AFS program and the Gas Turbine Filter Decision Guide

- *This sequence of power points will be displayed at 3 PM on April 28 and will be the background for the discussion*

- AFS Program Overview
- Decision Guide, Decision Orchard, AFS, and International Filter News
- Hot Gas Filtration Decision Guide

Program Overview

General

- 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 Gas Turbine Combined Cycle Decisions Orchard.
- 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.

Specific: GT Inlet Air Filters

- Provide access to GT Inlet Air Filter Decision Guide upon registration
- Provide updated version of GT Inlet Air Filter Decision Guide prior to the event
- Provide contact among presenters and attendees before, during and after the event
- Conduct the program as a series of panels
- Continue upgrading of GT Inlet Air Filter Decision Guide
- Post presentations into the Decision Orchard
- Publish articles in International Filtration News

GT Inlet Air Filter Decision Guide is part of a whole system

IFN article

Gas Turbine and Combined Cycle Decisions Program with GTCC Decision Orchard, decision guides, and operating system

4As Operating system

- **Alerts**: Weekly GTCC Alert and articles in CCJ and IFN
- **Answers**: Orchard Answers with Decision guide locator
- **Analysis**: conference debates, hot topic hours , expert support , white papers and **InterWebviews™** in many languages
- **Advancement**: recorded webinars and access to program

------------------------------------ Global Decisions Orchard ------------------------------------

This GdPS is part of a whole system. It is route map to the larger database and 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.

Panelists

Company	Name
Ahlstrom	Ina Parker
Clarcor	Steve Hiner
Donaldson	Eli Ross
Freudenberg	Mike Garnett
Hollingsworth & Vose	Andre Boni Mike Malloy
Lydall	Geoff Crosby
W.L. Gore	Tom Kelmartin

Gas Turbine Inlet Air Filtration Decision Guide

A route map and summary of options available and the merits of each based on purchaser's unique circumstances

Modified for AFS April 28 Discussion

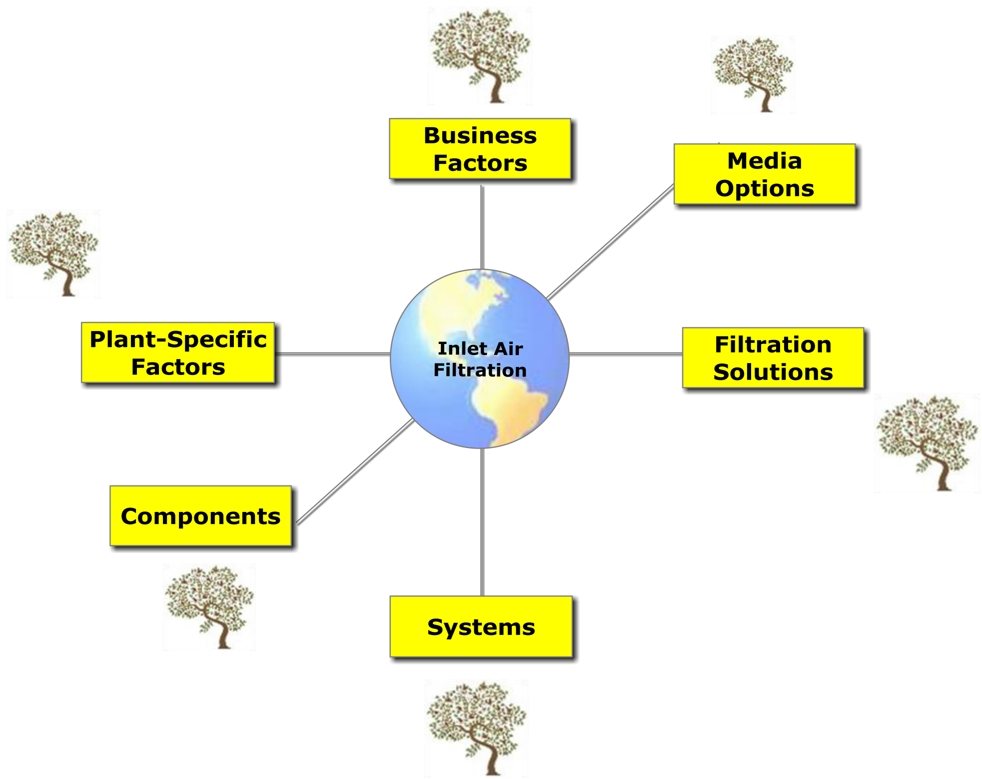
4/20/15 DRAFT

Inlet Air Filtration [R]

Decision Guide

(Orchard route map)

Click on Cells for Information



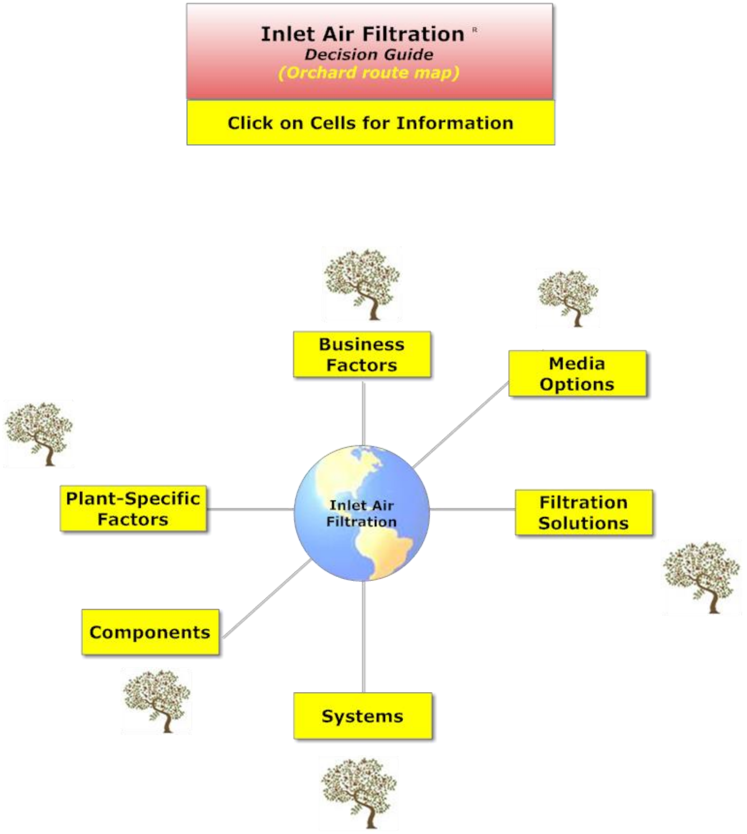
Business Factors

Regulatory

- U.S
- EU
- China
- Other

Economic

- Macro
- Micro
  - Plant life
  - Parasitic power cost



I. Regulatory, Economic and Site Specific Impacts on Filter Choice

Subject	Slide Contributor	Relevant decision
Regulatory Impacts	McIlvaine	Gas and renewable generation will grow as coal and nuclear plants are retired
Priority Ranking	Barilla	What factors must clearly be considered vs. more “grey” factors?
Overview of Environmental Conditions	GE	What challenges are presented by various regional environments?
Coastal, Marine and Offshore Conditions	McIlvaine	What considerations are involved in designing air inlet filtration systems for coastal environments?
Desert Conditions	McIlvaine	Same – for desert environments.
Arctic Conditions	McIlvaine	Same – for arctic environments.
Tropical Conditions	McIlvaine	Same – for tropical environments.

Regulatory Impacts:
Gas turbine capacity will grow as regulations shift the energy mix away from coal and nuclear generation

Coal plants are being retired worldwide due to environmental concerns and regulations

- Mercury, particulates, SO2, NOx
- Greenhouse gas regulations such as New Source Performance Standards (NSPS) for new plants and Clean Power Plant Program for existing plants in the U.S.

Nuclear plants are being retired in Japan, Germany and elsewhere as a consequence of the Fukushima disaster

Gas-fired power generation will increase to fill the gap

In addition, greenhouse gas regulations are promoting ***renewable energy***, which will require quick-start gas-fired units for backup

Priority ranking of filter selection factors (Barilla)

[Gas Turbine Inlet Filters - Value Considerations in Filter Selection by Paul Barilla - Hot Topic Hour May 15, 2014]

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

Plant specific factors

Environment

- Coastal
- Marine
- Offshore
- Desert
- Arctic
- tropical

Combustion

- turbine design
- Fuel additives
- Fuel
- Heat recovery

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

Coastal, Marine and Offshore Conditions

Guideline for Gas Turbine Inlet Air Filtration Systems
Understanding the Benefits and Limitations of EPA Filtration--Filtration News, April 2015
Filtration Efficiency's Impact on Compressor Health--Filtration News, April 2015

- The main difference between coastal and land based applications is the concentration of ***salt*** in the atmosphere. Salt is a main contributor to corrosion and can lead to fouling of compressor blades.
- ***Coastal environments*** refer to gas turbines installed on land but within 10 miles of a salt-water shoreline. At 8 to 12 miles from the shoreline, salt concentrations in the air drop to natural background levels.
- ***Marine environments*** refer to gas turbines installed on vessels, where the inlet is generally within 100 feet from the ocean's surface.
- ***Offshore applications*** are typically oil production platforms with gas turbine inlets more that 100 feet from the ocean's surface.
- Air intake filtration systems must be designed to handle moisture and salt and are typically include:
  - Weather protection (such as a weather hood)
  - Vane separators or coalescers to address <u>moisture</u>
  - Pre-filters and/or high efficiency filters to address <u>salt</u>

Desert Conditions

- ***Dust and sand*** are the main contaminants in desert environments. Initial separators can remove the larger dust particles, followed by pre-filters and high efficiency filters to remove the smaller particles.
  - However, modern self-cleaning cartridge filters with pulse cleaning have largely replaced separator/pre-filter/high efficiency filter arrangements, which tend to be more expensive due to the cost of frequent filter change outs.
- Some desert locations experience periods of ***dense fog and high humidity***, particularly in coastal regions in the Middle East. The moisture can collect on the surface of cartridge and self-cleaning filters, causing the dirt to form a cake which reduces the effectiveness of the filter and pulse-cleaning
- mechanism.
- Air intake filtration systems in desert environments typically include:
  - Weather protection (such as a weather hood)
  - Vane separators or coalescers, where appropriate, to address <u>moisture</u>
  - Self-cleaning cartridge filters to address <u>dust and sand</u>

Arctic Conditions

[Guideline for Gas Turbine Inlet Air Filtration Systems]

- Arctic environments are characterized by lengthy periods of time with temperatures below 32° F (0° C). The main concern for air intake systems is the ***removal of snow and prevention of ice formation and buildup.***
- Inlet filter housings should be elevated to minimize the ***ingestion of snow and ice***, with consideration given to the expected height of snow in winter months.
- Weather hoods should have a large entrance areas which decreases velocity and the likelihood that show will be pulled into the filtration system.
- Ice can be formed if the temperature of humid air in the inlet system decreases, causing water particles to freeze. Moisture in the air can be due to:
  - ***Cooling tower drift.*** The plant should be laid out to minimize the potential cooling tower aerosols to enter the intake system.
  - ***Ice fog***, which typically starts to form at temperatures below -15° F,
- ***Anti-icing systems*** mix heated air (from compressor bleed or gas turbine exhaust) with cold inlet air. Alternatively, ***pulse cleaning systems*** have been found to be effective in preventing ice build up.
- Air intake filtration systems in artic environments include:
  - Elevated intake structures
  - Weather protection (such as a weather hood or louvers)
  - An anti-icing system with pre-filters OR self-cleaning filters
  - High efficiency filters

Tropical Conditions

[Guideline for Gas Turbine Inlet Air Filtration Systems]

- Tropical environments are characterized by high temperatures, high humidity, monsoons, high winds and insect swarms. Due to extensive vegetation, it is considered a low dust environment.
- The primary contaminants are ***water and insects, and salt*** for locations near the shoreline.
- Filtration systems in the topics are specifically built to handle large amounts of rain. Weather hoods are used as a primary defense, typically followed by a vane axial separator and coalescers to reduce water intake.
- Large area insect screens with low inlet velocities are used to block ingestion of insects.
- High temperatures and high humidity lead to the formation of mold fungus and corrosion. Therefore, all metal inlet parts should be made of corrosive resistant materials or coated with ***corrosion protection***.
- Air intake filtration systems in tropical environments include:
  - Weather protection (such as a weather hood)
  - Insect screens
  - Vane axial separator, coalesce
  - Pre-filter and high efficiency filter
  - Corrosion resistant metal parts

Decision Route – Regulatory, Economic and Site Specific Issues

Webinars (Protected)

Date	Recording Title
February 5, 2015	**Gas Turbine Regulatory Drivers** 120 minutes
May 15, 2014	**Gas Intake Filters: HEPA or Medium Efficiency** 101 minutes

InterWebViews™ (Free)

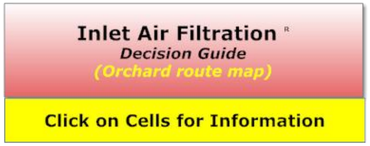
Date	Topic

Intelligence System Key Words

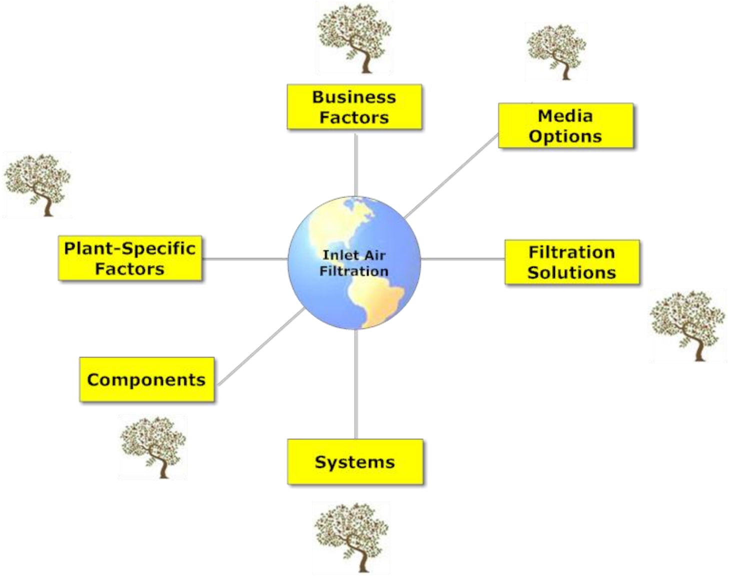
Search Category	Key Words
By Product	Air Filter Air Inlet House
By Company	General Electric, Nederman
By Person	Barilla
By Regulation	Greenhouse Gas
By Topic	Humidity Moisture

Media options

- Non woven



- Woven glass
- Membranes
- Ceramic
- metallic



II. Fiber and Media Choices

Subject	Slide Contributor	Relevant decision
Overview of Media Options	McIlvaine	What factors should be considered in selecting the filter media?
Efficiency Levels	Mcilvaine	What are EPA, HEPA and ULPA filters?
Efficiency Levels	Gore	What are the differences between high and very high efficiency filters? (2 slides)
Air Filter Standards	Freudenberg	What are the EN779, Ashrae and ISO standards applicable to air intake filters? (2 slides)
Media Selection	Hollingsworth & Vose	What factors should be considered in selecting the filter media? (6 slides)
Combo vs Synthetic or Glass	Midwesco	How does the performance of a synthetic/glass combo filter compare to other media?
Expanded Metal & Plastic	Dexmet	How can expanded metal and plastic media be used in gas turbine applications?
Nanofibers	Lydall	What are the benefits of nanofibers?

