Gas turbine inlet air treatment GdPS

A route map and summary of options available and merits of each based on purchasers unique circumstances

Modified for AFS April 28 Discussion

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FILTER CHOICES

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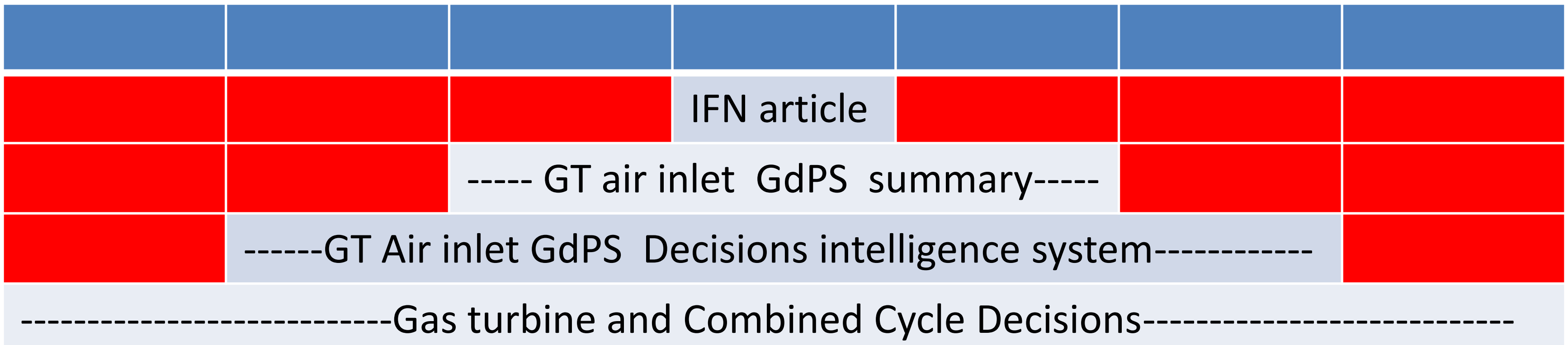
Inlet filter decision system is integrated into a network

- GT filter selection can be likened to a trip with GPS as a guide *-Global Decisions Positioning System™ (GdPS*
- This summary is part of a whole network of initiatives
  - Summary of GT inlet filter options
  - Use of this summary in AFS April 28 Discussion
  - Articles in Filtration News and International Filtration News
- This summary is a guide to more complete resources including
  - Gas Turbine and Combined Cycle Decisions
  - Hot topic hour live and recorded webinars
  - InterWEBviews™
  - Instant phone consulting with world experts

GT air Inlet Summary is part of whole system



The summary is part of a whole system. It is route map to the larger database display (GT Air Inlet Intelligence system) This in turn is part of a complete service for gas turbine operators- *Gas Turbine and Combined Cycle Decisions.* The June Filtration news article will be a compressed version of the revised summary as shaped by the AFS session.

AFS session on April 28 will expand and review the summary

- The 90 minute session will be focused on a slide by slide display of the summary power points.
- As each slide is displayed there is the opportunity for discussion. It would start with the slide author if he so wishes
- Designated panelists as well as the entire group will be encouraged to ask questions and make observations
- Panelists and participants are encouraged to submit power points to be included in the summary
- Anyone is encouraged to submit articles and presentations for inclusion in the GT Air Inlet Intelligence System
- The Filtration News article in June will be based on the conclusions reached in the session
- The summary and the intelligence system will be continually updated

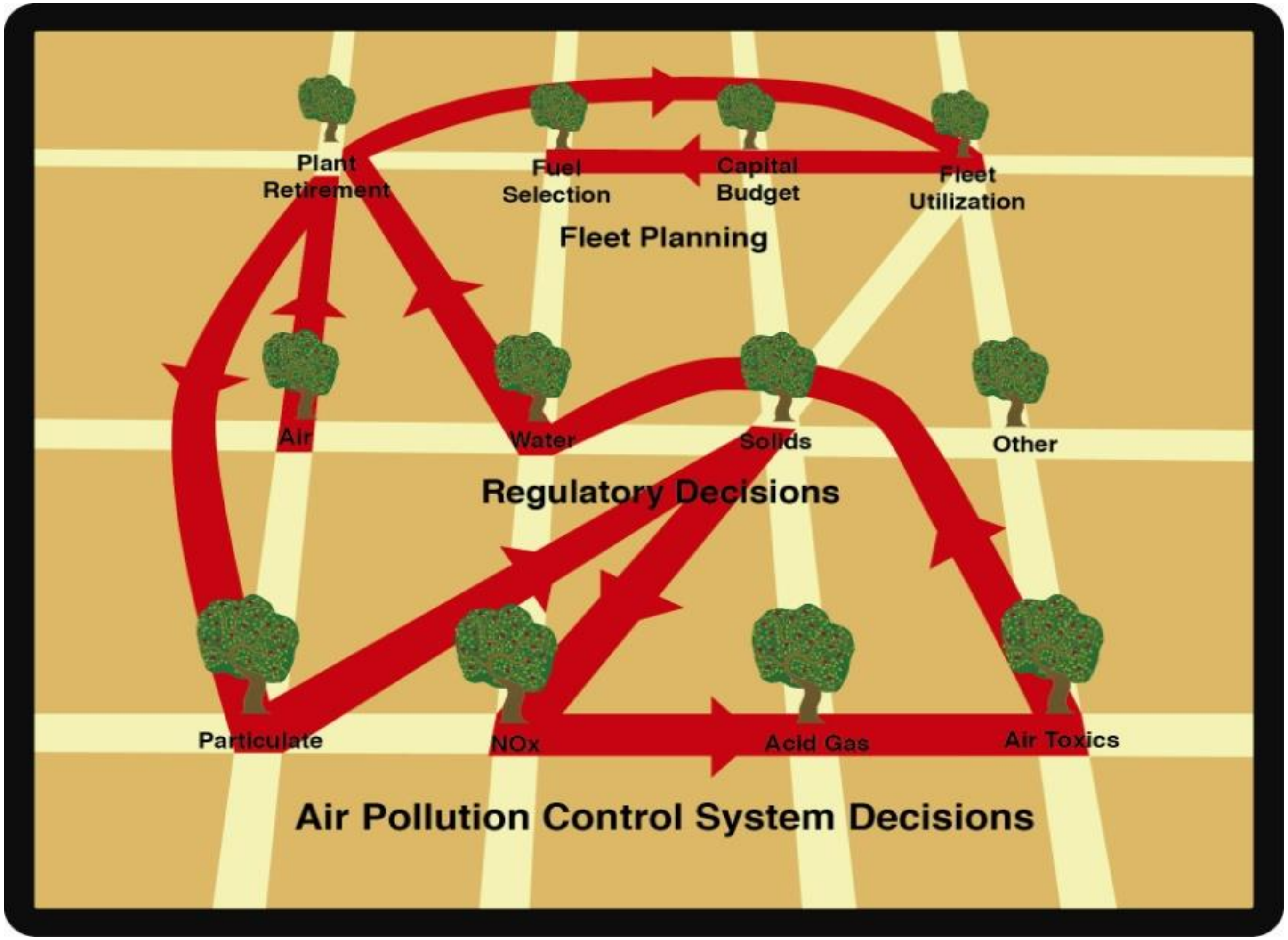
Panelists

Company	Name
Donaldson	Eli Ross
Freudenberg	Mike Garnett
Hollingsworth & Vose	Andre Boni Mike Malloy
Lydall	Geoff Crosby
W.L. Gore	Wilson Poon

The specifier must travel back and forth among decision trees

GAS TURBINE INLET FILTER DECISION TREES	
Air regulations Emission limit may be lower than inlet air concentration. So HEPA filter may be necessary	**location** Arctic, marine, offshore, industrial, and desert have unique challenges
Economic decisions Pressure drop, filter life, and performance all impact cost	**Process options** Location of coalescer, cooling of inlet air, turbine wash cycles, turbine design
Filter selection Static or pulsed, panel or bag, membrane or microglass, number of stages	**Operation** Cycling frequency, maintenance intervals, filter accessibility , performance monitoring

GT filter selection can be likened to a trip with GPS as a guide *-Global Decisions Positioning System™ (GdPS)*



Regulatory, Economic and plant specific impacts on filter choice.

