

Indoor Environmental Quality Standard

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27 **Foreword**

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45 **Introduction**

46 Indoor Environmental Quality (IEQ) refers to the environmental conditions inside regularly occupied space  
47 that is determined by many factors, including indoor air quality (IAQ), thermal comfort, visual comfort,  
48 acoustic comfort as well as ergonomics. IEQ has an impact on health, comfort, and safety, which in turn  
49 affects productivity of occupants.

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

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

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

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

72 There are several other IEQ elements and parameters that could have been included in this standard.  
73 However, wherever reliable supporting data, published studies, and affordable measuring instruments are  
74 not easily available, this version of the standard has excluded such elements and parameters. It is also  
75 envisaged that effect of most such parameters is likely to be covered through occupant satisfaction survey.  
76 Efforts have been made to utilise the knowledge and research presented in several India specific studies.

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

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120 1. Scope

121 This standard defines the classification of built environment based on threshold values for below mentioned  
122 Indoor Environment Quality elements in a regularly occupied space of residential and non-residential  
123 buildings with low and moderate level of activities. This standard is applicable for Naturally ventilated ,  
124 Mixed mode and Air conditioned building types.

125 The IEQ parameters under the scope of this standard are :

- 126 a. Indoor air quality
- 127 b. Thermal comfort
- 128 c. Visual comfort
- 129 d. Acoustic comfort

130 This standard also defines the test requirement and test method for measurement of the IEQ parameters.  
131

132 Out of Scope

133 The below type of built environment is out of scope of this standard.

- 134 a) Spaces used for high intensity activities.
- 135 b) Special purpose built environment for Specific requirements such as Operation Theatres, Intensive  
136 Care Units, clean room, scientific laboratories, industry and other specialized applications.
- 137 c) Indoor environmental quality parameters such as water quality, odours ergonomics,  
138 electromagnetic radiations, vibrations and others.

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154        2. Normative References

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

159        IS 5182 – Part 2: *Methods for Measurement of Air Pollution, Part 2: Sulphur Dioxide*

160        IS 5182 – Part10: *Methods for Measurement of Air Pollution, Part 10: Carbon Monoxide*

161        IS 5182 – Part 9: *Methods for measurement of air pollution, Part 9: Oxidants*

162        IS 36461: *Code of Practice for Interior Illumination*

163        IS 3646-1: Code of practice for interior illumination

164        NBC 2005: *the National Building Code of India 2005*

165        Central Pollution Control Board - Indoor Air Pollution Monitoring Guidelines, 2014

166        Central Pollution Control Board – *the Noise Pollution (Regulation and Control) Rules, 2000*

167        ISO 3382 – Part 1: *Acoustics — Measurement of room acoustic parameters — Part 1: Performance*  
168        *spaces*

169        ISO 3382 – Part 2: *Acoustics — Measurement of room acoustic parameters — Part 2: Reverberation time*  
170        *in ordinary rooms*

171        ISO 3382 – Part 3: *Acoustic parameters — Part 3: Open plan offices*

172        ISO 18233: *Acoustics — Application of new measurement methods in building and room acoustics*

173        ISO 1996-2: *Acoustics -- Description, measurement and assessment of environmental noise — Part 2:*  
174        *Determination of environmental noise levels*

175        ISO 16283-1: *Acoustics — Field measurement of sound insulation in buildings and of building elements*  
176        *— Part 1: Airborne sound insulation*

177        ISO 16283-1: *Acoustics — Field measurement of sound insulation in buildings and of building elements*  
178        *— Part 2: Impact sound insulation*

179        ISO 16017-1: *Indoor, ambient and workplace air -- Sampling and analysis of volatile organic compounds*  
180        *by sorbent tube/thermal desorption/capillary gas chromatography — Part 1: Pumped sampling*

181        ISO 16000-3: *Determination of formaldehyde and other carbonyl compounds in indoor air and test*  
182        *chamber air -- Active sampling method*

183        ISO 16000-5: *Sampling strategy for volatile organic compounds (VOCs)*

184 ISO 16000-6: *Determination of volatile organic compounds in indoor and test chamber air by active*  
185 *sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS or MS-FID*

186 ISO 16000-15: *Sampling strategy for nitrogen dioxide (NO<sub>2</sub>)*

187 ISO 16000-16: *Detection and enumeration of moulds — Sampling by filtration*

188 ISO 16000 -17: *Detection and enumeration of moulds — Culture-based method*

189 ISO 16000 -18: *Detection and enumeration of moulds — Sampling by impaction*

190 ISO 16000 -19: *Sampling strategy for moulds*

191 ISO 16000 -20: *Detection and enumeration of moulds -- Determination of total spore count*

192 ISO 16000 -21: *Detection and enumeration of moulds — Sampling from materials*

193 ISO 16000-26: *Sampling strategy for carbon dioxide (CO<sub>2</sub>)*

194 ISO 16000-34: *Strategies for the measurement of airborne particles (PM 2.5 fraction)*

195 ISO 16000-37: *Strategies for the measurement of PM 2.5*

196 ISO 7730 - *Ergonomics of the thermal environment -- Analytical determination and interpretation of*  
197 *thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria*  
198

199 IEC 60268 – Part 16: *Objective rating of speech intelligibility by speech transmission index.*

200 IEC 61672: *Electro acoustics – Sound level meters – Part 1: Specifications*

201 ANSI S1.13 *Measurement of Sound Pressure Levels in Air*

202 ASHRAE 55-2013: *Thermal Environment Conditions for Human Occupancy*

203 ASHRAE HANDBOOK – 2011: *HVAC Applications*  
204

205 ASTM E – 1130: *Objective measurement of speech privacy using Articulation Index.*  
206

207 ASTM E – 1374: *Guide for open office acoustics and applicable standards.*

208 ASTM International Designation E336-97: *Standard Test Method for Measurement of Airborne Sound*  
209 *Insulation in Buildings*  
210

211 ANSI S12.60: *Guidelines for classroom acoustics.*

212 BS8233:1999 —*Sound Insulation and noise reduction for buildings – Code of practice.*  
213

214 BS EN ISO 717-1:1997 *Acoustics —Rating of sound insulation in buildings and of building elements –*  
215 *Part 1 Airborne sound insulation.*

- 216 WELL v2™- *The WELL Building Standard™*
- 217 REHVA Guidebook n° 14: *Indoor Climate Quality Assessment*
- 218 CIBSE: *The SLL Code for Lighting*
- 219 IS SP 72 National Lighting Code -2010
- 220 EN-12464-1 Light and lighting - Lighting of work places - Part 1:
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- 259 3. Terms and Definitions  
260 3.1. General  
261 This section of the standard provides the general terms and definitions applicable to this  
262 standard. The Indoor Environment Quality (IEQ) specific parameter wise terms and definitions  
263 are provided in subsequent clauses.  
264 3.1.1. Accuracy  
265 It is the amount of uncertainty in a measurement with respect to an absolute standard. Accuracy  
266 specifications usually contain the effect of errors due to gain and offset parameters.  
267 3.1.2. Indoor Environmental Quality Elements  
268 In this standard the term 'elements' refer to thermal comfort, indoor air quality, lighting and  
269 acoustic related dimensions of indoor environment.  
270 3.1.3. Indoor Environmental Quality (IEQ)  
271 Indoor environmental quality (IEQ) refers to the quality of a built environment in relation to the  
272 health and wellbeing of those who occupy space within it  
273 3.1.4. Range  
274 The upper and lower limits to which an instrument can measure a value or signal  
275 3.1.5. Representative Occupant  
276 An individual or composite or average of several individuals that is representative of the  
277 population occupying a space for 15 minutes or more. In this standard, the term 'occupant'  
278 refers to 'representative occupant'.  
279 3.1.6. Resolution  
280 Resolution is the ability to 'resolve' differences; that is, to draw a distinction between two things.  
281 High resolution means being able to resolve small differences. In a digital system, resolution  
282 means the smallest increment or step that can be taken or seen. In an analog system, it means  
283 the smallest step or difference that can be reliably observed.  
284 3.2. Thermal comfort  
285 3.2.1. General  
286 The IEQ parameter - Thermal comfort related terms and definitions are provided in this  
287 section of the standard.  
288 3.2.2. Acceptable thermal environment  
289 Thermal environment that a substantial majority of the occupants find thermally acceptable.  
290 3.2.3. Adaptive model  
291 A model that relates indoor design conditions or acceptable ranges of indoor environment  
292 parameters, such as temperature, to outdoor meteorological or climatological parameters. It  
293 also encompasses gradual diminution of the people's response to repeated environmental  
294 stimulation and subsumes all processes which building occupants undertake in order to  
295 improve the comfort of the indoor environment.  
296 3.2.4. Average air speed  
297 The air speed surrounding a representative occupant averaged with respect to location and  
298 time. The spatial average is for three heights as defined for average air temperature.  
299 3.2.5. Average air temperature  
300 The air temperature surrounding a representative occupant averaged with respect to location  
301 and time.  
302 3.2.6. Clo  
303 A unit used to express the thermal insulation provided by garments and clothing ensembles,  
304 where 1 clo = 0.155 m<sup>2</sup> K/W.  
305 3.2.7. Draft  
306 The unwanted local cooling of the body caused by air movement.  
307

- 308 3.2.8. Floor temperature  
309 The surface temperature of the floor where it is in contact with the occupant's feet.
- 310 3.2.9. Local thermal discomfort  
311 The thermal discomfort caused by locally specific conditions such as a vertical air  
312 temperature difference between the feet and the head, by radiant temperature asymmetry,  
313 by local convective cooling (draft), or by contact with a hot or cold floor.
- 314 3.2.10. Metabolic rate  
315 The rate of transformation of chemical energy into heat and mechanical work by metabolic  
316 activities of an individual, per unit of skin surface area and expressed in units of met, equal  
317 to  $58.2 \text{ W/m}^2$ , which is the energy produced per unit skin surface area of an average person  
318 seated at rest.
- 319 3.2.11. Mean Radiant Temperature  
320 The uniform temperature of an imaginary enclosure in which the radiant heat transfer from  
321 the human body is equal to the radiant heat transfer in the actual non-uniform enclosure.
- 322 3.2.12. Mixed Mode  
323 "Mixed-mode" refers to a hybrid approach to space conditioning that uses a combination of  
324 natural ventilation from operable windows (either manually or automatically controlled), and  
325 mechanical systems that include air distribution equipment and refrigeration equipment for  
326 cooling.
- 327 3.2.13. Operative Temperature:  
328 A uniform temperature of a radiantly black enclosure in which an occupant would exchange  
329 the same amount of heat by radiation plus convection as in the actual non-uniform  
330 environment. It is the combined effect of the mean radiant temperature and air temperature  
331 and is the mean of these two under specific conditions. It is also known as dry resultant  
332 temperature or resultant temperature.
- 333 3.2.14. Radiant Temperature Asymmetry  
334 The difference between the plane radiant temperature ( $t_{pr}$ ) in opposite directions. The vertical  
335 radiant temperature asymmetry is with plane radiant temperatures in the upward and  
336 downward directions. The horizontal radiant temperature asymmetry is the maximum radiant  
337 temperature asymmetry for all horizontal directions. The radiant temperature asymmetry is  
338 determined at waist level, 0.6 m for a seated occupant and 1.1 m for a standing occupant.
- 339 3.2.15. Relative Humidity  
340 Ratio of the partial pressure of actual water vapour in the air as compared to the partial  
341 pressure of maximum amount of water vapour that may be contained at its dry bulb  
342 temperature.
- 343 3.2.16. Thermal comfort  
344 The condition of mind that expresses satisfaction with the thermal environment and is  
345 assessed by subjective evaluation.
- 346 3.2.17. Thermal environment  
347 The environmental conditions that affect a person's thermal balance with surroundings.
- 348 3.2.18. Vertical air temperature difference  
349 Air temperature difference between head and ankle level of occupant.
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- 351 3.3. Indoor air quality
- 352 3.3.1. General
- 353 The IEQ parameter - Indoor Air Quality related terms and definitions are provided in this  
354 section of the standard.  
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- 357 3.3.2. Indoor Air Quality  
358 Air quality that refers to the nature of unconditioned or conditioned air that circulates  
359 throughout the space where one works or lives, that is, the air one breathes when indoors.
- 360 3.3.3. Particulate Matter  
361 A complex mixture of tiny particles that consists of dry solid fragments, solid cores with liquid  
362 coatings, and small droplets of liquid. These particles vary greatly in shape, size and chemical  
363 composition, and can be made up of many different materials such as metals, soot, soil, and  
364 dust. Particulate matter that has an aerodynamic diameter of 10  $\mu\text{m}$  and below is referred to  
365 as  $\text{PM}_{10}$ . Particles that are 2.5  $\mu\text{m}$  aerodynamic diameters and smaller are  $\text{PM}_{2.5}$ . Thus all  
366  $\text{PM}_{2.5}$  is included in  $\text{PM}_{10}$ , although the converse is not true.
- 367 3.3.4. Volatile Organic Compounds (VOCs)  
368 Organic, and therefore carbon and hydrogen containing, materials which evaporate and  
369 diffuse easily at ambient temperature. VOCs are emitted by a wide array of building materials,  
370 paints and common consumer products.
- 371 3.3.5. Total Volatile Organic Compounds (TVOCs)  
372 Sum of the concentrations of identified and unidentified volatile organic compounds eluting  
373 between and including n-hexane and n-hexadecane.
- 374 3.3.6. Colony-forming unit  
375 Is a measure of viable bacterial or fungal cells. In direct microscopic counts where all cells,  
376 dead and living, are counted, but CFU measures only viable cells. For convenience the results  
377 are given as (colony-forming units per cubic meter) or  $\text{CFU}/\text{m}^3$  for air (grab) sample or  $\text{CFU}/\text{m}^2$   
378 for surface (swab) sample.
- 379 3.4. Visual comfort
- 380 3.4.1. General  
381 The IEQ parameter - Visual comfort related terms and definitions are provided in this  
382 section of the standard.
- 383 3.4.2. Back Ground Area  
384 In indoor work places, particularly a large part of the area surrounding an active and occupied  
385 task area which needs to be illuminated. This area is known as the 'background area'. Should  
386 be a border at least 3 m wide adjacent to the immediate surrounding area within the limits of  
387 the space.
- 388 3.4.3. Circadian Rhythm  
389 Internal clock that keeps the body's hormones and bodily processes on a roughly 24 hour  
390 cycle, even in continuous darkness.
- 391 3.4.4. Correlated Colour Temperature  
392 Spectral distribution of electromagnetic radiation of a blackbody at a given temperature. For  
393 example, the colour temperature during the daytime is approximately 15,000 K, while during  
394 sunset is approximately 1,850K.
- 395 3.4.5. Daylight factor  
396 Ratio of the luminance at a point on a given indoor plane due to the light received directly or  
397 indirectly from the sky of assumed or known luminance distribution, to the luminance on a  
398 horizontal plane from an unobstructed hemisphere of the same sky. The contribution to direct  
399 sunlight to both luminance is excluded. It is expressed in percentage.
- 400 3.4.6. Disability Glare  
401 Disability glare is the loss of retinal image contrast as a result of intra-ocular light scatter, or  
402 stray light. It has been described as a reduction of visual acuity caused by light elsewhere in  
403 the field of vision. Disability glare can be produced directly or by reflection.  
404