Overview of Filter Media Options

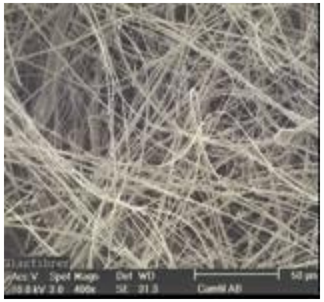
Two primary types of media are available:

- Synthetic, typically with coarser fibers
  - 3.0 to 4.0 µm diameter
- Glass, typically extruded to a smaller fiber diameter
  - 1.0 to 1.3 µm diameter
  - Higher dust holding capacity
  - Stiffer fibers, able to resist higher pressure drops and last longer

Synthetic Media

Fiber selection criteria:

- Efficiency rating
- Fiber size, diameter
- If synthetic, which resins



Glass Media

Three Levels of High Efficiency

The three common types of high efficiency filters are EPA, HEPA, and ULPA, defined as follows:

- EPA filters have a minimum efficiency of 85% for removal of 0.3 µm diameter or larger particles
- HEPA (High Efficiency Particulate Air) filters have a minimum efficiency of 99.97% for removal of 0.3 µm diameter or larger particles
- ULPA (Ultra Low Penetration Air) filters have a minimum efficiency of 99.9995% for removal of 0.12µm diameter or larger particles

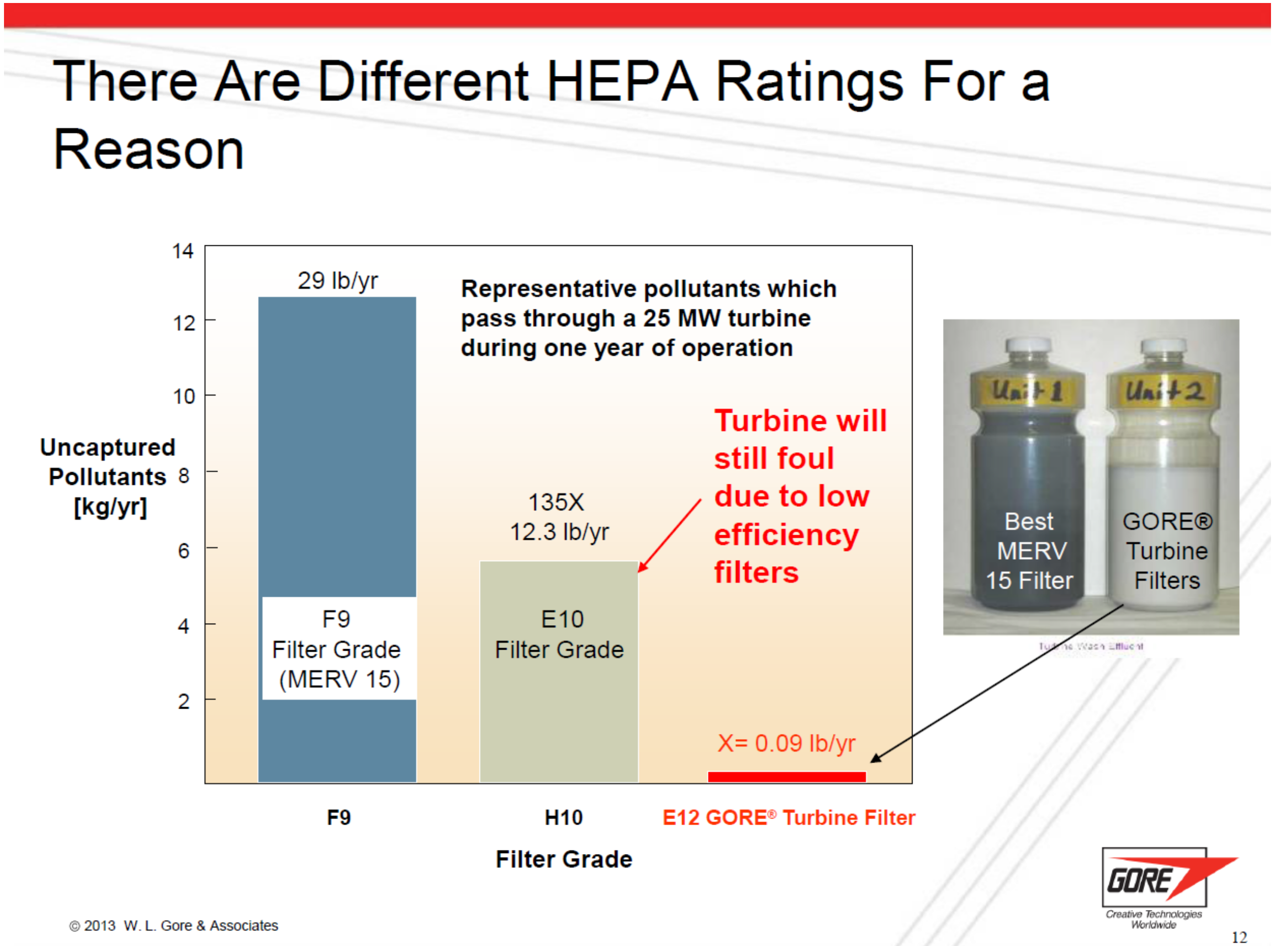
Differences Between High and Very High Efficiency Filters (Gore)

Filter Classifications

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

GORE Creative Technologies Worldwide

Make Sure to Use Relevant HEPA Rating (Gore)



Air Filtration Standards (Freudenberg)

EN779: 2012 supersedes 2002.

Europe use EN779 (Fine filters) & EN1822 (EPA)

North America: Ashrae 52:2 (MERV) & DOP

Rest of the World is a mixture of both standards.

Japan: JIC

New ISO test protocol dedicated to rotating equipment is a worldwide standard. (Different to old EN779 which was based on HVAC filter testing).

Air Filtration Standards (Freudenberg)

ISO / FDIS 29461 -1:2011 (E) ISO/TC 142/SC WG9
Air intake filter systems for rotary machinery

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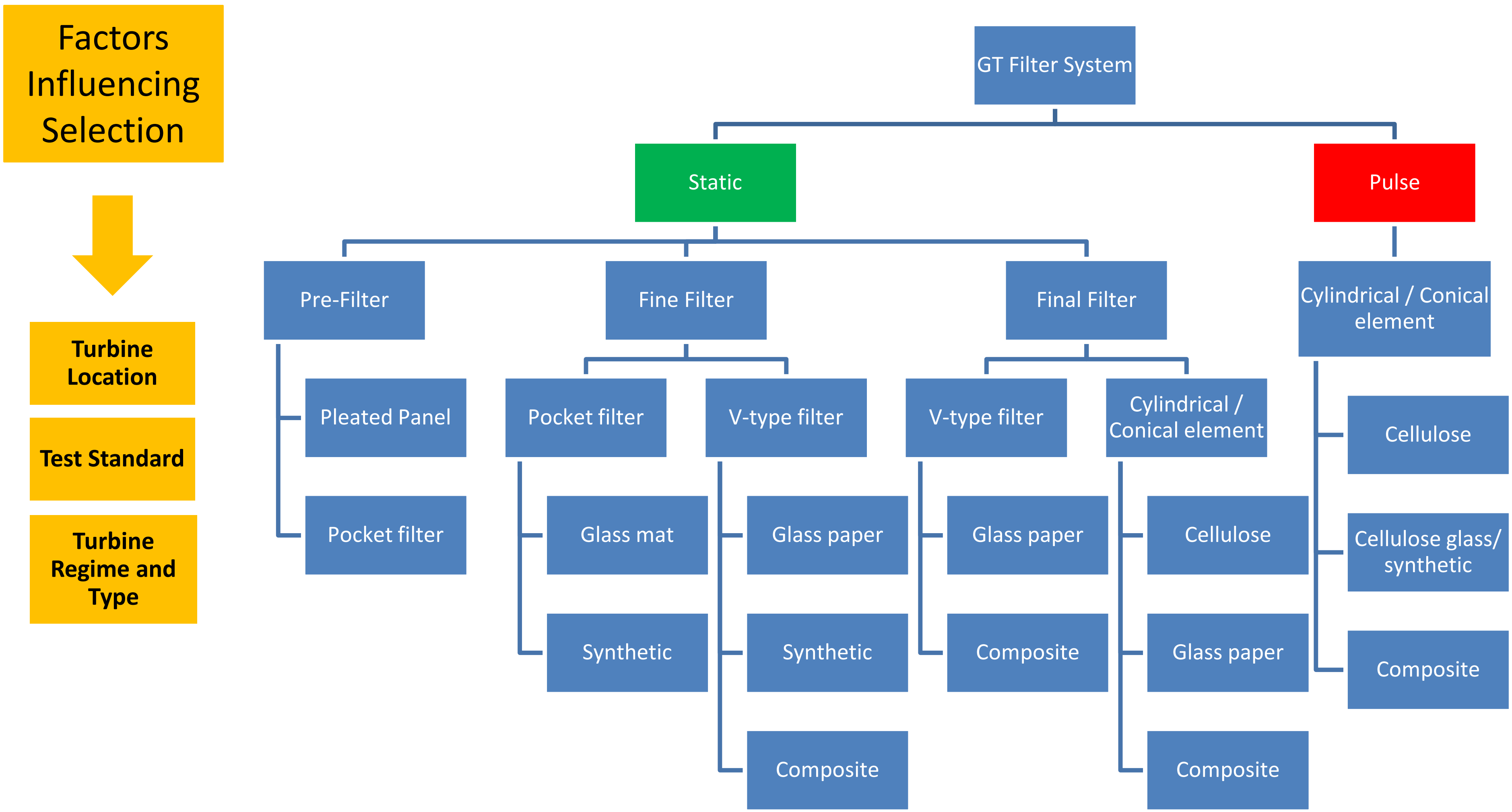
- Part 1: Test method and classification for static filter elements. *(Introduction of a discharge test ,minimum 04.um percentages & higher final differential pressure limits).*
- Part 2: Test method and classification for cleanable (Pulse Jet) filter <u>systems</u>

  (draft being reviewed)
- Part 3: Integrity testing (environmental conditions, mechanical strength).
- Part 4: In-Situ testing – real operating performance.
- Part 5: Marine and Off-shore - (*draft being compiled)*
- Part 6: Cartridge testing method for individual cartridges. (d*raft being compiled*)

