HEPA FILTERS: ARE THEY FLAWLESS?

WHILE THEY CAN SUBSTANTIALLY REDUCE FOULING AND PERFORMANCE DEGRADATION, INDUSTRY ASKS FOR MORE APPLICATIONS

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The compressor of a gas turbine consumes a significant portion of the overall cycle energy during operation. Therefore, the efficiency of the compressor has to be maintained for optimum turbine performance.

During operation, the gas turbine ingests a humongous amount of air to burn fuel and produce power. This air contains not just particular matter but also moisture, salts and chemicals in microscopic quantities – all of which can damage compressor parts.

Particles that have sufficient mass to irreversibly wear the internal rotating components are typically identified as being greater than 10 microns in diameter. Their hardness, velocity and concentration in the air stream can cause erosion. Particles less than 5 microns do not have sufficient mass to cause wear, but through impact, change blade profile. They also clog cooling air holes, increasing operating temperatures locally. This phenomenon of fouling leads to performance losses.

Further, if airborne salts pass through the filter system, a chemical process occurs that is not dependent on particulate size but on the presence of moisture and an electrolytic reaction between salts and metals. Airborne salt and water causes low-temperature corrosion, while the combination of sodium chloride with air-fuel-borne sulfur results in hot corrosion.

To protect rotating machinery from the impact of fouling, erosion or corrosion, gas turbine OEMs issue mandatory air quality requirements. These requirements include recommendations for filtration, regular waterwashing – online and offline — and maintenance.

Gas turbines have traditionally employed barrier filters that provide efficiencies of F8/F9 as per European test standard EN 779 or MERV 14/15 to the American ASHRAE 52.2 test standard. While these may be considered ventilation filters, a class of "clean room" filters with high efficiencies that are normally associated with micro-electronics production and laboratory-hospital protection are now being increasingly used in gas turbine installations.

These High Efficiency Particulate Arrestor (HEPA) filters block the tiniest of particles of sizes down to one tenth of a micron and smaller. It should be noted that typically particles of size 40 microns and above are visible to the human eye.

Figure 1: AAF Power & Industrial's H12 HEPA final stage filters behind canisters (left)
Figure 2: Self-cleaning stage in front of HEPA filters (above)

Arresting degradation

HEPA filter classifications have changed over the years. At one point there were 95% ASHRAE, HEPA, and ULPA grades. HEPA was defined as 99.97% efficient on 0.3 micron. Then there were "H" class filters based on most penetrating particle size (now called "E" class in the latest EN1822 standard). H12 (or E12) is the rating that indicates HEPA filtration.

HEPA filters remove sub-micron sized particles and droplets using proven techniques of particle attraction and diffusion, says James Kenneth Ross of AAF Power & Industrial, a supplier of gas turbine filters including HEPA devices. A major component of this technique is the air speed past the fibers and the diameter of these fibers. This means that a lower airstream velocity will result in improved particle removal efficiency. "Optimum filter media areas are determined by test and it is recognized that pleat shape and size contribute greatly to the overall performance of the filter," adds Ross.

Where H12 filters are applied as the final stage, tertiary filters should ideally be F8, says Ross (Figures 1, 2). "Typically a G3-F5 pre-filter stage is also used but commercial and practical restructions may mean that only one pre-filter stage is selected."

By providing efficient filtration, HEPA filters promise to arrest performance degradation that may occur due to fouling and, in the process, minimize or make waterwashing unnecessary. It should be noted that not all the performance degradation can be regained through waterwashing, and some of the loss is permanent. However, observers point to some concerns regarding HEPA claims.

Good filtration is only one component to an effective gas turbine maintenance program, says Bruce Tassone of ECT, Inc., a supplier of waterwashing systems. "The over-riding goal of the operator is to impact the degradation curve. This is accomplished by slowing the buildup of foulant and reducing the total level of contamination. Filtration and online cleaning both achieve these operational objectives," he says.

In comparison to online cleaning, there is a substantial upfront cost for HEPA filters. This cost should be weighed against the present value of the avoided cost of cleaning plus any negative impact on plant efficiencies due to constricted airflow at the inlet, adds Tassone. "While HEPA manufacturers claim to remove more contaminant, this also means filters will foul faster than conventional filters. This leads to an accelerated increase in pressure drop across the filter along with an escalating forward maintenance costs for these types of filters."

