Abstract: A filter system for a duct; the filter system comprising a plurality of layers made from filter material, such that at least one layer has at least one macro channel therethrough in the direction of fluid flow through and at least one layer has no macro channels therethrough, the at least one layers being separated by air gaps.
IMPROVED FILTER CONFIGURATION

FIELD OF THE INVENTION

The present invention is directed to filters for removing solid particles from fluids, specifically for removing particles from gases and most particularly to air filter configurations for air-conditioning units and similar applications.

BACKGROUND OF THE INVENTION

An air filter for removing particles is a device composed of porous material which removes solid particulates such as dust, fibers, pollen, mold, and bacteria from the air. Air filters may consist of open pour foams or of fibrous materials. They are used in a variety of applications where air quality is important, notably in building air handling systems. Air filters are also used in air cooling systems for electronic equipment such as behind the air vents for cooling the microprocessors of computers, air cooling systems for electrical motors and pumps, as well as the air intakes of gas turbines, internal combustion engines, etc.

Air handling units (AHU) are used in air conditioning and ventilation systems for commercial, residential and industrial buildings. Prior art AHU filters typically comprise a thick filter medium having microscopic channels therethrough. Thin pleated filter media are used as well. The filter media may consist of cotton, cellulose, glass or synthetic fibers or may be created from open cell foam.

There are a wide range of fibrous and open-cell foam-like materials having microscopic passages therethrough that may be placed in air ducts and serve to entrap dust and other particles, whilst letting air pass there through. There is, nevertheless, a pressure drop across the filter, which is referred to as the 'filter resistance'.

The size of the micro-passages determines the size of the particles that are trapped. The thicker the layer of filter material, the more particles within the specific size range that are trapped, however there is generally a 'law of diminishing returns'.

The build up of particulate material on the surface of the filter material facing the air intake direction is known as caking. Caking increases the pressure drop and significantly contributes to the filter resistance. This reduces the airflow through the filter. Caking may eventually block the passage of air to the extent that the filter needs maintenance, with the filter material needing to be cleaned, or more typically, to be discarded. The down-time required to access and switch or to clean such filters is considerable and significantly increases operating costs. Generally such filters are disposable and there is a cost to such filters as well. Because of the combined labor costs, down-time costs and material costs of filters, it is desirable to maximize the working life of filters, i.e. the operating time between filter changes.
It is well known, that common filter media used for removing dust from air have a huge theoretical potential to retain dust. For example, a filter with a thickness of 50 mm (approx. 2"), having only 1% of the filter volume is filled by dust, can store 1000 g/m². In real conditions, this level is never reached, and the volume occupied by dust is much less than 1%. Nonetheless, due to dust caking up on the filter surface airflow pressure drops to unacceptable layers well before the filter medium as a whole becomes clogged.

There is a general need to configure air filters to maximize the time between filter replacements, i.e. to maximize the amount of particulate material that can be removed from the airflow and stored by the filter, before it requires attention.

The amount of dust that can be stored by the filter is known as its dust holding capacity or DHC. In general, filters are required to have a large dust holding capacity and to trap a large amount of material, prevent particles from passing whilst simultaneously having a low filter resistance, maintaining a reasonable pressure there-across. The main problem is to prevent dust caking in a relatively narrow upstream surface layer to the extent that the filter becomes blocked, well before the filter as a whole traps and removes a significant amount of dust. Preventing caking choking the filter is thus the main key to extending the working life of a filter.

One solution described in the prior art is to use a filter medium having a graduated density, with the air inlet surface being low density, with a density build up into the filter. This type of structure results in more material being trapped over a greater depth of the material and allows air passage for longer. Whilst this approach does increase the mean time between filter replacements, further improvements are required.

Another approach to caking prevention is documented in United States Patent Number US 7,708,794 to Dullien and Grinbergs, titled "Separator made of a fibrous porous material such as a felt" which describes a separator made of a porous material, intended to treat gaseous effluents which contain particles whose size is substantially less than one micrometer or of the order of one micrometer. The porous material includes channels. The channels are delimited by a fibrous porous material in the form of at least one sheet comprising the channels extending therethrough, wherein the at least one sheet is supported by a plate made of an impermeable material having the same surface area as the at least one sheet and provided with holes corresponding to the channels of the at least one sheet.

The technology described has through-holes that allow the passage of air. Notably, although a backing support plate is suggested, as is the use of multiple layers separated by air gaps, it is a feature of the embodiments described and a characteristic of the technology that the channels are uninterrupted and aligned in the direction of flow through the duct. Thus the
backing plate has corresponding holes therethrough and the individual layers are set up such that corresponding channels are aligned. It is possible to shine a light or thread a long inflexible wire from one side of the arrangement to the other, through the channels.

Though primarily designed for filtering diesel and other heavy fluids, the filter is allegedly suitable to filter dust as well.

