

Just as the power output of your gas turbine can vary based on air temperature and cleanliness, the performance of an inlet air filter can also vary. Variables such as airflow, concentrations and types of ambient contaminants, relative humidity, and other factors can impact a filter's performance. Today there are a number of combustion turbine (CT) inlet air filter manufacturers/suppliers offering filters. When considering inlet filter options how do you know what to look for? How do you know what is good and what may not be so good? What information do you need to make the right decision? The information contained in this paper will increase your understanding of important variables and key filter performance data including ASHRAE 52.2 test reports. This information will guide you in making well educated decisions regarding the inlet air filtration for your CT.

COMMON INFORMATION AVAILABLE

When marketing CT inlet air filters manufacturers provide a wide range of information for you to evaluate and compare. Following are several types of information commonly provided.

1. Filter media type: The material make up of the filter media. Cellulose (paper), cellulose & synthetic blend, fully synthetic, spunbond, nano-fibers (Donaldson's Spider-Web[®]), membrane (ePTFE), glass, melt blown, etc. Different media types will have different filtration performance and life characteristics in different types of environments and applications.

2. Media area: The square feet of media contained in a filter. The media area in a filter MAY provide an indication of filter performance (restriction, life expectancy, dust holding capacity, etc.).

3. Filter element dimensions & liner/cap materials: The dimensions of the filter element and the material make up of the liners & end caps.

4. Restriction/resistance to airflow (ΔP): This is the measure of resistance across a filter at a specific air flow. Restriction will vary based on airflow and based on the amount of and type of contaminant loaded on the filter. For the North American market restriction is commonly measured in inches of water gauge (WG). Generally speaking, the lower the restriction the better.

5. Particle removal (filtration) efficiency: Based on the ASHRAE 52.2 standard the filtration efficiency is the measure of particles of a specific size removed by an air filter at a specific airflow and at various intervals of dust loading. The ASHRAE 52.2 test determines the filter's minimum efficiency rating value (MERV). In most cases a filter's minimum efficiency is the initial (new & clean) efficiency. Generally speaking, the higher the filtration efficiency the better. However, higher efficiency filters may have higher restriction than lower efficiency filters, which can impact filter life and CT output. It is important to understand this relationship and how a particular filter may perform in your specific application.

6. Dust holding capacity: Many filter suppliers provide a value for dust holding capacity. This value is generally understood to be the Dust Fed to Final Resistance in an ASHRAE 52.2 test. The industry standard pre-determined final resistance for CT inlet filtration is 4.00" WG. Important note: Using a dust other than ASHRAE test dust can alter dust holding capacity values by a factor of 4 or more depending on the type of dust used.

7. Filter life: The useful life of an air filter is based on two primary factors: 1.) level of restriction and 2.) degradation of the filter/filter components. As the restriction across an air filter rises in a CT application

the fuel efficiency of the CT will go down resulting in less power output per unit of fuel. As a result when a filter reaches a certain level of restriction it must be replaced to recover fuel efficiency/power output. In some applications air filters may begin to degrade before they reach a level of restriction that requires replacement. Operating a CT with filters that exhibit degradation may be a risk of dirty air bypass and

possibly foreign object damage (FOD). Gaskets, liners, and filter media are the key components of the air filter that should be closely monitored for degradation.

8. Other: In most applications there are additional factors that should be considered when selecting inlet filters. These factors will be discussed in more detail later in this paper.

UNDERSTAND YOUR APPLICATION

Understanding your specific application is critical. An air filter will perform differently at different airflows and in different configurations. The configuration of the inlet system and the amount of airflow that an air filter is subjected to can have a major impact on its performance.

Gas Turbine Inlet Configuration Examples:

7FA Gas Turbine that has an inlet air flow of 772,000 CFM. Note: Airflow may vary depending on vintage of CT.

