Air distribution design based on EN ISO 7730 with the help of a computer program

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ABSTRACT

Klima ADE is a program for fast selection and calculation of air diffusion devices, which is based on:

- Design criteria for the thermal environment are based on EN ISO 7730 (optimal operative temperature and maximum mean air velocity in occupied zone). The human response to the thermal environment is expressed by the predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD) indices.
- Perceived air quality according to CEN CR 1752.
- Air flow rate required from a health point of view (carbon dioxide) according to CEN CR 1752.
- Air flow rate required for thermal design.
- Acoustic environment according to CEN CR 1752 (permissible A-weighted sound pressure level in occupied zone).
- Space and occupied zone definition.
- Air distribution design—optimized selection of air devices (grilles, spiro duct grilles, diffusers, variable diffusers and slot diffusers).
- Advanced calculations and modelling are used to obtain graphical presentation of the results. Air flow patterns are calculated on the basis of extensive measurements in our laboratory.

INDEX TERMS

Design criteria; Perceived air quality; Thermal environment; Acoustic environment; Air distribution

THERMAL ENVIRONMENT

The design criteria for the thermal environment (Figure 1) is based on EN ISO 7730. The human response to the thermal environment is expressed by the predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD) indices, which predict the percentage of the occupants feeling too warm or too cool for the body as a whole. Prediction of the percentage of dissatisfied is used to establish requirements or the thermal environment and for ventilation.

In the occupied zone, the combined effect of air temperature and the radiant temperature of the surrounding surfaces must be taken into account. This temperature is referred to as the operative room temperature (also termed ‘perceived temperature’). For a given space there exists an optimum operative temperature corresponding to PMV = 0, depending on the activity and the clothing of the occupants. The optimum operative temperature is the same for the three categories, while the permissible range around the optimum operative temperature varies. The operative temperature at all locations within the occupied zone of a space should at all times be within the permissible range.

