Recommended criteria for thermal comfort and indoor air quality in International standards (ASHRAE-ISO-CEN)

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INDOOR ENVIRONMENT

- THERMAL
- AIR QUALITY
- ACOUSTIC
- LIGHT

EVALUATION OF THE INDOOR ENVIRONMENT

- DESIGN LEVEL
- COMMISSIONING
- TESTING
- COMPLAINTS

STANDARDS

- **ISO EN 7730-2005**
  - 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 55-2016**
  - Thermal environment conditions for human occupancy
- **ASHRAE 62.1 and 62.2 -2016**
  - Ventilation and indoor air quality
- **EN15251**
  - Indoor environmental input parameters for design and assessment of energy performance of buildings- addressing indoor air quality, thermal environment, lighting and acoustic
- **EN 13779**
  - Ventilation for non-residential buildings - performance requirements for ventilation and room-conditioning systems

International Standards
Indoor Environmental Quality

- **prEN16798-1 and ISO 17772-1:**
  - Indoor environmental input parameters for the design and assessment of energy performance of buildings.
- **TR16798-2 and ISO TR 17772-2:**
  - Guideline for using indoor environmental input parameters for the design and assessment of energy performance of buildings.
- **EN 16798-3 and TR 16798-4**
  - Ventilation for non-residential buildings - performance requirements for ventilation and room-conditioning systems

MODERATE ENVIRONMENTS

- GENERAL THERMAL COMFORT
  - PMV / PPD, OPERATIVE TEMPERATURE
- LOCAL THERMAL DISCOMFORT
  - Radiant temperature asymmetry
  - Draught
  - Vertical air temperature difference
  - Floor surface temperature

THERMAL COMFORT

- OPERATIVE TEMPERATURE
- $-0,5 < PMV < +0,5$; $PPD < 10\ \%$
- SPACES WITH MAINLY SEDENTARY OCCUPANTS :
  - SUMMER CLOTHING 0,5 clo
  - ACTIVITY LEVEL 1,2 met
- $23\ °C < t_o < 26\ °C$.

GENERAL THERMAL COMFORT

- Personal factors
  - Clothing
  - Activity

- Environmental factors
  - Air temperature
  - Mean radiant temperature
  - Air velocity
  - Humidity

Categories

Cate-gory	Explanation
I	High level of expectation and also recommended for spaces occupied by very sensitive and fragile persons with special requirements like some disabilities, sick, very young children and elderly persons, to increase accessibility.
II	Normal level of expectation
III	An acceptable, moderate level of expectation
IV	Low level of expectation. This category should only be accepted for a limited part of the year

Recommended 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

Evaluation standard for indoor thermal environment in civil buildings
Chinese standard

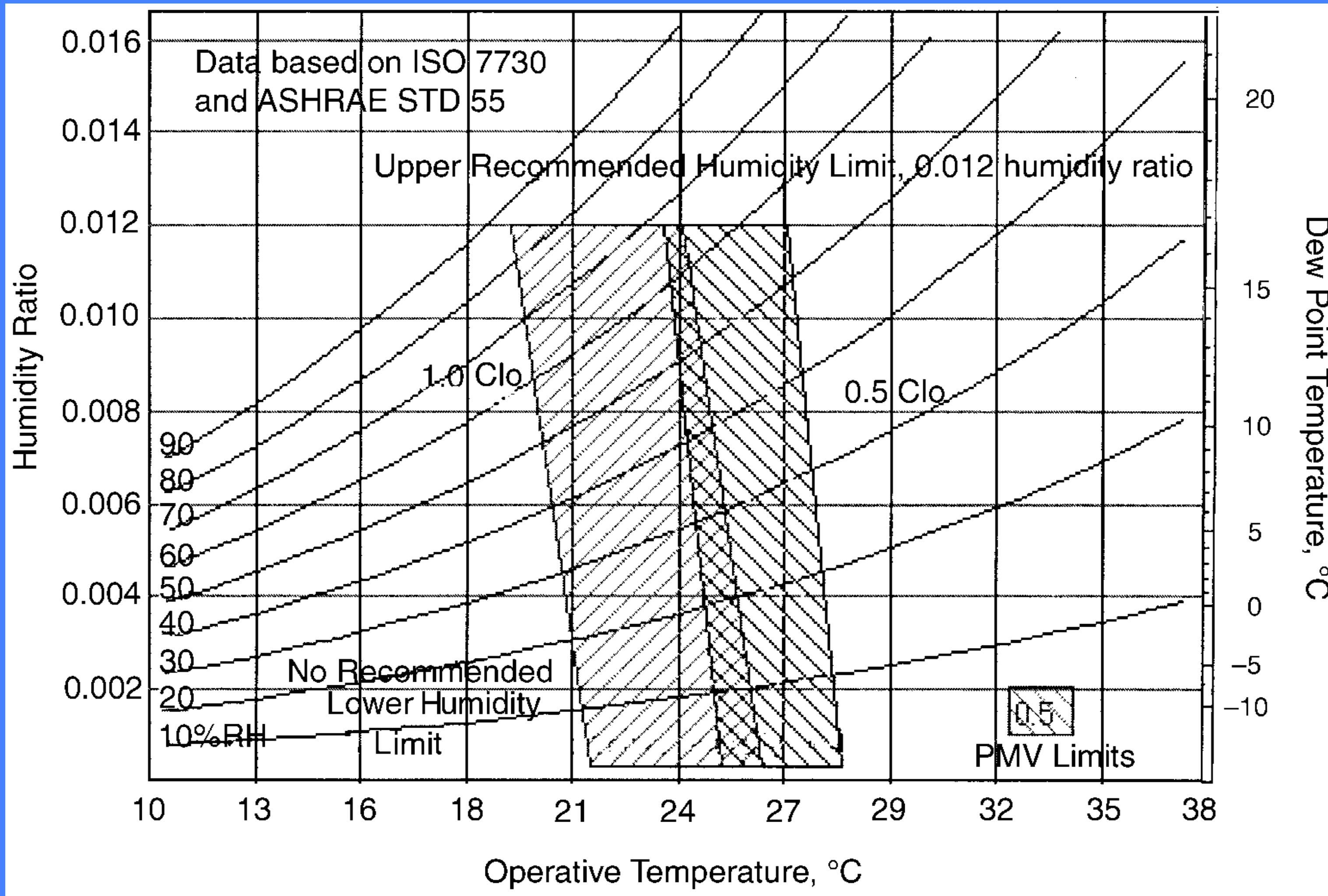
Table 4.2.4-1 overall thermal comfort index value

