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THE EFFECT OF AIR FILTRATION ON GAS TURBINE PERFORMANCE DEGRADATION – ISO 16890 AND ITS APPLICATION TO REAL ENGINE DATA

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Motivation

Publication of ASME GT2016-56292 “Gas turbine power degradation as a function of air filter classes” based on real engine data.

ISO 16890

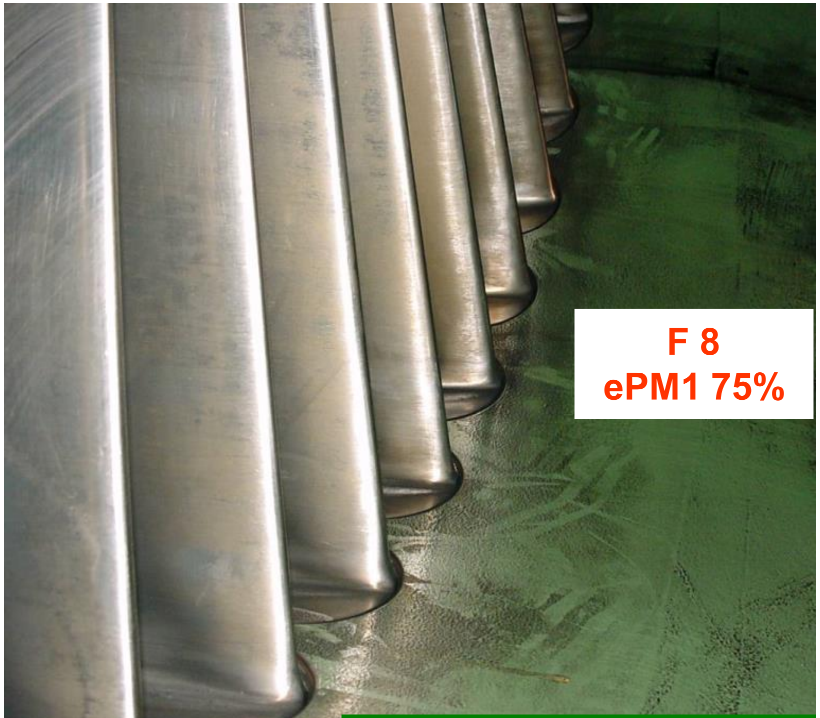
New air filter test standard ISO 16890 is rating air filters based on separation efficiencies for dust fractions PM1, PM2.5 and PM10.

Can we find a correlation between the amount of dust in the combustion air after the filter system and the power loss of a gas turbine?

e.FFECT
electronic Freudenberg Filter Efficiency Calculation Tool

The software e.FFECT calculates clean air dust concentrations based on PM2.5 and PM10 and filter efficiencies

