AIR FILTRATION

AND THE USE OF HEPA FILTERS IN BIOLOGICAL SAFETY CABINETS

The Safer Choice

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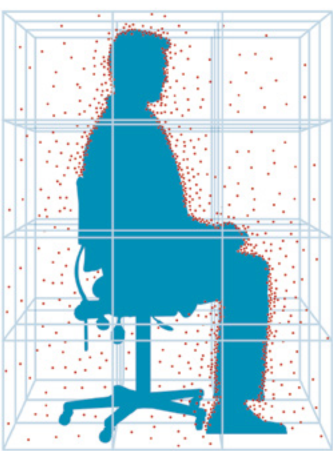
Efficient, high-quality, air filtration is instrumental in meeting occupational safety requirements, addressing environmental concerns, or improving indoor air quality in the home. Control of airborne particulate in indoor environments is critical to develop quality products, protect employees from contact with hazardous materials, or prevent health problems from prolonged exposure to allergens. How airborne particulate is controlled varies from industry to industry and from an occupational setting to a home environment. To better understand why HEPA filters are used in the biological safety cabinet industry, it is necessary to explore particle sizes, types of filters available for home and occupational use, efficiency and penetration, filter standards, and performance testing.

Particles and Relative Micron Size

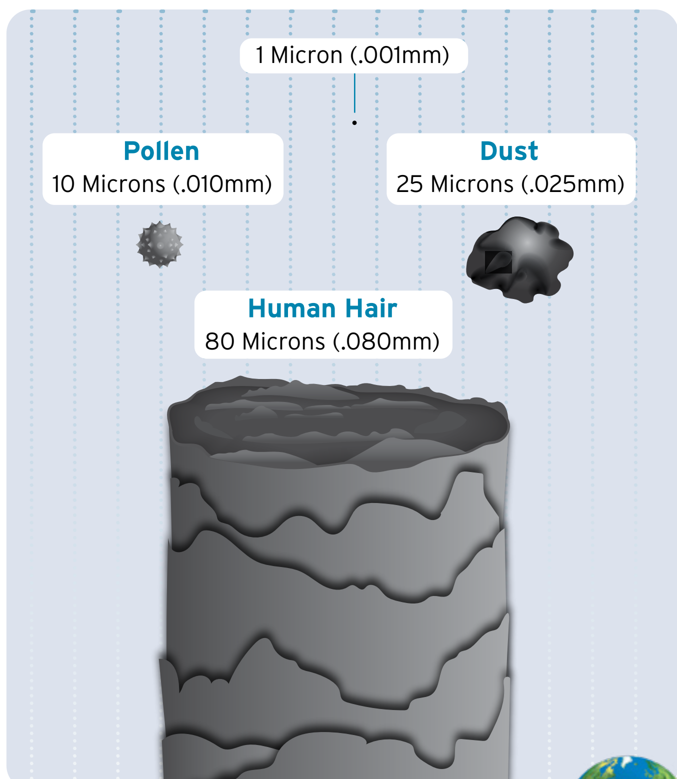
Particles are generated or become airborne with everyday human activity. Because many people spend the majority of their time indoors at work or home, the quantity of suspended particulate is of great concern. For example, a sedentary person in a standing or sitting position generates approximately 100,000 particles per cubic foot of atmosphere with which they are in contact. Standing up from a sitting position generates up to 2.5 million particles per cubic foot, while moderate activity generates up to 30 million particles per cubic foot of atmosphere. Industrial processes in manufacturing or machine shops generate billions of particles per cubic foot.



Particle dispersion generated by a sedentary person.

Airborne particles vary in size depending upon the source. A strand of human hair is a good reference point when considering the relative size of large and small airborne particles. Consider the following household materials and their relative size measured in microns (one millionth of a meter):

- **Human Hair:** 50-150 microns
- **Household Dust and Lint:** 0.01-100 microns
- **Pollen:** 10-110 microns
- **Mold:** 1-50 microns
- **Pet Dander:** 0.1-10 microns
- **Tobacco Smoke or Soot:** 0.01-1 micron
- **Viruses and Bacteria:** 0.001-10 microns



Why be concerned about the size of the above particles? Solid and liquid particles smaller than 10 microns can aggravate health conditions and cause respiratory problems in humans. A healthy human body can mitigate the effects of inhaling particles as small as the 3-5 microns via the respiratory system. However, exposure to smaller sub-micron particulate matter can present health risks in humans.

