EUROPEAN
TURBINE
NETWORK

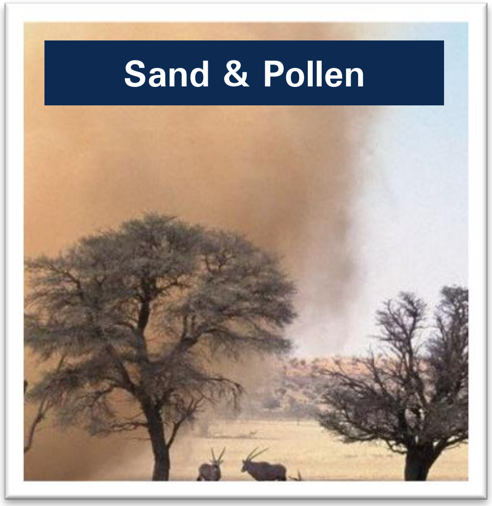
Filtration Workshop

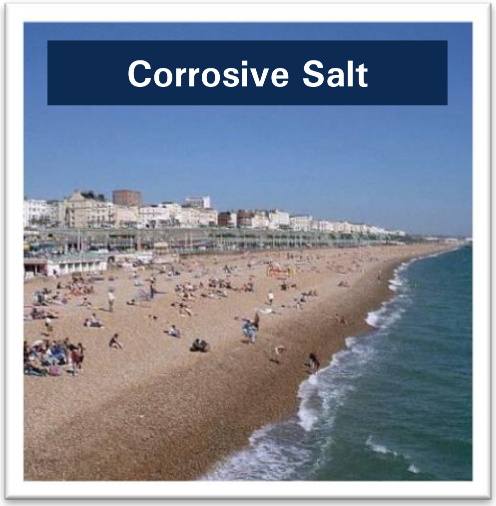
What do we want to achieve?

- **Understand why filtration is needed**
- Understand what is filtration
- What standards are available
- A closer look to EN779 and EN1822
- Understand your actual application
- Capex and opex considerations

Why filtration for turbomachinery

Operating environments





Why filtration for turbomachinery

Air is the working fluid

Consumed air volume

- Soccer field of 234m high
- Contains sand, pollen, hydrocarbons...
- Examples:
  - Urban = 15 µg/m³ =>0,025 kg/h
  - Coastal = 25 µg/m³ => 0,040 kg/h
  - Desert = 120 µg/m³ => 0,200 kg/h

Why filtration for turbomachinery

Erosion (particles > 5-10µm)

Fouling (particles < 5µm)

Corrosion (pitting)

- Wet corrosion, hot corrosion

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What is filtration?

Is a filter a strainer?

No, it is not!

A Very Simple Word…

Everybody knows the meaning of this word

For A Very Complex Discipline…

(Too) Many parameters for the known equations affecting this phenomenon

What is filtration?