405 3.4.7. Discomfort Glare  
406 Glare that causes discomfort without necessarily impairing the vision of objects. Discomfort  
407 glare can be produced directly or by reflection  
408 3.4.8. Equivalent Melanopic Lux (EML)  
409 A measure of light used to quantify how much a light source will stimulate melanopsin's light  
410 response.  
411 3.4.9. Glare  
412 Glare is the sensation produced by bright areas within the visual field, such as lit surfaces,  
413 parts of the luminaires, windows and/or roof lights. Glare shall be limited to avoid errors,  
414 fatigue and accidents. Glare is the visual sensation produced by bright areas within the field  
415 of view and may be experienced either as discomfort glare or disability glare. Glare may also  
416 be caused by reflections in specular surfaces usually known as veiling reflections or reflected  
417 glare.  
418 *Note:*  
419 • Disability glare is more common in exterior lighting but may also be experienced from  
420 spotlights or large bright sources such as a window in a relatively poorly lit space.  
421 • In interior workplaces discomfort glare usually arises directly from bright luminaires or  
422 windows. If the discomfort glare limits are met then disability glare is not usually a major  
423 problem.  
424 3.4.10. Illuminance  
425 Illuminance is the incident luminous flux density on a differential element of surface located  
426 at a point and oriented in a particular direction, expressed in lumens per unit area. Since the  
427 area involved is differential, it is customary to refer to this as illuminance at a point. The unit  
428 of measurement is lux  
429 3.4.11. Illuminance of the immediate surrounding areas  
430 A zone of at least 0.5 m width surrounding the task area within the field of vision.  
431 3.4.12. Lux  
432 Unit of illuminance, one lux being equivalent to one lumen per square meter.  
433 3.4.13. Reflected Glare  
434 The variety of ill effects on visual efficiency and comfort produced by unwanted reflection in  
435 and the task area.  
436 3.4.14. Task Area  
437 The partial area in the workplace in which the visual task is located and carried out.  
438 3.4.15. Working plane  
439 The reference surface defined as the plane at which work is usually done.  
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441 3.5. Acoustic comfort  
442 3.5.1. General  
443 The IEQ parameter - Acoustic comfort related terms and definitions are provided in this  
444 section of the standard.  
445 3.5.2. A-Weighted Decibel  
446 Ten times the common logarithm of the square of the ratio of time-averaged A-weighted  
447 sound pressure to the reference sound pressure of 20 micro-pascals. Unit of A weighted  
448 decibel  
449 3.5.3. Decibel  
450 Ten times the common logarithm of the square of the ratio of the sound pressure to the  
451 reference sound pressure of 20 micropascals.  
452  
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- 454 3.5.4. Indoor Ambient Noise  
 455 The all-encompassing Noise in a given situation at a given time, usually composed of noise  
 456 from many sources, inside and outside the building, but excluding noise from activities of the  
 457 occupants.
- 458 3.5.5. Noise Criteria  
 459 Noise criteria is a single numerical index commonly used to define design goals for the  
 460 maximum allowable noise in a given space. The noise criterion equals the lowest curve which  
 461 is not exceeded in the spectra ranging from 63 – 8000 Hz.
- 462 3.5.6. Noise Isolation Class  
 463 Noise Isolation Class is a method for rating a partition's ability to block airborne noise transfer.  
 464 *Note: Similar to a field STC test, NIC is often specified on certain projects (such as spaces with operable walls,*  
 465 *hotels, education facilities). For a field STC test, the individual transmission loss measurements are modified based*  
 466 *on the reverberation time, the size of the room and the size of the test partition. The NIC does not include these*  
 467 *modifications and simply measures the transmission loss between 125 and 4,000Hz.*
- 468 3.5.7. Octave Band  
 469 Band of frequencies in which the upper limit of the band is twice the frequency of the lower  
 470 limit.
- 471 3.5.8. Pink noise  
 472 Pink noise is acoustical energy distributed uniformly by octave throughout the audio spectrum  
 473 (the range of human hearing, approximately 20 Hz to 20 kHz).
- 474 3.5.9. Privacy Index  
 475 Privacy Index is a measure for rating speech privacy performance (or lack of speech  
 476 intelligibility) of an architectural space.
- 477 3.5.10. Reverberant sound or Reverberation  
 478 The sound in an enclosed space, which results from, repeated reflections at the boundaries.
- 479 3.5.11. Reverberation time  
 480 Reverberation time is the time required for a steady-state sound to reach one millionth or -  
 481 60dB of its original intensity.
- 482 3.5.12. Sound  
 483 A vibrational disturbance, exciting hearing mechanism, transmitted in a predictable manner  
 484 determined by the medium through which it propagates. To be audible the disturbance shall  
 485 have to fall within the frequency range of 20Hz to 20000 Hz.
- 486 3.5.13. Sound Level Difference  
 487 Difference between the sound pressure level in the source room and the sound pressure  
 488 level in the receiving room.
- 489 3.5.14. Sound pressure level  
 490 Ten times the logarithm to the base 10 of the ratio of the square of the sound pressure, p, to  
 491 the square of a reference value,  $p_o$ , expressed in decibels

$$L_p = 10 \log \frac{p^2}{p_o^2} dB$$

494 Where the reference sound pressure value  $p_o$  is 20 Pa;

495  $L_p$  is Sound pressure level.

496  $p$  is the sound pressure

- 497 3.5.15. Sound Source  
498 Equipment or phenomena which generate sound. Source room is the room containing sound  
499 source.
- 500 3.5.16. Sound Transmission Class  
501 The Sound Transmission Class is a single number rating of the effectiveness of a material  
502 or construction assembly to retard the transmission of airborne sound. It is also known as  
503 Sound Reduction Index (SRI). Sound Transmission Class rates a partition's resistance to  
504 airborne sound transfer at the speech frequencies (125-4000 Hz). The higher the number,  
505 the better the isolation.
- 506 3.5.17. Speech Transmission Index  
507 Speech transmission index is a parameter that defines the clarity of the sound inside a space.  
508 It is rated between 0 and 1, 0 being worst and 1 being best.
- 509 3.5.18. Standardized Level Difference  
510 Difference in sound level between a pair of rooms, in a stated frequency band, normalized to  
511 a reverberation time of 0.5 s for dwellings.
- 512 3.5.19. Third Octave Band  
513 Band of frequencies in which the upper limit of the band is  $2^{1/3}$  times the frequency of the  
514 lower limit.
- 515 3.5.20. Time-averaged sound level  
516 A-weighted equivalent sound pressure level in dB measured over a period of time t.
- 517 3.5.21. Weighted Level Difference  
518 Single number quantity that characterises airborne sound insulation between rooms but  
519 which is not adjusted to reference conditions.
- 520 3.5.22. Weighted Standardized Level Difference  
521 Single number quantity that characterises airborne sound insulation between rooms.  
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534 4. Classification

535 The built environment is classified as Class A - Aspirational, Class B – Acceptable and Class C –  
536 Minimum acceptable based on the measured values for individual parameters of IEQ elements as  
537 specified in the Table 2 and 3 for Thermal comfort, Table 5, for IAQ, Table 12 for Visual comfort  
538 and Table 13 & 14 for Acoustic comfort.  
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583 5. Abbreviations, symbols and units

584 5.1. 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
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 Standardization
NBC	National Building Code
NC	Noise Criteria
NCB	Balanced Noise Criteria
NIC	Noise Isolation Class
PM	Particulate Matter
RH	Relative Humidity
STC	Sound Transmission Class
STI	Sound Transmission Index
TVOC	Total Volatile Organic Compound

585 5.2. Symbols

a	Ambient
C <sub>6</sub> H <sub>6</sub>	Benzene
CH <sub>2</sub> O	Formaldehyde
CO	Carbon monoxide
CO <sub>2</sub>	Carbon dioxide
D	Sound Level Difference
D <sub>nt</sub>	Standardisation Level Difference
D <sub>nt, w</sub>	Weighted Standardisation Level Difference
D <sub>w</sub>	Weighted Difference Level
L <sub>Aeq,T</sub>	A-weighted equivalent sound pressure level in dB measured over a period of time t.
NO <sub>2</sub>	Nitrogen dioxide
O <sub>3</sub>	Ozone
SO <sub>2</sub>	Sulphur dioxide
T	Reverberation Time
t <sub>a</sub>	Ambient Temperature
t <sub>mr</sub>	Mean Radiant Temperature
t <sub>o</sub>	Operative Temperature
t <sub>pr</sub>	Plane Radiant Temperature
ϑ	Velocity

## 586 5.3. 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 Million
s	Second
W	Watt

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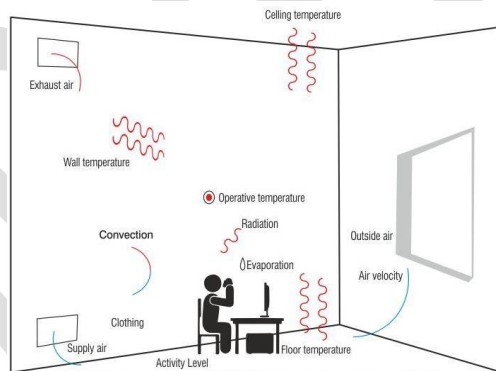
- 619 6. Indoor Environmental Quality elements and parameters - tests and testing methods  
 620 6.1. General  
 621 This section of the standard defines testing method of every parameter of four IEQ elements. Measurement  
 622 sampling shall be representative of locations where the occupants are known to, or, are expected to spend  
 623 their time. All measurements shall be carried out at steady indoor conditions. The sampling duration must  
 624 represent both, “peak” and “average” indoor exposure. For any IEQ parameter, wherever the representative  
 625 measurement location is specified in particular, it supersedes this clause.  
 626  
 627 6.2. Thermal comfort  
 628 6.2.1. General

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

- 631 a. Atmospheric pressure equivalent to altitudes up to 3000 m  
 632 b. Indoor spaces designed for human occupancy for periods not less than 15 minutes.

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

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



638 **Figure 1 Factors affecting thermal comfort in an indoor environment**

639 Physical parameters

- 640  
 641 a. Air temperature  
 642 b. Vertical air temperature difference  
 643 c. Mean radiant temperature  
 644 d. Radiant temperature asymmetry  
 645 e. Floor surface temperature  
 646 f. Relative Humidity  
 647 g. Air speed

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

649 Physiological factors

- 650 a. Metabolic rate  
 651 b. Clothing insulation

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

653

654 6.2.2. Thermal comfort threshold values

655 The values for quality of thermal environment for representative occupant of a space shall be as  
 656 specified in table 1

657 Table 1: Conditions for thermal comfort measurement

Air velocity	Weather condition	Level of activity	Reference table for Threshold Values
Up to 0.2m/s	Summer / winter	Low and medium	Table 3
Above 0.2m/s	Summer / winter	Low and medium	Chart 1

658

659 Table 2. Acceptable range of thermal comfort parameters with air velocity up to 0.2 m/s and low / medium  
 660 activity level in summer / winter condition

Parameters	Units		Class A	Class B	Class C
Operative Temperature	°C	If air velocity < 0.2 m/s	Table 3		
		If air velocity > 0.2 m/s	Calculate using Chart 1		
Relative Humidity	%		30 – 70	30 – 70	a. 30 – 70 (where, humidity control exists) b. Building must demonstrate 80% occupant satisfaction with respect to relative humidity (where, humidity controls 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 (only for floor based cooling/heating)	°C		17 - 31	-	-
Occupant Satisfaction	%		90	80	-

661

662 Table 3. Acceptable range of operative temperature with air velocity up to 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

663

664 Calculating operative temperature for air velocity up to 0.2 m/s

665

666 The operative temperature shall be calculated as below.

$$667 \quad t_o = \frac{(t_{mr} + (t_a \times \sqrt{10\vartheta}))}{1 + \sqrt{10\vartheta}}$$

668

669 where,  $\vartheta$  = air velocity

670  $t_a$  = air temperature

671  $t_{mr}$  = mean radiant temperature

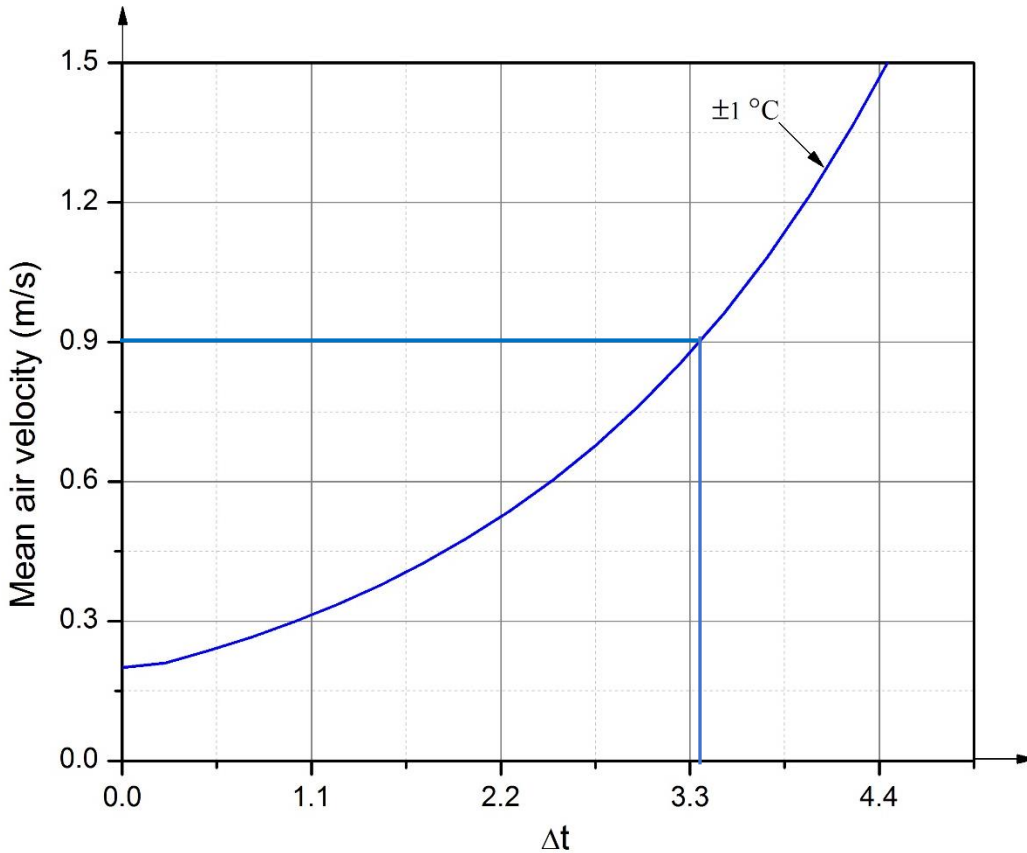
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673 It is also acceptable to approximate this relationship for occupants engaged in near sedentary physical  
674 activity (with metabolic rates between 1.0 met and 1.3 met), not in direct sunlight, and not exposed to air  
675 velocities greater than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

676

$$677 \quad t_o = \frac{(t_{mr} + t_a)}{2}$$

678



679

680 **Chart 1. Required Air Speed to Offset Increased Temperature**

681

682 Example: If in a given room, an occupant is involved in the moderate level of activity, air speed in room is  
 683 0.9 m/s and operative temperature is 27°C, then by using above mentioned graph  $\Delta t$  is 3.3°C. It makes  
 684 acceptable room air temperature as 27°C + 3.3°C.

