

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 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

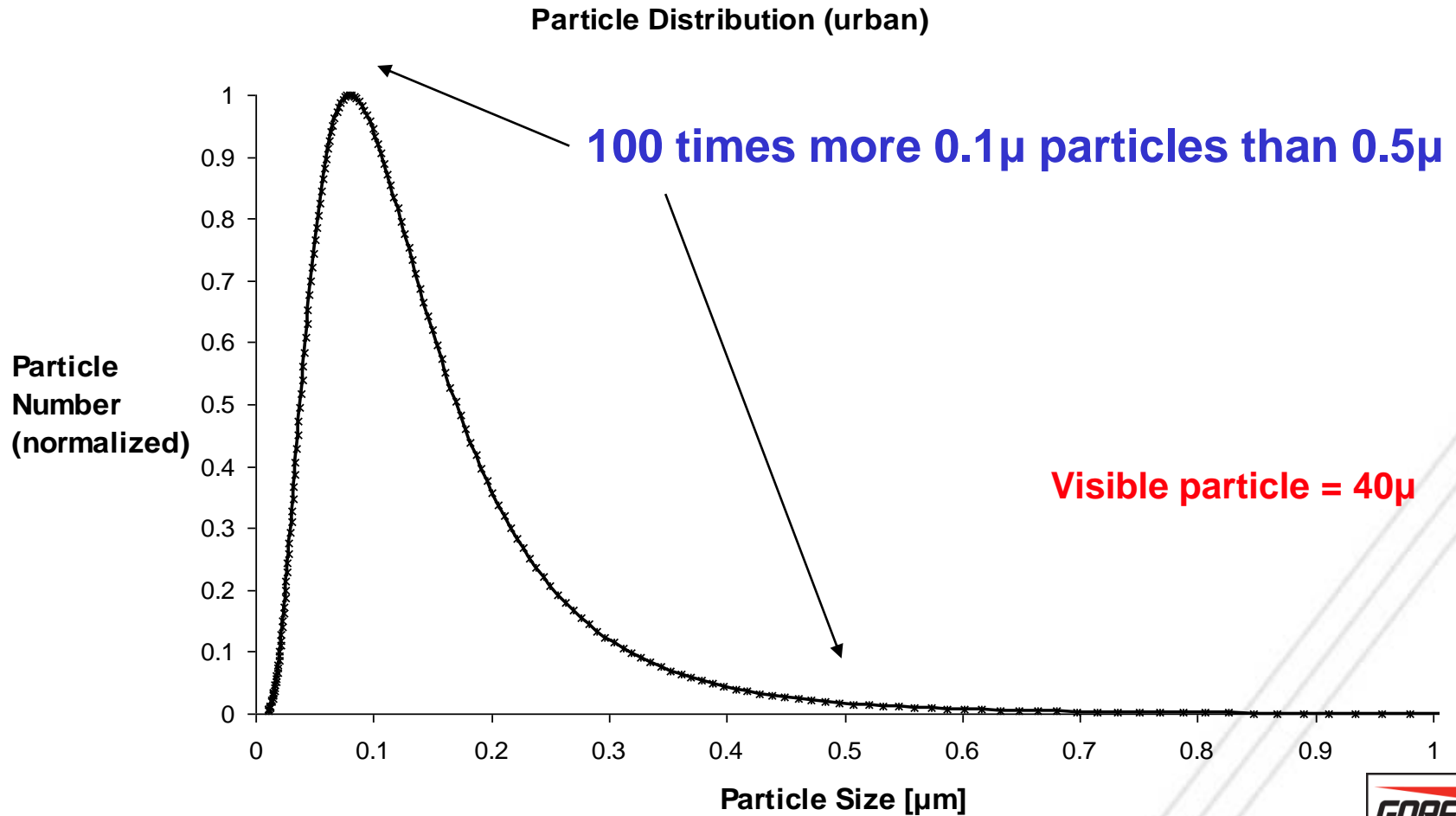
The Problem

- Inlet air filtration aims to reduce contaminants in the air stream without imposing a large pressure drop penalty
- Conventional filters are very 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

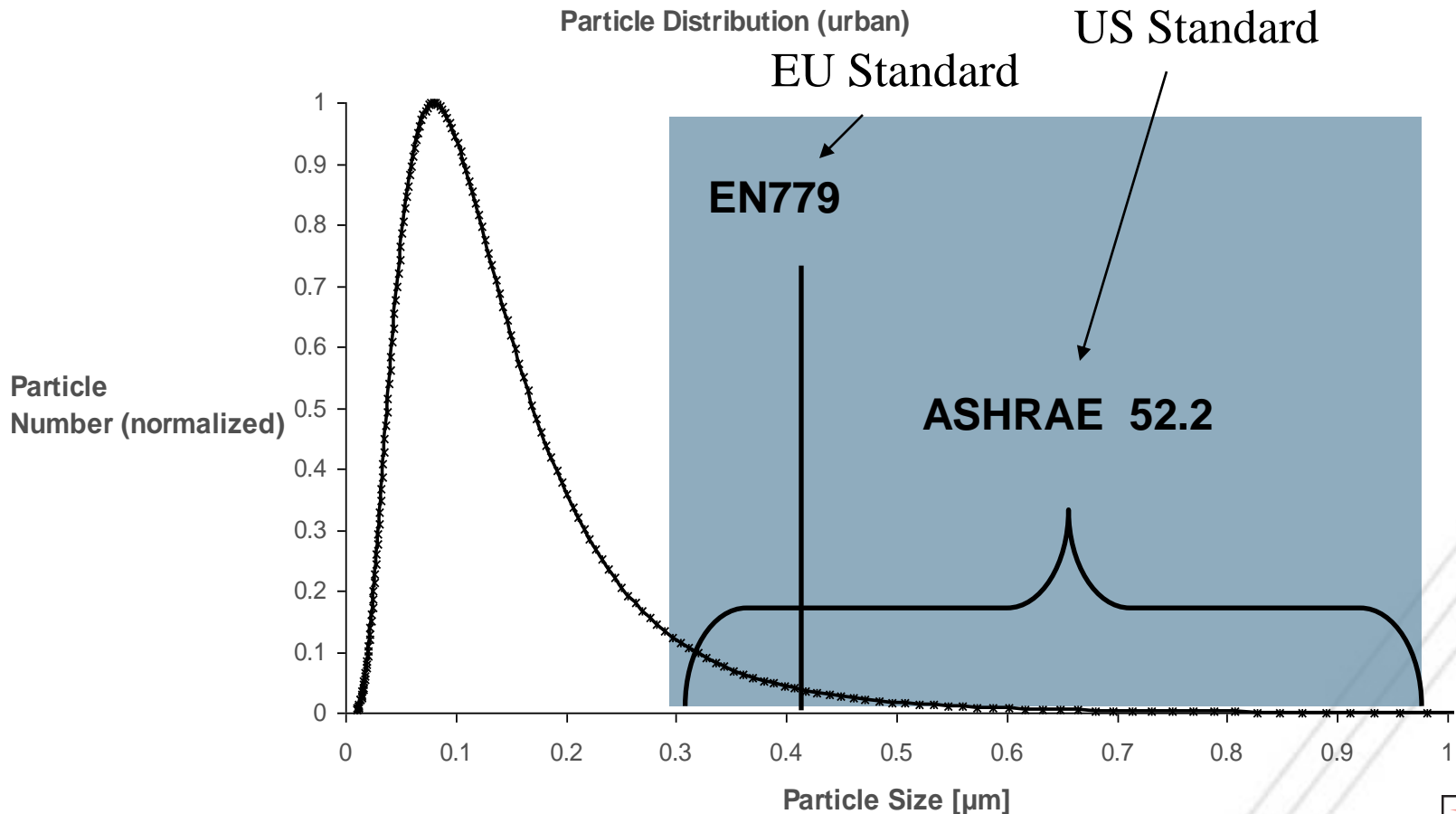
What is HEPA Filtration?