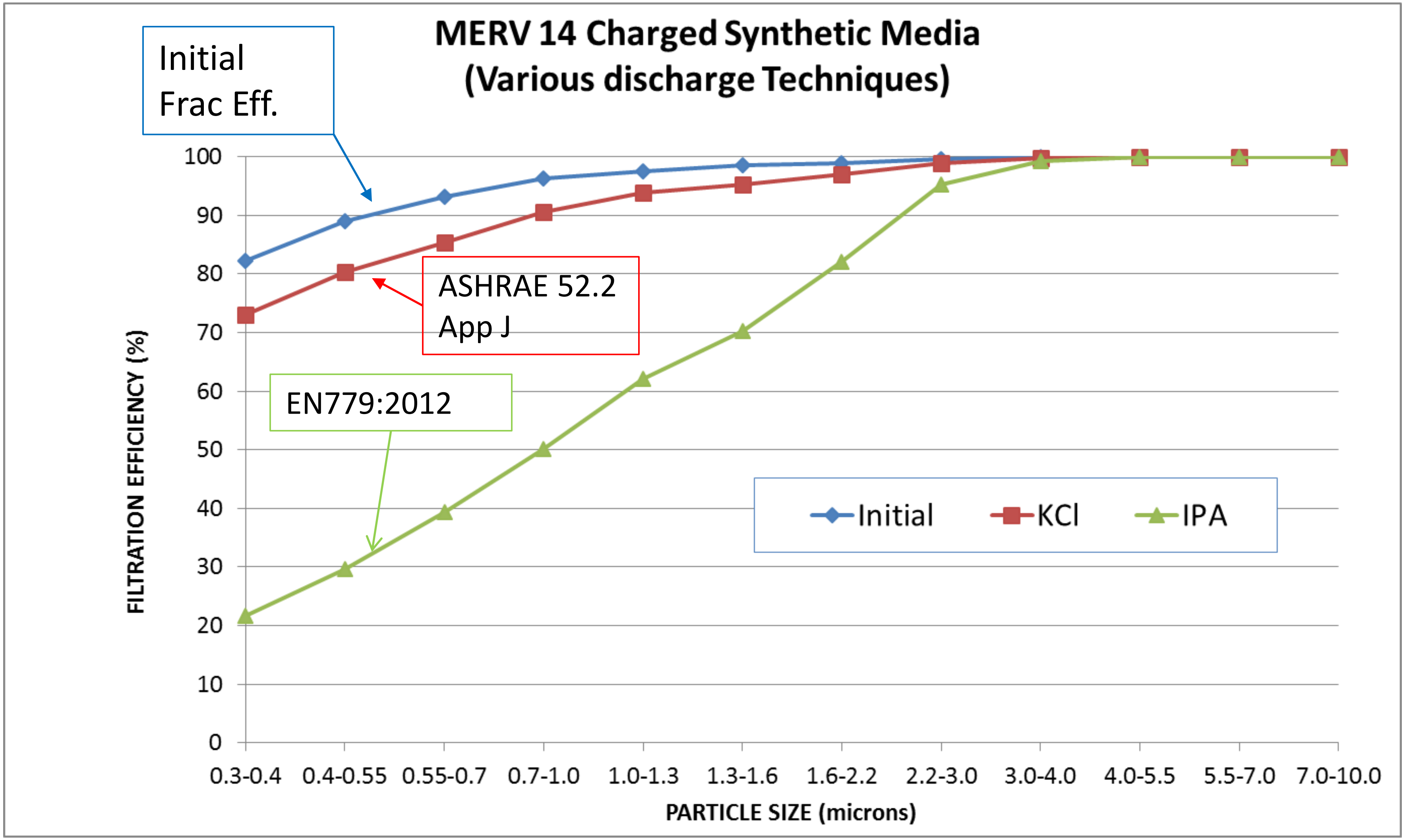
Media Selection = f(Filter System, Element type) (Hollingsworth & Vose)



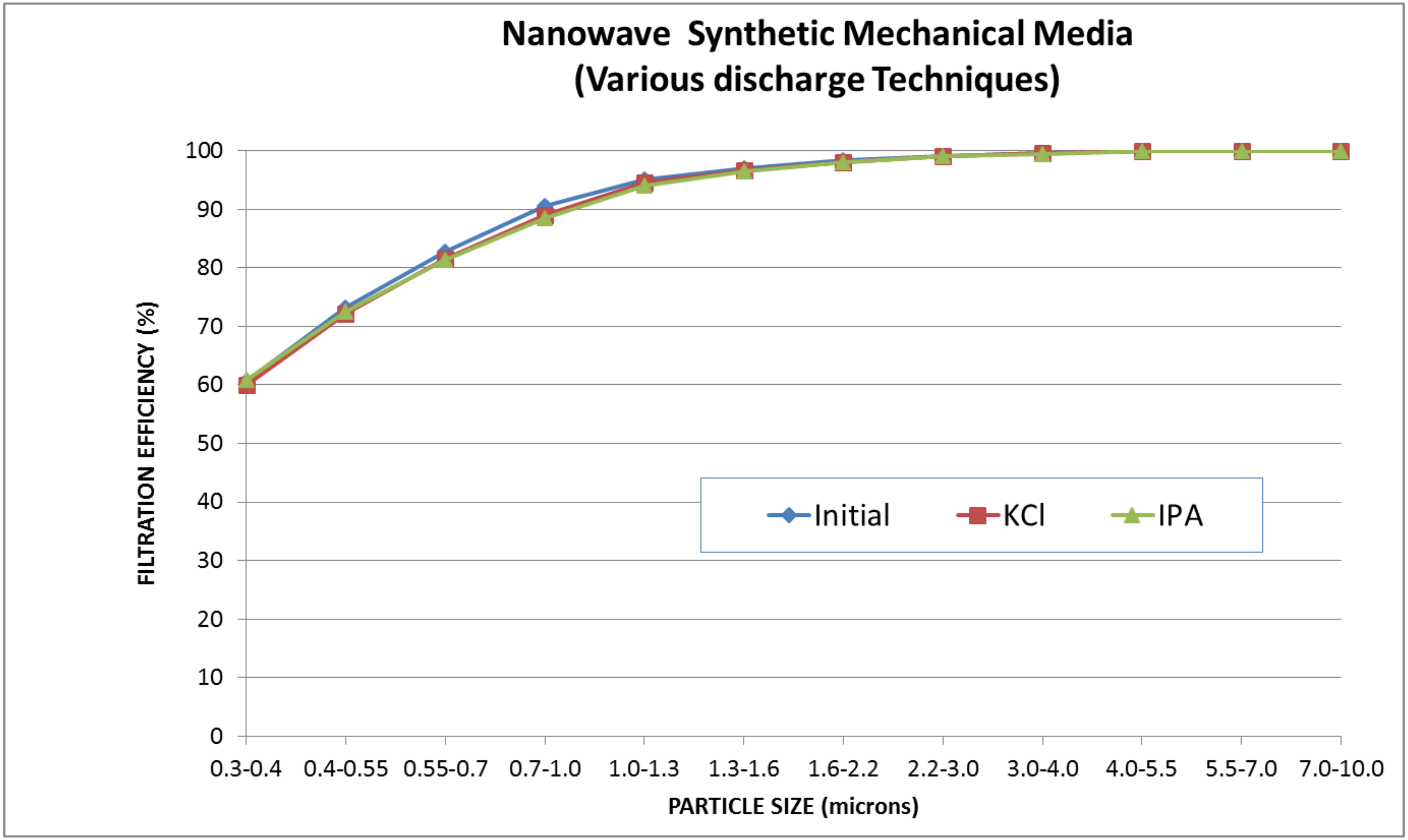
Test Standard to be Considered (Hollingsworth & Vose)

- Mechanical vs Charged Media
  - There are major differences in the test – and classification systems of standards and their revision
    - ASHRAE 52.2 : 2007 or 2015, Appendix J
      - » Discharging is not mandatory and has no effect on classification
    - EN779 : 2002 or 2012
      - » 2002: discharged value is reported but has no effect on classification
      - » 2012: discharging is mandatory for F7 – F9 and influences classification

HVAC – Discharge Impact of Charged Media (Hollingsworth & Vose)

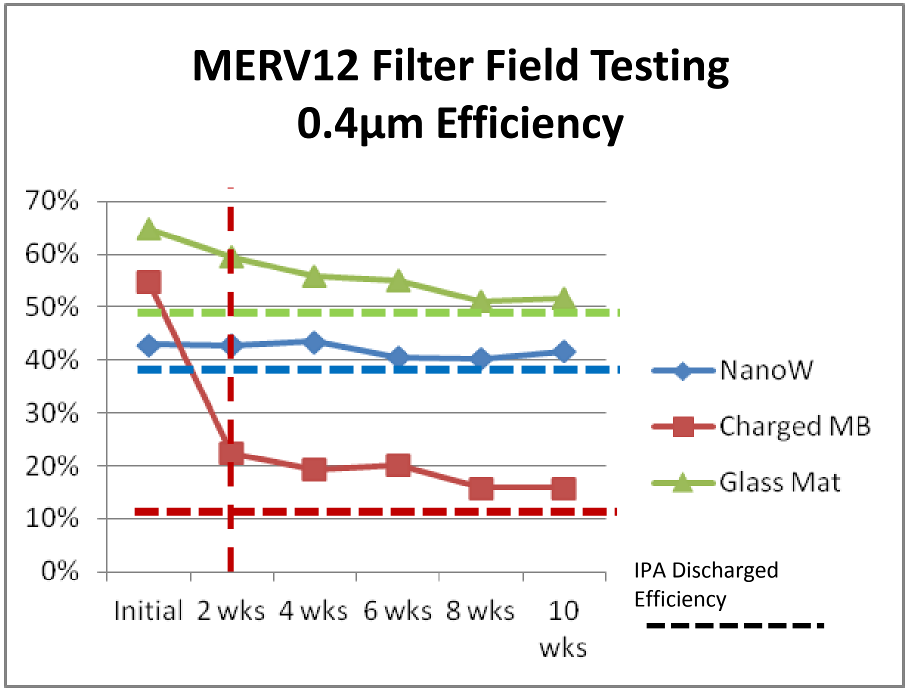


Discharge Characteristic of Mechanical Media
Wet laid glass and NanoWave®
(Hollingsworth & Vose)



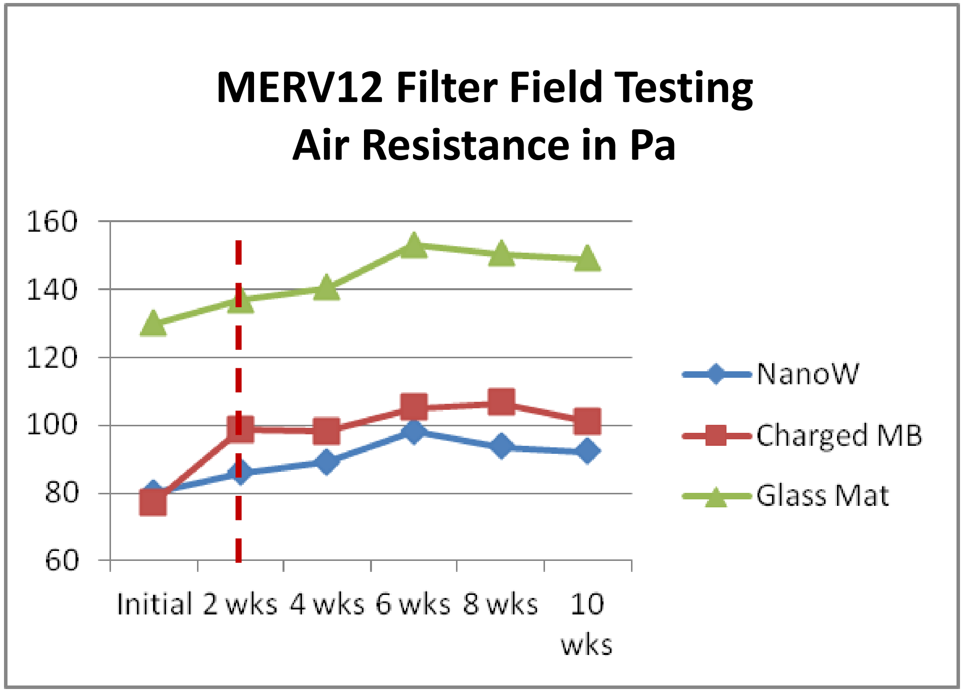
Evolution of Filter Performance (Hollingsworth & Vose)

Rapid Loss of 0.4µm Efficiency



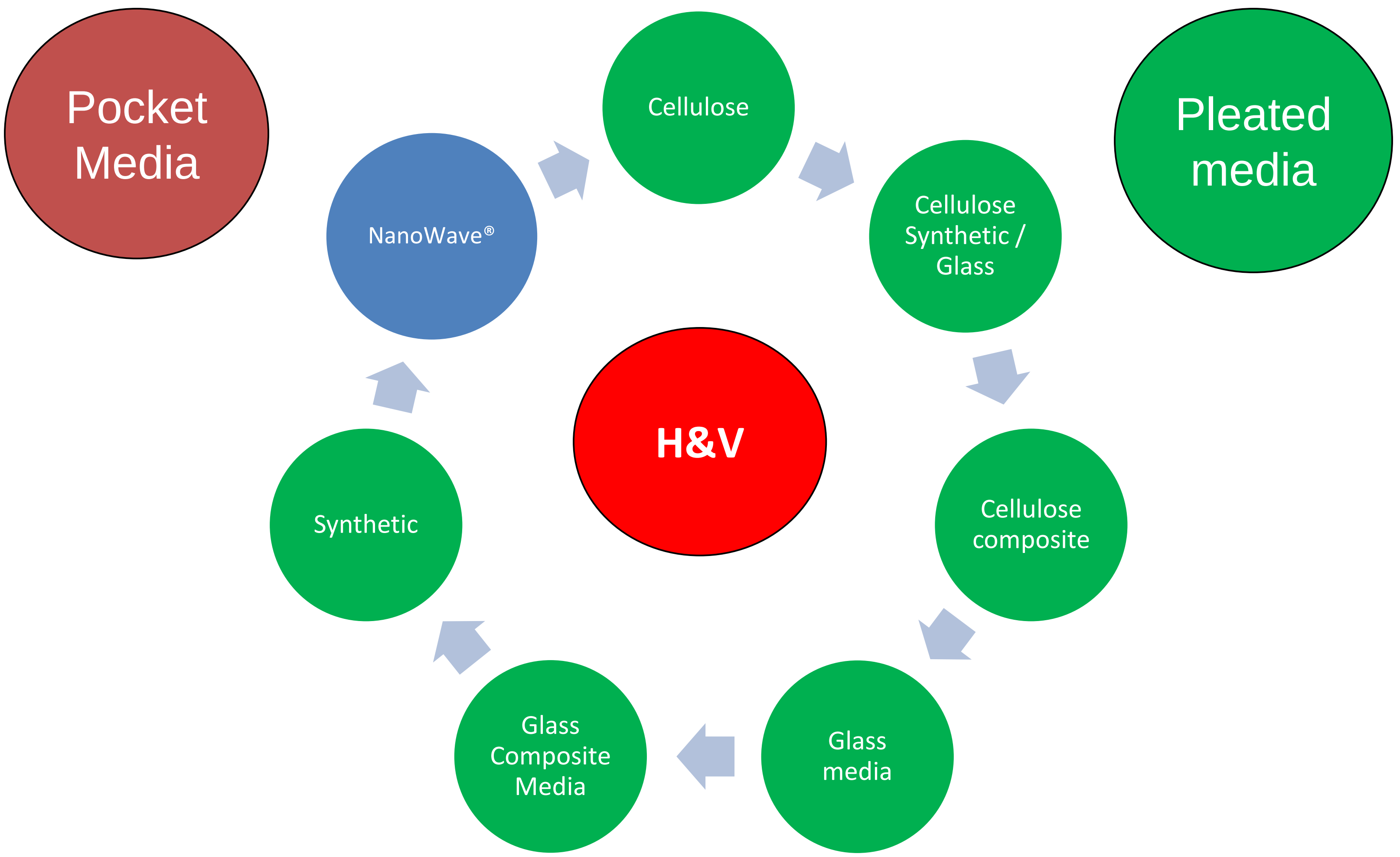
- Charged media can rapidly lose all performance
- IPA discharge simulates real life