685

686 6.2.3. Testing Methods of Thermal comfort

687 The representative sample locations shall be the locations where most extreme values of the  
 688 thermal parameters are observed or estimated to occur (e.g., potentially occupied areas near  
 689 windows, diffuser outlets, corners, and entries).

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

692

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

697

698 The measurement method at selected locations shall be as defined in Table 4.

**Table 4 Testing methods of thermal comfort**

Parameter	Measurement Methodology
Air temperature & Average air speed (The temperature of the air surrounding the occupant.)	a. Air temperature and average air speed ( $\vartheta_a$ ) 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. * c. Speed is averaged over an interval not less than 1 minute and not more than 3 minutes. Variations that occur over a period greater than 3 minutes shall be treated as multiple different air speeds. d. 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.
Vertical air temperature difference	a. Shall be calculated by arithmetic difference of air temperature measured at 0.1 m and 1.1 m levels for seated occupants. b. Calculations for standing occupants shall be made for air temperature measured at 0.1 m and 1.7 m levels.
Mean radiant temperature	a. Shall be measured at the 0.6 m level for seated occupants and the 1.1 m level for standing occupants.
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.

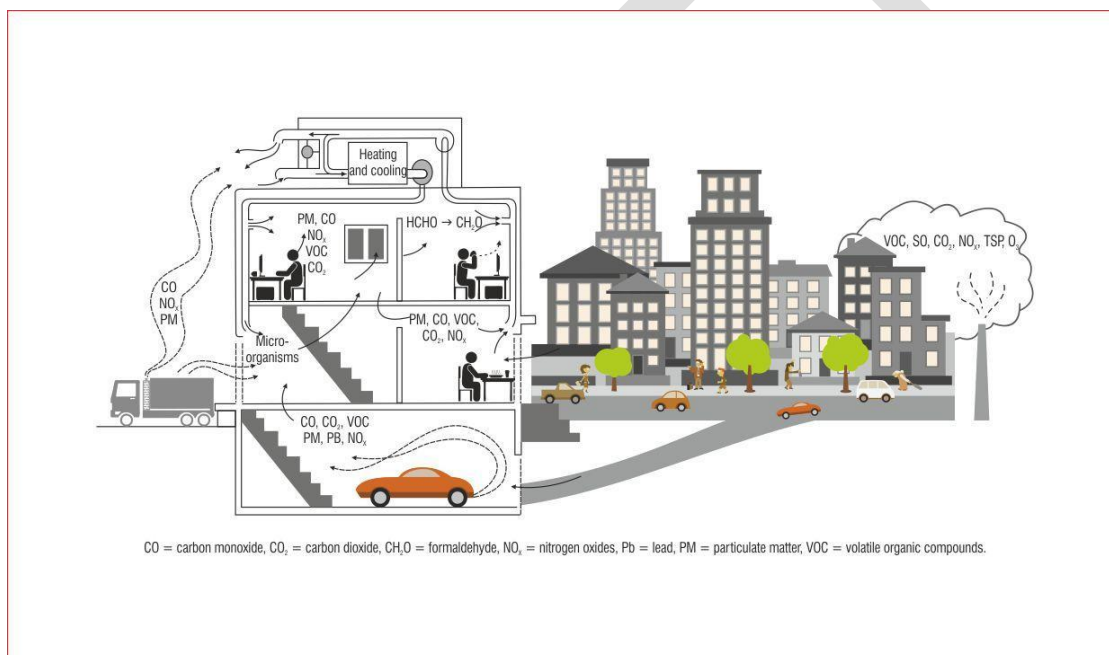
\* Mean value of these parameters at respective location shall be considered for calculating operative temperature

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718 6.3. Indoor air quality  
719 6.3.1.General:

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

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



731 **Figure 2 Indoor air pollutants in a typical built environment**  
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733 *Note: Details of the pollutants and their effects are given in Annex B.1*

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740 6.3.2. Indoor air quality parameters Threshold values

741 Threshold values for select indoor air quality parameters in an occupied space for Class A, Class B and  
 742 Class C are given in Table 5.

743 **Table 5 Threshold values for indoor air quality parameters**

Parameters		Units	Classification		
			Class A	Class B	Class C
Basic IAQ parameters	CO <sub>2</sub>	ppm	Ambient + 350	Ambient + 500	Ambient + 700
	PM 2.5	µg/m <sup>3</sup>	<15	<25	<25
	CO	ppm	<2	<9	< 9
	TVOC (equivalent to isobutylene)	µg/m <sup>3</sup>	<200	<400	<500
Complementary IAQ parameters	PM 10	µg/m <sup>3</sup>	<50	<100	<100
	CH <sub>2</sub> O	µg/m <sup>3</sup>	<30	<100	-
	SO <sub>2</sub>	µg/m <sup>3</sup>	<40	<80	-
	NO <sub>2</sub>	µg/m <sup>3</sup>	<40	<80	-
	O <sub>3</sub>	µg/m <sup>3</sup>	<50	<100	-
	Total Microbial Count	CFU/m <sup>3</sup>	Indoor ≤ ambient	Indoor ≤ ambient	-
Occupant Satisfaction		%	90	80	-

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

747 *Note 2: In case the values of TVOC are higher than the specified threshold value as given in table 5,*  
 748 *individual VOCs shall be analysed. At least the following VOCs that are toxic and common in indoor*  
 749 *environments, need to be analysed.*

750 *Table 5a. Threshold value for various VOCs in IAQ*

Parameter	Unit	Threshold value
Formaldehyde (HCHO)	µg/m <sup>3</sup>	30
Toluene	µg/m <sup>3</sup>	300
Acetone (2-propanone) (C <sub>3</sub> H <sub>6</sub> O)	µg/m <sup>3</sup>	
Benzene	µg/m <sup>3</sup>	3
Acetaldehyde	µg/m <sup>3</sup>	140
Epichlorohydrin (106-89-8)	µg/m <sup>3</sup>	3
Naphthalene (91-20-3)	µg/m <sup>3</sup>	9

751  
 752 *In case a wider range of VOCs are analysed, the following threshold values should be used to evaluate*  
 753 *the harmfulness of each VOC:*

754

755

756 *Table 5b: Threshold of VOCs for detailed analysis*

Carbon disulfide	800 µg/m <sup>3</sup>	Carbon tetrachloride	40 µg/m <sup>3</sup>
Chlorobenzene	1000 µg/m <sup>3</sup>	Chloroform	300 µg/m <sup>3</sup>
Dichlorobenzene (1, 4-)	800 µg/m <sup>3</sup>	Dichloroethylene (1,1)	70 µg/m <sup>3</sup>
Dioxane (1, 4-)	3000 µg/m <sup>3</sup>	Ethylbenzene	2000 µg/m <sup>3</sup>
Ethylene glycon	400 µg/m <sup>3</sup>	Ethylene glycon monoethyl ether	70 µg/m <sup>3</sup>
Ethylene glycon monoethyl ether acetate	300 µg/m <sup>3</sup>	Ethylene glycon monomethyl ether	60 µg/m <sup>3</sup>
Ethylene glycon monomethyl ether acetate	90 µg/m <sup>3</sup>	Hexane (n-)	7000 µg/m <sup>3</sup>
Isophorone	2000 µg/m <sup>3</sup>	Isopropanol	7000 µg/m <sup>3</sup>
Methyl chloroform	1000 µg/m <sup>3</sup>	Methylene chloride	400 µg/m <sup>3</sup>
Methyl <i>t-butyl ether</i>	8000 µg/m <sup>3</sup>	Phenol	200 µg/m <sup>3</sup>
Propylene glycol monomethyl ether	7000 µg/m <sup>3</sup>	Styrene	900 µg/m <sup>3</sup>
Tetrachloroethylene (Perchloroethylene)	35 µg/m <sup>3</sup>	Trichloroethylene	600 µg/m <sup>3</sup>
Vinyl acetate	200 µg/m <sup>3</sup>	Xylenes, technical mixture (m-, o-, p-xylene combined)	700 µg/m <sup>3</sup>

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

760

761 6.3.3. Testing Methods of Indoor Air Quality parameters

762 IAQ measurements / monitoring shall be carried out as follows:

763

764 6.3.3.1. Sampling :

765 The general sampling strategy shall be as defined in ISO 16000-1.

766 For formaldehyde, the sampling strategy shall be as defined in ISO 16000-2.

767 The sampling for TVOC shall be as defined in ISO 16000-5.

768 The sampling for NO<sub>2</sub> shall be as defined in ISO 16000-15.

769 The sampling for CO<sub>2</sub> shall be as defined in ISO 16000-26.

770 *Note:*

771 *It is not recommended to carry out the particulate matter or microbial count measurements in a rain fall season as the*  
 772 *low outdoor PM concentration and high microbial background contamination may skew the results and results do not*  
 773 *represent the average indoor air conditions.*

774 *When IAQ measurements are carried out, the ventilation system shall operate in a 'normal' operation mode at least*  
 775 *previous 48 hours and during the measurement. Example: if the ventilation normally operates from 8 am to 6 pm with*  
 776 *50% speed, the previous two days this operation mode shall be followed and ventilation shall not be boosted or operated*  
 777 *longer periods.*

778

779 6.3.3.2. Measurement conditions:

780 IAQ measurements shall be carried out only after the flush out period of minimum 24 hours in a newly  
 781 constructed or refurbished space as the initial emissions of indoor impurities are much higher during that  
 782 period.

783 IAQ measurements and monitoring shall be carried out either following Path A or Path B:

784

785

786 6.3.3.3. Path A:  
 787 Measurement of all basic IAQ parameters two times in each season, three times a day, example  
 788 morning 9-11 am, early afternoon 12-2 pm, late afternoon 3-5 pm, 18 results per year, all  
 789 complementary IAQ parameters twice a year three times a day, 6 results per year and  
 790 formaldehyde & microbial count measurements twice a year once a day, 2 results per year, all as  
 791 a short term measurement example 3-15 min average value. The methodology for measurements  
 792 at selected location shall be as defined below are as defined in Table 10.  
 793

794 6.3.3.4. Path B:  
 795 Continuous monitoring of basic IAQ parameters (CO in case of combustion) with results recorded  
 796 at least once an hour round the year, 8760 results per year), measurement of all basic IAQ  
 797 parameters once a year (to validate the continuous monitoring sensors), all complementary IAQ  
 798 parameters (and CO if not continuously monitored) twice a year three times a day (6 results per  
 799 year), and formaldehyde & microbial count measurements once a day (2 results per day), all as a  
 800 short term measurement.  
 801  
 802

**Table 10 Measurement location and conditions for indoor air quality parameters**

Parameter	Measurement Methodology (Path A)	Measurement Methodology (Path B)
CO <sub>2</sub> *	<p>a. Shall be measured when there is minimum 90% of occupants present.</p> <p>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.</p> <p>c. For A Class - Measurement twice in each season, three times a day (e.g. morning 9-11 am, early afternoon 12-2 pm, late afternoon 3-5 pm) (18 results per year)            For B &amp; C Class - measured twice a year three times a day (6 results per year), all as short term measurements</p>	<p>a. Continuous monitoring with results recorded at least once an hour round the year (8760 results per year)</p> <p>b. At least one continuous monitoring location per floor or in one location for each set of rooms with the same activity</p> <p>c. Lab Measurement once a year (to validate the continuous monitoring sensors)</p> <p>d. Historical data should be available for at least previous 3 months **            (recommended to keep data for continuous improvement)</p>
CO	<p>a. Shall be measured at the outdoor 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.</p>	<p>a. Continuous monitoring with results recorded at least once an hour round the year (8760 results per year) ONLY if combustion activity present in building</p>

	<p>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.</p> <p>c. For buildings with combustion devices, the measurement shall also be carried out in each space with combustion equipment while combustion device is in use.</p> <p>D. For A Class - Measurement twice in each season, three times a day (e.g. morning 9-11 am, early afternoon 12-2 pm, late afternoon 3-5 pm) (18 results per year) For B &amp; C Class - measured twice a year three times a day (6 results per year), all as short term measurements</p>	<p>b. At least one continuous monitoring location per floor or in one location for each set of rooms with the same activity <b>ONLY</b> if combustion activity present in building</p> <p>c. Lab Measurement once a year (to validate the continuous monitoring sensors) if required</p> <p>d. For underground car parking in the building, the continuous monitoring shall be done in occupied space at the floor level near the doorways leading to the car parking space</p>
<p>PM 2.5*</p>	<p>a. Shall be measured at least in three locations that are served with a same outdoor air intake unit / method <b>as well as in the spaces with combustion devices.</b></p> <p>B. For A Class - Measurement twice in each season, three times a day (e.g. morning 9-11 am, early afternoon 12-2 pm, late afternoon 3-5 pm) (18 results per year) For B &amp; C Class - measured twice a year three times a day (6 results per year), all as short term measurements</p>	<p>a. Continuous monitoring with results recorded at least once an hour round the year (8760 results per year)</p> <p>b. At least one continuous monitoring location per floor or in one location for each set of rooms with the same activity</p> <p>c. Lab Measurement once a year (to validate the continuous monitoring sensors)</p> <p>d. Historical data should be available for at least previous 3 months ** (recommended to keep data for continuous improvement)</p>

PM 10*	<p>a. Shall be measured at least three locations that are served with a same outdoor air intake unit / method <b>as well as in the spaces with combustion devices.</b></p> <p>B. To be measured twice a year three times a day (6 results per year), all as short term measurements</p>	<p>a. Continuous monitoring with results recorded at least once an hour round the year (8760 results per year)</p> <p>b. At least one continuous monitoring location per floor or in one location for each set of rooms with the same activity</p> <p>c. Lab Measurement once a year (to validate the continuous monitoring sensors)</p> <p>d. Historical data should be available for at least previous 3 months (recommended to keep data for continuous improvement)</p> <p>OR</p> <p>Same as Path A</p>
CH <sub>2</sub> O**	<p>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.</p> <p>B. measurements twice a year once a day (2 results per year), all as a short term measurement.</p>	Same as Path A
SO <sub>2</sub>	<p>a. Shall be measured at the outdoor air intake in to the building (AHU air intake or air vent or open window).</p> <p>b. In case values of SO<sub>2</sub> concentration are higher than the specified threshold value as given in section 6.3.2 at air intake, additional measurements need to be taken inside the space.</p>	Same as Path A
NO <sub>2</sub>	<p>a. Shall be measured at the outdoor air intake in to the building (AHU air intake or air vent or open window).</p> <p>b. In case values of NO<sub>2</sub> concentration are higher than the specified threshold value as given in section 6.3.2 at intake, additional measurements need to be taken inside the space.</p>	Same as Path A
O <sub>3</sub>	<p>a. Shall be measured at the outdoor air intake in to the building (AHU air intake or air vent or open window).</p>	Same as Path A

	<p>b. Shall be measured in the indoor spaces that have sources of internal generation of ozone.</p> <p>c. In case values of O<sub>3</sub> concentration are higher than the specified threshold value as given in section 6.3.2 at air intake, additional measurements need to be taken inside the space.</p>	
TVOC	<p>a. Shall be measured at least in 2 locations per floor and wing or in one location for each set of rooms with the similar activity, one measurement in the perimeter zone (within 1.5 m from the façade and one in the centre of the space..</p> <p>b. In case the values of TVOC are higher than the specified threshold value as given in section 6.3.2, at least the individual VOCs listed in appendix X recommended to be analysed and the threshold values given in Appendix X.</p>	<p>a. Continuous monitoring with results recorded at least once an hour round the year (8760 results per year)</p> <p>b. At least one continuous monitoring location per floor or in one location for each set of rooms with the same activity</p> <p>c. Lab Measurement once a year (to validate the continuous monitoring sensors)</p> <p>d. Historical data should be available for at least previous 3 months (recommended to keep data for continuous improvement)</p> <p>OR</p> <p>Same as Path A</p>
Total Microbial Count <sup>#</sup>	<p>a. Shall be measured in spaces where there are visible signs of moisture damage or where there is a high risk of water leakage.</p> <p>B. measurements twice a year once a day (2 results per year), all as a short term measurement.</p>	<p>Same as Path A</p>

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\* Reference value shall be measured near the air intake in to the building (AHU air intake or air vent or open window) for comparison and to find source of contaminate. This shall be done simultaneously (within 2 hours) 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.