Home Consumer Air Filtration Products

Air cleanliness is a trend in the home consumer product market due to increased awareness of health problems caused by allergens. Consumers now have a wide variety of filtration products available to help control unwanted allergens including animal dander, dust, pollen, mold spores, and lint. While the following filters used in the household product industry are effective to a certain degree at trapping particulate matter suspended in the air flowing through them, note that none are effective at controlling vapors or odors.

Home HVAC systems can be fitted with conventional disposable fiberglass filters to trap large particles such as lint and dust. The primary function of such filters is to protect the heating and cooling unit from large particles prematurely wearing the fan motor and components. Because fiberglass filters are a flat design and the media is relatively porous, such filters are only 2% effective at trapping sub-micron particles.

Disposable, pleated media home furnace filters have folds in the filter media to increase the surface area of the filter in order to trap a wider size range of particles. Even with the additional filter media and increased surface area, this type filter will typically trap only 5-10% sub-micron particles.

Washable fiberglass media filters are also available for home HVAC systems. Despite the fact that these filters are reusable, the filters will retain some particulate after washing, thus reducing the life of the filter with every cleaning and increasing particulate retained in the filter.

Electrostatic charged filter media uses positively and negatively charged filter media to attract oppositely charged particles from the air passing through the filter. This feature is added to a pleated filter design to improve trapping of particles to the 0.3 to 1 micron range. The addition of the electrostatic charge improves trapping efficiency to 20-60% of sub-micron particles.

Electronic air filters are available as units fitted to a home heating and cooling system or as stand-alone filtering systems. These filters employ an electric field to attract and trap charged particles to plates within the system. While effective at trapping smaller particles, routine maintenance involves weekly or monthly cleaning for peak performance.

Ionic filtering systems add negatively charged ions to filter media to cause particles to adhere to one another in the air, creating larger particles that are more easily trapped by air filter media, or these filters cause particles to settle within the room. Ionic systems are commonly sold as stand-alone air purifying units.

Activated carbon filter systems can be added to an HVAC system to help control odors in the home. This type of filter is an absorbent filter that will retain certain vapors passing through it to control odors or chemical smells. Because it does not trap particulate, an activated carbon filter is typically used in tandem with another particulate retention filter.

High efficiency particulate air (HEPA) filters are becoming more commonplace in the household market. In the past, these filters where used primarily in the clean room and biosafety technology markets. However, HEPA filters have become a household name as consumer product manufacturers market HEPA filters to improve home air quality. Vacuum cleaners and HVAC systems are now often fitted with HEPA filters. Generally, HEPA filters are 99.97% efficient at the 0.3 micron particle size and are therefore very effective on sub-micron particles. However, as with any media-type filter, the surface area or the size of the filter and the number of air exchanges through the filter will ultimately determine how effective the filter is at retaining particles. For example, although many household vacuum cleaners have HEPA filters attached to the air intake on the vacuum, the diminutive size of the filter and the limited time the vacuum is operating during household cleaning compared to the size of the living space equates to a minimal effect on the overall air quality within the home.

In occupational settings, HEPA filters control particulates to protect the product, personnel, and environment or all three. Depending on the requirements within the industry, various types of HEPA filters are used to achieve the desired effect.

