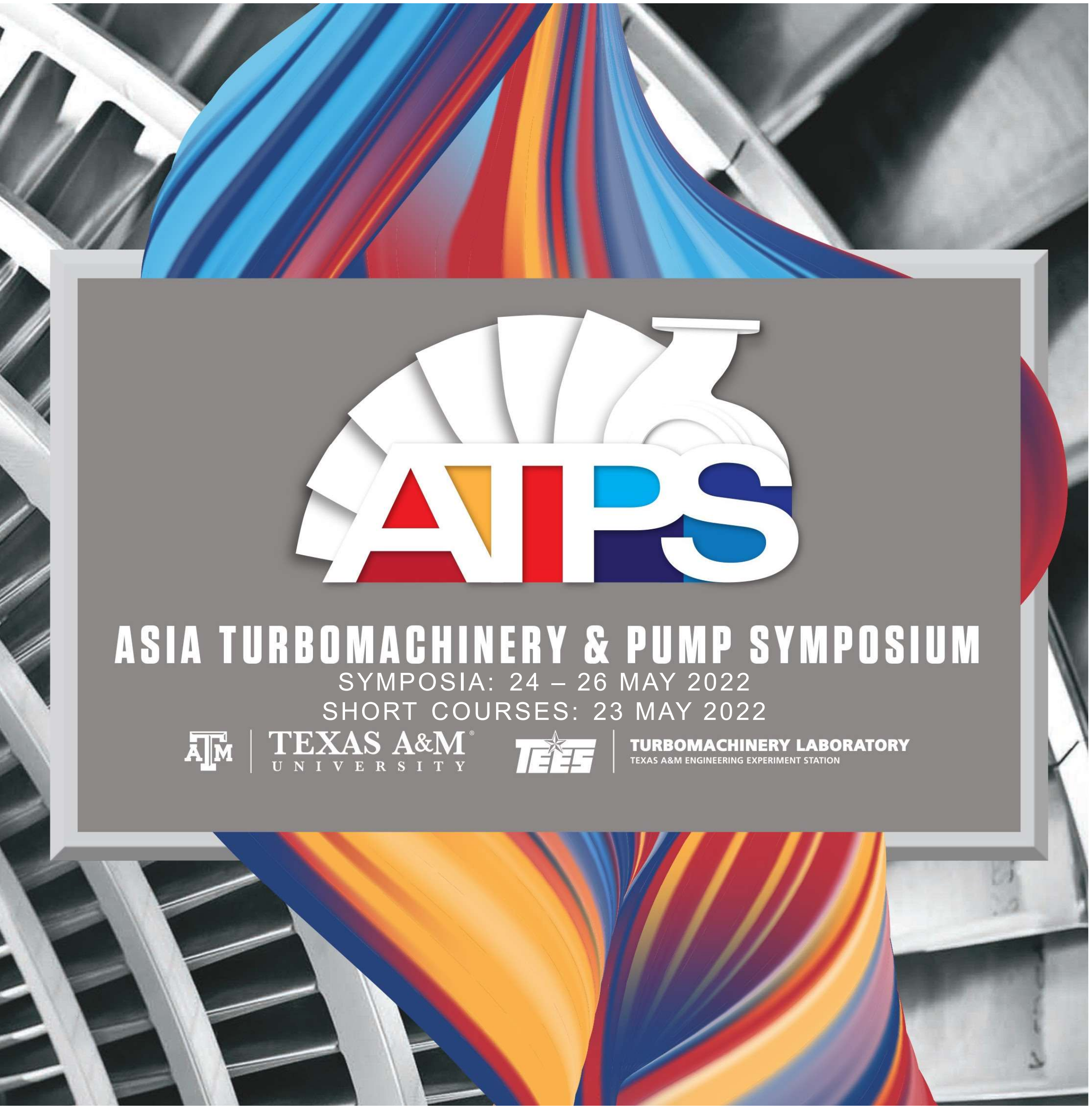

GAS TURBINE COMPRESSOR INLET AIR FILTERS PERFORMANCE COMPARISON

SUTANTO A. PERNAMA – EXXONMOBIL
ASHUTOSH VENGURLEKAR – EXXONMOBIL
DOUGLAS LEONARD – EXXONMOBIL
NG WEI SING – EXXONMOBIL
GAUTAM MARWAHA – CAMFIL POWER

ExxonMobil camfil POWER SYSTEMS

AUTHORS

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ASIA TURBOMACHINERY & PUMP SYMPOSIUM

ABSTRACT

Gas Turbine compressor efficiency and long term operability are highly affected by the air quality entering the compressor through its intake air filtration system.

This case study presented the experience of an industrial Gas Turbine application in Singapore that has had a retrofitting project to improve the filtration system performance. The retrofitting scope comprised mainly of an upgrade to filter efficiency class and the intake system design to minimize fouling agent and rainwater ingression into the compressor. The two-pronged approach resulted in slower deterioration of compressor efficiency as well as reduction of offline water wash frequency. While the results benefited the compressor performance, the filters run length was found to be too short than expected.

The second part of the study covered another Gas Turbine application in Singapore where its filtration system was designed well in accordance to the site ambient condition. It covered an in-depth evaluation of the EPA filter performance after running for 2+ years. The filters remaining life assessment in terms of its fractional efficiency and differential pressure across the filter media will be shared in conjunction with the media SEM photos showing particles type trapped in the media.

