Effects of outdoor air supply rates on call handling performance in three call centers in the tropics

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Willem, H. C., Tham, K., Wargocki, P., Wyon, D. P., Fanger, P. O.
Number of pages: 202
Publication date: 2006

Host publication information
Title of host publication: Proceedings of Healthy Buildings 2006 : Lisboa, Portugal
Volume: A
Source: orbit
Source-ID: 189571
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2006 ›
Research › peer-review

Effects of outdoor air supply rates on subjective factors in three call centers in the Tropics (a principal component analysis approach)

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Willem, H. C., Tham, K. W., Wargocki, P., Wyon, D. P., Fanger, P. O.
Pages: 69-73
Publication date: 2006

Host publication information
Title of host publication: Proceedings of Healthy Buildings 2006 : Lisboa, Portugal
Volume: I
Source: orbit
Source-ID: 189570
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2006 ›
Research › peer-review

Experimental determination of the limiting criteria for human exposure to low winter humidity indoors (RP-1160)

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Wyon, D. P., Fang, L., Lagercrantz, L. P., Fanger, P. O.
Pages: 201-213
Publication date: 2006
Peer-reviewed: Yes

Publication information
Journal: H V A C & R Research
Volume: 12
Issue number: 2
ISSN (Print): 2374-4731
Ratings:
Scopus rating (2006): SJR 0.843 SNIP 1.29
Web of Science (2006): Indexed yes
Original language: English
Source: orbit
Source-ID: 193810
Research output: Contribution to journal › Journal article – Annual report year: 2006 › Research › peer-review

Human response to five designs of personalized ventilation

General information
Publication status: Published
Influence of ozone-limonene reactions on perceived air quality,

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Tamas, G., Weschler, C. J., Toftum, J., Fanger, P. O.
Pages: 168-178
Publication date: 2006
Peer-reviewed: Yes

Publication information
Journal: Indoor Air
Volume: 16
Issue number: 3
ISSN (Print): 0905-6947
Ratings:
Scopus rating (2006): SJR 0.635 SNIP 2.515
Web of Science (2006): Indexed yes
Original language: English
Source: orbit
Source-ID: 193805
Research output: Contribution to journal › Journal article – Annual report year: 2006 › Research › peer-review

The impact of sorption on perceived indoor air quality

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering, Concordia University
Contributors: Sakr, W., Weschler, C. J., Fanger, P. O.
Pages: 98-110
Publication date: 2006
Peer-reviewed: Yes

Publication information
Journal: Indoor Air
Volume: 16
Issue number: 2
ISSN (Print): 0905-6947
Ratings:
Scopus rating (2006): SJR 0.635 SNIP 2.515
Web of Science (2006): Indexed yes
Original language: English
Source: orbit
Source-ID: 193806
Research output: Contribution to journal › Journal article – Annual report year: 2006 › Research › peer-review
Thermal sensation and thermophysiological responses with metabolic step-changes

This study investigated the effect on thermal perception and thermophysiological variables of controlled metabolic excursions of various intensities and durations. Twenty-four subjects alternately were seated on a chair or exercised by walking on a treadmill at a temperature predicted to be neutral at sedentary activity. In a second experimental series, subjects alternated between rest and exercise as well as between exercise at different intensities at two temperature levels. Measurements comprised skin and oesophageal temperatures, heart rate and subjective responses. Thermal sensation started to rise or decline immediately (within one minute) after a change of activity, which means that even moderate activity changes of short duration affect thermal perceptions of humans. After approximately 15-20 min under constant activity subjective thermal responses approximated the steady-state response. The sensitivity of thermal sensation to changes in core temperature was higher for activity down-steps than for up-steps. A model was proposed that estimates transient thermal sensation after metabolic step-changes. Based on predictions by the model, weighting factors were suggested to estimate a representative average metabolic rate with varying activity levels, e.g. for the prediction of thermal sensation by steady-state comfort models. The activity during the most recent 5 min should be weighted 65%, during the prior 10-5 min 25% and during the prior 20-10 min 10%.

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Goto, T., Toftum, J., deDear, R., Fanger, P. O.
Pages: 323-332
Publication date: 2006
Peer-reviewed: Yes

Publication information
Journal: International Journal of Biometeorology
Volume: 50
Issue number: 5
ISSN (Print): 0020-7128
Ratings:
Scopus rating (2006): SJR 0.664 SNIP 1.108
Web of Science (2006): Indexed yes
Original language: English
Source: orbit
Source-ID: 194152
Research output: Contribution to journal › Journal article – Annual report year: 2006 › Research › peer-review

What is IAQ?
In spaces for human occupancy indoor air quality (IAQ) is often defined as the extent to which human requirements are met. But what requirements do people have in relation to indoor air? The desire is that the air be perceived as fresh and pleasant, that it has no negative impact on their health, and that the air is stimulating and promotes their work, i.e. it increases their productivity and the learning of their children in the classroom at school. Present ventilation standards and guidelines do not care about productivity and learning and have the very modest requirement that the indoor air shall be 'acceptable,' meaning that the most sensitive group of persons (usually 20%) perceive the air as unacceptable while the remaining less sensitive persons may find the air barely acceptable. With such a modest aim it is not surprising that comprehensive field studies in many countries in buildings in which ventilation standards are met show high percentages of dissatisfied persons and of those suffering from sick building syndrome symptoms. Recent studies show that improvement of IAQ by a factor of 2-7 compared with existing standards increases office productivity and school learning significantly, while decreasing the risk of allergic symptoms and asthma in homes. To make indoor air acceptable, even for the most sensitive persons, an improvement of 1-2 orders of magnitude may be required. The paper will discuss the development of new methods that can provide such substantial improvements of IAQ while maintaining or even decreasing ventilation and energy usage. A paradigm shift is required and further future shifts are foreseen where we learn how to make indoor air equally fresh and pleasant as outdoors when it is best. Or even better, i.e. "out of this world.'

General information
Publication status: Published
Organisations: Department of Mechanical Engineering
Contributors: Fanger, P. O.
Pages: 328-334
Publication date: 2006
Peer-reviewed: Yes

Publication information
Journal: Indoor Air
Cerebral blood flow, fatigue, mental effort and task performance in an office with two different pollution loads

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering, Waseda University
Contributors: Nishihara, N., Wargocki, P., Wyon, D., Fanger, P. O., Tanabe, S.
Pages: 377-382
Publication date: 2005

Host publication information
Title of host publication: Proceedings of Indoor Air 2005, The 10th International Conference on Indoor Air Quality and Climate, Beijing, China
Volume: 1
Source: orbit
Source-ID: 184917
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2005 › Research › peer-review

Effects of indoor pollution sources and ventilation rate on ozone’s surface removal rate and the occurrence of oxygenated VOCs in an office space

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Pages: 2320-2324
Publication date: 2005

Host publication information
Title of host publication: Proceedings of Indoor Air 2005
Volume: Volume 2
Source: orbit
Source-ID: 184940
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2005 › Research › peer-review

Effects of indoor pollution sources and ventilation rate on ozone surface removal rate and the occurrence of oxygenated VOCs in an office space

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Pages: 2320-2324
Publication date: 2005

Host publication information
Title of host publication: Proceedings of Indoor Air 2005, The 10th International Conference on Indoor Air Quality and Climate, Beijing, China
Volume: II/2
Source: orbit
Experimental investigation of the air cleaning effect of a desiccant dehumidifier on perceived air quality

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Fang, L., Zhang, G., Fanger, P. O.
Pages: 2976-2980
Publication date: 2005

Host publication information
Title of host publication: Proceedings of Indoor Air 2005
Volume: Volume 4
Source: orbit
Source-ID: 184945

Findings of personalized ventilation studies in a hot and humid climate

General information
Publication status: Published
Organisations: Department of Mechanical Engineering, Indoor Environment
Contributors: Sekhar, S., Gong, N., Tham, K. W., Cheong, K., Melikov, A. K., Wyon, D., Fanger, P. O.
Pages: 603-620
Publication date: 2005
Peer-reviewed: Yes

Publication information
Volume: 11
Issue number: 4
Original language: English
Source: orbit
Source-ID: 188802

Improve indoor air and energy

General information
Publication status: Published
Organisations: Department of Mechanical Engineering, Indoor Environment
Contributors: Fanger, P. O.
Pages: 27-27
Publication date: 2005

Host publication information
Title of host publication: Proceedings of International Conference “Energy Efficient Technologies in Indoor Environment” : Book of Abstracts
Source: orbit
Source-ID: 184981