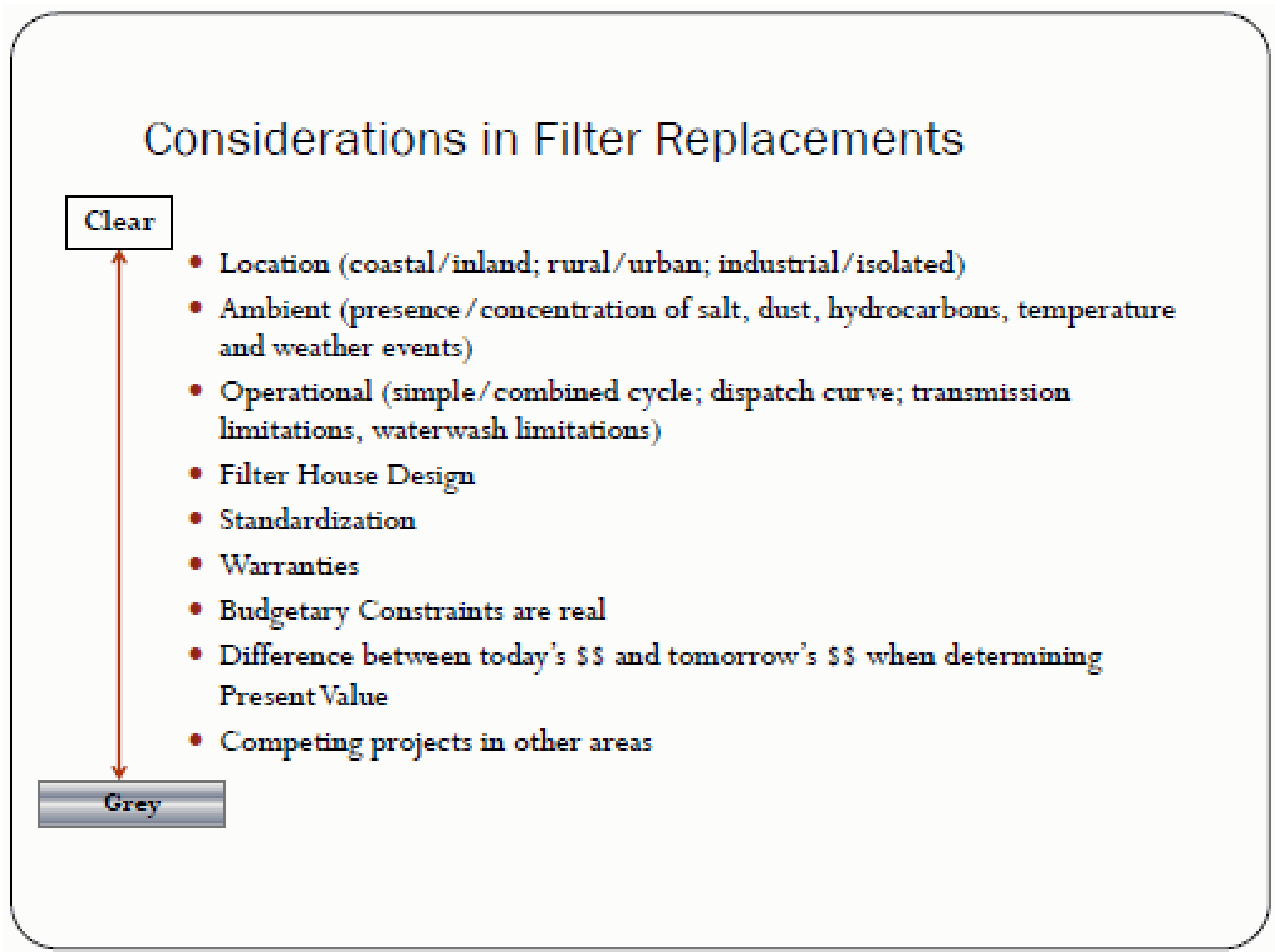
Filter decisions will be impacted by

- Air regs such as NSPS , ambient
- Ambient conditions such as seaside or offshore
- Air quality such as a levels in a refinery or power plant near heavy industry.
- Cycling or base load
- Other air treatment such as weather protection, cooling

Power Points and Authors

Subject	author
Priority ranking	Barilla
Coastal, marine,	Mcilvaine
arctic	tbd
Conditions	GE
Moisture removal	Nederman
TBD	
TBD	
TBD	
TBD	

GT filter- decision trees- priority ranking from clear to grey (Barilla)



Considerations in Filter Replacements

Clear

- Location (coastal/inland; rural/urban; industrial/isolated)
- Ambient (presence/concentration of salt, dust, hydrocarbons, temperature and weather events)
- Operational (simple/combined cycle; dispatch curve; transmission limitations, waterwash limitations)
- Filter House Design
- Standardization
- Warranties
- Budgetary Constraints are real
- Difference between today's $$ and tomorrow's $$ when determining Present Value
- Competing projects in other areas

Grey

Coastal marine and offshore

- Coastal, Marine, or Offshore. Gas turbines operating near or on the ocean are classified as being in a coastal,marine, or offshore environment.
- The gas turbine is in a coastal environment when the gas turbine is installed on land and within 10 miles (16 km) of the ocean.
- At distances from approximately 8 to 12 miles (13 to 19 km) from the shoreline, the salt concentration in the air drops to natural background levels for an environment far away from the ocean.
- The offshore and marine environments are defined as being in the middle of the ocean. The gas turbine is considered an offshore environment when it is located at least 100 ft(30.5m) off of the ocean surface.
- Gas turbines located below 100 ft (30.5m) are considered to be in a marine environment.
- The primary contaminant that is a concern in the coastal,marine, and offshore environments is salt. Which can lead to fouling and corrosion.
- Salt is prevalent in these environments due to the sea water.
- In coastal environments, it is present as dry contaminants (areas with lower humidity), sticky contaminants (humidity between 40and 70 percent), or as liquid aerosols (higher humidity)

