International Standards for the Indoor Environment Revision of ISO17772-1 dealing with Indoor Environmental Quality.

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International Standards for Indoor Environmental Quality

- ISO EN 7730
  - Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort effects.
- ASHRAE 55
  - Thermal environment conditions for human occupancy
- ASHRAE 62.1
  - ANSI/ASHRAE Standard 62.1 Ventilation for Acceptable Indoor Air Quality,
- ASHRAE 62.2
  - ANSI/ASHRAE Standard 62.2 Ventilation and Acceptable Indoor Air Quality in Residential Buildings

International Standards
Indoor Environmental Quality

- EN16798-1 and ISO 17772-1:
  - Indoor environmental input parameters for the design and assessment of energy performance of buildings.
- EN TR16798-2 and ISO TR 17772-2:
  - Guideline for using indoor environmental input parameters for the design and assessment of energy performance of buildings.

Structure for 52007 (Revised 17772-1/2)

Document and title		Responsible Committee(s)
ISO 52007-1	Overarching standard	Overarching TC163/205JWG with members from TC274 and TC43/SC 2
ISO 52007-2	Technical Report	
ISO 52007-3	Thermal Comfort	Thermal Comfort TC163/205JWG
ISO 52007-4	Technical Report and Guidance for part 3	
ISO 52007-5	Indoor Air Quality	Indoor Air Quality TC163/205JWG
ISO 52007-6	Technical Report and Guidance for part 5	
ISO 52007-7	Lighting	TC 274/JWG 1 (- CIE JTC6) Collaboration route recommendation expected from the ISO/TC 274/JAG
ISO 52007-8	Technical Report and Guidance for part 7	
ISO 52007-9	Acoustic	TC 43/SC 2
ISO 52007-10	Technical Report and Guidance for part 9	

Categories in ISO 17772-1

Category	Level of expectation
IEQ_I	High
IEQ_{II}	Medium
IEQ_{III}	Moderate
IEQ_{IV}	Low

- The categories are related to the level of expectations the occupants may have.
- A normal level would be "Medium".
- A higher level may be selected for occupants with special needs (children, elderly, handicapped, etc.).
- A lower level will not provide any health risk but may decrease comfort.

Recommended thermal comfort categories for design of mechanical heated and cooled buildings

Category	Thermal state of the body as a whole	
	PPD %	Predicted Mean Vote
I	< 6	-0.2 < PMV < + 0.2
II	< 10	-0.5 < PMV < + 0.5
III	< 15	-0.7 < PMV < + 0.7
III	< 25	-1.0 < PMV < + 1.0

Temperature ranges for dimensioning and hourly calculation of cooling and heating energy in four categories of indoor environment

Cat.	Heating season (1.0 clo) °C	Cooling season, (0.5 clo) °C
I	21.0 - 23.0	23.5 - 25.5
II	20.0 - 24.0	23.0 - 26.0
III	19.0 - 25.0	22.0 - 27.0
IV	17.0 - 25.0	21.0 - 28.0

- Temperature ranges consider for the four categories of indoor environment recommended for sedentary work (1.2 met) in ISO 17772-1.
- Air velocity is assumed below 0.1 m/s and the relative humidity is 40% for heating seasons and 60% for cooling seasons.

This will work for establishing design values for dimensioning of heating and cooling systems by using the lower value in heating season for the heating system and the upper value in cooling season for the cooling system.

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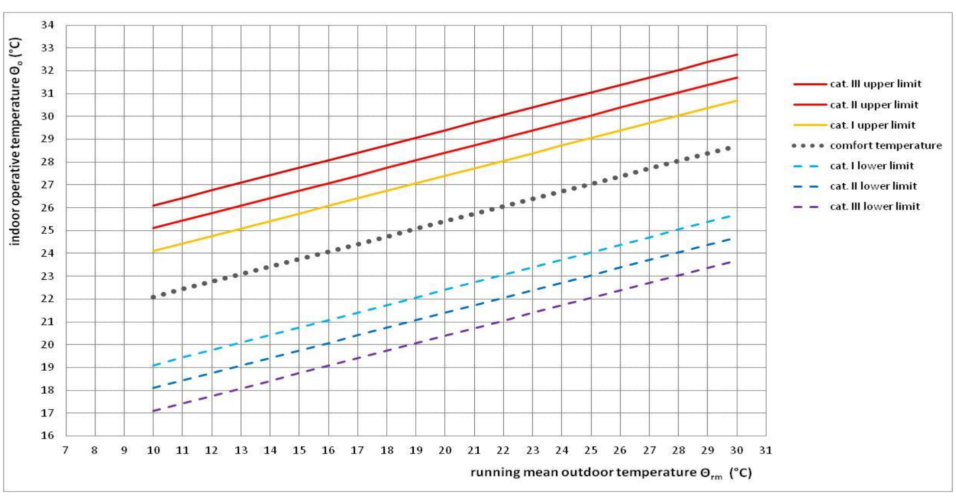
Adapted method in ISO17772-1

