INDOOR ENVIRONMENTAL QUALITY STANDARDS AND WELLNESS

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STANDARDS

- ISO EN 7730–2005
  - Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort effects.

- ASHRAE 55–2013
  - Thermal environment conditions for human occupancy

- ASHRAE 62.1 and 62.2 –2013
  - Ventilation and indoor air quality

- EN15251 (EN16798–1)
  - Indoor environmental input parameters for design and assessment of energy performance of buildings–addressing indoor air quality, thermal environment, lighting and acoustic

- EN 13779 (EN16798–3 and –4)
  - Ventilation for non–residential buildings – performance requirements for ventilation and room–conditioning systems
EN16798–1 and ISO 17772–1:
- Indoor environmental input parameters for the design and assessment of energy performance of buildings.

CEN TR16798–2 and ISO TR 17772–2:
- Guideline for using indoor environmental input parameters for the design and assessment of energy performance of buildings.
WELL v2™ pilot

The next version of the WELL Building Standard™
POINTS-BASED SCORING

WELL Platinum: 80 – 100 points
WELL Gold: 60 – 79 points
WELL Silver: 50 – 59 pts

100 POINTS AVAILABLE (+10 POINTS IN INNOVATIONS), MORE.WAYS TO GET THERE
This is not a standard like ASHRAE, ISO or CEN standards. This is a method to evaluate “Well Being” in a building established by the Well-Being Institute. The founders and concept is similar to the LEED program. Can you substitute ventilation with apples?
## Recommended categories for design of mechanical heated and cooled buildings

<table>
<thead>
<tr>
<th>Category</th>
<th>PPD %</th>
<th>Predicted Mean Vote</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>&lt; 6</td>
<td>-0.2 &lt; PMV &lt; + 0.2</td>
</tr>
<tr>
<td>II</td>
<td>&lt; 10</td>
<td>-0.5 &lt; PMV &lt; + 0.5</td>
</tr>
<tr>
<td>III</td>
<td>&lt; 15</td>
<td>-0.7 &lt; PMV &lt; + 0.7</td>
</tr>
<tr>
<td>III</td>
<td>&lt; 25</td>
<td>-1.0 &lt; PMV &lt; + 1.0</td>
</tr>
</tbody>
</table>
Temperature ranges for hourly calculation of cooling and heating energy in three categories of indoor environment

<table>
<thead>
<tr>
<th>Type of building/ space</th>
<th>Category</th>
<th>Operative Temperature for Energy Calculations °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Heating (winter season), ~ 1,0 clo Cooling (summer season), ~ 0,5 clo</td>
</tr>
<tr>
<td>Offices and spaces with similar activity (single offices, open plan offices, conference rooms, auditorium, cafeteria, restaurants, class rooms, Sedentary activity ~1,2 met)</td>
<td>I</td>
<td>21,0 – 23,0 23,5 - 25,5</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>20,0 – 24,0 23,0 - 26,0</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>19,0 – 25,0 22,0 - 27,0</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>17,0 – 26,0 21,0 - 28,0</td>
</tr>
</tbody>
</table>
Humidity limits according to ASHRAE-55-2016

Data based on ISO 7730 and ASHRAE STD 55

Upper Recommended Humidity Limit, 0.012 humidity ratio

Lower Humidity Limit

10% RH

No Recommended

PMV Limits

0.5 Clo

1.0 Clo

0.5 Clo

10.0

9.0

8.0

7.0

6.0

5.0

4.0

3.0

2.0

1.0

0.0

0.002

0.004

0.006

0.008

0.010

0.012

0.014

0.016

Operative Temperature, °C

Dew Point Temperature, °C

Humidity Ratio

PMV Limits
WELL BEING STANDARD
Thermal Comfort

Letter of Assurance MEP
On Site Spot Measurement

PART 1 Ventilated Thermal Environment
All spaces in mechanically-ventilated projects (including circulation areas) meet the design, operating and performance criteria:
• ASHRAE Standard 55-2013 Section 5.3, Standard Comfort Zone Compliance.