But HEPA filter suppliers believe that the economic benefits of avoiding performance degradation far outweigh higher initial cost, possible requirement for earlier change out of filter, and increased air resistance. "Field experience shows that higher system resistance has had little negative impact," says Ross, who points out that HEPA filters have logged signif-

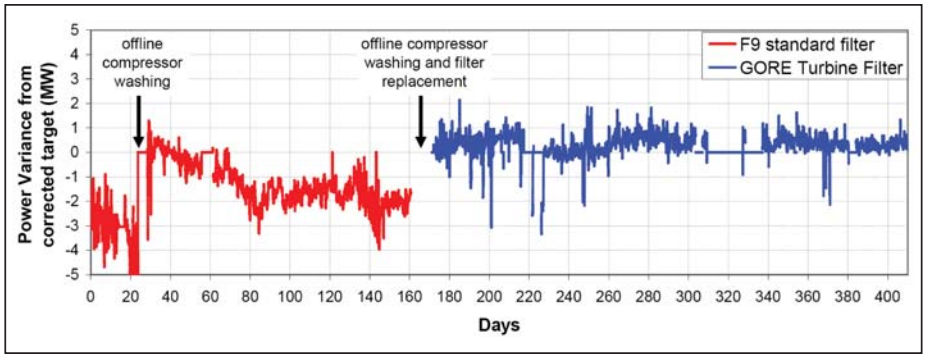

Figure 3: Power output variance from corrected target in a Rolls-Royce RB211 installation using Gore Turbine Filters. (left in red: conventional F9 filter with 2 offline washings, right in blue: H12 filter without any washings)

Figure 4: New panel design with the membrane-based H12 HEPA media

icant operating hours and there is data to prove their performance. Some of the earlier installed systems have run past 80,000 hours.

"Compressor fouling has proven to be more influential in the health, life and economics of the engine than initial resistance," adds Ross. For dust-laden and high-hydrocarbon environments, Ross recommends a single-stage reverse jet pulse filter can be used as pre-filters for subsequent HEPA filters.

HEPA filters for gas turbine inlets typically use deep pleat panels and mini-pleat style filters, says Mike Handley, Product Manager at Donaldson Company, Inc. "We also supply some round cartridge HEPA filters but they are less common. We apply HEPA filters downstream of a F8 or F9 filter stage to extend the life of the HEPA."

Using membranes

W.L. Gore & Associates has introduced a HEPA filter using expanded Polytetrafluoroethylene (ePTFE), which is claimed to reduce pressure drop across the filter, and increase life. A patented 3-layer construction uses a prefilter layer that removes the bulk of coarse and submicron particles, storing them in its depth with a minor increase of pressure drop. The second layer consists of an ePTFE membrane that removes small particles, water, and dissolved salt crystals. The layer presents an increased surface area through its nanostructure and uses the phenomenon of "slip flow" to keep pressure drop low. Finally, a high-strength backer provides burst strength under wet conditions.

The combination of these filtration layers is pleated and integrated into standard cartridge or panel designs, which can be easily retrofitted into existing filter houses. A Z-panel design (Figure 4) decreases the pressure drop even further (135 Pa at 3,400 m^3/hr airflow, 180 Pa at 4,250 m^3/hr airflow).

Installations of GORE Turbine Filters on sites have reported elimination of compressor fouling and a filter lifetime similar to the F8- or F9-rated cartridge filters. Operating a Rolls-Royce RB211 showed no fouling or drop in power output observed (Figure 3).

Changeout times

So how long do these HEPA filters last? Donaldson's Handley says that he has seen some last up to eight years whereas some last only six months. "It really depends on the quantity and type of contaminants and the quality of filtration upstream of the HEPA filters."

Many filter manufacturers recommend that HEPA filters should be changed when the restriction increases by 1 inch of water over new and clean. For the longest time, the rule of thumb was that low restriction equaled more power. "One major OEM calculation shows 4 inches water restriction costs 1.4% of turbine output. Even 0.1 inches water was money saved. However, power loss due to fouling and corrosion is proving to be a far greater output loss. We are working with some end-users to establish the approximate lifecycle cost of these systems but the data is still preliminary right now," says Handley.

"We have participated in side-by-side testing that shows increasing efficiency dramatically reduces the need for water washing," Handley adds. The more efficient the filter the more it will stop and hold. As most filters load they increase in efficiency. "Essentially, you can either catch the contaminants in the filter or ingest it in the turbine."

Meanwhile, some OEMs, such as Siemens, are backing HEPA filters. Siemens cites its extensive operating experience in Japan (Figure 5) and also the increasing number of sites that have retrofitted HEPA systems to support its conclusions. "General experience with HEPA filters is that online washing is eliminated and cold washes are reduced or eliminated, although this cannot be guaranteed beforehand."