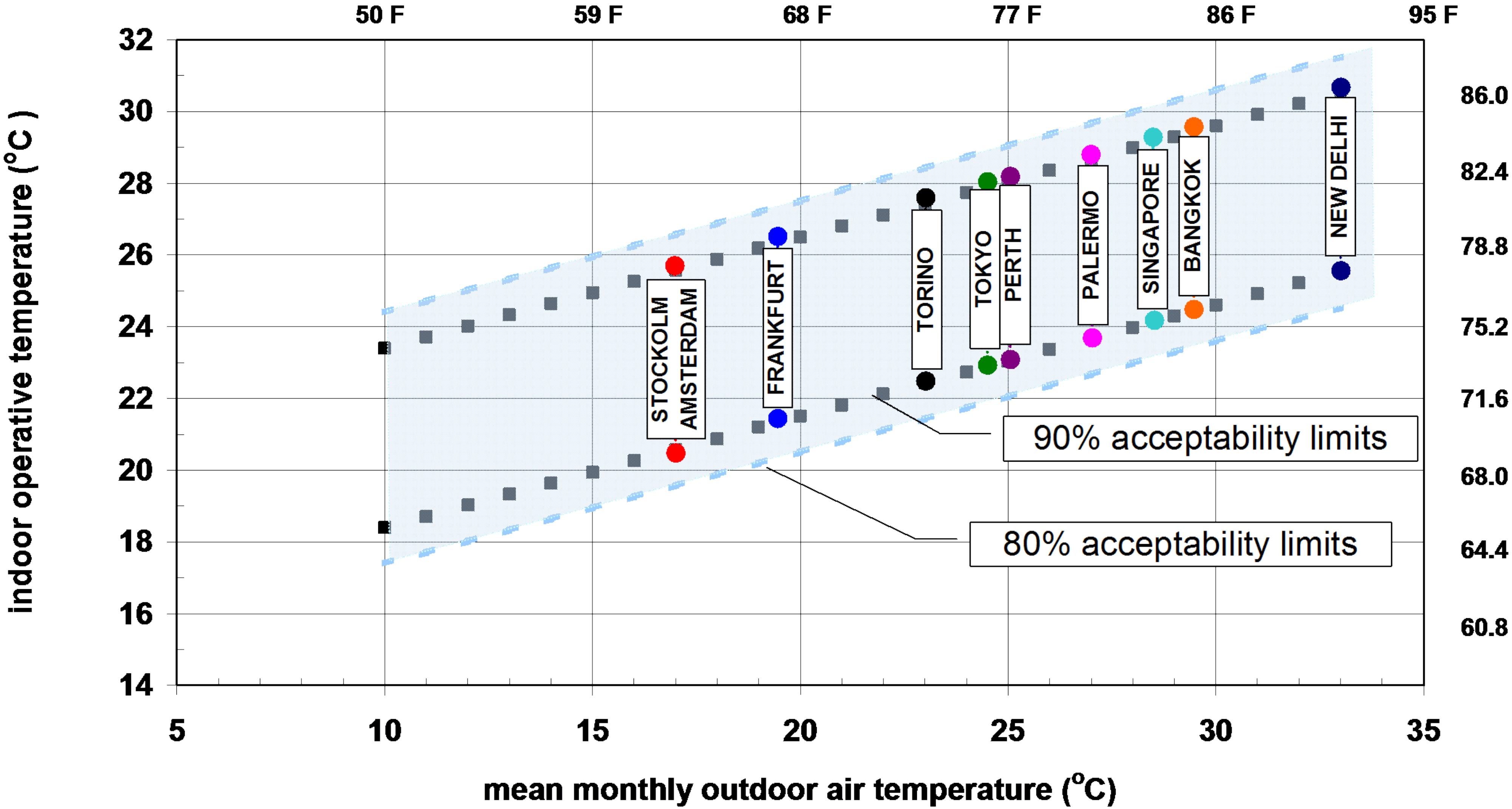
Grade	Overall thermal comfort index	
I	PPD≤10 %	-0.5≤PMV≤+0.5
II	10%<PPD≤25 %	-1≤PMV<-0.5or+0.5<PMV≤+1
III	PPD>25%	PMV<-1 or PMV>+1