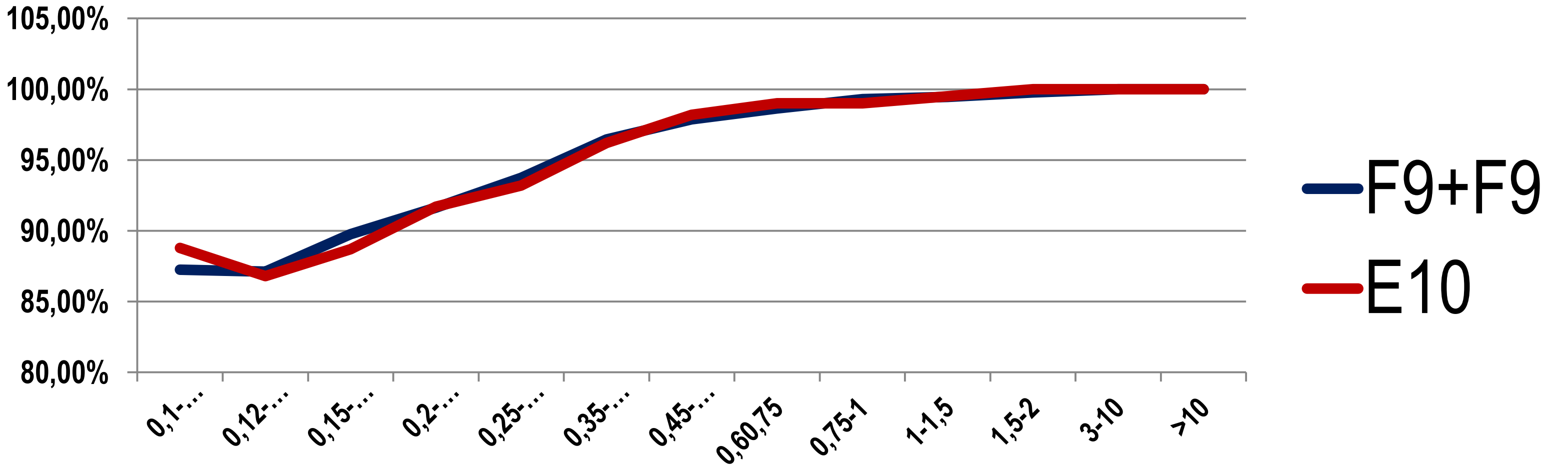
Filtration is **%**

75%x50% = 37,5% penetration

50%x50% = 25% penetration

75%x10% = 7,5% penetration

10%x10% = 1% penetration

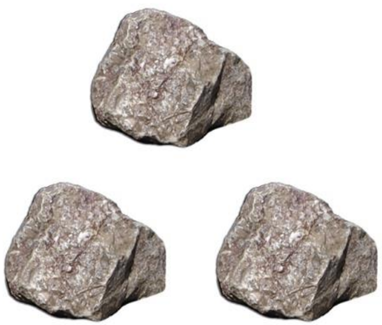


Particulate efficiency vs Arrestance

Arrestance = Mass efficiency

Mass: 81,4%

1pcs = 100g
1pcs = 62,5%
1pcs = 3%

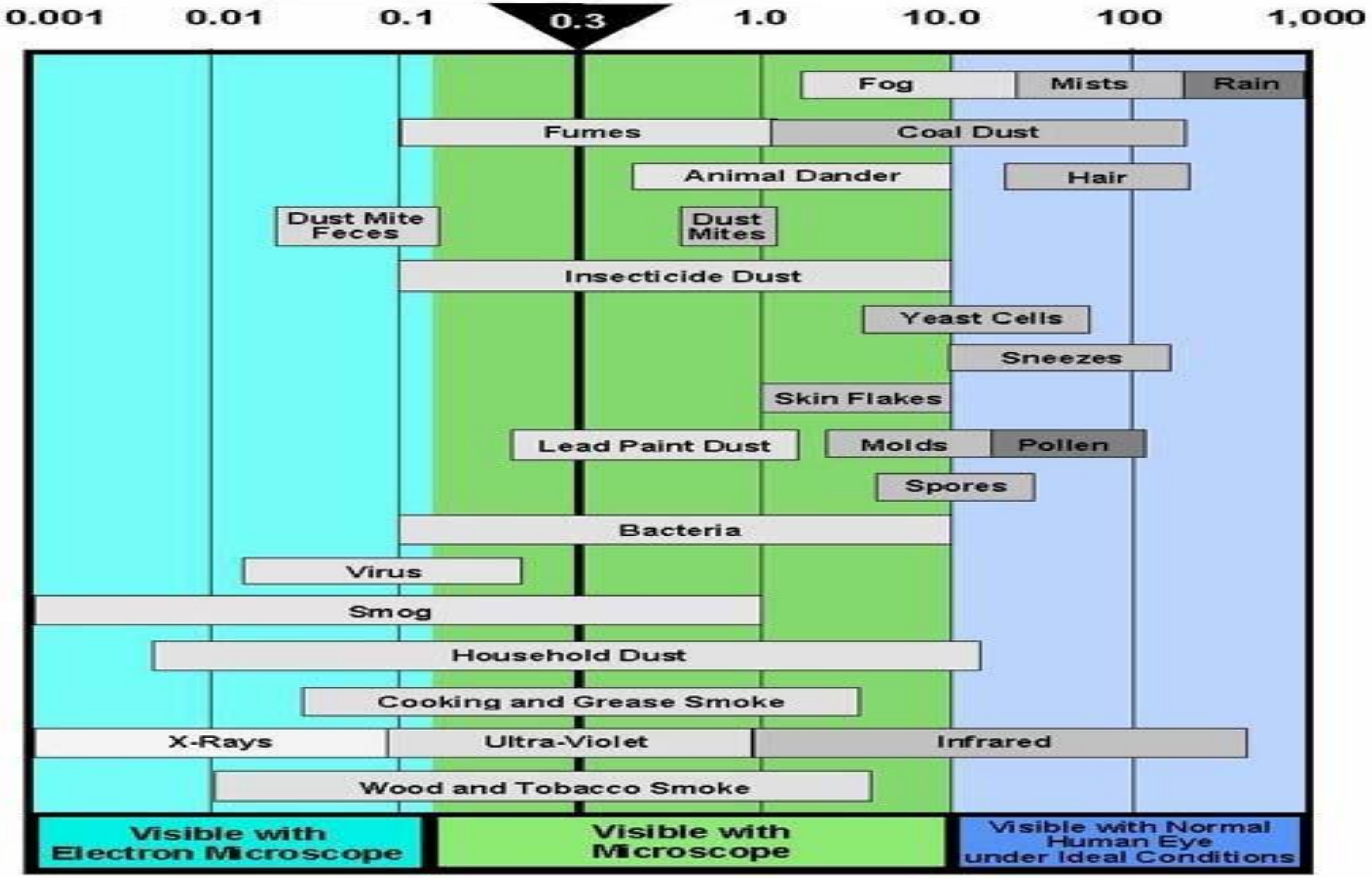


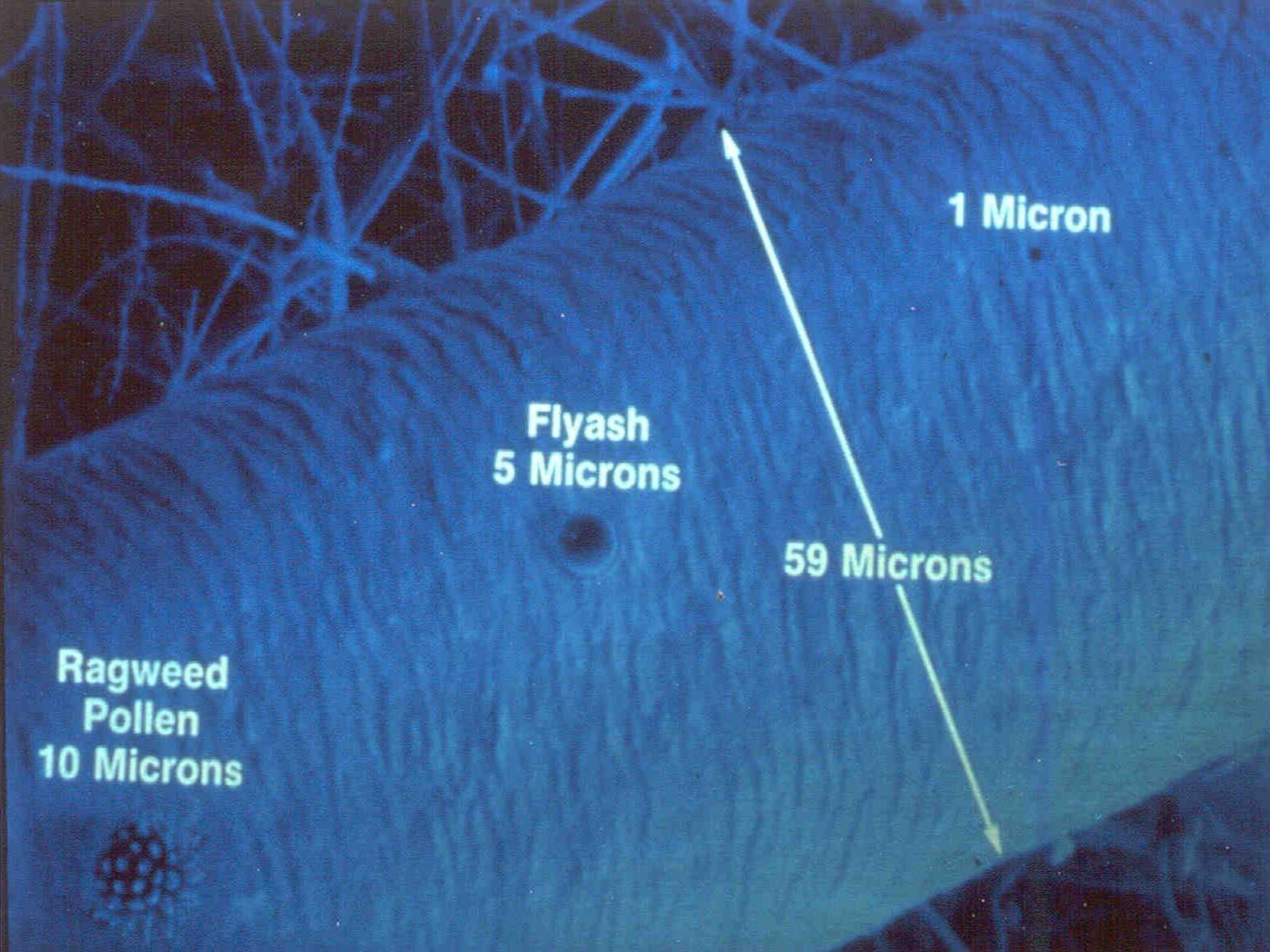
1pcs = 10g
1pcs = 6,3%
1pcs = 3%

1pcs = 1g
1pcs = 0,6%
1pcs = 3%

What is filtration

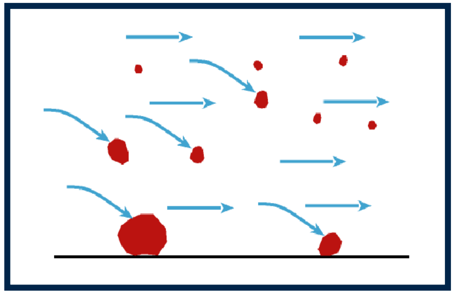
Filtration – Particle Size Comparison



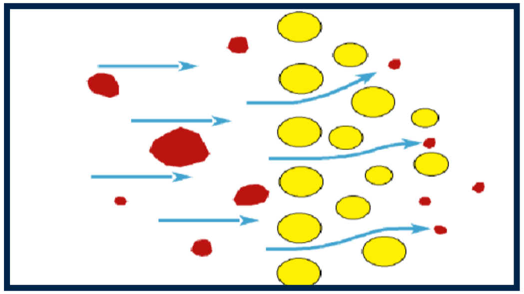

1 Micron
Flyash
5 Microns
59 Microns
Ragweed
Pollen
10 Microns

What is filtration

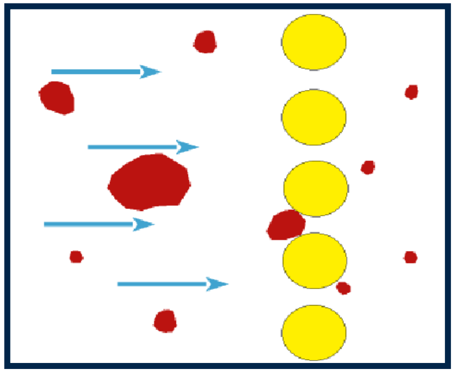
Sedimentation



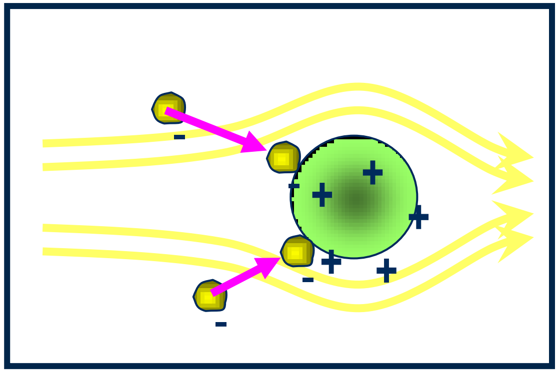
Inertial effects



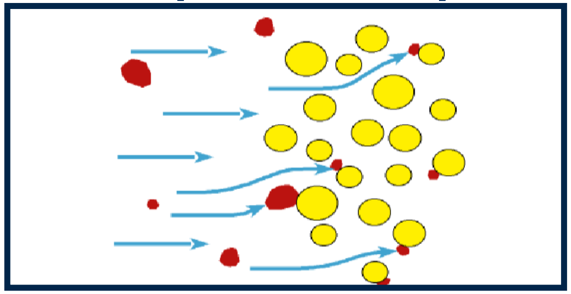
Straining



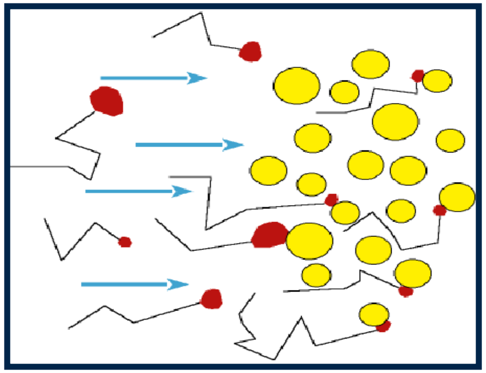
Electrostatic charge



Interception/adsorption