(High Efficiency Particulate Air)

Sub-Micron Distribution in Urban Air

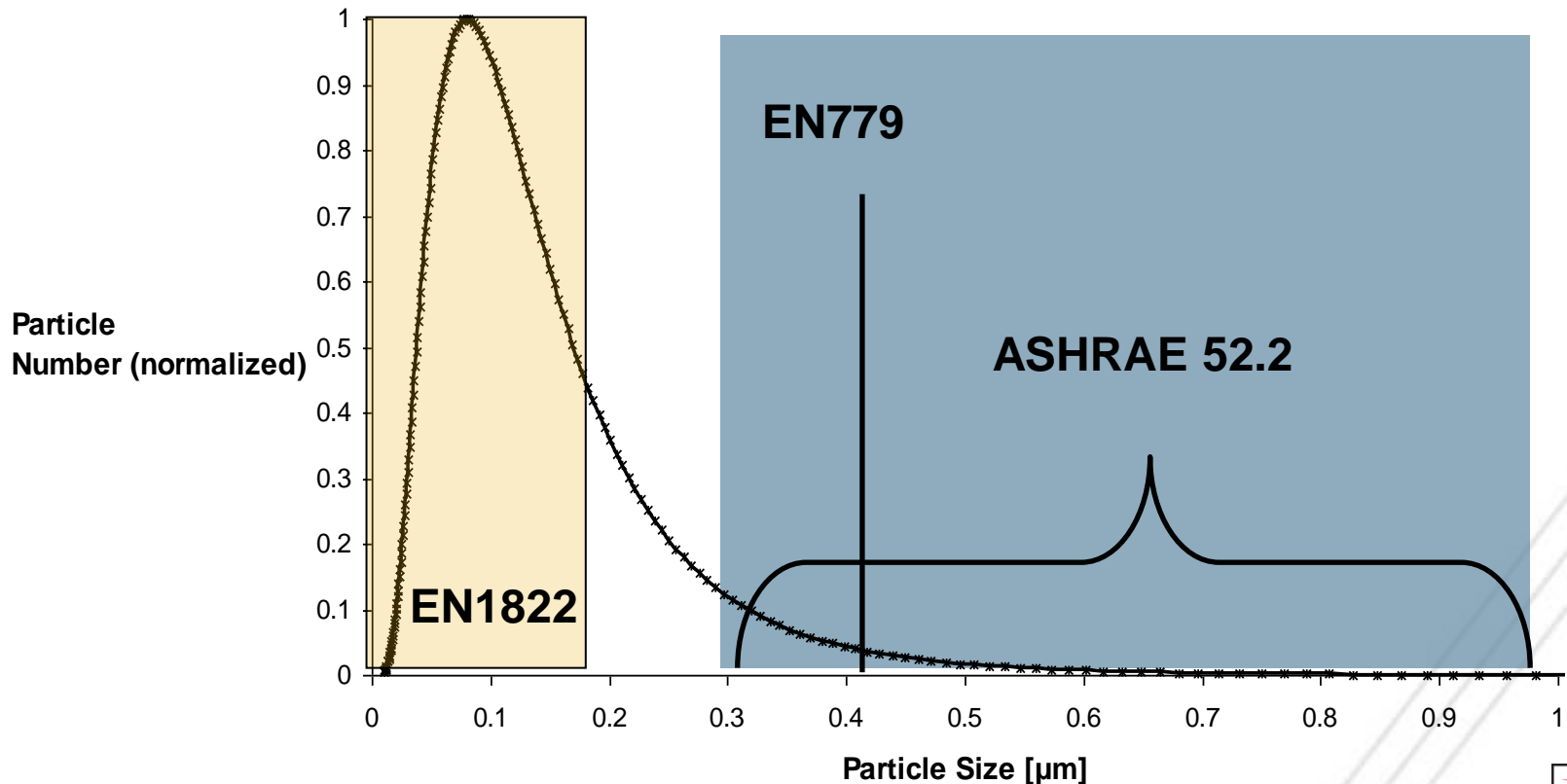


Particle Size Range of Current Standards (Don't measure below 0.3μ)



