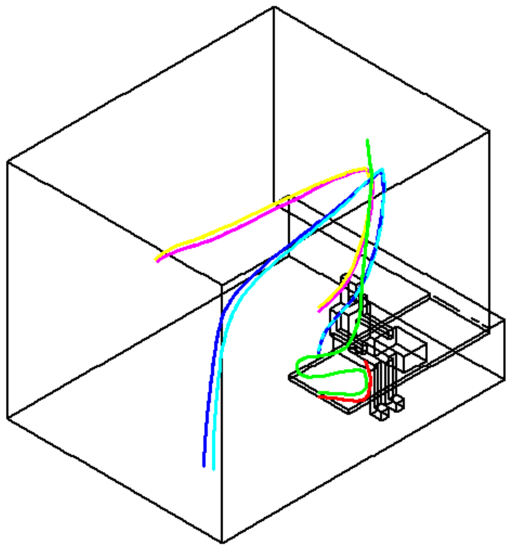


The present model use a zero-equation model with a constant turbulent viscosity. This method use much less time for calculations and does not need grid refinement or the use of special wall functions, two factors that significantly speed up the working and iteration process.

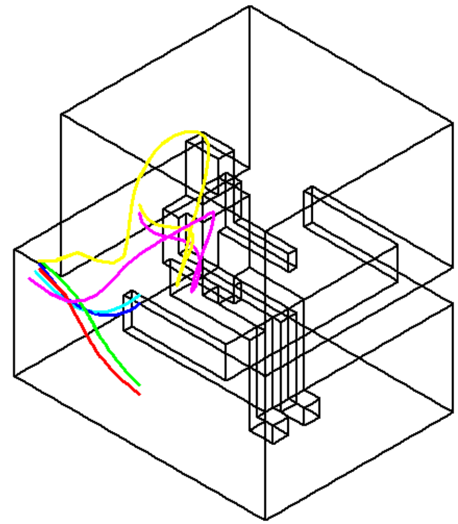
Experiments and computer simulations

This concept can be used to evaluate and develop both real and virtual environments, minimising the need for subjective tests.

