GT Air Intake Filtration - Filtration Reliability Vs Filters' Life

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Introduction

Gas Turbine Air Intake Filtration (AIF hereafter) has become a popular topic in view of the asset and performance costs resulting by letting dirt, solubles, corrosive and erosive particles through to the compressor and to the GT hot parts.

Extensive research has been conducted and many papers have been written on the topic of GT AIF with reference to the available standards En779-2002, En779-2012, ISO16890 and ISO29463. However, as we see following, these standards bear shortcomings.

The following chart shows the minimum filtration efficiency curves relative to the grades defined by the standards:

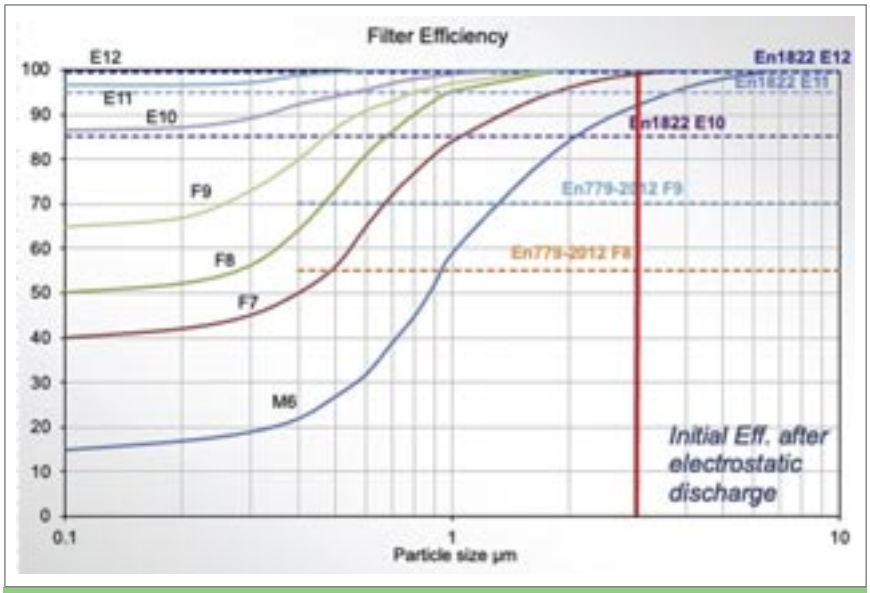


Figure 1: Minimum filtration efficiency curves relative to the grades defined by the standards

Accordingly, any fine filter (>F7) should filter out all solubles and dust particles larger than 3micron.

Tests and experience, however, lead to the conclusion that solubles and/or dust larger than 3micron do penetrate through filters eventually, typically pushed by water droplets over time.

In fact it is not uncommon to see dirty puddles downstream of fine filters, especially in case the intake

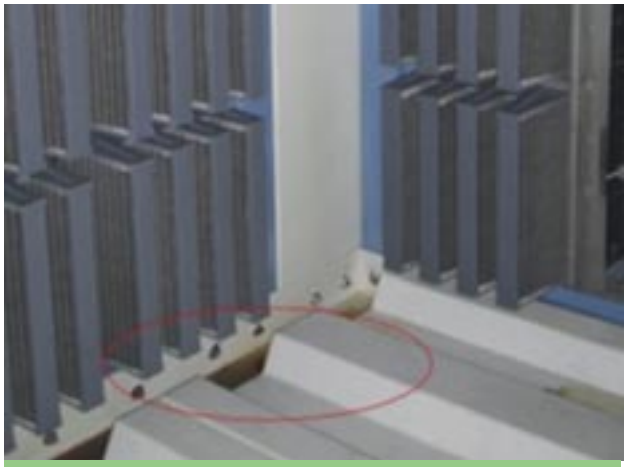


Figure 2: Dirty water puddles

plenum is large enough to allow for slow air velocity.

Therefore, the reality is that filters' efficiency either fluctuates or deteriorates over time, depending on the specific environment at the site of interest.

