Donaldson. FILTRATION SOLUTIONS

WHITE PAPER

Three Pillars of Gas Turbine Filtration: Ranking Performance Priorities

By Michael Roesner and Jason Tiffany, Donaldson Company Inc. - Gas Turbine Systems Division

Gas turbines are designed to mix dry, clean air with fuel to produce energy. Because intake air quality is important, inlet design and air filtration are paramount in turbine performance. Based on air pollution data from the US Environmental Protection Agency, an average of approximately 1,300 pounds of particulate could enter a gas turbine housing and inlet air filter in a year of operation[1]. Airborne dirt and contaminants can cause decrease of power output, drive up fuel costs, and potentially damage vital components.

Filtration needs are largely driven by local air quality, but nearly every operator needs to evaluate three performance factors: efficiency, watertightness, and, in pulse-cleanable applications, pulse recovery rate. These can be viewed as the key filtration "pillars" that support optimal GTS operation. In most cases, all of these properties are important, but their ranking may vary depending on local environments and operating conditions. The three pillars can be summarized as follows:

Efficiency: The proportion of inlet air particulates captured by the filter is the most widely recognized performance metric. Because higher-efficiency filters have associated costs, operators need to determine an efficiency rating that delivers a return on investment.

Watertightness: In humid or ocean-front locations, resistance to moisture becomes a high priority. Salts and other dissolved solids carried by water can be highly corrosive and often more detrimental than airborne contaminants.

Pulse Recovery Rate: How readily filters regain peak performance after cleaning is a third key factor. High pulse recovery rises to top priority in desert or arctic environments, where there is either continual exposure to dust, snow, and ice buildup, or potentially sudden episodes of heavy loading.

Careful evaluation is necessary on a case-by-case basis to determine the ranking of these factors for a local situation and operating budget. Identifying priorities will enable you to incorporate the most appropriate inlet design and filter combination to be incorporated into your gas turbine system.

To assist owners in this evaluation process, Donaldson now tests and rates its gas turbine inlet filters on all three characteristics, using these abbreviations and performance scores.

- Efficiency (Er0 to Er5)
- Watertightness (W0 to W5)
- Pulse Recovery Rate (S to P5)

Introducing Donaldson's New User-Friendly Filter Rating System

Donaldson is helping gas turbine operators select filters that match their unique needs for efficiency, watertightness, and pulse recovery rate in the priority order they require. Based on our decades of experience serving gas turbine operators in all climates and conditions, we have developed a 0-5 point rating scale for each critical attribute, and now rate each of our filters on all three scales. This framework will make balancing filter characteristics both precise and simple for a wide range of operators globally.

Here is a discussion of each pillar and why it needs to be properly rated, ranked and balanced with the others to optimize system performance and operating cost:

Efficiency: Balancing Ratings with Cost

Higher filtration efficiency produces cleaner air, which supports more efficient combustion, sustained power output, and longer lasting turbines. Lower efficiency filtration introduces particles that can foul turbine components, decrease compression efficiency, and adversely affect compressor health. Figure 1 illustrates that a lower-efficiency Er2 filter allows significantly more fouling after only 1,200 hours than a high-efficiency Er5 filter after 5,000 hours.

