

20th SYMPOSIUM ON INDUSTRIAL APPLICATIONS OF GAS TURBINES



Long Term Assessment of Hydrophobic HEPA Filters for Improving Availability of Pipeline Gas Turbines

By

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Operate a Fleet of Turbines on the Alliance Gas Pipeline



Fleet Details

19 Dry Low Emissions (DLE) turbines from Solar, Siemens and GE in Base Load operation

- 1 Solar Taurus and 2 Siemens SGT-200 Tornados in the collection fields in British Columbia and Alberta
- 2 GE LM2500 Plus & 1 GE LM2500 Plus G4 at the first mainline pumping station
- 12 GE LM2500 Base & 1 GE LM2500 Plus spaced about 125 miles apart across Canada and into US

Fleet Details

19 Dry Low Emissions (DLE) turbines from Solar, Siemens and GE in Base Load operation

- Units run 24/7/365 with the exception of the outages for maintenance
- Fewer shut downs = Fewer potential start up problems

Offline Water Washes

- The environment surrounding the units at Alliance Pipeline forced us to water wash each gas turbine three times per year - spring, summer and fall.
- 19 GT's x 3 water washes = **57 water washes/year**
 - Required more than 1000 man hours to service these washes
 - Additional disposal of 13,000 liters of demineralized water and 120 liters of soap

Why Water Wash?

- Particulate fouling

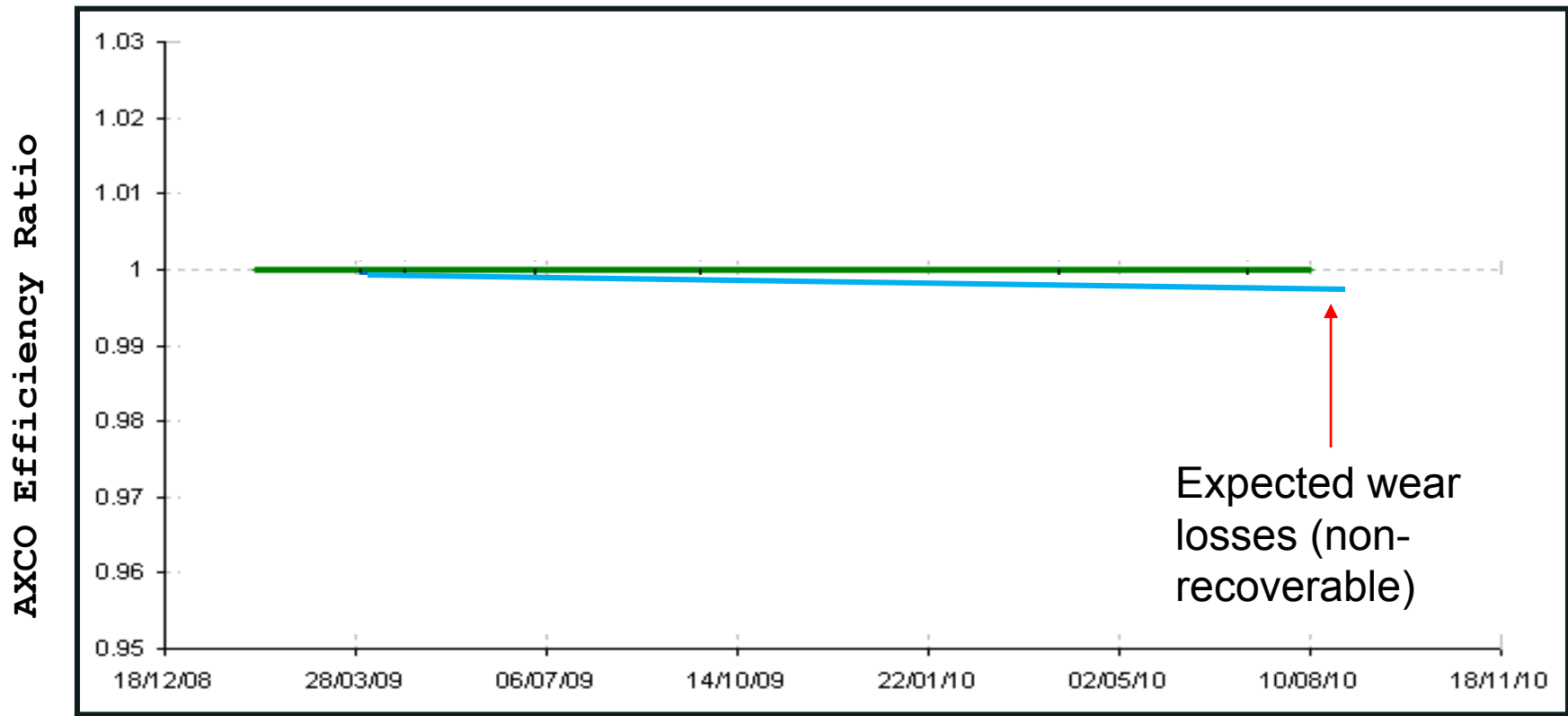
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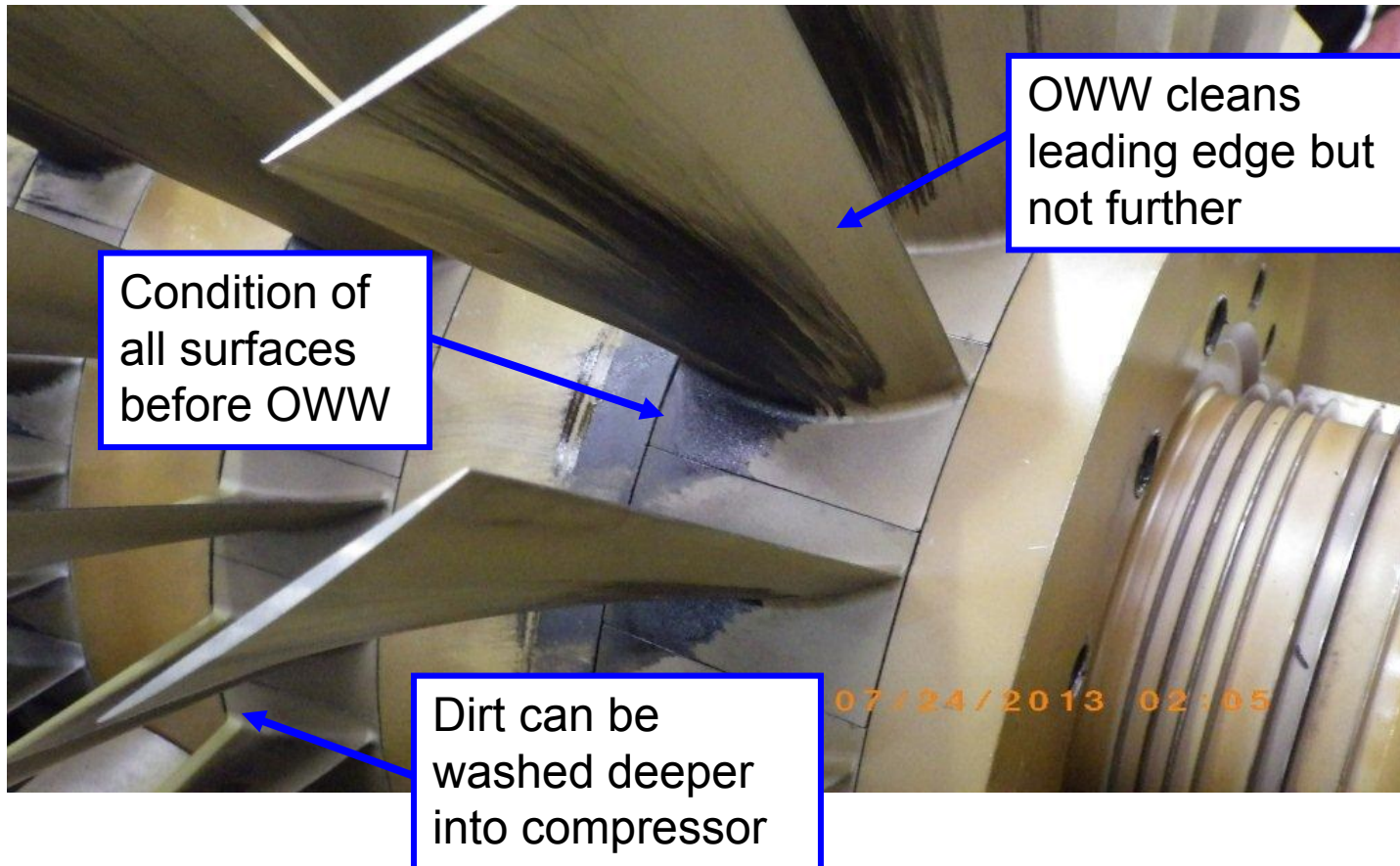
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Recoverable Efficiency Losses from Fouling (Triangles indicate efficiency losses)