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PROBLEM STATEMENT

Pitting corrosion on compressor blades

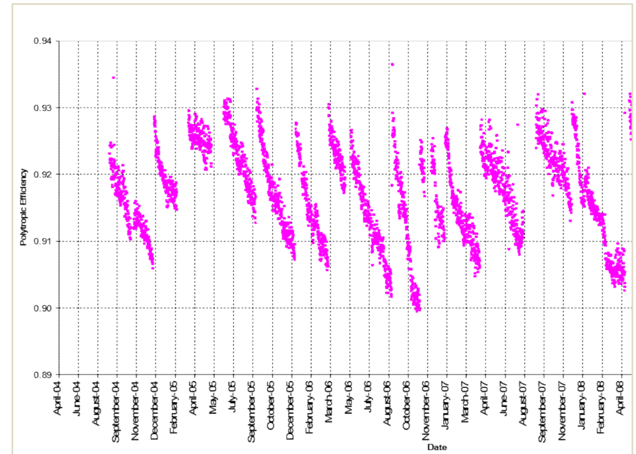
⬇

Blade cracking, failure & rotor imbalance

Fouling compressor rotor

⬇

Premature replacement before blades End of Life



Rapid reduction in **compressor efficiency**

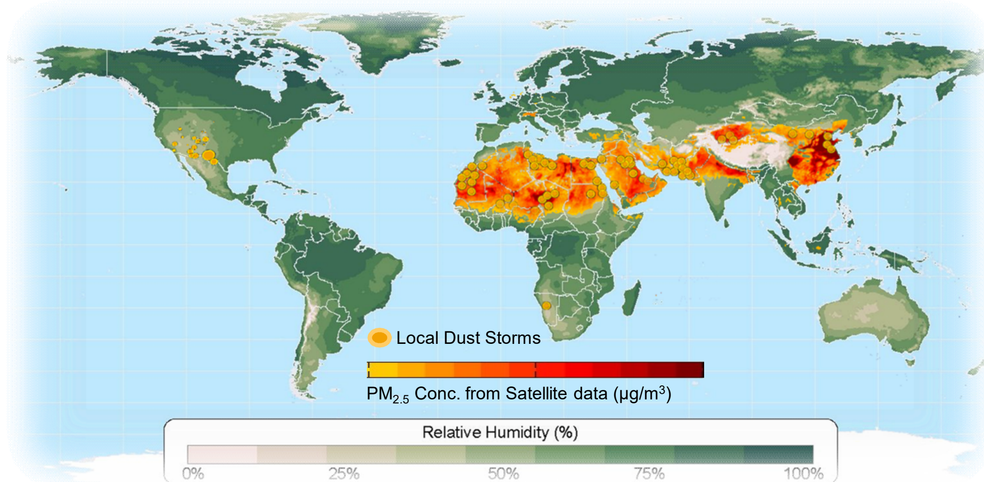
⬇

Frequent **downtime** for offline water wash

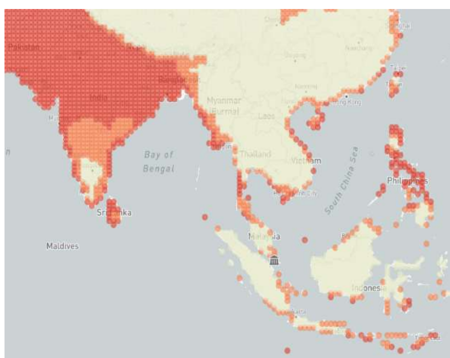
ASIA TURBOMACHINERY & PUMP SYMPOSIUM

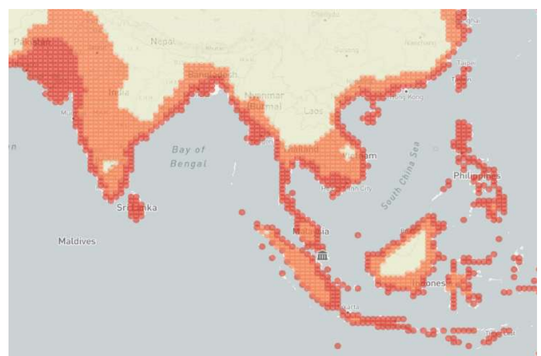
PROBLEM STATEMENT

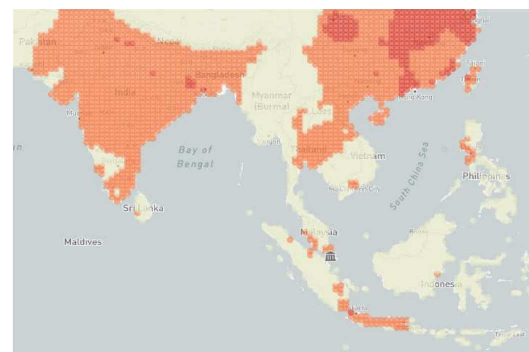
Global Humidity, Dust & Dust Storms



Southeast Asia


Coarse Dust

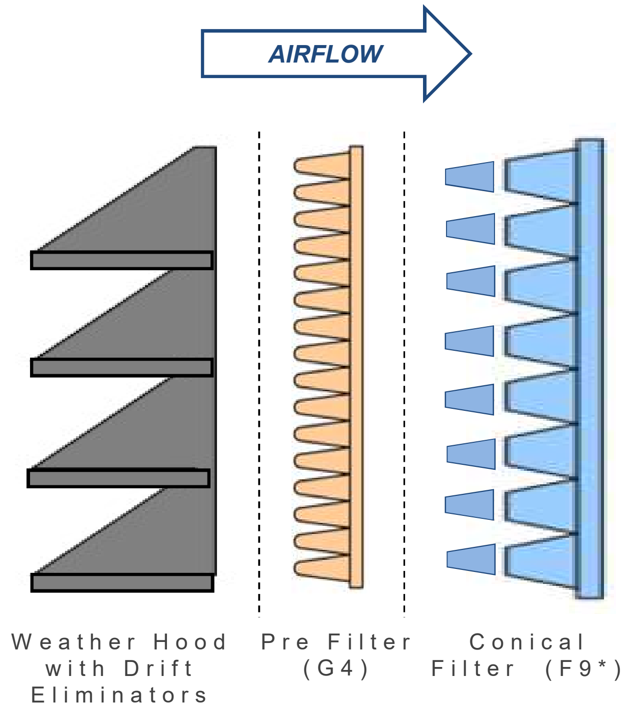

Salt


Sulphur

PROBLEM STATEMENT

Original Design Built

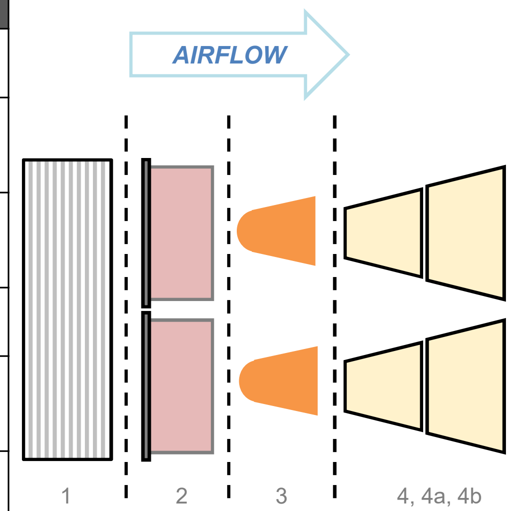
Design Element	Consequences
Filter House sizing	High media velocity and closely-spaced element
Weather hood with horizontal drift eliminators	Rain water ingress into filter house and bypassing across filters
Filter efficiency class	Typical efficiency class for ambient condition