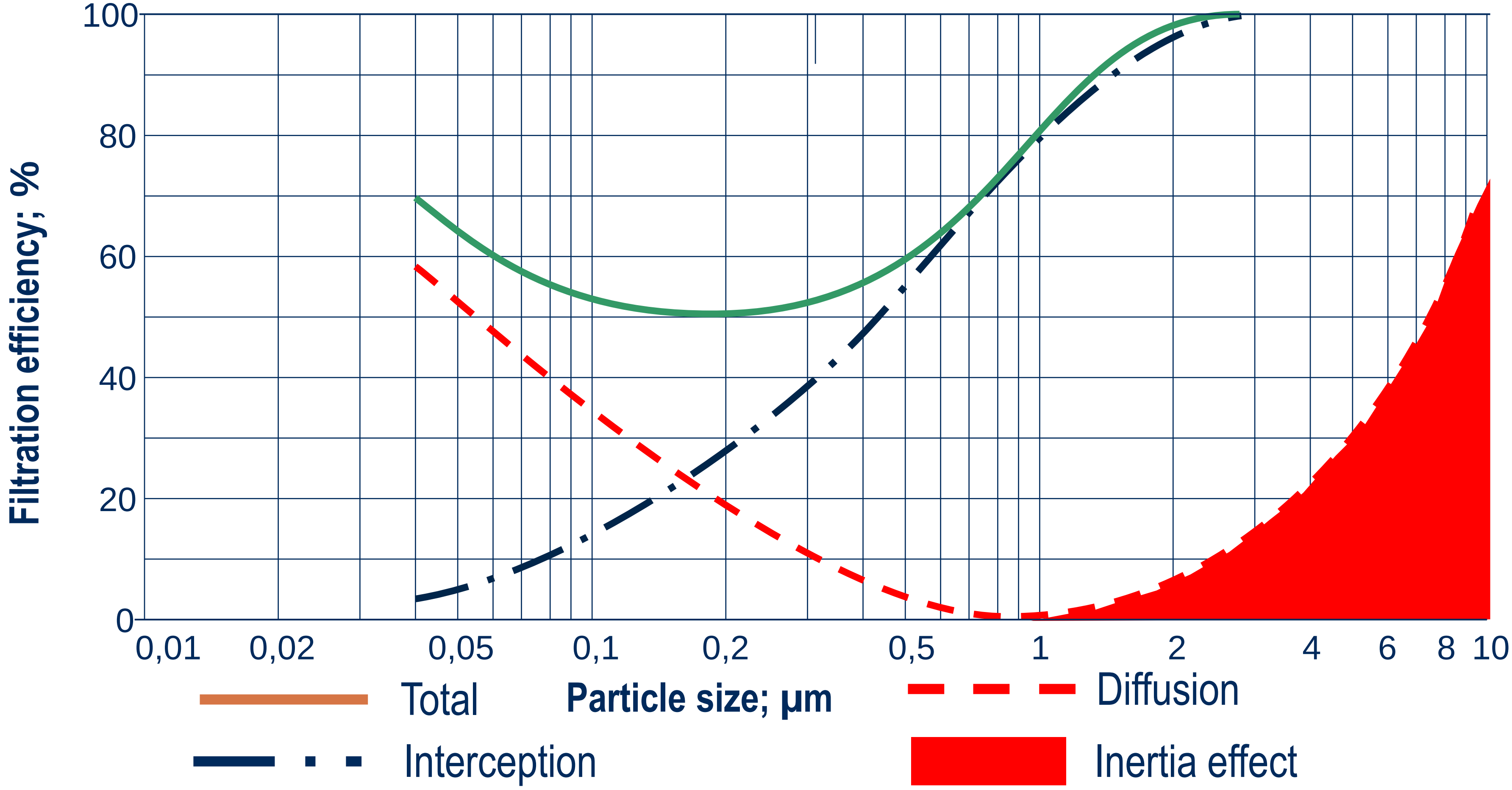
Diffusion



What is filtration

Combined filtration efficiency

filtration principle as an influence on filtration efficiency



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What is filtration

Parameters influencing a filter’s efficiency

Fouling / Dust cake

Charged Fibers

Type of particles

Filtration Efficiency

Relative Humidity

Charged Particles

Others (pH,…)

Temperature

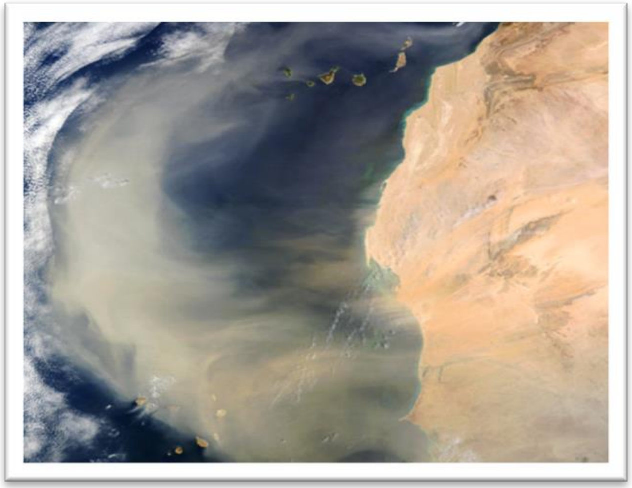
What is filtration

Understanding other factors…

- Dust Concentration
- Environmental Changes
- Usage Conditions (Operating Load)

Operating loads can be defined by the following:

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



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- **What standards are available**
- A closer look to EN779 and EN1822
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- Capex and opex considerations

What standards are available?

