Title: AIR CLEANER ARRANGEMENT AND METHODS

Abstract: An air cleaner arrangement is provided having an element with Z-media. The Z-media has a recessed upstream face. Structure from the housing helps to support the element by extending into the recess. In some embodiments, the element has a receiving pocket for receiving a projection from the housing to help further support the element. In preferred embodiments, the downstream face of the element is projecting to form a nose.
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
AIR CLEANER ARRANGEMENT AND METHODS

This application is being filed as a PCT International Patent application in the name of Donaldson Company, Inc., a U.S. national corporation, applicant for the designation of all countries except the US, and Sheldon Anderson, a U.S. citizen, applicant for the designation of the US only, and claims priority to U.S. provisional application 60/530,475, filed 16 December 2003.

FIELD OF THE INVENTION

The present disclosure relates to air filtration. A typical application is in air cleaner arrangements to be used for air filtration, for example filtration of intake air for internal combustion engines.

BACKGROUND

Gas streams often carry particulate material therein. In many instances it is desirable to remove some or all of the particulate material from the gas flow stream. For example, air intake streams to engines for motorized vehicles or power generation equipment often include particulate material therein. The particulate material, should it reach the internal workings of the mechanisms involved, can cause substantial damage. It is therefore preferred, for such systems, to remove the particulate material from the gas flow upstream of the engine or other equipment involved. A variety of air cleaner arrangements have been developed for particulate removal.

There has been a general trend for the utilization of air cleaner arrangements that utilize, as a media pack, z-filter media constructions. In general z-filter media constructions can be characterized as comprising a fluted sheet secured to a facing sheet, formed into a media pack configuration. Examples of z-filter arrangements are described in PCT Publication WO 97/40918, published November 6, 1997; U.S. patents 6,190,432 and 6,350,291; PCT application US 04/07927, filed March 17, 2004; U.S. Provisional application 60/532,783, filed December 22, 2003; PCT Publication 03/095068, published November 20, 2003; PCT publication WO 04/007054, published January 22, 2004; PCT publication WO 03/084641, published October 16, 2003; and, U.S. Provisional Application 60/543,804, filed February 11, 2004.

In general, improvements have been sought.
SUMMARY

A filter element is provided including a media pack comprising a plurality of inlet flutes and outlet flutes extending between first and second, opposite, flow faces and formed from an arrangement of facing sheet secured to corrugated sheet; the media pack having an outer periphery; the first flow face having a first profile including: (A) a flat planar portion at a geometric center and extending at least 20% of a widest dimension across the first flow face; and (B) a slanted portion extending from the flat portion to the outer periphery at an angle of at least 5°; the second flow face having a second profile including: (A) a flat planar portion at a geometric center and extending at least 20% of a widest dimension across the second flow face; and (B) a slanted portion extending from the flat portion to the outer periphery at an angle of at least 5°; and a radial seal member oriented to form a radially directed seal with an annular surface of a housing, when the filter element is operably installed in the housing.

An air cleaner is provided including a housing defining an interior; rib structure within the housing interior; and a filter element operably mounted and sealed within the housing interior; the filter element including a media pack comprising a plurality of inlet flutes and outlet flutes extending between first and second, opposite, flow faces and formed from an arrangement of facing sheet secured to corrugated sheet; the media pack having an outer periphery; the first flow face having a first profile including: (A) a flat planar portion at a geometric center and extending at least 20% of a widest dimension across the first flow face; and (B) a slanted portion extending from the flat portion to the outer periphery at an angle of at least 5°; the rib structure supporting the filter element within the housing by extending into the first flow face.

A method of servicing an air cleaner includes removing a filter element from an air cleaner housing; and operably installing a new filter element into the air cleaner housing including orienting the filter element such that rib structure in the air cleaner housing extends into a first flow face of the new filter element to support the new filter element; the new filter element including a media pack comprising a plurality of inlet flutes and outlet flutes extending between first and second, opposite, flow faces and formed from an arrangement of facing sheet secured to corrugated sheet; the media pack having an outer periphery; the first flow face having a first profile including: (A) a flat planar portion at a geometric center and extending at least 20% of a widest dimension across the first flow face; and a slanted portion extending from the flat portion to the outer periphery at an angle of at least 5°.
BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side view of an air cleaner assembly constructed according to principles of this disclosure;

Fig. 2 is a schematic cross-sectional view of the air cleaner assembly;

Fig. 3 is a schematic cross-sectional view of the air cleaner assembly with a second embodiment of a filter element therein;

Fig. 4 is an enlarged, fragmentary, view of z-filter media useable in the air cleaner assembly of Figs. 2 and 3;

Fig. 5 is a schematic, cross-sectional view of a portion of the media depicted in Fig. 4;

Fig. 6 is a schematic view of examples of various corrugated media definitions;

Fig. 7 is a schematic view of a process for manufacturing media according to the present disclosure;

Fig. 8 is a cross-sectional view of an optional end dart for media flutes useable in arrangements according to the present disclosure; and

Fig. 9 is a schematic view of a system using an air cleaner having a filter cartridge component according to the present disclosure.

DETAILED DESCRIPTION

General Background and Overview

Referring to Fig. 1, the air cleaner assembly 160 is of the type typically used for filtering engine intake air for internal combustion engines. For example, the air cleaner assembly 160 can comprise an air cleaner for use with a vehicles such as trucks or tractors. As an example, the precleaner could be used with class 2 - class 4 trucks, such as pickup trucks, SUVs, tow trucks, and delivery trucks, although many other applications are possible.

In general, such air cleaners include a housing 250 having, positioned therein, a serviceable air filter or air filter element, not shown in Fig. 1. By the term "serviceable" in this context, it is meant that the air filter element can be removed, to be refurbished or to be replaced. In general, to accommodate this, the housing 250 is provided with an access panel or cover, in this instance indicated at 251, which can be removed from a remainder 252 of the housing 250, for access to the interior, by loosening of bolts 253 (one bolt not being viewable in Fig. 1.)

In typical operation, air enters air cleaner 160 by entrance into precleaner 254 in the direction of arrow 255. Air exits through outlet 256 in the
direction of arrow 257, to be directed to an engine intake manifold, or other equipment structure.

The air cleaner assembly 160 can be mounted on the equipment, by posts 3d.

Typically, serviceable air filter elements comprise media through which the air to be filtered is passed, in use. The media captures or traps a portion of particulate contaminant, such as dust or ash, carried within the air. The service interval is generally related to the time of operation it takes for the filter element to become sufficiently loaded with dust or other material such that the restriction across the air filter element, and thus across the air cleaner, is undesirably increased. That is, as material is loaded onto the filter element during the filtering operation, restriction across the air filter increases. Generally, the service interval is recommended by the engine manufacturer or vehicle manufacturer to occur at a point in time prior to an undesirable restriction having been reached. This service interval can be defined, for example, by hours of operation or miles of operation for the equipment involved.

The particular air cleaner 160 depicted in Fig. 2, includes thereon a restriction indicator. The restriction indicator 260 can be configured to indicate when the restriction across the air filter has reached a point that service is required or is recommended.