Figure 1: Er2 at 1,200 hours vs. Er5 at 5,000 hours

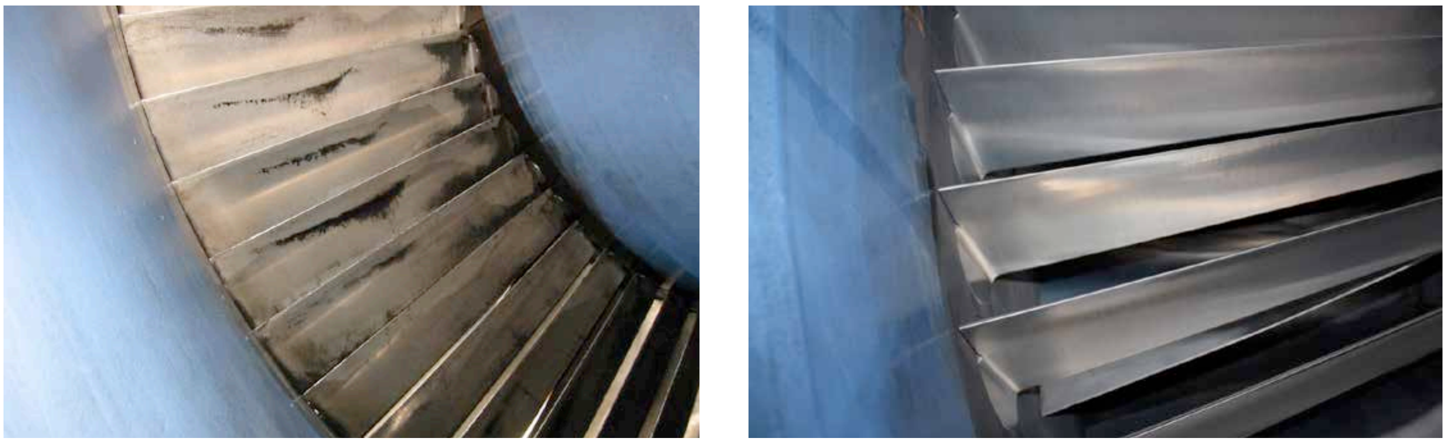

Figure 1: Inlet guide vanes (left) after 1,200 hours of lower-efficiency filtration (Er2), compared with the same inlet guide vanes (right) after 5,000 hours with higher-efficiency filtration (Er5).

Gas turbine compressor water washing can be used to regain power output due to fouling; however, an overall decrease in efficiency may occur after repeated washings. Figure 2 depicts power output and compares the trend of a gas turbine equipped with an Er3 / F-class system experiencing multiple washings with that of the same system using a high-efficiency particulate air Er5 / (H)EPA filter that did not require washings. The downward-sloped lines of the F-class filter represent typical output decreases due to fouling, followed by upward swings due to washing. After multiple washings, the output of a gas turbine equipped with an Er3 filter efficiency will likely be less than that of an Er5 filter with no washings.

An Er5 filter can reduce the need for compressor washes and maintain higher turbine efficiency. This also can help reduce “soft costs” related to maintenance and equipment downtime. With turbine availability often a key factor in evaluating the financial bottom line, operators want to diminish downtime costs whenever possible.

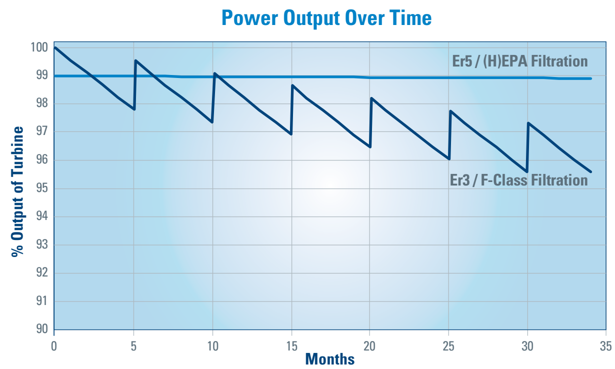

Figure 2: Typical pattern of compressor efficiency recovery after water washings (example data). Multiple compressor washes are required over time to recover efficiency and power output loss. An Er5 / (H)EPA filter maintains compressor efficiency and output without water washing.

Other factors affecting filter efficiency include airflow and pressure drop. Reductions in inlet pressure from blockages or undersized filter elements can compromise turbine output. If a filter operates at a flow rate that exceeds design specifications, the resulting pressure drop can lower system performance. Pressure drop will often increase as the filter loads. However, there are trade-offs to consider, and a balance must be achieved. Because the increased pressure drop of a higher-efficiency filter can still support long-term gains, system owners and operators should work closely with their filter supplier to determine optimal ratings and filter characteristics.

Various efficiency rating systems have been in use across the filtration industry (see sidebar "Efficiency Rating and Classification Methods"). For simplicity, Donaldson now combines the different approaches into one efficiency scale, from Er0 to Er5, as shown in figure 3.

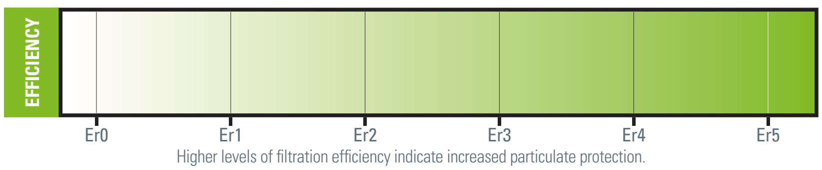

Figure 3: Higher levels of efficiency indicate increased particulate protection. This simple classification method by Donaldson integrates all major testing standards.

Efficiency Rating and Classification Methods

Filter efficiency indicates how well a filter performs by comparing the concentration of particles upstream and downstream of the filter. This removal efficiency is typically expressed as a percentage of capture. However, filtration efficiency classifications have varied.