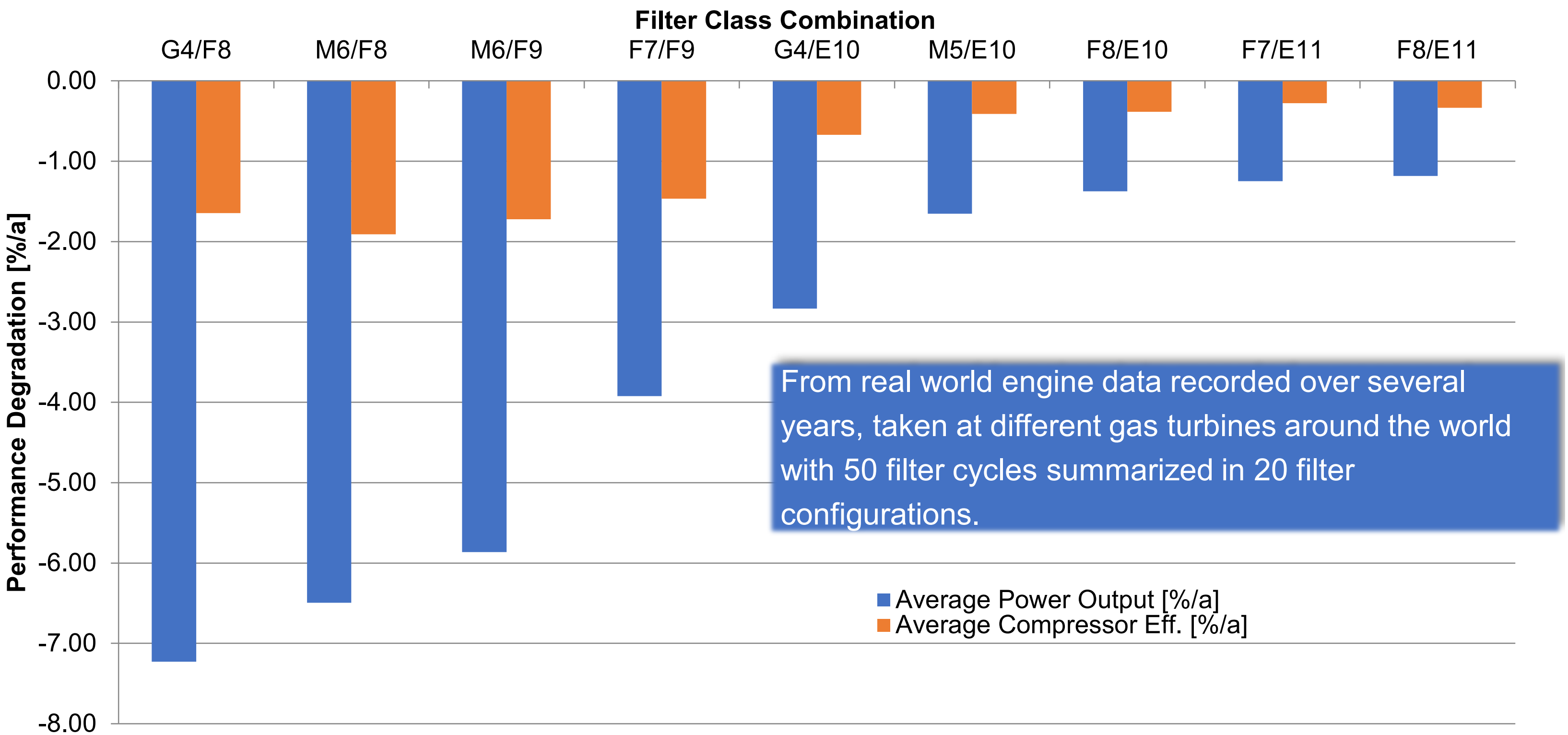
Better Filtration Reduces Fouling on Turbine Blades



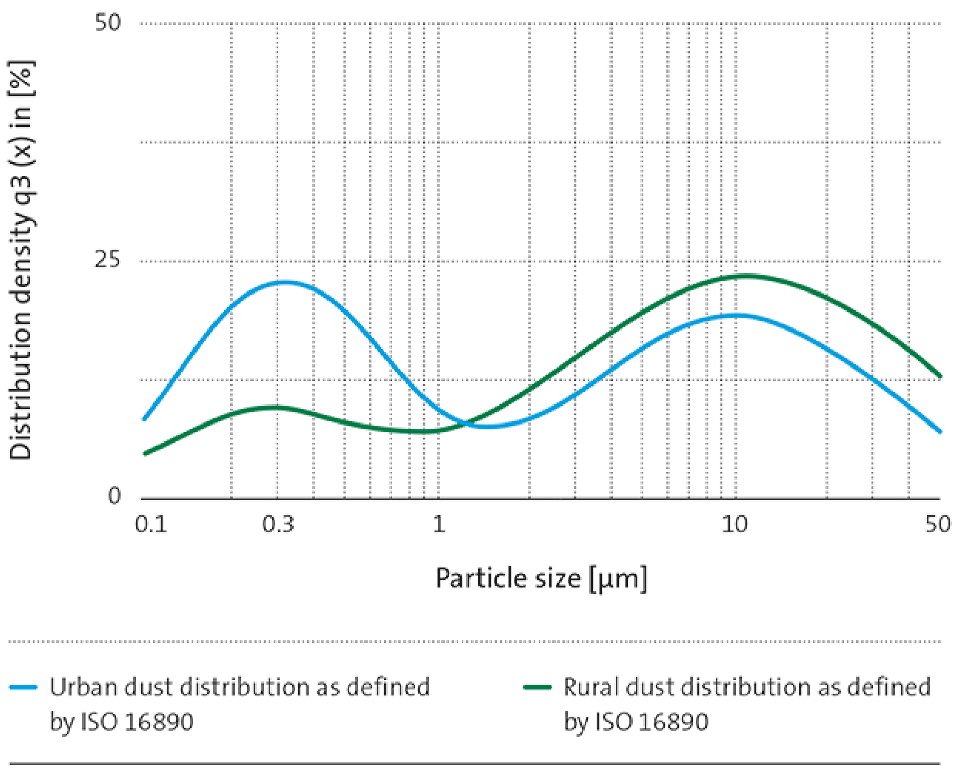
2 months with F8 fine filters after last off-line