Improving human health, productivity and learning by upgrading indoor air quality

General information
Publication status: Published
Organisations: Department of Mechanical Engineering, Indoor Environment
Contributors: Fanger, P. O.
Improving human productivity, learning and health by upgrading indoor air quality

General information
Publication status: Published
Organisations: Department of Mechanical Engineering, Indoor Environment
Contributors: Fanger, P. O.
Publication date: 2005

Host publication information
Title of host publication: Proceedings of Third International Conference Healthy Buildings
Source: orbit
Source-ID: 184977
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 2005

Influence of ozone-limonene reactions on perceived air quality

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Tamás, G., Weschler, C. J., Toftum, J., Fanger, P. O.
Pages: 448-492
Publication date: 2005

Host publication information
Title of host publication: Proceedings of James H. (Jimmy) Belfer Memorial Symposium on Control of the Indoor Air Quality for Improving Human Well-being, Comfort and Productivity
Source: orbit
Source-ID: 184984
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 2005

Poor indoor air quality slows down metabolic rate of office workers

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Bako-Biro, Z., Wargocki, P., Wyon, D., Fanger, P. O.
Pages: 76-80
Publication date: 2005

Host publication information
Title of host publication: Proceedings of Indoor Air 2005, The 10th International Conference on Indoor Air Quality and Climate, Beijing, China
Volume: I/1
Source: orbit
Source-ID: 184914
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 2005

What is IAQ?
In spaces for human occupancy indoor air quality (IAQ) is often defined as the extent to which human requirements are met. But what requirements do people have in relation to indoor air? The desire is that the air be perceived as fresh and pleasant, that it has no negative impact on their health, and that the air is stimulating and promotes their work, i.e., it increases their productivity and the learning of their children in the classroom at school. Present ventilation standards and guidelines do not care about productivity and learning and have the very modest requirement that the indoor air shall be acceptable, meaning that the most sensitive group of persons (usually 20%) perceive the air as unacceptable while the remaining less sensitive persons may find the air barely acceptable. With such a modest ambition it is not surprising that comprehensive field studies in many countries in buildings where ventilation standards are met show high percentages of dissatisfied persons and of those suffering from SBS symptoms. Recent studies show that improvement of IAQ by a factor of 2-7 compared to existing standards increases office productivity and school learning significantly, while decreasing the risk of allergic symptoms and asthma in homes. To make indoor air acceptable, even for the most sensitive persons, an improvement of 1-2 orders of magnitude is required. The paper will discuss the development of new methods that can provide such substantial improvements of IAQ while maintaining or even decreasing ventilation and energy usage. A paradigm shift is required and further shifts are foreseen where we learn how to make indoor air equally fresh and pleasant as outdoors when it is best. Or even better, i.e. out of this world.
Effects of air pollutants on the carbon dioxide (CO2) emission rate of human subjects

Several laboratory studies have shown the negative effects of emissions from typical indoor pollution sources on perceived air quality, SBS symptoms and the performance of office work. The subjects performed typical office tasks at their own pace while they were exposed for several hours to different air quality conditions. A re-analysis of the CO2 measurements obtained in two independent studies showed that human CO2 emission rates were affected by air quality.

Effects of pollution from personal computers on perceived air quality, SBS symptoms and productivity in offices

How to make indoor air quality one hundred times better while saving energy
Human response to personalized ventilation and mixing ventilation

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Kaczmarczyk, J., Melikov, A. K., Fanger, P. O.
Pages: 17-29
Publication date: 2004
Peer-reviewed: Yes

Publication information
Journal: Indoor Air
Volume: 14
Issue number: Suppl. 8
ISSN (Print): 0905-6947
Ratings:
Web of Science (2004): Indexed yes
Original language: English
Source: orbit
Source-ID: 155873
Research output: Contribution to journal › Journal article – Annual report year: 2004 › Research › peer-review

Impact of indoor air temperature and humidity in an office on perceived air quality, SBS symptoms and performance

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Fang, L., Wyon, D., Clausen, G., Fanger, P. O.
Pages: 74-81
Publication date: 2004
Peer-reviewed: Yes

Publication information
Journal: Indoor Air
Volume: 14
Issue number: Suppl. 7
ISSN (Print): 0905-6947
Ratings:
Web of Science (2004): Indexed yes
Original language: English
Source: orbit
Source-ID: 155876
Research output: Contribution to journal › Journal article – Annual report year: 2004 › Research › peer-review

New indoor environment chambers and field experiment offices for research on human comfort, health and productivity

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Toftum, J., Langkilde, G., Fanger, P. O.
Pages: 899-903
Publication date: 2004
Peer-reviewed: Yes

Publication information
Journal: Energy and Buildings
One hundred times better indoor air quality

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Fanger, P. O.
Pages: 385-394
Publication date: 2004

Sensory pollution loads in six office buildings and a department store

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Wargocki, P., Fanger, P. O., Krupicz, P., Szczecinski, A.
Pages: 995-1001
Publication date: 2004
Peer-reviewed: Yes

The performance and subjective responses of call-center operators with new and used supply air filters at two outdoor air supply rates

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Wargocki, P., Wyon, D., Fanger, P. O.
Pages: 7-16
Publication date: 2004
Peer-reviewed: Yes
The potential to improve indoor air quality one hundred times while saving energy

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Fanger, P. O.
Pages: 7-18
Publication date: 2004

Host publication information
Title of host publication: Procedings of Installations for Constructions and the Surrounding Comfort
Place of publication: Timisoara, Romania
Publisher: Editura Politehnica
Editors: Retezan, A., Sarbuy, I., Borza, I., Cinca, M.
Source: orbit
Source-ID: 155828

Thermal sensation and comfort with five different air terminal devices for personalized ventilation

Occupants' response to individual control of the airflow rate, the direction of the airflow and the positioning of a Personalized Ventilation System (PVS) was studied. Thirty human subjects participated in 3 h 45 min experiments performed in an office set-up with installed mixing ventilation and the PVS. Six desks, each equipped with a PVS, were placed in the office. The PVS allowed each occupant to select his/her preferred position of the air terminal device (ATD), the direction of the air supplied and its flow rate (up to 15 L/s.person). The airflow rate from each PVS was measured and recorded for the whole duration of the experiment. The positioning of the ATD was registered as well. Subjects were exposed to four experimental conditions: PVS supplying outdoor air at: (1) 20°C; (2) 23°C; (3) PVS supplying re-circulated room air; and (4) mixing ventilation, without PVS. The room temperature was kept constant at 23°C and relative humidity at 30%. A total supply of 90 L/s outdoor air was maintained with PVS and mixing ventilation or only with mixing ventilation. Air quality in the low-polluting office space was decreased by a 20-year-old used carpet that was placed behind a screen, so that subjects could not see it. During exposures, subjects performed typical office work. Several times during the experiment they answered questions regarding air quality and SBS symptoms, thermal sensation, draught risk, and reported changes made in the PVS. Results showed that all participants actively made use of the facility provided to control the airflow rate and the position and direction of the ATD. The preferred airflow rate varied from 3 L/s to 15 L/s.person. It was observed that over time, participants tended to change the position of the ATD less frequently. Analysis of the positioning at the end of each experiment revealed that almost one third of the participants chose the same position, but typical for each individual, at least at two out of three experimental conditions with PVS.

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Kaczmarczyk, J., Melikov, A. K., Bolashikov, Z., Nikolaev, L., Fanger, P. O.
Publication date: 2004
Peer-reviewed: No
Event: Abstract from Manuel Carlos Gameiro da Silva Roomvent2004, Coimbra, Portugal,
Source: orbit
Source-ID: 155744
Research output: Contribution to conference – Conference abstract for conference – Annual report year: 2004 – Research – peer-review

Transient thermal sensation and comfort resulting from adjustment of clothing insulation

General information
Publication status: Published
Organisations: Department of Mechanical Engineering, Indoor Environment
Contributors: Goto, T., Toftum, J., Fanger, P. O., Yoshino, H.
Chemical emission rates from personal computers

Chemical emission measurements from different brands of personal computers (PCs) were conducted in a 1 m³ glass chamber. Eight PCs were tested individually. Each consisted of the same brand of PC tower and one of the 4 different brands of PC monitors. Within each brand both cathode-ray tube (CRT) and thin-film transistor (TFT) flat panel monitors were evaluated. Volatile organic compounds (VOCs) and aldehydes were quantified using GC/MS and HPLC, respectively. Compared with PCs with TFT monitors, PCs with CRT monitors had slightly higher emission rates of formaldehyde and acetaldehyde, emitted greater quantities of C₃-C₆ aldehydes having low odor thresholds and had higher emissions of aromatic hydrocarbons. Emission rates of aliphatic hydrocarbons were low for both PCs with CRT and TFT monitors. However, estimated concentrations of these chemicals in a normal office space based on the measured emission rates were much lower than the odour thresholds.