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

Type of building/ space	Category	Operative Temperature for Energy Calculations °C	
Offices and spaces with similar activity (single offices, open plan offices, conference rooms, auditorium, cafeteria, restaurants, class rooms, Sedentary activity ~1,2 met		Heating (winter season), ~ 1,0 clo	Cooling (summer season), ~ 0,5 clo
	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 – 26,0	21,0 - 28,0

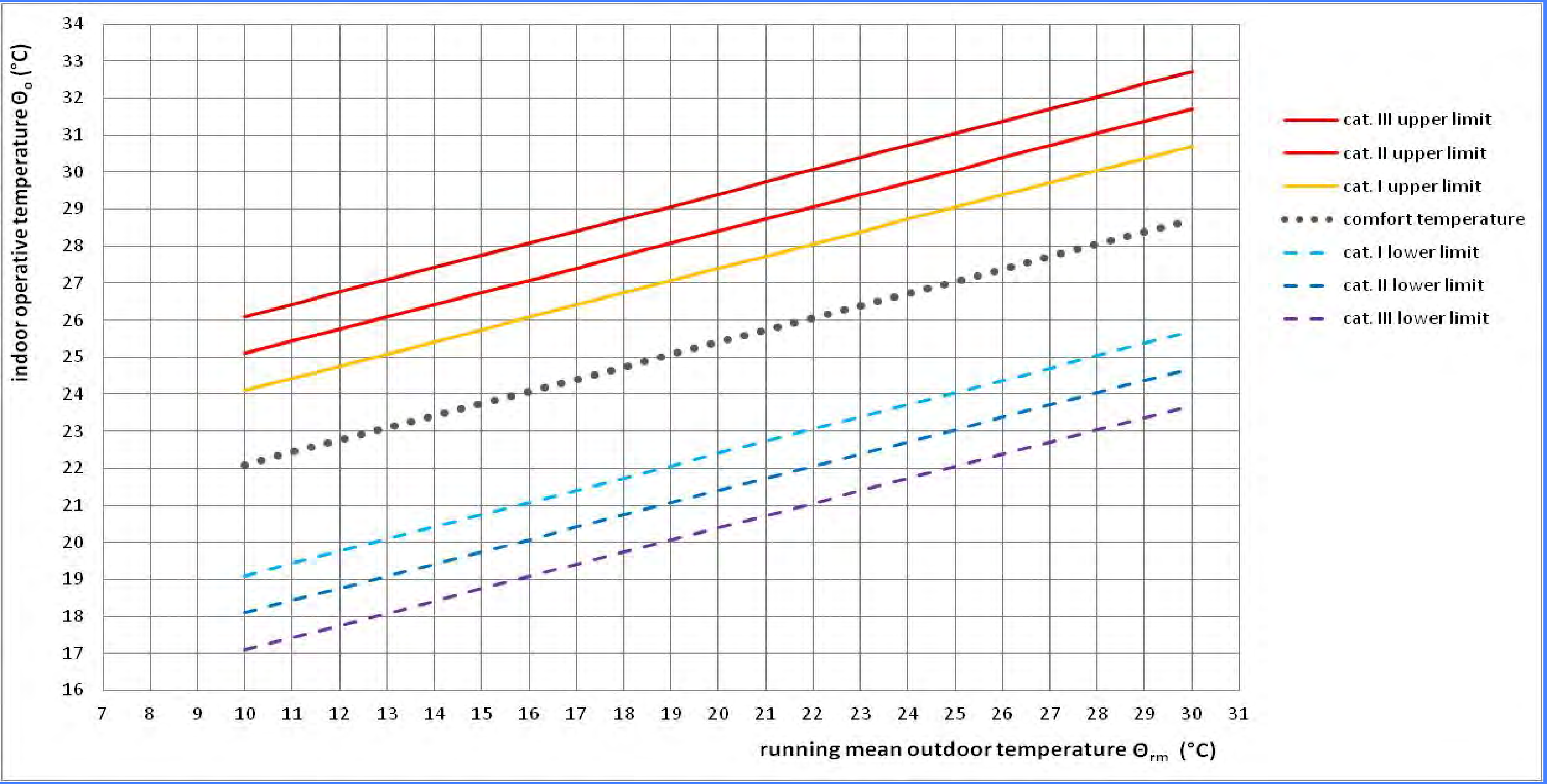
Humidity limits according to ASHRAE-55-2016





50 F
59 F
68 F
77 F
86 F
95 F
32
30
28
26
24
22
20
18
16
14
86.0
82.4
78.8
75.2
71.6
68.0
64.4
60.8
indoor operative temperature (°C)
STOCKOLM
AMSTERDAM
FRANKFURT
TORINO
TOKYO
PERTH
PALERMO
SINGAPORE
BANGKOK
NEW DELHI
90% acceptability limits
80% acceptability limits
5
10
15
20
25
30
35
mean monthly outdoor air temperature (°C)

ISO DIS 17772-1



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

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.