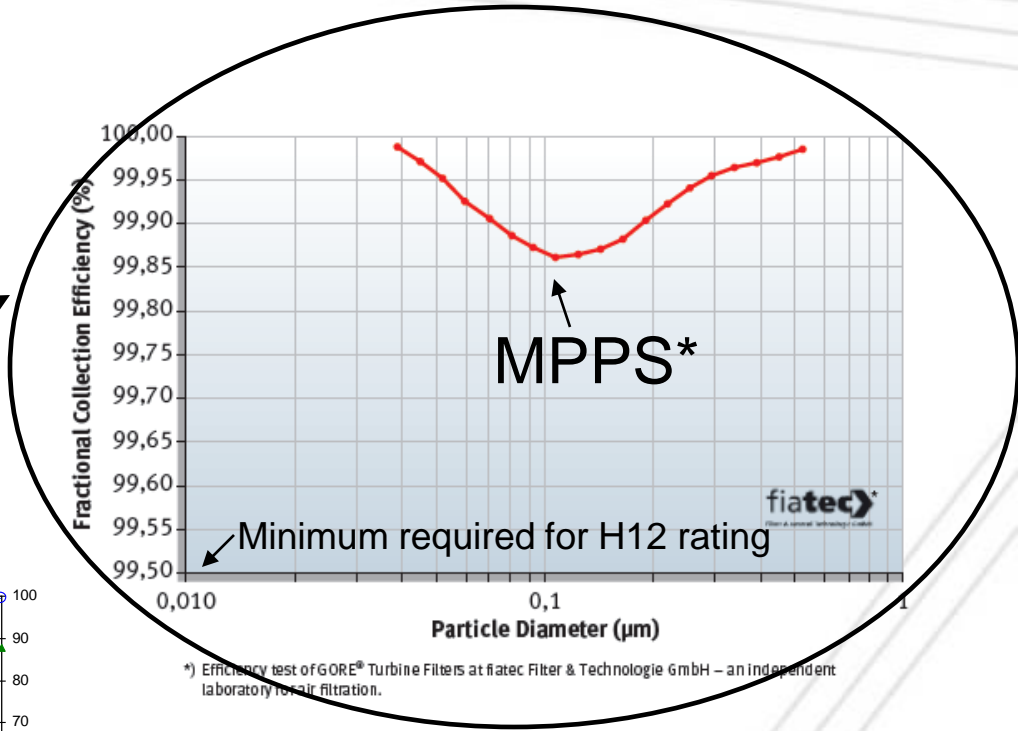
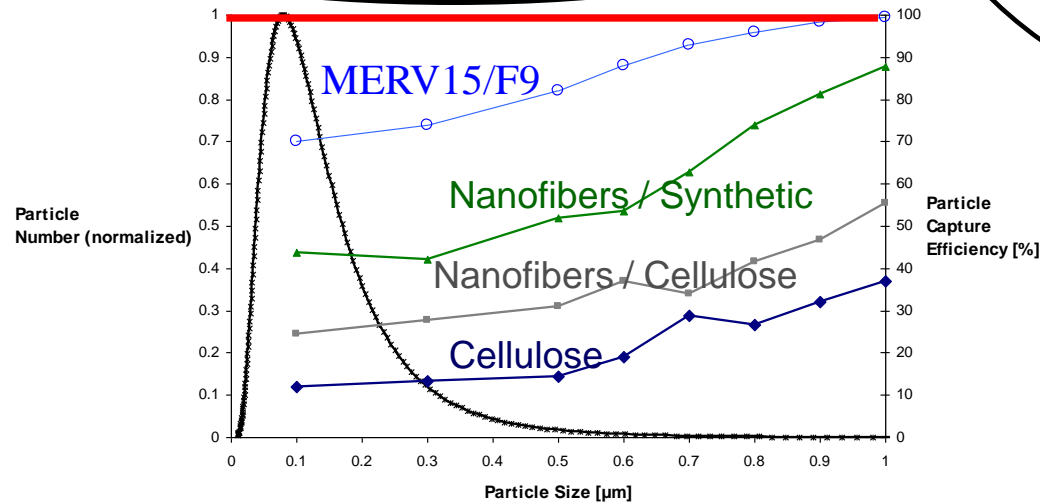
HEPA Standard EN1822 Addresses <0.3 Micron Issue

Particle Distribution (urban)



To Capture the Performance of HEPA Filters, Need a Different Test (EN1822) and Scale

GORE H12/E12



*) Efficiency test of GORE® Turbine Filters at fiatec Filter & Technologie GmbH – an independent laboratory for air filtration.

*Most Penetrating Particle Size

Filter Classifications

Ventilation

Ventilation

Cleanroom

| Filter Class | Efficiency | Particle Size | EN779 | ASHRAE E 52.2 | EN1822 2005/2009 |
|------------------|--|------------------------------|-----------|---------------------------------------|------------------|
| Fine Filters | $80\% \leq E_m \leq 90\%$ $E1 <$ | 0.4 μ m/ 0.3-1.0 avg. | F7 | MERV | |
| | $80\% \leq E_m \leq 95\%$ $75\% \leq E1 \leq 85\%$ | 0.4 μ m/ 0.3-1.0 avg. | F8 | 13 MERV | |
| | $95\% \leq E_m$ $85\% \leq E1 \leq 95\%$ $95\% < E1$ | 0.4 μ m/ 0.3-1.0 avg. | F9 | 14 MERV 15 | |
| EPA/HEPA Filters | >85% | MPPS | | MERV 16 | H10/E10 |
| | >95% | MPPS | | | H11/E11 |
| | >99.5% | MPPS | | | H12/E12 |

