Laboratory Test Simulating In-Situ Water and Salt Water Coalescence/Migration for Gas Turbine Filters

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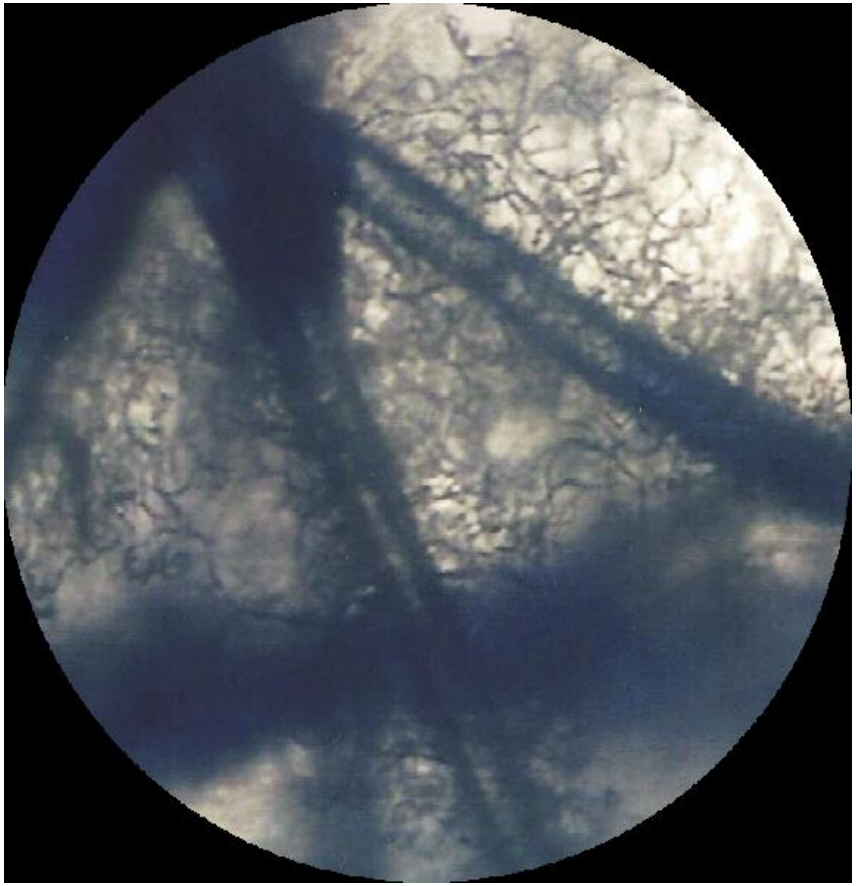
LMS A CORE FACILITY FOR AIR FILTRAION

- Filter and media testing
- Sale of fully automated testing system for all standards
- Contract product development
- Contract development for new Standards
- Internal technology development
  - Incorporation of nano fibers onto single fibers
  - Soft impaction Technology

Innovative nano-fiber Technology



Background

- Gas turbine and aerospace filters endure very harsh environments specially at coastal sites
- Existing tests do not correspond to the real world applications
- A laboratory test is needed to simulate the important natural phenomena and eliminate the variable factors

Factors Of Interest

- Coalescence – translates to the efficiency of the filter for liquid droplets
- Migration – suspended particles or dissolved salts traveling through media pores

High and Low Efficiency Filters

- High efficiency (conical, cylindrical, and V-bank filters) F & E class filters
- Low efficiency (louvers and pre-filters)
  - Requires the most care in testing
  - Creates most of the problems

  - Multistage System Testing

Detection Instruments

- SMPS Range of size 2.5-1000 nanometers
- Time-of-flight particle sizer 0.2-750 micron
- Sodium flame photometry
  - Accuracy very much size distribution dependant

Simulation Test Duct

Test Capabilities:

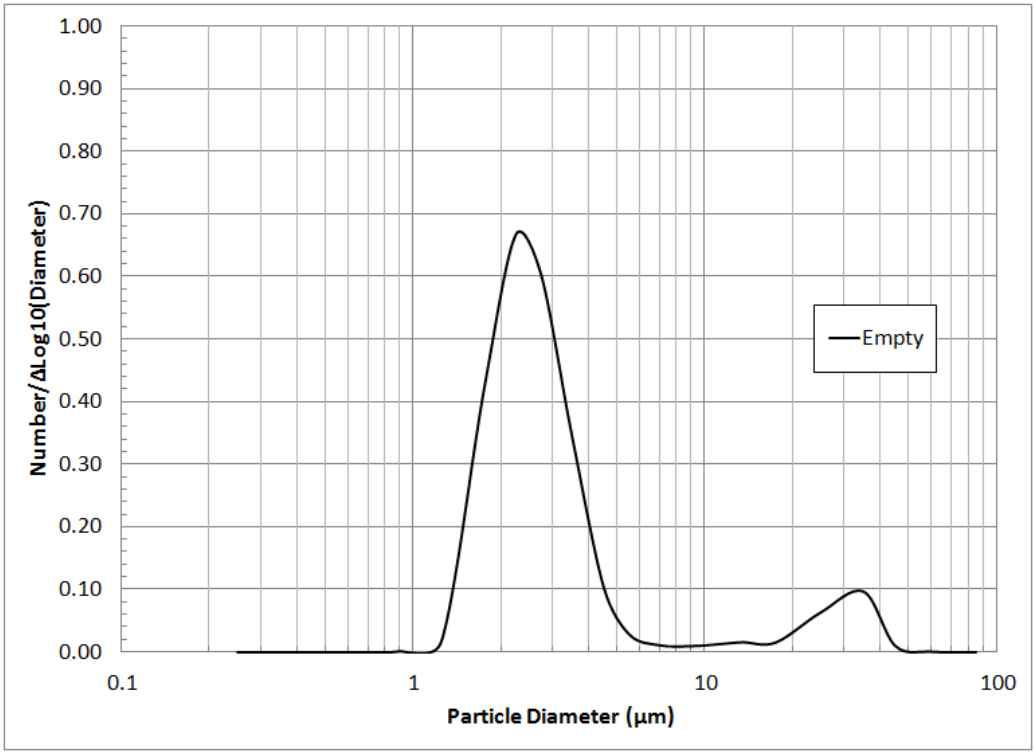
- Able to control and perform tests under specified conditions between:
- 1,000 – 15,000 CFM system airflow
- Greater than 10 inches water gauge (2.5 kPa) restriction
- 0 – 160 PSI (0-1100 kPa) pulse pressures
- 20° to 120° F (10 – 50° C) **temperatures**
- 20% – 97+% **RH**
- 0 – 500 gram per minute dust feed – Proprietary design with no dust loss
- Standard or customer specified dusts and aerosols
- Rain or mist simulation
- Full directional water spray (Other fluids may be available)
- 0-120 MPH upstream **wind speeds to mimic sand storm with up to 500 grams of dust per minute (in addition to system flow)**
- Fractional efficiency of test dust and salt at requested intervals
- **Water fractional efficiency using proprietary particle counters and methods**
- Gravimetric efficiency at requested intervals
- Sampling with 0.45 micrometer membrane filters
- Load up – pulse down sequences

Advanced Features:

- **Snow and ice rain and salt water rain generation**
- Fractional efficiency for wet or dry **paint**
- Gas detection and analysis for 135 different **gases**
- Specialty cigarette smoke to study **soot**
- Fractional efficiency with high concentration **oil up to liters/minute spray**
- **Sodium Flame Photometer for salt migration and efficiency test**