Artic, industrial, desert conditions require special designs

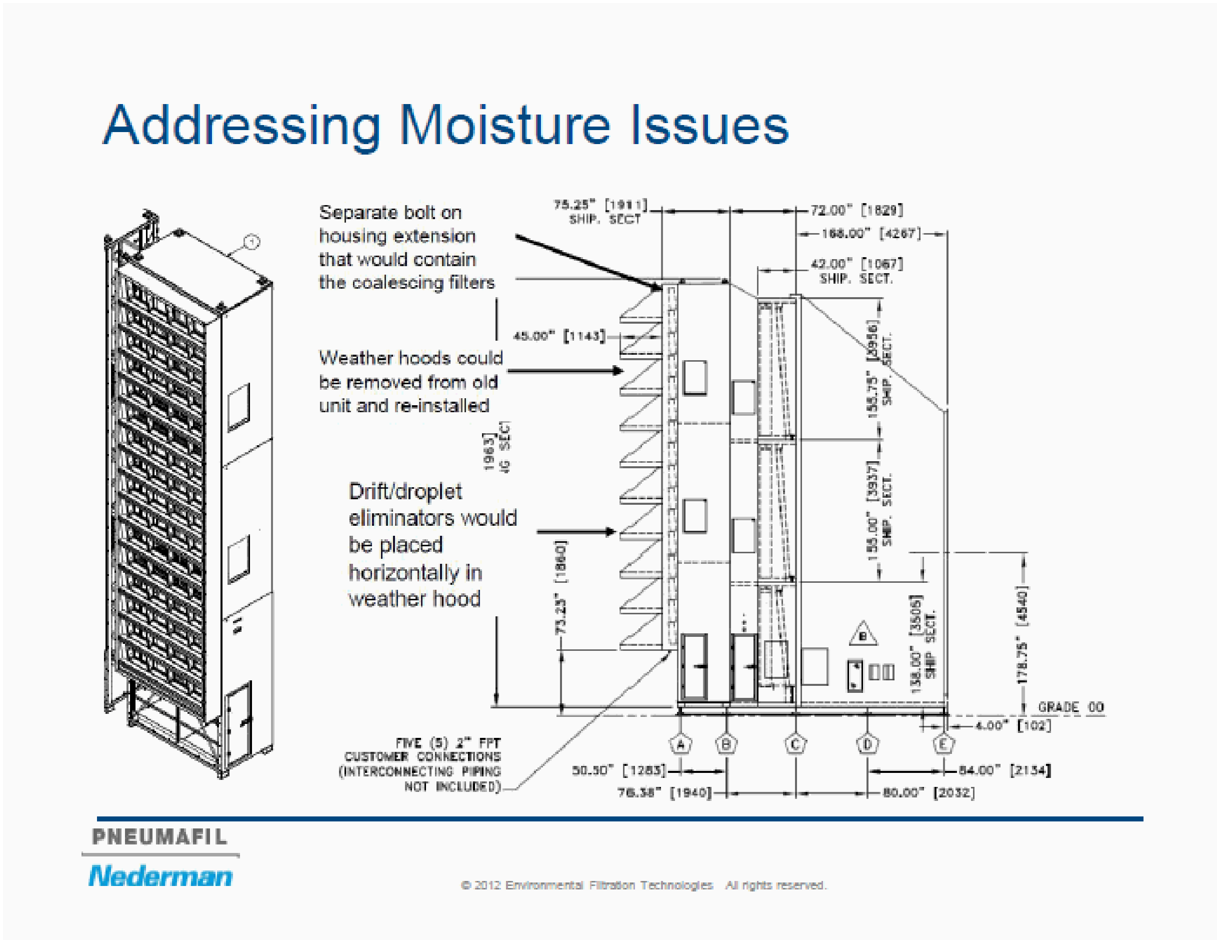
- xxxxx

Conditions encountered depending on location-GE

Environment type	Salt levels	Dust levels	Other challenges
Marine	High	Low	Bulk water
Offshore	High	Medium	Vapors
Coastal	Medium	Medium	Vapors
Dusty	None	High	Vapors
Dusty Coastal	Medium	High	Vapors
Desert	None	Very High	-
Urban	None	Medium	Vapors
Sub... Arctic	-	-	Snow and Ice
Sub… Tropical	-	-	Bulk water

To further evaluate these contaminants, consider the following ad

Filter house design to reduce moisture



Decision Route – regulatory, economic, and plant specific issues

Webinars and InterWEBviews™

February 5, 2015	**Gas Turbine Regulatory Drivers** 120 minutes **MORE**
May 15, 2014	**Gas Intake Filters: HEPA or Medium Efficiency** 101 minutes **MORE**
January 29, 2 InterWEBview	xxxxx
Februaryxxx InterWebView	xxxxxx

Intelligence system key words

categorys	keywords
regulatory	CSAPR. NAAQS
Analysis by consul-ants	AECOM, Barilla Burns & McDonnell, Golder, Kiewit,
Other organiz-ations	EPRI,, Troutman-Sanders

Fiber and Media choices

Many fiber and media combinations

- Glass, synthetics, or mix
- If synthetic which resins
- Fiber selection including diameter e.g nanofiber
- Non woven or other

- Treatment: membrane film?
- Effficiency to meet ambient limits lower than inlet

Power Points and Authors

Micro glass fiber	
Filter media options	Ahlstrom
Combo vs synthetic or glass	Midwesco
nanofibers	Lydall
TBD	
TBD	
TBD	
TBD	
TBD	