Why filtration standards are needed:

- Need for evaluating & comparing filter performances to make correct choice for applications
- Reproducibility / repeatability of tests
- Create uniform classifications / avoid creation of all kinds of custom(er) standards

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What standards are available?

Standards used today for turbo machinery:

Europe:

- EN779 (general ventilation / coarse and fine)
- EN1822 (clean room / very high efficiency)

US:

- ASHRAE 52.1 (general ventilation) →Obsoleted
- ASHRAE 52.2 (general ventilation / replaces 52.1)

→ Standards for particulate filters

NEW INITIATIVE

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A closer look at EN779:2012

ETN

EN779:2012

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Kommitee für Normung

- ‘Particulate air filters for general ventilation’
- Filter element test (no system test)
- Accelerated test (vs. real life conditions)
- Coarse (G-class), Medium (M-class) and Fine filters (F-class)

A closer look at EN779:2012

Test procedure (**F**-class):

- Measure initial fractional efficiency w/ **DEHS**
- Load 30g of **ASHRAE 52.1** dust: measure initial gravimetric efficiency & fractional efficiency w/ **DEHS**
- Load **ASHRAE 52.1** dust until 450Pa restriction
  - At min. 4 steps during loading measure:
  - Fractional efficiency w/ **DEHS**
  - Arrestance on **ASHRAE 52.1 dust**
  - Weight of **ASHRAE 52.1** dust added

Note: test procedure for G-class filters reports dust arrestance performance (no DEHS used)

A closer look at EN779:2012

Changes in the NEW EN779:2012

Discharging of media by soaking media in Isopropanol

Table 1— Classification of air filters 1)

Group	Class	Final test pressure drop Pa	Average arrestance (A_m) of synthetic dust %	Average efficiency (E_m) of 0,4 µm particles %	Minimum Efficiency [a] of 0,4 µm particles %
Coarse	G1	250	$50 \leq A_m < 65$	-	-
	G2	250	$65 \leq A_m < 80$	-	-
	G3	250	$80 \leq A_m < 90$	-	-
	G4	250	$90 \leq A_m$	-	-
Medium	M5	450	-	$40 \leq E_m < 60$	-
	M6	450	-	$60 \leq E_m < 80$	-
Fine	F7	450	-	$80 \leq E_m < 90$	35
	F8	450	-	$90 \leq E_m < 95$	55
	F9	450	-	$95 \leq E_m$	70

[a] Minimum efficiency is the lowest efficiency among the initial efficiency, discharged efficiency and the lowest efficiency throughout the loading procedure of the test.

A closer look at EN779:2012

Type of media:	Net effective filtering area:	Filter dimensions (width x height x depth):
Glass	19.0 m²	592 mm x 592 mm x 292 mm

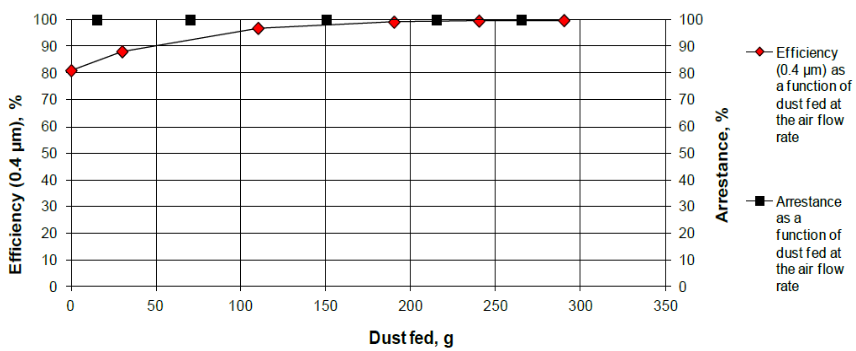
TEST DATA

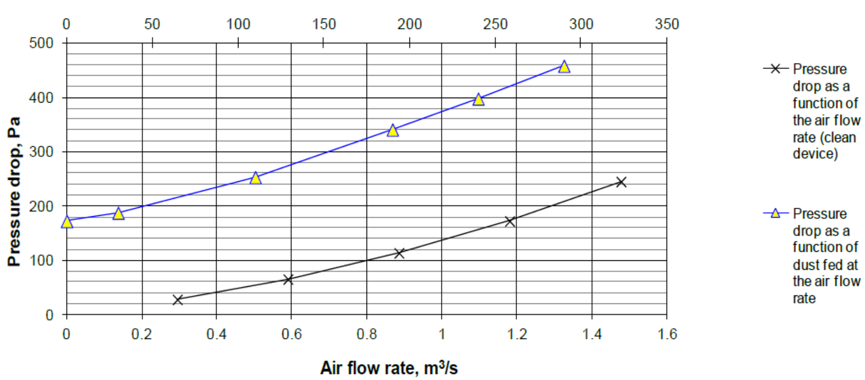
Test air flow rate:	Test air temperature:	Test air relative humidity:	Test aerosol:	Loading dust:
1.181 m^3/s	27 to 34 °C	17 to 28 %	DEHS	ASHRAE Test Dust

RESULTS

Initial pressure drop:	Initial arrestance:	Initial efficiency (0.4 µm):	Test dust capacity:	Untreated/ discharged efficiency of media (0.4 µm):
172 Pa	>99 %	81 %	104 / 196 / 280 g	84% / 83%
Final test pressure drop:	Average arrestance:	Average efficiency (0.4 µm):	Filter class (450 Pa):	Remarks:
250 / 350 / 450 Pa	>99% / >99% / >99%	90% / 94% / 96%	F9 (1.181 m³/s)	

Note: The performance results are only valid for the tested item and cannot by themselves be quantitatively applied to predict efficiency and lifetime in service





Filter class (450 Pa):
F9 (1.181 m³/s)

Initial efficiency (0.4 µm):
81 %

Average efficiency (0.4 µm):
90% / 94% / 96%

Loading dust:
ASHRAE Test Dust

Untreated/ discharged efficiency of media (0.4 µm):
84% / 83%

A closer look at EN779:2012

Filtration efficiency

Air filter's ability to remove dust.

- Particulate Efficiency: **%**
- Weight Efficiency = Arrestance: **%**

The terms mean:
Coarse filter = weight efficiency
Fine filter = particulate efficiency
EPA / HEPA = particulate efficiency

Focus on different %!