1. Donaldson TTD (self-cleaning) inlet system that has a total of 1,296 cylindrical filter elements that are mounted vertically. Airflow per filter element equals 595 CFM.
2. Donaldson GDx (self-cleaning) inlet system that has a total of 528 conical cylindrical filter element pair that are mounted horizontally. Airflow per filter pair equals 1,462 CFM.
3. Donaldson GDS (static) inlet system that has a total of 480 conical cylindrical filter element pairs that are mounted horizontally. Airflow per filter pair equals 1,608 CFM.

P191280 26" Cylindrical Filter Element		P191280 & P191281 26" Conical & 26" Cylindrical Pair		P191280 & P191281 26" Conical & 26" Cylindrical Pair	
Duratek™ Spider-Web® Filter Media		Duratek™ Spider-Web® Filter Media		Duratek™ Spider-Web® Filter Media	
Airflow: 630 CFM		Airflow: 1,462 CFM		Airflow: 1,630 CFM	
Media Type:	Blended w/ Nano Fiber	Media Type:	Blended w/ Nano Fiber	Media Type:	Blended w/ Nano Fiber
Media Area:	226 ft²	Media Area:	494 ft²	Media Area:	494 ft²
Initial Restriction:	0.69	Initial Restriction:	0.85	Initial Restriction:	1.00
Initial Efficiency (per ASHRAE 52.2)	MERV 13	Initial Efficiency (per ASHRAE 52.2)	MERV 13	Initial Efficiency (per ASHRAE 52.2)	MERV 13
Dust Holding Capacity:	1,390 grams	Dust Holding Capacity:	2,758 grams	Dust Holding Capacity:	2,700 grams

These performance data tables illustrate how the performance of a filter media varies in different configurations and at different airflows.

1. Brand X 2-Stage static inlet system with 504 panel filters (24" X 24" X 12" WAVE™ panel filters). Airflow per filter equals 1,532 CFM.
2. Brand X 2-Stage static inlet system with 320 panel filters (24" X 24" X 12" WAVE™ panel filters). Airflow per filter equals 2,413 CFM.
3. Brand X 2-Stage static inlet system with 320 panel filters (24" X 24" X 17" WAVE™ panel filters). Airflow per filter equals 2,413 CFM.

P039204 WAVE™ Panel Filter - 12" depth		P039204 WAVE™ Panel Filter - 12" depth		P039203 WAVE™ Panel Filter - 17" depth	
Synthetic Spider-Web® Filter Media		Synthetic Spider-Web® Filter Media		Synthetic Spider-Web® Filter Media	
Airflow: 1,968 CFM		Airflow: 2,520 CFM		Airflow: 2,520 CFM	
Media Type:	Fully Synthetic w/Nano Fiber	Media Type:	Fully Synthetic w/Nano Fiber	Media Type:	Fully Synthetic w/Nano Fiber
Media Area:	215 ft²	Media Area:	215 ft²	Media Area:	308 ft²
Initial Restriction:	0.34	Initial Restriction:	0.66	Initial Restriction:	0.37
Initial Efficiency (per ASHRAE 52.2)	MERV 14	Initial Efficiency (per ASHRAE 52.2)	MERV 14	Initial Efficiency (per ASHRAE 52.2)	MERV 14
Dust Holding Capacity:	465 grams	Dust Holding Capacity:	185 grams	Dust Holding Capacity:	833 grams

These performance data tables illustrate how the performance of a filter media varies in different configurations and at different airflows.

UNDERSTANDING OTHER FACTORS THAT CAN IMPACT FILTER PERFORMANCE AND LIFE

Location/ambient environment:

1. Relative Humidity (RH) & Liquid Water (Fog & Rain): Increasing levels of RH and liquid water have an increasingly negative effect on an air filter’s performance as the dust load of that air filter increases. The moisture in conjunction with the dust load will increase the restriction across the filter. In addition the water can convert some contaminants into a liquid form and assist them in migrating downstream of the filter media (i.e. salt).

2. Snow & Frost: When directly exposed to an air filter, snow and frost can blind over the filter media causing a rapid increase in restriction.

3. Hydrocarbons: Hydrocarbons and oil mists can significantly decrease the life of particular types of filters as they tend to blind over certain types of media.