Some air cleaners are provided with precleaners. A precleaner is an arrangement that allows for separation of a portion of dust or other material entrained within the air to be cleaned, prior to the air passing through the serviceable air filter element. Precleaners generally operate by imparting a circular, cyclonic or coiled momentum to the incoming air, and the entrained material, as opposed to passage of the air through a filter media. This circular (cyclonic or coiled) momentum causes a deposition of a portion of the entrained material from the air flow, before the air is transferred into a region of the air cleaner assembly that includes the serviceable filter element. Precleaners of this type are described for example in U.S. 5,545,241; 6,039,778; and 5,401,285. For the types of systems described in the 5,454,241 and 6,039,778 patents, the precleaner comprises an arrangement which drives inlet air to the air cleaner into a cyclonic flow around the serviceable filter element, combined with a drop tube for ejection of the material separated by the precleaner from the system.

For the type of air cleaner described in U.S. 5,401,285, the precleaner comprises a panel of individual dust separator tubes, each of which provides for some separation prior to air entry into the main body of the air cleaner which includes the serviceable element(s). A variety of separator tubes of this type are
shown, for example, in U.S. patents 4,008,059; 4,050,913; 4,289,611; 3,448,563; 3,713,280; 4,985,058; 4,976,748; 5,403,367; and 5,480,464.

Another example of a precleaner including a plurality of separator tubes is provided in PCT application number PCT/US03/10258 filed July 18, 2003. In this example, the precleaner arrangement, including separator tubes, a down flow tube and an evacuator valve, is positioned upstream of a main air cleaner which includes therein a serviceable filter element comprising z-filter media.

Referring to Figs. 1-3, the air cleaner assembly 160 comprises precleaner 254 and a main air cleaner 262. Main air cleaner 262 comprises housing 250 having an access cover 251, which is selectively removable from a remainder 252 of the housing 250. The housing 250 can be mounted in position (in equipment for use) by post(s) 263.

The housing 250 defines an interior 264, in which is operably placed a removable and replaceable, i.e., serviceable, primary filter element 162.

In operation, air enters the air cleaner assembly 160 by flow in the direction of arrow 255 into precleaner 254. The air then passes into the main air cleaner 262 and through the main filter element 162 and outwardly through outlet 256.

In some applications, a secondary or safety filter element may be positioned between the primary filter element 162 and the outlet 256. Examples of secondary or safety elements of this type, for such applications, are described for example in U.S. 6,221,122 and 6,179,890. Of course, the housing 250 would need to be configured to accommodate such a secondary or safety filter element.

Referring again to Fig. 2, within the precleaner 254, vane structure 265 imparts circular, (i.e., coiled or cyclonic) momentum to the air flow. This cyclonic momentum will cause at least a portion of material entrained within the air, to be directed against inner surface 266 of the precleaner 254. A portion of this dust, moisture, or other material will eventually be ejected into down tube 267 and evacuation valve 268 (FIG. 1). Down tubes and evacuation valves similar in construction to down tube 267 and evacuation valve 268 are known and are shown, for example, in U.S. patents 5,545,241 and 6,039,778 and PCT application PCT/US03/10258 filed July 18, 2003.

As indicated above, reference numeral 162 indicates the primary filter element which, periodically, is removed and refurbished or replaced, i.e., serviced.

The particular filter element 162 depicted, utilizes a media pack of z-filter media, discussed in detail below. In general, z-filter media is generally configured for straight through flow from a most upstream face 195 to a most
downstream 196. The media typically comprises an arrangement of corrugated media secured to flat media, and then stacked or coiled (sometimes with a center core, not shown) to form a plurality of flutes. One set of flutes (inlet flutes) is open at the upstream face 195 and closed at the downstream face 196; and, a second set of flutes (outlet flutes) is closed at the upstream face 195 and open at the downstream face 196. The air to be filtered can enter the inlet set of flutes, but in order to exit the element 162 it must pass through the media and into the outlet flutes. Examples of such z-filter arrangements are described for example in U.S. 6,190,432; 6,350,291; 6,179,890; 6,235,195; 5,820,646; 5,772,883; and, 5,902,364.

**Z-Filter Media Configurations, Generally**

Fluted filter media can be used to provide fluid filter constructions in a variety of manners. One well known manner is as a z-filter construction. The term "z-filter construction" as used herein, is meant to refer to a filter construction in which individual ones of corrugated, folded or otherwise formed filter flutes are used to define sets of longitudinal, typically parallel, inlet and outlet filter flutes for fluid flow through the media; the fluid flowing along the length of the flutes between opposite inlet and outlet flow ends (or flow faces) of the media. Some examples of z-filter media are provided in U.S. patents 5,820,646; 5,772,883; 5,902,364; 5,792,247; 5,895,574; 6,210,469; 6,190,432; 6,350,296; 6,179,890; 6,235,195; Des. 399,944; Des. 428,128; Des. 396,098; Des. 398,046; and, Des. 437,401.

One type of z-filter media, utilizes two specific media components joined together, to form the media construction. The two components are: (1) a fluted (typically corrugated) media sheet; and, (2) a facing media sheet. The facing media sheet is typically non-corrugated, however it can be corrugated, for example perpendicularly to the flute direction as described in U.S. provisional 60/543,804, filed February 11, 2004.

The fluted (typically corrugated) media sheet and the facing media sheet together, are used to define media having parallel inlet and outlet flutes. In some instances, the fluted sheet and facing sheet are secured together and are then coiled to form a z-filter media construction. Such arrangements are described, for example, in U.S. 6,235,195 and 6,179,890. In certain other arrangements, some non-coiled sections of fluted media secured to facing media, are stacked on one another, to create a filter construction. An example of this is described in Fig. 11 of 5,820,646.

For specific applications as described herein, coiled arrangements are preferred. Typically, coiling of the fluted sheet/facing sheet combination around
itself, to create a coiled media pack, is conducted with the facing sheet directed outwardly. Some techniques for coiling are described in U.S. provisional application 60/467,521, filed May 2, 2003 and PCT Application US 04/07927, filed March 17, 2004. The resulting coiled arrangement generally has, as the outer surface of the media pack, a portion of the facing sheet.

The term "corrugated" used herein to refer to structure in media, is meant to refer to a flute structure resulting from passing the media between two corrugation rollers, i.e., into a nip or bite between two rollers, each of which has surface features appropriate to cause a corrugation affect in the resulting media. The term "corrugation" is not meant to refer to flutes that are formed by techniques not involving passage of media into a bite between corrugation rollers. However, the term "corrugated" is meant to apply even if the media is further modified or deformed after corrugation, for example by the folding techniques described in PCT WO 04/007054, published January 22, 2004.

Corrugated media is a specific form of fluted media. Fluted media is media which has individual flutes (for example formed by such techniques as corrugating or folding) extending thereacross.