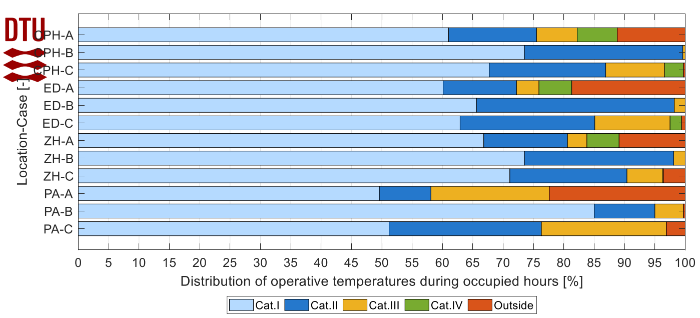


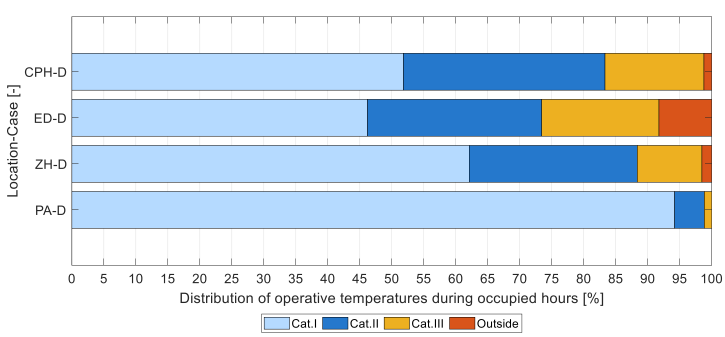
$$\Theta_{rm} = (\Theta_{ed\,-1} + 0{,}8\,\Theta_{ed\,-2} + 0{,}6\,\Theta_{ed\,-3} + 0{,}5\,\Theta_{ed\,-4} + 0{,}4\,\Theta_{ed\,-5} + 0{,}3\,\Theta_{ed\,-6} + 0{,}2\,\Theta_{ed\,-7})/3{,}8$$

Issues

- No yearly Key Performance Indicator (KPI) for thermal comfort, while for energy you have one value kWh/m^2 per year (or equivalent CO_2 emission)
  - A KPI can be calculated based on the percentage of occupied hours inside the categories of indoor environmental quality defined in ISO 17772-1.
  - The score assigned weighted values for % time spent in each category, and provides a single value from 1 (Best) to 5 (Worst) equation (2)

$$TCS = \%Cat.I * 1 + (\%Cat.II - \%Cat.I) * 2 + (\%Cat.III - \%Cat.II) * 3 + (\%Cat.IV - \%Cat.III) * 4 + \%outside * 5 \qquad (2)$$