Dust **H**olding **C**apacity

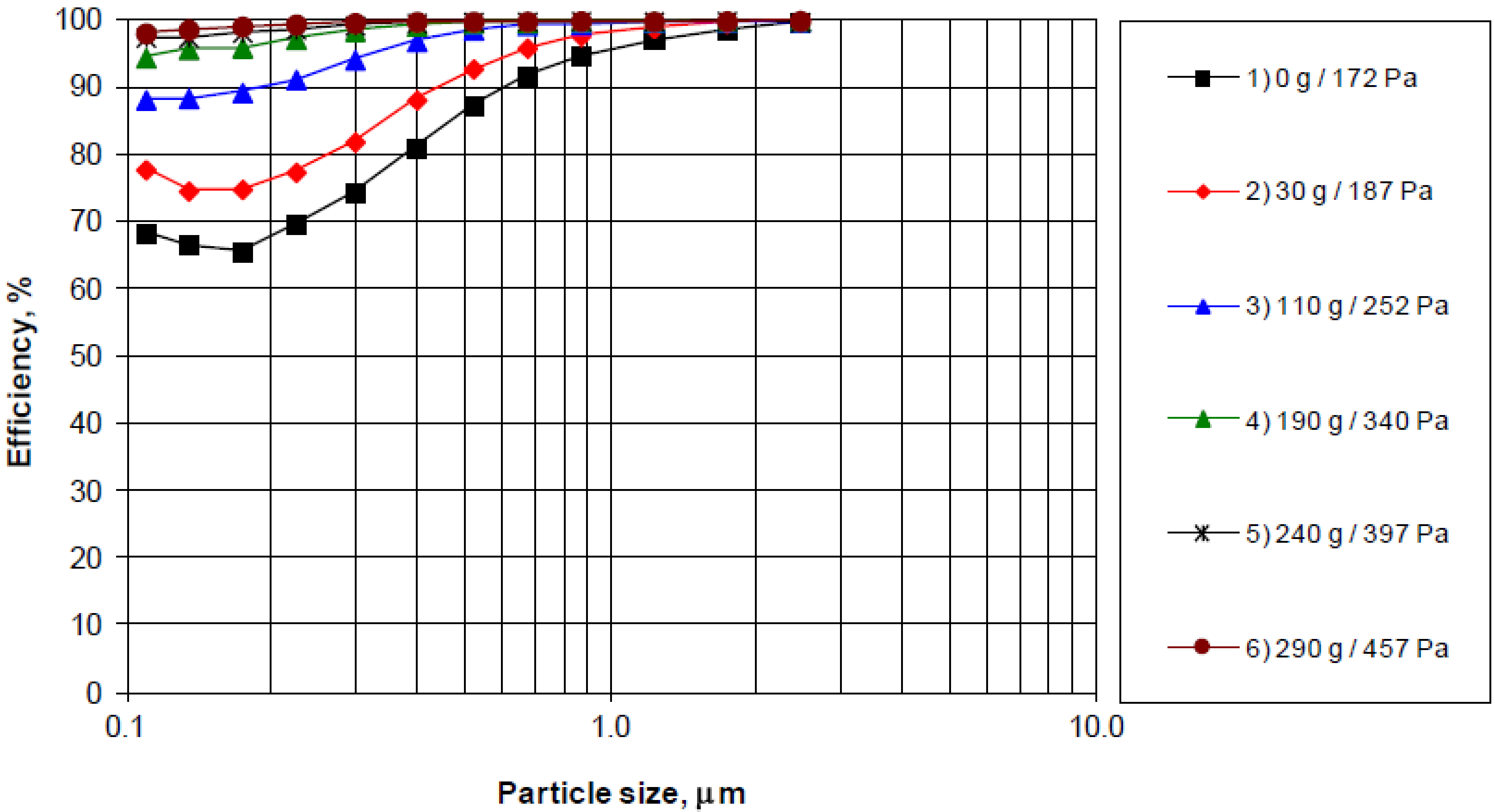
Specifies the amount of dust that collects in a filter during the operation period until the final pressure drop. *(I.e. 450Pa acc. EN779 std)*
Expressed in grams [g].

Rule of thumb:
The higher the filter class the less dust holding capacity,
and vice versa.

Pay attention to test dust used!

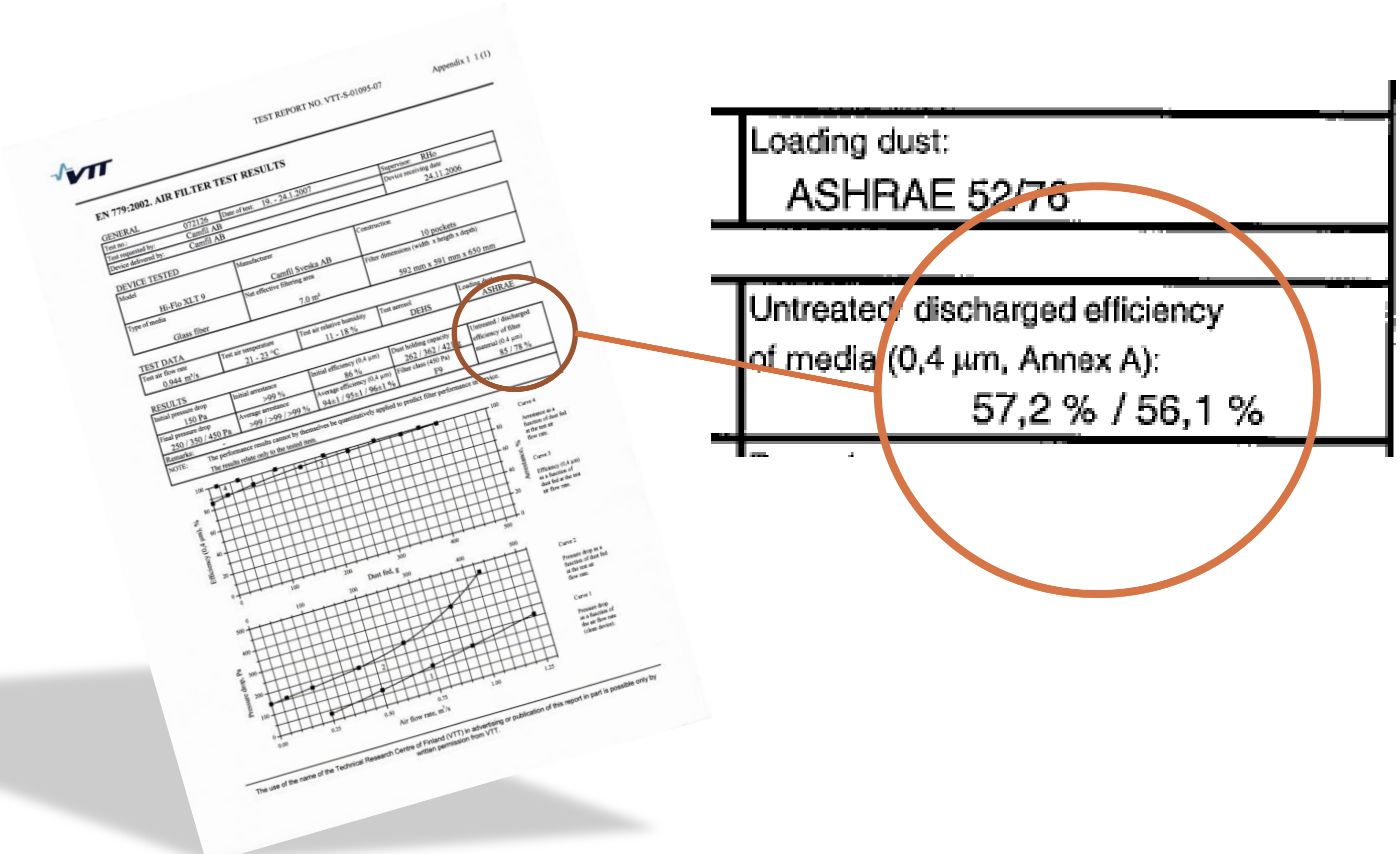
A closer look at EN779:2012

Filter efficiency development during an EN779 test



A closer look at EN779:2012

It is mandatory for all test reports to include a discharged (ME) value to be compliant