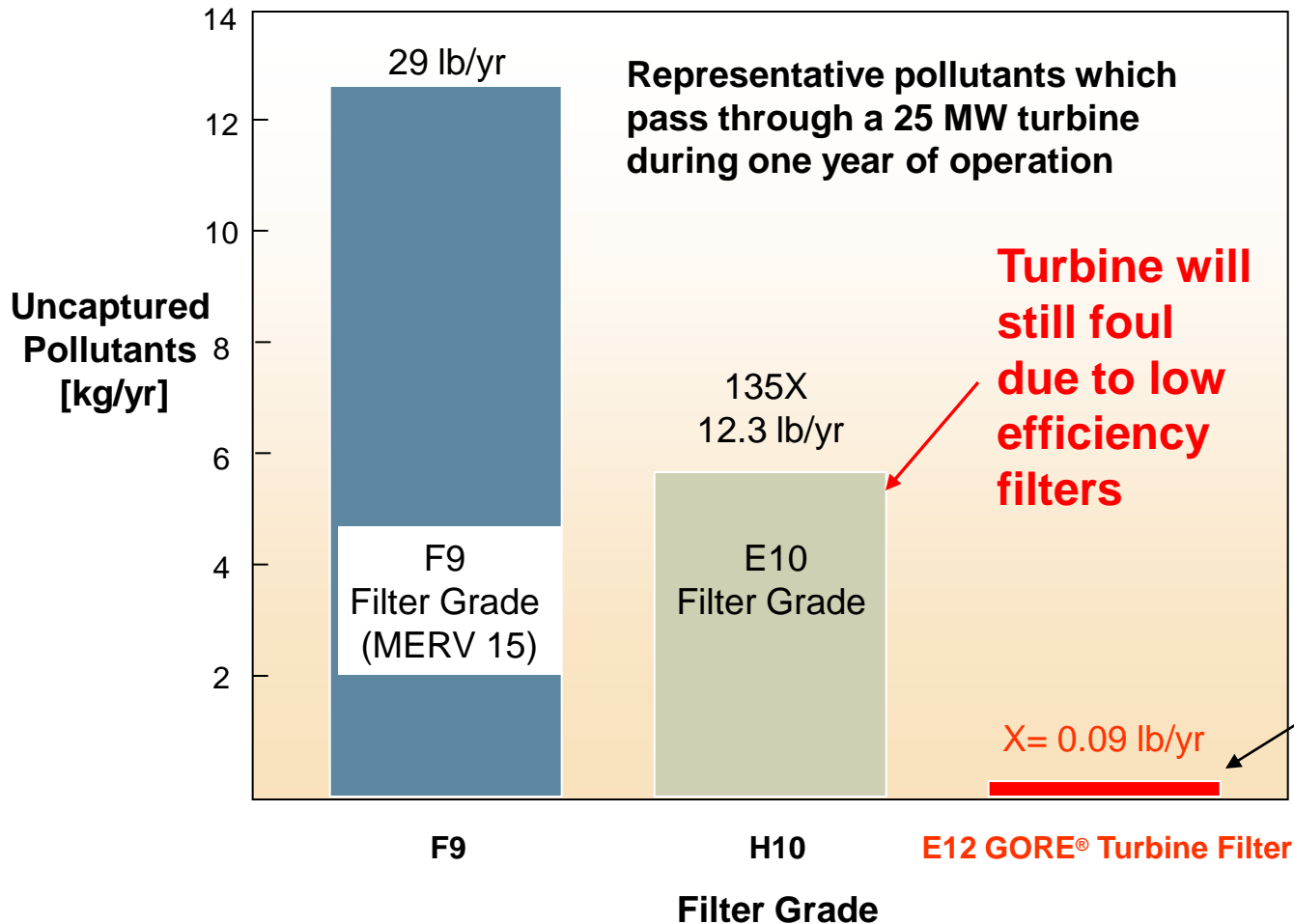


What is a HEPA Filter?

- 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

| <u>HEPA Rating</u> | <u>Efficiency at MPPS</u> |
|--------------------|---------------------------|
| H10/E10 | > 85% |
| H11/E11 | > 95% |
| H12/E12 | > 99.5% |

There Are Different HEPA Ratings For a Reason

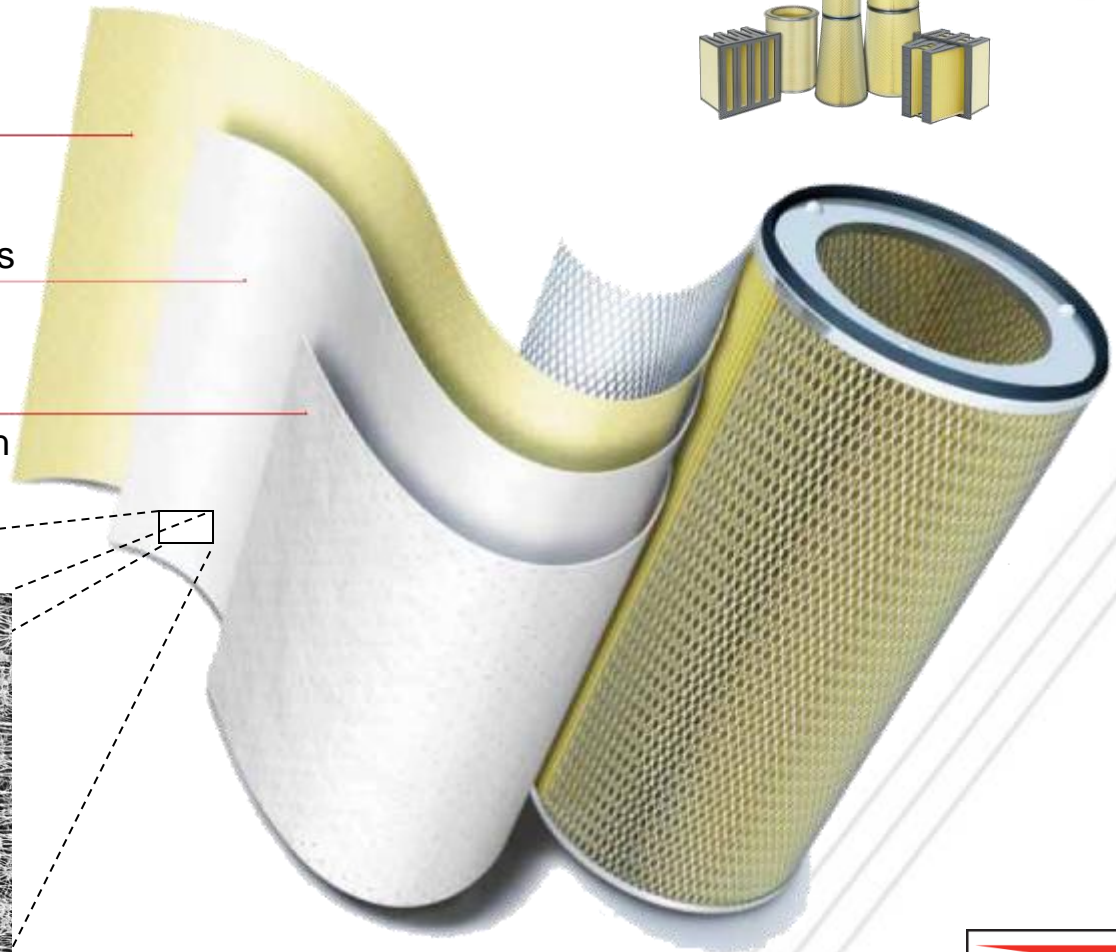
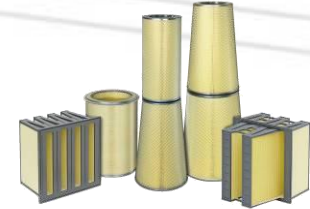
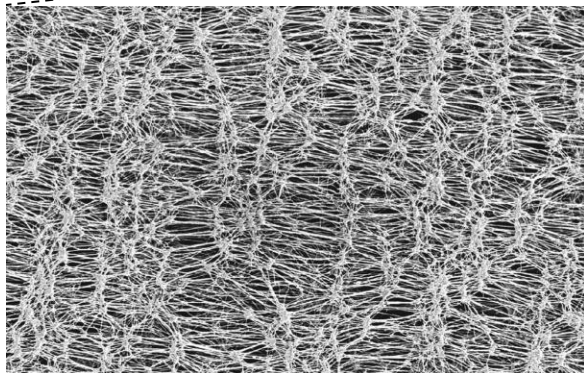


GORE® Turbine Filters: High Efficiency (E12) with Low Pressure Drop

Pre-filter Layer removes
Bulk of large Particles

High Efficiency Membrane Removes
Submicron Dust, Water, and Salt

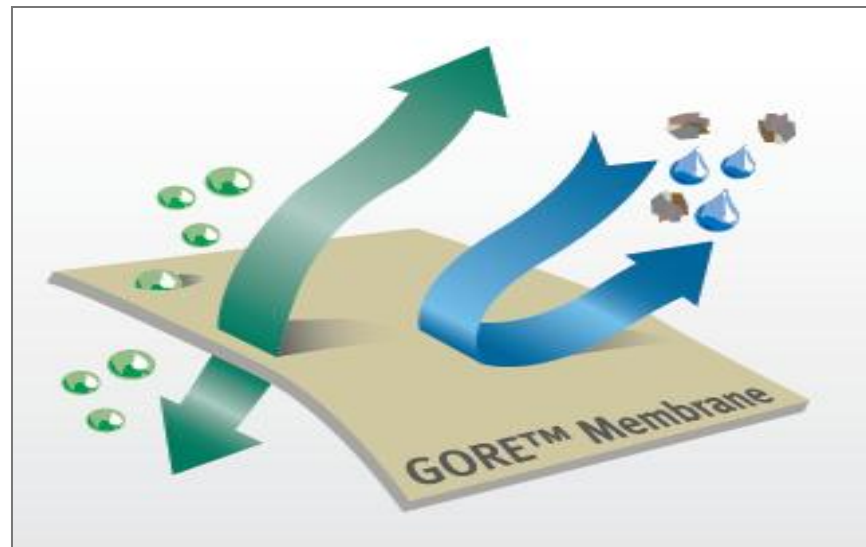
High Strength Backer
Provides Burst Strength