When water/solubles/dust penetrate through, it can be said that the filters have failed. But we are prompted with more challenging questions:

- Have the filters surpassed their useful life despite the DP may be still low?
- What timeframe should be expected for filters to retain their filtration efficiency?

The concept that the life of filters' efficiency may be shorter than the life defined by the filters' DP is in conflict with the current standards, including the latest ISO16890.

The GT community realizes this shortcoming and new standards are being developed specifically for Gas Turbine air filters.

Figure 3: All the water droplets generated must impact the tested filter

- No water goes through the filters reliably
- Over time, the DP increases but not beyond certain thresholds

These water tests are relatively simple to execute, and at the same time they provide important information relative to the manufacturing quality of the filters and the quality of the filtration media.

These tests are recommended for all types of final stage filters, whether F-graded or EPA-graded, whether static or pulse, and whether Vbank or Box or Panel or cylindrical/conical in shape.

Basic Filtration Reliability

What seems to be the common trigger for the penetration of solubles and dust through the filters is water droplets from rain, fog or condensation due to high RH.

For this reason, major GT OEMs have developed proprietary tests to challenge air filters with water over a number of hours. The ISO organisation has embraced the same approach and a new standard called ISO29461-7 is currently under review.

In the most basic form, these tests are to verify that:

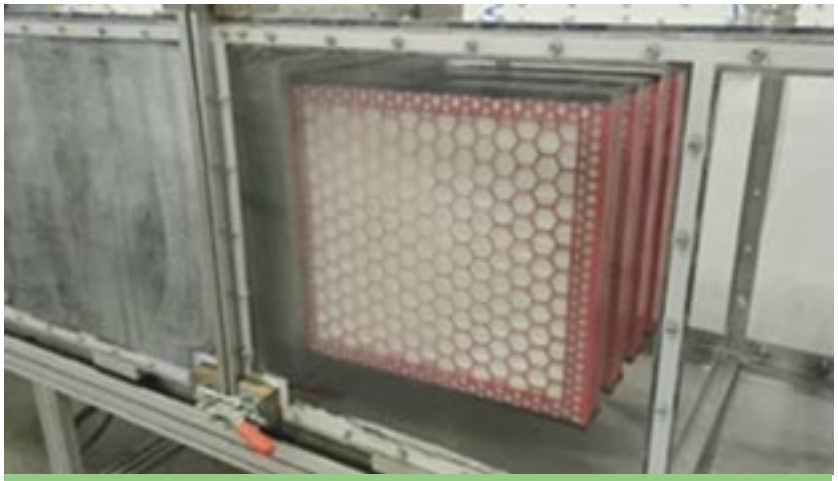


Figure 4: Filter after water test

The ability of a filter to not let water through provides operators with confidence that the filters will not deteriorate in filtration efficiency too quickly after the installation. This is critical to provide confidence on the *basic filtration reliability*.

Flow-rate= 4,250m3/h *Water input = 0.4l/min* *Duration = 5hrs* *Filter grade = F9*	A	**B**	**C**	D
Initial DP	150	**110**	**110**	150
Final DP	220	**140**	**130**	**FAIL (water leached through after 10mins)**
Increase in DP (%)	46.6%	**27.3%**	**18.2%**	N.A.

Figure 5: 5hrs of water tests performed on 4 different filters

Comparative Analysis

The usefulness of the water tests goes further since they allow to compare the initial and final DP between same graded filters. Therefore, they allow operators to compare filters' reliability between competing products.

An example is given in the table Figure 5 (above), which compares the results of 5hrs water tests performed on 4 different filters.

In this example, the filter C has the most impressive performance, with the filter B not far behind, while the filter A is significantly higher in DP and the filter D fails prematurely to withstand water ingress.

These simple objective results would prompt an operator to procure the filter B or the filter C depending on the budget available.