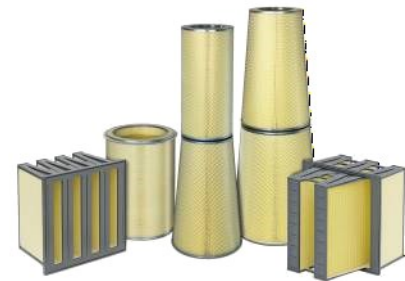
Offline Water Washing can only do so much

- Seimens Unit from Alliance Fleet.
- Visible dirt is remaining following Offline Water Wash



An Alternative to Water Washing

- What if we could eliminate fouling through better air inlet filtration?
- In early 2010, HEPA filters were being introduced by W.L. Gore & Associates to this industry and were being tested at various locations, claiming:
 - Simple replacement retrofit
 - Eliminate off-line washing
 - Operate filters at same pressure drop as current lower efficiency filters
 - Expect similar filter life as current filters
 - Stop water and salt ingress into the turbine from hydrophobic nature of the filter media



Installation of Demo Units

- Reached an agreement with Gore to install full scale Demonstration sets of filters at two Alliance sites
- Chose to test in two different environments:
 - Windfall, Alberta, Canada
 - LM2500 Plus G4,
 - forestry environment.
 - This is the highest horsepower unit in the fleet
 - Kerrobert, Saskatchewan, Canada
 - LM2500 Base,
 - agricultural environment

Installed 2 Demo sites in Spring 2010



**Simple replacement
retrofit**



Minor Repairs to Meet HEPA Quality Filter House Sealing



- Cleaned sealing surfaces
- Replaced rusted & bent bolts
- Replaced worn access hatch gaskets

Check-up on Windfall Unit (Forestry Environment)

- Shutdown at 8000 hrs (~ 1 yr) year for Hot Section Exchange
 - Borescope inspection revealed clean compressor
 - Offline water wash performed to check filter performance
 - Wash water came out clean, not dirty
 - No efficiency gain or power recovery (none was lost)
- No water washes in following 18,450 hrs (2.5 years)

