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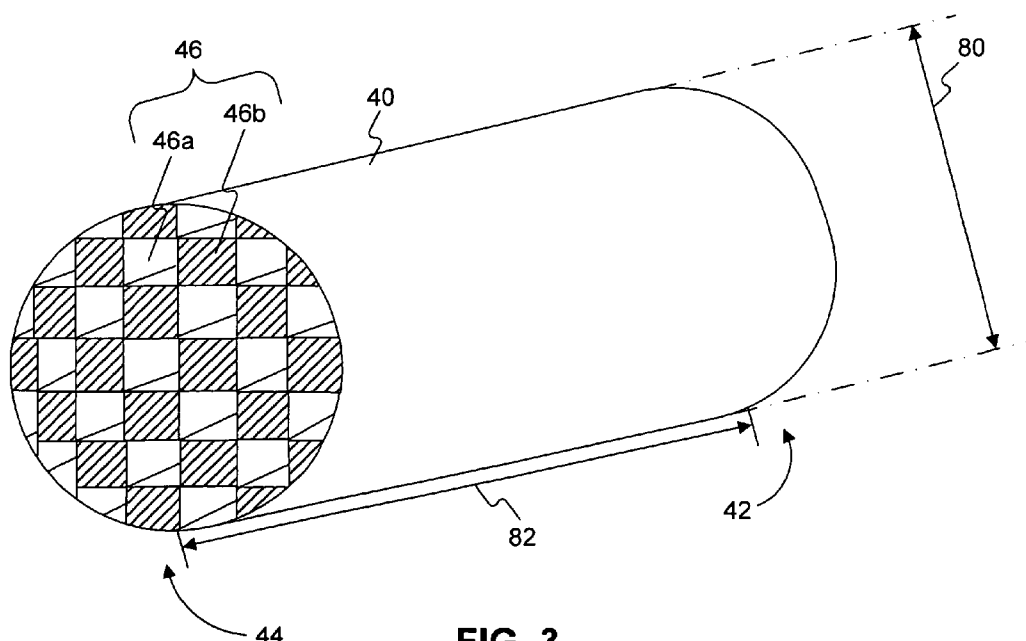


FIG. 3

(57) **Abstract:** A filter media (40) is disclosed. The filter media includes a plurality of channels (46) separated by porous sidewalls (50) extending longitudinally from a first end (44) to a second end (42). The plurality of channels includes a plurality of first channels (46a) and a plurality of second channels (46b). The first channels are open at both the first end and the second end and have a first width. The second channels are closed at the first end and open at the second end and have a second width greater than the first width.

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Description

PARTIAL FLOW EXHAUST FILTER

Technical Field

5 The present disclosure relates generally to a partial flow filter, and more particularly, to a partial flow exhaust filter.

Background

Internal combustion engines exhaust a complex mixture of chemical species as a byproduct of the combustion process. In diesel engines, the condensed phase chemical species are composed of three main fractions, namely, elemental carbon and inorganic ash (solid), soluble organic fraction (SOF and liquid), and sulphate particulates (liquid). Due to heightened environmental concerns, exhaust emission standards have become increasingly stringent over the years. As part of these emission standards, regulations prescribe the amount of chemical species that can be emitted from an engine depending on the type, size, and/or class of the engine. One method used by engine manufacturers to comply with these regulations is to remove the offending chemical species from the exhaust flow of the engine. Different techniques are typically used to remove solid phase and gaseous phase chemical species from the exhaust flow. One common method used to remove solid phase (and to some extent, liquid phase) particulate matter contained in the exhaust is to capture and oxidize these particulate matter using diesel particulate filters (DPF).

DPF's are typically located along the path of the exhaust flow and they operate by forcing the exhaust flow through a filter media of the DPF. There are many types of filter media that have been used in DPF's. Ceramic wall-flow monoliths are by far the most common type of filter elements used in

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DPF's. A ceramic wall-flow filter element has parallel channels (called "honeycomb" structure) alternately plugged at each end in order to force the exhaust gases through the porous ceramic walls. That is, channels that are exposed at the inlet end (called "inlet channels") are plugged at the outlet end, and channels that are plugged at the inlet end (called "outlet channels") are exposed at the outlet end. Therefore, exhaust gases that enter the inlet channels at the inlet end are forced to percolate through the walls of the filter element to the outlet channels in order to exit the filter element. Thus, the walls of the filter media act as a filter. These filter elements are commonly made of ceramic materials, such as cordierite (a synthetic ceramic composition having the formula $2\text{MgO} \cdot 2\text{Al}_2\text{O}_3 \cdot 5\text{SiO}_2$), that are characterized by good porosity, high temperature resistance and good mechanical strength. The ceramic walls of the filter media block some or all of the particulate matter in the exhaust while allowing the exhaust gases to flow through. Over time, the particulate matter may clog the filter media, impeding the flow of gas through it, resulting in increased pressure drop across the filter (engine back pressure) and reduced engine efficiency. Filter regeneration is one way to remove the particulate build up within the filter media. Regeneration is the process of increasing the temperature of the filter media until the organic components of the particulate matter such as the soot and the soluble organic fraction (SOF) that accumulates in the filter media oxidize. The regeneration process exposes the filter media to large temperature cycles that negatively impact the durability of the filter media.

U.S. Patent No. 4,417,908 (the '908 patent) to Pitcher, Jr. describes a honeycomb filter element that decreases the back pressure generated by the filter without sacrificing filtration efficiency. The filter media of the '908 patent reduces backpressure by increasing the number of inlet channels as opposed to the outlet channels. The increased number of inlet channels increases the surface area of the inlet channel walls through which the exhaust gases can

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percolate into the outlet channels. The increased surface area delays clogging of filter media and hence, pressure build up.

While the filter media of the '908 patent may delay back pressure buildup, the accumulating soot in the filter media may eventually increase back pressure and require regeneration to maintain engine efficiency. By increasing the surface area available for soot accumulation, the filter element of the '908 patent may increase the quantity of soot that has to be burned off during regeneration. This increased quantity of soot burned during regeneration may increase the high temperature exposure and the temperature gradients in the filter element, thereby negatively impacting its durability. The present disclosure is directed to solving one or more of the problems set forth above.

Summary of the Invention

In one aspect, a filter media is disclosed. The filter media includes a plurality of channels separated by porous sidewalls extending longitudinally from a first end to a second end. The plurality of channels includes a plurality of first channels and a plurality of second channels. The first channels are open at both the first end and the second end and have a first width. The second channels are closed at the first end and open at the second end and have a second width greater than the first width.

In another aspect, a particulate filter is disclosed. The particulate filter includes a housing and a filter media with a first end and a second end positioned within the housing. The filter media includes a plurality of first channels extending from the first end to the second end. Each first channel has substantially rectangular cross-sectional shape and is open at both the first end and the second end. The filter media also includes a plurality of second channels extending from the first end to the second end. Each second channel of the plurality of second channels is closed at the first end and open at the second end,

and adjacent to a first channel of the plurality of first channels. Each second channel also has a substantially octagonal cross-sectional shape.

In yet another aspect, a method of filtering exhaust gas of an internal combustion engine is disclosed. The method includes directing the exhaust gas into a first channel extending from an inlet end to an outlet end. The first channel has a first cross-sectional area and is open at both the inlet end and the outlet end. The method also includes passing a first portion of the exhaust gas into a second channel. The second channel is adjacent to the first channel and has an inlet end and an outlet end. The second channel is closed at the inlet end and open at the outlet end and has a second cross-sectional area greater than the first cross-sectional area. The method further includes directing the first portion of the exhaust gas out of the outlet end of the second channel, and directing a portion of the exhaust gas out of the outlet end of the first channel.

