AAF | Flanders®

Bringing clean air to life®

Testing HEPA Filters: Guidelines for the Factory and Field

HEPA Filter Classification Comparison EN-1822 & ISO-29463

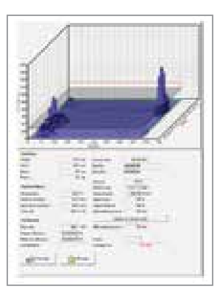
Group		EN-1822	1S0 29463	Integral Value		Local Value		Leakage Factor
				Efficiency at MPPS	Penetration at MPPS%	Efficiency at MPPS	Penetration at MPPS%	
Group	EPA	E10		≥85	≥15			
		E11	ISO 15 E	≥95	≥5			
			ISO 20 E	≥99	≥1			
		E12	ISO 25 E	≥99.5	≥0.5			
			ISO 30 E	≥99.9	≥0.1			
	HEPA	H13	ISO 35 E	≥99.95	≥0.05	≥99.75	≥0.25	5
			ISO 40 H	≥99.99	≥0.01	≥99.95	≥0.05	5
		H14	ISO 45 H	≥99.995	≥0.005	≥99.975	≥0.025	5
			ISO 50 H	≥99.999	≥0.001	≥99.995	≥0.005	5
	ULPA	U15	ISO 55 H	≥99.9995	≥0.0005	≥99.9975	≥0.0025	5
			ISO 60 U	≥99.9999	≥0.0001	≥99.9995	≥0.0005	5
		U16	ISO 65 U	≥99.99995	≥0.00005	≥99.99975	≥0.00025	5
			ISO 70 U	≥99.99999	≥0.00001	≥99.9999	≥0.0001	10
		U17	ISO 75 U	≥99.999995	≥0.000005	≥99.9999	≥0.0001	20

IEST RP-CC001 Classification

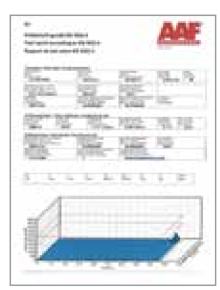
Filter Type		Particle Size for Testing	Overall Value Efficiency	Local Value Leakage
Filter Type	A	0.3*	≥99.97	
	B	0.3*	≥99.97	
	E	0.3*	≥99.97	
	H	0.1-0.2 or 0.2-0.3**	≥99.97	
	I	0.1-0.2 or 0.2-0.3**	≥99.97	
	C	0.3*	≥99.99	1
	J	0.1-0.2 or 0.2-0.3**	≥99.99	1
	K	0.1-0.2 or 0.2-0.3**	≥99.999	1,6
	D	0.3*	≥99.999	5
	F	0.1-0.2 or 0.2-0.3**	≥99.9995	5
	G	0.1-0.2 or 0.2-0.3**	≥99.9999	10

**Although the mass median diameter of thermally generated particles are approximately 0.3 micron, the count mean is under 0.2 micron or close to the MPPS.*

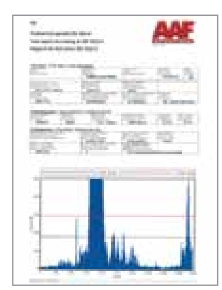
Typical HEPA/ULPA Auto-Scan Equipment



Typical Scan Test Protocol



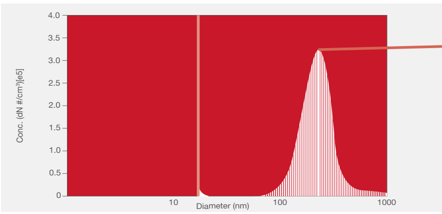
PASS



FAIL

Aerosol Distribution for 'Hot' (Thermal) and 'Cold' (Laskin Nozzle) Generators

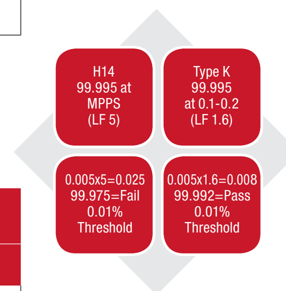
PAO-4 Particulate Size Distribution of a Thermal Condensation Generator (ATI-5C)