Increased Air Resistance in 2 weeks



- Charged synthetic media quickly increases air resistance
- High air resistance and energy usage

H&V Media Selection for GT (Hollingsworth & Vose)



Polymer Group Gas Turbine Media

Everist™ high efficiency filtration media

outperforms traditional mechanical and synthetic composite media

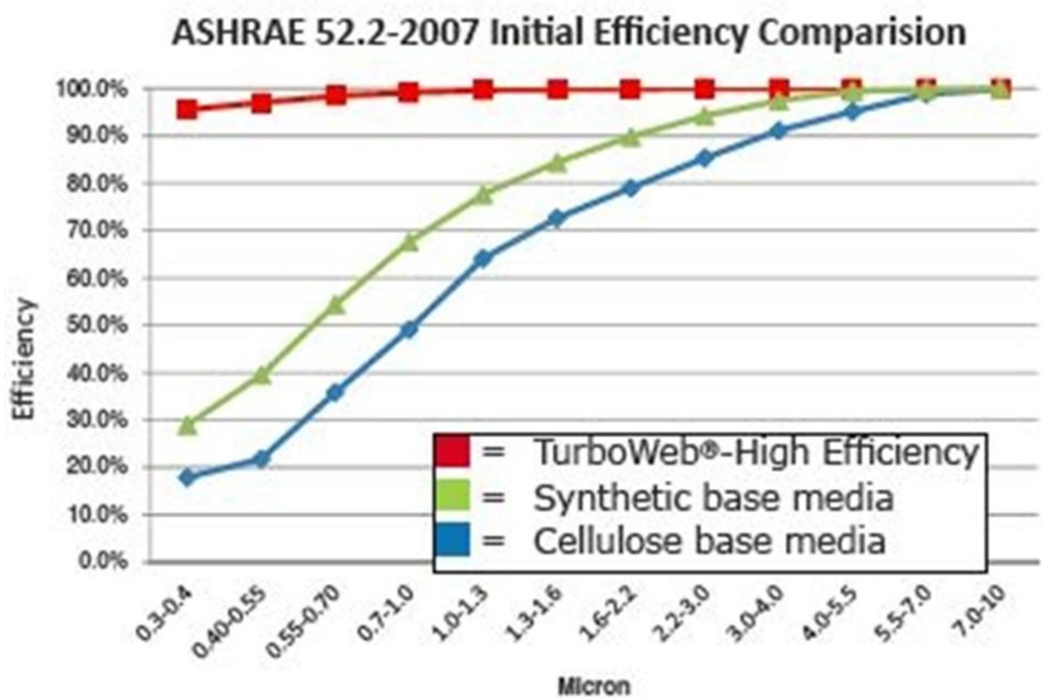
meets all demands put forward by gas turbine manufacturers

- ❖ Nanofiber-based technology
- ❖ Enhanced Efficiency
  - Everist media provides a higher initial efficiency and the same mechanical efficiency as glass, while providing the same initial efficiency and a higher discharge efficiency vs. synthetics
- ❖ Low Pressure Drops
  - The nanofiber-based technology in Everist media provides half the pressure drop of glass media and is similar to electrostatically-charged synthetics.
- ❖ Excellent Dirt Holding Capacity
  - PGI's Everist media doubles the dirt holding capacity of synthetic composites and has a similar capacity to glass
- ❖ Best-in-Class Processing
  - Everist media pleats on both rotary and blade pleaters and can be sonically welded
- ❖ High Durability and Sustainability
  - This new technology is both more durable than glass and greener than traditional media

TurboWeb^{TM} Filter Compared to Other Media (Midwesco)

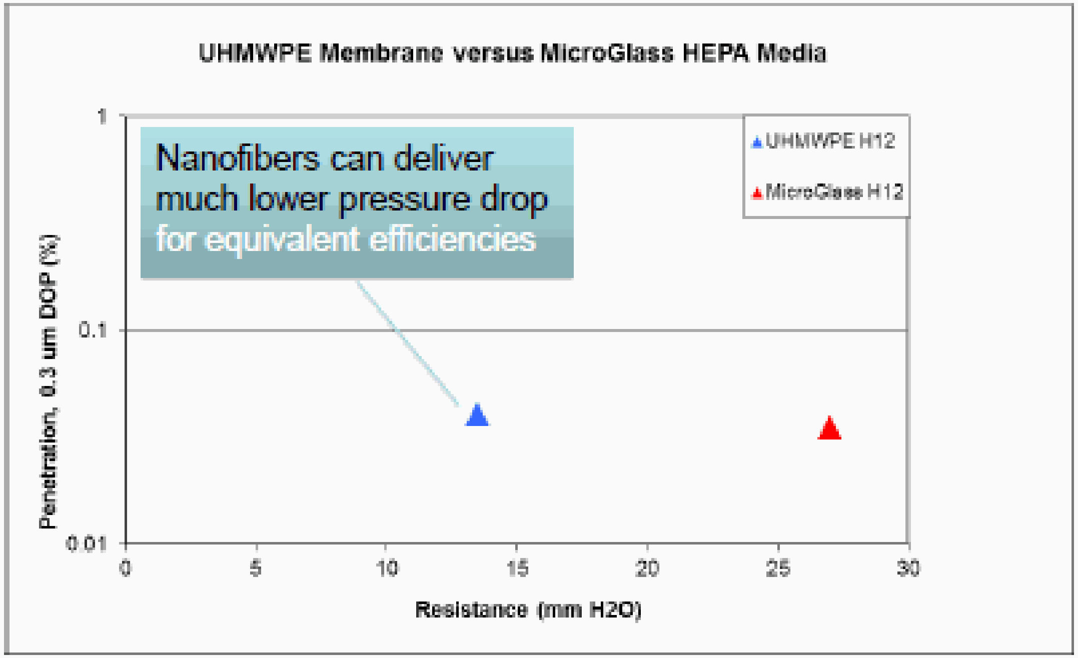
TurboWeb^{TM} is a 3 layer ultra-high efficiency media.

- 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.

Lydall Gas Turbine Filter Media Simplified Decision Matrix

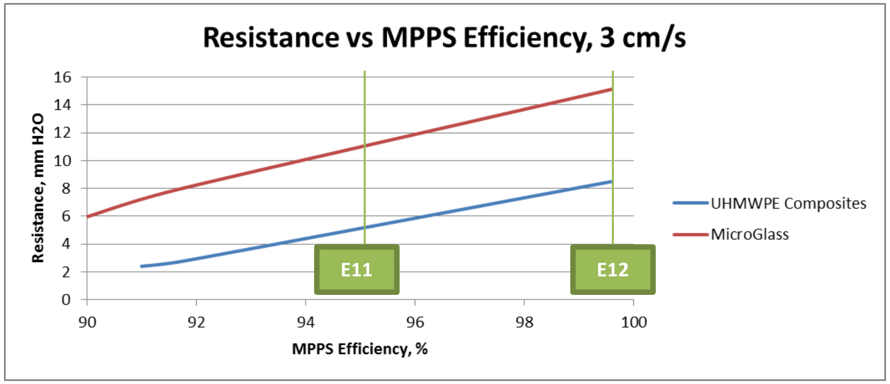
Solution	Technology	Filtration Efficiency				Cleaning Mode		Filtration Mechanism		Water Resistance	Oil Management
		MERV 11-15 F6-F8	MERV 16 F9	E10	E12	Pulse	Static	Mech.	Charged		
Arioso Composites	Membrane Composites		+	+	+	+	+	+		+++	+++
LydAir MG ASHRAE	MicroGlass	+	+				+	+		+	+
LydAir MG HEPA	MicroGlass			+	+		+	+		++	++
LydAir SC	Synthetic Composite	+	+			+	+		+	+	++
LydAir MB	Meltblown	+	+				+		+	+	++

Note: Lydall Lamination Techologies and multiple Functional Support Layers are available for use with all product families.

Gas Turbine Air Inlet Filtration: Membrane Composite Considerations

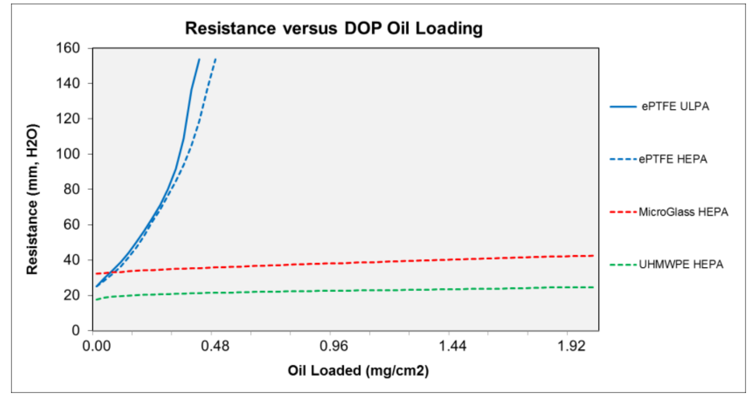
Mechanical Filtration Efficiency

Tests at design velocity to prove E10 to E12 performance



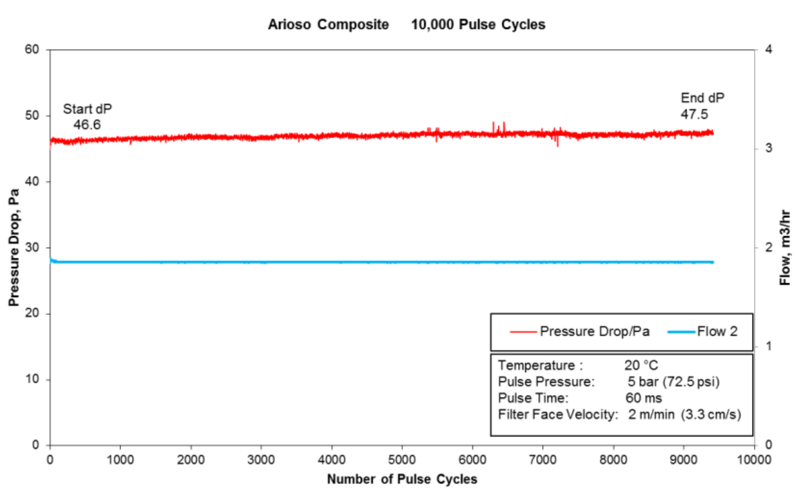
Oil & Hydrocarbon Management

Oil loading to simulate oily/hydrocarbon environments



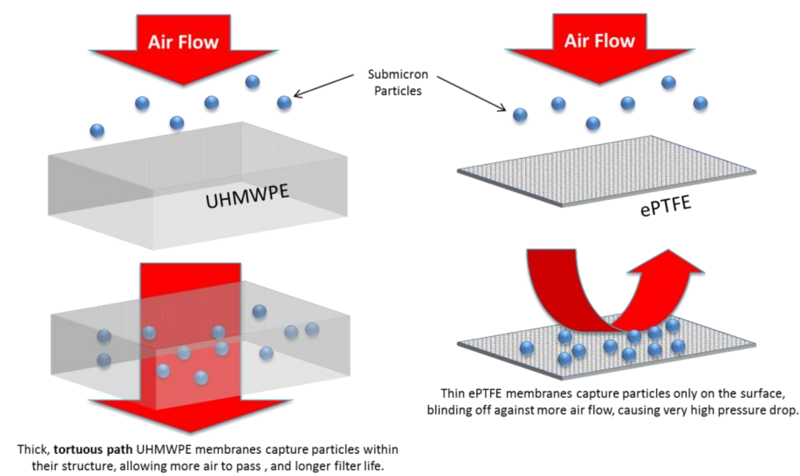
Designs for Pulse or Static Operation

Pulse testing to validate durability and dust release



Filter Life

Depth loading membranes, versus surface loading



Decision Route – Fibers and Media

Webinars (Protected)

Date	Recording Title
February 5, 2015	**Gas Turbine Regulatory Drivers** 120 minutes
May 15, 2014	**Gas Intake Filters: HEPA or Medium Efficiency** 101 minutes