Test Parameters - Low Efficiency

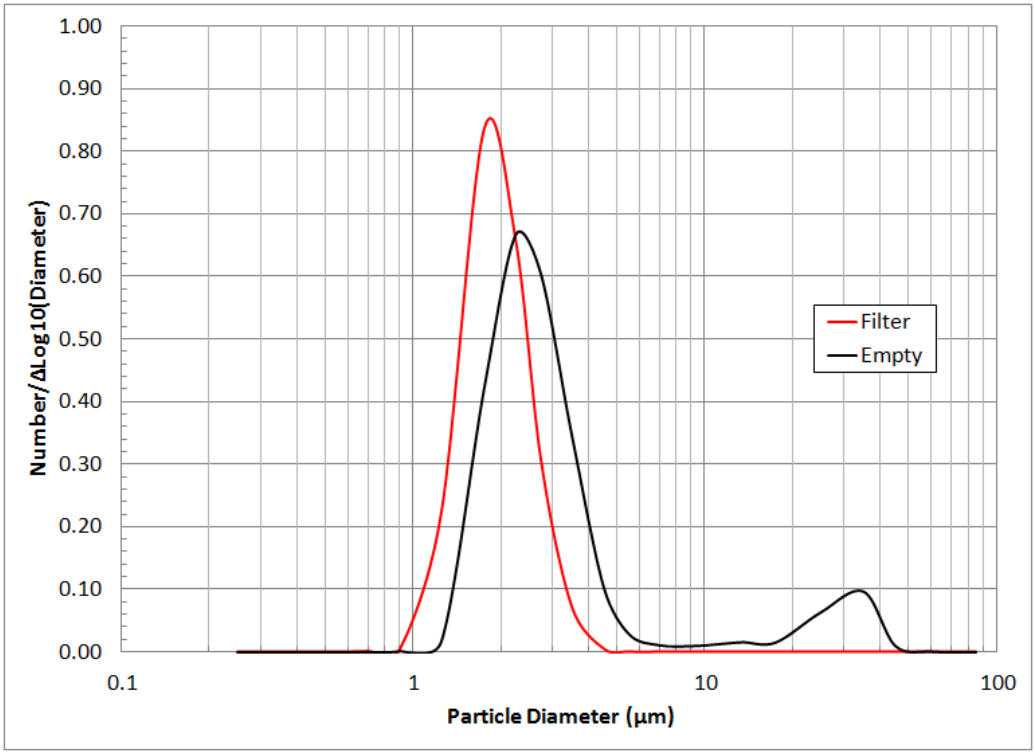
- Wide spectrum particle size distribution
  - 0.3 - 100 microns
- 0.5 - 2 liters per minute liquid flow rate
- 60 - 80% relative humidity
- Minimum of 1 hour challenge time



Aerosizer measurements

Observations - Low Efficiency

- Shattering leads to negative efficiencies in the sub-micron range
- Build up and release of large water particles (up to 750 microns)



Aerosizer measurements

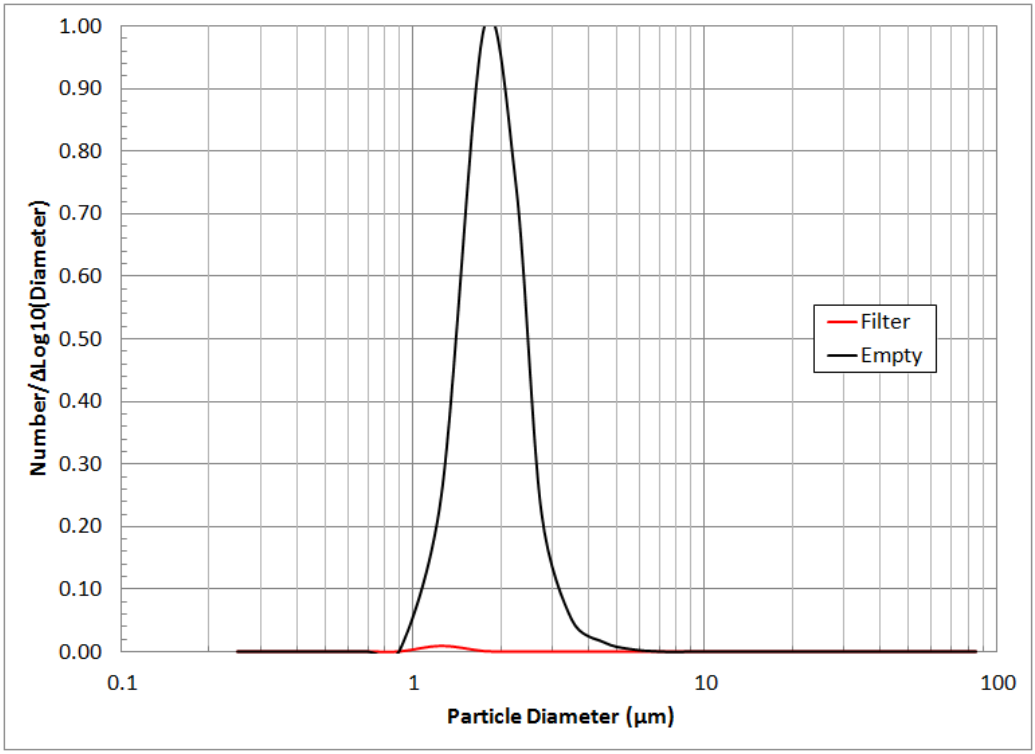
Time Elapsed, min.:	1 min.	2 min.	3 min.	4 min.	5 min.	6 min.	7 min.	8 min.	9 min.	10 min.	**Average**
Size Range (μm)	**Initial**			Fractional Efficiency (%)							
0.2-0.3	**Water Break-Up Region - No Filtration**										**0.0**
0.3-0.4											**0.0**
0.4-0.6											**0.0**
0.6-0.8											**0.0**
0.8-1.0											**0.0**
1.0-1.5	7.1	0.0	8.1	6.8	8.3	8.4	0.0	7.9			**5.8**
1.5-2.0	35.1	0.0	35.6	35.5	35.9	35.4	0.0	35.4			**26.6**
2.0-2.5	64.8	0.0	64.9	65.6	65.2	65.3	0.0	65.0			**48.9**
2.5-3.0	76.6	0.0	75.9	76.1	76.3	76.3	0.0	76.6			**57.2**
3-4	92.8	0.0	93.6	93.5	93.7	93.3	0.0	93.5			**70.1**
4-5	99.8	0.0	99.7	100.0	100.0	100.0	0.0	99.9			**74.9**
5-6	99.9	0.0	100.0	100.0	100.0	100.0	0.0	100.0			**75.0**
6-8	100.0	0.0	100.0	100.0	100.0	100.0	0.0	100.0			**75.0**
8-10	100.0	0.0	100.0	100.0	100.0	100.0	0.0	100.0			**75.0**
10-12	100.0	0.0	100.0	100.0	100.0	100.0	0.0	100.0			**75.0**
12-15	100.0	0.0	100.0	100.0	100.0	100.0	0.0	100.0			**75.0**
15-20	100.0	0.0	100.0	100.0	100.0	100.0	0.0	100.0			**75.0**
20-30	100.0	0.0	100.0	100.0	100.0	100.0	0.0	100.0			**75.0**
30-40	100.0	0.0	100.0	100.0	100.0	100.0	0.0	100.0			**75.0**
40-50	100.0	0.0	100.0	100.0	100.0	100.0	0.0	100.0			**75.0**
50-70	100.0	0.0	100.0	100.0	100.0	100.0	0.0	100.0			**75.0**
70-100	100.0	0.0	100.0	100.0	100.0	100.0	0.0	100.0			**75.0**