Micro-glass fiber

Important properties

X

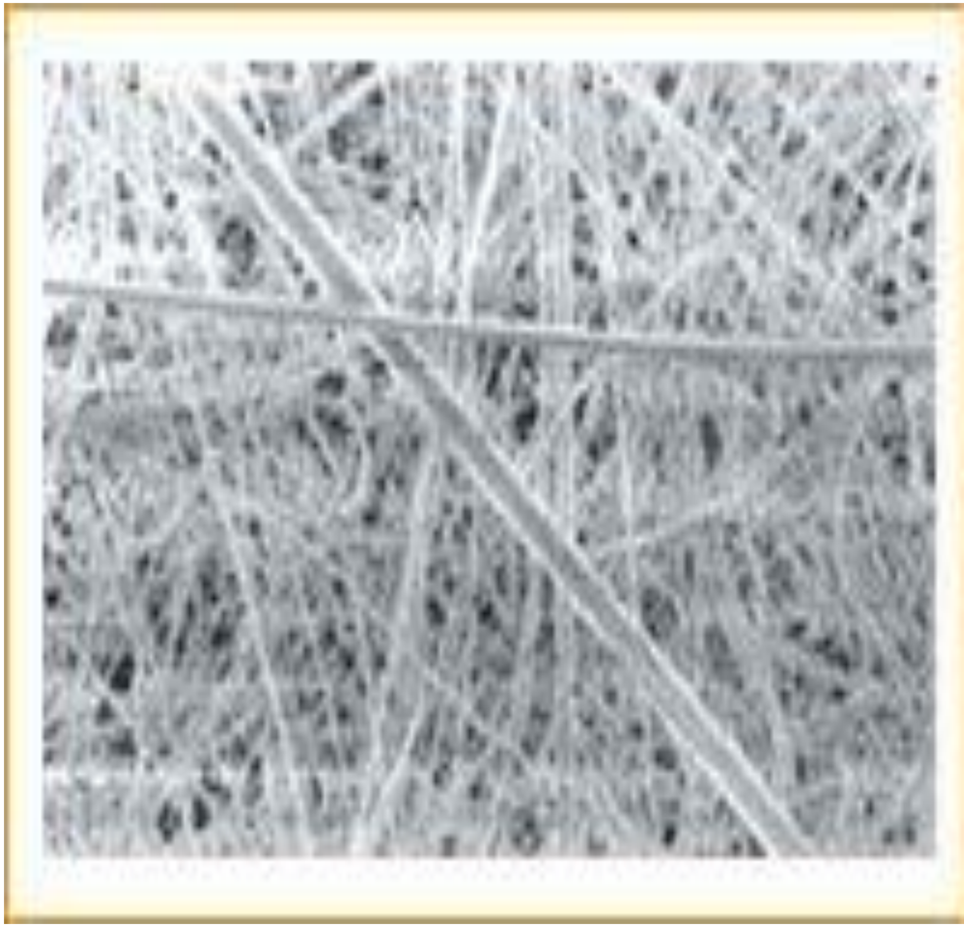
X

X

Combination with Synthetics

X

x

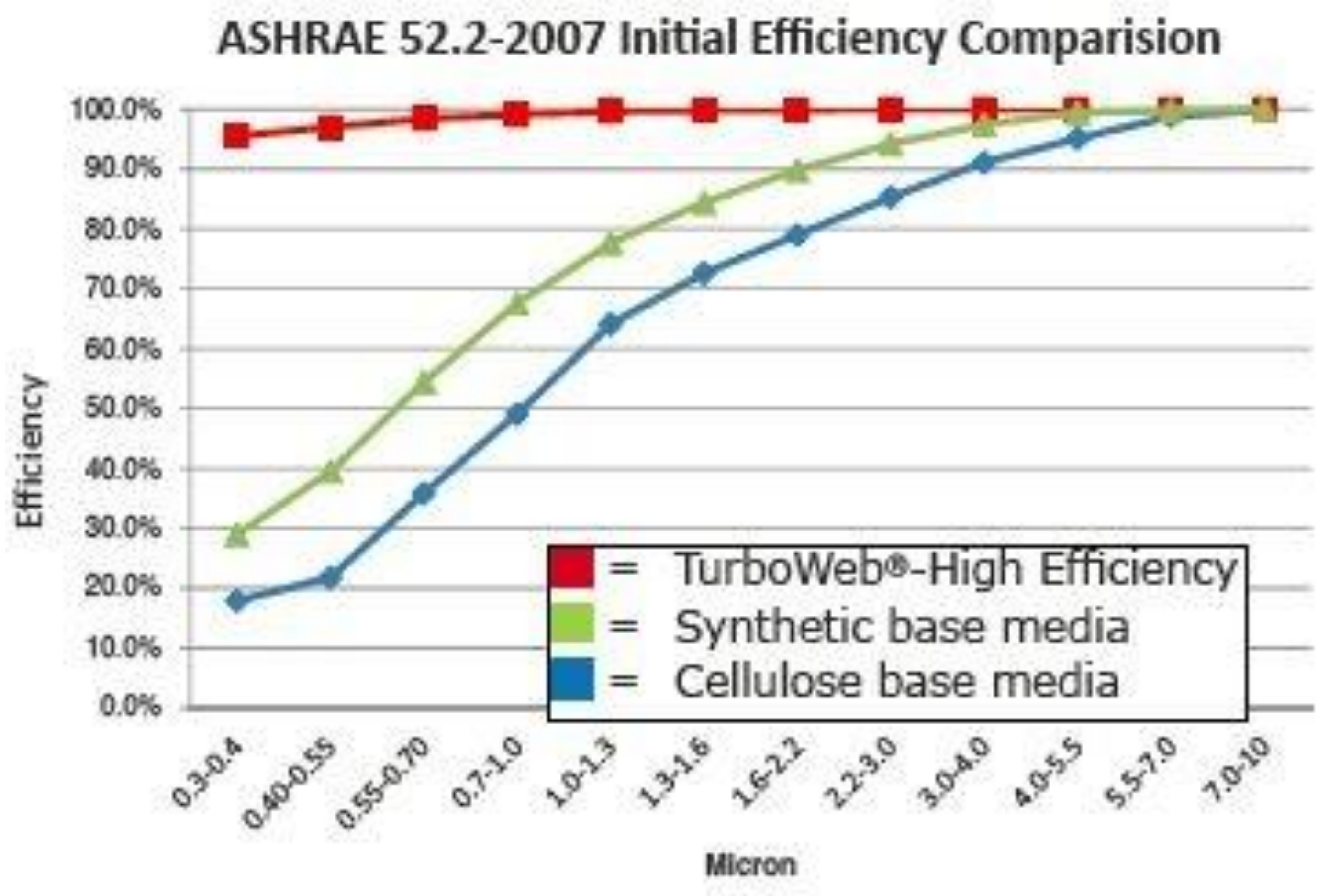


Ahlstrom filter media options

Name	Material	Pre filter Static	Pre filer Pulse	Fine filter Static	Fine filter Pulse	HEPA Static
Trinitex GT	Synthetic	x	x	x	x	
Three layers can be tailored to obtain high strength and superior performance removing diesel soot, high humidity						
Microglass GT				x		x
possibility of additives and blends with synthetic fibers to enhance strength and pleatability						
Cellulose GT		x	x	x	x	
80 % polyester and 20% cellulose, good pleatability, excellent in dusty environments						
Cellulose fine fiber GT		x	x	x	x	
Layer of fine fiber on cellulose carrier sheet						
Nano GT			x		x	
Nanofiber from electro spinning on cellulose carrier sheet						

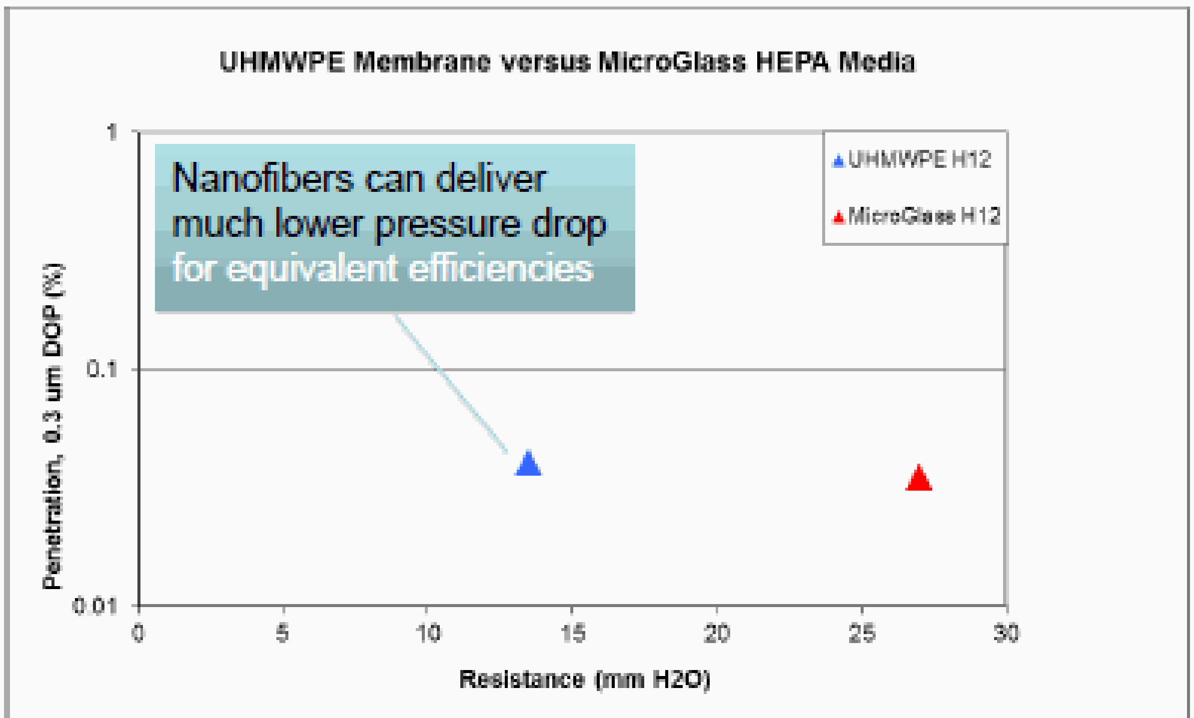
Midwesco filter Turboweb comparison

LAYER 1 Proprietary high efficiency laminate > LAYER 2 Special treatment to resist moisture and salt from entering the media > LAYER 3 100% synthetic



Nanofibers- lydall

Nanofibers: Energy Reduction Possibilities



* The efficiency ratings for this test used 0.3 micron DOP particles on a TSI Model 8160 automated test stand on flat sheet media samples at 5.33 cm/second.