4. Dust Concentration: The level of ambient dust concentrations should be considered when selecting a filter. Some air filters that might be sufficient in a mild atmosphere may not meet performance expectations in an aggressive atmosphere.

5. Environmental Changes: Many sites will experience changes in environmental conditions. It is very important to understand all environmental factors that may impact your filter’s performance. Examples of environmental changes could be seasonal contaminants such as cotton wood seed, bugs, smoke, or other factors including those listed previously. The important point here is to recognize these changes and make sure your filter selection and/or maintenance plan is appropriate for your environment.

Your ambient environment conditions should be considered when selecting a filter. The performance of various filter media types may be largely impacted by the environment. A cellulose or blended filter media

may perform great in a dry environment and very poorly in a wet environment. It is recommended that you gather as much information as you can from your filter suppliers to make sure you understand what filter options are available for the various types of ambient environments.

Usage conditions (load):

Another factor you may want to consider when selecting an air filter is your CT operating load. The amount of hours that your CT is in operation could have an impact on your air filter selection.

Operating loads can be defined by the following:

1. Base Load - >6,500 hours
2. Intermediate – 3,000 – 6,500 hours
3. Peaker - <3,000 hours

ASHRAE 52.2 TEST STANDARD

The ASHRAE 52.2 standard is an internationally recognized standard, authored by the American Society of Heating, Refrigeration and Air-Conditioning Engineers. This standard provides a basis for comparison of different air filters’ performances by end users, suppliers and OE’s by determining an air filter’s resistance to airflow and ability to remove contaminant from the air stream.

The ASHRAE 52.2 standard states what equipment needs to be in place to test an air filter, such as the basic components shown in Figure (1). The test duct and equipment need to be calibrated per the procedure called out in the standard. Once this equipment is in place the proper testing of an air filter can be accomplished.

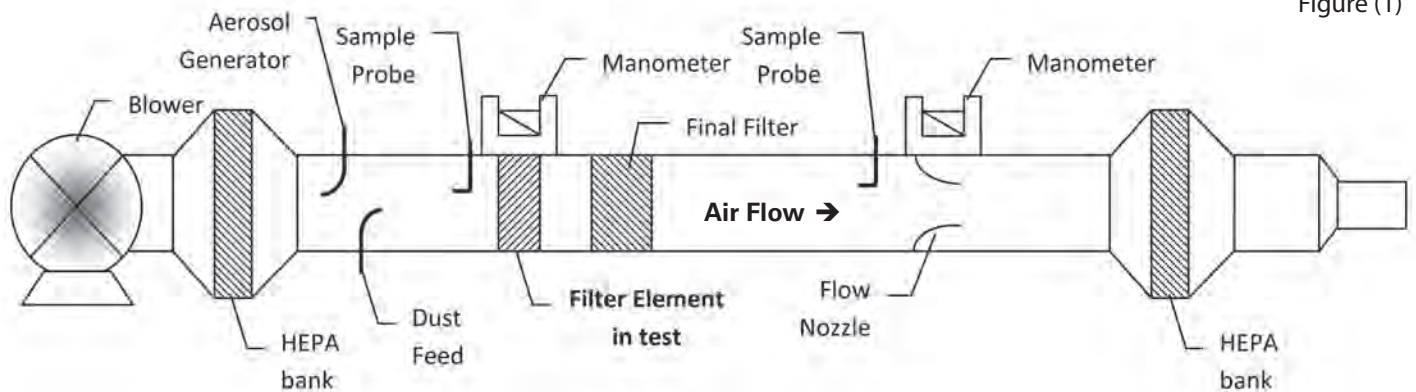


Figure (1)

Resistance to Airflow:

The ASHRAE 52.2 test first determines the resistance to airflow of a clean air filter at 25%, 50%, 75%, 100% and 125% of a filter’s test airflow rate specified by the filter supplier.