Brief Description of the Drawings

- FIG. 1 is an illustration of an exemplary disclosed engine system;
FIG. 2 is a cut away illustration of the diesel particulate filter (DPF) of FIG. 1;
FIG. 3 is an illustration of an embodiment of the filter media of the DPF of FIG. 1;
FIG. 4 is a cross-sectional illustration of the DPF of FIG. 1;
FIG. 5 is an illustration of a magnified view of the filter media of the DPF of FIG. 1;
FIGS. 6A-6D are illustrations of another embodiment of the filter media of the DPF of FIG. 1;
FIG. 7A illustrates the flow fraction filtered as a function of orifice size in an embodiment of the filter media of the DPF of FIG. 1; and
FIG. 7B illustrates the pressure drop as a function of orifice size in an embodiment of the filter media of the DPF of FIG. 1.

Detailed Description

FIG. 1 illustrates an engine system 100. Engine system 100 may have, among other systems, a power source 10, and an induction system 14, and an exhaust system 12. Power source 10 may include an engine such as, for
5 example, a diesel engine, a gasoline engine, a natural gas engine, or any other engine apparent to one skilled in the art. Fuel may be combusted in power source 10 to produce mechanical power. Combustion of the fuel may produce exhaust gas 25. The exhaust gas 25 may be exhausted to the atmosphere through the exhaust system 12.

10 Induction system 14 may be configured to introduce compressed air into a combustion chamber (not shown) of power source 10. Induction system 14 may include components configured to introduce compressed air and fuel into the power source. These components may include any components known in the art such as, valves, air coolers, air cleaners, control system, etc.

15 Exhaust system 12 may be configured to direct hot exhaust gas 25 from power source 10 to the atmosphere. Exhaust system 12 may include components that are configured to extract power from exhaust gas 25. These components may include a turbocharger 18. Turbocharger 18 may consist of a turbine 18A connected to a compressor 18B by a shaft. The turbine 18A may
20 receive exhaust gas 25 from the power source 10 causing a turbine wheel to rotate. This rotation may drive the compressor 18B, compressing air in induction system 14.

Exhaust gas 25 may also contain solid particulate matter and various chemicals in liquid or gaseous form. The solid particulate matter may
25 include combustible organic constituents (such as elemental carbon) and incombustible inorganic constituents (such as ash). Some of the exhaust gas constituents may be regulated by regulatory agencies, and hence may need to be removed/reduced before exhaust gas 25 is released to the atmosphere. Exhaust system 12 may include components that may be configured to separate these

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regulated constituents from exhaust gas 25. These components may include, among others, one or more filters. These filters may include a diesel particulate filter (DPF) 30, and a catalytic converter 16.

Catalytic converter 16 may be a device configured to chemically
5 convert some of the constituents of exhaust gas into less harmful constituents. For example, catalytic converter 16 may reduce oxides of nitrogen in exhaust gas 25 to nitrogen and oxygen, oxidize carbon monoxide in exhaust gas 25 to less harmful carbon dioxide, and oxidize un-burnt hydrocarbons in exhaust gas 25 to carbon dioxide and water. Catalytic converter may include a substrate through
10 which exhaust gas 25 may be flown through. The substrate may include a catalyst deposited thereon, to facilitate the oxidation and reduction reactions. Although FIG. 1 depicts catalytic converter 16 to be located downstream of turbocharger 18 and DPF 30 to be located upstream of the turbocharger 18, in general, catalytic converter 16 and DPF 30 may be located either upstream or
15 downstream of turbocharger 18. Catalytic converter 16 may typically be located downstream of DPF 30. However, it is contemplated that other arrangements are possible.

DPF 30 may separate some of the solid and liquid particulate matter ("particulate matter") from exhaust gas 25. FIG. 2 illustrates a cutaway
20 view of DPF 30. DPF 30 may include a housing 32 enclosing a filter media 40. Although a cylindrical housing is depicted in FIG. 2, housing 32 may be of any shape. Housing 32 may be made of any material, such as steel, that may reliably withstand the temperatures and constituents of exhaust gas 25. In some embodiments, heaters may also be embedded in DPF 30 to heat filter media 40 to
25 regeneration temperature. Filter media 40 may be positioned within housing 32 such that exhaust gas 25 flowing through DPF 30 flows through filter media 40. Exhaust gas 25 may enter filter media 40 at an inlet end 44 and exit filter media 40 at outlet end 42.

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Filter media 40 may have a porous structure. In some embodiments, filter media 40 may be made of a porous material such as cordierite or silicon carbide, while in other embodiments, filter media 40 may be made of a metallic mesh or a metallic foam. The porous nature of filter media 40 may filter some of the particulate matter from the exhaust gas 25 passing through it. Due to this filtering of particulate matter, the particulate matter content of exhaust gas 25 exiting filter media 40 at outlet end 42 may be less than particulate matter content of exhaust gas 25 entering filter media 40 at inlet end 44.

FIG. 3 illustrates an embodiment of filter media 40. Filter media 40 may have a cylindrical shape, with length 82 and diameter 80 suited to fit within the cylindrical DPF housing 32. However, other shapes of filter media 40 are also contemplated. Length 82 and diameter 80 may have any value depending upon the application. Filter media 40 may include multiple parallel channels 46 running in a longitudinal direction. Alternating adjacent channels 46 may be plugged at the inlet end 44 of filter media 40 to create inlet channels 46a and outlet channels 46b. Inlet channels 46a may be channels 46 with the inlet end 44 open and outlet channels 46b may be channels 46 with the inlet end 44 plugged. Inlet channels 46a and outlet channels 46b may together create a checker board pattern of channels 46 at inlet end 44.

FIG. 4 shows a cross-sectional view of DPF 30 showing filter media 40. Inlet channels 46a and outlet channels 46b may be separated by porous side walls 50 having thickness 54. Outlet channels 46b may have their outlet ends 42 open. Inlet channels 46a, on the other hand, may have their outlet end 42 plugged. Some of the plugged outlet ends 42 of inlet channels 46a may have an orifice 52 associated therewith. Orifice 52 may be an opening that may fluidly connect inlet channel 46a to the down stream side of DPF 30. In some embodiments, orifice 52 may be included in the plugged outlet ends 42 of all inlet channels 46a. While in other embodiments, orifice 52 may only be included in

the plugged outlet ends 42 of selected inlet channels 46a. For instance, every alternate inlet channel 46a. Orifice 52 may be a substantially circular opening in some embodiments, while in other embodiments, orifice 52 may have other shapes. The size of orifice 52 may vary with application and the desired filter performance. In some embodiments, orifice 52 may be a small opening while in other embodiments, orifice 52 may occupy the entire outlet end 42 of an inlet channel 46a. In these embodiments, the outlet end 42 of inlet channels 46a may also be open like the outlet end of outlet channels 46b. It is also contemplated that, in some embodiments, orifice 52 included in different inlet channels may have different sizes. For instance, the size of an orifice 52 may be function of its distance from the center of the filter media 40. Some of the factors that may determine the size of orifice 52 will be described more in subsequent paragraphs.

