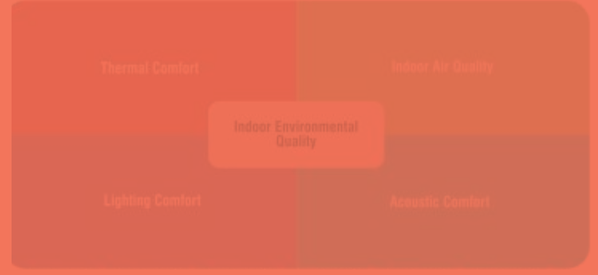
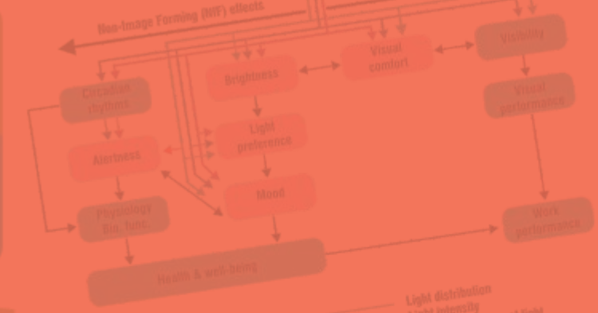
Indoor Environmental Quality Standard

ISHRAE Standard- 10001:2016

Indoor Environmental Quality Standard
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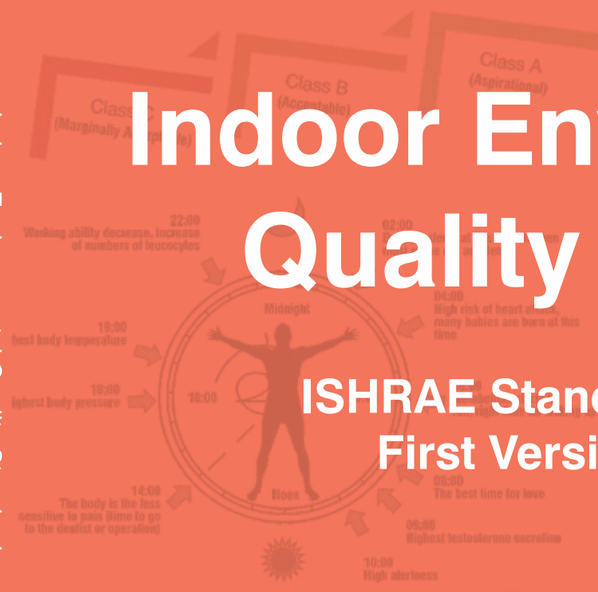




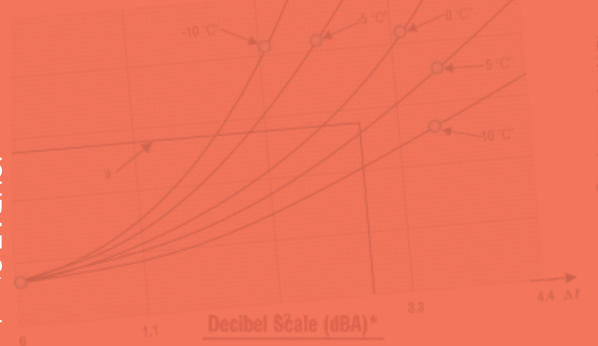


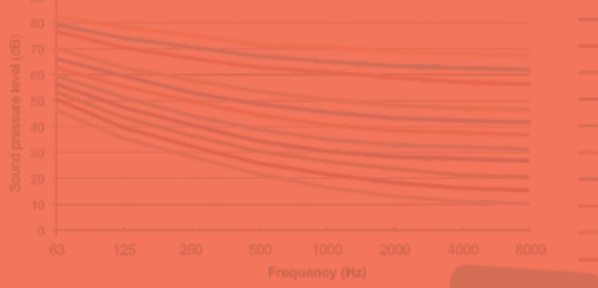
Indoor Environmental Quality Standard

ISHRAE Standard - 10001:2016
First Version: 2016-2017

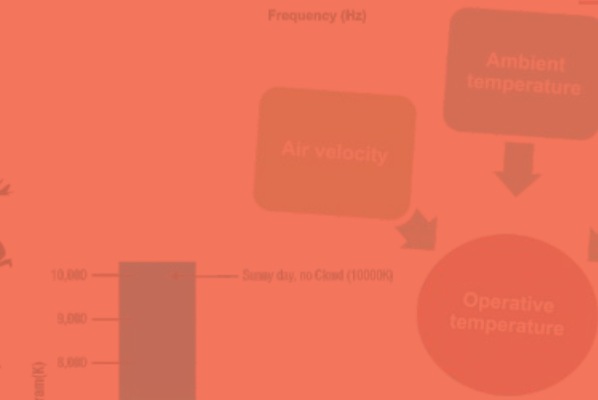


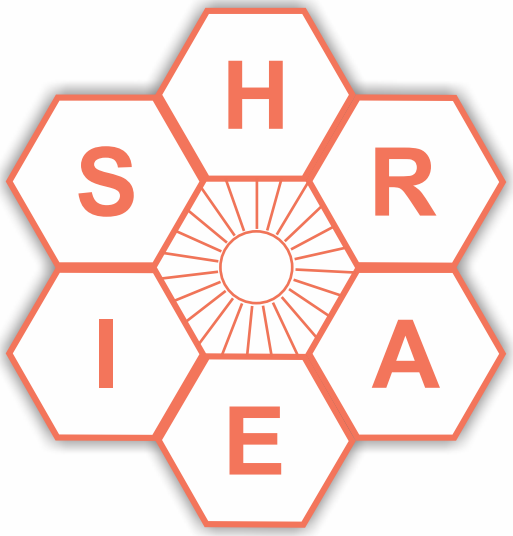











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Indoor Environmental Quality Standard

ISHRAE Standard - 10001:2016
First Version: 2016-2017

Foreword

Dear Friends,

On behalf of IEQ Standard Committee, it gives me immense pleasure to present the first ever Indian Standard on Indoor Environmental Quality. The idea of putting together a Standard was conceived a year back when the world attention was drawn towards India due to wrong reasons of growing outdoor air pollution. To the surprise of ISHRAE team, we discovered that though there were norms in the country for Outdoor Air pollutants levels, however, one had to refer to International standards for Indoor pollutants concentrations recommended in indoor spaces. In addition, the Green Building rating systems have for long focused on Indoor Environmental Quality (IEQ) but largely relied on International standards as a reference. The most striking fact related to Thermal Comfort wherein the threshold limits of Indians were completely disregarded in absence of any local research data and the indoor design conditions were prescribed from the research & standards emanating from developed countries.

ISHRAE Standards Committee formed a committee comprising of leading experts from India and also included International community members who had experience of working in the country. The team had a fine mix of Users, Specifiers, Academicians & Testing agency representative that worked incessantly for nearly 52 weeks to compile this fine document which is probably the first of its kind from a Developing country. While the reference was made to the current International works on this subject but in addition the research done by local institutions like MNIT Jaipur has been included for Thermal Comfort section. An important aspect of the Standard is to set the indoor pollutant benchmark for entry level buildings, average building and finally an aspirational building. The ISHRAE IEQ document was also sent out for peer review to large number of Indian & International organizations working on this subject. The ISHRAE Standard committee members painstakingly incorporated the comments and this document is set to be a stepping stone for further work in this field of growing importance.

I am grateful to entire ISHRAE IEQ team and particularly my co-chairs Mr Manjunath & Dr Jyotirmay Mathur who have worked tirelessly to create this document. My acknowledgement also goes out to Nikhil Jain who got involved as a research scholar from MNIT and has now made a career in the field of IEQ. He has been a valuable asset to entire committee.

Please feel free to reach out to Committee members for any suggestions & improvements.

Best regards

Ashish Rakheja
Chairman ISHRAE Standards Committee

INDEX

Committee Members i

Foreword iii

Disclaimer vii

Introduction 1

1. Scope 3
1.1. Scope 3
1.2. Out of Scope 3

2. Normative References 3

3. Terms and Definitions 5
3.1. General 5
3.2. Thermal comfort 5
3.3. Indoor air quality 8
3.4. Lighting comfort 10
3.5. Acoustic comfort 11

4. Abbreviations, symbols and units 12
4.1. Abbreviations 12
4.2. Symbols 13
4.3. Units 13

5. Indoor Environmental Quality 13
5.1. Introduction 13
5.2. Threshold values of IEQ parameters 17

6. Measurement 22
6.1. General 22
6.2. Thermal comfort 22
6.3. Indoor air quality 23
6.4. Lighting comfort 25
6.5. Acoustic comfort 25

7. Specifications of Instruments 26

8. Occupant satisfaction survey 27
8.1. General 27
8.2. Survey Questions 27

9. Documentation methodology 29
9.1. Report format 29
9.2. Format for reporting measured values of different parameters 30
9.3. Format for reporting results of satisfaction survey 31

Annex A Thermal comfort 32
A.1 (Normative): Calculation of Operative Temperature (to) 32
A.2 (Normative): Required Air Speed to Offset Increased Temperature 33
A.3 (Normative): Factors leading to local thermal discomfort 33
A.4 (Normative): Measurement Sensor location for thermal comfort 35

Annex B Indoor air quality 36
B.1 (Normative): Definition of Indoor Air Pollutants 36
B.2 (Informative):Important types of indoor environment and sources of air pollutants 40
B.3 (Informative):Sources of indoor air pollutants and their most important emissions 41
B.4 (Informative): Typical pollutants and their sources in indoor environment 44

Annex C Lighting comfort 45
C.1 (Normative): Circadian Lighting Design 45
C.2 (Normative): Recommended methodology to calculate
Equivalent Melanopic Lux (EML) for different type of lighting conditions 46

Annex D Acoustic comfort 48
D.1 (Normative): Noise criterion curves 48
D.2 (Informative): Noise level associated with typical activities 49

About ISHRAE 50

FIGURES AND TABLES

Figure 1	Factors affecting thermal comfort in an indoor environment	19
Figure 2	Indoor air pollutants in a typical built environment	20
Figure 3	Effects of lighting condition	21
Figure 4	Noise source in a typical indoor environment	22
Figure 5	Categories of Indoor Environmental Quality parameters	22
Figure 6	Parameters influencing operative temperature	39
Figure 7	Required Air Speed to Offset Increased Temperature	40
Figure 8	Radiant Temperature Symmetry caused by a cold wall, a warm ceiling, a cold ceiling, or	41
Figure 9	Local thermal discomfort caused by vertical air temperature difference (left) and floor surface temperature (right)	41
Figure 10	Position of the probes at different height according to standing and sitting position	42
Figure 11	Comparison of PM size with human hair diameter and beach sand particle size	43
Figure 12	Circadian rhythms in humans	52
Figure 13	Correlated Colour Temperature (K) corresponding to typical lighting conditions	53
Figure 14	Noise criterion curves	55
Figure 15	Estimating NC – Noise Criterion	56
Figure 16	Noise level corresponding to typical equipment and activities	57

Table 1	Acceptable range of thermal comfort parameters with air velocity upto 0.2 m/s	23
Table 2	Acceptable range of operative temperature with air velocity upto 0.2 m/s	23
Table 3	Threshold values for indoor air quality parameters	24
Table 4	Threshold values of parameters for lighting comfort	24
Table 5	Threshold Illuminance level depending upon type of space	26
Table 6	Requirements of Acoustic comfort	27
Table 7	Measurement methodology for thermal comfort	29
Table 8	Measurement methodology of indoor air quality parameters	30
Table 9	Measurement methodology for acoustic comfort	32
Table 10	Specifications of the instruments to be used for measuring IEQ parameters	32
Table 11	Sources of Formaldehyde in indoor environment	44
Table 12	Light source and melanopic ratio corresponding to different CCT (K)	53

Disclaimer

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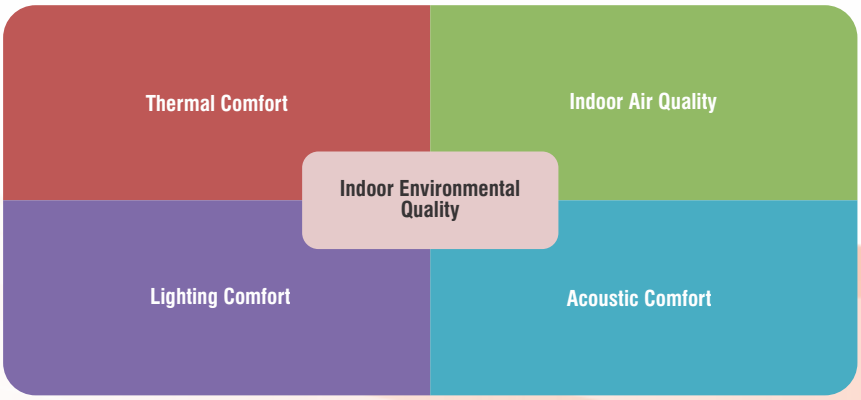
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Introduction

Indoor Environmental Quality (IEQ) refers to the environmental condition inside buildings that is determined by many factors, including indoor air quality (IAQ), thermal comfort, lighting comfort, acoustic comfort as well as furniture and space layout. IEQ has an impact on health, comfort, and safety, which in turn affects productivity of building occupants.

Research has shown that poor indoor environmental quality can have short and long term health effects. Indoor air pollutants can lead to health disorders such as headaches, allergies, asthma, and other respiratory diseases. Furthermore, conditions such as temperature, relative humidity, noise and lighting levels outside the acceptable comfort ranges could increase the stress level in human body, thus creating health issues like sleep disorder, digestive problems, and memory and concentration impairment besides resulting into discomfort of occupant.

In a good indoor environment, work efficiency of occupants gets enhanced, learning results are better among students and absenteeism is lower. This in-turn increases workplace productivity and test scores in schools, which is supported by research.



This standard identifies thermal comfort, indoor air quality, lighting comfort and acoustic comfort as four critical elements of IEQ. Each of these elements have been covered by defining their threshold levels of IEQ parameters. Three levels for defining threshold values have been created: Class A (Aspirational), Class B (Acceptable) and Class C (Marginally acceptable). The defined threshold levels become more stringent for Class B and Class A. Some parameters have been omitted in Class B and Class C as the standard is applicable to variety of buildings ranging from unconditioned residences to large air conditioned commercial complexes. Class A is comparable with internationally prevalent standards.