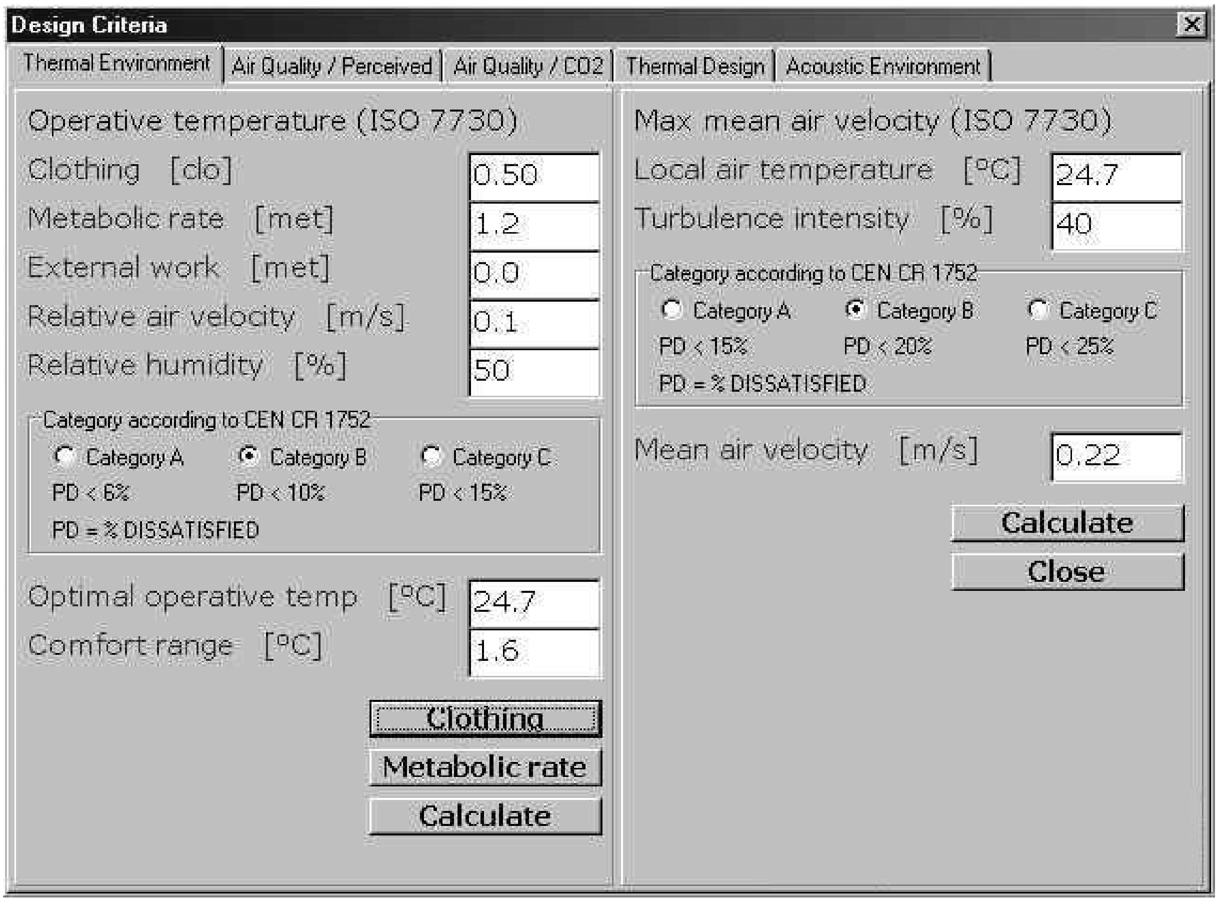

Figure 1 Thermal environment.

At low activity levels people are very sensitive to air velocities, and therefore draft is a very common cause for occupant complaints in ventilated and air-conditioned spaces. Fluctuations of the air velocity have a significant influence on a person's sensation of draft. The percentage of people feeling draft (draft rating) may be estimated from the draft model. EN ISO 7730 recommends three categories for draft. Permissible mean air velocity is calculated as a function of local air temperature and turbulence intensity for the three categories of draft.

PERCEIVED AIR QUALITY

Studies in naturally and mechanically ventilated buildings have shown that more complaints related to building sickness were found among occupants of the mechanically ventilated buildings. It is believed that these complaints are caused more by pollutants emitted internally by building materials, furnishing, equipment and ventilation plants than by the occupants of the building themselves.

Humans perceive the air by two senses. The olfactory sense is situated in the nasal cavity and is sensitive to several hundred thousand odorants in the air. The general chemical sense is situated all over the mucous membranes in the nose and the eyes and is sensitive to a similarly large number of irritants in the air. It is the combined response of these two senses that determines whether the air is perceived as fresh and pleasant or stale, stuffy and irritating.

In 1988, Professor Fanger introduced two units, the olf (derived from the Latin word *olfactus*, i.e. olfaction) to quantify the strength of air pollution sources and the decipol (derived from the Latin word *pollutio*, i.e. pollution) to quantify the air pollution perceived by a person. One olf is defined as the emission rate of air pollutants (bio-effluents) from a standard person. The unit can also be used to express the strength of other pollution sources as equivalent to a number of standard persons (olfs) required to cause the same dissatisfaction as the actual source of pollution. The perceived intensity of air pollution caused by one typical person (1 olf) ventilated by 1 l/s of unpolluted air is 1 pol. More conveniently, Fanger suggested the use of the unit decipol (dp), which is 0.1 pol. One decipol, therefore, is defined as the pollution caused by one typical person (1 olf) ventilated by 10 l/s of unpolluted air (1 dp = 0.1 olf/(l/s)).

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CARBON DIOXIDE

Humans produce carbon dioxide proportional to their metabolic rate. In terms of quantity it is the most important human bio-effluent. Although present in low concentrations indoors, CO_2 is harmless and not perceived by humans; still it is a good indicator of the concentration of other human bio-effluents being perceived as a nuisance.

