THE VALUE RATING FOR
GAS TURBINE FILTERS

THE VALUE RATING

THE EASIEST WAY TO SELECT THE BEST FILTERS FOR YOUR GAS TURBINES

Clean air solutions for turbomachinery

IN THIS PAPER:

ABBREVIATIONS

dP: **Pressure drop**
ePM: **Particulate matter efficiency**
ISO: **International Standards Organization**
MPPS: **Most penetrating particle size**

UNITS

MJ: Megajoule
MW: Megawatt
MWh: Megawatt-hours
TWh: Terrawatt-hours
m^3 / h: Cubic meters per hour

PURPOSE

In a market full of choices, it's imperative a product's strengths and weaknesses are easy to see. It's become commonplace for industries to provide you the specialized tools you need to make an informed decision. Air filters for gas turbines are no different. The Value Rating system aims to address this, providing you simple metrics to determine the best air filtration solution.

Filtration standards today revolve around how efficiently a filter can stop air particulates from reaching the turbine. For gas turbines, while filter efficiency is important, it does not show the whole picture. While an E10 may be better at stopping particles than an F9, how does it effect turbine performance? The pressure drop caused by an air filter limits a turbine's ability to do useful work, but by how much? The Value Rating converts an air filter's performance into real-world impact, so you can decide what's best for your operation.

Air filters will impact gas turbine performance by two main mechanisms: fouling and pressure drop.

Fouling is the accumulation of fine particles (<2µm) on air compressor blades. The build up of dirt changes the air profile of the blades, resulting in an overall lower compressor efficiency. High efficiency filters using fine fibres are required to stop the large amounts of particulates in order to minimize fouling.

Any grade of filtration adds resistance to the inlet airflow, quantified as **pressure drop**. The more particulates that get collected over time, the higher the pressure drop rises. This effects both the available power output and the heat rate of the gas turbine. Therefore, while the air might be cleaner, a higher efficiency filter has the adverse effect of limiting the useful work a turbine can perform.

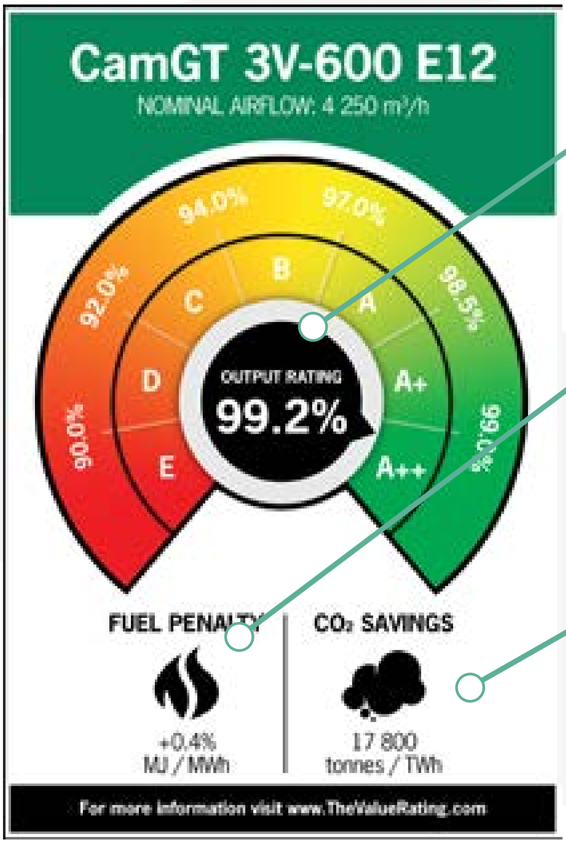
The Value Rating aims to compute information useful to real-world gas turbine operation. Fouling and pressure drop impact the fuel consumption and power output of a gas turbine. Combining them allows us to predict how a gas turbine will perform. The amount of fuel consumed directly impacts how much CO_2 is emitted. In a time where carbon footprint is a major concern also this is a valuable metric to predict.

The Value Rating aims at facilitating the selection of final filter based on the relative impact a filters' efficiency, dust loading behaviour, and pressure drop have on the gas turbine.

One should always keep in mind additional requirements for filter selection related to the environmental conditions in which the gas turbine operates. For example, hydrophobic properties are extremely important offshore to prevent corrosion due to salts, whereas pulse performance might impact operational pressure significantly in an area prone to dust storms.

As international standards evolve on these topics, so will The Value Rating.

INTRODUCING THE VALUE RATING



1 **OUTPUT RATING:** How does your final filter impact your average power output compared to a clean engine?