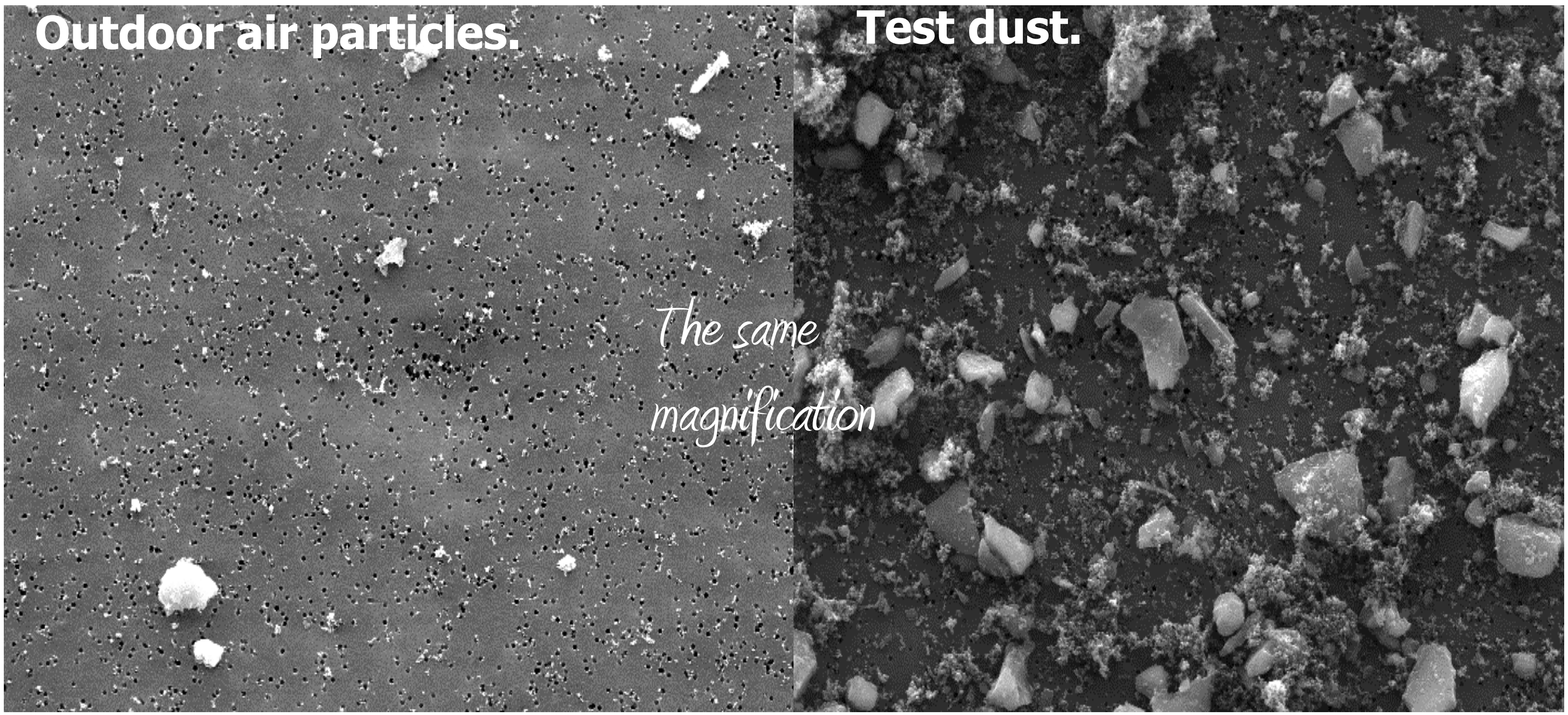


Shortcomings of EN779:2012

- Test dust vs real life dust
  (SEM pictures on next slide)
- Pulse clean ability: not covered
- Pre-filtration: not considered
- High humidity
- IPA soaking effect on media
- Often manipulated (test dust, final dP etc)

ETN

The difference between the laboratory and the real life



- Tests in laboratories are in a unique and ideal/controlled environment.
- Test dust and dust input rate is artificial.
- Filtration efficiency at 0.4 microns gives a hint at the comparison with real life.

Coffee break

(20 min)

A closer look at EN1822:2009

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EN1822:2009

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Kommitee für Normung

EPA = Efficient Particulate Air

HEPA = High Efficiency Particulate Air

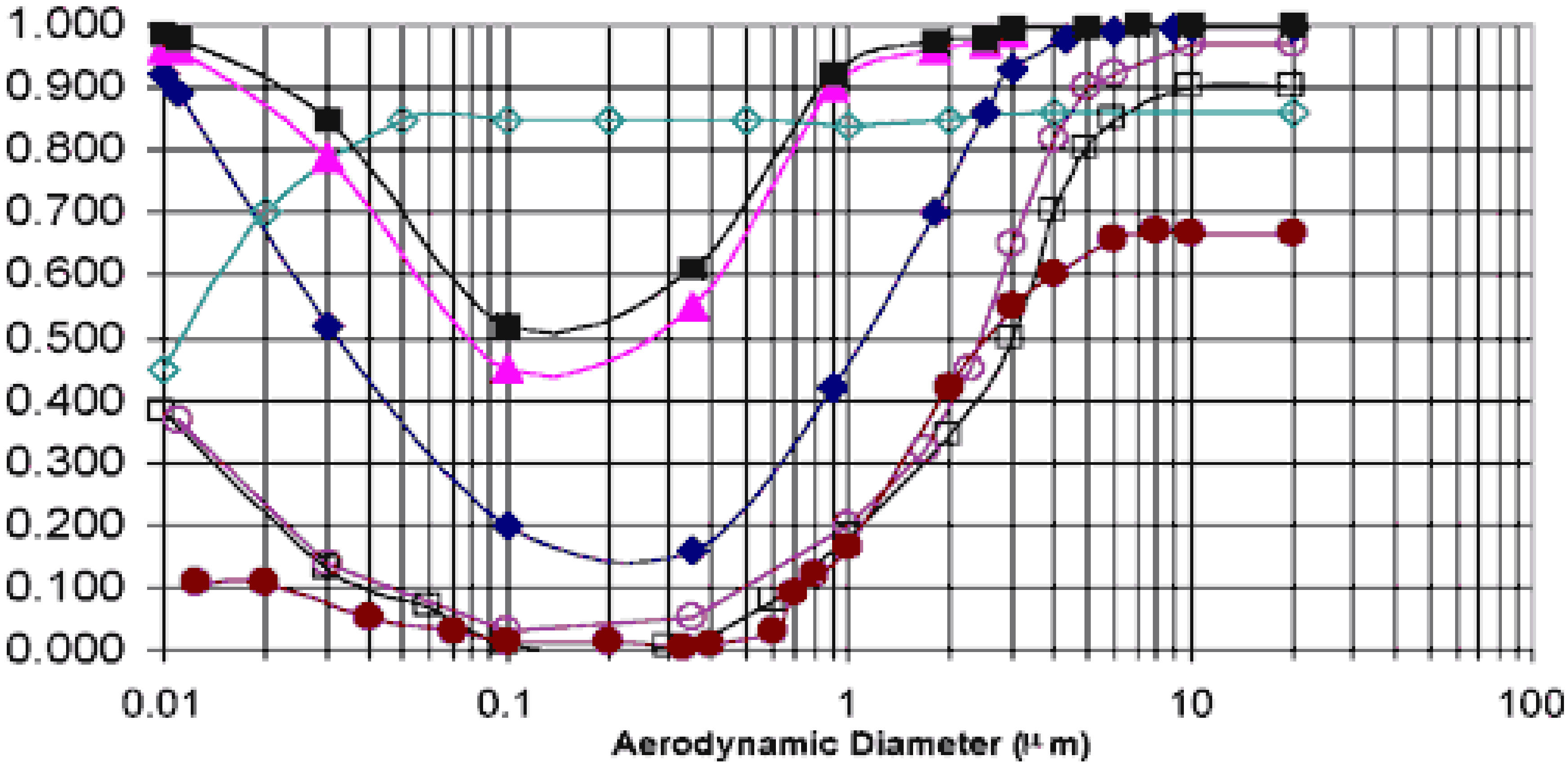
ULPA = Ultra Low Penetration Air

A closer look at EN1822:2009

Test procedure (**E**-class):

- Scope: ‘High efficiency air filters’
- Focus is on efficiency – but on least efficient particle size (MPPS)
- **M**ost **P**enetrating **P**article **S**ize or MPPS
  - Usually 0,1µm < MPPS < 0,3µm
  - EPA (E-class), HEPA (H-class) and ULPA (U-class) filters
- Non-destructive test - DEHS
  (No dust loading as on EN779:2012)
- Also includes discharging for synthetic filters.