	Particle Size			
	Number	Surface	Mass	Volume
Median (nm)	221	282	373	373
Mean (mn)	237	364	488	488
Geo. Mean (nm)	219	317	421	421
Mode (nm)	225	269	479	479
Geo. Std. Dev.	1.5	1.65	1.73	1.73

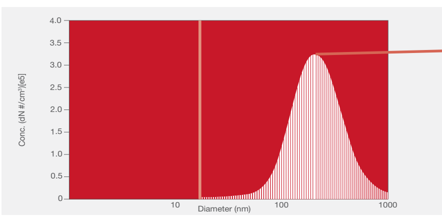
The ATI-SC aerosol distribution listed above is characteristic of the operating conditions and settings present at the time of testing. Particle size distributions generated during field usage will change depending upon ambient temperature, humidity and equipment settings in use.

Operating at standard set up parameters of 408ªC (765ªF) with 50 psig inert gas supply.



Impact of a factory setting Leakage Factor (LF) on penetration

Type 111-Laskin Nozzle at 23 psi using PAO-4 (Cold)



	Particle Size			
	Number	Surface	Mass	Volume
Median (nm)	215	392	513	513
Mean (mn)	252	434	536	536
Geo. Mean (nm)	218	383	487	487
Mode (nm)	209	414	615	615
Geo. Std. Dev.	1.72	1.67	1.59	1.59

**Important to note that particle size distribution will vary in the field and is very much dependent on ambient temperature, humidity and equipment settings while in use.*

Filter 'Bleedthru'

The term bleedthru was a phrase coined by industry professionals when multiple filters (normally installed in a Grade A space) were exposed to a thermal ('hot smoke') challenge aerosol. The filters installed had excessive penetration through the media, hence the term 'bleedthru'.

A lot has been written about this topic from 'not thick enough media' to 'we must now use ULPA filters', but the issue and 'fix' can be summerized below.

The three main factors to be aware of are:

1. Higher than expected or design velocity. (We should look at effective filter area not the nominal frame size)
2. Challenge aerosol type. ('Hot' smoke mean particle size can be close to the MPPS)
3. Filter Specification. (The traditional 99.99 at 0.3 micron can 'fail' a scan test when exposed to a thermally generated aerosol especially at higher than design or factory tested velocity in the field)

How to solve the problem:

1. Understand the actual media face velocity when selecting/specifying filters. A nominal '4x2' or 1200x600mm filter can be as high as 20% smaller when installed in a given housing or ceiling grid, therefore increasing the actual face velocity which can contribute to higher penetration values. Most filter manufacturers test filters at 120 fpm or 0.6 m/s to minimize risk. Some older facilities due to the specific site design have higher than recommended filter face velocities. Filters can be manufactured to perform at elevated velocities if known ahead of time. The only negative of course is the penalty paid in a higher energy cost due to the increased pressure drop. (Membrane eFRM media can reduce DP substantially in these applications)
2. Understand where possible how your filters are being tested. A 'hot smoke' (thermal) has a higher penetration than 'cold smoke' (Laskin Nozzle) in the field as stated above.
3. To minimize risk, specify filters with an efficiency of H14 (99.995) at MPPS in accordance with EN-1822 or Type K (99.995) at 0.1-0.2 micron in accordance with IEST CC001. The leakage factor for the H14 filter should be 1.6 (Type K) instead of 5, therefore giving a maximum penetration of 0.008% assuming a standard velocity of 120 fpm or 0.6 m/s.

It's important all parties involved from the end user, specifier, certifier and filter vendor understand the site specific variables. Again, filter efficiency specified, actual on site HEPA media velocity, and the equipment and specification of how filters are tested both in the factory and field are key parameters.