United States Patent Number US 6,238,464, also to Dullien, titled "Method and apparatus for separating droplets for particles from a gas stream" describes a separator intended for processing gas streams containing liquid or solid particles substantially smaller than one micrometer or of the order of the one micrometer, comprising reticulated foam delimiting channels intended for turbulent flow of the gas streams, said channels being such that the gas streams flow through said foam from one end of the channels to the other, wherein said foam includes cells adjacent said channels forming stagnant and turbulent-free subareas into which said liquid or solid particles carried by eddies of the gas streams are deposited.

Again, the separator is characterized by unblocked passages from one side to another. This is clear from the claimed method, which describes a process for separating particles from a gas stream in which they are contained, comprising the following stages: (i) passing said gas streams through at least one straight passageway, and (ii) arranging a plurality of surfaces transversely to the direction of flow of the gas stream, said surfaces extending from said at least one straight passageway and being spaced apart so as to define a plurality of interconnected subareas forming together a stagnant and non-turbulent area communicating freely with said at least one straight passageway, each subarea occupying substantially all of the space between adjacent surfaces so that turbulent streams of the gas stream enter said spaces between the surfaces and decay in said subareas, said particles being trapped and deposited mechanically on the surfaces defining the stagnant and non-turbulent area.

It will be appreciated that perforated filters such as those described above, require rather high air velocity along the channels in order to create intensive turbulence and thereby, powerful eddies, which deliver the particles from the channel streams to stagnant zones in the channel walls. Therefore the described technology requires a high pressure drop along the filter that is much larger than the pressure drop acceptable in many applications, such as ventilation and air conditioning systems for example. Furthermore, the described technology implies long channels in order to achieve acceptable particle arrestance and efficiency. It will be appreciated that in air conditioning systems, where filter thicknesses are generally limited to 2" or 4", the air passing through the macro channels would not be filtered.
Conventional non-perforated filters become ineffective and require changing when caking causes the pressure drop there-across to reach unacceptable levels. In contrast, perforated filters generally do not become blocked. Rather, with increased flow through the perforations as dust cake builds up elsewhere, their arrestance tails off, i.e. they simply become less effective at stopping dust.

There is an ongoing need for cheap reliable filter solutions which can be operated for extensive periods of time without maintenance, particularly in ventilation and air conditioning systems. There is a specific need for cost-effective improved means for minimizing cake build-up without sacrificing filtration efficiency, maintaining arrestance of particles whilst maintaining a sufficient pressure across the filters. Emobodiments of the present invention addresses these needs.

SUMMARY OF THE INVENTION
In accordance with one embodiment of the invention, there is provided a filter system comprising a plurality of layers made from porous filter material, such that at least one layer has at least one macro channel therethrough and at least one layer has no macro channels therethrough.

Typically the filter system is installed in a duct.

Typically the at least one macro channel is substantially parallel to the duct.

Optionally, the at least one macro channel has a diameter that is several orders of magnitude larger than the pores within the filter material.

Typically the at least one macro channel has a diameter of more than 1 mm.

Typically the at least one macro channel has a diameter of less than 20 mm.

Optionally the filter material of the at least one layer having the macro channel therethrough comprises an open pore foam.

Optionally the filter material of the at least one layer having the macro channel therethrough comprises fibers.

Typically the filter material is a felt comprising fibers selected from the group of cellulose fibers, ceramic fibers, glass fibers, synthetic fibers, cotton fibers and carbon fibers.

Optionally the filter material of the at least one layer having no macro channels therethrough comprises an open pore foam.

Optionally the filter material of the at least one layer having no macro channel therethrough comprises fibers.
Typically the at least one layer of filter material comprising at least one macro channel is upstream from the at least one layer of filter material not comprising at least one macro channel.

Optionally at least one layer of filter material comprising at least one macro channel is upstream from the at least one layer of filter material not comprising at least one macro channel and is separated therefrom by a gap.

Optionally the layers of filter material and the air gap are perpendicular to a direction of fluid flow.

Typically the duct is a gas duct and the fluid is a gas.

Most typically the filter is an air filter and the fluid is air.

Typically the at least one macro channel is cylindrically.

Alternatively, the at least one macro channel tapers inwards from inlet to outlet.

Alternatively again, the at least one macro channel tapers outwards from inlet to outlet.

Optionally the at least one macro channel has at least one baffle therein, obstructing the direct flow of air through the channels and directing the air flow towards the walls of the channels.

Optionally the at least one baffle is a fixed cone.

Alternatively the at least one baffle is a twisted helical insert.

Optionally a baffle selected from the group comprising static and freely turning propellers is aligned with the at least one macro channel in a position selected from the group comprising: opposite an outlet to the macro channel, opposite an inlet to the micro channel and within the micro channel.

Typically the diameter of the macro channel is at least an order of magnitude larger than the average diameter of the micro channels of the porous filter medium.

Typically the diameter of the macro channel is at least two orders of magnitude larger than the average diameter of the micro channels of the porous filter medium.

