SIST

SLOVENSKI STANDARD
SIST CR 1752:1999

01-september-1999

Prezračevanje zgradb - Merila za projektiranje notranjega okolja

Ventilation for buildings - Design criteria for the indoor environment

Ta slovenski standard je istoveten z: CR 1752:1998

ICS:

91.140.30	Prezračevalni in klimatski sistemi	Ventilation and air-conditioning

SIST CR 1752:1999 **en**

CEN REPORT

RAPPORT CEN

CEN BERICHT

CR 1752

December 1998

ICS 91.140.30

Descriptors:

English version

Ventilation for buildings - Design criteria for the indoor environment

This CEN Report was approved by CEN on 11 November 1998. It has been drawn up by the Technical Committee CEN/TC 156.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Central Secretariat: rue de Stassart, 36 B-1050 Brussels

Ref. No. CR 1752:1998 E

Contents

Foreword

This Technical Report has been prepared by Technical Committee CEN/TC 156, Ventilation for buildings. It received approval from the CEN Technical Board on 199X.

Annexes A to H are all informative. Annexes A to G cover the details of development and determination of design criteria, practical examples, data, WHO guidelines, ventilation effectiveness, guidelines for low-polluting buildings. Annex H is a bibliography.

Introduction

This Technical Report is intended to assist in providing an acceptable indoor environment for people in ventilated buildings. The indoor environment comprises the thermal environment, the air quality and the acoustic environment. Good ventilation provides a comfortable indoor environment with a low health risk for the occupants and uses a small amount of energy. Reducing the indoor sources of pollution and preferably adapting the ventilation rate to the actual demand are more important than increasing the outside airflow rate.

The quality of the indoor environment may be expressed as the extent to which human requirements are met. Requirements vary, however, for different individuals. Some people are rather sensitive to an environmental parameter and are difficult to satisfy, whereas others are less sensitive and are easier to satisfy. To cope with these individual differences the environmental quality can be expressed by the percentage of persons who find an environmental parameter unacceptable (= % dissatisfied). If there are few dissatisfied, the quality of the environment is high. If there are many dissatisfied, the quality is low. Prediction of the percentage of dissatisfied is used to establish requirements for the thermal environment and for ventilation. A predicted value may not be equal to the actual percentage of dissatisfied in practice, where other factors such as stress can have an influence. This Technical Report is intended to specify the requirements whilst also indicating methods currently in use and those under development.

Although aspects of the indoor environment (thermal, air quality and acoustic) are dealt with separately, the indoor environment is considered as a whole. Conflict can arise between the different environmental requirements and designers may therefore be required to find a compromise.

A ventilation or air-conditioning system is usually designed to operate under certain assumptions concerning the application of the building, internal loads, meteorological conditions etc. The desired indoor environment will therefore only be provided when these assumptions are valid.

> NOTE A rationale which specifies how the quality of the indoor environment can be expressed is provided in annex A. Annex B gives a step-by-step method for determining the criteria. The application of annex A is illustrated in annex C by a number of practical examples. The examples cover spaces in different types of buildings under conditions frequently occurring in practice.

1 Scope

This Technical Report specifies the requirements for, and methods of expressing the quality of the indoor environment for the design, commissioning, operation and control of ventilation and air-conditioning systems.

This Technical Report covers indoor environments where the major concern is the human occupation but excludes dwellings. This Technical Report does not cover buildings where industrial processes or similar operations requiring special conditions are undertaken.

The practical procedures, including selection of parameters to be measured during commissioning, control and operation, are not covered.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this Technical Report. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

EN ISO 7730, *Moderate thermal environments — Determination of the PMV and PPD indices and specification of the conditions for thermal comfort.*
ISO 9920, *Ergonomics of the thermal environment — Estimation of the thermal insulation and evaporative resistance of a clothing ensemble.*
ISO 8996, *Ergonomics — Determination of metabolic heat production.*
EN ISO 11201, *Acoustics — Noise emitted by machinery and equipment. Guideline for the preparation of test code of engineering grade requiring noise measurements at the operator's or bystander's position.*
EN ISO 3744, *Acoustics — Determinators of sound power levels of noise sources — Engineering methods for free field conditions over a reflecting plane.*

3 Definitions

For the purposes of this Technical Report, the following definitions apply:

3.1
draught
unwanted local cooling of the body caused by air movement and temperature

3.2
draught rating (*DR*)
percentage of people predicted to be dissatisfied due to draught

3.3
external work
energy spent in overcoming external mechanical forces on the body; also expressed as a fraction of metabolic energy production, where the fraction value defines the mechanical efficiency.