Serviceable filter element or filter cartridge configurations utilizing z-filter media are sometimes referred to as "straight through flow configurations" or by variants thereof. In general, in this context what is meant is that the serviceable filter elements generally have an inlet flow end (or face) and an opposite exit flow end (or face), with flow entering and exiting the filter cartridge in generally the same straight through direction. The term "serviceable" in this context is meant to refer to a media containing filter cartridge that is periodically removed and replaced from a corresponding fluid cleaner. In some instances, each of the inlet flow end and outlet flow end will be generally flat or planar, with the two parallel to one another. However, variations from this, for example non-planar faces are possible.

A straight through flow configuration (especially for a coiled media pack) is, for example, in contrast to serviceable filter cartridges such as cylindrical pleated filter cartridges of the type shown in U.S. Patent No. 6,039,778, in which the flow generally makes a turn as it passes through the serviceable cartridge. That is, in a 6,039,778 filter, the flow enters the cylindrical filter cartridge through a cylindrical side, and then turns to exit through an end face (in forward-flow systems). In a typical reverse-flow system, the flow enters the serviceable cylindrical cartridge through an end face and then turns to exit through a side of the cylindrical filter cartridge. An example of such a reverse-flow system is shown in U.S. Patent No. 5,613,992.
The term "z-filter media construction" and variants thereof as used herein, without more, is meant to refer to any or all of: a web of corrugated or otherwise fluted media secured to facing media with appropriate sealing to allow for definition of inlet and outlet flutes; or, such a media coiled or otherwise constructed or formed into a three dimensional network of inlet and outlet flutes; and/or, a filter construction including such media.

In Fig. 4, an example of media 1 useable in z-filter media is shown. The media 1 is formed from a corrugated (fluted) sheet 3 and a facing sheet 4.

In general, the corrugated sheet 3, Fig. 4, is of a type generally characterized herein as having a regular, curved, wave pattern of flutes or corrugations 7. The term "wave pattern" in this context, is meant to refer to a flute or corrugated pattern of alternating troughs 7b and ridges 7a. The term "regular" in this context is meant to refer to the fact that the pairs of troughs and ridges (7b, 7a) alternate with generally the same repeating corrugation (or flute) shape and size.

(Also, typically in a regular configuration each trough 7b is substantially an inverse of each ridge 7a.) The term "regular" is thus meant to indicate that the corrugation (or flute) pattern comprises troughs and ridges with each pair (comprising an adjacent trough and ridge) repeating, without substantial modification in size and shape of the corrugations along at least 70% of the length of the flutes. The term "substantial" in this context, refers to a modification resulting from a change in the process or form used to create the corrugated or fluted sheet, as opposed to minor variations from the fact that the media sheet 3 is flexible. With respect to the characterization of a repeating pattern, it is not meant that in any given filter construction, an equal number of ridges and troughs is necessarily present. The media 1 could be terminated, for example, between a pair comprising a ridge and a trough, or partially along a pair comprising a ridge and a trough. (For example, in Fig. 4 the media 1 depicted in fragmentary has eight complete ridges 7a and seven complete troughs 7b.) Also, the opposite flute ends (ends of the troughs and ridges) may vary from one another. Such variations in ends are disregarded in these definitions, unless specifically stated. That is, variations in the ends of flutes are intended to be covered by the above definitions.

In the context of the characterization of a "curved" wave pattern of corrugations, the term "curved" is meant to refer to a corrugation pattern that is not the result of a folded or creased shape provided to the media, but rather the apex 7a of each ridge and the bottom 7b of each trough is formed along a radiused curve. Although alternatives are possible, a typical radius for such z-filter media would be at least 0.25 mm and typically would be not more than 3 mm. (Media that is not curved, by the above definition, can also be useable.)
An additional characteristic of the particular regular, curved, wave pattern depicted in Fig. 4, for the corrugated sheet 3, is that at approximately a midpoint 30 between each trough and each adjacent ridge, along most of the length of the flutes 7, is located a transition region where the curvature inverts. For example, viewing back side or face 3a, Fig. 4, trough 7b is a concave region, and ridge 7a is a convex region. Of course when viewed toward front side or face 3b, trough 7b of side 3a forms a ridge; and, ridge 7a of face 3a, forms a trough. (In some instances, region 30 can be a straight segment, instead of a point, with curvature inverting at ends of the straight segment 30.)

A characteristic of the particular regular, curved, wave pattern corrugated sheet 3 shown in Fig. 4, is that the individual corrugations are generally straight. By "straight" in this context, it is meant that through at least 70% (typically at least 80%) of the length between edges 8 and 9, the ridges 7a and troughs 7b do not change substantially in cross-section. The term "straight" in reference to corrugation pattern shown in Fig. 4, in part distinguishes the pattern from the tapered flutes of corrugated media described in Fig. 1 of WO 97/40918 and PCT Publication WO 03/47722, published June 12, 2003. The tapered flutes of Fig. 1 of WO 97/40918, for example, would be a curved wave pattern, but not a "regular" pattern, or a pattern of straight flutes, as the terms are used herein.

Referring to the present Fig. 4 and as referenced above, the media 1 has first and second opposite edges 8 and 9. When the media 1 is coiled and formed into a media pack, in general edge 9 will form an inlet end for the media pack and edge 8 an outlet end, although an opposite orientation is possible.

Adjacent edge 8 the sheets 3, 4 are sealed to one another, for example by sealant, in this instance in the form of a sealant bead 10, sealing the corrugated (fluted) sheet 3 and the facing sheet 4 together. Bead 10 will sometimes be referred to as a "single facer" bead, when it is applied as a bead between the corrugated sheet 3 and facing sheet 4, to form the single facer or media strip 1. Sealant bead 10 seals closed individual flutes 11 adjacent edge 8, to passage of air therefrom.

Adjacent edge 9, is provided sealant, in this instance in the form of a seal bead 14. Seal bead 14 generally closes flutes 15 to passage of unfiltered fluid therein, adjacent edge 9. Bead 14 would typically be applied as the media 1 is coiled about itself, with the corrugated sheet 3 directed to the inside. Thus, bead 14 will form a seal between a back side 17 of facing sheet 4, and side 18 of the corrugated sheet 3. The bead 14 will sometimes be referred to as a "winding bead" when it is applied as the strip 1 is coiled into a coiled media pack. If the media 1 were cut in strips and stacked, instead of coiled, bead 14 would be a "stacking bead."
In some applications, the corrugated sheet 3 is also tacked to the facing sheet 4 at various points along the flute length, as shown at lines 4a.

Referring to Fig. 4, once the media 1 is incorporated into a media pack, for example by coiling or stacking, it can be operated as follows. First, air in the direction of arrows 12, would enter open flutes 11 adjacent end 9. Due to the closure at end 8, by bead 10, the air would pass through the media shown by arrows 13. It could then exit the media pack, by passage through open ends 15a of the flutes 15, adjacent end 8 of the media pack. Of course operation could be conducted with air flow in the opposite direction. However, in typical air filter applications, at one end or face of the media pack unfiltered air flow in, and at an opposite end or face the filtered air flow out, with no unfiltered air flow through the pack or between the faces.

