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Turbulence and draft

The turbulence of airflow has a significant impact on the sensation of draft

By P.O. Fanger, A.K. Melikov, H. Hanzawa, and J. Ring

Fellow ASHRAE

Draft is a serious problem in many ventilated or air-conditioned buildings. It also is a frequent nuisance in automobiles, trains and airplanes. Draft usually is defined as an unwanted local cooling of the human body caused by air movement. It is not sufficient that people feel thermally neutral as described, for instance, by the PMV-index (1,2). For sedentary people, an additional requirement to the air movement is needed to decrease the risk of draft.

It has for a long time been well-known that the risk of draft increases with increasing mean air velocity and decreasing air temperature. Fanger and Pendersen (3) recognized that the fluctuations of the velocity also contributed to the sensation of draft. And the air velocity does fluctuate in real rooms, a shown in *Figure 1.* The airflow is turbulent.

Velocity fluctuations may be characterized by the turbulence intensity, defined in *Figure 1.* Field studies (4,5) have identified turbulence intensity to be around 30 to 60 percent in spaces with traditional (mixed) ventilation. Fanger and Christensen (6) published a draft chart predicting the risk of draft as a function of mean velocity and temperature in such spaces. In rooms with displacement ventilation or in naturally ventilated rooms (7) the turbulence often may be lower. In the present investigation, the quantitative impact of turbulence intensity on the risk of draft was systematically studied. The research is described in detail in reference (8).

Experiments

An experiment with 75 male and 75 female subjects, dressed to obtain a neutral thermal sensation, participated in three experiments exposed to airflow with different levels of turbulence intensity (0-70 percent) and at air temperatures of 20-26°C (68-79°F). The turbulence intensity was varied by modification of the air distribution system in an environmental chamber, 450 experiments took place in the chamber. Each experiment lasted 2.5 hours and the sendentary subject was exposed to six mean air velocities ranging from 0.05 to 0.40 m/s (10-80 fpm). A flow direction from behind the subject was provided. The subject was asked whether and where air movement could be felt and whether or not it was uncomfortable.

Model of draft risk

The results showed that the turbulence intensity had a significant impact on the sensation of draft. Based on the results,

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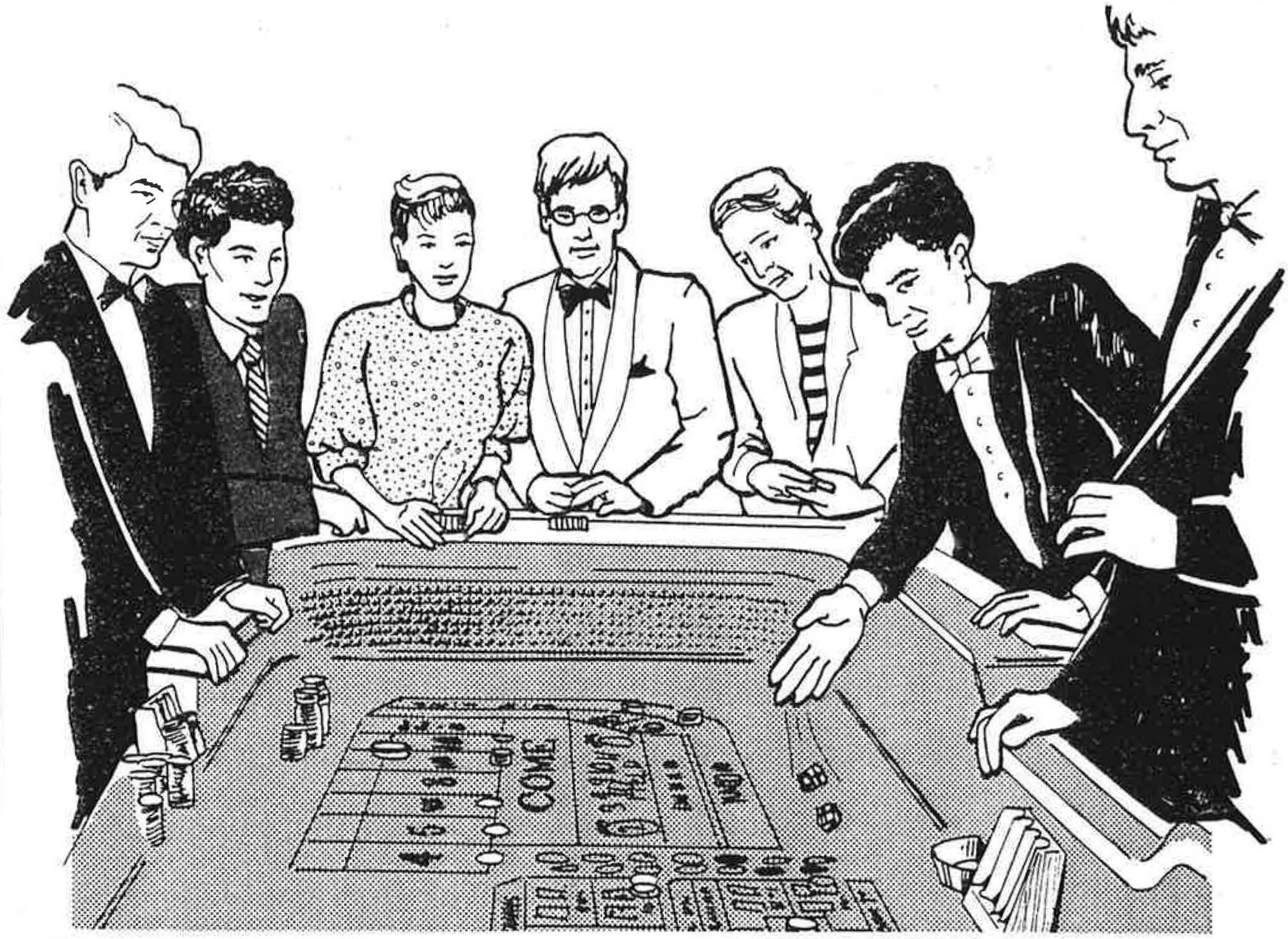