NOTE For most activities external work may be disregarded.

3.4
humidity, absolute
absolute amount of water vapour in the ambient air expressed in g/kg or m³ dry air. It can also be expressed by the partial water vapour pressure (p_v) in Pa or by the dewpoint (t_d) in °C

3.5
humidity, relative
mass of water vapour in the air by volume divided by mass of water vapour by volume at saturation at the same temperature

3.6
insulation, clothing (i_{cl})
resistance to sensible heat transfer provided by a clothing ensemble (i.e. more than one garment)

NOTE It is described as the intrinsic insulation from the skin to the clothing surface, not including the resistance provided by the air layer around the clothed body and is expressed in the clo unit or in m² × K/W; 1 clo = 0,155 m² × K/W.

3.7
insulation, garment (i_{clu})
increased resistance to sensible heat transfer obtained from adding an individual garment over the nude body; the effective increase in overall insulation attributable to the garment and expressed in the clo unit or in m² × K/W

3.8
metabolic rate (*M*)
rate of energy production of the body

NOTE The metabolic rate varies with the activity. It is expressed in the met unit or in W/m²; 1 met = 58,2 W/m². One met is the energy produced per unit surface area of a sedentary person at rest. The surface area of an average person is about 1,8 m².

3.9
perceived air quality in decipol (c_c)

perceived air quality in a space with a sensory pollution load of 1 olf ventilated by 10 l/s of clean air

3.10
predicted mean vote (PMV)
index that predicts the mean value of the thermal sensation votes of a large group of persons on a 7-point scale

3.11
predicted percentage of dissatisfied (PPD)
index that predicts the percentage of a large group of people likely to feel thermally dissatisfied for the body as a whole, i.e. either too warm or too cool

3.12
sensory pollution load in olf
1 olf is the sensory load on the air from an average sedentary adult in thermal neutrality

3.13
sound pressure level in decibel
ten times the logarithm to the base 10 of the ratio of the square of the sound pressure to the square of the reference sound pressure

NOTE The weighting network used is indicated: for example, A-weighted sound pressure level, dB(A). The reference sound pressure is 20 μPa.

3.14
sound power level in decibel
ten times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power

NOTE The weighting network used is indicated: for example, A-weighted sound power level. The reference sound power is 1 pW (= 10^{-12} W).

3.15
temperature, mean radiant ($\overline{t_r}$)
uniform surface temperature of an enclosure in which an occupant would exchange the same amount of radiant heat as in the actual non-uniform enclosure

3.16
temperature, operative (t_o)
uniform temperature of an enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment

3.17
temperature, optimum operative
operative temperature that satisfies the greatest possible number of people at a given clothing and activity level

3.18
temperature, plane radiant (t_{pr})
uniform temperature of an enclosure where the radiance on one side of a small plane element is the same as in the non-uniform actual environment

3.19
temperature asymmetry, radiant (Δt_{pr})
difference between the plane radiant temperature of the two opposite sides of a small plane element

3.20
temperature difference, vertical air
air temperature difference between head and ankles of a person

NOTE For a sedentary person this is 1,1 and 0,1 m above the floor

3.21
thermal comfort
that condition of mind which expresses satisfaction with the thermal environment

3.22
thermal environment
characteristics of the environment which affect the heat exchange between the human body and the environment

3.23
thermal sensation
conscious feeling commonly graded into the categories, cold, cool, slightly cool, neutral, slightly warm, warm and hot

3.24
turbulence intensity (Tu)
ratio of the standard deviation of the air velocity to the mean air velocity

3.25
velocity, relative air (v_{ar})
air velocity relative to the occupant, including body movements

3.26
ventilation effectiveness (ε_v)
measure of the relationship between the pollutant concentration in the exhaust air and the pollutant concentration in the breathing zone

NOTE Another term frequently used for the same concept is “contaminant removal effectiveness”.