This standard is designed in such a way that an IEQ rating system can be evolved. Any building evaluated using this standard, can be assessed as Class A, Class B, and Class C while complying with any individual parameter. It is possible that for one parameter; example IAQ, a building may perform better than Class A, whereas, for some other, it might not even meet threshold level as Class C.

There are several other IEQ elements and parameters that could have been included in this standard. However, wherever reliable supporting data, published studies, and affordable measuring instruments are not easily available, this version of the standard has excluded such

elements and parameters. It is also envisaged that effect of most such parameters is likely to be covered through occupant satisfaction survey. Efforts have been made to utilise the knowledge and research presented in several India specific studies.

IEQ considerations need not be a constraint for energy efficiency in buildings. An integrated design approach that considers both indoor environmental quality and energy efficiency is crucial for the long term sustainability of buildings in India.

1. Scope

This standard defines the recommended values and methods of measurement including technical specification of the measuring instruments for the following elements of IEQ:

a) Indoor air quality
b) Thermal comfort
c) Lighting comfort
d) Acoustic comfort

1.1. Scope

The occupied built environment covered in this standard are:

a) Naturally ventilated buildings
b) Mixed mode buildings
c) Air conditioned buildings

This standard is applicable to regularly occupied spaces in residential and non-residential buildings for low and moderate level of activities.

This standard defines three levels of values for individual IEQ parameters under Class A (Aspirational), Class B (Acceptable) and Class C (Marginally acceptable).

1.2. Out of Scope

a) Spaces used for high intensity activities or special purposes such as gymnasiums, indoor sports facilities, wedding halls and similar applications.
b) Specific requirements for specialised built environment such as Operation Theatres, Intensive Care Units, clean room, scientific laboratories, industry and other specialised applications.
c) Other Indoor environmental quality parameters such as ergonomics, electromagnetic radiations and vibrations.
d) Pollutants such as Lead, Benzene, Styrene, Ammonia, Radon, Asbestos and others not specified in this standard.

2. Normative References

The following standards contain provision which through reference in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

IS 5182 – Part 2: Methods for Measurement of Air Pollution, Part 2: Sulphur Dioxide
IS 5182 – Part10: Methods for Measurement of Air Pollution, Part 10: Carbon Monoxide
IS 5182 – Part 9: Methods for measurement of air pollution, Part 9: Oxidants
IS 36461: Code of Practice for Interior Illumination
NBC 2005: the National Building Code of India 2005
Central Pollution Control Board - Indoor Air Pollution Monitoring Guidelines, 2014
Central Pollution Control Board – the Noise Pollution (Regulation and Control) Rules, 2000
ISO 3382 – Part 1: Acoustics — Measurement of room acoustic parameters — Part 1: Performance spaces
ISO 3382 – Part 2: Acoustics — Measurement of room acoustic parameters — Part 2: Reverberation time in ordinary rooms
ISO 3382 – Part 3: Acoustic parameters — Part 3: Open plan offices
ISO 18233: Acoustics — Application of new measurement methods in building and room

	acoustics
ISO 1996-2:	Acoustics -- Description, measurement and assessment of environmental noise — Part 2: Determination of environmental noise levels
ISO 140-7:	Acoustics - Measurement of sound Insulation in buildings and of building elements. Part 7: Field measurements of impact sound insulation of floors
ISO 16017-1:	Indoor, ambient and workplace air -- Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography — Part 1: Pumped sampling
ISO 16000-3:	Determination of formaldehyde and other carbonyl compounds in indoor air and test chamber air -- Active sampling method
ISO 16000-5:	Sampling strategy for volatile organic compounds (VOCs)
ISO 16000-6:	Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS or MS-FID
ISO 16000-15:	Sampling strategy for nitrogen dioxide (NO_2)
ISO 16000-16:	Detection and enumeration of moulds — Sampling by filtration
ISO 16000 -17:	Detection and enumeration of moulds — Culture-based method
ISO 16000 -18:	Detection and enumeration of moulds — Sampling by impaction
ISO 16000 -19:	Sampling strategy for moulds
ISO 16000 -20:	Detection and enumeration of moulds -- Determination of total spore count
ISO 16000 -21:	Detection and enumeration of moulds —Sampling from materials
ISO 16000-26:	Sampling strategy for carbon dioxide (CO_2)
ISO 16000-34:	Strategies for the measurement of airborne particles (PM 2.5 fraction)
ISO 16000-37:	Strategies for the measurement of PM 2.5
ISO 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 criteria
ASHRAE 55-2013:	Thermal Environment Conditions for Human Occupancy
ASHRAE HANDBOOK – 2011:	HVAC Applications
ASTM International Designation E336-97:	Standard Test Method for Measurement of Airborne Sound Insulation in Buildings
WELL - The WELL Building Standard, February 2016	
IEC 61672:	Electro acoustics – Sound level meters – Part 1: Specifications
REHVA Guidebook No 14:	Indoor Climate Quality Assessment
Hongkong BEAM:	BEAM Plus for New Buildings, Version 1.2 (2012.07)
CIBSE:	The SLL Code for Lighting (March 2012)

3. Terms and Definitions

3.1. General

3.1.1. Accuracy

It is the amount of uncertainty in a measurement with respect to an absolute standard. Accuracy specifications usually contain the effect of errors due to gain and offset parameters.

3.1.2. Climate data

Hourly, site-specific values of representative meteorological data, such as temperature, wind speed, solar irradiation, and relative humidity.

3.1.3. Elements

In this standard the term 'elements' refer to thermal comfort, indoor air quality, lighting and acoustic related dimensions of indoor environment.

3.1.4. Indoor Environment Quality (IEQ)

The combination of indoor air quality, and thermal, visual, acoustic, ergonomic comfort; which influences indoor well-being and productivity in indoor environments.

3.1.5. Objective method

Method that quantifies the physical, physiological or psychological condition of a person by the use of instrumentation or measures of output such as performance measures.

3.1.6. Range

The upper and lower limits to which an instrument can measure a value or signal

3.1.7. Resolution

Resolution is the ability to 'resolve' differences; that is, to draw a distinction between two things. High resolution means being able to resolve small differences. In a digital system, resolution means the smallest increment or step that can be taken or seen. In an analog system, it means the smallest step or difference that can be reliably observed.

3.1.8. Sick Building Syndrome

Symptoms such as headache, fatigue, eye irritation, and breathing difficulties that typically affect workers in modern airtight office buildings, and that are believed to be caused by indoor pollutants and poor environmental control.

3.1.9. Subjective method

Method that quantifies the responses of people to an environment using subjective scales.

3.2. Thermal comfort

3.2.1. Acceptable thermal environment

Thermal environment that a substantial majority of the occupants find thermally acceptable.

3.2.2. Adaptive model

A model that relates indoor design conditions or acceptable ranges of indoor environment parameters, such as temperature, to outdoor meteorological or climatological parameters. It also encompasses gradual diminution of the people's response to repeated environmental stimulation and subsumes all processes which building occupants undertake in order to improve the comfort of the indoor environment.

3.2.3. Air temperature

The temperature of the air surrounding the occupant.

3.2.4. Ambient air

The air surrounding a building; the source of outdoor air brought into a building.

3.2.5. Average air speed (v_a)

The air speed surrounding a representative occupant averaged with respect to location and time. The spatial average is for three heights as defined for average air temperature (t_a). The air speed is averaged over an interval not less than 1minute and not more than 3 minutes. Variations that occur over a period greater than 3 minutes shall be treated as multiple different air speeds.

3.2.6. Average air temperature (t_a)

The air temperature surrounding a representative occupant averaged with respect to location and time. The spatial average is the numerical average of the air temperature at the ankle level, the waist level, and the head level. These levels are 0.1 m, 0.6 m, and 1.1 m for seated occupants and 0.1 m, 1.1 m, and 1.7 m for standing occupants. Time averaging is over a period not less than 3 minutes and not more than 15 minutes.

3.2.7. Clo

A unit used to express the thermal insulation provided by garments and clothing ensembles, where 1 clo = 0.155 $m^2 \cdot °C/W$.

3.2.8. Draft

The unwanted local cooling of the body caused by air movement.

3.2.9. Garment

A single piece of clothing

3.2.10. Floor temperature

The surface temperature of the floor where it is in contact with the occupant's feet.

3.2.11. Local thermal discomfort

The thermal discomfort caused by locally specific conditions such as a vertical air temperature difference between the feet and the head, by radiant temperature asymmetry, by local convective cooling (draft), or by contact with a hot or cold floor.

3.2.12. Metabolic rate

The rate of transformation of chemical energy into heat and mechanical work by metabolic activities of an individual, per unit of skin surface area and expressed in units of met, equal to 58.2 W/m^2, which is the energy produced per unit skin surface area of an average person seated at rest.

3.2.13. Mean Radiant Temperature

The uniform temperature of an imaginary enclosure in which theradiant heat transferfrom thehuman body is equal to the radiant heat transfer in the actual non-uniform enclosure.

3.2.14. Mixed Mode

“Mixed-mode” refers to a hybrid approach to space conditioning that uses a combination of natural ventilation from operable windows (either manually or automatically controlled), and mechanical systems that include air distribution equipment and refrigeration equipment for cooling.

3.2.15. Operative Temperature:

A uniform temperature of a radiantly black enclosure in which an occupant would exchange the same amount of heat by radiation plus convectionas in the actual non-uniform environment. It is the combined effect of the mean radiant temperature and air temperature and is the mean of these two under specific conditions. It is also known as dry resultant temperature or resultant temperature.

3.2.16. Predicted Mean Vote

An index that predicts the mean value of the thermal sensation votes (self-reported perceptions) of a large group of persons on a sensation scale expressed from -3 to +3 corresponding to the categories “cold," "cool," "slightly cool," "neutral," "slight warm," "warm," and "hot."

3.2.17. Radiant Temperature Asymmetry

The difference between theplane radiant temperature (t_{pr}) in opposite directions. Thevertical radiant temperature asymmetry is with plane radianttemperatures in the upward and downward directions. The horizontal radiant temperature asymmetry is the maximumradiant temperature asymmetry for all horizontal directions.The radiant temperature asymmetry is determined at waistlevel, 0.6 m for a seated occupant and 1.1 m for a standing occupant.

3.2.18. Representative Occupant

An individual or composite or average of several individuals that is representative of the population occupying a space for 15 minutes or more. In this standard, the term 'occupant' refers to 'representative occupant'.

3.2.19. Relative Humidity

Ratio of the partialpressure of actual water vapour in the air as compared to the partial pressure of maximum amount of water vapour that may be contained at its dry bulb temperature.

3.2.20. Standard Effective Temperature(SET)
The temperature of an imaginary environment at 50% RH, less than 0.1 m/s average air speed (v_a), and, in which the total heat loss from the skin of an imaginary occupant with an activity level of 1.0 met and a clothing level of 0.6 clo is the same as that from a person in the actual environment, with actual clothing and activity level.

3.2.21. Thermal comfort
The condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation.

3.2.22. Thermal environment
The environmental conditions that affect a person's thermal balance with surroundings.

3.2.23. Thermal sensation
A conscious subjective expression of an occupant's thermal perception of the environment, commonly expressed using the categories “cold,” “cool,” “slightly cool,” “neutral,” “slightly warm,” “warm,” and “hot.”

3.2.24. Vertical air temperature difference
Air temperature difference between head and ankle level of occupant.

3.3. Indoor air quality

3.3.1. Asthma
A chronic inflammatory disease of the respiratory airways, often triggered by exposure to allergens.

3.3.2. Carbon Monoxide
Colourless, odourless and highly poisonous gas formed by incomplete combustion. Replaces oxygen inhaemoglobin, limiting ability of blood to deliver oxygen and can lead to death.

3.3.3. Carcinogen
A compound which increases the risk of developing cancer.

3.3.4. Chronic Disease
Any disease that is persistent or has long-lasting health effects.

3.3.5. Chronic Exposure
Continuous exposure to a substance or condition over an extended period from several years to a lifetime.

3.3.6. Contaminant
An unwanted airborne constituent that may reduce acceptability of the air.

3.3.7. Formaldehyde (CH_2O)

It is an organic compound which is present naturally and it emitted through various indoor articles as off-gas. In and indoor space, it is released through various household products, paints, varnishes, wax, cleaning & disinfecting agents, cosmetic, degreasing and hobby products.

3.3.8. High Efficiency Particulate Air (HEPA) filter

Filter which can remove 99.97% of thermally generated particles of 0.3 micron size of Dioctyl Phthalate (DOP) or specified alternative aerosol.

3.3.9. Indoor air

The air in an enclosed occupiable space.

3.3.10. Indoor Air Quality (IAQ)

Air quality that refers to the nature of unconditioned or conditioned air that circulates throughout the space where one works or lives, that is, the air one breathes when indoors.

3.3.11. Nitrogen Dioxide (NO_2)

A product of combustion mainly found near burning sources (for instance, wood smoke and traffic combustion).

3.3.12. Ozone (O_3)

A triatomic compound, very reactive form of oxygen that is bluish irritating gas of pungent odour. It is a major air pollutant in the lower atmosphere but a beneficial component of the upper atmosphere, and used for oxidising, bleaching, disinfecting, and deodorising.

3.3.13. Particulate Matter (PM)

A complex mixture of tiny particles that consists of drysolid fragments, solid cores with liquid coatings, and small droplets of liquid. These particles vary greatly in shape, size and chemical composition, and can be made up of many different materials such as metals, soot, soil, and dust. Particulate matter (PM) that has an aerodynamic diameter of 10 μm and below is referred to as PM_{10}. Particles that are 2.5 μm aerodynamic diameters and smaller are $PM_{2.5}$. Thus all $PM_{2.5}$ is included in PM_{10}, although the converse is not true.

3.3.14. Volatile Organic Compounds (VOCs)

Organic, and therefore carbon and hydrogen containing, materials which evaporate and diffuse easily at ambient temperature. VOCs are emitted by a wide array of building materials, paints and common consumer products.

3.3.15. Sulphur dioxide (SO_2)

It is a colourless gas produced when either Sulphur or material containing Sulphur is burnt. Sulphur dioxide plays a role, along with particular matter, in forming smog especially during winters.

