Understanding Filtration Efficiency Ratings

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Presentation Objectives

1. Suggest key factors to consider when beginning to evaluate filter options for your inlet system.

2. Provide general understanding of criteria used to establish filtration efficiency ratings based on the following standards...
   - ASHRAE 52.2
   - EN1822
   - ISO 29461-1 (new standard)

3. Follow up with a reference tool to help remember key points from each standard.

4. Address questions.
Your Inlet System

- Pulse vs. Static
- Turbine inlet airflow (800,000 – 890,000 CFM)
- Number of air filters/filter pairs
- Airflow per filter/filter pair (Turbine inlet airflow divided by number of filters/filter pairs)
- Type of filters
  - Panel filters
  - Canister type filters
  - Cylindrical filters
  - Cylindrical/cylindrical pairs
  - Conical/cylindrical pairs
Your Application

- Operating mode (base, intermediate, peak)
- Inlet operation mode (pulsing operation)
- Environment
  - Moisture (RH, coastal, rain, fog, mist, snow, sleet, cooling tower drift, etc.)
  - Hydrocarbons, salts, dust concentration
  - Local or seasonal airborne contaminants (pollen, cotton seed blossom, insects, etc.)
- O&M Opportunities/Challenges
  - Power degradation
  - Maintenance; flexibility, costs
  - Compressor cleanliness
Filter Construction Materials

● Media
  - Glass fiber
  - Cellulose & Synthetic blend (*blended media*)
  - Nano-fibers (*Donaldson Spider-Web®*)
  - Membrane (*ePTFE*)
  - Spunbond
  - Meltblown
  - Proprietary blends
  - Proprietary composites
  - Charged medias
Filter Efficiency

- MERV Rating
- G Rating
- M Rating
- F Rating
- EPA
- HEPA
- ULPA

ASHRAE52.2
EN779
EN1822
## The Filter Test “In General”

<table>
<thead>
<tr>
<th>Pre-determined filter configuration &amp; Pre-treatment</th>
<th>Conical/Cylindrical Pair. IPA soak/spray/vapor required in some cases.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-determined test airflow rate</td>
<td>1,630 (ideally at or above your inlet actual airflow rate)</td>
</tr>
<tr>
<td>Measure restriction</td>
<td>25%, 50%, 75%, 100%, &amp; 125% of pre-determined test airflow or simply 100%.</td>
</tr>
<tr>
<td>“The Challenge” – Initial Efficiency</td>
<td>Introduce challenge aerosol into airstream, categorize by size and count particles on upstream and downstream side of filter (dirty air/clean air).</td>
</tr>
<tr>
<td>“Dust Loading”</td>
<td>Some standards load dust to a final restriction point and measure efficiency at various intervals.</td>
</tr>
</tbody>
</table>
Resulting Data “In General”

● **Resistance to airflow**
  • Filter type and configuration
  • Test airflow rate (*flow per filter/filter pair*)

● **Filtration efficiency data**
  • Initial/Minimum efficiency (*initial is not always minimum; static charged filters*)
  • Minimum efficiency
  • Average efficiency

● **Dust Holding Capacity** (if applicable)

● **Filter Rating**
ASHRAE52.2

● **Efficiency Rating**
  • MERV (minimum efficiency reporting value)

● **Resistance to airflow**
  • Measured at 25%, 50%, 75%, 100%, & 125% of test airflow

● **Challenge**
  • Dry potassium chloride aerosol (KCL)

● **Filtration Efficiency**
  • Initial/minimum efficiency; average of “E1” category (0.3µ - 1.0µ, high efficiency filters, MERV13 and up)