Decision Route – fibers and emdia

Webinars

Feb 5, 2015	**Gas Turbine Regulatory Drivers** 120 minutes **MORE**
May 15, 2014	**Gas Intake Filters: HEPA or Medium Efficiency** 101 minutes **MORE**
INTER WEB VIEW	xxxxx

Intelligence system key words

category	keywords
Fiber suppliers	Eastman, xxx Lauscha xx
Filter media descriptor	HEPA, micro-glass, xxxxxx
media	Ahlstrom, H&V, Lydall, xxxx Xxxxx xxxxxx
xxxx	xxxx

Filter choices

options

- Static filter or pulsed
- If static how many stages
- Design shape of filter elements
- Method of preventing leakage around filter element
- Ease of removal and replacement of elements
- Coalescing filter?

Power points and authors

Pre filters	Southwest
Pre-filter options	AAF, generic
Efficiency levels	Mcilvaine
Efficiency definition	Gore
Pressure loss	Southwest
HEPA static design	Southwest
Cartridge design	Southwest
Staging	Southwest

Filter Choices 2-3

2nd series of Filter Choice PPT

Subject	Author
Life cost	Southwest
Particulate problems	Mcilvaine
Filter selection vs particulate load	GE
Options for Snow/ice	GE
selection vs environment	GE
Selection by filter type	GE
Correct HEPA rating	Gore
Cartridge with pre filter	Gore
Pulsing for constant pressure drop	Gore

3rd series of Filter Choice PPT

Subject	author
Comparison of pulse and static	Gore

Pre-filters

If a one-stage high efficiency filter is used, the
build-up of large and small solid particles can quickly lead
to increased pressure loss and filter loading.

Prefilters are used to increase the life of the downstream high efficiency filter by capturing the larger solid particles. Therefore, the
high efficiency filter only has to remove the smaller particles
from the air stream which increases the filter life.

Prefilters normally capture solid particles greater than 10 μm, but some
prefilters will also capture the solid particles in the 2 to
5 μmsize range.

These filters usually consist of large diametersynthetic fiber in a disposable frame structure

Bag filters arealso commonly used for prefilters. These offer higher surface
area that reduces the pressure loss across the filter

Pre-filter options-which , where?

Panel- AmAir 300GT

Bag-V Bank

Three levels of high efficency

- Three common types ofhigh efficiency filters are EPA, HEPA, and ULPA.
- EPA and HEPA filters are defined as having a minimum efficiency of85 percent and 99.95 percent, respectively, for all particles greater than or equal to 0.3 um
- . ULPA filters have a minimum efficiency of 99.9995 percent for particles the same size or larger than 0.12 um .

Difference between high and very high efficiency

Filter Classifications

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

High efficiency filter pressure loss

- The high-efficiency filters used with gas turbines have pleated media that increase the surface area.
- In order to achieve the high filtration efficiency, the flow through the filter fiber is highly restricted which creates a high pressure loss, unless the face velocity is kept low.
- The pleats help reduce this pressure loss.
- Initial pressure loss on high efficiency filters can be up to 1 inH2O (250 Pa) with a final pressure loss in the range of 2.5 inH2O (625 Pa) for rectangular filters and 4 inH2O (2000 Pa) for cartridge filters.

High efficiency static filter design

- There are many different constructions of high efficiency type filters:
  - rectangular,
  - cylindrical/cartridge,
  - bag filters
- The rectangular high efficiency filters are constructed by
- folding a continuous sheet of media into closely spaced pleatsin a rectangular rigid frame.
- Rectangular filters are depth loaded; therefore, once they reach the maximum allowable pressure loss, they should be replaced
- Cartridge filters are also made up of closely spaced pleats,
- but they are in a circular fashion
- . Air flows radially into the cartridge. They are installed in a horizontal or
- vertical fashion (hanging downward).
- These types of filters can be depth or surface loaded

Cartridge systems

- The self-cleaning system operates primarily with surface loaded high-efficiency cartridge filters.
- . Once the pressure loss reaches a certain level, the filter is cleaned with air pulses.
- The pressure of the air pulses ranges from 80 to 100 psig
- (5.5 to 6.9 barg).
- The reverse jet of compressed air (or pulse)occurs for a length of time between 100 and 200 ms.
- To avoid disturbing the flow and to limit the need for compressed air, the system typically only pulses 10 percent of the elements
- at a given time.
- With this type of cleaning, the filter can be brought back to near the original condition

staging

- Any gas turbine application typically Needs more than one type of filter, and there are no “universal filters” that will serve all needs.
- two-stage or three-stage filtration systems are used.
- A prefilter or weather louver can be used first to remove erosive contaminants, rain, and snow.
- The second may be a lowto-medium-performance filter selected for the type of finersized particles present or a coalescer to remove liquids.
- The third filter is usually a high-performance filter to remove smaller particles less than 2 um in size from the air..
- This arrangement is not correct for all cases due to the fact that the
- filter stages are highly influenced by the environment
- .

Filter life cycle cost considerations

- initial cost (filters, filtration system, spares filters, instrumentation),
- installing and commissioning costs (labor, cost of installation equipment (such as cranes), shipping costs),
- energy costs (pulse system for self-cleaning filters),
- operating costs (labor, inspections),
- (maintenance (replacing filters, repairing system,
- labor for maintenance),
- downtime (replace filters, complete offline water washes, anything outside of normal shutdowns for other maintenance),
- gas turbine effects (degradation, performance loss),
- decommissioning and disposal (disposal of filters).

Problems with particulate

Corrosion

Corrosion is the loss of material caused by chemical reaction between machine components and contaminants which can enter the gas turbine through the gas stream, fuel system or water/steam injection system. Salts, mineral acids, elements such as sodium, vanadium, and gas, including chlorine and sulphur oxides in combination with water, can cause corrosion, especially in the

Erosion

Erosion is the abrasive removal of material by hard particles suspended in the gas stream. Particles causing erosion are normally 10 microns or larger in diameter. Particles with diameters between 5 and 10 microns fall in a transition zone between fouling and erosion.

Erosion damage increases with increasing particle diameter and density, flow turning and gas velocity, and with decreasing blade size. Turbine and compressor manufacturers minimize erosion by increasing trailing edge thickness, installing field replaceable shields and using improved alloys. Nevertheless, they all recommend fine inlet filtration to prevent hard particles from entering the turbines.

Fouling

Fouling is the adherence of particles and droplets to the surface of the turbomachine blading. This degrades flow capacity and reduces efficiency in a short period of time. Fouling can normally be reversed by cleaning, but it often requires downtime. Fouling is a serious problem, particularly in the oil and gas industry where sticky hydrocarbon aerosols are universally present. Traditionally, no accommodation has been made in designing turbines to tolerate deposition tendencies of particulate-laden gas streams. Although the deposition trajectories can be predicted for some turbine blades, the actual fouling is very much dependent on inlet gas cleanliness which varies unless it is control

GEA recommends alternative selections for dust loads above and below 0.2 mg/NM3

Selection criteria and modules

Whether desert or tropical climate, always the suitable solution

Sand storms cause different problems than monsoon rains. Operators of compressors, turbines and motors therefore need filter systems that are individually adapted to the climatic conditions, dust concentrations and additional local parameters. Our selection diagram facilitates the selection of the correct system. Apart from our flexibly combinable standard system, we also offer you harmonized customized systems for your application. In addition we offer comprehensive services such as the professional assembly, commissioning and maintenance.