In lecture theatres, assembly halls and similar rooms with high occupancy, which may change in a short time, CO_2-monitoring is a well-established practice for controlling the supply of outdoor air.

If sedentary occupants are assumed to be the only source of pollution, CEN CR 1752 recommends the CO_2 concentration above the outdoor level corresponding to the three categories A: 460 ppm, B: 660 ppm and C: 1190 ppm. The concentration of carbon dioxide outdoors is typically around 700 mg/m^3 (350 ppm).

The primary indoor source of CO_2 in office buildings is the respiration of the building occupants. CO_2 concentrations in office buildings typically range from 350 to 2500 ppm. Elevated indoor CO_2 concentrations may indicate inadequate ventilation per occupant and elevated indoor pollutant concentrations, leading to sick building syndrome (SBS) symptoms. Some SBS symptoms associated with CO_2 are headache, fatigue, eye symptoms, nasal symptoms and respiratory tract symptoms.

ACOUSTIC ENVIRONMENT

CEN CR 1752 acoustic environment (Figure 2) specifies permissible A-weighted sound pressure level generated and/or transmitted by the ventilation or air-conditioning system in different types of spaces for three categories.

Ventilation noise originates primarily from fans and the air turbulence generated inside ducts and around supply air and exhaust air terminal devices. The noise level and the frequency characteristics are also determined by the velocity of the air inside ducts and around terminal devices, where factors such as dimensions and placement of the ducts and terminal devices may play a decisive role in the appearance of the noise.

Room reverberation time is specified according VDI 2081 Code of Practice (noise generation and noise reduction in air-conditioning systems).

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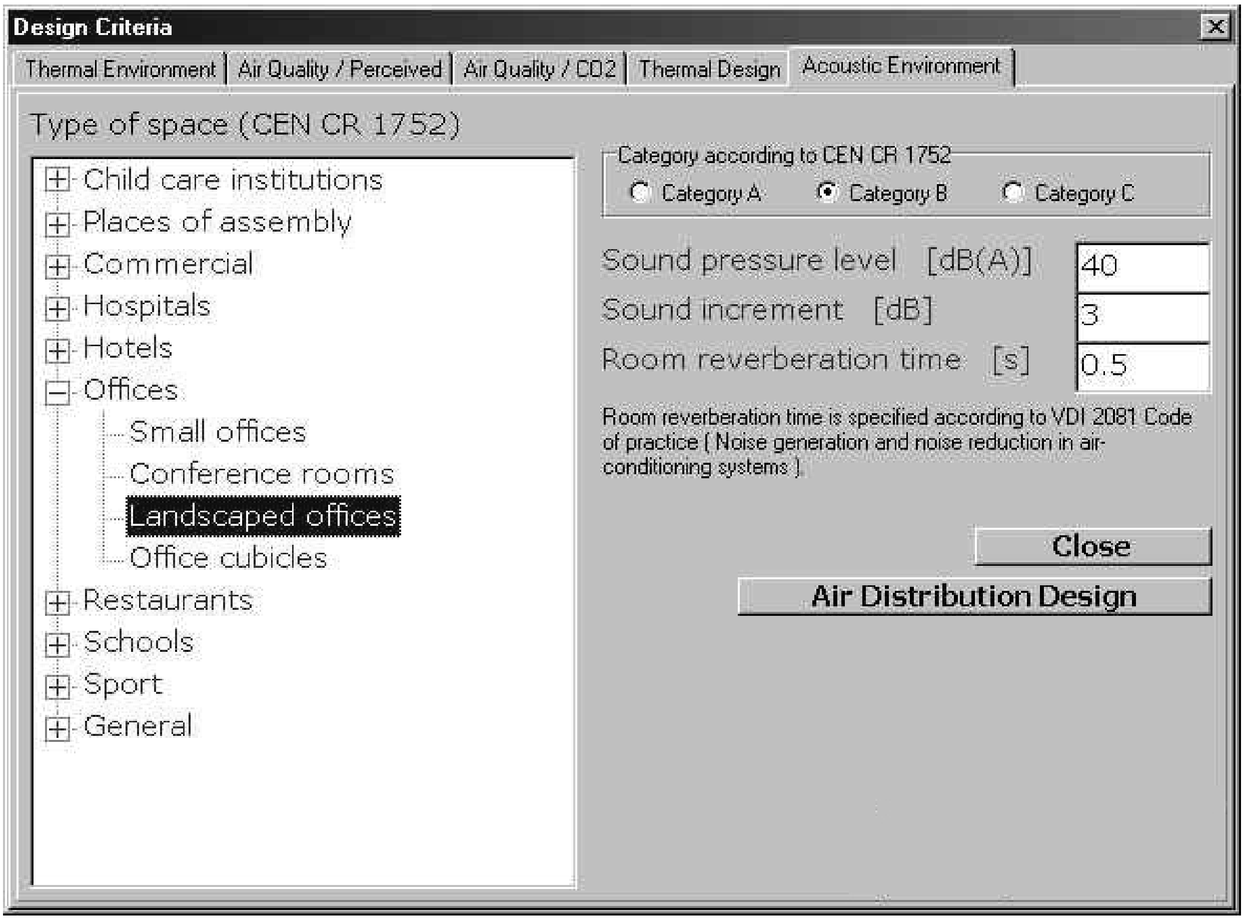