815 6.3.3.5. Test method and measurement:  
 816 The testing for various IAQ elements shall be done as per the reference standard specified below. The  
 817 measurement equipment, accuracy, uncertainty of measurement shall conform to requirement as specified  
 818 in the standards below.

819 Table 11a: IAQ Parameter Test method and measurement equipment – for Path A measurement

IAQ element	Test method
CO <sub>2</sub>	ISO 16000-26 Sampling strategy for Carbon dioxide (CO <sub>2</sub> ); <i>Note: Except for the screening measurement using sampling tubes, the CO<sub>2</sub> concentration is recorded continuously using an automatic instrument.</i>
CO	Annex C of ISO 16000-26 Sampling strategy for Carbon dioxide (CO <sub>2</sub> ); <i>Note: Except for the screening measurement using sampling tubes, the CO<sub>2</sub> concentration is recorded continuously using an automatic instrument.</i>
NO <sub>2</sub>	ISO 16000-15 Sampling strategy for Nitrogen dioxide (NO <sub>2</sub> );
Formaldehyde	ISO 16000-3: Determination of formaldehyde and other carbonyl compounds in indoor air and test chamber air – Active sampling method or ISO 16000 – 4: Determination of formaldehyde – Diffusive sampling method
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
O <sub>3</sub>	ISO 13964 : Determination of Ozone in ambient air – Ultraviolet photometric method
PM 10 and PM 2.5	ISO 16000-34: Strategies for the measurement of airborne particles

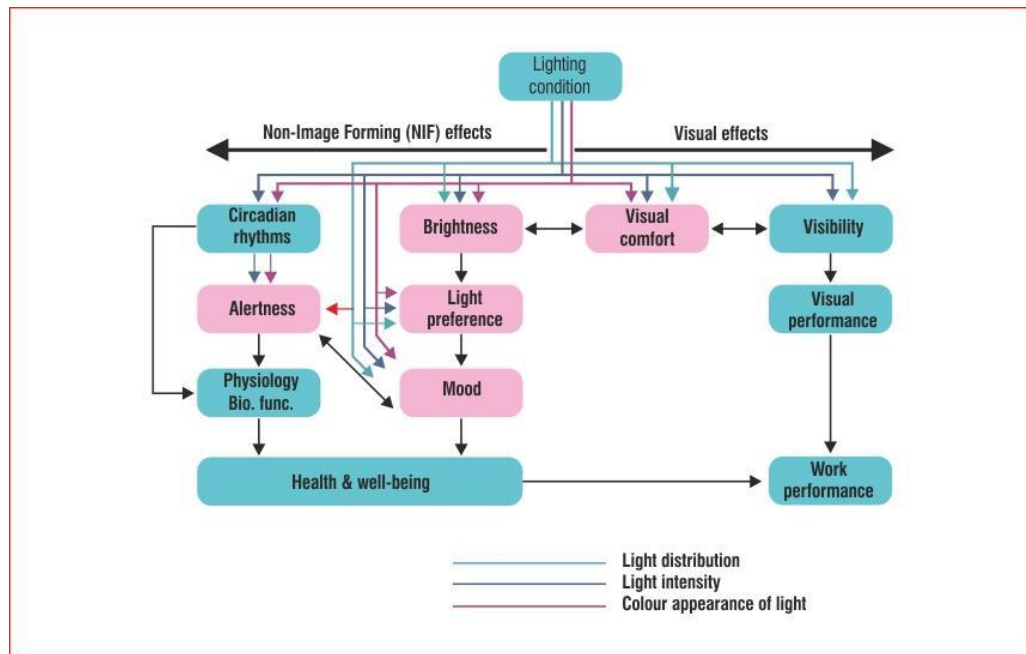
PARAMETER	SENSOR QUALITY SPECIFICATIONS FOR PATH B
CO <sub>2</sub>	Data Output Interval - 10 Minutes for each reading max Operating Temp Range: 0-40 degrees C Operating Range of RH - 10-85% (non condensing) Measurement Range : 400ppm - 5000ppm Resolution : 5 ppm maximum Accuracy: 400 - 2000ppm : ±5% 2000 - 5000ppm : ±5% Lower Detection Limit - 400ppm Recalibration capability – Required
CO	Data Output Interval - 1 Minutes for each reading max Operating Temp Range: 0-40 degrees C Operating Range of RH : 10-85% (non condensing) Measurement Range from : 0ppm till 1,500ppm Resolution: 1 ppm maximum Accuracy: 2% of reading Lower Detection Limit - 0ppm Recalibration capability – Required

PM2.5	<p>Data Output Interval - 10 Minutes for each reading max          Operating Temp Range: 0-40 degrees C          Operating Range of RH - 10-85% (non condensing)          Measurement Range: 0 ug/m<sup>3</sup> to 500 ug/m<sup>3</sup>          Resolution : 1 ug/m<sup>3</sup>          Accuracy: 0 - 150 ug/m<sup>3</sup> : ±5ug/m<sup>3</sup>          150 - 500 : ±5ug/m<sup>3</sup>          Lower Detection Limit - 0 ug/m<sup>3</sup>          Recalibration capability – Required</p>
TVOC	<p>Data Output Interval - 10 Minutes for each reading max          Operating Temp Range: 0-40 degrees C          Operating Range of RH - 10-85% (non condensing)          Installation - should have ability to install permanent          Measurement Range: 150 ug/m<sup>3</sup> to 2000 ug/m<sup>3</sup>          Resolution of 10 ug/m<sup>3</sup>          Accuracy: 150 - 600 ug/m<sup>3</sup> : ±20ug/m<sup>3</sup>          600 - 2000 : ±20ug/m<sup>3</sup>          Lower Detection Limit - 150 ug/m<sup>3</sup>          Recalibration capability – Required</p>

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834 6.4. Visual comfort  
835 6.4.1.General

836 Light has significant impact on many bodily functions, including the nervous system, circadian rhythms,  
837 pituitary gland, endocrine system, pineal gland and alertness as these are affected by different wavelengths  
838 of light.  
839



840  
841 **Figure 3 Effects of lighting condition**

842 Variations over time in lighting conditions, in terms of intensity, illumination levels, distribution, ambient  
843 lighting and colour temperature, can stimulate alertness and well-being of people as shown in Figure 3.

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

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854 **6.4.2. Threshold values for visual comfort parameters**

855 The threshold values of parameters affecting visual comfort are defined in Table 12. Threshold illuminance  
 856 level depending upon type of space is defined in Table 13.

857 **Table 12 Threshold values of parameters for lighting comfort**

Parameters	Units	Type of Space	Classification		
			Class A	Class B	Class C
Illuminance	Illuminance should be as per the value/ range defined in NLC 2010 at the task				
Circadian Lighting Design (for workspaces)	Equivalent Melanopic Lux (EML)		At least 240 EML in regularly occupied spaces, through electric light only.	At least 150 EML in regularly occupied spaces, through electric light only.	
Uniformity of illuminance at Task area			0.7	0.7	0.7
Uniformity of illuminance at Immediate surrounding area			0.5	0.5	0.5
Illuminance of the immediate surrounding areas			As per the above table given in NLC 2010		
Percentage of the workstations meeting the required illuminance at task plane	%		100	90	90
Occupant Satisfaction	%		90	80	-
Controllability of lighting environment			Yes	Yes	No

858  
 859  
 860  
 861

**Table 13 Threshold Illuminance level depending upon type of space**

<b>Building</b>	<b>Type of space</b>	<b>Illuminance (Lux)</b>
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

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873 Table 14: Instrumentation Specifications

Equipment Type	Purpose	Measurement Uncertainty and Range	Meter Characteristics
Illuminance Meter	Establish functional performance of baseline and new lighting equipment	Uncertainty: 3% Range: ≤0.1 fc (0.01 lux) to ≥10,000 fc (100,000 lux)	<3% deviation from cosine function for reported single value or ≤10% at incidence angle of 60° for multiple angle reported values. Spectral response within 10% of the CIE spectral luminous efficiency function

874

875

876 **6.4.3. Measurement methodology - Illuminance grid**

877 Grid systems shall be created to indicate the points at which the illuminance values are calculated and  
878 verified for the task area(s), immediate surrounding area(s) and background area(s).

879 Grid cells approximating to a square are preferred, the ratio of length to width of a grid cell shall be kept  
880 between 0,5 and 2. The maximum grid size shall be:

881 
$$p = 0,2 \cdot 5 \log_{10}(d) \quad (1)$$

882 where

883 
$$p \leq 10 \text{ m}$$

884  $d$  is the longer dimension of the calculation area (m), however if the ratio of the longer to the shorter  
885 side is 2 or more then  $d$  becomes the shorter dimension of the area, and  $p$  is the maximum grid cell size  
886 (m).

887 The number of points in the relevant dimension is given by the nearest whole number of  $d/p$ .

888 The resulting spacing between the grid points is used to calculate the nearest whole number of grid points  
889 in the other dimension. This will give a ratio of length to width of a grid cell close to 1.

890 A band of 0.5 m from the walls is excluded from the calculation area except when a task area is in or  
891 extends into this border area.

892 An appropriate grid size shall be applied to walls and ceiling and a band of 0,5 m may be applied also.

893 NOTE 1 :The grid point spacing should not coincide with the luminaire spacing.

894 NOTE 2 : Formula (1) (coming from CIE x005-1992) has been derived under the assumption that  $p$  is  
895 proportional to  $\log(d)$ , where:

896  $p = 0,2 \text{ m}$  for  $d = 1 \text{ m}$ ;

897  $p = 1 \text{ m}$  for  $d = 10 \text{ m}$ ;

898  $p = 5 \text{ m}$  for  $d = 100 \text{ m}$ .

899

900 **Values of grid point spacing**

901 Typical values of grid point spacing are given in Table based on Formula above.

902 Table XX — Recommended number of grid points

903

Length of the area	Maximum distance between grid points	Minimum number of grid points
m	M	
0.40	0.15	3
0.60	0.20	3
1.00	0.20	5
2.00	0.30	6
5.00	0.60	8
10.00	1.00	10
25.00	2.00	12
50.00	3.00	17
100.00	5.00	20

904

905 **Measure and Record Illuminance**

906 • Schedule and take all measurements to minimize the effects of other light sources and location  
 907 conditions on the results.

908

909 • Schedule measurements for both baseline and post-installation when there is no daylight in the space.  
 910 This typically requires taking measurements after sunset. Adjacent electric lighting need not be blocked or  
 911 turned off as long as it is noted and remains the same for both the baseline and the post-installation  
 912 measurements.

913 • Ensure that potential temporary obstructions such as occupants, temporary materials, and furniture are  
 914 removed for both the baseline and the post-installation measurements.

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927 6.5. Acoustic comfort

928 6.5.1.General

929 Sound is a pressure fluctuation in the air. In general, the greater the amplitude of the pressure  
 930 fluctuation, the "louder" the sound will be perceived by people. Loudness is a subjective measure  
 931 of the amplitude that varies from one person to the next and will depend on many parameters,  
 932 some of which are nonphysical. Sound pressure level is this objective measure. The total ambient  
 933 sound that exists at a given point in space is usually due to a composite of many different sounds  
 934 with different strengths and frequency content. The composite sound may be a combination of  
 935 background noise and sound from a single identifiable source; it may be a combination from several  
 936 individual sources; and it may include reflections from room surfaces or reflecting objects. This  
 937 standard is primarily concerned with the measurement of the level of the composite sound at a  
 938 given point or in measuring changes in that level caused by a certain sound of interest. The  
 939 acoustical parameters such as Noise criteria, Reverberation time and Speech transmission index  
 940 are representative of acoustical comfort.

941

942 6.5.2.Threshold values for acoustical parameters

943 Threshold values for acoustical parameters for typical space are given in Table 13 . Additionally,  
 944 values for the acoustical parameter - Noise isolation (applicable for Class A) are given in Table 14.  
 945 The noise criterion (NC) values shall be arrived using NC curves as given in 6.3.3.

946

947

**Table 13 Requirements of Acoustic comfort**

No	Types of Buildings	Noise Criterion			Reverberation time			Speech Transmission Index		
		A	B	C	A	B	C	A	B	C
1	<b>Residences, Apartments, Condominiums</b>	30	35	40	<0.8s	NA	NA	*0.6	*0.5	*NA
								Applicable for Atriums & corridors		
2	<b>Hospitality</b>									
	Individual rooms or suites	30	35	40	<0.8s	<0.6s	<1.0	0.6	0.5	NA
	Meeting / banquet rooms	30	35	40	<0.5s			0.7	0.6	0.5
	Corridors, lobbies	40	45	45	NA			NA	NA	NA
	Service / Support areas	40	45	50	NA			0.5	NA	NA
	All day dining and restaurants	45	50	50	<1.2s	<1.5s	<1.75s	0.6	0.5	NA
3	<b>Office buildings</b>									
a.	Executive and private offices	30	35	40	<0.6s	<0.7s	<0.8s	0.6	0.5	NA
b.	Conference rooms	30	35	35	<0.6s			0.7	0.6	0.5

c.	Teleconference rooms	25 (max)			<0.6s			0.7	0.6	0.5
d.	Open – plan offices	35	40	40	<0.8s			0.6	0.5	NA
e.	Corridors and lobbies	40	45	45	NA			NA	NA	NA
f.	Collaborative space				<0.8s			0.5	NA	NA
g.	Cafeteria/Town Hall	40	45	45	<1.0s	<1.2s	<1.2s	0.6	0.5	NA
4	<b>Education</b>									
a.	Class rooms up to 70 m <sup>2</sup>	40 (max)						0.6	0.5	NA
b.	Class rooms over 70 m <sup>2</sup>	35 (max)			<0.6s	<0.8s	<1.0s	0.6	0.5	NA
c.	Large lecture rooms, without speech amplification	35 (max)						0.6	0.55	0.5
5	<b>Libraries</b>	35	40	40	<1.0s	<1.2s	<1.2s	0.6	0.5	NA
6	<b>Health care*</b>									
a.	Open Ward	35	35	45	<1.0s			0.7	0.6	0.5
b.	Individual rooms or suites	30	35	40	<0.8s			0.7	0.6	0.5
c.	Meeting rooms / Conference room	25	30	35	<0.6s	<0.8s	<1.0s	0.5	NA	NA
d.	Teleconferencing rooms	25	NA	NA	<0.6s			0.7	0.6	0.5
e.	Operating Rooms	35	40	45	<0.8s			0.6	0.5	NA
f.	Corridors, lobbies	35	45	45	<1.0s			NA	NA	NA
g.	Testing/research lab, minimal speech	45	50	55	<0.8s			0.5	NA	NA
h.	Research lab, extensive speech	40	45	50	<0.8s			0.7	0.6	0.5
i.	Auditoria, large lecture rooms	25	30	NA	< 0.8s			0.6	0.5	NA

948 Note 1: In this table are given the performance requirements in terms of recommended dBA noise level (ideal), the  
949 not to exceed noise level (max), and the maximum acceptable reverberation time (T60) for many spaces including  
950 offices.