PART 2 Natural Thermal Adaptation
All spaces in naturally-conditioned projects meet the following criteria:
• ASHRAE Standard 55-2013 Section 5.4, Adaptive Comfort Model.
PART 4

Ventilation Rates for Residences

The following requirements are met:

- Ventilation rates are designed to comply with all requirements set in ASHRAE 62.2-2013 (or more recent version) for dwelling units.
- Ventilation rates are designed to comply with all requirements set in ASHRAE 62.1-2013 for common areas and other spaces apart from dwelling units.
Concept for calculation of design ventilation rate

People Component

Building Component

Breathing Zone
Outdoor Airflow

\[ V_{bz} = R_p P_z + R_s S_d + R_a A_z \]

- Minimum l/s/Person
- Number of People
- Ventilation per Smoker
- Number of Smokers
- Minimum l/s/m²
- Building Area

Number of Smokers
PERCEIVED AIR QUALITY
% DISSATISFIED (PD)

VENTILATION RATE (q)

CEN CR 1752
prEN15251
ASHRAE 62.1
DIN 1946

Category C

A

B

0
5
10
15
20
25
30
35
40
45
50
55
60

0
10
20
30
40
50
60

l/s • standard person
CO2 as reference

\[ PD = 395 \cdot \exp(-15.15 \cdot C_{CO2}^{-0.25}) \]
Basic required ventilation rates for diluting emissions (bio effluents) from people for different categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Expected Percentage Dissatisfied</th>
<th>Airflow per non-adapted person l/(s.pers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>II</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>III</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>IV</td>
<td>40</td>
<td>2.5*</td>
</tr>
</tbody>
</table>

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

ASHRAE Standard 62.1 : Adapted persons  2.5 l/s person (Cat. II )
Design ventilation rates for diluting emissions from buildings

<table>
<thead>
<tr>
<th>Category</th>
<th>Very low polluting building l/(s m²)</th>
<th>Low polluting building l/(s m²)</th>
<th>Non low-polluting building l/(s m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.5</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>II</td>
<td>0.35</td>
<td>0.7</td>
<td>1.4</td>
</tr>
<tr>
<td>III</td>
<td>0.2</td>
<td>0.4</td>
<td>0.8</td>
</tr>
<tr>
<td>IV</td>
<td>0.15</td>
<td>0.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Minimum total ventilation rate for health</td>
<td>4 l/s person</td>
<td>4 l/s person</td>
<td>4 l/s person</td>
</tr>
</tbody>
</table>
Total ventilation rate

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

\[ q_{supply} = q_{tot} / \varepsilon_v \]

- Where
- \( \varepsilon_v \) = the ventilation effectiveness (EN13779)
- \( q_{supply} \) = ventilation rate supplied by the ventilation system
- \( q_{tot} \) = total ventilation rate for the breathing zone, l/s
- \( n \) = design value for the number of the persons in the room,
- \( q_p \) = ventilation rate for occupancy per person, l/s, pers
- \( A_R \) = room floor area, m\(^2\)
- \( q_B \) = ventilation rate for emissions from building, l/s, m\(^2\)
<table>
<thead>
<tr>
<th>Type of building/space</th>
<th>Occupancy person/m²</th>
<th>Category CEN</th>
<th>Occupants only l/s person</th>
<th>Additional ventilation for building (add only one) l/s-m²</th>
<th>Total l/s-m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>10</td>
<td>1,0 2,0</td>
<td>2</td>
</tr>
<tr>
<td>Single office (cellular office)</td>
<td>0,1</td>
<td>B</td>
<td>7</td>
<td>0,7 1,4</td>
<td>0,3 1,4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>4</td>
<td>0,4 0,8</td>
<td>0,3 0,8</td>
</tr>
<tr>
<td>Landscaped office</td>
<td>0,07</td>
<td>A</td>
<td>10</td>
<td>1,0 2,0</td>
<td>0,3 1,7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>7</td>
<td>0,7 1,4</td>
<td>0,3 1,2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>4</td>
<td>0,4 0,8</td>
<td>0,3 0,7</td>
</tr>
<tr>
<td>Conference room</td>
<td>0,5</td>
<td>A</td>
<td>10</td>
<td>1,0 2,0</td>
<td>0,3 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>7</td>
<td>0,7 1,4</td>
<td>0,3 4,2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>4</td>
<td>0,4 0,8</td>
<td>0,3 2,4</td>
</tr>
</tbody>
</table>

1 l/s m² = 0.2 cfm/ft²
PART 1 Increased Outdoor Air Supply
One of the following is required in all regularly occupied spaces:

- Exceed outdoor air supply rates met in ASHRAE 62.1 (62.2) by 30%.
- Follow CIBSE AM10, Section 4, Design Calculations, to predict that room-by-room airflows will provide effective natural ventilation.
PART 2 Demand Controlled Ventilation

For all spaces 46.5 m² [500 ft²] or larger with an actual or expected occupant density greater than 25 people per 93 m² [1,000 ft²], one of the following requirements is met:

A demand controlled ventilation system regulates the ventilation rate of outdoor air to keep carbon dioxide levels in the space below 800 ppm (measured at 1.2-1.8 m [4-6 ft] above the floor).