● **Element Pre-Treatment**
  • None

● **Dust Loading**
  • ASHRAE dust to 4.0”WG
<table>
<thead>
<tr>
<th>Group</th>
<th>MERV Rating</th>
<th>(E1) Composite Avg. Particle Size Efficiency (PSE) 0.3 - 1.0 Microns</th>
<th>(E2) Composite Avg. Particle Size Efficiency (PSE) 1.0 - 3.0 Microns</th>
<th>(E3) Composite Avg. Particle Size Efficiency (PSE) 3.0 - 10.0 Microns</th>
<th>Average Arrestance by ASHRAE 52.1 Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MERV 1</td>
<td>---</td>
<td>---</td>
<td>Less than 20%</td>
<td>&lt; 65%</td>
</tr>
<tr>
<td></td>
<td>MERV 2</td>
<td>---</td>
<td>---</td>
<td>Less than 20%</td>
<td>65% - 69.9%</td>
</tr>
<tr>
<td></td>
<td>MERV 3</td>
<td>---</td>
<td>---</td>
<td>Less than 20%</td>
<td>70% - 74.9%</td>
</tr>
<tr>
<td></td>
<td>MERV 4</td>
<td>---</td>
<td>---</td>
<td>Less than 20%</td>
<td>≥ 75%</td>
</tr>
<tr>
<td>2</td>
<td>MERV 5</td>
<td>---</td>
<td>---</td>
<td>20% - 34.9%</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>MERV 6</td>
<td>---</td>
<td>---</td>
<td>35% - 49.9%</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>MERV 7</td>
<td>---</td>
<td>---</td>
<td>50% - 69.9%</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>MERV 8</td>
<td>---</td>
<td>---</td>
<td>70% - 84.9%</td>
<td>---</td>
</tr>
<tr>
<td>3</td>
<td>MERV 9</td>
<td>---</td>
<td>Less than 50%</td>
<td>≥ 85%</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>MERV 10</td>
<td>---</td>
<td>50% - 64.9%</td>
<td>≥ 85%</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>MERV 11</td>
<td>---</td>
<td>65% - 79.9%</td>
<td>≥ 85%</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>MERV 12</td>
<td>---</td>
<td>80% - 89.9%</td>
<td>≥ 90%</td>
<td>---</td>
</tr>
<tr>
<td>4</td>
<td>MERV 13</td>
<td>Less than 75%</td>
<td>≥ 90%</td>
<td>≥ 90%</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>MERV 14</td>
<td>75% - 84.9%</td>
<td>≥ 90%</td>
<td>≥ 90%</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>MERV 15</td>
<td>85% - 94.9%</td>
<td>≥ 90%</td>
<td>≥ 90%</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>MERV 16</td>
<td>≥ 95%</td>
<td>≥ 90%</td>
<td>≥ 90%</td>
<td>---</td>
</tr>
</tbody>
</table>
EN779:2002

- **Efficiency Rating**
  - “G”, “M”, “F”

- **Resistance to airflow**
  - Measured at 25%, 50%, 75%, 100%, & 125% of test airflow

- **Challenge**
  - Neutralized DEHS aerosol (oil)

- **Filtration Efficiency**
  - Weighted avg efficiency @ 0.4µ particle size (initial & loaded up to 1.8”WG resistance (6 points, initial plus 5))

- **Element Pre-Treatment**
  - None

- **Dust Loading**
  - ASHRAE dust to 450 Pa/1.8”WG
## EN779:2002

<table>
<thead>
<tr>
<th>Group</th>
<th>Class</th>
<th>Final test pressure drop (Pa)</th>
<th>Average arrestance (Am) of synthetic dust (%)</th>
<th>Average efficiency (Em) of 0.4μ particles (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse</td>
<td>G1</td>
<td>250</td>
<td>50 (\leq) Am (&lt; 65)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>G2</td>
<td>250</td>
<td>65 (\leq) Am (&lt; 80)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>G3</td>
<td>250</td>
<td>80 (\leq) Am (&lt; 90)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>G4</td>
<td>250</td>
<td>90 (\leq) Am</td>
<td>-</td>
</tr>
<tr>
<td>Medium</td>
<td>M5</td>
<td>450</td>
<td>-</td>
<td>40 (\leq) Em (&lt; 60)</td>
</tr>
<tr>
<td></td>
<td>M6</td>
<td>450</td>
<td>-</td>
<td>60 (\leq) Em (&lt; 80)</td>
</tr>
<tr>
<td>Fine</td>
<td>F7</td>
<td>450</td>
<td>-</td>
<td>80 (\leq) Em (&lt; 90)</td>
</tr>
<tr>
<td></td>
<td>F8</td>
<td>450</td>
<td>-</td>
<td>90 (\leq) Em (&lt; 95)</td>
</tr>
<tr>
<td></td>
<td>F9</td>
<td>450</td>
<td>-</td>
<td>95 (\leq) Em</td>
</tr>
</tbody>
</table>
EN779:2012