3.3.16. Total Microbial Count

It is a quantitative measurement of the number of colony forming units of micro-organisms in 1 cubic metre sample of air.

3.3.17. Total Volatile Organic Compounds (TVOCs)
Sum of the concentrations of identified and unidentified volatile organic compounds eluting between and including n-hexane and n-hexadecane.

3.4. Lighting comfort

3.4.1. Circadian Lighting Design
An approach that aims to provide lighting conditions that reinforce the natural patterns of the human circadian cycle, which determines sleep and wake cycles.

3.4.2. Circadian Rhythm
Internal clock that keeps the body's hormones and bodily processes on a roughly 24 hour cycle, evenin continuous darkness.

3.4.3. Correlated Colour Temperature
Spectral distribution of electromagnetic radiation of a blackbody at a given temperature. For example, the colour temperature during the daytime is approximately 15,000 K, while during sunset is approximately 1,850K.

3.4.4. Daylight factor
Ratio of the luminance at a point on a given indoor plane due to the light received directly or indirectly from the sky of assumed or known luminance distribution, to the luminance on a horizontal plane from an unobstructed hemisphere of the same sky. The contribution to direct sunlight to both luminance is excluded. It is expressed in percentage.

3.4.5. Equivalent Melanopic Lux (EML)
A measure of light used to quantify how much a light source will stimulate melanopsin's light response.

3.4.6. Frequency
The number of times an event repeats itself per a specified unit of time. Hertz (Hz) is a common unit for frequency and equals cycles per second i.e. 1 Hz is equal to 1 cycle per second. Most commonly used with waves (sound and light) and is the number of times the wave repeats itself at its particular wavelength.

3.4.7. Illuminance
Illuminance is the incident luminous flux density on a differential element of surface located at a point and oriented in a particular direction, expressed in lumens per unit area. Since the area involved is differential, it is customary to refer to this as illuminance at a point. The unit name depends on the unit of measurement for area: foot-candles if square feets are used and lux if square meters are used.

3.4.8. Intrinsically Photoreceptive Retinal Ganglion Cells (ipRGCs)
Relay environmental light levels to the suprachiasmatic nucleus through the retinohypothalamic tract. It is most sensitive to blue light.

3.4.9. Illuminance of the immediate surrounding areas

The immediate surrounding area is taken to be a band with a width of at least 0.5 m.

3.4.10. Lux

Unit of illuminance, one lux being equivalent to one lumen per square meter.

3.4.11. Melatonin

"Sleep hormone" whose production by the body is regulated by the circadian rhythm and the presence of light.

3.5. Acoustic comfort

3.5.1. A-Weighted Decibel (dB (A))

Acoustic decibel modified using "A-weighting" to adjust the frequency-dependent response of human hearing.

3.5.2. Noise Criteria (NC)

Noise criteria (NC) is a single numerical index commonly used to define design goals for the maximum allowable noise in a given space. The noise criterion equals the lowest curve which is not exceeded in the spectra ranging from 63 – 8000 Hz.

3.5.3. Reverberation time

Reverberation time is the time required for a steady-state sound to reach one millionth or -60dB of its original intensity.

3.5.4. Sound pressure

Difference between an instantaneous total pressure and the corresponding static pressure

3.5.5. Sound pressure level

Ten times the logarithm to the base 10 of the ratio of the time-mean-square of a sound pressure signal to the square of the reference value (The reference value is 20 μPa.).

3.5.6. Sound Transmission Class (STC)

The Sound Transmission Class is a single number rating of the effectiveness of a material or construction assembly to retard the transmission of airborne sound. It is also known as Sound Reduction Index (SRI).

3.5.7. Time-averaged sound level ($L_{Aeq,T}$)

A-weighted equivalent sound pressure level in dB measured over a period of time t.

4. Abbreviations, Symbols and Units

4.1. Abbreviations

AHU	Air Handling Unit
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASTM	American Society for Testing and Materials
BEAM	Building Environment Assessment Method
CCT	Correlated Colour Temperature
CFL	Compact Fluorescent Lamp
EML	Equivalent Melanopic Lux
HEPA	High Efficiency Particulate Air
HVAC	Heating, Ventilating, and Air Conditioning
IAQ	Indoor Air Quality
IEC	International Electrotechnical Commission
IEQ	Indoor Environmental Quality
IS	Indian Standard
ISHRAE	Indian Society of Heating, Refrigerating, and Air Conditioning Engineers
ISO	International Organization for Standarization
NABERS	National Australian Built Environment Rating System
NBC	National Building Code
NC	Noise Criteria
NCB	Balanced Noise Criteria
NIC	Noise Isolation Class
PM	Particulate Matter
RC	Room Criteria
RH	Relative Humidity
RSPM	Respirable Suspended Particulate Matter
SBS	Sick Building Syndrome
SET	Standard Effective Temperature
STC	Sound Transmission Class
STI	Sound Transmission Index
TVOC	Total Volatile Organic Compound

4.2. Symbols

a	Ambient
C_6H_6	Benzene
CH_2O	Formaldehyde
CO	Carbon monoxide
CO_2	Carbon dioxide
D_w	Weighted Difference Level
$L_{Aeq,T}$	A-weighted equivalent sound pressure level in dB measured over a
	period of time t.
NO_2	Nitrogen Dioxide
O_3	Ozone
SO_2	Sulphur Dioxide
t_a	Ambient Temperature
t_{mr}	Mean Radiant Temperature
t_o	Operative Temperature
t_{pr}	Plane Radiant Temperature
v	velocity

4.3. Units

°C	degree Celsius
µg	microgram
clo	Clothing Insulation
CFU	Colony Forming Units
dB	Decibel
$D_{nT,w}$	Weighted Standardized Level Difference
Hz	Hertz
K	Kelvin
L	lux
m	meter
met	Metabolic Rate
Pa	Pascal
PPM	Parts Per Milliom
s	second
W	Watt

5. Indoor Environmental Quality

5.1. Introduction

This standard defines IEQ by elements mentioned below:

a) Thermal comfort
b) Indoor air quality
c) Lighting comfort
d) Acoustic comfort

5.1.1. Thermal comfort

Thermal conditions play a critical role in influencing occupant comfort and well-being. This standard specifies thermal environmental conditions acceptable for healthy adults at

a) Atmospheric pressure equivalent to altitudes up to 3000 m

b) Indoor spaces designed for human occupancy for periods not less than 15 minutes.

This standard specifies set of thermal conditions which are based upon adaptive thermal comfort approach. It also encompasses gradual diminution of the people's response to repeated environmental stimulation and subsumes all processes which building occupants undertake in order to improve the comfort of the indoor environment.

Thermal comfort is affected by physical and physiological parameters as shown in Figure 1.

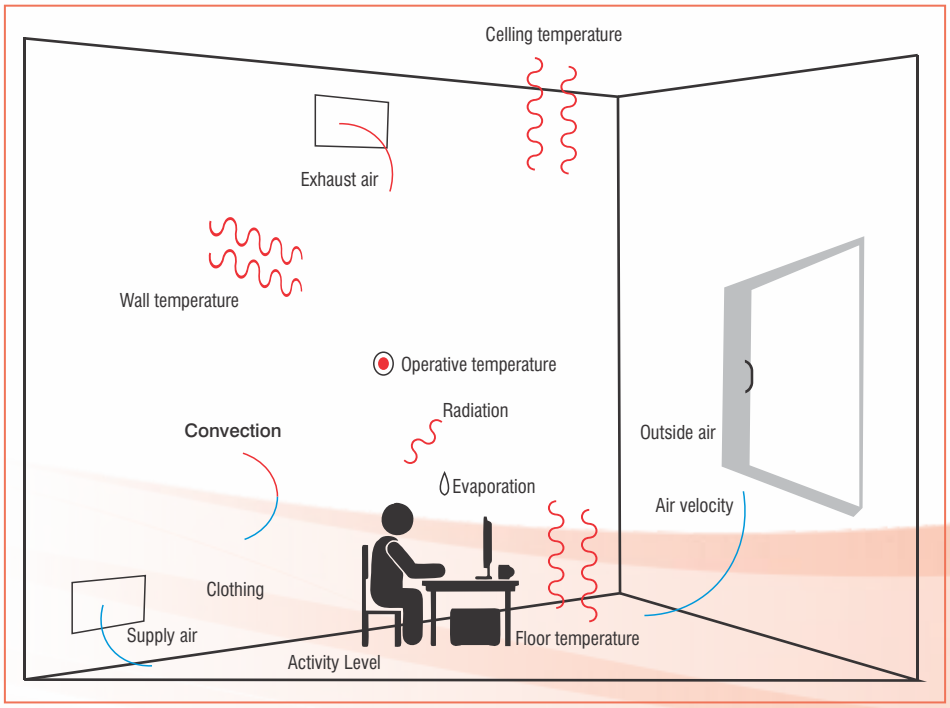


Figure 1 - Factors affecting thermal comfort in an indoor environment

5.1.1.1. Physical parameters

a) Air temperature
b) Vertical air temperature difference
c) Mean radiant temperature
d) Radiant temperature asymmetry
e) Floor surface temperature
f) Relative Humidity
g) Air speed

Note: The details of above parameters are specified in Annex A

5.1.1.2. Physiological factors

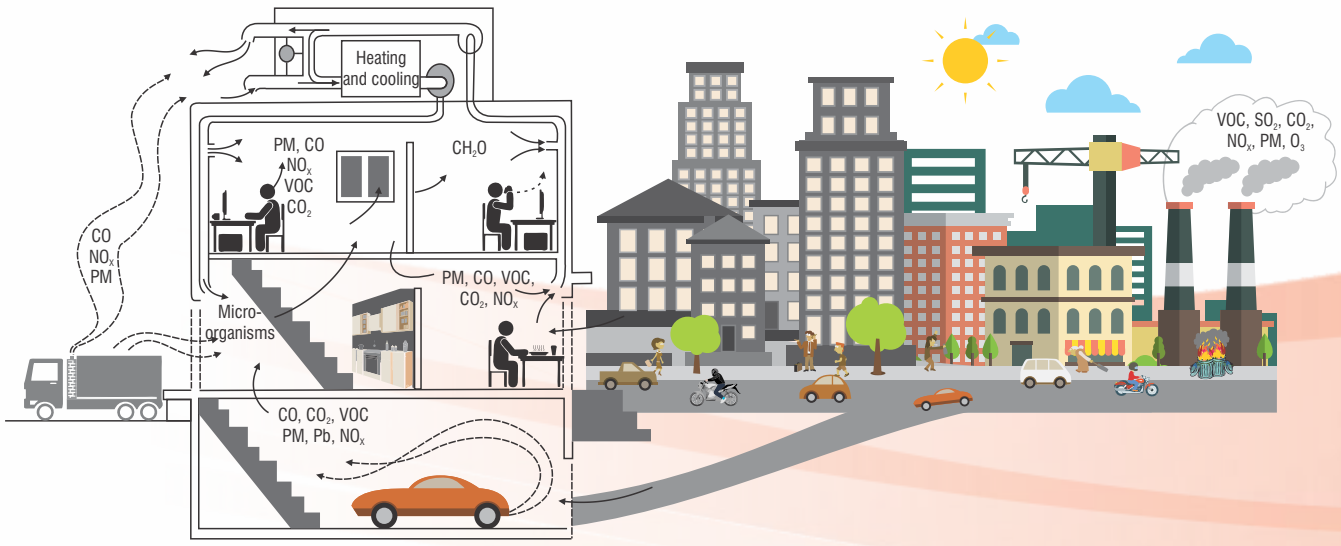
a) Metabolic rate
b) Clothing insulation

Note: Effects of these physiological factors on thermal comfort are out of scope of this standard.

5.1.2. Indoor air quality

Indoor air is considered to be healthy when the air does not contain contaminants in harmful concentrations and is acceptable when the majority of people feel satisfied. A human being breathes about 12,000 litres of air every day and is vital for our health. Exposure to hazardous airborne agents present in indoor spaces causes adverse effects such as respiratory and cardiovascular diseases, allergy, and irritation of the respiratory tract and possibly leads to cancer.

Main source of indoor air pollutants are household cooking (especially cooking with biomass or frying), tobacco smoking, polluted ambient air, cleaning agents, resuspension of dust during the cleaning activities, construction materials & paints, copy machines & printers as well as other human activities. Respectively, ambient air pollutant sources are vehicle emissions, thermal power plants, biomass burning, construction work, unattended debris, open sewage pipes, fossil fuel based power generators and various industrial processes as seen in Figure 2.



CO = carbon monoxide, CO_2 = carbon dioxide, CH_2O = formaldehyde, NO_x = nitrogen oxides, Pb = lead, PM = particulate matter, VOC = volatile organic compounds, O_3 = ozone, SO_2 = sulphur dioxide

Figure 2 - Indoor air pollutants in a typical built environment

Note: Details of the pollutants and their effect is given in Annex B.1

5.1.3. Lighting comfort

Light has significant impact on many bodily functions, including the nervous system, circadian rhythms, pituitary gland, endocrine system, pineal gland and alertness as these are affected by different wavelengths of light.

Variations over time in lighting conditions, in terms of intensity, illumination levels, distribution, ambient lighting and colour temperature, can stimulate alertness and well-being of people as shown in.