3.27
zone, occupied
that part of a space designed for human occupancy and where the design criteria are required to be met

4 Categories of indoor environment

This Technical Report specifies categories of environmental quality which shall be selected for a space to be ventilated. Category A corresponds to a high level of expectation, category B to a medium level of expectation and category C to a moderate level of expectation.

NOTE Designers may also select different levels using annex A. A different category may be selected for the thermal environment, the indoor air quality and the acoustic environment for a space or building. A different category may be selected for summer and winter.

5 Design assumptions

A ventilation or air-conditioning system shall be designed to provide the required indoor environment under specified conditions. The designer shall specify the conditions and any assumptions made including the indoor environmental requirements the system is designed to achieve.

Information on the following assumptions is required:

— application and flexibility of the space, including a specification of the occupied zone;

— number of occupants present (per m² floor) and their estimated activity and clothing behaviour;

— pollution load caused by materials used in the building including carpets and furnishing;

— percentage of smokers, if smoking is permitted;

— available outdoor air quality;

— outdoor noise level.

Consideration shall be given to the following:

— maximum and minimum outdoor weather conditions, e.g. corresponding to a certain percentage of a normal year;

— area of glass and the transmission of glass;

— the possibility of opening the windows;

— application of solar shading devices;

— cooling/heating load caused by occupants, machines, illumination, solar radiation, etc;

— physical properties of the materials used in the building;

— room reverberation time;

— proper commissioning and maintenance of the ventilation or air-conditioning system;

— proper cleaning of the spaces;

— proper use of the ventilation or air-conditioning system.

The design assumptions shall be listed in the operational guide for the ventilation or air-conditioning system and it shall be stated that the indoor environment for which the system is designed can only be achieved if these conditions are met. Owners and users of the building shall be warned that changes in the application of spaces, or in thermal load or pollution load, can result in the system being unable to meet the indoor environmental requirements for which it was designed.

6 Design criteria

The design criteria specified in Table 1 are derived under certain assumptions and include the minimum requirements for the design of a ventilation or air-conditioning system for the appropriate application.

For the thermal environment the criteria for the operative temperature are based on typical levels of activity given in Table 1 for a clothing of 0.5 clo during summer (cooling season) and 1.0 clo during winter (heating season). The criteria for the mean air velocity apply for a turbulence intensity of approximately 40 % (mixing ventilation). The design criteria for the required ventilation rate comprises a minimum ventilation rate to handle the pollution caused by the occupants only, plus an additional ventilation rate to handle the pollution caused by the building (including building materials, furnishings and HVAC equipment). Table 1 applies for low-polluting buildings. Annex G provides guidelines for such buildings. Ventilation rates for different types of building, including those that are not low-polluting are given in annex C (Table C.1). If smoking is permitted, additional ventilation is required. The last column of Table 1 specifies the additional ventilation required for comfort if 20 % of the occupants are smokers. The health risk of passive smoking should be considered separately. The ventilation rates in Table 1 are based on the assumption that the ventilation effectiveness is one and that outdoor air of excellent quality is available. The design criteria in Table 1 are only valid for the occupancy conditions described in the table. For occupancy densities other than those listed in Table 1, the required ventilation can be modified using information in Table 2. In practice, partial load conditions can often prevail during the normal hours of occupancy, and in such cases the ventilation should be matched to the actual demand.

NOTE Table 1 may also be used for other types of spaces with similar use as the spaces given in the table.

The designer may also decide to assume that the occupants are the only pollution source in a space, i.e. that the building does not pollute at all, in which case the required ventilation rate shall be determined per occupant from Table 2. Table 2 also takes into account the level of tobacco smoking, if any, occurring in a space. Knowing the occupancy density, expressed in persons/(m^2 floor), the ventilation rate can then be expressed in l/s (m^2 floor).

NOTE Buildings may not satisfy the conditions specified in Tables 1 and 2, in which case the design criteria may be determined from annex A.