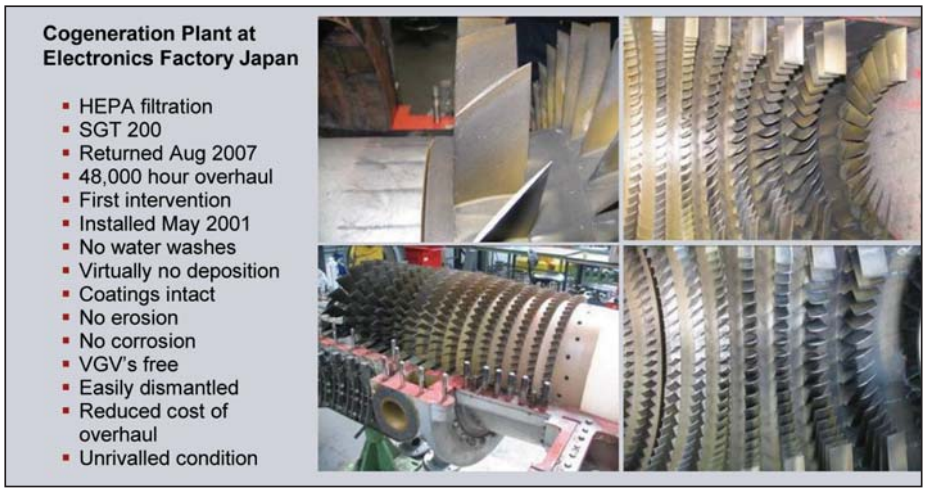

Figure 5: Siemens SGT200 after 48,000 hours of operation with HEPA filters

Filtration Efficiency	F7/F8	H12
Wash frequency – Hours	750	8000
Filter life (months)	24	12
Filter costing (Filters+Labour) / year	$10,000	$40,000
Annual Washing Cost (12 hrs off-line/event)	$29,167	$2,497
Annual Production loss (20,000 barrels oe/d @ $75 / barrel)	**$8,823,072**	**$755,400**
Total Annual Cost Impact	$8,862,239	$797,897
Net Annual benefit with H12 Filtration– per machine		**$8,064,342**

Table: AAF's case study on an oil and gas installation using H12 filters on a 25 MW gas turbine

The Japanese market has embraced HEPA filtration more than others. Mitsubishi says that it has used HEPA filters for many years, for instance at its T-point power plant. HEPA filters have completely eliminated the need for waterwash in the plant, according to Mitsubishi.

Is waterwashing needed?

HEPA filter vendors, however, say that few customers that have installed these filters are actually willing to stop online washing. They cite the following reaons:

- It is easy to continue the washing since users already have the equipment in place
- Users cannot stop for fear of losing their warranty protection from the OEM, which may not support elimination of washing
- Users fear stopping will cause them to lose insurance coverage because they have gone outside of OEM recommended practices.

"We are confident users can stop offline washes, and many of our customers have indeed stopped offline washing after installing the Gore filters," says Steve Medvetz of W. L. Gore & Associates.

ECT's Tassone says that there are contaminants, such as organic vapors and dissolved solids in the air stream, which cannot be removed by filtration alone. His verdict: "Crank washes are still required to recover lost performance due to fouling with engines that have HEPA filtration. Filtration cannot replace cleaning but it is just another tool in the arsenal to combat the effects of fouling and complement an effective maintenance program."

Many factors influence the specification of a filter system and the permutation and combination of filter stages within that system. There is no 'one solution fits all' available, says an OEM, and any selection will always have to be a compromise between conflicting demands.

HEPA filters do provide fine filtration and have been shown to reduce, if not avoid, performance degradation in many case studies, which have also demonstrated early payback. For instance, in an oil and gas facility with a HEPA filter by AAF Power & Industrial, the key requirement was to avoid shutdown to maximize production. Since HEPA filters were able to help in that, production losses were cut by on-tenth, which meant savings of over $8 million (Table).

More studies

"HEPA filters are an interesting development area, but a lot more operating experience and cost benefit analyses are needed before definitive conclusions or generalizations can be made regarding their impact on waterwashing," an observer says. "HEPA experience also needs to be recorded over a wide operating spectrum involving different gas turbine applications, plant size, with different local environments and so on." More studies and experience will help the industry standardize the benefits of HEPA filters for various site conditions with respect to waterwashing, initial pressure drop, and higher capital costs. TI