# The HEVAC Guide to Filtration

# A Training Manual

# 2008 Issue

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# HEVAC Guide to Filtration

**Contents**

# Air Filtration - Training Manual

## 1. Introduction

This manual has been prepared especially for use by heating, ventilation and air conditioning engineers and specifiers as a valuable source of reference. It contains in-depth information on aspects of air filtration, which we are sure will be of benefit to all who will use it.

A knowledge of the current filter test methods and standards covering air filtration for general ventilation and air conditioning is necessary when comparing and selecting products being offered by filter manufacturers.

### 1.1 The Need for Filtration

The air we breathe is a mixture of gases, principally Oxygen and Nitrogen. It also contains particulate material and gases generated by nature, by man and by industrial processes.

Principal sources of this contamination are particulates generated by construction and demolition, carbon, oil and exhaust fumes from traffic and other combustion processes, such as fly ash from stack and chimney emissions. Natural causes are elemental erosion of the landscape and buildings as well as eruptions etc. Others include sea salt, sand, pollen, moulds, bacterial spores. More localised sources of dust are ourselves, generated by the shedding of skin, and fibres from the clothes we wear.

Basically, the air that surrounds us is **not** clean.

We are concerned with the particulate matter and gases which influence our health and comfort, which affect the spaces we occupy, the products we manufacture or the equipment we use.

Regardless of it's source, an airborne contaminant is classified as either an aerosol or a gas.

An **Aerosol** is a suspension of solid or liquid particles in the air. There are different aerosols depending on how they are generated.

Dusts are solid aerosols generated by the reduction of larger solid materials. Typically large dust particles (those greater than 10.0 microns) settle rapidly and smaller dust particles (in the range 1.0 to 10.0 microns) tend to stay suspended in the air by currents or to settle very slowly. On the other hand, particles in the range 0.1 to 1 microns have negligible settling velocities.

Fumes are solid aerosols formed by the condensation of vapours of solid materials, such as are caused by an arc welding process. Very small fume particles tend to agglomerate forming larger particles.

Fogs are liquid aerosols formed by the condensation of water vapour.

Mists are liquid aerosols formed by the atomization of liquids.

Smokes are liquid or solid aerosols formed by the incomplete combustion of organic substances.

**Gases** are materials existing as molecules, which have the tendency to expand indefinitely to uniformly fill the container, or space they occupy. Gases are formed in chemical processes where they are deliberately prepared for other uses or where they may be the unwanted by-products which are either leaked or vented deliberately through stacks or chimneys.

Gases which can be of particular nuisance are also formed as a result of the more obvious biological processes relating to sewage, and from plastics and other materials used in the manufacture of household items such as furniture and floor coverings.

Vapours are gases formed by the evaporation of materials which are normally solid or liquid.

## 1.2 **The Importance of Air Filtration**

Air filtration provides the means of obtaining the level of particulate cleanliness required;

a) To provide healthier and more comfortable living and working conditions for occupants of buildings.
b) To reduce the risk of infection in hospital 'critical areas' or other related environments.
c) To prevent the contamination of foodstuffs, pharmaceutical products and delicate electronics during manufacture.
d) To prevent the build up of contaminants on heater or condenser coils and other ventilation system components.
e) To protect expensive or delicate machinery from avoidable wear and subsequent maintenance and/or replacement.
f) To prevent the ingress or emission of hazardous substances.

When specifying or selecting secondary filtration grades it is important to consider particle penetration as opposed to stated filter efficiency.
Section 6.3.3 provides an example of particle penetration for filter grades F7,8 & 9 and includes a HEVAC Filter Group recommendation for the minimum grade of secondary filtration to be specified.

## 1.3 General Air Filtration

In general air filtration takes place in one of three scenarios. The filtration of atmospheric inlet air to a system, process or occupied space, the filtration of internally recirculated air and the filtration of exhausted air from the system, process or occupied space to the atmosphere.

The need for filtration is therefore unquestionable and consequently the vast majority of applications relate to inlets for ventilation, air conditioning and process machinery.

For HVAC applications air enters a building by means of a Air Handling Unit or AHU and is filtered for a variety of reasons so that the cleanliness of the filtered air is sufficient to meet the requirements of the application. Once air has passed through an AHU it will have been through several stages of progressively finer filtration. AHU's can also contain heating and cooling coils, as well as humidifiers.

When air emerges from the AHU and enters the ventilation ducting, it is regarded as being 'conditioned', and is ready to be ducted to whatever application it has been processed for.

Once inside a building, the air is constantly being re-contaminated by means of internally generated particulate from industrial processes or the occupants and fittings. To maintain the cleanliness in the building, the air is re filtered through a separate filter installation, namely the recirculation system. If the industrial process produces excessive particulate this would be extracted to atmosphere by means of a specific filtration system.

Recirculation provides the means of changing the air within an occupied space without replacing it with conditioned air from outside. This facility has significant benefits for operating costs. The accepted standard for the amount of air changes is 0.8 $l/s/m^2$ for unoccupied space, and 5 l/s/person in occupied space. Typically, such systems operate on a 90% recirculation with 10% make up of fresh 'conditioned' air.

As can be surmised from the information provided, the range of applications and operating conditions varies enormously. This in turn has led to the development of a comparable range of filtration devices and systems to cater for these applications.

## 2. **Filter Facts**

### 2.1 **Glossary of Terms**

Terms related to air filtration have been standardised since the previous issue of this document.

The primary reference for air filtration terms in Europe is EN 14799 : 2005 Air filters for general air cleaning – Terminology

### 2.2 **Useful Conversions**

Conversions of units are readily obtained using one of many good quality widely available freeware converters.

## 3. **Basic Principles of Filtration**

Simply put, air filters are devices that remove particulate from an air stream as the particulate laden air passes through them.

There are two basic types of air filters: Mechanical air filters and Electrostatic air filters.

### 3.1 **Mechanical Air Filters**

Mechanical filters remove particulate by capturing it on the filter media (the material that comprises the filter element. There are four different processes responsible for the capture of the particulate. One of these mechanisms usually predominates in a specific filter, but rarely is it exclusive.

* Impingement
* Interception/Diffusion
* Straining
* Adsorption

A fifth mechanism is applied to a range of media free filters.

* Inertial separation

*Impingement* is the mechanism by which large, high density particles are captured. As the particulate laden air passes through the filter media, the air tends to pass around the fibres. Inertia of the particulate causes it to separate from the airstream to collide with the fibres to which they become attached.

*Interception* occurs when a particle follows the airstream but still comes into contact with a fibre as it passes around it. If the forces of attraction (electrostatic in nature) are stronger than those provided by the airstream to dislodge it, the particle will be retained.

*Diffusion* occurs specifically with very small particles which follow irregular patterns in a manner similar to gases, not necessarily following the airstream. This irregular pattern is known as Brownian motion and increases the particles chance of capture through contact with the fibres.

*Straining* is the most basic form of filtration, where the smallest dimension of the particle is larger than the space between adjoining fibres.

*Adsorption* is the mechanism used by carbon filters to remove gases and vapours from the air. The porous characteristics of the carbon surface allows it to adsorb contaminants as they come into contact with it much like the ability of a sponge to retain water.

*Inertial* filtration is similar to the impingement principle, but without the presence of media. The filter system utilises acute changes in direction of the airstream to separate the particulate. The separated particulate is normally collected or extracted to atmosphere.

### 3.2 **Electrostatic Air Filters**

Electrostatic air filtration devices often referred to as electronic air cleaners, typically have high efficiency allied to low air resistance to airflow, and will usually consume significantly less energy in operation than conventional barrier filtration types.
In operation the dust laden air passes through the ionisation section of “collector cells” in which the particles of dust are charged (ionised), and then collected on downstream plates parallel to the airstream

Ashrae 52.1 efficiency for the “washable” type electrostatic devices is typically 90% and this efficiency is delivered the instant the system is energised.
These “pure” electrostatic devices, as opposed to passive devices such as electrets, may have a typically 50 Pascal resistance at 2.5m/s which is constant throughout its operational period. Barrier filtration types will in comparison, have a higher initial resistance, allied to increasing resistance and efficiency characteristics throughout their life.