Table 1 — Design criteria for spaces in different types of buildings[a)]

Type of building/ space	Activity met	Occupancy person/ m^2	Category	Operative temperature[b)] °C		Maximum mean air velocity m/s		Sound pressure dB (A)	Ventilation rate $l/s \times m^2$	Additional ventilation when smoking is allowed[c),d)] $l/s \times m^2$
				Summer (cooling season)	Winter (heating season)	Summer (cooling season)	Winter (heating season)			
Single office (cellular office)	1,2	0,1	A	24,5 ± 1,0	22,0 ± 1,0	0,18	0,15	30	2,0	—
			B	24,5 ± 1,5	22,0 ± 2,0	0,22	0,18	35	1,4	—
			C	24,5 ± 2,5	22,0 ± 3,0	0,25	0,21	40	0,8	—
Landscaped office	1,2	0,07	A	24,5 ± 1,0	22,0 ± 1,0	0,18	0,15	35	1,7	0,7
			B	24,5 ± 1,5	22,0 ± 2,0	0,22	0,18	40	1,2	0,5
			C	24,5 ± 2,5	22,0 ± 3,0	0,25	0,21	45	0,7	0,3
Conference room	1,2	0,5	A	24,5 ± 1.0	22,0 ± 1,0	0,18	0,15	30	6,0	5,0
			B	24,5 ± 1,5	22,0 ± 2,0	0,22	0,18	35	4,2	3,6
			C	24,5 ± 2,5	22,0 ± 3,0	0,25	0,21	40	2,4	2,0
Auditorium	1,2	1,5	A	24,5 ± 1,0	22,0 ± 1,0	0,18	0,15	30	16[(e)]	—
			B	24,5 ± 1,5	22,0 ± 2,0	0,22	0,18	33	11,2	—
			C	24,5 ± 2,5	22,0 ± 3,0	0,25	0,21	35	6,4	—
Cafeteria or restaurant	1,2	0,7	A	24,5 ± 1,0	22,0 ± 1,0	0,18	0,15	35	8,0	—
			B	24,5 ± 2,0	22,0 ± 2,5	0,22	0,18	45	5,6	5,0
			C	24,5 ± 2,5	22,0 ± 3,5	0,25	0,21	50	3,2	2,8
Classroom	1,2	0,5	A	24,5 ± 0,5	22,0 ± 1,0	0,18	0,15	30	6,0	—
			B	24,5 ± 1,5	22,0 ± 2,0	0,22	0,18	35	4,2	—
			C	24,5 ± 2,5	22,0 ± 3,0	0,25	0,21	40	2,4	—
Kindergarten	1,4	0,5	A	23,5 ± 1,0	20,0 ± 1,0	0,16	0,13	30	7,1	—
			B	23,5 ± 2,0	20,0 ± 2,5	0,20	0,16	40	4,9	—
			C	23,5 ± 2,5	20,0 ± 3,5	0,24	0,19	45	2,8	—
Department store	1,6	0,15	A	23,0 ± 1,0	19,0 ± 1,5	0,16	0,13	40	4,2	—
			B	23,0 ± 2,0	19,0 ± 3,0	0,20	0,15	45	3,0	—
			C	23,0 ± 3,0	19,0 ± 4,0	0,23	0,18	50	1,6	—

NOTES

a) This table applies for the occupancy listed in the table and for a ventilation effectiveness of one.

b) For many types of buildings and spaces with moderate heating or cooling loads the air temperature will be approximately equal to the operative temperature. For design, the upper end of the temperature range can be used during summer and the lower end during winter.

c) Additional ventilation required for comfort when 20 % of the occupants are smokers. The health risk of passive smoking shall be considered separately.

d) Where no value is listed, data from Table 2 may be used.

e) It may be difficult to meet the Category A draught criteria.

Table 2 — Required ventilation rate per occupant[a), b)]

Category	Required ventilation rate l/s × occupant			
	No smoking	20 % smokers	40 % smokers[c)]	100 % smokers[c)]
A	10	20	30	30
B	7	14	21	21
C	4	8	12	12

NOTES
[a)] This table applies if it is assumed that the occupants are the only source of pollution.
[b)] The table applies to a non-smoking environment and for different levels of tobacco smoking.
[c)] For 40–100 % smokers, the required ventilation is equal to the value for 40 % smokers, since smokers are more tolerant towards environmental tobacco smoke than non-smokers.

Annex A (informative)

Development of design criteria

A.1 General

This annex specifies how the quality of the indoor environment can be expressed; **A.2** deals with the quality of the thermal environment ; **A.3** with the quality of the indoor air; and **A.4** with the requirements for the acoustic environment. A step-by-step method for determination of design criteria is given in annex B.