Cone design	Cantilever effect causing air bypassing filters
Material selection	Corrosion effect causing yoke bolt/nut corroded and carried over to compressor



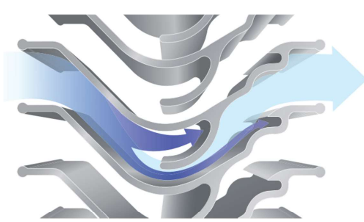
*Per EN 779:2002

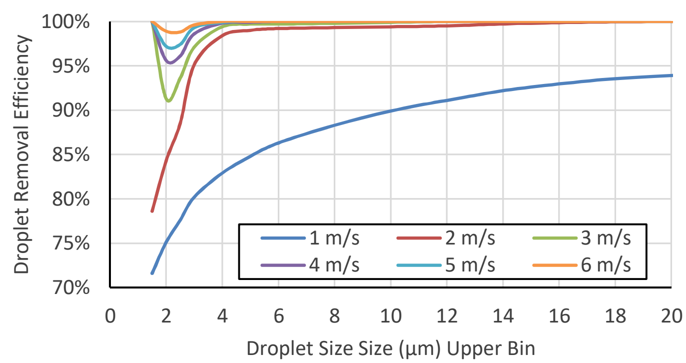
RETROFITTING EXISTING INTAKE SYSTEM *(CASE 1)*

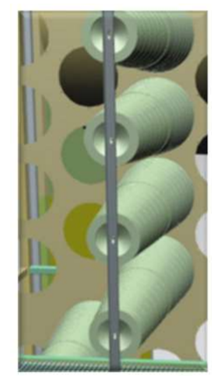
	Original Design		Retrofit Design		Intent
	Grade	Penetration Size	Grade	Penetration Size	
1. Intake	Weather Hood, Drift Eliminator	99% of > 50 µm droplet	Vertical Marine Louvre	99.5% of > 25 µ droplet	Minimize rain water entry to filter house
2. Coalescing Filter	None	N/A	Pocket Filter G4	Droplet	Capture and drain smaller droplet from airflow
3. Pre-Filter	G4	> 5 µm	F5	> 2 µm	Capture coarse particles
4. Final Filter	F9 EN 779:2002	> 1 µm	E12 EN 1822:2009	> 0.01 µm	Capture finer particles/salt Hydrophobic media
4a. Support Bar	N/A	N/A	N/A	N/A	Prevent filter sagging/bypass
4b. Mounting Hardware	N/A	N/A	N/A	N/A	Prevent corrosion over time



NOTE: ISO29461-1:2021 was released specifically designed for turbomachinery applications.