For the particular arrangement shown herein in Fig. 4, the parallel corrugations 7a, 7b are generally straight completely across the media, from edge 8 to edge 9. Straight flutes or corrugations can be deformed or folded at selected locations, especially at ends. Modifications at flute ends for closure are generally disregarded in the above definitions of "regular," "curved" and "wave pattern."

Z-filter constructions which do not utilize straight, regular curved wave pattern corrugation (flute) shapes are known. For example in Yamada et al. U.S. 5,562,825 corrugation patterns which utilize somewhat semicircular (in cross section) inlet flutes adjacent narrow V-shaped (with curved sides) exit flutes are shown (see Figs. 1 and 3, of 5,562,825). In Matsumoto, et al. U.S. 5,049,326 circular (in cross-section) or tubular flutes defined by one sheet having half tubes attached to another sheet having half tubes, with flat regions between the resulting parallel, straight, flutes are shown, see Fig. 2 of Matsumoto '326. In Ishii, et al. U.S. 4,925,561 (Fig. 1) flutes folded to have a rectangular cross section are shown, in which the flutes taper along their lengths. In WO 97/40918 (FIG. 1), flutes or parallel corrugations which have a curved, wave patterns (from adjacent curved convex and concave troughs) but which taper along their lengths (and thus are not straight) are shown. Also, in WO 97/40918 flutes which have curved wave patterns, but with different sized ridges and troughs, are shown.

In general, the filter media is a relatively flexible material, typically a non-woven fibrous material (of cellulose fibers, synthetic fibers or both) often including a resin therein, sometimes treated with additional materials. Thus, it can be conformed or configured into the various corrugated patterns, without unacceptable media damage. Also, it can be readily coiled or otherwise configured for use, again without unacceptable media damage. Of course, it must be of a nature such that it will maintain the required corrugated configuration, during use.
In the corrugation process, an inelastic deformation is caused to the media. This prevents the media from returning to its original shape. However, once the tension is released the flute or corrugations will tend to spring back, recovering only a portion of the stretch and bending that has occurred. The facing sheet is sometimes tacked to the fluted sheet, to inhibit this spring back in the corrugated sheet.

Also, typically, the media contains a resin. During the corrugation process, the media can be heated to above the glass transition point of the resin. When the resin then cools, it will help to maintain the fluted shapes.

The media of the corrugated sheet 3, facing sheet 4 or both, can be provided with a fine fiber material on one or both sides thereof, for example in accord with U.S. 6,673,136.

An issue with respect to z-filter constructions relates to closing of the individual flute ends. Typically a sealant or adhesive is provided, to accomplish the closure. As is apparent from the discussion above, in typical z-filter media, especially that which uses straight flutes as opposed to tapered flutes, large sealant surface areas (and volume) at both the upstream end and the downstream end are needed. High quality seals at these locations are critical to proper operation of the media structure that results. The high sealant volume and area, creates issues with respect to this.

Attention is now directed to Fig. 5, in which a z-filter media construction 40 utilizing a regular, curved, wave pattern corrugated sheet 43, and a facing (in this instance non-corrugated) sheet 44, is depicted. The distance D1, between points 50 and 51, defines the extension of facing media 44 in region 52 underneath a given corrugated flute 53. The length D2 of the arcuate media for the corrugated flute 53, over the same distance D1 is of course larger than D1, due to the shape of the corrugated flute 53. For a typical regular shaped media used in fluted filter applications, the linear length D2 of the media 53 between points 50 and 51 will generally be at least 1.2 times D1. Typically, D2 would be within a range of 1.2 - 2.0 time D1, inclusive. One particularly convenient arrangement for air filters has a configuration in which D2 is about 1.25 - 1.35 x D1. Such media has, for example, been used commercially in Donaldson Powercore™ Z-filter arrangements. Herein the ratio D2/D1 will sometimes be characterized as the flute/flat ratio or media draw for the corrugated (fluted) media.

In the corrugated cardboard industry, various standard flutes have been defined. For example the standard E flute, standard X flute, standard B flute, standard C flute and standard A flute. Figure 6, attached, in combination with Table A below provides definitions of these flutes.
Donaldson Company, Inc., (DCI) the assignee of the present disclosure, has used variations of the standard A and standard B flutes, in a variety of z-filter arrangements. These flutes are also defined in Table A and Fig. 6.

<table>
<thead>
<tr>
<th>TABLE A</th>
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<tbody>
<tr>
<td>(Flute definitions for Fig. 6)</td>
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<tr>
<td>DCI A Flute: Flute/flat = 1.52:1; The Radii (R) are as follows:</td>
</tr>
<tr>
<td>R1000 = .0675 inch (1.715 mm); R1001 = .0581 inch (1.476 mm);</td>
</tr>
<tr>
<td>R1002 = .0575 inch (1.461 mm); R1003 = .0681 inch (1.730 mm);</td>
</tr>
<tr>
<td>DCI B Flute: Flute/flat = 1.32:1; The Radii (R) are as follows:</td>
</tr>
<tr>
<td>R1004 = .0600 inch (1.524 mm); R1005 = .0520 inch (1.321 mm);</td>
</tr>
<tr>
<td>R1006 = .0500 inch (1.270 mm); R1007 = .0620 inch (1.575 mm);</td>
</tr>
<tr>
<td>Std. E Flute: Flute/flat = 1.24:1; The Radii (R) are as follows:</td>
</tr>
<tr>
<td>R1008 = .0200 inch (.508 mm); R1009 = .0300 inch (.762 mm);</td>
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<tr>
<td>R1010 = .0100 inch (.254 mm); R1011 = .0400 inch (1.016 mm);</td>
</tr>
<tr>
<td>Std. X Flute: Flute/flat = 1.29:1; The Radii (R) are as follows:</td>
</tr>
<tr>
<td>R1012 = .0250 inch (.635 mm); R1013 = .0150 inch (.381 mm);</td>
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<tr>
<td>Std. B Flute: Flute/flat = 1.29:1; The Radii (R) are as follows:</td>
</tr>
<tr>
<td>R1014 = .0410 inch (1.041 mm); R1015 = .0310 inch (.7874 mm);</td>
</tr>
<tr>
<td>R1016 = .0310 inch (.7874 mm);</td>
</tr>
<tr>
<td>Std. C Flute: Flute/flat = 1.46:1; The Radii (R) are as follows:</td>
</tr>
<tr>
<td>R1017 = .0720 inch (1.829 mm); R1018 = .0620 inch (1.575 mm);</td>
</tr>
<tr>
<td>Std. A Flute: Flute/flat = 1.53:1; The Radii (R) are as follows:</td>
</tr>
<tr>
<td>R1019 = .0720 inch (1.829 mm); R1020 = .0620 inch (1.575 mm).</td>
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</table>

Of course other, standard, flutes definitions from the corrugated box industry are known.

In general, standard flute configurations from the corrugated box industry can be used to define corrugation shapes or approximate corrugation shapes for corrugated media. Comparisons above between the DCI A flute and DCI B
flute, and the corrugation industry standard A and standard B flutes, indicate some convenient variations.