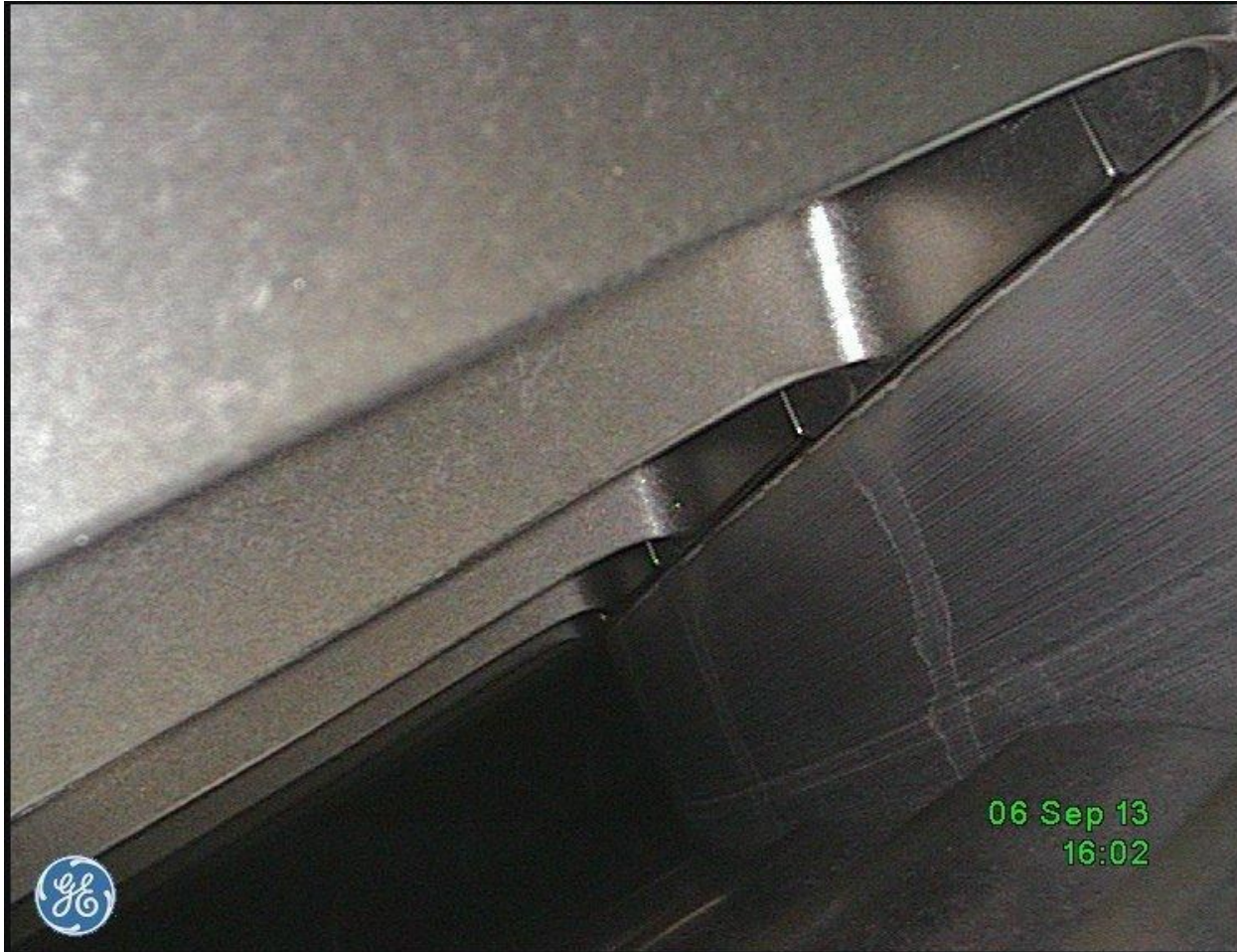
Stage 2 VSV Inner Shroud



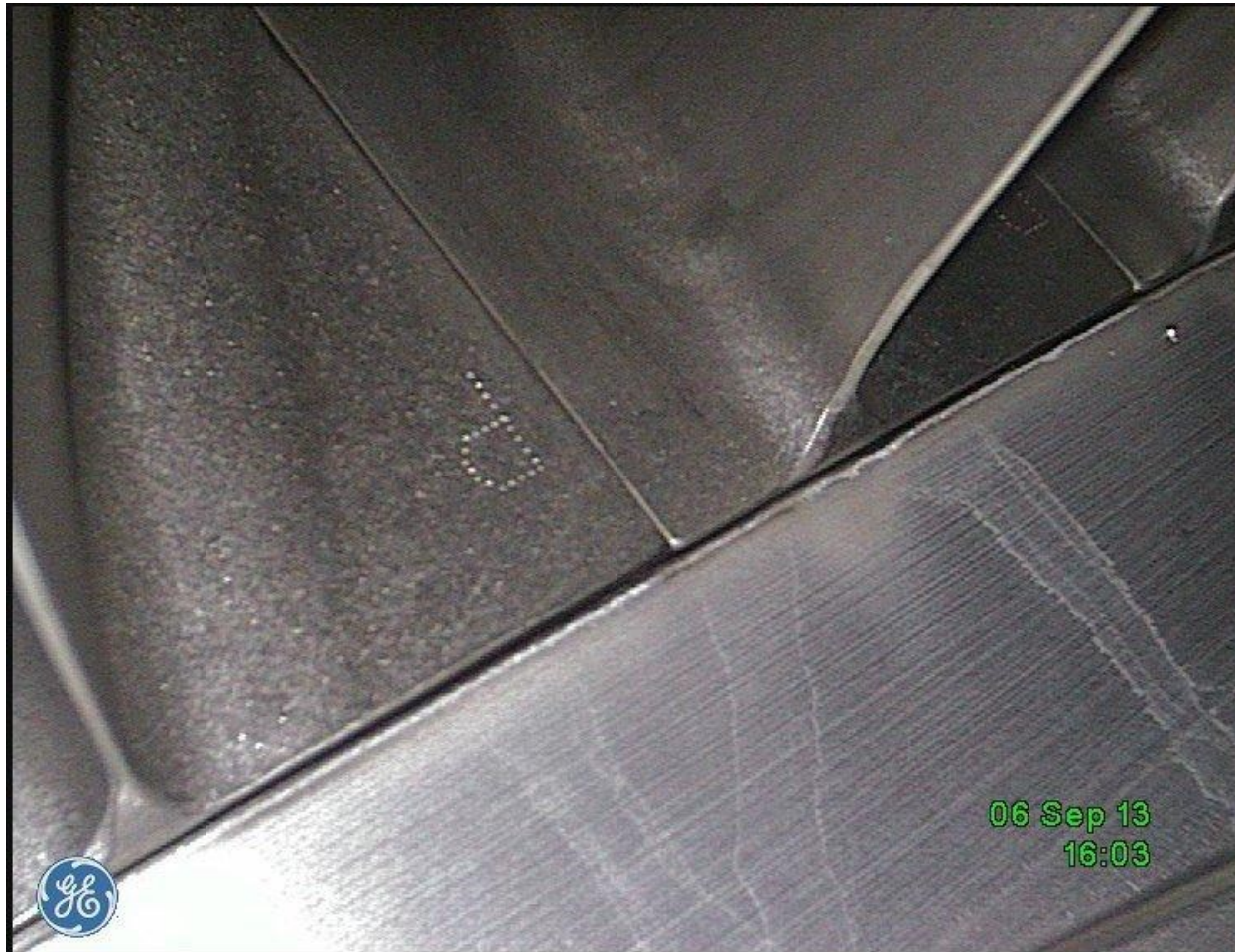
Stage 2 VSV Outer Bearings



Stage 3 Blade Roots



Stage 3 Blade Roots



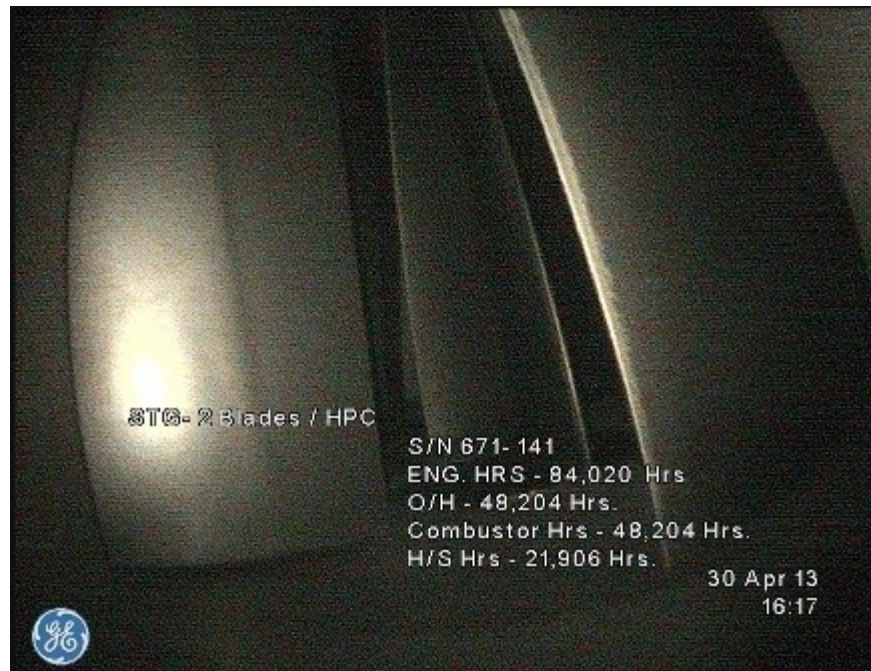
Stage 3 Stator Tips & Blade Roots



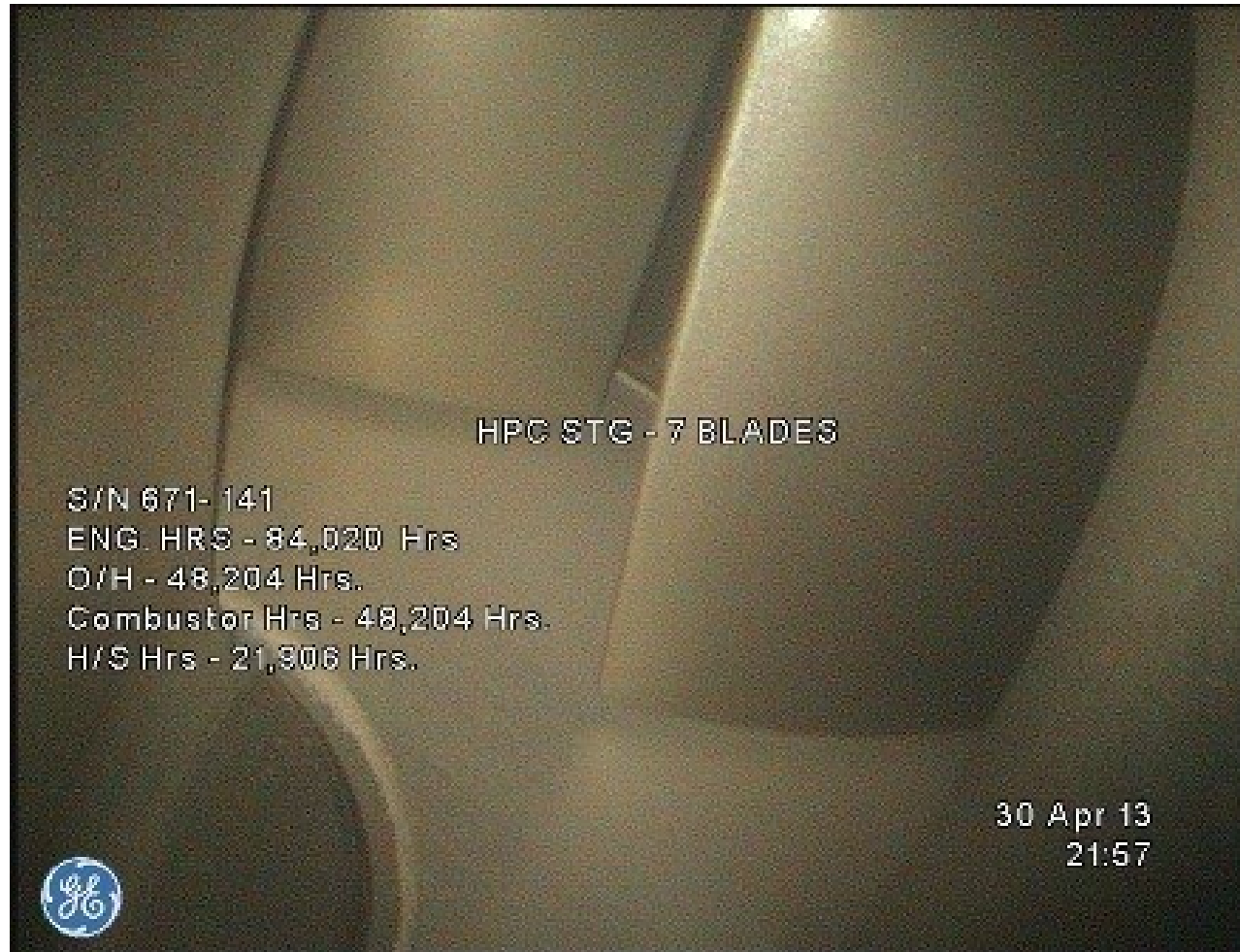
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3 Year Check up on Kerrobert Site (Agricultural)

