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ANNEX STRUCTURE
Operation Agents

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- Dr. Pawel Wargocki, Technical University of Denmark.

- PREPARATION PHASE 01-07-2018 TO 30-06-2019  
- WORKING PHASE 01-07-2019 TO 30-06-2023  
- REPORTING PHASE 01-07-2012 TO 30-06-2024
ANNEX STRUCTURE

- Subtask A: Energy benefits using gas phase air cleaning
  - Subtask leader: Alireza Afshari, Denmark
  - Co-leader: Sasan Sadraizadeh, Sweden
- Subtask B: How to partly substitute ventilation by air cleaning
  - Subtask leader: Pawel Wargocki, Denmark
  - Co-leader: Shin-Ichi Tanabe, Japan
- Subtask C: Selection and testing standards for air cleaners
  - Subtask leader: Paolo Tronville, Italy
  - Co-leader: Jinhan Mo, China
- Subtask D: Performance modelling and long-term field validation of gas phase air cleaning technologies
  - Subtask leader: Karel Kabele, Czech
  - Co-leader: Jensen Chang, US

Concept for calculation of design ventilation rate
ISO  CEN ASHRAE

\[
V_{bz} = R_p P_z + R_u A_z
\]

- Minimum l/s/Person
- Number of People
- Building Area
- Minimum l/s/m²
Experimental setup

Air temperature 23°C
Relative humidity 35%

Sensory measurements

- Panel of 50 untrained subjects assessed acceptability of air quality

ACCEPTABILITY SCALE
Clearly acceptable
Just acceptable
Just not acceptable
Clearly not acceptable
Results: Bldg mat, PCs, filters

Results: Human bioeffluents
Effect of air cleaning on perceived Air Quality

Sources:
- People
- Building materials
- Used filters

Clean Air Delivery rate per person
ISO 10121-2:2014

This part of ISO 10121 aims to provide an objective test method to estimate the performance of any full size gas filtration device (GPACD) for general filtration regardless of media or technique used in the device.

To ensure objectivity for test equipment suppliers, no specific design of the test apparatus is specified.

This part of ISO 10121 can also be used with technologies such as scrubbers, absorbers, non-sorptive devices or packed columns as long as they fit into the test apparatus, can be meaningfully judged by the test method and are intended for general ventilation applications, both residential and non-residential.

**Figure 1 — Normative section of test stand showing ducting, measurement parameters and sampling points**
Table 2 — Challenge gases and concentrations for the simplified benchmark test

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Selected gas</th>
<th>Challenge level</th>
<th>Unit</th>
<th>Reference analysis technique</th>
<th>Face velocity [m/s]</th>
<th>$T_0$ [°C]</th>
<th>$RH_0$ [%]</th>
<th>Maximum permissible efficiency decay during test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
<td>SO$_2$</td>
<td>450</td>
<td>ppb(v)</td>
<td>UV fluorescence$^d$</td>
<td>2.5</td>
<td>23</td>
<td>50</td>
<td>5 %</td>
</tr>
<tr>
<td>Base</td>
<td>NH$_3$</td>
<td>450</td>
<td>ppb(v)</td>
<td>chemiluminescence$^d$</td>
<td>2.5</td>
<td>23</td>
<td>50</td>
<td>5 %</td>
</tr>
<tr>
<td>VOC</td>
<td>toluene</td>
<td>5</td>
<td>ppm(v)</td>
<td>PID$^d$ or FID$^d$</td>
<td>2.5</td>
<td>23</td>
<td>50</td>
<td>5 %</td>
</tr>
</tbody>
</table>

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<th>Challenge level</th>
<th>Unit</th>
<th>Reference analysis technique</th>
<th>Face velocity [m/s]</th>
<th>$T_0$ [°C]</th>
<th>$RH_0$ [%]</th>
<th>Minimum permissible efficiency decay after 12 h$^c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
<td>SO$_2$</td>
<td>9/90$^c$</td>
<td>ppm(v)</td>
<td>UV fluorescence$^d$</td>
<td>2.5</td>
<td>23</td>
<td>50</td>
<td>$&gt;10 %$</td>
</tr>
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</tbody>
</table>

$^a$ For other acid gases SO$_2$ may not be representative. In applications for H$_2$S, NO, NO$_2$, etc. it may be better to test with the gas in question.

$^b$ A test for initial efficiency should not decay during the test but this may be the case if the selected low concentration is well beyond challenge capacity of the filter. Therefore, a maximum permissible efficiency decay during the initial efficiency test is given. A GPCBD not filling this demand may still be tested according to 5.4.