Projects that have met the Operable windows feature demonstrate that natural ventilation is sufficient to keep carbon dioxide levels below 800 ppm (measured at 1.2-1.8 m [4-6 ft] above the floor) at maximum intended occupancies.
Low ventilation rate requirements (!)

### Fresh outdoor air supply

- **EN 15251 Cat II:** High ventilation requirements
- **National Dutch office requirements:** Moderate ventilation requirements
- **WELL F03 / A03:** Low ventilation requirements
Indoor Air Quality Procedure

The required ventilation rate is calculated as:

\[ Q = \frac{G}{(C_i - C_o) \cdot E_v} \] l/s

where

- \( G \) = Total emission rate \( \text{mg/s} \)
- \( C_i \) = Concentration limit \( \text{mg/l} \)
- \( C_o \) = Concentration in outside air \( \text{mg/l} \)
- \( E_v \) = Ventilation effectiveness
<table>
<thead>
<tr>
<th>Pollutant</th>
<th>WHO Indoor Air Quality guidelines 2010</th>
<th>WHO Air Quality guidelines 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>No safe level can be determined</td>
<td>-</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>15 min. mean: 100 mg/m³  1h mean: 35 mg/m³  8h mean: 10 mg/m³  24h mean: 7 mg/m³</td>
<td>-</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>30 min. mean: 100 µg/m³</td>
<td>-</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>Annual mean: 10 µg/m³</td>
<td>-</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>1h mean: 200 µg/m³  Annual mean: 40 mg/m³</td>
<td>-</td>
</tr>
<tr>
<td>Polyaromatic Hydrocarbons (e.g.</td>
<td>No safe level can be determined</td>
<td>-</td>
</tr>
<tr>
<td>Benzo Pyrene A B[a]P)</td>
<td>100 Bq/m³  (sometimes 300 mg/m³, country-specific)</td>
<td>-</td>
</tr>
<tr>
<td>Radon</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Trichlorethylene</td>
<td>No safe level can be determined</td>
<td>-</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>Annual mean: 250 µg/m³</td>
<td>-</td>
</tr>
<tr>
<td>Sulfure dioxide</td>
<td></td>
<td>10 min. mean: 500 µg/m³  24h mean: 20 mg/m³</td>
</tr>
<tr>
<td>Ozone</td>
<td></td>
<td>8h mean: 100 µg/m³</td>
</tr>
<tr>
<td>Particulate Matter PM 2,5</td>
<td></td>
<td>24h mean: 25 µg/m³  Annual mean: 10 µg/m³</td>
</tr>
<tr>
<td>Particulate Matter PM 10</td>
<td></td>
<td>24h mean: 50 µg/m³  Annual mean: 20 µg/m³</td>
</tr>
</tbody>
</table>
WELL BEING STANDARD
Air Quality Standards

On site performance test

PART 1. Standards for Volatile Substances
• Formaldehyde levels less than 27 ppb.
• Total volatile organic compounds less than 500 μg/m³.

PART 2. Standards for Particulate Matter and Inorganic Gases
• Carbon monoxide less than 9 ppm.
• PM$_{2.5}$ less than 15 μg/m³.
• PM$_{10}$ less than 50 μg/m³.
• Ozone less than 51 ppb.

PART 3 Radon
Radon less than 0.148 Bq/L [4 pCi/L] in the lowest occupied level of the project.
### Table 3: Threshold values for indoor air quality parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Classification</th>
<th>Class A</th>
<th>Class B</th>
<th>Class C</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>ppm</td>
<td></td>
<td>Ambient + 350</td>
<td>Ambient + 500</td>
<td>Ambient + 800</td>
</tr>
<tr>
<td>PM 2.5</td>
<td>µg/m³</td>
<td></td>
<td>&lt;15</td>
<td>&lt;25</td>
<td>&lt;60</td>
</tr>
<tr>
<td>PM 10</td>
<td>µg/m³</td>
<td></td>
<td>&lt;50</td>
<td>&lt;100</td>
<td>&lt;100</td>
</tr>
<tr>
<td>CO</td>
<td>ppm</td>
<td></td>
<td>&lt;9</td>
<td>&lt;9</td>
<td>&lt;9</td>
</tr>
<tr>
<td>TVOC</td>
<td>µg/m³</td>
<td></td>
<td>&lt;200</td>
<td>&lt;400</td>
<td>&lt;600</td>
</tr>
<tr>
<td>CH₂O</td>
<td>µg/m³</td>
<td></td>
<td>&lt;30</td>
<td>&lt;100</td>
<td>-</td>
</tr>
<tr>
<td>SO₂</td>
<td>µg/m³</td>
<td></td>
<td>&lt;40</td>
<td>&lt;80</td>
<td>-</td>
</tr>
<tr>
<td>NO₂</td>
<td>µg/m³</td>
<td></td>
<td>&lt;40</td>
<td>&lt;80</td>
<td>-</td>
</tr>
<tr>
<td>O₃</td>
<td>µg/m³</td>
<td></td>
<td>&lt;50</td>
<td>&lt;100</td>
<td>-</td>
</tr>
<tr>
<td>Total Microbial Count</td>
<td>CFU/m³</td>
<td>Indoor ≤ ambient</td>
<td>Indoor ≤ ambient</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>User Satisfaction</td>
<td>%</td>
<td></td>
<td>90</td>
<td>80</td>
<td>-</td>
</tr>
</tbody>
</table>
HEALTH CRITERIA FOR VENTILATION