Typically the diameter of the macro channel is several orders of magnitude larger than the average diameter of the micro channels of the porous filter medium.

Typically the at least one macro channel has an average diameter and the air gap between the at least one layer with macro channels and the at least one layer without macro channels is at least as thick as the average diameter.

Optionally, the filter comprises a plurality of layers each having at least one macro channel.

In some embodiments, a first, upstream layer having at least one macro channel has more channels than a subsequent inner layer having at least one macro channel.
In some embodiments, a first layer having at least one macro channel has wider or narrower macro channels than an inner layer having at least one macro channel.

The macroscopic channels can be provided with inserts that provide baffles, preventing the flow of air directly through the channels and directing the air flow towards the cylindrical surface of the channels.

Optionally the filter layers have graded densities, with a lower density side towards air inlet and a higher density side towards air outlet.

Alternatively, the layers have a fixed density.

A second aspect of the invention is directed to providing a continuous multilayer sheet of filter comprising a first layer of filter medium with macro channels therethrough coupled to a second layer of filter medium without macro channels therethrough.

Typically the first layer is spaced from the second layer with spacers to create a gap therebetween.

The continuous multilayer sheet may be supplied on a roll.

A third aspect of the invention is directed to an airconditioning system comprising a filter system comprising a plurality of layers made from porous filter material, such that at least one layer has at least one macro channel therethrough and at least one layer has no macro channels therethrough.

A fourth aspect of the invention is directed to use of a filter system in an airconditioning system, the filter system comprising a plurality of layers made from porous filter material, such that at least one layer has at least one macro channel therethrough and at least one layer has no macro channels therethrough.

BRIEF DESCRIPTION OF THE FIGURES

For a better understanding of the invention and to show how it may be carried into effect, reference will now be made, purely by way of example, to the accompanying Figures, wherewith it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention.

Fig 1 is a schematic cross-section of a prior art filter material positioned within a duct.

Fig. 2 is a cross section of a filter system in accordance with a first embodiment, consisting of a layer of porous filter material with macro channels there through in the direction
of air flow, the first layer is aligned in parallel with a second layer of porous filter material, this
time not having macro channels there through. As illustrated, the two layers are separated by an
air gap.

Fig. 3 is a filter system in accordance with a second embodiment, consisting of a first
layer with a high density of macro channels there through, a second layer with less macro
channels, and a third layer without macro channels; the three layers being separated by gaps.

Fig. 4 is a filter system in accordance with a third embodiment, consisting of a first layer
with a high density of macro channels there through, a second and third layer without macro
channels, the three layers separated by air gaps.

Fig. 5 is a filter system in accordance with a fourth embodiment consisting of a first
layer with a high density of macro channels there through, a second layer without macro
channels, an additional filter layer, this time a pleated filter.

Fig. 6 is a filter system in accordance with a fifth embodiment consisting of a first layer
with a high density of macro channels there through and a second layer without macro channels,
wherein both layers are pleated filters.

Fig. 7 is a sixth embodiment consisting of a first layer with a high density of macro
channels there through, a second and third layer, both without macro channels, wherein all three
layers are pleated filters.

Fig. 8 is schematic, cross-sectional representation of bulk sheet of filter material that
may be rolled or unrolled, and cut to size, as can a regular filter medium; wherein the filter
material consists of a first layer with a high density of macro channels there through and a
second layer without macro channels, the layers being largely separated by gaps, and linked
together by occasional spacers (not shown).

Fig. 9 is a schematic, cross-sectional representation of a bulk sheet of filter material that
may be rolled or unrolled, and cut to size, as can a regular filter medium; wherein the filter
material consists of a first layer with a high density of macro channels there through and second
and third layers without macro channels; the layers being largely separated by gaps, and linked
together by occasional spacers (not shown).

Fig. 10 is a filter system in accordance with a seventh embodiment, consisting of a first
layer with a high density of macro channels there through, a second and third layer without
macro channels, the three layers separated by air gaps, wherein fixed baffles, in the shape of
chevrons or cones are positioned within the macro channels and facilitate turbulent flow there
through, directing the air flow towards the walls of the channels.
Fig. 11 is a filter system in accordance with an eighth embodiment, consisting of a first layer with a high density of macro channels there through, a second and third layer without macro channels, the three layers separated by air gaps, wherein baffles in the shape of turbines or propellers are positioned within the macro channels.

Fig. 12 is a filter system in accordance with a ninth embodiment, consisting of a first layer with a high density of macro channels there through, a second and third layer without macro channels, the three layers separated by air gaps, wherein turbines are positioned at the inlets to the macro channels..

Fig. 13 is a filter system in accordance with a tenth embodiment, consisting of a first layer with a high density of macro channels there through, a second and third layer without macro channels, the three layers separated by air gaps, wherein turbines are positioned at the exits from the macro channels.