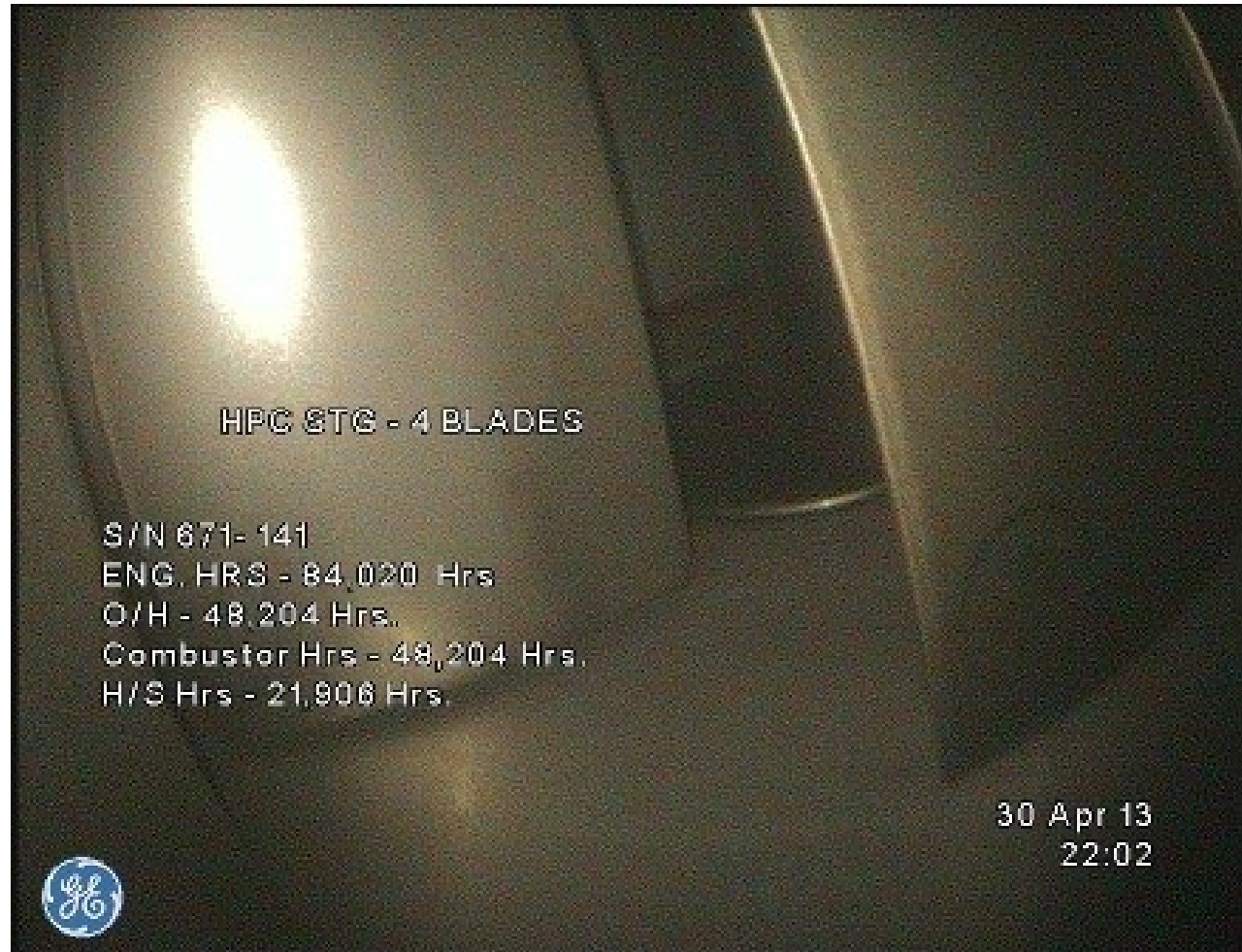
- 21,900 fired hours
- “Major”overhaul in October 2010 (6 months after HEPA install)
- No water washes since install



High Pressure Compressor Stage 7 Blades



High Pressure Compressor - Stage 4 Blades



High Pressure Compressor – Stage 11 Platform/Lock



High Pressure Compressor – Stage 7 Platform/Lock



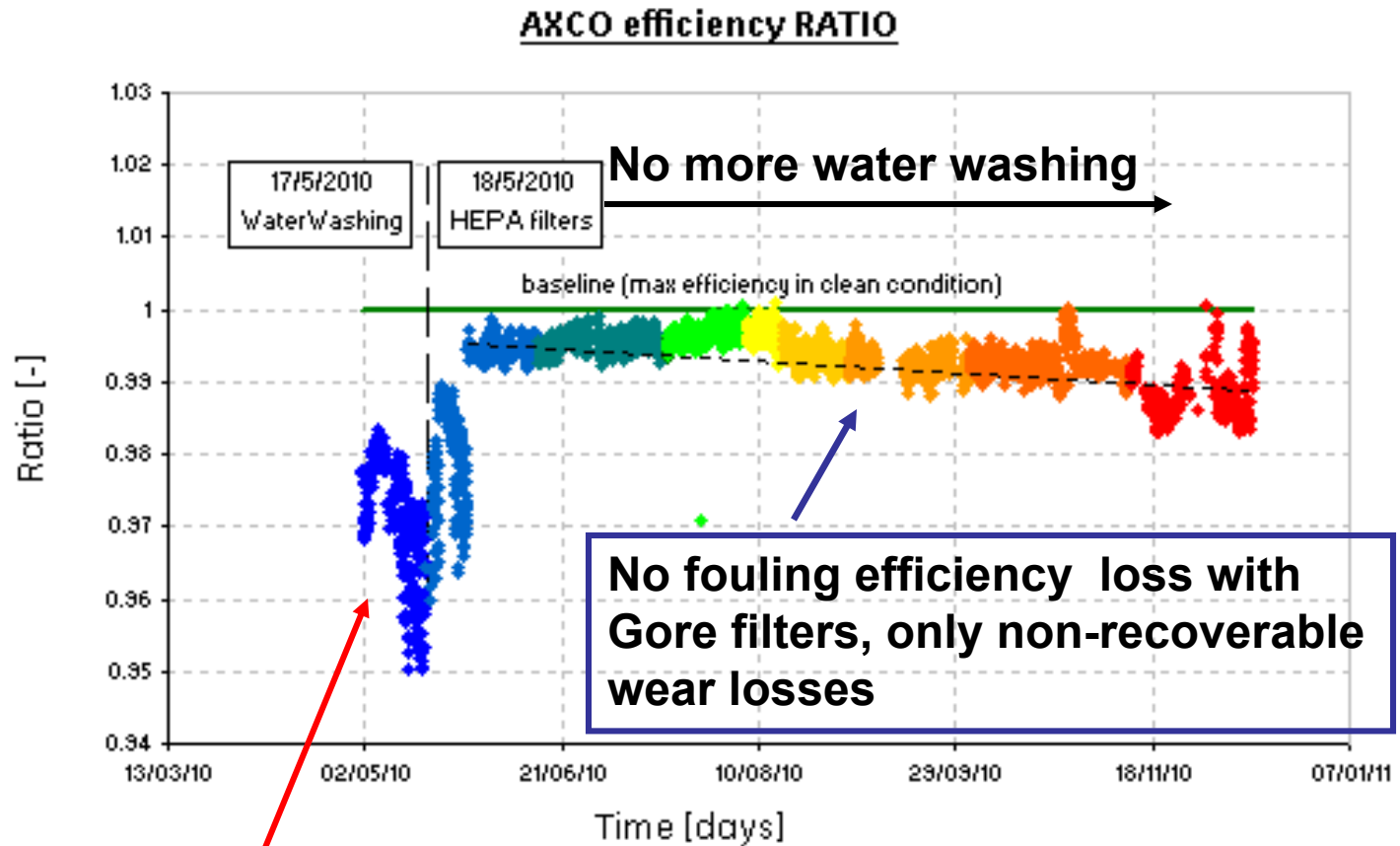
High Pressure Compressor – Stage 4 Platform/Lock



Inlet Guide Vanes



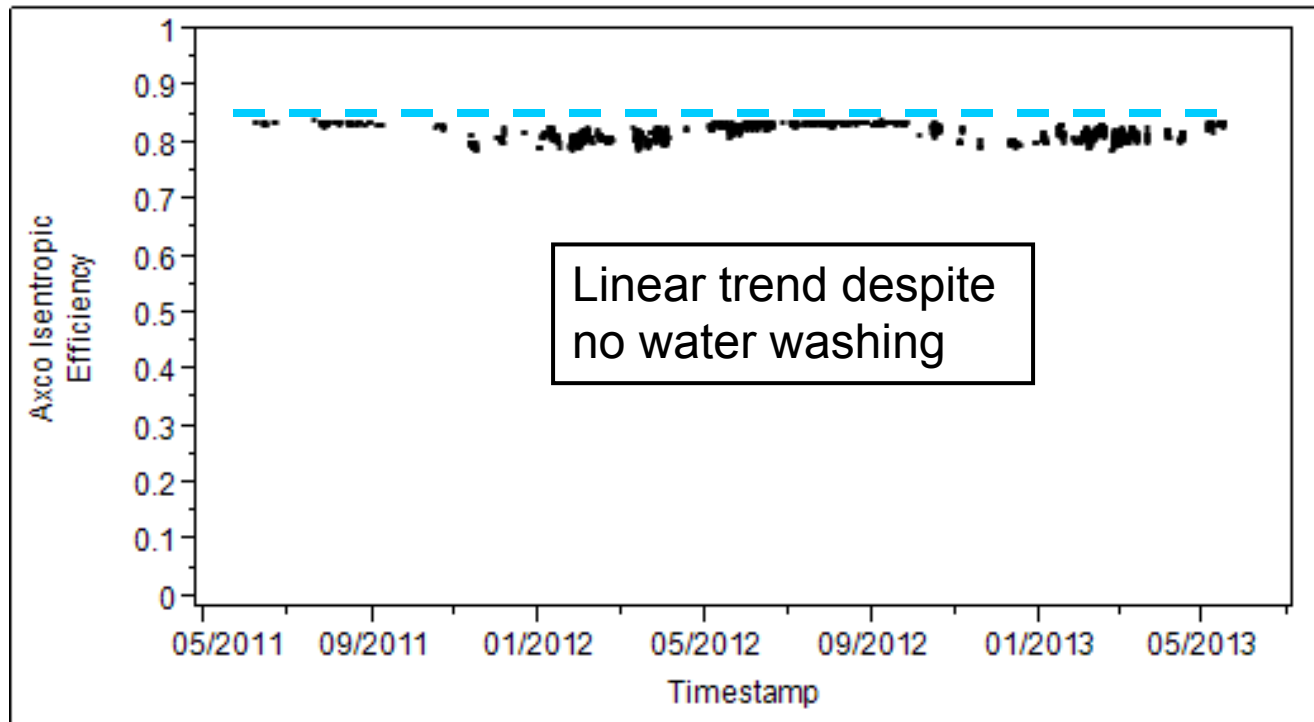
Efficiency Loss Comparison – HEPA vs. Old Filters