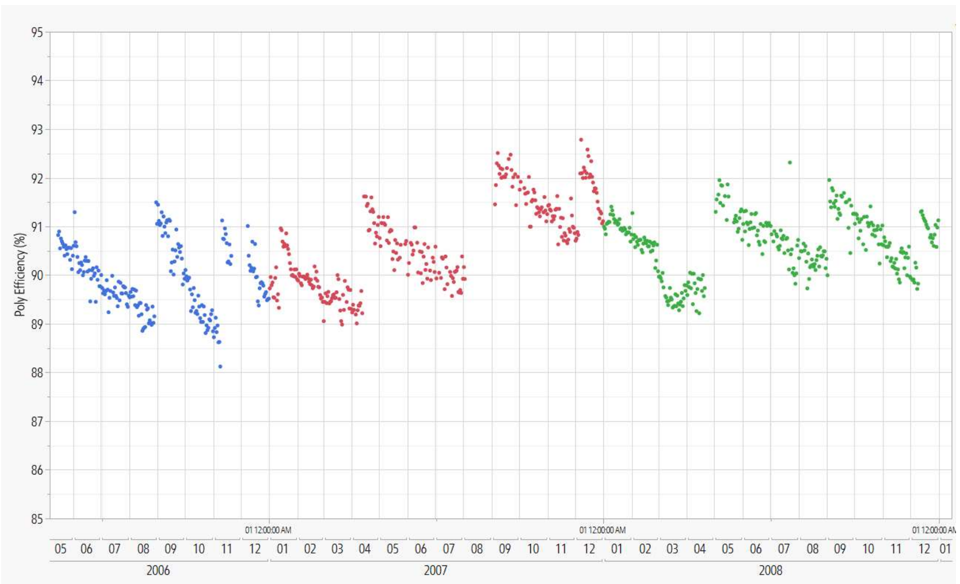




ASIA TURBOMACHINERY & PUMP SYMPOSIUM

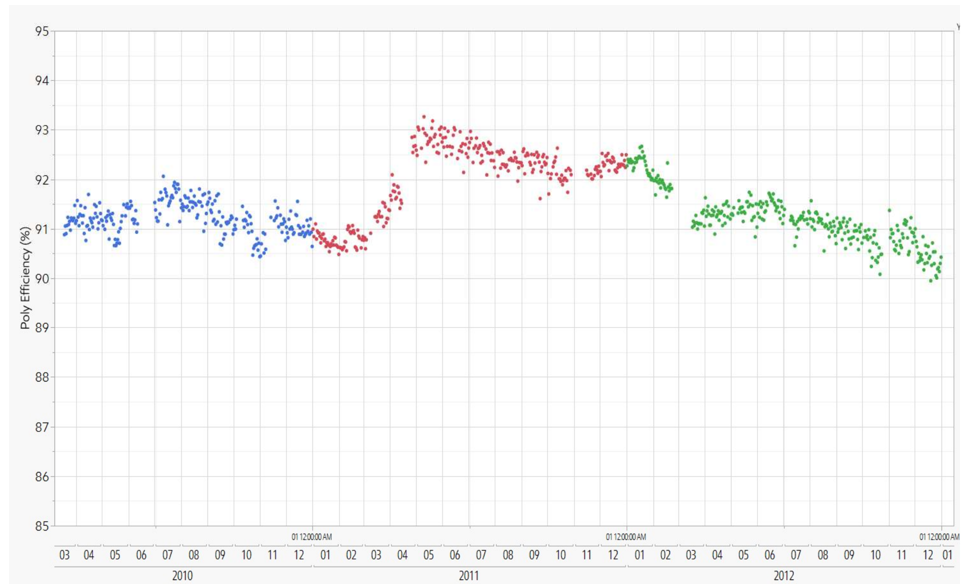
RESULT OF RETROFITTING EFFORTS

Before Retrofit (F9)



- Efficiency dropped by ~1% in < 1 month

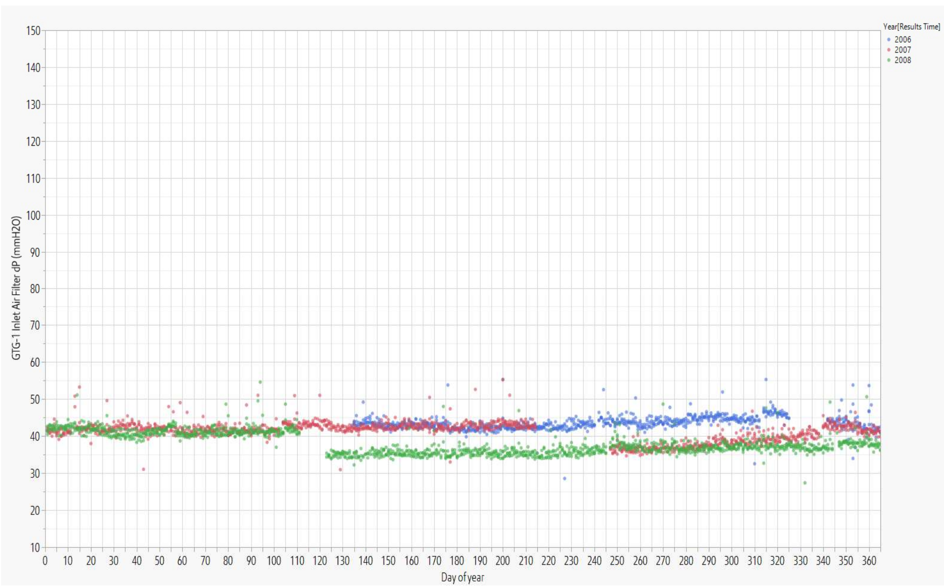
After Retrofit (E12)