In the United States, filters have historically been classified with a Minimum Efficiency Reporting Value (MERV) rating, which was developed by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE). MERV ratings range from 1 to 16, with a higher score indicating better performance. In Europe, two standards have been used: European Normative (EN) 779 and EN 1822. EN 779 standards include ratings of G1-G4, M5-M6, and F7-F9, which generally encompass the same range of efficiencies as MERV ratings 1-15.

The terms "efficient particulate air" (EPA) and "high-efficiency particulate air" (H)EPA are the most familiar measures regarding premium levels of filtration efficiency. According to the EN 1822 standards, (H)EPA has been defined as a minimum of 99.5 percent removal of the most penetrating particle size (MPPS). EN 1822 filters have ratings of E10-E12, generally corresponding to EPA and (H)EPA filtration levels.

More recently, a new standard, ISO 16890, has been introduced worldwide to unify how filters are tested and rated. The methodology focuses more on particulate matter (PM) classes. The ISO 16890 test protocol challenges filters with particulates in a broad range of diameter sizes, then measures average capture in three specific ranges: PM1, PM2.5, and PM10. Because of the complex nature of multiple testing standards, Donaldson has designed an efficiency tool that combines these testing standards into one, simple-to-use efficiency scale, ranging from Er0 to Er5, as shown in Figure 3.

Watertightness: Preventing Corrosion

Much like dust that escapes a less efficient filtration system, water can also impact turbine performance. Moisture that enters the airstream can introduce dissolved salts and other solids. Compounds such as iron oxides, chlorides, and other contaminants can cause corrosion over time, as shown in Figure 4. Turbine blades then may have to be sanded, repaired, and re-balanced—which operators want to avoid.

Figure 4: Water and dissolved solids can lead to corrosion of turbine blades.

Watertightness is particularly important in coastal areas, with salt-laden ocean moisture subjecting equipment to accelerated corrosion. Consequently, protection from saltwater represents a key factor affecting the life of gas turbines[2]. Gas turbine manufacturers usually recommend less than 0.01 ppm of salt enter the gas turbine. In coastal environments, airborne salt can easily range from 0.05 to 0.5 ppm on a typical day. According to data compiled by the National Atmospheric Deposition Program[3], chloride concentrations in the atmosphere along coastal areas are sometimes more than 10 times the concentrations of inland areas, as shown in Figure 5.

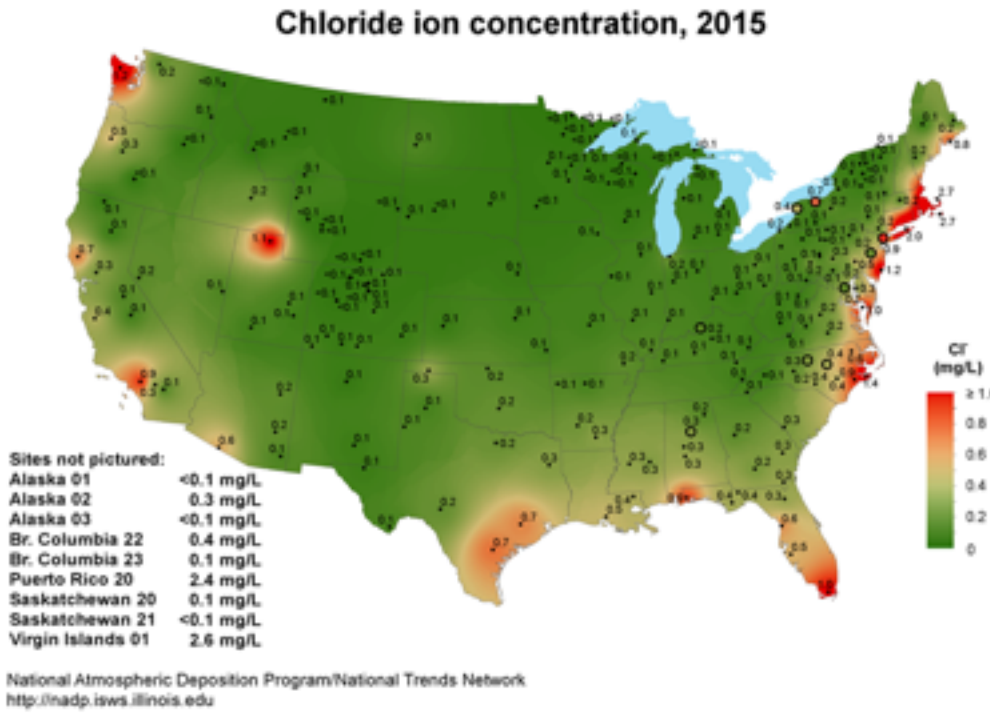

Figure 5: Chloride concentrations are generally higher in coastal areas.