2 **FUEL PENALTY:** How does your filter impact your fuel consumption per MWh due to inefficiencies?

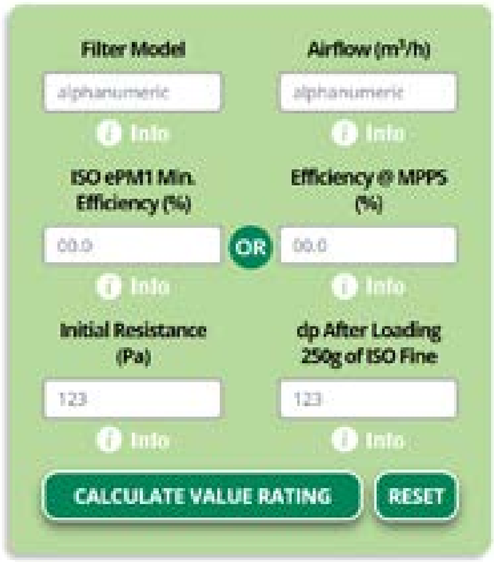
3 **CO_2 SAVINGS:** How much would your final filter help reduce your carbon emissions when compared to a low grade benchmark M6 filter?

THE VALUE RATING CALCULATOR

To introduce The Value Rating system to the industry, Camfil has created a publicly available tool to calculate The Value Rating of any gas turbine air inlet filter.

Try it out here:

www.TheValueRating.com



HOW IT WORKS

The Value Rating takes a filter's operating efficiency and pressure drop, and yields the combined effect of fouling and pressure drop on turbine performance.

The pressure drop at 250g ISO A2 fine dust indicates the performance after being dust-loaded. When compared to the "clean" initial pressure drop, we can predict the average performance from clean to dirty.

The filter's efficiency is taken after discharge. Initially, filters are electrostatically charged which helps collect small particulates, but this benefit is short lived. This value is used to predict how much fouling an engine would encounter. Fouling causes a reduced power output and an increased heat rate, lowering the output rating and increasing the fuel consumption respectively.

The Value Rating inputs create a semblance of the air filter's true performance, not just the values that look best. As a result, the predictions approximate the real-world impact air filters have on gas turbine power output and fuel consumption.

Carbon emissions is rapidly becoming a deciding factor of an energy source's viability in the future. Since the inlet air filters will impact how much fuel is consumed, it will also determine if additional CO_2 is emitted. Selecting the right air filter allows you to minimize this, protecting the environment and your bottom line.

CALCULATOR INPUTS

ISO ePM_1 Minimum Efficiency

The ePM_1 minimum efficiency is the percentage of all incoming particles smaller than 1μm that are caught by the filter, by weight, when the filter has no electrostatic charge.

dP @ 250g ISO (A2) Fine

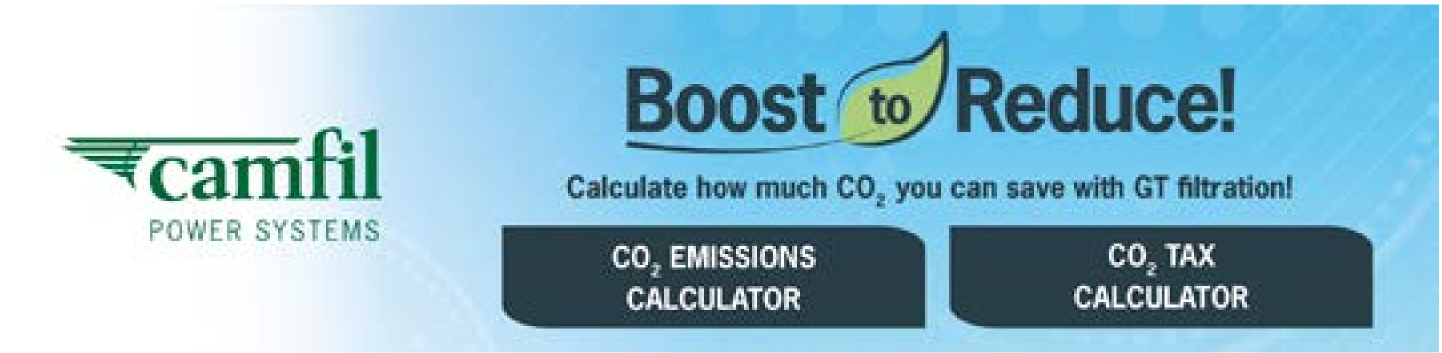
This value corresponds to the filter's pressure drop after stopping 250g of fine dust, the average amount of dust a filter will encounter in one year.