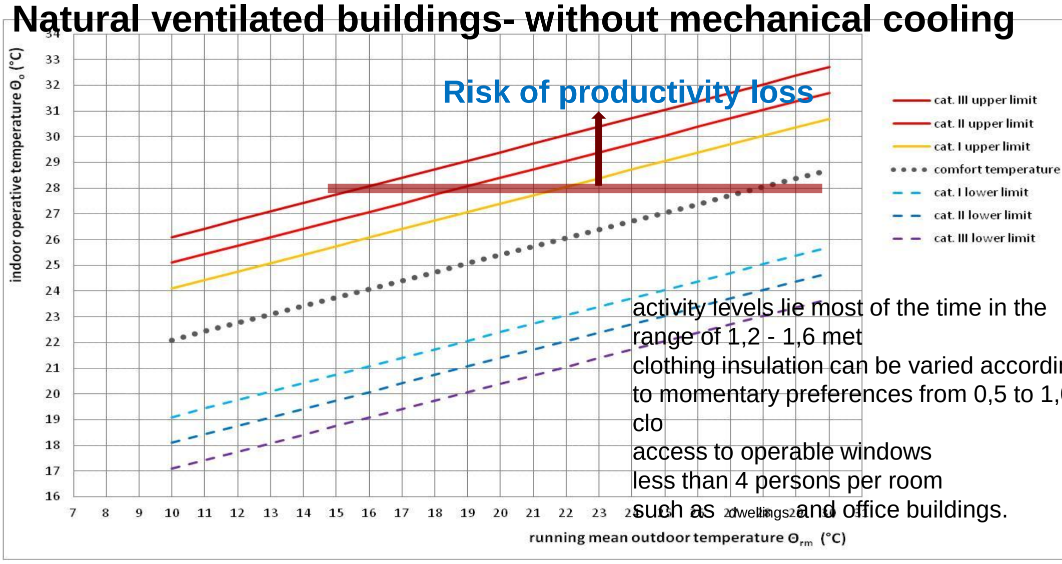




Location		CPH	ED	ZH	PA
TCS	A	1.93	2.11	1.80	2.37
	B	1.27	1.36	1.28	1.21
	C	1.49	1.55	1.46	1.79
TCS ACM	D	1.71	2.00	1.56	1.10

EN16798-1 and ISO 17772-1 Adapted approach

Natural ventilated buildings- without mechanical cooling



activity levels lie most of the time in the range of 1,2 - 1,6 met
clothing insulation can be varied according to momentary preferences from 0,5 to 1,0 clo
access to operable windows
less than 4 persons per room
such as dwellings and office buildings.

$$\Theta_{rm} = (\Theta_{ed\,-1} + 0{,}8\,\Theta_{ed\,-2} + 0{,}6\,\Theta_{ed\,-3} + 0{,}5\,\Theta_{ed\,-4} + 0{,}4\,\Theta_{ed\,-5} + 0{,}3\,\Theta_{ed\,-6} + 0{,}2\,\Theta_{ed\,-7})/3{,}8$$

Concept for calculation of design ventilation rate according to ISO 17772-1 Method 1

People Component

Building Component

Breathing Zone Outdoor Airflow

$$V_{bz} = R_p P_z + R_a A_z$$

Minimum l/s/Person

Number of People

Building Area

Minimum l/s/m²

Total ventilation rate

$$q_{tot} = n \cdot q_p + A_R \cdot q_B$$

$$q_{supply} = q_{tot} / \varepsilon_v$$

- Where
- ε_v = the ventilation effectiveness (EN16798-3/4)
- q_{supply} = ventilation rate supplied by the ventilation system
- q_{tot}= total ventilation rate for the breathing zone, l/s
- n = design value for the number of the persons in the room,
- q_p = ventilation rate for occupancy per person, l/s, pers
- A_R= room floor area, m^2
- q_B = ventilation rate for emissions from building, l/s,m^2

Concept for calculation of design ventilation rate ISO 17772-1

Table 1: Design ventilation rates for non-adapted persons for diluting emissions (bio effluents) from people and for buildings for different categories

		People component, q_p	Building Component, q_B		
Indoor Environmental Category	Expected Percentage Dissatisfied %	Airflow per non-adapted person l/(s.pers)	Very low polluting building l/(s m^2)	Low polluting building l/(s m^2)	Non low polluting building l/(s m^2)
IEQ_I	15	10	0,5	1,0	2,0
IEQ_{II}	20	7	0,35	0,7	1,4
IEQ_{III}	30	4	0,2	0,4	0,8
IEQ_{IV}	40	2,5	0,15	0,3	0,6