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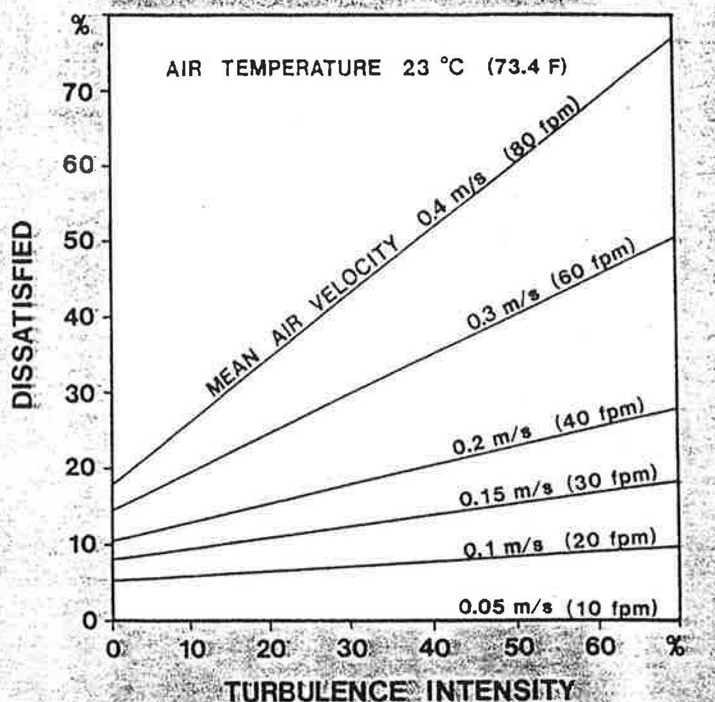

Figure 3. Percent dissatisfied as a function of turbulence intensity and mean air velocity calculated from the model of draft risk. The diagram applies for an air temperature of 23°C.