Figure 2 Acoustic environment.

GRILLES

Data, such as optimal operative temperature, permissible mean air velocity, required supply air flow rate and permissible sound pressure level are transferred from Design Criteria to Air Distribution Design window.

If two or more supply grilles are arranged close to one another and are discharging in parallel, the throw length will increase. The actual increase in throw length is dependent on the number of supply grilles and the distance between them in relation to the width of the jet. Selection of the supply grille is facilitated by introducing calculation coefficients. Optimized selection of supply grilles is based on minimal interaction between parallel jets (throw coefficient) and requested supply air flow rate in space (volume coefficient).

On the basis of empirical expressions derived from measurements and Prandtl–Schlichting theory of a two-dimensional turbulent wake behind a body, a calculation model has been developed in order to sufficiently describe the interaction of air devices discharging in parallel. Basically there are two regions of interest: interaction between parallel plane jets and interaction between offset jet and a solid wall. Far downstream from the grilles, the parallel jets will combine to form a single free jet while the offset jet will develop into a wall jet.

Point of separation for cooling (separation point of a cooled jet from a ceiling) is calculated.

To assure optimal conditions within the occupied zone the following results are presented:

- placement of the grilles;
- throw length of the jet;
- temperature difference at throw length;
- induction at throw length;

- pressure drop at the grille;
- sound power level of the grille;
- sound pressure level in space at 1.8 m.

SLOT AND DUCT DIFFUSERS

Various types of air supply are supported:

- cooling one sided with Coanda effect;
- cooling two sided with Coanda effect;
- cooling alternate sided with Coanda effect;
- cooling wall supply;
- heating vertical (discharge angle of 90°);
- heating two sided (discharge angle of 60°);
- heating alternate sided (discharge angle of 60°);
- heating wall supply.

Advanced calculations and modelling are used to obtain graphical presentation of the results (Figure 3). Air flow patterns are calculated on the basis of extensive measurements in the laboratory.

Point of separation for cooling (separation point of a cooled jet from a ceiling) and penetration distance for heating (maximum throw of the diffuser) are calculated.

To assure optimal conditions within the occupied zone the following results are presented:

- mean air velocity between the diffusers at the distance $H1$ for cooling;
- mean air velocity by the wall at the distance L for cooling;
- vertical throw of the diffuser for heating;
- temperature quotient between the diffusers;
- temperature quotient by the wall;
- pressure drop on the diffuser;
- sound power level of the diffuser;
- sound pressure level in space at 1.8 m.