Minimum 4 l/s/person
Filtration and air cleaning

• The influence of position of outdoor air intakes, filtration and air cleaning shall be considered. (EN 16798-3, ISO TR 17772-2)

• If filtration and air cleaning is used the following points shall be considered:
  – Reducing the amount of airborne pollutants (pollens, molds, spores, particles, dust) from the outdoor air intake by circulating the air through a filter.
  – Circulating secondary air through a filter or other air cleaning technology to reduce the amount of pollutants in the air
  – Reduce the concentration of odors and gaseous contaminants by circulating the secondary air or recirculating the return air (gas phase air cleaning)

  » Note: Design guidelines on air cleaning and filtration are given in EN 16798-2 and EN 16798-4. How to partially substitute outside air by air cleaning is described in ISO TR 17772-2
From Individuel Buildings to Smart Communities and Smart Cities
The SMART movement

• Smart Energy
• Smart Grid
• Smart Cities
• Smart Communities
• Smart Buildings
  – Smart ready buildings
  – Resilient buildings
  – Smart ventilation
  – Smart control
• Sheila Hayter
• ASHRAE President 2018-2019

• **Smart Grid Community**
• **Cyber Security Community**
• **Wellness Community**

**BUILDING OUR NEW ENERGY FUTURE**
Data transfer between buildings and grid

• Two-way energy flow
• Data from the grid to the building/occupants
  – Information on when to use el-energy
    • Washing
    • Charging (cars, batteries and others)
  – Information on indoor environment and energy use
    • When to use solar blinds
    • Open-close windows
• Data from the building/occupants
  – Information from system sensors
  – Information from room sensors (temperature, humidity, ventilation, IAQ, daylight etc.)
• Cyber security
Grid-Buildings-Occupants

• The grid sells energy to "buildings"
• The grid should sell comfort to people
• Too high and too low ventilation you pay more
• Room Temperatures outside the comfort range you pay more
  – Heating season
    • Too low room temperature-building damage, health
    • Too high room temperature-energy costs
  – Cooling season
    • Too low room temperature-energy costs
    • Too high room temperatures-decreased IAQ
• Feed-back from the grid to the occupants
CONCEPT - SMART READINESS INDICATOR – SRI

Figure 1 – Expected advantages of smart technologies in buildings
**Figure 3 – Three key functionalities of smart readiness in buildings**
SRI - CALCULATION METHODOLOGY

ONE SINGLE SCORE CLASSIFIES THE BUILDING'S SMART READINESS

8 IMPACT CRITERIA
The total SRI score is based on average of total scores on 8 impact criteria.

- energy
- flexibility for the grid
- self-generation
- comfort
- convenience
- wellbeing & health
- maintenance & fault prediction
- information to occupants

An impact criterion score is expressed as a % of the maximum score that is achievable for the building type that is evaluated.

energy

\[ x\% = \frac{a}{b} \]

\[ a = \text{score} \]
\[ b = \text{max. building} \]
Ten domains structuring the SRI catalogue

- Heating
- Cooling
- Domestic hot water
- Controlled ventilation
- Lighting
- Dynamic building envelope
- On site renewable energy generation
- Demand side management
- Electric vehicle charging
- Monitoring and control
Wellness Community
CONCLUSIONS

• Thermal Comfort
  – Standards from ASHRAE, ISO and CEN are very similar
  – Uses PMV/PPD method and adaptive approach

• IAQ-Ventilation
  – Concept for estimating the required ventilation rate is equal for ASHRAE, ISO and CEN standards
  – ISO and CEN standards recommend higher ventilation rates than ASHRAE standards
  – The required ventilation rate is in most cases based on Perceived Air Quality
  – Criteria for individual substances are limited
  – ASHRAE allow the use of the IAQ procedure to evaluate the performance of gas phase air cleaners
  – No test standard for gas phase air cleaners are using PAQ as measure