**Manufacture of Coiled Media Configurations Using Fluted Media, Generally**

In Fig. 7, one example of a manufacturing process for making a media strip corresponding to strip 1, Fig. 4 is shown. In general, facing sheet 64 and the fluted (corrugated) sheet 66 having flutes 68 are brought together to form a media web 69, with an adhesive bead located therebetween at 70. The adhesive bead 70 will form a single facer bead 10, Fig. 4. An optional darting process occurs at station 71 to form center darted section 72 located mid-web. The Z-filter media or Z-media strip 74 can be cut or slit at 75 along the bead 70 to create two pieces 76, 77 of Z-filter media 74, each of which has an edge with a strip of sealant (single facer bead) extending between the corrugating and facing sheet. Of course, if the optional darting process is used, the edge with a strip of sealant (single facer bead) would also have a set of flutes darted at this location.

Also, if tack beads or other tack connections 4a, Fig. 4, are used, they can be made, as the sheets 64, 66 are brought together.

Techniques for conducting a process as characterized with respect to Fig. 4 are described in PCT WO 04/007054, published January 22, 2004.

Still in reference to Fig. 7, before the Z-filter media 74 is put through the darting station 71 and eventually slit at 75, it must be formed. In the schematic shown in Fig. 4, this is done by passing a sheet of media 92 through a pair of corrugation rollers 94, 95. In the schematic shown in Fig. 7, the sheet of media 92 is unrolled from a roll 96, wound around tension rollers 98, and then passed through a nip or bite 102 between the corrugation rollers 94, 95. The corrugation rollers 94, 95 have teeth 104 that will give the general desired shape of the corrugations after the flat sheet 92 passes through the nip 102. After passing through the nip 102, the sheet 92 becomes corrugated across the machine direction and is referenced at 66 as the corrugated sheet. The corrugated sheet 66 is then secured to facing sheet 64. (The corrugation process may involve heating the media, in some instances.)

Still in reference to Fig. 7, the process also shows the facing sheet 64 being routed to the darting process station 71. The facing sheet 64 is depicted as being stored on a roll 106 and then directed to the corrugated sheet 66 to form the Z-media 74. The corrugated sheet 66 and the facing sheet 64 are secured together by adhesive or by other means (for example by sonic welding).

Referring to Fig. 7, an adhesive line 70 is shown used to secure corrugated sheet 66 and facing sheet 64 together, as the sealant bead. Alternatively, the sealant bead for forming the facing bead could be applied as shown as 70a. If
the sealant is applied at 70a, it may be desirable to put a gap in the corrugation roller 95, and possibly in both corrugation rollers 94, 95, to accommodate the bead 70a.

The type of corrugation provided to the corrugated media is a matter of choice, and will be dictated by the corrugation or corrugation teeth of the corrugation rollers 94, 95. One preferred corrugation pattern will be a regular curved wave pattern corrugation of straight flutes, as defined herein above. A typical regular curved wave pattern used, would be one in which the distance D2, as defined above, in a corrugated pattern is at least 1.2 times the distance D1 as defined above. In one preferred application, typically D2 = 1.25 - 1.35 x D1. In some instances the techniques may be applied with curved wave patterns that are not "regular," including, for example, ones that do not use straight flutes.

As described, the process shown in Fig. 7 can be used to create the center darted section 72. Fig. 8 shows, in cross-section, one of the flutes 68 after darting and slitting.

A fold arrangement 118 can be seen to form a darted flute 120 with four creases 121a, 121b, 121c, 121d. The fold arrangement 118 includes a flat first layer or portion 522 that is secured to the facing sheet 64. A second layer or portion 124 is shown pressed against the first layer or portion 122. The second layer or portion 124 is preferably formed from folding opposite outer ends 126, 127 of the first layer or portion 122.

Still referring to Fig. 8, two of the folds or creases 121a, 121b will generally be referred to herein as "upper, inwardly directed" folds or creases. The term "upper" in this context is meant to indicate that the creases lie on an upper portion of the entire fold 120, when the fold 120 is viewed in the orientation of Fig. 8. The term "inwardly directed" is meant to refer to the fact that the fold line or crease line of each crease 121a, 121b, is directed toward the other.

In Fig. 8, creases 121c, 121d, will generally be referred to herein as "lower, outwardly directed" creases. The term "lower" in this context refers to the fact that the creases 121c, 121d are not located on the top as are creases 121a, 121b, in the orientation of Fig. 8. The term "outwardly directed" is meant to indicate that the fold lines of the creases 121c, 121d are directed away from one another.

The terms "upper" and "lower" as used in this context are meant specifically to refer to the fold 120, when viewed from the orientation of Fig. 8. That is, they are not meant to be otherwise indicative of direction when the fold 120 is oriented in an actual product for use.

Based upon these characterizations and review of Fig. 8, it can be seen that a preferred regular fold arrangement 118 according to Fig. 8 in this disclosure is one which includes at least two "upper, inwardly directed, creases."
These inwardly directed creases are unique and help provide an overall arrangement in which the folding does not cause a significant encroachment on adjacent flutes. A third layer or portion 128 can also be seen pressed against the second layer or portion 124. The third layer or portion 128 is formed by folding from opposite inner ends 130, 131 of the third layer 128.

Another way of viewing the fold arrangement 118 is in reference to the geometry of alternating ridges and troughs of the corrugated sheet 66. The first layer or portion 122 is formed from an inverted ridge. The second layer or portion 124 corresponds to a double peak (after inverting the ridge) that is folded toward, and in preferred arrangements folded against, the inverted ridge.

Techniques for providing the optional dart described in connection with Fig. 8, in a preferred manner, are described in PCT WO 04/007054. Techniques for coiling the media, with application of the winding bead, are described in PCT application US 04/07927, filed March 17, 2004.

Techniques described herein are particularly well adapted for use with media packs that result from coiling a single sheet comprising a corrugated sheet/facing sheet combination, i.e., a "single facer" strip. Certain of the techniques can be applied with arrangements that, instead of being formed by coiling, are formed from a plurality of strips of single facer.

Coiled media pack arrangements can be provided with a variety of peripheral perimeter definitions. In this context the term "peripheral, perimeter definition" and variants thereof, is meant to refer to the outside perimeter shape defined, looking at either the inlet end or the outlet end of the media pack. Typical shapes are circular as described in PCT WO 04/007054 and PCT application US 04/07927. Other useable shapes are obround, some examples of obround being oval shape. In general oval shapes have opposite curved ends attached by a pair of opposite sides. In some oval shapes, the opposite sides are also curved. In other oval shapes, sometimes called racetrack shapes, the opposite sides are generally straight. Racetrack shapes are described for example in PCT WO 04/007054 and PCT application US 04/07927.

Another way of describing the peripheral or perimeter shape is by defining the perimeter resulting from taking a cross-section through the media pack in a direction orthogonal to the winding axis of the coil.

Opposite flow ends or flow faces of the media pack can be provided with a variety of different definitions. In many arrangements, the ends are generally flat and perpendicular to one another. In other arrangements, the end faces include tapered, coiled, stepped portions which can either be defined to project axially outwardly from an axial end of the side wall of the media pack; or, to project axially
inwardly from an end of the side wall of the media pack. Examples of such media pack arrangements are shown in US Provisional Application 60/578,482, filed June 8, 2004.