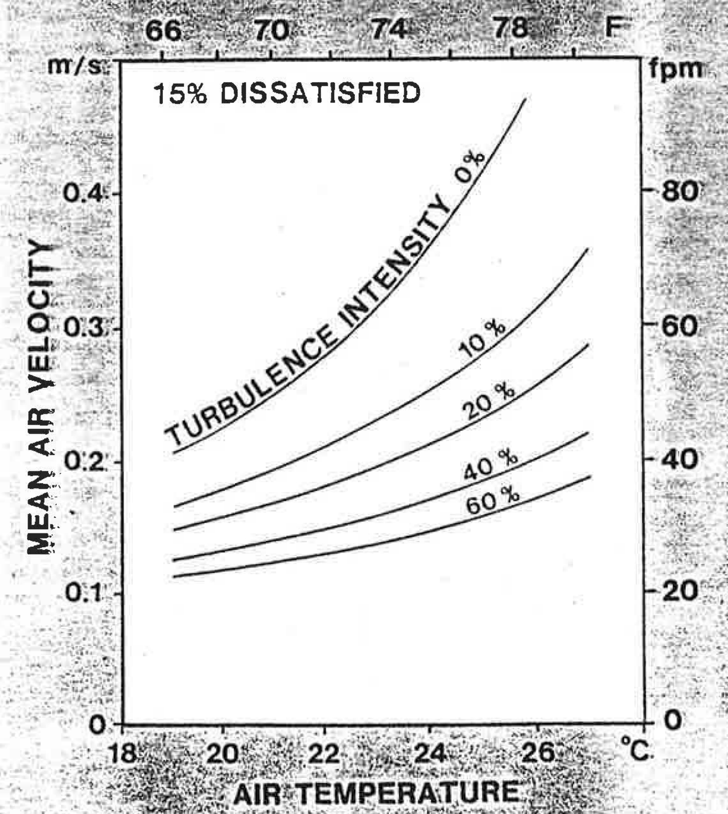

Figure 4. Combinations of mean air velocity, air temperature and turbulence intensity, which will cause 15 percent to be dissatisfied. Calculated from the model of draft risk.

space, although it may tend to overestimate the draft risk at arms and feet when these parts of the body are covered with clothing (e.g. long sleeves, trousers and socks).

For practical applications the model may be used to quantify the draft risk in existing spaces by measurements of mean air velocity, turbulence intensity and air temperature in the occupied zone of the space. The model may also estimate the draft risk from computer predictions of mean velocity, turbulence intensity and air temperature in ventilated spaces.

For rating the performance of air distribution systems in spaces the Air Diffusion performance Index (ADFI) has frequently been used (9,10). The new model offers an updated method of rating the performance of air distribution systems by predicting the draft risk. Systems should be compared at a fixed air temperature in the occupied zone, e.g. 22°C (72°F) at a given height above the floor. This use of the model should encourage future development of air distribution systems with a low draft risk.

Systems providing low turbulent airflow seem promising. This has already been utilized to a certain extent in displacement ventilation systems (12), where the supply air is introduced directly into the occupied zone from large outlets with low velocity and turbulence intensity.

The impact of turbulence intensity on draft sensation may explain many complaints occurring in practice, although the mean velocity and the air temperature may meet existing comfort standards (2,11). There seems to be a need to update these standards to include this new insight into the causes of draft. A standard may define a realistic acceptable percentage of dissatisfied due to draft, e.g. 15 percent. The model identifies then a limit for acceptable air movement as shown in *Figure 4*.

Conclusions

- The turbulence of an airflow has a significant impact on the sensation of draft.

- A mathematical model of draft risk has been developed, which predicts the percentage of people dissatisfied due to draft as a function of mean air velocity, turbulence intensity and air temperature. The model applies for sedentary persons.

- The model can be a useful tool for quantifying the draft risk in rooms by measuring the three previously mentioned physical parameters.

- The model provides a rational basis for revising the limits for air movement in existing thermal comfort standards.