A typical electrostatic power pack to deliver 12KV at 32ma for ionisation, consumes 500 watts.
A single 500 watt power pack could handle a volume of up to 20m3/s.
This energy consumption may be considered insignificant when compared to the extra energy required to overcome alternative higher resistance barrier filter types throughout their system operational resistance life.

Their use for general air conditioning applications has declined considerably, due to their high initial capital cost.
Typical industrial applications will be to remove nuisance dusts and fine fumes, to a high level and improve the “in-plant” environment.

In general electrostatic filter types should not be used on air containing, water droplets, explosive gases, or where maintenance is likely to be problematic

The elimination of the consumption and subsequent disposal of spent barrier filter types, could be considered another positive environmental benefit accrued from electrostatic filtration.

**Ozone**
Devices employing high voltage or electrical arcing generate small amounts of ozone.

Office copiers, arc welders, ultraviolet lamps, hand drills and all electronic air cleaner products produce some ozone.
No commercial electronic air cleaner should produce ozone in dangerous quantities and should be significantly lower than the 0.10ppm OSHA standard.

### 3.3 Factors relating to Filter Performance

Media filter performance is essentially determined by the properties of the material used to actually do the filtering, known the 'media'. As described in 3.1 the various mechanisms for removing the contaminant from an airstream rely on the interaction between the particles and the fibres that make up the filter media.

Imagine a simple woven mesh cloth. Logic tells you that the coarser the weave and thread, the larger the openings, or pores, between the fibres. Conversely, a fine weave with the same thread will have smaller pores between the fibres. If this material is used as a simple filter, the mechanism would be sieving, ie all those particles whose largest dimension was less than the pore size would penetrate.

The effectiveness could be improved by using multiple layers to increase the probability of a particle coming into contact with a fibre. Alternatively, progressively smaller diameter fibres can be used. This sieving method of filtration was the basis of the technology available today. With weaving, there are always pores where the fibres interlock, and there is therefore a limit to the effectiveness of such filters.

To remove the finest particles, techniques were developed to randomly lay down very fine, even micro fine fibres, in such a manner that virtually no direct path exists through the material.

Consequently filters are made of a range of materials which vary in complexity and expense depending on the required effectiveness of the filter.

To summarise, the media characteristics that determine performance are governed by parameters such as :

Fibre diameter or range of diameters.
Fibre length or combination of lengths.
Fibre Orientation.
Packing density.
Pore size.
Pore size distribution.
Thickness or loft.
Surface weight.
Method of media manufacture. i.e Needling, weaving, resin impregnation, thermal bonding etc.

Filter media of whatever type is essentially a permeable barrier, which when placed in an airstream, produces a resistance to the free flow of air due to the blockage, in the form of pressure loss.

The degree of blockage is dependant on the type, orientation, and packing density of the fibres which make up the media. As a result, for a particular area of filter media confronted with a particular airflow, different types of media give a wide range of flow resistance or pressure loss values.

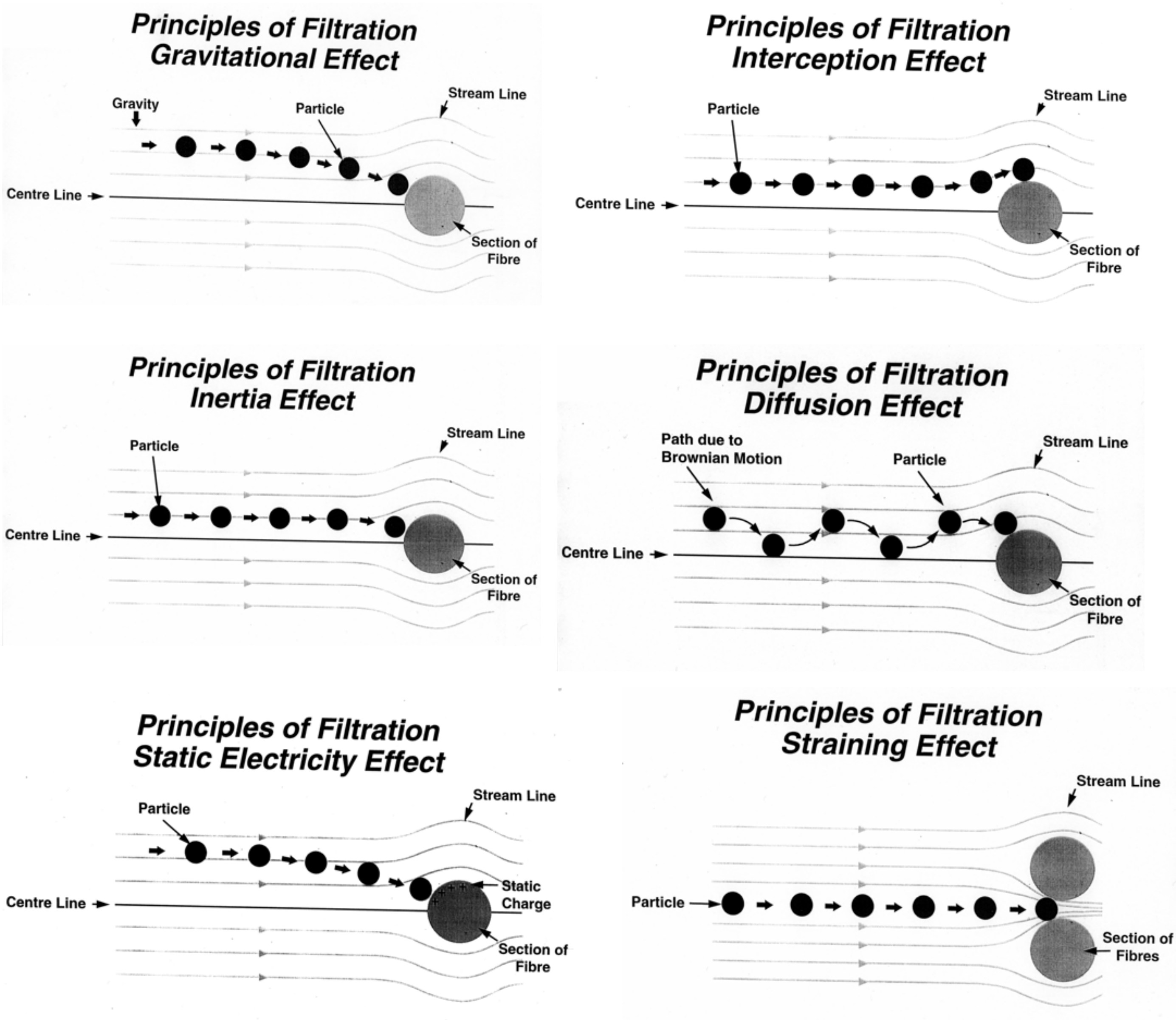
If the filter is not a media type it will generally be a mechanical or inertial device. In these cases the pressure loss is as a direct result of the resistance to the free flow of air caused by the position and orientation of impermeable surfaces.

Pressure loss is quantified by Bernoulli's equation, which when analysed, results in the expression:

$$P_2 - P_1 = K \quad 2\ \rho\ V^2$$

| | | | |
|---|---|---|---|
| Where: | $P_2 - P_1$ | = | The difference in total pressure across the installed filter in Pascals (Pa). |
| | K | = | Non dimensional loss coefficient of the installed filter. |
| | $\rho$ | = | Air density in $kg/m^3$ |
| | V | = | Face velocity of the installed filter in m/s. |

The expression $2\ \rho\ V^2$ is known as the dynamic pressure, which is often noted as q. As K is essentially non dimensional, the pressure loss of a filter is dependant on density and filter face velocity. It is however the case that filter media are compressible and hence vary in permeability. For this reason the coefficient K tends to vary at velocities above 1 m/s.




Principals of Filtration - Illustrated

## 4.0 Size of Contaminants

### 4.1 General

The unit of measurement which is appropriate to air filtration technology particle sizing is the 'micron', or micrometer. (see 2.1) What is not normally considered is the aspect ratio of particles, that is the ratio of length to diameter. If for example a particle is 10 microns long and 1 micron wide, it will be assumed to be a ten micron particle. Few particles are spherical, most are irregular in shape and form and vary between crystalline and fibrous.