$^c$ The lower or higher concentration is selected depending on filter type/ weight/ purpose/ data sheet. The lower concentration is preferred for toluene while the higher concentration may be needed for all gases to reach the minimum permissible efficiency decay after 12 h.

$^d$ The reference techniques are the ones preferred in this part of ISO 10121. However, other techniques may be used provided that the test supplier can show documented correlation versus the reference technique.

**EXPRESSION OF PERFORMANCE**

- Clean Air Delivery Rate (CADR)
  
  \[ \text{CADR} = \varepsilon_{PAQ} \times Q_{AP} \times (3.6/V) \]
  
  where:
  
  \( Q_{AP} \) is the air flow through the air cleaner, l/s;
  
  \( V \) is the volume of the room, m$^3$.
  
- Air Cleaning Efficiency
  
  \[ \varepsilon_{clean} = 100(C_U - C_D)/C_D \]
  
  where:
  
  \( \varepsilon_{clean} \) is the air cleaning efficiency;
  
  \( C_U \) is the gas concentration before air cleaner;
  
  \( C_D \) is the gas concentration after air cleaner.

- Higher Air Quality Category
  
  \[ \varepsilon_{PAQ} = Q_o / Q_{AP} \times (PAQ / PAQ_{AP} - 1) \times 100 \]
  
  where:
  
  \( \varepsilon_{PAQ} \) is the air cleaning efficiency for perceived air quality;
  
  \( Q_o \) is the ventilation rate without air cleaner, l/s;
  
  \( Q_{AP} \) is the ventilation rate with air cleaner, l/s;
  
  \( PAQ \) is the perceived air quality without the air cleaner, decipol;
  
  \( PAQ_{AP} \) is the perceived air quality without the air cleaner, decipol.
EXPRESSION OF PERFORMANCE

- Reduced Energy Use
  - Heating/Cooling of Supply Air
  - Reduced energy for humidification and/or De-humidification
  - Fan Energy
  - Energy Use of Air Cleaner
  - Heat Recovery or not

- Noise level
  - Reduced air flow in AHU
  - Noise from air cleaner

- Draught level
  - Reduced air flow in occupied space
  - Draught from portable air cleaner

\[
\varepsilon_v = \frac{Q_h}{C_{h,i} - C_{h,o}} \cdot \frac{1}{\varepsilon_v}
\]

where

- \( Q_h \) is the ventilation rate required for dilution, in \( m^3 \) per second;
- \( G_h \) is the generation rate of the substance, in micrograms per second;
- \( C_{h,i} \) is the guideline value of the substance, in micrograms per \( m^3 \);
- \( C_{h,o} \) is the concentration of the substance of the supply air, in micrograms per \( m^3 \);
- \( \varepsilon_v \) is the ventilation effectiveness.

\[ PD = 395 \cdot \exp (-15.15 \cdot C_{CO_2} ^{-0.25}) \]
Issues

• International Standards for Ventilation (Indoor Air Quality) like EN16798-1, ISO17772-1 and ASHRAE 62.1 are mainly based on criteria for the Perceived Air Quality (PAQ), sometimes expressed as levels of CO₂ as a tracer for emission from occupants.
• If air cleaning is used, an equivalent level of air quality will be reached at higher CO₂ concentrations.
• It is also assumed that when ventilation is used for PAQ, the required ventilation will also dilute other substances like Radon, VOCs.
• The decreased ventilation rate when using gas phase air cleaning may not be sufficient.

ΔCO₂ levels considering a 30 % reduced ventilation rate due to air cleaners

<table>
<thead>
<tr>
<th>Space type</th>
<th>Category</th>
<th>Derived from qtot</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Indoor CO₂ level above outdoor level ΔCO₂ [ppm]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very low-polluting building</td>
</tr>
<tr>
<td>Single office</td>
<td></td>
<td>IEQₜ</td>
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<tr>
<td></td>
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<td>IEQₜ</td>
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<tr>
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With air cleaner

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<td>With air cleaner</td>
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</table>
Issues

- Today, gas phase air cleaners are tested based on a chemical measurement, which do not account for the influence on PAQ and human bio effluents as a source of pollution.
- Studies have shown that some gas phase air cleaning technologies will not work when humans are the source, and the evaluation is done by PAQ.
- There is a need for new test standards
- Testing with PAQ requires a measurement of subjective reactions
- Testing with human bio effluents as a source requires the use of humans as a source

Testing Issues

- If only a test with chemical measurements is done, should it be allowed to reduce the building component?
- How to standardise the building source?
- How to standardise the human bio effluent source?
- It is a relative measurement, which makes some of the issues less important
- A test method using PAQ is voluntary; but will give the industry a possibility to show that their air cleaner can improve the IAQ and the ventilation rate can be decreased.