Challenge Aerosol Types

Challenge Aerosol	Aerosol Type	Name	Aerosol Generation Method	Industry Type	Plus/Minus
PAO	Liquid	Poly Alpha Olefin	Laskin Nozzle/ Thermal	Life Science	Long established synthetic hydrocarbon test aerosol, easy to understand and measure. The leak threshold limit is 0.01% of the upstream concentration allowable downstream. Higher risk of filter contamination due to traditional aerosol generation methods.
DEHS	Liquid	Di Ethyl Hexyl Sebacate	Laskin Nozzle/ Thermal	Life Science	Proven test aerosols for factory and field testing. It is a non soluble colorless and odorless liquid which is suitable for producing a consistent aerosol. The main proportion of droplets generated (ATM) can be stated at MPPS. A droplet with 0.3 micron diameter has a life time of 4 hours. Long life time, spherical particle, well known optical properties. DEHS has a long lifetime.
PSL	Solid	Polystyrene Latex Spheres	Ultrasonic	Microelectronics	Consistent repeatable, uniform, monodispersed, PSL aerosol utilized by filter manufacturers. No 'oil' contamination and suited well for particle counters. Available from sizes 0.12-3.0 micron. Can be costly where large concentrations of aerosols are required in semiconductor type applications.
Slica	Solid	Si 02	Gravity Feed-Compressed Air	Microelectronics	Not commonly used Non toxic, has a size distribution of 0.08-0.15 micron. Has a tendancy to 'float' and can leave coatings on surfaces.
DOP*	Liquid	Di Octyl Phthalate	Laskin Nozzle/ Thermal	Life Science	Original aerosol of choice. Rarely used today (Nuclear applications can still apply) due to *Carcnogenic health risks.

ATI's 2i Photometer Detects Leaks in HEPA Filters

ATI's iProbe, Paired with a Photometer, Scans HEPA Filters to Detect Leaks

ATI's 4B Laskin Nozzle Aerosol Generator

ATI's 5D Thermal Aerosol Generator

Filling a Laskin Nozzle Generator with an Oil Reagent to Create a Challenge Aerosol

Filter Efficiency vs. Filter Integrity (Global vs. Local)

Efficiency:
Measure of the filter's overall (global) value as a % of 100.

EN-1822-5 (Single point measurement fixed)

IEST-RP-CC001

IEST-RP-CC007

Integrity:
Measure of the filters local leakage threshold within specified limits. (Penetration through the filter that falls under the probe)

EN-1822-1 (Single point measurement during scan test)

EN-1822-4 (Mean value of the local values measured)

IEST-RP-CC001

IEST-RP-CC034

Isokinetic Sampling

There has been confusion over what penetration or efficiency means when we discuss 'local' leak testing vs. 'global' leak testing.

This might be explained better by stating the local penetration at the filter that falls under the scan probe. The integrity (or local efficiency) of the rest of the filter is not being considered at that moment.

When measuring a leak, the probe is only over the area of the filter media. The area being sampled is equal to the area of the probe when under isokinetic conditions.

When utilizing a 1CFM instrument and 90ft/min filter face velocity, the probe area is a defined value (0.11ft^2) The penetration of particles through a filter area is now defined by the isokinetic probe of a 1CFM instrument.

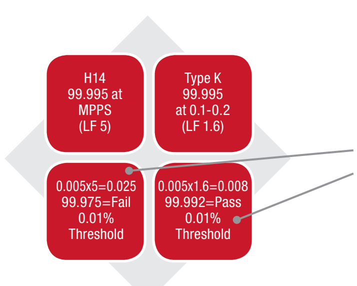
Isokinetic- Isokinetic sampling is when the sampling velocity is equal to the system or approach air velocity. Isokinetic sampling produces the most accurate results while leak scan testing.

How big is the defect?

In terms of area: The probe area = 0.011ft^2

0.01% of 0.011ft^2 is 1.1E-6 ft^2 or 102,000µm^2

If the defect were round, the diameter would be 360µm! HUGE compared to test particles, it does not matter if you look at 0.1µm,0.3µm or 0.5µm particles, they will pass freely through the defect.



Influence of Leakage Factor (LF) when testing filters.

In this example a H14 or Type K filter with a LF of 5 fails while a LF of 1.6 passes

Is isokinetic sampling important?

When scanning a filter for leaks, we are always considering a localized area of the filter. The filter media surrounding the defect is intact, therefore the air around the defect should be particle free, at least close to particle free.

When the filter velocity is lower than the probe velocity, the probe is capturing all that is passing through the defect and drawing additional clean air from the local area. This is ok for both scanning and leak sizing since we are capturing all the unfiltered air from the defect diluting it with clean air into a total volumetric flow of 1CFM.

When the filter face velocity is higher than the probe velocity, the probe may not be capturing all that is passing through the defect as some of the leak may be spilling out of the probe. This is NOT ok for scanning.