Efficiency at MPPS

The filter's efficiency at the most penetrating particle size (MPPS), usually between 0.1 - 0.2 μm.

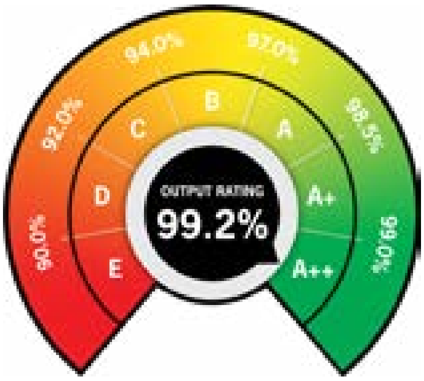
Clean dP

Also known as the "initial dP," where dP is pressure drop at the beginning of the filter's life.



OUTPUT RATING GRADES

The letter grades assigned to filters help demonstrate the relative performance of one filter to another: it's evident that an A+ is preferable to a D grade. That is why the grade ranges vary, to maintain a distribution of filters to maintain their distinction. Only a small amount of filters are currently able to achieve an A++. The grading scheme will update over time as air filtration science evolves.



2020 VERSION

Rating	Minimum	Maximum
E	00.0%	90.0%
D	90.0%	92.0%
C	92.0%	94.0%
B	94.0%	97.0%
A	97.0%	98.5%
A+	98.5%	99.0%
A++	99.0%	100.0%

INTERPRETING RESULTS*

	CamGT 4V-300 E11	**CamGT 3V-440 E11**	**CamGT 4V-300 E12**
Output Rating	A+ (98.8%)	A++ (99.0%)	A+ (98.9%)
Fuel Penalty	0.5% MJ / MWh	0.5% MJ / MWh	0.4% MJ / MWh
CO_2 Savings	17 200 tonnes / TWh	17 300 tonnes / TWh	17 500 tonnes / TWh

COMPARISON INSIGHTS

- Two filters of the same efficiency class, E11, do not have the same impact on engine performance.
- The CamGT 4V-300 E12 is outperformed by the CamGT 3V-440 E11 in terms of power output, despite being a higher filter class.
- The CamGT 3V-440 E11 has the best output rating, but this does not automatically translate to the best fuel penalty or CO_2 savings.
- Filter efficiency effects output and fuel differently: that is why the CamGT 3V-440 E11 is better for those seeking to maximize power output, while the CamGT 4V-300 E12 is superior for sustainability. The Value Rating calculates the total impact of pressure drop and fouling together, so you can choose what to prioritize.

* *It is important to make sure your filtration solution meets the needs of your environmental conditions. Environmental conditions are not yet accounted for in The Value Rating system.*

ECONOMIC SAVINGS

Equipped with the output rating, fuel penalty, and CO_2 savings, you can perform your own in-house estimate on economic value. Here is a walkthrough on how to calculate how much you will save, comparing a basic F9 filter to a CamGT 3V-440 E10 over the course of one year.

	Typical F9	CamGT 3V-440 E10
Output Rating	C (93.8%)	A+ (98.7%)
Fuel Penalty	3.1% MJ / MWh	0.6% MJ / MWh
CO_2 Savings	6 800 tonnes / TWh	16 900 tonnes / TWh

Power Output:

The F9 filter imposes a significant drop in power output, losing 4.9% more power than the CamGT filter. That's a 4.9% reduction in revenue. To calculate just how drastic this can be, let's look at a 125MW turbine operating 8 000 h / year:

(98.7% - 93.8%) x 125MW x 8 000 h/year = 49 000 MWh/year

A gas turbine equipped with CamGT 3V-440 E10 final filters will produce 49 000 MWh more power than a typical F9 filter. Find out how much more annual revenue is generated by multiplying the price of 1 MWh of energy:

49 000 MWh x 35 $/MWh = 1 715 000 $/year

Fuel Savings:

The fouling and pressure drop imposed by the filter results in a lower compressor efficiency, ultimately consuming more fuel per MWh produced. The F9 filter will impose 2.5% more fuel to be consumed than the CamGT filter. Assuming a heat rate of 8 000 MJ / MWh, the total amount of fuel consumed in a year by the clean turbine would be:

125 MW x 8 000 h/year x 8 000 MJ /MWh = 8 000 000 GJ/year

The typical F9 filter will result in a total of 8 000 000 GJ more fuel consumed annually. Multiply this by the cost of natural gas:

(3.1% - 0.6%) x 8 000 000 GJ/year x 3.65 $/GJ = 730 000 $/year

Carbon Savings:

In addition to environmental protection, as carbon taxes become more common, the amount of CO_2 emitted becomes an important factor in economic savings. Instead of an expensive gas turbine upgrade, a better air filter can reduce the amount of CO_2 emitted.