Energy efficiency potential of personalized ventilation system in the tropics

The aim of this study was to evaluate the present ASHRAE Standard 55-92 draft criteria and to describe how air movement is perceived at thermal sensations slightly cooler and slightly warmer than neutral. At temperatures 18°C, 20°C, 23°C, 26°C, and 28°C (64.4°F, 68°F, 73.4°F, 78.8°F, and 82.4°F), 40 subjects at slightly cool, neutral and slightly warm overall thermal sensation were exposed to air velocities that were increased step-by-step from less than 0.1 m/s to 0.8 m/s (19.7 fpm to 157.5 fpm). Subjects who felt cool or slightly cool perceived air movement as being uncomfortable at lower air velocities than did subjects feeling neutral or warmer. No difference in draft sensitivity between subjects feeling neutral, slightly warm or warm was observed. A smaller percentage of subjects were dissatisfied due to draft than
prescribed by ASHRAE Standard 55 guidelines on air movement. The discrepancy could be explained by the effect of thermal sensation and activity level on draft sensitivity. Permissible mean air velocities as recommended by the standard thus provide a conservative upper limit for air velocity that protects occupants who are sensitive to air movement, occupants who feel cooler than neutral or occupants who are occupied mostly with sedentary work. To accommodate all occupants in a given indoor environment, it is therefore recommended that air movement generated by the HVAC system be designed according to the criteria in the current Standard 55 to minimize complaints of draft. To provide comfort for occupants who prefer more air movement, local air movement under individual control is easy to generate, e.g. by a desk fan.

General information
Publication status: Published
Organisations: Department of Mechanical Engineering
Contributors: Toftum, J., Melikov, A. K., Tynel, A., Bruzda, M., Fanger, P. O.
Pages: 187-202
Publication date: 2003
Peer-reviewed: Yes

Publication information
Volume: 9
Issue number: 2
ISSN (Print): 2374-4731
Ratings:
Scopus rating (2003): SJR 1.055 SNIP 1.28
Web of Science (2003): Indexed yes
Original language: English
Source: orbit
Source-ID: 25508
Research output: Contribution to journal › Journal article – Annual report year: 2003 › Research › peer-review

Indoor air quality in cold climates

General information
Publication status: Published
Organisations: Department of Mechanical Engineering
Contributors: Fanger, P. O., Hanssen, S. O. (ed.)
Publication date: 2003

Host publication information
Title of host publication: Proceedings of 4th International Conference on Cold Climate
Place of publication: Trondheim
Publisher: CC HVAC 2003
Source: orbit
Source-ID: 25626
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2003 › Research › peer-review

Low winter humidity indoors has a negative effect on the performance of offic

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Wyon, D., Fang, L., Fanger, P. O.
Publication date: 2003

Host publication information
Title of host publication: Proceedings of the 4th International conference on Cold Climate HVAC
Volume: CD-Rom
Place of publication: Trondheim
Publisher: SINTEF
Source: orbit
Source-ID: 155809
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2004 › Research › peer-review
New air terminal devices with high efficiency for personalized ventilation application

Two air terminal devices (ATD) for personalized ventilation (PV) were developed: Round Movable Panel (RMP) and Headset-Incorporated Supply (Headset). The performance of the ATDs was tested at three combinations of room air temperature and supply personalized air temperature: 23/23°C, 23/20°C and 26/20°C respectively, and at different flow rates of personalized air, ranging from 5 to 15 L/s for RMP and 0.18 to 0.5 L/s for Headset. A breathing thermal manikin was used to evaluate the inhaled air quality achieved with the developed ATDs as well as the performance in regard to thermal comfort. The results revealed that inhaled air consisting of 100% personalized air was achieved with the RMP and up to 80% with the Headset. The change in room temperature that would have affected whole-body heat loss equivalently, ranged from less than 0.5 K to 2.2 K for RMP and almost 0 K for the Headset.

General information
Publication status: Published
Organisations: Department of Mechanical Engineering
Contributors: Bolashikov, Z., Nikolaev, L., Melikov, A. K., Kaczmarczyk, J., Fanger, P. O.
Pages: 850-855
Publication date: 2003

Host publication information
Title of host publication: Proceedings of Healthy Buildings 2003
Place of publication: Department of Buildings
Publisher: NUS Press
Source-ID: 25655

Personalized ventilation: air terminal devices with high efficiency

General information
Publication status: Published
Organisations: Department of Mechanical Engineering
Contributors: Bolashikov, Z. D., Nikolaev, L., Melikov, A. K., Kaczmarczyk, J., Fanger, P. O.
Pages: 850-855
Publication date: 2003

Host publication information
Title of host publication: Proceedings of Healthy Buildings 2003
Place of publication: Singapore
Publisher: Healthy Buildings 2003
Source-ID: 25670

Preliminary findings of a pilot study of personalized ventilation in a hot and humid climate

General information
Publication status: Published
Organisations: Department of Mechanical Engineering
Contributors: Sekhar, S., Nan, G., Maheswaran, C., Tham, K. W., Melikov, A. K., Fanger, P. O.
Pages: 825-830
Publication date: 2003

Host publication information
Title of host publication: Proceedings of Healthy Buildings 2003
Place of publication: Singapore
Publisher: Healthy Buildings 2003
Source-ID: 25668
Providing indoor air for human health, comfort and productivity

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Fanger, P. O.
Pages: 31-44
Publication date: 2003

Host publication information
Title of host publication: Proceedings of Healthy Buildings
Place of publication: Sofia, Bulgaria
Publisher: Technical University of Sofia
Editor: Stankov, P.
Source: orbit
Source-ID: 155804
Research output: Chapter in Book/Report/Conference proceeding > Article in proceedings – Annual report year: 2004 > Research > peer-review

Sensory emission rates from personal computers and television sets
Sensory emissions from personal computers (PCs), PC monitors + PC towers, and television sets (TVs) having been in operation for 50, 400 and 600 h were assessed by a panel of 48 subjects. One brand of PC tower and four brands of PC monitors were tested. Within each brand, cathode-ray tube (CRT) and thin-flat-transistor (TFT) monitors were selected. Two brands of TVs were tested. All brands are prevalent on the world market. The assessments were conducted in low-polluting 40 m³ test offices ventilated with a constant outdoor air change rate of 1.3 ± 0.2 h⁻¹ corresponding to 7 L/s per PC or TV with two units placed at a time in the test offices; air temperature was controlled at 22 ± 0.1°C and relative humidity at 41 ± 0.5%. The subjects entered the offices individually and immediately assessed the air quality. They did not see the PCs or TVs that were placed behind a screen and were in operation. The average sensory emission rate for PCs with CRT monitors was 2.7 ± 1.7 olf/PC after 50 h of operation. It decreased to 1.4 ± 1.2 olf/PC when the operation time was 600 h, suggesting a half-life equal to 4 months of normal use. The sensory emission rates for PCs with TFT monitors were negligible. The average sensory emission rate for TVs was 1 ± 0.6 olf/TV after 50 h of operation. It decreased to 1.4 ± 1.2 olf/PC when the operation time was 600 h, suggesting a half-life equal to 4 months of normal use. The sensory emission rates for PCs with TFT monitors were negligible.