Fig. 14 is a cross-section of a filter system in accordance with an eleventh embodiment, consisting of a layer of filter material with macro channels there through in the direction of airflow, the layer aligned in parallel with a second layer of filter material, this time not having macro channels there through. As illustrated, the two layers are separated by an air gap. Twisted (helical) inserts are positioned within the macro channels.

Fig. 15 shows an alternative configuration for the macro channels within the first layer of filter material.

Fig. 16 shows how a filter with macro channels can be retrofitted in series with a prior art filter as shown in Fig. 1, thereby comprising a system of the invention, and

Fig. 17 shows how a basic filter system of the invention, such as that of Fig. 2, need not operate as a stand-alone filter and can be set up in series with a regular filter, thereby creating more complex filter solutions, such as that of Fig. 3.

DESCRIPTION OF EMBODIMENTS

With reference to Fig. 1, a schematic cross-section of a prior art filter material 8 positioned within a duct 5 is shown. Prior art filter include, inter alia, open pore foams and fibrous felts having two or three dimensional anisotropy. They may be fabricated from a range of materials, including, inter alia, cellulose fibers, ceramic fibers, glass fibers, cotton fibers, synthetic fibers and carbon fibers. In general, the thicker the layer of filter and the denser, the more effective it is at stopping particles, however, the more it obstructs fluid flow therethrough. When used as an air filter, the pressure drop can be considerable. Mostly the pressure drop is a function of dust caking, and whilst it is desirable to have a large dust holding capacity within the
filter, it is further desirable to minimize dust caking at the surface facing the air inlet, i.e. the upstream surface, so that dust is distributed through the filter.

Cost also increases with thickness, and there is a spatial cost as well. The appropriate filter material and dimensions, particularly the thickness of the layers are dependent on the requirements of the application, the nature of the fluid to be filtered and the particle size and density to be removed.

As shown in US 7,708,794 and US 6,238,464, the utility of macro channels within filter material layers has been established. In spite of the perforations a significant part of the dust is captured by the filter.

Such filters work well provided they are used in situations with high air velocity, and where very thick filters can be used. They are not suitable for use in airconditioning systems where filters are required to be a total of 2" to 4" thick, and where air speeds are much lower.

Graduated density filters are also known. These filters are typically arranged with lower density surface upstream, facing the fluid intake, with a gradual increase in density through the filter towards the downstream surface. Such filters are designed to maintain a reasonable flow there-through, minimizing pressure drop. Their efficacy is, however, adversely affected by dust cake build up on the upstream surface. This clogging results in such filters becoming ineffective and thus disposed of well before the internal space of the filter medium is fully utilized.

The prior art thus includes both simple filter layers without macro channels and filter layers incorporating macro channels, and both constant density and graduated filter media. Actual dust holding capacity remains far below theoretical levels due to dust caking on surfaces facing the air intake results in unacceptable pressure drops long before the maximum acceptable pressure drop would be reached by dust distributed more evenly through the material.

The present invention includes both filter layers with macro channels and filter layers without such macro channels in series. The combination of both types of filters is counterintuitive. Nevertheless, a dramatic increase in dust holding capacity occurs. The combination teaches is away from both US 7,708,794 and US 6,238,464 where it is clear that the macro channels contemplated are unobstructed through-holes.

Thus in accordance with embodiments of the invention, a filter system is provided for insertion into a fluid flow, such as within a duct, for example. The filter system comprises a plurality of layers made from porous filter material, such that at least one layer has at least one macro channel therethrough in the direction of fluid flow through the duct and at least one layer has no macro channels therethrough.
With reference to Fig. 2, a cross section of a filter system 10 in accordance with a first embodiment is shown. The filter system 10 consisting of a layer of filter material 12 with macro channels 14 therethrough in the direction of air flow, the layer of filter material 12 is aligned in series with a second layer of filter material 18, this time not having macro channels therethrough. Macro channels 14 for aiding air flow through the filters are incorporated in the first layer 12, but the second layer 18 does not have such macro channels. As illustrated, the two layers 12, 18 are separated by an air gap 16.

It has been surprisingly found that having a conventional layer of filter material without macro channels, in series with the layer having macro channels therethrough, provides increased dust accumulation, better filtering, and significantly increases the effective life times of such systems.

Without wishing to be bound by theory, it is believed that there are a number of contributory effects that prevent dust cake build up clogging the second layer.

1. After installation and before dust build up, whilst the surface of the first layer 12 remains relatively clean, a significant proportion of the air flow passes through the filter material of the first layer, with only a small proportion of the air flow passing through the macro pores. This differs from systems such as that shown in US 7,708,794 and US 6,238,464 in three ways: (i) in US 7,708,794 and US 6,238,464 a backing plate is considered, thus the dust trapping effect by air passing through the filter medium is insignificant, (ii) the thickness of the layer with macro channels in US 7,708,794 and US 6,238,464 is much greater than that of the present invention, and (iii) the flow rates in US 7,708,794 and US 6,238,464 are typically much higher, so the flow through the channels in US 7,708,794 and US 6,238,464 is turbulent, whereas flow through the macro channels of the present invention tends to be more laminar, and baffles are preferably added to increase turbulence.