% of Test Airflow	Airflow (CFM)	Resistance (in WG)
0%	0	0
25%	366	0.11
50%	731	0.27
75%	1097	0.51
100%	1462	0.85
125%	1828	1.27

Particle size removal efficiency (PSE):

The clean air filter is then tested for its dust removal efficiency by taking measurements upstream and downstream of the air filter as the challenge aerosol, made up of dry potassium chloride (KCl), is fed into the airstream within the duct. From this, particle size removal efficiency (PSE) measurements are taken for the 12 size ranges of dust particles called out in the standard. The air filter is then incrementally loaded with dust and PSE measurements against the challenge aerosol are taken along the way. The test dust, or loading dust, is dictated by the ASHRAE 52.2 standard to be made up of combination of SAE Standard J726 test dust (fine), carbon black and milled cotton linters. Throughout the duration of the PSE testing the airflow is constant at 100% of the specified test airflow rate.

Points at which PSE measurements are taken:

1. **Initial:** Clean filter prior to introducing any ASHRAE test dust into the air stream.
2. **Load 1:** Approximately 30 grams of ASHRAE test dust is fed into the airstream or an increase of 0.04" WG resistance across the filter in test is reached, whichever happens first.
3. **Load 2:** Initial resistance (IR) plus 25% of the difference between pre-determined final resistance (4.00" WG) of the filter in test and initial resistance.
*Calculation: IR + (25% * (4.00" - IR)) = Load 2.*
4. **Load 3:** Initial resistance (IR) plus 50% of the difference between pre-determined final resistance (4.00" WG) of the filter in test and initial resistance.
5. **Load 4:** Initial resistance (IR) plus 75% of the difference between pre-determined final resistance (4.00" WG) of the filter in test and initial resistance.
6. **Load 5:** When pre-determined final resistance is reached (4.00" WG).

Six PSE curves are then plotted and used to determine a composite minimum efficiency curve by plotting

the minimum PSE in each of the 12 size ranges from these curves. The 12 size ranges are then broken down into three size range groups and the 4 minimum PSE's in each size range are averaged to determine the average minimum PSE's (E1, E2, and E3). The average minimum PSE values are then used to determine the air filter's Minimum Efficiency Reporting Value or MERV rating, based off of the rating system that is contained within the ASHRAE 52.2 standard. A filter's MERV rating is generally based on the initial efficiency as that is when the efficiency is the lowest (minimum).

Group	#	Size Range
E ₁	1	0.30 - 0.40 µm
	2	0.40 - 0.55 µm
	3	0.55 - 0.70 µm
	4	0.70 - 1.00 µm
E ₂	5	1.00 - 1.30 µm
	6	1.30 - 1.60 µm
	7	1.60 - 2.20 µm
	8	2.20 - 3.00 µm
E ₃	9	3.00 - 4.00 µm
	10	4.00 - 5.50 µm
	11	5.50 - 7.00 µm
	12	7.00 - 10.00 µm

MERV: Minimum Efficiency Reporting Values

Group	MERV Rating	(E1) Composite Avg. Particle Size Efficiency (PSE) 0.3 - 1.0 Microns	(E2) Composite Avg. Particle Size Efficiency (PSE) 1.0 - 3.0 Microns	(E3) Composite Avg. Particle Size Efficiency (PSE) 3.0 - 10.0 Microns	Average Arrestance by ASHRAE 52.1 Method
1	MERV 1	---	---	Less than 20%	< 65%
	MERV 2	---	---	Less than 20%	65% - 69.9%
	MERV 3	---	---	Less than 20%	70% - 74.9%
	MERV 4	---	---	Less than 20%	≥ 75%
2	MERV 5	---	---	20% - 34.9%	---
	MERV 6	---	---	35% - 49.9%	---
	MERV 7	---	---	50% - 69.9%	---
	MERV 8	---	---	70% - 84.9%	---
3	MERV 9	---	Less than 50%	≥ 85%	---
	MERV 10	---	50% - 64.9%	≥ 85%	---
	MERV 11	---	65% - 79.9%	≥ 85%	---
	MERV 12	---	80% - 89.9%	≥ 90%	---
4	MERV 13	Less than 75%	≥ 90%	≥ 90%	---
	MERV 14	75% - 84.9%	≥ 90%	≥ 90%	---
	MERV 15	85% - 94.9%	≥ 90%	≥ 90%	---
	MERV 16	≥ 95%	≥ 95%	≥ 95%	---

ASHRAE 52.2 EXAMPLES

Refer to the ASHRAE 52.2 test report for P191280 & P191281 at the end of this paper.