- Efficiency dropped by ~1% in 3 months; one third the degradation rate with original filters

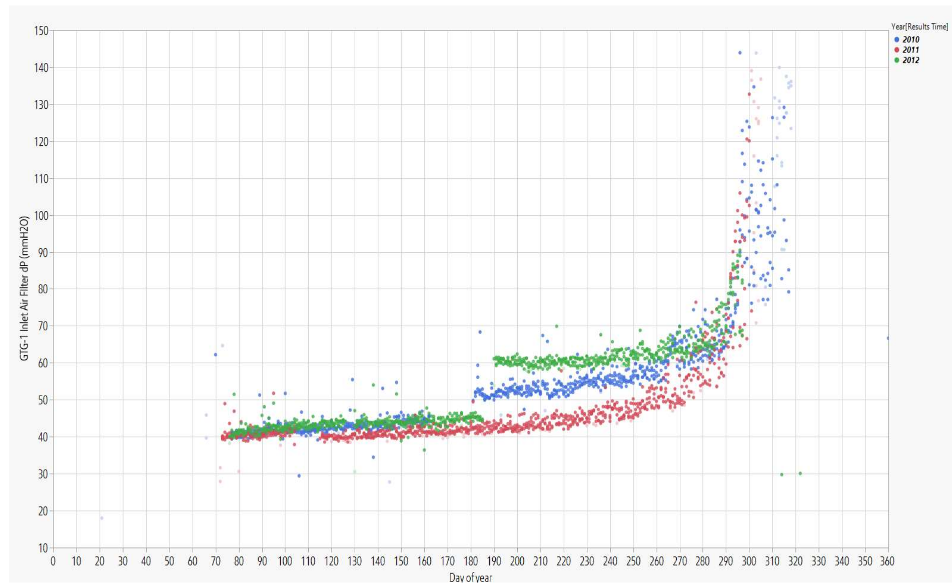
RESULT OF RETROFITTING EFFORTS

Before Retrofit (F9)



- Minor dP increment (filter plugging) over a period of 1 year.
- Possibility of water/air bypass through the filters.

After Retrofit (E12)



- Filter dP stable for the first 3 months before it creep up until it hit alarm set point after another 4-5 months.
- High pressure drop toward end of filter life.

SUMMARY OF RETROFITTING EFFORTS

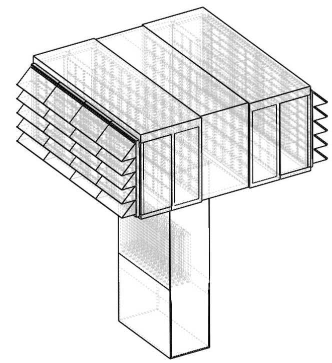
- ✓ Initial intake system was modified within practical limits of constraints shown in Case 1 with limited success.
- ✓ Improved weather protection and EPA-grade filters are effective at reducing compressor contaminants, however it comes at the expense of more frequent filter change out due to faster plugging rate.
- ✓ A properly designed system in following Case 2 would have been able to avoid both of these issues.

ASIA TURBOMACHINERY & PUMP SYMPOSIUM

DESIGNING GT INTAKE SYSTEM (Case 2)

Key Elements

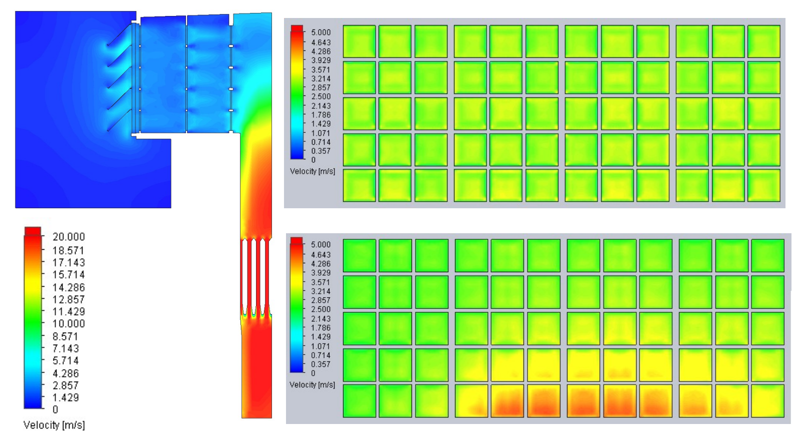
- Choosing filtration system based on environment type
- Intake system sizing based on operational requirements
- Filtration efficiency based on local conditions and operational requirements



Filtration Type and Intake Sizing

- Site located in SE Asia: High concentration of fine particles & salt, Rel. Humidity, Precipitation
- Online filter replacement required for operability reasons