HEALTH CRITERIA FOR VENTILATION

Minimum 4 l/s/person

ISO 17772-1 and prEN16798-1

Increased ventilation during Pandemic

Reducing cross contamination

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Design ventilation rates

Type of building or space	Category	Floor area m²/person	q_p	q_p	q_B	q_{tot}		q_B	q_{tot}		q_B	q_{tot}	
			minimum ventilation rate										
			l/ (s m²)	l/s pers.	l/s, m²	l/s, m²	l/s,pers	l/s, m²	l/s, m²	l/s,pers	l/s, m²	l/s, m²	l/s,pers
			for occupancy only		for very low-polluted building (Tekst)			for low-polluted building			for non-low-polluted building		
Single office	I	10	1	10	0,5	1,5	15	1	2,0	20,0	2	3,0	30
	II	10	0,7	7	0,35	1,1	11	0,7	1,4	14,0	1,4	2,1	21
	III	10	0,4	4	0,2	0,6	6	0,4	0,8	8,0	0,8	1,2	12
	IV	10	0,25	2,5	0,15	0,4	4	0,3	0,6	5,5	0,6	0,9	9
Landscaped office	I	15	0,7	10	0,5	1,2	18	1	1,7	25,0	2	2,7	40
	II	15	0,5	7	0,35	0,8	12	0,7	1,2	17,5	1,4	1,9	28
	III	15	0,3	4	0,2	0,5	7	0,4	0,7	10,0	0,8	1,1	16
	IV	15	0,2	2,5	0,15	0,3	5	0,3	0,5	7,0	0,6	0,8	12
Conference room	I	2	5	10	0,5	5,5	11	1	6,0	12,0	2	7,0	14
	II	2	3,5	7	0,35	3,9	8	0,7	4,2	8,4	1,4	4,9	10
	III	2	2	4	0,2	2,2	4	0,4	2,4	4,8	0,8	2,8	6
	IV	2	1,25	2,5	0,15	*(1,4) 1,8*	*(3) 4*	0,3	*(1,6) 2*	*(3,1) 4*	0,6	1,9	4

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Table B2.5 - Example of equivalent increase in CO_2 levels indoor for the total ventilation rates specified in Table B2.3

Type of building or space	Category	occupancy person/m²	ΔCO_2 [ppm] Very low-polluting	low-polluting	Not low-polluting
Single office	I	0,1	370	278	185
	II	0,1	529	397	265
	III	0,1	926	694	463
	IV	0,1	1389	1010	654
Land-scaped office	I	0,07	317	222	139
	II	0,07	454	317	198
	III	0,07	741	556	347
	IV	0,07	1235	794	483
Conference room	I	0,5	505	463	397
	II	0,5	722	661	567
	III	0,5	1263	1157	992
	IV	0,5	*1462*	*1389*	1502
Auditorium	I	1,33	535	517	483
	II	1,33	765	738	690
	III	1,33	1347	1300	1208
	IV	1,33	*1576*	*1398*	*1576*

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ASHRAE 62.1 – ISO 17772-1

Type of building/ space	Occupancy person/m²	Category CEN	Occupants only l/s person ASHRAE Rp	Occupants only l/s person CEN	Additional ventilation for building (add only one) l/s·m² CEN low-polluting building	CEN *Non*-low-polluting building	ASHRAE Ra	Total l/s·m² CEN Low Pol.	Total l/s·m² ASHRAE
Single office (cellular office)	0,1	A	2,5	10	1,0	2,0	0,3	2	0,55
		B		7	0,7	1,4		1,4	
		C		4	0,4	0,8		0,8	
Land-scaped office	0,07	A	2,5	10	1,0	2,0	0,3	1,7	0,48
		B		7	0,7	1,4		1,2	
		C		4	0,4	0,8		0,7	
Conference room	0,5	A	2,5	10	1,0	2,0	0,3	6	1,55
		B		7	0,7	1,4		4,2	
		C		4	0,4	0,8		2,4	

1 l/s m² = 0.2 cfm/ft²

Adapted or Un-adapted ?

Minimum 4 l/s person

- Conference rooms. Adapted?
- Classrooms. Adapted?

Restaurants. Un-adapted

Stores. Un-adapted

Specific Pollutants-Method 2

The ventilation rate required to dilute a pollutant shall be calculated by this equation:

$$Q_h = \frac{G_h}{C_{h,i} - C_{h,o}} \cdot \frac{1}{\varepsilon_v} \qquad \text{Eq (2)}$$

where:

- Q_h is the ventilation rate required for dilution, in litre per second;
- G_h is the pollution load of a pollutant, in micrograms per second;
- $C_{h,i}$ is the guideline value of a pollutant, see Annex B6 , in micrograms per m^3;
- $C_{h,o}$ is the supply concentration of pollutants at the air intake, in micrograms per m^3;
- ε_v is the ventilation effectiveness

NOTE. $C_{h,i}$ and $C_{h,o}$ may also be expressed as ppm (vol/vol). In this case the pollution load G_h has to be expressed as l/s.