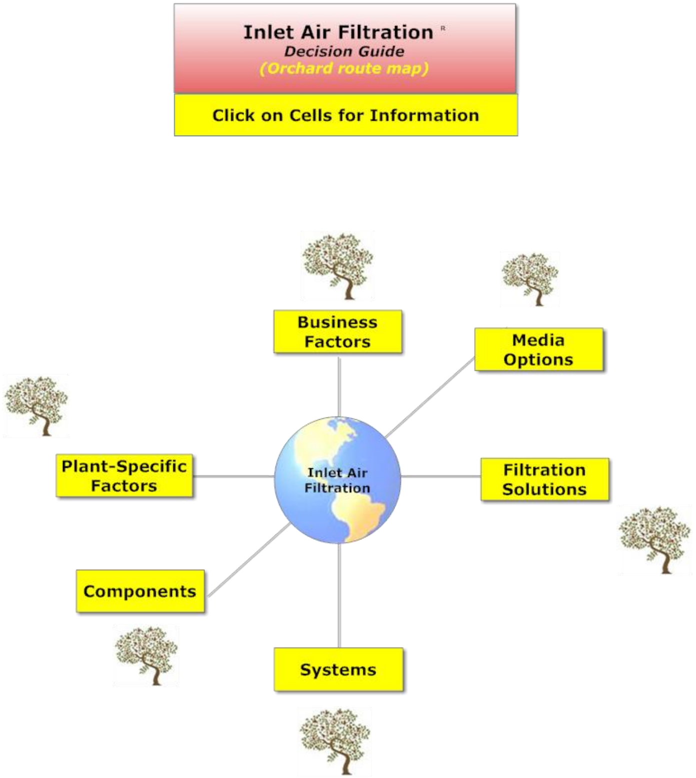
InterWebViews™ (Free)

Date	Topic

Intelligence System Key Words

Search Category	Key Words
By Product	Air Filter Air Intake House
By Company	Dexmet, Hollingsworth & Vose, Lydall, Midwesco
By Topic	Efficiency

Filter Choices



III. Filter Choices #1 - Performance

Subject	Slide Contributor	Relevant decision
Performance Criteria		
Pressure Losses	Southwest	**What filter designs provide acceptable pressure losses?**
Problems with Particulates	Mcilvaine	**How can air inlet systems be designed to address corrosion, erosion or fouling issues?**
Problems with Particulates	Clarcor	**How can air inlet systems address fouling? (4 slides)**
Problems with Moisture	Nederman	**How should a filter house be designed to address moisture issues?**
Problems with Moisture	Freudenberg	**How can air inlet systems be designed to address moisture issues? (3 slides)**
Options for Snow and Ice	GE	**What options are most effective in dealing with snow and ice?**

High Efficiency Filter Pressure Losses (Southwest)

- 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 initial pressure loss on high efficiency filters can be up to 1-in. H_2O (250 Pa) with a final pressure loss in the range of 2.5-in. H_2O (625 Pa) for rectangular filters and 4-in. H_2O (2000 Pa) for cartridge filters.

- High efficiency filters used with gas turbines have pleated media that increase the surface area and reduce the pressure loss.

Filter Performance: Problems with Particulates

Corrosion

- Loss of material caused by a 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.

Erosion

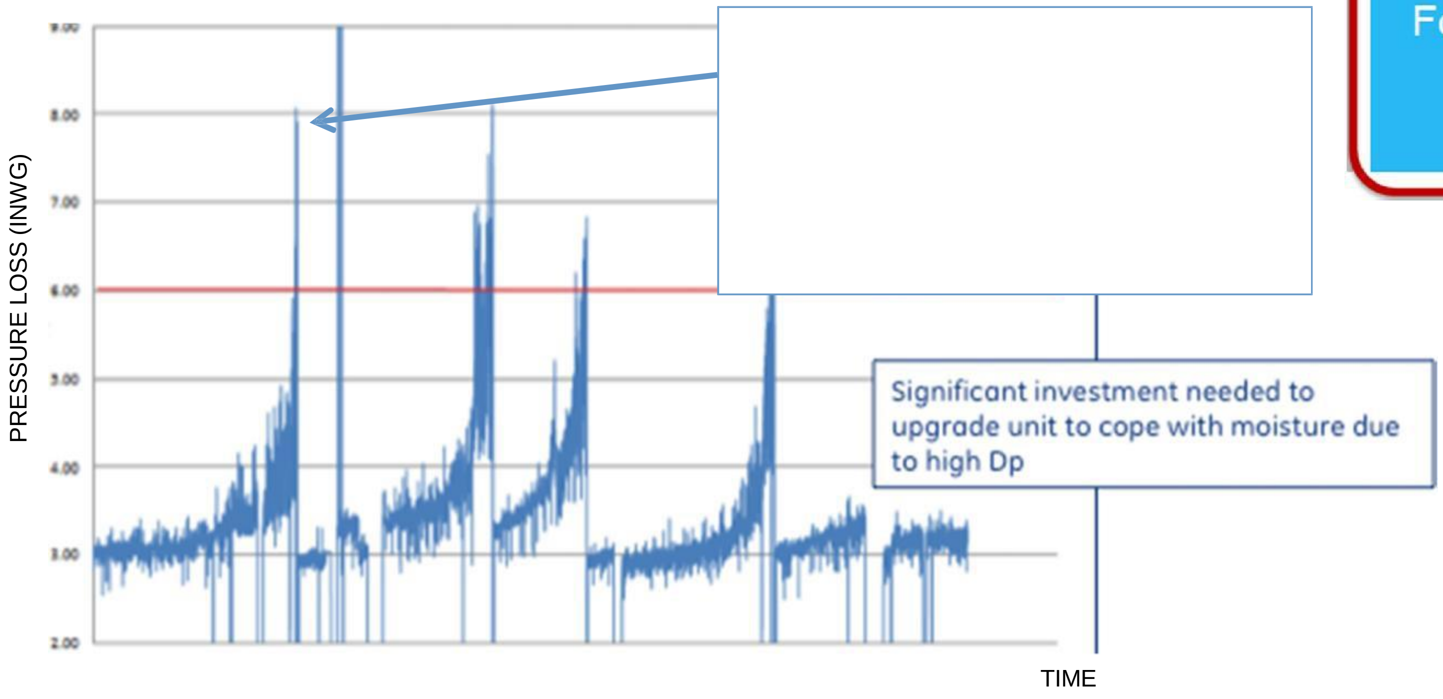
- Erosion is the abrasive removal of material by hard particles suspended in the gas stream.
- Particles causing erosion are normally 10 microns or larger in diameter. Particles with diameters between 5 and 10 microns fall in a transition zone between fouling and erosion.
- Erosion damage increases with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

Two ways to stop fouling –

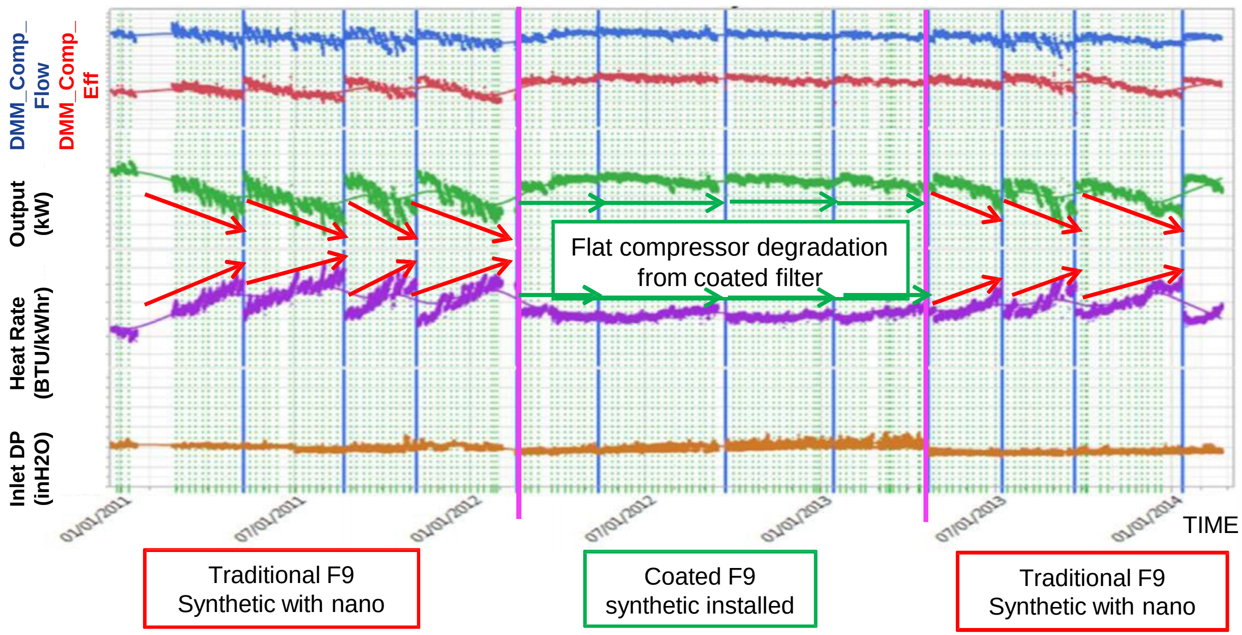
1. Stop fine (<1 micron) particulate reaching the GT
   - Use of high efficiency filters, typically E10 or above
   - EPA / HEPA alone only addresses dry contaminants
   - Filter likely to be more sensitive to moisture



Two ways to stop fouling –

2. Stop contaminants from sticking to the compressor blades
   - Sticky contaminants such as, salts and hydrocarbons etc. are much more likely to cause fouling by making the blades sticky which then enable them to foul with dry inert particulate.
   - Use of hydrophobic and advanced fibre coated filters can significantly reduce sticky contaminants getting to the GT

EXAMPLE



Industry trend (*Clarcor*)

The industry trend is for increased GT availability in all environments while using ever newer, more complex and sensitive gas turbines.

This results in a need for:-

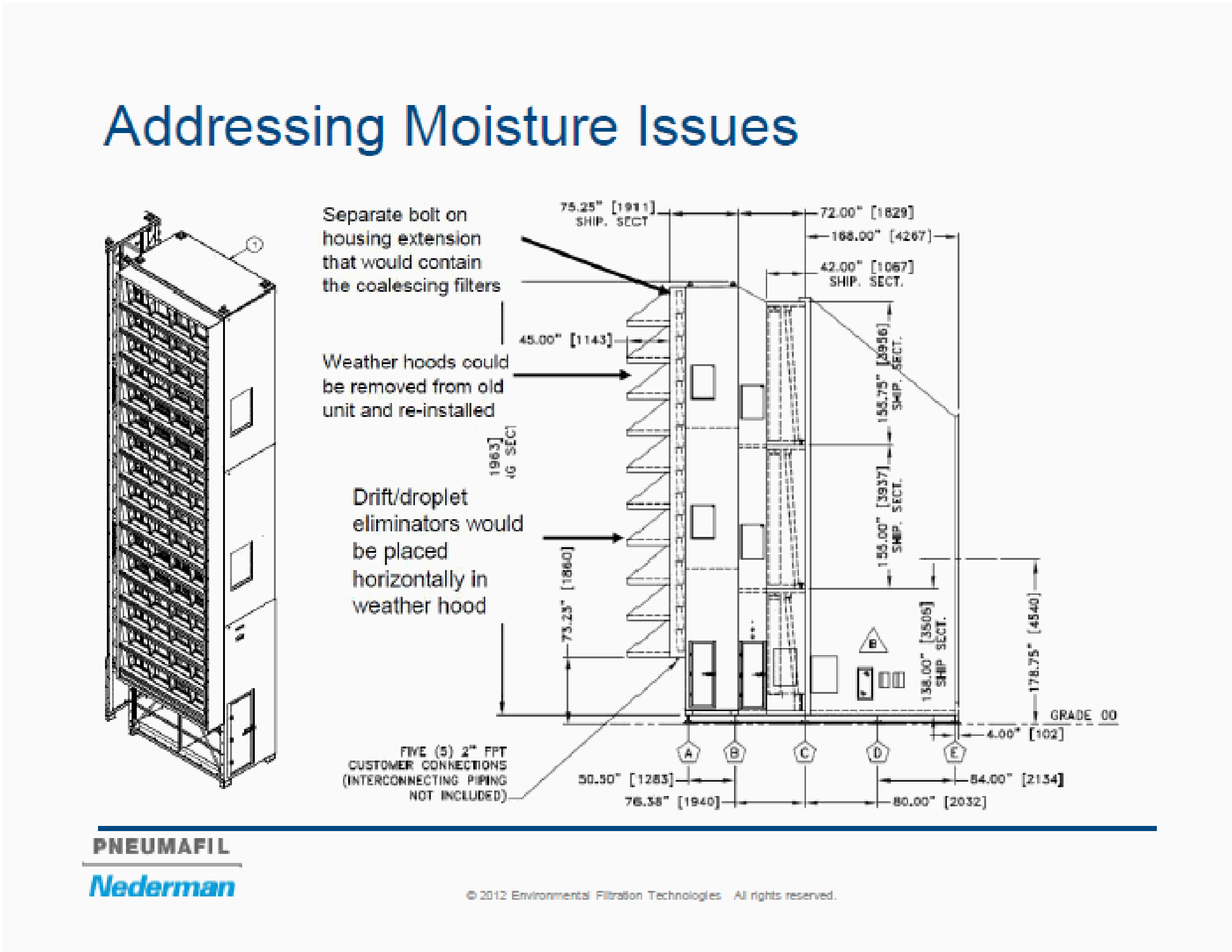
1. Higher efficiency filters – Fine fibre (Nano)
2. Filters with longer life – Multi layer composites that are highly pleatable
3. Filters with predictable performance and no surprises – Advanced coatings with moisture management addressed that have been extensively tested in the real world
4. Robustly designed filters – Strong filter media

Challenges for the Nonwovens Industry

1. Higher efficiency (EPA / HEPA) media that is less sensitive to mist, fog or hydrocarbons especially when loaded in the real world
2. As 1 above specifically for surface loading media for pulse cleanable products
3. Proven through life (real world) hydrophobic properties
4. Synthetic media that truly holds or improves it's efficiency through real world loading
5. Longer life media
6. Higher strength media that can be pulsed
7. Focus on pleating, self supporting, corrugation etc.
8. Advanced fibre coatings

Essentially there is a growing need for cost effective, composite media using multiple non-woven and coating technologies in a single media available from multiple global locations

Filter house design to reduce moisture (Nederman)



Superior filtration solutions to improve the quality of life.