General information
Publication status: Published
Organisations: Department of Mechanical Engineering, Warsaw University of Technology, Waseda University, Technical University of Denmark
Pages: 169-175
Publication date: 2003

Host publication information
Title of host publication: Healthy Buildings 2003 : Proceedings of the 7th International Conference
Volume: Vol. 3
Place of publication: Singapore
Publisher: University of Singapore
Keywords: Perceived air quality, Sensory, Emissions, Personal computers, Electronic equipment
Source: orbit
Source-ID: 25700
Research output: Chapter in Book/Report/Conference proceeding > Article in proceedings – Annual report year: 2003 > Research > peer-review

Sick building syndrome symptoms caused by low humidity

General information
Publication status: Published
Organisations: Department of Mechanical Engineering
Contributors: Fang, L., Wyon, D., Fanger, P. O.
Pages: 1-6
Publication date: 2003

Host publication information
Title of host publication: Proceedings of Healthy Buildings 2003
The impact of a personalized ventilation system on indoor air quality at different levels of room air temperature

General information
Publication status: Published
Organisations: Department of Mechanical Engineering
Contributors: Yang, J., Kaczmarsczyk, J., Melikov, A. K., Fanger, P. O.
Pages: 345-350
Publication date: 2003

Host publication information
Title of host publication: Healthy Buildings 2003
Volume: 2
Place of publication: Singapore
Publisher: Healthy Buildings 2003
Source-ID: 25689
Research output: Chapter in Book/Report/Conference proceeding

Transient thermal sensation and comfort resulting from adjustment of clothing insulation
This study investigated the transient effects on human thermal responses of clothing adjustments. Two different levels of activity were tested, and the temperature was set to result in a warm or cool thermal sensation at each activity level. The subjects (12 females and 12 males) wore identical uniforms and were asked to take off or don a part of the uniform after they had adapted to the experimental conditions for more than 20 minutes. The results showed that the thermal sensation votes responded immediately to the adjustment of clothing insulation and reached a new steady-state level within 5 minutes after both an increase and a decrease of clothing insulation, independent of the activity level.

General information
Publication status: Published
Organisations: Department of Mechanical Engineering, Indoor Environment
Contributors: Goto, T., Toftum, J., Fanger, P. O., Yoshino, H.
Pages: 835-840
Publication date: 2003

Host publication information
Title of host publication: Proceedings of Healthy Buildings 2003
Place of publication: Singapore
Publisher: NUS Press
Source-ID: 155847
Research output: Chapter in Book/Report/Conference proceeding

Ventilation for health, comfort and productivity

General information
Publication status: Published
Organisations: Department of Mechanical Engineering
Contributors: Fanger, P. O.
Pages: 1-7
Publication date: 2003

Host publication information
Title of host publication: Proceedings of 4th International Symposium on HVAC
Place of publication: Beijing
Publisher: Tsinghua University Press
Air quality in a simulated office environment as a result of reducing pollution sources and increasing ventilation

Air quality was studied in an office space classified as low-polluting and ventilated with outdoor air at a rate of 1 h\(^{-1}\). The pollution load in the space was changed by introducing or removing common building-related indoor pollution sources (linoleum, sealant and wooden shelves with books and paper documents) so that the space could no longer be classified as low-polluting. The outdoor air supply rate in the office was altered from 1 to 3 h\(^{-1}\) (0.83 and 2.5 l/s per m\(^2\) floor, respectively) when sources were present and absent. Air temperature of 23 deg.C, relative humidity of 50\% and noise level of 35 dB(A) remained unchanged. Under each of the four conditions of air quality in the office, concentrations of volatile organic compounds (VOCs) were measured and perceived air quality was assessed by a panel of 30 female subjects. Removing the sources reduced the chemical and sensory pollution load in the office, and increasing the outdoor air supply rate decreased concentrations of many VOCs, including those emitted by building materials and furnishing, and human bioeffluents. The perceived air quality in the office was consequently improved. The improvement in air quality obtained by removing the sources was similar to that obtained by increasing the outdoor air supply rate. The study, thus, confirmed that the systematic use of low-polluting building materials will lead to improved air quality.

Call-centre occupant response to new and used filters at two outdoor air supply rates

A 2x2 replicated field intervention experiment was conducted in a call-centre providing a public telephone directory service: outdoor air supply rate was 8% or 80% of the total airflow of 430 L/s providing 3.5 h\(^{-1}\); and the supply air filters were either new or used (i.e. used in place for 6 months). Each of these 4 conditions was maintained for a full working week at a time. Room temperature and humidity averaged 24 deg.C and 27% RH. The 26 operators were blind to conditions and assessed perceived air quality (PAQ), the intensity of Sick Building Syndrome (SBS) symptoms and self-estimated performance. Increasing the outdoor air supply rate with a new filter in place significantly alleviated many symptoms, as did changing from used to new supply air filters at the low outdoor air supply rate, but filter condition made little difference at the high outdoor air supply rate.

Comparison between full- and small-scale sensory assessments of air quality

Thirty-nine untrained subjects made small- and full-scale evaluations of the acceptability of the quality of air at 22 deg.C and 40\% RH, polluted by either carpet, felt floor covering, painted gypsum board, linoleum or chipboard. Small-scale evaluations were made on the air extracted from 200-L glass chambers ventilated at an airflow of 0.9 L/s. Full-scale
assessments were made immediately upon entering offices ventilated at an outdoor air supply rate of 1.9 h⁻¹. The ratio of ventilation rate to surface area of a building material was identical in the chambers and in the offices. Full-scale sensory ratings of acceptability of air polluted by carpet and by linoleum were systematically better than small-scale assessments, but not for the other three materials. Calculated sensory emission rates from carpet and linoleum were significantly lower in full scale than in small scale. When modelling the perceived air quality in spaces, sensory emission rates estimated in small scale may require a correction, probably depending on the nature of the chemicals emitted by a building material.

Cost-benefit analysis of improved air quality in an office building
A cost-benefit analysis of measures to improve air quality in an existing air-conditioned office building (11581 m², 864 employees) was carried out for hot, temperate and cold climates and for two operating modes: Variable Air Volume (VAV) with economizer; and Constant Air Volume (CAV) with heat recovery. The annual energy cost and first cost of the HVAC system were calculated using DOE 2.1E for different levels of air quality (10-50% dissatisfied). This was achieved by changing the outdoor air supply rate and the pollution loads. Previous studies have documented a 1.1% increase in office productivity for every 10% reduction in the proportion of occupants entering a space who are dissatisfied with the air quality. With this assumption, the annual benefit due to improved air quality was always at least 10 times higher than the increase in annual energy and maintenance costs. The payback time of the HVAC first costs involved in improving the air quality was always less than 4 months.

Extension of the PMV model to non-air-conditioned building in warm climates
The PMV model agrees well with high-quality field studies in buildings with HVAC systems, situated in cold, temperate and warm climates, studied during both summer and winter. In non-air-conditioned buildings in warm climates, occupants may sense the warmth as being less severe than the PMV predicts. The main reason is low expectations, but a metabolic rate that is estimated too high can also contribute to explaining the difference. An extension of the PMV model that includes an expectancy factor is introduced for use in non-air-conditioned buildings in warm climates. The extended PMV model agrees well with quality field studies in non-air-conditioned buildings of three continents.
Human preference for air movement

Human preference for air movement was studied at slightly cool, neutral, and slightly warm overall thermal sensations and at temperatures ranging from 18 deg.C to 28 deg.C. Air movement preference depended on both thermal sensation and temperature, but large inter-individual differences existed between subjects. Preference for less air movement was linearly correlated with draught discomfort, but the percentage of subjects who felt draught was lower than the percentage who preferred less air movement.

Human requirements in future air-conditioned environments

Air-conditioning of buildings has played a very positive role for economic development in warm climates. Still its image is globally mixed. Field studies demonstrate that there are substantial numbers of dissatisfied people in many buildings, among them those suffering from SBS symptoms, even though existing standards and guidelines are met. A paradigm shift from rather mediocre to excellent indoor environments is foreseen in buildings in the 21st century. Based on existing information and on new research results, five principles are suggested as elements behind a new philosophy of excellence in the built environment: better indoor air quality increases productivity and decreases SBS symptoms; unnecessary indoor pollution sources should be avoided; the air should be served cool and dry to the occupants; personalized ventilation, i.e. small amounts of clean air, should be provided gently, close to the breathing zone of each individual; individual control of the airflow and/or the thermal environment should be provided. These principles of excellence should be combined with energy efficiency and sustainability of future buildings.
Impact of personalized ventilation on human response: comparison between constant and fluctuating airflows under warm condition

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Contributors: Yang, J., Melikov, A. K., Fanger, P. O., Li, X., Yan, Q.
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Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2002 › Research › peer-review

Increased office productivity through improved indoor air quality
Control of indoor pollution sources and ventilation are both means of improving indoor air quality. Three independent experiments have recently documented that removing a pollution source or increasing the ventilation rate will improve perceived air quality, reduce the intensity of several Sick Building Syndrome (SBS) symptoms and improve the productivity of office workers. In these experiments, the performance of simulated office work (text typing, addition and proof-reading, all typical office tasks requiring concentration) improved monotonically as the proportion of persons dissatisfied with the air quality was reduced by either measure. The quantitative relationship was 1.1% change in performance per 10% dissatisfied, in the range 25-70% dissatisfied, or 0.5% change in performance per 1 decipol (dp), in the range 2-13 dp. Significant improvements in performance occurred only when the intensity of general SBS symptoms such as headache and difficulty in thinking clearly were significantly reduced, which implies that this was the mechanism of causation. The performance of simulated office work increased monotonically with decreasing pollution load by a 1.6% increase in performance for each twofold decrease of pollution load in the range 0.3-2 off/m²floor, and with increasing outdoor air supply rate by a 1.8% increase in performance for each twofold increase in the outdoor air supply rate in the range 0.8-5.3 L/s per off. As these results clearly justify increased initial and operating costs, future developments in HVAC&R technology may include "personalized air", new ways of improving the quality of supply air (e.g., by filtration), more extensive use of heat recovery from exhaust air and systematic selection of low-polluting building and furnishing materials.