951 *Note 2: For the Class A and Class B, a building should score 90% and 80% respectively on the occupant satisfaction*  
 952 *survey. There is no such requirement to achieve Class C.*  
 953 *Note 3: Any other type of space not mentioned in the Table 14 shall meet requirements of the nearest representative*  
 954 *category of that space.*  
 955 *Note 4: For more details on Reverberation Time, refer graph with respect to volume & application in annexure*  
 956 *Note 6 : \* values measured in unoccupied condition*

957 **Table 14 Threshold Noise Isolation Criteria level depending upon type of space**

Building	Type of space	Dw / NIC
Office	Between two offices	38dB
	Where privacy is important	48dB
	Cellular offices	40dB
Residential	Partitions separating a water closet (WC) from a noise sensitive room	38 dB
Hospitality	Partitions and floors between rooms and corridors	50 dB
Hospital or Health care*	Patient Room to Patient Room / Public Space	40 dB
	Patient Room to Service Area	50 dB
	Patient Room to Corridor (with entrance)	25 dB.
	Consultation Room to Public Space / Patient Rooms	40 dB.
	Consultation Room to Corridor (with entrance)	25 dB.

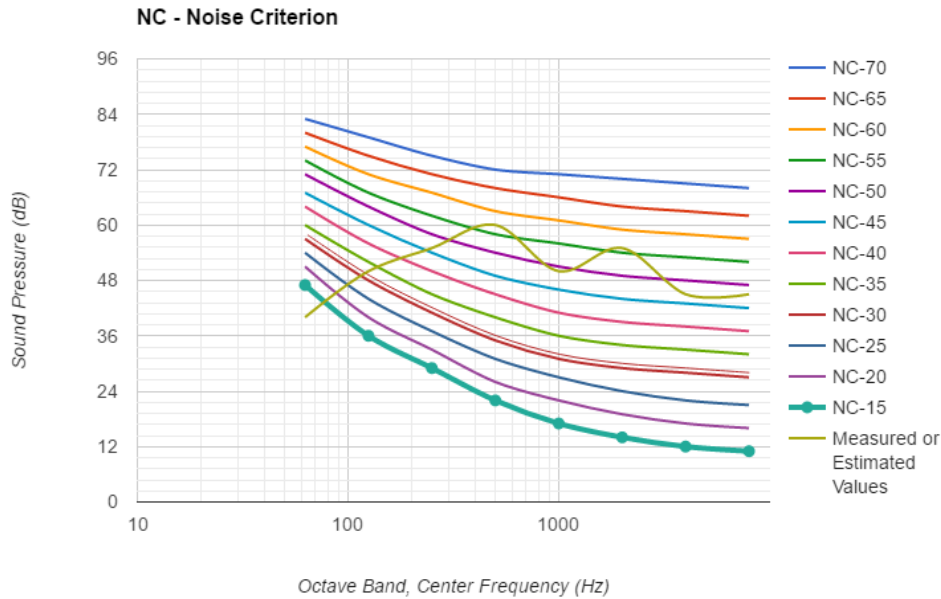
958 **Note:**  
 959 **Weighted Level Difference (Dw)** a single integer number found by comparing the measured spectrum with the  
 960 'standard' curves for airborne and impact insulation.  
 961 The Dw value is where the curve meets the 500 Hz curve and the unfavourable deviation is 32 dB. Dw will be identical  
 962 to  $D_{nT,W}$  when  $T = 0.5$  seconds.  
 963 **Noise Isolation Class NIC** a single number rating of the degree of speech privacy achieved through the use of an  
 964 acoustical ceiling and sound absorbing screens in an open office. NIC has been replaced by the articulation class rating  
 965 method.

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981 6.5.3. Estimating NC - Noise Criterion  
 982 For a measured noise spectrum as below:  
 983

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

984  
 985 Plot the measured values on the NC Curve. The NC curve tangent to the value at 1000 Hz is NC – 57 as  
 986 depicted in the graph below. Hence, the NC value = 57dB  
 987  
 988



989  
 990  
 991 6.5.4. The procedure for testing RT 60

- 992 1. The sound source (Speaker) to be placed at 1.2m above the floor level and the pink noise of about  
 993 90dB was generated which was provided with the analyser (sound level meter).
- 994 2. The analyzer is calibrated by using 1000Hz calibrator before starting the measurement in order to  
 995 eliminate minor errors due to instrumentation.
- 996 3. The analyser to be placed at the height of 1.2m from the floor level with face of the mic head  
 997 perpendicular to the sound source face for grazing incidence. The loudspeaker and  
 998 microphone/analyser are all in the same line.
- 999 4. The files of each measurement shall be stored and recorded.
- 1000 5. The recorded files shall be processed to give a final report of measurement.

1001 Note: For the small rooms the ideal point to measure the Reverberation Time (RT) is at the center of the  
 1002 room/area.

- 1011 6.5.5. The procedure for testing the Impact sound isolation  $L'_{nT,w}$   
1012 The measurement shall be done as defined in ISO 140-7:  
1013 a. The equipment shall comply with as defined in ISO 140 - 7.  
1014 b. The standard tapping machine shall be mounted on a horizontal platform with legs in line  
1015 with the floor.  
1016 c. The test procedure and evaluation shall be in accordance with Clause 5 of ISO 140 - 7  
1017 d. A standardized impact sound generator shall be used, consisting hammers of standardized  
1018 weight that drop from a standard height at a standard repetition rate.  
1019 e. The vibration from the tapping machine is transmitted through the building structure into  
1020 the air in the receiving room. This sound level ( $L_2$ ) is measured and compared to building  
1021 regulation after correction for reverberation time ( $T_2$ ) and possible influence of background  
1022 noise ( $B_2$ ).  
1023 f. The tapping machine shall have 5 hammers each weighing 500 g and dropping from a  
1024 height of 40 mm every two seconds, giving an operating frequency of 10 Hz.  
1025 g. The tapping machine should be placed minimum at 1 meter away from the perimeter of the  
1026 specimen to be tested.  
1027 h. The results shall be presented in accordance with ISO 140 - 7.  
1028 i. The impact sound levels measured in the receiving room must be normalised using a  
1029 reference equivalent absorption area ( $A$ ) of 10 m<sup>2</sup>.  
1030 j. A single figure rating ( $L'_{nT,w}$ ) shall be calculated in accordance with ISO 717-24 .  
1031  
1032

1033 6.5.6. Procedure for testing the Speech Transmission Index

- 1034 a. The test shall use the speakers existing in the room and the Speech Transmission Index  
1035 Public Address system (STIPA) of about 100dB generated and is provided with the sound  
1036 level meter.  
1037 b. The analyser to be placed at the height of 1.2m from the floor level with face of the  
1038 microphone head perpendicular to the sound source face for grazing incidence. The  
1039 loudspeaker and microphone shall have to be placed on same line.  
1040 c. The testing shall be carried out at different places in the hall.  
1041

1042 *Note: The Sound level meter is calibrated by using 1000Hz calibrator before starting the measurement in*  
1043 *order to eliminate minor errors due to instrumentation.*  
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1060 7. Occupant satisfaction survey  
1061 7.1. General

1062 Subjective methods quantify the responses of occupants to an environment using subjective scales. Such  
1063 scales are based upon psychological continua (or constructs) that are relevant to the psychological  
1064 phenomenon of interest. It is important to know the properties of the scales in order to correctly interpret  
1065 the results. Scales of sensation (e.g. hot or cold), preference, comfort, annoyance, smell and stuffiness are  
1066 often used in occupant comfort assessment.

1067 Advantages of subjective methods are that they are simple to administer and are directly related to the  
1068 psychological phenomenon. Many aspects of occupant comfort, which are difficult to quantify or cannot be  
1069 directly measured such as glare, smell, but are very important for evaluating occupant comfort, can be  
1070 covered through such surveys.

1071 The following are the minimum questions required for gaining feedback for the long term satisfaction of  
1072 occupants for thermal comfort, indoor air quality, lighting comfort and acoustic comfort in the building.

1073 7.2. Survey Questions

1074 1. Personal details :

1075 a. Please specify your gender

1076 Male / Female

1077 b. Please specify your weight (kg)

1078 40 – 50; 51 – 60; 61-70; 71 – 80; 81 and above

1079 c. Please specify your age

1080 21 – 25; 25 – 30; 31 – 35; 36 – 40; 41 – 45; 45 – 50; 51 – 60; 61 and above

1081 d. Please specify your height

1082 Below 150 cm; 151 cm – 160 cm; 162 cm – 170 cm; 171 cm and above

1083 e. Please specify your residing years in present city: 1 year / 2 years / 3 years / >3 years

1084 8. Please rate your satisfaction with temperature conditions of your normal work area.

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1085 Unsatisfactory

Satisfactory

1086 9. Please rate your satisfaction with local thermal discomfort conditions of your normal work area  
1087 (e.g. vertical air temperature difference between feet and head, local convective cooling, hot or cold floor).

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1088 Unsatisfactory

Satisfactory

1089 10. Please rate your satisfaction with the air movement available to you in your normal work area.

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1090 Unsatisfactory

Satisfactory

1091 11. Please rate your satisfaction with the overall humidity in your normal work area.

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1092 Unsatisfactory

Satisfactory

1093 12. Please rate your satisfaction with the overall air quality in your normal work area (e.g. stuffiness,  
1094 staleness).

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1095 Unsatisfactory Satisfactory

1096 13. Odours in your normal work area.

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1097 Unsatisfactory Satisfactory

1098

1099 14. Please rate your satisfaction with fresh air in your normal work area.

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1100 Unsatisfactory Satisfactory

1101

1102 15. Your work area's layout enables you to work without unwanted noise interruptions.

1	2	3	4	5	6	7
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1103 Disagree Agree

1104

1105 16. Your normal work area provides adequate sound privacy (not being overheard by others).

1	2	3	4	5	6	7
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1106 Disagree Agree

1107 17. Please rate your satisfaction with the overall noise in your normal work area.

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1108 Unsatisfactory Satisfactory

1109 18. Please rate your satisfaction with regard to acoustical privacy in enclosed rooms

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1110 Unsatisfactory Satisfactory

1111 18. Please rate your satisfaction with overall noise level in common areas like cafeteria, breakout area,  
1112 etc

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1113 Unsatisfactory Satisfactory

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1116 19. Please rate your satisfaction with regard noise from machineries (AHU,HVAC ducts, AC units,  
1117 chillers, DG, Servers..etc)

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1118 Unsatisfactory Satisfactory

1119 20. Please rate your satisfaction with the lighting level on workplane/ table top.

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1120 Unsatisfactory Satisfactory

1121 21. Do the lighting fixtures cause direct or indirect (reflections in computer screen) glare at your  
1122 workstation? Please rate your experience

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1123 High Glare (Irritating) No glare (very comfortable)

1124 22. Within your field of view do you see lot of contrast difference (bright and dark surfaces).

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1125 Yes (lot of bright and dark patches) No (well balanced brightness of  
1126 surfaces)

1127 20. Please rate your satisfaction with the lighting comfort of your normal work area (e.g. amount of  
1128 light, glare, reflections, contrast).

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1129 Unsatisfactory Satisfactory

1130 21. Please rate your satisfaction with the external view from your normal work area.

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1131 Unsatisfactory Satisfactory

1132 22. Please rate your satisfaction with lighting controls in your normal work area (provisions of controls  
1133 for blinds on windows or provision of dimming or controlling lighting equipment in the room)

1	2	3	4	5	6	7
---	---	---	---	---	---	---

1134 Unsatisfactory Satisfactory

1135  
1136 23. Please rate your satisfaction with the access to daylight from your normal work area.

1	2	3	4	5	6	7
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1137 Unsatisfactory Satisfactory

1138

- 1139 8. Documentation methodology
- 1140
- 1141 8.1. Report format

1142 Table 15 - The measurement report shall contain following information:

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

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8.2. Format for reporting measured values of different parameters  
Table 16: IEQ Reporting format

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

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1155 8.3. Format for reporting results of satisfaction survey

1156 Occupant satisfaction survey presented in section 7.2, questions from 8 to 11, 10to 13, 14 to 16,  
1157 17 to 23 are to evaluate satisfaction level corresponding to thermal comfort, indoor air quality,  
1158 lighting comfort and acoustic comfort respectively.

1159 Care should be taken to avoid administering occupant satisfaction survey on a potentially biased  
1160 subject who is not a regular occupant of the building, or have been under some medical treatment  
1161 or any other similar reason. The survey must be administered to all occupants in a building and  
1162 the response rate should be 40% of occupants surveyed. The survey designed to gain long term  
1163 feedback should be administered before physical measurements are undertaken, and no changes  
1164 should be made to the normal operation of the building between survey administration and  
1165 physical measurement.

1166 Questions are administered on a seven point scale where 1 is the worst and 7 is the best score.  
1167 In each case the % of satisfied occupants is denoted as all those rating 4, 5, 6 and 7 on this  
1168 scale. Where, there is more than one question under each category, the average satisfaction  
1169 across all the constituent questions is to be considered.

1170 For every element 90% and 80% satisfaction level should be met for building being classified as  
1171 Class A and Class B respectively. Occupant satisfaction survey is not applicable to Class C  
1172 building except when assessing humidity.

1173 Format for reporting results of satisfaction survey shall be following:

1174 Table 17: Occupant satisfaction survey report format

Elements	Occupant satisfaction (%)	Classification (Class A / Class B/ Class C)	Remarks
Thermal comfort			
Indoor air quality			
Lighting comfort			
Acoustic comfort			

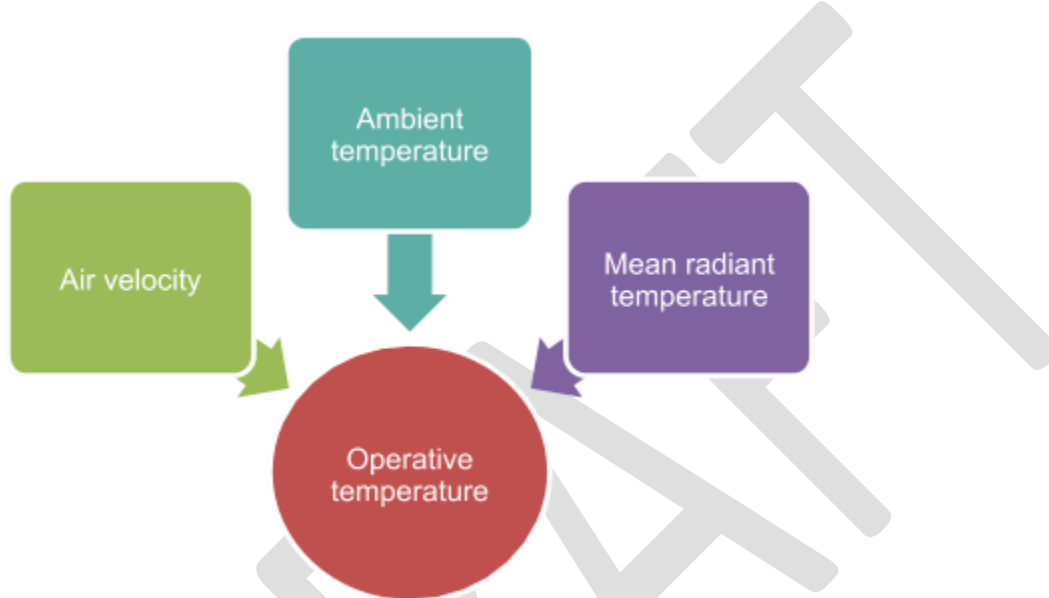
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Annexure A  
**Thermal comfort**

1191 **A1. Calculation of Operative Temperature (to)**

1192 Operative temperature can be defined as uniform temperature of a radiantly black enclosure in which an  
1193 occupant would exchange the same amount of heat by radiation plus convection as in the actual non-  
1194 uniform environment. It is the combined effect of the mean radiant temperature, air temperature and velocity  
1195 as shown in Figure 8. It is also known as dry resultant temperature or resultant temperature.