Biological Safety Cabinets and HEPA Filters

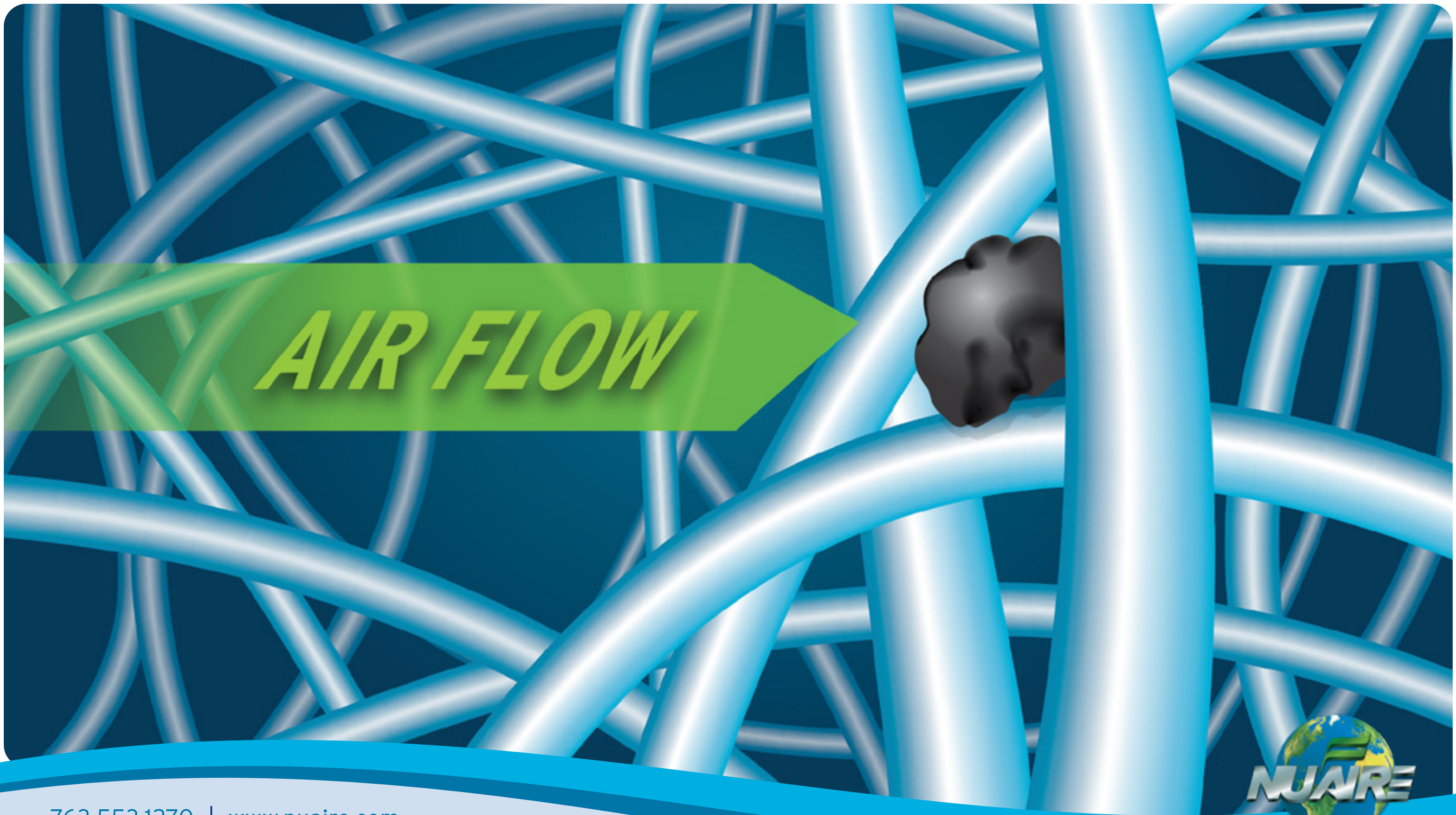
The efficiency rating of a filter describes the relationship between the number of particles retained by the filter to the number of particles which enter the filter. For example a 99.97% efficient filter indicates that 99.97% of particles of a given size range entering the filter are removed. A filter is also rated according to the size of particle most likely to pass through, or the weakest point of particle penetration. Filter penetration is defined as the ratio of particles which pass through the filter to the number of particles entering the filter.