GORE Membrane Technology

Waterproof Media Provides Water & Salt Retention

Salt dust, water, and aqueous salt solutions are repelled

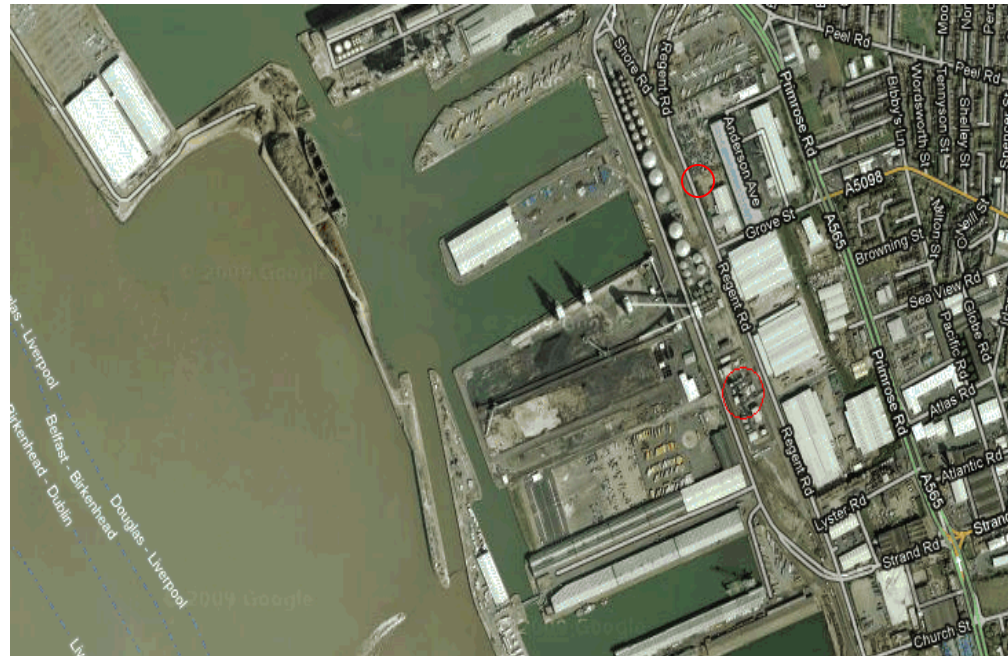


Air can pass
through the membrane

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



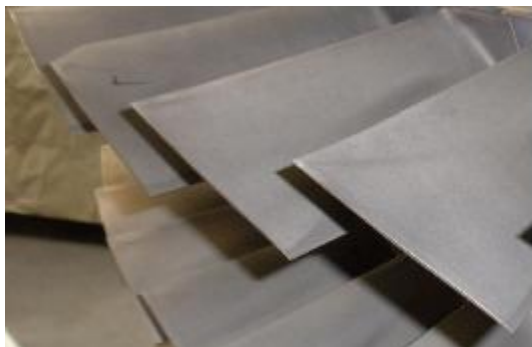
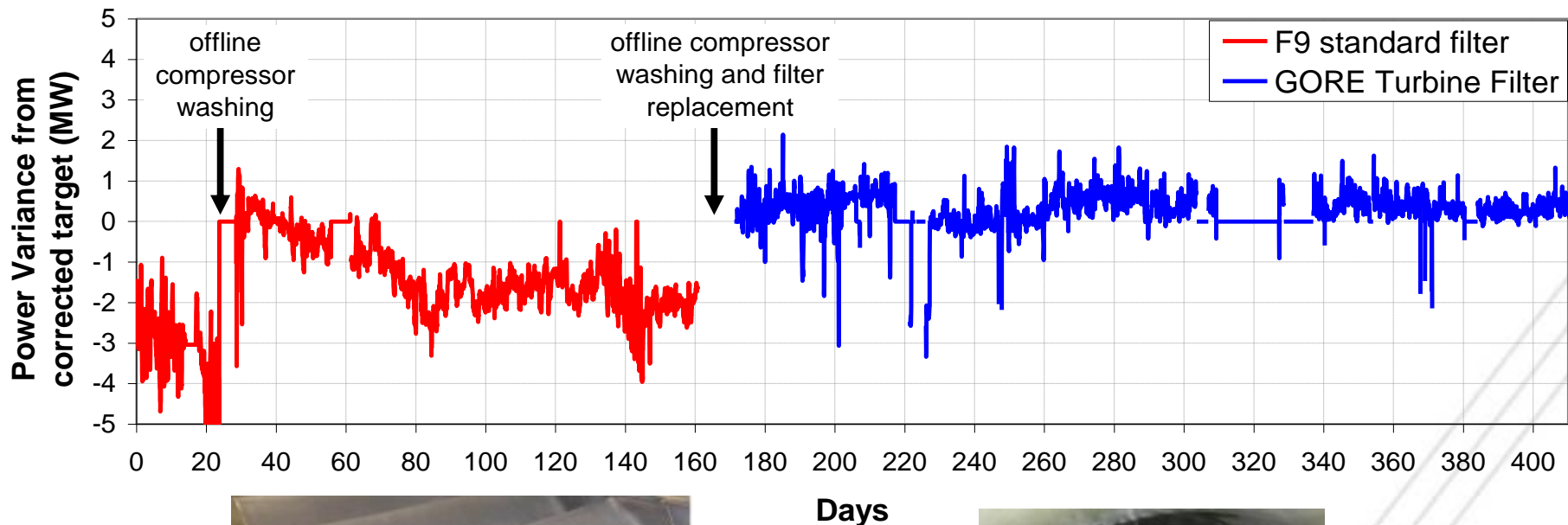
Constant Power Output with Gore Filters Coastal Power Plant (RB211-30MW) - UK

Current Filters

3 off-line washings/yr.

Gore Filters

0 off-line washings/yr.