GENERAL THERMAL COMFORT

- AIR VELOCITY
  - Draught
  - Preferred air velocity at increased temperature
  - Direction of air velocity
  - Large individual differences
  - Personal control (fans, windows)

ASHRAE 55-2016

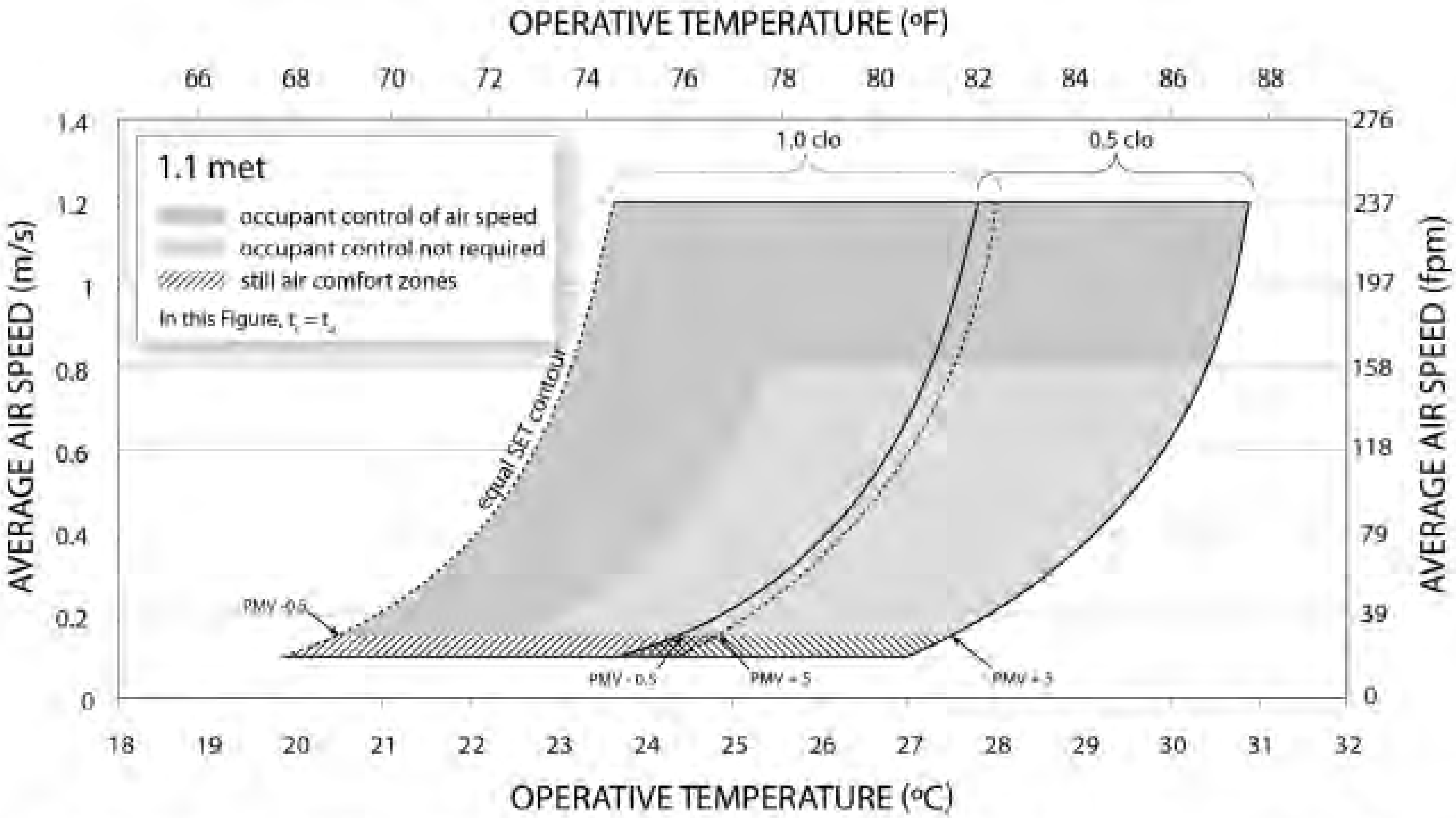


FIGURE 5.3.3A Acceptable ranges of operative temperature (t_o) and average air speed (V_a) for the 1.0 and 0.5 clo comfort zone presented in Figure 5.3.1.1, at humidity ratio 0.010.

LOCAL THERMAL DISCOMFORT

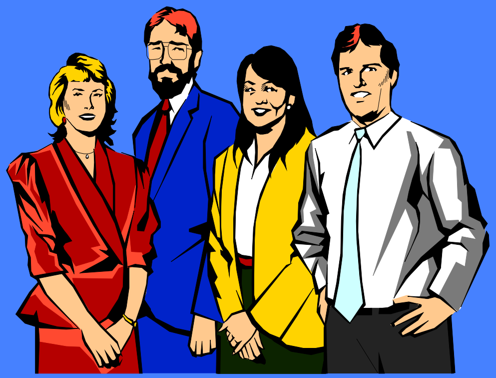
- FLOOR SURFACE TEMPERATURE
- VERTICAL AIR TEMPERATURE DIFFERENCE
- DRAUGHT
- RADIANT TEMPERATUR ASYMMETRI