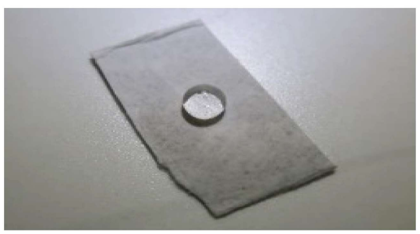
➡ Multi-stage static system selected, configuration validated via CFD Modeling



DESIGNING GT INTAKE SYSTEM

Filter Selection (Performance Criteria)

- Hydrophobic media
- Good drainage (for wet conditions)
- Good sealing (prevent bypass across filters)
- High filtration efficiency
- High mechanical efficiency (non-charged)
- High burst strength

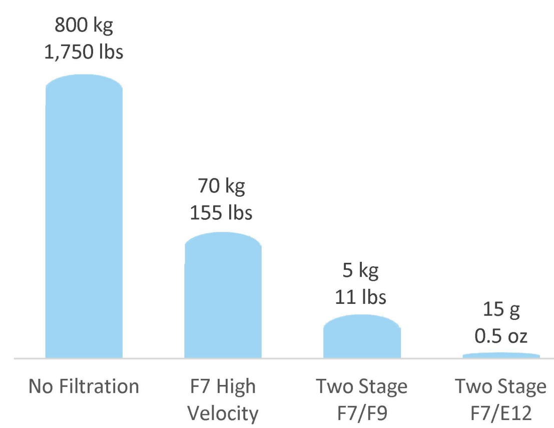


Hydrophobic media offers high resistance to water bypass

Interrupted vertical pleats & drainage channels in the filter construction help remove water from the filters

High burst strength ensures filters can continue to perform in tough conditions

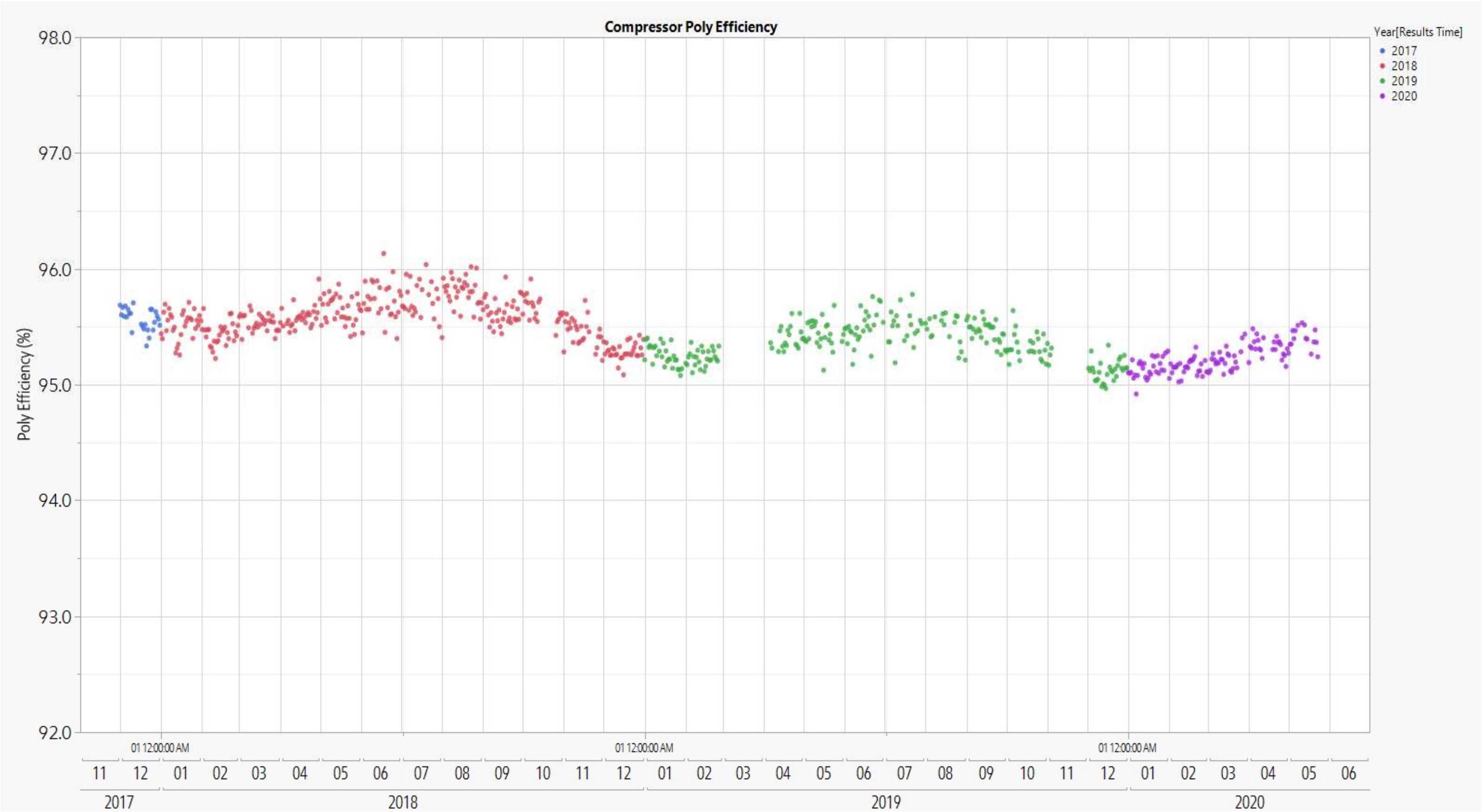
EPA-grade filtration offers high level of protection from fouling & corrosion (salt)