ANALYZING TECHNICAL DATA - ASHRAE 52.2 TEST DATA & MANUFACTURER SPEC SHEETS

When making a comparison of one filter to another it is critical that the data being analyzed was captured under the same parameters and that those parameters are relevant to your application.

Data from a filter supplier's specification sheet may be misleading as often times there is a lot of data presented from various sources, filter configurations, and airflow rates. These specification sheets should be reviewed cautiously and the data within them must be backed by a third party ASHRAE 52.2 test report.

Things to watch for:

- Technical data without an ASHRAE 52.2 test report for validation:

Often times filter suppliers communicate technical data such as restriction, filtration efficiency, and dust holding capacity on product specification sheets. It is very important to understand the airflow at which restriction was measured; the point at which filtration efficiency measures were taken; and the test dust that was used to determine dust holding capacity.

1. Airflow: All performance data provided should be at or above the airflow in your specific application. Performance data provided below the airflow of your inlet system is not relevant to your application as the filter will not achieve the stated performance at higher airflows.

2. Partical Removal (Filtration) Efficiency: It is important to verify the minimum or "Initial" efficiency of the air filter. Watch for terms such as "Operational" efficiency and beware of inconsistencies between stated MERV ratings and particle removal efficiency tables that illustrate much higher levels of efficiency. Some filter suppliers today promote efficiency levels after dust loading, which can be much different than minimum or initial values.

3. Dust Holding Capacity: ASHRAE 52.2 test reports will provide a value for the Dust Fed to Final Resistance of the test. This is also known as Dust Holding Capacity and commonly marketed on filter specification sheets. Major variations from one filter to another could mean different dusts were used in the ASHRAE test. ASHRAE dust is prescribed in the standard, but there are some suppliers that have substituted ISO fine dust which may show a dust holding capacity of more than 4 times that of ASHRAE dust.

The best way to validate performance claims is to request an ASHRAE 52.2 test report from an independent, qualified third party test laboratory. Most reputable filter manufacturers/suppliers will be able to provide this information.

- Electrostatic charged filters:

Some manufactures use electrostatic charge as a filtration mechanism to boost initial efficiency. It is important to understand if this is the case for the filters being considered. You may want to request test data for that same element after the charge has been neutralized to understand the "worst case" scenario in the event that the electrostatic charge is lost after the element has been installed in your inlet system. An electrostatic charge on a filter may impact the initial efficiency by 2 – 3 MERV ratings.

ANALYZING OTHER DATA

It is also important that other information about the filter and your specific application be considered, i.e. is your inlet system self-cleaning or static? Fellow users that have similar applications and operating conditions may have very useful real world data to share. What type of filters do they use? How long did they last? What type of power output and maintenance data is available, etc.? It is always a good idea to balance test data with relevant real world data if available.

CONCLUSION

In summary, when considering replacement filters, remember these things:

1. Understand your application - specifically, the air filter configuration and airflow per filter/filter pair in your inlet system.
2. Understand your environment and usage conditions. What levels of precipitation and relative humidity do you deal with? What is your operating load? These factors may influence your decision to select one filter over another.
3. Demand a relevant ASHRAE 52.2 test report from an independent, qualified third party test laboratory for all filters being considered. Verify that the data provided by each supplier is relevant to your inlet system, and compare various restrictions & efficiencies. Ask your suppliers questions based on the information provided in this paper.
4. Solicit filter and turbine performance data from your fellow 7FA users.

Following these basic guidelines will help ensure the proper evaluation of inlet filtration options which will likely save you considerable time, headaches and money.

SOURCES:

ASHRAE Standard – Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size. ANSI/ASHRAE Standard 52.2-2007.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

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