Perceived air quality
Un-adapted persons

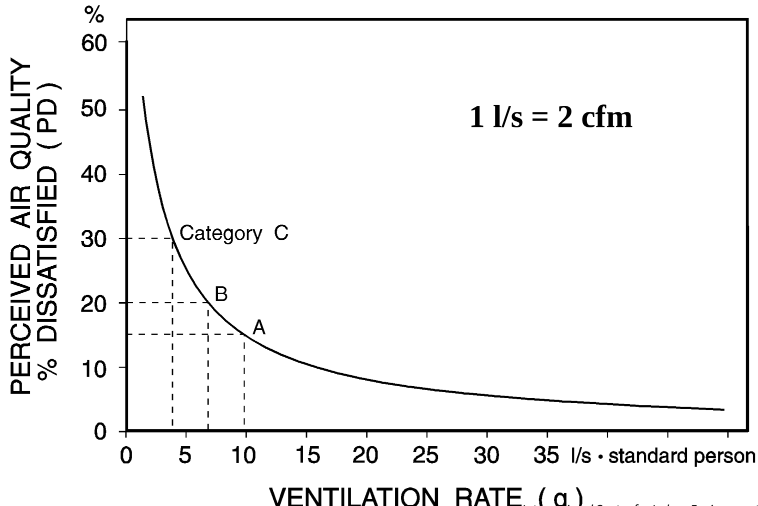
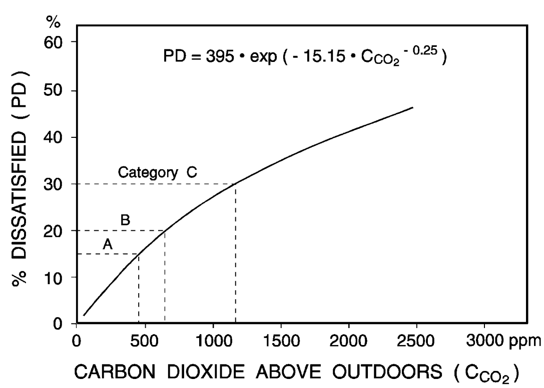


Diagram based on studies with Danish subjects (Fanger et.al).

Similar results obtained by North-American subjects (Cain et.al.)

Similar results obtained with Japanese subjects (Tanabe)

CO_2 as reference not consistent with Method 1



Category	Corresponding CO_2 concentration above outdoors in PPM for non-adapted persons
I	550 (10)
II	800 (7)
III	1 350 (4)
IV	1 350 (4)

Comparison of methods

Category CO_2/ls^{-1} pers)	Corresponding CO2 concentration above outdoors in PPM for non-adapted persons CO_2 emission of 20 L/(h per person)			
	Method 2	Method 1 Single office 0,1 pers/m^2 Low polluting	Method 1 Conference room 0,5 pers/m^2 Low polluting	**Diagram**
I	**550** /10	**278**/20	**463**/25	**450**
II	**800** /7	**397**/14	**661**/17,5	**650**
III	**1 350** /4	**694**/8	**1157**/10	**1200**
IV	**1 350** /4	**1010**/5,5	**1389**/7	

Pollutant	WHO Indoor Air Quality guidelines 2010	WHO Air Quality guidelines 2005
Benzene	No safe level can be determined	-
Carbon monoxide	15 min. mean: 100 mg/m³ 1h mean: 35 mg/m³ 8h mean: 10 mg/m³ 24h mean: 7 mg/m³	-
Formaldehyde	30 min. mean: 100 µg/m³	-
Naphthalene	Annual mean: 10 µg/m³	-
Nitrogen dioxide	1h mean: 200 µg/m³ Annual mean: 40 mg/m³	-
Polyaromatic Hydrocarbons (e.g. Benzo Pyrene A B[a]P)	No safe level can be determined	-
Radon	100 Bq/m³ (sometimes 300 mg/m³, country-specific)	-
Trichlorethylene	No safe level can be determined	-
Tetrachloroethylene	Annual mean: 250 µg/m³	
Sulfure dioxide	-	10 min. mean: 500 µg/m³ 24h mean: 20 mg/m³
Ozone	-	8h mean:100 µg/m³
Particulate Matter PM 2,5	-	24h mean: 25 µg/m³ Annual mean: 10 µg/m³
Particulate Matter PM 10	-	24h mean: 50 µg/m³ Annual mean: 20 µg/m³

WHO guidelines values for indoor and outdoor air pollutants

Issues

- Need for better emission data for building materials, furniture , etc.
- Difficult to estimate what building type you have
- Need for health and comfort criteria for individual pollutant

Issues

- Target CO_2 concentration should correctly be set as difference between inside and outside
- Target CO_2 concentration for the same level of air quality depends on occupant density
- Should we allow to use a dynamic formular for individual substances (meeting rooms, class rooms, etc.)
- If air cleaning technologies are used and partly substituting for outside air the resulting room concentration of CO2 will be higher for the same level of air quality.