Petrochemical environments also present challenges, as hydrocarbons can enter the airstream without adequate water-tightness. These products can place gummy deposits on blades and adversely affect performance.

Watertightness should be simple for an operator to evaluate. Ask your filter supplier to provide an independent laboratory test report verifying that a particular filter option is watertight and if not, how it will work under wet conditions.

Donaldson has developed a new methodology for testing filters in a controlled environment to determine how much, if any, water can pass through a filter. The test directs a 60-liter-per-hour water spray at the filter over an eight-hour period. The filter pressure drop and volume of water passing through the filter are recorded.

Based on this information, Donaldson is rating its gas turbine filters on a scale of W0 to W5, with higher values indicating greater watertightness. A filter rated at W0 would not be able to withstand any moisture, while a W5 filter could survive the test with at least 99.5 percent water stoppage and no more than a 2-inch water-gauge (WG) increase in pressure drop. A graphical display of these ratings is shown in Figure 6. Donaldson has tested and rated its most commonly used gas turbine air filters on this scale of watertightness. Figure 7 shows how higher rated filters reduce the increase in pressure drop over time.

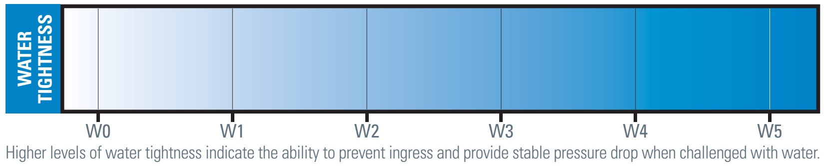

Figure 6: Higher levels of watertightness indicate the ability to prevent ingress and provide stable pressure drop when challenged with water.

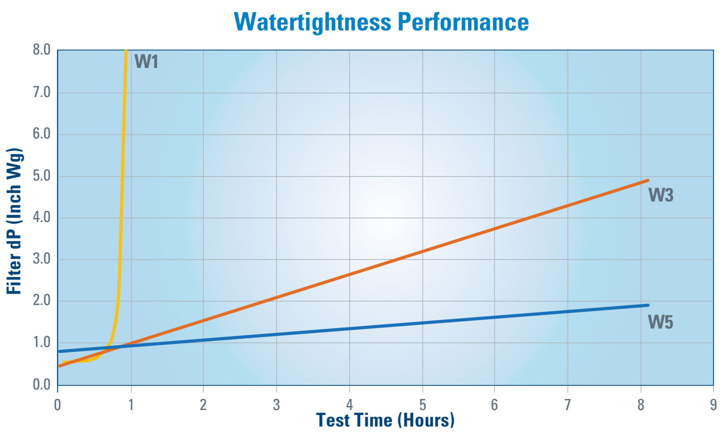

Figure 7: Filter testing indicates how pressure drop increase is reduced with higher rated filters.

Recovery Rate: Pulse Cleaning Filters Effectively

Inlet designs include both static and self-cleaning (pulse) systems. Pulse recovery rate measures how often filters can be cleaned, and how much pressure drop can be recovered each time.

In pulse-designed filter housings, filters can be cleaned by introducing compressed air "pulses" from the clean air side of the filter. This will dislodge dirt particles and debris from the upstream side of the media of a dirty filter. This practice can help reduce the cost of operation by minimizing pressure drop, lengthening the life of the filters, and preventing unscheduled shutdown due to fouling of the filters. In a pulse-cleanable system, this can be done during operation of the turbine.

The recovery rate is the rate at which the filter comes back to a "like-new" condition and stabilizes the pressure drop to allow continuous operation. The higher the pulse recovery rate, the more "cleanable" a filter is. Recovery rates in pulsed systems are largely dependent on the environment and media type in the filter: surface-loading or depth-loading. Depth-loading filters have layers that trap progressively smaller particles across the media thickness. While they retain a wide range of particle sizes, they cannot be pulse cleaned. Surface-loading filters, on the other hand, trap all particles on the top media layer, and form a slight "dust cake" that is easily removed by pulse cleaning, extending filter life.