Example graphs of MPPS



A closer look at EN1822:2009

Table 1 — Classification of EPA, HEPA and ULPA filters

Filter Group Filter Class	Integral value		Local value [a b]	
	Efficiency (%)	Penetration (%)	Efficiency (%)	Penetration (%)
E 10	≥ 85	≤ 15	---[c]	---[c]
E 11	≥ 95	≤ 5	---[c]	---[c]
E 12	≥ 99,5	≤ 0,5	---[c]	---[c]
H 13	≥ 99,95	≤ 0,05	≥ 99,75	≤ 0,25
H 14	≥ 99,995	≤ 0,005	≥ 99,975	≤ 0,025
U 15	≥ 99,999 5	≤ 0,000 5	≥ 99,997 5	≤ 0,002 5
U 16	≥ 99,999 95	≤ 0,000 05	≥ 99,999 75	≤ 0,000 25
U 17	≥ 99,999 995	≤ 0,000 005	≥ 99,999 9	≤ 0,000 1

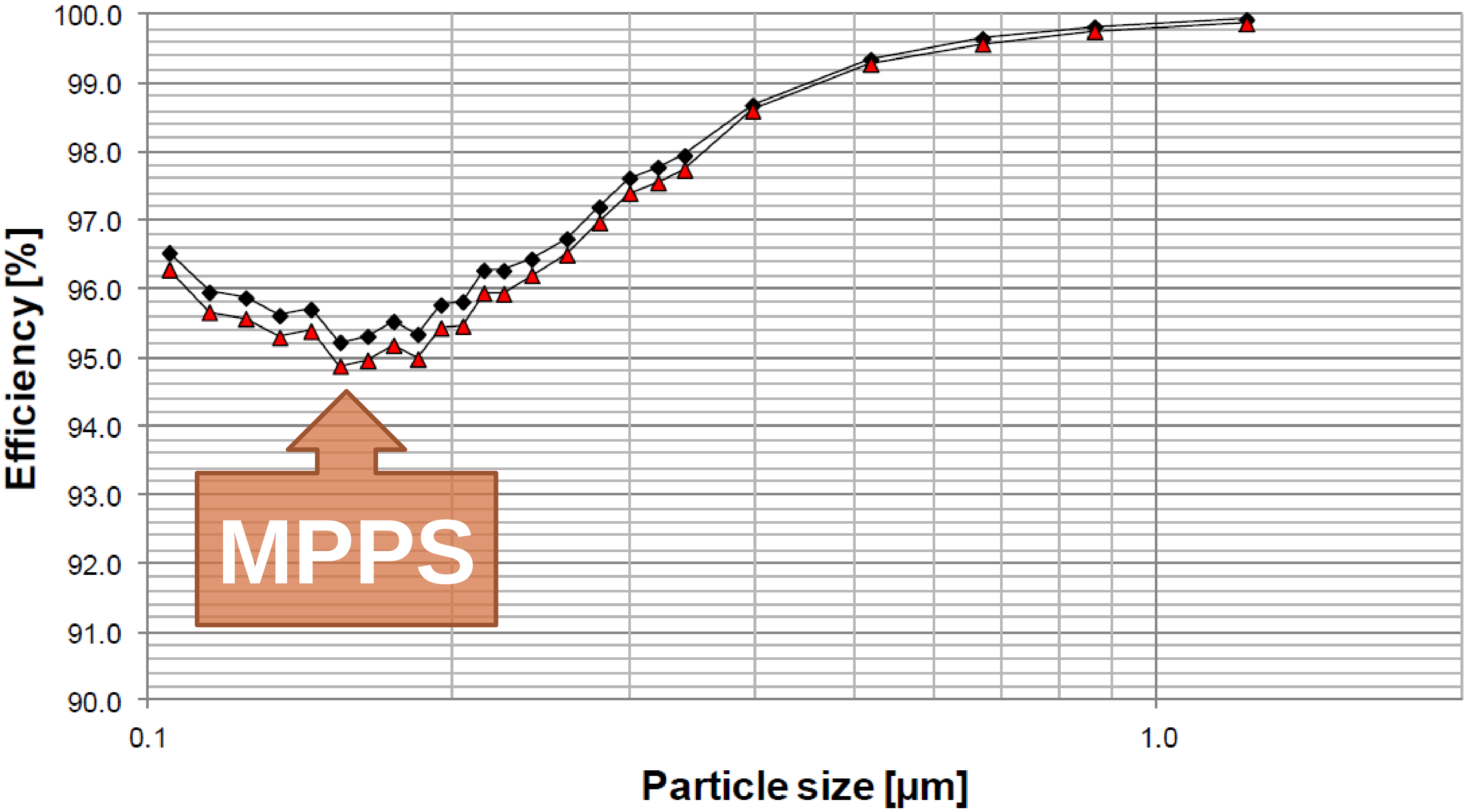
[a] See 7.5.2 and EN 1822-4.

[b] Local penetration values lower than those given in the table may be agreed between supplier and purchaser.

[c] Group E filters (Classes E10, E11 and E12) cannot and shall not be leak tested for classification purposes.

A closer look at EN1822:2009

Efficiency curve example



Filtration Standards: Overview

Standard	Ratings	Description	Efficiency testing	Efficiency determination	Dust loading
Ashrae 52.2	MERV 1-16	American standard commonly used also for GT filters	Initial efficiency and 4 increments of dust loading	Initial efficiency – based on average efficiency based on three particle size groups (E1, E2 & E3)	Ashrae dust to 1000Pa
EN779	G1-G4, M5-M6, F7-F9	European standard commonly used for GT filters. Globally used and accepted.	Initial efficiency and 4 increments of dust loading	Initial efficiency – based on average efficiency based on 0,4μm particle size.	Ashrae dust to 450 Pa
EN1822	E10-E12, H13-H4, U15-U17	Internationally accepted as the standard for measuring EPA, HEPA and ULPA efficient filters.	Initial efficiency only	Initial efficiency rating – based on efficiency on MPPS. Where filter is least efficient.	No dust loading

What about ASHRAE 52.2

ASHRAE Standard 52.2-1999				ASHRAE 52.1		EN779 Efficiency	EN 1822 Efficiency
Minimum Eff Reporting Value	Composite Average Particle Size Efficiency, % in Size Range, µm			Average Arrestance	Average Dust Spot Efficiency	Average Eff at 0.4 µm	Average Eff at MPPS
	Range 1	Range 2	Range 3				
MERV	0.30 - 1.0	1.0 - 3.0	3.0 - 10.0	%	%		%
1	n/a	n/a	$E_3<20$	$A_{avg}<65$	<20	G1	
2	n/a	n/a	$E_3<20$	$A_{avg}<65$	<20	G2	
3	n/a	n/a	$E_3<20$	$A_{avg}<70$	<20		
4	n/a	n/a	$E_3<20$	$A_{avg}<75$	<20		
5	n/a	n/a	$E_3\geq20$	80	20	G3	
6	n/a	n/a	$E_3\geq35$	85	20-25		
7	n/a	n/a	$E_3\geq50$	90	25-30	G4	
8	n/a	n/a	$E_3\geq70$	92	30-35		
9	n/a	n/a	$E_3\geq85$	95	40-45	M5	
10	n/a	$E_2\geq50$	$E_3\geq85$	96	50-55		
11	n/a	$E_2\geq65$	$E_3\geq85$	97	60-65	M6	
12	n/a	$E_2\geq80$	$E_3\geq90$	98	70-75		
13	n/a	$E_2\geq90$	$E_3\geq90$	98	80-85	F7	
14	$E_1\geq75$	$E_2\geq90$	$E_3\geq90$	99	90-95	F8	
15	$E_1\geq85$	$E_2\geq90$	$E_3\geq90$	99	95	F9	
16	$E_1\geq95$	$E_2\geq95$	$E_3\geq95$	100	99	E10	<85
N/A	N/A	N/A	N/A	N/A	N/A	E11	<95
						E12	<99.5
						H13	<99.95
						H14	<99.995
						U15	<99.9995
						U16	<99.99995
						U17	<99.999995

Note: The final MERV value is the highest MERV where the filter data meets all requirements of that MERV.