The flute seals (for example from the single facer bead, winding bead or stacking bead) can be formed from a variety of materials. In various ones of the cited and incorporated references, hot melt or polyurethane seals are described as possible for various applications. Such materials are also useable for arrangements as characterized herein.

When the media is coiled, generally a center of the coil needs to be closed, to prevent passage of unfiltered air between the flow faces; i.e., through the media pack. Some approaches to this are referenced below. Others are described in U.S. Provisional 60/578,482, filed June 8, 2004; and U.S. Provisional 60/591,280, filed July 26, 2004.

The media chosen for the corrugated sheet and facing sheet can be the same or different. Cellulose fiber, synthetic fiber or mixed media fiber materials can be chosen. The media can be provided with a fine fiber layer applied to one or more surface, for example in accord with U.S. patent 6,673,136, issued January 6, 2004. When such material is used on only one side of each sheet, it is typically applied on the side(s) which will form the upstream side of inlet flutes.

**General Background Regarding Air Cleaner Systems.**

The principles and arrangements described herein are useable in a variety of systems. One particular system is depicted schematically in Fig. 9, generally at 150. In Fig. 9, equipment 152, such as a vehicle 152a having an engine 153 with some defined rated air flow demand, for example in the range of 50 cfm to 2000 cfm (cubic feet per minute) (i.e., 1.4-57 cubic meters/minute) is shown schematically. Although alternatives are possible, the equipment 152 may, for example, comprise a bus, an over-the-highway truck, an off-road vehicle, a tractor, a light-duty or medium-duty truck, or a marine vehicle such as a power boat. The engine 153 powers the equipment 152 upon fuel combustion. In Fig. 9, air flow is shown drawn into the engine 153 at an air intake at region 155. An optional turbo 156 is shown in phantom, as optionally boosting the air intake to the engine 153. The turbo 156 is shown downstream from an air cleaner 160, although alternate arrangement are possible.

The air cleaner 160 has a filter cartridge 162 and is shown in the air inlet stream to the engine 153. In general, in operation, air is drawn in at arrow 164 into the air cleaner 160 and through the filter cartridge 162. Upon passage through the air cleaner 160, selected particles and contaminants are removed from the air.
The cleaned air then flows downstream at arrow 166 into the intake 155. From there, the air flow is directed into the engine 153.

In a typical air cleaner 160, the filter cartridge 162 is a serviceable component. That is, the cartridge 162 is removable and replaceable within the air cleaner 160. This allows the cartridge 162 to be serviced, by removal and replacement, with respect to remainder of air cleaner 160, when the cartridge 162 becomes sufficiently loaded with dust or other contaminant, to require servicing.

**Example Constructions**

Filter constructions can be sealed to housings in a variety of manners. For Z-filters, typically a gasket material is secured at some location to the Z-filter construction, either directly or indirectly. By "directly" in this context, it is meant that the seal is secured directly to the media. By indirectly it is meant that the gasket material secured to some structure which is itself secured to the media.

The element 162 has a seal arrangement secured to the outside of the media 200. The particular arrangement depicted in Figs. 2 and 3, show an example. In this instance, a seal member at 198 is secured to a framework 199 which is itself secured to the media 200. The seal member 198 forms a radial seal 201 with housing 250, specifically, a peripherally surrounding surface 352 of a housing. The framework 199 has an extension 199' that projects from the element 162 in a same direction as the flutes of the filter media. In the embodiment shown, the framework 199 also includes: a band 350, which circumscribes and is secured to the outer periphery of the filter media 200; and a bend 351 between the band 350 and the extension 199'. The bend 351 projects free of the filter media 200; that is, the bend 351 does not have filter media 200 directly secured to it. The bend 351 is angled radially inwardly from a direction of the outer periphery of the element toward the geometric center of the filter element. The extension 199' projects axially from the bend 351. The seal member 198 is secured to the extension such that radial seal 201 is formed between and against the extension 199' and the peripherally surrounding surface 352 (annular surface) of the housing 250. As can be seen in FIG. 2, the seal member 198 is adjacent to the second flow face 196.

This type of seal arrangement, which uses an outwardly directed radial seal, is described for example in U.S. 6,350,291. Alternate seals can be used, if desired.

The particular air cleaner housing 262 depicted in Fig. 1, is constructed for "side load" or "side service." That is, element 162 is inserted (or dismounted) through a side of housing 250, by passage through an opening made available by removal of access cover 251.
In the embodiment shown in Fig. 2, the media pack of the filter element 162 has a conical configuration. By "conical", it is meant that the upstream face 195 and downstream face 196 have slanted portions, resembling a cone. The upstream face 195 is not flat and planar; rather, the upstream face 195 has first profile which is a concave or indented configuration. As can be seen in FIG. 2, the upstream face 195 has a section of media that is a flat, planar portion 200 at the geometric center and a portion near the geometric center. The flat portion 200 extends at least 20%, not greater than 50%, and typically 25% - 45% of the total diameter of the element 162. Extending from the flat, planar portion 200 is a section of filter media that is a slanted portion 202. The slanted portion 202 extends from the flat portion 200 to the outermost periphery 204, at an angle of at least 5°, and typically 10° - 30°.

In the embodiment shown, the downstream face 196 has a second profile shaped so that it has surfaces that parallel the first profile surfaces 200, 202 of the upstream surface 195. As such, the downstream surface 196 is non-flat and non-planar. The downstream surface 196 has a somewhat convex shape. There is a section of media that is a flat, planar portion at 206, at the geometric center and nearby vicinity, extending at least 20%, not greater than 50%, and typically 25% - 45% of the total diameter of the element 11. Extending from the flat portion 206 is a section of media that is a slanted surface 208. The slanted surface 208 extends from the planar portion 206 to the outside perimeter 204. The slanted portion 208 extends from the flat portion 206 in a direction toward the upstream surface 195 at an angle of at least 5° and typically 10° - 30°. The flat portion 206 is parallel to the flat portion 200.

In the embodiment shown, the element 162 further includes a core construction 210. The core construction 210 can be provided as described in U.S. Patent Application Publication 2002/0184864, published December 12, 2002. The core construction 210 shown is generally a cylindrical, hollow piece 211 with an impervious wall 212 closing the hollowed interior 211. In the embodiment shown, the core construction extends between the first flow face 195 and the second flow face 196. The wall 212 prevents the passage of unfiltered gas from flowing through the core construction 210. At the inlet end of the core construction 210, there is defined a hollow 214. The hollow 214 extends from the upstream face 195 to the wall 212. The hollow 214 defines a receiving pocket 216 for receiving portions of the air cleaner housing. In the embodiment shown, the receiving pocket 216 receives projection 220. Projection 220 extends from a rib structure 222. The rib structure 222 extends from housing piece 224 located near the outside housing wall 226. Piece 224, in the embodiment shown, is an inner wall that helps to support the
end of the element 162. The rib structure 222 extends from the wall 224 and also helps to support the element 162. Note in Fig. 2 how the rib structure 222 generally follows the contour of the upstream flow face 195. That is, the rib structure 222 is generally convex to follow the generally concave shape of the upstream face 195.

