Donaldson.
Filtration Solutions

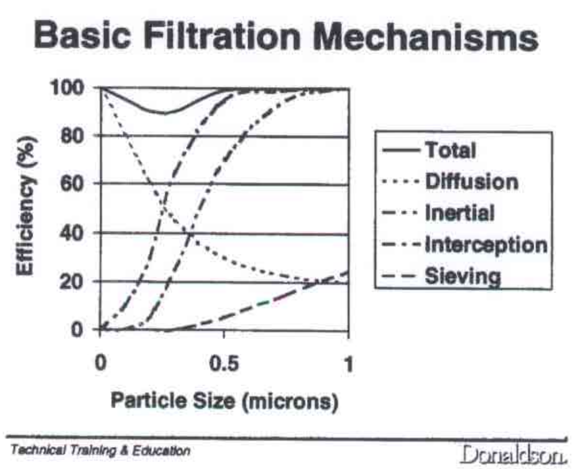
Donaldson Company Inc.
High Purity Products
PO Box 1299
Minneapolis, MN 55440

Tel: 612.887.3815
Fax: 612.887.3612

Aircraft Cabin Air Filters - Efficiency

Filter efficiency is a function of the size of the challenge contaminant. Therefore, an efficiency measurement is meaningless without information regarding the test method. A couple of test methods are most relevant to aircraft cabin filtration. The first is the ASHRAE 52 test method. This is used for relatively low efficiency filters and uses a contaminant mixture consisting of sub-micron carbon black, super-micron sand, and fibrous cotton linters. A measure of the portion of the contaminant that passes through the filter is then obtained and used to calculate what is referred to as the ASHRAE Dust-Spot efficiency.

The second commonly used test method is often referred to as MIL-STD-282 or DOP efficiency. The important aspect of this test is that the challenge used is 0.3 micron diameter oil particles. Historically, DOP or dioctyl phthalate has been used for the challenge source. Concerns over the safety of DOP aerosol have lead to the replacement of DOP in filter testing with other oils such as PAO. The relative concentration of the aerosol is measured upstream and downstream of the filter to determine the fractional efficiency. This test method is typically used for high efficiency filters. For filters of this type, 0.3 micron particles are a standard that approximates the most penetrating particle size (MPPS). Much of the public is not aware that filter efficiency increases as particles become larger or smaller than the MPPS. As particles become very small, the effects of Brownian motion allow the particles to impact on fibers not directly in their streamline. A standard microglass fiber filter media efficiency versus particle size chart is shown below.

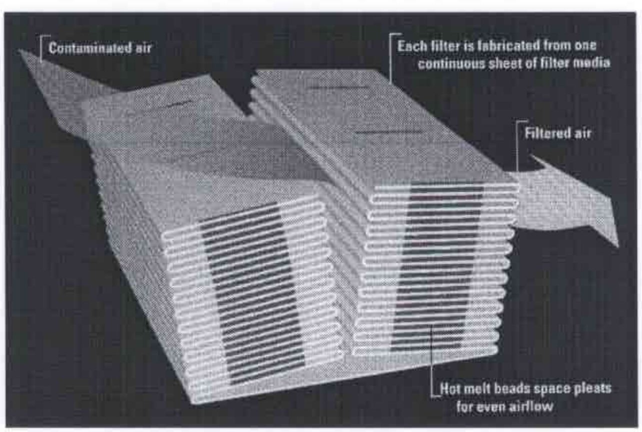


Because filter efficiency on 0.3 micron particles is much lower than it is on all of the components of ASHRAE test dust, a filter rated as 95% ASHRAE Dust Spot, is probably less than 50% efficient on 0.3 micron particles. Although the MIL-STD-282 test method is well recognized, it is extremely out of date with available technology and safety requirements. IEST (Institute of Environmental Sciences and Technology) has published an efficiency test method for high efficiency filters (IES-RP-CC007.1) which addresses these problems and is becoming an industry standard. Other test methods besides these also exist for measuring filter efficiency at or near the MPPS such as BS 3928 and DIN 24184.

Aircraft designed in the late 1960's and into the 1970's, such as the Boeing 747, 757, and 767 and McDonnell Douglas's MD-11 and MD-80 utilize recirculating air and were equipped with filters that ranged in efficiency from 95% ASHRAE Dust Spot to 95% on 0.3 μm particles. These filters are typically constructed of pleated microglass fiber media with aluminum separators to maintain pleat spacing. When compared to filters used in other enclosed environments such as office buildings, restaurants, and homes, the efficiency levels of these filters are high. Studies of the particulate levels on commercial aircraft, other public transportation, other public facilities, and outdoors, the have repeatedly found that with 95% (@ 0.3 μm) filters, aircraft cabin air is among the cleanest available. For example, the Harvard School of Public Health found particle concentrations of 3 to 10 $\mu g/m^3$ on aircraft during cruise compared to 150 to 410 $\mu g/m^3$ measured on trains. Other studies have found particle concentrations of 150-200 $\mu g/m^3$ on airplanes.

Although technical data is available regarding the cleanliness of air with 95% (@ 0.3 μm) filters, the public opinion of air quality aboard aircraft has degraded over the last decade or two. Some of this is attributable to an overall increase in awareness in air quality by the public. People are more aware now then they were 20 years ago that the air they breath can have serious effects on their health. Lawsuits regarding asbestos, second hand smoke, sick office syndrome, and the liability of cigarette manufacturers have given a great deal of publicity to air quality. The threat of similar lawsuits has resulted in a response from those responsible for public transportation and facilities to take all actions available to provide air quality consistent with best available technology.

Achieving high efficiency levels (99.9% and above) on 0.3 μm particles in an aircraft cabin filter is well within the filter industry's capabilities. Filter efficiencies as high as 99.9995% on 0.3 μm particles are currently manufactured for the cleanroom industry. The difficulty arises when higher efficiency is needed within the size and life constraints previously defined for lower efficiency filters. To give some idea of the scope of the challenge, consider that a move from a 99% filter to a 99.9% filter is not a 0.9% improvement, but actually an order of magnitude decrease in the number of particles allowed to pass through the filter (0.1% versus 1%). Therefore the move from 95% filters to 99.97% filters is actually a 167x decrease in penetration levels. Increases in filter media efficiency come at the expense of filter media restriction. For this level of efficiency change, media restriction increases by about 80%. A direct substitution of higher efficiency media into 95% (0.3 μm) filter will lead to a much higher pressure loss and a decrease in the filter life. In order to achieve the goal of higher efficiency with equal life and size, filter manufacturers have adopted media packaging techniques that increase the amount of media in a filter. A common approach for doing this is through the use of very high pleat densities and short pleat heights. The pleated element is then arranged within the filter frame to form multiple V's. An illustration of this configuration is shown below.



The use of increased amounts of media reduces the air velocity through the media, thereby reducing the restriction. The decrease in element restriction by increasing pleat density cannot occur if pleat spacing is not done precisely. Variation in pleat spacing distance will result in ineffective use of all of the media in the filter and short life. Although a much more difficult filter to produce, 99.97% (@ 0.3 μm) efficiency with equal or better filter life has been achieved within the space originally specified for 95% (@ 0.3 μm) filters.