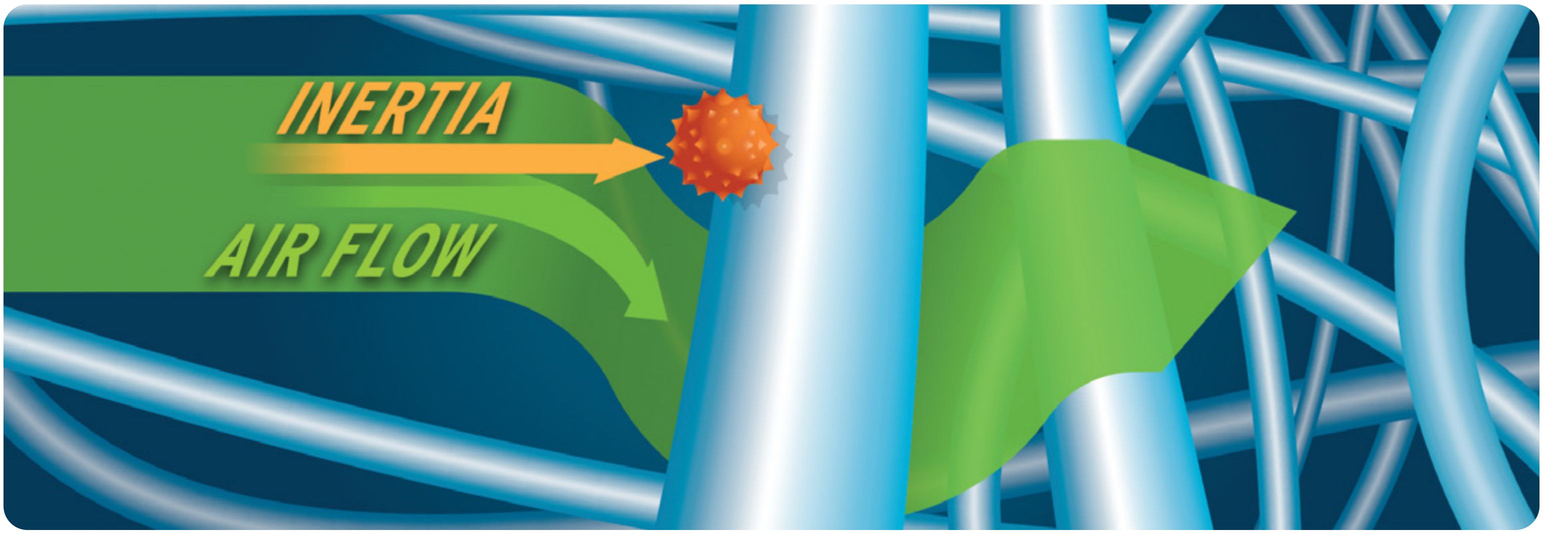
In biological laboratories, personnel regularly work with microorganisms in biological safety cabinets (BSCs). HEPA filters used in these cabinets must effectively trap hazardous bacterium and viruses to provide personnel protection. Although an individual virus particle ranges in size from 0.005 to 0.1 micron, viruses generally only survive to travel through the air as part of larger particles (0.3 micron or larger), for example, attached to mucous particles. Because it is difficult to disperse or aerosolize single viral particles and because of the particle collection mechanisms of HEPA filters, particles larger and smaller than a filter's most penetrating size are collected with greater efficiency.

Sieving

As the air comes into contact with the bends and folds of the pleated HEPA filter media, the volume of airflow divides into numerous smaller air streams as its own velocity and the velocity of the air upstream forces the air through the filter. Some particles become trapped because they are larger than the pores of the filter media, and cannot pass through. This process, known as sieving, takes place throughout the filter media, not solely at the surface.

Sieving - A particle is forced by air flow into an opening between filter media fibers of smaller diameter than the particle. The particle remains trapped within the filter.





Inertial Impaction - A particle continues on a straight path due to inertia rather than flowing around the filter media fiber in the same path as the air flow. The impact of the particle causes it to become lodged in the filter media.

Impaction

For particles having a diameter greater than 1.0 micron, the primary collection mechanism is impaction. Impaction occurs when air and suspended particles entering the filter contact a web of randomly positioned fibers in the folded filter media. Air flow can change direction relatively easily as it weaves through the filter fibers. However, due to inertia, the tendency of solid particles is to continue on the same trajectory and to collide with the filter media, resulting in entrapment.