CRITERIA FOR INDOOR AIR QUALITY ~VENTILATION RATES

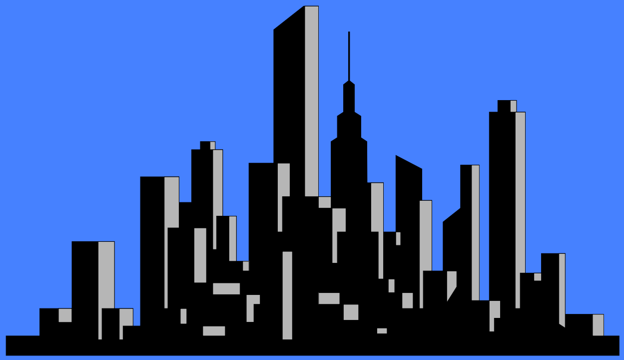
- COMFORT (Perceived Air Quality)
- HEALTH
- PRODUCTIVITY
- ENERGY

Concept for calculation of design ventilation rate

People Component



Building Component



Breathing Zone Outdoor Airflow

$$V_{bz} = R_p P_z + \cancel{R_s S_d} + R_a A_z$$

Minimum l/s/Person

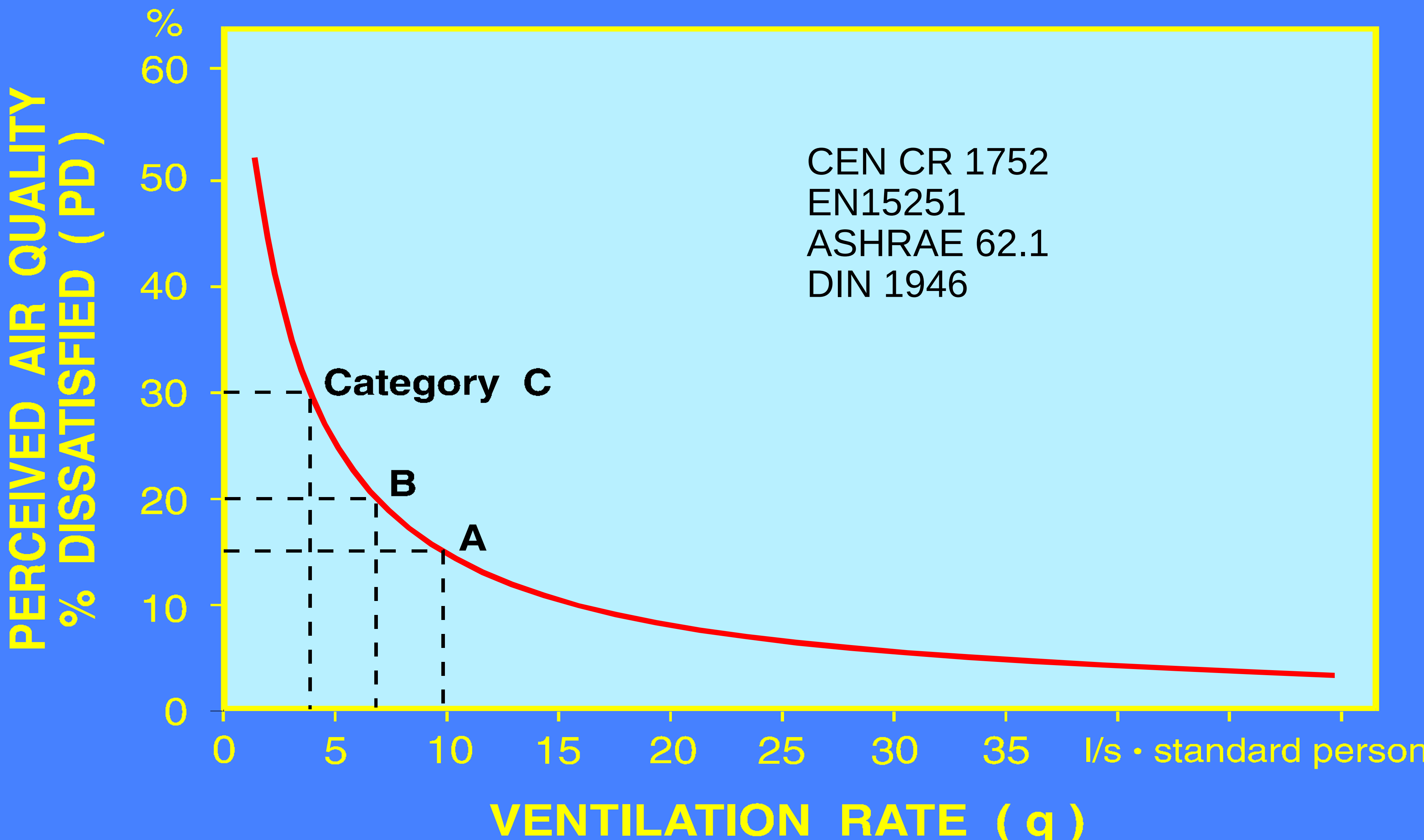
Number of People

~~Ventilation per Smoker~~

~~Number of Smokers~~

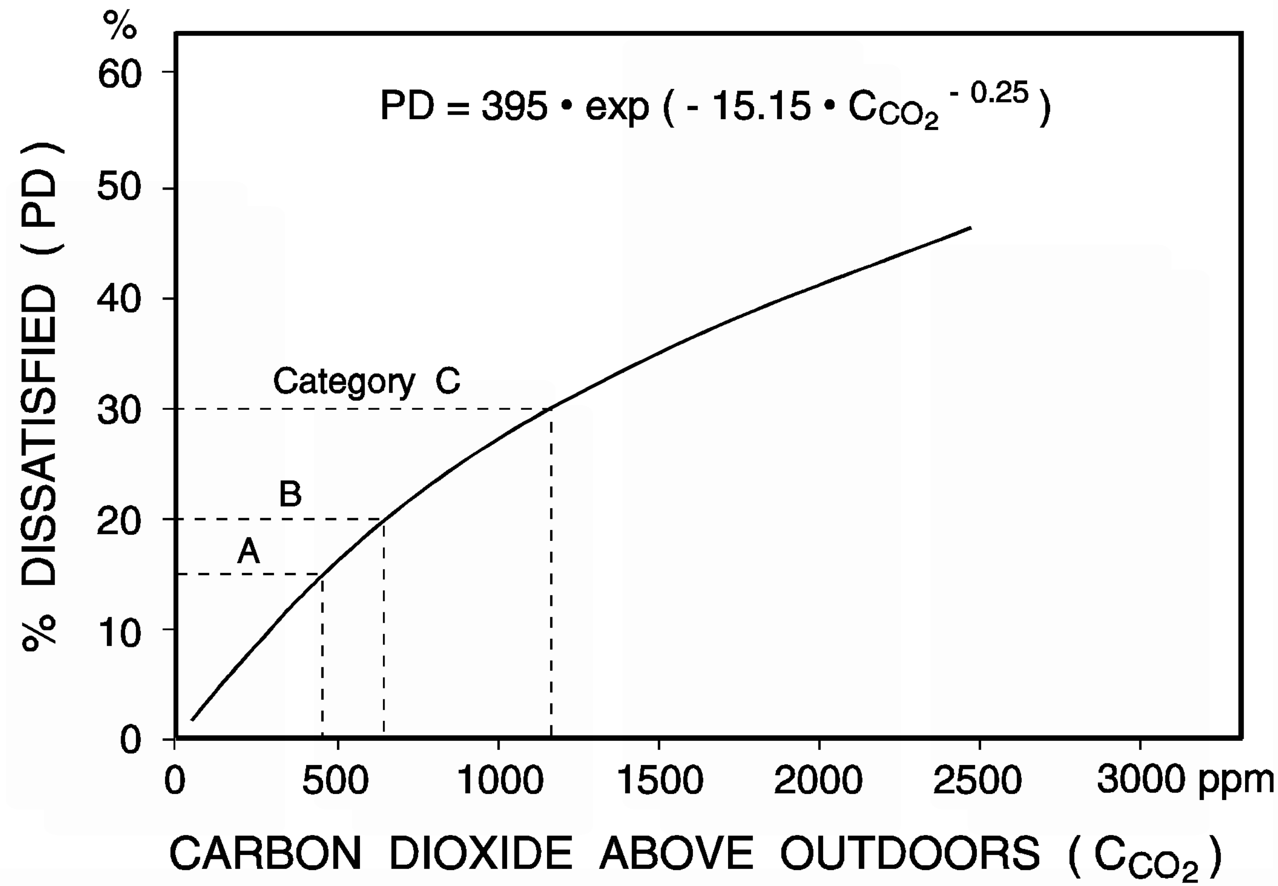
Building Area

Minimum l/s/m^2



%
60
50
40
30
20
10
0
PERCEIVED AIR QUALITY
% DISSATISFIED (PD)
CEN CR 1752
EN15251
ASHRAE 62.1
DIN 1946
Category C
B
A
0
5
10
15
20
25
30
35
l/s • standard person
VENTILATION RATE (q)

CO2 as reference



ASHRAE 62.1

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p	Area Outdoor Air Rate R_a	Notes	Default Values		Air Class
				Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)	
	cfm/person	cfm/ft^2		#/1000 ft^2	cfm/person	
Office Buildings						
Office space	5	0.06		5	17	1
Reception areas	5	0.06		30	7	1

MINIMUM VENTILATION RATES IN BREATHING ZONE

						Default Values		
Occupancy Category	People Outdoor Air Rate R_P		Area Outdoor Air Rate R_A		Notes	Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)	