The smallest particle which can be seen by the human eye without the aid of magnification is approximately ten microns. More than 99% of the particles which are present in the air are below one micron.

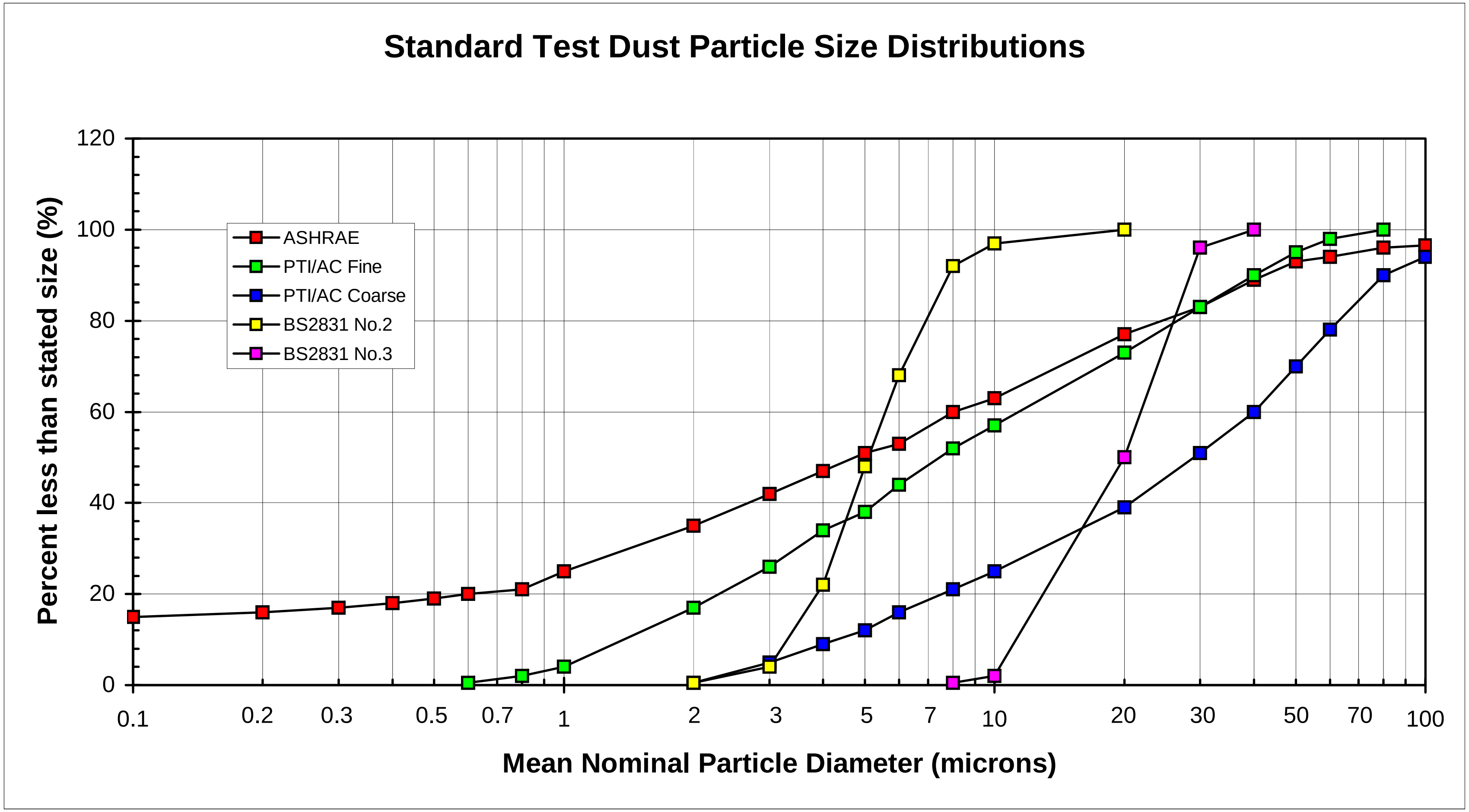
Particle concentration: In the average industrial area there are around two and a half billion particles per cubic foot present in the air, although the levels of concentration will vary considerably depending on location, elevation and season. (See attached chart)

Particle sizes of between 0.3 and 50 microns will normally be considered when making a filter selection.

The attached particle size distribution for common test dusts shows the percentage of a dust less than the stated size. i.e. for the most common test dust ASHRAE, it can be seen that 50% is less than 5 microns, and 25% is less than 1 micron. The effective density of ASHRAE dust is approx 770 $kg/m^3$. In comparison, another common test dust is SAE Fine (or PTI Fine). This dust has 50% less than 7 microns, but only 4% less than 1 micron. The effective density of SAE Fine is 1270 $kg/m^3$. These dusts when used as a challenge will result in significantly different filter performance properties.

For example: loading characteristics of a particular type of filter depend on particle size of the challenge, the media velocity, the type of media, etc etc. (see section 5) Care must be taken to compare filter performance to ensure that the test parameters are similar.

'Atmospheric' dust is generally very small and remains almost perpetually airborne if less than 2 microns. It is claimed that 99% is actually less than 3 microns, and consequently it is almost impossible to artificially duplicate.


Standard Test Dust Particle Size Distributions
ASHRAE
PTI/AC Fine
PTI/AC Coarse
BS2831 No.2
BS2831 No.3
Percent less than stated size (%)
0
20
40
60
80
100
120
0.1
0.2
0.3
0.5
0.7
1
2
3
5
7
10
20
30
50
70
100
Mean Nominal Particle Diameter (microns)

**Typical contaminants, concentrations and size range per environment**

| Environment | Rural | City | Industrial | Desert | Tropical | Arctic | Mobile | Marine |
|---|---|---|---|---|---|---|---|---|
| **Particulate** | Insects, Vegetable matter, Dust | Carbonaceous matter, Dust, Insects | Hydrocarbons, other effluents | Fine and coarse sand particles | Insects, Vegetable matter | Snow, Ice, Insects | All forms | Salt, Ice, Dust, Insects |
| **Concentration (mg/m$^{3}$)** | 0.01 to 0.1 | 0.03 to 5 | 0.1 to 10 | 0.1 to 700 | 0.01 to 0.25 | 0.01 to 0.2 | 0.01 to 700 | 0.01 to 0.10 |
| **Particle Size (μm)** | 0.01 to 3 | 0.01 to 10 | 0.01 to 50 | 1.0 to 500 | 0.01 to 10 | 0.01 to 10 | 0.01 to 500 | 0.01 to 5 |

## 4.2 Types and Sizes of Contaminants

**Particulates** are regarded as solid matter which are carried by an airstream or remain suspended in air. Size range: ≥ 0.01 microns.

**Fibres** occur in natural and synthetic materials. Their structure is thread like, their length being several times greater than their diameter.
Natural fibres include: Cotton, Wool, Silk, Asbestos. Synthetic fibres include: Nylon, Polyester, Glass.

**Smoke** is a visible airborne product emitted from burning Carbon based material. Smoke contains ash and soot particles which makes it visible. Particles of smoke range in size from 0.01 to 1 micron. Smoke also contains CO and $CO_2$, as well as water vapour.

**Gases** and **vapours** contain molecules with sizes of the order of 0.004 microns.

**Viruses** have a rod like structure which measures approximately 0.04 microns in length and 0.005 in diameter.

**Bacteria** are larger, measuring upto 30 microns in length and 0.2 microns in diameter.

**Pollens** range in size from 10 to 100 microns.

**Plant spores** range in size from 10 to 30 microns.

**Aerosols** are split into various 'modes' which define their characteristics. **Coarse** mode aerosols are greater than 2 microns. **Intermediate** mode at between 0.1 and 1 micron, and **nucleic** mode at less than 0.3 microns.

## 5. Filter Testing/Standards

Testing of filters is generally carried out to show compliance with process specifications or as a comparative indicator between different filters.

In general filtration it is normal practice to manufacture filters based on development test results, and then to type test on an as required basis. All similar filters are then deemed to have comparable performance to the test filter. Manufacturers may or may not have controls in place to check media on receipt or during the manufacturing process itself.