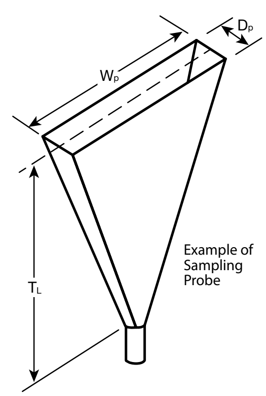
Summary

All of the leak % or standard local penetration basics apply to photometers and particles counters.

A 0.01% leak is LARGE compared to the particles being used to size the leak.

Isokinetic sampling is not very critical as long as the filter face velocity is below the probe inlet velocity.

Scanning is only used for leak detection and not to size leaks



Probe Design and Isokinetic Sampling

$$W_pD_pV_{filter} = F_a$$

W_P = *probe dimension perpendicular to the scan direction in cm (or in.)*

D_P = *probe dimension parallel to the scan direction in cm (or in.)*

V_{filter} = *average exit airflow velocity of the filter*

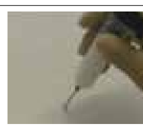
F_a = *flow rate of the instrument*

Source: DMA

Where and How is the Test Aerosol Generated?

Aerosol Generator Location		How Aerosol is Typically Generated	Positive	Negative
	Supply Air AHU	Thermal	Good aerosol distribution, dispersed over multiple filters simultainously which saves time	Excess aerosol exposure; Potential risk of 'bleedthru' if correct filter efficiency is not specified
	Supply Duct Work in the Plenum	Laskin Nozzle	Good aerosol distribution, dispersed over multiple filters simultainously which saves time	Access to the plenum-ability to measure upstream concentrations
	Locally through Aerosol Dispersion Ring in the Housing	Laskin Nozzle	Minimizes aerosol exposure to multiple filters	Aerosol dispersion ring or distribution needs to be validated to ensure adequate upstream challenge
	Low Wall Return Air Ductwork	Thermal	Good aerosol distribution, dispersed over multiple filters simultainously which saves time	Excess aerosol exposure; Potential risk of 'bleedthru' if correct filter efficiency is not specified

Guidelines for Factory and Field Repairs

Location		Repair Limits	Guideline	Repair Equipment
	Factory	Up to 13 cm^2 (2sq in) in any one patch or a total of 1% on the area of the face being patched	IEST-RP-CC001.6	EFD Dispense Gun 
	Factory	Up to 0.5% of the face area. No single repair larger than 1.2" (30mm) in any dimesnion	EN-1822-4	EFD Dispense Gun 
	Field	Up to an additional 3% of the face area. No single repair larger than 1.5" (38mm) in any dimension	IEST-RP-CC034.2	RTV 162 or 108 or Dow 732 is a suitable repair material
	Field	No repairs allowed in a Grade A Space. Some will specify no factory repairs for which there is typically a premium from the manufacturer. (Average factory repairs are 5-8%) 95% of end users follow industry norms/repair levels.	End Users	Manufacturers will repair with urethane, media or hot melts used in the production process. Repairs should be recorded on the scan test reports for a given filter. Filters should always be re-scanned after repair in the factory and re-tested in the field.
	Field	Less is more 	Experience 	Covering filters with more silicone does not mean you will 'seal the leak'. Leaks 'travel' and you will end up chasing leaks. Leave repairs to professionals.

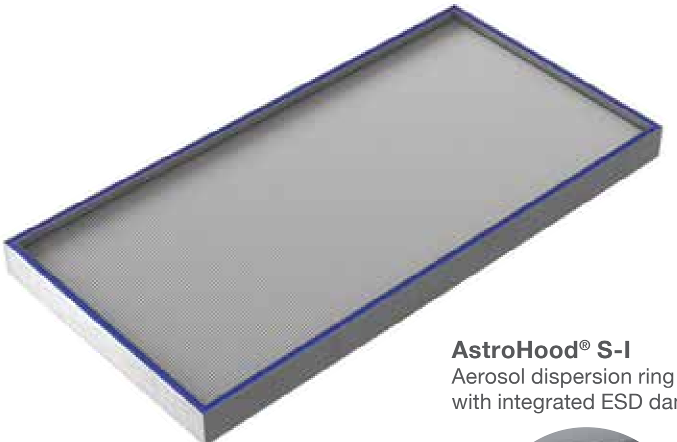
FRM or PTFE membrane technology utilizing Daikin's unique recipe and manufactured by AAF is the filter of choice if your facility is concerned or has a history of HEPA filter "failures".