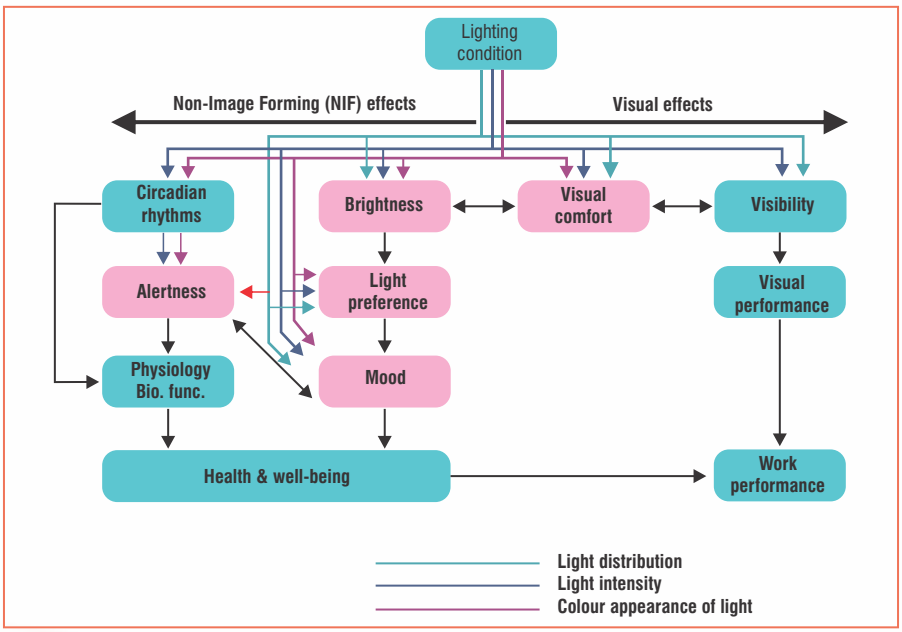


Figure 3 - Effects of lighting condition

Note: Details of the circadian rhythm are given in Annex C.1

5.1.4. Acoustics comfort

Noise is an unwanted sound. Noise can cause stress, alter sleep patterns, lead to hearing loss and affect heart rate. The gives typical noise sources and its transmission in indoor environment.

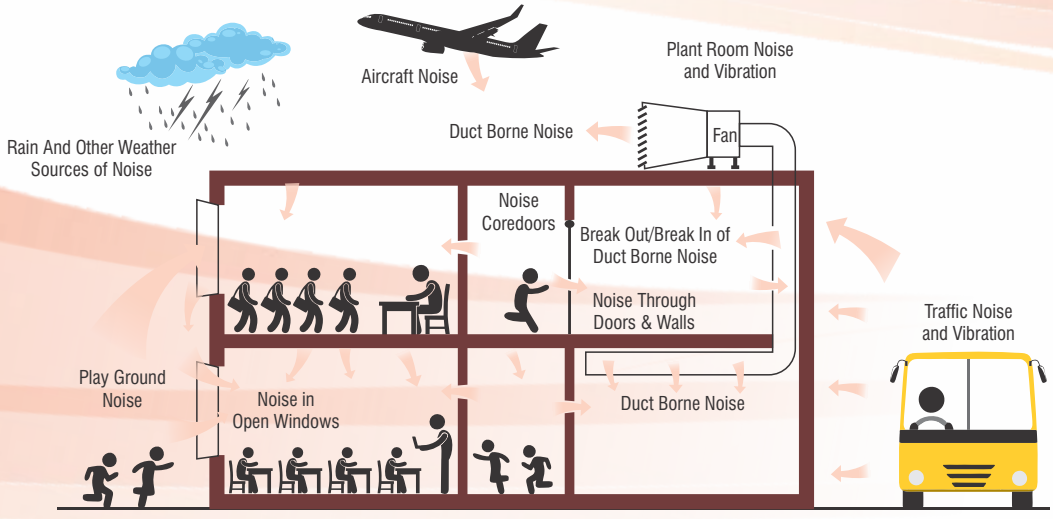


Figure 4 - Noise source in a typical indoor environment

5.2. Threshold values of IEQ parameters

This section of the standard defines threshold values of the IEQ parameters in three categories – Class A, Class B and Class C.

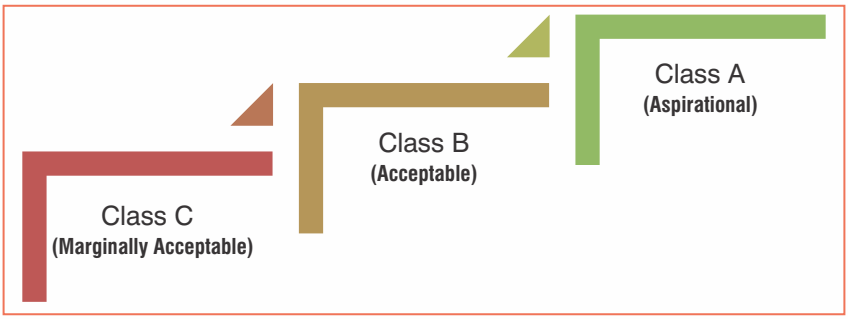


Figure 5 - Categories of Indoor Environmental Quality parameters

a) Class C (Minimum Acceptable)

Class C defines the minimum acceptable value for critical parameters of IEQ elements in the space.

b) Class B (Acceptable)

Class B defines the acceptable value for parameters of IEQ elements in the space.

c) Class A (Aspirational)

Class A defines the aspirational value for parameters of IEQ elements in the space.

5.2.1. Threshold values for thermal comfort parameters

This section shall be used to determine quality of thermal environment for representative occupant of a space.

Acceptable range of thermal comfort parameters for air velocity up to 0.2 m/s is given in Table 1. Typical values of operative temperature with air velocity up to 0.2 m/s for summer and winter conditions with low and medium level activities are provided in Table 2.1.

Note: Operative temperature is calculated using the methodology provided in Annex A.1

Table1 Acceptable range of thermal comfort parameters with air velocity upto 0.2 m/s

Parameters	Units		Class A	Class B	Class C
Operative Temperature	°C	If air velocity < 0.2 m/s	Table 2		
		If air velocity > 0.2 m/s	Annex A.2		
Relative Humidity	%		30 – 70	30 – 70	1. 30 – 70 (where, humidity control exists) 2. Building must demonstrate 80% occupant satisfaction w.r.t humidity (where, humidity control does not exists)
Radiant Temperature Asymmetry	°C	Warm Ceiling	<7	-	-
		Cool Wall	<13	-	-
		Cool Ceiling	<18	-	-
		Warm Wall	<35	-	-
Vertical Air Temperature Difference	°C		≤4	-	-
Floor Surface Temperature	°C		17 - 31	-	-
Occupant Satisfaction	%		90	80	-

Table 2 Acceptable range of operative temperature with air velocity upto 0.2 m/s

Level of Activity	Type of Building/Space	Operative Temperature (°C)	
		Summer (Cooling season) ~0.5 clo	Winter (Heating season) ~1.0 clo
Low	Offices, Conference room, Auditorium, Cafeteria / Restaurant, Classroom	24.5 ± 2.5	22.0 ± 3.0
Medium	Retail stores, Shopping Malls	23.0 ± 3.0	19.0 ± 4.0

5.2.2. Threshold values for indoor air quality parameters

Threshold values for select indoor air quality parameters in an occupied space for Class A, Class B and Class C are given in Table 3.

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 + 700
PM 2.5	$\mu g/m^3$	<15	<25	<25
PM 10	$\mu g/m^3$	<50	<100	<100
CO	ppm	<2	<9	< 9
TVOC * (equivalent to isobutylene)	$\mu g/m^3$	<200	<500	<500
CH_2O	$\mu g/m^3$	<30	<100	-
SO_2	$\mu g/m^3$	<40	<80	-
NO_2	$\mu g/m^3$	<40	<80	-
O_3	$\mu g/m^3$	<50	<100	-
Total Microbial Count	CFU/m^3	Indoor ≤ ambient	Indoor ≤ ambient	-
Occupant Satisfaction	%	90	80	-

Note 1: Depending upon the building location, interiors and other local factors, pollutants that significantly affect human health should be considered and corresponding standard should be referred.

Note 2: Detailed explanation of parameters is given in Annex B.1

5.2.3. Threshold values for lighting comfort parameters

The threshold values of parameters affecting lighting comfort are defined in Table 4. Threshold illuminance level depending upon type of space is defined in Table 5.

Table 4 Threshold values of parameters for lighting comfort

Parameters	Units	Type of Space	Classification		
			Class A	Class B	Class C
Illuminance	Table 5				
Circadian Lighting Design	Equivalent Melanopic Lux (EML)		At least 250 EML is present within at least 75% of workstations	At least 250 EML is present within at least 75% of workstations	
Uniformity of illuminance			0.7	0.7	-
Illuminance of the immediate surrounding areas			Ratio between a task and immediately adjacent surroundings should be 3:1	-	-
Percentage of the task area meeting the required illuminance	%		90	80	80
Occupant Satisfaction	%		90	80	-

Table 5 Threshold Illuminance level depending upon type of space

Building	Type of space	Illuminance (Lux)
Residential	Living room	300
	Bed room	100
Child care institutions	Child care institutions, Nursery schools	300
	Day nurseries	300
Places of assembly	Auditoriums	100
	Libraries	500
	Cinemas (Seating area)	200
	Court rooms	300
	Museums	300
Commercial	Retail shops	300
	Department stores	300
	Supermarkets	300
	Computer rooms, large	500
	Computer rooms, small	500
Hotels	Lobbies	100
	Reception rooms	300
	Hotel rooms (during night-time)	100
	Hotel rooms (during daytime)	100
Offices	Small offices	300
	Conference rooms	500
	Landscaped offices (Open plan office)	500
	Office cubicles	500
Restaurants	Cafeterias	300
	Restaurants	300
	Kitchens	500
Schools	Classrooms	300
	Corridors	100
	Teacher rooms	300

5.2.4. Threshold values for acoustical parameters

Threshold values for acoustical parameters for typical space are given in Table 6. Additionally, values for the acoustical parameter - Noise isolation (applicable for Class A) are given in section 5.2.4.1. The noise criterion (NC) values shall be arrived using NC curves as given in Annex D.1.

Table 6 Requirements of Acoustic comfort

No	Types of Buildings	Noise Criterion			Reverberation time		
		A	B	C	A	B	C
1	**Residences, Apartments, Condominiums**	30	35	40	0.8s	NA	NA
2	**Hotels / Motels**						
I.	Individual rooms or suites	30	35	40	0.8s	NA	NA
II.	Meeting / banquet rooms	30	35	40			
III.	Corridors, lobbies	40	45	45	NA		
IV.	Service / Support areas	40	45	50	NA		
3	**Office buildings**						
I.	Executive and private offices	30	35	40	1.0 s	NA	NA
II.	Conference rooms	30	35	35			
III.	Teleconference rooms	25 (max)					
IV.	Open – plan offices	35	40	40			
V.	Corridors and lobbies	40	45	45	NA		
4	**Performing arts spaces**						
I.	Drama theatres	25 (max)			1.0s	NA	NA
II.	Concert and recital halls	25 (max)					
III.	Music teaching studios	25 (max)					
IV.	Music practice rooms	35 (max)					
5	**Schools**						
I.	Class rooms up to 70 m^2	40 (max)			0.8s	NA	NA
II.	Class rooms over 70 m^2	35 (max)					
III.	Large lecture rooms, without speech amplification	35 (max)					
6	**Libraries**	35	40	40	NA	NA	NA
7	**Courtrooms**						
I.	Unamplified speech	30	35	35	0.8s	NA	NA
II.	Amplified speech	35	40	40			

Note 1: For the Class A and Class B, a building should score 90% and 80% respectively on the occupant satisfaction survey. There is no such requirement to achieve Class C.

Note 2: Any other type of space not mentioned in the Table 6 shall meet requirements of the nearest representative category of that space.

5.2.5. Noise Isolation Class

The noise isolation criteria for various types of spaces shall be as described below.

5.2.5.1. Office premises:

a) Between two offices D_w = 38 dB minimum
b) Where privacy is important: D_w = 48 dB
c) Noise Isolation Class (NIC) of at least 40 dB for cellular offices

5.2.5.2. Residential premises and hotel rooms:

a) Partitions separating a water closet (WC) from a noise sensitive room: $D_{nT,w}$ of at least 38 dB.
b) In hotels, partitions and floors between rooms and between rooms and corridors: $D_{nT,w}$ of at least 50 dB.

Note: Noise isolation is directly associated with the Sound Transmission Class (STC) of the material used. STC of building material used has to be considered by designers for Noise Isolation as required. Designers are advised to obtain the STC test report of the material used from the manufacturer, tested at an accredited lab.

6. Measurement

6.1. General

This section of the standard defines methodology for measurement of IEQ parameters defined in section . Measurement sampling shall be representative of locations where the occupants are known to, or, are expected to spend their time. Measurement should be carried out at steady indoor conditions. The sampling duration must represent both, “peak” and “average” indoor exposure.

6.2. Thermal comfort

In addition to the representative sample locations as mentioned in clause 6.1, locations where the most extreme values of the thermal parameters are observed or estimated to occur (e.g., potentially occupied areas near windows, diffuser outlets, corners, and entries) shall also be considered for measurement.

At locations where occupancy distribution cannot be observed or estimated, the measurement locations shall include:

a) The center of the room or space
b) 1.0 m inward from the center of each of the walls.
c) In the case of exterior walls with windows, the measurement location shall be 1.0 m inward from the center of the largest window.

The methodology for measurement at selected locations shall be as defined in Table

Table 7 Measurement methodology for thermal comfort

Parameter	Measurement Methodology
Air temperature & Average air speed	a) Air temperature and average air speed (v_a) shall be measured at the 0.1 m, 0.6 m, and 1.1 m levels for seated occupants at plan locations * b) Measurements for standing occupants shall be made at the 0.1 m, 1.1 m, and 1.7 m levels. *
Operative temperature	a) Shall be measured or calculated at the 0.6 m level for seated occupants and the 1.1 m level for standing occupants.
Floor temperature	a) Shall be measured at the surface by contact thermometer or infrared thermometer.
Radiant temperature asymmetry	a) Shall be measured in the affected occupants' locations, with the sensor oriented to capture the greatest surface temperature difference.

* Mean value of these parameters at respective location shall be considered for calculating operative temperature

6.3. Indoor Air Quality

The measurement duration shall depend on the parameter, type of space and the measuring instrument as defined below. IAQ measurements needs to be planned and executed based on the ISO 16000-1 and ISO 16000-32 standards, as appropriate.

a) As a spot measurement, minimum three times a day or as a single short term measurement between 1 to 24 hours depending on the parameter and application.

b) In addition, it is recommended to carry out atleast two times a year - summer and winter are preferred as the high background of microbial contamination during the monsoon may skew the results.

The methodology for measurements at selected location shall be as defined in Table 8 .