Type testing on batch produced filters is very rare, consequently the variation of 'off the shelf' filters in terms of performance, even if process controls are used, can be significant, and if it occurs, is generally attributed to manufacturing and testing tolerances. The effect of these controlled variations on the end user tend not to be noticeably significant. It is however variations outside acceptable tolerances resulting from a lack of control which tend to lead to process difficulties for the end user.

The requirement of testing from the users point of view is that it allows comparisons to be made between competitive products under perceived identical conditions. It is however the operating conditions of the filter that will be critical, and therefore there are several key concerns.

a) With what efficiency will the filter remove the contaminant in question? Will it be sufficient to meet the requirements?
b) Will the life of the filter be sufficient to make the maintenance interval economic?
c) What is the operating energy cost of the filter? Is the pressure loss range from installation to replacement sufficient?

All filter test methods attempt to address the validity of direct comparisons between similar products that will allow the process of evaluation to take place.

It is vital that any engineer considering obtaining supplies of filters from a manufacturer clearly understands that the filter test data he is presented has been achieved under standardised, and therefore idealised laboratory conditions. The information can only be used as a comparison with other equivalent data. It can however be used as guidance to estimating in service performance. The best possible evaluation is based on actual operating performance.

The growth of the HVAC industry, and the need to be able to achieve comparisons and evaluations, particularly in the 60's and 70's, spawned a number of test standards on both sides of the Atlantic, all of which were application limited and none addressed the problem of how to test all the various types of air filters that were available.

It was ASHRAE, the American Society of Heating Refrigeration and Air-conditioning Engineers who first launched a widely applicable test standard. ASHRAE 52-68. This was subsequently updated to form the most widely adopted test standard ever developed, ASHRAE 52-76.

ASHRAE 52-76 was adopted in UK as BS 6540 part 1:1985

ASHRAE 52-76 was adopted in Europe as Eurovent 4/5 recommended practice.

Eurovent 4/5 used the EU classification ideas from DIN 24185 in conjunction with ASHRAE 52-76 to produce a test standard that was widely adopted within Europe, although the basic methodology was unchanged.

ASHRAE 52.1-1992 made some refinements to the original standard, but the major change related to the EU classification system originated in Europe.

Eurovent 4/5/ASHRAE 52.1.9 -1992 were co-adopted with some slight modifications as EN 779 in 1993, a European standard common in all participating countries.

For the past twenty years, the characteristics of general ventilation filters have been established using the ASHRAE 52-76 method. The conventional nature of the method is no longer sufficient to reflect the more and more technical approach to describing filter and filtration characteristics.

The significant developments in aerosol metrology that have been made allow individual particles to be characterised by size. The effectiveness of filters to remove specific particle sizes, otherwise known as *Fractional Efficiency*, gives an unparalleled opportunity to fully characterise the behaviour of a filter.

The particular emergence of Indoor Air Quality concerns and cleanliness requirements for industrial processes requires the knowledge of Fractional Efficiency characteristics to select the appropriate type of filter.

New standards have been developed to meet this need since the previous issue of this document.

Standardisation work is continuing with the re-establishment of the ISO technical committee on filtration. TC142 will be responsible for the development of a worldwide filter standard based on a combination of ASHRAE 52.2:2001 and EN 779:2003. This work commenced in early 2005. Anticipated completion would be in 2008.

## 5.1 General Ventilation Filter Test Methods

### i) ASHRAE 52.1-1992 (was 52-76)

ASHRAE 52.1-1992 describes two test methods for evaluating the performance of air filters. The first method covers the 'determination of atmospheric dust spot efficiency', the second method covers 'determination of synthetic dust weight arrestance'. In addition to the two performance methods, procedures for dust loading and average efficiency and average arrestance are covered.

The notion that efficiency is related to 'the dust spot method' and arrestance to the 'synthetic test dust method' is introduced. Limits of acceptability for the test are also indicated.

*Efficiency* is determined by comparing the discolouration of two sampling filters, one sampling atmospheric air upstream of the filter under test, the other on the downstream side. As the filter will remove some of the atmospheric dust, the downstream sample will be less discoloured than the upstream sample. A light meter is used to measure the discolouration. Filters with efficiencies below 20% and above 98% are not suitable for this test method.

*Arrestance*, as defined in section 2, is a measure of the ability of an air filter to remove a synthetic dust from the air. In the case of the ASHRAE standards, this dust is clearly defined. The dust is as implied synthesised from a mixture of materials in a consistent manner to produce a universal test dust. The dust is fed in known quantities for known intervals upstream of the test filter. The amount of dust retained is compared to the dust fed to achieve the incremental arrestance value. The increments are summated to calculate the average arrestance and the dust retained. The arrestance or *gravimetric* efficiency test is that common to all tests using standard test dusts.

*Dust Holding Capacity* (DHC) or dust retained by a filter is recorded by taking the total amount of dust fed through the test from the beginning to the point where the filter reached it's recommended final resistance, and multiplying it by the average synthetic dust weight arrestance.

The major disadvantage with the ASHRAE test method is the time required to complete a test. Up to 6 working days for a medium efficiency product. The inconsistency from test rig to test rig due to the variability of the localised atmospheric aerosol was the major source of controversy.

ii) **ASHRAE 52.2.2001**

ASHRAE 52.2 is the new ANSI standard for testing general ventilation air cleaning devices for removal efficiency by particle size.

The test procedure uses laboratory generated Potassium Chloride particles 0.3 to 10 μm as the challenge aerosol. Particle sizing is carried out using optical particle counters.

The standard also delineates a method of loading the air filter with synthetic dust to simulate field conditions. A set of particle size removal curves at incremental dust loading levels are combined with the clean filter performance to produce a composite curve representing the minimum performance in each size range. The data on the composite curve is used to determine the filter classification.

Coarse filters are still tested in accordance with the ASHRAE 52.1-1992 method.

The standard establishes performance criteria for the equipment required to carry out the tests, it defines methods of calculating and reporting the results obtained from the test data and establishes the performance classification system.

The cost of the equipment and the problems associated with the corrosivity of Potassium Chloride were seen as the main obstacles to the wide introduction of the standard.

iii) **EN 779:2002**

This method is based on the Eurovent 4/9 recommended practice.

The new test method has the following objectives:

- To establish filter characteristics in terms of human health risk from given aerosols. (for example PM2.5)
- To establish filter characteristics in terms of cleanliness constraints within a process.
- To establish filter characteristics that will allow those established by use of test rigs to be transposed to in service characteristics.
- To provide technical information to establish a baseline for filter ageing.
- To contribute to the establishment of a quicker and simpler test method to achieve more control of the testing process.
- To be able to transpose the method, if required, directly into an on site filter testing recommended practice. (Note: The current Eurovent 4/10 recommended practice)

EN 779:1993 establishes the requirement concerning the equipment required and defines the analysis and presentation of the results. Application is limited to general ventilation filters with a face velocity of at least 0.6 m/s.

The test method for fine filters (> G4) uses a test aerosol of either LATEX or DEHS in the range 0.1 to 5 μm. An optical particle counter (OPC) is used to size the particulate upstream and downstream of the filter under test.

The counts for identical size bands can be compared and the filter effectiveness, or fractional efficiency, can be established for each size range.

The filter is then dust loaded to a specified pressure loss interval, where the fractional efficiency measurements are repeated. The dust loading and fractional efficiency cycle is repeated until the recommended final pressure loss is reached.

Curves of the variation of fractional efficiency with particle size pressure drop interval are produced.

The classification system is deliberately similar to the superseded EN779:1993 by means of the correllation between the previously used dust spot efficiency values and fractional efficiencies at 0.4 μm. Dust arrestance is only quoted for the coarse filters.

The obvious difference between the new method and EN 779:1993 is that atmospheric air is no longer used as the challenge, and therefore eliminates the previous major source of inconsistency.

Overall the test method is straight forward and much quicker than EN 779:1993, but the initial capital cost is greater.

Annexes included in the document provide methodologies for the determination of the potential effects of electrostatic discharge and shedding on installed filter performance.

## 5.2 HEPA Test Methods

HEPA filters in their various forms are by their nature specialist products, of relatively high unit cost, which are designed to produce very clean air for sensitive process installations such as; Hospitals, Laboratories, Pharmaceutical Facilities, Electromechanical Production Facilities, and the Nuclear Industry.