- Improve Performance of Air Filters
- Establish Minimum Efficiency defined as lowest efficiency of the following…
  - Initial efficiency
  - Treated initial efficiency (flat sheet)
  - Average efficiency (dust loading)
EN779:2012

- **Efficiency Rating**
  - “G”, “M”, “F”

- **Resistance to airflow**
  - Measured at 25%, 50%, 75%, **100%**, & 125% of test airflow

- **Challenge**
  - Neutralized DEHS aerosol (oil)

- **Filtration Efficiency**
  - Minimum efficiency (initial, IPA treated initial, average)

- **Element Pre-Treatment**
  - IPA soak, flat sheet.

- **Dust Loading**
  - ASHRAE dust to 450 Pa/1.8”WG
The characteristics of atmospheric dust vary widely compared to those of the synthetic dust used in the EN779 tests. Because of this, the test results do not provide a completely accurate basis for predicting either operational performance or service life. Loss of media charge or shedding of particles or fibers can also adversely affect efficiency.

Minimum efficiency is the lowest of any of the following three values: initial efficiency, discharged efficiency or efficiency throughout the test’s loading procedure.
EN1822

- Efficiency Rating
  - “E”, “H”, “U” (EPA, HEPA, ULPA)

- Resistance to airflow
  - 100% of test airflow

- Challenge
  - Neutralized DEHS aerosol (oil)

- Filtration Efficiency
  - Initial efficiency @ most penetrating particle size (generally 0.1µ for gas turbine inlet filters)

- Element Pre-Treatment
  - Mfg obliged to IPA in 2009 standard when deliberately charged material is used.

- Dust Loading
  - None
### Table 1 — Classification of EPA, HEPA and ULPA filters

<table>
<thead>
<tr>
<th>Filter Group</th>
<th>Filter Class</th>
<th>Integral value</th>
<th>Local value</th>
<th>Efficiency (%)</th>
<th>Penetration (%)</th>
<th>Efficiency (%)</th>
<th>Penetration (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Efficiency (%)</td>
<td>Penetration (%)</td>
<td></td>
<td></td>
<td>Local value</td>
<td>Penetration (%)</td>
</tr>
<tr>
<td></td>
<td>E 10</td>
<td>≥ 85</td>
<td>≤ 15</td>
<td></td>
<td></td>
<td>...c</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E 11</td>
<td>≥ 95</td>
<td>≤ 5</td>
<td></td>
<td></td>
<td>...c</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E 12</td>
<td>≥ 99,5</td>
<td>≤ 0,5</td>
<td></td>
<td></td>
<td>...c</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H 13</td>
<td>≥ 99,95</td>
<td>≤ 0,05</td>
<td>≥ 99,75</td>
<td>≤ 0,25</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>H 14</td>
<td>≥ 99,995</td>
<td>≤ 0,005</td>
<td>≥ 99,975</td>
<td>≤ 0,025</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>U 15</td>
<td>≥ 99,999 5</td>
<td>≤ 0,000 5</td>
<td>≥ 99,997 5</td>
<td>≤ 0,002 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>U 16</td>
<td>≥ 99,999 95</td>
<td>≤ 0,000 05</td>
<td>≥ 99,999 75</td>
<td>≤ 0,000 25</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>U 17</td>
<td>≥ 99,999 995</td>
<td>≤ 0,000 005</td>
<td>≥ 99,999 9</td>
<td>≤ 0,000 1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**a** See 7.5.2 and EN 1822-4.