Fouling, recoverable efficiency loss from old filters



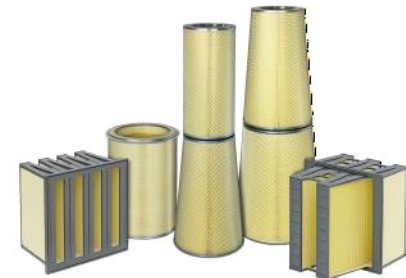
Windfall Axial Compressor Efficiency (years 2-3)



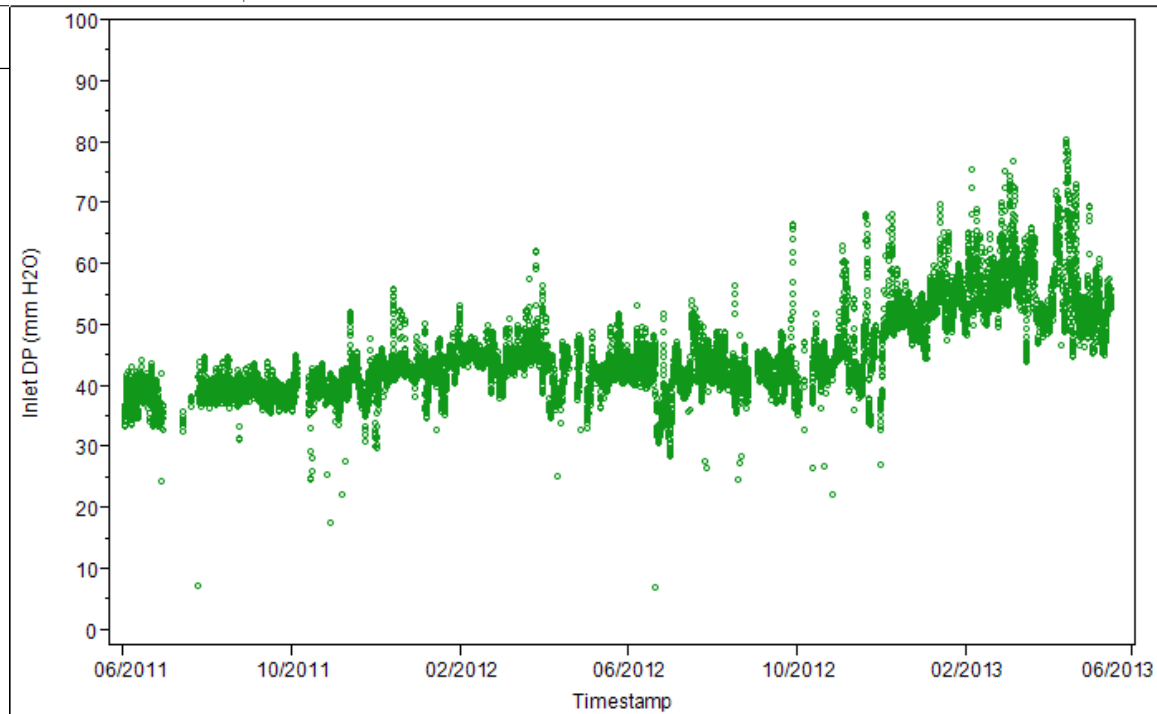
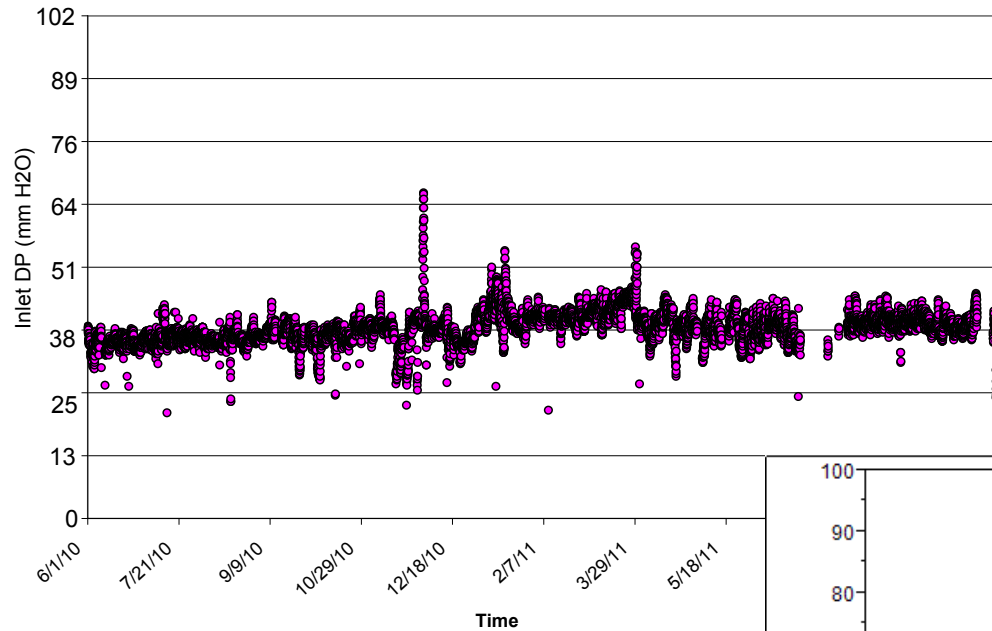
Confirmation of Filter Performance Claims

- **Filter claims by Gore**

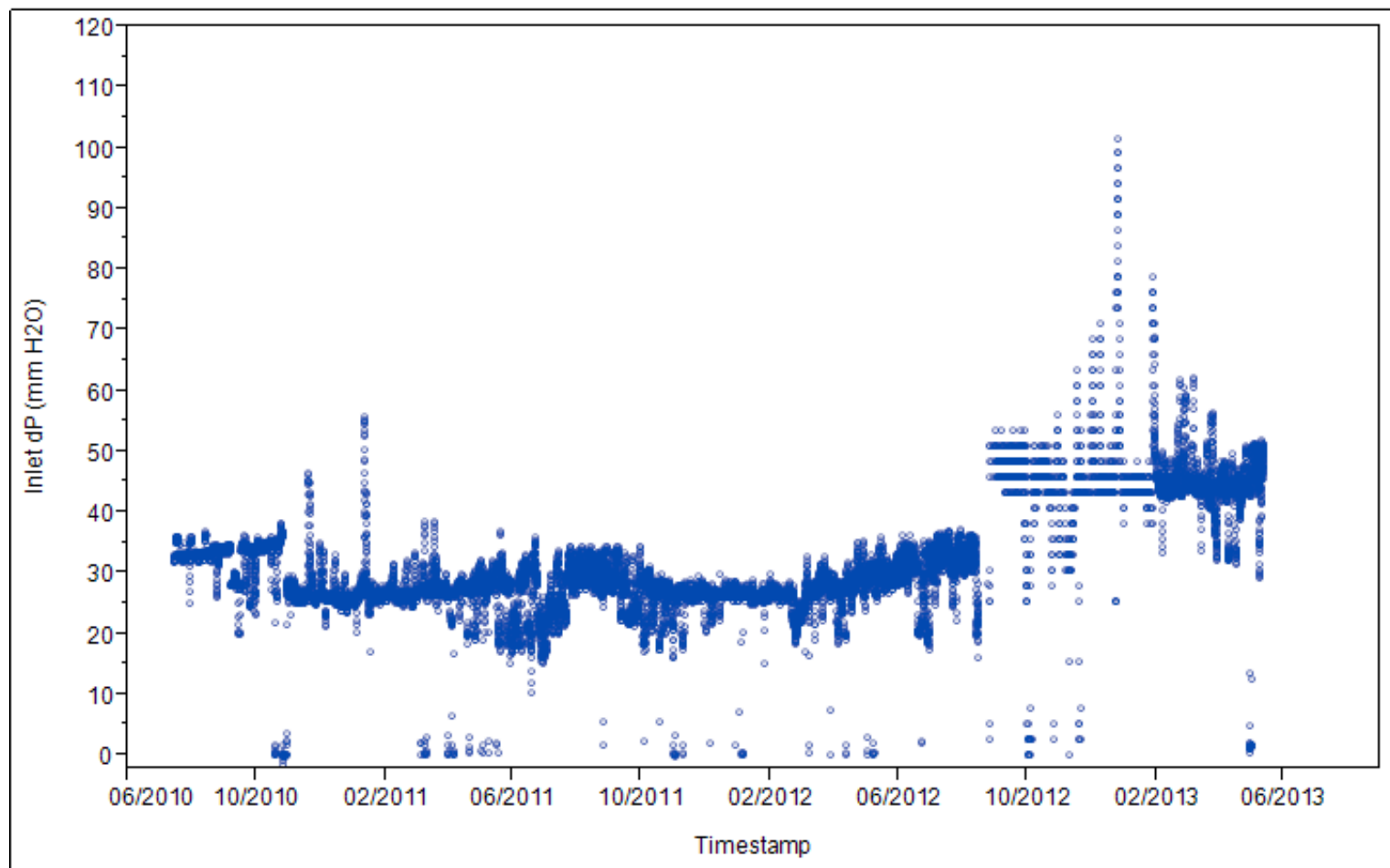
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Windfall (G4) Inlet Δp June 2010 to June 2013