Individual control and people's preferences in experiments with personalized ventilation system

General information
Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Indoor environment in the 21st century: impact on human productivity, health and comfort

Although air-conditioning has played a positive role for economic development in warm climates, its image is globally mixed. Comprehensive field studies in Europe, Asia and America demonstrate that there are substantial numbers of dissatisfied people in many buildings, among them those suffering from SBS symptoms, even though existing standards and guidelines are met. A paradigm shift from rather mediocre to excellent indoor environments is foreseen in the 21st century. Based on existing information and on new research results, five principles are suggested as elements behind a new philosophy of excellence: better indoor air quality increases productivity and decreases SBS symptoms; unnecessary indoor pollution sources should be avoided; the air should be served cool and dry to the occupants; "personalized ventilation", i.e. small amounts of clean air, should be served gently, close to the breathing zone of each individual; individual control of the thermal environment should be provided. It is foreseen that these principles of excellence will be combined with strong efforts to improve energy efficiency and sustainability.

Limiting criteria for human exposure to low humidity indoors

Thirty subjects (17 female) were exposed for 5 hours to clean air at 5%, 15%, 25% and 35% RH at 22 deg.C. Another 30 subjects (15 female) were similarly exposed to air polluted by carpet and linoleum at 18, 22 and 26 deg.C with humidity 2.4 g/kg dry air (=15% RH at 22 deg.C), and at 22 deg.C, 35% RH. The subjects performed simulated office work throughout each exposure. Building Related Symptom (BRS) intensity was reported on visual-analogue scales. Tests of eye, nose and skin function were applied. In these short exposures subjective discomfort, though significantly increased by low humidity, was very moderate even at 5% RH. However, tear film quality as indicated by the Mucous Ferning Test deteriorated significantly at RH22 deg.C, significantly more rapid blink rates were observed at 5% than at 35% RH, and skin became significantly more dry at 15% than at 35% RH.

Perceived air quality and sensory pollution loads in six Danish office buildings

Perceived air quality and sensory pollution loads were measured in 6 office buildings with mechanical ventilation without recirculation, in each buildings in 6 representative non-smoking medium-sized and small offices with mixing ventilation. An untrained panel of 43 subjects assessed the air quality on a normal weekday when the building was occupied, and on a weekend without occupants in the building. On both occasions the ventilation system was in operation as on a normal
working day. Outdoor air supply rate, air temperature, relative humidity, concentration of carbon dioxide and ultrafine particles were measured. The percentage of persons dissatisfied with air quality ranged from 3 to 30%, decreasing with increasing outdoor air supply rate from 1 to 4 L/(s·m²·floor). Total sensory pollution loads ranged from 0.08 to 0.37 olf/m²·floor in occupied buildings and from 0.04 to 0.27 olf/m²·floor in unoccupied buildings. They are somewhat lower than the loads measured in earlier studies.

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Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Wargocki, P., Krupicz, P., Szczecinski, A., Fanger, P. O., Clausen, G.
Publication date: 2002

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Source: orbit
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Perceived air quality and thermal sensation with personalised ventilation system

Perceived air quality, thermal comfort, and SBS symptoms at low air temperature and increased radiant temperature
This study investigated if low air temperature, which is known to improve the perception of air quality, also can reduce the intensity of some SBS symptoms. In a low-polluting office, human subjects were exposed to air at two temperatures 23 deg.C and 18 deg.C both with and without a pollution source present at the low temperature. To maintain overall thermal neutrality, the low air temperature was partly compensated for by individually controlled radiant heating, and partly by allowing subjects to modify clothing insulation. A reduction of the air temperature from 23 deg.C to 18 deg.C suggested an improvement of the perceived air quality, while no systematic effect on symptom intensity was observed. The overall indoor environment was evaluated equally acceptable at both temperatures due to local thermal discomfort at the low air temperature.

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Organisations: Indoor Environment, Department of Mechanical Engineering, Technical University of Denmark
Contributors: Toftum, J., Reimann, G. P., Foldbjerg, P., Clausen, G., Fanger, P. O.
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Source: orbit
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Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2002 › Research › peer-review

Personal computers pollute indoor air: effects on perceived air quality, SBS symptoms and productivity in offices
Perceived air quality and Sick Building Syndrome (SBS) symptoms were studied in a low-polluting office space ventilated at an air change rate of 2 h⁻¹ (10 L/s per person with 6 people present) with and without personal computers (PCs). Other environmental parameters were kept constant. Thirty female subjects were exposed for 4.8 h to each of the two conditions in the office and performed simulated office work. They remained thermally neutral by adjusting their clothing and were blind to the interventions. In the absence of PCs in the office the perceived air quality improved, odour intensity was reduced and air freshness increased; all effects were significant. In the presence of PCs the performance of text typing
significantly decreased. The sensory pollution load of the PCs was found to be 3 olf per PC, i.e. three times the load of the occupants. Present results indicate negative effects of PCs on human comfort and performance.

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**Prediction of thermal sensation in non-air-conditioned buildings in warm climates**
The PMV model agrees well with high-quality field studies in buildings with HVAC systems, situated in cold, temperate and warm climates, studied during both summer and winter. In non-air-conditioned buildings in warm climates, occupants may sense the warmth as being less severe than the PMV predicts. The main reason is low expectations, but a metabolic rate that is estimated too high can also contribute to explaining the difference. An extension of the PMV model that includes an expectancy factor is introduced for use in non-air-conditioned buildings in warm climates. The extended PMV model agrees well with quality field studies in non-air-conditioned buildings of three continents.

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Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Fanger, P. O., Toftum, J.
Publication date: 2002

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Source-ID: 62562

**Sensory source strength of used ventilation filters**
A two-year-old filter was placed in a ventilation system recirculating the air in an experimental space. Via glass tubes supplied with a small fan it was possible to extract air upstream and downstream of the filter to an adjacent room. A panel could thus perform sensory assessments of the air from the experimental space after facial exposure, without entering the space. Alternatively, the panel could enter the space and evaluate the air quality after full exposure to the air. The sensory pollution load of the filter determined from full exposure was approximately 7 times lower than when determined after facial exposure. Even with the lower values of the sensory pollution load found in the present study, model predictions of the perceived air quality in a typical office show that used filters may still be important sources of indoor air pollution.

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Publication status: Published
Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Clausen, G., Alm, O. M., Fanger, P. O.
Publication date: 2002

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Source-ID: 62569

**Sick Building Syndrome symptoms and performance in a field laboratory study at different levels of temperature and humidity**
Thirty female subjects were exposed for 280 minutes to four conditions in balanced order of presentation: to 20 deg.C/40%, 23 deg.C/50%, 26 deg.C/60% RH at 10 L/s/p outside air, and to 20 deg.C/40% RH at 3.5 L/s/p. They performed simulated office work throughout each exposure and repeatedly marked a set of visual-analogue scales to indicate their perception of environmental conditions and of the intensity of SBS symptoms at the time. They were
repeatedly reminded to adjust their clothing so as to remain in thermal comfort, and succeeded in doing so. Although perceived air quality improved at lower indoor air temperature and humidity and at the higher ventilation rate, this could not be shown to be associated with any effects on task performance. However, subjects reported significantly more intense SBS symptoms associated with decreased productivity, including fatigue, headache and difficulty in thinking clearly, when they were exposed to raised levels of temperature and humidity.

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Organisations: Indoor Environment, Department of Mechanical Engineering
Contributors: Fang, L., Wyon, D., Clausen, G., Fanger, P. O.
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Subjective perceptions, symptom intensity and performance: a comparison of two independent studies, both changing similarly the pollution load in an office
The present paper shows that introducing or removing the same pollution source in an office in two independent investigations, one in Denmark and one in Sweden, using similar experimental methodology, resulted in similar and repeatable effects on subjective assessments of perceived air quality, intensity of sick building syndrome symptoms and performance of office work. Removing the pollution source improved the perceived air quality, decreased the perceived dryness of air and the severity of headaches, and increased typing performance. These effects were observed separately in each experiment and were all significant (P less than/equal to 0.05) after combining the data from both studies, indicating the advantages of pollution source strength control for health, comfort, and productivity.