2. By virtue of the channels 14 providing a bypass, the pressure drop due to caking of the first layer 12 increases only very slowly over time.

3. As the first layer 12 gets clogged, the fluid flow rate through the macro channels 14 of the first layer 12 increases. The accelerated fluid impinging on the second layer 18, which is, higher than the fluid velocity entering the system as a whole, disrupts dust cake build up on the facing surface of the second layer 18.
4. In contrast to the even dust cake build up on a continuous surface exposed to an
even, dust-carrying air stream, the localized, high velocity particle-laden
airstream exiting the macro channels 14 impinges the second filter medium 18 in
localized areas, surrounded by a surface exposed to a lower velocity air stream.
Consequently, particles passing through the macro channels are deposited in
isolated islands of dust cakes, resulting in such caking being irregular, thus more
unstable and tending to become dislodged, falling down into the air gap, but
nevertheless remaining trapped within the filter system.

5. Even where local caking occurs, islands of dust are created. These islands do not
block fluid flow, since air can flow around such islands.

6. The second filter medium 18 downstream of the perforated first layer 12, causes
turbulence between the higher velocity streams exiting the macro channels 14 of
the first filter layer 12 and the lower pressure velocity air flowing through the
first medium, aiding dust deposition.

7. The increased velocity of fluid through the macro channels of the first layer
seems to result in vibration of the second layer which dislodges cakes of dust
deposited thereupon.

It will be appreciated that caking over the entire upstream surface of the second medium
18, blocking the filter, would result in a significant pressure drop, however the turbulence
inhibits this, making it more likely for particle laden fluid to penetrate more deeply into the
second medium 18. Relatively large dust particles impinging the second filter 18 tend to bounce
off and eventually accumulate in low velocity areas, without blocking the air stream.

Although not fully understood and regardless of the underlying explanation, it has been
demonstrated that filter systems incorporating a multi-layer structure, combining at least one
filter layer with macro channels, with at least one filter layer not having such channels, results in
the pressure drop across the system building up only very slowly. Consequently, the captured
dust mass / Pressure drop is more favorable than that of conventional filters consisting only of
conventional filter layers without macro channels.

Thus by having at least one perforated layer separated by a gap from at least one non-
perforated layer, the overall filter volume is more effectively utilized and more dust is removed,
with the effect of caking minimized, and the effective dust holding capacity is increased.
typically, as shown, the layer with at least one macro channel is positioned upstream in the fluid flow and one or more layers without macro channels are positioned downstream thereof. it appears that this configuration is the superior one.

filter layers equipped with macro channels may be fabricated from open pore foams, fibers, and other known filter materials. similarly, the filter material from which the at least one layer having no macro channels therethrough may be fabricated from an open pore foam or from a fiberous material such as a felt. the combination of both type of filter layers in series is not dependent on the filter medium. choice of filter medium depends on the fluid to be filtered, temerature, size of particles to be removed, etc., and the various considerations are well known, so will not be discussed further hereinbelow.

in some embodiments, the at least one layer of filter material comprising at least one macro channel is upstream from the at least one layer of filter material not comprising at least one macro channel. in other embodiments, the at least one layer of filter material comprising at least one macro channel is abutting the at least one layer of filter material not comprising at least one macro channel.

optionally and preferably the layers are separated by a gap. such a gap induces turbulence, removes streams and averages air velocity before the airflow enters the outlet filter.

since filter media are highly porous, the air gap, though highly desirable, is no essential, and where the layers are in contact, some advantage in terms of dust accumulation/drop in pressure flow is obtained.

typically the layers of filter material are perpendicular to a direction of fluid flow and the at least one air gap is parallel to the direction of fluid flow. it will, however, be appreciated that both features may be angled to the incoming fluid flow in which they are situated, whilst still having a positive effect.

generally filters of the present invention are placed in gas ducts and used to filter gaseous fluids, including but not limited to air filters for filtering air.

the basic system is capable of various refinements and sophistications.

whereas the two-layer filter shown in fig. 2 can theoretically provide a huge dhc due to deep dust penetration, the dust arrestance of such a filter has been found to be only about 50-75%. the macro channels 14 of the first layer 12 are believed to help penetrate the second layer by creating fast laminar flow.

with reference to fig. 3, a filter system 30 in accordance with a second embodiment is shown, consisting of a first layer 32a with a high density of macro channels 34 there through, a
second layer 32B with less macro channels 34, and a third layer 38 without macro channels; the
three layers being separated by gaps 36A, 36B.

As shown in Fig. 4, a filter system 40 in accordance with a third embodiment, consisting
of a first layer 42 with a high density of macro channels 44 there through, a second 48B and
third layer without macro channels 48A, the three layers separated by air gaps 36A, 36B.