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1198

**Figure A1 Parameters influencing operative temperature**

1199 **A1. Factors leading to local thermal discomfort**

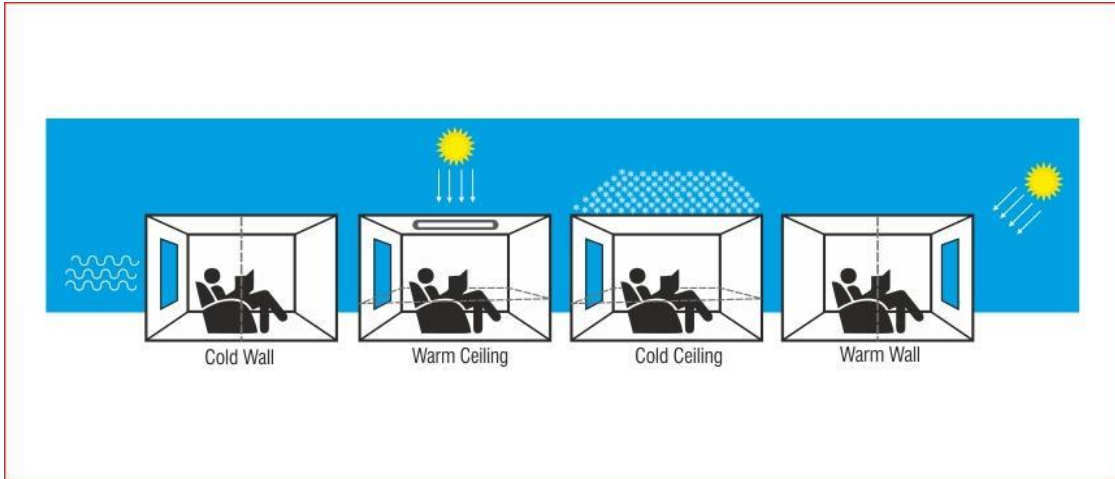
1200 **A1.1 Radiant Temperature Asymmetry**

1201

1202 The thermal radiation field about the body may be non-uniform due to hot and cold surfaces and direct  
1203 sunlight. This asymmetry may cause local discomfort and reduce the thermal acceptability of the space. In  
1204 general, people are more sensitive to asymmetric radiation caused by a warm ceiling than that caused by  
1205 hot and cold vertical surfaces.

1206 Radiant temperature asymmetry may occur in an enclosed space because of cold and warm walls as well  
1207 as warm and cold ceiling. People are more sensitive to warm ceiling than other three.

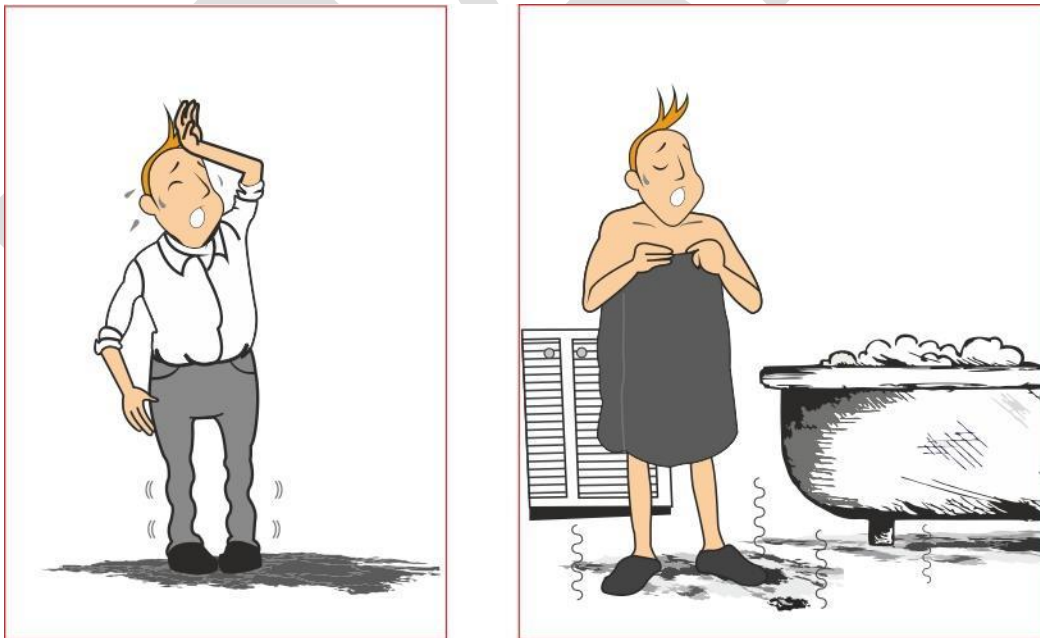
1208



1209  
 1210 **Figure A2 Radiant Temperature Symmetry caused by a cold wall, a warm ceiling, a cold ceiling, or**  
 1211 **a warm wall**  
 1212

1213 **A1.2 Vertical Air Temperature Difference and floor surface temperature**

1214 As demonstrated in Figure A3, an individual may feel local discomfort when temperature difference between  
 1215 warm head and cold feet increases beyond defined limit in Table 2. Occupants may also feel discomfort in  
 1216 the enclosed spaces where floor is colder or warmer than defined limit. It is applicable only when a person  
 1217 is wearing light indoor shoes  
 1218

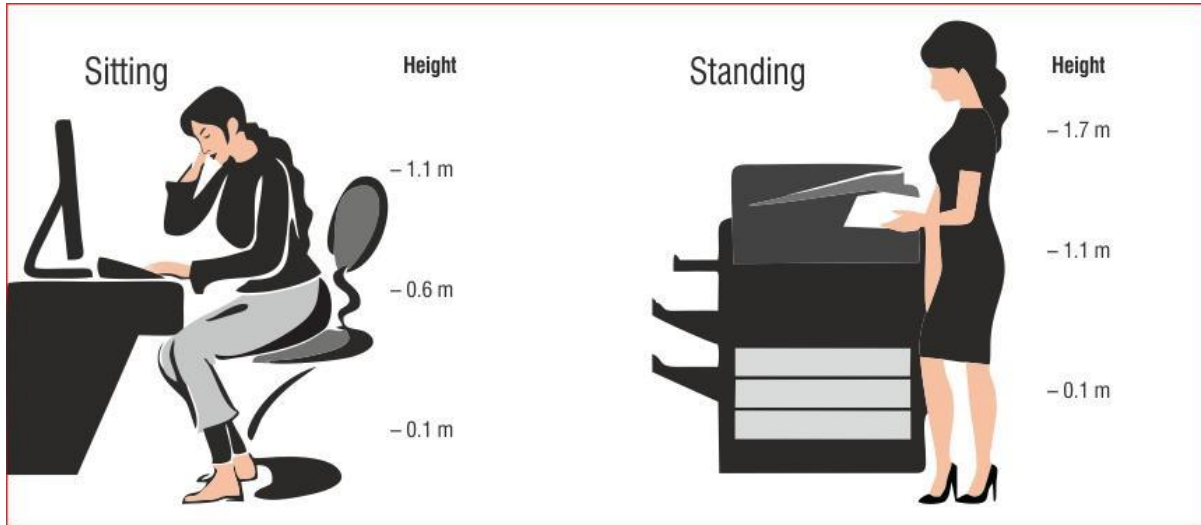


1219  
 1220 **Figure A3 Local thermal discomfort caused by vertical air temperature difference (left) and floor**  
 1221 **surface temperature (right)**  
 1222

1223  
 1224

1225 **A1.3 Measurement Sensor location for thermal comfort**

1226 For the measurement of thermal comfort for sitting position and standing position of the occupant, the  
1227 measurement probes shall be located as shown in Figure A4.  
1228



1229  
1230 **Figure A4 Position of the probes at different height according to standing and sitting position**

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1240 **Annexure B**  
1241 **Indoor air quality**

1242 **B.1 Definition of Indoor Air Pollutants**

1243 **B1.1 Carbon dioxide (CO<sub>2</sub>)**

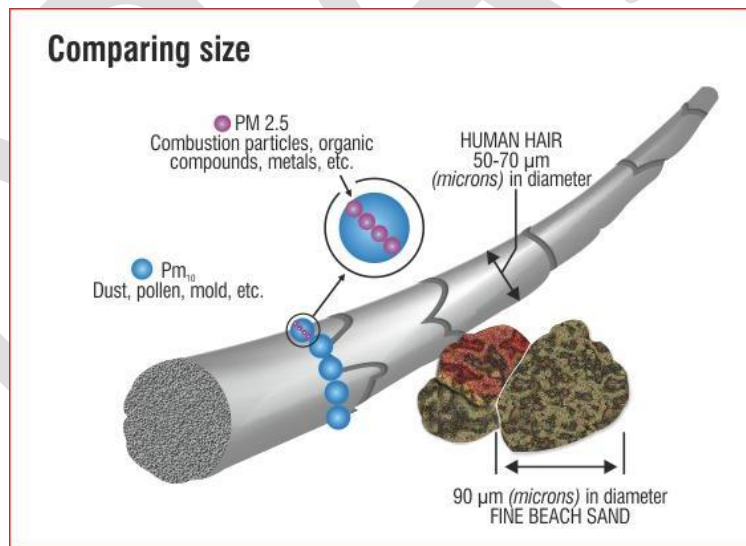
1244 Carbon dioxide (CO<sub>2</sub>) is a colourless, odourless gas vital to life on Earth. Carbon dioxide exists in the Earth's  
1245 atmosphere as a trace gas at a concentration of about 0.045 percent (450 ppm) by volume.  
1246

1247 Main source of CO<sub>2</sub> in buildings is people. CO<sub>2</sub> in indoor air is not itself a pollutant or a health risk in typical  
1248 indoor concentrations. However, high levels of CO<sub>2</sub> reduce human comfort and productivity significantly.  
1249 CO<sub>2</sub> level, that is relatively easy to measure and is used as a general indicator of ventilation system  
1250 efficiency.

1251 **B1.2 Respirable Suspended Particulate Matter (RSPM)**

1252 Respirable Suspended Particulate Matter (RSPM) refers to those dust particles that are small enough (less  
1253 than 10 µm) to penetrate the nose and upper respiratory system and deep into the lungs. Smaller the  
1254 particulate size is, higher is the health risk as the smaller particulates penetrates deeper into alveoli.

1255 Respirable Suspended Particulate Matter (RSPM) is one of the main ambient air pollutants in India. Main  
1256 sources of particulate matter are vehicle emissions, household cooking (especially cooking with biomass  
1257 and frying), thermal power plants, biomass burning, construction work, unattended debris, fossil fuel (such  
1258 as diesel) based power generation and various industrial processes. CO<sub>2</sub> shall also be measured at ambient  
1259 to find threshold values as specified in the standard.



1260  
1261  
1262 **Figure B1 Comparison of PM size with human hair diameter and beach sand particle size**

1266 **B1.3 Carbon Monoxide (CO)**

1267 Carbon monoxide (CO) is a colourless, odourless and tasteless gas that is slightly less dense than air.  
 1268 Main source of CO are vehicles (combustion engines), fuel-burning appliances (e.g. furnaces, chullahs,  
 1269 gas stoves, cooking ranges, fossil fuel based water heaters, gas and kerosene room heaters), diesel  
 1270 generators, fireplaces and charcoal that is burned in enclosed areas.  
 1271 CO is toxic to humans when encountered in concentrations above about 35 ppm. It is a serious health risk  
 1272 and may cause an immediate death.

1273 **B1.4 Total Volatile Organic Compounds (TVOC)**

1274 Sum of the concentrations of identified and unidentified volatile organic compounds eluting between and  
 1275 including n-hexane and n-hexadecane.

1276 The main sources of TVOC in buildings are furniture, construction materials, paints and cleaning products.  
 1277 Sometimes human activities and office equipment also increases the VOC level.

1278 The prevalent TVOCs in indoor air are typically Formaldehyde, Benzene, Toluene, Ethylbenzene, O-  
 1279 xylene, Dodecane, Limonene, and Halogenated hydrocarbons. However, there are hundreds of other VOC  
 1280 that may reduce the indoor air quality. In case, TVOC level is high, more detailed analysis are required to  
 1281 find out which specific TVOC concentrations are high.

1282 **B1.5 Formaldehyde (CH<sub>2</sub>O)**

1283 Formaldehyde (CH<sub>2</sub>O) is a colourless gas with a pungent odour and is highly reactive. Formaldehyde occurs  
 1284 in indoor air often due to the use of certain wood-based construction boards and furnishing. Increased  
 1285 concentrations may also be caused by other products, like certain disinfectants, cleaning agents, adhesives  
 1286 and paints. Table 13 provides overview of the most important formaldehyde sources in the indoor  
 1287 environment.

1288 Inhalation exposure to Formaldehyde in humans can result in respiratory symptoms as well as eye, nose,  
 1289 and throat irritation.

1290 In high humidity and temperature, Formaldehyde emission increases considerably. Therefore, the relative  
 1291 humidity and air temperature needs to be measured simultaneously.

1292  
 1293 **Table B1 Sources of Formaldehyde in indoor environment**

1294 The following standards need to be followed when measuring CH<sub>2</sub>O: ISO 16000 – 2, 3 and 4, as appropriate.

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 <sup>a</sup>	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
<sup>a</sup> Might be important with heavy traffic	

1295 **B1.6 Ozone (O<sub>3</sub>)**  
1296 A triatomic compound, very reactive form of oxygen that is bluish irritating gas of pungent odour. It is a  
1297 major air pollutant in the lower atmosphere but a beneficial component of the upper atmosphere, and used  
1298 for oxidising, bleaching, disinfecting, and deodorising.

1299  
1300 Ambient ground level Ozone (O<sub>3</sub>) is not emitted directly into the air, but is created by chemical reactions  
1301 between oxides of nitrogen (NO<sub>x</sub>) and volatile organic compounds (VOC) in the presence of sunlight. Inside  
1302 the building some equipment like copiers and printing machines, some room air purification technologies  
1303 (e.g. ionization, some UV-lights and ozonisers) produce Ozone. Ozone levels are typically highest on hot,  
1304 sunny days.

1305 Even relatively low levels of Ozone can cause health effects. Breathing Ozone can trigger a variety of health  
1306 problems including chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis,  
1307 emphysema, and asthma. Ground level ozone also can reduce lung function and inflame the linings of the  
1308 lungs. Repeated exposure may permanently scar lung tissue.