ASIA TURBOMACHINERY & PUMP SYMPOSIUM

FILTER PERFORMANCE AND EVALUATIONS

3-stages filters of Marine Louvre + M6 + F9 + E12



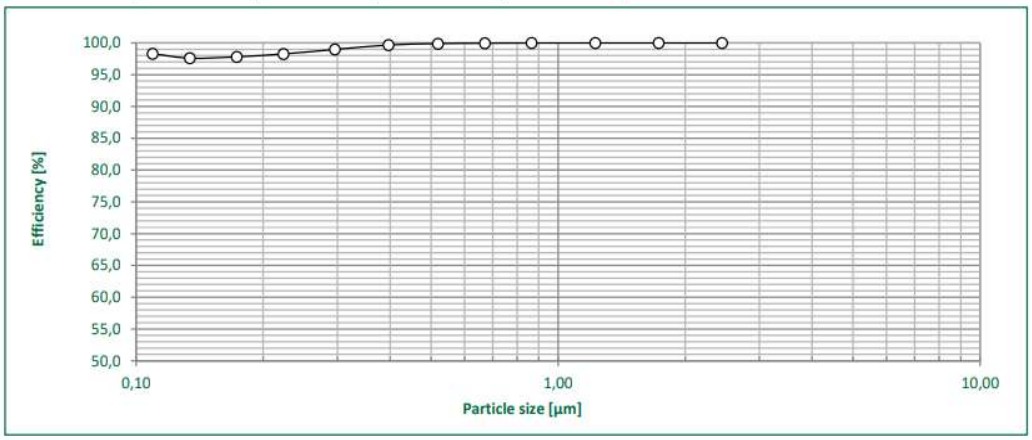
FILTER PERFORMANCE AND EVALUATION

Run Length: 2.5 years

MPPS	0,13	Efficiency 95%min at MPPS	97,5
Efficiency at MPPS	97,6		

Size	Counts [Particles]		Efficiency	Stdev
[µm]	Before	After	[%]	[+/-]
0,11	131563	2153	98,3	0,38
0,13	163885	3927	97,6	0,16
0,17	295855	6476	97,8	0,06
0,22	274625	4763	98,3	0,09
0,30	439450	4541	99,0	0,07
0,40	266655	885	99,7	0,06
0,52	144320	157	99,9	0,02
0,67	78000	33	100,0	0,01
0,87	40000	3	100,0	0,01
1,22	11000	0	100,0	0,00
1,73	7500	0	100,0	0,00
2,45	0	0	100,0	0,00
Total	1852853	22938	98,8	

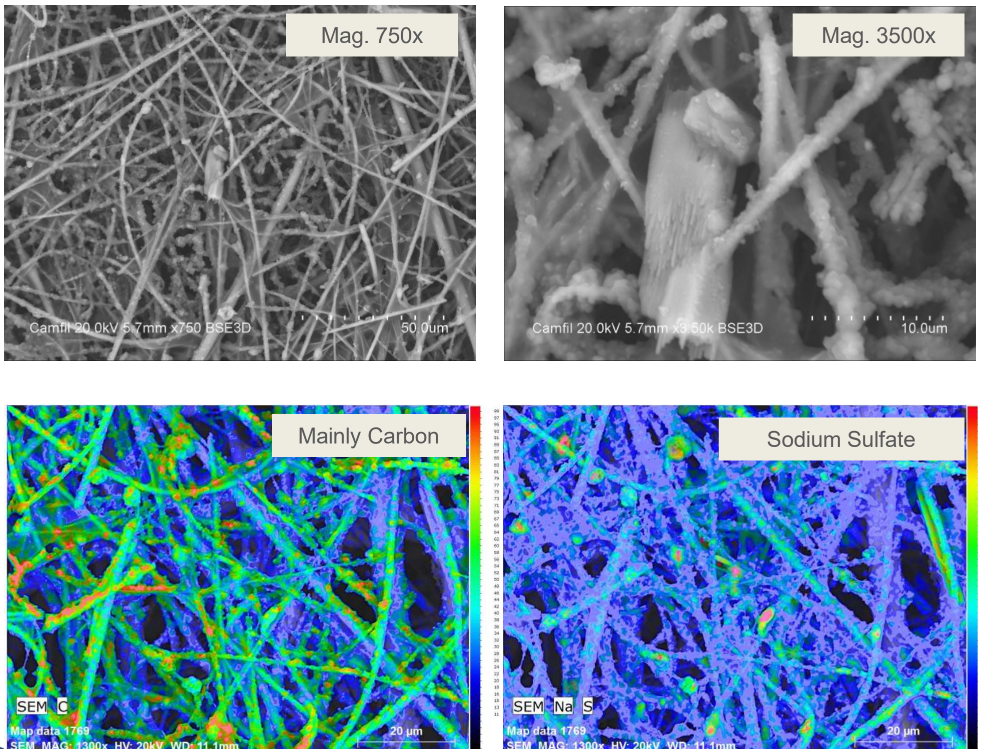
- Factional efficiency slight drop to 97.6%, ΔP drop was 374 Pa.
- No signs of bypass of particles/liquids around the gasket; frames looked clean.
- Hydrophobicity (Water repellency) properties of the media in both upstream and downstream was still intact.
- Calculated amount of particles ingested annually through the filters was 217 grams (~1.5 TBSP / month).