Wet laid glass fiber HEPA media by nature is very fragile and will fail from a pinhole leak due to mishandling of the filter.

Illustration of Equipment and Test Protocol in the Life Science Industry

Control of viable and non-viable particles is crucial in many process applications in the Life Science industry. Protection of people from hazardous or potent compounds is equally important. There is a wide variety of supply, exhaust and recirculated air housings and filter types to address each application. It is important to utilize a manufacturer who can offer a fully integrated solution in order to minimize risk and points of potential failure.

A	MEGApleat®
B	VariCel® VXL/DriPak® NX
C	Sensor360®
D	Test Port
E	AstroSafe® V-BIBO
F	AstroHood® S-I
G	AstroHood® S-II
H	AstroHood® S-III
I	Injection Port
J	Central Test Port
K	AstroHood® E-I
L	AstroHood® Plenum
M	MEGAcel® eFRM
N	AstroFan®
O	AstroDrive™
P	ESD Damper



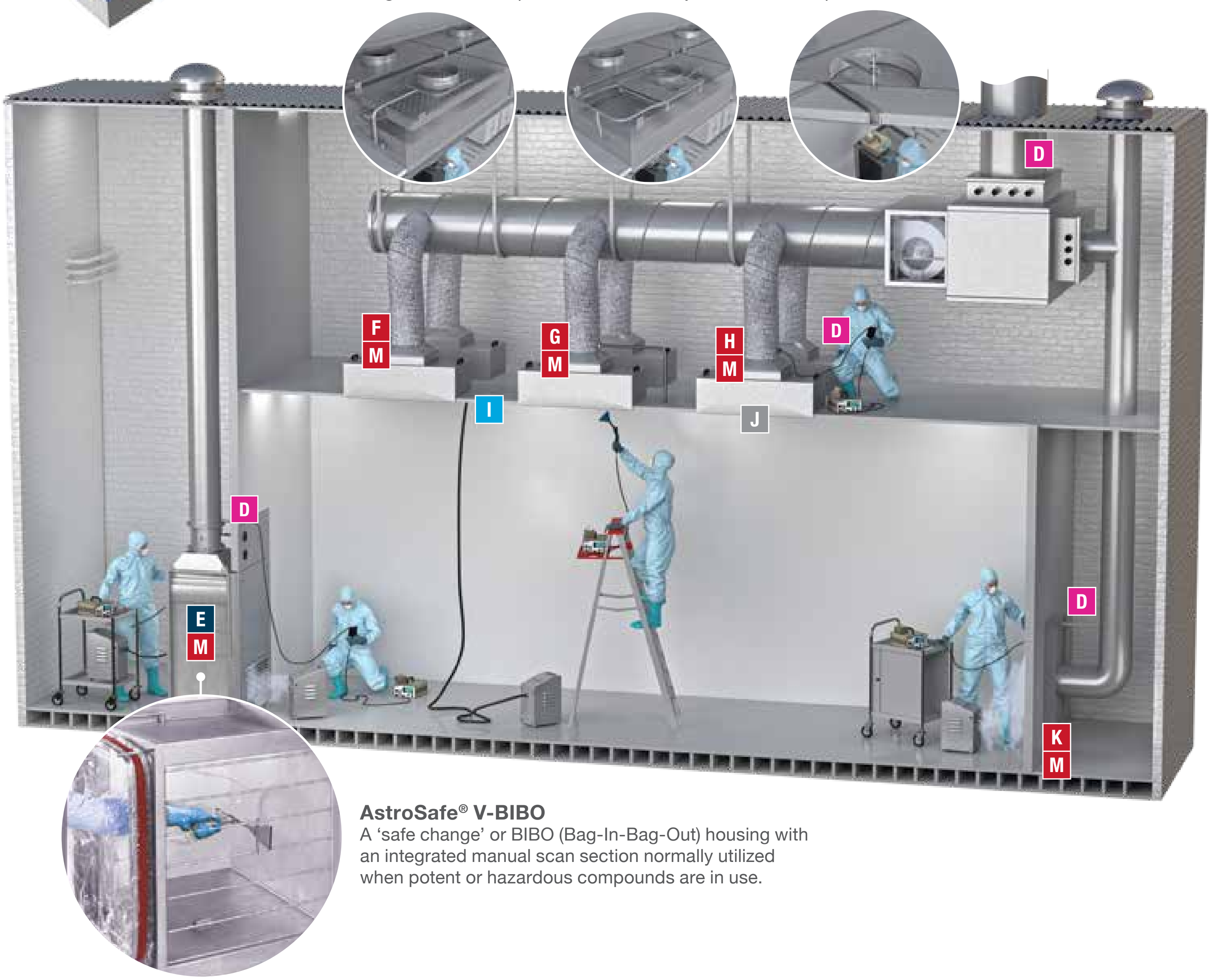
MEGAcel® eFRM M
eFRM media exceeds industry requirements from an efficiency and aerosol challenge compatibility standpoint.