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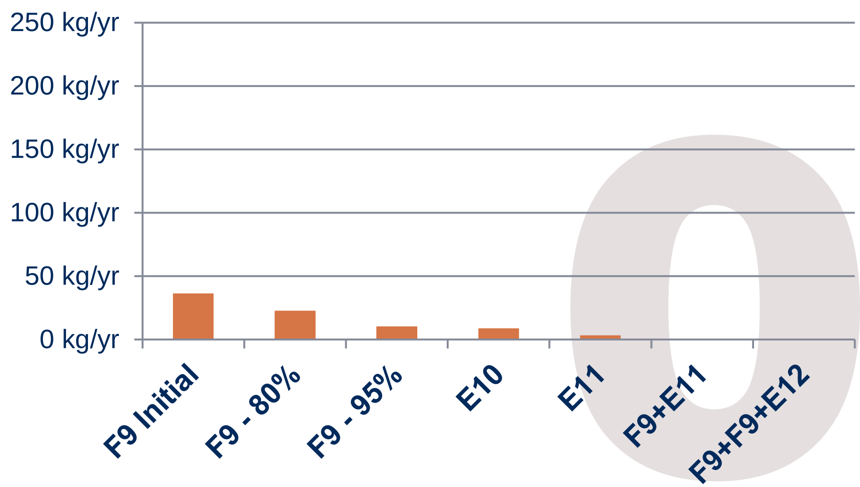
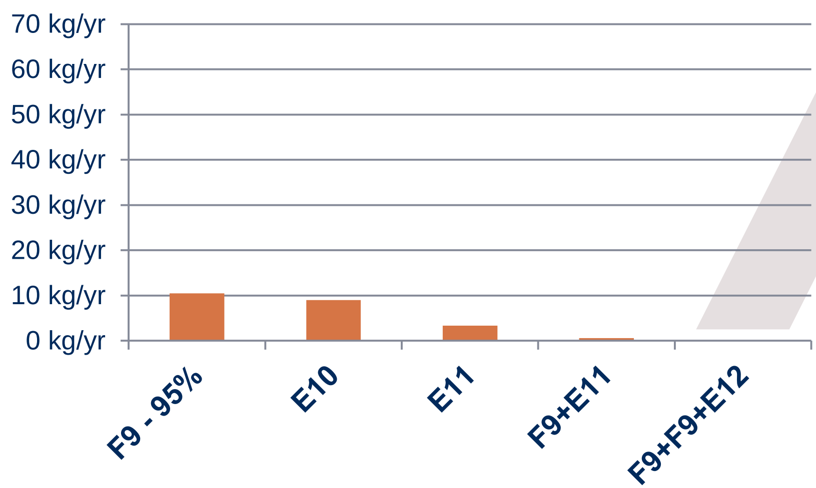
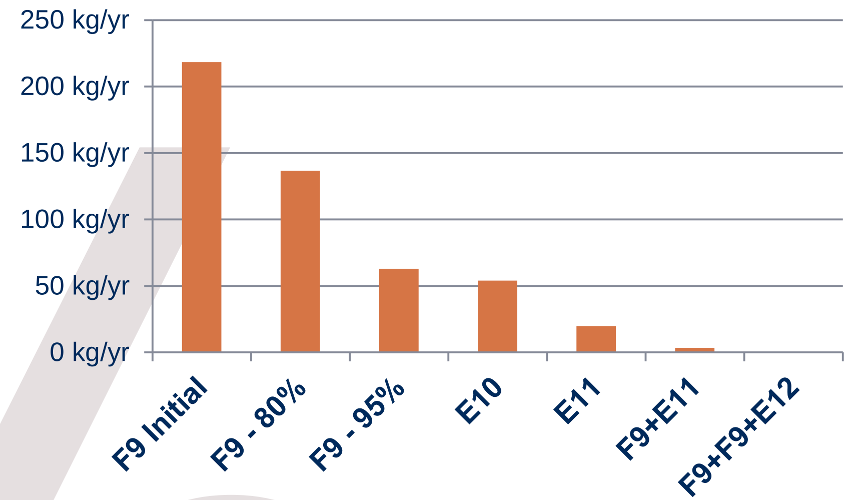
DUST PENETRATION

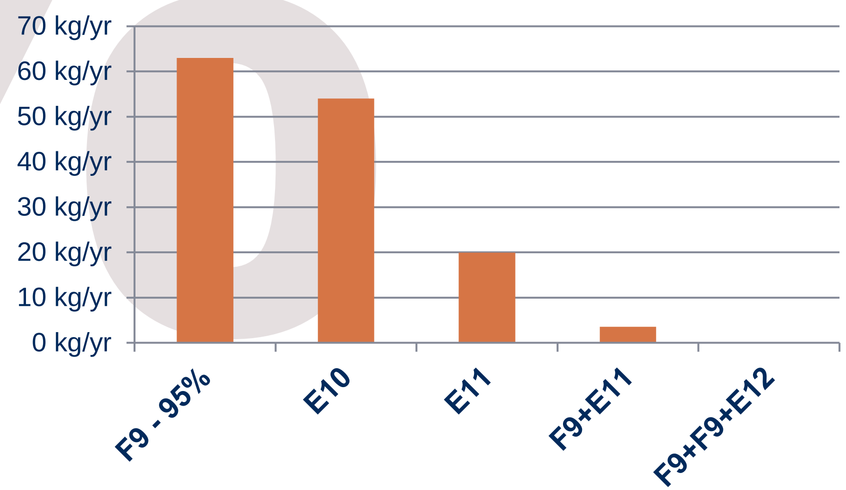
PM$_{10}$: 20μg/m³ (i.e. Europe)





PM$_{10}$: 120μg/m³ (i.e. Middle East))





Filter Performance

A higher filter class means:

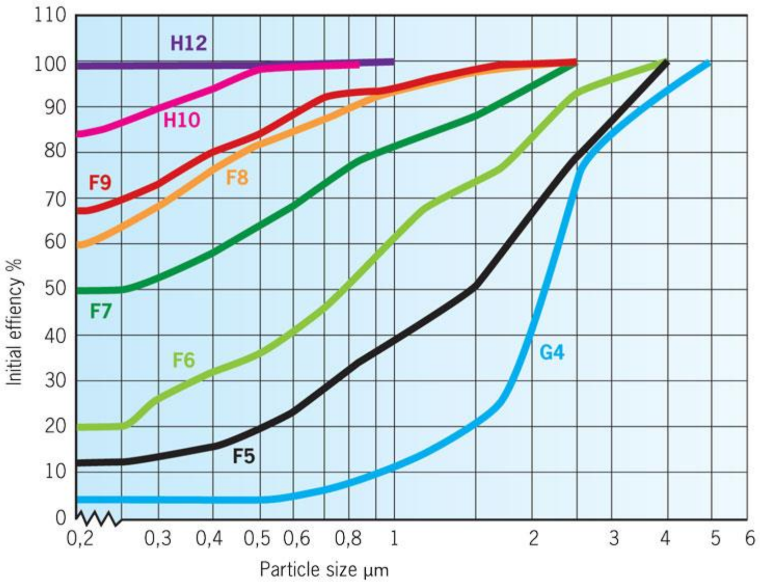
A higher degree of separation

A cleaner engine

Longer service intervals

Higher availability

Lower operating costs



For example: penetration on 0.4 µm particles is reduced typically 25% for an F8 filter to less than 0.5% in an E12 filter

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