Freudenberg Filtration Technologies. Air filtration.

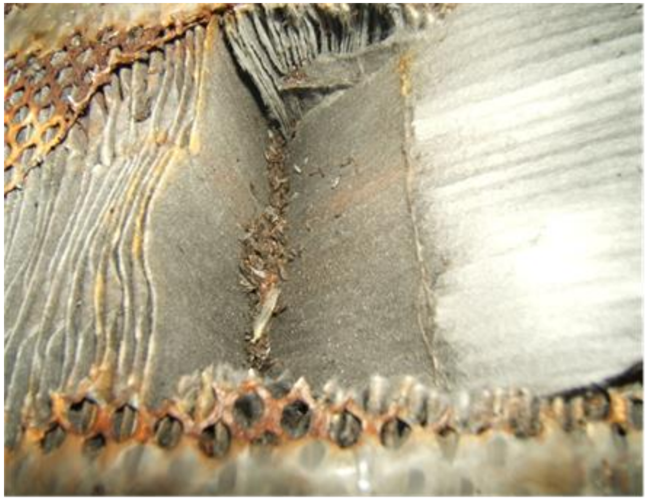
M. Garnett

28TH APRIL 2015

Industrial Air Filtration
Liquid Filtration
Automotive Filters
Human Protection
Engineering & Services

energy efficiency
performance

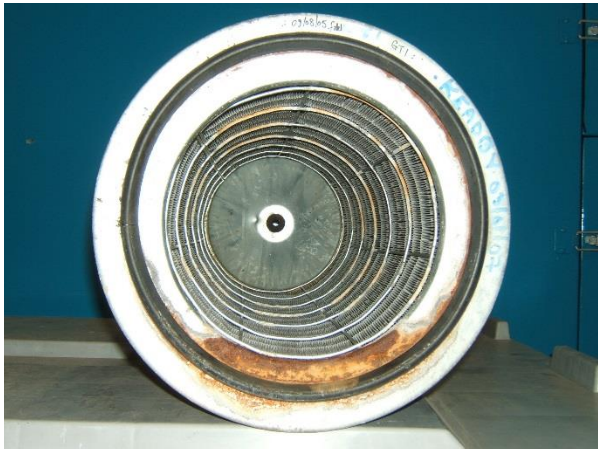
Consideration of the Condition of the Air Inlet Housing & Filters.

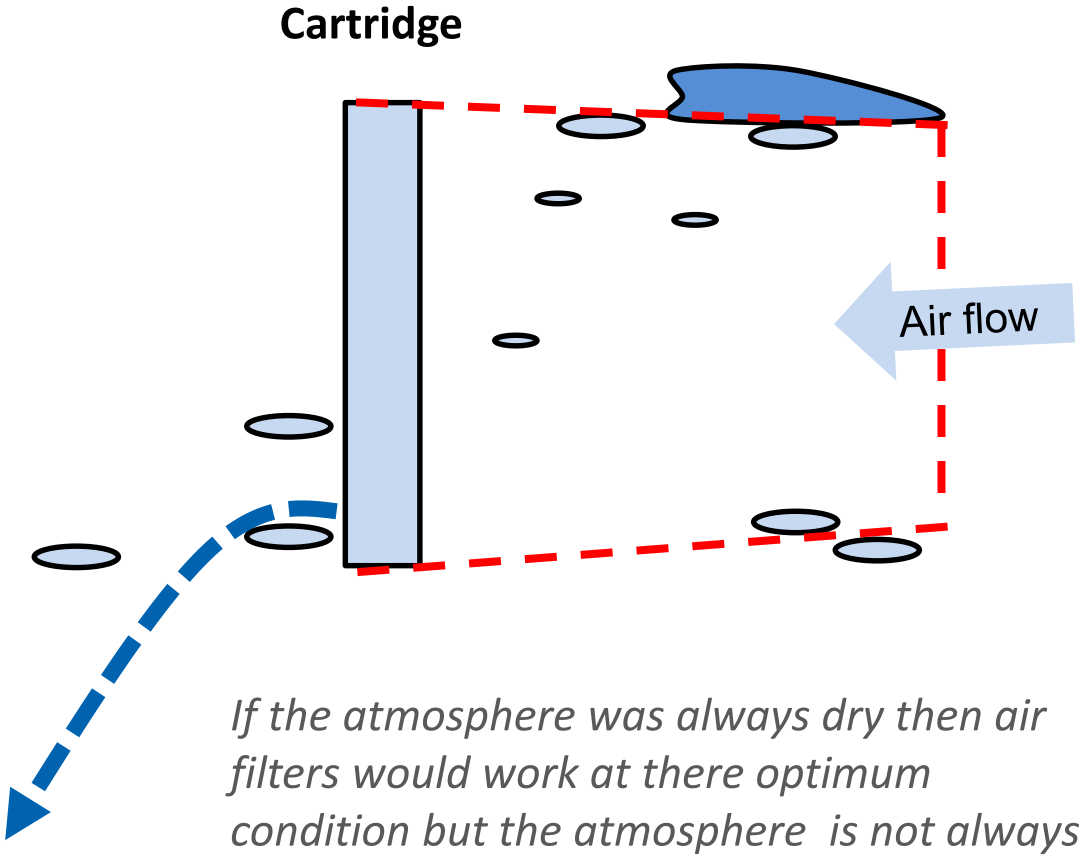







Particle Removal - Liquids - Single stage Filter Configuration





If the atmosphere was always dry then air filters would work at there optimum condition but the atmosphere is not always dry.

Options for Snow and Ice (GE)

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

+ (Most favorable)
0 (Unbiased)
– (Least favorable)

III. Filter Choices #2 - Design Decisions

Subject	Slide Contributor	Relevant decision
Design Decisions		
Life Cycle Costs	Clarcor	What factors should be considered besides filter efficiency?
Life Cycle Costs	Southwest	What life cycle costs should be taken into account?
Static Design	Southwest	What shape and size of filter?
Self-Cleaning Filters	Southwest	How do self-cleaning filters work?
Pulsing for Constant Pressure Drop	Gore	What are the advantages of pulsing over static filters?
Pulsing to Eliminate Off-line Washes	Gore	What are the advantages of pulsing over static filters?
Static vs. Pulse	GE	Under what conditions are static and pulse filters most effective?

Evaluate Filters Based on Overall Performance – not just Efficiency

Filtration Efficiency's impact on compressor health-Filtration News, April 2015.

- Clarcor says that based on total performance, which includes turbine maintenance plus pressure loss and filter degradation. The EPA filter is not necessarily the best.

- Maintenance of long term turbine health can be offset by
  - Operational degradation
  - Higher dP spikes
  - Unpredictable end of life
  - Unplanned outages

Filter Life Cycle Cost Considerations (Southwest)

- Initial costs
  - Equipment (filters, filtration system, spares filters, instrumentation)
  - Installation and commissioning (labor, cost of installation equipment such as cranes)
- Energy costs (pulse system for self-cleaning filters)
- Operating costs (labor and inspections)
- Maintenance costs (replacing filters, repairs, and associated labor)
- Downtime (to 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)

High Efficiency Static Filter Design (Southwest)

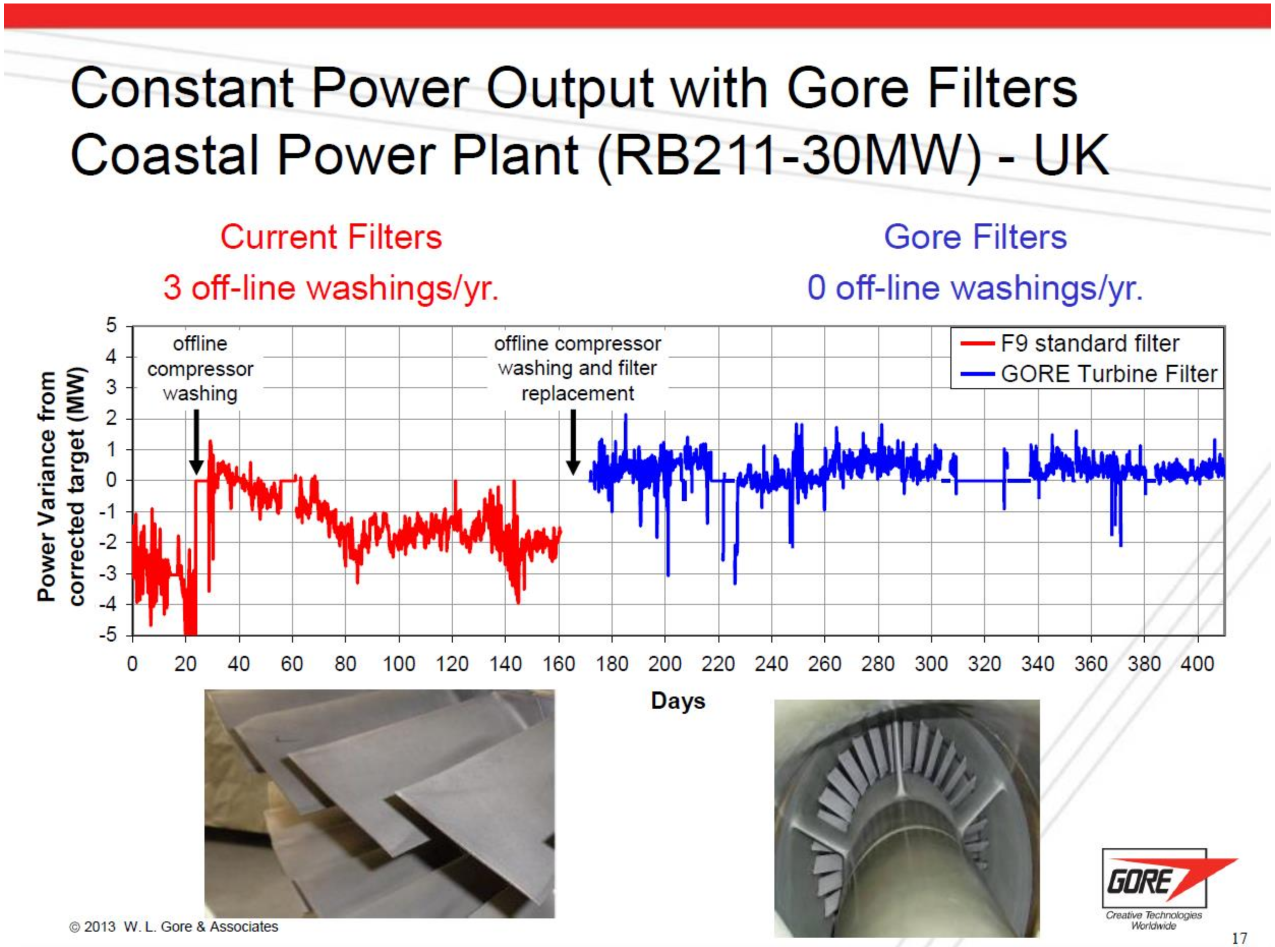
- There are many different constructions of high efficiency-type filters:
  - rectangular,
  - cylindrical/cartridge,
  - bag filters
- Rectangular high efficiency filters are constructed by folding a continuous sheet of media into closely spaced pleats in a rectangular rigid frame.
  - Rectangular filters 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 in a circular fashion
  - Air flows radially into the cartridge
  - They can be installed in a horizontal or vertical fashion (hanging downward)
  - Cartridge filters can be depth or surface loaded

Self-Cleaning Cartridge Systems (Southwest)

Self-cleaning systems operate primarily with surface loaded high-efficiency cartridge filters.

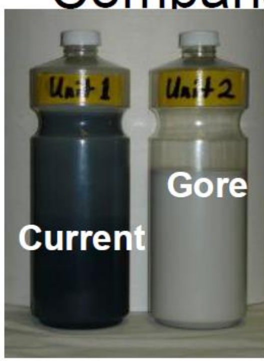
- Once the pressure loss reaches a pre-defined level, the filter is cleaned with air pulses.
- The pressure of the air pulses ranges from 80 to 100 psig (5.5 to 6.9 barg).
- A reverse jet of compressed air (or pulse) occurs for a length of time between 100 and 200 milliseconds.
- To avoid disturbing 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

Pulsing Prevents Pressure Peaks (Gore)

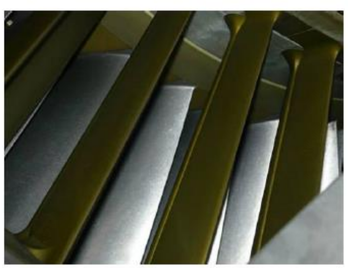


Pulsing Eliminates Off-line Washes (Gore)

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 Creative Technologies Worldwide

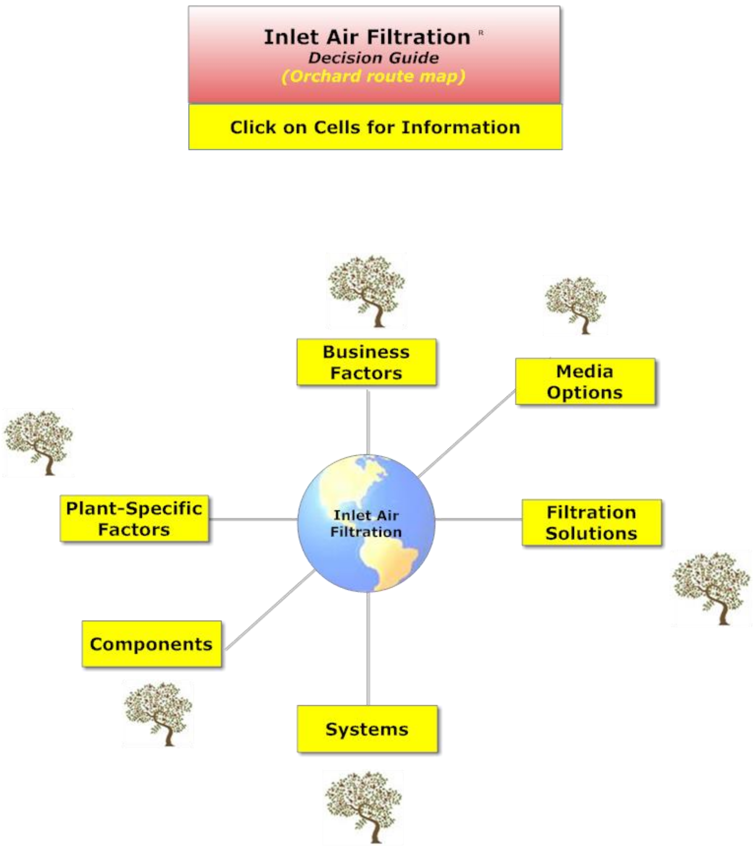
Static vs. Pulse Filter Options (GE)