E F G H K N P

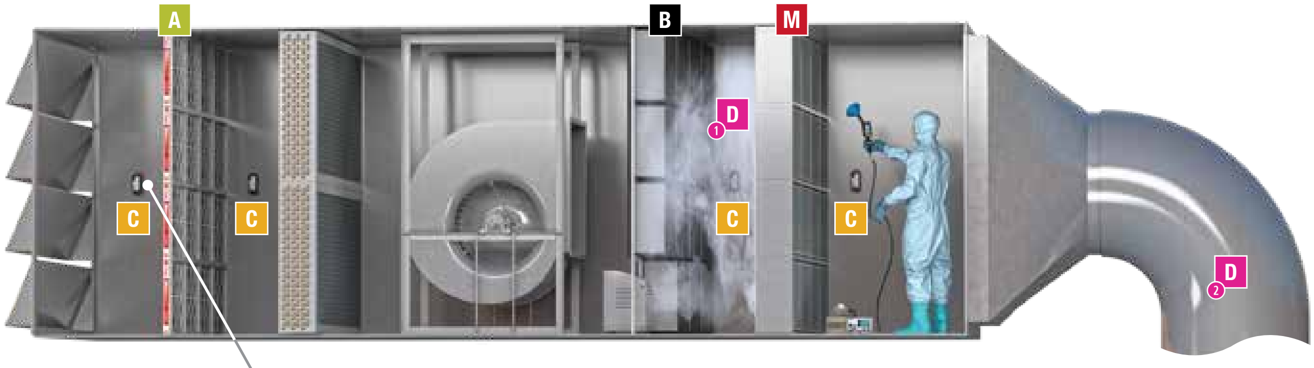
AstroHood® S-I
Aerosol dispersion ring with integrated ESD damper

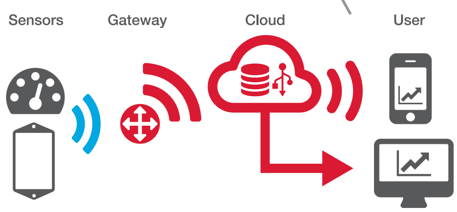
AstroHood® S-II
Guillotine damper and aerosol injection

AstroHood® S-III
Integrated centerboard test port and diffusion disc



AstroSafe® V-BIBO
A ‘safe change’ or BIBO (Bag-In-Bag-Out) housing with an integrated manual scan section normally utilized when potent or hazardous compounds are in use.





Sensor360®
Cloud-based air quality and pressure drop measurement technology.

AHU Filter Testing
In situ integrity testing of HEPA filter banks is accomplished by injecting an aerosol upstream of the filters and manually scanning the downstream side of the filters.

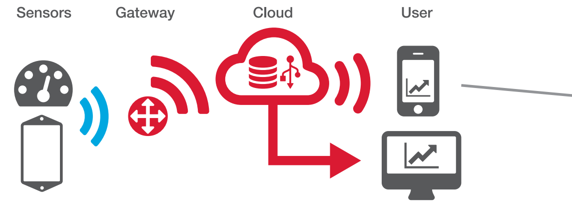
Alternate Overall Efficiency Test This can be performed by measuring a single point *upstream* ❶ and *downstream* ❷ of the filter.

MEGAcel® eFRM ESD Damper
HEPA/ULPA filter with integrated airflow uniformity Energy Saving Damper.

AstroFan® EC Controls
Intelligent controls gives you continuous motor speed monitoring and modulation, tailoring fan speed to match demand.