Such an arrangement has been found to provide a higher arrestance. It is believed that a
second gap 46B followed by a second layer 48A results in a more homogeneous flow across the
full face of the third layer 48A. Preferably the first gap 46A is approximately the thickness of
the diameter of the macro channels, whilst a wider gap 46B is preferred between the two non-
perforated filter layers 48A and 48B.

Fig. 5 shows a fourth embodiment of a filter system 50 consisting of a first layer 52 with
a high density of macro channels 54 there through, a second layer 58A without macro channels,
and an additional filter layer - this time a pleated filter 58B.

Pleated filters are, of course, known. No novelty is claimed for such a layer, apart from
in conjunction with a two layer system of the invention one layer with macro channels and the
other layer without macro channels.

With reference to Fig. 6, a fifth embodiment of a filter system 60 is shown, mutatis
mutandis, consisting of a first layer 62 with a high density 64 of macro channels there through,
and a second 68 without macro channels, wherein both layers are pleated type filters. In Fig. 7, a
sixth embodiment including both a second non-perforated layer 68A and a third layer 68B is
shown. These embodiments work largely the same way as the systems described hereinabove.

It will be noted that the term non-perforated with reference to embodiments of the
invention, means without macro channels. The filter media are, nevertheless porous.

With reference to Figs. 8 and 9, both two and three layer filter materials separated by
gaps (with occasional spacers - not shown) in accordance with the present invention, may be
manufactured in large sheets that may be supplied flat or rolled. Such sheets may be, cut to size
as can traditional filter media.

An additional aspect of some embodiments of the invention are that the macroscopic
channels can be provided with inserts that provide baffles, preventing the flow of air directly
through the channels and directing the air flow towards the cylindrical surface of the channels.
Unlike the simple, open, through-channels of the prior art, as exemplified by US 7,708,794 and
US 6,238,464, where turbulence is created by the thickness of the layer and the high air flow
rates through the macro channels, in typical embodiments of the present invention, such as are
used for air conditioning systems and the like, laminar flow is more typical. Since a turbulent
regime is desirable to cause dust passing through the macro channels to be deposited on the channel walls, baffles may usefully be deployed in association with the macro channels. This approach has proven successful in further increasing the dust uptake of the filter, whilst maintaining a reasonable air flow pressure through the filter.

Without wishing to be bound by theory, it is believed that such baffles in macro channels create turbulent flow therethrough which, whilst maintaining a reasonably air flow through the filter and preventing caking over the entire surface area, nevertheless filters out particles by directing solid matter towards the surface of the macro channels, perhaps by centrifugal force, created eddies, surface drag and similar means.

Thus Fig. 10 shows a filter system 70 in accordance with a seventh embodiment, consisting of a first layer 72 with a high density of macro channels 74 there through, a second and third layer without macro channels 78A, 78B, the three layers separated by air gaps 76A, 76B, wherein fixed baffles 75, in the shape of chevrons or cones are positioned within the macro channels 74 and facilitate turbulent fluid flow there through.

Fig. 11 is a filter system 80 in accordance with an eighth embodiment, consisting of a first layer 82 with a high density of macro channels 84 there through, a second 88A and third layer 88B without macro channels, the three layers separated by air gaps 86A, 86B, wherein baffles 85, in the shape of turbines or propellers are positioned within the macro channels 84 and facilitate turbulent flow there through. Such propellers are typically static, but may be freely turning propellers or even driven by an external force. Not all propellers need be configured in the same way, nor must they direct air flow there-past to eddy in the same rotation. Thus adjacent propellers, whether rotating or static, may be configured as right and left hand propellers, directing the air through the macro channels to provide turbulence by urging the air flow into a right or left spin.

As shown in Fig. 12, in a filter system 90 in accordance with a ninth embodiment, there is provided a first layer 92 with a high density of macro channels 94 there through; a second 98B and third layer 98A without macro channels, the three layers separated by air gaps 96A, 96B, wherein turbines 95 are positioned at the inlets to the macro channels 94 and facilitate turbulent flow there through.

Similarly, Fig. 13 is a filter system 100 in accordance with a tenth embodiment, consisting of a first layer 102 with a high density of macro channels there through 104, a second 108A and third layer 108B without macro channels; the three layers separated by air gaps 106, wherein turbines 105 are positioned at the exits from the macro channels and facilitate turbulent flow there through.
Fig. 14 is a cross-section of a filter system 110 in accordance with an eleventh embodiment, consisting of a layer of filter material 112 with macro channels 114 therethrough in the direction of air flow, aligned in parallel with a second layer of filter material 118 not having macro channels therethrough. As illustrated, the two layers are separated by an air gap 116, as per the first embodiment of Fig. 2, mutatis mutandis. However, helical baffles in the form of twisted inserts 119 are positioned within the macro channels 114 to aid turbulent flow therethrough and the shedding of particulates, depositing the particles into the filter material of the first layer 112.