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

+ (Most favorable)
0 (Unbiased)
– (Least favorable)

Filter systems

- Multi stage designs
- Pre filter options



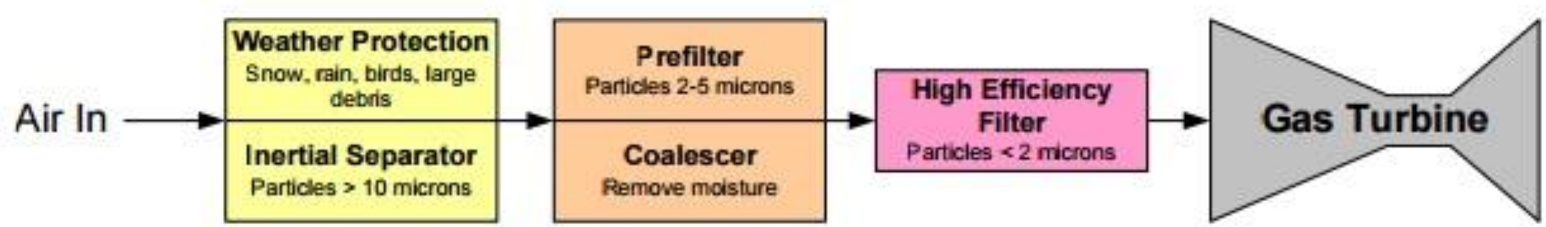
III. Filter Choices #3 - Multi-stage Designs

Subject	Slide Contributor	Relevant decision
Multi-stage Designs	Southwest	**Will more than one type of filter be required?**
Pre-filter Options	AAF	**Why should pre-filters be used?**
Pre-filter Options	AAF	**Which option is best and when?**
Cartridge/Pre-filter	Gore	**Gore offers a cartridge filter with an integral pre-filter.**

Multi-Stage Filtration Systems (Southwest)

Any gas turbine application typically needs more than one type of filter, and there are no “universal filters” that will serve all needs. So, two-stage or three-stage filtration systems are typically used.

- A weather louver can be used first to remove erosive contaminants, rain and snow.
- The second stage may be a low to medium performance pre-filter selected for the type of finer sized particles present, or a coalescer to remove liquids.
- The third stage is usually a high-performance filter to remove smaller particles less than 2 μm in size from the air.
- The arrangement will very based on site specific environmental considerations.



Pre-filter Options (AAF)

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.

Pre-filters 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.

Pre-filters normally capture solid particles greater than 10 μm, but some pre-filters will also capture the solid particles in the 2 to 5 μm size range.

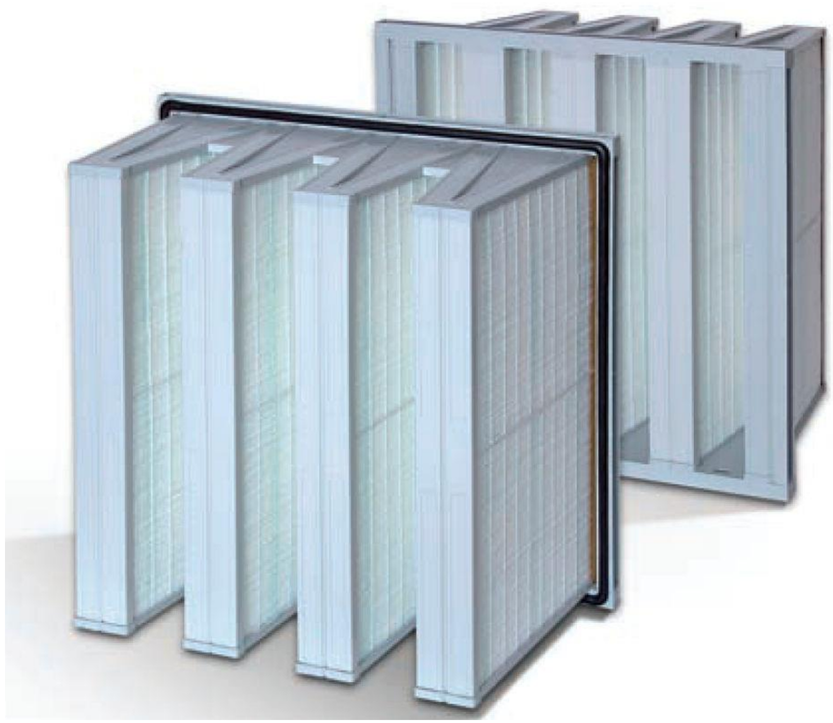
- These filters usually consist of large diameter synthetic fiber in a disposable frame structure.

Bag filters are also commonly used for pre-filters. These offer higher surface area that reduces the pressure loss across the filter.

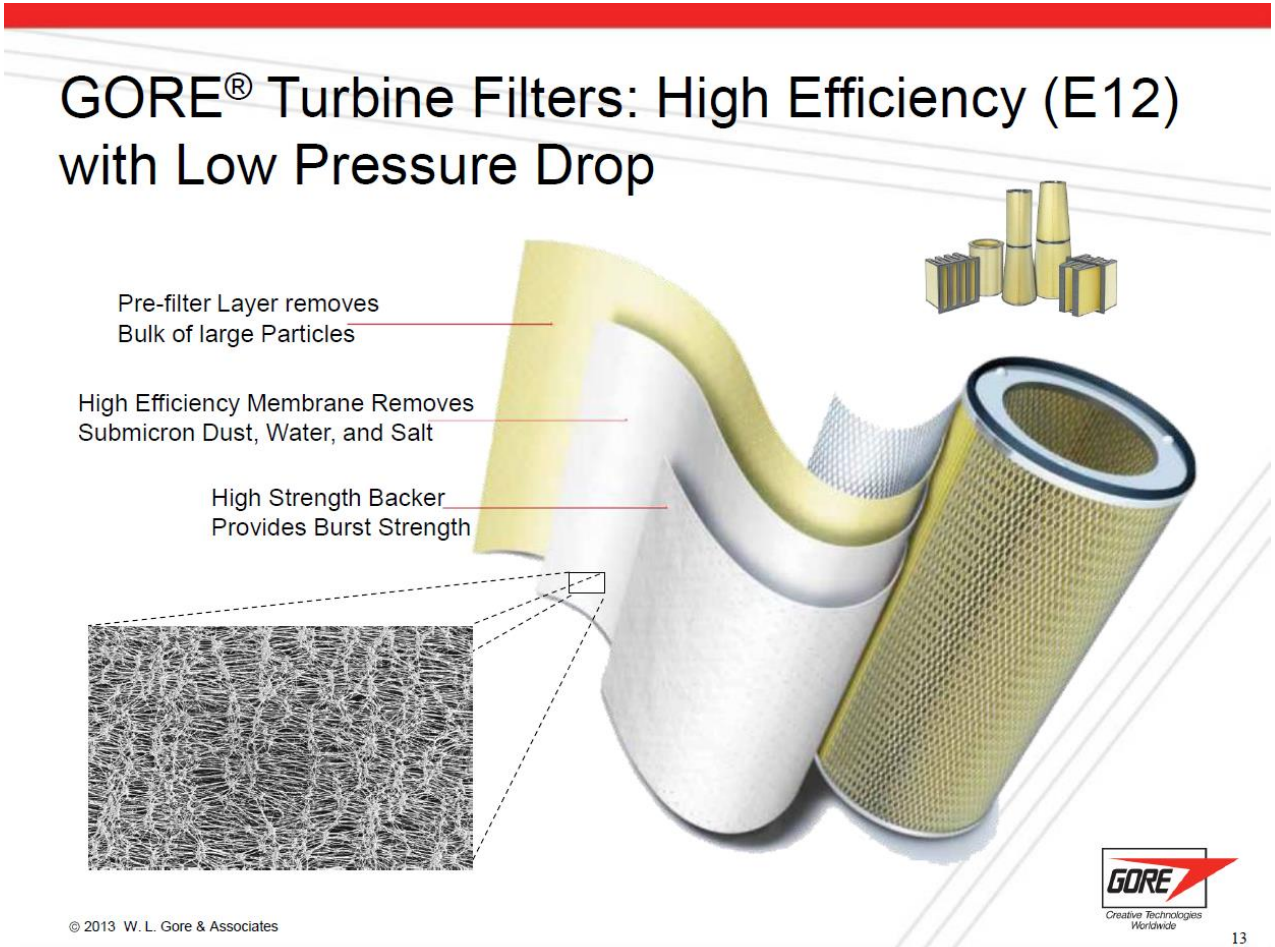
Pre-filter options – Which, where? (AAF)

Panel - AmAir 300GT

Bag-V Bank



Cartridges with Integral Pre-filters (Gore)



III. Filter Choices #4 - Decision Diagrams

Subject	Slide Contributor	Relevant decision
Filter Options	Ahlstrom	What filter options are available?
Selection Based on Operating Conditions	GE	What filter should be selected based on dust loading, remoteness of operation and other conditions?
Selection Based on Environment	GE	What filter systems are recommended for each type of environment?
Selection Based on Environment	GEA	What filter systems are recommended for each type of environment?

Trends in Gas Turbine Air Intake Filtration

Gas Turbine Air Intake Filtration

TRENDS

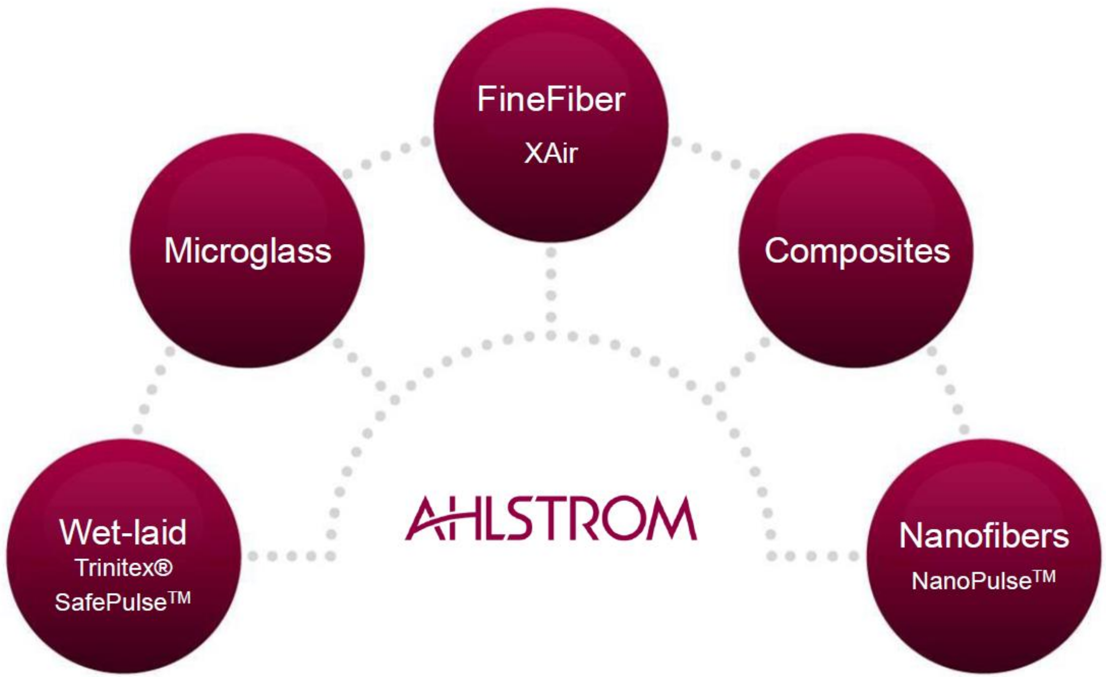
- ✓ Growing awareness in the market-place of the benefits with improved filtration performance on turbine compressor health and energy throughput.
- ✓ A need for widening the product portfolio to meet the cost /performance demands for inland vs. off-shore, static vs. pulse-jet, and turbines running at peak vs. base-load applications.
- ✓ A never-ending stream of new filter materials entering the market-place with a focal point towards synthetic media with better water repellency and efficiency/pressure drop ratios.
- ✓ More awareness of the need for on-site testing using ambient air to simulate "real life" performance beyond currently used laboratory scale test procedures such as e.g. EN779-2012, ASHRAE 52.2, and EN1822.

OUR RESPONSE

- ✓ Upgrading of our global product portfolio on the Americas, EMEA, and Asia axis.
- ✓ Continious product portfolio upgrade of our higher end GT solutions including Trinitex®, Microglass, and recent launches such as NanoPulse™ and SafePulse™.
- ✓ Investments in new testing capabilities applied in order to better simulate in lab scale real life GT filter performance.

