A new HEPA solution for gas turbine inlet air filtration

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Agenda

• The Problem
• What is HEPA Filtration?
• New HEPA Filtration Solution
• Case Studies
The Problem

• Gas turbines consume enormous amounts of air for combustion
  – GE 7FA: 360 Billion Ft$^3$/year

• That air contains contaminants large and small
  – Dirt, salt, moisture, sand, soot, insects, corrosive gasses….

• Dirty air causes lost efficiency and can ultimately destroy a turbine
  – Compressor fouling, blocked cooling passages, blade erosion, low and high temp corrosion, foreign object damage
The Problem

• Inlet air filtration aims to reduce contaminants in the air stream without imposing a large pressure drop penalty

• Conventional filters are very inefficient at capturing sub-micron particles and allow liquids and dissolved contaminants to pass

• HEPA filters are better at capturing submicron particles, but in the past have been challenged by relatively high pressure drops and limited life
What is HEPA Filtration?
(High Efficiency Particulate Air)
Sub-Micron Distribution in Urban Air

Particle Distribution (urban)

100 times more 0.1µ particles than 0.5µ

Visible particle = 40µ
Particle Size Range of Current Standards
(Don’t measure below 0.3µ)

Particle Distribution (urban)

EU Standard

EN779

US Standard

ASHRAE 52.2
HEPA Standard EN1822 Addresses <0.3 Micron Issue
To Capture the Performance of HEPA Filters, Need a Different Test (EN1822) and Scale

- MERV15/F9
- GORE H12/E12
- Nanofibers / Synthetic
- Nanofibers / Cellulose
- Cellulose

*Most Penetrating Particle Size (MPPS)*

Minimum required for H12 rating
## Filter Classifications

<table>
<thead>
<tr>
<th>Filter Class</th>
<th>Efficiency</th>
<th>Particle Size</th>
<th>EN779</th>
<th>ASHRAE 52.2</th>
<th>EN1822 2005/2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine Filters</td>
<td>80% ≤ $E_m$ ≤ 90% E1 &lt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>75% ≤ $E_m$ ≤ 95% 75% ≤ E1 ≤ 85%</td>
<td>0.4µm/0.3-1.0 avg.</td>
<td>F7</td>
<td>MERV 13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>95% ≤ $E_m$ 85% ≤ E1 ≤ 95% 95% &lt; E1</td>
<td>0.4µm/0.3-1.0 avg.</td>
<td>F8</td>
<td>MERV 14</td>
<td></td>
</tr>
<tr>
<td>EPA/HEPA Filters</td>
<td>&gt;85%</td>
<td>MPPS</td>
<td></td>
<td>MERV 16</td>
<td>H10/E10</td>
</tr>
<tr>
<td></td>
<td>&gt;95%</td>
<td>MPPS</td>
<td></td>
<td></td>
<td>H11/E11</td>
</tr>
<tr>
<td></td>
<td>&gt;99.5%</td>
<td>MPPS</td>
<td></td>
<td></td>
<td>H12/E12</td>
</tr>
</tbody>
</table>
What is a HEPA Filter?

- Rating is based on the minimum capture rate of the Most Penetrating Particle Size (MPPS), typically about 0.1 microns.

<table>
<thead>
<tr>
<th>HEPA Rating</th>
<th>Efficiency at MPPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>H10/E10</td>
<td>&gt; 85%</td>
</tr>
<tr>
<td>H11/E11</td>
<td>&gt; 95%</td>
</tr>
<tr>
<td>H12/E12</td>
<td>&gt; 99.5%</td>
</tr>
</tbody>
</table>
There Are Different HEPA Ratings For a Reason

Uncaptured Pollutants [kg/yr]

- F9 Filter Grade (MERV 15) 29 lb/yr
- E10 Filter Grade 135X 12.3 lb/yr
- E12 GORE® Turbine Filter X = 0.09 lb/yr

Representative pollutants which pass through a 25 MW turbine during one year of operation.

Turbine will still foul due to low efficiency filters.
GORE® Turbine Filters: High Efficiency (E12) with Low Pressure Drop

- Pre-filter Layer removes Bulk of large Particles
- High Efficiency Membrane Removes Submicron Dust, Water, and Salt
- High Strength Backer Provides Burst Strength
GORE Membrane Technology

Waterproof Media Provides Water & Salt Retention

Salt dust, water, and aqueous salt solutions are repelled

Air can pass through the membrane
Stopping the Fouling from small particles

Example of benefits realized by Turbine Operators
Coastal Operation With Coal Dust, Losing 10% Power Between Offline Washes - (RB211-30MW) - UK
Constant Power Output with Gore Filters
Coastal Power Plant (RB211-30MW) - UK

Current Filters
3 off-line washings/yr.

Gore Filters
0 off-line washings/yr.

Power Variance from corrected target (MW)

Days
Reduced Engine Wear: Coastal & Coal Dust - (RB211-30MW) - UK

20,000 hrs w/ no on- or off-line washes
Coastal Petrochemical Plant (Texas) That Cannot Shutdown for 1 Year

GORE® E12 Turbine Filters With Coalescers
Constant Power Output with Gore Filters
Petrochemical Plant (GE Frame 6B - 35MW) - Texas
8,000+ hrs
No Wash
Constant Power Output with Gore Filters
Petrochemical Plant (GE 6B – 35MW) – Texas

GE Frame 6B

Power Load

Compressor Efficiency

80°F < Temperature ≤ 90°F

Hrs of Operation

7,850 Hrs

34.4 MW (GORE)
31.0 MW (F8)
3.4 MW Gain

90.2% (GORE)
87.6% (F8)
2.6% Gain

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LM6000 after >2 years with GORE® Turbine Filters

After 15075 hrs.

After 18500 hrs.

After 8500 hrs.
Clean Power Plant Turbine – Oregon
Mitsubishi 501G (265MW)

After 2000 hours
After 4000 hours
After 10,000 hours
Eliminating Off-Line Washes - Confirmed via Boroscope and Wash Water Comparison

<table>
<thead>
<tr>
<th>End User</th>
<th>Off-line washes/yr with F-Class (MERV) filters</th>
<th>Off-line washes/yr after installing GORE® H12 Turbine Filters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastics Mfg. (coastal)</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Brewery (coastal)</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Food</td>
<td>26</td>
<td>0</td>
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<tr>
<td>University</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Ceramics</td>
<td>52</td>
<td>0</td>
</tr>
<tr>
<td>Power (coastal)</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Power - Refinery (coastal)</td>
<td>9</td>
<td>0</td>
</tr>
</tbody>
</table>
GORE® HEPA Turbine Filters Eliminate Compressor Fouling:

Simple retrofit

- Similar initial pressure drop
- Similar filter life
Should I Invest in HEPA Filtration?

1. Compare power output versus previous experience. Power output will be effectively constant with Gore filters. Can also measure compressor efficiency as a proxy for power output.

2. Quantify value of stopping off-line washes (availability, cost of shutdown with no power output). Gore product eliminates off-line washes.

3. Quantify value of constant heat rate versus previous increases, fuel savings.

4. Compare reduced costs due to elimination of extensive compressor section cleaning during scheduled major maintenance.

5. Measure blade or rotor corrosion rates over time.
Turbine Filters

MORE POWER, LESS WEAR

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