Many air extraction systems in some of these industries also require HEPA filters to remove potentially harmful contaminants before discharge to atmosphere.

As a result of being used in such critical and often high cost applications, it is totally unacceptable to have below specification filtration performance.

The production testing of HEPA filters on an individual basis is essential in achieving the quality control required by industry.

### i) BS 3928:1969

It is necessary for HEPA filters which are supplied into sensitive areas to be subject to individual process controls to ensure that the minimum required standard is met.

Each production absolute is normally individually tested and uniquely identified.

The test method is low in cost and very quick. The principal disadvantage is that it is not a leak test, and consequently is perceived to be in favour of the manufacturer, as it is not as onerous as a CNC or DOP method, which will be discussed at a later stage.

The BS 3928 method determines the efficiency of filters to a challenge of NaCl particles in the range 0.02 to 2 μm, with a mean diameter of 0.6 μm.

The NaCl aerosol is produced by atomising a 2% solution. The design of the ducting eliminates large droplets and leaves a dry aerosol at the test filter.

The principle of the Sodium Flame photometry that is used is well known, but the range of calibrated optical filters used allows efficiencies of 0 to 99.999% to be determined.

As mentioned previously, the test result is obtained almost instantaneously, and due to the low loading of the filter, (14 $mg/m^3$), the method lends itself ideally to production testing.

In practice when testing filters of the same grade and media batch which have similar pressure loss characteristics, the upstream concentration is only measured on the first filter.

It has historically been the normal practice, particularly in the UK, to express HEPA filter performance as a penetration, rather than an efficiency, but this is no longer the case and both can, and are, used. i.e The expressions "0.001% penetration" or "99.999% efficiency" are equally well understood.

ii) **BS 4400:1969**

BS 4400 (1969) is similar in principle to BS 3928, other than the aerosol is 1% NaCl in water and the recommended flow rate for the rig ranges from 0.9 $m^3$/hr to 5.1 $m^3$/hr.

This equipment is used for flat sheet testing of filter media for purposes of pre-selection of filter papers or for batch evaluation prior to manufacture.

The additional controls (media batch testing at source, preproduction checks to BS4400 or similar, approved testers etc.), that are in place ensure that each filter can be traced to the master roll from which the media was produced.

iii) **EN 1822:1999**

EN1822 is the new test European standard for post manufacture testing HEPA and ULPA filters. The standard specifies two primary methods for determining performance.

Part 4 specifies a test method based on scanning with a LPC or CNC particle counter at the MPPS (Most Penetrating Particle Size) of the filter. In most cases the instrument is a laser light source particle counter (LPC) that also sizes the individual particles. In some cases condensation nuclei counters (CNC) are used. Light source particle counters are fairly common, but CNC equipment is less so.

The principle of CNC is as follows: Sampled particles are passed through a chamber where alcohol is condensed onto the particles in the sample flow regardless of chemical composition, thus creating droplets large enough to be detected efficiently using a light scattering technique. Droplets leaving the condenser pass one at a time through a single particle counting optical detector. the pulse of light scattered by a droplet traversing the beam is transformed into an electrical signal proportional to it's size.

Part 4 is primarily for use with high grade HEPA and ULPA terminal filters, and uses challenges of natural and oil based aerosols. All aerosols capable of interpretation at MPPS are accepted by BS EN 1822. The standard aerosol used with this test method is a synthetic oil which is atomised to produce an aerosol of 0.1 to 0.5 µm mmd, or at the MPPS of the filter.
where MPPS is the Maximum Penetrating Particle Size for a particular media or finished filter.

The efficiency of filter is dependant on the removal of particles from the air passing through it by a combination of the classic removal principles of interception, inertia, impingement, diffusion and straining.

As the particle size reduces the dynamic separation techniques become less effective until at about 0.1µm the diffusion principle is the primary removal technique. The efficiency curve typically passes through a minimum for HEPA and ULPA filters between 0.12 and 0.25 microns dependant on velocity and media quality.

The principle of the test is to surface scan the downstream face of the filter and to determine local efficiencies in relation to a continuous upstream sample. The local efficiencies are then integrated to determine an overall efficiency. The standard specifies acceptance criteria based on both local and overall efficiency.

Part 5 of the standard describes an oil thread method largely based on DIN 24184 and is primarily suited for in duct HEPA filters up to grade H14.

vi) **Dry Testing**

Some industries require the evaluation of cleanroom filters for local leaks using atmospheric air or polystyrene latex. This is particularly relevant to semiconductor applications where contamination with DOP, or equivalent oil based aerosols and solvents, cause production problems.

It appears that IEST RP is being prepared in the USA for 'dry' testing, which may or may not eventually form part of ISO 14644.

Problems are also known to exist with Latex because it is water based and humidity can affect the filter media and hence the test, unless the equipment allows for the aerosol to dry before reaching the filter. Another problem is the low particle concentration when compared to DEHS or equivalent materials.

This means that filter manufacturers such as ourselves will test filters at the rated face velocity and use the data to determine overall efficiency (assuming the local leak requirements are also met), or they will scan the filter using an automated scanner at a very low scanning rate. The scanning rate, maximum efficiency and leak detection is limited by the low particle concentration. (A 5 minute scan time is typical for a 1200 x 600 mm H14 panel)

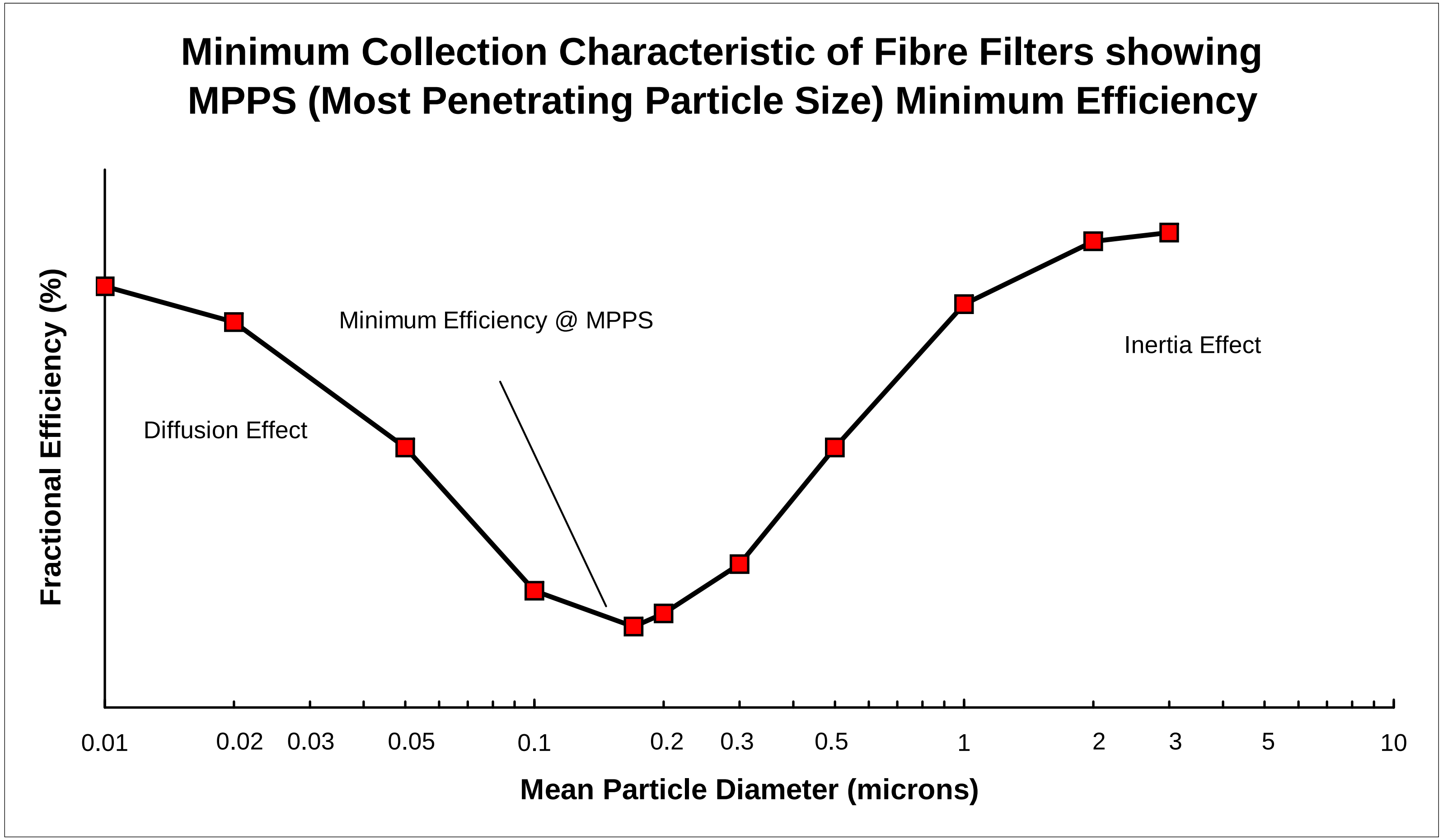
There could also be a problem with a CN counter because these are not able to discriminate particle sizes and the distribution curve for Latex is known to produce shadow peaks which would influence the efficiency calculation and leak detection.