At the center of the rib structure 222 is the projection 220. The projection 220 is received within the receiving pocket 216, and helps to provide further stabilization and support to the filter element 11 within the housing. It should be understood that the media pack in the filter element 162 is closed to unfiltered flow therethrough.

In reference now to Fig. 3, the air cleaner 3 is shown with an alternate embodiment of a filter element 411. The element 411 depicted is constructed the same as the element 162 in Fig. 2, only the element 411 does not have the center core construction 210, i.e., the element 411 is coreless. The rib structure 422 does not have the center projection 220. The rib structure 422 and the wall 404 help to support the element 411 within operable orientation in the housing 250.

In the embodiment shown in Figs. 2 and 3, the element 162, 411 has a circular cross-section (i.e., is cylindrical in shape). It has a straight sidewall 230 extending between upstream face 195 and downstream face 196. As described, the upstream face 195 is indented, concave, or recessed. The downstream face 196 forms a nose 197 and is projecting or somewhat convex. The overall shape of elements 162, 411 is sometimes described as conical or frusto-conical because the upstream face 195 and downstream face 196 has a conical shape or a truncated cone ("frusto-conical"). Because the elements 162, 411 are made by coiling the media 300, the upstream flow face 195 and downstream flow face 196 are stepped and unsmooth.

The seal arrangement 198, if projecting beyond the nose 197, will project not more than 2 inches, typically not more than 1 inch, and sometimes not more than 0.5 inch beyond the nose 197.

The upstream face 195 is recessed from the exit point of the precleaner 254 by a predetermined distance. For example, the flat portion 200 is spaced at least 1 inch, and typically at least 2 inches, for example 2.3 - 4.0 inches from point 152 on the precleaner 254.

In operation, to service the air cleaner 160, the old filter element 162, 411 is removed from the air cleaner housing 250. A new filter element 162, 411 is operably installed into the air cleaner housing 250 including orienting the filter element 162, 411 such that rib structure 222, 422 in the air cleaner housing extends into the first flow face 195 of the new filter element 222, 422 to support the new filter element 162, 411. In preferred methods, the step of operably installing includes forming radial seal 201 between the new filter element 162, 411 and the
housing 250. In preferred embodiments, the step of operably installing includes inserting the new filter element 162, 411 through a side of the housing 250 after removing the cover 251 to expose an opening in the side of the housing.

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Selected Inventive Concepts

A filter element comprising a media pack comprising a plurality of inlet flutes and outlet flutes extending between first and second, opposite, flow faces and formed from an arrangement of facing sheet secured to corrugated sheet; the media pack having an outer periphery; the first flow face having a first profile including: (A) a flat planar portion at a geometric center and extending at least 20% of a widest dimension across the first flow face; and (B) a slanted portion extending from the flat portion to the outer periphery at an angle of at least 5°; the second flow face having a second profile including: (A) a flat planar portion at a geometric center and extending at least 20% of a widest dimension across the second flow face; and (B) a slanted portion extending from the flat portion to the outer periphery at an angle of at least 5°; and a radial seal member oriented to form a radially directed seal with an annular surface of a housing, when the filter element is operably installed in the housing.

In certain embodiments, the radial seal member is adjacent to the second flow face.

In certain embodiments, the first profile and the second profile are parallel.

In certain embodiments, the first profile is concave with the first flow face flat portion being axially inwardly more than an end of the first flow face slanted portion at the outer periphery; and the second profile is convex with the second flow face flat portion being axially outwardly more than an end of the second flow face slanted portion at the outer periphery.

In certain embodiments, the first flow face flat planar portion extends 25%-45% of a widest dimension across the first flow face; and the second flow face flat portion extends 25%-45% of a widest dimension across the second flow face.

In certain embodiments, the first flow face slanted portion extends from the first flow face flat portion at an angle of 10°-30°; and the second flow face slanted portion extends from the second flow face flat portion at an angle of 10°-30°.

In certain embodiments, the media pack defines a nose at the second flow face flat portion; and the radial seal member projects not more than 2 inches beyond the nose.

In certain embodiments, the radial seal member is secured to a frame, the frame being secured to the outer periphery of the media pack.
In certain embodiments, the media pack is cylindrical in shape. In certain embodiments, a core construction extends through the media pack; the core construction having an inlet end and defining a receiving pocket at the inlet end; the receiving pocket being oriented to receive portions of an air cleaner housing, when the filter element is operably mounted in an air cleaner housing.

In certain embodiments, the core construction includes a cylindrical hollow piece having a hollow interior and extending between the first flow face and second flow face; the core construction also including an impervious wall closing the hollow interior; the receiving pocket being defined between the impervious wall and the core construction inlet end.

In certain embodiments, the media pack is coreless.

An air cleaner comprising a housing defining an interior; rib structure within the housing interior; and a filter element operably mounted and sealed within the housing interior; the filter element including a media pack comprising a plurality of inlet flutes and outlet flutes extending between first and second, opposite, flow faces and formed from an arrangement of facing sheet secured to corrugated sheet; the media pack having an outer periphery; the first flow face having a first profile including: (A) a flat planar portion at a geometric center and extending at least 20% of a widest dimension across the first flow face; and (B) a slanted portion extending from the flat portion to the outer periphery at an angle of at least 5°; the rib structure supporting the filter element within the housing by extending into the first flow face.

In certain embodiments, there is an inner wall within the housing; the inner wall circumscribing the outer periphery of the media pack; and the rib structure extends radially and axially from the inner wall.

In certain embodiments, the filter element includes a core construction extending through the media pack; the core construction having an inlet end and defining a receiving pocket at the inlet end; the rib structure includes a projection; the projection extending into the receiving pocket.

In certain embodiments, the second flow face has a second profile including: a flat planar portion at a geometric center and extending at least 20% of a widest dimension across the second flow face; and a slanted portion extending from the flat portion to the outer periphery at an angle of at least 5°.

In certain embodiments, the filter element is removably sealed within the housing with a radially directed seal.

In certain embodiments, the media pack defines a nose at the second flow face; and the radially directed seal projects not more than 2 inches beyond the nose.
In certain embodiments, the filter element includes a frame secured to the outer periphery of the media pack; the radially directed seal includes a seal member secured to a frame.

In certain embodiments, the housing includes an access cover; the access cover being removable to selectively expose an opening in a side of the housing; the filter element being insertable and removable through the opening in the housing.

A method of servicing an air cleaner including removing a filter element from an air cleaner housing; and operably installing a new filter element into the air cleaner housing including orienting the filter element such that rib structure in the air cleaner housing extends into a first flow face of the new filter element to support the new filter element; the new filter element including a media pack comprising a plurality of inlet flutes and outlet flutes extending between first and second, opposite, flow faces and formed from an arrangement of facing sheet secured to corrugated sheet; the media pack having an outer periphery; the first flow face having a first profile including: (A) a flat planar portion at a geometric center and extending at least 20% of a widest dimension across the first flow face; and a slanted portion extending from the flat portion to the outer periphery at an angle of at least 5°.