	cfm/person	L/s•person	cfm/ft^2	L/s•m^2		#/1000 ft^2 (#/100 m^2)	cfm/person	L/s•person
Correctional								
Cell	5	2.5	0.12	0.6		25	10	4.9
Day room	5	2.5	0.06	0.3		30	7	3.5
Guard stations	5	2.5	0.06	0.3		15	9	4.5
Booking/waiting	7.5	3.8	0.06	0.3		50	9	4.4
Educational Facilities								
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6
Classrooms (ages 5-8)	10	5	0.12	0.6		25	15	7.4
Classrooms (age 9	10	5	0.12	0.6		35	13	6.7
Lecture classroom	7.5	3.8	0.06	0.3		65	8	4.3
Lecture hall (fixed	7.5	3.8	0.06	0.3		150	8	4.0
Art classroom	10	5.0	0.18	0.9		20	19	9.5

Basic required ventilation rates for diluting emissions (bio effluents) from people for different categories

Category	Expected Percentage Dissatisfied	Airflow per non-adapted person l/(s.pers)
I	15	10
II	20	7
III	30	4
IV	40	2,5*

*The total ventilation rate must never be lower than 4 l/s per person

ASHRAE Standard 62.1 : Adapted persons 2,5 l/s person (Cat. II)

Design ventilation rates for diluting emissions from buildings

Category	Very low polluting building l/(s m^2)	Low polluting building l/(s m^2)	Non low-polluting building l/(s m^2)
I	0,5	1,0	2,0
II	0,35	0,7	1,4
III	0,2	0,4	0,8
IV	0,15	0,3	0,6
Minimum total ventilation rate for health	4 l/s person	4 l/s person	4 l/s person