Fig. 15 shows an alternative configuration for the macro channels 124 within the first layer 122 of filter material having a truncated conical shape. Specifically, instead of cylindrical macro channels, such as shown in Fig. 2, the macro channels 124 are cylindrical and taper into the material. Thus although typically the at least one macro channel is cylindrical, in some embodiments, at least some macro channels taper and the channels thus have truncated conical shapes. Although tapering channels typically taper inwards from inlet to outlet. Alternatively, at least one macro channel tapers outwards from the inlet to outlet. The embodiments of the invention with this feature of non-cylindrical macro channels 124 in a first layer 122, couple this layer 122 with a second downstream layer without macro channels. Other features, including air gaps, additional layers and baffles as described hereinabove may be incorporated into such embodiments. Due to the wide range of possibilities, the various embodiments are not shown.

In addition to providing the multi layer filter systems as a unit, it will be appreciated that the two layer filter system with at least one layer having macro channels and at least one layer not having macro channels may be formed by applying an additional layer to an existing filter. Thus with reference to Fig. 16, a filter 132 with macro channels 134 can be retrofitted in series with a prior art filter 8 as shown in Fig. 1, thereby comprising a system 130 in accordance with the invention. As explained hereinabove, the layer with through channels is usually upstream from the layer without through channels. As shown in Fig. 17, a basic filter system 20 such as that of Fig. 2, need not operate as a stand-alone filter, but can be set up in series with a regular filter, e.g. a simple filter 8 of Fig. 1 thereby creating more complex filter solutions, such as that of Fig. 3 (30), for example.

The size of the macro channels, their shape and the number of macro channels are scenario specific design features. Generally, the macro channels are at least 1 mm in diameter and more typically are several millimeters in diameter. They will rarely be more than about 20 mm in diameter. Typically, the air gap between the layer with macro channels and the
subsequent continuous filter layer is generally about the same as the diameter of the macro channels.

Typically the diameter of the macro channel is at least an order of magnitude larger than the average diameter of the micro channels of the porous filter media, and will be equal or less than the thickness of the filter layer through which it passes.

Optionally the filter layers have graded densities. Preferably they will be configured with the lower density side towards the air inlet and the higher density side towards the air outlet. Alternatively, the layers have a fixed density.

As a result of the multiple layer construction with one layer having through holes and one layer not having through holes and thus no through holes passing right through the filter system, in contradistinction to regular media filters, cakes of dust do not build up on the inlet surface so quickly and the pressure drop through the filter goes up at a much slower rate. Consequently, the time between maintenance events - cleaning or replacement of the filter is much longer.
Experimental Proof of Concept

A number of tests of various materials and composite constructions based on a DOE (design of experiment) have been performed at Blue Heaven Technologies Inc. test rig.

Two and 4 inch filter layers were used. A three layer combination consisting of a synthetic filter layer with macro channels coupled with a second synthetic filter layer without macro channels and separated therefrom by an air gap was coupled with a single 2 inch layer of fiberglass. The total thickness of the system including the air gaps was 4 inches. This combination was found to be more effective at removing dust than either a single 2 inch layer of the same fiberglass filter medium or a double layer of having an overall thickness 4 inches. An improvement in Dust Holding Capacity (DHC) from 200 to 400% was obtained with little impact on arrestance.

Thus it has been demonstrated that the combination of a filter with a macro channel followed by a filter without macro channels is better than the same overall thickness made from two similar layers (both with or both without macro channels), even including a similar sized intermediate air gap between the two filters. Positioning baffles in the macro channels or at the entrances or exits thereof, particularly helixes or propellers to creat turbulence is additionally beneficial, and dividing the non perforated layer into two filters separated by an air gap is also useful.

It will be understood that the various embodiments described hereinabove are discussed in minimum detail, and dimensions have not been given. Furthermore, Features shown or discussed with one embodiment may be combined with features described in other embodiments. Thus the scope of the present invention is defined by the appended claims and includes both combinations and sub combinations of the various features described hereinabove as well as variations and modifications thereof, which would occur to persons skilled in the art upon reading the foregoing description.

In the claims, the word "comprise", and variations thereof such as "comprises", "comprising" and the like indicate that the components listed are included, but not generally to the exclusion of other components.
I. A filter system comprising a plurality of layers made from filter material, such that at least one layer has at least one macro channel therethrough in the direction of fluid flow through the duct and at least one layer has no macro channels therethrough.

2. The filter system of claim 1 for positioning in a duct.

3. The filter system of claim 1 for use in an airconditioning system.

4. The filter system of claim 1, wherein the at least one macro channel has a diameter of at least 1 mm.

5. The filter system of claim 1, wherein the at least one macro channel has a diameter of up to 20 mm.

6. The filter system of claim 1, wherein the filter material of the at least one layer having the macro channel therethrough comprises an open pore foam.

7. The filter system of claim 1, wherein the filter material of the at least one layer having the macro channel therethrough comprises fibers.