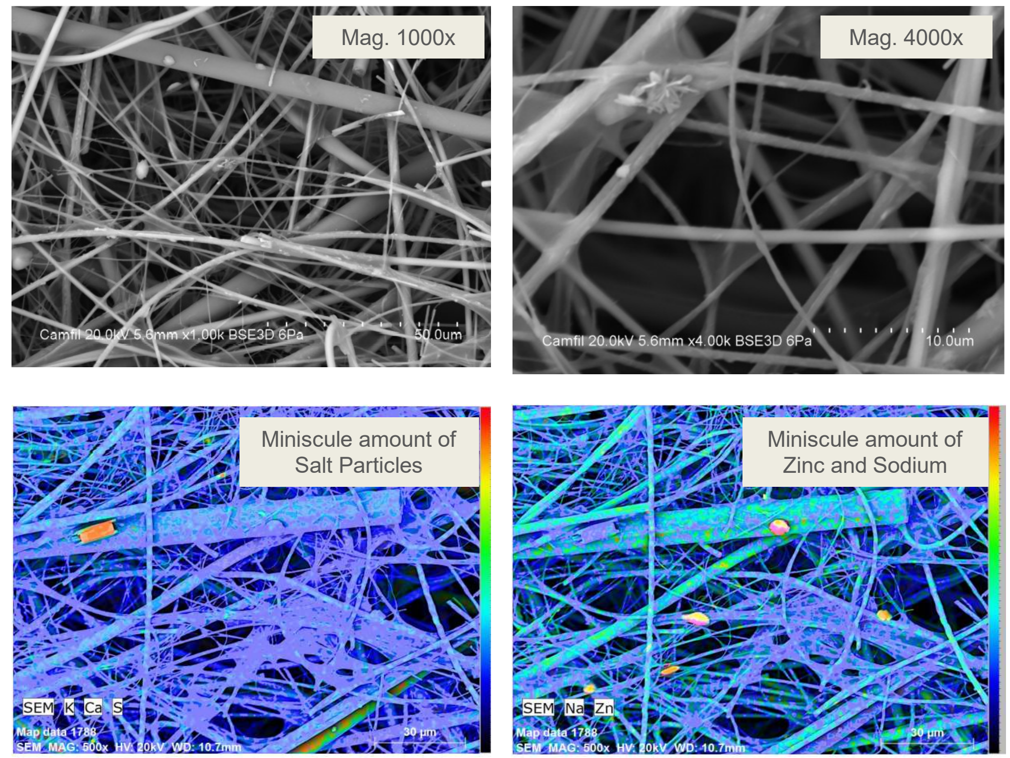
Water repellency test
(Upstream Filter Media)

FILTER PERFORMANCE AND EVALUATION

Upstream of E12 Filter:



Downstream of E12 Filter:



SEM was utilized to identify fouling element captured on the filters.

ASIA TURBOMACHINERY & PUMP SYMPOSIUM

KEY TAKEAWAYS

Filter selection & replacement based on operational costs

INCREASE FUEL EFFICIENCY

INCREASE POWER OUTPUT

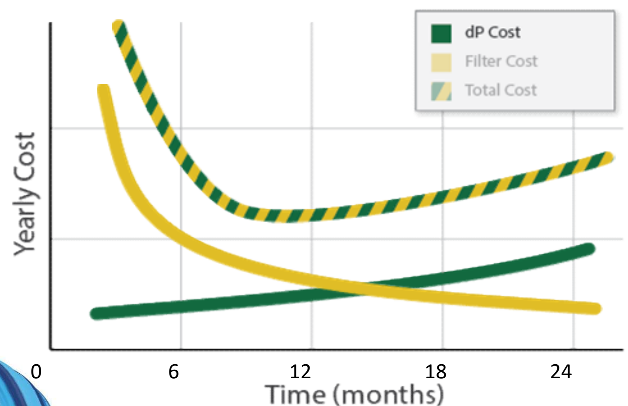
REDUCE CO2 EMISSIONS

INCREASE RELIABILITY

INCREASE UPTIME

INCREASE PROFITS

Minimizing Total Cost of Ownership



Drop in compressor efficiency and increase in inlet filter dP will affect generator output and combustion heat rate.

Optimize changeout for:

- Savings based on changing early
- Savings from inventory management

Online monitoring to ensure system is performing as expected

KEY TAKEAWAYS

- ✓ Both Case 1 and Case 2 showcased how intake system design can affect GTG performance. Comparison of Case 1 and Case 2 demonstrated how initial design can impact the total cost of ownership of the intake system.

- ✓ Gas Turbine compressor intake system should be designed specifically based on ambient condition and operational requirement in order to achieve an optimum Gas Turbine performance and operability.