Kerrobert Inlet Δp June 2010 to June 2013



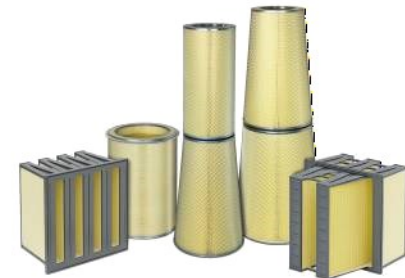
Hoar Ice Event – Only Had 2.5" Δp Total



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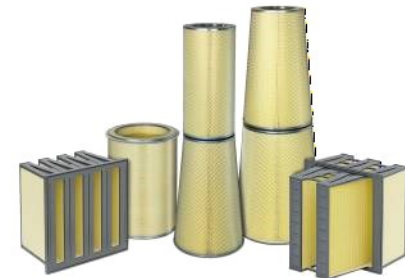
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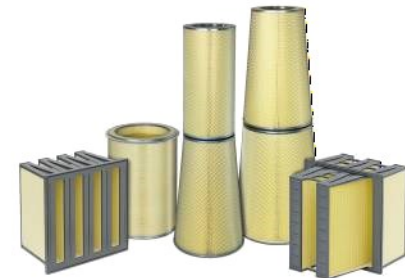
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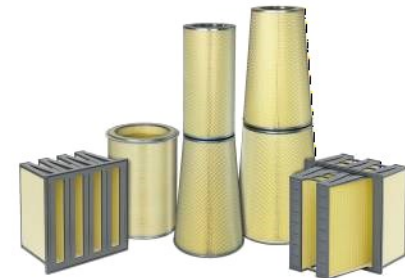
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What is HEPA Filtration?

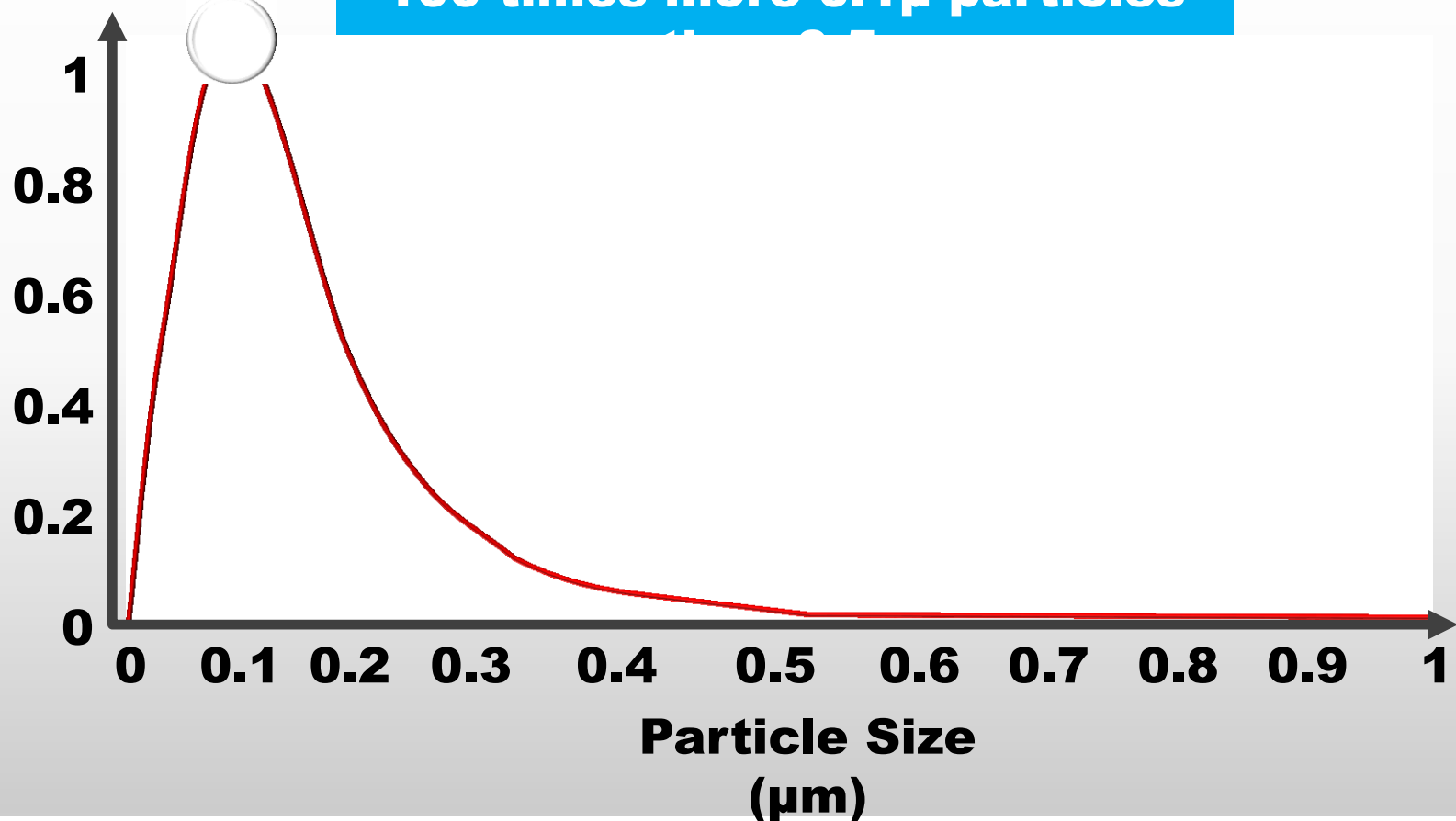
- Filtration Standards
 - F-Class vs. MERV vs. HEPA
- How do these filters work?
 - Unique filtration materials and construction

Sub-Micron Distribution in Urban Air

**Particle
Number**

Particle Distribution (urban)