Table 8 Measurement methodology of indoor air quality parameters

Parameter	Measurement Methodology
CO_2*	a) Shall be measured when there is 90% minimum occupancy. b) Shall be measured at least in one location per floor and wing or in one location for each set of rooms with the same activity.
CO	a) Shall be measured at the air intake in to the building (AHU air intake or air vent or open window) to ensure that the air intakes are not too close to roadways, loading docks or other local sources of CO. b) For underground car parking in the building, the measurement shall also be done in occupied spaces at the floor level near the doorways leading to the car parking. c) For residential buildings, the measurement shall also be carried out in each space with cooking equipment or fire place, while cooking is going on or fire place is in use.
PM 2.5*	a) Shall be measured at least in one location per floor and wing or in one location for each set of rooms with the same activity.
PM 10*	a) Shall be measured at least in one location per floor and wing or in one location for each set of rooms with the same activity
CH_2O**	a) Shall be measured at least in one location per floor and wing or in one location for each set of rooms with the similar activity.
SO_2	a) Shall be measured at the air intake in to the building (AHU air intake or air vent or open window). b) At air intake, for values of SO2 concentration higher than the specified threshold value as given in section 5.2.2, additional measurements need to be taken inside the space.
NO_2	a) Shall be measured at the air intake in to the building (AHU air intake or air vent or open window). b) At air intake, for values of NO_2 concentration higher than the specified threshold value as given in section 5.2.2, additional measurements need to be taken inside the space.
O_3	a) Shall be measured in the indoor spaces that have sources of internal generation of ozone. b) At air intake, for values of O_3 concentration higher than the specified threshold value as given in section 5.2.2, additional measurements need to be taken inside the space.
TVOC	a) Shall be measured at least in one location per floor and wing or in one location for each set of rooms with the similar activity. b) In case the TVOC value is above the limit value, the individual VOCs present in the indoor air need to be analysed.
Total Microbial Count#	a) Shall be measured at least in one location per floor and wing or in one location for each set of rooms with the similar activity.

* Reference value shall be measured near the air intake in to the building (AHU air intake or air vent or open window) for comparison. This shall be done simultaneously with corresponding indoor air measurements.

** Measurements shall also be taken in locations where the most extreme values of the thermal parameters are observed or estimated to occur (e.g., potentially occupied areas near windows, diffuser outlets, corners, and entries)

Above point in * and ** are applicable

6.4. Lighting comfort

In addition to the representative sample locations as mentioned in section 6.1, locations where the most extreme values of the lighting parameters are observed or estimated to occur (e.g., potentially occupied areas near windows, shades and any other object resulting into shadowing on workspace of occupants) shall also be considered for measurement. For e.g. there is an obviously bright or dark area that complies with the sampling location (e.g. not in an enclosed office or kitchen), that shall also be included.

Note: Lighting conditions are not to be altered while taking the readings. Blinds (if present) are to be left as found and cannot be opened or closed when taking the measurements. For this reason, the location where the readings are taken should be occupied or should have been occupied within the past hour.

6.5. Acoustic comfort

The testing and measurement carried out according to the standards as given in Table 9 below.

Table 9 Measurement methodology for acoustic comfort

Parameter	Measurement Methodology
Sound level	Measurement method for the noise level shall be as defined in ISO 1996 - 2
Noise Isolation	Measurement method for the noise isolation shall be as defined in ISO 16283 – 1 and ISO 16283 – 2.
Reverberation Time	Assessment method for the reverberation time shall be as defined in ISO 3382-2

7. Specifications of Instruments

The minimum resolution and accuracy of the instruments for each of the parameters are summarised in Table 10.

Table 10 Specifications of the instruments to be used for measuring IEQ parameters

Element	Parameters	Resolution	Accuracy	Remark
Thermal Comfort	Air temperature	0.1 °C	± 0.5 °C	
	Mean radiant temperature	0.1 °C	± 0.5 °C	
	Plane radiant temperature	0.1 °C	± 0.5 °C	
	Surface temperature	0.5°C	± 1 °C	
	Relative humidity	1 %	± 3 %	
	Air velocity	0.01 m/s	± 0.05 m/s	In case of air velocities higher than 0.2 m/s or where fans are used locally to create air velocity close to the occupant, use of omni-directional air movement sensor is required.
Indoor Air Quality				**IAQ: Preferred measurement methods**
	CO_2	1 ppm	± 5%	Non-dispersive Infra-red (NDIR)
	PM 10	1 µg/m^3	± 5%	Gravimetric or Light-scattering
	PM 2.5	1 µg/m^3	± 5%	Gravimetric or Light-scattering
	CO	0.1 ppm	± 5%	Non-dispersive Infra-red (NDIR) or Electro-chemical Sensor
	TVOC	0.1 ppm (229.49 µg/m^3 equivalent to isobutylene)	± 0.05 ppm (115 µg/m^3)	Dual section, charcoal tube, polymer absorber based samplers followed by Gas Chromatography (GC) or Photoionization Detector (PID)
	CH_2O	0.01 ppm (12.28 µg/m^3)	± 0.005 ppm (6.14 µg/m^3)	Solvent extraction followed by High-performance Liquid Chromatography (HPLC) / GC analysis or PID
	SO_2	0.001 ppm (2.6 µg/m^3)	± 0.005 ppm (13 µg/m^3)	Improved West & Gaek, Ultraviolet Fluorescence method or Fourier Transform Infrared Spectroscopy (FTIR) Sensor
	NO_2	0.001 ppm (1.9 µg/m^3)	± 0.005 ppm (10 µg/m^3)	Modified Jacob and Hochheiser method Chemiluminescence or FTIR sensor
	O_3	0.001 ppm (2.0 µg/m^3)	± 0.005 ppm (10 µg/m^3)	UV Photometric Chemiluminescence Chemical method or FTIR
	Total Microbial Count	10 CFU/m^3	± 50 CFU/m^3	Anderson samplers, Gravimetric followed by culture method
Lighting comfort	Illuminance	10 lux	±5 %	Measurements should be taken using a portable light meter and it should be calibrated within the last 12 months.
Acoustic comfort	Sound	1dB	±1 %	a) Measurements should be taken using a level 1 or level 2 sound meters, set to read on "A" scale to record dB(A). b) Measuring equipment shall conform to the accuracy requirements given in IEC 60804.

Note: Measurement error because of the "experimenter" interference with instruments such as by leaning over a light meter, talking when taking noise measurements, or an equipment case shading a globe thermometer, are all examples of practical errors that shall be avoided.

8. Occupant satisfaction survey

8.1. General

Subjective methods quantify the responses of occupants to an environment using subjective scales. Such scales are based upon psychological continua (or constructs) that are relevant to the psychological phenomenon of interest. It is important to know the properties of the scales in order to correctly interpret the results. Scales of sensation (e.g. hot or cold), preference, comfort, annoyance, smell and stuffiness are often used in occupant comfort assessment.

Advantages of subjective methods are that they are simple to administer and are directly related to the psychological phenomenon. Many aspects of occupant comfort, which are difficult to quantify or cannot be directly measured such as glare, smell, but are very important for evaluating occupant comfort, can be covered through such surveys.

The following are the minimum questions required for gaining feedback for the long term satisfaction of occupants for thermal comfort, indoor air quality, lighting comfort and acoustic comfort in the building.

8.2. Survey Questions

1. Please rate your satisfaction with temperature conditions of your normal work area in summer

   Unsatisfactory | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Satisfactory

2. Please rate your satisfaction with temperature conditions of your normal work area in monsoon.

   Unsatisfactory | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Satisfactory

3. Please rate your satisfaction with temperature conditions of your normal work area in winter.

   Unsatisfactory | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Satisfactory

4. Please rate your satisfaction with the air movement available to you in your normal work area.

   Unsatisfactory | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Satisfactory

5. Please rate your satisfaction with the overall humidity in your normal work area.

   Unsatisfactory | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Satisfactory

6. Please rate your satisfaction with the overall air quality in your normal work area (e.g. stuffiness, staleness, smell).

Unsatisfactory | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Satisfactory

7. My work area's layout enables me to work without unwanted noise interruptions.

Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Agree

8. My normal work area provides adequate sound privacy (not being overheard by others)..

Disagree | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Agree

9. Please rate your satisfaction with the overall noise in your normal work area.

Unsatisfactory | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Satisfactory

10. Please rate your satisfaction with the lighting comfort of your normal work area (e.g. amount of light, glare, reflections, contrast).

Unsatisfactory | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Satisfactory

11. Please rate your satisfaction with the external view from your normal work area.

Unsatisfactory | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Satisfactory

12. Please rate your satisfaction with the access to daylight from your normal work area.

Unsatisfactory | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Satisfactory

9. Documentation methodology

9.1. Report format

The measurement report shall contain following information:

Name of the project			
Name of the responsible person			
Location of the project/ Project address			
Sampling time			
Sampling date			
Building type	Commercial ( )	Residential ( )	Mixed ( )
Building usages			
Schedule (usage)			
Building	Naturally Ventilated ( )	Air Conditioned ( )	Mixed Mode ( )
Year of construction			
No. of floors			
No. of occupants present at the time of sampling			
No. of sampling locations			
Floor plan of the building attached	Yes ( )	No ( )	
Sampling locations marked on the floor plan	Yes ( )	No ( )	
List of all the national or international standards followed for IEQ assessment:			
Any observation about sampling locations:			
Remark:			

9.2. Format for reporting measured values of different parameters

Element	Parameters	Measured values	Units	Classification (Class A / Class B/ Class C)	Remarks
Thermal Comfort	Air temperature				
	Air speed				
	Relative humidity				
	Operative temperature				
Indoor air auality	Carbon dioxide				
	PM 2.5				
	PM 10				
	Carbon Monoxide				
	Total Volatile Organic Compounds				
	Formaldehyde				
	Sulphur dioxide				
	Nitrogen dioxide				
	Ozone				
	Total microbial count				
Lighting comfort	Illuminance				
	Circadian Lighting Design				
	Uniformity of illuminance*				
	Illuminance of the immediate surrounding areas**				
	Percentage of the task area meeting the required illuminance				
Acoustic comfort	Noise Criteria (NC)				
	Reverberation time				
	Noise background				

9.3. Format for reporting results of satisfaction survey

Occupant satisfaction survey presented in section 8.2, questions from 1 to 5, 4 to 6, 7 to 9, 10 to 12 are to evaluate satisfaction level corresponding to thermal comfort, indoor air quality, lighting comfort and acoustic comfort respectively.

Care should be taken to avoid administering occupant satisfaction survey on a potentially biased subject who is not a regular occupant of the building, or have been under some medical treatment or any other similar reason. The survey must be administered to all occupants in a building and the response rate should be 40% of occupants surveyed. The survey designed to gain long term feedback should be administered before physical measurements are undertaken, and no changes should be made to the normal operation of the building between survey administration and physical measurement.

Questions are administered on a seven point scale where 1 is the worst and 7 is the best score. In each case the % of satisfied occupants is denoted as all those rating 4, 5, 6 and 7 on this scale. Where, there is more than one question under each category, the average satisfaction across all the constituent questions is to be considered.

For every element 90% and 80% satisfaction level should be met for building being classified as Class A and Class B respectively. Occupant satisfaction survey is not applicable to Class C building except when assessing humidity.

Annex A Thermal Comfort

A.1 (Normative): Calculation of Operative Temperature (t_o)

Operative temperature can be defined as uniform temperature of a radiantly black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment. It is the combined effect of the mean radiant temperature, air temperature and velocity as shown in Figure 6. It is also known as dry resultant temperature or resultant temperature.

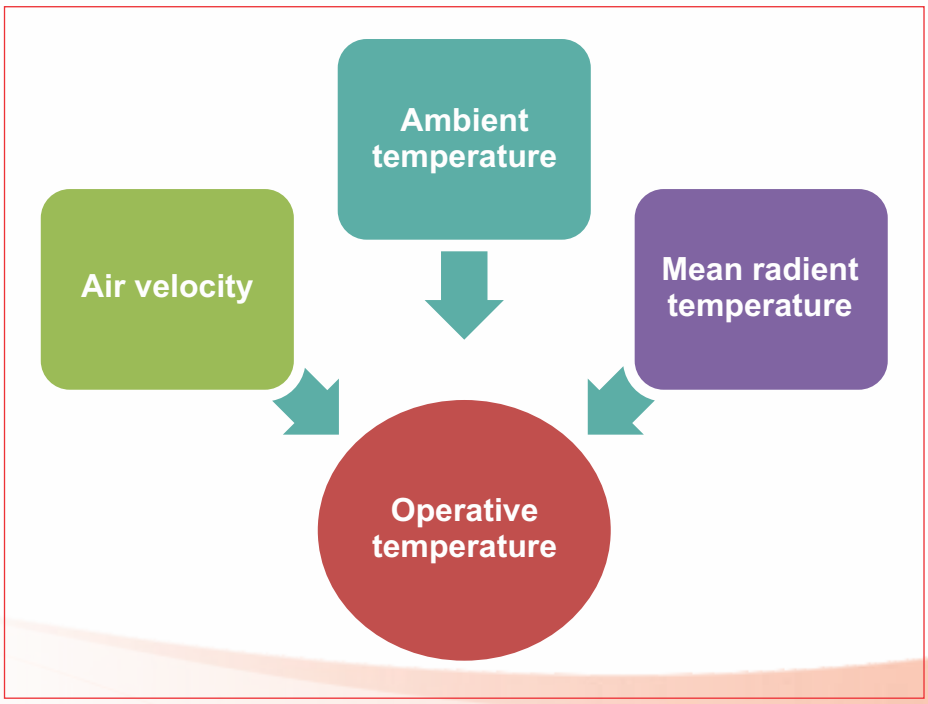


Figure 6 - Parameters influencing operative temperature

The operative temperature shall be calculated as below.

$$t_o = \frac{((t_a \times \sqrt{10\vartheta}) + t_{mr}))}{1 + \sqrt{10\vartheta}}$$

where, ϑ = air velocity

t_a = air temperature

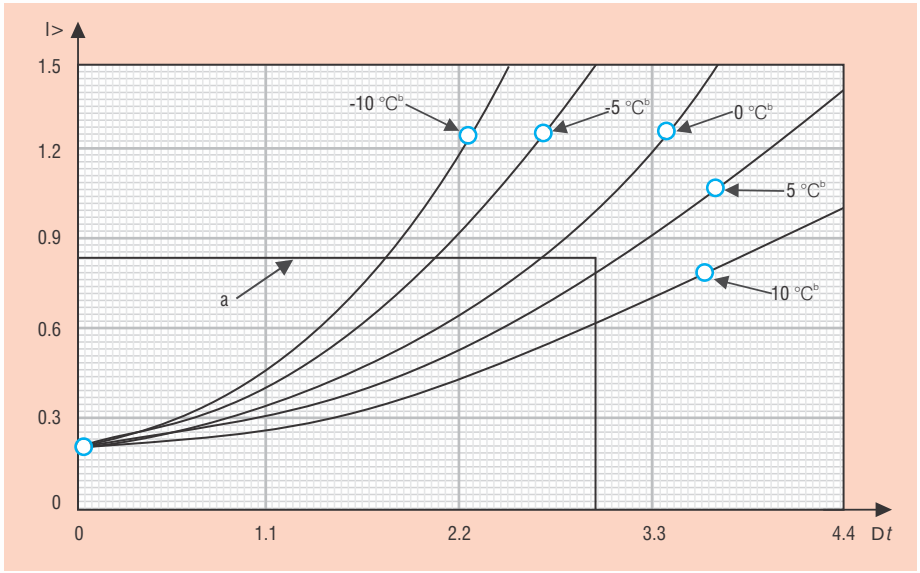
t_{mr} = mean radiant temperature

It is also acceptable to approximate this relationship for occupants engaged in near sedentary physical activity (with metabolic rates between 1.0 met and 1.3 met), not in direct sunlight, and not exposed to air velocities greater than 0.20 m/s.

$$t_o = \frac{(t_a + t_{mr})}{2}$$

A.2 (Normative): Required Air Speed to Offset Increased Temperature

Below mentioned methodology from ISO 7730 can be used to find increase in acceptable operative temperature at elevated air speed.