Exhaust gas 25 enters inlet channels 46a of filter media 40 at the inlet end 44. Some exhaust gas 25 may also enter outlet channel 46b through porous walls of plugged inlet end 44 of outlet channel 46b. A portion of exhaust gas 25 in the inlet channels 46a may percolate into the outlet channels 46b through the porous side walls 50 of inlet channel 46a. Orifice 52 at the outlet end 42 of inlet channel 46a may restrict the free flow of exhaust gas 25 through inlet channel 46a. This restriction to the flow may also force an additional portion of exhaust gas 25 through the porous side walls 50 into outlet channels 46b. The remaining portion of exhaust gas 25 may exit inlet channels 46a through orifice 52. Decreasing thickness 54 of side wall 50 may increase the portion of exhaust gas 25 that percolates into outlet channels 46b. Increasing size of orifice 52 may also decrease the portion of exhaust gas 25 that is forced through side walls 50.

FIG. 5 is an illustration of a magnified view of side wall 50 of filter media 40. When exhaust gas 25 percolates through the porous side walls 50 of inlet channels 46a, some of particulate matter 48 is filtered by side walls 50. This filtration may be the result of a number of mechanisms. In some embodiments, mean pore size of filter media 40 may be smaller than a mean size

of particulate matter 48. In these embodiments, the filter media 40 may only allow exhaust gas 25 to pass through its pores while blocking larger particulate matter 48. Thus, particulate matter 48 may be deposited on side walls 50 through sieving. As particulate matter 48 builds up on side wall 50, the accumulated
5 particulate matter 48 may also filter exhaust gas 25 leading to more particulate matter accumulation. In some embodiments of filter media 40, the mean pore size of filter media 40 may be larger than the mean diameter of particulate matter 48. In these embodiments, particulate matter 48 may be deposited on side walls 50 through a combination of depth filtration mechanisms which are driven by
10 various force fields. For example, the force fields may be related to velocity or concentration gradients of exhaust gas 25.

A portion of particulate matter 48 present in exhaust gas 25 may, thus, be filtered while percolating through side walls 50 of filter media 40. The remaining portion of particulate matter 48 may pass through DPF 30 along with
15 the portion of exhaust gas 25 exiting filter media 40 through orifice 52. A ratio of the amount of particulate matter 48 filtered by filter media 40 to the total amount of particulate matter 48 present in exhaust gas 25 may be a measure of filtration efficiency of DPF 30. The portion of particulate matter 48 escaping with exhaust gas 25 passing through orifice 52 may contribute to a reduction in
20 filtration efficiency of DPF 30. The amount of exhaust gas 25 flowing through orifice 52, and the amount of escaping particulate matter 48 may increase with size of orifice 52. Therefore, filtration efficiency may decrease with orifice size.

As particulate matter 48 accumulates in filter media 40, the resistance to exhaust flow through DPF 30 may increase. This resistance to
25 exhaust flow may, in turn, increase the pressure of exhaust gas 25 in filter media 40 ("back pressure"). The increase in back pressure may adversely affect the performance of power source 10. Continued accumulation of particulate matter 48 may eventually clog the pores of side walls 50 thereby preventing further percolation of exhaust gas 25 through side walls 50. The increase in back

pressure associated with clogging may in some instances cause catastrophic failure of exhaust system 12. The ability of exhaust gas 25 to exit filter media 40 through orifice 52, may however, prevent catastrophic failure of exhaust system 12.

5 When the back pressure, resulting from particulate matter 48 build up in DPF 30, affects engine performance, DPF 30 may be regenerated. Regeneration is the process of oxidizing (that is, burning) a part of the particulate matter 48 accumulated in the filter media 40. During regeneration, the combustible portion of the accumulated particulate matter 48 may be oxidized to
10 carbon dioxide or carbon monoxide. Oxidation of the combustible part of particulate matter 48 may occur at a regeneration temperature between about 550°C and 650°C or by the oxidation of carbon by NO₂ at a temperature above about 225°C. In some embodiments, this regeneration temperature may be decreased using a catalyst. The accumulated particulate matter may be heated to
15 the regeneration temperature using a variety of ways. In some embodiments, a heater embedded in DPF 30 or filter media 40 may be used to raise the temperature of accumulated particulate matter 48. In some embodiments, the temperature of the exhaust gas 25 may be increased when a regeneration event is triggered. The temperature of exhaust gas 25 may be increased in a number of
20 ways. For instance, a regeneration assist system (not shown) located upstream of DPF 30 may be used to heat exhaust gas 25.

 A regeneration event may be triggered depending upon the amount of accumulated particulate matter 48 in DPF 30. In some embodiments, the amount of accumulated particulate matter 48 may be directly measured (for
25 instance, by using a RF measuring device), while in other embodiments, a threshold value of back pressure may trigger regeneration. During uncontrolled regeneration, the combustible portion of accumulated particulate matter 48 burns, resulting in a rapid increase in temperature, sometimes exceeding 650°C. Due to non-uniform deposition of particulate matter 48 on filter media 40, the

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temperature of some regions of filter media 40 may be significantly higher than other regions causing a large temperature gradient in filter media 40 during regeneration. These high temperatures and temperature gradients may result in filter media 40 damage. In some applications, filter media 40 may be cooled
5 during regeneration by the stream of exhaust gas 25. Increasing amounts of accumulated particulate matter 48 in filter media 40 may increase the temperature and duration of regeneration. The ability of exhaust gas 25 to cool filter media 40 during regeneration may also be compromised by increasing particulate matter 48 build up. The portion of particulate matter 48 exiting filter media 40 may
10 decrease the accumulation of particulate matter 48 in filter media 40, thereby decreasing the possibility of filter damage during regeneration and decreasing the frequency at which regeneration may be required.

Regeneration clears accumulated particulate matter 48 from filter media 40 by converting them into gaseous compounds. The incombustible
15 portion of particulate matter 48 (for example, ash), however, does not get removed by regeneration. This portion of particulate matter 48 gets removed from filter media 40 along with the portion of exhaust gas 25 passing through orifice 52. Increasing size of orifice 52 allows this incombustible particulate matter 48 to be removed from filter media 40 easily.

20 Therefore, increasing filtration efficiency (that is, reducing the amount of particulate matter released from DPF 30) may favor a small orifice 52. While lower back pressure, lower regeneration temperature and duration, lower frequency of regeneration, and lower ash buildup in the DPF 30 may favor a larger orifice 52 size. The choice of orifice size in an application may, thus,
25 involve a tradeoff between these and other factors. In general, orifice size may vary from a smallest size that may be reliably produced in filter media 40 to the size of inlet channel 46a.

In general, decreased side wall thickness 54 may increase filtration efficiency. However, the strength of the filter media 40 may be adversely

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affected. Decreasing side wall thickness may also increase cost and complexity of fabrication. In general, any side wall thickness 54 may be used in an application. Side wall thickness 54 selected for an application may depend on performance, strength, cost, and other factors.

5 The size of inlet channel 46a, outlet channel 46b, and side wall thickness 54 may also depend on the application. In some embodiments, inlet channels 46a and outlet channels 46b may be substantially equally sized. The size of these channels may also be designed to achieve the required filtration efficiency while reducing back pressure and regeneration temperature. In some
10 embodiments, inlet channel 46a and/or outlet channel 46b may be tapered. That is, the width of these channels may vary along a length of the channel.