16 900 - 6 800 = 10 100 tonnes CO_2 / TWh

In the case of a 125 MW turbine operating for 8 000 hours annually, 1 TWh is generated. Therefore, the CamGT 3V-440 E10 will emit 10 100 fewer tonnes of CO_2 annually. A 35 $/tonne CO_2 tax, as proposed by the United States Energy Information Administration, would result in a difference of[1]:

35 $/tonne x 10 100 tonnes = 353 500 $/year

THE FUTURE AHEAD

The Value Rating system aims to meet the needs of turbomachinery operators, providing an accurate and easy way to understand the impact of air filtration on gas turbine performance. The Value Rating aspires to be adopted widespread, and offers the free online calculator to use on any filter to achieve that. The system needs input from voices from all corners of the air filtration industry to excel.

The Value Rating system will continue to evolve. ISO29461 is a standard that is currently developing, which will later be tied into The Value Rating system, enabling hydrophobicity, pulsing performance to be accounted for. As filtration technology advances, this grading scheme, too, will be updated to continue to help distinguish between filters.

ASSUMPTIONS

- The engine operates at ISO conditions
- The heat rate is 8 000 MJ / MWh
- The site is located in an industrial, non-coastal area
- The filter is installed on a clean engine
- The input data is collected at the same airflow as the operation

Assumptions for CO_2 savings' calculations

- Low sulfur natural gas is being combusted, emitting 0.05 kg CO_2 per MJ energy
- A negligible amount of CO is released by the engine

If you have any questions, please

Contact Us

REFERENCES

[1] U. Schirmeister and F. Mohr, "Impact of Enhanced GT Air Filtration on Power Output and Compressor Efficiency Degradation," in Volume 3: Coal, Biomass and Alternative Fuels; Cycle Innovations; Electric Power; Industrial and Cogeneration; Organic Rankine Cycle Power Systems, Seoul, South Korea, Jun. 2016, p. V003T08A003, doi: 10.1115/GT2016-56292.

[2] U.S. Energy Information Administration, "Carbon Dioxide Emissions Coefficients," Feb. 2016. Accessed: Jul. 17, 2020. [Online]. Available: https://www.eia.gov/environment/emissions/co2_vol_mass.php.

[3] U.S. Energy Information Administration, "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2020," U.S. Department of Energy, AEO2020, Feb. 2020. Accessed: Jul. 17, 2020. [Online]. Available: http://www.eia.gov.

[4] U.S. Energy Information Administration (last), "Natural Gas Annual 2018," U.S. Department of Energy, Washington, DC 20585, Jan. 2019. Accessed: Jul. 17, 2020. [Online]. Available: http://www.eia.gov.

[5] C. B. Meher-Homji, M. Chaker, and A. F. Bromley, "The Fouling of Axial Flow Compressors: Causes, Effects, Susceptibility, and Sensitivity," in Volume 4: Cycle Innovations; Industrial and Cogeneration; Manufacturing Materials and Metallurgy; Marine, Orlando, Florida, USA, Jan. 2009, pp. 571–590, doi: 10.1115/GT2009-59239.

POWERED BY CAMFIL

Camfil – a global leader in air filters and clean air solutions

For more than half a century, Camfil has been helping people breathe cleaner air. As a leading manufacturer of premium clean air solutions, we provide commercial and industrial systems for air filtration and air pollution control that improve worker and equipment productivity, minimize energy use, and benefit human health and the environment. We firmly believe that the best solutions for our customers are the best solutions for our planet, too. That's why every step of the way – from design to delivery and across the product life cycle – we consider the impact of what we do on people and on the world around us. Through a fresh approach to problem-solving, innovative design, precise process control and a strong customer focus we aim to conserve more, use less and find better ways – so we can all breathe easier.

The Camfil Group is headquartered in Stockholm, Sweden, and has 30 manufacturing sites, six R&D centres, local sales offices in 30 countries, and 4,800 employees and growing. We proudly serve and support customers in a wide variety of industries and in communities across the world. To discover how Camfil can help you to protect people, processes and the environment, visit us at www.camfil.com.