Selection criteria for intake systems

Dust concentration
low
<0.2 mg/m3

Dust concentration
high
>0.2?mg/m3

Climate	Climate	Climate		Climate
dry < 80 % rel. humidity	humid > 80% rel. humidity	dry < 80% rel. humidity		dry < 80% rel. humidity

Sand storms possible

Tailored systems

Configuration 1	Configuration 2	Configuration 3	Configuration 4	Configuration 5
Weather-protection Pre-filter Fine filter Possibly anti-icing *or alternative* Pre-filter Depth filter cartridges	Droplet separator Pre-filter Fine filter Possibly anti-icing *or alternative* Pre-filter Depth filter cartridges	Possibly fine filter	Pulse filter *or alternatively* Configuration 1	Inertial separator Possibly coalescer Pre-filter Fine filter *or alternatively* Configuration 2

Standard systems

System A	System B	System C	System D	System E
Duct air filters MultiMaster Vario	Duct air filters MultiMaster Vario	Pulse filter PowerTower	Rotary oil bath filter RotaClean	Rotary oil bath filter RotaClean
Weather protection Pre-filter Fine filter Possible anti-icing	Droplet separator Pre-filter Fine filter Possible anti-icing		Possibly fine filter *or alternative* (equipped with sand	Droplet separator Possibly fine filter

GE Design comparison

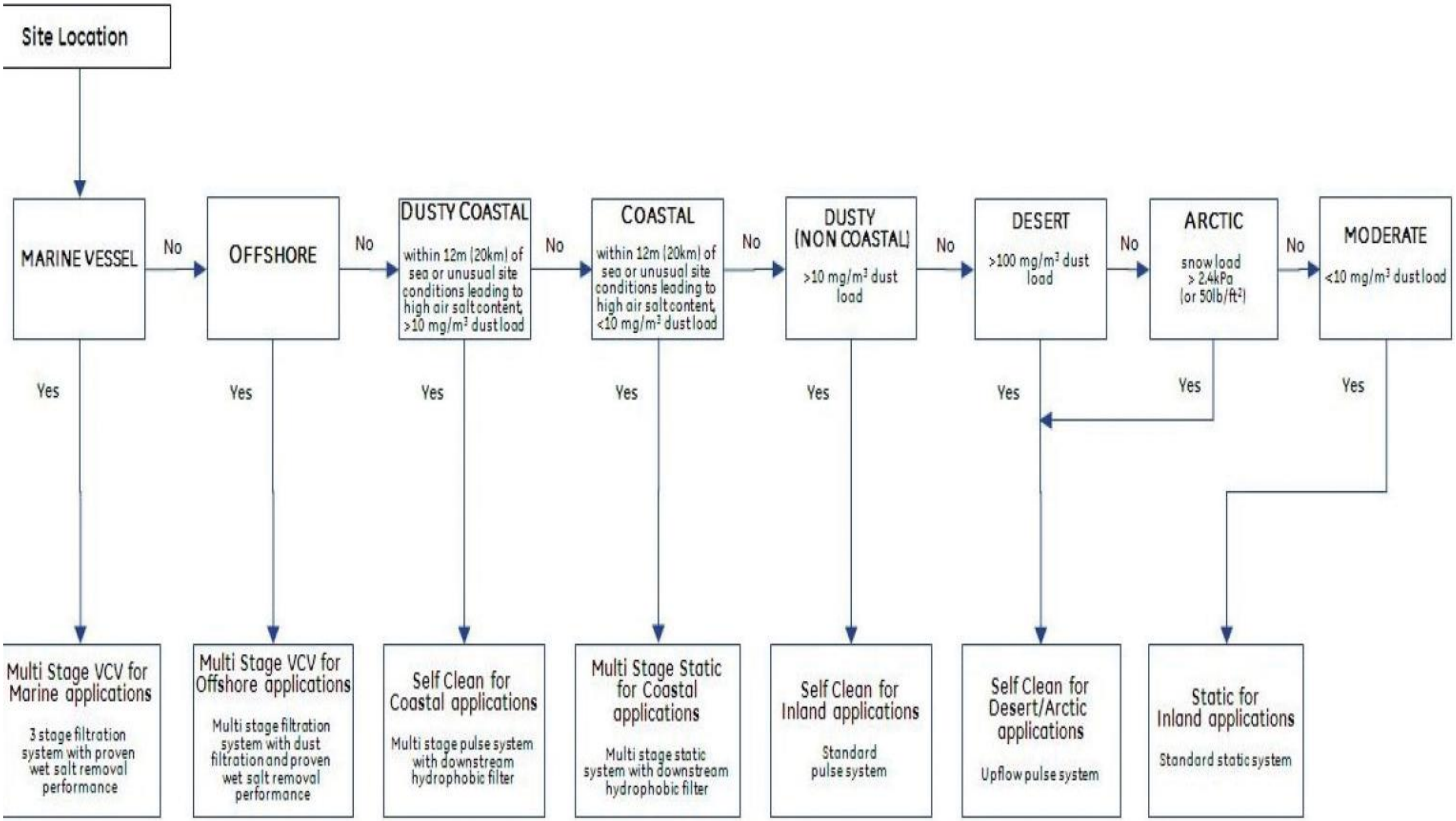
+(most favorable) 0(unbiased) –(least favorable)

Benefit	Static	Standard Pulse	Upflow Pulse
Initial dust efficiency	+	-	-
Filter life	-	0	+
Sensitivity to fog / mist	+	-	-
Compactness	+	0	-
Cost	+	0	-