 FIGS. 6A-6D illustrates another embodiment of filter media 40. FIG. 6A shows a cross-sectional view of filter media 40 of this embodiment, while FIGS. 6B and 6C shows side views of inlet end 44 and outlet end 42,
15 respectively. FIG. 6D shows a magnified view of the inlet end 44. In the description below, reference is made to FIGS. 6A-6D. In the embodiment depicted in FIGS. 6A-6D, the outlet ends 42 of input channels 46a may be open (see FIGS. 6A and 6C) or partially open with a similar orifice as discussed previously. The size of inlet channel 46a may also smaller than the size of the
20 outlet channel 46b. The inlet channel 46a may have a substantially rectangular shape, while outlet channel 46b may have a substantially octagonal shape (see FIGS. 6B-6D). In this disclosure, substantially rectangular shape is used generally to represent any quadrilateral shape (such as, rectangle, square, rhombus, parallelogram, trapezoid, irregular quadrilateral, etc.), and substantially
25 octagonal shape is used generally to represent any eight sided shape (for example, regular octagon, irregular octagon, etc.). These sides may intersect each other at a sharp point or a curve. The width of a side of inlet channel 46a may be w_i . This width w_i may be defined as the size of inlet channel 46a. The distance between opposite walls of the octagonal outlet channel 46b may be w_o . This

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width w_o may be defined as the size of outlet channel 46b. Widths w_i and w_o may have any value. It should be pointed out that, due to the geometrical arrangement of inlet and outlet channels, when width w_o is $\sqrt{2}$ times w_i , the octagon shape of outlet channels may collapse into a square shape. Thus, when
5 $w_o = (\sqrt{2} \times w_i)$, the geometrical arrangement of inlet and outlet channels of this embodiment may resemble the arrangement depicted in FIG. 3. In embodiments with tapered channels, inlet channel width w_i and/or outlet channel width w_o may vary along the length of length of the channel.

As shown in FIG. 6A, exhaust gas 25 may enter the inlet
10 channel 46a at inlet end 44 and travel down the length of the channel towards outlet end 42. The pressure of the exhaust gas in the channel may force a portion of exhaust gas 25 to percolate into adjacent outlet channels 46b through side wall 50. As described earlier, particulate matter 48 may be separated from exhaust gas 25 as it passes through side wall 50. A portion of particulate matter 48 may also
15 escape filter media 40 through the open outlet ends 42 of inlet channels 46a. A larger proportion of exhaust gas 25 percolating into outlet channels 46b may increase the particulate matter 48 filtered by filter media 40. Reducing the size of inlet channel 46a may force more exhaust gas 25 into outlet channels 46b, and thus increase filtration efficiency. However, back pressure may increase with
20 decreasing inlet channel 46a size. Decreasing size of inlet channels 46a may also increase manufacturing complexity and therefore, cost. The inlet channel 46a and outlet channel 46b size in an embodiment may involve a tradeoff between the afore mentioned factors, and depend on the application. In some embodiments, the sizes of inlet channel 46a and outlet channel 46b may be such that w_o is
25 approximately equal to 1.7 to 2 times w_i (that is, $w_o \approx (1.7 \text{ to } 2) \times w_i$). While computational fluid dynamic (CFD) simulations indicate that filter media 40 may have desirable characteristics when the ratio w_o/w_i equals to about 1.7 to 2, it is contemplated that inlet and outlet channels 46a, 46b may have other sizes. In

some embodiments, some of the particulate matter that escapes DPF 30 may be captured by other filters downstream of DPF 30.

Industrial Applicability

The disclosed embodiments relate to a partial flow filter to
5 separate particulate matter from engine exhaust. The filter includes a porous filter media with multiple parallel channels running from an inlet end to an outlet end. Alternate adjacent channels of the filter media are plugged at the inlet end of the filter. These plugged channels may be open at the outlet end of the filter media. Some or all of the channels which are not plugged at the inlet end may
10 include an orifice at the outlet end. The size of the orifice may be small or may be as large as the size of the channel. The size of the channels may also vary. Exhaust from an engine may be passed through the filter. These exhaust may enter the channels of the filter media that are open at the inlet end (inlet channels). Due to the pressure of exhaust gas in the inlet channel, some of the
15 exhaust gas may percolate into the adjacent channels through the porous walls of the channel. During percolation through these porous walls, particulate matter contained in the exhaust may be filtered. The decreasing size of the inlet channels and/or decreasing size of the orifice may increase the amount of particulate matter filtered by the filter media and improve filter efficiency.
20 However, small orifices and small inlet channels may increase the back pressure of filter and negatively affect engine efficiency. Therefore, the selection of orifice size and channel size in an application may involve application specific factors. To illustrate an application of the disclosed partial flow filter, an exemplary embodiment will now be described.

25 A diesel engine exhaust may be directed to a DPF 30. The DPF 30 may contain a cylindrical filter media 40. Filter media 40 may be made of a cordierite ceramic having a porosity of 38% and a micron hole size of 11. Filter media 40 have a diameter 80 of about 7.5 inches and a length 82 of about 8

inches. Filter media 40 may include multiple parallel channels 46 running from an inlet end 44 to an outlet end 42. Each channel 46 may be separated from adjacent channels by a wall having thickness 54 of about 0.012 inches. Alternate adjacent channels of filter media 40 may be plugged at inlet end 44 to create a checker board pattern of channels (as seen in FIG. 3) at inlet end 44. These channels are referred as outlet channels 46b. The outlet channels 46b may be open at outlet end 42 of filter media 40. The channels 46 that are open at inlet end 44 (referred to as inlet channels 46a) may have an orifice 52 at the outlet end 42. These inlet channels 46a may have a square cross-section with a width w_i of about 1.5mm. The outlet channels 46b may have an octagonal cross-section, as illustrated in FIG. 6A-6D, with width w_o being about 3mm.

Parametric CFD simulations were carried out on filter media 40 to determine the impact of orifice size on filter performance parameters. Keeping all variables of filter media 40 constant, orifice diameter was varied in each simulation. The ratio of the amount of exhaust flow percolating through side walls 50 to the total exhaust flow into DPF ("flow fraction filtered"), and the pressure drop across filter media 40, were recorded in each case. Increasing values of flow fraction filtered may indicate increased particulate matter 48 filtration, and therefore, increased filtration efficiency. While increasing values of pressure drop across filter media 40 may indicate increasing back pressure, and therefore, decreasing engine performance.

FIGS. 7A and 7B illustrate the impact of orifice size on flow fraction filtered by, and pressure drop across, filter media 40. At an orifice size of "0" (that is, the outlet end of inlet channels 46a are closed) all the exhaust may be forced to percolate through side walls 50. Thus, flow fraction filtered may be "1" (as indicated by FIG. 7A), when orifice size is "0." FIG. 7B indicates that the corresponding pressure drop across filter media 40 when orifice size is "0" to be 9 kilo Pascals (kPa). The impact on engine performance at a filter pressure drop of 9kPa may be unacceptable for the application. FIG. 7A indicates the

flow fraction filtered at the largest orifice size evaluated (when the inlet channel 46a is open at outlet end 42) to be approximately "0.2." That is, when the inlet channel 46a is open at outlet end 42, approximately 20% of exhaust flow percolates through side walls 50. FIG. 7B indicates that the pressure drop
5 associated with such a geometry may be about 3.5Kpa. While this low value of pressure drop through filter media 40 may be attractive, the filtration efficiency associated with 20% of exhaust flow filtration may be unacceptable for some applications.

In between these two extreme cases (that is, the case where orifice
10 size is "0," and the case where the outlet end of inlet channel is open), FIG. 7A indicates that increasing values of orifice size decreases the fraction of exhaust flow filtered. FIG. 7B indicates that the pressure drop across the filter media associated with this decreased amount of flow through the filter walls may also be correspondingly lower. Operating conditions (such as, amount of particulate
15 matter that can be released to the atmosphere) and the efficiency requirements, may indicate acceptable values of flow fraction filtered and pressure drop for an application. Based on these acceptable values, an appropriate orifice size may be chosen.

