A New HEPA Solution for GT Inlet Air Filtration

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Frame 6 Users Group
League City, TX

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Agenda

• The Problem
• What is HEPA Filtration?
• Gore’s HEPA Technical Approach
• Case Studies
The Problem

• Gas turbines consume enormous amounts of air for combustion
  – GE 7FA: ~360 Billion Ft³/year
  – GE 6B: ~115 Billion Ft³/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 good at capturing large particles.

- 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)

US Standard

EU Standard

EN779

ASHRAE 52.2

Particle Size [μm]

Particle Number (normalized)
HEPA Standard EN1822 Addresses <0.3 Micron Issue

Particle Distribution (urban)

Particle Size [µm]

Particle Number (normalized)

EN1822

EN779

ASHRAE 52.2
To Capture the Performance of HEPA Filters, Need a Different Test (EN1822) and Scale
## 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><strong>Fine Filters</strong></td>
<td>80% ≤ (E_m) ≤ 90% (E_1 &lt;)</td>
<td>0.4μm/0.3-1.0 avg.</td>
<td>F7</td>
<td>MERV 13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>75% ≤ (E_m) ≤ 95% (75% ≤ E_1 ≤ 85%)</td>
<td>0.4μm/0.3-1.0 avg.</td>
<td>F8</td>
<td>MERV 14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>95% ≤ (E_m) (85% ≤ E_1 ≤ 95%) 95% &lt; (E_1)</td>
<td>0.4μm/0.3-1.0 avg.</td>
<td>F9</td>
<td>MERV 15</td>
<td></td>
</tr>
<tr>
<td><strong>EPA/HEPA Filters</strong></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?

- Defined by EN1822 standard. Were called “H”, now “E” ratings
- 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

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

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

Turbine will still foul due to low efficiency filters

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Frame 6B User’s Conference/June 2013
Tom Kelmartin
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
Panel Filter Case Study – BASF, Geismar LA
Panel Filter Case Study – BASF, Geismar LA

- Objective: Determine the effectiveness and service lifetime of an E12 HEPA inlet filter system
  - V-Panel style

- GE 6B, base loaded
- Heavy industrial, agricultural, coastal (Mississippi River)
- 120 Gore “V-Panel” filters, MERV12 pre-filter with a disposable G2 coarse pad
Panel Filter Case Study – BASF, Geismar LA

- On-line data collection for filter flow and individual filter stage DP
- Installed May 2011 and continuing
Panel Filter Case Study – BASF, Geismar LA

- On-line data collection for filter flow and individual filter stage DP
- Installed May 2011 and continuing
BASF Geismar LA, Frame 6B
(Data Courtesy BASF/JC Rawls)

Compressor Efficiency

Inlet Temp °F

Predicted MW

Actual MW

Inlet Filter DP
BASF Geismar Filter DP (Inch WG)

- Total DP
- MERV12 Prefilter + G2 Wrap
- G2 Wrap
- V-Panel

2 Years

Continuing Ops
G2 Wrap Change-out (Inch WG)

- Change-out
- Total DP
- V-Panel
- Prefilter + G2
- G2

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Observations from BASF-Geismar

• HEPA filter system has succeeded in keeping the compressor efficiency and power output steady
• Maintenance of pre-filters is effectively protecting V-panels, extending lifetime
• Regularly scheduled off-line washes no longer required, on-line washing eliminated
• Filter replacement frequency reduced
Cartridge Filter Case Study – Chevron, El Segundo CA
Cartridge Filter Case Study
– Chevron, El Segundo CA

• Objective: Determine the effectiveness and service lifetime of an E12 HEPA inlet filter system
  – Cartridge (cylindrical) style

• GE 6B, base loaded
• Heavy industrial, urban, coastal (Pacific Ocean)
• 448 Gore cartridge filters with coalescing wrap
Chevron El Segundo CA, Frame 6B
(Data Courtesy Chevron/Mike Wenschlag)

GT Upgrade

Filter Approaching End of Service Lifetime

Comp Eff % vs. DP Inch WG

2 Years
Continuing Ops

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Chevron El Segundo CA, Frame 6B
(Data Courtesy Chevron/Mike Wenschlag)

A-Train Raw MW

(Data courtesy Chevron/Mike Wenschlag)
Observations from Chevron-El Segundo

- Compressor efficiency and power output steady
- 2 years+ HEPA filter lifetime achieved
- Need for off-line washes greatly diminished
- Impact of moisture/fog on filter DP very minor during first 2 years of operation
  - Frequent DP spikes during fog events indicates nearing end of filter service life
Coastal Petrochemical Plant (Texas)
(Courtesy ExxonMobil-Greg Polasek)

GORE® E12 Turbine Filters With Coalescers
Petrochemical Plant (GE Frame 6B - 35MW)  
(Courtesy ExxonMobil-Greg Polasek)

8,000+ hrs 
No Wash
Petrochemical Plant (GE 6B – 35MW) – Texas
(Data Courtesy ExxonMobil-Greg Polasek)

GE Frame 6B

Compressor Efficiency

Power Load

Hrs of Operation

80°F < Temperature ≤ 90°F

34.4 MW (GORE)
31.0 MW (F8)

7,850 Hrs

3.4 MW Gain

90.2% (GORE)
87.6% (F8)

2.6% Gain
Should I Invest in HEPA Filtration?

1. Compare power output versus previous experience. Power output will be effectively constant. Will this reduce the need to purchase power?

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

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.
Annual Power Replacement Cost
(8,000 Hours)

MW Lost Between Washes
$1,000's

$20/MWHr

$40/MWHr

$60/MWHr

$80/MWHr
Annual Power Replacement Cost
(8,000 Hours)

For Example: 3MW loss at $40/MWHr replacement cost = $480,000 annual cost
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New V-Panel design – resulted from customer feedback during trials
GORE® HEPA Turbine Filters Eliminate Compressor Fouling:

Simple retrofit

- Similar initial pressure drop
- Similar filter life
Acknowledgements

• JC Rawls

• Mike Wenschlag

• Greg Polasek/Jeff Gillis
Thank-you!

Turbine Filters
MORE POWER, LESS WEAR