Example on how to define low and very low polluting buildings

SOURCE	Low emitting products for low polluted buildings	Very low emitting products for very low polluted buildings
Total VOCs TVOC (as in CEN/TS 16516)	< 1.000 µg/m³	< 300 µg/m³
Formaldehyde	< 100 µg/m³	< 30 µg/m³
Any C1A or C1B classified carcinogenic VOC	< 5 µg/m³	< 5 µg/m³
R value (as in CEN/TS16516)	< 1.0	< 1.0

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 (EN13779)
- 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

Example of design ventilation air flow rates for a single-person office of 10 m^2 in a low polluting building (un-adapted person)

Cate-gory	Low-polluting building l/(s*m^2)	Airflow per non-adapted person l/(s*person)	Total design ventilation air flow rate for the room l/s	l/(s*person)	l/(s* m^2)
I	1,0	10	20	20	2
II	0,7	7	14	14	1,4
III	0,4	4	8	8	0,8
IV	0,3	2,5	5,5	5,5	0,55

Type of building/ space	Occu-pancy person/m²	Cate-gory CEN	Occupants only l/s person		Additional ventilation for building (add only one) l/s·m²			Total l/s·m²	
			ASH-RAE Rp	CEN	CEN low-polluting building	CEN *Non*-low-polluting building	ASH-RAE Ra	CEN Low Pol.	ASH-RAE
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	
Confe-rence 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	

$1\ l/s\ m^2 = 0.2\ cfm/ft^2$

The design *zone outdoor airflow* (*Voz*)

The outdoor airflow that must be provided to the zone by the supply air distribution system, shall be determined in accordance:

$$Voz = Vbz/Ez$$

ASHRAE 62.1

Air Distribution Configuration	E_z
Ceiling supply of cool air	1.0
Ceiling supply of warm air and floor return	1.0
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return. Ceiling supply of warm air less than 15°F (8°C) above space temperature and ceiling return provided that the 150 fpm (0.8 m/s) supply air jet reaches to within 4.5 ft (1.4 m) of floor level. Note: For lower velocity supply air, E_z= 0.8.	0.8 1.0
Floor supply of cool air and ceiling return provided that the 150 fpm (0.8 m/s) supply jet reaches 4.5 ft (1.4 m) or more above the floor. Note: Most underfloor air distribution systems comply with this proviso.	1.0
Floor supply of cool air and ceiling return, provided low- velocity displacement ventilation achieves unidirectional flow and thermal stratification	1.2
Floor supply of warm air and floor return	1.0
Floor supply of warm air and ceiling return	0.7
Makeup supply drawn in on the opposite side of the room from the exhaust and/or return	0.8
Makeup supply drawn in near to the exhaust and/or return location	0.5

TABLE 6-2
Zone Air Distribution Effectiveness

HEALTH CRITERIA FOR VENTILATION ISO 17772-1 and prEN16798-1

Minimum 4 l/s/person

Indoor Air Quality Procedure

The required ventilation rate is calculated as:

$$Q = \frac{G}{(C_i - C_o) \cdot E_v} \quad \text{l/s}$$

where G =	Total emission rate	mg/s
Ci =	Concentration limit	mg/l
C_o =	Concentration in outside air	mg/l
E_v =	Ventilation effectiveness	

EPA Ambient-Air Quality Standards Contaminant	Long Term Concentration Averaging $\mu g/m^3$	ppm		Short Term Concentration Averaging $\mu g/m^3$	ppm	
Sulfur dioxide	80	0.03	1 year	365[a]	0.14[a]	24 hours
Particles (PM 10)	50[b]	—	1 year	150[a]	—	24 hours
Carbon monoxide				40,000[a]	35[a]	1hour
Carbon monoxide				10,000[a]	9[a]	8 hours
Oxidants (ozone)				235[c]	0.12[c]	1 hour
Nitrogen dioxide	100	0.055	1 year			
Lead	1.5	—	3 months[d]			

a Not to be exceeded more than once per year.
b Arithmetic mean.
c Standard is attained when expected number of days per calendar year with maxi-mal hourly average concentrations above 0.12 ppm (235 $\mu g/m^3$) is equal to or less than 1, as determined by Appendix H to subchapter C, 40 CFR 50.
d Three-month period is a calendar quarter.

WHO guidelines values for indoor and outdoor air pollutants

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/m^3 1h mean: 35 mg/m^3 8h mean: 10 mg/m^3 24h mean: 7 mg/m^3	-
Formaldehyde	30 min. mean: 100 µg/m^3	-
Naphthalene	Annual mean: 10 µg/m^3	-
Nitrogen dioxide	1h mean: 200 µg/m^3 Annual mean: 40 mg/m^3	-
Polyaromatic Hydrocarbons (e.g. Benzo Pyrene A B[a]P)	No safe level can be determined	-
Radon	100 Bq/m^3 (sometimes 300 mg/m^3, country-specific)	-
Trichlorethylene	No safe level can be determined	-
Tetrachloroethylene	Annual mean: 250 µg/m^3	
Sulfure dioxide	-	10 min. mean: 500 µg/m^3 24h mean: 20 mg/m^3
Ozone	-	8h mean:100 µg/m^3
Particulate Matter PM 2,5	-	24h mean: 25 µg/m^3 Annual mean: 10 µg/m^3
Particulate Matter PM 10	-	24h mean: 50 µg/m^3 Annual mean: 20 µg/m^3