Illustration of Equipment and Test Protocol in the Microelectronics Industry

Historically the need to control particulate in semiconductor applications has been addressed with conventional HEPA/ULPA filtration. In the last decades the need to control AMC (Airborne Molecular Contamination) has increased where specific grades of chemical filters and membrane ULPA filters have been deployed. Reduction of energy consumption by optimizing construction and media types has become 'the norm' as the industries thirst for lower operating costs and increased yields continues to drive our product development and technical leadership in this segment.



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Cloud-based air quality and pressure drop measurement technology.

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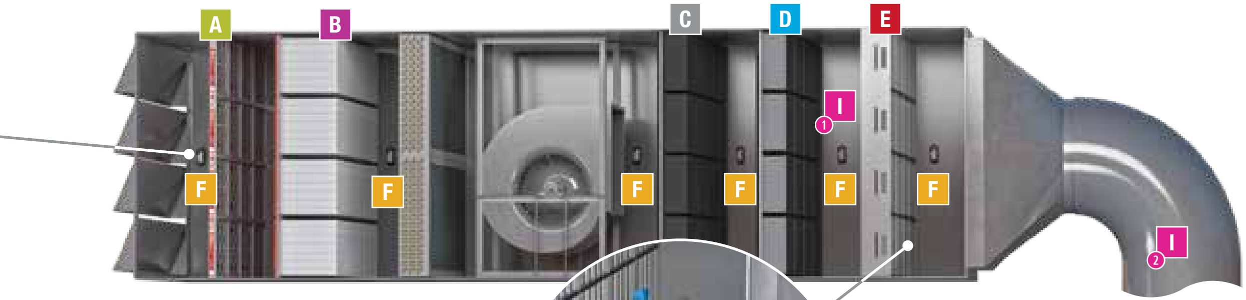
High tensile strength, boron-free media with ultra-high efficiency and the lowest pressure drop.

AstroDrive™
Control options range from 0-10 V potentiometers to fully customizable PLCs and PC displays.

MEGAcel® ePTFE Walk-on Back Plate
For open plenum applications, HEPA/ULPA filters can be supplied with walk-on back plates to facilitate ease of maintenance.

MEGAcel® ePTFE ESD Damper
HEPA/ULPA filter with integrated airflow uniformity Energy Saving Damper.



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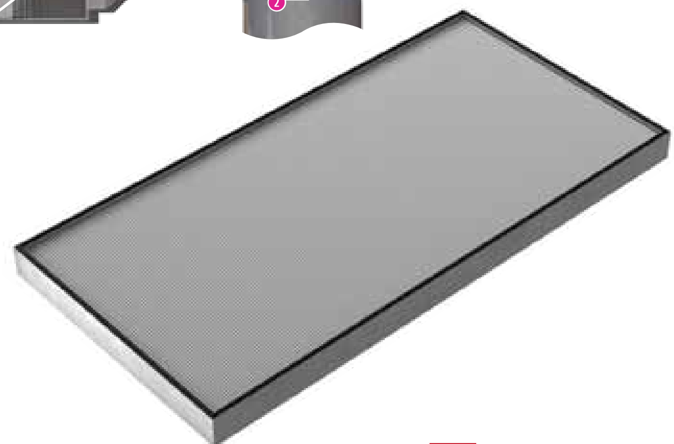

MEGAcel® ePTFE M
The industry standard with the lowest TCO and durability. The cleanest product for the most sensitive processes.

H J K L N

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C	VariSorb®
D	VariCel® VXL
E	MEGAcel® III
F	Sensor360®
G	AstroDrive™
H	AstroFan® FFU
I	Test Port
J	AstroHood® S-III
K	ESD Damper
L	Walk-on Back Plate
M	MEGAcel® ePTFE
N	In-room HEPA Test Bench

AstroHood® S-III
Disposable ducted HEPA with integrated centerboard test port and diffusion disc.

AAF International Plant Locations

AAF, the world's largest manufacturer of air filtration solutions, operates production, warehousing and distribution facilities in 22 countries across four continents. With its global headquarters in Louisville, Kentucky, AAF is committed to protecting people, processes and systems through the development and manufacturing of the highest quality air filters, filtration equipment, and associated housing and hardware available today.

Contact your local AAF Flanders representative for a complete list of AAF Flanders Air Filtration Product Solutions.

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