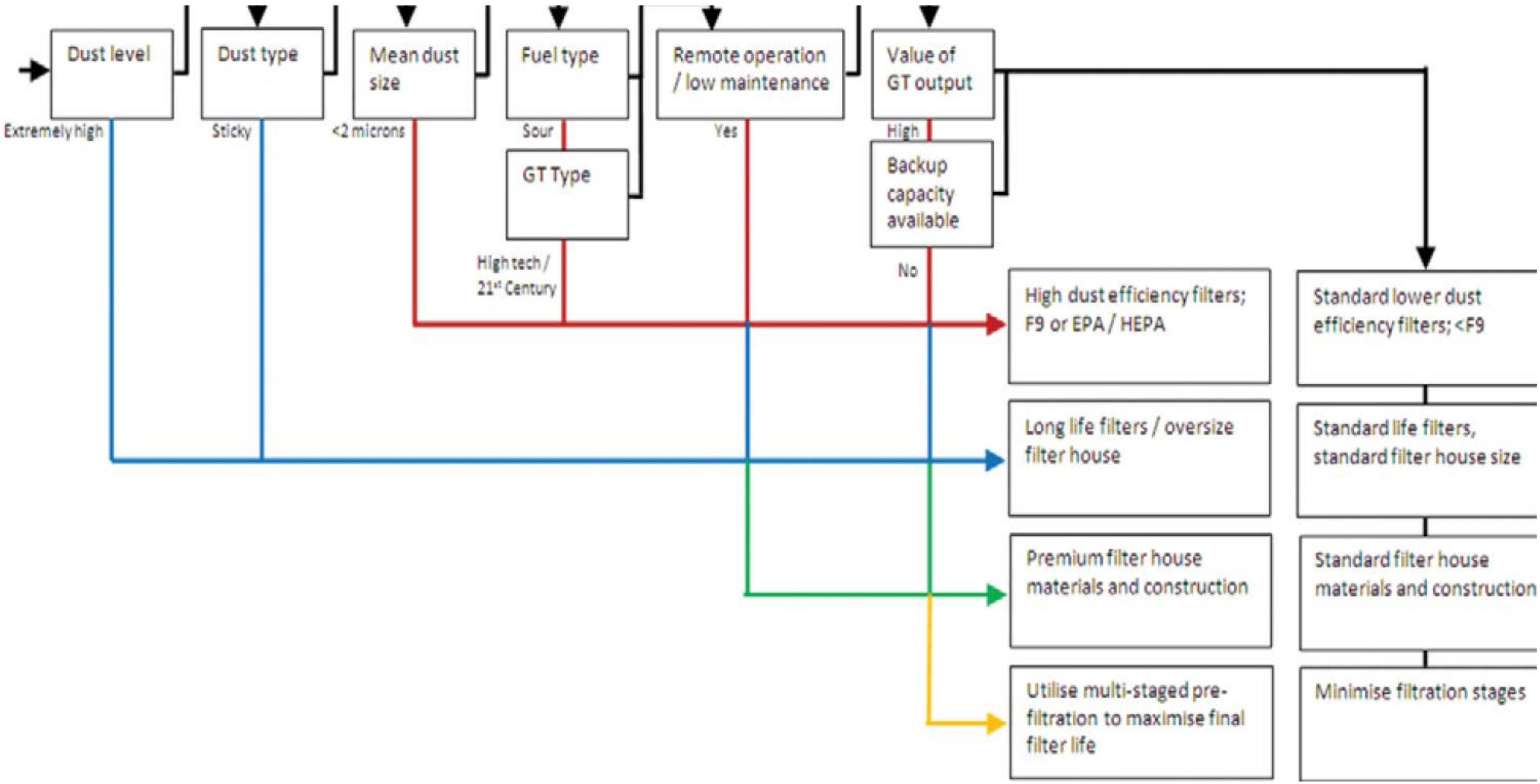
Options for Snow and Ice-GE

Benefit	Snow Hood	Upflow Pulse	Inlet Heating
Effectiveness vs. Ice	-	0	+
Effectiveness vs. Snow	-	0	+
Cost	+	-	-

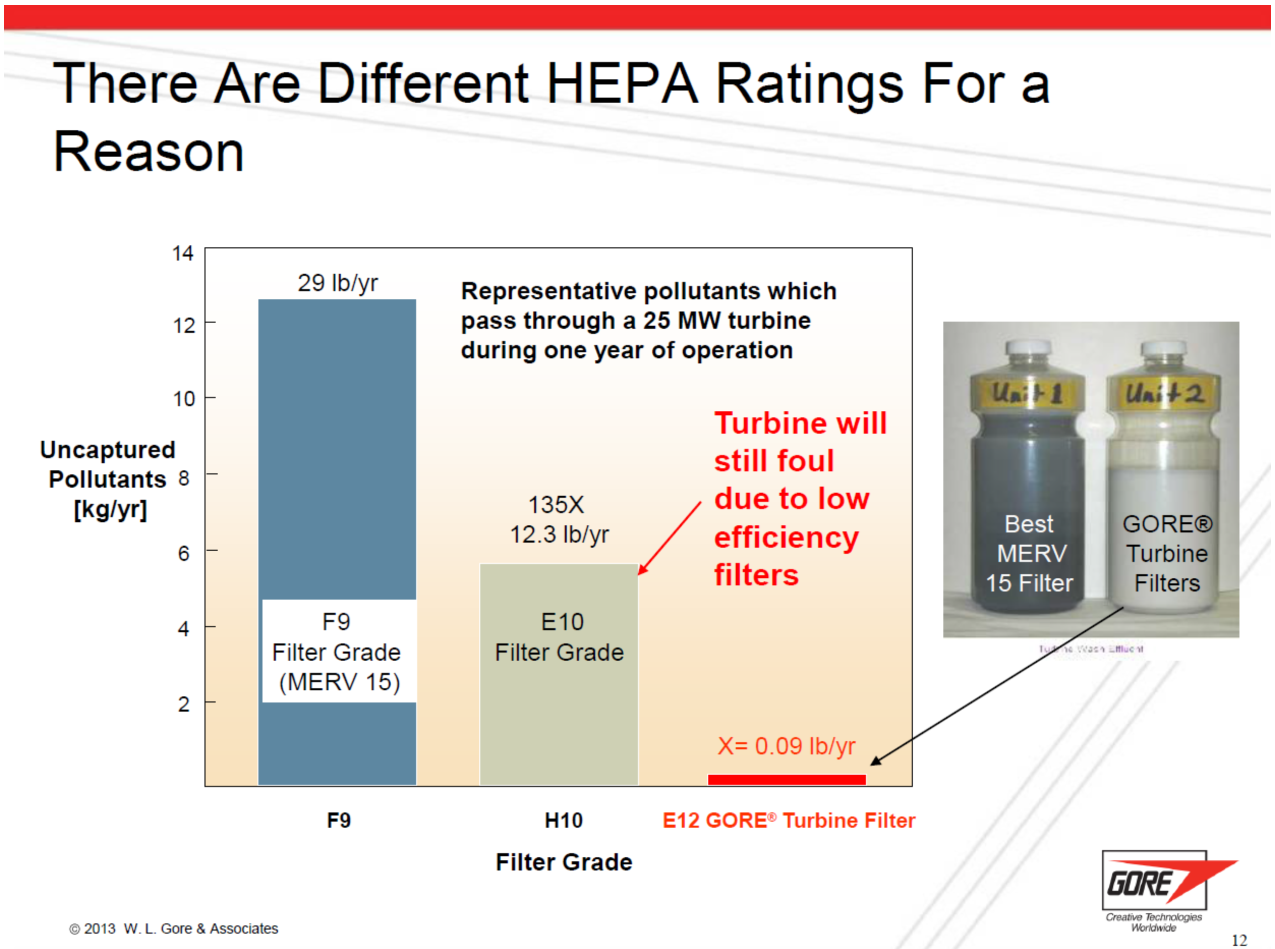
GE filter recommendations depending on environment