This is a major breakthrough in the market since at this stage most of the procurement decisions are based on the following:

- Cost
- OEM installation / GT OEM approval
- Brand / historical customer-supplier relationship
- References
- Filter grade, DP and DHC

Water tests introduce an additional objective performance comparison method focusing on *filtration reliability*.

Experience with water tests also leads to the conclusion that filters with more efficient drainage are more likely to perform better. A simple visualization is through the comparison of the ISO29461-7 test reports on same graded Vbank and cylinder/cone filters as shown if Figures 6 and 7.

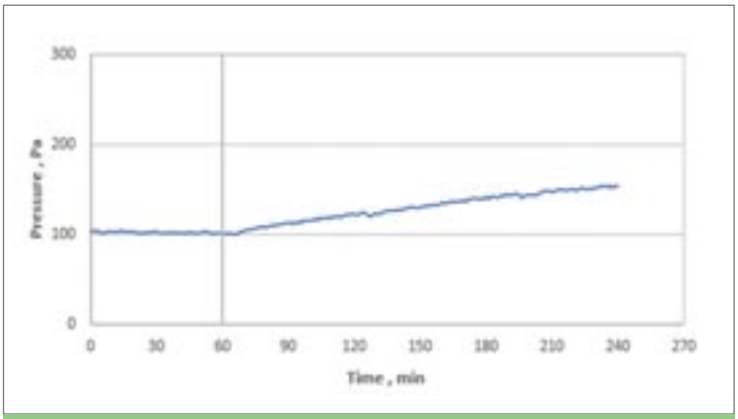


Figure 6: Note: No water permeate through the sample during the testing process.

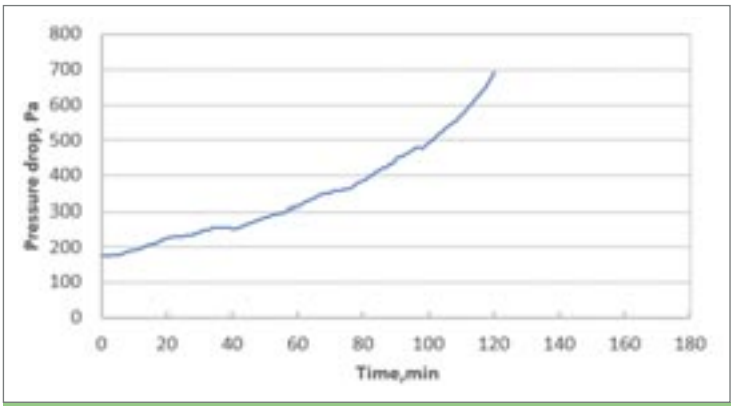


Figure 7: Note: No Leakage

It can be seen from the DP charts that the DP of the cylinder/cone arrangement increases much faster. This is due to the difficulty for water, which has deposited on the top surfaces, to drain out.

Multi-Stage Filter Systems

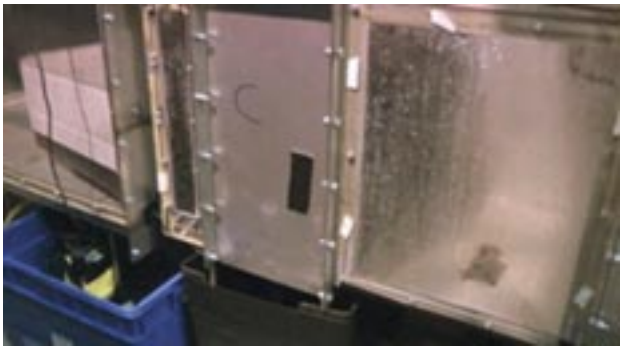
Even if a filter passes the water tests, still over time water/solubles/dust will penetrate through.

Therefore, passing the water test means that the penetration will not be instantaneous and rather that it will take years for the filters to fail.

It is common for GT AIF systems to host a number of filter stages. Pre-filter stages are critical then to lengthen the time before water/solubles/dust penetrate through the final stage filters.