Cat.	Method 2 CO_2 above outdoors PPM (l/s*pers.)	Method 1 Single office Low-pol. building CO_2 above outdoors PPM (l/s*pers.)	From Basic data PPM (l/s*pers.)
I	550 (10)	278 (20)	450
II	800 (7)	397 (14)	650
III	1350 (4)	694 (8)	1200
IV	1350 (4)	1010 (5.5)	1350 (4)

Influence of using gas phase air cleaner with 30% efficiency

Space type	Occupancy [pers/m²]	Category	Derived from Method 1 q_{tot}	
			Low-polluting building **No air cleaning**	Low-polluting building **With air cleaning** 30% efficiency
			ΔCO_2 [ppm]	
Single office	0.1	I	278	397
		II	397	567
		III	694	992 (**817**)
		IV	1010 (**794**)	1443 (**911**)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Respiratory infection risk-based ventilation design method

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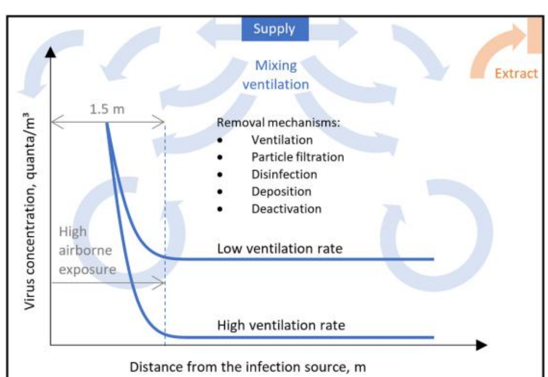
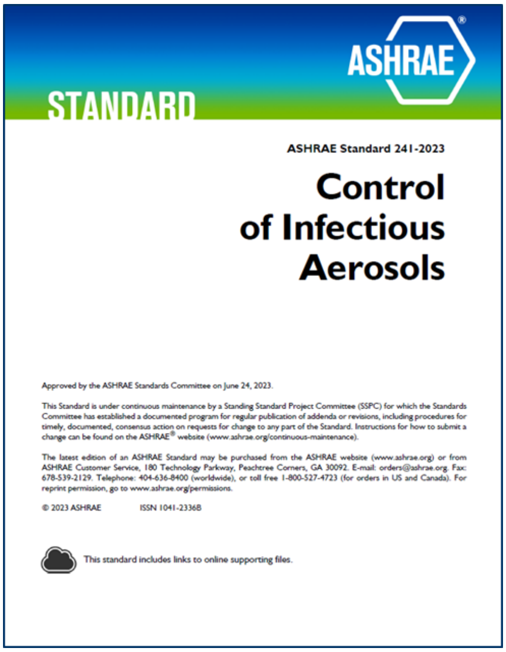
Risk-based ventilation design





STANDARD

ASHRAE

ASHRAE Standard 241-2023

Control of Infectious Aerosols

Approved by the ASHRAE Standards Committee on June 24, 2023.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

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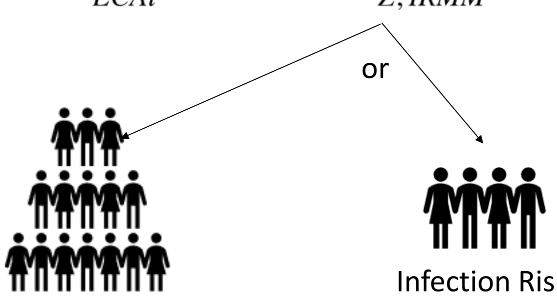
ASHRAE Standard 241-2023
Control of Infectious Aerosols