8. The filter system of claim 1, wherein the filter material is a felt comprising fibers selected from the group of cellulose fibers, ceramic fibers, glass fibers, cotton fibers, synthetic fibers and carbon fibers.

9. The filter system of claim 1, wherein the filter material of the at least one layer having no macro channels therethrough comprises an open pore foam.

10. The filter system of claim 1, wherein the filter material of the at least one layer having no macro channel therethrough comprises fibers.

II. The filter system of claim 1, wherein the at least one layer of filter material comprises at least one macro channel is upstream from the at least one layer of filter material not comprising at least one macro channel.

12. The filter system of claim 1, wherein the at least one layer of filter material comprises at least one macro channel is upstream from the at least one layer of filter material not comprising at least one macro channel and is separated therefrom by a gap.
13. The filter system of claim 1, wherein the layers of filter material are perpendicular to a direction of fluid flow and the at least one air gap is parallel to the direction of fluid flow.

14. The filter system of claim 1 wherein the at least one macro channel has an average diameter and the air gap between the at least one layer with macro channels and the at least one layer without macro channels is at least as thick as the average diameter.

15. The filter system of claim 1 for positioning in a gas duct wherein the fluid is a gas.

16. The filter system of claim 1, wherein the filter is an air filter and the fluid is air.

17. The filter system of claim 1, wherein the at least one macro channel is cylindrical.

18. The filter system of claim 1, wherein the at least one macro channel tapers inwards from inlet to outlet.

19. The filter system of claim 1, wherein the at least one macro channel tapers outwards from inlet to outlet.

20. The filter system of claim 1, wherein the at least one macro channel has at least one baffle therein to create turbulent flow therethrough.

21. The filter system of claim 19, wherein the at least one baffle is selected from the group comprising a cone and a twisted helical insert.

22. The filter system of claim 19, wherein the at least one baffle comprises a propeller selected from the group comprising driven, static and freely turning propellers is aligned with the at least one macro channel in a position selected from the group comprising: opposite an outlet to the macro channel, opposite an inlet to the micro channel and within the micro channel.

23. The filter system of claim 1, wherein the diameter of the macro channel is at least an order of magnitude larger than the average diameter of the micro channels of the filter media.

24. The filter system of claim 1, wherein the filter comprises a plurality of layers having at least one macro channel per layer.
25. The filter system of claim 1, wherein a first layer having at least one macro channel has more channels than an inner layer having at least one macro channel.

26. The filter system of claim 1, wherein macro channels in a first layer having at least one macro channel are wider or narrower than macro channels in an inner layer having at least one macro channel.

27. The filter system of claim 1, wherein at least one filter layer has a graded density, with a lower density side towards air inlet and a higher density side towards air outlet.

28. The filter system of claim 1, wherein at least one filter layer has a fixed density.

29. The filter system of claim 1 comprising two layers without macro channels separated by a gap.

30. A continuous multilayer sheet of filter comprising a first layer of filter medium with macro channels therethrough coupled to a second layer of filter medium without macro channels therethrough.

31. The continuous multilayer sheet of claim 30 wherein the first layer is spaced from the second layer with spacers to create a gap therebetween.

32. The continuous multilayer sheet of claim 30 supplied on a roll.

33. An airconditioning system comprising the filter system of claim 1.

34. Use of claim 1 in an airconditioning system.
Fig. 1

Prior Art

Fig. 2

Fig. 3
INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL 10/00595

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B01D 39/16; B32B 3/10; B32B 3/18 (2010.01)
USPC - 156/182; 156/251; 493/941

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - B01D 39/16; B32B 3/10; B32B 3/18 (2010.01)
USPC - 156/182; 156/251; 493/941

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC(8) - B01D 25/00 (2010.01); USPC - 55/318, 482, 485, 486, 487; 95/286, 287, Patents, Non-Patent literature (search term limited)

Electronic database consulted during the international search (name of data base and, where practicable, search terms used)
USPTO-PubWEST; Google. Search terms: air, aircondition, apart, aperture, channel, condition, diameter, filter, filtering, filtration, foramen, foraminous, gap, gas, gaseous, gram, hole, inch$, layers, microchannel, micrometer, micron, millimeter, mm, multilayer, opening, passage, pore, porous, radius, radius, separate, size, space, vapor, void

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
<tr>
<td>X</td>
<td>US 6,923,911 B1 (Beier et al.) 02 August 2005 (02.08.2005), fig. 5; col 1-3</td>
<td>1-3, 11-17, 23-25, 33, 34</td>
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<td>Y</td>
<td>US 6,409,805 B1 (Beier et al.) 25 June 2002 (25.06.2002), fig. 5; col 1-3</td>
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<td>US 2005/001 1172 A1 (Lindblom) 10 January 2005 (10.01.2005), entire document</td>
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"A" document defining the general state of the art which is not considered to be of particular relevance
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

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Date of mailing of the international search report 20 DEC 2010

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