INDIA-Indoor Environmental Quality

Table3 Threshold values for indoor air quality parameters

Parameters	Units	Classification		
		Class A	Class B	Class C
CO_2	ppm	Ambient + 350	Ambient + 500	Ambient + 800
PM 2.5	µg/m^3	<15	<25	<60
PM 10	µg/m^3	<50	<100	<100
CO	ppm	<9	<9	< 9
TVOC	µg/m^3	<200	<400	<600
CH_2O	µg/m^3	<30	<100	-
SO_2	µg/m^3	<40	<80	-
NO_2	µg/m^3	<40	<80	-
O_3	µg/m^3	<50	<100	-
Total Microbial Count	CFU/m^3	Indoor ≤ ambient	Indoor ≤ ambient	-
User Satisfaction	%	90	80	-

Residential buildings

Category	Total ventilation including air infiltration (1)		Supply air flow per. person (2)	Supply air flow based on perceived IAQ for adapted persons (3)		Supply air flow Bed room level (l/s) (4)		Exhaust air flow, l/s peak or boost flow for high demand		
	l/s,m^2	ach	l/s*per	q_p l/s*per	q_B l/s,m^2	Master bed-room l/s	Other bed-room l/s	Kit-chen (3a)	Bath-rooms (3b)	Toilets (3c)
I	0,49	0,7	10	3,5	0,25	20	10	28	20	14
II	0,42	0,6	7	2,5	0,15	14	8	20	15	10
III	0,35	0,5	4	1,5	0,1	8	4	14	10	7
IV*	0,23	0,4				5*	2,5*	10	6	4

$$Q_{tot} = 0.15A_{floor} + 3.5(N_{br} + 1) \qquad \text{(SI)} \quad (4.1b)$$

where

Q_{tot} = total required ventilation rate, L/s

A_{floor} = dwelling-unit floor area, m^2

N_{br} = number of bedrooms (not to be less than 1)

ASHRAE 62.2 Residential

Occupant density:

Two persons (studio, one-bedroom

Plus one person i.e. plus 3.5 L/s for

each additional bedroom

TABLE 4.1b (SI) Ventilation Air Requirements, L/s

	Bedrooms				
Floor Area, m^2	**1**	**2**	**3**	**4**	**5**
<47	14	18	21	25	28
47–93	21	24	28	31	35
94–139	28	31	35	38	42
140–186	35	38	42	45	49
187–232	42	45	49	52	56
233–279	49	52	56	59	63
280–325	56	59	63	66	70
326–372	63	66	70	73	77
373–418	70	73	77	80	84
419–465	77	80	84	87	91

Example criteria for personalized systems

Aspect	Requirement
'Temperature' control winter	At workstation level, the (operative/equivalent) temperature is adjustable with a response speed of at least 0,5 K/minute within a range of 5 K, from 18 °C to 23 °C.
'Temperature' control summer	At workstation level, the (equivalent) temperature is adjustable (with a response speed of at least 0,5 K/minute within a range of 5 K, from 22 °C to 27 °C.
Fresh air supply control	Local fresh air supply (per workstation) is adjustable from around 0 to at least 7 l/s.
Delivered air quality	For requirements related to air cleaning technology: see Annex K.
Installation noise	Noise level – with the personalized system in the highest setting – should not be higher than 35 dB(A).

This is a topic under IEA -EBC Annex 69 "Thermal Comfort"

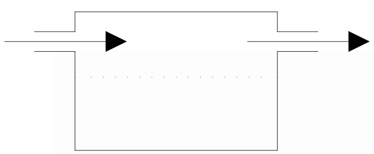
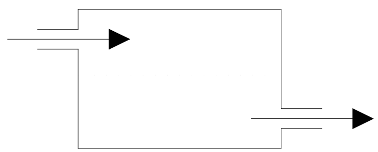
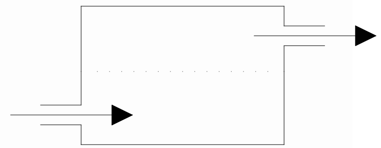
Air Distribution Effectiveness

$$\varepsilon_V = \frac{C_E - C_S}{C_I - C_S}$$

CEN Report CR 1752 (1998)

Concentrations:

C_E	**exhaust air**
C_S	**supply air**
C_I	**breathing zone**

Mixing ventilation		Mixing ventilation		Displacement ventilation		Personalized ventilation	
							
T supply - T inhal °C	Vent. effect. -	T supply - T inhal °C	Vent. effect. -	T supply - T inhal °C	Vent. effect. -	T supply - T room °C	Vent. effect. -
< 0	0,9 - 1,0	< -5	0,9	<0	1,2 - 1,4	-6	1,2 - 2,2
0 - 2	0,9	-5 - 0	0,9 - 1,0	0-2	0,7 - 0,9	-3	1,3 - 2,3
2 - 5	0,8	> 0	1	>2	0,2 - 0,7	0	1,6 - 3,5
> 5	0,4 - 0,7						

COMFORT-PRODUCTIVITY
Building costs

People	100
Maintenance	10
Financing	10
Energy	1

This clearly show that buildings are for people not for saving energy