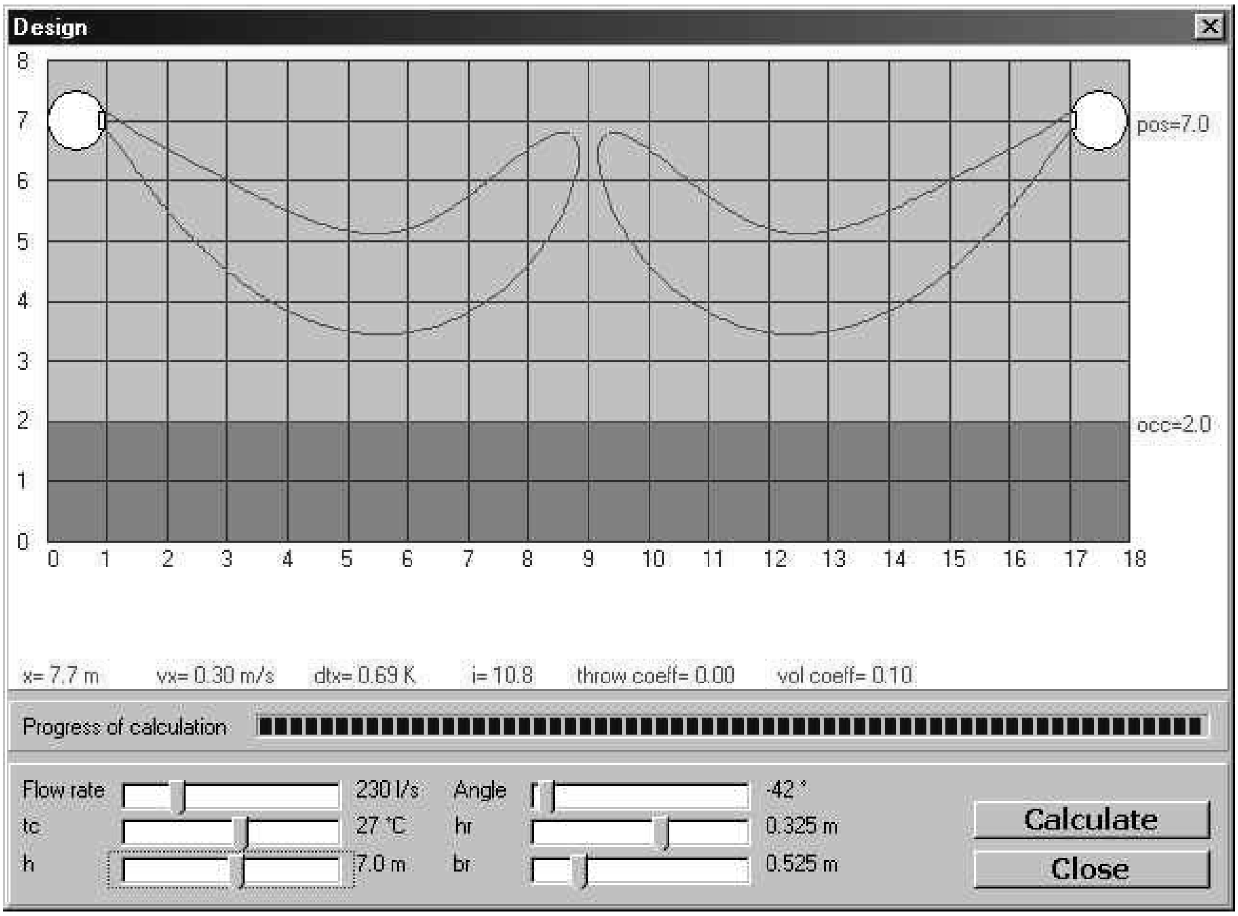

Figure 3 Results of the design criteria.