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



Coastal Petrochemical Plant (Texas) That Cannot Shutdown for 1 Year

GORE® E12 Turbine
Filters With
Coalescers



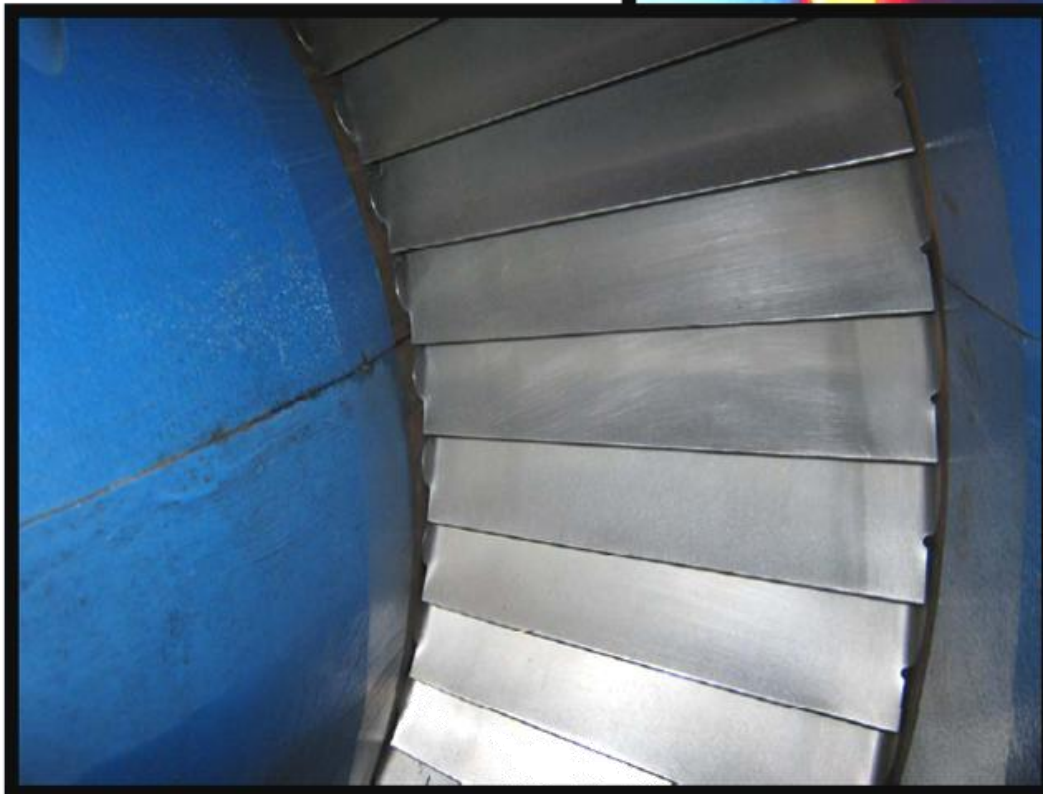
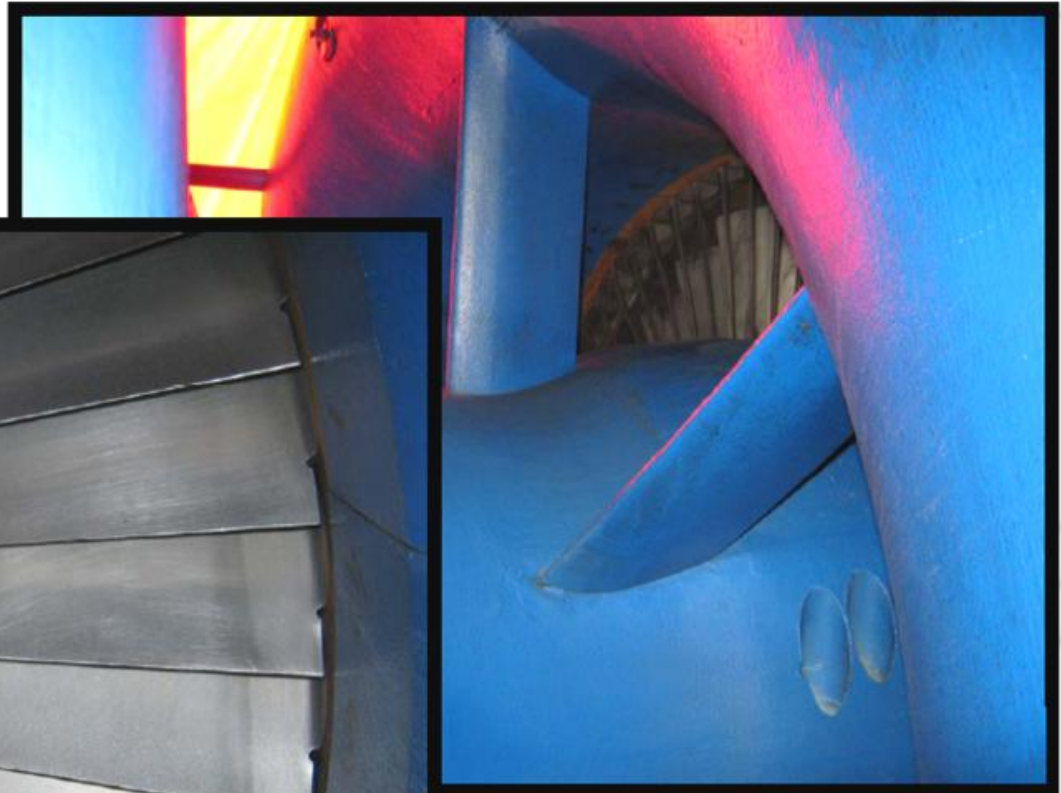
Constant Power Output with Gore Filters