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Original language: English
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The effect of a personalized ventilation system on perceived air quality and SBS symptoms
Perceived air quality, SBS symptoms and performance were studied with 30 human subjects. Experiments were performed in an office set-up with six workplaces, each equipped with a Personalized Ventilation System (PVS). Each PVS allowed the amount of supply air and its direction to be controlled. Subjects participated in four experiments: (1) PVS supplying outdoor air at 20 deg.C; (2) PVS supplying outdoor air at 23 deg.C; (3) PVS supplying recirculated room air; and (4) mixing ventilation. Room temperature was kept constant at 23 deg.C and relative humidity at 30%. Results showed that the best condition in regard to perceived air quality, perception of freshness and intensity of SBS symptoms was when PVS supplied outdoor air at 20 deg.C. Perceived air quality in this case was significantly better (p
The impact of air pollution from used ventilation filters on human comfort and health
The comfort and health of 30 women was studied during 4 hours’ exposure in an experimental room with either a used or a new filter present in the ventilation system. All other environmental parameters were kept constant. The presence of the used filter in the ventilation system had a significant adverse impact on several perceptions and symptoms, both immediately upon entering the office and throughout the exposure period. None of the perceptions or symptoms were better when the used filter was in the system.

Thermal sensation and comfort with transient metabolic rates
This study investigated the effect on thermal perceptions and preferences of controlled metabolic excursions of various intensities (20%, 40%, 60% relative work load) and durations (3-30 min) imposed on subjects that alternated between sedentary activity and exercise on a treadmill. The thermal environment was held constant at a temperature corresponding to PMV=0 at sedentary activity. Even low activity changes of short duration (1 min at 20% relative work load) affected thermal perceptions. However, after circa 15 min of constant activity, subjective thermal responses approximated the steady-state response, after both up-steps and down-steps of activity.

The role of ventilation and HVAC systems for human health in nonindustrial indoor environments. A supplementary review by EUROVEN group
A continuation of the earlier work of the multidisciplinary group of European scientists, EUROVEN, is presented. The group has previously concluded that increased ventilation rates in indoor nonindustrial environments are strongly associated with improved comfort and health and may be associated with increased productivity, and that air-conditioning systems may increase the risk of sick building syndrome (SBS) symptoms. Taking these findings into account, the group has elaborated 35 hypotheses on the role of ventilation and HVAC systems in nonindustrial indoor environments with regard to human health; 108 peer-reviewed papers have been reviewed among which 74 supported or refuted the hypotheses. The group concluded that increasing outdoor air supply rates is necessary for dilution/removal of pollutants generated indoors (including allergens), and that improper design, functioning and maintenance of ventilation and air-conditioning systems, as well as their intermittent operation, may be potential reasons for health problems of people staying indoors.
Ventilation and health in non-industrial indoor environments: report from a European Multidisciplinary Scientific Consensus Meeting (EUROVEN)

Scientific literature on the effects of ventilation on health, comfort, and productivity in non-industrial indoor environments (offices, schools, homes, etc.) has been reviewed by a multidisciplinary group of European scientists, called EUROVEN, with expertise in medicine, epidemiology, toxicology, and engineering. The group reviewed 105 papers published in peer-reviewed scientific journals and judged 30 as conclusive, providing sufficient information on ventilation, health effects, data processing, and reporting, 14 as providing relevant background information on the issue, 43 as relevant but non-informative or inconclusive, and 18 as irrelevant for the issue discussed. Based on the data in papers judged conclusive, the group agreed that ventilation is strongly associated with comfort (perceived air quality) and health (Sick Building Syndrome (SBS) symptoms, inflammation, infections, asthma, allergy, short-term sick leave), and that an association between ventilation and productivity (performance of office work) is indicated. The group also concluded that increasing outdoor air supply rates in non-industrial environments improves perceived air quality; that outdoor air supply rates below 25 l/s per person increase the risk of SBS symptoms, increase short-term sick leave, and decrease productivity among occupants of office buildings; and that ventilation rates above 0.5 air changes per hour (h⁻¹) in homes reduce infestation of house dust mites in Nordic countries. The group concluded additionally that the literature indicates that in buildings with air-conditioning systems there may be an increased risk of SBS symptoms compared with naturally or mechanically ventilated buildings, and that improper maintenance, design, and functioning of air-conditioning systems contributes to increased prevalence of SBS symptoms.

Human requirements in future air-conditioned environments

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Contributors: Fanger, P. O.
Publication date: 2001

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Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2001 › Research › peer-review
Human requirements in future air-conditioned environments

Although air-conditioning has played a positive role for economic development in warm climates, its image is globally mixed. Field studies demonstrate that there are substantial numbers of dissatisfied people in many buildings, among them those suffering from Sick Building Syndrome (SBS) symptoms, even though existing standards and guidelines are met. A paradigm shift from rather mediocre to excellent indoor environments is foreseen in the 21st century. Based on existing information and on new research results, five principles are suggested as elements behind a new philosophy of excellence: better indoor air quality increases productivity and decreases SBS symptoms; unnecessary indoor pollution sources should be avoided; the air should be served cool and dry to the occupants; “personalized air”, i.e. a small amount of clean air, should be served gently, close to the breathing zone of each individual; individual control of the thermal environment should be provided. These principles of excellence are compatible with energy efficiency and sustainability.
Thermal comfort in the future - excellence and expectation

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- Organisations: Indoor Environment, Department of Mechanical Engineering
- Contributors: Fanger, P. O., Toftum, J.
- Publication date: 2001

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Ventilation and health in nonindustrial indoor environments

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Air-conditioning in the 21st century: impact on human productivity and energy consumption

**General information**
- Publication status: Published
- Organisations: Department of Energy Engineering
- Contributors: Fanger, P. O.
- Publication date: 2000

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- Place of publication: Hannover
- Source-ID: 176000

Discomfort due to skin humidity with different fabric textures and materials

**General information**
- Publication status: Published
- Organisations: Department of Energy Engineering, Novenco
- Contributors: Toftum, J., Rasmussen, L. W., Mackeprang, J., Fanger, P. O.
Good air quality in offices improves productivity

Three recent independent studies have documented that the quality of indoor air has a significant and positive influence on the productivity of office workers. A combined analysis of the results of the three studies shows a significant relationship between productivity and perceived indoor air quality. The impact on productivity justifies a much higher indoor air quality than the minimum levels prescribed in present standards and guidelines. One way of providing air of high quality for people to breathe, without involving excessive ventilation rates and energy use, is to provide “personalized air” to each individual. The application of this concept is discussed in this paper. (C) 2000 Journal of Mechanical Engineering.
Human requirements in future air-conditioned environments: a search for excellence

General information
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Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
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Indoor air quality in the 21st century: search for excellence

General information
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Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
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Perceived air quality and ventilation requirements

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Contributors: Fanger, P. O.
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Pollution source control and ventilation improve health, comfort and productivity

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Organisations: Department of Energy Engineering
Contributors: Wargocki, P., Wyon, D., Fanger, P. O.
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Pollution source control and ventilation improve health, comfort and productivity

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Publication date: 2000

Pollution source control and ventilation improve health, comfort and productivity

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Productivity is affected by the air quality in offices

General information
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Provide good air quality for people and improve their productivity

Temperature and humidity: important factors for perception of air quality and for ventilation requirements

The Effects of Outdoor Air Supply Rate in an Office on Perceived Air Quality, Sick Building Syndrome (SBS) Symptoms and Productivity
Air humidity requirements for human comfort

Upper humidity limits for the comfort zone determined from two recently presented models for predicting discomfort due to skin humidity and insufficient respiratory cooling are proposed. The proposed limits are compared with the maximum permissible humidity level prescribed in existing standards for the thermal indoor environment. The skin humidity model predicts discomfort as a function of the relative humidity of the skin, which is determined by existing models for human heat and moisture transfer based on environmental parameters, clothing characteristics and activity level. The respiratory model predicts discomfort as a function of the driving forces for heat loss from the respiratory tract, namely the air temperature and humidity of the surrounding air. An upper humidity limit based on a relative skin humidity of 0.54, corresponding to 20% dissatisfied, results in a maximum permissible humidity level near 100% rh. For respiratory comfort the requirements much more stringent and results in lower permissible indoor air humidities. Compared with the upper humidity limit specified in existing thermal comfort standards, e.g. ASHRAE Addendum 55a, the humidity limit based on skin humidity was less restrictive and the humidity limit based on respiratory comfort was far more restrictive.