Time Elapsed, min.:	1 min.	2 min.	3 min.	4 min.	5 min.	6 min.	7 min.	8 min.	9 min.	10 min.	**Average**
Size Range (μm)	**Initial**			Fractional Efficiency (%)							
0.2-0.3	**Water Break-Up Region - No Filtration**										**0.0**
0.3-0.4											**0.0**
0.4-0.6											**0.0**
0.6-0.8											**0.0**
0.8-1.0											**0.0**
1.0-1.5											**0.0**
1.5-2.0											**0.0**
2.0-2.5											**0.0**
2.5-3.0											**0.0**
3-4											**0.0**
4-5	5.2	5.8	5.9	3.1	2.6	5.1	1.9	2.8	3.1	4.6	**5.0**
5-6	9.8	10.1	11.6	8.1	6.3	8.9	7.7	5.6	6.9	11.0	**10.8**
6-8	**Water Break-Up Region - No Filtration**										**0.0**
8-10											**0.0**
10-12											**0.0**
12-15											**0.0**
15-20											**0.0**
20-30											**0.0**
30-40											**0.0**
40-50											**0.0**
50-70											**0.0**
70-100											**0.0**

Velocity	1 m/s	2 m/s	3 m/s	4 m/s	5 m/s	6 m/s
Size Range (μm)	Fractional Efficiency (%)					
0.2-0.3	**No Efficiency Region**					
0.3-0.4						
0.4-0.6						
0.6-0.8				16.3%	15.3%	6.2%
0.8-1.0				27.4%	25.8%	21.1%
1.0-1.5				35.0%	35.7%	32.5%
1.5-2.0			9.5%	45.5%	40.9%	44.4%
2.0-2.5			19.0%	47.1%	41.4%	43.2%
2.5-3.0		18.5%	24.1%	56.2%	45.7%	45.7%
3-4		39.6%	31.1%	68.5%	58.4%	56.4%
4-5		58.6%	79.5%	77.7%	79.3%	77.6%
5-6		60.4%	88.4%	81.9%	87.5%	85.2%
6-8	2.9%	61.3%	91.3%	83.0%	92.1%	94.5%
8-10	19.1%	66.0%	94.7%	83.2%		
10-12	39.5%	72.9%	97.0%	90.2%		
12-15	53.6%	83.5%	99.0%			
15-20	60.2%	93.2%				
20-30	63.0%	**100% Filtration Region**				
30-40	80.8%					
40-50						
50-70						
70-100						