Petrochemical Plant (GE Frame 6B - 35MW) -

Texas

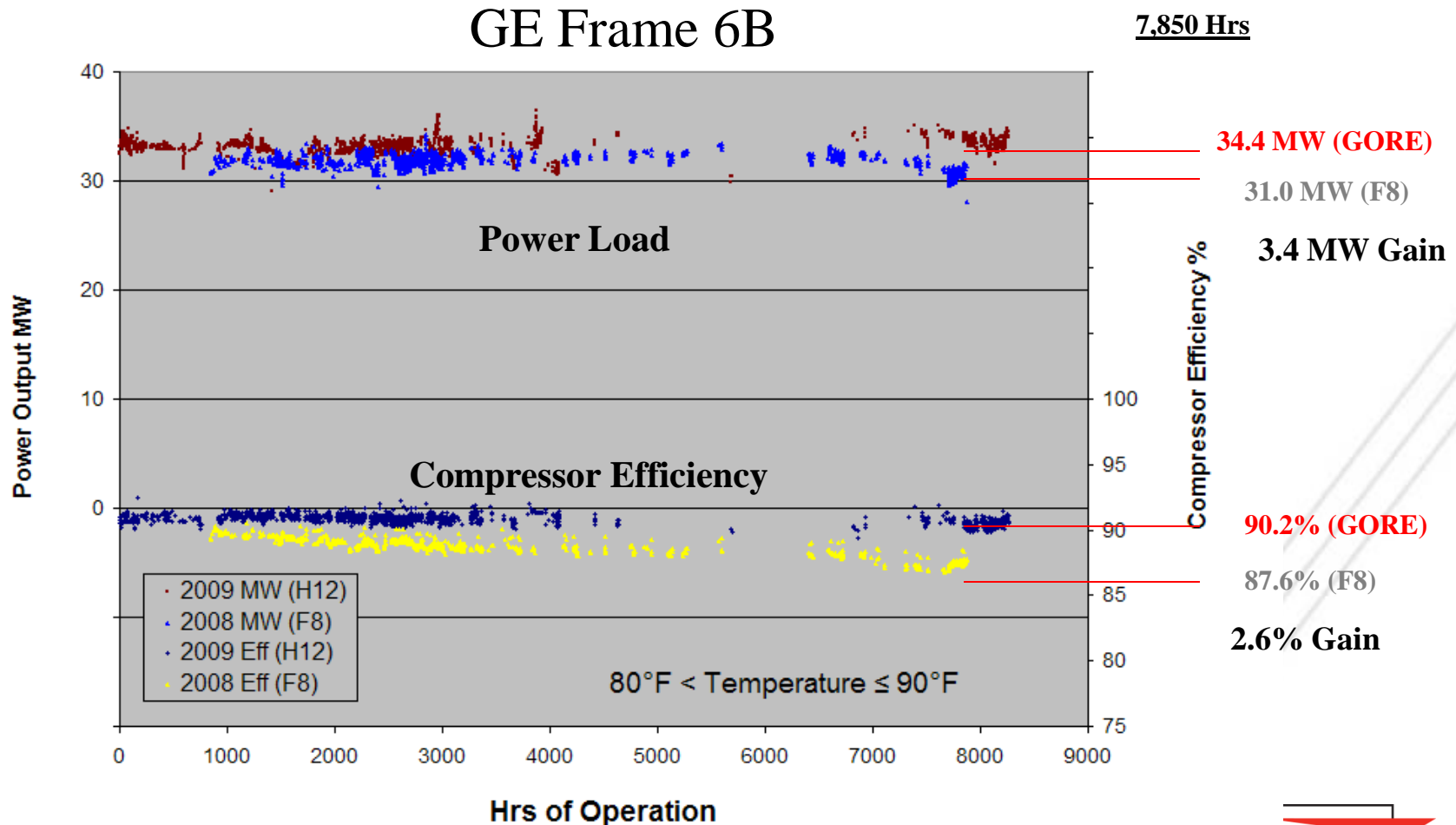
8,000+ hrs

No Wash



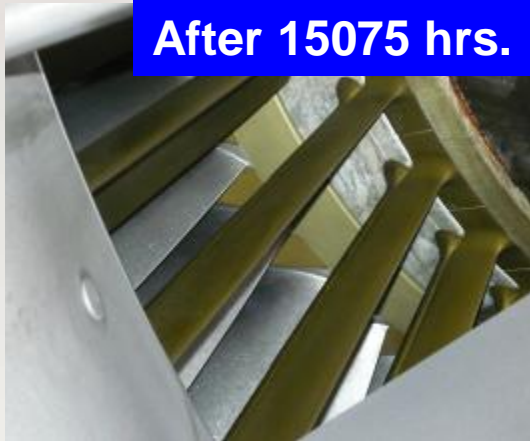
Constant Power Output with Gore Filters

Petrochemical Plant (GE 6B – 35MW) – Texas

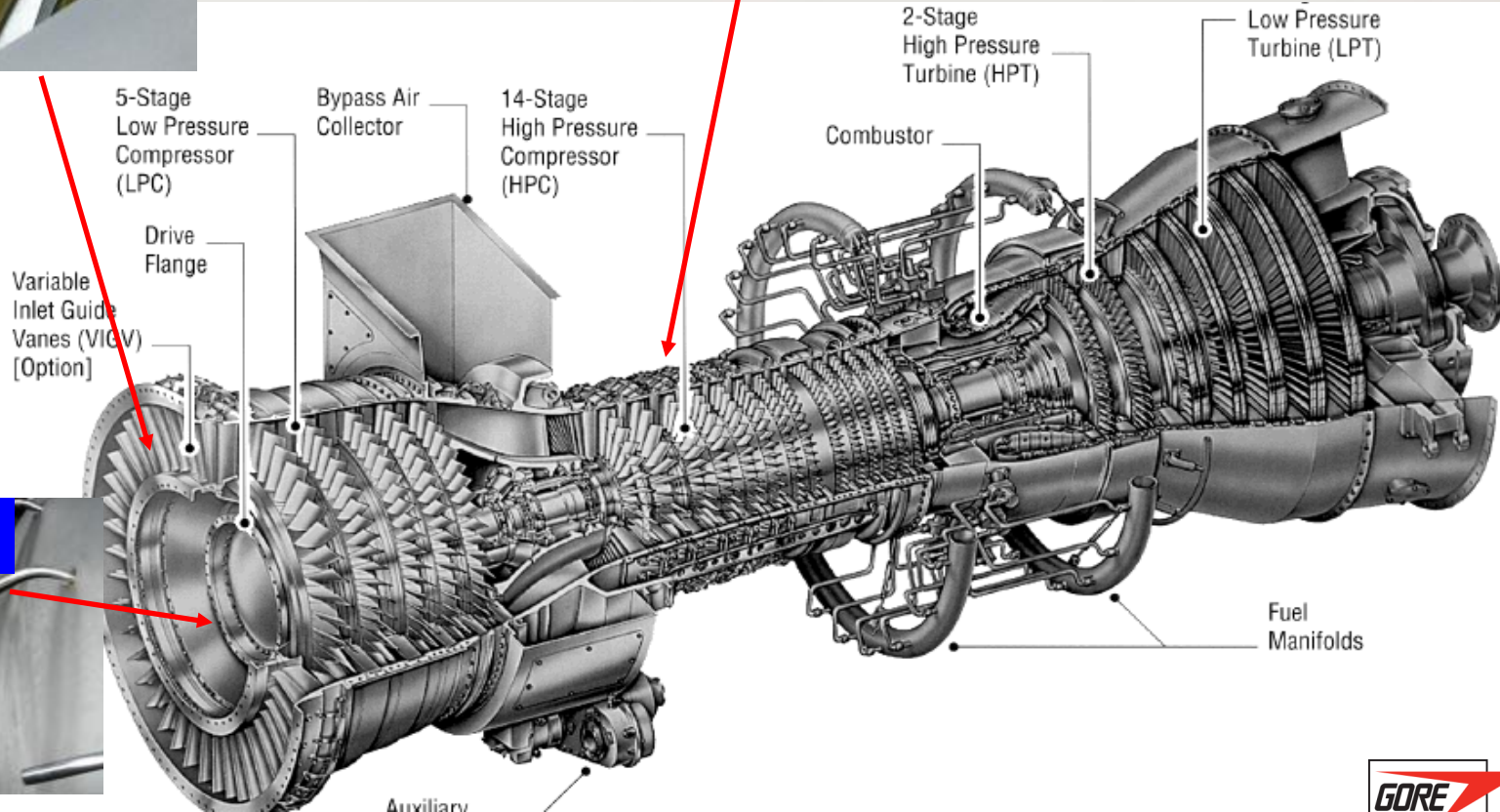


LM6000 after >2 years with GORE® Turbine Filters

After 15075 hrs.