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A transfer model between perceived air quality judged by a trained panel and by an untrained panel

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Organisations: Department of Energy Engineering
Contributors: Wargocki, P., Fanger, P. O.
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CEN CR 1752 - European design criteria for the indoor environment published

General information
Effect of fabric texture and material on perceived discomfort at high humidity

General information
Publication status: Published
Organisations: Department of Energy Engineering
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Publisher: Construction Research Communications, Ltd.
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Effects of exposure to noise and indoor air pollution on human perception and symptoms

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Source-ID: 172584
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 1999 – Research › peer-review

Effekt af tekstilmateriale og -struktur på menneskers komfort ved høj fugtighed: (Effect of fabric texture and material on perceived discomfort at high humidity)

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Organisations: Department of Energy Engineering
Contributors: Toftum, J., Rasmussen, L., Mackeprang, J., Fanger, P. O.
Publication date: 1999

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Field study on the impact of temperature, humidity and ventilation on perceived air quality

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Human requirements in future air-conditioned environments

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Contributors: Fanger, P. O.
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Human requirements in future air-conditioned environments: a search for excellence

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Pages: 86-92
Publication date: 1999

Host publication information
Title of host publication: Proc. of ISHVAC 99
Place of publication: Shenzhen
Publisher: ISHVAC
Source: orbit
Source-ID: 175655

HVAC: Five principles for the future

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Pages: 24-25
Publication date: 1999
Peer-reviewed: No
Hvorfor ventilere?

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Pages: 6-7
Publication date: 1999
Peer-reviewed: No

Impact of temperature and humidity on chemical and sensory emissions from building materials

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fang, L., Clausen, G., Fanger, P. O.
Pages: 193-201
Publication date: 1999
Peer-reviewed: Yes

Impact of ventilation rates on SBS symptoms and productivity in offices

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Wargocki, P., Fanger, P. O.
Publication date: 1999
New human requirements in air-conditioned spaces

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Publication date: 1999

Host publication information
Title of host publication: New human requirements in air-conditioned spaces
Source: orbit
Source-ID: 176157
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 1999 – Research

Perceived air quality, SBS-symptoms and productivity in an office at two pollution loads

General information
Publication status: Published
Organisations: Department of Energy Engineering, Technical University of Denmark
Contributors: Wargocki, P., Wyon, D., Baik, Y., Clausen, G., Fanger, P. O.
Pages: 131-136
Publication date: 1999

Host publication information
Title of host publication: Proc. of 8th International Conference on Indoor Air Quality and Climate
Place of publication: London
Publisher: Construction Research Communications, Ltd.
Source: orbit
Source-ID: 172406
Research output: Chapter in Book/Report/Conference proceeding – Article in proceedings – Annual report year: 1999 – Research – peer-review

Perceived air quality, Sick Building Syndrome (SBS) symptoms and productivity in an office with two different pollution loads

General information
Publication status: Published
Organisations: Department of Energy Engineering, Technical University of Denmark
Contributors: Wargocki, P., Wyon, D., Baik, Y., Clausen, G., Fanger, P. O.
Pages: 165-179
Publication date: 1999
Peer-reviewed: Yes

Publication information
Journal: Indoor Air
Volume: 9
Issue number: 3
ISSN (Print): 0905-6947
Original language: English
Source: orbit
Source-ID: 172404
Research output: Contribution to journal – Journal article – Annual report year: 1999 – Research – peer-review

The impact of human perception of simultaneous exposure to thermal load, low-frequency ventilation noise and indoor air pollution

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Alm, O., Witterseh, T., Clausen, G., Toftum, J., Fanger, P. O.
Pages: 270-275
Publication date: 1999
A moderate enthalpy and a low pollution load in healthy buildings

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Pages: 608-613
Publication date: 1998

Building and people: new evidence for air conditioning

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Pages: 1-4
Publication date: 1998

Discomfort caused by odorants and irritants in the air

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Pages: 81-86
Publication date: 1998
Peer-reviewed: Yes

Publication information
Journal: Indoor Air
Issue number: Suppl.4
ISSN (Print): 0905-6947
Original language: English
Source: orbit
Source-ID: 172397
Research output: Contribution to journal › Journal article – Annual report year: 1998 › Research › peer-review

Engineering, standards and patience
Feuchtigkeit und Enthalpie - wichtig für empfundene Luftqualität und erforderliche Lüftungsrate

Healthy buildings with moderate enthalpy and low pollution load

Impact of pollution emitted from a carpet on SBS-symptoms and productivity in offices
Impact of temperature and humidity on perception of indoor air quality during immediate and longer whole-body exposures

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fang, L., Clausen, G., Fanger, P. O.
Pages: 276-284
Publication date: 1998
Peer-reviewed: Yes

Publication information
Journal: Indoor Air
Volume: 8
ISSN (Print): 0905-6947
Original language: English
Source: orbit
Source-ID: 170961
Research output: Contribution to journal › Journal article – Annual report year: 1998 › Research › peer-review

Impact of temperature and humidity on the perception of indoor air quality

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fang, L., Clausen, G., Fanger, P. O.
Pages: 80-90
Publication date: 1998
Peer-reviewed: Yes

Publication information
Journal: Indoor Air
Volume: 8
Issue number: 2
ISSN (Print): 0905-6947
Original language: English
Source: orbit
Source-ID: 169811
Research output: Contribution to journal › Journal article – Annual report year: 1998 › Research › peer-review

Ny forskning - ny optimisme

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Pages: 5
Publication date: 1998
Peer-reviewed: No

Publication information
Journal: DANVAK
Volume: 6
Original language: Danish
Source: orbit
Source-ID: 169821
Research output: Contribution to journal › Journal article – Annual report year: 1998 › Research

The "maximum source principle" as a basis for ventilation standards?

General information
Publication status: Published
Organisations: Department of Energy Engineering
Upper limits for air humidity based on human comfort

**Publication information**
- Journal: Heating/Piping/Air Conditioning
- Volume: May
- Original language: English
- Source: orbit
- Source-ID: 169823

**Upper limits for air humidity to prevent warm respiratory discomfort**

**Publication information**
- Journal: Energy and Buildings
- Volume: 28
- Issue number: (3)
- Original language: English
- Source: orbit
- Source-ID: 169816

**Upper limits for indoor air humidity to avoid uncomfortably humid skin**

**Publication information**
- Journal: Energy and Buildings
- Volume: 28
- Issue number: (3)
Impact of temperature and humidity on acceptability of indoor air quality during immediate and longer whole-body exposures

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fang, L., Clausen, G., Fanger, P. O.
Publication date: 1997

Host publication information
Title of host publication: Proceedings of Healthy Buildings/IAQ'97
Place of publication: Washington D.C.
Source-ID: 167644
Research output: Chapter in Book/Report/Conference proceeding – Annual report year: 1997

New trends in international standards on the indoor environment

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Publication date: 1997

Publication information
Journal: Emirates Journal for Engineering Research
Volume: 2
Issue number: (1)
Original language: English
Source-ID: 168656
Research output: Contribution to journal – Journal article – Annual report year: 1997

Oplevet luftkvalitet og ventilation

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Publication date: 1997

Publication information
Original language: Danish
Source-ID: 168660
Sensory characterization of emissions from materials

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Knudsen, H., Fanger, P. O.
Pages: 107-115
Publication date: 1997
Peer-reviewed: Yes

Publication information
Journal: Indoor Air
Volume: 7
Issue number: 2
ISSN (Print): 0905-6947
Original language: English
Source: orbit
Source-ID: 168664
Research output: Contribution to journal › Journal article – Annual report year: 1997 › Research › peer-review

Sensory pollution load caused by HVAC components

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Pejtersen, J. H., Clausen, G., Fanger, P. O.
Pages: 545-550
Publication date: 1997

Host publication information
Title of host publication: Proc. of Healthy Buildings/IAQ ’97
Publisher: Hlthy Bdgs
Source: orbit
Source-ID: 168665
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 1997 › Research › peer-review

The philosophy of ventilation: past, present and future

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Pages: 355-365
Publication date: 1997

Host publication information
Title of host publication: Proc. of SITHOK-2
Publisher: Universities of Maribor and Ljubljana
Source: orbit
Source-ID: 168658
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 1997 › Research