In some engine applications, complete removal of particulate
20 matter from exhaust flow may not be required. The disclosed filter embodiments may enable the tradeoff of filter efficiency to decrease exhaust back pressure. The disclosed filter elements may be designed to achieve a desired filtration efficiency at a lower value of exhaust back pressure. Since all the exhaust gas flowing through the DPF may not be filtered, the amount of particulate matter
25 accumulation in the filter media may also be lower. This lower particulate matter accumulation may decrease the temperature, temperature gradient, and time of exposure of the filter media to high temperature during regeneration. Lower particulate matter accumulation in the filter media may also decrease the frequency of regeneration, thereby decreasing the number of times the filter

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media is exposed to regeneration temperature. Since the outlet end of the inlet channels may also include an opening, incombustible particulate matter (ash) may be blown out of the filter media along with the exhaust flow, thereby reducing ash buildup in the filter media. This reduction in ash buildup may delay
5 (or even eliminate) filter service needed to remove the accumulated ash, and thereby prolong filter life.

It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed partial flow filter. Other embodiments will be apparent to those skilled in the art from consideration
10 of the specification and practice of the disclosed partial flow filter. It is intended that the specification and examples be considered as exemplary only, with a true scope being indicated by the following claims and their equivalents.

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Claims

1. A filter media (40) comprising:
5 a plurality of channels (46) separated by porous sidewalls (50) extending longitudinally from a first end (44) to a second end (42), the plurality of channels including a plurality of first channels (46a) and a plurality of second channels (46b), wherein,
the first channels being open at both the first end and the
10 second end and having a first width, and
the second channels being closed at the first end and open at the second end and having a second width greater than the first width.
2. The filter media of claim 1, wherein the first channels have
15 a substantially rectangular cross-sectional shape and the second channels have a substantially octagonal cross-sectional shape.
3. The filter media of claim 2, wherein the first width is the
largest width of the cross-section of the first channels, and the second width is the
20 largest width of the cross-section of the second channels.
4. The filter media of claim 1, wherein each first channel is adjacent to a second channel and separated by the side wall.
- 25 5. The filter media of claim 1, wherein the first channels includes an orifice (52).
6. The filter media of claim 1, wherein a ratio of the second width to the first width is greater than about 1.5.

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7. A method of filtering exhaust gas (25) of an internal combustion engine (100) comprising;

5 directing the exhaust gas into a first channel (46a) extending from an inlet end (44) to an outlet end (42), the first channel having a first cross-sectional area and being open at both the inlet end and the outlet end;

passing a first portion of the exhaust gas into a second channel (46b), the second channel being adjacent to the first channel and having an inlet end and an outlet end, the second channel being closed at the inlet end and open
10 at the outlet end and having a second cross-sectional area greater than the first cross-sectional area;

directing the first portion of the exhaust gas out of the outlet end of the second channel; and

15 directing a portion of the exhaust gas out of the outlet end of the first channel.

8. The method of claim 7, wherein a cross-sectional shape of the first channel is substantially rectangular and a cross-sectional shape of the second channel is substantially octagonal.

20

9. The method of claim 8, wherein passing a first portion includes passing a first portion into the second channel having a width greater than about 1.5 times a width of the first channel.

25

10. The method of claim 7, wherein directing a portion of the exhaust gas includes directing the portion of exhaust gas out of an orifice (52) at the outlet end of the first channel.