After 18500 hrs.



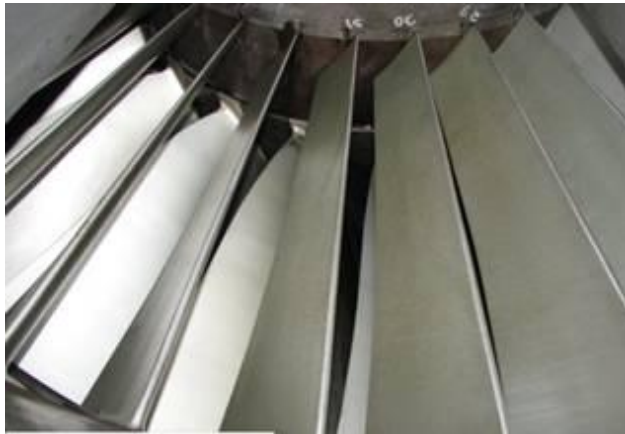
After 8500 hrs.



Clean Power Plant Turbine – Oregon

Mitsubishi 501G (265MW)

After 2000 hours



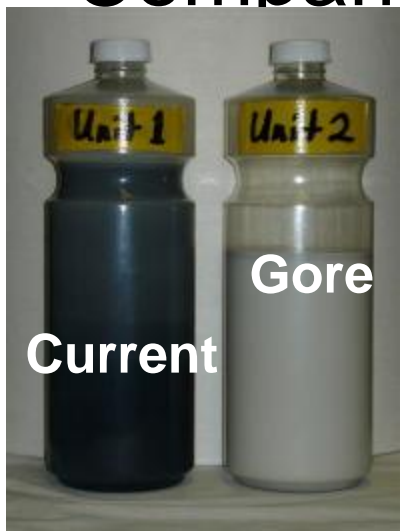
After 4000 hours



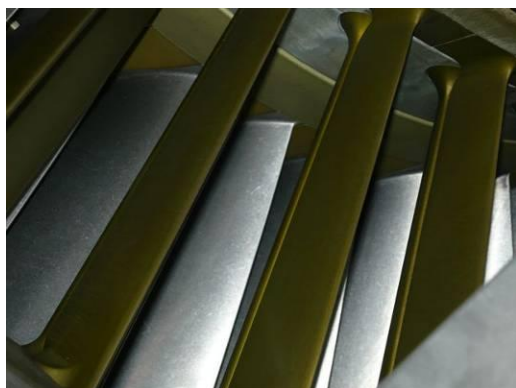
After 10,000 hours



Eliminating Off-Line Washes - Confirmed via Boroscope and Wash Water Comparison



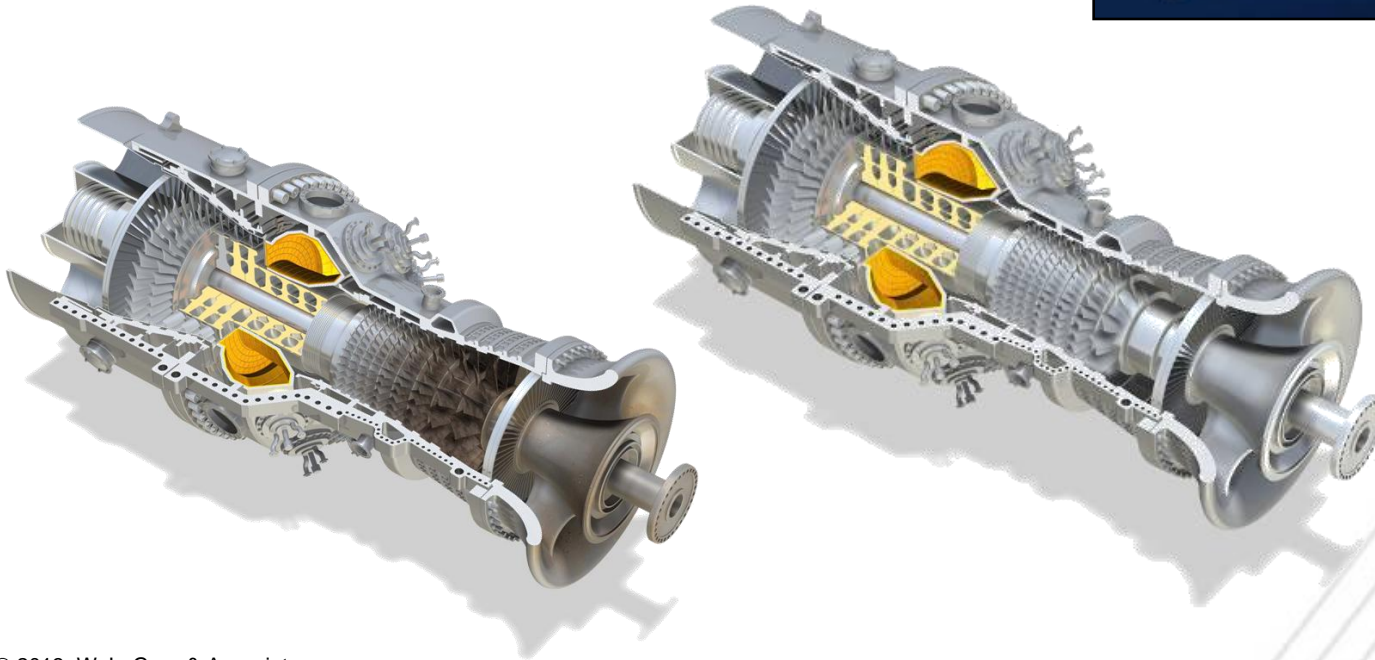
| End User | Off-line washes/yr with F-Class (MERV) filters | Off-line washes/yr after installing GORE® H12 Turbine Filters |
|----------------------------|--|---|
| Plastics Mfg. (coastal) | 20 | 0 |
| Brewery (coastal) | 17 | 0 |
| Food | 26 | 0 |
| University | 7 | 0 |
| Ceramics | 52 | 0 |
| Power (coastal) | 3 | 0 |
| Power - Refinery (coastal) | 9 | 0 |



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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