For light primarily sedentary activity, Dt should be <3 °C and n <0.82 m/s.

Key

Dt temperature rise above 26 °C
n mean air velocity, m/s
a Limits for light, primarily sedentary, activity.
b ($t_t - t_a$), °C (t_a, air temperature, °C; t_t, mean radiant temperature, °C).

Figure 7 Required Air Speed to Offset Increased Temperature

The example to illustrate the use of air speed to offset increased temperature:

Example 1: If in a given room, an occupant is involved in the moderate level of activity, air speed in room is 1.2 m/s and operative temperature is 26°C, then by using above mentioned graph Δt is 3.3°C. It makes acceptable room air temperature as 26°C + 3.3°C.

A.3 (Normative): Factors leading to local thermal discomfort

A.3.1 Radiant Temperature Asymmetry

The thermal radiation field about the body may be non-uniform due to hot and cold surfaces and direct sunlight. This asymmetry may cause local discomfort and reduce the thermal acceptability of the space. In general, people are more sensitive to asymmetric radiation caused by a warm ceiling than that caused by hot and cold vertical surfaces.

Radiant temperature asymmetry may occur in an enclosed space because of cold and warm walls as well as warm and cold ceiling. People are more sensitive to warm ceiling than other three.

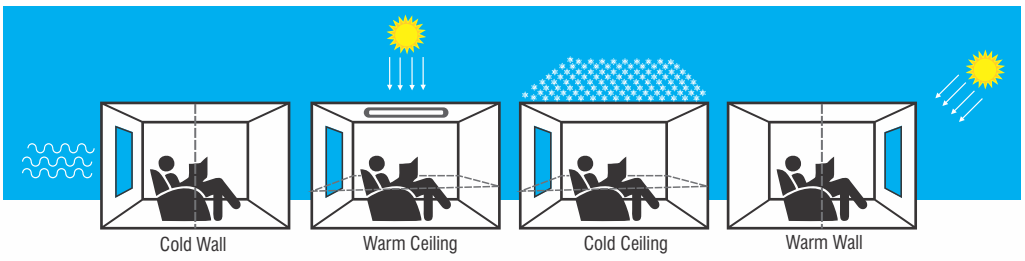


Figure 8 - Radiant Temperature Symmetry caused by a cold wall, a warm ceiling, a cold ceiling, or a warm wall

A.3.2 Vertical Air Temperature Difference and floor surface temperature

As demonstrated in Figure 9, an individual may feel local discomfort when temperature difference between warm head and cold feet increases beyond defined limit in Table 1. Occupants may also feel discomfort in the enclosed spaces where floor is colder or warmer than defined limit. It is applicable only when a person is wearing light indoor shoes

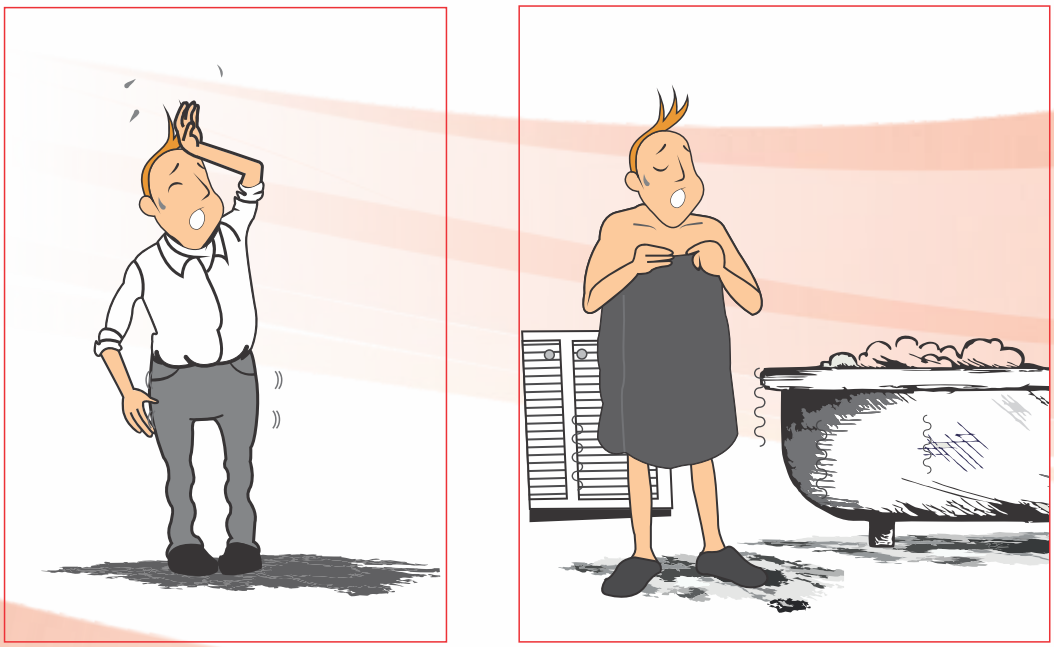


Figure 9 - Local thermal discomfort caused by vertical air temperature difference (left) and floor surface temperature (right)

A.4 (Normative): Measurement Sensor location for thermal comfort

For the measurement of thermal comfort for sitting position and standing position of the occupant, the measurement probes shall be located as shown in figure

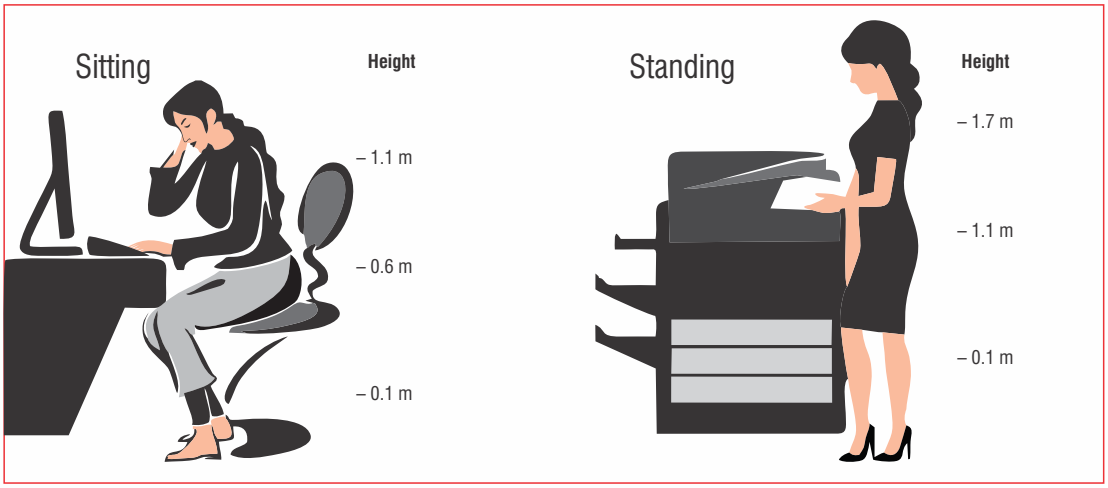


Figure 10 - Position of the probes at different height according to standing and sitting position

Annex B Indoor Air Quality

B.1 (Normative): Definition of Indoor Air Pollutants

B.1.1 Carbon dioxide (CO_2)

Carbon dioxide (CO_2) is a colourless, odourless gas vital to life on Earth. Carbon dioxide exists in the Earth's atmosphere as a trace gas at a concentration of about 0.045 percent (450 ppm) by volume.

Main source of CO_2 in buildings is people. CO_2 in indoor air is not itself a pollutant or a health risk in typical indoor concentrations. However, high levels of CO_2 reduce human comfort and productivity significantly. CO_2 level, that is relatively easy to measure and is used as a general indicator of ventilation system efficiency.

B.1.2 Respirable Suspended Particulate Matter (RSPM)

Respirable Suspended Particulate Matter (RSPM) refers to those dust particles that are small enough (less than 10 μm) to penetrate the nose and upper respiratory system and deep into the lungs. Smaller the particulate size is, higher is the health risk as the smaller particulates penetrates deeper into alveoli.

Respirable Suspended Particulate Matter (RSPM) is one of the main ambient air pollutants in India. Main sources of particulate matter are vehicle emissions, household cooking (especially cooking with biomass and frying), thermal power plants, biomass burning, construction work, unattended debris, fossil fuel (such as diesel) based power generation and various industrial processes.

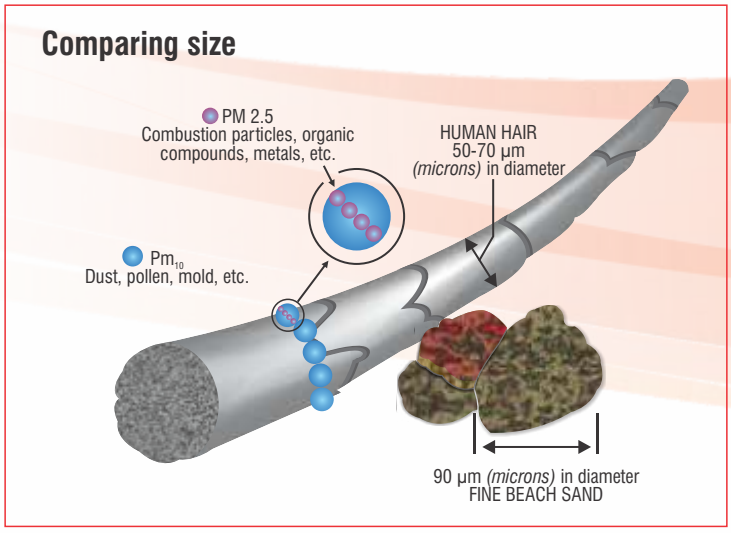


Figure 11 - Comparison of PM size with human hair diameter and beach sand particle size

B.1.3 Carbon Monoxide (CO)

Carbon monoxide (CO) is a colourless, odourless and tasteless gas that is slightly less dense than air.

Main source of CO are vehicles (combustion engines), fuel-burning appliances (e.g. furnaces, chullahs, gas stoves, cooking ranges, fossil fuel based water heaters, gas and kerosene room heaters), diesel generators, fireplaces and charcoal that is burned in enclosed areas.

CO is toxic to humans when encountered in concentrations above about 35 ppm. It is a serious health risk and may cause an immediate death.

B.1.4 Total Volatile Organic Compounds (TVOC)

Sum of the concentrations of identified and unidentified volatile organic compounds eluting between and including n-hexane and n-hexadecane.

The main sources of TVOC in buildings are furniture, construction materials, paints and cleaning products. Sometimes human activities and office equipment also increases the VOC level.

The prevalent TVOCs in indoor air are typically Formaldehyde, Benzene, Toluene, Ethylbenzene, O-xylene, Dodecane, Limonene, and Halogenated hydrocarbons. However, there are hundreds of other VOC that may reduce the indoor air quality. In case, TVOC level is high, more detailed analysis are required to find out which specific TVOC concentrations are high.

B.1.5 Formaldehyde (CH_2O)

Formaldehyde (CH_2O) is a colourless gas with a pungent odour and is highly reactive. Formaldehyde occurs in indoor air often due to the use of certain wood-based construction boards and furnishing. Increased concentrations may also be caused by other products, like certain disinfectants, cleaning agents, adhesives and paints. Table11 provides overview of the most important formaldehyde sources in the indoor environment.

Inhalation exposure to Formaldehyde in humans can result in respiratory symptoms as well as eye, nose, and throat irritation.
In high humidity and temperature, Formaldehyde emission increases considerably. Therefore, the relative humidity and air temperature needs to be measured simultaneously.

The following standards need to be followed when measuring CH_2O: ISO 16000 – 2, 3 and 4, as appropriate.

Table 11 - Sources of Formaldehyde in indoor environment

Source	Examples for use
Adhesive, glue	Wallpaper pastes; gluing tiles, veneer, panelling, carpets and vinyl floor
Combustion processes	Gas stove operation
Disinfectants	Sprays and solutions for surface disinfection
Internal combustion engines[a]	Transportation
Particle board and other pressed - wood products	Walls (outdoors and indoors), ceilings, false ceilings, floors, baseboards, doors and doorframes, stairs, plywood panelling, furniture
Tobacco	Tobacco smoke
Treated textiles	Furnishings
Urea-formaldehyde foams	Wall cavity insulation, roof insulation
Wallpaper, lacquers, varnishes, paints	Interior decoration

[a] Might be important with heavy traffic

B.1.6 Ozone (O_3)

A triatomic compound, very reactive form of oxygen that is bluish irritating gas of pungent odour. It is a major air pollutant in the lower atmosphere but a beneficial component of the upper atmosphere, and used for oxidising, bleaching, disinfecting, and deodorising.