Equivalent Clean Airflow, ECAi depends on space type, number of people, activity

$$V_{ECAi} = ECAi \times P_{Z,IRMM}$$



Design occupancy

Infection Risk Management Mode, (IRMM) occupancy

Occupancy Category	ECAi cfm/person	ECAi L/s/person
Correctional Facilities		
Cell	30	15
Dayroom	40	20
Commercial/Retail		
Food and beverage facilities	60	30
Gym	80	40
Office	30	15
Retail	40	20
Transportation waiting	60	30
Educational Facilities		
Classroom	40	20
Lecture hall	50	25
Industrial		
Manufacturing	50	25
Sorting, packing, light assembly	20	10
Warehouse	20	10
Health Care		
Exam room	40	20
Group treatment area	70	35
Patient room	70	35
Resident room	50	25
Waiting room	90	45
Public Assembly/Sports and Entertainment		
Auditorium	50	25
Place of religious worship	50	25
Museum	60	30
Convention	60	30
Spectator area	50	25
Lobbies	50	25
Residential		
Common space	50	25
Dwelling unit	30	15

Examples of lighting criteria for some buildings and spaces

Ref. no. acc. to EN 12464-1	Type of area, task or activity	$\bar{E}_m$ lx	UGR_L –	U_o –	R_a –	Specific requirements
5.26.2 5.26.5	Offices - Writing, typing, reading, data processing. Conference and meeting rooms	500	19	0,60	80	DSE-work, see 4.9 Lighting should be controllable.
5.36.1-5.36.3	Educational buildings - Classrooms, tutorial rooms, Classroom for evening classes and adults education, Auditorium, lecture halls	500	19	0,60	80	Lighting should be controllable.
5.36.24	Educational premises – Educational buildings - Sports halls, gymnasiums, swimming pools	300	22	0,60	80	See EN 12193 for training conditions.

Daylight availability classification as a function of the daylight factor $D_{Ca,j}$ of the raw building carcass opening and D_{SNA} 15193

Vertical Facades Daylight factor $D_{Ca,j}$	Roof lights Daylight factor D_{SNA}	Classification of daylight availability
$D_{Ca,j} \geq 6$ %	7 % < D_{SNA}[a]	Strong
6 % > $D_{Ca,j} \geq 4$ %	7 % > $D_{SNA} \geq 4$ %	Medium
4 % > $D_{Ca,j} \geq 2$ %	4 % > $D_{SNA} \geq 2$ %	Low
$D_{Ca,j}$ < 2 %	2 % > $D_{SNA} \geq 0$ %	None
[a] Values of D_{SNA} > 10 % should be avoided due to danger of overheating		

NOISE

Building	Type of space	Equivalent Continuous Sound Level, Leq, nT,A [dB(A)]		
		I	II	III
Residential	Living room	≤30	≤34	≤38
	Bed room	≤26	≤30	≤34
Places of assembly	Auditoriums	≤20	≤24	≤28
	Libraries	≤24	≤28	≤32
	Cinemas	≤20	≤24	≤28
Hospitals	Bedrooms night-time	≤22	≤26	≤30
	Bedrooms daytime	≤24	≤28	≤32
Hotels	Hotel rooms (during night-time)	≤24	≤28	≤32
	Hotel rooms (during daytime)	≤26	≤30	≤34
Offices	Small offices	≤24	≤28	≤32
	Landscaped offices	≤26	≤30	≤34
Restaurants	Restaurants	≤28	≤32	≤36
Schools	Classrooms	≤24	≤28	≤32
	Teacher rooms	≤28	≤32	≤36

Night Ventilation-Night Cooling

- Remove building emissions
- Allow lower room temperature 1 hour in the morning
  - Included in Danish Ventilation standard DS447
  - Higher activity level arriving to work

CRITERIA FOR INDOOR AIR QUALITY ~VENTILATION RATES

- COMFORT (Perceived Air Quality)
- HEALTH
- PRODUCTIVITY
- ENERGY
- ~~Cross contamination~~

ISSUES for REVISION

- Not consistent requirements based on CO_2
- Include recommended criteria for particles (WHO)
- Need health/comfort criteria for substances not included in WHO guideline
- Demand Control Ventilation based on CO_2 requires different set-points:
  - Influenced by occupant density
  - If required ventilation is partly substituted by air cleaning
- Ventilation and cross contamination (pandemic, flue, etc.)
- Personalized Environmental Control Systems (personalized ventilation)
- More focus on ventilation efficiency
- Should productivity be discussed?
- KPIs for yearly performance

Thank You

IT IS A MUCH CLEVERER THING
TO TALK NONSENSE THAN TO LISTEN TO IT
OSCAR WILDE

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