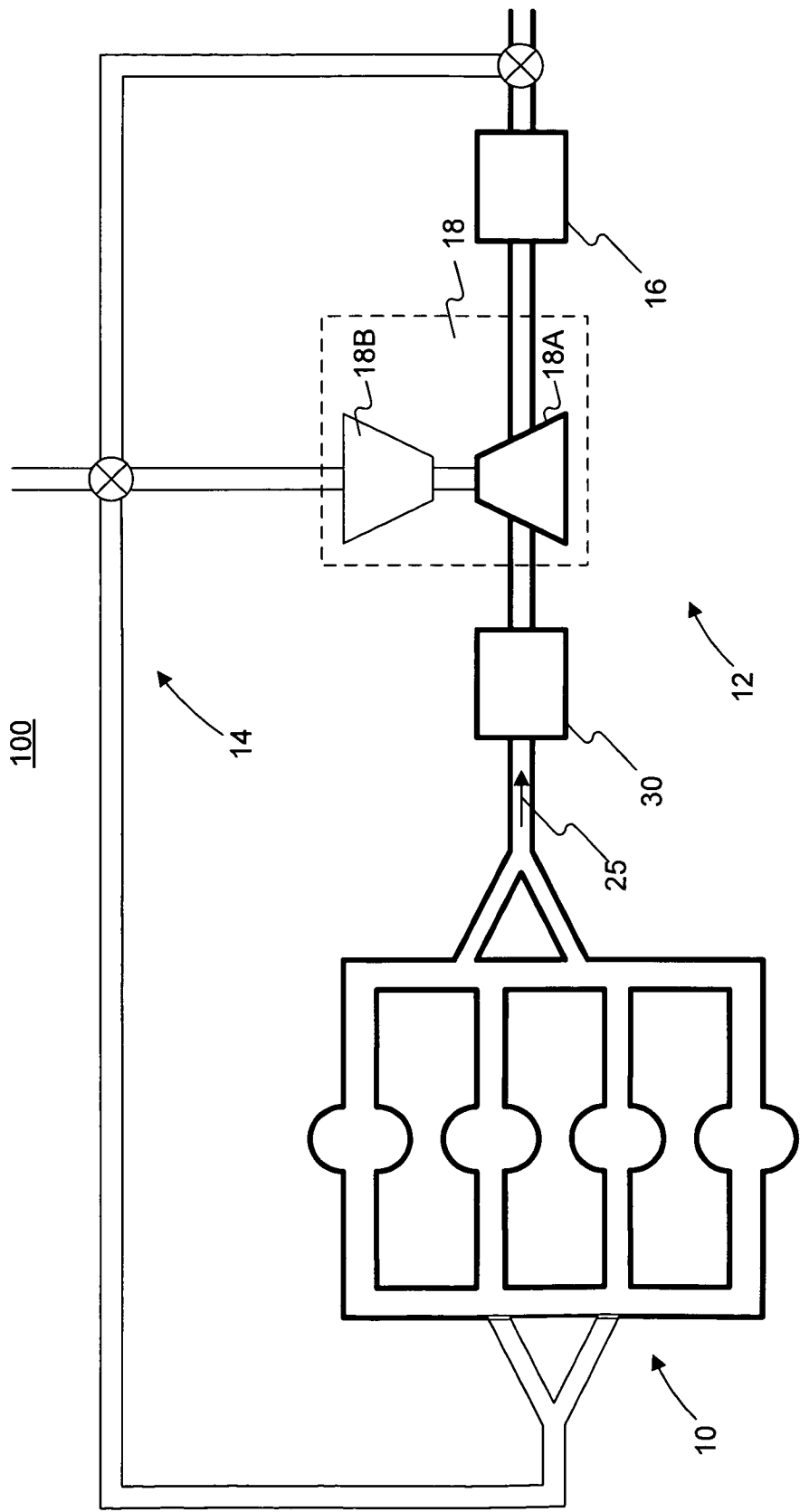


FIG. 1

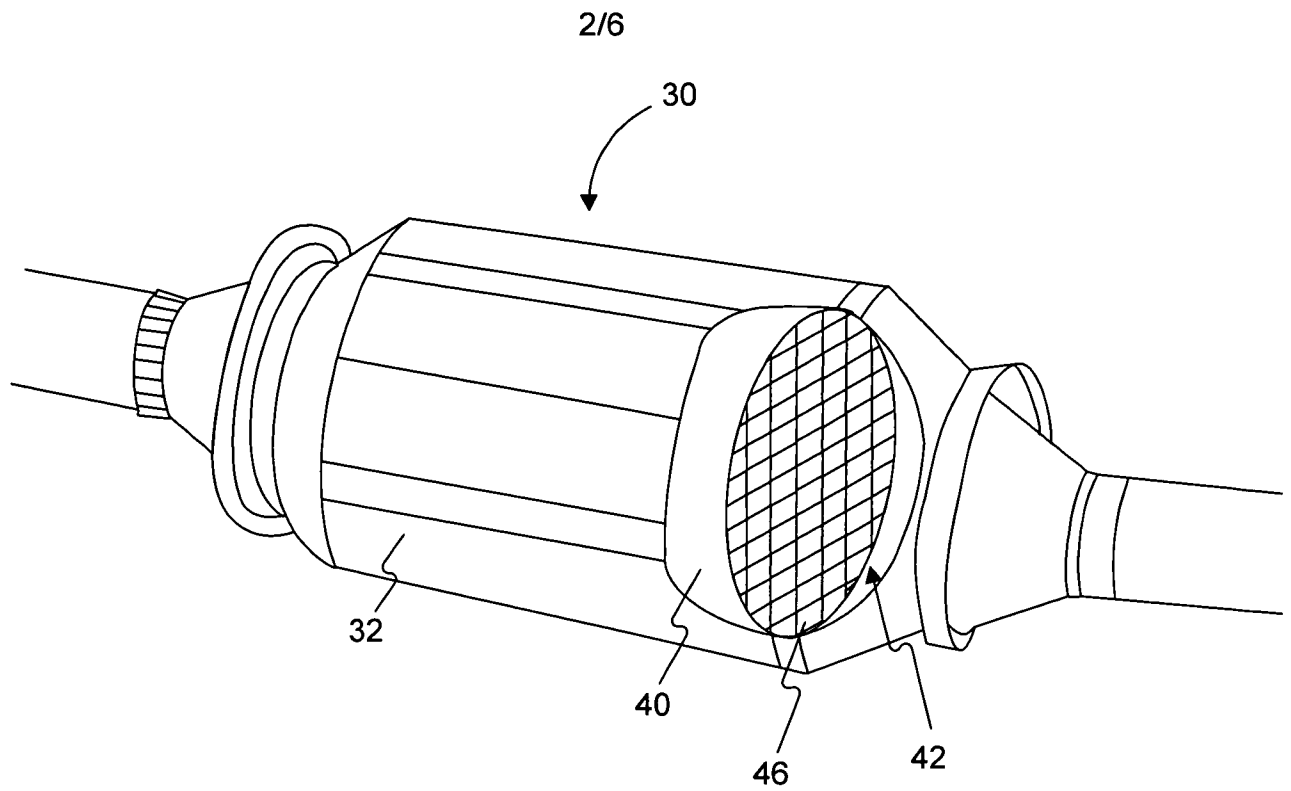


FIG. 2

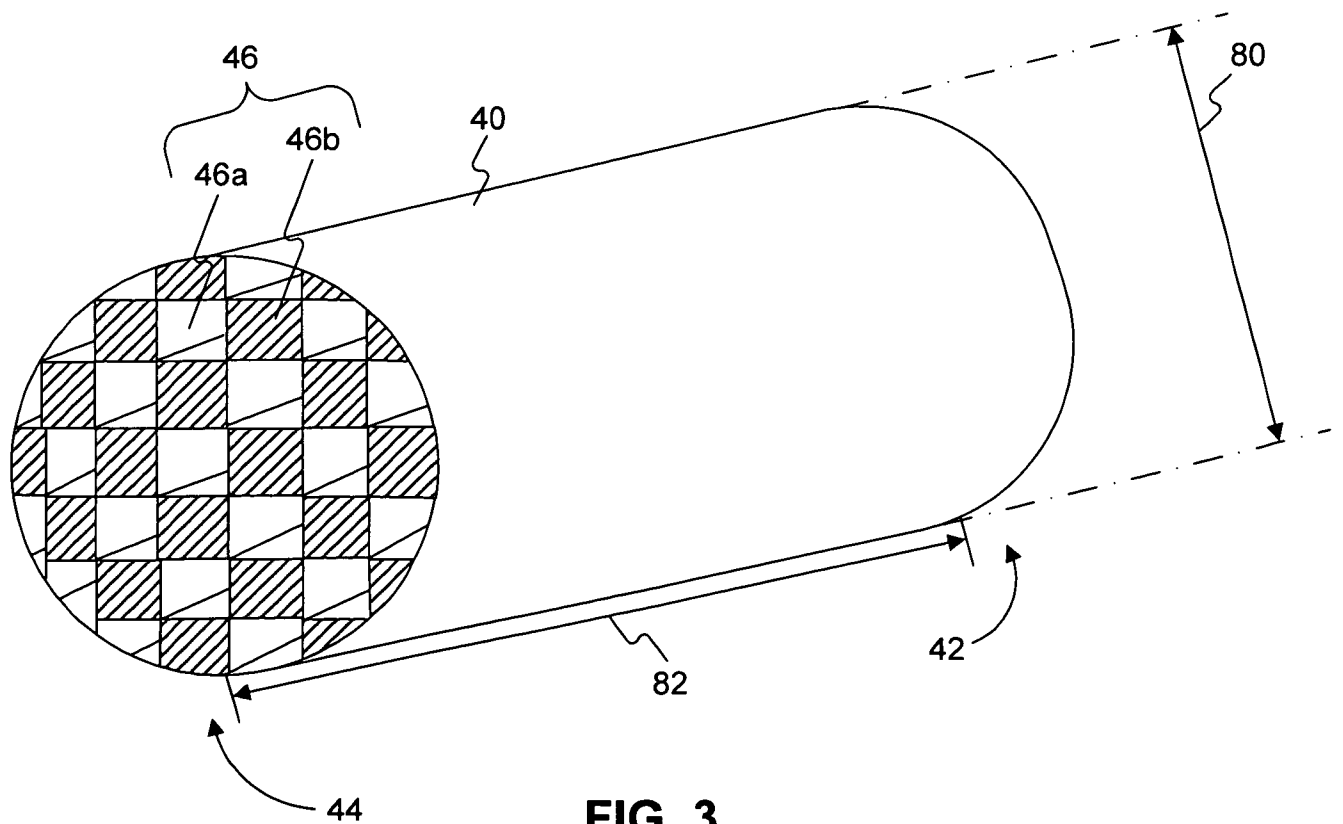


FIG. 3

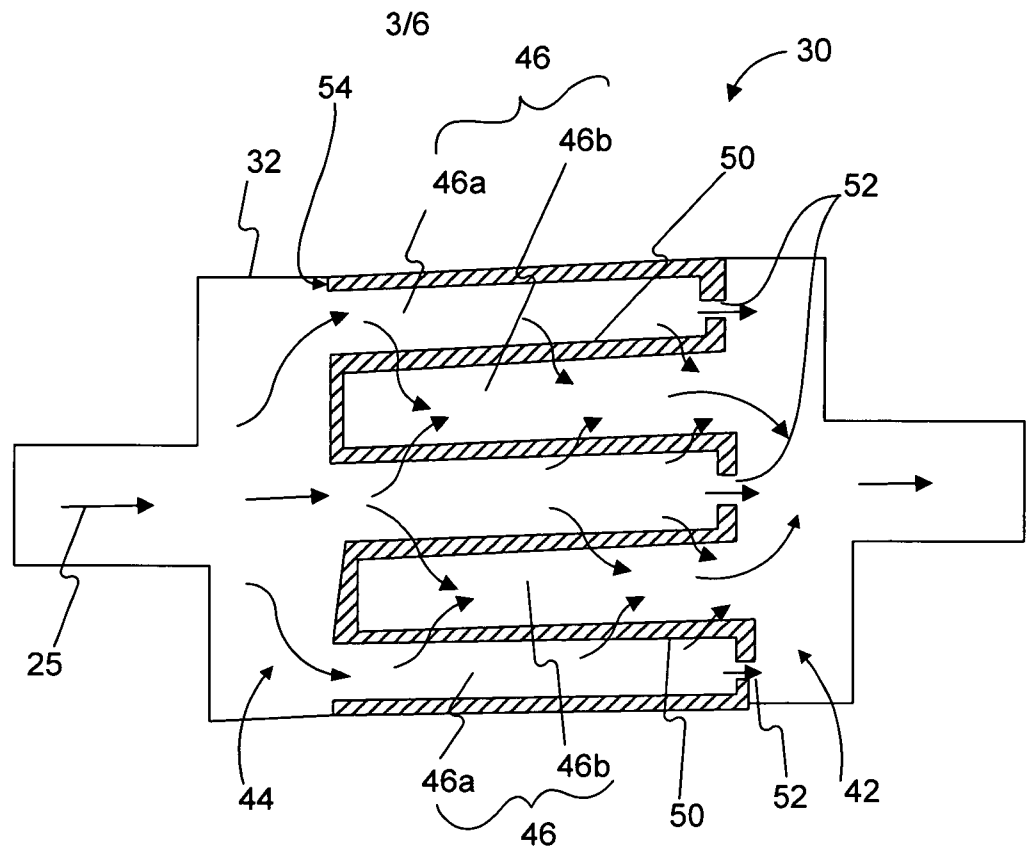


FIG. 4

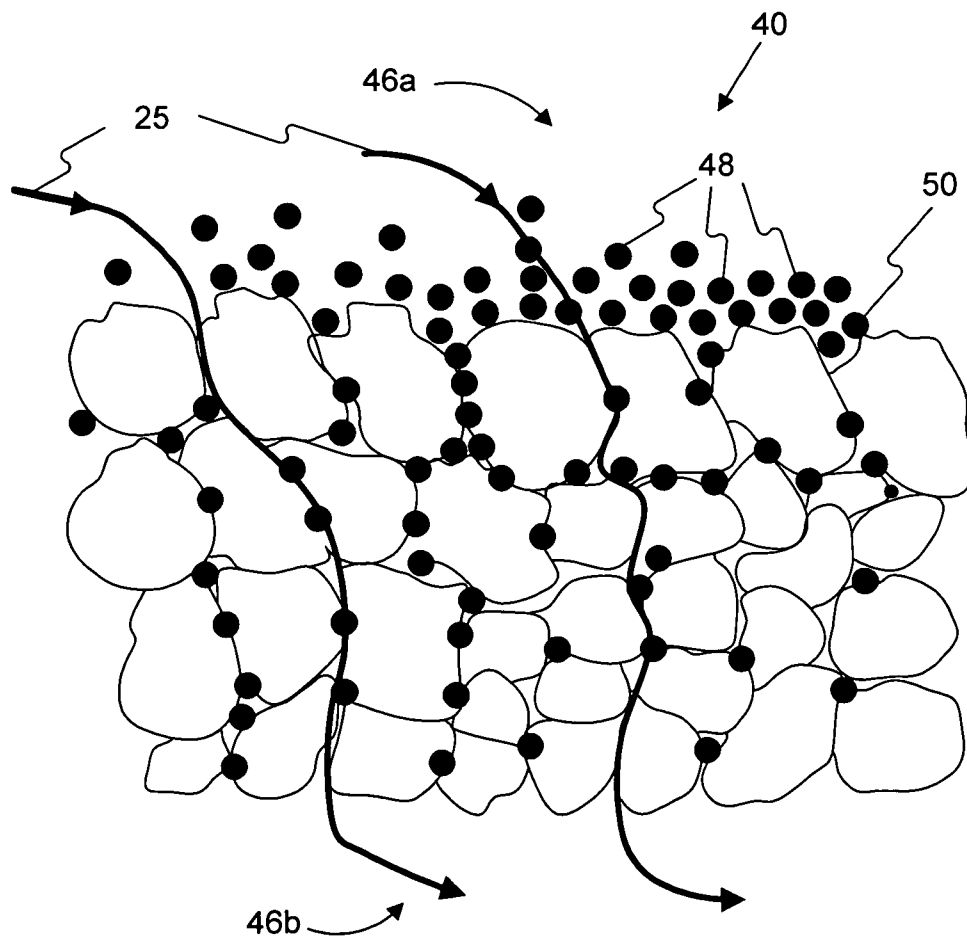


FIG. 5

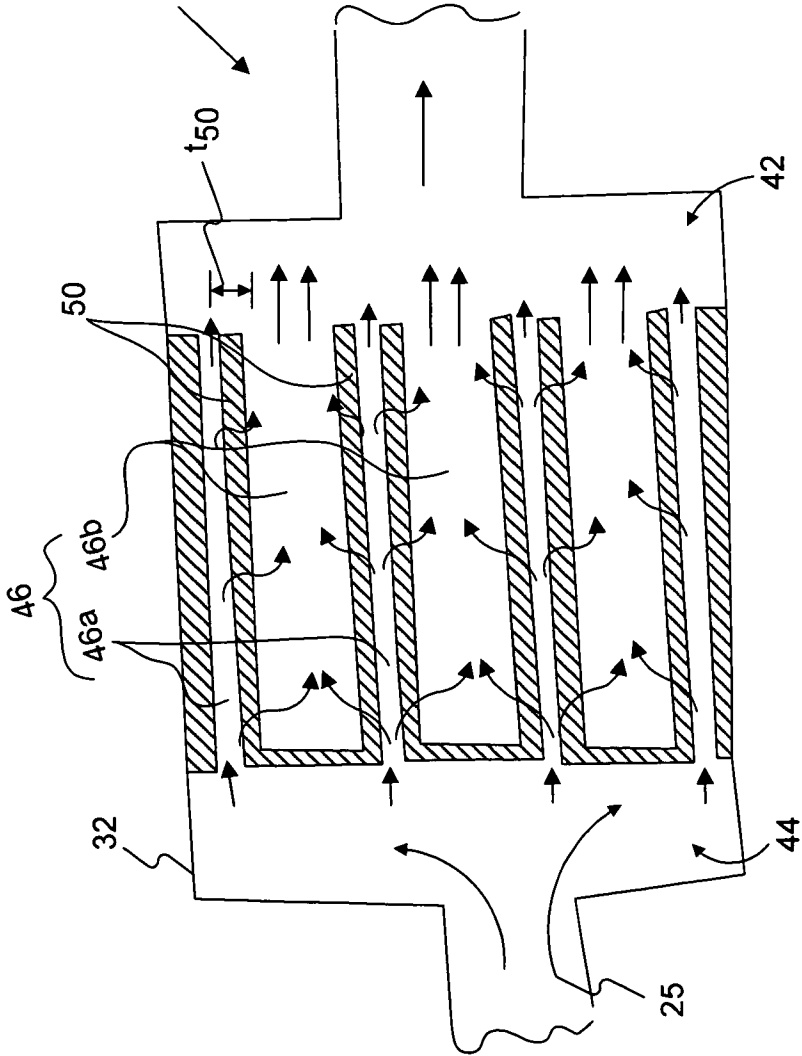


FIG. 6A

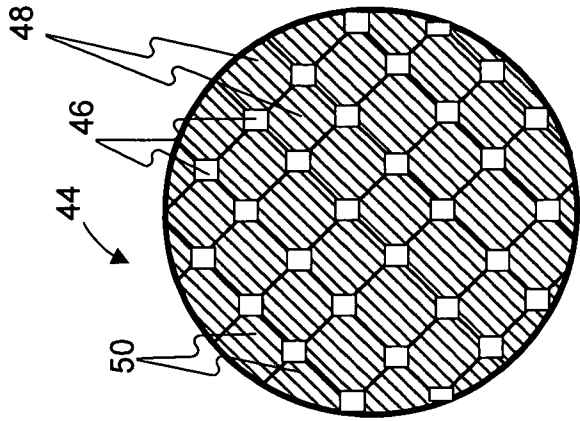


FIG. 6B

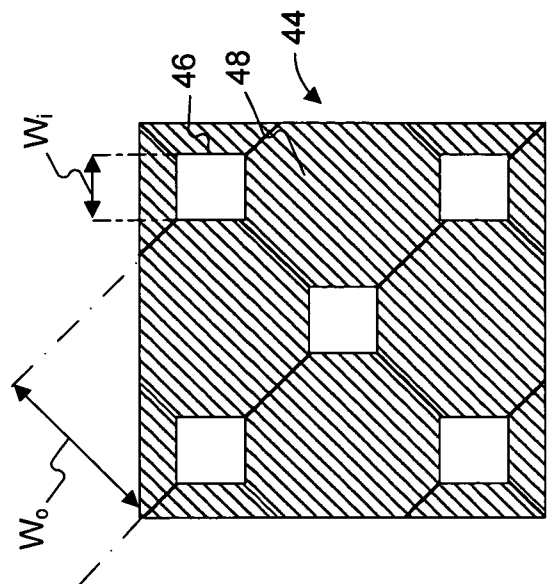


FIG. 6D

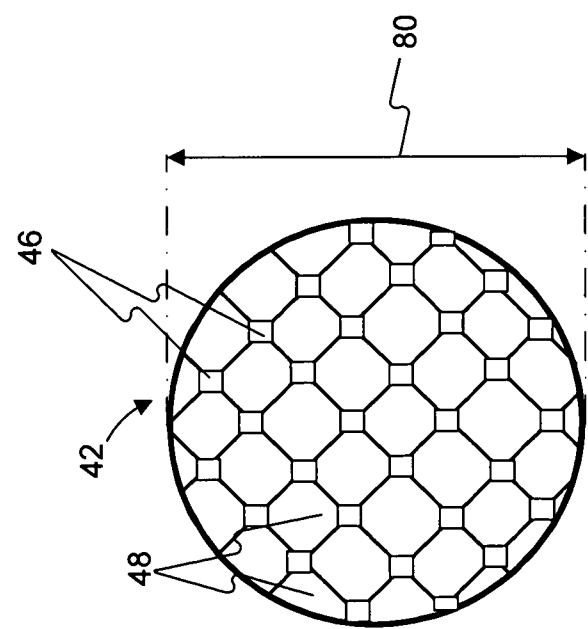
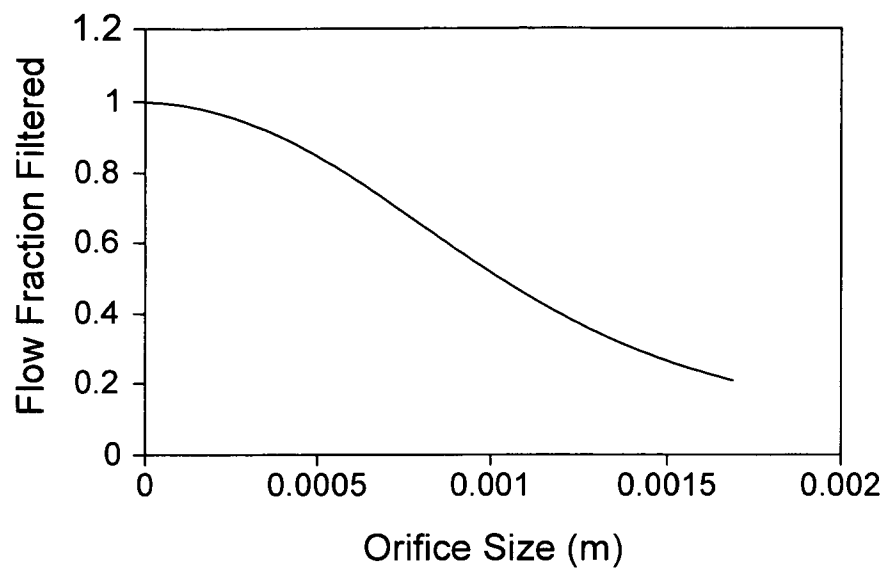
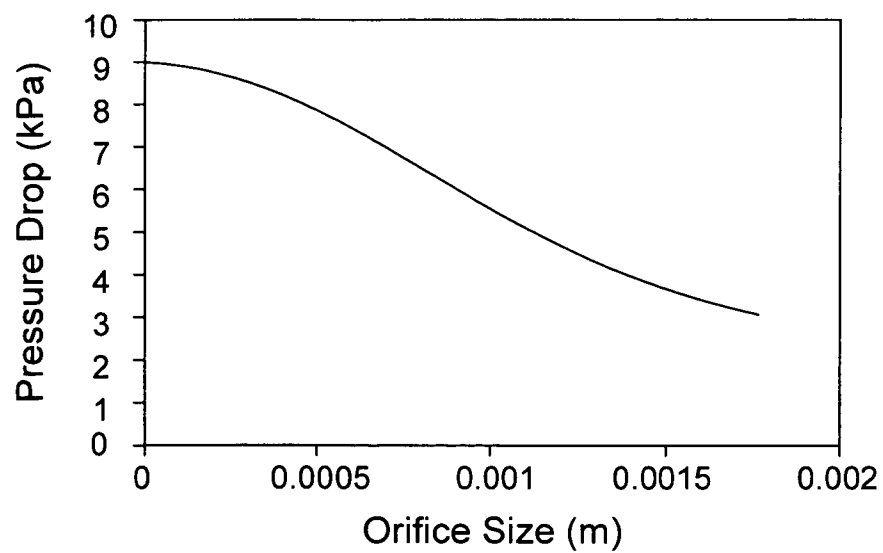


FIG. 6C

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**FIG. 7A****FIG. 7B**

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2008/010173

A. CLASSIFICATION OF SUBJECT MATTER

INV. F01N3/022

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)

F01N B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 03/014539 A (TOYOTA MOTOR CO LTD [JP]; NAKATANI KOICHIRO [JP]; HIROTA SHINYA [JP];) 20 February 2003 (2003-02-20) page 28, line 7 - page 30, line 3; figures 9A,9B	1,4-7,9,10
Y	US 4 519 820 A (OYOB KAZUO [JP] ET AL) 28 May 1985 (1985-05-28) column 3, line 30 - line 59 column 5, line 42 - line 49; figures 10a,10b	1-10
Y	JP 2002 119867 A (TOYOTA MOTOR CORP) 23 April 2002 (2002-04-23) abstract; figure 3	1,3-7,9,10
	-/--	

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

19 December 2008

Date of mailing of the international search report

09/01/2009

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2008/010173

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

International application No

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FR 2879236	A	16-06-2006	NONE	