1309  
1310 Ozone shall also be measured in spaces that have equipment producing ozone. Best time for Ozone  
1311 measurement is during summer (sunny and warm days).The Ozone shall be measured as per IS 5182 –  
1312 Part 9.

1313 **B1.7 Sulphur dioxide (SO<sub>2</sub>)**

1314 Sulphur dioxide (SO<sub>2</sub>) is a highly reactive and toxic gas with a pungent, irritating and rotten smell. The  
1315 largest sources of SO<sub>2</sub> emissions are from fossil fuel combustion at power plants and other industrial  
1316 facilities. Other sources include industrial processes such as extracting metal from ore, and the burning of  
1317 high sulphur containing fuels by locomotives, large ships, and non-road equipment. SO<sub>2</sub> can react with other  
1318 compounds in the atmosphere to form small particulates.

1319 Short term exposures to SO<sub>2</sub> (up to 24 hours) can cause adverse respiratory effects including bronchiolitis  
1320 and increased asthma symptoms. Particulates carrying SO<sub>2</sub> penetrate deeply into sensitive parts of the  
1321 lungs and can cause or worsen respiratory disease, aggravate existing heart disease and may lead to  
1322 premature death.

1323 Emissions that lead to high concentrations of SO<sub>2</sub> generally also lead to the formation of other oxides of  
1324 Sulphur (SO<sub>x</sub>). Therefore SO<sub>2</sub> is used as the indicator for the larger group of gaseous sulphur oxides.

1325 SO<sub>2</sub> shall be measured in the air intake in to the building (each AHU air intake or air vent or open window).At  
1326 air intake, for values of SO<sub>2</sub> concentration higher than the specified threshold value as given in section  
1327 6.2.2, additional measurements need to be taken inside the space.

1328 The following standards needs to be followed when measuring SO<sub>2</sub>: IS 5182 – part 2, as appropriate.

1329 **B1.8 Nitrogen dioxide (NO<sub>2</sub>)**

1330 Nitrogen dioxide (NO<sub>2</sub>) is one of highly reactive gasses known as oxides of Nitrogen (NO<sub>x</sub>).Other nitrogen  
1331 oxides include nitrous acid and nitric acid.

1332  
1333 The major source of NO<sub>2</sub>is high temperature combustion as in vehicles and power plants. NO<sub>2</sub> react with  
1334 ammonia, moisture, and other compounds to form small particulates. Ozone (O<sub>3</sub>) is generated when NO<sub>2</sub>  
1335 and VOCs react in the presence of heat and sunlight.

1336 Even short term NO<sub>2</sub> exposures (less than 24 hours) can cause adverse respiratory effects including airway  
1337 inflammation in healthy people and increased respiratory symptoms in people with asthma.

1338

1339 NO<sub>2</sub> shall be measured at air intake to building, (e.g. AHU air intake, air vent, open window) and after the  
1340 filters in case of mechanical ventilation. The measurement inside the building shall be done in two locations  
1341 - one near the main doors and the other one in the main occupied area.

1342 The following standards needs to be followed when measuring NO<sub>2</sub>: ISO 16000-15 and IS 5182 - part 6,  
1343 as appropriate.  
1344

#### 1345 **B1.9 Total Microbial Count**

1346 It is a quantitative measurement of the number of colony forming units of micro-organisms in 1 cubic  
1347 metre sample of air.

1348 One of the major purposed of the microbial count measurement is to compare indoor and outdoor air  
1349 samples and find any visible or hidden mould growth. Therefore, it is important to use same method for  
1350 both measurements and carry them out at the same time. Due to differences in sampling times, volumes,  
1351 and principles, the results given by different devices and methods are not comparable. Several air samples  
1352 needs to be collected in different parts of the building and at different times. The outdoor air samples, that  
1353 are collected simultaneously with each indoor air sample (same day and in same weather conditions), are  
1354 needed for comparison. The air handling unit or ventilation system may be a source of microbiological  
1355 contamination. Therefore in each measurement zone, one sample shall be collected from the supply air  
1356 near the terminal unit.

1357 When there is dampness and mould in a building, airborne fungal and bacteria concentrations of indoor air  
1358 are often (but not always) higher than the concentrations in ambient air at the same time. For fungal spores  
1359 and bacteria, the seasonal variation is considerable. Therefore measurements shall be taken only during  
1360 summer and winter months.  
1361

1362 There are no established health-based guidelines or standards for fungal or bacteria concentrations in the  
1363 indoor air because different types of fungi or bacteria may have different health effects. There is also not  
1364 enough research of “healthy” buildings during different seasons available in India to give India specific  
1365 target values for fungal count levels. Furthermore, there are no uniformly accepted or valid, quantitative  
1366 environmental sampling methods with which to assess exposures to mould and other agents associated  
1367 with damp indoor environments.  
1368

1369 Relative humidity measurements are recommended together with total microbial count measurements. The  
1370 following standards need to be followed when measuring total fungal count: ISO 16000 – 16, 17, 18, 19, 20  
1371 and 21, as appropriate.

1372 *Note: Even then measurements in different seasons or weather conditions cannot be compared.*  
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**B2. Important types of indoor environment and sources of air pollutants**

Type of indoor environment	Emitting sources or processes (examples)
<b>Private dwellings and living rooms</b>	
<b>a. General sources</b>	Man, building materials, furnishings, renovation materials, cleaning agents, biocide-containing products, ventilation and air-conditioning systems, outdoor air, heating appliances, microbial growth
<b>b. Special areas</b>	
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
<b>Public buildings</b>	
<b>a. General sources</b>	Man, building materials, furnishings, renovation materials, cleaning agents, biocide-containing products, ventilation and air-conditioning systems, outdoor air
<b>b. Special areas</b>	
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
<b>Transport vehicles</b>	Fuel tanks, internal combustion engines, internal fitting materials, outdoor air

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**B3. Sources of indoor air pollutants and their most important emissions**

Ask this	Process/activity	Products used, sources in a narrower sense	Substances emitted
<b>Biological sources</b>			
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
<b>Building products, building equipment</b>			
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
		Scrubbers, filters, insulating and sealing	

Ventilation and air-conditioning system	Product processing, renovation, outgassing	materials, deposits, heat exchangers Furniture, floor coverings, domestic textiles, paints and varnishes, wall coverings	Microorganisms (e.g. legionella), biocides, fibres, odoriferous substances
Room furnishings	Product processing, renovation, outgassing		Monomers and oligomers from plastics, resins, surface coatings, adhesives (e.g. formaldehyde), fibres, solvents, plasticizers, stabilizers, biocides
<b>Indoor activity</b>			
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	Paints, lacquers, adhesives, sprays, handicraft products, soldering irons	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	Tobacco products	Inorganic and organic gaseous and aerosol-type substances, particularly propellants and solvents, dusts, suspended

Tobacco	Smoking	Fuels, paints, lacquers, cleaning agents, etc.	particulate matter, metal vapours, monomers, biocides  Carbon monoxide, nitrogen oxides, nicotine, aldehyde, nitrosamines and numerous other organic substances (e.g. polycyclic aromatic hydrocarbons, aerosols)
Garage store room	Storage		Fuel vapours, exhaust gas, solvents
<b>Transportation</b>			
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)
<b>Outdoor air pollution</b>			
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

**B4. Typical pollutants and their sources in indoor environment**

Pollutants	Sources
<b>Inorganic components</b>  Carbon monoxide (CO)  Carbon dioxide (CO <sub>2</sub> )  Nitrogen dioxide (NO <sub>2</sub> )  Sulphur dioxide (SO <sub>2</sub> )  Ozone (O <sub>3</sub> )  Ammonia  Radon  Mercury  Lead	  Open fires, tobacco smoke, vehicle exhaust gases  Open fires, tobacco smoke, people, vehicle exhaust gases  Open fires, gas appliances, tobacco smoke, vehicle exhaust gases (in vehicle)  Sulphur-containing fuels  Photocopiers, laser printers  Flooring, concrete, levelling agents, mortar/plasters  Uranium and radium deposits close to the surface, building materials (granite, pumice stone and tuffaceous rock), artificial plaster  Broken thermometer, plasters  Paints
<b>Particles</b>  Settled dusts  Asbestos  Fibrous dusts  Aerosols  Suspended particulate matter (PM) PM2.5 PM 10 TPM (total particulate matter)	  Tracked-in dusts  Insulating materials, freeable asbestos  Mineral wool, building materials  Tobacco smoke  Fuel combustion., cooking, fungi spores, pollen, animals, humans, bacteria, windblown dust

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1403

### Lighting comfort

#### C1. Circadian Lighting Design

1405 Light is one of the main drivers of the circadian system, which starts in the brain and regulates physiological  
 1406 rhythms throughout the body's tissues and organs, affecting hormone levels and the sleep-wake cycle.  
 1407 Circadian rhythms as shown in Figure C1 are kept in sync by various cues, including light which the body  
 1408 responds to in a way facilitated by intrinsically photosensitive retinal ganglion cells (ipRGCs): the eye's non-  
 1409 image-forming photoreceptors. Through ipRGCs, lights of high frequency and intensity promote alertness,  
 1410 while the lack of this stimulus signals the body to reduce energy expenditure and prepare for rest.

1411  
 1412 This feature promotes lighting environments for circadian health. The biological effects of light on humans  
 1413 can be measured in Equivalent Melanopic Lux (EML), a proposed alternate metric that is weighted to the  
 1414 ipRGCs instead of to the image forming photo receptors - cones, which is the case with traditional lux.  
 1415

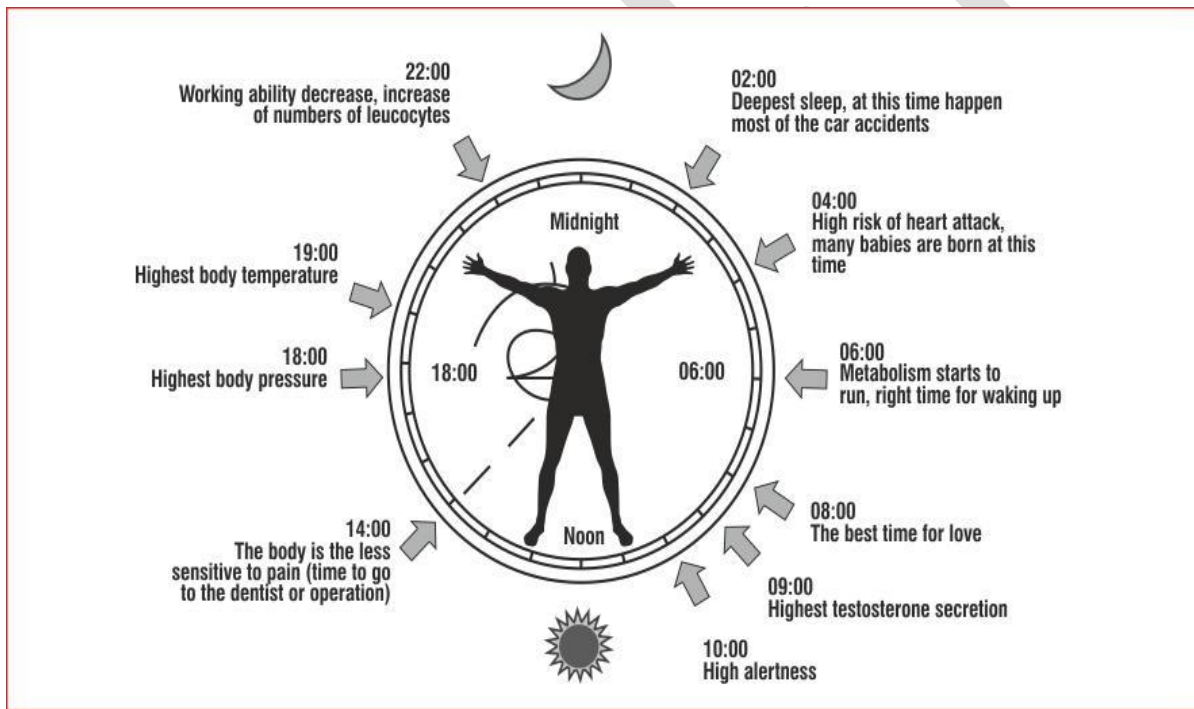


Figure C1 Circadian rhythms in humans

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1417

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#### C1.1 Glare

1420 Glare is the result of sudden large changes in brightness of the light source, which leads to lower efficiency  
 1421 of the vision. An occupant under the effect of glare fails to notice subtle changes and details of a scene. It  
 1422 is mainly classified into two types Direct Glare and Reflected Glare

1423

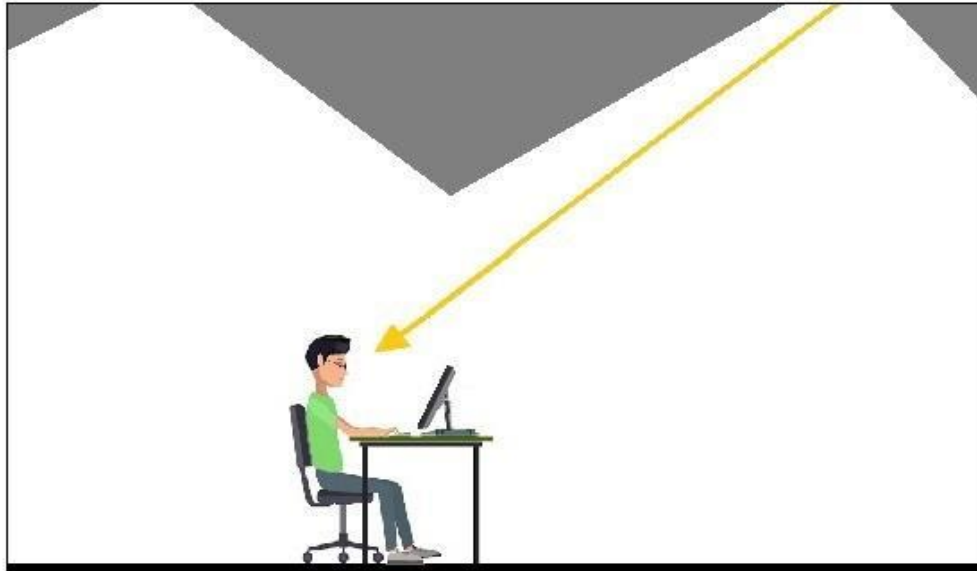
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1427 **C1.2 Direct Glare**

1428 Direct Glare is caused when within an occupant's field of vision, the luminaires of a room are without glare  
1429 control thereby making the task area and surfaces very bright resulting in glare. The effects of it are fatigue,  
1430 frequent mistakes and loss of concentration.

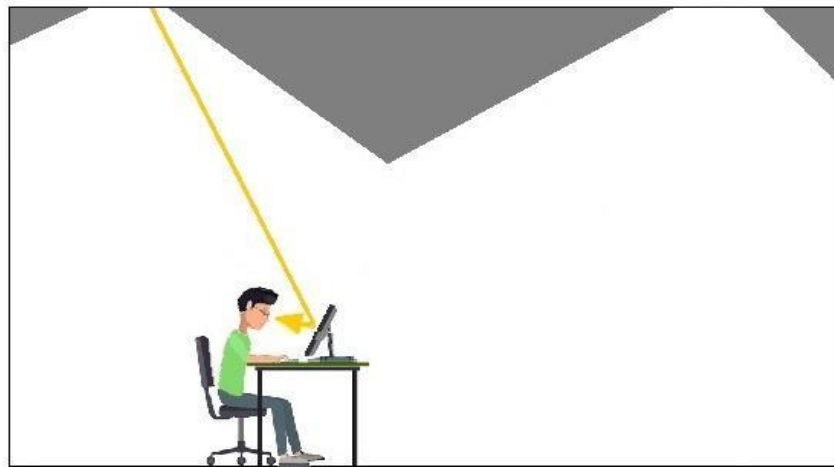


1431  
1432

**Figure C2 Direct glare**

1433 **C1.3 Reflected Glare**

1434 Reflected Glare is caused due to reflections coming from light sources or surfaces of excessive brightness  
1435 which is the result of incorrect Luminaire arrangement and incorrect workstation position. The effects of it  
1436 are fatigue, frequent mistakes and loss of concentration.