AHLSTROM

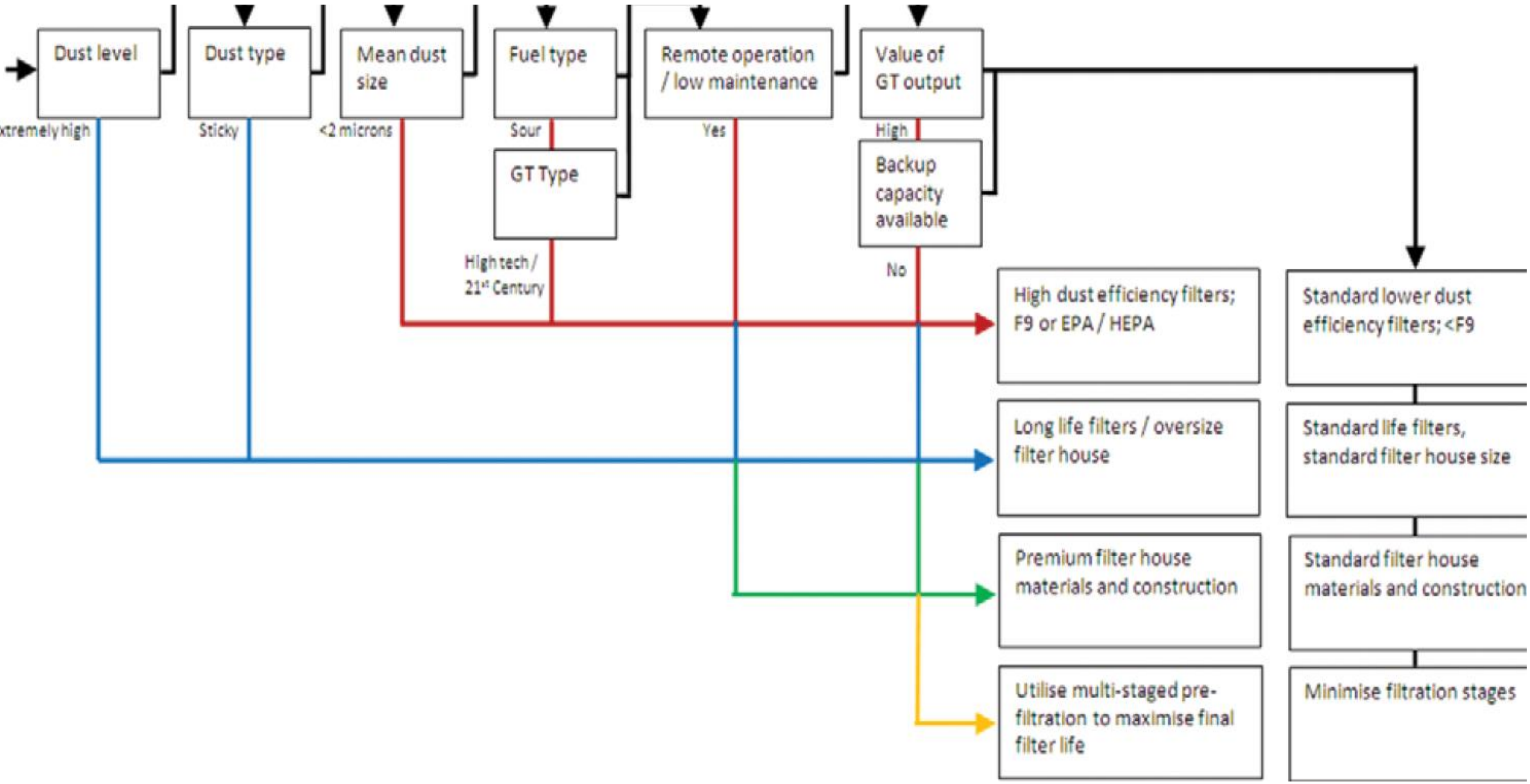
Filtration technology portfolio



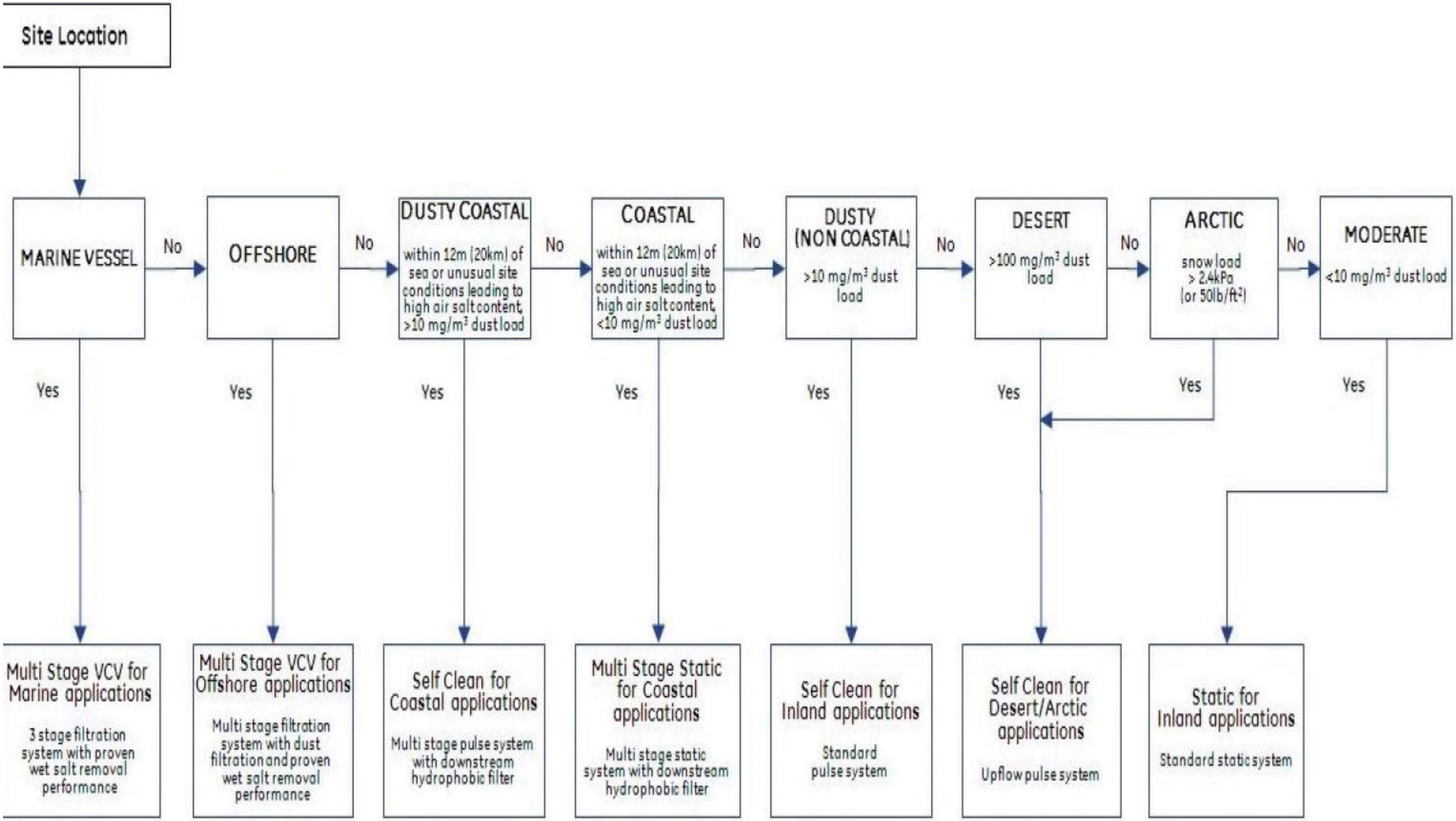
Filter Options (Ahlstrom)

Name	Material	Pre filter Static	Pre filer Pulse	Fine filter Static	Fine filter Pulse	HEPA Static	HEPA Pulsed
Trinitex GT	Synthetic	x	x	x	x		
Three layers can be tailored to obtain high strength and superior performance removing diesel soot, high humidity and salt							
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							

Filter Recommendations
Based on Operating Conditions (GE)



Filter Recommendations Depending on Environment (GE)



Selection Criteria for Intake Systems (GEA)

Dust concentration
Low
< 0.2 mg/m³

Climate
Dry
< 80% rel. humidity

Climate
Wet
> 80% rel. humidity

Dust concentration
High
> 0.2 mg/m³

Climate
Dry
< 80% rel. humidity

Sandstorms are possible

Climate
Wet
> 80% rel. humidity

Customised systems

Configuration 1
Weather protection
Pre-filter
Fine filter
Anti-icing if required

Or, as alternative
Pre-filter
Depth filter cartridge

Configuration 2
Droplet separator
Pre-filter
Fine filter
Anti-icing if required

Or, as alternative
Pre-filter
Depth filter cartridge

Configuration 3
Pulse filter
Fine filter if required

Configuration 4
Pulse filter

Or, as alternative
Configuration 1

Configuration 5
Inertial separator
Coalescer, if required
Pre-filter
Fine filter

Or, as alternative
Configuration 2

Standard systems

System A
Duct air filter
MultiMaster Vario

Weather protection
Pre-filter
Fine filter
Anti-icing if required

System B
Air-duct filter
MultiMaster Vario

Droplet separator
Pre-filter
Fine filter
Anti-icing if required

System C
Pulse filter
PowerTower

Or, as alternative
System D

System D
Rotary oil bath filter
RotaClean

Fine filter, if required

Or, as alternative (equipped with sand filters)
System A

System E
Rotary oil bath filter
RotaClean

Droplet separator
Fine filter, if required

Or, as alternative
System B

Decision Route – Filter Choices

Webinars (Protected)

Date	Recording Title
February 5, 2015	**Gas Turbine Regulatory Drivers** 120 minutes
May 15, 2014	**Gas Intake Filters: HEPA or Medium Efficiency** 101 minutes

InterWebViews™ (Free)

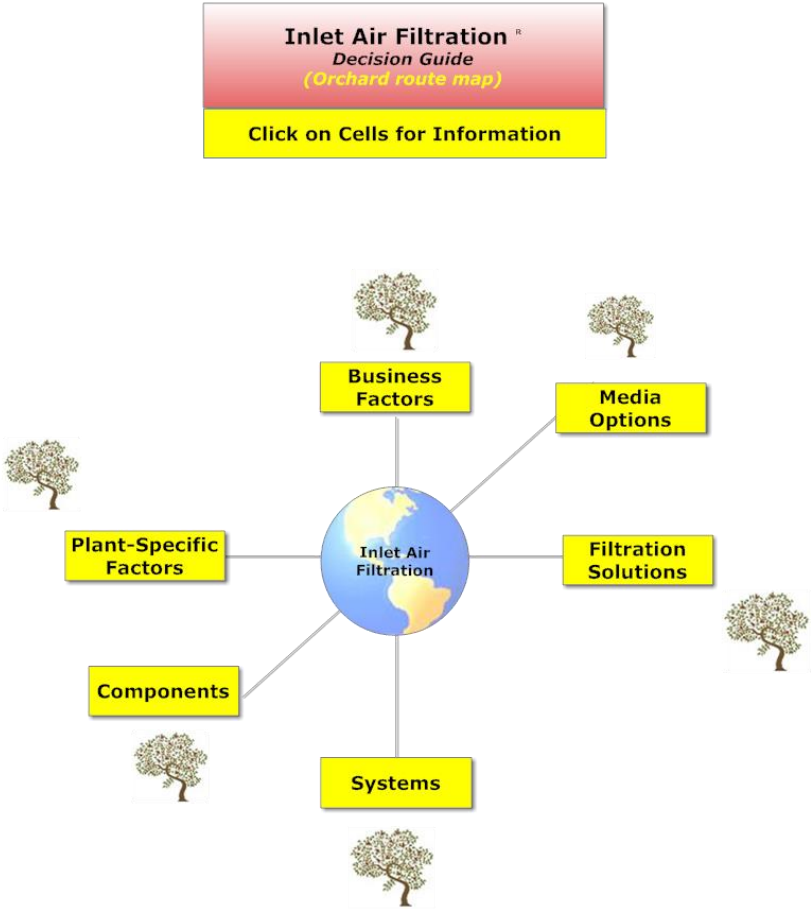
Date	Topic

Intelligence System Key Words

Search Category	Key Words
By Product	Air Filter Air Inlet House
By Company	AAF, Ahlstrom, Clarcor, Donaldson, Freudenberg, Hollingsworth & Vose, GE, GEA, Gore, Midwesco, Nederman
By Topic	Efficiency Humidity Moisture

Components

- Support mesh
- adhesives



Variety of materials and mesh sizes can be use to support the media

- Dexmet polygrid and microgrid products can be used in several gas turbine filter applications including
- Internal Core Material: Media Support & Backing
- Primary Filtration
- Pre-Filters
- There is a range of metals and high temperature as well as low temperature plastics available. Pore size can be varied from 25 microns upward. Dexmet is an exhibitor at AFS and wants to explore the expanded use of their materials in the tough offshore, artic an desert environments for the filters. Also they want to match their pore capabilities to the industry needs as it switches to the EPA from the medium efficiency filters

adhesives

- Site testing has shown that ensuring efficiency under humid conditions was more challenging than under dry conditions, highlighting the importance of water tightness in a filter to prevent any by-pass. Factors influencing water tightness includes the design around the sealing of the media pack within the filter, and, on static filters, how many sides are glued.
- MULTIPLE APPLICATIONS OF GLUE
- The latest generation of filters has been moving towards double sealing design where there are multiple applications of glue. Drainage is also critical for water tightness, and features such as vertical pleating and water drains in the frame help by avoiding any water accumulation. If drainage is not achieved quickly enough, the accumulated water will build pressure drop to a point where water will be forced through the media no matter what its efficiency is. It is also important when looking at vertical pleats to ensure that the glue beads are open enough not to reduce the drainage effectiveness.
-

- Henkel- Dan Oberle will be giving a speech Wednesday on adhesives
- Franklin Adhesives will be an exhibitor