100 times more 0.1 μ particles

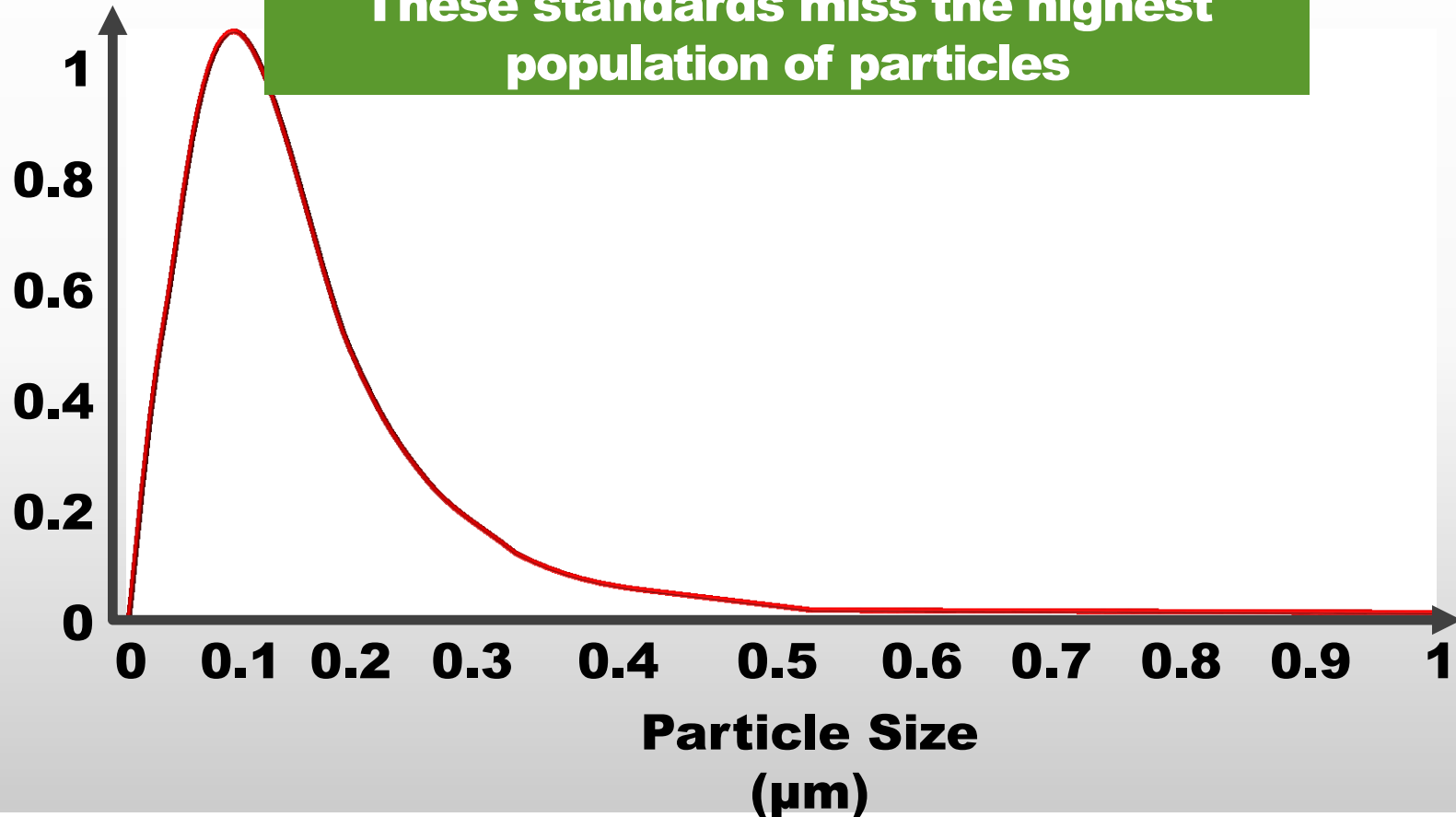


Standards For Lower Efficiency Filtration

**Particle
Number**

Particle Distribution (urban)

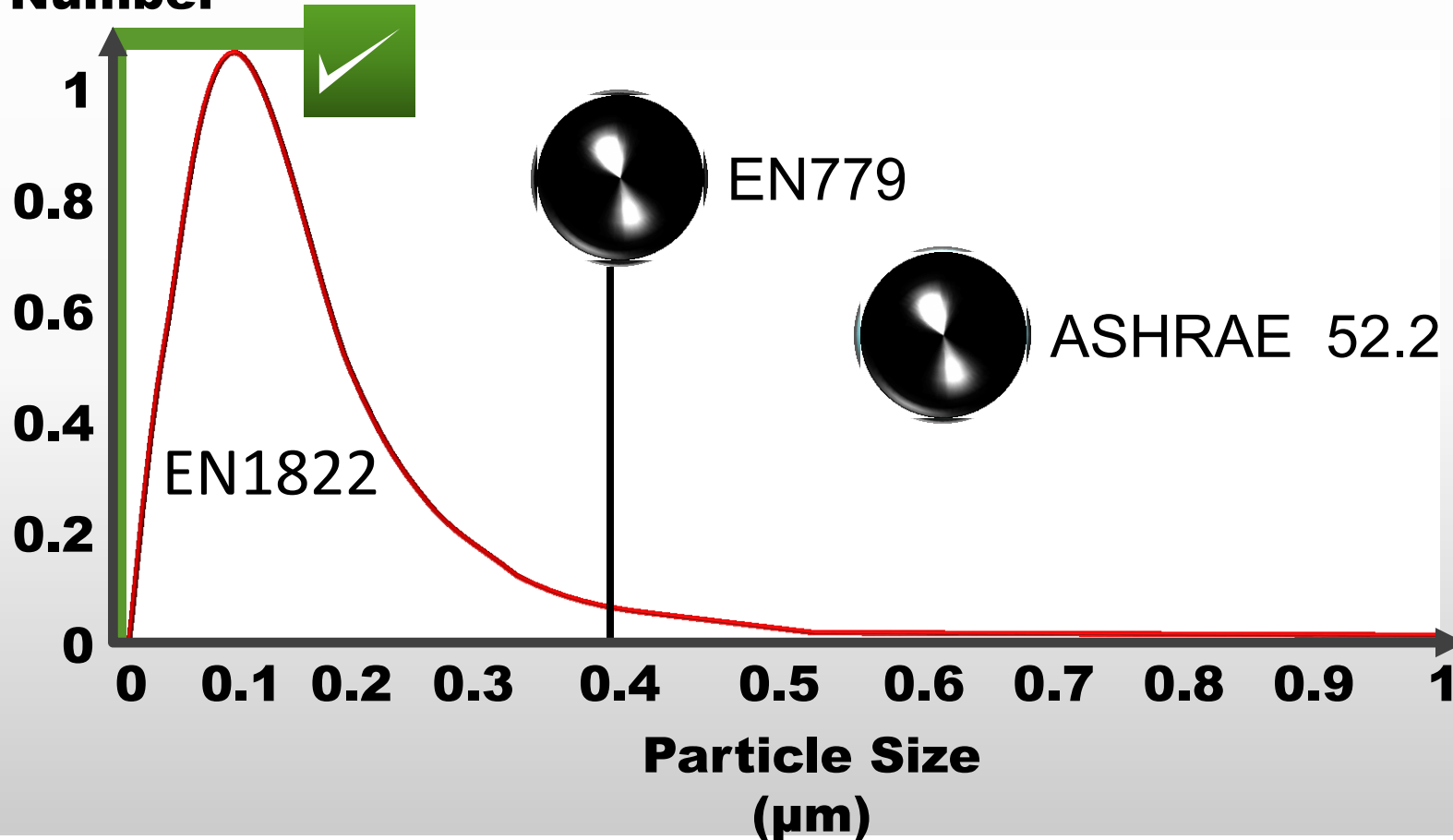
**These standards miss the highest
population of particles**



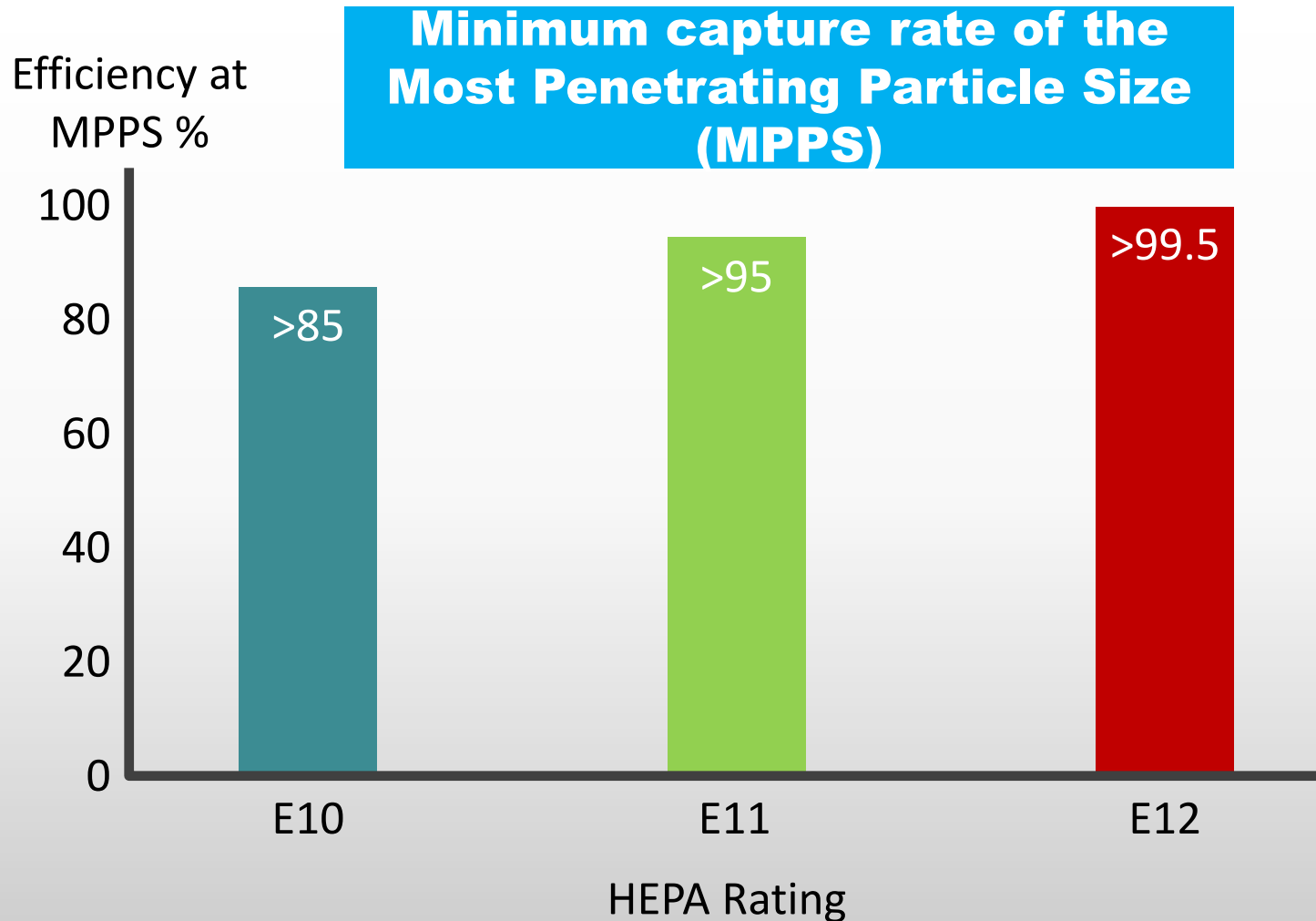
<0.3 Micron Issue

Particle
Number

Particle Distribution (urban)