European data base on indoor air pollution sources in buildings

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Clausen, G., Oliveira Fernandes, E. D., Fanger, P. O.
Publication date: 1996
European indoor air quality audit project in 56 office buildings

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Bluyssen, P., Oliveira Fernandes, E. D., Groes, A. L., Clausen, G., Fanger, P. O., Valbjørn, O., Bernhard, C., Roulet, C.
Pages: 221-238
Publication date: 1996
Peer-reviewed: Yes

Publication information
Journal: Indoor Air
Volume: 6
ISSN (Print): 0905-6947
Original language: English
Source: orbit
Source-ID: 167502
Research output: Contribution to journal › Journal article – Annual report year: 1996 › Research › peer-review

Field study on addition of indoor air sensory pollution sources

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Wargocki, P., Clausen, G., Fanger, P. O.
Publication date: 1996

Host publication information
Title of host publication: Proceedings
Place of publication: Nagoya, Japan
Publisher: 7th International Conference on Indoor Air Quality and Climate
Source: orbit
Source-ID: 167472
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 1996 › Research › peer-review

Filozofia wentylacji

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Pages: 461-466
Publication date: 1996
Peer-reviewed: Yes

Publication information
Journal: Ciepłownictwo, Ogrzewnictwo, Wentylacja
Volume: XXVIII(9)
Original language: Polish
Source: orbit
Source-ID: 167470
Research output: Contribution to journal › Journal article – Annual report year: 1996 › Research › peer-review
Impact of temperature and humidity on perception and emission of indoor air pollutants

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fang, L., Clausen, G., Fanger, P. O.
Publication date: 1996

Host publication information
Title of host publication: Proceedings
Place of publication: Leipzig
Publisher: Deutsche Kälte-Klima-Tagung
Source: orbit
Source-ID: 167484
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 1996 › Research › peer-review

Last chance for a common European prestandard on design criteria for the indoor environment

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Pages: 6-7
Publication date: 1996
Peer-reviewed: Yes

Publication information
Journal: REHVA Newsletter
Issue number: Sept.
Original language: English
Source: orbit
Source-ID: 167469
Research output: Contribution to journal › Journal article – Annual report year: 1996 › Research › peer-review

Murovue tendencu razvutu standartov ventilatzu

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Pages: 6-10
Publication date: 1996
Peer-reviewed: Yes

Publication information
Journal: ABOK Journal
Volume: 1
Issue number: 2
Original language: Russian
Source: orbit
Source-ID: 167471
Research output: Contribution to journal › Journal article – Annual report year: 1996 › Research › peer-review

Panel heating and cooling: comfort and standards

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Pages: 8-19
Publication date: 1996
Perceived air quality in a displacement ventilated room

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Brohus, H., Knudsen, H., Nielsen, P., Clausen, G., Fanger, P. O.
Publication date: 1996

Required ventilation according to the proposed new European standard - myths and realities

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Pages: 31-48
Publication date: 1996

The impact of temperature and humidity on perception and emission of indoor air pollutants

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fang, L., Clausen, G., Fanger, P. O.
Publication date: 1996

The philosophy behind ventilation: past, present and future

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O., Fanger, P. O.
Publication date: 1996

Host publication information
Title of host publication: Proceedings
Place of publication: Nagoya, Japan
Publisher: 7th International Conference on Indoor Air Quality and Climate
Source: orbit
Source-ID: 167467

The philosophy behind ventilation: past, present and future

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Fanger, P. O.
Pages: 13-20
Publication date: 1996

Host publication information
Title of host publication: Transactions
Place of publication: Istanbul
Publisher: Society of Heating, Ventilation, Air Conditioning & Sanitary Engineers
Source: orbit
Source-ID: 167468

VOC generation system for indoor air quality studies

General information
Publication status: Published
Organisations: Department of Energy Engineering
Contributors: Wargocki, P., Mølhave, L., Fang, L., Melikov, A. K., Clausen, G., Fanger, P. O.
Publication date: 1996

Host publication information
Title of host publication: Proceedings
Place of publication: Nagoya, Japan
Publisher: 7th International Conference on Indoor Air Quality and Climate
Source: orbit
Source-ID: 167473

Spot Cooling - Part 1: Human response to cooling with air jet

General information
Publication status: Published
Organisations: Department of Mechanical Engineering
Contributors: Melikov, A. K., Helkjær, A., Arakelian, R., Fanger, P. O.
Pages: 476-499
Publication date: 1994
Peer-reviewed: Yes

Publication information
Journal: A S H R A E Transactions
Volume: 100
Issue number: 2
ISSN (Print): 0001-2505
Original language: English
Spot Cooling - Part 2: Recommendations for design of spot cooling systems

General information
Publication status: Published
Organisations: Department of Mechanical Engineering
Contributors: Melikov, A. K., Helkjær, A., Arakelian, R., Fanger, P. O.
Pages: 500-510
Publication date: 1994
Peer-reviewed: Yes

Publication information
Journal: ASHRAE Transactions
Volume: 100
Issue number: 2
ISSN (Print): 0001-2505
Original language: English

Turbulence and draft

General information
Publication status: Published
Organisations: Technical University of Denmark, Takenaka Corporation, Hamilton College
Contributors: Fanger, P. O., Melikov, A. K., Hanzawa, H., Ring, J.
Pages: 18-25
Publication date: 1989
Peer-reviewed: Yes

Publication information
Journal: ASHRAE Journal
Issue number: April
ISSN (Print): 0001-2491
Original language: English

Airflow characteristics in the occupied zone of heated spaces without mechanical ventilation

General information
Publication status: Published
Organisations: Technical University of Denmark, Takenaka Corporation
Contributors: Melikov, A. K., Hanzawa, H., Fanger, P. O.
Pages: 52-70
Publication date: 1988
Peer-reviewed: Yes

Publication information
Journal: ASHRAE Transactions
Volume: 94
Issue number: 1
ISSN (Print): 0001-2505
Original language: English

Air Turbulence and sensation of draught
The impact of turbulence intensity (Tu) on sensation of draught has been investigated. Fifty subjects, dressed to obtain a neutral thermal sensation, were in three experiments exposed to air flow with low (Tu<12%), medium (20%<Tu<35%) and
high (Tu>55%) turbulence intensity. In each experiment the sedentary subjects were exposed to six mean air velocities ranging from 0.05 m/s to 0.40 m/s. The air temperature was kept constant at 23°C. They were asked whether and where they could feel air movement and whether or not it felt uncomfortable. The turbulence intensity had a significant impact on the occurrence of draught sensation. A model is presented which predicts the percentage of people dissatisfied because of draught as a function of air temperature, mean velocity and turbulence intensity. The model can be a useful tool for quantifying the draught risk in spaces and for developing air distribution systems with a low draught risk.

**General information**
Publication status: Published
Organisations: Technical University of Denmark, Hamilton College, Takenaka Corporation
Contributors: Fanger, P. O., Melikov, A. K., Hanzawa, H., Ring, J.
Pages: 21-39
Publication date: 1988
Peer-reviewed: Yes

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Journal: Energy and Buildings
Volume: 12
ISSN (Print): 0378-7788
Original language: English
DOI: 10.1016/0378-7788(88)90053-9
Source: PublicationPreSubmission
Source-ID: 101898721
Research output: Contribution to journal › Journal article – Annual report year: 1988 › Research › peer-review

*Airflow characteristics in the occupied zone of ventilated spaces*

Airflow is one of the most common causes of complaint in ventilated or air-conditioned spaces. Therefore, knowing the turbulent airflow in these spaces and the impact of this flow on the sensation of draft is very important. The characteristics of turbulent flow (turbulence intensity, length scales of turbulence, turbulence kinetic energy, etc.) were investigated in 20 typically ventilated spaces. Relationships between these characteristics and the mean velocity were found. The turbulence energy spectra are similar to those in a fully developed turbulent flow. The spectra reveal the major contribution to total turbulent energy made by the larger eddies in the low-wave number range. Some of the experimental results were compared with existing numerical predictions.

**General information**
Publication status: Published
Organisations: Technical University of Denmark, Takenaka Corporation
Contributors: Hanzawa, H., Melikov, A. K., Fanger, P. O.
Pages: 524-539
Publication date: 1987
Peer-reviewed: Yes

**Publication information**
Journal: A S H R A E Transactions
Volume: 93
Issue number: 1
ISSN (Print): 0001-2505
Original language: English
DOI: 101898730
Source: PublicationPreSubmission
Source-ID: 101898730
Research output: Contribution to journal › Journal article – Annual report year: 1987 › Research › peer-review