As with efficiency and watertightness, pulse recovery can be rated using laboratory test data. Donaldson has developed a process for measuring pulse recovery. Exposing filters to a long duration of simulated sandstorm conditions, filter pressure drop and efficiency are measured to arrive at pulse recovery ratings, as shown in Figure 8. On Donaldson's scale, an S filter would be considered unable to be pulse-cleaned without damage, while the remainder of the P ratings indicate the level of pulse recovery. There are a variety of performance factors with static (S) filters and Donaldson is currently developing an independent rating system for these applications.

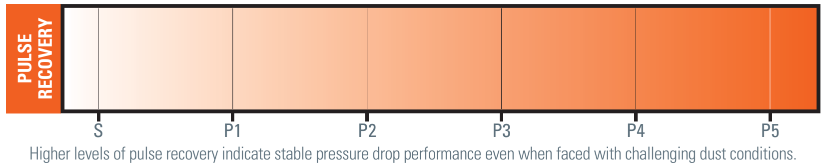

Figure 8: Higher levels of pulse recovery indicate stable pressure-drop performance under challenging dust conditions.

If your filter housing does not have a pulse system, static filtration solutions are most appropriate. A typical static solution utilizes depth-loading filter media and focuses on maximizing filter life by balancing pressure drop and dust holding capacity.

However, the advantages of a pulsable filter system can be illustrated with a simplified example. If 10 grams of particles per day were captured by a filter, in 100 days, a total of 1,000 grams would be captured. The buildup of particles would also result in a pressure drop increase in the system. If the pressure drop were deemed to be approaching allowable limits, the filter would either need to be replaced or cleaned. A surface-loading filter could be cleaned during operation, while a depth-loading filter would need to be replaced.

Pulsable systems are often most valuable in areas with significant dust, snow, and potential ice build-up. In these conditions, the longevity benefits of the filtration system can far outweigh the additional cost of a pulse cleaning system. In areas less prone to dust, snow, and ice, pulsable systems may not be as cost-effective.

There are considerable advantages to operating a pulse-cleaned system. Much like an automobile windshield wiper, pulse-cleaning may be mainly a contingency for adverse weather events. But when a demand occurs, and a power interruption could be unwanted, the value of pulse-cleaning becomes clear. A fully functional system – including elements compatible with pulse-cleaning – can provide operators with a system that can continue to run while pulse cleaned. If you inherited an existing system with pulse-cleaning, in most cases the advantages of maintaining and equipping it with a pulsing-compatible filter outweigh the costs of an unplanned outage.

The relationship of recovery rate and pressure drop can be seen in Figure 9. This graph illustrates how long three filtration systems with various pulse recovery rates maintained acceptable filter pressure drop over time in a simulated dust-challenged environment. Generally, filters with higher recovery rates maintained lower pressure drops for longer durations.

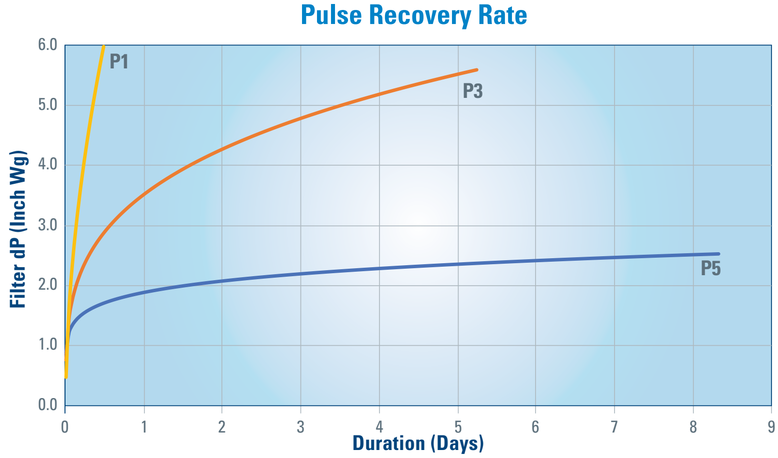

Figure 9: Filters with higher pulse recovery rates generally maintain lower pressure drops for longer durations.

Operation of pulse-cleaning systems also needs proper consideration. Systems are generally operated by one of three methods: 1) manual; 2) automated based on pressure drop; or 3) automated based on time intervals. Regardless of whether manual or automated methods are used, cleaning needs to occur before fouling reaches a problematic state. For example, if a cleaning is not triggered by an appropriate time interval, fouling can reach the point of causing significant operational problems. As with any operation and maintenance function, neglect increases the risk of failure.