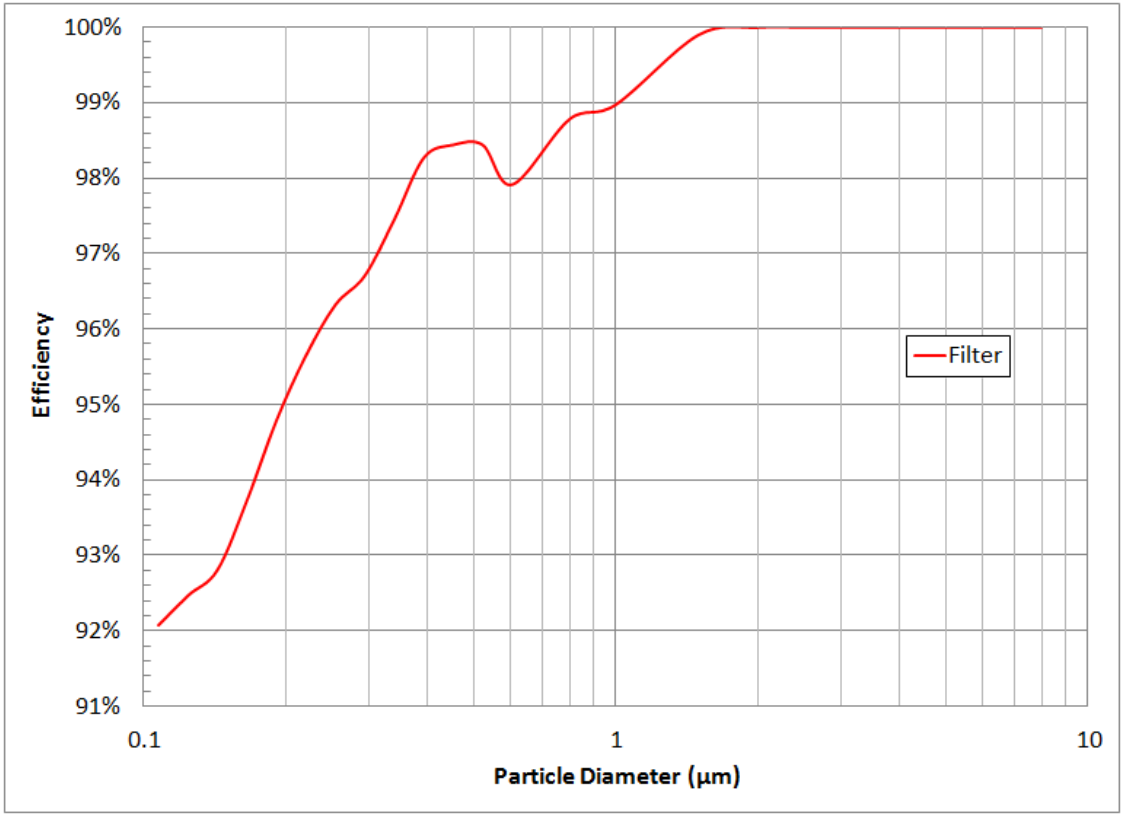
Test Parameters - High Efficiency

- Narrow spectrum particle size distribution
  - Up to 10 microns
- 0.5 - 1 liter per minute liquid flow rate
- >80% relative humidity



Aerosizer measurements

Test Result - High Efficiency



Combined SMPS and time-of-flight measurements

Observations - High Efficiency

- Migration effects
  - Build up of ice or water in the pleat packs
  - Dissolved salt water particles are forced through the pores
  - Sodium flame photometer is a better tool for measuring migration, as it recognizes only salt particles passing through
  - If all stages are tested

Conclusions

- For low efficiency filters, the phenomenon of water shattering and Burp have been observed and measured
- For high efficiency filters, ice build up on the pleats has been simulated
- Dissolved salt water particles migrating through the high efficiency filter has been measured
- The Simulation Test Duct is a good system to simulate the real world environment of water and salt water coalescence/migration for gas turbine filters

Q & A

Thank You