Ambient ground level Ozone (O_3) is not emitted directly into the air, but is created by chemical reactions between oxides of nitrogen (NO_x) and volatile organic compounds (VOC) in the presence of sunlight. Inside the building some equipment like copiers and printing machines, some room air purification technologies (e.g. ionization, some UV-lights and ozonisers) produce Ozone. Ozone levels are typically highest on hot, sunny days.

Even relatively low levels of Ozone can cause health effects. Breathing Ozone can trigger a variety of health problems including chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis, emphysema, and asthma. Ground level ozone also can reduce lung function and inflame the linings of the lungs. Repeated exposure may permanently scar lung tissue.

Ozone shall also be measured in spaces that have equipment producing ozone. Best time for Ozone measurement is during summer (sunny and warm days).The Ozone shall be measured as per IS 5182 – Part 9.

B.1.7 Sulphur dioxide (SO_2)

Sulphur dioxide (SO_2) is a highly reactive and toxic gas with a pungent, irritating and rotten smell. The largest sources of SO_2 emissions are from fossil fuel combustion at power plants and other industrial facilities. Other sources include industrial processes such as extracting metal from ore, and the burning of high sulphur containing fuels by locomotives, large ships, and non-road equipment. SO_2 can react with other compounds in the atmosphere to form small particulates.

Short term exposures to SO_2 (up to 24 hours) can cause adverse respiratory effects including bronchiolitis and increased asthma symptoms. Particulates carrying SO_2 penetrate deeply into sensitive parts of the lungs and can cause or worsen respiratory disease, aggravate existing heart disease and may lead to premature death.

Emissions that lead to high concentrations of SO_2 generally also lead to the formation of other oxides of Sulphur (SO_x). Therefore SO_2 is used as the indicator for the larger group of gaseous sulphur oxides.

SO_2 shall be measured in the air intake in to the building (each AHU air intake or air vent or open window).At air intake, for values of SO_2 concentration higher than the specified threshold value as given in section 5.2.2, additional measurements need to be taken inside the space.

The following standards needs to be followed when measuring SO_2: IS 5182 – part 2, as appropriate.

B.1.8 Nitrogen dioxide (NO_2)

Nitrogen dioxide (NO_2) is one of highly reactive gasses known as oxides of Nitrogen (NO_x).Other nitrogen oxides include nitrous acid and nitric acid.

The major source of NO_2 is high temperature combustion as in vehicles and power plants. NO2 react with ammonia, moisture, and other compounds to form small particulates. Ozone (O_3) is generated when NO_2 and VOCs react in the presence of heat and sunlight.

Even short term NO_2 exposures (less than 24 hours) can cause adverse respiratory effects including airway inflammation in healthy people and increased respiratory symptoms in people with asthma.

NO_2 shall be measured at air intake to building, (e.g. AHU air intake, air vent, open window) and after the filters in case of mechanical ventilation. The measurement inside the building shall be done in two locations - one near the main doors and the other one in the main occupied area.

The following standards needs to be followed when measuring NO_2: ISO 16000-15 and IS 5182 - part 6, as appropriate.

B.1.9 Total Microbial Count

It is a quantitative measurement of the number of colony forming units of micro-organisms in 1 cubic metre sample of air.

One of the major purposed of the microbial count count measurement is to compare indoor and outdoor air samples and find any visible or hidden mould growth. Therefore, it is important to use same method for both measurements and carry them out at the same time. Due to differences in sampling times, volumes, and principles, the results given by different devices and methods are not comparable. Several air samples needs to be collected in different parts of the building and at different times. The outdoor air samples, that are collected simultaneously with each indoor air sample (same day and in same weather conditions), are needed for comparison. The air handling unit or ventilation system may be a source of microbiological contamination. Therefore in each measurement zone, one sample shall be collected from the supply air near the terminal unit.

When there is dampness and mould in a building, airborne fungal and bacteria concentrations of indoor air are often (but not always) higher than the concentrations in ambient air at the same time. For fungal spores and bacteria, the seasonal variation is considerable. Therefore measurements shall be taken only during summer and winter months.

There are no established health-based guidelines or standards for fungal or bacteria concentrations in the indoor air because different types of fungi or bacteria may have different health effects. There is also not enough research of “healthy” buildings during different seasons available in India to give India specific target values for fungal count levels. Furthermore, there are no uniformly accepted or valid, quantitative environmental sampling methods with which to assess exposures to mould and other agents associated with damp indoor environments.

Relative humidity measurements are recommended together with total microbial count measurements.The following standards need to be followed when measuring total fungal count: ISO 16000 – 16, 17, 18, 19, 20 and 21, as appropriate.

Note: *Even then measurements in different seasons or weather conditions cannot be compared.*

B.2 (Informative): Important types of indoor environment and sources of air pollutants

Type of indoor environment	Emitting sources or processes (examples)
Private dwellings and living rooms	
a) General sources	Man, building materials, furnishings, renovation materials, cleaning agents, biocide-containing products, ventilation and air-conditioning systems, outdoor air, heating appliances, microbial growth
b) Special areas	
Kitchens	Gas appliances, cooking, cleaning products
Living rooms, bedrooms, bathrooms	Tobacco smoke, fireplaces, biocide-containing products, cosmetics, disinfectants
Basements, hobby rooms	Hobby activities, tobacco smoke, soil outgassing
Garages	Fuel, solvents
Public buildings	
a) General sources	Man, building materials, furnishings, renovation materials, cleaning agents, biocide-containing products, ventilation and air-conditioning systems, outdoor air
b) Special areas	
Offices	Office machines and supplies
School and day care centers	Teaching materials, toys
Hospitals	Disinfectants, cleaning agents, anesthetics, sterilizing agents
Garages	Fuel, automobiles
Swimming pools	Outgassing from water
Transport vehicles	Fuel tanks, internal combustion engines, internal fitting materials, outdoor air

B.3 (Informative): Sources of indoor air pollutants and their most important emissions

Ask this	**Process/activity**	**Products used, sources in a narrower sense**	**Substances emitted**
Biological sources			
People, domestic animals	Breathing		Carbon dioxide, water vapour, odours substances from food; bacteria and viruses
	Sweating		Water vapour. Odoriferous substances
	Digestion, excretion, skin scaling		Intestinal gases. Odoriferous substances and excrement, decomposition products or pathological excretions, bacteria and viruses, allergenic dust
Cockroaches, dust mites and other insects	Excretion		Allergenic dusts
Rats, mice and other pets	Excretion		Allergenic dusts, bacteria, viruses. Odoriferous substances
	Loss of hair and scaling		Allergenic dust
House plants	Evaporation		Terpenes and other odoriferous substances, water vapour
Mould growth	Primary and secondary metabolism, spore release		Fungal propagules, bacterial cells and components, microbial VOC, mycotoxins
Building products, building equipment			
Building and materials	Product processing, outgassing, ageing, abrasion, decomposition	Building substances, building preservatives and corrosion prevention agents, insulating materials, sealing materials, paints, concrete additives	Various gaseous and particles, e.g. solvents, plasticizers, monomers, oligomers, wood preservatives, flame-proofing agents, fibres (asbestos, minerals wool), radon (e.g. from granite), amines and ammonia
Ventilation and air-conditioning system	Product processing, renovation, outgassing	Scrubbers, filters, insulating and sealing materials, deposits, heat exchangers	Microorganisms (e.g. legionella), biocides, fibres, odoriferous substances
Room furnishings	Product processing, renovation, outgassing	Furniture, floor coverings, domestic textiles, paints and varnishes, wall coverings	Monomers and oligomers from plastics, resins, surface coatings, adhesives (e.g. formaldehyde), fibres, solvents, plasticizers, stabilizers, biocides

Indoor activity			
Cooking and heating appliance	Combustion processes (heating, cooking), open fires	Coal, heating oil, gas, wood, foodstuff	Gases (municipal, bottled, natural), heating oil vapour, carbon dioxide, carbon monoxide, nitrogen oxides, water vapour, suspended particulate matter, hydrocarbons and many other organic substances (combustion and carbonization products)
Hygiene and personal care	Body and cosmetic care	Cosmetics and consumer products; shower and bath water	Solvents, propellants, perfumes, inorganic and organic aerosols (dyes, pigments, lacquers, resins), halocarbon
Sanitation products	Cleaning and care procedure; pest control	Detergents and cleaning agents, polishes, disinfectants, pesticides	Water, ammonia, chlorine, organic solvents, insecticides, bactericides and chlorine compounds, domestic dust
Home office	Office activities	Office supplies, EDP equipment, copiers	Organic solvents, low-volatility organic substances (plasticizers, flame proofing agents), toner components, ozone
Hobby and DIY (do-it-yourself) products	DIY activities, renovation, painting and the like	Paints, lacquers, adhesives, sprays, handicraft products, soldering irons	Inorganic and organic gaseous and aerosol-type substances, particularly propellants and solvents, dusts, suspended particulate matter, metal vapours, monomers, biocides
Tobacco	Smoking	Tobacco products	Carbon monoxide, nitrogen oxides, nicotine, aldehyde, nitrosamines and numerous other organic substances (e.g. polycyclic aromatic hydrocarbons, aerosols)
Garage store room	Storage	Fuels, paints, lacquers, cleaning agents, etc.	Fuel vapours, exhaust gas, solvents
Transportation			
Vehicles	Vehicle (car, use of vehicle, trucks, caravan, public transport)	Fuels, plastic and rubber materials, insulating material, ventilation	Vehicle exhaust gases and particles, carbon monoxide, nitrogen oxides, hydrocarbons, polycyclic aromatics, benzene, lead-containing suspended particulate matter, diesel soot), plasticizers (e.g. phthalates) and other additives, aldehyde, monomers (e.g. styrene), ozone (aircraft cabins)

Outdoor air pollution			
Emissions due to human activities	Ventilation, infiltration and diffusion through building exterior	Trade and industrial establishments, traffic, house fire, agriculture, outside burning	Inorganic and organic gases and aerosols, solvents, ammonia, odorous substances, PAHs
Natural emissions	Ventilation, penetration of soil gases, windborne dust	Plants in flower, occurrence of radium in soil, sea spray, soil re-suspension, natural decay	Pollen, radon, methane, sea salts, particles, microbes
Livestock	Excretion	Intestinal gases, odoriferous substances and excrement decomposition [products or pathological excretions; bacteria and viruses, allergenic dust	Ammonia and Sulphur compounds

B.4 (Informative): Typical pollutants and their sources in indoor environment

Pollutants	Sources
Inorganic components	
Carbon monoxide (CO)	Open fires, tobacco smoke, vehicle exhaust gases
Carbon dioxide (CO_2)	Open fires, tobacco smoke, people, vehicle exhaust gases
Nitrogen dioxide (NO_2)	Open fires, gas appliances, tobacco smoke, vehicle exhaust gases (in vehicle)
Sulphur dioxide (SO_2)	Sulphur-containing fuels
Ozone (O_3)	Photocopiers, laser printers
Ammonia	Flooring, concrete, levelling agents, mortar/plasters
Radon	Uranium and radium deposits close to the surface, building materials (granite, pumice stone and tuffaceous rock), artificial plaster
Mercury	Broken thermometer, plaints
Lead	Paints
Particles	
Settled dusts	Tracked-in dusts
Asbestos	Insulating materials, freeable asbestos
Fibrous dusts	Mineral wool, building materials
Aerosols	Tobacco smoke
Suspended particulate matter (PM) PM2.5 PM 10 TPM (total particulate matter)	Fuel combustion., cooking, fungi spores, pollen, animals, humans, bacteria, windblown dust

Annex C Lighting comfort

C.1 (Normative): Circadian Lighting Design

Light is one of the main drivers of the circadian system, which starts in the brain and regulates physiological rhythms throughout the body's tissues and organs, affecting hormone levels and the sleep-wake cycle. Circadian rhythms as shown in Figure 12 are kept in sync by various cues, including light which the body responds to in a way facilitated by intrinsically photosensitive retinal ganglion cells (ipRGCs): the eye's non-image-forming photoreceptors. Through ipRGCs, lights of high frequency and intensity promote alertness, while the lack of this stimulus signals the body to reduce energy expenditure and prepare for rest.

This feature promotes lighting environments for circadian health. The biological effects of light on humans can be measured in Equivalent Melanopic Lux (EML), a proposed alternate metric that is weighted to the ipRGCs instead of to the image forming photo receptors - cones, which is the case with traditional lux.