Typically, coalescers and pre-filters do not pass water tests due to construction and type of media. However, a type of pocket filters called Drop-Safe exists on the market that warrants no water breakthrough with stable DP.

The following results are drawn from an independent ISO29461-7 test executed on a M6+ Drop-Safe filter.



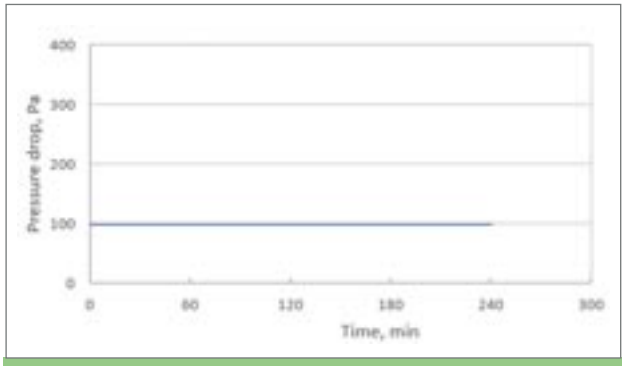


Figure 8: Note: No water permeate through the sample during the testing process

The chart above shows that the filter is completely stable in DP despite 4hrs exposure to water ingress.

This performance is unique for a pre-filter such that it has prompted a number of GT OEMs to implement the Drop-Safe as standard 1st stage filter, both in Power Generation and Oil & Gas installations.

If both 1st stage and 2nd stage filters can avoid water passing through, the filter system can be reliably reduced to 2 stages including EPA grade, with the following benefits:

- Compact filter house
- Low total average DP
  (Note that every 1mBar dictates a reduction in GT output by approx.. 0.13%)
- Simplified maintenance

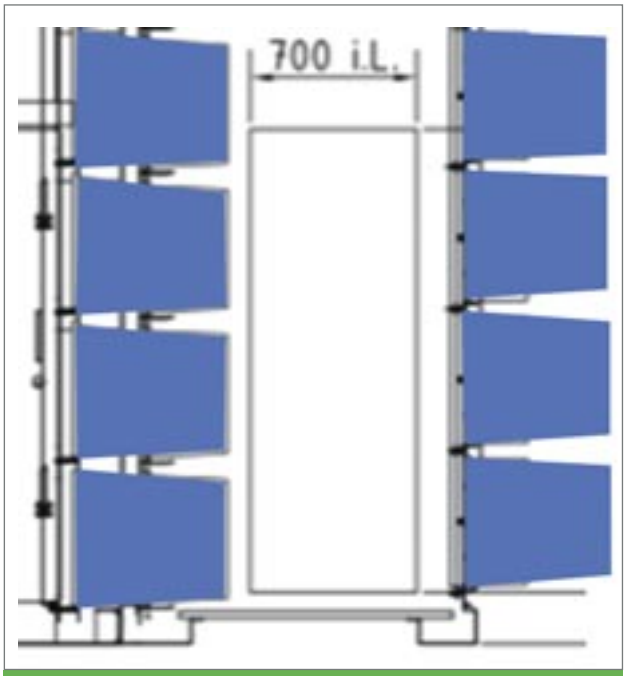


Figure 9: Total Initial Dp @ 4,250m3/h = 270Pa

DS-M6/F7

FVXX-E11

What Time-Frame should be expected for filters to retain their filtration efficiency

The answer to this depends on many variables and is not straightforward to define. Some key variables are:

- Specific environment at the site of interest (eg. cold and wet affects negatively)
- Number of filters' stages (whether Drop-Safe technology is employed, and whether the stages are physically spaced out so to allow for