A.2 Thermal environment

A.2.1 *Criteria*

The design criteria for the thermal environment are based on EN ISO 7730. The human response to the thermal environment is expressed by the predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD) indices which predict the percentage of the occupants feeling too warm or too cool for the body as a whole. The human response is also expressed by the percentages of occupants predicted to feel dissatisfied due to different types of local thermal discomfort. Such discomfort may be caused by draught, by an abnormally high vertical temperature difference, by too warm or too cool a floor or by too high a radiant temperature asymmetry.

A.2.2 *Thermal indices*

The PMV is an index that predicts the mean value of the thermal sensation votes of a large group of persons on the following 7-point scale:

+3	hot
+2	warm
+1	slightly warm
0	neutral
-1	slightly cool
-2	cool
-3	cold

The PMV depends on the following six parameters:

- — the occupants' physical activity (metabolic rate);
- — the thermal resistance of their clothing;
- — air temperature;
- — mean radiant temperature;
- — air velocity;
- — partial water vapour pressure.

The last four are the environmental parameters.
Tables and mathematical relations between these six parameters and PMV are given in EN ISO 7730. An estimate is required of the occupants' metabolic rate and of the thermal insulation of their clothing. Such data for typical applications are given in annex D.

The PPD index predicts the percentage of a large group of people likely to feel thermally dissatisfied, i.e. feel too warm or too cool. The PPD depends on PMV as shown in Figure A.1.

The PPD is one measure of the quality of the thermal environment. A certain quality (defined by a permissible PPD value) may be selected for a space; the corresponding PMV range can be found from Figure A.1. The corresponding permissible range of operative temperatures in the space can then be found from PMV tables or a computer program, e.g. in EN ISO 7730.

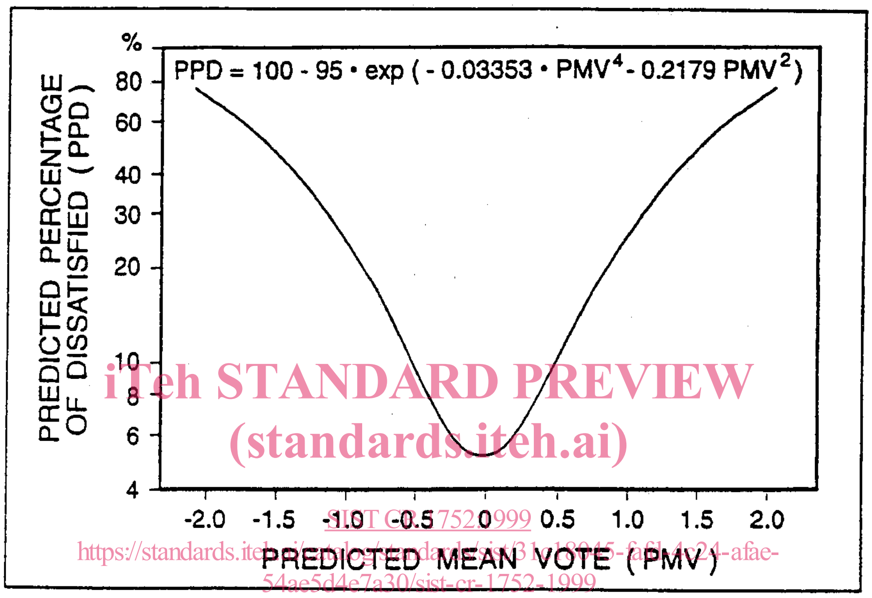

Figure A.1 — Predicted percentage of dissatisfied (PPD) as a function of predicted mean vote (PMV)

A.2.3 *Local thermal discomfort*

The PMV and PPD indices express warm and cold discomfort for the body as a whole. But thermal dissatisfaction may also be caused by unwanted cooling (or heating) of one particular part of the body (local discomfort). The most common cause of local discomfort is draught. But local discomfort may also be caused by an abnormally high vertical temperature difference between head and ankles, by too warm or too cool a floor or by too high a radiant temperature asymmetry.

People engaged in light sedentary activity are most sensitive to local discomfort. **A.2.4.3** to **A.2.4.6** apply to this group of people with a thermal sensation for the whole body close to neutral. When engaged in more vigorous activities, people are less thermally sensitive and consequently the risk of local discomfort is lower.