**b** Local penetration values lower than those given in the table may be agreed between supplier and purchaser.

**c** Group E filters (Classes E10, E11 and E12) cannot and shall not be leak tested for classification purposes.
New Series for Rotating Machinery

- **ISO 29461-1**: Static filter elements – published 2013
- ISO 29461-2: Pulse jet filter systems
- ISO 29461-3: Integrity testing
- ISO 29461-4: In-situ testing
- ISO 29461-5: Marine and Off-shore filters
- ISO 29461-6: Pulse jet cartridge testing method
<table>
<thead>
<tr>
<th>Standard</th>
<th>Ratings</th>
<th>Description</th>
<th>Resistance to Airflow</th>
<th>Filtration Efficiency</th>
<th>Dust Loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASHRAE 52.2</td>
<td>MERV (minimum efficiency rating value)</td>
<td>Broadly accepted as the standard for measuring GT inlet filtration efficiency in North America.</td>
<td>Initial &amp; 5 increments of dust loading</td>
<td>Minimum Efficiency Rating - based on average efficiency particle size groups (E1, E2, E3).</td>
<td>ASHRAE Dust to 4.0&quot; WG.</td>
</tr>
<tr>
<td>EN779:2002</td>
<td>F7 - F9</td>
<td>Broadly accepted as the standard for measuring GT inlet filtration efficiency in Europe and to some degree North America.</td>
<td>Initial &amp; 5 increments of dust loading</td>
<td>Average Efficiency Rating - based on weighted average efficiency @ 0.4µ particle size.</td>
<td>ASHRAE Dust to 1.8&quot; WG.</td>
</tr>
<tr>
<td>EN779:2012</td>
<td>F7 - F9</td>
<td>Recently updated version of EN779:2002. Rating is now based on minimum efficiency</td>
<td>Initial &amp; 5 increments of dust loading</td>
<td>Lowest efficiency @ 0.4µ particle size of the following; 1.) Initial efficiency 2.) Treated initial efficiency, 3.) Average efficiency (dust loading)</td>
<td>ASHRAE Dust to 1.8&quot; WG.</td>
</tr>
<tr>
<td>EN1822</td>
<td>E10 - E12 H13, H14 U15 - U17</td>
<td>Internationally accepted as the standard for measuring EPA, HEPA, and ULPA filtration efficiency.</td>
<td>Initial only</td>
<td>Initial Efficiency Rating - based on efficiency at most penetrating particle size.</td>
<td>No dust loading.</td>
</tr>
</tbody>
</table>
## Summary: Filtration Efficiency Measurements

<table>
<thead>
<tr>
<th>Size Range μ</th>
<th>0.05</th>
<th>0.10</th>
<th>0.15</th>
<th>0.20</th>
<th>0.25</th>
<th>0.30</th>
<th>0.35</th>
<th>0.40</th>
<th>0.45</th>
<th>0.50</th>
<th>0.55</th>
<th>0.60</th>
<th>0.65</th>
<th>0.70</th>
<th>0.75</th>
<th>0.80</th>
<th>0.85</th>
<th>0.90</th>
<th>0.95</th>
<th>1.00</th>
<th>2.00</th>
<th>3.00</th>
<th>4.00</th>
<th>5.00</th>
<th>6.00</th>
<th>7.00</th>
<th>8.00</th>
<th>9.00</th>
<th>10.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
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<td>E2</td>
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<td>E3</td>
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</tbody>
</table>

- **EN1822 (0.05μ - 0.52μ)**
- **ASHRAE 52.2 (0.3μ - 10.0μ)**
- **EN779 (0.2μ - 10.0μ)**
Conclusion

- It is very important to understand your inlet, application, environment, and filtration objectives when choosing GT inlet filters.
- 3rd party test reports can offer valuable information to help compare filters.
- Understanding how factors such as static charged filter media can effect test results and performance is very important.
- Leverage key industry resources:
  - Your past experience.
  - Fellow users
  - Credible vendors/partners