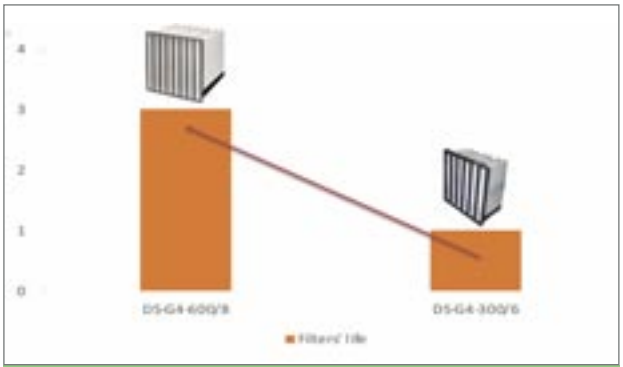


Figure 10: DV size

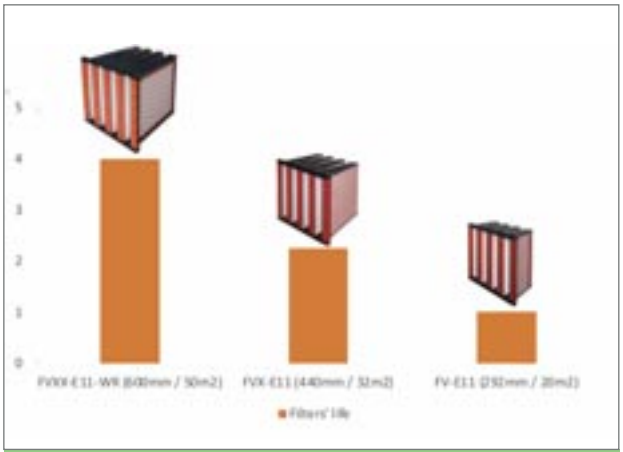


Figure 11: FV size

drainage of water/solubles/dust up to the final stage filters)

- Air-flow rate per filter (in m3.h or cfm)
- Size/Capacity of the filters - see Figures 10 and 11, noticing also that the longer a filter lasts, the more environmentally friendly it can be classed.

Baseload Vs Peaking

Operators of both baseload and peaking Gas Turbines should aspire to *high filtration reliability*. Therefore, the recommendations made so far are applicable to both running regimes.

As the filtration materials are the same, the multi-stage architecture may not differ considerably except for the filtration grades.

E10-E12 filtration efficiency reduces drastically the GT output and HR degradation according to the volume of air ingested over time. Therefore, it makes sense for baseload operators to install filter systems with E10-E12 as final stage filters (with reasonably graded pre-filters).

Peaking operators are more concerned with the cost of the consumables. Therefore, economical F-graded filters may represent a more valuable solution. Typically, the grades F8 or F9 are recommended.