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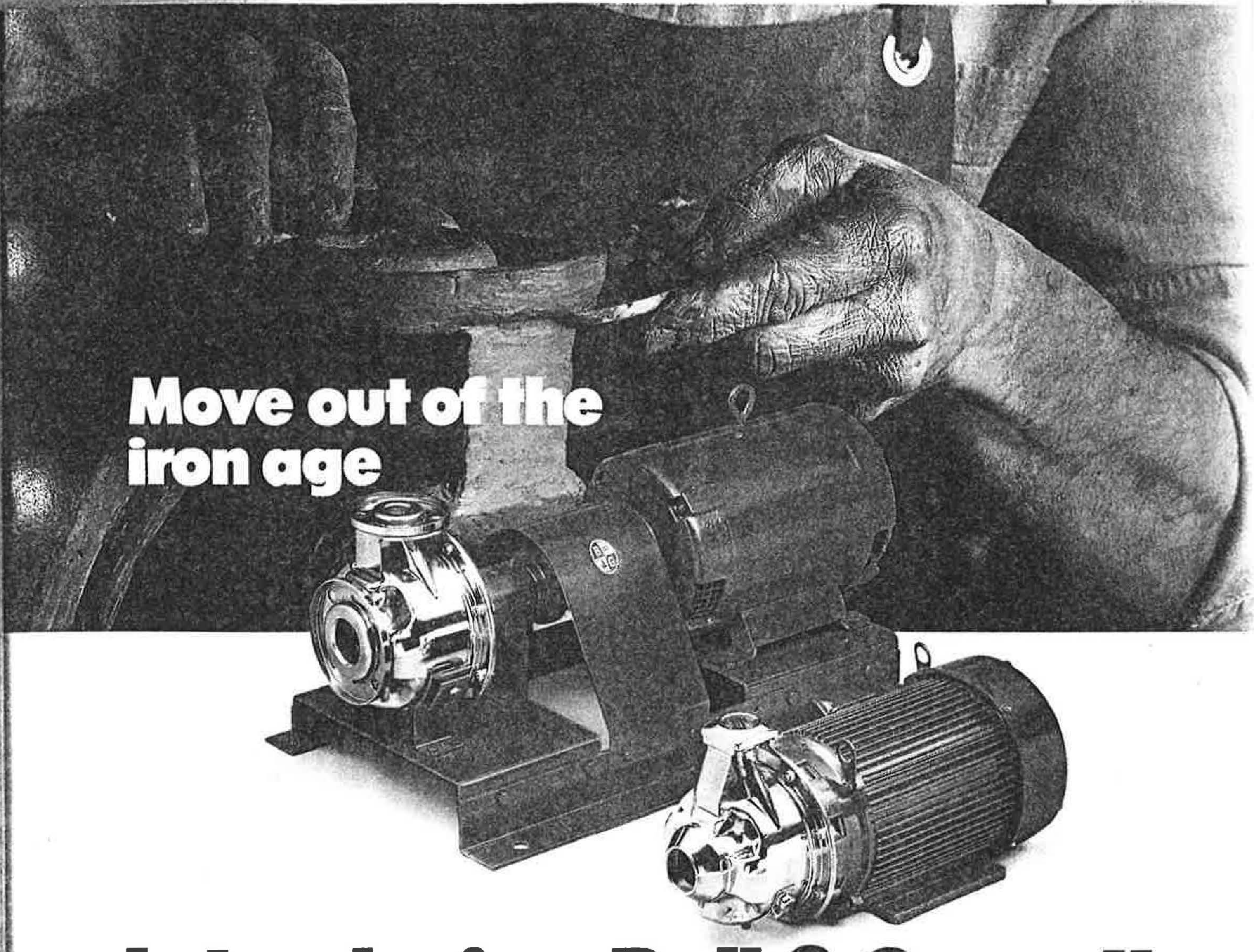

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Dr. P.O. Fanger, Fellow ASHRAE, is a professor at the Laboratory of Heating and Air Conditioning, Technical University of Denmark. He has been published extensively on the impact of the indoor environment on human beings and has received numerous international awards. He is president of SCANVAC, the federation of Scandinavian Heating, Air-Conditioning and Sanitary Engineers.

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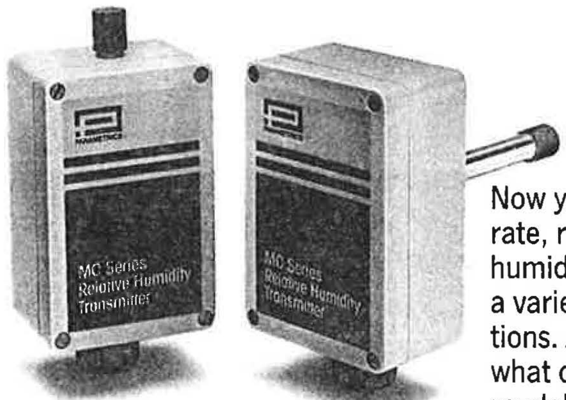

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