After 4 months with E11 filters without off-line

Higher Filtration Results in Less Degradation
[Source: ASME GT2016-56292]



Typical Particle Mass Distribution Density for Urban and Rural Environments [Used in ISO 16890]



Air Filter Rating according to ISO 16890

KEY DATA		eMaxx-98	eMaxx-E10	eMaxx-E11
Nominal volume flow rate	m^3/h	4,250	4,250	3,400
Initial pressure drop	Pa	135	195	170
Class to ISO 16890		ISO ePM1 80%	ISO ePM1 > 95%	ISO ePM1 > 95%
Particulate matter efficiency ISO ePM1 ISO ePM2,5 ISO ePM10	%	 83 87 95	 97 98 99	 98 99 > 99

Simplified explanation of PM fractions (PM = Particulate Matter):

- PM10 is the mass concentration of all airborne particles smaller than 10 µm
- PM2.5 is the mass concentration of all airborne particles smaller than 2.5 µm
- PM1 is the mass concentration of all airborne particles smaller than 1 µm

Dimension of PMx is $\mu g/m^3$

Typical Mass Concentrations of PM2.5 and PM10 Dust at Differently Characterized Locations

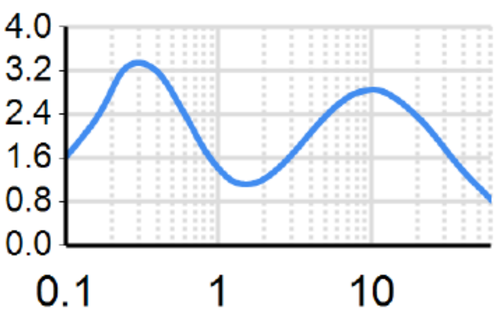
REGION	RESIDENTIAL AREAS	COUNTRY AREAS	LIGHT-INDUSTRY AND URBAN AREAS	HEAVY-INDUSTRY AREAS	URBAN HIGHLY POLLUTED AREAS	COASTAL REGIONS AND OFFSHORE	DESERT AREAS	ARCTIC AREAS	TROPICAL AREAS
Ann. average PM10 [µg/m³]	20 – 25	10 – 20	25 – 30	25 – 50	> 50	10 – 30	10 – 5,000	10 – 30	10 – 50
Ann. average PM2,5 [µg/m³]	10 – 15	5 – 10	15 – 30	15 – 40	> 30	5 – 20	10 – 1,000	5 – 20	5 – 30

Sources for data:

- European Environment Agency (EEA) http://www.eea.europa.eu/themes/air/interactive/pm10-interpolated-maps
- World Health Organization (WHO) http://www.who.int/phe/health_topics/outdoorair/databases/cities/en
- Environmental Protection Agency (USA) https://www.epa.gov/outdoor-air-quality-data/interactive-map-air-quality-monitors
- Own measurements of dust fractions