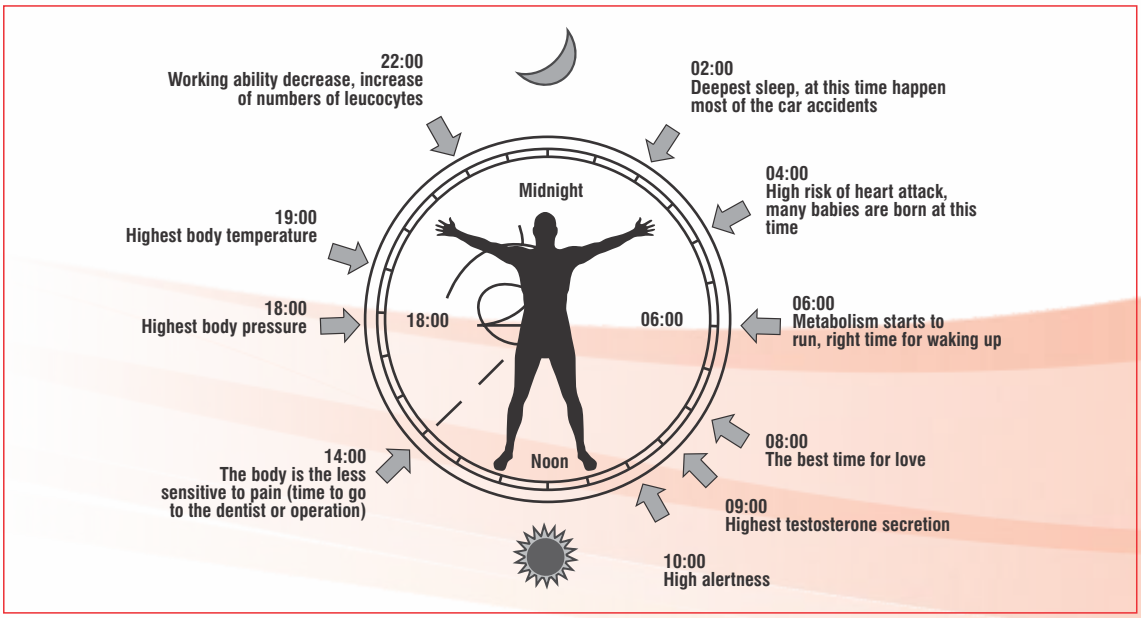


Figure 12 - Circadian rhythms in humans

C.2 (Normative): Recommended methodology to calculate Equivalent Melanopic Lux (EML) for different type of lighting conditions

To calculate the Equivalent Melanopic Lux (EML), multiply the visual lux (L) designed for or measured in a building by Melanopic ratio (R).

$$EML = L \times R$$

Where values of ratio R are given in Table 12

Table 12 - Light source and melanopic ratio corresponding to different CCT (K)

CCT (K)	Light Source	Melanopic Ratio
2950	Fluorescent	0.43
2700	LED	0.45
2800	Incandescent	0.54
4000	Fluorescent	0.58
4000	LED	0.76
5450	CIE E (Equal Energy)	1.00
6500	Fluorescent	1.02
6500	Daylight	1.10
7500	Fluorescent	1.11

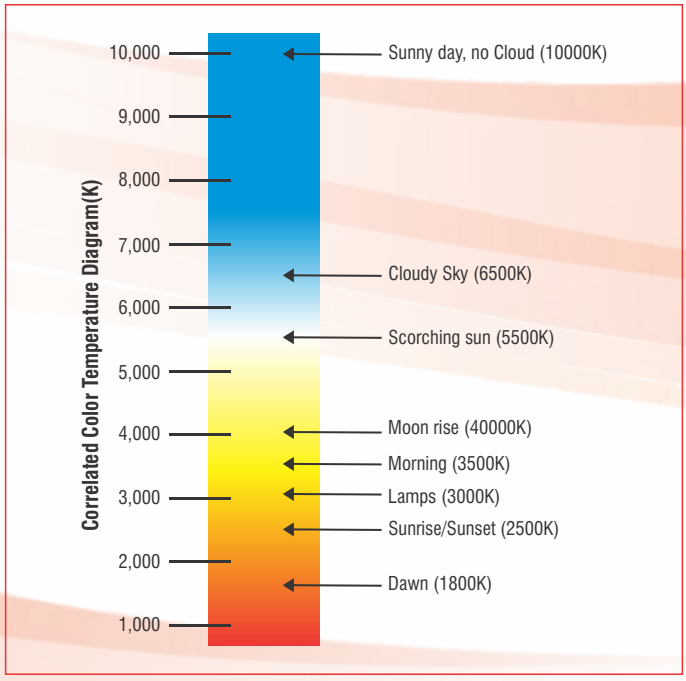


Figure 13 - Correlated Colour Temperature (K) corresponding to typical lighting conditions

Example 1:

If incandescent lights provide 200 lux in a space, they will produce equivalent melanopic lux of:

$$EML = 200 \times 0.54$$
$$EML = 108$$

Example 2:

If fluorescent lighting of 6500 K CCT provides 200 lux in a space, then the EML will be

$$EML = 1.02 \times 200$$
$$EML = \text{which is 204 EML.}$$

Example 3:

If CFL of CCT 6500 and LED of CCT 4000 combine provide 300 lux, then the EML can be calculated by the following method:

Lux levels provided by CFL is 100 (can be determined by switching off LEDs)

$$EML_{CFL} = 100 \times 1.02 = 102 \text{ EML}$$

Lux levels provided by LED is 200 (can be determined by switching off CFLs)

$$EML_{LED} = 200 \times 0.76 = 152 \text{ EML}$$

Total EML shall be calculated

$$EML_{total} = EML_{CFL} + EML_{LED} = 254$$

Example 4:

If fluorescent lighting of 7500 K CCT and daylighting provide 500lux
Lux levels provided by daylight is 400 (can be determined by switching off fluorescent lights)

$$EML_{daylight} = 400 \times 1.10 = 440 \text{ EML}$$

Lux levels provided by fluorescent are 100 (total lux –daylight lux)

$$EML_{fluorescent} = 100 \times 1.11 = 111$$
$$EML_{total} = EML_{fluorescent} + EML_{daylight} = 551$$

Annex D Acoustic Comfort

D.1 (Normative): Noise criterion curves

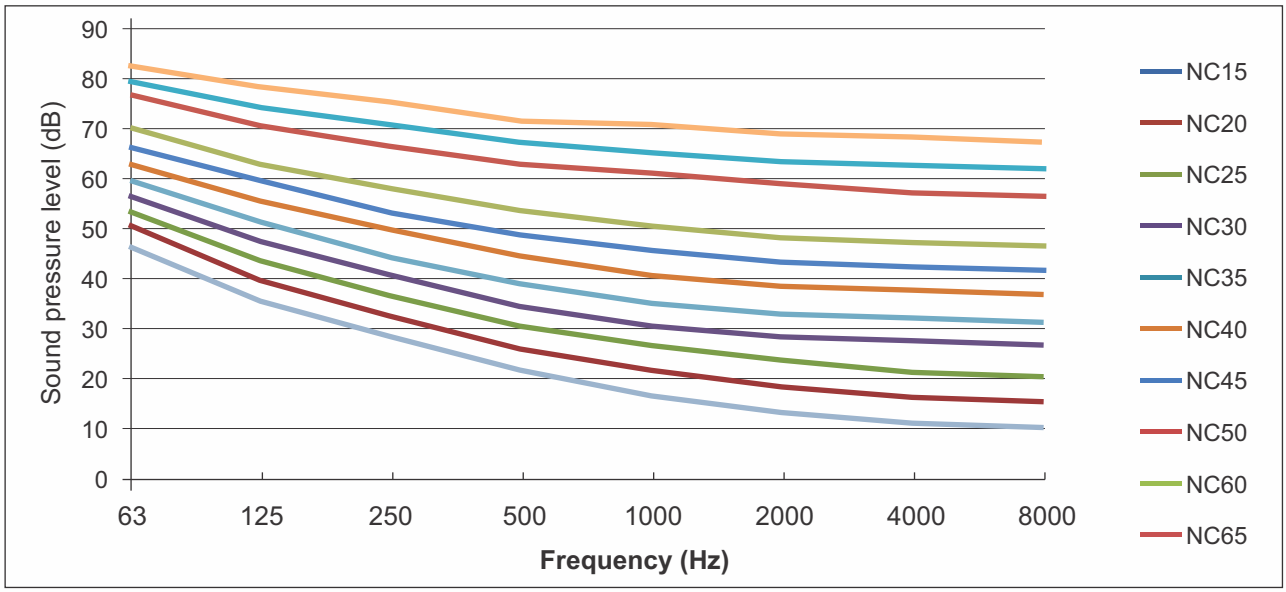


Figure 14 - Noise criterion curves

Example 1: Estimating NC - Noise Criterion

For a measured noise spectrum as below:

Freq. Hz	62.5	125	250	500	1000	2000	4000	8000
dB	40	50	55	60	50	55	45	45

Plot the measured values on the NC Curve. The NC curve tangent to the value at 1000 Hz is NC – 57 as depicted in the graph below. Hence, the NC value = 57dB

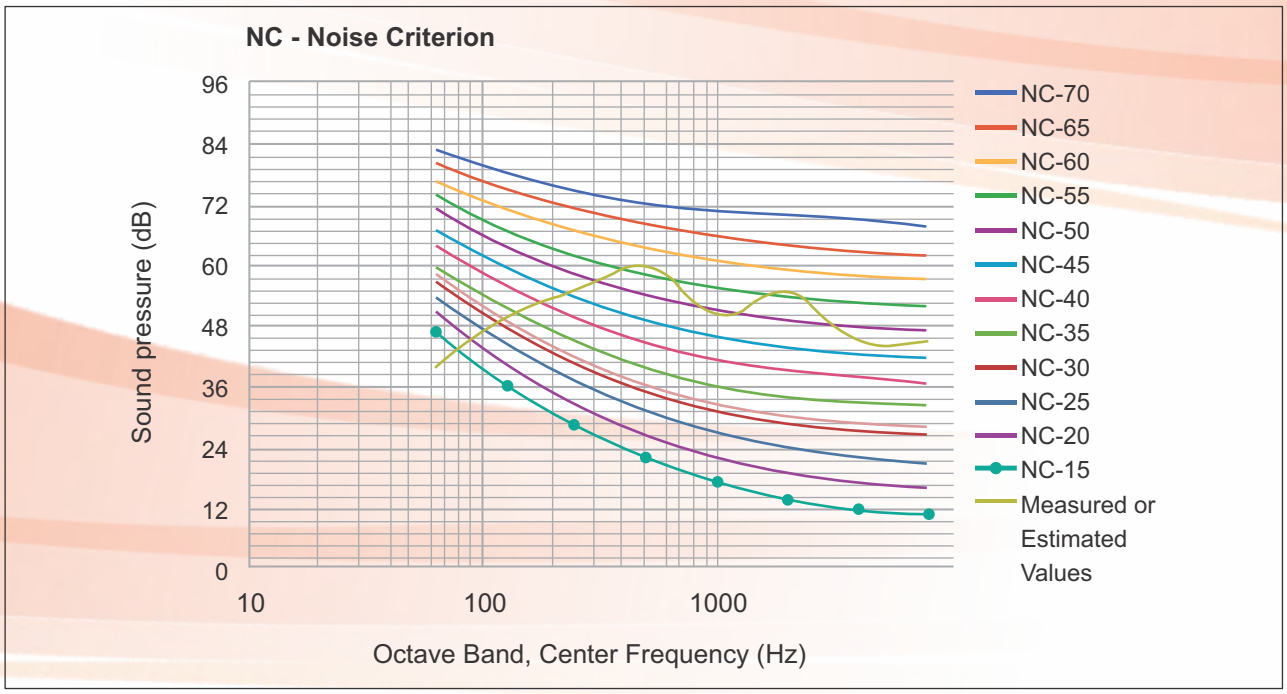


Figure 15 - Estimating NC – Noise Criterion

D.2 (Informative): Noise level associated with typical activities

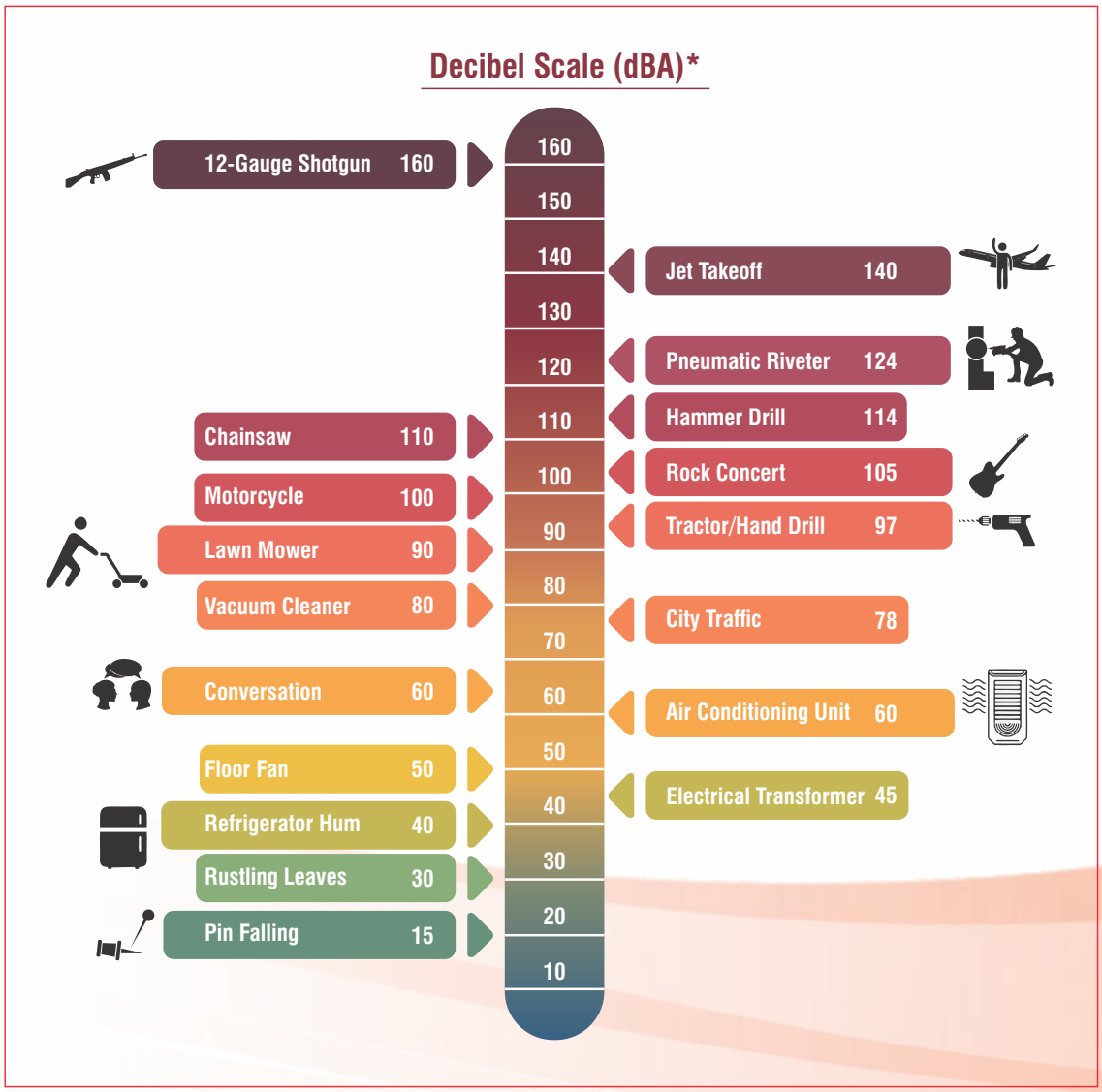


Figure 16 - Noise level corresponding to typical equipment and activities