1437  
1438

**Figure C3 Reflected glare**

1439 In general, Glare mainly experienced either as physiological effect known as Disability glare or  
1440 psychological glare known as Discomfort glare

1441 **C1.4 Disability glare**

1442 Disability glare is direct impairment of visibility and visual capacity by the effect of glare. As an effect of  
1443 glare occurs due to luminance from immediate background light source disability glare is happed.  
1444 Discomfort does not necessarily causes by disability glare.

1445 **C1.5 Discomfort glare**

1446 Discomfort glare is disturbance, which impairs our sense of wellbeing by the effect of glare. The level of  
1447 discomfort occurs due to glare is depends upon size of glare source and the luminance. Discomfort glare  
1448 does not necessarily impairs object observation. As passing of time discomfort tends to increase and  
1449 causes nervous tension and fatigue. Object observation impairment does not necessarily causes by  
1450 discomfort glare

1451

1452 **C 2. Basic Light Level Measurement Protocols**

1453 Light level (i.e., illumination) measurements are critical to comparing the capabilities of different lighting  
1454 technologies. It is important to measure only the light being provided by the technologies being tested,  
1455 which represents the actual illumination provided by the system being measured. The following guidelines  
1456 will help to ensure accurate and representative light level data.

1457 Follow these guidelines for all measurements as applicable:

1458 • Where possible, use the same calibrated illuminance measurement meter (see Section 2.1). If the same  
1459 meter is not available, use the same make and model of calibrated meter to minimize underlying  
1460 differences in accuracy and internal meter spectrum correction characteristics.

1461 • When taking measurements, verify that occupants and objects/materials are not blocking any light to the  
1462 meter head. The use of a remote meter head cabled to the meter body is recommended to prevent the  
1463 operator from blocking the meter's "view" of the lighting system being measured. Measurement points that  
1464 are shaded, even partially, by obstructions that are not moveable should be noted for potential  
1465 elimination.

1466 • Identify the appropriate task plane at which to take the measurements. For most outdoor areas and  
1467 indoor corridors, gathering spaces, and warehousing or manufacturing spaces, this plane will be the  
1468 ground or floor surface (where walking is the primary task). For most other indoor areas, the task plane  
1469 will be a typical office desk height (30 inches above the floor).

1470 • Identify the measurement locations by marking and/or mapping. It is important to measure the same  
1471 locations for the baseline and post-installation lighting systems, or the same representative type of  
1472 locations if fixtures are relocated for the retrofit. Therefore, it is necessary to provide some permanent  
1473 record of measurement point locations.

1474 – For interior areas, mapping (e.g., using a sketch or marked-up plans with dimensions) is usually the  
1475 best option because marking on measurement surfaces will often not be allowed or will not be retained  
1476 between measurements. Make sure to reference the measurement points to some permanent features of  
1477 the space because desks and other furniture may be moved between the baseline and post-installation  
1478 measurements.

1479

1480 • Photographs of the test site conditions, meter setup, and measurement layout are recommended to  
1481 provide a record of the conditions to be applied for repeated sets of measurements. These will help  
1482 identify obstructions and other conditions that may affect readings. Note that using photos for color  
1483 comparisons of baseline and retrofit installations may not provide accurate results because camera model  
1484 settings including white (color) balance and exposure may vary. If photos are to be used for comparison  
1485 purposes, the camera color accuracy should be assessed, and appropriate caveats noted.

1486 • Record time and ambient temperature at start and finish of measurements.

1487

**Annex D (Normative)**

1488

**Recommended methodology to calculate Equivalent Melanopic Lux (EML) for different type of lighting conditions**

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1490

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

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1494

$$EML = L \times R$$

1495

Where values of ratio R are given in Table D1

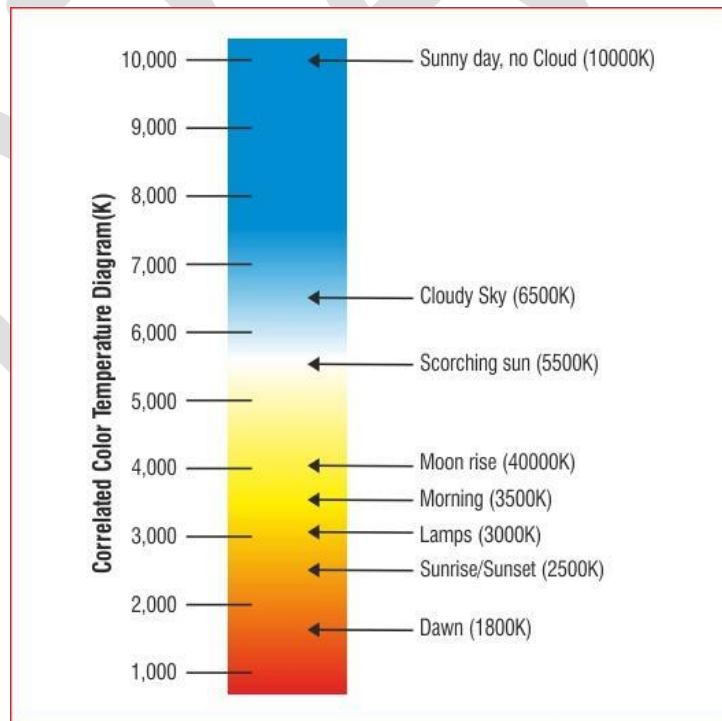
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**Table D1 Light source and melanopic ratio corresponding to different CCT (K)**

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

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**Figure D1 Correlated Colour Temperature (K) corresponding to typical lighting conditions**

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1503 **Example 1:**

1504 If incandescent lights provide 200 lux in a space, they will produce equivalent melanopic lux of:

1505 
$$\text{EML} = 200 \times 0.54$$

1506 
$$\text{EML} = 108$$

1507

1508 **Example 2:**

1509 If fluorescent lighting of 6500 K CCT provides 200 lux in a space, then the EML will be

1510 
$$\text{EML} = 1.02 \times 200$$

1511 
$$\text{EML} = \text{which is } 204 \text{ EML.}$$

1512

1513

1514 **Example 3:**

1515 If CFL of CCT 6500 and LED of CCT 4000 combine provide 300 lux, then the EML can be calculated by  
1516 the following method:

1517 Lux levels provided by CFL is 100 (can be determined by switching off LEDs)

1518 
$$\text{EML}_{\text{CFL}} = 100 \times 1.02 = 102 \text{ EML}$$

1519 Lux levels provided by LED is 200 (can be determined by switching off CFLs)

1520 
$$\text{EML}_{\text{LED}} = 200 \times 0.76 = 152 \text{ EML}$$

1521 Total EML shall be calculated

1522 
$$\text{EML}_{\text{total}} = \text{EML}_{\text{CFL}} + \text{EML}_{\text{LED}} = 254$$

1523

1524 **Example 4:**

1525 If fluorescent lighting of 7500 K CCT and daylighting provide 500 lux

1526 Lux levels provided by daylight is 400 (can be determined by switching off fluorescent lights)

1527 
$$\text{EML}_{\text{daylight}} = 400 \times 1.10 = 440 \text{ EML}$$

1528 Lux levels provided by fluorescent are 100 (total lux – daylight lux)

1529 
$$\text{EML}_{\text{fluorescent}} = 100 \times 1.11 = 111$$

1530 
$$\text{EML}_{\text{total}} = \text{EML}_{\text{fluorescent}} + \text{EML}_{\text{daylight}} = 551$$

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1532

1533

1534 4. **Recommended methodology to calculate lighting comfort parameters**

1535 If the Illuminance at three points (varies according to size of task area) of task area (varies according to the  
1536 nature of activity) are 515 Lux, 535 Lux and 550 Lux, further the Illuminance at three points (varies according  
1537 to size of immediate surroundings area) of immediate surroundings area are 430 Lux, 465 Lux and 495 Lux  
1538 then Illuminance of task area shall be calculated by averaging the measured illuminance within the task  
1539 area

1540 
$$\text{Illuminance} = 515 + 535 + 550 / 3$$

1541 
$$\text{Illuminance} = 533 \text{ Lux}$$

1542 Uniformity of Illuminance shall be calculated by ratio of minimum illuminance to average illuminance within  
1543 the task area

1544 
$$\text{Uniformity of Illuminance} = 430 / 533$$

1545 
$$\text{Uniformity of Illuminance} = 0.807$$

1546 Illuminance of the immediate surrounding areas shall be calculated by averaging the measured illuminance  
1547 within the immediate surrounding areas

1548 
$$\text{Illuminance of immediate surroundings} = 430 + 465 + 495 / 3$$

1549 
$$\text{Illuminance of immediate surroundings} = 463 \text{ Lux}$$

1550 Ratio between a task area illuminance and immediately adjacent surroundings illuminance =  $533 / 463 = 1.15$

1551 Percentage of the task area meeting the required illuminance

1552 If in a conference room there are five occupants, the measured illuminance of their task areas are 510 Lux,  
1553 580 Lux, 455 Lux, 550 Lux and 535 Lux. Thus 4 out of 5 locations are meeting the threshold value, and then  
1554 the Percentage of the task area meeting the required illuminance can be calculated by

1555 
$$\text{Percentage of the task area meeting the required illuminance} = 4 / 5 * 100 = 80 \%$$

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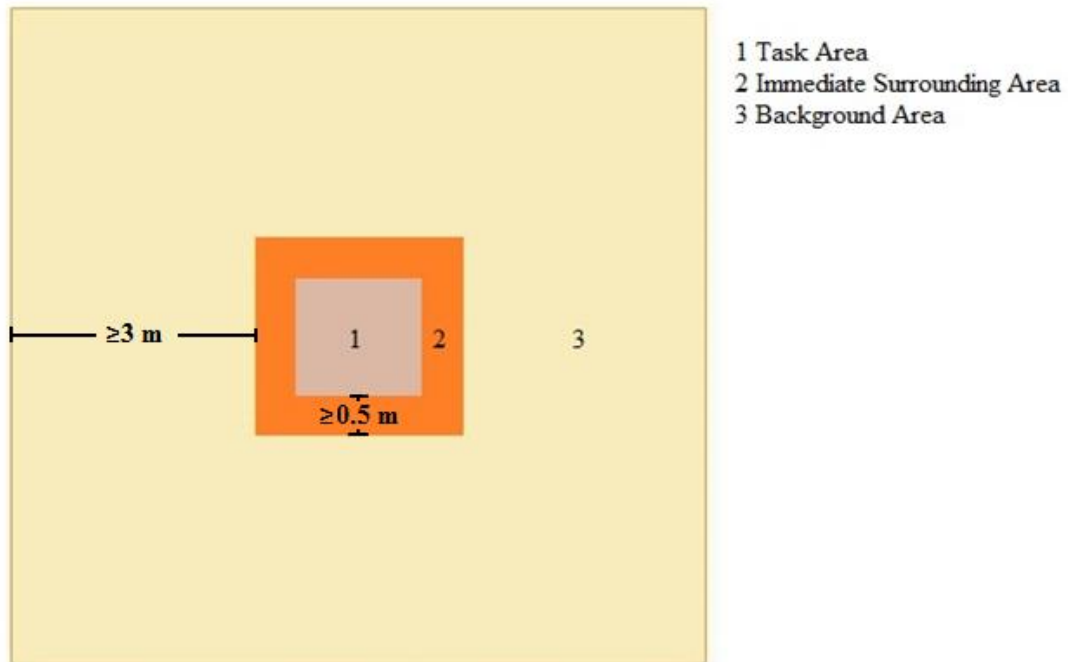
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1565

## Annexure E (Normative)

1566

### Recommended methodology to calculate lighting comfort parameters



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**Figure E1 Task, immediate surrounding and background areas**

1570 Area where the visual task is performing defined as the task area. The visually relevant elements such as  
1571 background contrast, size of objects, presentation time and luminance of objects are used to determine the  
1572 visual performance required for the visual task. The reference surface of the visual task can be vertical,  
1573 horizontal or inclined.

1574 At least 0.5 m band width area surrounding the task area within the field of vision is defined as the immediate  
1575 surrounding area.

1576 Background area is defined as the band of at least 3 m wide adjacent to the immediate surrounding area  
1577 within the limits of the space.

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**Annexure F**  
**Acoustic comfort**

1584  
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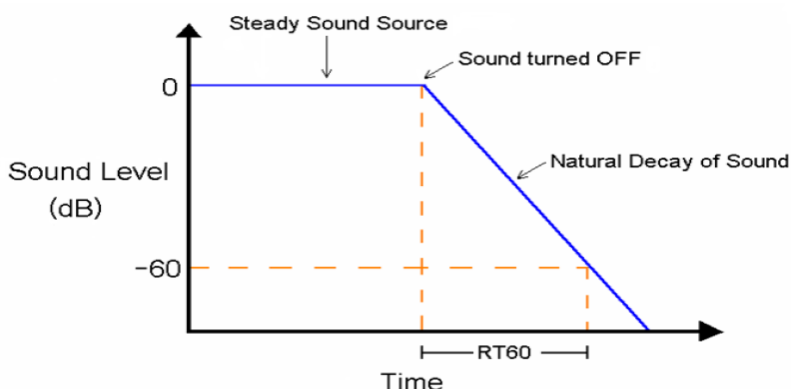
**F.1 Reverberation time,**

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T60, is a metric which describes the length of time taken for a sound to decay by 60 dB from its original level. The optimal reverberation time for any room depends on both the intended use of the space and the volume of the space, and additionally, reverberation is frequency dependent. The clarity of speech and music at any location within a room is dependent on the size, shape, and surface materials in the space, and as such, the clarity is highly dependent on the reverberation time. Short reverberation times are recommended for speech, whereas longer reverberation times are recommended for music.

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Not only does the reverberation affect quality of sound, but it also affects the level (dB) of sound within the space from all sources including noise. In spaces with long reverberation, the sound of voices and footsteps take longer to dissipate, contributing to higher levels of ambient noise. The added noise produced by reverberation can decrease speech intelligibility and in some situations cause additional stress.



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Figure F1: Reverberation time

**F 2 Weighted Level Difference (Dw)**

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The Table F1 shows the Dw values and its reaction

1602  
1603

**Table F1 D<sub>w</sub> Values and its Reaction**

D <sub>w</sub> / NIC	What can be heard
25	Normal speech can be understood quite easily and distinctly through wall
30	Loud speech can be understood fairly well, normal speech heard but not understood
35	Loud speech audible but not intelligible
40	Onset of "privacy"
45	Loud speech not audible; 90% of statistical population not annoyed
50	Very loud sounds such as musical instruments or a stereo can be faintly heard; 99% of population not annoyed
55	Superior soundproofing; most sounds inaudible

DRAFT