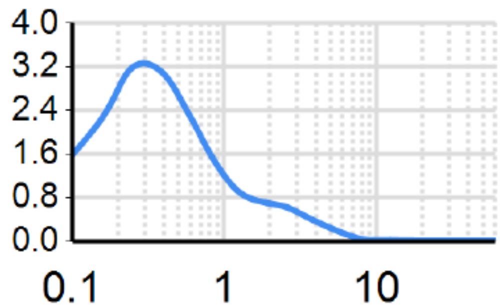
Calculation for Multi-Stage Filtration Systems
[Based on ISO 16890-1 Methodology]

Dust distribution in ambient air



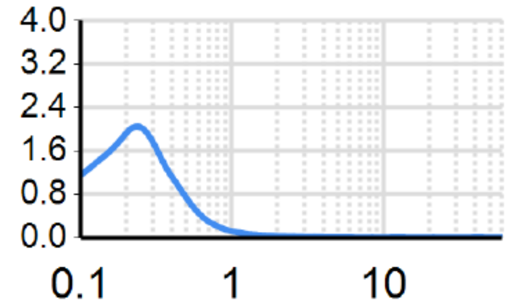
Particle size [µm]

Dust distribution after 1st filter



Particle size [µm]

Dust distribution after 2nd filter



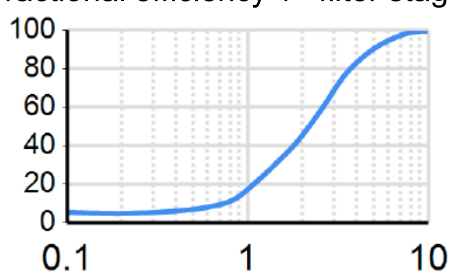
Particle size [µm]

34.4 µg/m³

16.2 µg/m³

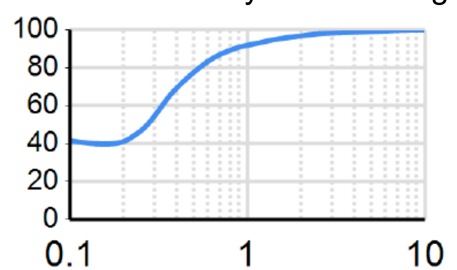
5.6 µg/m³

Fractional efficiency 1st filter stage



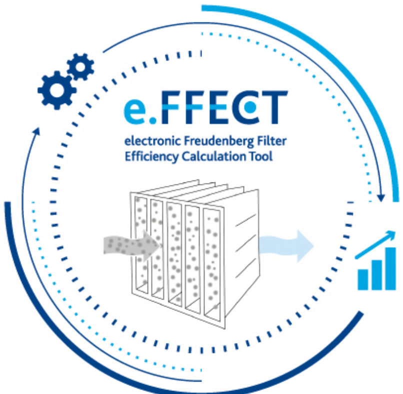
Particle size [µm]

Fractional efficiency 2nd filter stage



Particle size [µm]

e.FFECT Software for Calculating the Clean Gas Concentration by Using Ambient Air Data



Machine type:	F-Class Turbine
Flow rate:	1,800,000 m³/h
Yearly operating hours:	6,000 h/year
Dust characteristics:	Urban (according ISO 16890)
Input dust concentration:	25.0 µg/m³ PM10

Input dust concentration: 25.0 µg/m³ PM10

Total dust concentration: 34.4 µg/m³

Filter Stage 1:

480 T 60 1/1
3750 m³/h per filter

Filter Stage 2:

480 MX 95
3750 m³/h per filter

Filter Stage 3:

480 eMaxx E11
3750 m³/h per filter

SUMMARY OF SYSTEM PERFORMANCE

Total dust collected:	370.
*Total efficiency:	99.6
Total PM10 efficiency:	99.8
Total PM2.5 efficiency:	99.7%
Total PM1 efficiency:	99.5%