Diffusion

For particles less than 1.0 micron in diameter, diffusion is the primary collection mechanism. Small aerosolized particles behave similarly to gases in that they move from an area of higher concentration to an area of lower concentration. Particles are removed from the air stream as they settle in areas of low air-stream concentration at the fiber surface where other particles are already trapped. The combination of aforementioned collection mechanisms results in effective removal of particles from a HEPA filtered air stream.

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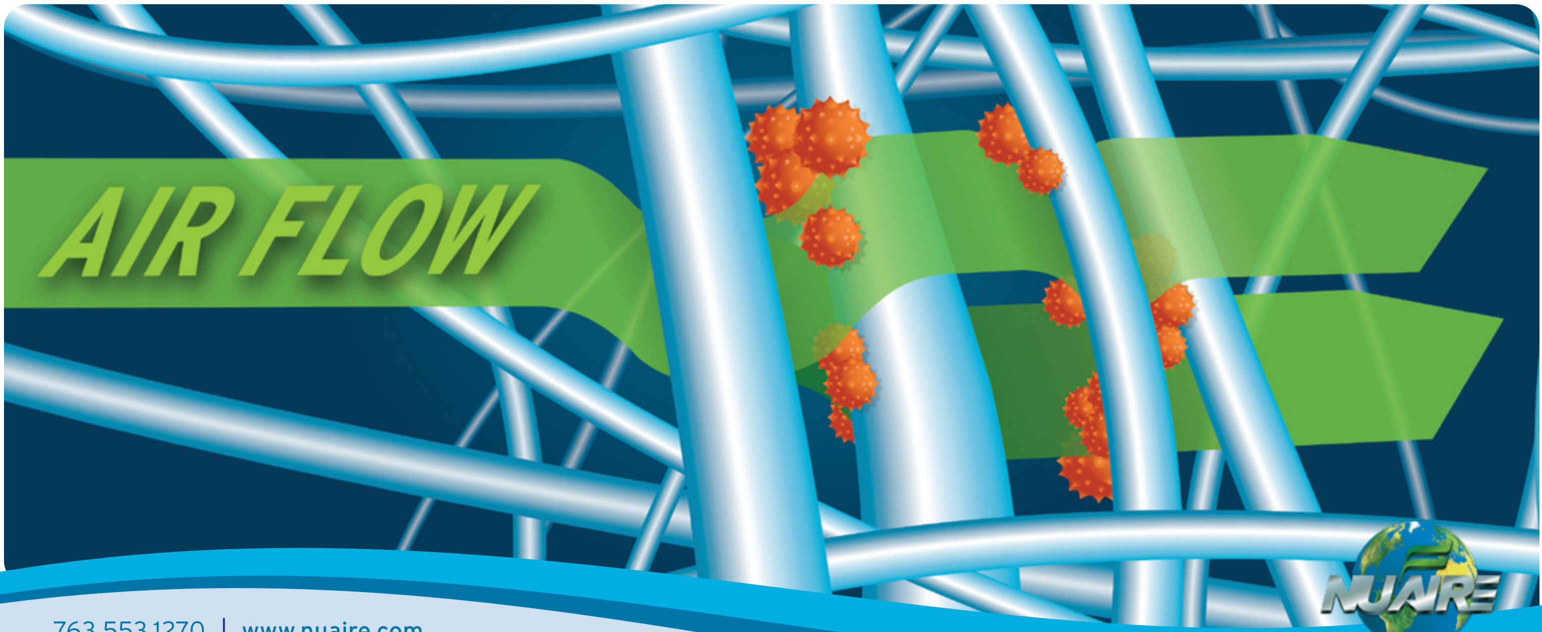
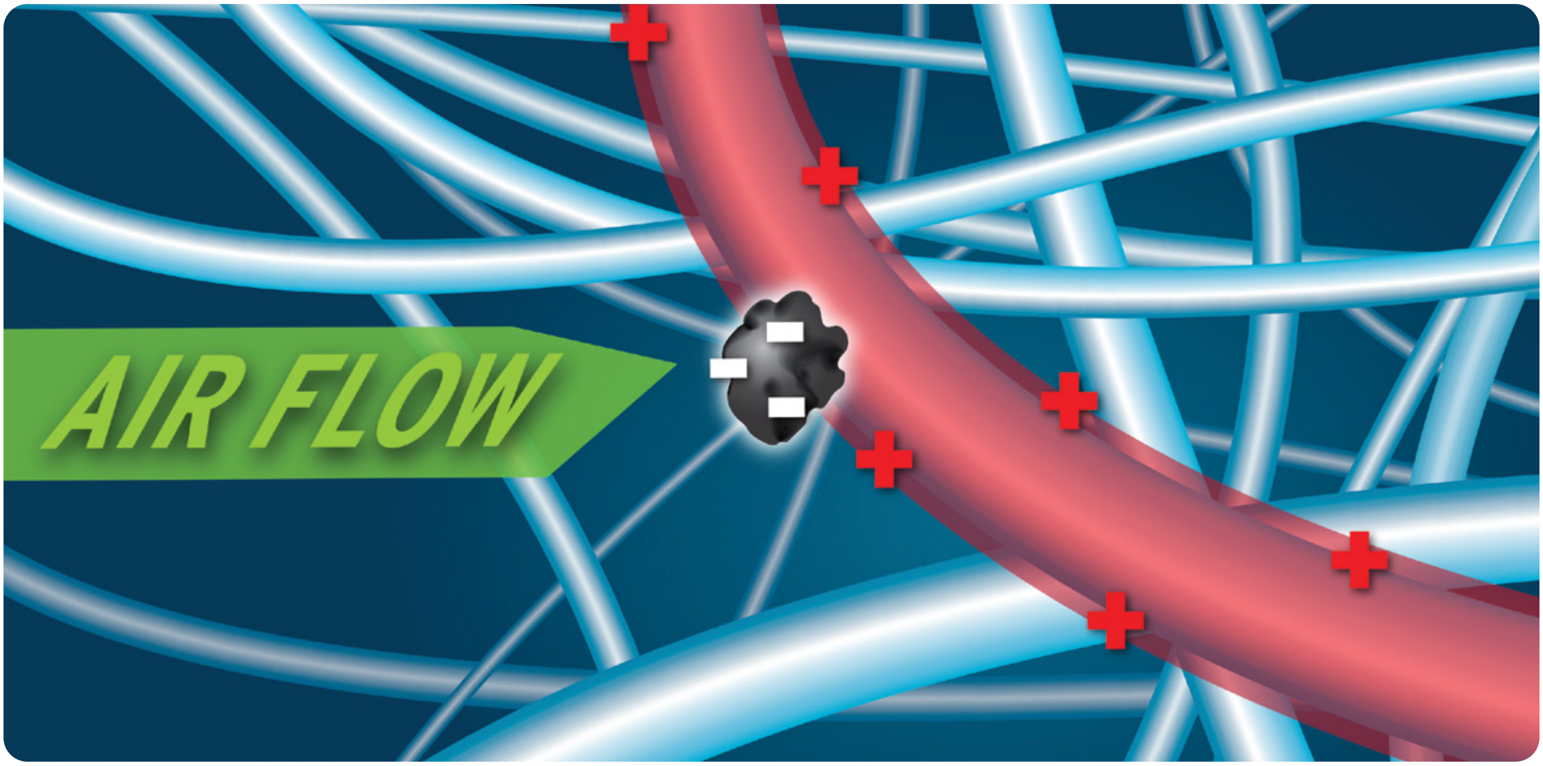
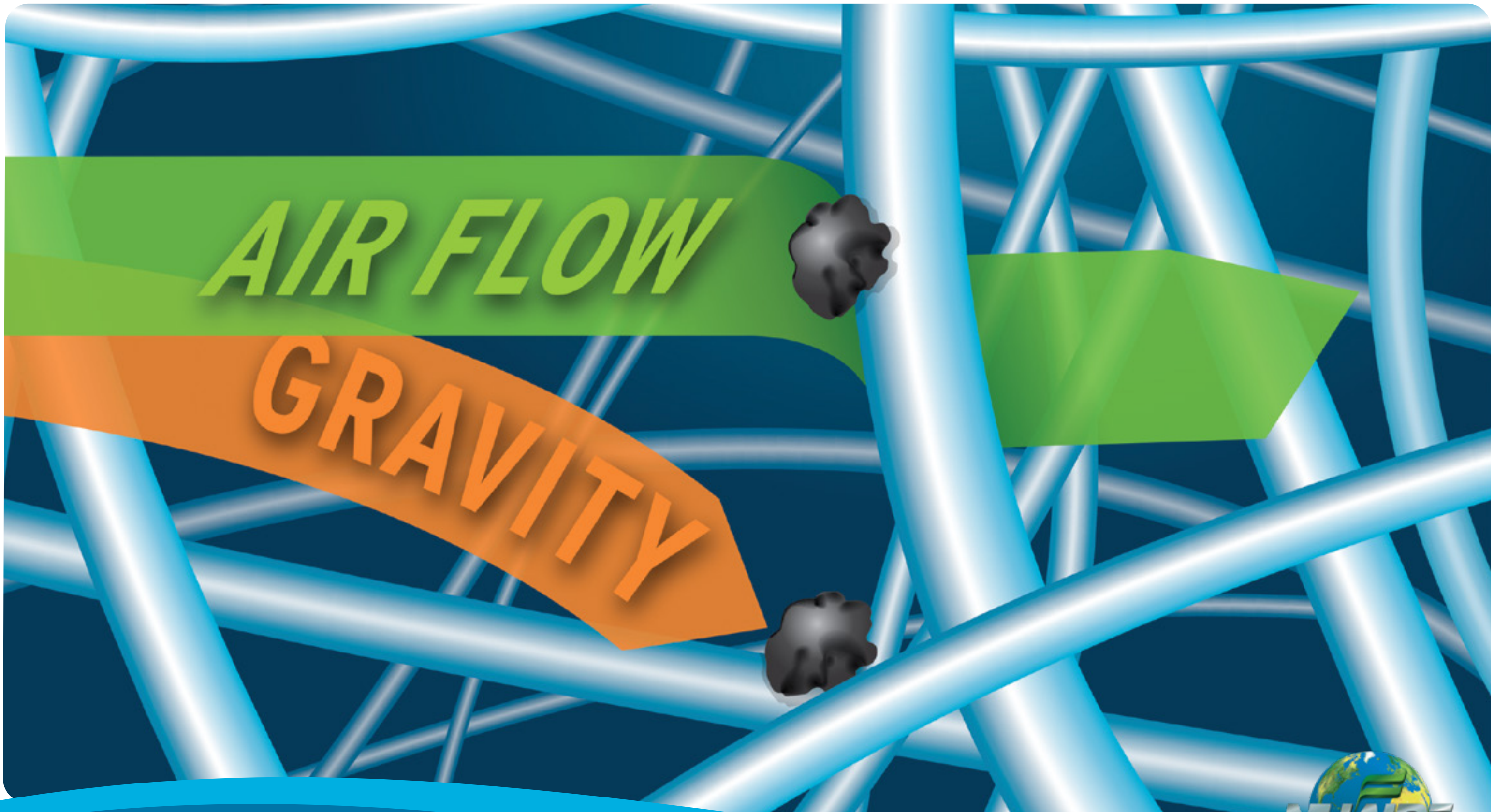