Overall, we can be pretty sure that the techniques of EN 1822 and ISO 14644 will be applied to both terminal and in duct HEPA's.

The cost of the complex test equipment that is required is likely to prevent a number of current manufacturers from supplying certificated products to EN 1822 in the future.

These companies will however be able to use BS 3928 for supplying some local needs, as this standard will not be superseded in the near future.

A possible product classification system is shown by 5.3.


Minimum Collection Characteristic of Fibre Filters showing
MPPS (Most Penetrating Particle Size) Minimum Efficiency
Fractional Efficiency (%)
Minimum Efficiency @ MPPS
Inertia Effect
Diffusion Effect
0.01
0.02
0.03
0.05
0.1
0.2
0.3
0.5
1
2
3
5
10
Mean Particle Diameter (microns)

## 5.3 Filter Classification

### Typical Selection Guide for Filters which incorporates BS EN 779 and BS EN 1822

**Classification to BS EN 779**

| Product | Grade | $E_m$ @ 0.4 µm |
|---|---|---|
| a | G1 | $A_m$ < 65 |
| b | G2 | 65 # $A_m$ < 80 |
| c | G3 | 80 # $A_m$ < 90 |
| d | G4 | 90 # $A_m$ |
| e | F5 | 40 # $E_m$ < 60 |
| f | F6 | 60 # $E_m$ < 80 |
| g | F7 | 80 # $E_m$ < 90 |
| h | F8 | 90 # $E_m$ < 95 |
| i | F9 | 95 # $E_m$ |

**Classification to EN 1822**

| Product | Grade | $E_m$ @ 0.3 µm | $E_m$ @ MPPS |
|---|---|---|---|
| j | H10 | > 95 | > 85 |
| k | H11 | > 98 | > 95 |
| l | H12 | > 99.99 | > 99.5 |
| m | H13 | > 99.997 | > 99.95 |
| n | H14 | > 99.999 | > 99.995 |

| Product | Grade | $E_m$ @ 0.12µm | $E_m$ @ MPPS |
|---|---|---|---|
| o | U15 | > 99.9995 | > 99.9995 |
| p | U16 | > 99.99995 | > 99.99995 |
| q | U17 | > 99.999995 | > 99.999995 |

Notes:

1. Leak allowances are 5 x the overall penetration. DOP values can be read across to H10 - 14 @ 0.3 µm only.
2. The EU filter classification system is widely referred to. Simply remove the EN grade prefix (G, F, H, U) and replace with the EU prefix. i.e H10 = EU10 etc.

5.4 **Flammability**

This section is intended to illustrate the various Fire and Toxicity test standards commonly misunderstood and/or mis-applied to filter materials and associated equipment. HEVAC in the UK have been instrumental in attempting to rationalise this confusing situation by introducing a more representative test method. (see UL900)

The prolific range of sometimes seemingly unrelated test methods is limited to clean filters or filter materials. It is of course the case that filters in operation collect lints, dusts, hydrocarbons etc that will burn and very likely emit smoke. Such an event will invalidate the effect of the fire test on the clean filter or filter media. As a result, great emphasis is placed on the maintenance and inspection of installations prone to the ingestion of combustibles.

The standards most commonly referred to are briefly explained, discussed and compared with some international equivalents.

i) **BS 476**

BS 476 is the general standard for fire tests on building materials and structures rather than for fabrics, but has been largely referred to as an extension of the building or surrounding structure classification.

Only some parts of BS 476 are similar in content to ISO documents.
However, a full review is currently being made on all aspects of combustion of building materials by ISO/TC 92.

ia) **BS 476 part 4 (Similar in content to ISO 1182)**

BS 476 Part 4 : 1984 refers to the non-combustibility of materials, or where a sample is placed in a furnace at 750 $^{o}$C, and a continuous monitoring of the furnace temperature is made to see whether the sample produces a flame.

Materials are classified combustible or non-combustible by identifying those which make little or no contribution to the heat of the furnace, and do not produce a flame.The remaining materials being combustible.

The practical aspect is, that if a material is more than 3% organic in composition, it will combust and fail the test.

ib) **BS 476 part 5 (Similar in content to ISO 5657)**

BS 476 Part 5 : 1979 describes the method of test for ignitability characteristics of the exposed surfaces of essentially flat, rigid, or semi rigid building materials or composites, when tested in the vertical position.

A flame is applied to the bottom edge of the material for a specific period of time, and is then removed.
Observations are made for the presence of any flaming and the spread of flame to boundaries, again for a specific period after flame removal.

The material is deemed 'non-ignitable' if any flaming lasts for less than 10 seconds after flame removal, and that the flame does not spread to any boundary within that time.

NB. This section has now been superseded by BS 476 part 12 which identifies a range of flame intensity to which a specimen is subjected, increasing from class A, low intensity, to class G, a high intensity Bunsen burner.

ic) **BS 476 part 7**

BS 476 Part 7 : 1987 describes the method for classification of the lateral spread of flame along the surface of a specimen in the vertical position.
It was designed for comparing the performance of essentially flat materials, composites or assemblies used as exposed surfaces of walls and ceilings.
A flame is applied to the face of the material for 1 minute (a long time compared to most standards), and the spread of flame and its rate are noted after the flame has been withdrawn.

The material is classified by rate and the degree of spread. No debris must fall from the specimen, whether flaming or not.
The material must also retain its structure within the sample holder so that the measurement of flame spread can be made.

These requirements are quite stringent, which makes the test unsuitable for unsupported synthetic materials, which even if they do not burn so that there is no 'flame spread', will melt, deform, and maybe sag, rendering the test invalid
To enable us to have a synthetic material that complies with the requirements, it would need to have a integral sub-layer of a fine mesh say, needled into the material.

Note that BS 476 part 6 : 1989 is very similar in content to part 7 and is the propagation test method, and has virtually the same pass criteria. Note that a material that meets part 7 is also likely to pass part 6.

ii) **BS 2963**

BS 2963 : 1958 describes the tests for the flammability of fabrics, and has now been withdrawn, although it continues to be referred to.
It is the closest comparable test method to both DIN 53438 and UL 94, and was used extensively in conjunction with BS 3119, BS 3120 and BS 3121, which described the test methods for low flammability or 'flameproof' fabrics.

All these British Standards have now been collectively superseded by one test method, namely BS 5438.

BS 2963 describes two basic test methods, one a vertical strip test, the other a $45^{o}$ test, which is more severe.
The materials are classified by the time taken for a flame front to travel between two marks 1270 mm apart.

However, materials that extinguish before the second mark is reached are self extinguishing, and materials that extinguish before the first mark is reached are flameproof and are classified as 'flame not propagated'.

iii) **BS 5438**

BS 5438 : 1989 describes the methods of test for the flammability of textile fabrics when subjected to an igniting flame applied to the face or bottom edge of a vertically oriented specimen.
The three methods given are used extensively for determining the flammability of household items such as blankets, curtains (see BS 5867), and clothing etc., and are very similar to ISO 6940 and ISO 6941, which were adapted from BS 5438 : 1976.