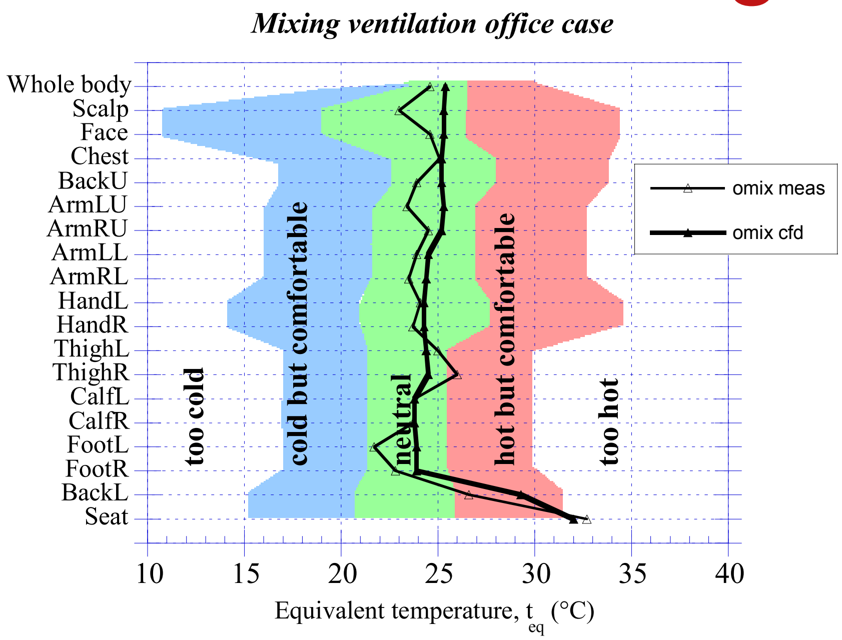
Offices

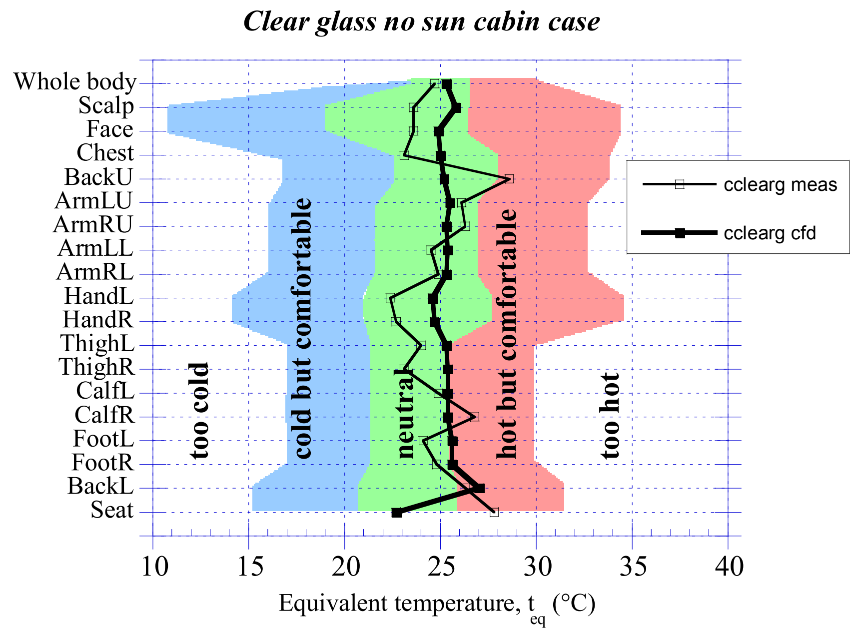


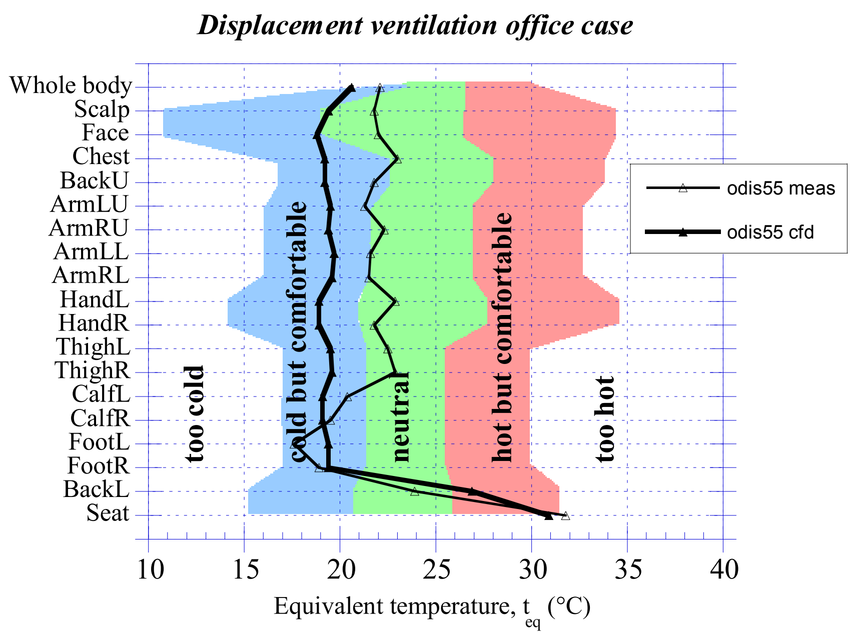
Vehicles

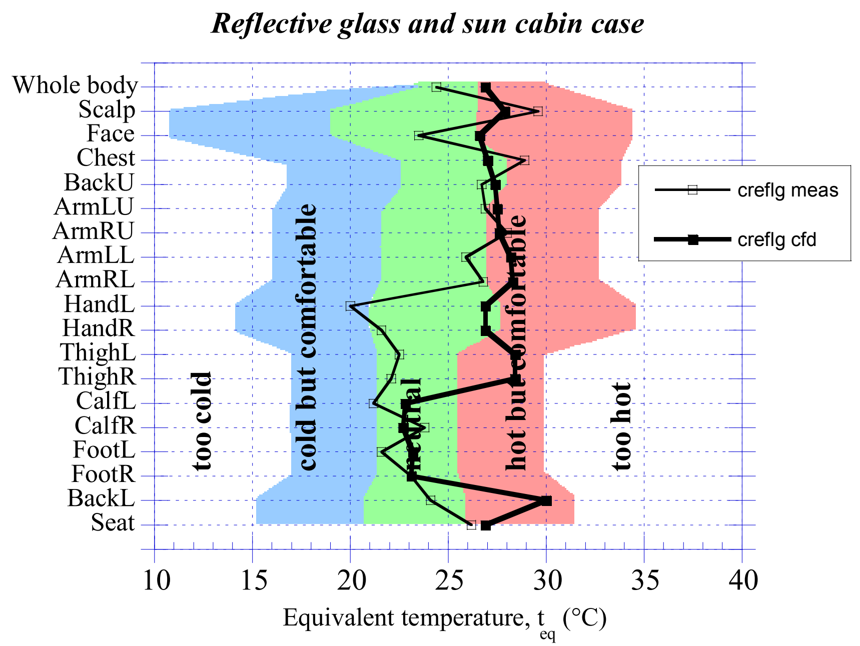


Comfort zone diagrams - some results









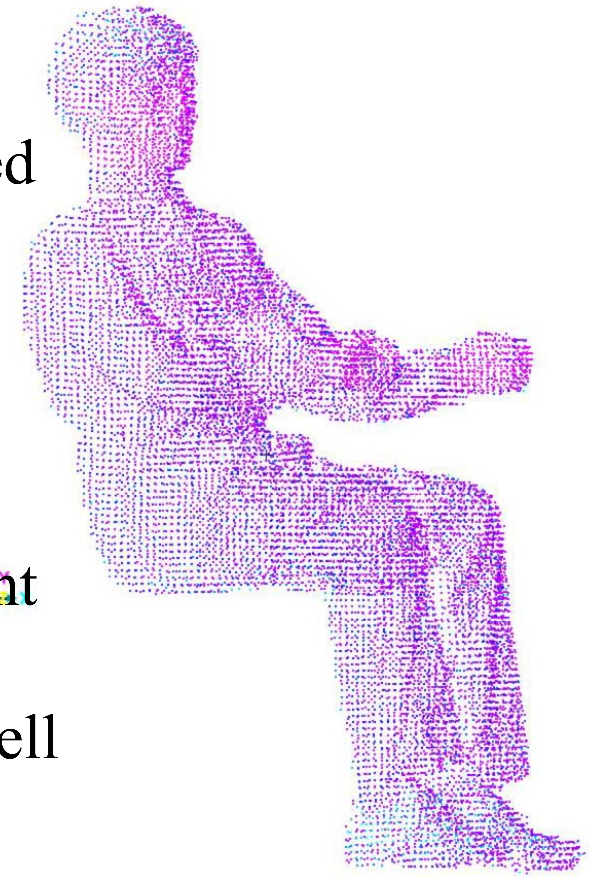
Conclusions

Subjects and real manikins are used to develop a new type of virtual manikin to be used in CFD simulations.

The surface temperature of the manikin is regulated continuously through the iteration process. This procedure together with a new model for virtual calibration form the basis of this new numerical manikin concept.

Results are visualised in new “clothing independent comfort zone diagrams”, showing how an average human being would perceive the whole body as well as local climate.

There is a need for continued validation of CFD-results with real life measurements and benchmark tests.



Laboratory of Ventilation and Air Quality

Whole-field measuring methods for temperature, contaminant concentrations, particle concentrations and three-dimensional velocities. Eight test rooms with equipment for measurement of temperatures, velocities, humidity, particles and tracer gas concentrations.

Publications and more information: www.hig.se/~hnn