In some instances, the pulse system will only be needed to prevent fouling. In periods of ice, snow, extreme frosting, and sandstorms, the pulse system can actually keep the turbine running by using the pulse system as a preventive measure.

Summary: Evaluate Your Needs

Environmental conditions largely drive decisions on inlet system design and filters. The three pillars—efficiency, watertightness, and pulse recovery rate—typically do not stand alone, but require an integrated approach. Identifying the ideal balance and combination for your gas turbine should factor in potential downtime costs and long-term return on investment (ROI).

In evaluating ROI, numerous factors can impact filtration costs. Each operator's scenario needs to be evaluated, as not everyone's ROI will be the same. For example, in evaluating filtration efficiency, a higher efficiency rating cannot always be justified. Only if increased output offsets the cost of a slightly increased pressure drop can a financial ROI be realized. Lower efficiency can sometimes actually be more cost-effective in the long run. Similarly, watertightness might outweigh efficiency in coastal areas, but not in arid locations, where exposure to corrosive ocean air is unlikely.

Every situation is different, and thorough review of operator needs is necessary to identify the optimum filter design. Economic impacts, not just technical factors need to be considered for each plant. The bottom line is to evaluate which factors are most important to meet the operator's needs.

Integrating the Three Pillars: A Case Example

As an example of how efficiency, watertightness, and pulse recovery consideration should be integrated in filter selection, consider a peaking plant in a coastal environment. Because the plant only operates for short durations, a high-efficiency filter may be difficult to justify economically. The payback for the additional cost of high-efficiency filters would likely be much longer than for that of a continuously running plant. Because the plant is in a coastal area, watertightness may be important, but pulse recovery may be less critical if dust exposure is minimal. A filter with Er4, W5, and P1 ratings in efficiency, watertightness, and pulse recovery, respectively, might serve the needs of such a situation, as shown in Figure 10.

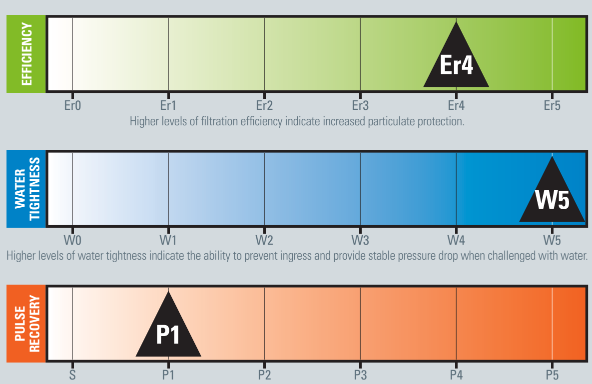

Figure 10: A filter with Er4, W5, and P1 ratings in efficiency, water tightness, and pulse recovery, respectively, might serve the needs of a coastal peaking plant.

-end-

About Donaldson

Founded in 1915, Donaldson Company (NYSE: DCI) is a global leader in the filtration industry, with approximately 140 sales, manufacturing, and distribution locations in 44 countries. Donaldson's innovative filtration technologies improve people's lives, enhance customers' equipment performance and protect the environment. For more information, visit www.Donaldson.com.

About the authors

- Mike Roesner is the Sales Manager for the Gas Turbine Systems group at Donaldson Company, Inc.
- Jason Tiffany is the Product Development Team Lead for the Gas Turbine Systems group at Donaldson Company, Inc.

References:

1. "How to Select the Optimal Inlet Air Filters for Your Engine," Combined Cycle Journal, Sept. 26, 2017. http://www.ccj-online.com/how-to-select-the-optimal-inlet-air-filters-for-your-engine/
2. "Technology Review of Modern Gas Turbine Inlet Filtration Systems," International Journal of Rotating Machinery, Volume 2012 (2012). http://dx.doi.org/10.1155/2012/128134
3. National Atmospheric Deposition Program/National Trends Network. http://nadp.slh.wisc.edu/maplib/pdf/2015/Cl_conc_2015.pdf

Donaldson Company, Inc.
Gas Turbine Systems
P.O. Box 1299
Minneapolis, MN 55440-1299 U.S.A.
donaldson.com

North & South America
800-431-0555
filterinfo@donaldson.com

Europe, Mid-East, & Africa
+32-16-38-3940
GTS-europe@donaldson.com

Asia Pacific
86-21-23137027
gtssales.apac@donaldson.com

Donaldson.
FILTRATION SOLUTIONS

GAS TURBINE SYSTEMS