The tests measure the ignitability and flame spread for flame applications of different durations and for both faces of the material, something not previously covered.
There are also strict limitations for afterflame and afterglow. ie the flame spread and glowing of the material after the flame has been withdrawn.

A material can as a result fail rather than be given a rating.

As mentioned previously, this standard supersedes all previous flammability standards, namely BS 3119, BS 3120, BS 3121 and BS 2963.

iv) **BS 5588**

BS 5588 : 1989 is the Code of Practice for ventilation and air conditioning ductwork, and replaced CP 413 : 1973.
The standard requires the filter to be subjected to fire (ignition), smoke production, and toxicity evaluations. The standard complies to the outdated, but still commonly referred to LSS performance requirements for filters.

This standard is most commonly applied to products sold in the UK H&V industry.

v) **BS 5867**

BS 5867 : 1980 is a commonly referred to standard for flammability which uses the methods described by BS 5438, and refers to fabrics for curtains and drapes with specific additional procedures to be used with BS 5438.

As a result, filters can be tested according to BS 5867 using the methods described by BS 5438, where the latter is by far the most important reference.

vi) **DIN 53438**

DIN 53438 : 1977 is the standard by Deutsche Normen covering the testing of combustible materials, specifically using a Bunsen type flame.
It is similar in content to BS 2963 and some aspects of BS 5867 (BS 5438), with the flame being applied to the surface or bottom edge, and the flame spread and rate being noted.

The material is classified by the time taken to burn between two marks.

Information supplied gives details about the smoke quantity and density emitted, any debris produced, and the degree of afterglow and afterflame.

vii) **UL 94**

UL 94 : 1979 is one of a number of flammability standards issued by Underwriter Laboratories in the States covering a range of materials, and covers the test for plastic materials for parts in devices and appliances.

Synthetic materials are generally polymeric compounds and are classified as 'plastic' in nature, it is for this reason that UL 94 is specified.

UL 94 determines the ignitability and flame spread/rate in various sample orientations. Classification is determined by a series of rate and spread limitations.

The standard is therefore similar in content to BS 2963, DIN 53438, and aspects of BS

5867 (BS 5438).

Tests to this standard can be carried out in this country if required.

viii) **UL 900**

UL 900 is a flammability specification designed for the testing of filters under dynamic conditions, and has been the subject of review by HEVAC & TBV in the UK, who in turn had co-sponsored the adoption of prEN12009 within Europe. It is felt that 12009 is a more realistic test method than that used for UL 900, on which it is based.

CEN members rejected 12009 in 1995, but it was accepted by ISO as ISO 12009.
No test rigs exist within Europe that can test to either UL 900 or ISO 12009. Although it is a recognised method of testing, it has to date not been adopted by the UK or the rest of Europe.

UL 900 is extensively required by the insurance companies within the US and therefore some filter suppliers who are also US based will be marketing the standard in the UK without it being applicable.

UL 900 has two basic classifications; *Class 1* filters are those which, when clean, do not contribute fuel when attacked by flames and which emit only negligible amounts of smoke; *Class 2* filters are those which, when clean, burn moderately when attacked by flame and emit only moderate amounts of smoke.

## 5.5 Toxicity Tests

Toxicity seems to be becoming a more and more emotive issue, but is poorly supported by standards, particularly in this country. The fact that the most common cause of death in house fires is due to the toxic fumes given of by carpets, and most modern furniture including curtains etc. has not seemed to galvanise the authorities responsible.

In available international standards such as the American NFPA 258, the toxicity rating is determined by the fatal dosage of gaseous products of combustion to laboratory animals, the human dosage being factored up accordingly.

The individual gases are not differentiated and concentrations are based on the combined product only.

The **only** available standard which determines all gases emitted and their concentrations during combustion is **NES 713**.

NES 713 is a Naval Engineering Specification dating back to the 1960's as result of the study of toxic gases emitted by fires in specifically submarines.

Since the introduction of the standard, all materials supplied to the Royal Navy are categorised according to the toxicity rating and the gases emitted.

Naval Engineering Standard 713 Issue 3 describes the determination of the toxicity index of the products of combustion from small specimens of materials, where analytical data of certain small molecular gaseous species arising from the complete combustion under flaming conditions, at 1150 $^{o}$C, of the material under test are computed, using the exposure level (in ppm) of each gas to produce fatality in 30 minutes as a base, to derive a combined toxicity index.

The interpretation of the allowable index varies, but the Royal Navy accepts a maximum material index of 5.

A secondary consideration are the actual gas groups emitted, where the nature, noticeability, and effects of the gases are compared. ie. molecular weight, miscibility, odour, colour and respiratory effects.

## 6.0 Filter Selection and Comparison

### 6.1 Filter Selection

Filter selection is difficult to discuss in general terns since each application introduces it's particular problems. Usually, there will be a number of different types of filters which may be suitable, although specific applications adopt certain types as being virtual standard on the basis of proven performance, experience, cost, availability etc. etc.

The primary reason for selecting a particular type of filter or system is the degree of cleanliness required for the application, whether this is for a process or an environment. It is therefore essentially a technical requirement which drives the process.

The parameters of filter selection based on the operating parameters of the installation would primarily include:

System Flow Rate
Available Duct Area for filter installation.
System Pressure Loss limits, clean and dirty.
Efficiency Grade or Cleanliness requirement for the Process or Environment.
Airborne Particulate/Dust Quantity/Size, if known.
Airborne Gaseous Pollutants, if any.

The filter parameters that would influence selection would primarily include:

Rated Flow Capacity per filter
Dimensions, casing primarily, but also the mounting frame
Efficiency
Arrestance
Initial Pressure Loss at the rated flow
Final Pressure Loss at the rated flow
Dust Holding Capacity

Common selection pitfalls

1. Filter rating alone (efficiency) is not an absolute selection criterion.

2. In conditions of heavy airborne contamination, a filter with high efficiency may clog too quickly for economic use. In this case the filter area can simply be increased to delay clogging. Alternatively a different type of filter can be used, such as a self cleaning system.
3. Is Prefiltration needed? Prefiltration is needed if the application requires a high cleanliness level and the contamination level is above normal. The

majority of the contaminant should be removed prior to the high efficiency filter to make the process economic. Also, prefilters are required if system maintenance is required on line, or if carbon filters are used.

Overall, there are many potential aspects which can be investigated depending on the complexity of the installation requirements.

As far as the filter is concerned, it's in service performance is of prime importance and every effort should be made by the specifier in establishing the validity of the available test data. For example, most filters are type tested at some stage, but, is the filter in question covered by independent, or in house, accredited data.

Simple questions could be:

Are filters grade or type tested, and if so, how often.
Are they tested as part of the production process.
Does the supplier conform to a recognised quality system.

i.e all of these factors would give an indication of whether the information supplied can be relied upon to reflect the performance of the filter.

Lastly, and more often than not, most importantly, there are however a number of commercial considerations that need to be borne in mind during the selection process, as they could significantly influence the outcome.

These include:

Primary cost
Installation cost
Operating cost
Maintenance cost & frequency
Replacement cost & frequency

As far as installation and maintenance is concerned, questions such as; how are the filters installed and maintained, and, what is the in service reliability etc. should be considered.

The remaining intangibles that will need to influence the selection process are to do with the service provided by the supplier; including; available product range, backup, problem solving, technical assistance etc.

## 6.2 Filter Comparison

In most industry sectors where filtration products are used, there are a number of suppliers that can offer the complete range of products required, and in these cases it is necessary to perform a comparison of the products on offer in order to make the appropriate decision. Suppliers that are manufacturers will generally differ from each other in the detailed manner in which the filters are constructed.

The comparison process must be based on both technical and commercial considerations as mentioned in 6.1. It is important to carry out the comparison taking account of the most relevant aspects of the specification and the cost/benefit advantages offered by the products in question.

A valuable comparator is to look at samples, or even in service products, as a guide to quality. It is not uncommon for users to discuss their experiences between themselves.

Choosing a filter is an important decision, and even though the cost of a filter installation is relatively low compared to the capital plant it is intended to protect, it is precisely that point which can be overlooked.