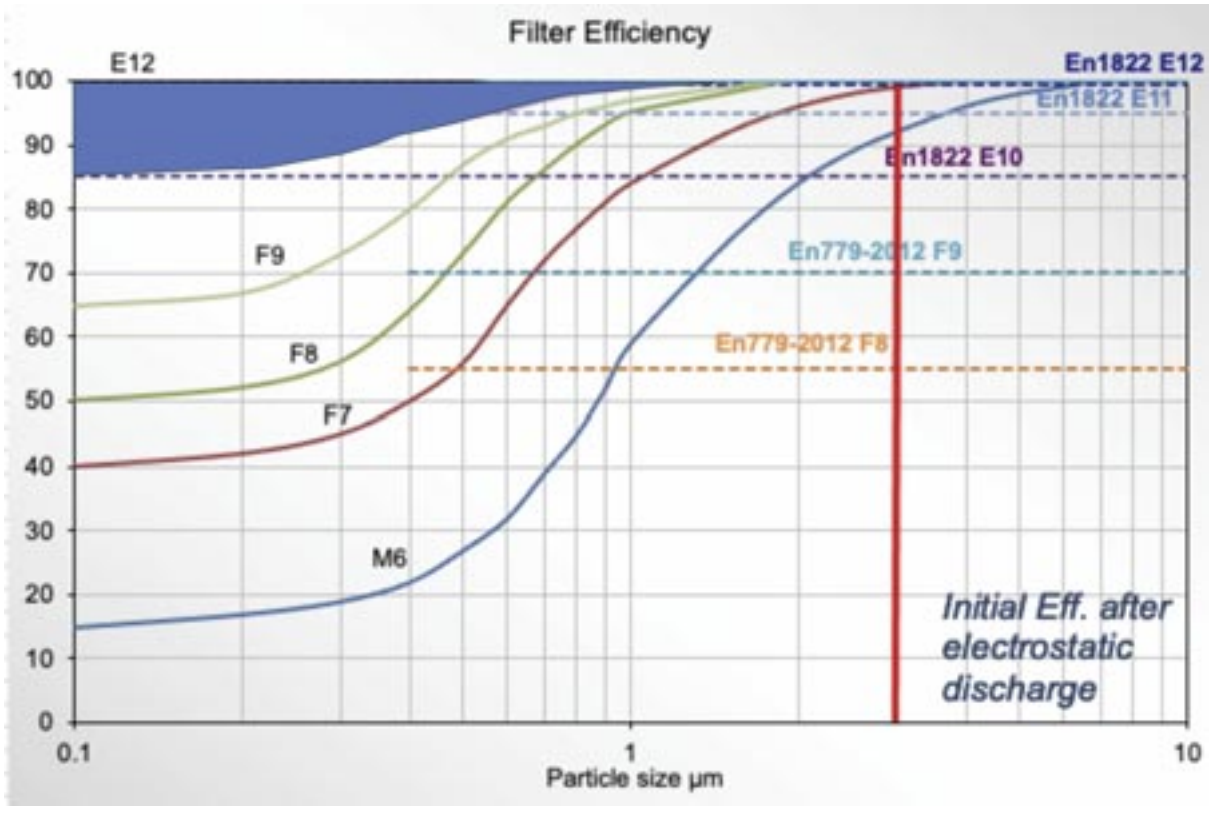


Figure 12: Filter efficiency

Looking at the latest GT installations in the UK, the points raised through this paper are implemented consistently:

- Keadby 2
  - → Base load 9000HL
  - → E10 final stage filter
  - → Drop-Safe technology as 1st stage with M6 grade
- Spalding 2
  - → Peaking 4000F
  - → F8 final stage filter
  - → Drop-Safe technology as 1st stage with G4 grade

Conclusions & "Continuous Improvement"

In conclusion, there is ample evidence to warrant that:

1. *Filtration reliability* is critical and can be measured by means of water test protocols, developed by GT OEMs as well as the ISO29461-7
2. Solubles and/or dust penetrate through the filters eventually, pushed by water over time
3. Multi-stage filtration systems are beneficial to extend the time before solubles and/or dust penetrate through the final stage filters and reach the GT
4. Pre-filters called Drop-Safe exist that can pass water tests, which extend the time further and/or allow more competitive 2-stage low-DP filtration systems
5. Both baseload and peaking GT operators should aspire to high filtration reliability, ie filters that pass water tests. EPA filtration is recommended for baseload operators in view of the reduction in output and HR degradation

The ISO organisation is also developing a water & salt test protocol, called ISO29461-5, which will shed more light on the journey of salt through the filters.

Preliminary tests already lead to the conclusion that water droplets act as trigger for the final release of salt particles downstream the filters, which is in line with assertions provided in this Paper.

References & Readings

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Mr de Arcangelis has worked in the field of gas turbine air intake filtration for 2 decades. He started his career as UK agent and distributor for various filter brands, which continued on for the first 10 years.

Later on, he became involved in the development of GT air filter system designs, advising End-Users as well as GT OEMs, both in the Power Generation and Oil & Gas markets. More recently, he became involved in the development of filter elements, which is ongoing in collaboration with major GT OEMs.

Over the years, he has been researching, developing, testing various filters and filtration hardware. His tests and papers have provided valuable input also to the development of new test specifications.

Mr de Arcangelis holds a Mechanical BEng (with Honours) CEng and a Masters in Science. ■