In certain embodiments, the step of operably installing includes forming a radial seal between the new filter element and the housing.

In certain embodiments, the step of operably installing includes inserting the new filter element through a side of the housing.
Claims:

1. A filter element comprising:
   (a) a media pack comprising a plurality of inlet flutes and outlet flutes extending between first and second, opposite, flow faces and formed from an arrangement of facing sheet secured to corrugated sheet;
   (i) the media pack having an outer periphery;
   (ii) the first flow face having a first profile including:
       (A) a section of filter media including a flat planar portion at a geometric center and extending at least 20% of a widest dimension across the first flow face; and
       (B) a section of filter media including a slanted portion extending from the flat portion to the outer periphery at an angle of at least 5°;
   (iii) the second flow face having a second profile including:
       (A) a section of filter media including a flat planar portion at a geometric center and extending at least 20% of a widest dimension across the second flow face; and
       (B) a section of filter media including a slanted portion extending from the flat portion to the outer periphery at an angle of at least 5°;
   (iv) the media pack being closed to unfiltered flow therethrough;
   and
   (b) a radial seal member oriented to form a radially directed seal with a peripherally surrounding surface of a housing, when the filter element is operably installed in the housing.

2. A filter element according to claim 1 wherein:
   (a) the radial seal member is adjacent to the second flow face.

3. A filter element according to claim 2 wherein:
   (a) the first profile and the second profile are parallel.

4. A filter element according to claim 3 wherein:
the first profile is concave with the first flow face flat portion being axially inwardly more than an end of the first flow face slanted portion at the outer periphery; and

the second profile is convex with the second flow face flat portion being axially outwardly more than an end of the second flow face slanted portion at the outer periphery.

5. A filter element according to any one of claims 1-4 wherein:
   (a) the first flow face flat planar portion extends 25%-45% of a widest dimension across the first flow face; and
   (b) the second flow face flat portion extends 25%-45% of a widest dimension across the second flow face.

6. A filter element according to any one of claims 1-5 wherein:
   (a) the first flow face slanted portion extends from the first flow face flat portion at an angle of 10°-30°;
   (b) the second flow face slanted portion extends from the second flow face flat portion at an angle of 10°-30°.

7. A filter element according to claim 4 wherein:
   (a) the media pack defines a nose at the second flow face flat portion;
   and
   (b) the radial seal member projects not more than 2 inches beyond the nose.

8. A filter element according to claim 7 wherein:
   (a) the radial seal member is secured to a frame, the frame being secured to the outer periphery of the media pack.

9. A filter element according to any one of claims 1-8 wherein:
   (a) the media pack is cylindrical in shape.

10. A filter element according to any one of claims 1-9 further comprising:
   (a) a core construction extending through the media pack;
   (i) the core construction having an inlet end and defining a receiving pocket at the inlet end;
(A) the receiving pocket being oriented to receive portions of an air cleaner housing, when the filter element is operably mounted in an air cleaner housing.

11. A filter element according to claim 10 wherein:
   (a) the core construction includes a cylindrical hollow piece having a hollow interior and extending between the first flow face and second flow face; the core construction also including an impervious wall closing the hollow interior;
   (i) the receiving pocket being defined between the impervious wall and the core construction inlet end.

12. A filter element according to any one of claims 1-9 wherein:
   (a) the media pack is coreless.

13. An air cleaner comprising:
   (a) a housing defining an interior;
   (b) rib structure within the housing interior; and
   (c) a filter element operably mounted and sealed within the housing interior; the filter element including a media pack comprising a plurality of inlet flutes and outlet flutes extending between first and second, opposite, flow faces and formed from an arrangement of facing sheet secured to corrugated sheet;
   (i) the media pack having an outer periphery;
   (ii) the first flow face having a first profile including:
        (A) a section of filter media including a flat planar portion at a geometric center and extending at least 20% of a widest dimension across the first flow face; and
        (B) a section of filter media including a slanted portion extending from the flat portion to the outer periphery at an angle of at least 5°;
   (iii) the rib structure supporting the filter element within the housing by extending into the first flow face; and
   (iv) the media pack being closed to unfiltered flow therethrough.

14. An air cleaner according to claim 13 further comprising:
(a) an inner wall within the housing; the inner wall circumscribing the outer periphery of the media pack; and
(i) the rib structure extending radially and axially from the inner wall.

15. An air cleaner according to any one of claims 13 and 14 wherein:
   (a) the filter element includes a core construction extending through the media pack;
   (i) the core construction having an inlet end and defining a receiving pocket at the inlet end;
   (b) the rib structure includes a projection; the projection extending into the receiving pocket.

16. An air cleaner according to any one of claims 13-15 wherein:
   (a) the second flow face has a second profile including:
   (i) a flat planar portion at a geometric center and extending at least 20% of a widest dimension across the second flow face; and
   (ii) a slanted portion extending from the flat portion to the outer periphery at an angle of at least 5°.

17. An air cleaner according to any one of claims 13-16 wherein:
   (a) the filter element is removably sealed within the housing with a radially directed seal.

18. An air cleaner according to claim 17 wherein:
   (a) the media pack defines a nose at the second flow face; and
   (b) the radially directed seal projects not more than 2 inches beyond the nose.

19. An air cleaner according to claim 18 wherein:
   (a) the filter element includes a frame secured to the outer periphery of the media pack; the radially directed seal includes a seal member secured to a frame.

20. An air cleaner according to any one of claims 13-19 wherein:
   (a) the housing includes an access cover; the access cover being removable to selectively expose an opening in a side of the housing;
(i) the filter element being insertable and removable through the opening in the housing.

21. A method of servicing an air cleaner including:
(a) removing a filter element from an air cleaner housing; and
(b) operably installing a new filter element into the air cleaner housing including orienting the filter element such that rib structure in the air cleaner housing extends into a first flow face of the new filter element to support the new filter element;
(i) the new filter element including a media pack comprising a plurality of inlet flutes and outlet flutes extending between first and second, opposite, flow faces and formed from an arrangement of facing sheet secured to corrugated sheet; the media pack being closed to unfiltered flow therethrough;
(ii) the media pack having an outer periphery;
(iii) the first flow face having a first profile including:
(A) a section of media including a flat planar portion at a geometric center and extending at least 20% of a widest dimension across the first flow face; and
(B) a section of media including a slanted portion extending from the flat portion to the outer periphery at an angle of at least 5°.

22. A method according to claim 21 wherein:
(a) the step of operably installing includes forming a radial seal between the new filter element and the housing.

23. A method according to claim 21 wherein:
(a) the step of operably installing includes inserting the new filter element through a side of the housing.
A. CLASSIFICATION OF SUBJECT MATTER
IPC 7  B01D46/52

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 7  B01D

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

Electronic database consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

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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<td>X</td>
<td>US 5 902 364 A (TOKAR ET AL) 11 May 1999 (1999-05-11) cited in the application abstract; figures 1,13,14 column 6, line 34 - column 7, line 4</td>
<td>1-23</td>
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Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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