Clean gas concentration: 0.15 µg/m³

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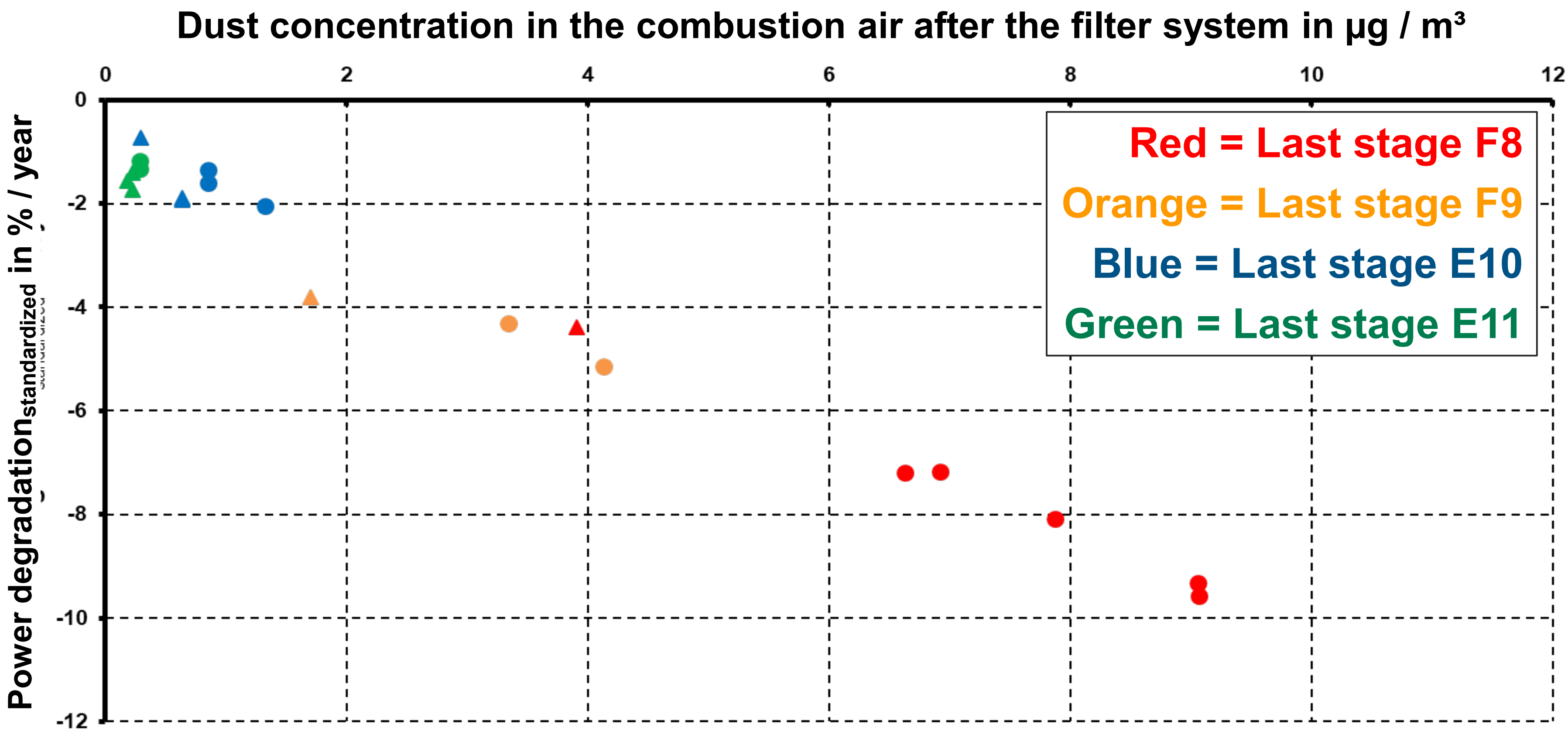
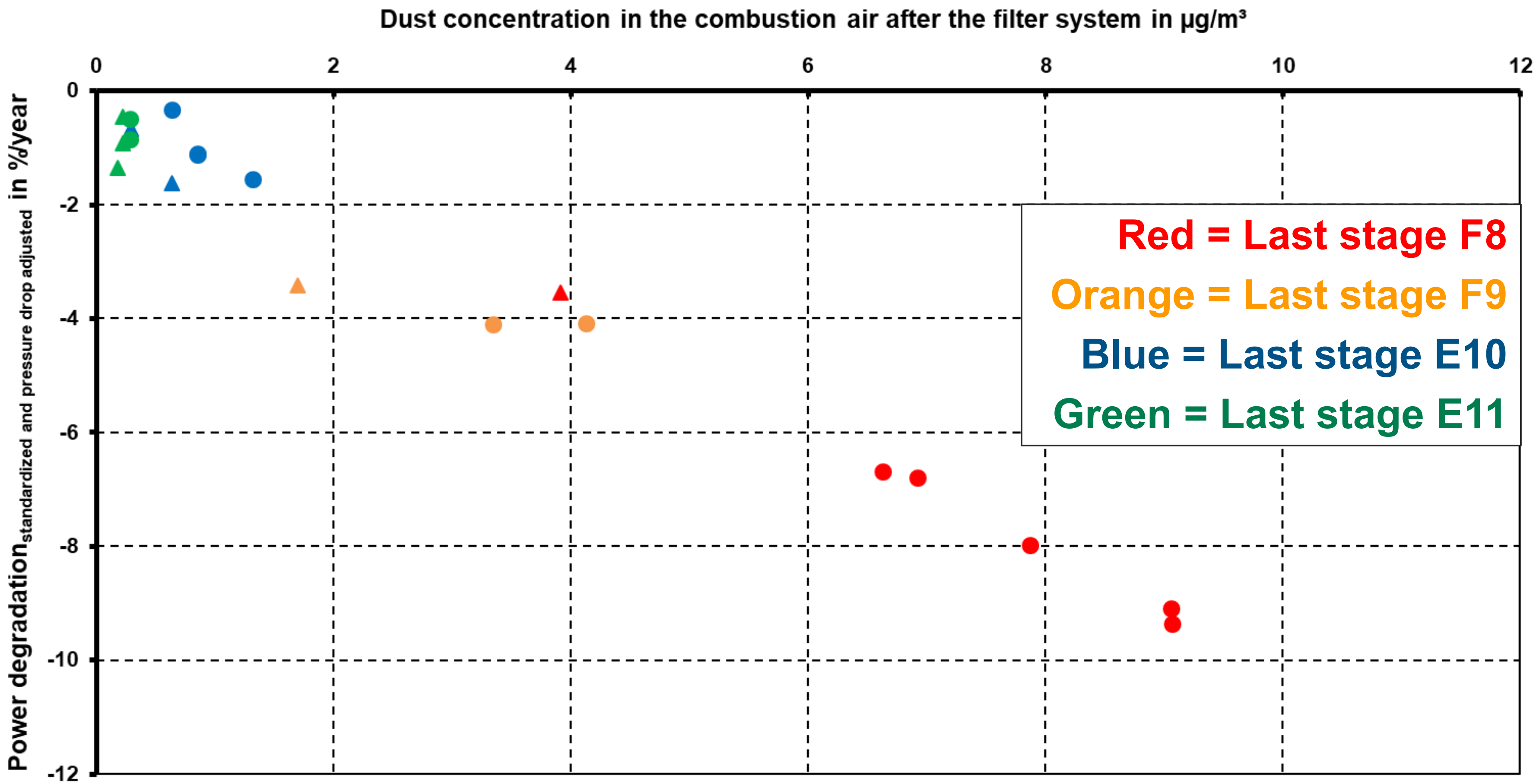
Power Degradation as a Function of Dust Ingress Taken from Real Engine Data of Heavy Duty Gas Turbines



Power Degradation as a Function of Dust Ingress / Adjusted by Pressure Drop of Filters



Conclusions

- The survey of real gas turbine data showed a good correlation between the mass concentration of dust in the combustion air after the filtration system and the annual power degradation.
  ➔ It is possible to quantify the benefits of enhanced filtration by calculating the resulting higher power output of a gas turbine.

- The amount of dust after the filter system can be calculated with the methodology of ISO 16890 based on ambient air data from an individual site by using the software e.FFECT.

- The power loss of a gas turbine is governed by the separation efficiency of the filter system while the pressure drop of the filters plays a subordinate role even for higher efficiency classes and multi-stage systems.