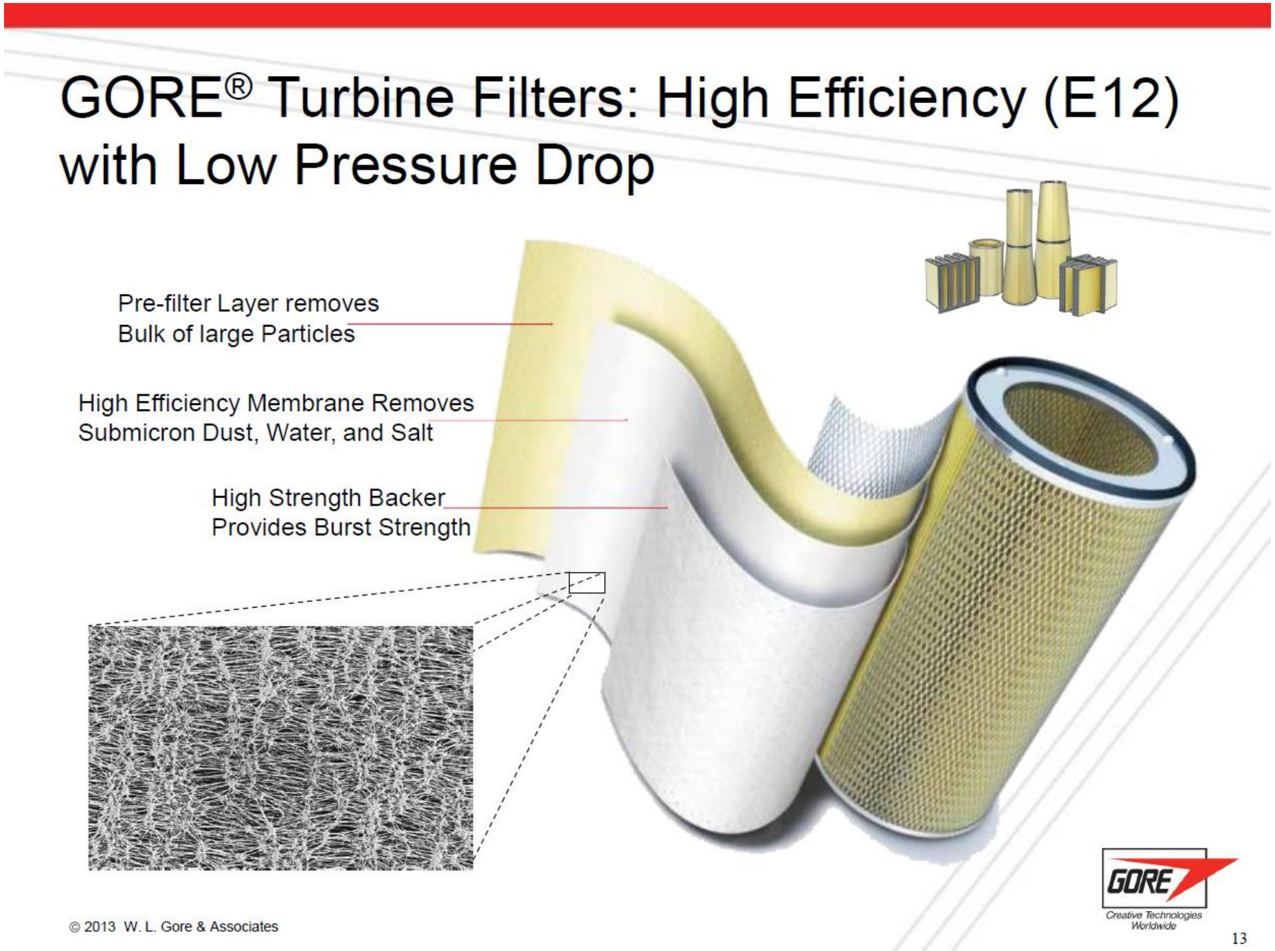
GE Selection recommendations



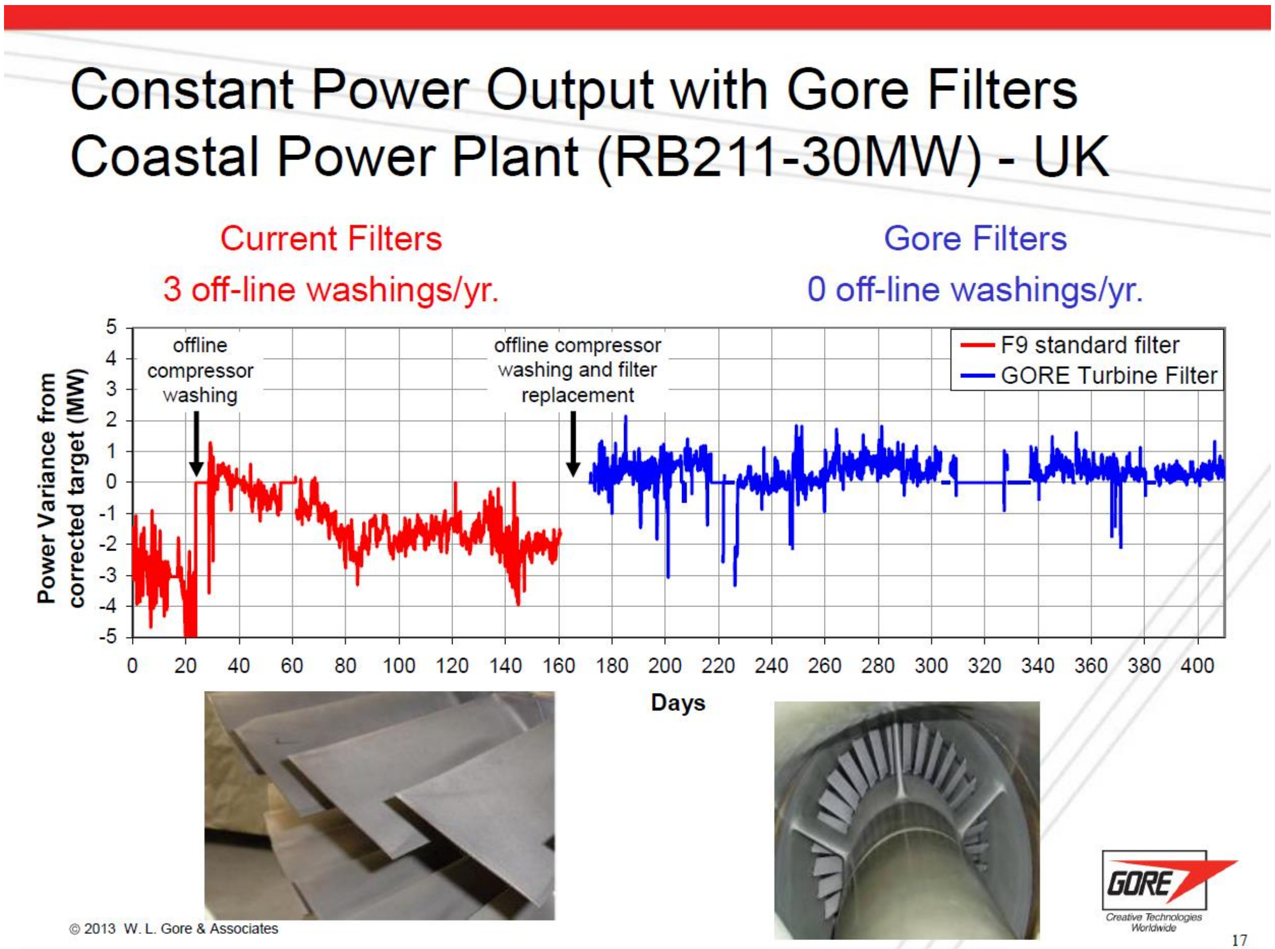
Make sure to use relevant HEPA rating



Cartridges with integral pre-filter

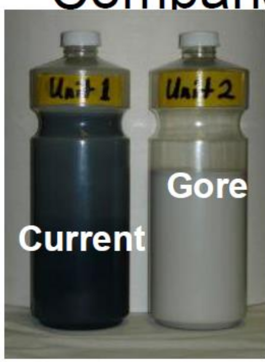


Pulsing prevents pressure peaks

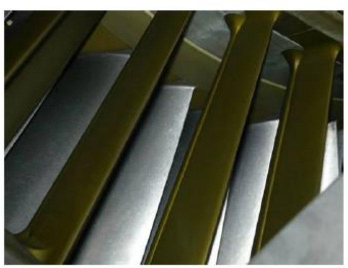


Comparison of pulse and static for industrial gas turbines

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



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Creative Technologies Worldwide

Decision Route – filters

Webinars

Feb 5, 2015	**Gas Turbine Regulatory Drivers** 120 minutes **MORE**
May 15, 2014	**Gas Intake Filters: HEPA or Medium Efficiency** 101 minutes **MORE**
INTER WEB VIEW	xxxxx

Intelligence system key words

category	keywords
Product descriptor	Bag, HEPA, cartridge, static, panel
Filter suppliers	AAF, Clarcor, Donaldson, Midwesco, Nederman, xxxx
xxxx	xxx
xxx	xxxx