Electrostatic Attraction - A negatively charged particle adheres to a filter media fiber of opposing charge.

Interception - Particles traversing the filter are collected when they come into contact with a filter media fiber.



Filter Performance and Industry Standards

In the United States, the Heating, Ventilating and Air Conditioning (HVAC) industry uses filter efficiency ratings defined by American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) 52.2 testing. A Minimum Efficiency Reporting Value or MERV rating is assigned to each filter. A higher MERV value indicates better filtration. MERV ratings are used in home consumer products to give an indicator of the product's effectiveness.

In Class II biological safety cabinets, the type of filter required is defined by a standards organization. In the North America, the NSF/ANSI 49 details the construction and performance requirements of Class II biological safety cabinets. To comply with the NSF standard, Class II cabinets must utilize Type C HEPA filters that are 99.99% efficient at 0.3 microns for the supply and exhaust airflow. The types of HEPA filters available are classified and defined by the IEST RP-CC-001.6 standard on HEPA and ULPA filters according to the filter's efficiency and penetration at a specific particle size. Although other types of HEPA filters with different efficiencies are classified by the IEST standard, the Type C filter is the standard for use in biological safety cabinets.

HEPA filters are tested by challenging the filters with an aerosolized substance of known size to determine the filter's efficiency at that specific size. For example, Dioctylphalate (DOP) or more commonly used today Polyalphaolefin (PAO) is pressurized through a Laskin nozzle generator that produces the test size particles to challenge the up stream side of the filter. The filter is then scanned using a photometer, or aerosol detection device, to measure the mass of the particles in the airflow both upstream and downstream of the HEPA filter and to ultimately calculate the efficiency of the filter at the testing particle size.

In addition to HEPA filters, the IEST standard also classifies ULPA (ultra low penetration filters) and Super ULPA filters by type. Generally ULPA filters have a higher efficiency rating from 99.999 to 99.9999% at a smaller micron size (0.1, 0.2 or MPPS). It may seem that the higher efficiency of a ULPA filter would be desirable in a biosafety cabinet. However, the additional particulate removed by a ULPA filter would be either smaller, or at lower concentration, than is necessary in biological research. ULPA filters are primarily intended for use in industries such as semi-conductor manufacturing, where removal of smaller or more dispersed particulate is much more critical.

For biological applications, there is little gain in using a ULPA filter compared to a HEPA filter. As explained previously, microorganisms and viruses are not typically airborne in single particles, but rather are grouped together as larger particles or are attached to other particles in air. Use of an ULPA filter in a biological safety cabinet creates more resistance in the air flow dynamics of the cabinet, requiring a larger blower motor to maintain proper airflow. A larger blower motor will increase the noise level of the cabinet, and potentially increase vibration. Additionally, ULPA filters require a different testing protocol with equipment that is generally not maintained by biological safety cabinet certification companies. To test ULPA filters, aerosolized polystyrene latex spheres of specific size are introduced to the air stream. A laser particle counter then measures the size and number of airborne spheres to determine efficiency of the ULPA filter.

In Europe, the EN standard 12469 defines Class II biological safety cabinets and filters that must be used for compliance to the standard. The EN 12469 requires a class H14 HEPA filter as defined by the EN 1822-1 standard classifying HEPA and ULPA filters. An H14 HEPA filter is 99.995% efficient at its most penetrating particle size (MPPS). A specific particle size is not assigned in the classification of H14 filters. Per EN 1822-1, to test the filter for its MPPS, airborne particles are forced through the filter at the flow rate at which the filter will ultimately be used. A five channel particle counter reading particles 0.1, 0.2, 0.3, 0.4 or 0.5 microns in size is used to determine which channel allows the most particles through the filter. The MPPS is calculated by determining which particle size which has most frequently penetrated through the filter. As with the IEST standard for filters, the EN 1822-1 also includes classifications of other types of HEPA and ULPA filters. However, none is required for use in biological safety cabinets.

HEPA Filtration in Biosafety Cabinets

After discussing particle size, various filter options, particle collection mechanisms, and filter performance testing, it is evident why HEPA filters are the industry standard in biological safety cabinets. Particles generated in biological work fall into the spectrum of particles efficiently trapped by HEPA filters. It is a common misconception that ULPA filters, given their smaller MPPS rating, are superior to HEPA filters for biological applications. The known behavior of viruses and bacterium and the tendency of microorganisms to be dispersed in air as part of larger particles support use of HEPA filters for biological work. In addition to utilizing HEPA filters, a properly designed BSC must meet performance standards for airflow velocities, structural requirements, and proven product containment capabilities to ensure user safety. HEPA filtration, biological safety cabinet design and user technique combined provide occupational safety in the biological laboratory.

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