## 6.3 Typical Filter Applications

### 6.3.1 Principal Grades of Filters G1 to H13 (EU1 to EU13)

This table is intended as an example of the types of filters that are typically used for a number of common applications. It has been included purely to give a feel for the relationship between cleanliness requirements and filter grades. It is by no means exhaustive.

| Application or Process | Cleanliness Requirement | Filter Efficiency/ Arrestance | Allowable Filter |
|---|---|---|---|
| Coarse prefiltration: Provision against accumulations of insects, textile fibres, coarse particulates | General protection to 15 - 20 µm | 50 - 80% Arrestance | G1, G2 |
| Medium level prefiltration: Protection against pollens. Simple ventilation units for factories, garages | General protection to 5 - 15 µm. Prefiltration for fine filters. | 80 - 90% Arrestance | G3 |
| High level prefiltration: Air conditioning of Paint booths, Kitchens. | Protection to 5 µm Prefiltration for fine filters. | >90 % Arrestance | G4 |
| Supply air and partial air conditioning for restaurants, gymnasia, food shops, schools, engineering workshops | Protection to 2 µm | 40 - 60 % @ 0.4 | F5 |
| Effective against all types of dust, including soots. Air conditioning for laboratories, offices, theatres, computer rooms, spray booths | Protection to 1 µm | 60 - 90 % @ 0.4 | F6/7 |

6.3.1 **Principal Grades of Filters G1 to H13 (EU1 to EU13)** (continued)

| **Application or Process** | **Cleanliness Requirement** | **Filter Efficiency/ Arrestance** | **Allowable Filter** |
|---|---|---|---|
| Effective against soots, oil mist, bacteria. Air conditioning of clean rooms, pharmaceutical, animal health, laboratories | Protection to < 1 μm | 90 - 95 % @ 0.4 μm | F8/9 |
| Highly effective against bacteria, smokes, aerosols. Uses in operating theatres, pill production, electronics, sterilisation. | Process Specified | 95 - 99.9 % NaCl<br>> 95 % @ 0.3 μm | H10 |
| Nuclear ventilation, micro-technology, photographic processes, bacteria free rooms, transplant operating theatres. | Process Specified | 99.9 - 99.99 NaCl<br>98 - 99.99 % @ 0.3 μm | H11/12 |
| Highest air quality applications. Sterile areas. class 1000 rooms, nuclear applications. bacteriological. animal health. isolation | Process Specified | 99.99 - 99.999 % NaCl<br>99.997 - 99.999 % @ 0.3 μm | H13 |

### 6.3.2 **Current Clean Room Standards and Minimum Filter Performance to Comply**

| US Fed 209D | US Fed 209E | ISO 14644 | Filter Efficiency | Allowable Filter |
|---|---|---|---|---|
| | M1 | | | |
| 1 | M1.5 | 3 | 1st Pre: 30% @ 0.4 μm<br>2nd Pre: 95% @ 0.4 μm<br>Final: 99.99995 @ 0.12 μm | G4/F5<br>F8/9<br>U16 |
| | M2 | | | |
| 10 | M2.5 | 4 | 1st Pre: 30% @ 0.4 μm<br>2nd Pre: 95% @ 0.4 μm<br>Final: 99.9995 @ 0.12 μm | G4/F5<br>F8/9<br>U15 |
| | M3 | | | |
| 100 | M3.5 | 5 | 1st Pre: 30% @ 0.4 μm<br>2nd Pre: 90% @ 0.4 μm<br>Final: 99.999% NaCl | G4/F5<br>F8<br>H14 |
| | M4 | | | |
| 1000 | M4.5 | 6 | 1st Pre: 30% @ 0.4 μm<br>2nd Pre: 90% @ 0.4 μm<br>Final: 99.99% NaCl | G4/F5<br>F8<br>H13 |
| | M5 | | | |
| 10000 | M5.5 | 7 | 1st Pre: 80% Arrestance<br>2nd Pre: 70-90% @ 0.4 μm<br>Final: 99.99% NaCl | G3<br>F6/7<br>H12 |
| | M6 | | | |
| 100000 | M6.5 | 8 | 1st Pre: 80% Arrestance<br>2nd Pre: 70-90% @ 0.4 μm<br>Final: 95% NaCl | G3<br>F6/7<br>H10 |
| | M7 | | | |

NB. The filter grades are for guidance only. Filter requirements may differ depending on operating conditions.

### 6.3.3 **Filter Grades and Particle Penetration**

When specifying or selecting secondary filtration grades it is important to consider particle penetration as opposed to stated filter efficiency.

A typical city centre air sample will contain tens of millions of airborne particles per cubic metre and the sample will contain in excess of 95% of particles below one micron in size. The particle quantity penetration for the filter grades F7, 8 & 9 is thus indicated in the table below based upon a city centre air sample of one million particles of less that one micron in size. Note that this concentration is an absolute minimum.

| Filter Grade | Average Efficiency Range % | Average Efficiency for these examples % | Average Penetration % | Particle Penetration Quantity per 1,000,000 |
|---|---|---|---|---|
| F7 | 80-90 | 85<br>(mid point) | 15 | 150,000 |
| F8 | 90-95 | 90<br>(low end) | 10 | 100,000 |
| F9 | >95 | 95<br>(low end) | 5 | 50,000 |

With ever increasing demands for improved cleanliness standards, the HEVAC Filter Group recommends that the minimum grade for secondary filtration should be F8.

## 7.0 Indoor Air Quality

### 7.1 Human Necessities

Fresh air is defined as outdoor air, that is, air sourced from outside of buildings. However, the quality of this air may be of uncertain purity. Occupants of a building require fresh air to control temperature, humidity, odours and Carbon Dioxide levels.

Air filtration is primarily concerned with the provision of clean air for respiration. The main requirement for respiration air is the removal of Carbon Dioxide, not the provision of Oxygen.

Guidelines published by ASHRAE and CIBSE quote fresh air ventilation rates for building occupancy. Section A1: Environmental Criteria for Design of the CIBSE guide advises that the maximum concentration of Carbon Dioxide for eight hour occupation should be 0.5% (5000 ppm in air). In section B1: Ventilation and Air Conditioning, minimum ventilation rates are quoted as:

| Activity | Minimum Ventilation Requirement (l/s/person) |
|---|---|
| Seated quietly | 0.8 |
| Light work | 1.3-2.6 |
| Moderate work | 2.6-3.9 |
| Heavy work | 3.9-5.3 |
| Very heavy work | 5.3-6.4 |

### 7.2 Filtration and IAQ

Much has been said and written on the subject of IAQ, and in particular, Sick Building Syndrome, or SBS. Air filtration cannot solve SBS, but it has a major role to play in making improvements. Listed below are the main problem area's relating to SBS which are associated with filters and filtration systems:

! Poor quality filters being used.
! Poorly designed systems:
  a) Inadequate sealing
  b) Incorrect selection of filter types
  c) Incorrect filter performance
! Lack of maintenance procedures and schedules
! Lack of filter monitoring

Most of an air conditioning system is hidden from view. There could be many metres of ducting in an office, process, factory or hospital where dirt can collect or germs breed.

One indicator of a contaminated air handling system is visible dirt on diffusers and associated stained ceilings and walls. However, as bad as this is, the worst harm can come from the reduction in efficiency of the plant. i.e If the fans and coils become coated in grime and dust, the result can mean greater energy consumption and reduced performance. Also of concern is the effect on safety equipment. Automatic fire dampers can become clogged, and if there is combustible debris in the ducting, the ventilation system can be turned into a fire hazard.

If dirt is present in the system it is a major exercise to clean the ductwork, which can be very expensive.

The main precaution within an air conditioning system to control air quality and halt the ingestion of contaminants is the installation of the correct grade and quality of filters. Filters are not a 'fit and forget' item and will require maintenance at regular intervals, which will entail replacement.

If filters are to do the job for which they are designed, all the air must pass through them. Damaged, ill-fitting or missing filters will allow the bypass of unfiltered air, which defeats the object of their installation.

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# Air Filtration - Training Manual

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**Freudenberg Nonwovens Group**
**KIMO UK**
**McQuay (UK) Ltd**
**Nationwide Filter Co Ltd**
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