HEPA Filter Classifications



To Capture the Performance of HEPA Filters – EN1822

**Fractional
Collection
Efficiency %**

E12 Rated HEPA Filter

MPPS*

**Minimum Required for E12
Rating**

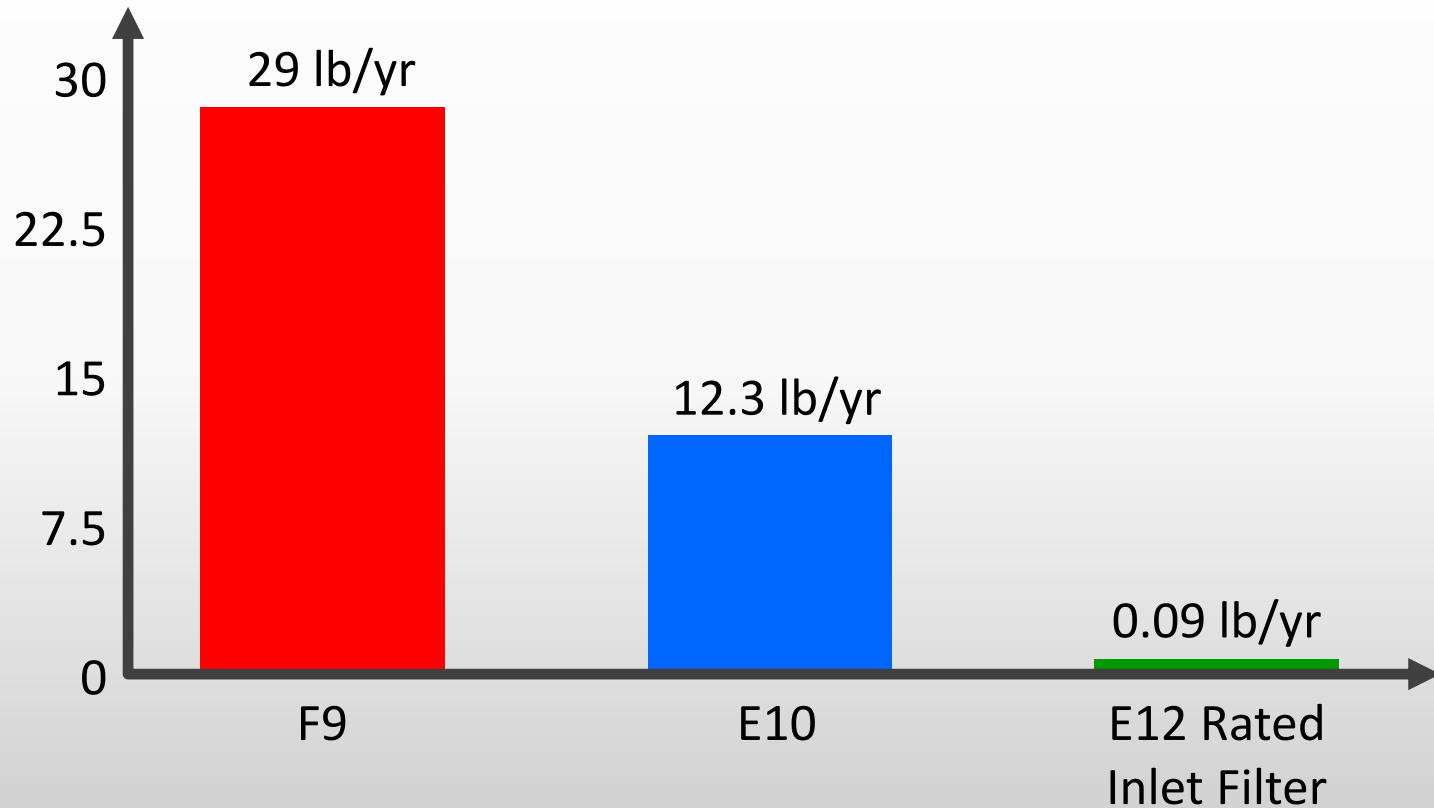
**Particle Diameter
(μm)**

*Most Penetrating Particle Size

Uncaptured Particle Comparison

**Un-captured
Pollutants [lb/yr]**

**25 MW Turbine, 1 Year
Operation**



GORE® Turbine Filters: High Efficiency (E12) with Low Pressure Drop

Pre-filter Layer
removes
Bulk of large Particles

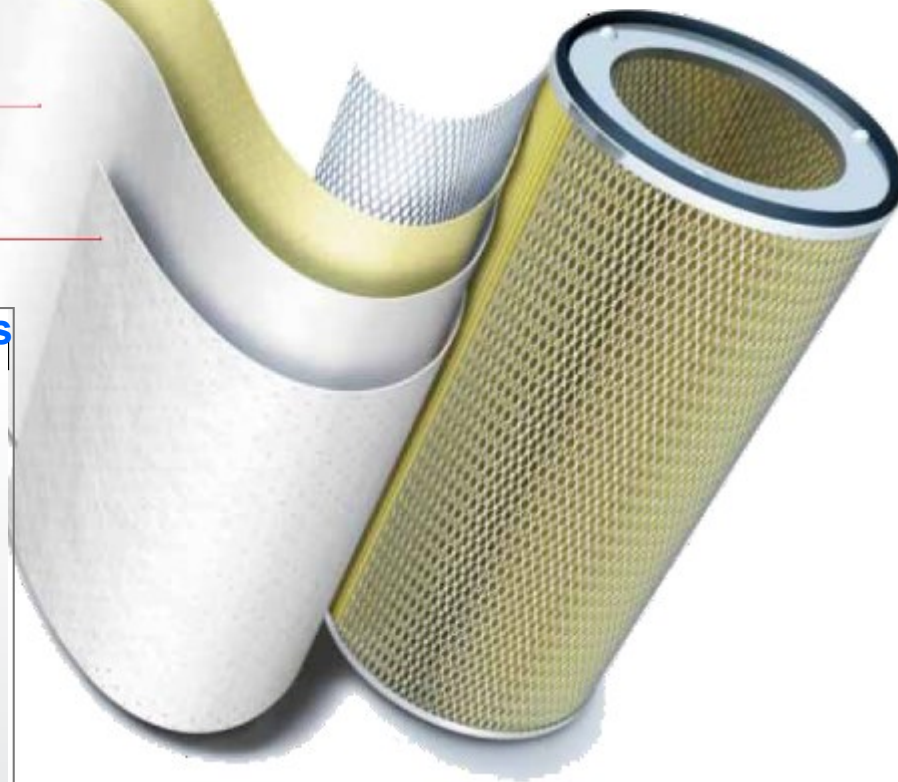
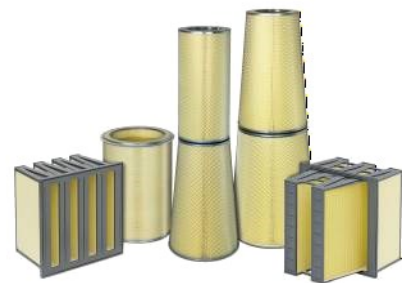
High Efficiency Membrane
Removes
Submicron Dust, Water, and Salt

High Strength Backer
Provides Burst Strength

**Air can pass
through
the membrane**

**Water and particles
are repelled**

GORE™ Membrane



Summary

- Windfall & Kerrobert Field Trials
 - Both sites now operating 3.5 yrs with HEPA filters
 - GT blades and components exhibit pristine cleanliness at 20,000+ Fired Hours with no offline water washes
- Fleetwide Adoption
 - Remaining fleet outfitted with HEPA for 2+ years
 - Offline water washes have ceased across entire fleet, resulting in 57 outages removed from annual schedule
 - Investigating HEPA filtration's ability to extend Gas Turbine maintenance cycles